



IEEE Standard for Local and Metropolitan Area Networks: Overview and Architecture

IEEE Computer Society

Developed by the
LAN/MAN Standards Committee

IEEE Std 802®-2024

(Revision of IEEE Std 802-2014 as amended by
IEEE Std 802d™-2017, IEEE Std 802c™-2017,
and IEEE Std 802f™-2023)



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Abstract: An overview to the family of IEEE 802[®] standards is provided in this standard. It describes the reference models for the IEEE 802 standards and explains the relationship of these standards to the higher layer protocols; it specifies the structure of IEEE 802 MAC addresses; it specifies identification of public, private, prototype, and standard protocols; it specifies an object identifier hierarchy used within IEEE 802 for uniform allocation of object identifiers used in IEEE 802 standards; and it specifies a method for higher layer protocol identification.

Keywords: BANs, body area networks, EtherTypes, IEEE 802[®], IEEE 802 architecture, IEEE 802 reference model, LANs, local area networks, MANs, metropolitan area networks, object identifiers, PANs, personal area networks, RANs, regional area networks, protocol identifiers, protocol types

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Introduction

This introduction is not part of IEEE Std 802-2024, IEEE Standard for Local and Metropolitan Area Networks Overview and Architecture.

This document is the third major revision of the IEEE 802[®] overview and architecture. This revision integrates into the previous revision of the standard, IEEE Std 802-2014, the three subsequent amendments:

- IEEE Std 802dTM-2017, which specifies a Uniform Resource Name (URN) root identifier for YANG data models
- IEEE Std 802cTM-2017, which specifies an optional local medium access control (MAC) address space structure
- IEEE Std 802fTM-2023, which specifies a YANG module that contains EtherType information

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IEEE Standard for Local and Metropolitan Area Networks: Overview and Architecture

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1. Overview

1.1 Scope

This standard contains descriptions of the IEEE 802[®] standards published by the IEEE for frame-based data networks as well as a reference model (RM) for protocol standards. ~~The IEEE 802 architecture is defined, and~~ A specification for the identification of public, private, and standard protocols is included.

1.2 Purpose

This standard serves as the foundation for the family of IEEE 802 standards published by IEEE for local area networks (LANs), metropolitan area networks (MANs), personal area networks (PANs), and regional area networks (RANs), etc.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall equals is required to*).

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).⁶

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).⁷

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used; therefore, each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

~~IEEE Std 802.1DTM, IEEE Standard for Local and metropolitan area networks—Media Access Control (MAC) Bridges.~~^{1,2}

IEEE Std 802.1QTM, IEEE Standard for Local and Metropolitan ~~area networks—Virtual Bridged Local Area Networks—Bridges and Bridged Networks.~~^{8,9}

IEEE Std 802.1ACTM, IEEE Standard for Local and Metropolitan Area Networks—Media Access Control (MAC) Service Definition.

⁶The use of the word *must* is deprecated and cannot be used when stating mandatory requirements, *must* is used only to describe unavoidable situations.

⁷The use of *will* is deprecated and cannot be used when stating mandatory requirements, *will* is only used in statements of fact.

^{8,9}The IEEE standards referred to in Clause 2 are trademarks owned by The Institute of Electrical and Electronics Engineers, Incorporated.²

⁹ ²IEEE publications are available from The Institute of Electrical and Electronics Engineers (<https://standards.ieee.org/>).
(~~<http://standards.ieee.org/>~~).

IETF RFC 2578, Structure of Management Information Version 2 (SMIV2).^{10 5}

[IETF RFC 3406, Uniform Resource Names \(URN\) Namespace Definition Mechanisms, October 2002.](#)

[IETF RFC 8069, URN Namespace for IEEE, February 2017.](#)

ISO/IEC/~~IEEE~~ 8802-2:1998, [International](#) Standard for Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements—Part 2: Logical link control. ^{11 3} ~~(ISO/IEC version of withdrawn standard IEEE Std 802.2)~~

ITU-T Recommendation X.660, Information technology—Procedures for the operation of object identifier registration authorities: General procedures and top arcs of the international object identifier tree. ^{12 4}

3. Definitions, acronyms and abbreviations

3.1 Definitions

For this document, the following terms and definitions apply. *The IEEE Standards Dictionary Online*¹³ should be consulted for terms not defined in this clause.^{14 6}

^{10 5}IETF documents (i.e., RFCs) are available the Internet Engineering Task Force (<https://www.rfc-archive.org/>). ~~(<http://www.rfc-archive.org/>)~~

^{11 3}ISO/IEC publications are available from the International Organization for Standardization (<https://www.iso.org/standards.html>) ~~(<http://www.iso.ch/>)~~ and the International Electrotechnical Commission (<https://www.iec.ch/>) ~~(<http://www.iec.ch/>)~~. ISO/IEC publications are also available in the United States from the American National Standards Institute (<https://www.ansi.org/>). ~~(<http://www.ansi.org/>). (ISO/IEC version of withdrawn standard IEEE Std 802.2)~~

^{12 4}ITU-T publications are available from the International Telecommunications Union (<https://www.itu.int/>).

¹³*The IEEE Standards Dictionary Online* is a compendium of balloted definitions from individual approved standards.

¹⁴*The IEEE Standards Dictionary Online* is available at <https://dictionary.ieee.org>. An IEEE Account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

⁶ ~~The IEEE Standards Dictionary Online subscriptions are available at http://www.ieee.org/portal/innovate/products/standard/standards_dictionary.html.~~

access domain: A set of stations in an IEEE 802[®] network together with interconnecting data transmission media and functional units (e.g., repeaters), in which the stations use the same medium access control (MAC) protocol to ~~access~~ ~~communicate over~~ a common communications channel to exchange information ~~physical medium~~.

bridge: In the general sense, a functional unit that interconnects two or more access domains. In the context of IEEE Std 802, this is narrowed to interconnecting two or more bridgeable IEEE 802[®] networks that use the same data link layer (DLL) protocols above the medium access control (MAC) sublayer, but can use different MAC protocols. Forwarding and filtering decisions are made on the basis of Layer 2 information.

bridgeable network: A communication resource that provides the medium access control (MAC) service specified in IEEE Std 802.1AC, between two or more MAC service access points (MSAPs), supporting the MAC Internal Sublayer Service.

~~**canonical format:** The format of a medium access control (MAC) data frame in which the octets of any 48-bit extended unique identifiers (EUI 48s) or 64-bit extended unique identifiers (EUI 64s) conveyed in the MAC user data field have the same bit ordering as in the hexadecimal representation.~~

end station: A functional unit in an IEEE 802[®] network that acts as a source of, and/or destination for, link layer data traffic carried on the network.

Ethernet: A communication protocol specified by IEEE Std 802.3[™].

EtherType: A 2-octet value, assigned by the IEEE Registration Authority (RA), that provides data field context for medium access control (MAC) frame interpretation ~~of a data field of a frame~~ (protocol identification).

Extended Unique Identifier (EUI): A 48-bit or 64-bit identifier intended to be globally unique and sub-assigned, by the assignee of a block of such identifiers assigned by the IEEE Registration Authority, to a hardware device instance or other object that requires unique identification.

filtering: A function in a bridge that is used to determine if a received medium access control (MAC) frame is to be forwarded or discarded on any given outbound port.

forwarding: A function in a bridge that transfers a received medium access control (MAC) frame to one or more outbound ports.

~~**frame:** The format of aggregated bits from a medium access control (MAC) sublayer entity that are transmitted together in time.~~

handover: [A](#) The process by which a mobile node obtains facilities and preserves traffic flows when traffic is switched from one link to another. ~~Different types of handover are specified based on the way facilities for supporting traffic flows are preserved.~~

~~**IEEE 802@ network:** A network consisting of one or more interconnected networks each using a medium access control (MAC) protocol specified in an IEEE 802 standard.~~

~~**interconnection:** A data communication path between stations in an IEEE 802@ network.~~

interworking: The use of interconnected stations in a network for the exchange of data, by means of protocols operating over the underlying data transmission paths.

local area network (LAN): A network of devices, whether indoors or outdoors, covering a limited geographic area, e.g., a building or campus.

local medium access control (MAC) address: A medium access control (MAC) address with the universally or locally administered (U/L) bit set to one.

logical link: A logical communication connection between two devices.

logical link control (LLC) entity: The instantiation of an active element embodying LLC-specific capabilities at a single station.

logical link control (LLC) protocol data unit (LPDU): An LLC protocol data unit carried in the data field of a frame as an medium access control (MAC) service data unit (MSDU).

medium access control (MAC) entity: The instantiation of an active element embodying MAC-specific capabilities at a single station.

medium access control (MAC) ~~data~~ frame: A data structure consisting of fields in accordance with a MAC protocol, for the communication of user data and [/or](#) control information in a network; ~~one of the fields contains a sequence of octets of user data.~~

medium access control (MAC) protocol: A protocol that governs access to the transmission medium in a network, to enable the exchange of data between stations in a network.

medium access control (MAC) service data unit (MSDU): Data sent within a MAC frame by a MAC entity for delivery to one or more MAC entities.

media-independent control function: A parallel control plane that provides control functions for different medium access control (MAC) and physical layer (PHY) sublayers and provides a media-independent abstraction to higher layer protocols.

media-independent handover function: A function that provides the ability to relocate traffic flows between different medium access technologies and associated physical media.

metropolitan area network (MAN): A network of devices, extending over a large geographical area such as an urban area, often providing integrated communication services such as data, voice, and video.

Network Unique Identifier (NUI): An identifier that is unique within the IEEE 802[®] local area network (LAN).

~~**noncanonical format:** The format of a medium access control (MAC) data frame in which the octets of 48-bit extended unique identifiers (EUI-48s) or 64-bit extended unique identifiers (EUI-64s) conveyed in the MAC user data field have the same bit ordering as in the bit-reversed representation.~~

personal area network (PAN): A network of devices extending over a region generally smaller than about ten meters ~~very limited geographical area~~, used to convey information among a group of participant stations.

private protocol: A protocol whose use and specification are controlled by a private organization.

protocol data unit: A unit of information transmitted among peer instances of a layer or sublayer comprising protocol-specific control information and user data.

public protocol: A protocol whose specification is published and known to the public, but controlled by an organization other than a formal standards body.

regional area network (RAN): A network of devices that generally covers a service area that is larger than metropolitan area networks (MANs), typically in sparsely populated areas.

repeater: A device used to interconnect segments of the physical communications media, for example, to extend the range of a network when the physical specifications of the technology would otherwise be exceeded, while providing a one access domain for the attached stations.

~~**repeater:** A device that interconnects segments of the physical medium by retransmitting a copy of the physical layer (PHY) frame.~~

~~**service data unit:** Information that is delivered between layers or sublayers.~~

~~**single access domain:** A set of stations such that, at most, only one can transmit at a given time, with all other stations acting as (potential) receivers.~~

standard protocol: A protocol whose specification is published and known to the public and is controlled by a standards body.

station: An end station or bridge. *See also:* **bridge; end station.**

Structured Local Address Plan (SLAP): An optional standardized specification to differentiate local medium access control (MAC) addresses.

universal address: A 48-bit Extended Unique Identifier (EUI-48) or 64-bit Extended Unique Identifier (EUI-64) that is used as a unique address.

3.2 Acronyms and abbreviations

AAI Administratively Assigned Identifier

AAI-48 48-bit AAI

AAI-64 64-bit AAI

AN auto negotiation

BAN body area network

BS base station

BSS basic service set

CID	Company ~~ID-identifier~~
<u>CGMII</u>	<u>100 Gb/s media-independent interface</u>
CPE	customer-premises equipment
CS	convergence sublayer
C-SAP	control service access point
<u>DCN</u>	<u>data center networking</u>
DLL	data link layer
<u>ELI</u>	<u>Extended Local Identifier</u>
<u>ELI-48</u>	<u>48-bit ELI</u>
<u>ELI-64</u>	<u>64-bit ELI</u>
~~EPD-~~	~~EtherType protocol discrimination~~
EPON	Ethernet passive optical networks
<u>EUI</u>	<u>Extended Unique Identifier</u>
EUI-48	48-bit <u>EUI</u> ~~extended-unique-identifier~~
EUI-64	64-bit <u>EUI</u> ~~extended-unique-identifier~~
<u>FEC</u>	<u>forward error correction</u>
HLPDE	higher layer protocol discrimination entity
<u>IANA</u>	<u>Internet Assigned Numbers Authority¹⁵</u>
<u>IEEE RA</u>	<u>Institute of Electrical and Electronic Engineers Registration Authority</u>
<u>IEEE RAC</u>	<u>Institute of Electrical and Electronic Engineers Registration Authority Committee</u>
I/G	individual/group
IM	implementation model
<u>IoT</u>	<u>Internet of things</u>

¹⁵See <https://www.iana.org>.

IP	Internet Protocol
LAN	local area network
LLC	logical link control
<u>LPDU</u>	<u>logical link control protocol data unit</u>
~~LPD-LLC~~	~~protocol discrimination~~
LSAP	link service access point
LSB	least significant bit
<u>LMSC</u>	<u>Local Area Network/Metropolitan Area Network (LAN/MAN) Standards Committee</u>
MAC	medium access control, media access control ^{16 17}
MA-L	MAC Address <u>Block</u> —Large
MA-M	MAC Address <u>Block</u> – Medium
MAN	metropolitan area network
MA-S	MAC Address <u>Block</u> – Small
MCPS	MAC common part sublayer
MCPS-SAP	MAC common part sublayer data service access point
<u>MDI</u>	<u>medium dependent interface</u>
MIB	management information base
MICF	media-independent control function
MICLSAP	media-independent control link service access point
MICPSAP	media-independent control physical service access point
MICSAP	media-independent control service access point
MIH	media-independent handover

^{16 17}Both forms are used, with the same meaning. This standard uses medium.

MIHF	media-independent handover function
MLME	MAC sublayer management entity
MSAP	MAC service access point
M-SAP	management service access point
MSB	most significant bit
<u>MSDU</u>	<u>medium access control protocol data unit</u>
<u>MSTP</u>	<u>multiple spanning tree protocol</u>
NCMS	network control and management system
<u>NETCONF</u>	<u>Network Configuration Protocol</u>
<u>NID</u>	<u>Namespace Identifier</u>
<u>NUI</u>	<u>Network Unique Identifier</u>
<u>NUI-48</u>	<u>48-bit NUI</u>
<u>NUI-64</u>	<u>64-bit NUI</u>
OAM	operations, administration, and maintenance
OID	object identifier
OLT	optical line terminal
<u>OMG®</u>	<u>Object Management Group®</u>
ONU	optical network unit
OSI/RM	Open Systems Interconnection basic reference model
OUI	Organizationally Unique Identifier
PAN	personal area network
<u>PCS</u>	<u>physical coding sublayer</u>
PDU	protocol data unit
<u>PIF</u>	<u>protocol identification field</u>

PHY	physical layer (OSI reference model and IEEE 802 [®] reference model)
PHY	physical layer device or entity (IEEE 802.3 [™] reference model)
PICS	protocol implementation conformance statement
PLME	physical layer management entity
<u>PMA</u>	<u>physical medium attachment</u>
PMD	physical medium dependent
PSAP	physical service access point
~~RA~~	~~Registration Authority~~
RAN	regional area network
RM	reference model
<u>RS</u>	<u>reconciliation sublayer</u>
RSTP	rapid spanning tree protocol
SAP	service access point
<u>SAI</u>	<u>Standard Assigned Identifier</u>
<u>SAI-48</u>	<u>48-bit Standard Assigned Identifier</u>
<u>SAI-64</u>	<u>64-bit Standard Assigned Identifier</u>
<u>SLAP</u>	<u>Structured Local Address Plan</u>
SNAP	Subnetwork Access Protocol
SNMP	Simple Network Management Protocol
<u>SPB</u>	<u>shortest path bridging</u>
SSF	spectrum sensing function
SS/MS	subscriber station/mobile subscriber station
<u>TSN</u>	<u>Time-Sensitive Networking</u>
U/L	universally or locally administered

UML™	unified modeling language®
URN	Uniform Resource Name
VLAN	virtual local area network
VOIP	voice over Internet protocol
WAN	wide area network
WLAN	wireless local area network
WPAN	wireless personal area network
WRAN	wireless regional area network
YANG	The name of the data modeling language specified in IETF RFC 6020 [B16]¹⁷ and IETF RFC 7950 [B18].

4. Family of IEEE 802 standards

4.1 Key concepts

[The family of IEEE 802 standards is the collection of standards that have been developed under the IEEE 802 LMSC; see 4.4 for a list of the IEEE 802 standards current as of the publication of this standard. The scope of IEEE 802 standards is not limited to the physical layers \(PHYs\) and data link layers \(DLLs\). IEEE 802 networks use frame-based communications with source and destination addressing](#) ~~IEEE 802 networks use frame-based communications~~ over a variety of media to connect various digital apparatus regardless of computer technology and data type. ~~However, the scope of IEEE 802 standards is not limited to the physical layers (PHYs) and data link layers (DLLs).~~

~~The basic communications capabilities provided by all IEEE 802 standards are frame-based with source and destination addressing and asynchronous timing. In a frame-based system, the format is a variable length sequence of data octets. By contrast, cell-based communication transmits data in fixed length units in specified time intervals while isochronous communication transmits data as a steady stream of octets, or groups of octets, at equal time intervals.~~

¹⁷[The numbers in brackets correspond to the numbers of the bibliography in Annex A.](#)

User and management data flowing within IEEE 802 networks can be secured by a variety of authentication, secure key exchange, and encryption mechanisms that are described in the various IEEE 802 standards. In addition, IEEE 802 standards specify mechanisms by which a station is able to discover neighboring networks information that may include IEEE 802 and non-IEEE 802 technologies. IEEE 802 standards also specify mechanisms to achieve service discovery (e.g., support for Internet or virtual private network service) and session continuity [e.g., a voice over Internet Protocol (VOIP) or multimedia session] in a heterogeneous networking environment when stations, while either stationary or in motion, have a choice of connecting to multiple access networks.

The early IEEE 802 local area network (LAN) wired technologies used shared-medium communication, with information broadcast for all stations to receive. That approach has evolved over the years, but in ways that preserve the appearance of simple peer-to-peer communications behavior for end stations. In particular, the use of bridges, as described in 5.3.2, 5.3.2, for interconnecting bridgeable IEEE 802 networks is now widespread. These bridges allow the construction of networks with much larger numbers of end stations and much higher aggregate throughput than would be achievable with a single shared medium. End stations attached to such a bridged IEEE 802 network can communicate with each other just as though they were attached to a single shared medium; however, the ability to communicate with other stations can be limited by use of management facilities in the bridges, particularly where broadcast or multicast transmissions are involved. A further stage in this evolution has led to the use of point-to-point full duplex communication in LANs, either between an end station and a bridge or between a pair of bridges.

Some IEEE 802 technologies, in particular wireless-based technologies, are inherently shared-medium communication systems. They too have been augmented over time. Many wireless local area networks (WLANs) support mobile node mobility and hence dynamic topologies. These additional facilities may, depending on the IEEE 802 technology in use, restrict bridged LAN interconnects to the static topology nodes within the wireless portion of a heterogeneous technology LAN. Additionally, it is common to interconnect individual networks and bridged networks at layers above the DLL with devices called routers. The specification of routers is not provided in IEEE 802 standards.

Personal area networks (PANs) are used to convey information among a small group of participant stations. Unlike a LAN, a connection made through a PAN typically involves little or no infrastructure or direct connectivity to the world outside the connection. This approach allows small, power-efficient, inexpensive solutions to be implemented. In the context of the family of IEEE 802 standards, PANs are implemented with wireless technology and are, therefore, sometimes referred to as wireless personal area networks (WPANs).

A body area network (BAN) is a short-range, wireless communication network in the vicinity of, or inside, a body (typically a human body). BANs are used for a variety of uses, including entertainment, medical and other healthcare services. Considerations for the design of BAN devices typically include effects on antenna patterns due to the presence of the wide variety of bodies, changes in the RF channel due to user motions, and radiation pattern shaping to minimize specific absorption rate into the body.

A ~~An~~ IEEE 802 LAN is a peer-to-peer communication network that enables stations to communicate directly on a point-to-point, or point-to-multipoint, basis without requiring them to communicate with any intermediate stations that perform forwarding or filtering above the PHY. LAN communication takes place at moderate to high data rates and with short transit delays, on the order of a few milliseconds or less.

A LAN is generally owned, used, and operated by a single organization. This is in contrast to wide area networks (WANs) that interconnect communication facilities in different parts of a country or are used as a public utility. LANs are useful for deployment on a variety of scales, whether indoors or outdoors, including covering a scale up to a large building or campus environment.

A metropolitan area network (MAN) is optimized for a larger geographical area than the area of ~~is~~ a LAN, ranging from several blocks of buildings to entire cities. As with local networks, MANs can also depend on communications channels of moderate to high data rates. A MAN might be owned and operated by a single organization, but it is usually used by many individuals and organizations. MANs might also be owned and operated as public utilities. They often provide means for internetworking of local networks.

~~Personal area networks (PANs) are used to convey information among a small group of participant stations. Unlike a LAN, a connection made through a PAN typically involves little or no infrastructure or direct connectivity to the world outside the connection. This approach allows small, power-efficient, inexpensive solutions to be implemented. In the context of the family of IEEE 802 standards, PANs are implemented with wireless technology and are, therefore, sometimes referred to as wireless personal area networks (WPANs).~~

Regional area networks (RANs) generally cover a service area that is larger than the MANs. A RAN is similar to a MAN in that it is typically owned and operated by a single organization, but it is usually used by many individuals and organizations. For wireless regional area networks (WRANs), the unique propagation characteristics of the frequency bands in which they operate, typically from 30 MHz to 1 GHz, require a specialized design of the PHY and the medium access control (MAC) that can absorb long channel impulse responses and large propagation delays. In some cases, operation in these bands is subject to coordination with existing users, e.g., television broadcast.

IEEE 802 networks can also be used to perform the task of an access network, i.e., to connect end stations to a larger, heterogeneous network, e.g., the Internet.

The early IEEE 802 standards for LAN and MAN technologies were all based on the use of copper or optical fiber cables as the physical transmission medium. However, in addition to the use of cable-based media, today's IEEE 802 standards include technologies, radio and optical, that use free space as the physical transmission medium. IEEE 802 standards for wireless networks include wireless LANs, MANs, RANs, and PANs. These technologies also target usage scenarios for both fixed and mobile wireless. These IEEE 802 network solutions address [the](#) challenges of mobility, higher error rates, and potentials for signal loss and interference that are inherent to using wireless [media medium](#).

4.2 Application and support

IEEE 802 networks are intended to have wide applicability in many environments. The primary aim is to provide for low-cost devices and networks, suitable for consumer, commercial, educational, governmental, and industrial applications. The following lists are intended to show some applications and devices and, as such, are not intended to be exhaustive, nor do they constitute a set of required items. IEEE 802 networks can be found in the following environments:

- Client/server applications
- Database access
- Desktop publishing
- Electronic mail
- File transfer
- Graphics
- ~~Handover services~~
- Multimedia
- Office automation
- Vehicular communication
- Process control
- Robotics
- Telecommunication
- Text processing
- Transaction processing

IEEE 802 networks are intended to support communication, for example, between: ~~various data devices, such as the following:~~

- Networking equipment, such as bridges, routers, and gateways
- Desktop, laptop and tablet computers
- Video, audio and multimedia equipment
- Cloud computing services, including web servers and data storage
- Monitoring and control equipment
- Scanners and printers
- Mobile phones and VOIP phones (desk phones)

— Internet of Things (IoT) devices, such as: thermostats, switches, and light bulbs

~~— Bridges, routers, and gateways~~

~~— Computers~~

~~— Image and video monitors~~

~~— Mass storage devices~~

~~— Monitoring and control equipment~~

~~— Photocopiers and facsimile machines~~

~~— Printers and plotters~~

~~— Terminals~~

~~— Wireless terminals~~

4.3 An international family of standards

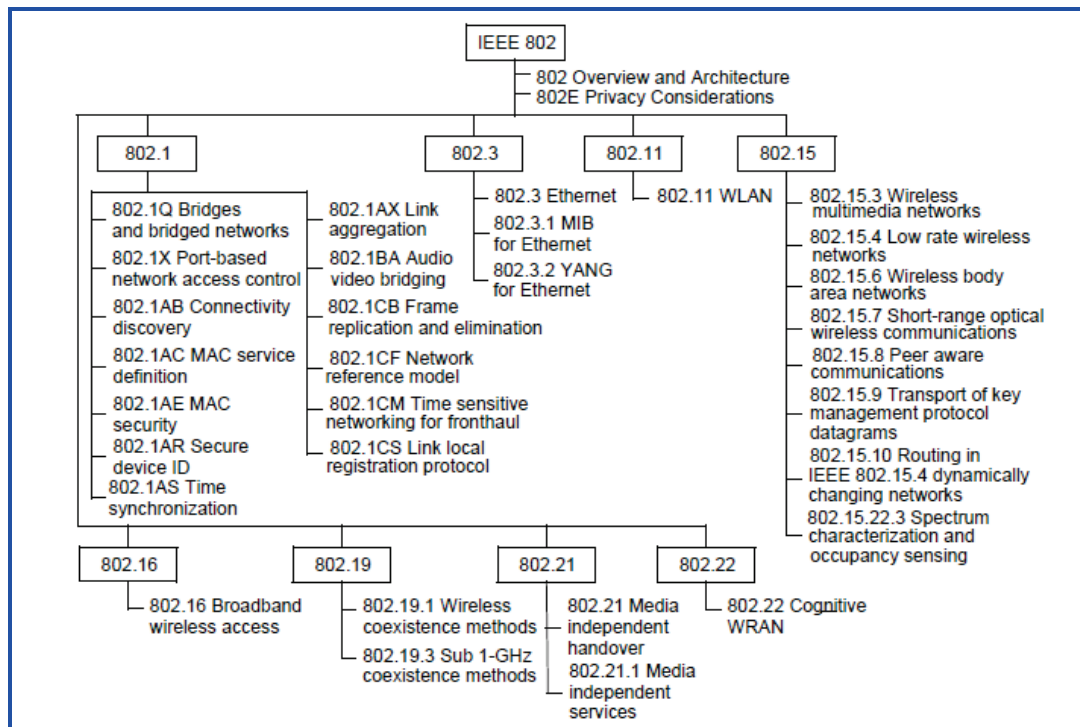
The terms PAN, BAN, LAN, *MAN*, ~~PAN~~, and *RAN* encompass a number of data communications technologies and applications of these technologies. So it is with the IEEE 802 standards. In order to provide a balance between the proliferation of a very large number of different and incompatible local and metropolitan networks, on the one hand, and the need to accommodate rapidly changing technology and to satisfy certain applications or cost goals, on the other hand, several types of medium access technologies are currently specified in the family of IEEE 802 standards. In turn, these MAC standards are specified for a variety of physical media. A secure data exchange standard and MAC bridging standards are intended to be used in conjunction with the MAC standards.

~~Architecture and protocols for the management of IEEE 802 networks are also specified.~~

The IEEE 802 standards have been developed and applied in the context of a global data communications industry. IEEE 802 standards are recognized to be international standards in their own right. In addition, some IEEE 802 standards have progressed to become standards within Joint Technical Committee 1 of the International Organization for Standardization and the International Electrotechnical Commission (ISO/IEC JTC 1), International Telecommunication Union Telecommunication Standardization Sector (ITU-T), International Telecommunication Union Radiocommunication Sector (ITU-R), and a wide variety of national body standards development organizations.

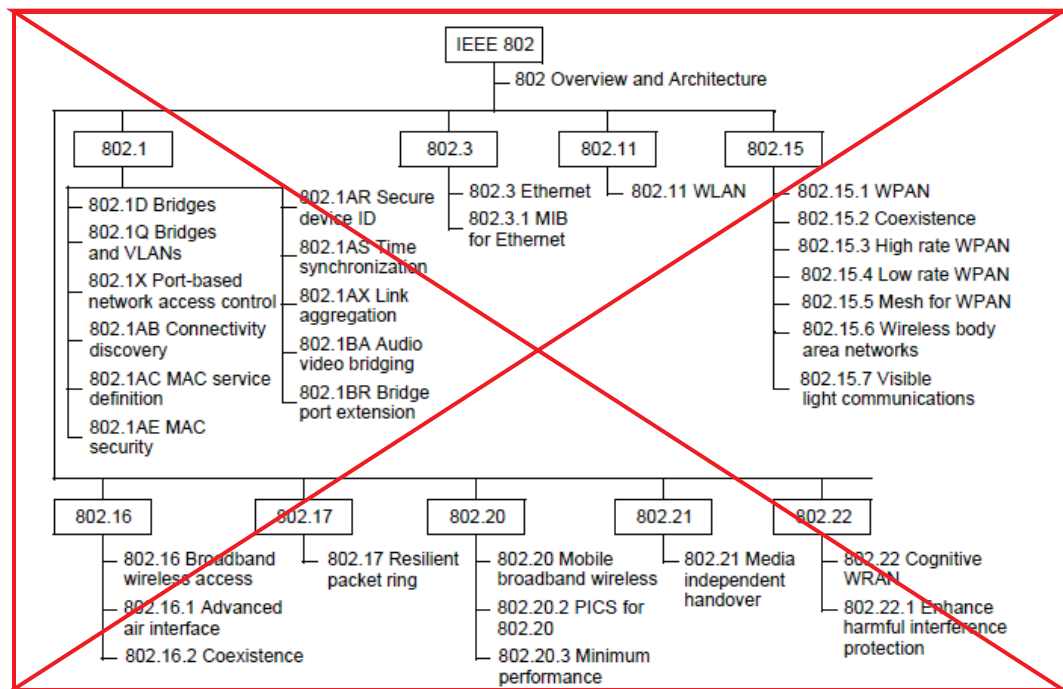
4.4 IEEE 802 standards

The IEEE 802 LAN/MAN Standards Committee sponsors a large number of standards projects. The current family state of IEEE 802 standards¹⁸ as of the approval of this standard ~~standards and recommended practices~~ is illustrated in Figure 1. ~~The IEEE 802 standards are under continuous development; committee is very active; therefore,~~ for the latest status ~~of the IEEE 802 working groups and standards,~~ refer to <https://www.ieee802.org> ~~http://www.ieee802.org~~.



(New)

¹⁸Throughout this standard, the term IEEE 802 standard is interpreted to include standards, recommended practices, and guides.

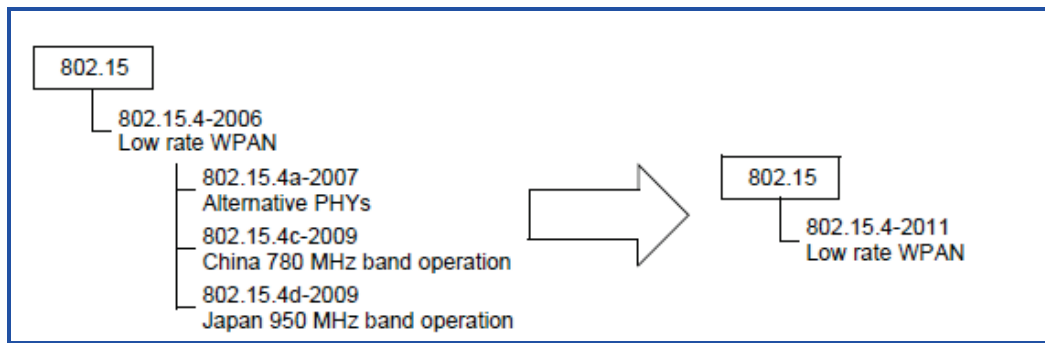


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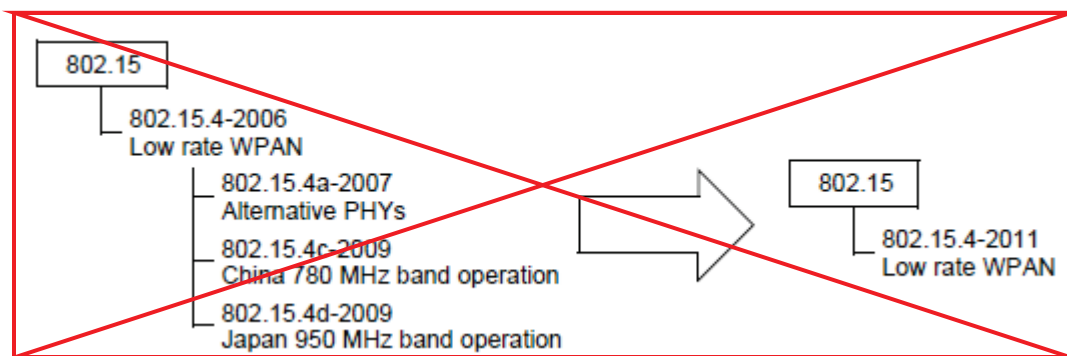
**Figure 1—Current family of IEEE 802 standards ~~and recommended~~
practices**

At any given time, an IEEE 802 standard may have one or more amendments related to it. Each amendment, once approved, is considered to be part of the base standard. At a future time, [through the periodic IEEE-SA revision process](#), these amendments are incorporated into the base standard so that a new single document can be issued. This process is illustrated in Figure 2 for IEEE Std 802.15.4™-2011, ¹⁹ ⁸ which incorporated the amendments IEEE Std 802.15.4a™-2007, IEEE Std 802.15.4c™-2009, and IEEE Std 802.15.4d™-2009 into the base standard IEEE Std 802.15.4-2006.

¹⁹ ⁸See Annex D for a list of approved IEEE 802 standards that were current when this standard was completed.



(New)



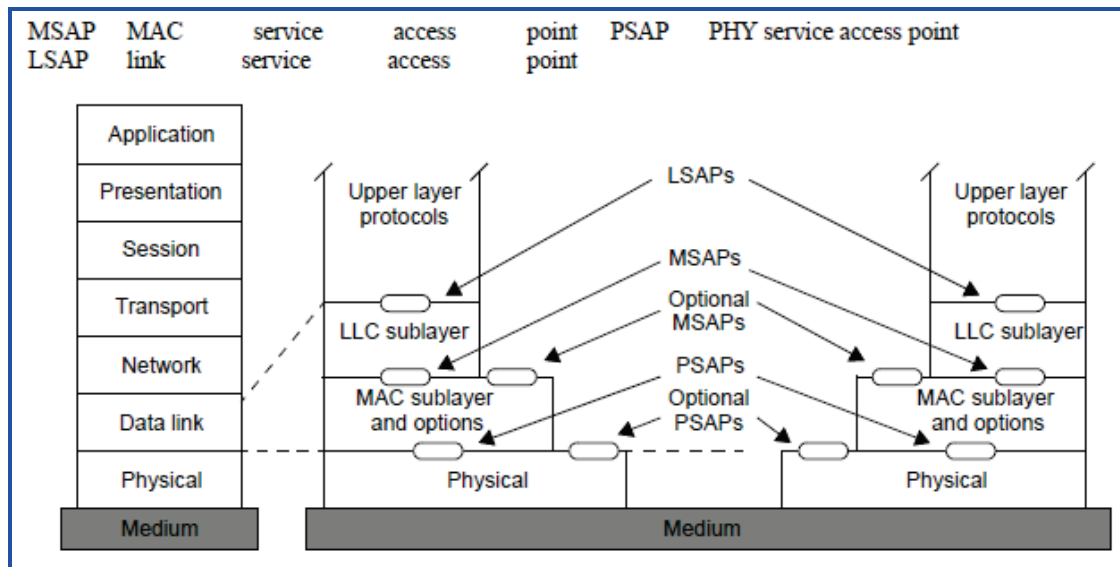
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Figure 2—Issuance of IEEE Std 802.15.4-2011 from previous base standard and amendments

5. Reference models (RMs)

5.1 Introduction

The IEEE 802 RM is derived from the Open Systems Interconnection basic reference model (OSI/RM), ISO/IEC 7498-1:1994 [B20].²⁰ [B7] It is assumed that the reader has some familiarity with the OSI/RM and its terminology. The IEEE 802 standards emphasize the functionality of the lowest two layers of the OSI/RM, i.e., PHY and DLL, and the higher layers as they relate to network management. The IEEE 802 RM is similar to the OSI/RM in terms of its layers and the placement of its service boundaries. Figure 3 shows the architectural view of IEEE 802 RM for end stations and its relation to the OSI/RM. A variation of the model applies within bridges, as described in 5.3.2.



(New)

²⁰ The numbers in brackets correspond to those of the bibliography in Annex A.

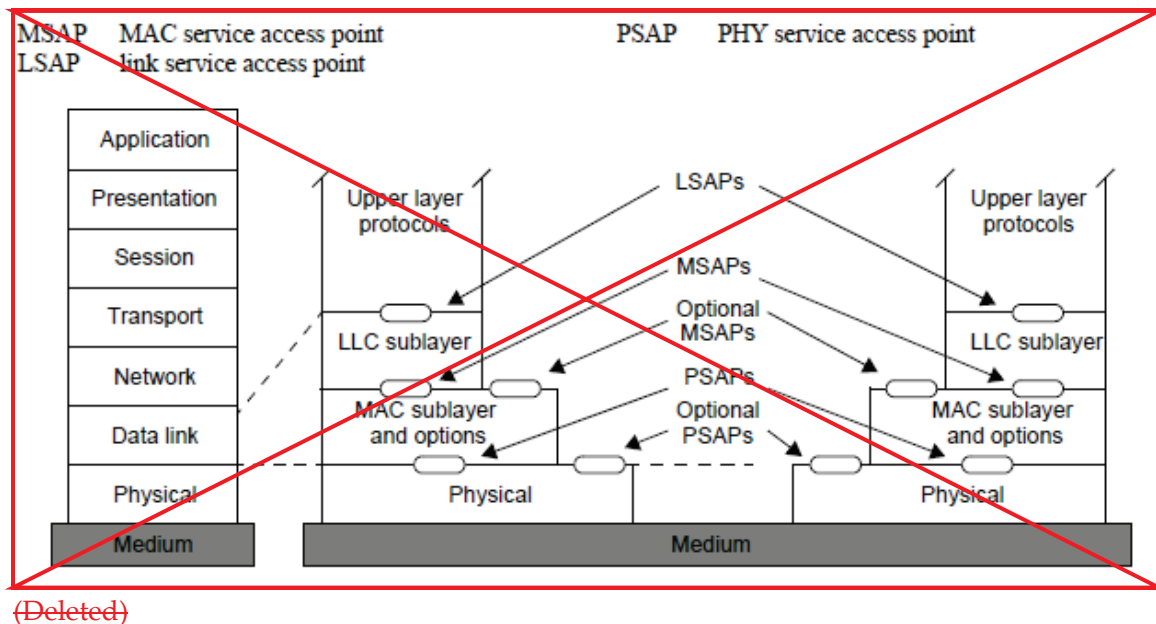


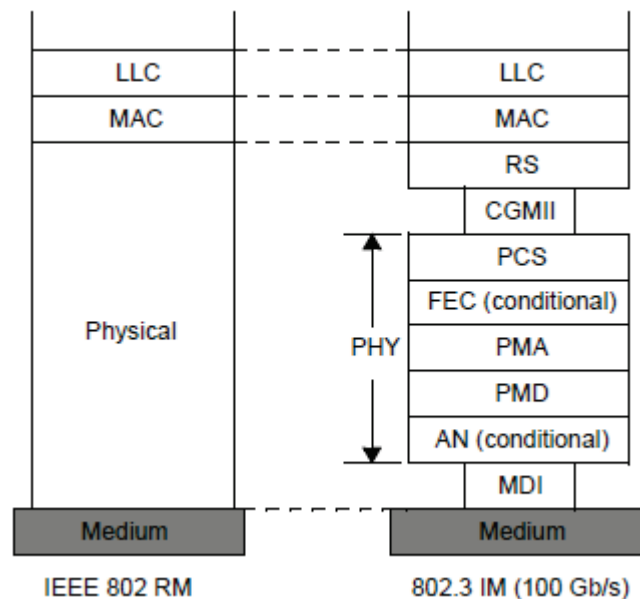
Figure 3—IEEE 802 RM for end stations

For the mandatory data services supported by all IEEE 802 networks, the DLL is structured as two sublayers, with the logical link control (LLC) sublayer, described in 5.2.2, operating over a MAC sublayer, described in 5.2.3.

Each IEEE 802 standard has RMs that are more detailed in order to describe the structure for that specific standard. The RMs for the IEEE 802 standards are given in Annex B.

The IEEE 802 [standards also provide](#) implementation models (IMs), [which](#) are more specific than the IEEE 802 RMs, allowing differentiation between implementation approaches (e.g., different MAC protocols and PHYs). Figure 4 illustrates an IEEE 802.3 IM and its relation to the IEEE 802 RM.

Considerations of management, security, and media-independent handover (MIH) in IEEE 802 networks are also covered by IEEE 802 standards; these optional features lead to an elaboration of the RM, as illustrated in Figure 5. IEEE 802 network management provides protocols for exchange of management information between stations. The media-independent control function (MICF) is a parallel control plane that provides control functions for different MAC and PHY sublayers. Some examples of this MICF are the media-independent handover function (MIHF) of IEEE Std 802.21™ and the control functions proposed in the IEEE 802.19.1 Task Group and IEEE Std 802.22™. IEEE Std 802.1X™ forms part of the LLC sublayer and provides a secure, connectionless service immediately above the MAC sublayer.



LLC — logical link control sublayer

MAC — medium access control sublayer

PHY — physical layer device

RS — reconciliation sublayer

CGMII — 100 Gb/s media-independent interface

PC — physical coding sublayer

FEC — forward error correction

PMA——physical medium attachment

PMD——physical medium dependent

AN——auto negotiation

MDI——medium dependent interface

Figure 4—An IEEE 802 IM (100 Gb/s) and its relation to the IEEE 802 RM
~~and an example of an end-station IM (100 Gb/s)~~

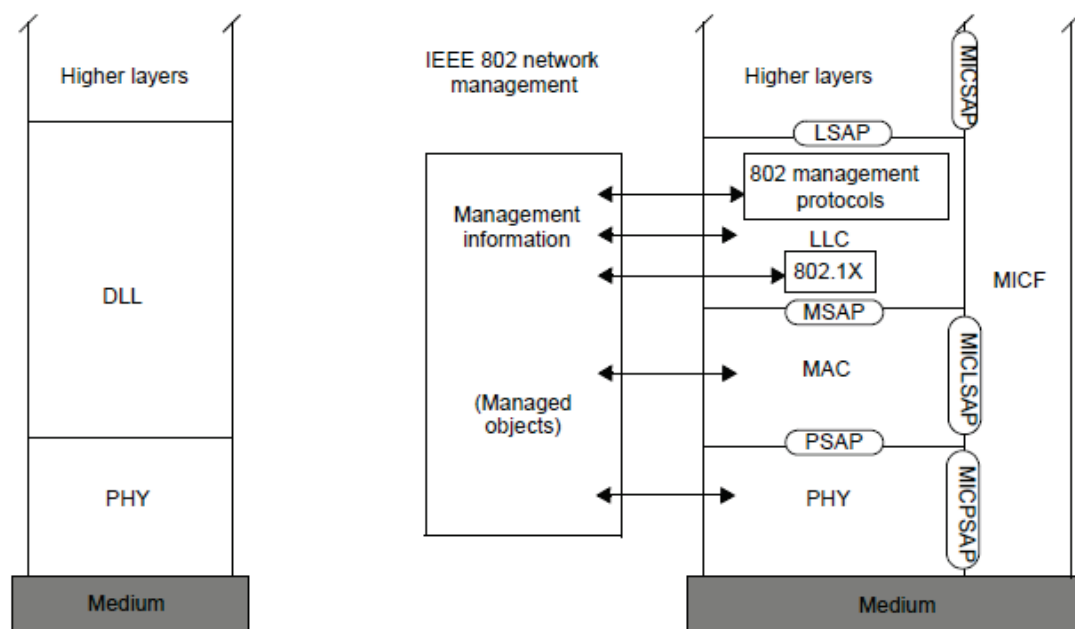


Figure 5—IEEE 802 RM with end-station management, security, and MIH

5.2 RM description for end stations

The IEEE 802 RM maps to the OSI/RM as shown in Figure-3. The applicable part of the OSI/RM consists of the lowest two layers: the DLL and the PHY. These map onto the same two layers in the IEEE 802 RM. The MAC sublayer of the IEEE 802 RM exists between the PHY and the LLC sublayer to provide a service for the LLC sublayer (certain MAC types provide additional MAC service features that can be used by LLC sublayer, in addition to the common core features). Service access points (SAPs) for connecting the layers and sublayers are shown in Figure 3.

5.2.1 SAPs

One or more link service access points (LSAPs) provide interface ports to support one or more higher layer users above the LLC sublayer.

In addition, the end station optionally provides one or more media-independent control service access points (MICSAPs) that interface between one or more higher layers and the control and management planes enabling higher layer information to pass to the MICF and vice versa.

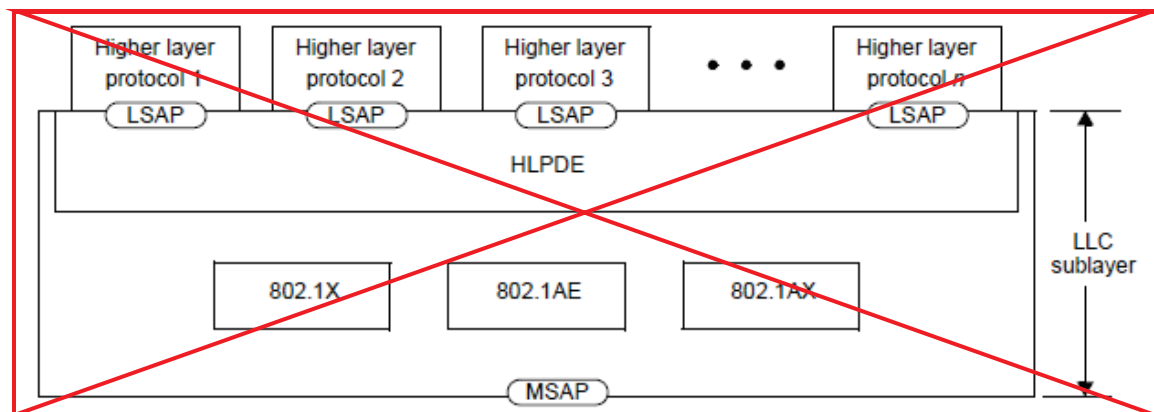
The MAC sublayer provides one or more MAC service access points (MSAPs) as interfaces to the LLC sublayer in an end station. Clause 8 provides details of how broadcast and group addresses are constructed. The MAC sublayer optionally provides a media-independent control link service access point (MICLSAP), which is used to provide an interface to support control of the MAC by the MICF.

The PHY provides a PHY service access point (PSAP). In addition, the PHY optionally provides a media-independent control PHY service access point (MICPSAP), which is used to provide an interface port for the control of the PHY by the MICF.

5.2.2 LLC sublayer

The LLC sublayer is between the MAC sublayer and the network layer (Layer 3) in the OSI model. In IEEE 802, the functions in the LLC are specified in IEEE Std 802.1 and in aspects of ISO/IEC/IEEE 8802-2:1998. Among the functions that can be present in the LLC are functions from the following:

~~The LLC sublayer contains a variety of entities, as illustrated in Figure 6.~~



(Deleted)

Figure 6—LLC sublayer in 802 RM

The higher layer protocol discrimination entity (HLPDE) is used by the LLC sublayer to determine the higher layer protocol to which to deliver an LLC sublayer protocol data unit (PDU). Two methods may be used in the HLPDE. The two methods are:

- 1) — Ethernet protocol discrimination (EPD), which uses the Ethernet value made available to the LLC sublayer through the MSAP
- 2) — LLC protocol discrimination (LPD), which uses the addresses defined in ISO/IEC 8802-2, including the Subnetwork Access Protocol (SNAP) format

IEEE Std 802.3™ is capable of natively representing the Ethernet within its MAC frame format, which is used to support EPD. IEEE Std 802.3 also natively supports ISO/IEC 8802-2 LPD (over a limited range of frame sizes). In other IEEE 802 networks, such as for IEEE Std 802.11™, LPD is also achieved using SNAP, as described in Clause 9. In either of these techniques, the Ethernet is effectively being used as a means of identifying an LSAP that provides LLC sublayer service to the protocol concerned. New IEEE 802 standards shall support protocol discrimination in the LLC sublayer using EPD.

- a) IEEE Std 802.1AE™ provides MAC security allowing authorized systems that attach to and inter-connect LANs in a network to maintain ~~with connectionless user data~~ confidentiality of transmitted data and to take measures against frames transmitted or modified by unauthorized devices ~~, frame data integrity, and data origin authenticity by media access independent protocols and entities that operate transparently to MAC clients.~~
- b) IEEE Std 802.1AX™ provides the ability to aggregate two or more links together to form a single logical link at a higher data rate.
- c) IEEE Std 802.1X provides authentication, authorization, and cryptographic key agreement mechanisms to support secure communication between end stations connected by IEEE 802 networks.

NOTE—Prior to the 2014 revision of this standard, the LLC layer was specified as only the functions described in IEEE Std 802.2. However, this did not allow for the other end-station functions developed by various IEEE 802.1 standards. Since 2014, the LLC layer has been specified to include all of the relevant functions that occur between the MAC sub-layer and the Network layer.

5.2.3 MAC sublayer

The MAC sublayer provides a data transfer service to the LLC sublayer; a data unit received by a MAC entity from its associated LLC entity is transferred to zero or more peer MAC entities for delivery to each peer MAC entity's associated LLC entity. The unit that carries the data for transfer ~~performs the functions necessary to provide frame-based, connectionless mode (datagram-style) data transfer between stations in support of the next higher sublayer, as described in 5.1, for networks that support it. The term MAC frame, or simply frame, is used to describe the datagrams transferred~~ between ~~peer~~ MAC sublayer entities is referred to as a MAC frame. In some MAC types, ~~some~~ MAC frames are also used to in support other of the MAC sublayer functionality, such as the ~~itself, rather than for~~ transfer of control or management information ~~data from the next higher sublayer.~~

The principal functions of the MAC sublayer comprise the following:

- MAC frame delimiting and recognition

- Addressing of destination stations (both as individual stations and as groups of stations)
- Conveyance of source-station addressing information
- Transparent data transfer of PDUs between peer ~~from the~~ next higher sublayers
- Protection against errors, generally by means of generating and checking MAC frame check sequences
- Control of access to the physical transmission medium
- Delivery to the next higher sublayer of data frames received with suitable destination addresses

Other functions of the MAC sublayer—applicable particularly when the supporting implementation includes interconnection devices such as bridges—include flow control between an end station and an interconnection device, as described in 5.3, and forwarding of MAC frames according to their destination addresses to reduce the extent of propagation of MAC frames in parts of an IEEE 802 network that do not contain communication paths leading to the intended destination end station(s).

The functions listed are those of the MAC sublayer as a whole. The responsibility for performing them is distributed across the transmitting and receiving end stations and any interconnection devices such as bridges. Devices with different roles, therefore, can behave differently in support of a given function. For example, the basic transmission of a MAC frame by a bridge is very similar to transmission by an end station, but not identical. Principally, the handling of source-station addressing is different.

The various MAC specifications all specify MAC frame formats in terms of a serial transmission model for the service provided by the supporting PHY. This model supports concepts such as “first bit (e.g., of a particular octet) to be transmitted” and a strict order of octet transmission in a uniform manner. However, the ways in which the model has been applied in different MAC specifications are not completely uniform with respect to bit-ordering within octets (see Clause 8, and particularly 8.6, for examples and explanation). The serial transmission model does not preclude current or future MAC specifications from using partly or wholly octet-oriented specifications of MAC frame formats or of the interface to the PHY.

5.2.4 PHY

MAC entities use their respective PHY entities to exchange bits with their peers. The PHY provides the capability to transmit and receive modulated signals assigned to one or more ~~specific frequency channels for broadband or wireless media or to a single baseband channel.~~

Whereas the service offered to the MAC sublayer is expressed as the transfer of bits (in sequences representing MAC frames), the symbols that are encoded for transmission do not always represent individual bits. In many cases ~~Particularly at speeds of 100 Mb/s and above or for wireless transmission,~~ the PHY can map blocks of multiple ~~several~~ bits ~~(e.g., 4, 5, or 8 bits)~~ to different multi-element symbols. In some PHY encodings, these symbols are subject to further transformation before transmission, and in some cases, the transmission is spread over multiple physical data paths.

5.2.5 Layer and sublayer management

The LLC, MAC, and PHY standards also include a management component that specifies managed objects and aspects of the protocol machine that provides the management view of these resources. See Clause 7 for further information.

5.3 Interconnection and interworking

In some cases, the end stations in an IEEE 802 network have no need to communicate with end stations on other networks. However, there are many cases in which end stations on an IEEE 802 network need to communicate with end stations on other networks; therefore, devices that interconnect the IEEE 802 network with other kinds of networks are required. In addition, several standard methods have been developed that permit a variety of interconnection devices to operate transparently to end stations on a network in order to extend the capabilities available to end stations, particularly in terms of the geographical extent and/or total number of end stations that can be supported.

Standard methods of interworking fall into the following three general categories, depending on the layer at which the corresponding interconnection devices operate:

- PHY interconnection, using devices usually termed *repeaters*, as described in 5.3.1
- MAC interconnection, using devices termed *bridges*, as described in 5.3.2

- Network-layer interconnection, using devices usually termed *routers*, as described in 5.3.3

5.3.1 Interconnection at the PHY

The original IEEE 802 standards were for end stations attached to a shared communication medium. This basic configuration is referred to as [an a-single](#) access domain; the domain consists of the set of stations such that, at most, only one can transmit at a given time, with all other stations acting as (potential) receivers. In this situation, the function of handling the “one-at-a-time” access arbitration is performed by the set of [MAC entities](#) ~~MACs~~ on a shared medium.

A repeater is a device used to interconnect segments of the physical communications media, for example, to extend the range of a network when the physical specifications of the technology would otherwise be exceeded, while providing [one a-single](#) access domain for the attached stations. ~~Repeaters used in support of multiple end stations attached by star-wired network topologies are frequently referred to as hubs.~~

5.3.2 MAC-sublayer interconnection: Bridges

5.3.2.1 ~~Bridges and bridged~~ IEEE 802 [bridged](#) networks

Bridges, [in the general sense](#), are stations that interconnect multiple access domains. [In this standard, the term bridge is restricted to a functional unit that provides](#) IEEE Std 802. [1Q²¹ capabilities](#) ~~1D⁴⁰ provides the basic specification~~ for bridge interworking among [bridgeable](#) IEEE 802 networks. A bridged IEEE 802 network consists of one or more bridges together with the complete set of access domains that they interconnect. A bridged IEEE 802 network provides end stations belonging to any of its access domains with the connectivity of a network that contains the whole set of attached end stations. ~~IEEE Std 802.1Q adds additional capabilities to the bridge specification in IEEE Std 802.1D including virtual local area networks (VLANs), priorities, and provider bridging, as described in 5.3.2.5.~~

[An IEEE 802](#) A bridged network can provide for the following:

- Communication between stations attached to networks of different MAC types that conform to the Internal Sublayer Service as specified in IEEE Std 802.1AC.

^{21,40}Information on normative references can be found in Clause 2.