
Information technology — Open Systems Interconnection — Systems Management: Time management function

*Technologies de l'information — Interconnexion de systèmes ouverts
(OSI) — Gestion-systèmes: Fonction de gestion du temps*



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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.

In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

International Standard ISO/IEC 10164-20 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 33, *Distributed application services*, in collaboration with ITU-T. The identical text is published as ITU-T Recommendation X.743.

ISO/IEC 10164 consists of the following parts, under the general title *Information technology — Open Systems Interconnection — Systems Management*:

- *Part 1: Object management function*
- *Part 2: State management function*
- *Part 3: Attributes for representing relationships*
- *Part 4: Alarm reporting function*
- *Part 5: Event report management function*
- *Part 6: Log control function*
- *Part 7: Security alarm reporting function*
- *Part 8: Security audit trail function*
- *Part 9: Objects and attributes for access control*
- *Part 10: Usage metering function for accounting purposes*
- *Part 11: Metric objects and attributes*
- *Part 12: Test management function*
- *Part 13: Summarization function*
- *Part 14: Confidence and diagnostic test categories*
- *Part 15: Scheduling function*
- *Part 16: Management knowledge management function*
- *Part 17: Change over function*

- *Part 18: Software management function*
- *Part 19: Management domain and management policy management functions*
- *Part 20: Time management function*
- *Part 21: Command sequencer for Systems Management*
- *Part 22: Response time monitoring function*

Annexes A, B, D and F to G form a normative part of this part of ISO/IEC 10164. Annexes C, H and I are for information only.

Introduction

ITU-T Rec. X.700 series | ISO/IEC 10164 is a Series of Recommendations | International Standards developed according to ITU-T Rec X.200 | ISO/IEC 7498-1 and ITU-T Rec. X.700 | ISO/IEC 7498-4. ITU-T Rec. X.700 series | ISO/IEC 10164 is related to the following International Standards:

- CCITT X.710 | ISO/IEC 9595:1990, Information technology – Open System Interconnection – Common management information service definition;
- CCITT X.711 and CCITT X.712 | ISO/IEC 9596:1990, Information technology – Open System Interconnection – Common management information protocol specification;
- CCITT X.701 | ISO/IEC 10040:1992, Information technology – Open Systems Interconnection – Systems management overview;
- CCITT Recs. X.730, X.740 series and ITU-T Rec. X.750 series | ISO/IEC 10064:1992, Information technology – Open Systems Interconnection – Systems Management.

OSI management standardization inevitably involves coordinated work by a number of standards bodies. ITU-T SG 7 and ISO/IEC JTC 1 SC 21/WG 4 are jointly responsible for the development of Recommendations | International Standards that describe the architecture for OSI management, the services, protocols, and functions that are used for systems management, and the structure of management information. Other working groups, in ITU-T, ISO/IEC JTC 1 SC 21, ISO/IEC JTC 1 SC 6 and elsewhere, are responsible for the development of Recommendations | International Standards that describe the management aspects of particular layers of the OSI Basic Reference Model; these may describe (N)-layer management protocols, management aspects of (N)-layer operation, and managed objects that provide a "management view" of aspects of the layer operation and are visible to systems management.

INTERNATIONAL STANDARD

ITU-T RECOMMENDATION

INFORMATION TECHNOLOGY – OPEN SYSTEMS INTERCONNECTION –
SYSTEMS MANAGEMENT: TIME MANAGEMENT FUNCTION**1 Scope**

This Recommendation | International Standard defines a Systems Management Function that may be used by an application process in a centralized or decentralized management environment to interact for the purpose of systems management, as defined by ITU-T Rec. X.200 | ISO/IEC 7498-1. This Recommendation | International Standard defines a function which consists of generic definitions, services, and functional units. This function is positioned in the application layer of ITU-T Rec.X.200 | ISO/IEC 7498-1 and is defined according to the model provided by ISO 9545. The role of systems management functions is described by CCITT Rec. X.701 | ISO /IEC 10040.

This Recommendation | International Standard:

- defines a service for the management of clocks for use by OSI management and available for use by OSI applications and others;
- establishes user requirements for this Recommendation | International Standard;
- establishes a time management function model, addressing the components of a generic time service involving communication between systems, that relates the service and generic definitions provided by this function to the user requirements;
- defines generic object classes, attribute types, operation types, notification types, and parameters documented in accordance with CCITT Rec. X.722 | ISO/IEC 10165-4;
- specifies compliance requirements placed on other standards that make use of these generic definitions;
- defines the services provided by the function;
- specifies the management protocol that is necessary in order to provide the services;
- defines the relationship between these services and systems management operations and notifications;
- specifies the abstract syntax necessary to identify and negotiate the function unit in the protocol;
- defines relationships with other systems management functions;
- specifies conformance requirements to be met by implementation of this Recommendation | International Standard;
- identifies time synchronization protocols.

This Recommendation | International Standard does not:

- address the provision of time information within a local system;
- define the nature of any implementation intended to provide the Time Management Function;
- specify the manner in which management is accomplished by the user of the Time Management Function;
- define the nature of any interaction which results in the use of the Time Management Function;
- specify the services necessary for the establishment, use, and normal or abnormal release of a management association.

2 Normative references

The following Recommendations and International Standards contain provisions which, through reference in this text, constitute provisions of this Recommendation | International Standard. At the time of publication, the editions indicated were valid. All Recommendations and Standards are subject to revision, and parties to agreements based on this Recommendation | International Standard are encouraged to investigate the possibility of applying the most recent

edition of the Recommendations and International Standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards. The Telecommunications Standardizations Bureau of the ITU maintains a list of currently valid ITU-T Recommendations.

2.1 Identical Recommendations | International Standards

- ITU-T Recommendation X.210 (1993) | ISO/IEC 10731:1994, *Information technology – Open Systems Interconnection – Basic Reference Model – Conventions for the definition of OSI services.*
- CCITT Recommendation X.701 (1992) | ISO/IEC 10040:1992, *Information technology – Open Systems Interconnection – Systems management overview*¹⁾.
- CCITT Recommendation X.720 (1992) | ISO/IEC 10165-1:1993, *Information technology – Open Systems Interconnection – Structure of management information: Management Information Model.*
- CCITT Recommendation X.721 (1992) | ISO/IEC 10165-2:1992, *Information technology – Open Systems Interconnection – Structure of management information: Definition of management information.*
- CCITT Recommendation X.722 (1992) | ISO/IEC 10165-4:1992, *Information technology – Open Systems Interconnection – Structure of management information: Guidelines for the definition of managed objects.*
- ITU-T Recommendation X.723 (1993) | ISO/IEC 10165-5:1994, *Information technology – Open Systems Interconnection – Structure of management information: Generic management information.*
- ITU-T Recommendation X.724 (1996) | ISO/IEC 10165-6:1997, *Information technology – Open Systems Interconnection – Structure of management information: Requirements and guidelines for implementation conformance statement proformas associated with OSI management.*
- CCITT Recommendation X.730 (1992) | ISO/IEC 10164-1:1993, *Information technology – Open Systems Interconnection – Systems Management: Object management function.*
- CCITT Recommendation X.731 (1992) | ISO/IEC 10164-2:1993, *Information technology – Open Systems Interconnection – Systems Management: State management function.*
- CCITT Recommendation X.732 (1992) | ISO/IEC 10164-3:1993, *Information technology – Open Systems Interconnection – Systems Management: Attributes for representing relationships.*
- ITU-T Recommendation X.738 (1993) | ISO/IEC 10164-13:1995, *Information technology – Open Systems Interconnection – Systems Management: Summarization function.*
- ITU-T Recommendation X.739 (1993) | ISO/IEC 10164-11:1994, *Information technology – Open Systems Interconnection – Systems Management: Metric objects and attributes.*
- CCITT Recommendation X.740 (1992) | ISO/IEC 10164-8:1993, *Information technology – Open Systems Interconnection – Systems Management: Security audit trail function.*
- ITU-T Recommendation X.741 (1995) | ISO/IEC 10164-9:1995, *Information technology – Open Systems Interconnection – Systems Management: Objects and attributes for access control.*
- ITU-T Recommendation X.742 (1995) | ISO/IEC 10164-10:1995, *Information technology – Open Systems Interconnection – Systems Management: Usage metering function for accounting purposes.*
- ITU-T Recommendation X.745 (1993) | ISO/IEC 10164-12:1994, *Information technology – Open Systems Interconnection – Systems Management: Test management function.*
- ITU-T Recommendation X.746 (1995) | ISO/IEC 10164-15:1995, *Information technology – Open Systems Interconnection – Systems Management: Scheduling function.*

¹⁾ As amended by ITU-T Rec. X.701/Cor.2 | ISO/IEC 10040/Cor.2.

2.2 Paired Recommendations | International Standards equivalent in technical content

- CCITT Recommendation X.208 (1988), *Specification of Abstract Syntax Notation One (ASN.1)*.
ISO/IEC 8824:1990, *Information technology – Open Systems Interconnection – Specification of Abstract Syntax Notation One (ASN.1)*.
- CCITT Recommendation X.209 (1988), *Specification of basic encoding rules for Abstract Syntax Notation One (ASN.1)*.
ISO/IEC 8825:1990, *Information technology – Open Systems Interconnection – Specification of Basic Encoding Rules for Abstract Syntax Notation One (ASN.1)*
- ITU-T Recommendation X.291 (1995), *OSI conformance testing methodology and framework for protocol Recommendations for ITU-T applications – Abstract test suite specification*.
ISO/IEC 9646-2:1994, *Information technology – Open Systems Interconnection – Conformance testing methodology and framework – Part 2: Abstract Test Suite specification*.
- ITU-T Recommendation X.296 (1995), *OSI conformance testing methodology and framework for protocol Recommendations for ITU-T applications – Implementation conformance statements*.
ISO/IEC 9646-7:1995, *Information technology – Open Systems Interconnection – Conformance testing methodology and framework – Part 7: Implementation Conformance Statements*.
- CCITT Recommendation X.700 (1992), *Management framework for Open Systems Interconnection (OSI) for CCITT applications*.
ISO/IEC 7498-4:1989, *Information processing systems – Open Systems Interconnection – Basic Reference Model – Part 4: Management framework*.
- CCITT Recommendation X.710 (1991), *Common management information service definition for CCITT applications*.
ISO/IEC 9595:1991, *Information technology – Open Systems Interconnection – Common management information service definition*.
- CCITT Recommendation X.711 (1991), *Common management information protocol specification for CCITT applications*.
ISO/IEC 9596-1:1991, *Information technology – Open Systems Interconnection – Common management information protocol – Part 1: Specification*.

2.3 Additional references

- ITU-T Recommendation M.3100 (1995), *Generic Network Information Model*.
- ITU-T Recommendation M.3101 (1995), *Managed object conformance statements for the Generic Network Information Model*.
- ISO/TR 8509:1987, *Information processing systems – Open Systems Interconnection – Service conventions*.

3 Definitions

For the purposes of this Recommendation | International Standard, the following definitions apply.

3.1 Management framework definitions

This Recommendation | International Standard uses the following term defined in CCITT Rec. X.700 | ISO/IEC 7498-4:

- managed object;

3.2 Systems management overview definitions

This Recommendation | International Standard uses the following terms defined in CCITT Rec. X.701 | ISO/IEC 10040:

- a) managed object class;
- b) Management Information Conformance Statement (MICS);
- c) Managed Object Conformance Statement (MOCS);

- d) MICS proforma;
- e) MOCS proforma;
- f) notification.

3.3 CMIS definitions

This Recommendation | International Standard uses the following term defined in CCITT Rec. X.710 | ISO/IEC 9595:

- attribute.

3.4 Management information model definitions

This Recommendation | International Standard uses the following terms defined in CCITT Rec. X.720 | ISO/IEC 10165-1:

- a) action;
- b) behaviour;
- c) name binding;
- d) package;
- e) superclass.

3.5 Guidelines for the definition of managed objects definitions

This Recommendation | International Standard uses the following term defined in CCITT Rec. X.722 | ISO/IEC 10165-4:

- template.

3.6 Implementation conformance statement proforma definitions

This Recommendation | International Standard uses the following terms defined in ITU-T Rec.X.724 | ISO/IEC 10165-6:

- a) Managed Relationship Conformance Statement (MRCS);
- b) Management Conformance Summary (MCS);
- c) MCS proforma;
- d) MRCS proforma.

3.7 Additional definitions

For the purposes of this Recommendation | International Standard, the following definitions apply.

3.7.1 actual clock rate: The actual clock rate is the frequency or rate at which a clock increments, including any modifications resulting from frequency adjustment or clock training. The actual clock rate is equivalent to the basic clock rate in the absence of or prior to any frequency adjustment modifications.

3.7.2 accuracy: Accuracy is a measure of how well a local clock's time value and frequency compare to UTC.

3.7.3 adjustment rate: Adjustment rate is the frequency or rate at which a single time adjustment is applied to the local clock.

3.7.4 basic clock rate: The basic clock rate is the frequency or rate at which a clock increments in the absence of any modifications resulting from frequency adjustment.

3.7.5 Coordinated Universal Time (UTC): The time reference that is assumed to be universally correct. UTC was adopted by CCIR Recommendation 470 and described in CCIR Report 517. This is not the ASN.1 representation of generalized time.

3.7.6 correct clock: A clock where the absolute value of the error is less than its maximum error.

3.7.7 frequency offset: The first derivative of the clock's error. That is, the frequency offset is the actual rate of change of error of the clock.

- 3.7.8 error of a clock:** The time offset between the clock's reading and UTC at a given instant.
- 3.7.9 functioning clock:** A clock in which either the frequency offset is within the maximum frequency error of the clock or the clock is undergoing an adjustment. A functioning clock may be correct or incorrect.
- 3.7.10 granularity:** The maximum precision permitted by a representation of time.
- 3.7.11 local clock:** The collection of hardware and software that comprises a local source of time for a system.
- 3.7.12 maximum drift of a clock:** The manufacturer's specified maximum value of frequency offset.
- 3.7.13 maximum error of a clock:** The maximum error bound of the absolute value of the error of a clock.
- 3.7.14 precision:** The smallest value by which a clock changes.
- 3.7.15 rapport:** The state when the local clock is correct and the maximum error of the clock is within the user specified maximum error.
- 3.7.16 synchronization domain:** The set of local clocks involved in the exchange of time information for the purposes of coordination. This includes local clock and clock coordination resources. The members of this set are defined by administrative, platform, or environmental considerations.
- 3.7.17 synchronization source:** The source chosen by an algorithm of policy for time synchronization.
- 3.7.18 time offset:** The algebraic difference between the readings of two clocks at a given instant in time.

4 Abbreviations

For the purposes of this Recommendation | International Standard, the following abbreviations apply:

DTS	Distributed Time Service
GPS	Global Positioning System
LAN	Local Area Network
NTP	Network Time Protocol
PCS	Probabilistic Clock Synchronization
RPC	Remote Procedure Call
UTC	Coordinated Universal Time

5 Conventions

This Recommendation | International Standard defines services for the Time Management function following the descriptive conventions defined in ISO/TR 8509.

The following notation is used in the service parameter tables:

- M The parameter is mandatory
- C The parameter is conditional
- (=) The value of the parameter is identical to the corresponding parameter in the interaction described by the preceding related service primitive
- U The use of the parameter is a service-user option
- The parameter is not present in the interaction described by the primitive concerned

6 Requirements

Systems management functions have requirements to record accurately the time of occurrence of alarm notifications, fault event notifications, summarization notifications, and accesses of attribute values of managed objects. Observations of attribute values of managed objects can be observation time of attribute value, time that attribute value was changed, and time interval calculations. Also, system management includes the scheduling of managed objects. Scheduling includes the control of object attributes such as start-time, stop-time, begin-time, and end-time, and involves the tracking of seconds, hours, weeks, months, and years. In addition, applications beyond the scope of systems management require a stable robust time service.

The service objective of the Time Management function is to provide correct, accurate, and stable time among systems. The implementation of the Time Management function shall be consistent with the user's communication system application.

The derived requirements are summarized below and detailed in the following subclauses:

The time management function shall:

- define a representation of time that incorporates both a time value and an accuracy, has a granularity of at least 1 nanosecond, has a range of at least AD 1 to AD 3000, and represents time instants that occur with leap days;
- provide accurate and correct time;
- minimize the time and frequency error of each system;
- accommodate the distribution of time-related information to other systems;
- preserve the correctness of clocks;
- be robust against single failures;
- provide mechanisms to set or adjust the time value of the local clock;
- provide mechanisms to automatically configure the synchronization subnet; and/or
- provide mechanisms to adjust the frequency of the local clock.

6.1 Time representation requirements

The time management function shall define a representation of time that incorporates both a time value and an accuracy. The time representation shall have a granularity equal to or smaller than 1 nanosecond. The time representation range shall cover the period AD 1 to AD 3000.

NOTE – The following information is provided to illustrate the period of time and granularity that can be represented in 64 bits. A time representation of 64 bits with a granularity of 100 nanoseconds will cover approximately 59,973 years. Reducing the granularity to 1 nanosecond will reduce the time range represented to approximately 600 years.

The time representation shall represent time instants that occur within leap days.

The time representation need not permit the direct representation of time instants that occur within leap seconds.

6.2 Time accuracy and precision requirements

Each time value shall have an accuracy and precision associated with it. The precision is reflected in the accuracy as well as being a separate parameter. The accuracy can be represented in terms of an estimated error.

NOTE – For specialized environments, it may be necessary for accuracy and precision requirements to be specified. This is discussed under the context of the user time service in Annex I.

The accuracy of any system's clock shall not be constrained by parameters in the time management function or the underlying time synchronization protocol. A time synchronization protocol will minimize the error and maximum error of a system's clock, subject to the limitations of the underlying hardware and networks.

The bound on the deviation of any two system's clocks shall not be constrained by parameters in the time management protocol. The time management protocol will minimize the deviation between any two system's clocks, subject to the limitations of the underlying hardware and networks.

The time management protocol shall provide an indication of the maximum error at each system. (This implicitly bounds the maximum possible deviation, since it is the sum of the two maximum errors.)

Optionally, the time management function will provide the user with a management parameter that allows the required accuracy of the local clock to be specified.

6.3 Time distribution requirements

The time management function shall allow for the distribution of time management information between systems. The time management function shall be capable of operating over a wide-area network that may have large stochastic delays on the transmission paths.

The time management function shall have a mechanism for accommodating leap seconds.

6.4 Time service reliability requirements

The time management function shall preserve the correctness of clocks. If all the clocks in a synchronization domain are functioning and are correct at some time, they will remain correct at future times.

The time management function shall be configurable such that it will be robust against single failures, including intentionally induced failures. More precisely, it should be possible to configure the time management function such that in a managed network if the clock on a single system fails or is compromised, this will not affect the correctness of the clocks on any other system. This should include the failure of an external reference clock.

Each local time system shall maintain information about the state of its own time service as well as that of time services with which it is exchanging time information. Upon detection of a fault within itself or at a remote system, notifications shall be raised for potential transmission to a managing system.

The time management function shall be self-correcting in the presence of single failures. Specifically, if a single system in a managed network has an incorrect but functioning clock, it will converge to become a correct clock.

The local clocks shall be able to provide accurate and correct time even with relatively large stochastic delays on the transmission paths.

6.5 Local clock requirements

The implementation of a local clock is outside the scope of this Recommendation | International Standard. However, in order to support the time management function, a local clock has the following requirements.

A local clock shall provide mechanisms to set its time in the event of initialization or fault and to adjust its time periodically during normal operation.

As part of the procedures for periodically adjusting the time during normal operation, a local clock shall provide mechanisms to prevent itself from running backward. A local clock which has a positive error shall temporarily slow down, and a local clock which has a negative error shall temporarily speed up. The adjustment rate of the local clock must be greater than the maximum drift rate of the clock. A local clock shall converge to correct time.

NOTE 1 – Care must be taken to correctly tune the adjustment rate. An adjustment rate that is too fast will result in an unstable clock, and an adjustment rate that is too small will never converge.

Optionally, a local clock shall provide mechanisms to effect permanent adjustment of the basic clock rate of the local clock. This adjustment is reflected in a new actual clock rate for the local clock. This may be accomplished using mechanisms either within or outside of the time management function protocol.

In order to minimize the human configuration management of local clocks, the time management function shall have an automatic mechanism to configure their local clocks to the most accurate and stable clock (reference source) within its synchronization domain. A mechanism to allow a method for a new local clock to request information on available references shall be provided. Frequent changing among reference sources shall be minimized.

NOTE 2 – A directory service mechanism may be used here.

The time management function shall compensate for the expected frequency offset of the local clock used in the local system.

The local clock shall be able to switch reference clocks in the event that:

- a) the current reference fails to respond for a period of time that threatens the accuracy of the local clock; or
- b) the synchronizing dispersion indicates that statistical tolerance limits have been exceeded at the current reference.

7 Model

The purpose of the time management function is to manage the resources related to the provision of quality time information in a system. In this clause, the generic functionality involved in the provision of time information is defined.

and the components of that functionality that are within the scope of the time management function are identified. The time-related resources in a system are identified. A model for the time management function is provided, and the clock coordination function is defined.

7.1 Generic time functionality

All of the components necessary to provide and manage time information in a system make up a set of generic time functions. The foundation of all these functions is a clock which includes a local clock and optionally external time references. These generic time functions can be organized as three basic components that interact with these clocks. These components are a clock coordination function, time management function, and time user function. Figure 1 illustrates generic time functionality.

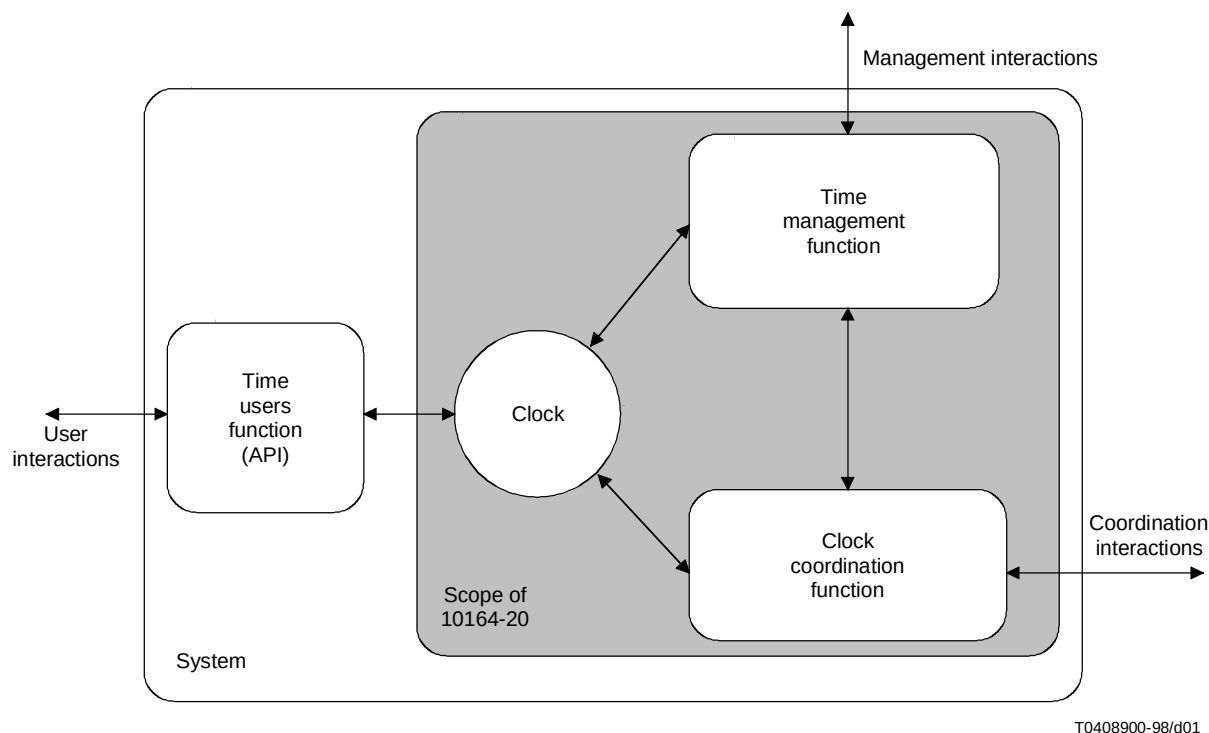


Figure 1 – Generic time functionality

The clock coordination function synchronizes individual clocks in different systems to each other and to national and international time standards. It includes the mechanisms necessary to exchange time information between individual local clocks and the algorithms required to process this information to arrive at meaningful conclusions. There may be multiple clock coordination solutions being utilized in a system.

The time management function includes the functionality necessary to monitor and control both the clocks and the clock coordination process.

Finally, the time user function of generic time functionality provides users with access to time information including the current time value and the accuracy of that value. A time user is any consumer of time values including application processes, operating systems, and OSI communication and management processes.

This Recommendation | International Standard addresses those components of generic time functionality that involve communication between systems. This includes the clock coordination and time management components defined above. Clock coordination is by its very nature a distributed algorithm; however, time management conforms to the standard manager/agent model present in other system management functions. The time user component, while very important to a local system, is considered a local issue and outside the scope of this effort.

NOTE – There are a number of issues related to the provision of a time user service in a local system. These are discussed in Annex I.

7.2 Time Management Function

This subclause identifies the resources managed by the Time Management Function and presents the model for the management of these resources.

7.2.1 Time-related resources

There are two resources related to the provision of time information to the users or consumers of that information. These resources are clocks and clock coordination tools.

Clocks can be either local clocks or external time references. A local clock is the collection of hardware and software components that comprises a single source of time information within a system. An external time reference is an interface located within a system that provides access to a specialized external clock with specified parameters and a relationship to national or international time standards.

Clock coordination is the collection of protocol mechanisms, procedures, and algorithms that are used to exchange time information between individual clocks and to process that information to provide for the coordination of the same clocks. Generally, this coordination takes place between local clocks in different systems using a clock coordination protocol. Clock coordination also takes place between local clocks and external references within a system. This coordination may be through either a clock coordination protocol or local means and is outside the scope of this Recommendation | International Standard.

The time management function is primarily concerned with managing two types of time-related resources, clocks and synchronization protocols. To this end, the time management function defines two classes and two subclasses of managed objects and the functions that pertain to the management of those objects. These objects include those that model time sources or clocks and those that model the clock coordination process. This relationship is shown in Figure 2.

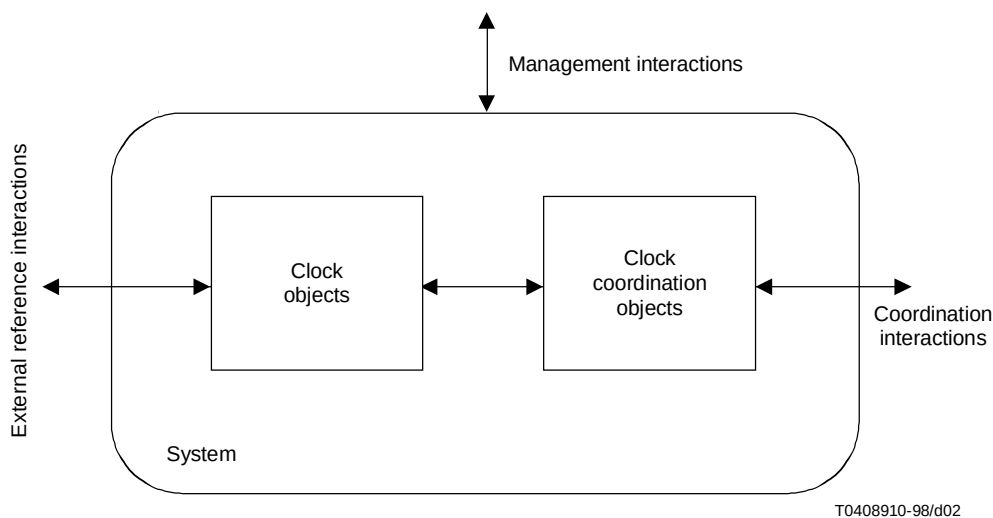


Figure 2 – Time-related resources

7.2.2 Time management functions

The following functions related to time management are identified. Of these, the first three are related to clock objects and the last four are related to clock coordination objects:

- Get Clock Status;
- Modify Clock parameters;
- Reset Clock;
- Distribute Leap Second Warning;
- Get Protocol Status (overall and per association);
- Modify Protocol Machine (add/remove peer, change polling interval, change required accuracy);
- Start/Stop Protocol Machine.

7.2.3 Time management function managed objects

The time management function defines four managed objects:

- 1) the clockSource object;
- 2) the localClock object;
- 3) the referenceClock object; and
- 4) the synchronizationProtocol object.

The first three objects are used to model time sources or clocks while the latter models the clock coordination process. The synchronizationProtocol object class can be specialized (i.e. subclassed) to represent specific time synchronization protocols. For example, Annex B specifies a subclass for the Network Time Protocol (NTP). The specification of further subclasses for additional time synchronization protocols is for further study. Figure 3 illustrates the inheritance hierarchy of the TMF, and Figure 4 shows the name bindings.

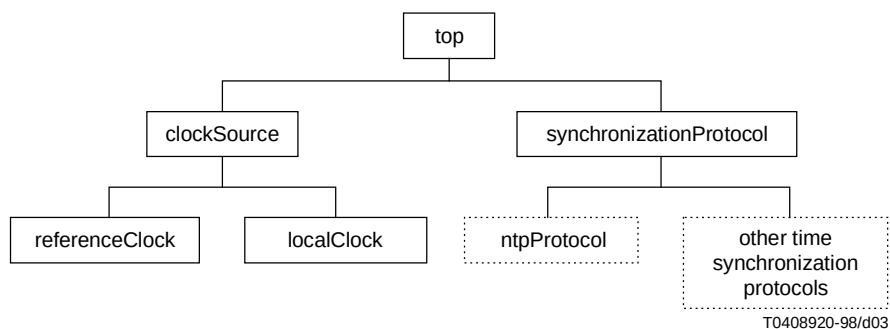


Figure 3 – Time management function inheritance hierarchy

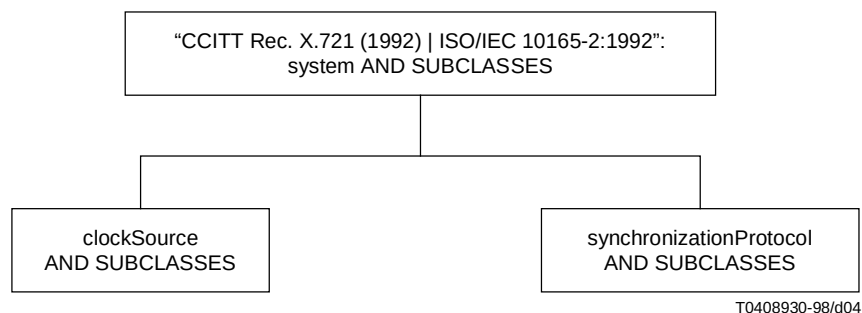


Figure 4 – TMF name bindings

7.2.4 The clockSource managed object

The clockSource object models the dynamic state of a clock. Two subclasses are defined to further distinguish between internal system clocks and external reference clocks. The clockSource object must contain the following attributes:

- the identity of the clock;
- the operational state;
- the clock status;
- the clock value;
- the clock event counter;
- the clock event code; and
- clock event time.

The clockSource object may contain the following attributes:

- precision;
- clock drift;
- the maximum error;
- the estimated error;
- the time, date and form (insert/delete) of the next leap second; and
- the time, type and total count of leap second clock events.

The clockSource object provides an action to:

- reset the clock.

The clockSource object provides a notification for:

- state change.

7.2.4.1 The localClock managed object

Each source of time information in a real system is considered to be a local clock. A local clock is conceptually the hardware and software that constitutes the source of time information in the system. A functioning local clock is one in which the maximum frequency error of the clock does not exceed the manufacturer's tolerance specified for that clock.

The above statement requires very little of a clock. It asserts only that a clock must run at about one second per second. This statement makes no assertion about the current time or the clock's correctness. It also makes no assertion about predicting the future rate of the clock based on its previous behaviour. As a statement about the properties of the local clock, this statement is manifestly independent of the network and the network's properties.

The local clock object is the model of the local clock resource used in the time management function. This object is derived from the clockSource object and contains the following attributes in addition to those specified in the clockSource object:

- the network address of the clock;
- the network addresses of its peer clocks;
- the adjustment interval of the clock;
- the current synchronization source for this clock;
- the maximum error acceptable for this clock;
- the clock stratum.

7.2.4.2 The referenceClock managed object

The reference clock object provides a mechanism for modeling the interfaces to unique sources of external time. This include interfaces to such time sources as Global Positioning System (GPS), radio sources (WWV), and atomic oscillators (cesium clock standards). It is expected that there would only be a few of these in any particular synchronization domain. The referenceClock object is derived from the clockSource object and contains the following attribute in addition to those specified in the clockSource object:

- the source/type of the external time.

7.2.5 The synchronizationProtocol managed object

A synchronizationProtocol object represents an individual instantiation of a protocol used to exchange time information between various local clocks. The synchronizationProtocol object can be used (e.g. as in subclasses) to represent different time synchronization protocols. The synchronizationProtocol object includes attributes to indicate:

- the identify of the time synchronization protocol;
- the type of the time synchronization protocol;
- the local clock(s) currently being coordinated;
- the list of other clocks with which time information has been exchanged.

The synchronizationProtocol object provides actions to:

- distribute leap second indications;
- reset the coordination protocol.

The synchronizationProtocol object class can be specialized (i.e. subclassed) to represent specific time synchronization protocols. For example, Annex B specifies a subclass for the Network Time Protocol (NTP). The specification of further subclasses for additional time synchronization protocols is for further study.

7.3 Clock coordination function

The clock coordination function provides for the coordination of clocks for the purposes of time synchronization. The clock coordination function represents one of the resources being managed by the time management function. Because of the lack of an appropriate Recommendation | International Standard defined elsewhere, it has been decided to define one solution for this function within the scope of this Recommendation | International Standard.

Different clock coordination functions exist and may be used. Multiple clock coordination functions can exist in a single system. The interaction between these various clock coordination functions is outside the scope of this Recommendation | International Standard. Additionally, local clock coordination functions between local clocks and external references within a single system are outside the scope of this Recommendation | International Standard. For completeness, one clock coordination function will be defined as part of this Recommendation | International Standard.

For the purposes of modeling, clock coordination is divided into two components, the time synchronization protocol and the time synchronization procedures. The time synchronization protocol includes the mechanism used to exchange time information between clocks in a synchronization domain. The time synchronization procedures component incorporates the procedures and algorithms required to process and act on this information locally for the purposes of clock coordination. An overview of these procedures is given in the following subclauses.

7.3.1 Time synchronization protocol

The time synchronization protocol is used to exchange time information between systems for the purposes of synchronization. There are a number of current time synchronization protocols identified and discussed in Annex H. The time management function will enable the management of these protocols. In addition, this function will define a time synchronization protocol that addresses the requirements identified in clause 6. The following procedures are identified for the time synchronization protocol.

7.3.1.1 Time inquiry procedure

The **time inquiry procedure** provides a mechanism to obtain a time value. The time inquiry procedure is abstractly presented as a remote procedure call. A time inquiry procedure is the mechanism by which the local clock obtains time information from other entities. Abstractly, it consists of a remote procedure call to remote local clocks on other real systems. The remote local clock returns the following information regarding itself: the time and maximum error, a warning concerning the time of occurrence of the next leap second (as available from a national means of dissemination), and a minimum bound on the time delay associated with processing the request at that system.

7.3.1.2 Time transmit procedure

The **time transmit procedure** provides an optional mechanism to periodically broadcast the current time and maximum error. This permits light-weight local clock implementations which obtain the time by listening for this broadcast and adjusting their local clocks accordingly.

7.3.2 Procedures for time synchronization

Time synchronization procedures are used to process and make decisions with the information collected by the time synchronization protocol. The protocols described in Annex H incorporate aspects of both the time synchronization protocol and the time synchronization procedures components of clock coordination.

7.3.2.1 Time supply procedure

The **time supply procedure** provides a mechanism to provide a time value upon request. The local clock presents this time value. The local clock may maintain its maximum error as well as its time. For instance, if the local clock is implemented as a counter in memory which is incremented by the clock precision at each clock tick, a second counter (the maximum error) would be incremented by the product of the clock precision and the maximum drift (as specified by the clock manufacturer) of the clock at each tick. This maintenance of the maximum error must imply the statement that a clock which is functioning and initially correct remains correct. The two values (time value and accuracy) are consistent with each other in reference to the same point in time (i.e. they are atomic at the interface to the time service).

7.3.2.2 Time synchronization procedure

The **time synchronization procedure** is periodically invoked to compute a new time offset for the local clock. This is done by invoking the time inquiry procedure for each of the local clocks currently sharing time information with this particular local clock. After the information is gathered, a network time and maximum error are computed based on the

responses. This is compared to the local clock's time, and a time offset is calculated. Based on the value of the time offset and the management policies for a particular local clock, either a time adjustment or a time update is performed.

7.3.2.3 Time adjustment procedure

The **time adjustment procedure** provides a mechanism to advance or retard the frequency of the local clock for a specified period of time. This results in an adjustment of the local clock's value by small amounts, gradually reducing the clock's error. This adjustment should use the clock adjustment rate. In this case, since the purpose of the adjustment is to reduce the error of the local clock, the maximum error should be reduced during the course of the adjustment by the magnitude of the adjustment so far completed.

7.3.2.4 Time update procedure

The **time update procedure** provides a mechanism to abruptly change the value of a clock when gradual adjustments will not suffice. This is most commonly used during initialization and when it has been determined that the local clock is faulty. It could also be used instead of the time adjustment procedure to make the standard adjustments necessary to maintain synchronization. Changing the time of the local clock requires specifying a maximum error. The update of the time and maximum error must be consistent with each error (atomic at the interface to the time service).

7.3.2.5 Next leap second procedure

The **next leap second procedure** provides a mechanism to specify the time of the next leap second and whether it is to be inserted or deleted. When the time of the next leap second is reached, the clock adjusts its time to compensate for the leap second. Whether this adjustment is a step adjustment or a gradual adjustment is currently a local matter. Systems requiring a more stable timeframe around the occurrence of a leap second will need to address this issue in a more rigorous manner.

7.3.2.6 Frequency adjustment computation procedure

The **frequency adjustment computation procedure** is periodically invoked to compute a new frequency adjustment for the local clock to be used by the frequency adjustment procedure. This is an optional procedure that examines the time offset adjustments required by previous time synchronization procedures. If the local clock exhibits an explicit systematic pattern of time offsets required, the local clock's frequency (actual clock rate) may be adjusted within the limits of the hardware and clock software.

7.3.2.7 Frequency adjustment procedure

The **frequency adjustment procedure** provides a mechanism to adjust the apparent frequency of the local clock (sometimes referred to as clock training). This is an optional procedure that changes the apparent frequency (actual clock rate) of the local clock. In this case, the mechanism must also permit modifying the specified maximum drift of the clock. The two attributes should be atomically updated.

7.4 Time user function

The time user function component provides users with access to time information including time values in various formats, the quality (accuracy, precision, etc.) of the time values, time interval counters, etc. However, this portion of generic time functionality is considered a local issue and outside the scope of the time management function.

8 Generic definitions

8.1 The representation of time

A representation of time for use by the time management function and any OSI management functions or user applications requiring this service shall include a time value, a maximum error, and an epoch. There are several additional representations of time specified by various international standards bodies.

This representation of time is two values representing the number of seconds plus the number of nanoseconds since an epoch, with a base date of 0 hours, 0 minutes, 0 seconds GMT on January 1, 1970. This representation has a precision of 1 nanosecond and a range of approximately 600 years per epoch. The occurrence of leap seconds will be noted for conversion to other time formats; however, it will not cause a discontinuity in this time representation. Additionally, the local time zone is noted for conversion to other time formats.

The representation of the maximum error of the time stamp is an integer representing a number of nanoseconds. The maximum error has a range of zero nanoseconds to approximately 3 days (281 474 976 710 654 nanoseconds). The maximum value represents the condition where there is no estimate of the error available.

The representation of the local time zone is an integer representing the number of minutes east of GMT. Values outside of the range from 780 to –780 minutes are undefined or unknown. The local time zone indicates the timezone in which the timestamp was created.

The representation of an epoch is an integer representing the approximately 600 year period (4 294 967 296 seconds) being represented (with an epoch of 0 indicating the period beginning in 1970). The epoch effectively increases the range of the representation to between approximately 74 800 BCE and AD 79 400, representing a range of around 154 000 years.

8.2 Managed object classes

8.2.1 Clock source

This object class provides information concerning the dynamic state of a clock within a system. Two subclasses are also defined to further distinguish between internal system clocks and external reference clock interfaces. An instantiation of this object is required for each manageable clock.

The clockSource object provides access to and information about a source of time within a system. The clockStatus attribute is identified as state attribute. A change in the value of the operationalState attribute or in the clockStatus attribute causes a stateChange notification to be emitted. This managed object class is a subclass of "CCITT Rec. X.721 | ISO/IEC 10165-2":top and adds the following attributes:

- clockID;
- "CCITT Rec. X.721 | ISO/IEC 10165-2": operationalState;
- clockStatus;
- clockValue;
- clockEventCounter;
- clockEventCode;
- clockEventTime.

If an instance supports more detailed clock source information, the following attributes are present:

- clockPrecision;
- clockDrift;
- clockMaximumError;
- clockEstimatedError.

If an instance supports leap second information, the following attributes are present:

- leapSecondIndication;
- leapSecondCount.

This managed object class adds the following notification:

- "CCITT Rec. X.721 | ISO/IEC 10165-2": stateChange.

This managed object class provides the following action:

- clockReset.

8.2.2 Local clock

This object class provides information concerning the dynamic state of a local clock internal to a system. It is a subclass of the managed object class clock source. The localClock object provides access to and information about an internal source of time within a system. This managed object class adds the following attributes:

- localClockAddress;
- peerClockAddresses;
- synchronizationSourceAddress;
- clockStratum;
- clockAdjustmentInterval.

8.2.3 Reference clock

This object class provides information concerning the dynamic state of a clock interface residing in a system and providing that system access to an external time reference. This is a subclass of the managed object class clock source. It adds the following attribute:

- referenceClockType.

8.2.4 Synchronization protocol

This object provides general information about clock coordination function present in a system and provides access to the basic parameters of the time synchronization protocol. It is a subclass of "CCITT Rec. X.721 | ISO/IEC 10165-2":top. It adds the following attributes:

- synchronizationProtocolID;
- synchronizationProtocolType;
- synchronizedClock;
- synchronizingClocks;

It adds the following actions:

- leapSecondAction;
- protocolResetAction.

8.3 Attribute definitions

8.3.1 Clock Adjustment Interval

This attribute specifies the interval over which gradual phase adjustments to the local clock are to be applied.

8.3.2 Clock Drift

This attribute indicates the clock manufacturer's specified value of drift.

8.3.3 Clock Estimated Error

This attribute indicates the estimated error of the clock.

8.3.4 Clock Event Code

This attribute identifies the latest clock system exception event.

8.3.5 Clock Event Counter

This attribute specifies a counter indicating the number of system exception events that have occurred since the last time the counter was checked and cleared.

8.3.6 Clock Event Time

This attribute indicates the time at which the latest system exception event occurred.

8.3.7 Clock ID

This attribute identifies the clock being modeled by the managed object.

8.3.8 Clock Maximum Error

This attribute indicates the maximum error of the clock.

8.3.9 Clock Precision

This attribute indicates the precision of the clock.

8.3.10 Clock Status

This attribute indicates the current status of the clock.

8.3.11 Clock Stratum

This attribute indicates the current stratum value for this local clock in this node.

8.3.12 Clock Value

This attribute indicates the current time of the clock.

8.3.13 Leap Second Count

This attribute specifies the cumulative number of leap seconds that have occurred since January 1, 1972.

8.3.14 Leap Second Indication

This attribute indicates that a leap second is going to occur at the end of the current day.

8.3.15 Local Clock Address

This attribute indicates the network address of this node.

8.3.16 Peer Clock Addresses

This attribute lists the network addresses of the peers currently being maintained by this node.

8.3.17 Reference Clock Type

This attribute specifies the type of reference clock or external source that this object represents.

8.3.18 Synchronization Protocol ID

This attribute identifies the synchronization protocol being modeled by the managed object.

8.3.19 Synchronization Protocol Type

This attribute identifies the synchronization protocol type being modeled.

8.3.20 Synchronization Source Address

This attribute specifies the network address or the reference clock type of the current synchronization source for this node.

8.3.21 Synchronized Clock

This attribute specifies the clock being synchronized by this instance of the time synchronization protocol.

8.3.22 Synchronizing Clocks

This attribute specifies the set of clocks exchanging information with this clock for the purposes of synchronization.

8.4 Action definitions

The set of generic action parameters and semantics defined by this Recommendation | International Standard provide the detail for the following general parameters of the M-ACTION service defined by CCITT Rec. X.710 | ISO/IEC 9595:

- action type;
- action information;
- action reply.

8.4.1 Clock reset

The clock reset action provides the capability to reset an instance of a clock source to a given value. This service uses the M-ACTION service and procedures defined in CCITT Rec. X.710 | ISO/IEC 9595.

8.4.2 Leap second

The leap second action provides the capability to distribute an indication that a leap second is about to occur. It includes a mechanism to set the appropriate parameters in the protocol. This service uses the M-ACTION service and procedures defined in CCITT Rec. X.710 | ISO/IEC 9595.

8.4.3 Protocol reset

The protocol reset action provides the capability to restart the time synchronization protocol. This service uses the M-ACTION service and procedures defined in CCITT Rec. X.710 | ISO/IEC 9595.

8.5 Name binding definitions

8.5.1 Clock Source – System

This name binding is used for naming a clock source object with respect to a system object.

8.5.2 Synchronization Protocol – System

This name binding is used for naming a synchronization protocol object with respect to a system object.

9 Service definitions

This Recommendation | International Standard defines three services; clock reset, leap second distribution, and protocol reset. These services are defined below. In addition, the use of services defined in other functions is described below.

Clock functions include:

- creation of a clock managed object;
- deletion of a clock managed object;
- modification of clock parameters;
- accessing clock status;
- reset of clock.

Clock coordination functions include:

- creation of clock coordination managed object;
- deletion of clock coordination managed object;
- modification of clock parameters;
- accessing clock coordination protocol status;
- reset of clock coordination protocol machine;
- leap second notification distribution.

9.1 PT-CREATE service

The PT-CREATE service defined in CCITT Rec. X.730 | ISO/IEC 10164-1 is used to allow one open system to request that another open system create a managed object to model either the clock or the clock coordination resources available in that system for the purposes of management. This does not create the underlying resource.

9.2 PT-DELETE service

The PT-DELETE service defined in CCITT Rec. X.730 | ISO/IEC 10164-1 is used to allow one system to request that another open system delete a managed object modeling either the clock or the clock coordination resources available in that system for the purposes of management. This does not delete the underlying resource.

9.3 PT-SET service

The PT-SET service defined in CCITT Rec X.730 | ISO/IEC 10164-1 is used to allow one open system to request that another open system change the value of settable attributes in either clock or clock coordination managed objects.

9.4 PT-GET service

The PT-GET service defined in CCITT Rec. X.730 | ISO/IEC 10164-1 may be used to retrieve any of the readable attributes of the clock or clock coordination managed objects.

9.5 State Change service

The State Change notification service defined in CCITT Rec. X.731 | ISO/IEC 10164-2 may be used to monitor the state status of the clock or clock coordination managed objects.

9.6 Clock Reset service

The Clock Reset service allows a manager to request that another open system (the managed system) reset the clock. Table 1 lists the parameters for this service.

The Clock Reset service uses the parameters defined in clause 8 in addition to the general M-ACTION service parameters defined in CCITT Rec. X.710 | ISO/IEC 9595.

Table 1 – Clock reset parameters

Parameter name	Req/Ind	Rsp/Conf
Invoke Identifier	P	P
Linked Identifier	–	P
Mode	P	–
Base object class	P	–
Base object instance	P	–
Scope	P	–
Filter	P	–
Managed object class	–	P
Managed object instance	–	P
Access Control	P	–
Synchronization	P	–
Clock reset type	M	C(=)
Clock reset info	M	–
Clock Value	M	–
Current time	–	P
Errors	–	C

9.7 Leap Second service

The Leap Second service allows a manager to request that another open system (the managed system) initiate distribution of a leap second indication. Table 2 lists the parameters for this service.

The Leap Second service uses the parameters defined in clause 8 in addition to the general M-ACTION service parameters defined in CCITT Rec. X.710 | ISO/IEC 9595.

9.8 Protocol Reset service

The Protocol Reset service allows a manager to request that another open system (the managed system) reset the time synchronization protocol. Table 3 lists the parameters for this service.

The Protocol Reset service uses the parameters defined in clause 8 in addition to the general M-ACTION service parameters defined in CCITT Rec. X.710 | ISO/IEC 9595.

Table 2 – Leap second parameters

Parameter name	Req/Ind	Rsp/Conf
Invoke Identifier	P	P
Linked Identifier	–	P
Mode	P	–
Base object class	P	–
Base object instance	P	–
Scope	P	–
Filter	P	–
Managed object class	–	P
Managed object instance	–	P
Access Control	P	–
Synchronization	P	–
Leap second type	M	C(=)
Leap second info	M	–
Leap Indication	M	–
Date of Leap	M	
Current time	–	P
Errors	–	C

Table 3 – Protocol reset parameters

Parameter name	Req/Ind	Rsp/Conf
Invoke Identifier	P	P
Linked Identifier	–	P
Mode	P	–
Base object class	P	–
Base object instance	P	–
Scope	P	–
Filter	P	–
Managed object class	–	P
Managed object instance	–	P
Access Control	P	–
Synchronization	P	–
Protocol reset type	M	C(=)
Protocol reset info	M	–
Current time	–	P
Errors	–	C