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Information processing systems — Open Systems Interconnection — Internal organization of the Network Layer

Systèmes de traitement de l'information — Interconnexion de systèmes ouverts — Organisation interne de la Couche Réseau

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 8648 was prepared by Technical Committee ISO/TC 97, *Information processing systems*.

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

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Information processing systems — Open Systems Interconnection — Internal organization of the Network Layer

0 Introduction

This International Standard defines an architectural organization of the Network Layer of the OSI Reference Model. It is concerned with the functional organization of Network Layer entities in open systems, and with the ways in which this organization can be mapped to "real world" components (e.g. "real" networks, switches, transmission media, etc.). This International Standard relates those "real world" objects which must be dealt with to a set of abstract elements. There may be a variety of mappings between an abstract element and the physical equipment used to realize it. The description of such mappings requires a clear distinction between architectural terms and real world terms.

The architectural organization defined in this International Standard identifies and categorizes the way in which functions can be performed within the Network Layer by Network Layer protocols. In so doing, it provides a uniform framework for describing how different Network Layer protocols, operating either individually or cooperatively, can be used to provide the OSI Network Service. By focusing attention on the common functional elements of Network Layer protocols, this framework is intended to

a) simplify the use of Network Layer protocols to provide the Network Service in different situations;

b) limit the uncoordinated proliferation of Network Layer protocols with overlapping functions; and

c) clarify the requirements for, and guide the development of, future Network Layer protocol standards.

This detailed internal structure is necessary in the case of the Network Layer for two reasons:

1. The Network Layer provides its users with a uniform Network Service, regardless of potentially wide variations in underlying "real-world" network services, technologies, and administrative organization. It is important to understand how the underlying components are organized and interact within the Network Layer, and how they can be efficiently and effectively used.

2. ISO 7498 specifies that the Network Layer performs routeing and relaying functions and may contain entities residing in intermediate systems as well as in end systems. It is necessary to describe events that take place within the Network Layer in both types of entities; i.e. in end systems (within which the Network Service is provided to NS users) and in intermediate systems (within which network-entities providing these relay and routeing functions do not provide the Network Service to NS users).

1 Scope and field of application

This International Standard provides an architectural model of the OSI Network Layer as a framework for OSI Network Layer standardization, allowing incorporation of existing networks within the OSI architecture.

This framework encourages the design of real subnetworks that fully support the OSI Network Service whilst accommodating the participation, in the OSI environment, of other subnetworks that do not fully support the OSI Network Service.

This International Standard is intended for use both in the design and application of Network Layer protocols, operating between network-entities either in end systems providing the OSI Network Service, or in intermediate systems providing the routeing and relay functions.

It shall be used to

a) provide a common set of concepts and terminology for use in Network Layer standards (such standards shall reference this International Standard);

b) analyse Network Layer functionality and classify Network Layer protocols;

c) specify how "real networks" should be used in supporting or providing the OSI Network Service, in particular, in circumstances where multiple "real networks" are to be interconnected and used.

The organization defined herein does not address Network Layer management; in particular it is not concerned with the relationships among Network Layer entities which may be required for Network Layer management purposes. In addition, this International Standard does not specify the operational requirements for relay functions in intermediate systems, nor address how specific combinations of permitted functions might be practically and efficiently utilized.

2 References

ISO 7498, *Information processing systems - Open Systems Interconnection - Basic Reference Model*

Note - See also CCITT Recommendation X.200 *Reference Model of Open Systems Interconnection for CCITT Applications.*

ISO 7498/Add. 1, *Information processing systems - Open Systems Interconnection - Basic Reference Model Addendum 1:Connectionless-mode transmission.*

ISO 8208, *Information processing systems - Data communications - X.25 Packet Level Protocol for Data Terminal Equipment.*

ISO 8348, *Information processing systems - Data communications - Network service definition*

Note - See also CCITT Recommendation X.213 *Network Service Definition for Open Systems Interconnection (OSI) for CCITT Applications.*

ISO 8348/Add. 1, *Information processing systems - Data communications - Network service definition Addendum 1: Connectionless-mode transmission.*

ISO/TR 8509, *Information processing systems - Open Systems Interconnection - Service conventions.*

Note - See also CCITT Recommendation X.210 *Open Systems Interconnection (OSI) Layer Service Definition Conventions.*

ISO 8802 - Part 2, *Information processing systems - Data Communications - Local Area Networks - Logical Link Control.*[1]

- Part 3, *Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications.*[1]

- Part 4, *Token-Passing Bus Access Method and Physical Layer Specifications.*[1]

- Part 5, *Token Ring Access Method and Physical Layer Specifications.*[1]

- Part 7, *Slotted Ring Access Method and Physical Layer Specifications.*[1]

CCITT Recommendation X.21, *General purpose interface between data terminal equipment and data circuit-terminating equipment for synchronous operation on public data networks.*

CCITT Recommendation X.25, *Interface between data terminal equipment and data circuit-terminating equipment for terminals operating in the packet mode on public data networks.*

3 Definitions

3.1 Reference model definitions

This International Standard makes use of the following terms defined in ISO 7498:

a) OSI Network Layer
b) OSI Network Service
c) OSI network-service-access-point
d) OSI network-service-access-point-address (network-address)
e) OSI network-entity
f) network-relay
g) routeing
h) service
j) protocol
k) protocol-control-information

3.2 Service conventions definitions

This International Standard makes use of the following terms defined in ISO/TR 8509:

l) service user
m) service provider

3.3 Network Layer architecture definitions

For the purpose of this International Standard, the following definitions apply:

n) **real subnetwork:** A collection of equipment and physical media which forms an autonomous whole and which can be used to interconnect real systems for purposes of communication.

p) **subnetwork:** An abstraction of a real subnetwork.

q) **interworking unit:** One or more items of equipment, or a part of an item of equipment, whose operation provides a network-relay function (that is, a real system which receives data from one correspondent network-entity and forwards it to another correspondent network-entity).

Note - Such equipment may be integrated into a real subnetwork which is being interconnected.

r) **relay system:** An abstraction of the equipment forming an interworking unit.

s) **intermediate system:** An abstraction of a real system providing a network-relay function.

t) **data transmission service:** The set of capabilities available from a real subnetwork which may be utilized by users of the real subnetwork for the purpose of sending and receiving data.

Note - This service is defined between the points where each user is connected to and accesses the real subnetwork; e.g. a DTE/DCE interface, and should not be confused with the notion of a service at a layer boundary as defined in ISO 7498.

[1] At present at the stage of draft; publication anticipated in due course

4 Abbreviations

For the purpose of this International Standard, the following abbreviations apply:

CO-NS	Connection-Mode Network Service
CL-NS	Connectionless-Mode Network Service
DCE	Data Circuit-terminating Equipment
DTE	Data Terminal Equipment
IWU	Interworking Unit
LAN	Local Area Network
NL	Network Layer
NSAP	Network-service-access-point
PCI	Protocol-control-information
SNAcP	Subnetwork Access Protocol
SNDCP	Subnetwork Dependent Convergence Protocol
SNICP	Subnetwork Independent Convergence Protocol

5 Network Layer concepts and terminology

This clause gives precise meaning to a number of terms used in the OSI Network Layer standards which have a range of interpretation in more general usage.

5.1 Real world objects and abstract elements

Throughout this sub-clause and in clause 8, diagrams are used to illustrate various configurations of interest in the Network Layer. Each diagram has two components. Real world objects are depicted at the top of each diagram, while representation of the corresponding abstract element is depicted at the bottom. Table 1 shows the graphical representations of the real world objects and abstract elements used in the diagrams.

In figures 2, 3 and 4, the basic combinations of interconnection of real world objects (and thus their corresponding abstract elements) are depicted. From this basic set of interconnections, an arbitrary number of permitted interconnections can be built up through the repeated and/or recursive invocation of the basic interconnections shown in figures 2, 3 and 4.

Note - In figure 5, and those which follow it, the graphical representation of abstract elements contains additional detail (e.g. to illustrate OSI layers, protocol roles, etc.).

5.2 End systems and intermediate systems

End systems and intermediate systems are abstractions of equipment which fulfil the requirements of the OSI standards necessary to provide the function of an open system (see ISO 7498). An intermediate system performs only functions allocated to the lowest three layers of the Reference Model. Interworking units and real subnetworks are real world examples of equipment fulfilling the intermediate system role. An end system must additionally provide the functions of the layers above the Network Layer. A real end system is any piece of equipment or collection of pieces of equipment which fulfils this end system role. Network Layer entities within end systems shall provide the same Network Layer inter-system communciation functions as those provided by Network Layer entities in intermediate systems, with the exception of relaying functions which are performed by intermediate systems only.

The same collection of physical equipment may be capable of operating as a real end system or as an interworking unit, or as both simultaneously, depending on the circumstances of its use. In a particular circumstance the functions being invoked correspond to those of an abstract end system or an intermediate system.

5.2.1 End system considerations

An end system can communicate with another end system either

a) directly, without an intervening intermediate system (see figure 1); or

b) through one or more intervening intermediate systems (see figure 2).

In this context, "directly" refers to that which involves only the network-entities in the two communicating end systems. Communication "through one or more intermediate systems" refers to communication that involves the performance of a network-relay function by one or more network-entities, in addition to the network-entities in the two communicating end systems.

In either case no constraints are placed on the way in which relays at lower layers (e.g. data-link-relays or physical-relays) might be used to provide communication between network-entities.

For example, the real subnetwork which directly connects two end systems, as depicted in figure 1, may be as simple as a direct point-to-point link between the two end systems, or as complex as an interconnected set of Local Area Networks (LANs).

5.2.2 Intermediate system considerations

An intermediate system is an abstraction of

a) a real subnetwork (e.g. see 5.3 and figure 2) other than one which is directly connected as in 5.2.1;

b) an interworking unit, connecting two or more real subnetworks (see 5.4 and figure 4 where only the case of two real subnetworks is shown); or

c) a real subnetwork with an associated interworking unit (see 5.4 and figure 3).

Any combination of the above may be referred to as an intermediate system.

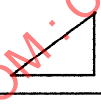
In some cases, it may be useful to identify and distinguish the abstract functionality of a real subnetwork from that of an interworking unit. In such circumstances, the abstract terms "subnetwork" and "relay system" may be used, respectively, to refer to these specific types of intermediate systems. (As described in following 5.3 and 5.4.)

5.3 Real subnetworks and subnetworks

A real subnetwork is a collection of equipment and physical media which forms an autonomous whole and which can be used to interconnect other real systems for purposes of communication (see figure 2). Examples of real subnetworks include

- commonly recognized, carrier supplied public networks;
- privately supplied and utilized networks;
- local area networks (LANs);
- any of the above, with associated interfacing equipment and/or interworking unit(s), considered together as forming a real subnetwork.

Table 1 – Correspondence between real world objects and abstract elements

Real world object	Graphical representation of real world object	Corresponding abstract element	Graphical Representation of abstract element
Real system		System	
Real open system		Open system	
Interworking unit	IWU	Relay system	Intermediate system
Real subnetwork	Real subnetwork	Subnetwork	* Intermediate system
Real end system		End system	End system

* Note – For end systems which are directly connected (see 5.2.1) their interconnection will be graphically depicted as a single link and not as an intermediate system.

All the pieces of equipment comprising such a real subnetwork can be represented by a single abstract subnetwork. It is important to note that a collection of physical equipment of the types listed above, and represented here as a "subnetwork", is commonly called a "network".

The externally visible properties of some real subnetworks are described by separate standards and Recommendations such as the CCITT X.21 circuit-switching and X.25 packet-switching Recommendations, or the ISO Local Area Network standards. More than one real subnetwork may be involved in an interconnection of other real systems. The term "subnetwork" may be applied recursively to collections of subnetworks interconnected in such a way that, to an attaching system, they can be viewed and treated as a single subnetwork.

A real subnetwork may be realized in such a way that it fully supports the OSI Network Service; that is, the functions supplied by the real subnetwork, suitably exploited by the real end systems that are attached to it, are fully equivalent in the abstract to those of the OSI Network Service (see 5.5). A real subnetwork which has this property is referred to as a subnetwork which supports all elements of the OSI Network Service. In having the capability to fully support the OSI Network Service, a real subnetwork must supply all mandatory elements of the OSI Network Service. It may additionally supply any provider option of the OSI Network Service but is not required to do so.

5.4 Relay systems and interworking units

A relay system is an abstraction of a piece of equipment (or collection of equipment) commonly referred to in the real world as an interworking unit. The purpose of an interworking unit is to facilitate the interconnection of distinct real subnetworks.

An interworking unit may reside within the authority of a real subnetwork supplier or may be administered by some other party. In cases where an interworking unit is physically separate from the real subnetworks it interconnects, the interworking unit may be represented as a separate intermediate system (see figure 4). An interworking unit may also be incorporated as an integral part of each real subnetwork being interconnected. In such a case, each real subnetwork and its associated interworking unit may be represented as a single intermediate system (see figure 3a). Alternatively each real subnetwork individually may be represented as an intermediate system connected by another intermediate system which represents the functionality of the combined intervening interworking units (figure 3b).

5.5 Data transmission service and subnetwork service

Any real subnetwork supplies a certain collection of functions to the real systems which use it. Some real subnetworks perform functions which are defined to be above the Network Layer of the OSI architecture (or outside of OSI entirely); such functions are outside of the scope of this International Standard. The abstraction of the set of capabilities available at the boundary between a real end system and a real subnetwork is a data transmission service. Different types of data transmission services are available, corresponding to different types of real subnetworks (for example, a packet-switched or circuit-switched data transmission service as defined by CCITT).

In the context of the OSI Network Layer, the abstraction of the subnetwork-provided functions along with the functions performed within open systems needed to exploit the subnetwork-provided functions is the subnetwork service. The subnetwork service incorporates the data transmission service, or a subset thereof. (See figure 5.)

A subnetwork service may therefore be

a) identical to the OSI Network Service in all instances of use (see 5.3);

b) different from the OSI Network Service in all instances of use;

c) different from the OSI Network Service in some instances of use but identical to the OSI Network Service in other instances.

When a real subnetwork supports a subnetwork service of type b) or c), it is necessary to perform additional Network Layer functions in order to provide the full OSI Network Service in all instances. These additional functions are performed in the end systems and/or relay systems invoking the subnetwork service on that real subnetwork.

A particular case of a subnetwork connection-mode service of type c) as defined in 5.5 is one in which a real subnetwork is defined so that its access protocol contains the functions needed to support the establishment and release of network-connections, but not all the functions needed to support data transfer on network-connections. Enhancement protocols will, therefore, be required for such a subnetwork during the data transfer phase but not during the establishment or release phases.

5.6 Service types

The OSI Network Service includes two basic service types:

a) a connection-mode service (CO-NS); and

b) a connectionless-mode service (CL-NS) (see ISO 8348 and ISO 8348/Add. 1).

Similarly, a subnetwork may provide either a connection-mode or connectionless-mode service or both. The operation of Network Layer protocols may enable either the CO- or the CL-NS or both to be provided using interconnected subnetworks that may provide either type of service in any combination (see clause 8 and table 2).

For a given instance of communication, the same service (i.e. connection-mode or connectionless-mode) is provided to both NS users. Choice of provision of connection-mode or connectionless-mode Network Service is provided in accordance with clause 6.2 of ISO 7498/Add. 1.

6 Organization of the Network Layer

There are circumstances in which, among real subnetworks which are interconnected, there are some real subnetworks that do not fully support the OSI Network Service. As a result, it is necessary to describe a Network Layer architectural framework for the provision of the OSI Network Service using such subnetworks. This International Standard provides such a framework which can be used in the development and application of standards related to real subnetwork interconnection.

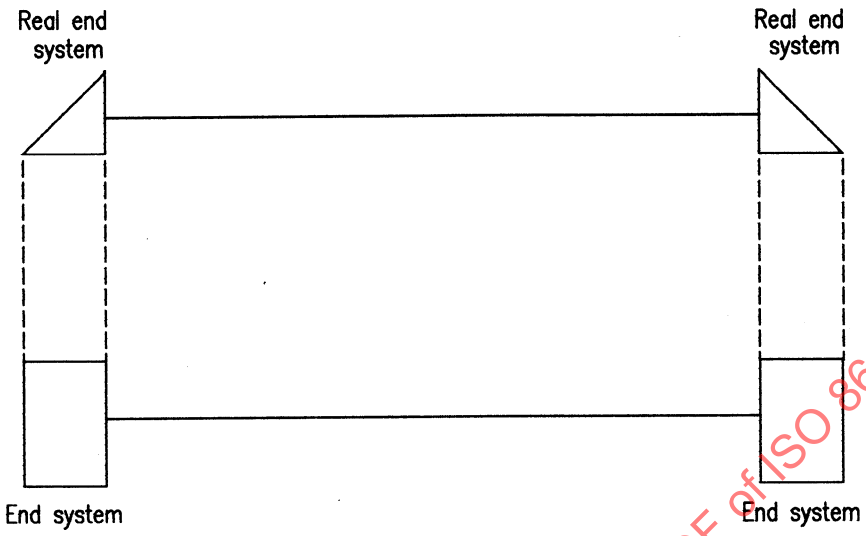


Figure 1 — "Direct" communication between end systems (without an intermediate system)

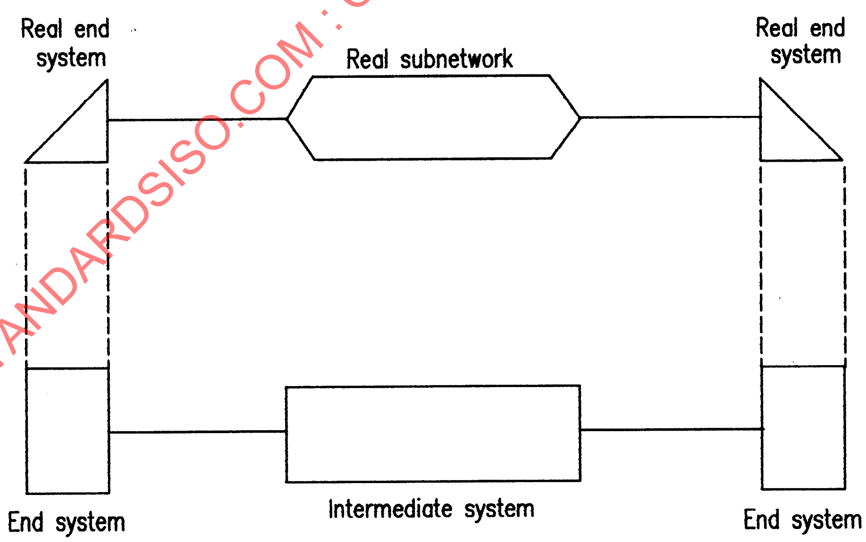
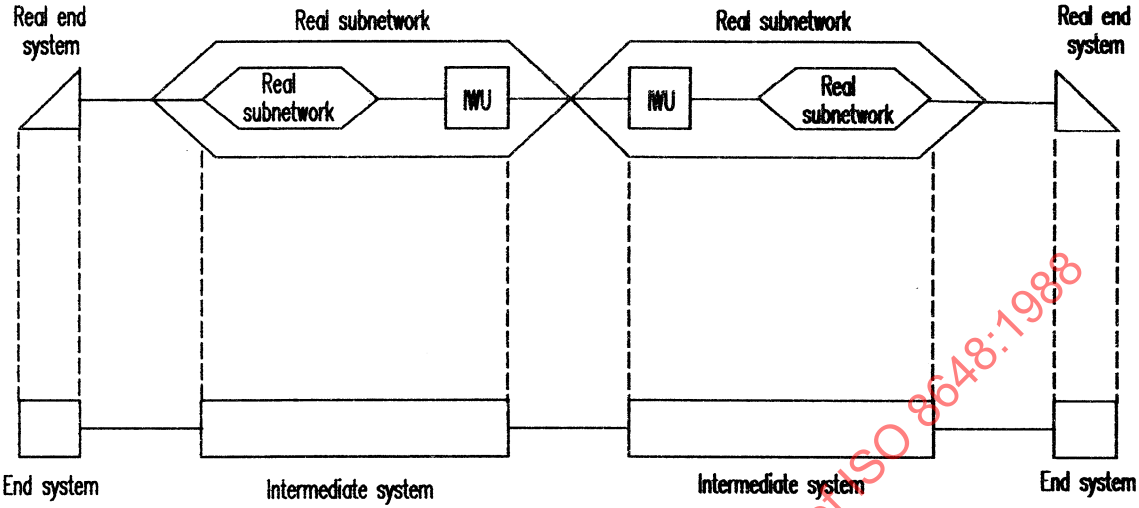
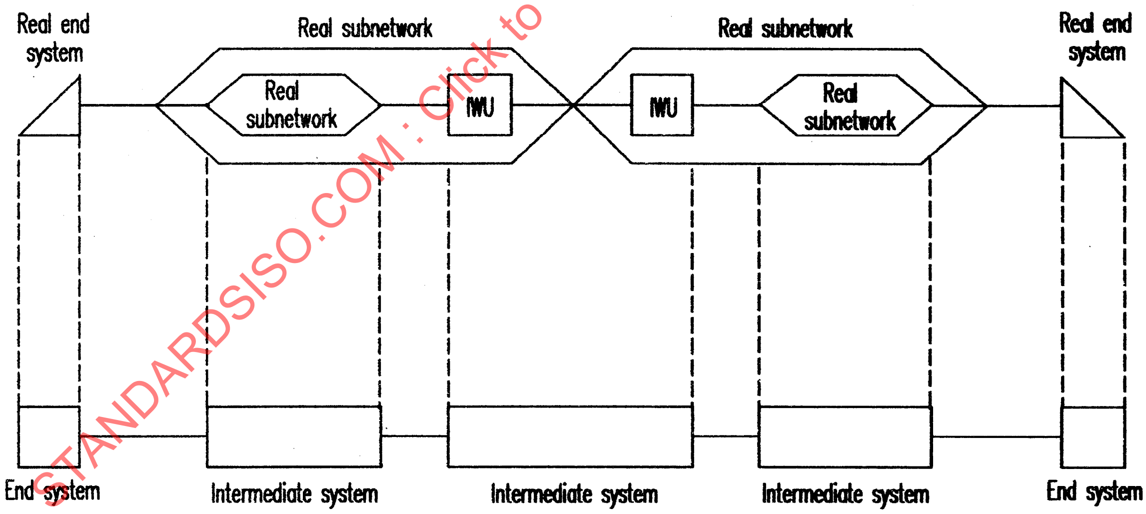


Figure 2 — End systems communicating through an intermediate system



a) Representation of each real subnetwork and interworking function as an intermediate system.



b) Representation of combined interworking functions as a separate intermediate system.

Figure 3 — Interconnection of real subnetworks that include integral interworking unit functionality

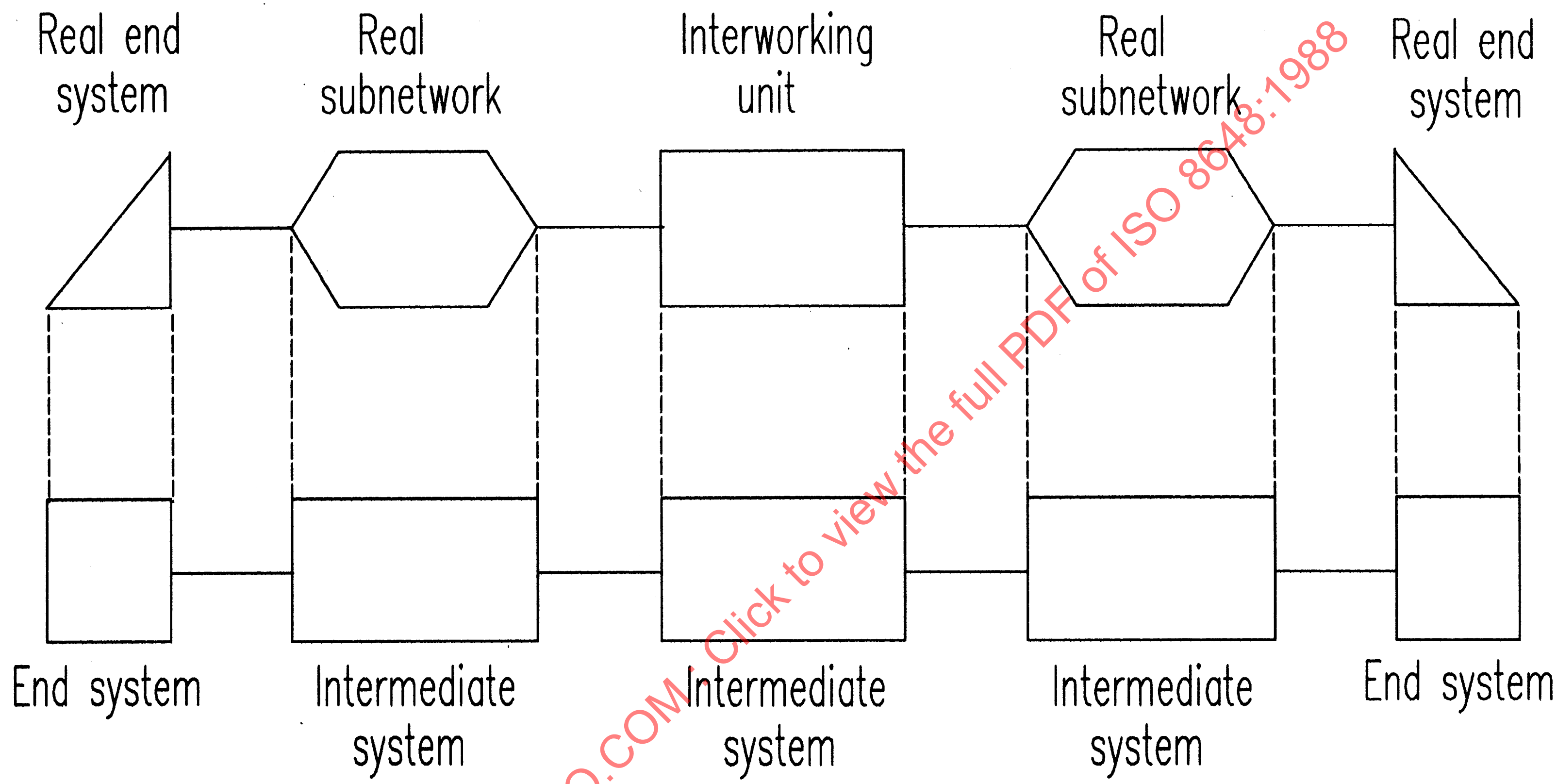
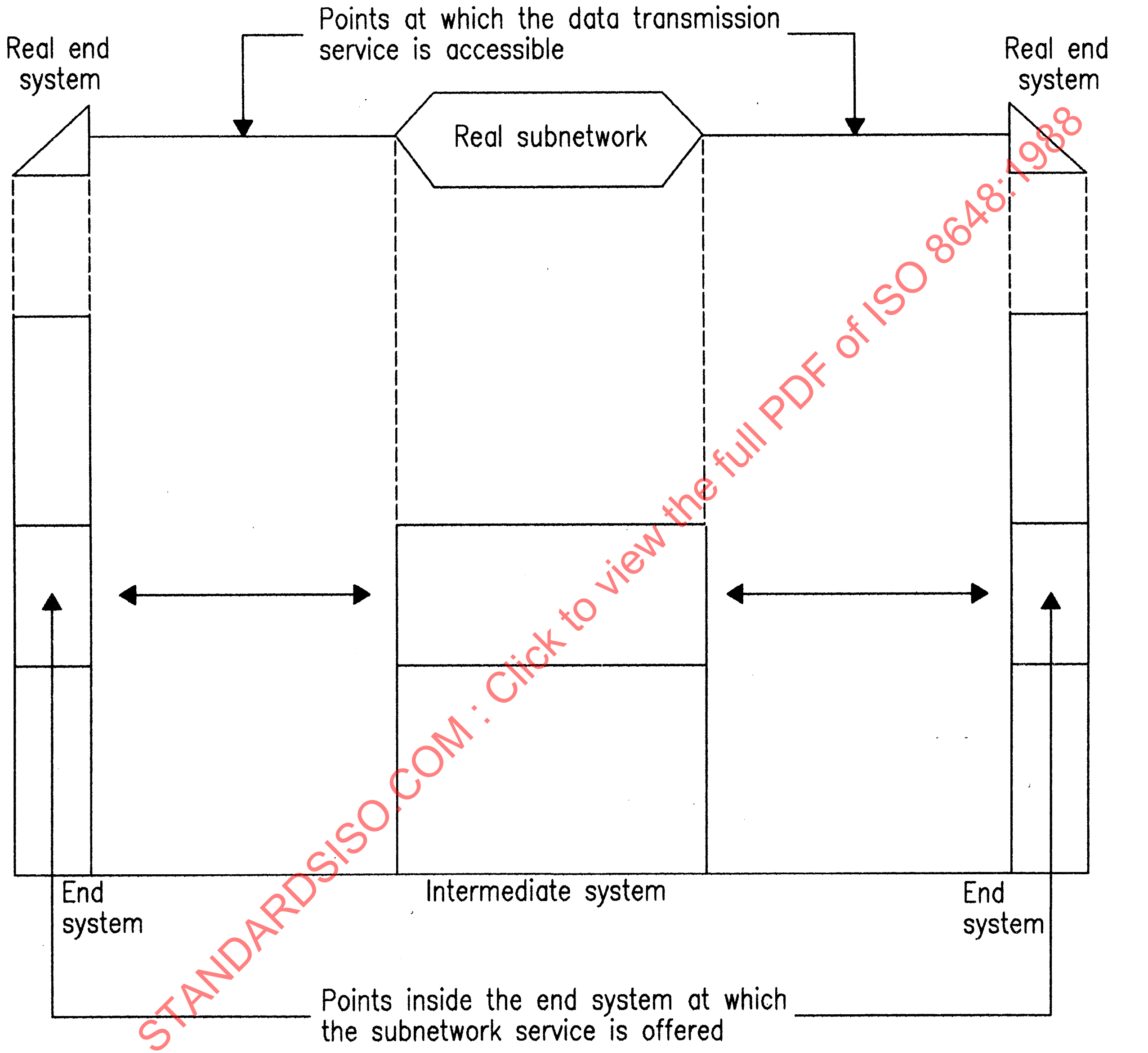


Figure 4 — Interconnection of real subnetworks by a separate interworking unit



Note – This figure depicts the case in which the subnetwork service is not identical to the OSI Network Service

Figure 5 — Relationship between subnetwork service and data transmission service

6.1 Factors which influence the internal organization of the Network Layer

In the provision of the OSI Network Service, there are cases in which all of the real subnetworks involved are subnetworks which support all elements of the Network Service. In those circumstances the OSI Network Service can be provided using a single Network Layer protocol in association with each subnetwork (see 6.7). In other circumstances, however, because of the variation among subnetwork services, the use of a single Network Layer protocol with each subnetwork may not be sufficient and therefore, multiple Network Layer protocols, operating together, may have to be employed in order to realize the OSI Network Service. Hence, for a given combination of interconnected end systems and intermediate systems, a particular Network Layer protocol may perform all, or only some, of the functions necessary to provide the OSI Network Service.

In order to understand under what circumstances and in which ways multiple Network Layer protocols may be employed to provide the OSI Network Service, it is useful to introduce the notion of the "role" that a Network Layer protocol performs when used in a given combination of systems. A Network Layer protocol's "role" is a definition of the functions it performs when contributing to the provision of the OSI Network Service. The "role" is determined by the combination in which the protocol is used and its relationship to any other protocols which may be operating. Role is therefore always relative.

Note - An element in determining the role of a protocol is the definition of both the agreed service to be provided by the protocol and the service assumed to underly it. Any protocol (for the Network or any other layer) is defined with respect to a specific underlying service; part of the definition of a protocol is the way in which it makes use of this service.

6.2 Description of the possible roles for a Network Layer protocol

Three roles for Network Layer protocols have been identified to describe how multiple Network Layer protocols may be employed to construct the OSI Network Service (see figure 6):

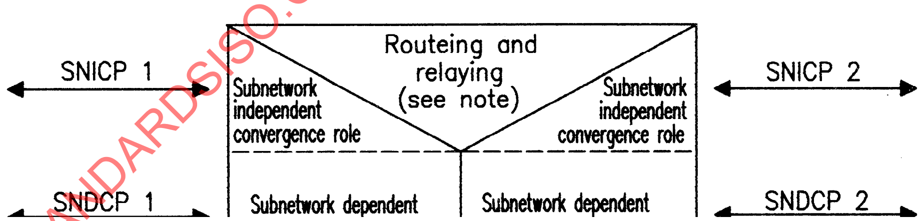
a) in the role of a Subnetwork Independent Convergence Protocol (SNICP);

b) in the role of a Subnetwork Dependent Convergence Protocol (SNDCP);

c) in the role of a Subnetwork Access Protocol (SNAcP).

A protocol at the Network Layer may fulfil one of these roles in a particular combination of systems; the same protocol may fulfil the same or different roles in different combinations. It is not necessarily the case that each role is fulfilled individually by a separate discrete protocol. The case where a single Network Layer protocol provides the OSI Network Service may be described as the case where that single protocol fulfils all of the defined protocol roles. An example of this kind of configuration is described in 6.7 and figures 7a), 8a), 9a) and 9b). Sub-clauses 6.3 to 6.5 and figures 10 to 21 inclusive describe configurations in which multiple Network Layer protocols are utilized.

The use of a separate, discrete protocol fulfilling each individual role in this figure is not a general requirement; for example, a single Network Layer protocol simultaneously fulfilling all Network Layer protocol roles can also provide the OSI Network Service. The notations "SNICP", "SNDCP" and "SNAcP" in figure 6 refer to the case where separate discrete protocols fulfil each of the SNICP, SNDCP and SNAcP roles. Those with subscript "1" may not be functionally equivalent to those with subscript "2".



6.3 Subnetwork access protocols

A protocol fulfilling the SNAcP role operates under constraints that are stated explicitly as characteristics of a specific subnetwork. The operation of such a protocol contributes to the provision of a subnetwork service which is specific to the subnetwork concerned; this subnetwork service may or may not coincide with the OSI Network Service. The way in which such a protocol contributes to the construction of the OSI Network Service is governed by the definition of the corresponding subnetwork service and by the way in which other Network Layer protocols (if any) choose to make use of that service in a particular configuration.

Within a given subnetwork, there may be relaying and routeing functions which govern the forwarding of information entirely within the subnetwork itself. The performance of subnetwork routeing and relaying functions is associated with the operation of protocols fulfilling the SNAcP role.

6.4 Subnetwork independent convergence protocols

A protocol fulfilling the SNICP role operates to construct the OSI Network Service over a well-defined set of underlying capabilities which need not be based on the characteristics of any particular subnetwork service.

The specification of a protocol intended for use in the SNICP role begins with a definition of such a set of underlying capabilities which it uses. Such capabilities are made available by the operation of other Network Layer protocols (or through provision of the Data Link Service).

The choice of a suitable set of underlying capabilities is based upon

a) the types of subnetworks and subnetwork combinations over which the protocol is expected to be used;

b) the technical and economic advantages and disadvantages associated with assuming one set of underlying capabilities rather than another;

c) the likelihood that the required capabilities can be readily constructed from the operation of other Network Layer protocols (or the Data Link Service);

d) the degree of complexity of protocol mechanisms in the SNICP itself which is justifiable and desirable to support.

A distinguishing characteristic of a protocol acting in the SNICP role is that the underlying capabilities upon which it depends need not be based on the characteristics of any particular subnetwork service.

6.5 Subnetwork dependent convergence protocols

A protocol fulfilling the SNDCP role by definition operates over a protocol providing the SNAcP role. It is used to provide the capabilities assumed by a protocol fulfilling the SNICP role or to provide the OSI Network Service by fulfilling the SNICP and SNDCP roles. A protocol in the SNDCP role is constrained by the specific characteristics of a particular subnetwork service and by the assumptions made by an SNICP.

6.5.1 Relationship of SNDCP to SNICP

The introduction of the SNDCP role permits the assumptions made by an SNICP to be decoupled from the detailed operation of particular SNAcPs, thus accommodating the desired generality of a protocol fulfilling the SNICP role.

The provision of the underlying capabilities required by an SNICP using a particular subnetwork service may require the operation of an explicit protocol (i.e. a protocol involving the explicit exchanges of protocol control information between peer network-entities) in the SNDCP role. However, there may also be cases where the "protocol" in the SNDCP role consists simply of a set of rules for manipulating the subnetwork service. This set of rules would be implemented in individual end and intermediate systems where required, but would not involve any explicit exchange of PCI.

6.5.2 Relationship of SNDCP to the OSI Network Service

In some circumstances, a protocol may operate directly over a particular subnetwork service (and its associated SNAcP), and provide capabilities completely equivalent to the OSI Network Service (rather than some set of capabilities different from the Network Service, intended to fulfil the requirements of an SNICP). When used in this manner, the protocol is acting to fulfil both the SNICP (provides the Network Service) role and the SNDCP (operates over a particular subnetwork service) role simultaneously.

6.6 Relaying and routeing

Relaying functions enable a network-entity to forward information received from one correspondent network-entity to another correspondent network-entity. Routeing functions determine an appropriate route between network-addresses.

Where multiple real subnetworks are present in a given configuration there are two approaches to the allocation of the relaying and routeing functions to individual network-entities. Either

a) the relaying and routeing functions are located in network-entities *outside* the real subnetworks, in which case an identifiable interworking unit connected to the two real subnetworks performs the function (see figure 4); or

b) the relaying and routeing functions are located in network-entities *inside* the real subnetworks, in which case it is considered that an IWU (or IWUs) in each real subnetwork performs these functions, and the real subnetworks can be represented, from a routeing and relaying perspective, as a single abstract subnetwork (see figure 3a).

A combination of real subnetworks with relaying and routeing functions performed outside of the real subnetworks may be interconnected to a combination where the relaying and routeing functions are inside the real subnetworks if the necessary interworking functions between the two combinations are provided.

6.7 Single Network Layer protocol fulfilling all protocol roles

It is a distinguishing characteristic of a subnetwork which supports all elements of the Network Service that no additional protocol is required between two corresponding OSI end systems or intermediate systems directly connected to those real subnetworks, on the top of the protocol established for using those real subnetworks (e.g. the protocol described in ISO 8208). The Network Layer protocol of a real subnetwork which has these properties is capable of conveying, between the appropriate combination of end and intermediate systems connected to it, all of the information necessary for the OSI Network Service to be provided.

7 Application of the Network Layer internal organization

The concepts of the Internal organization of the Network Layer presented in clause 6 can be used to describe particular approaches which are used in the interconnection of subnetworks and which are the subject of OSI standardization.

Such interconnection approaches are concerned with the provision of the OSI Network Service through the use of a combination of interconnected subnetworks. Functions, such as internetwork relaying and routeing, are combined with functions performed by the individual subnetworks in order to provide OSI network-connections or network connectionless-mode transmissions between end systems which may or may not be directly attached to the same subnetwork.

Three approaches for the application of the Internal organization of the Network Layer to the interconnection of subnetworks are described in the following clauses. They are

a) interconnection of subnetworks which support all elements of the OSI Network Service;

b) hop-by-hop harmonization over individual subnetworks; and

c) the use of an internetworking protocol approach over more than one subnetwork.

In the case of a connection-mode service, these three approaches may be applied independently to each of the three phases of a network-connection.

Note - The use of the word internetworking in the term internetworking protocol identifies a style of interconnection and does not refer to any specific protocol.

7.1 Interconnection of subnetworks supporting all elements of the OSI Network Service

The approach of interconnection of subnetworks supporting all elements of the Network Service assumes that all of the real subnetworks involved fully support the OSI Network Service. A single Network Layer protocol is used between the end and intermediate systems attached to each such subnetwork to provide the OSI Network Service (see 6.7). These subnetworks are interconnected by means of relay and routeing functions (see 6.6) so as to support the OSI Network Service end-to-end. In this type of interconnection NSAP-addresses are conveyed by means of the single Network Layer protocol used.

7.2 Hop-by-hop harmonization

The approach of hop-by-hop harmonization involves a subnetwork combination which includes at least one real subnetwork which does not support all elements of the Network Service. In this approach, the subnetwork service of each subnetwork which does not support all elements of the Network Service is "harmonized" such that it is identical to the OSI Network Service. The additional functions which are necessary to transform the subnetwork service to the OSI Network Service may, in general, include functions that mask certain features of the subnetwork service, as well as functions that extend or enhance the subnetwork service. In many cases, the addition of these harmonization functions will require the operation of one or more discrete protocols fulfilling the SNICP and, possibly, the SNDCP roles, on top of the SNAcP protocols.

When each subnetwork is thus harmonized to support the required OSI Network Service, the harmonized subnetwork services are interconnected by means of routeing and relay functions so as to support the required Network Service end-to-end. NSAP-addresses are conveyed on each subnetwork, either as PCI within the SNAcP or as PCI within the SNDCP or SNICP. The choice of the protocol which conveys addressing information depends upon the functionality of the underlying real subnetworks.

An important consequence of this interconnection approach is as follows. When the hop-by-hop harmonization extends across a given subnetwork, all real end systems and any interworking units connected to that real subnetwork are required to support the same protocol(s) used to provide the hop-by-hop harmonization in order to ensure the possibility of communication between all end systems.

7.3 Use of an internetworking protocol approach

The internetworking protocol approach defines protocols capable of operating over a series of interconnected subnetworks and over different types of subnetwork. The OSI Network Service may then be provided by utilizing a single protocol of this type operating in the role of an SNICP across a number of interconnected subnetworks and intermediate systems. An internetworking protocol, as any SNICP, must rely on some defined set of capabilities over which it is to operate. The specification of such a set of capabilities is an essential part of the specification of an internetworking protocol. It is an important consideration in the selection of subnetworks over which that internetworking protocol can be used.

In practice, various design choices may be made about the extent to which intermediate systems participate in the various internetworking protocol functions and thus the degree of complexity of the internetworking protocol itself. For example, an intermediate system may provide such functions as internetwork flow control, or functions to segment protocol data units, reassemble protocol data units which have previously been segmented, or both.

An internetworking protocol may be used over a subnetwork whose subnetwork service is not the same as the defined set of capabilities over which the internetworking protocol was specified to operate. In such cases, a protocol operating in the SNDCP role (i.e. an explicit protocol or simply a set of rules for manipulating the subnetwork service) is used to transform the subnetwork service to the capabilities which the SNICP requires. The internetworking protocol can then be operated over the SNDCP and SNAcP of the subnetwork (or of each of the subnetworks involved in an interconnection). NSAP-addresses in this case are conveyed over all the involved subnetworks as an element of the internetworking protocol.

When this approach to subnetwork interconnection is used, the possibility of communication between real systems, real end-systems and interworking units connected to real subnetworks can only be ensured in those cases where these systems use the same internetworking protocol.

7.4 Combinations of approaches for interconnecting subnetworks

With the application of the three different methods described in 7.1 to 7.3 for the interconnection of real subnetworks, it will, in principle, be possible that in a combination of interconnected subnetworks any combination of the different methods may be employed. In a combination approach where an internetworking protocol is utilized, but does not operate end-to-end, the internetworking protocol acts as a harmonization protocol over a number of hops.

8 Interconnection scenarios

The figures in this clause show a variety of interconnection scenarios, illustrating the application of the Internal organization of the Network Layer described in the preceding clauses. Table 2 summarizes these depicted scenarios in terms of the types of subnetwork service being used and whether the CO- or CL-NS is being provided.

Note - The same real subnetwork may be able to provide the CO-NS and CL-NS, although in any instance of data transmission, the mode of service provided will be the same for both subnetwork users.

In these figures, the notations "SNICP", "SNDCP" and "SNAcP" refer to individually identifiable protocols fulfilling the respective role. Where it is indicated that one or more of these protocols may be absent, one or more of the remaining protocols provide all the necessary functions that would have been provided by the absent protocols.

The figures summarized in table 2 depict particular combinations of protocols which are utilized in the Network Layer at a given instant of communication. Such combinations occur for connection-mode transmission at any time during which a network-connection exists between the real end systems shown in the figures. Where the CL-NS is being provided between the real end systems, such combinations may occur at any time that a connectionless-mode transfer is performed.

Note - Because the figures apply only to a given instant during data transmission, different scenarios can apply to different phases of a connection-mode service.

8.1 Single data-link/single subnetwork interconnection

Figures 7 and 8 respectively depict the range of possibilities for interconnection over

a) a single data-link;
b) a single subnetwork.

Two cases,

1) use of a single Network Layer protocol; and
2) use of multiple Network Layer protocols, are illustrated for both of these configurations.

The term single data-link covers a range of configurations as described in 5.2.1.

Table 2 – Summary of interconnection scenarios

Subnetwork service offered by subnet A	Subnetwork service offered by subnet B	OSI Network Service to be provided	Reference scenario
N/A	N/A	CO–NS or CL–NS	7
C/L or C/O	N/A	CL–NS or CO–NS	8
C/O	C/O	CO–NS	9,10,11
C/L	C/L	CL–NS	9,12,13
C/O	C/O	CL–NS	14,15
C/L	C/L	CO–NS	16,17
C/L	C/O	CL–NS	18,19
C/L	C/O	CO–NS	20,21

Key: N/A – Not applicable, no subnetwork present in this case
C/O – Connection–mode service
C/L – Connectionless–mode service

8.2 Interconnections involving subnetworks which support all elements of the Network Service

Figure 3 illustrates the interconnection of subnetworks as described in 7.1, both for the case where the real subnetworks are interconnected without a separate IWU (figure 9a) and for the case where a separate IWU is used (figure 9b) (see 5.2). In this scenario, either

a) both subnetworks offer a CO-subnetwork service and are used to provide the CO-NS; or

b) both subnetworks offer a CL-subnetwork service and are used to provide the CL-NS.

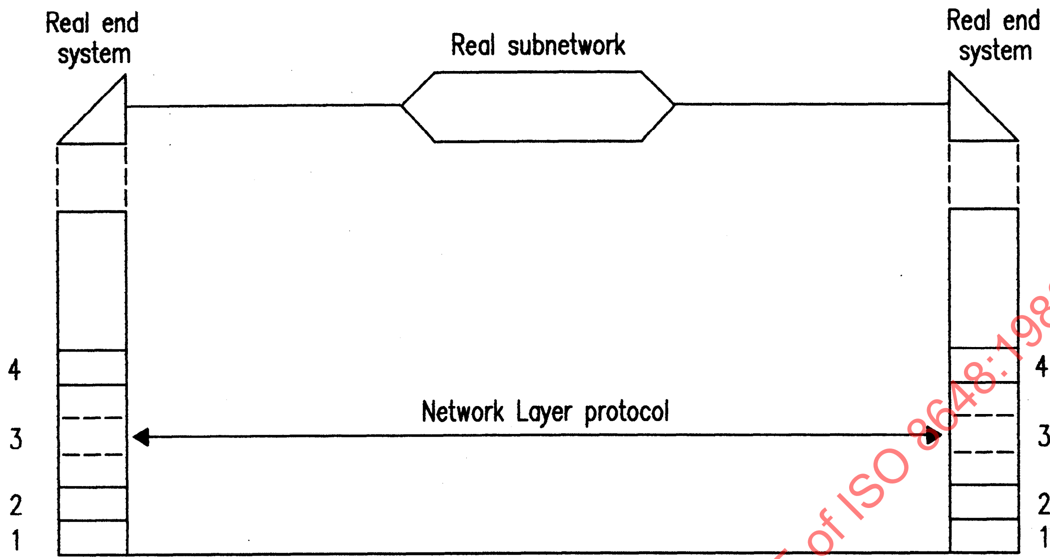
8.3 Interconnections involving multiple protocol combinations

Figures 10 to 21 depict interconnections where hop-by-hop harmonization or the use of an internetworking protocol is required. In these scenarios, the same or different types of subnetwork service are used to provide either a CO-NS or a CL-NS.

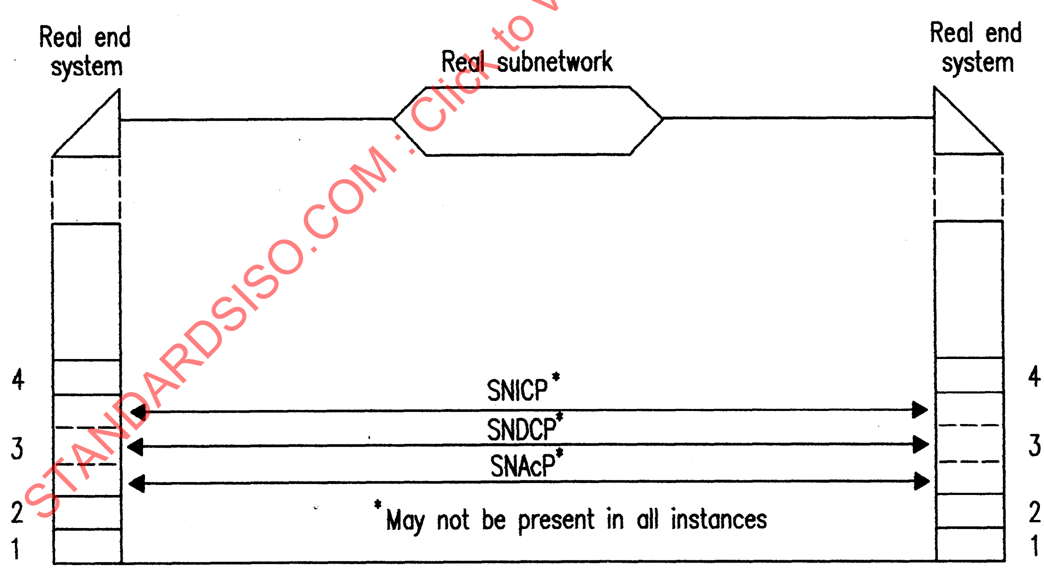
A number of possible situations exist for each scenario depicted. As an example, figure 10 illustrates three different cases in which the CO-NS is provided over the CO-subnetworks using hop-by-hop harmonization.

Figure 10a) shows two real subnetworks being interconnected without a separate IWU. In this case, *one* of the subnetworks is a subnetwork which supports all elements of the Network Service and thus a single Network Layer protocol is used with that subnetwork. Figure 10b) shows two real subnetworks interconnected via a separate IWU where again, one of the subnetworks is a subnetwork which supports all elements of the Network Service. In figure 10c), no subnetworks which support all elements of the Network Service are involved and several protocols in the Network Layer are used with each subnetwork.

Figures 11 to 21 inclusive illustrate a case of the various other interconnection scenarios which are summarized in table 2. In each of these figures, only the case where multiple Network Layer protocols are operating with each subnetwork is actually shown. (This is the case which parallels the case of figure 10c).) However, each scenario could equally be illustrated to show the case where one of the subnetworks is a subnetwork which supports all elements of the Network Service (these are the cases which parallel those in figures 10a) and 10b)). An important aspect to note in figures 11 to 21 is that SNDCPs and SNAcPs indicated on either side of an IWU are not necessarily identical protocols. However, in the case of the use of an SNICP when using the internetworking protocol approach in figures 11, 13, 15, 17, 19 and 21 the SNICP on either side of an IWU is by definition the same protocol.

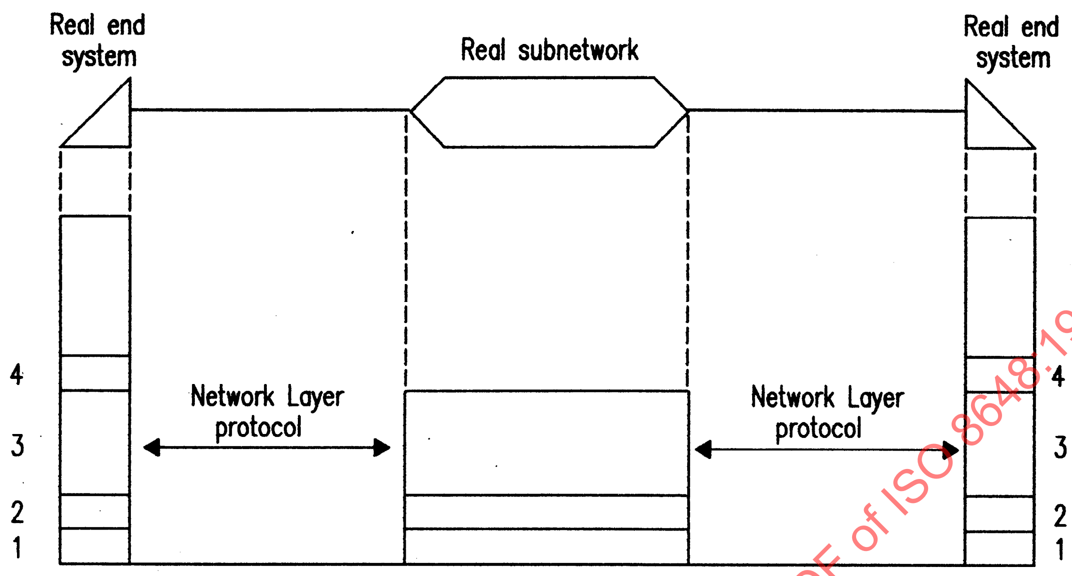


a) Use of single Network Layer protocol

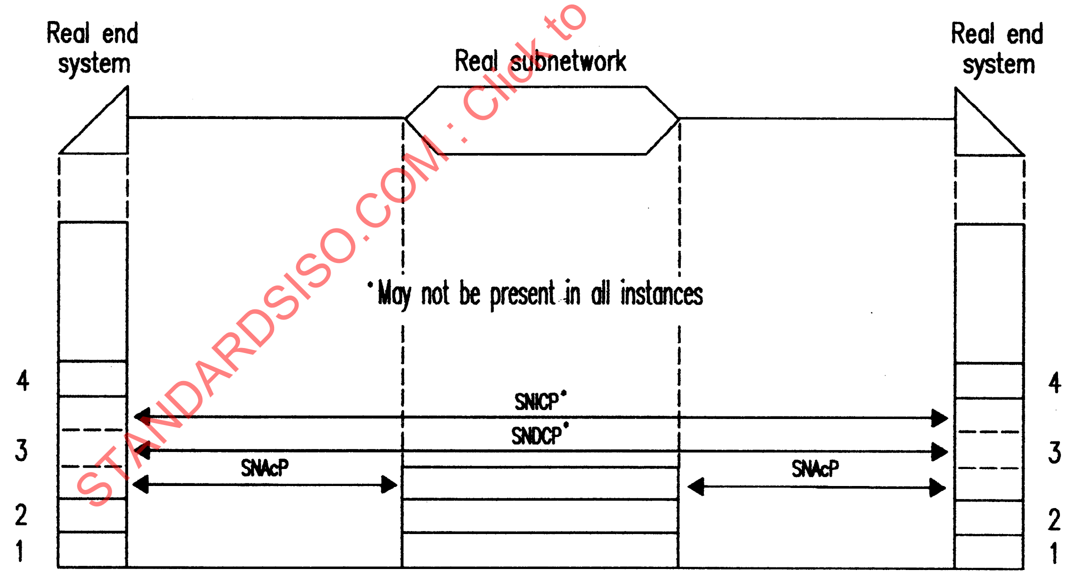


b) Possible use of several protocols

Figure 7 — Provision of CO-NS or CL-NS over a single data-link

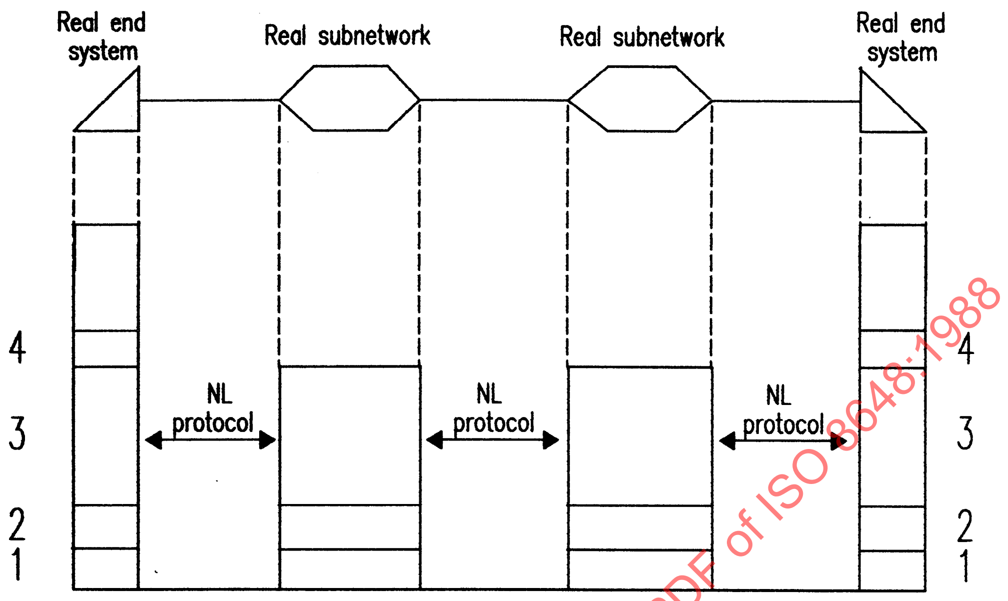


a) Use of a single Network Layer protocol

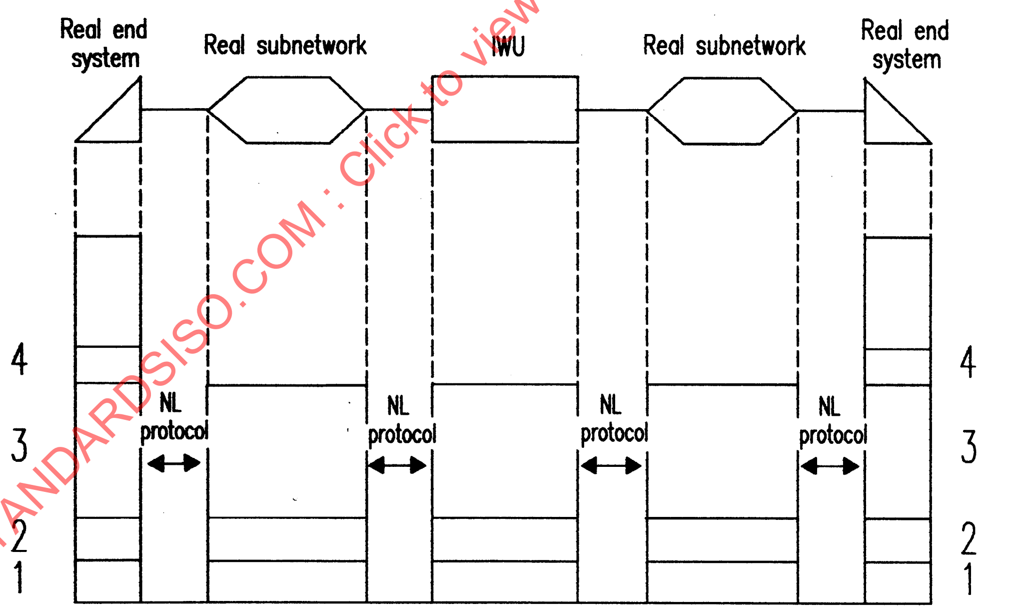


b) Possible use of several protocols

Figure 8 — Provision of CO-NS or CL-NS over a single subnetwork

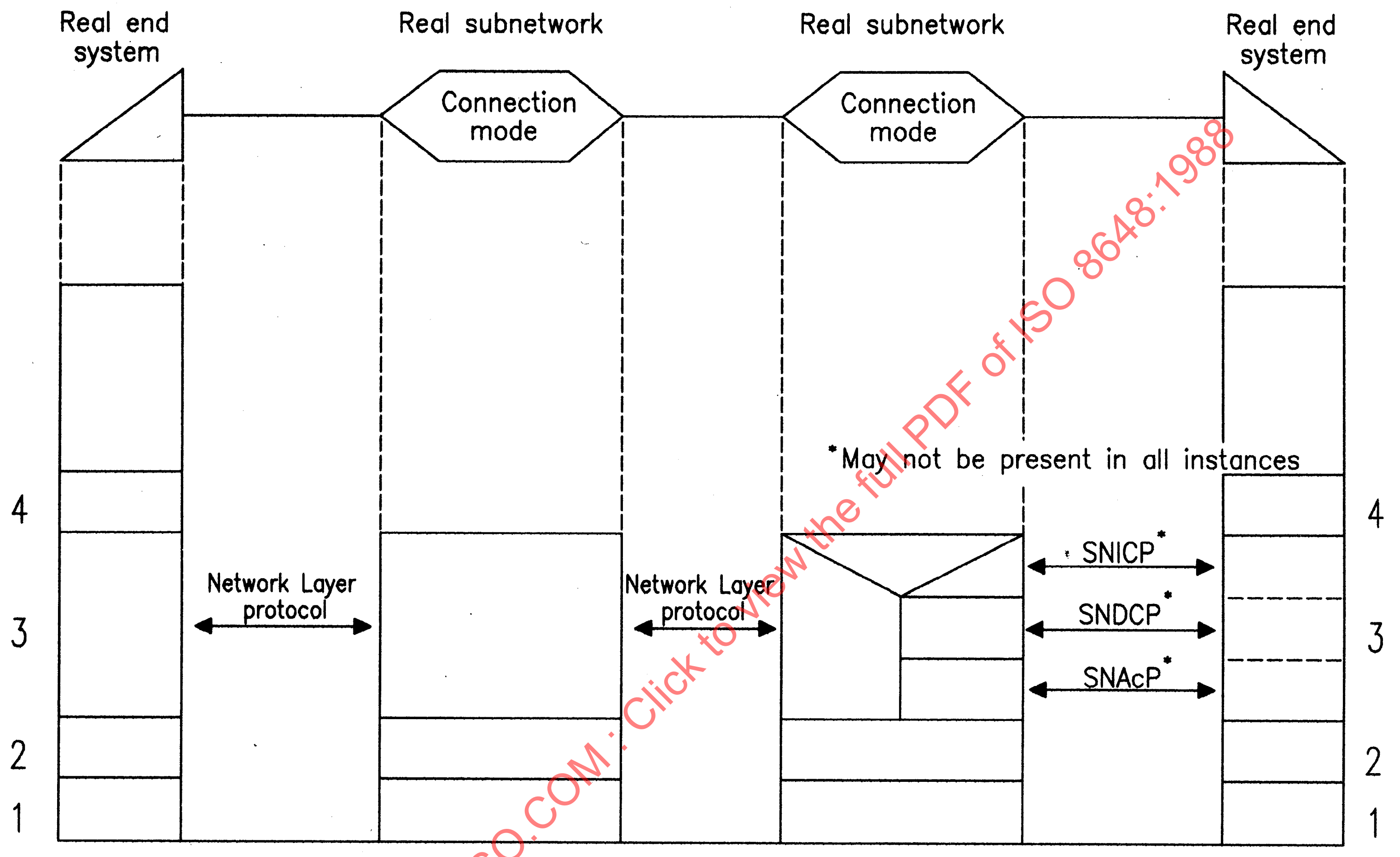


a) Direct connection without separate interworking units



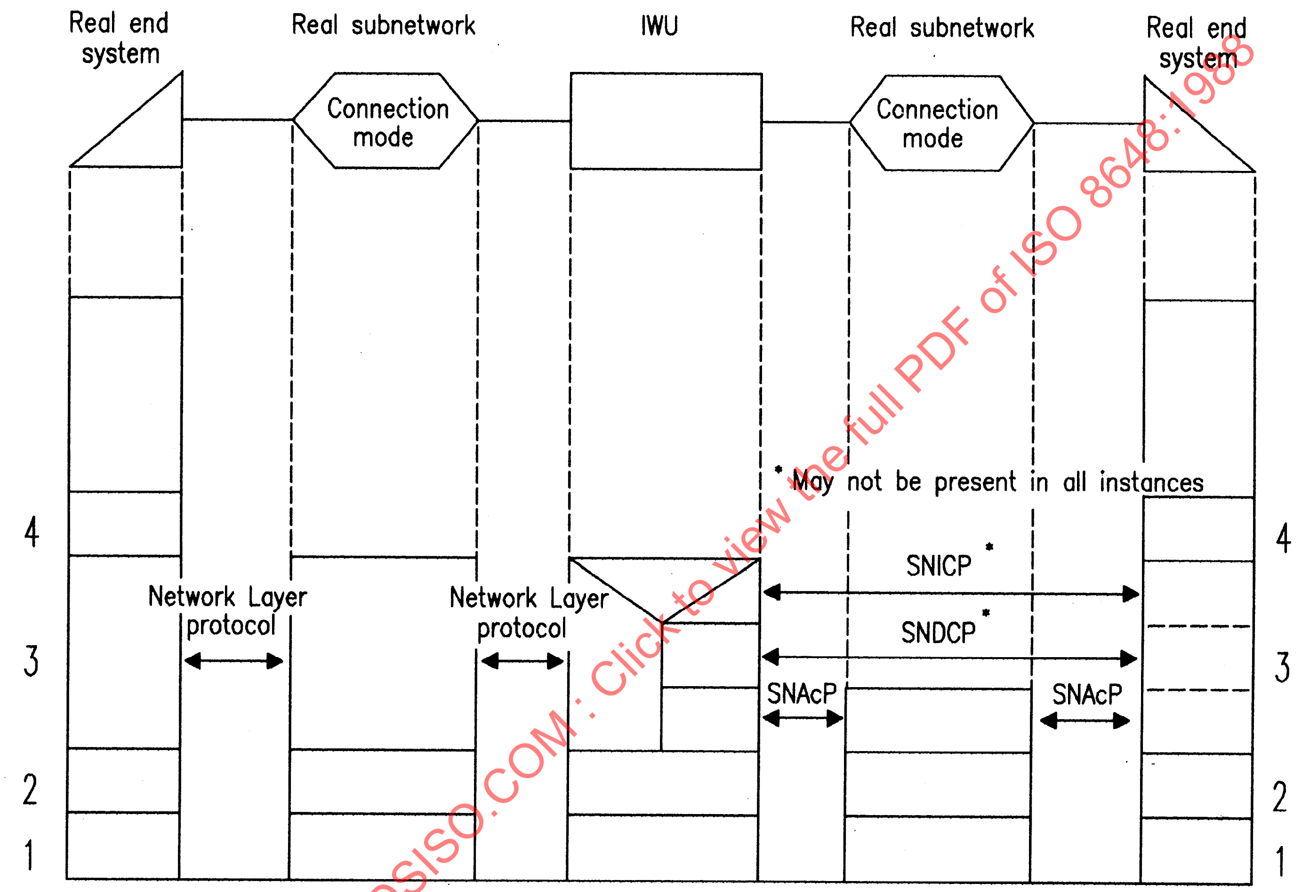
b) Use of a separate interworking unit

Figure 9 — Interconnection of subnetworks utilizing a single NL protocol to provide the CO-NS or CL-NS over two CO- or CL- subnetworks



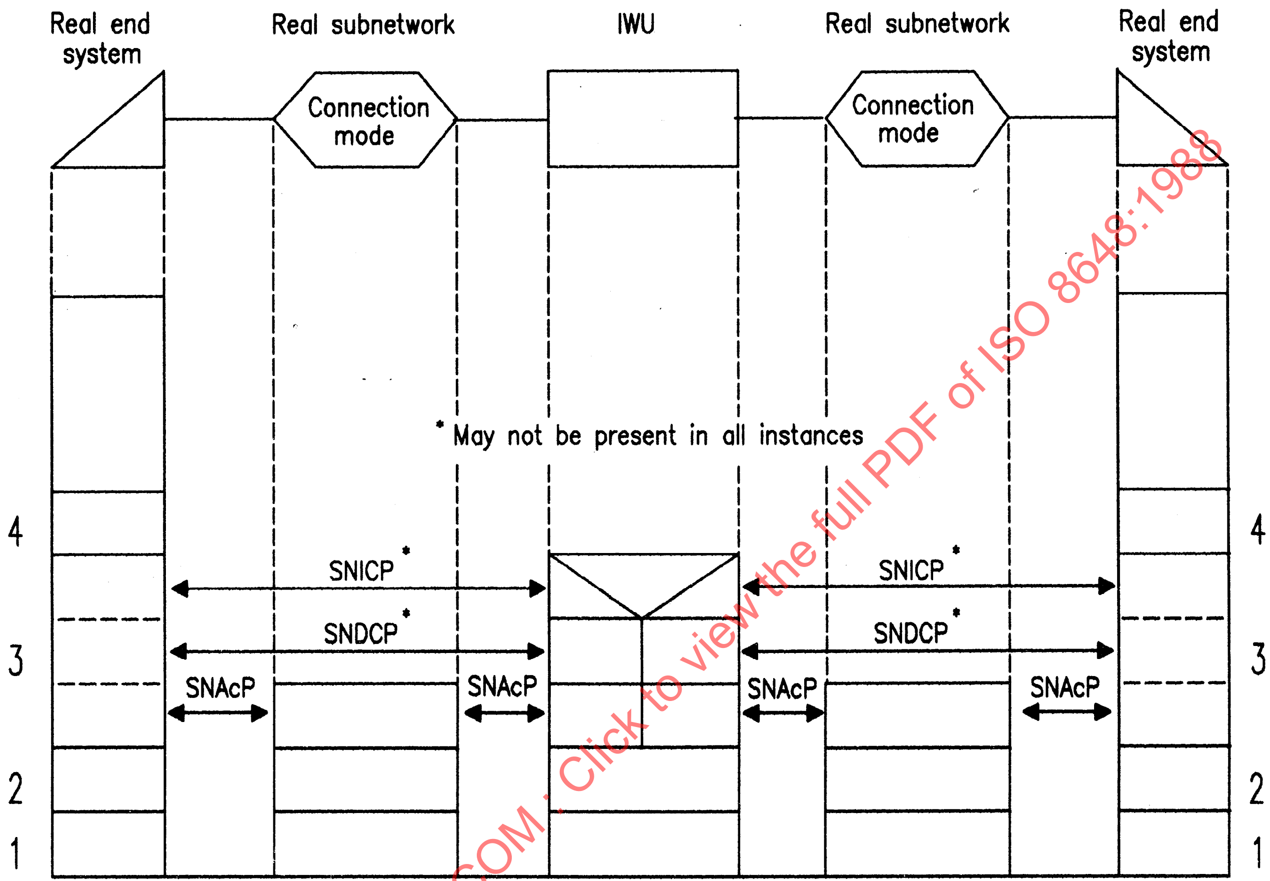
a) Direct connection between two subnetworks without a separate interworking unit and use of a single Network Layer protocol on one subnetwork

Figure 10a — Provision of the CO-NS over two CO-subnetworks using hop-by-hop harmonization



b) Use of a separate interworking unit and a single Network Layer protocol on one subnetwork

Figure 10b — Provision of the CO-NS over two CO-subnetworks using hop-by-hop harmonization



c) Possible use of several protocols on both subnetworks when interconnected by a separate interworking unit

Figure 10c — Provision of the CO-NS over two CO-subnetworks using hop-by-hop harmonization

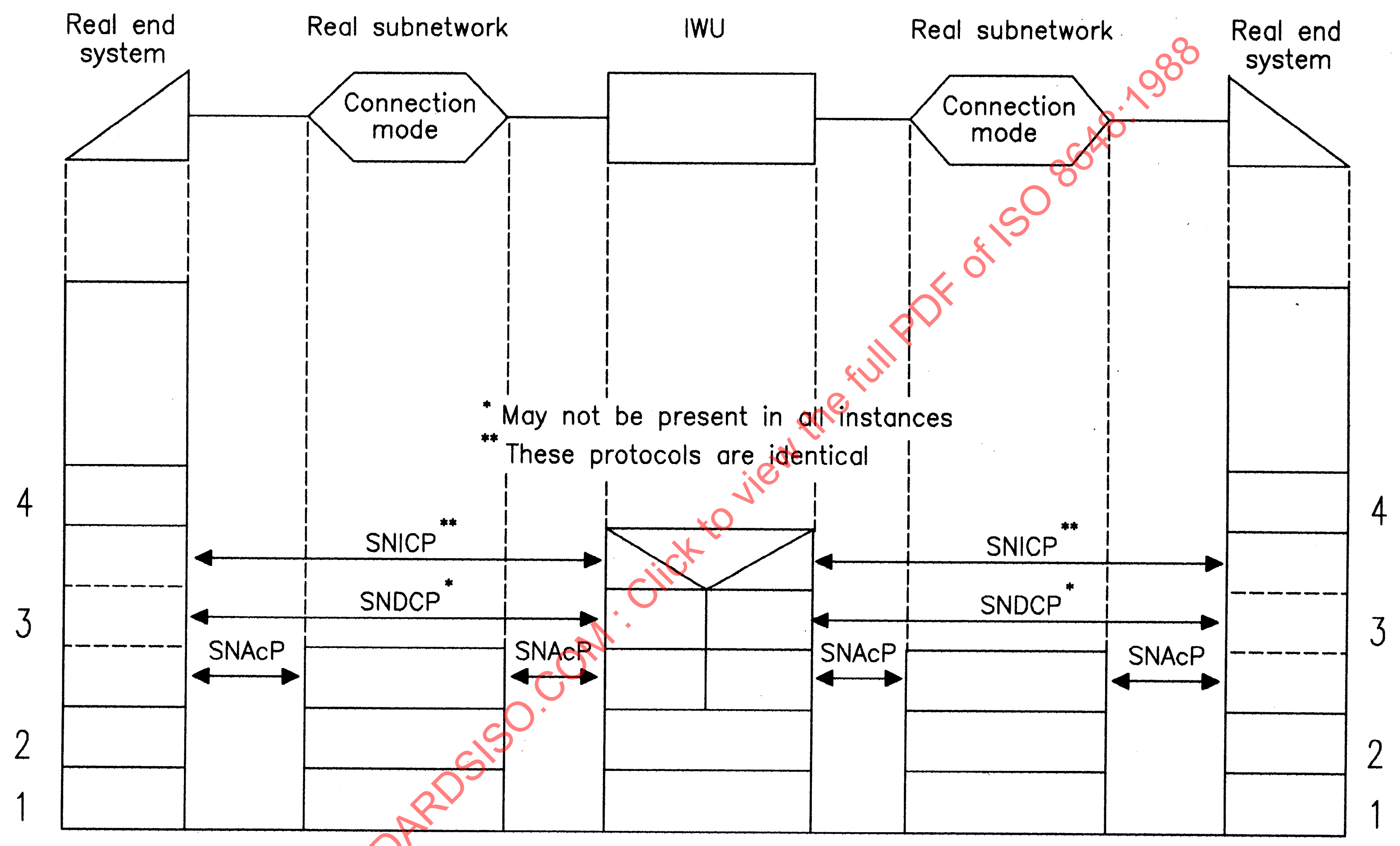


Figure 11 — Provision of the CO-NS over two CO-subnetworks using an internetworking protocol approach

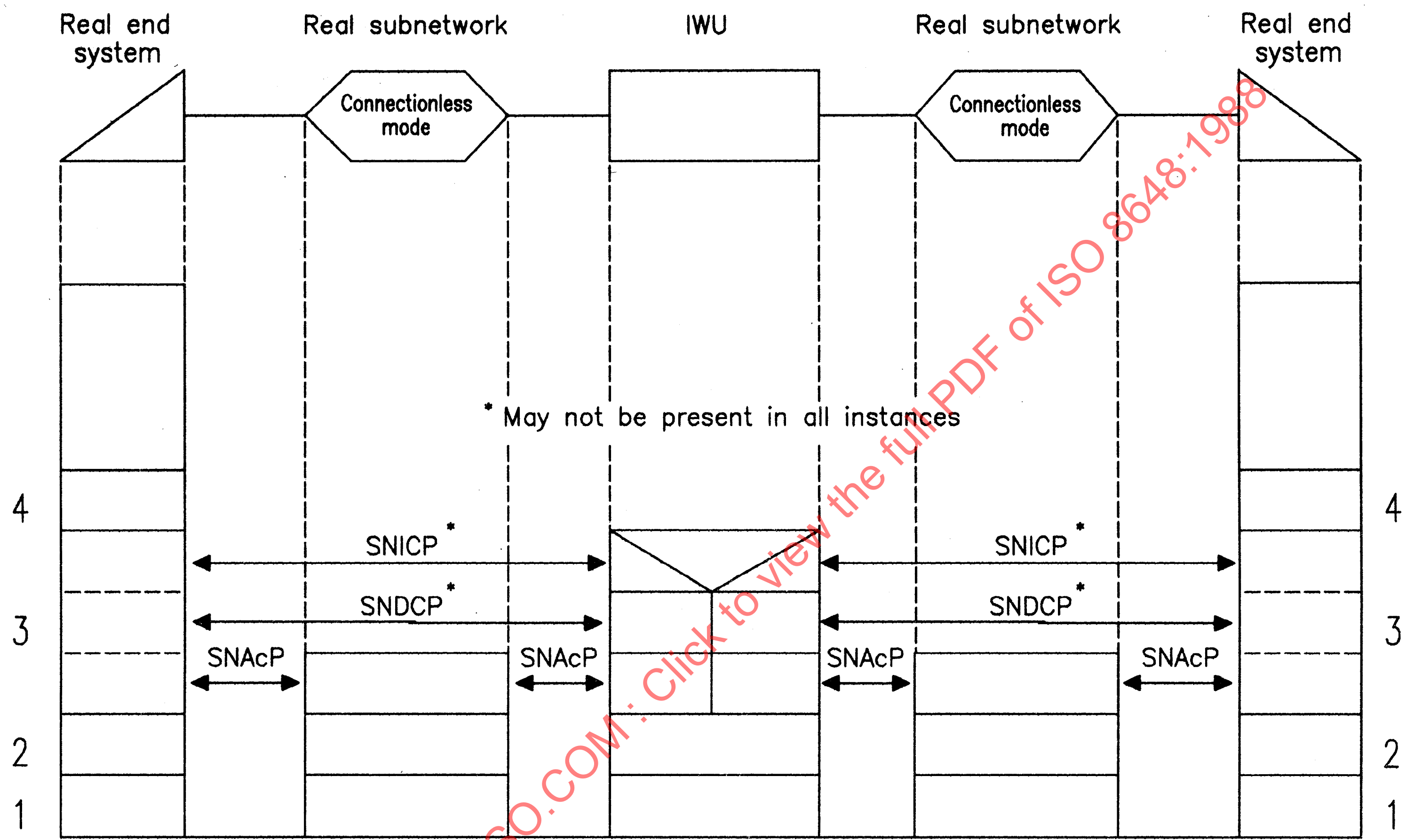


Figure 12 — Provision of the CL-NS over two CL-subnetworks using hop-by-hop harmonization

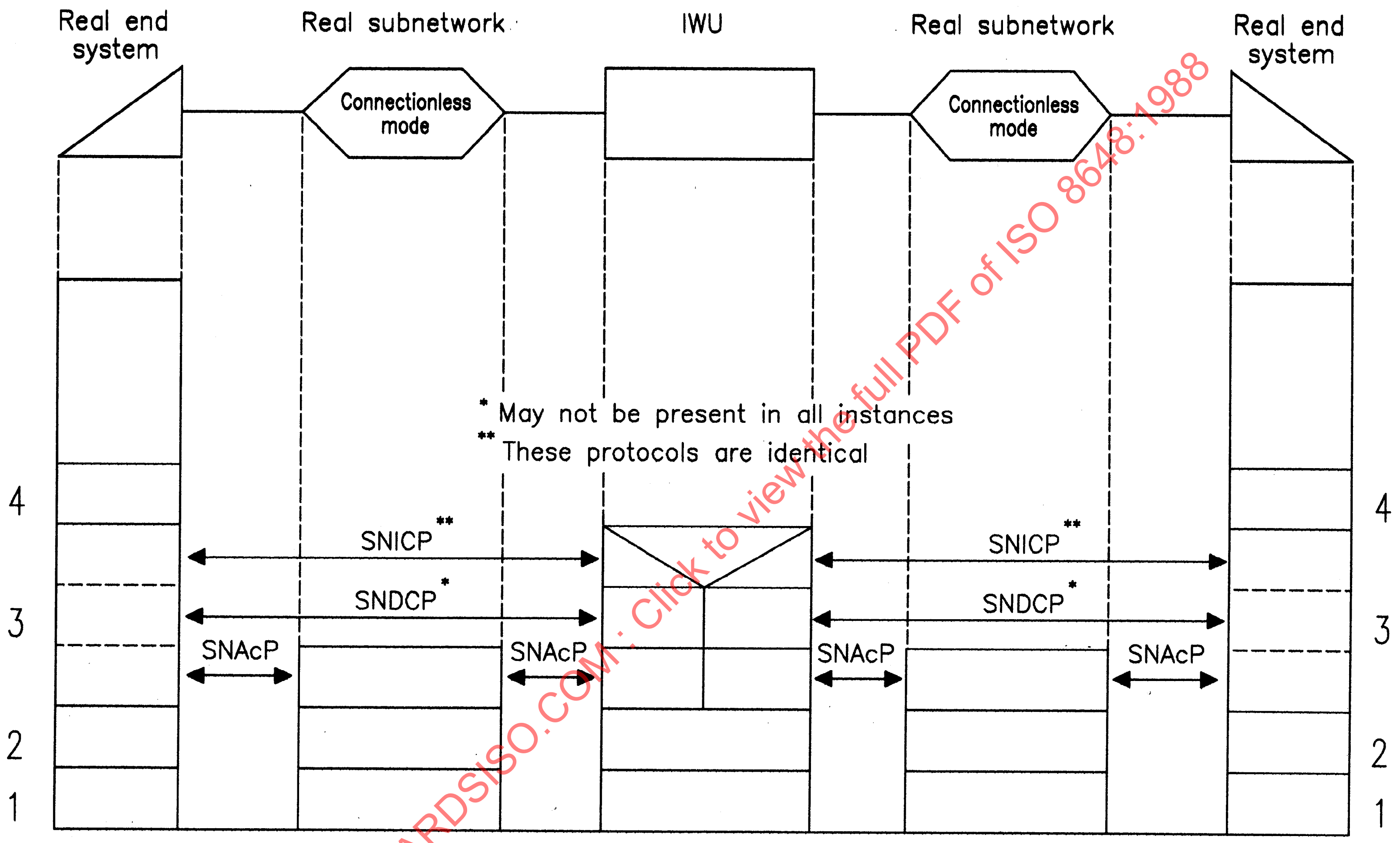


Figure 13 — Provision of the CL-NS over two CL-subnetworks using an internetworking protocol approach

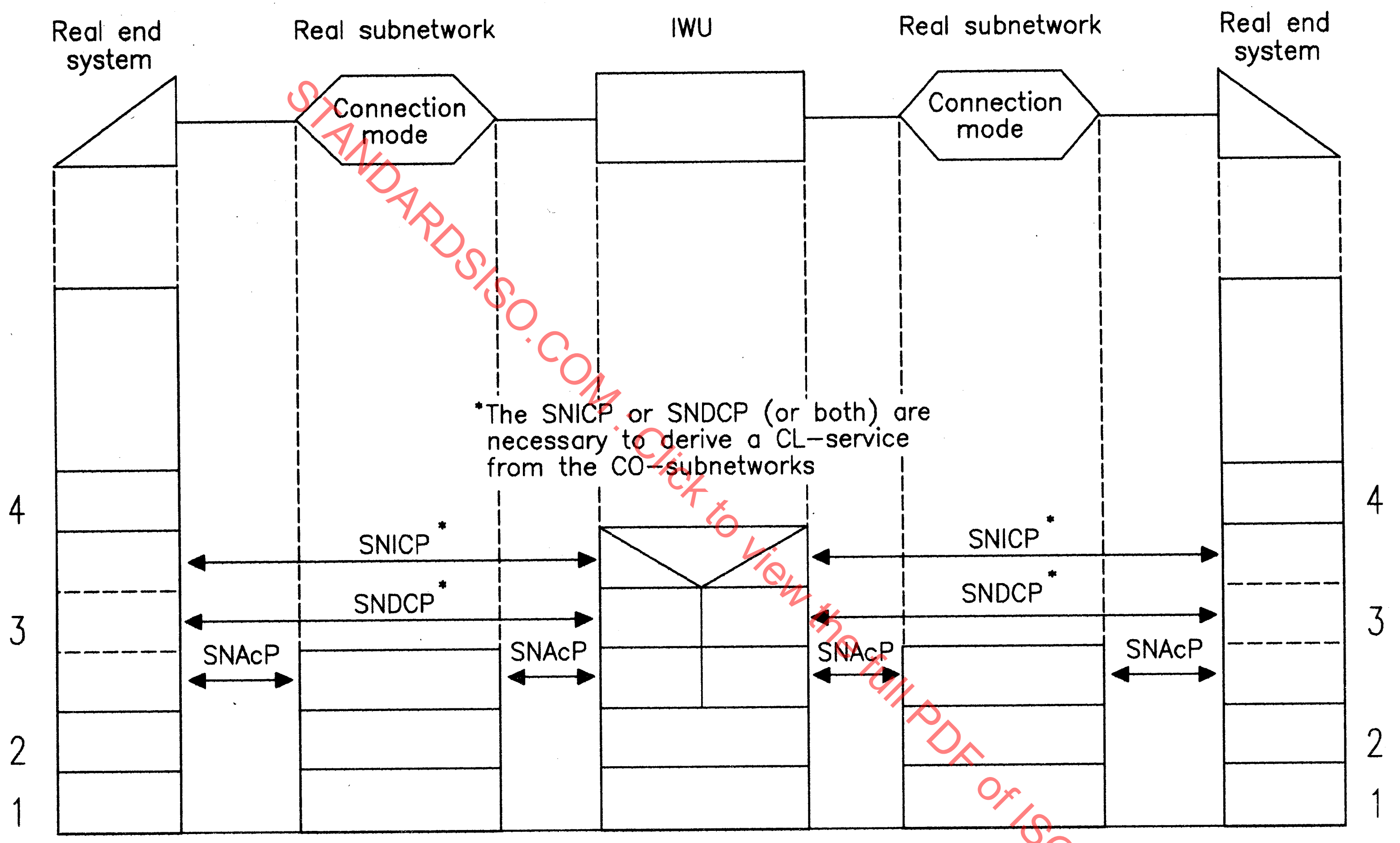


Figure 14 — Provision of the CL-NS over two CO-subnetworks using hop-by-hop harmonization