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**INTEGRATED SERVICES DIGITAL
NETWORK (ISDN)**

**OVERALL NETWORK ASPECTS
AND FUNCTIONS**

ISDN PROTOCOL REFERENCE MODEL

ITU-T Recommendation I.320

(Previously "CCITT Recommendation")

FOREWORD

The ITU-T (Telecommunication Standardization Sector) is a permanent organ of the International Telecommunication Union (ITU). The ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Conference (WTSC), which meets every four years, establishes the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

The approval of Recommendations by the Members of the ITU-T is covered by the procedure laid down in WTSC Resolution No. 1 (Helsinki, March 1-12, 1993).

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NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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ISDN PROTOCOL REFERENCE MODEL

*(Malaga-Torremolinos, 1984; amended at Melbourne, 1988
and at Geneva, 1993)*

1 Introduction

The objective of the ISDN Protocol Reference Model (ISDN PRM) is to model the interconnection and exchange of information – including user information and control information – to, through or inside an ISDN.

Communicating entities may be:

- ISDN users;
- an ISDN user and a functional entity within an ISDN, e.g. network control facilities;
- an ISDN user and a functional entity inside or outside an ISDN, e.g. an information storage/processing/messaging facility;
- various functional entities in an ISDN, e.g. a network management facility and a switching facility;
- an ISDN functional entity and an entity located in or attached to a non-ISDN network.

The purpose of communications between these functional entities is to support the telecommunication services introduced in Recommendations I.211 and I.212, by providing ISDN capabilities as defined in Recommendation I.310. Examples of these capabilities are:

- circuit-switched connection under the control of common channel signalling;
- packet-switched communication over B-, D- and H-channels;
- signalling between the users and network-based facilities (e.g. information retrieval systems such as videotex, operations databases such as directory);
- end-to-end signalling between users (e.g. to change mode of communication over an already established connection);
- combinations of the above as in multimedia communication, whereby several simultaneous modes of communication can take place under common signalling control.

With such diversity of ISDN capabilities (in terms of information flows and modes of communication), there is a need to model all these capabilities within a common framework (i.e. reference model). This would enable the critical protocol architectural issues to be readily identified and facilitate the development of ISDN protocols and associated features. It is not intended as a definition of any specific implementation of an ISDN or of any systems or equipment in, or connected to, an ISDN.

Examples of applications of this model are included in this Recommendation.

2 Modelling concepts

2.1 Relationship with the X.200-Series Recommendations

The ISDN Protocol Reference Model (PRM) and the Reference Model of Open Systems Interconnection for ITU-T Applications (OSI RM), defined by Recommendation X.200, have both commonalities and differences.

Both the ISDN PRM and the OSI RM organize communications functions into layers and describe the relation of these layers with respect to each other.

However, the scope of the ISDN PRM is different from the scope of the OSI RM.

The scope of the ISDN PRM is to model information flows across the range of telecommunication services defined in the I.200-Series Recommendations. These are bearer services, teleservices and supplementary services. This description necessarily incorporates ISDN-specific characteristics not encountered in other network types. Among these characteristics are multi-service types of communications which include voice, video, data and multimedia communications.

The scope of the OSI RM is not associated with any particular network type¹⁾. In that sense it is less specific than the ISDN PRM. Further, the scope of the OSI RM is tied to data communications and so, in that sense, its scope is more specific than the ISDN PRM. The OSI RM therefore has an important and limited application to the ISDN PRM – that application is to model data communications between open systems in an ISDN environment.

The relative scopes of the two models are illustrated by Figure 1. The existence of a common intersection shows that these models coexist and overlap.

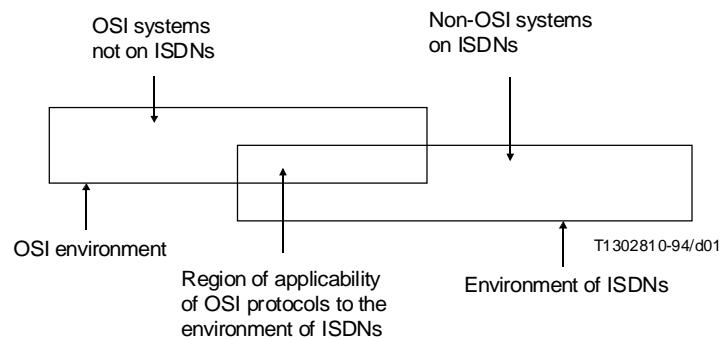


FIGURE 1/I.320

Applicability of OSI protocols to ISDN

However, in spite of these differences in scope, a number of concepts and the associated terminology which have been introduced in Recommendations X.200 and X.210 are fully applicable to the ISDN PRM. They include the concept of layer, layer service (see Recommendation X.200), and the notions of service primitive, peer entity and peer protocol (see Recommendation X.210).

The layer definition as provided in Recommendation X.200 for layers 4-7 is used in this Recommendation, as far as applicable (layering principles for scenarios outside the scope of OSI, e.g. telephony, are for further study).

For the combination of layers 1, 2 and 3, the sum of the functionalities as defined in Recommendation X.200 is adhered to, but a more flexible description method for the attribution of specific functionalities to specific (sub)layers is used. Layers 1-3, according to Recommendation X.200, are replaced by a stratum on top of an underlying Infrastructure Layer.

A stratum is a layered structure of typically two layers, supporting at least the following minimal set of functions:

- at the stratum network layer: routing and relaying, network connection;
- at the stratum data link layer: data link connection, sequencing, and other infrastructure enhancement functions. This layer is conceived as an “adaptation” layer, which adapts the infrastructure services to the network data transfer services.

¹⁾ Note that the term “network” in the ISDN corresponds to “sub-network” in the OSI terminology.

In addition, to complete the structure:

- at the infrastructure layer: infrastructure connections, infrastructure connection identifications. The infrastructure layer is allowed to be either the OSI Physical Layer, or a network connection of an underlying network.

The infrastructure layer is the lowest layer in the structure. When required for modelling purposes (e.g. for modelling overlaid networks), the infrastructure layer can be represented itself as another stratum with its own layered structure on top of an underlying infrastructure layer of a lower order. This recursion procedure can be applied as many times as needed.

Note that a stratum may be a concatenation of subnetworks in OSI sense.

Figure 2 gives the graphic representation of the stratification principles, showing also the recursive nature of the structure. It has to be noted that the stratum concept only applies at, or below, the network layer.

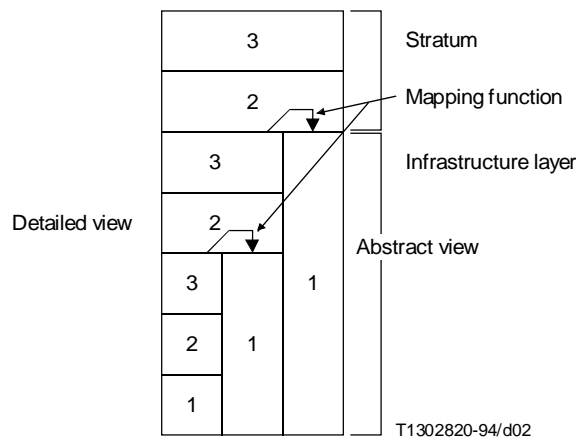


FIGURE 2/I.320
Stratification principle

The following ISDN needs have to be specifically catered for in this Recommendation:

- information flows for out-of-band call control processes, or more generally, information flows among multiple related protocols;
- information flows for selection of connection characteristics;
- information flows for re-negotiation of connection characteristics of calls;
- information flows for suspension of connections;
- information flows for overlap sending;
- information flows for multimedia calls;
- information flows for asymmetric connections;
- information flows for network management (e.g. change over and change back) and for maintenance functions (e.g. test loops);
- information flows for power activation/deactivation interworking;
- switching of information flows;
- new layer service definitions for non-data services;
- application to other than end-systems, e.g. signal transfer points (STPs) and interworking points;

- information flows for multi-point connections;
- information flows for applications such as:
 - i) voice (including A/μ law conversion);
 - ii) full motion video;
 - iii) transparent;
 - iv) telex.

2.2 Control and user planes and protocol blocks

- *PRM plane* – A PRM plane is composed of protocol blocks of the same type within a certain stratum pertaining to two or more connected systems, and having a well-defined peer-to-peer relationship.
- *Protocol block* – A layered stack of protocol entities with a single functional grouping.
- *User protocol block* – A protocol block with the exclusive task of transparent transfer or user information.
- *Control protocol block* – A protocol block with the exclusive task of supporting ISDN signalling.

Using the above defined terms, the User Plane and Control Plane definitions can be derived as:

- *U-plane* – A PRM U-plane is composed of user protocol blocks.
- *C-plane* – A PRM C-plane is composed of control protocol blocks.

The main rationale for protocols within the user plane is the transparent transfer of information among user applications.

The transparency requirement for a service is given by the value of the “data unit integrity” attribute of this service (see Recommendation I.140).

In certain cases this means that the raw bitstream (or the raw stream of delimited bitstrings) has to be passed unchanged from source to destination, as is usually the case for data transmission.

In certain other cases, however, this transparency requirement only holds for the semantics of the bitstream (or bitstrings) rather than for the bitstream (bitstrings) itself. For example, the transfer of voice may require recoding of the information (e.g. A/μ law conversion), so that the bitstream is changed, but the semantics of it (i.e. voice) remain preserved.

The main rationale for protocols within the control plane is the transfer of information for the control of user plane connections, e.g. in:

- controlling a network connection (such as establishing and clearing down);
- controlling multiple network connections for multimedia calls;
- controlling the use of an already established network connection (e.g. change in-service characteristics during a call such as alternate speech/unrestricted 64 kbit/s);
- providing supplementary services.

In addition to user information, any information which controls the exchange of data within a connection, but otherwise does not alter the state of this connection (e.g. flow control), pertains to the U-plane. All control information which involves resource allocation/deallocation by the ISDN pertains to the C-plane.

2.3 Local and global significance

The transfer of information in the Control Plane can have Local or Global Significance.

- a) *Local Significance* – Control information across one particular interface (i.e. the originating, the terminating access, or an interface between two adjacent network nodes).
- b) *Global Significance* – Control information which has non-local significance.

As an example from the ISDN user's point of view:

- the overall service to be provided to users has a global significance;
- the control of any resources to be used at the user-network interface has local significance;

and, from the network's point of view:

- the overall service to be provided by the ISDN (ISDN connection types, as introduced in Recommendation I.340) has global significance;
- the handling of connection elements has local significance.

Depending on their functional requirements, supplementary services relate to either the local or global perspective. For example:

- completion of calls to busy subscribers (CCBS) or User-to-User Signalling (UUS) have global significance;
- call waiting has local significance.

Global information falls into three classes:

- 1) the information is transported transparently;
- 2) the information may be processed, but remains unchanged (e.g. teleservices);
- 3) the information may be altered (e.g. destination number in relation with freephone or call forwarding supplementary services).

3 The model

The ISDN protocol reference model (PRM) is represented by a protocol block (see Figure 3), and further described by the concept of significance, as introduced above.

Such a protocol block can be used to describe various elements in the ISDN user premises and the network [e.g. terminal equipment (TE), ISPBX network termination (NT), exchange termination (ET), signalling point (SP) and signalling transfer point (STP), etc.].

3.1 Generic Protocol Block

The layering principles apply to the C- and to the U-planes: each plane can potentially accommodate a 7-layer stack of protocols. The plane management function shown in Figure 3 performs similar tasks to those of OSI Systems Management.

An example of one function of the Plane Management Functions is the Synchronization and Coordination Function (SCF).

The Generic Protocol Block is represented in Figure 3.

The following remarks apply:

- 1) Some layers may be empty, i.e. they provide no functionality. For example, it is likely that not all seven layers are required to serve the C-plane requirements; however, entities communicating in this plane are application layer entities. Note that this is not in contradiction with the OSI RM.
- 2) An element in the network, in user premises does not have to support in all cases protocols of both the C- and U-planes, allowing one of these planes to be ignored. For example, a network service centre accessed to provide a supplementary service (e.g. freephone) will be concerned by the C-plane only, and will have no knowledge of the U-planes.
- 3) A network element – unless it provides an HLF – will generally not support any U-plane protocol above layer 3.
- 4) The need for application processes specific to each plane, or for application processes able to access both planes, is for further study.

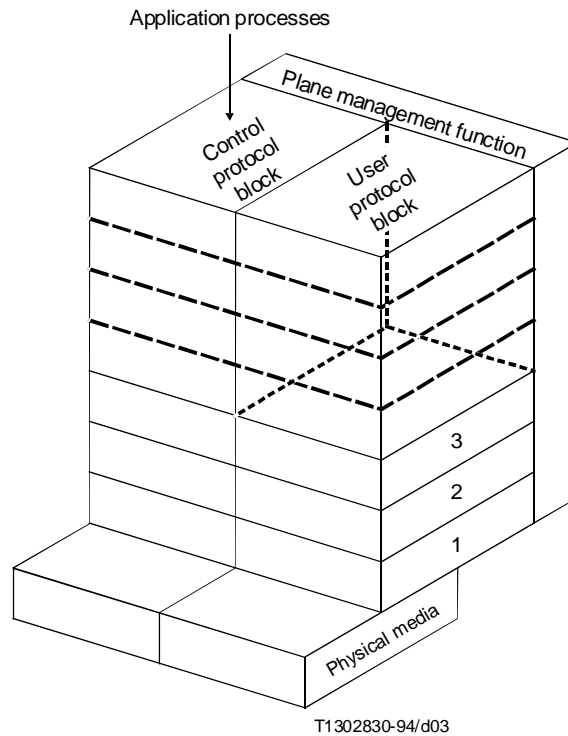


FIGURE 3/I.320
Global view of generic protocol block

3.2 Relations between layers in one protocol block

Adjacent layers within a plane communicate using service primitives. If a layer is null the parameters of primitives at the N-boundary are mapped onto parameters of primitives at the N-1 boundary, or transparency passed, as appropriate, and vice versa.

Further study is required on which layer services have to be specified in order to describe a telecommunication service.

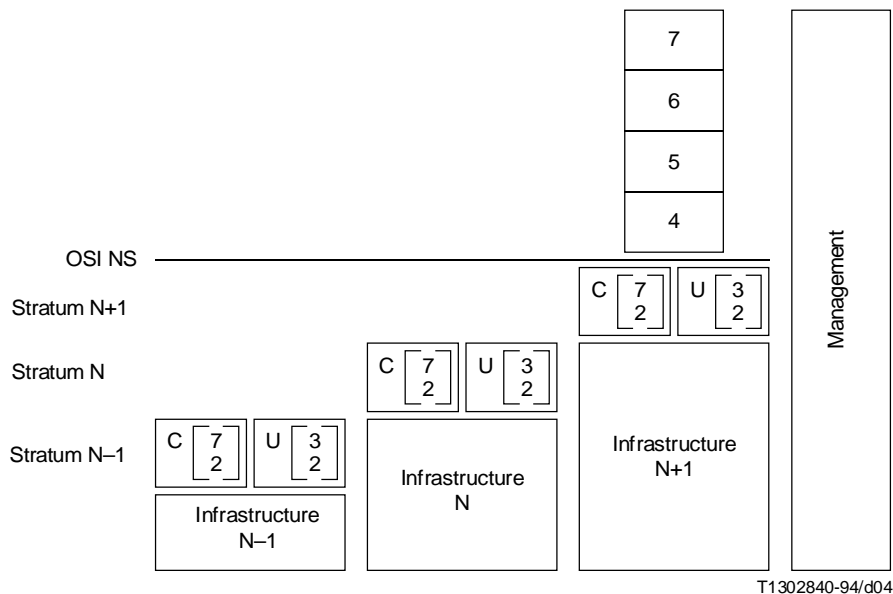
3.3 Synchronization and coordination function (SCF) relation between protocol blocks

For the provision of a certain stratum-network service, the C- and U-protocol blocks information will come together in an upper boundary, offered to the service user, and in a lower boundary, below which no more distinction can be made between the information flows. The upper and lower boundaries of the C- and U-protocol blocks coincide with the boundaries of the stratum within which these protocol blocks are defined.

A function is necessary to provide synchronization and coordination between the C- and U-protocol blocks information.

The SCF provides similar functionality as the local system environment (LSE) in OSI. SCF is a major component of the plane management function. The exact relation between LSE and SCF is for further study.

In order to emphasize the purpose of SCF, it is essential to mention that when the C-protocol block passes any user information, then no distinction can be made between the U- and C-protocol blocks in their functionality.



NOTES

- 1 The N-1 infrastructure can be further decomposed down to a physical layer.
- 2 This generic protocol block is directly applicable to OSI conforming applications. For non-OSI conforming services no higher layer (above the service offered by the network) structure is defined. In addition, an equivalent of the OSI NS (i.e. the highest level service the network is able tot provide) may be defined. This is for further study.

**FIGURE 4/I.320
Detailed view of generic protocol block**

For a given service, the SCF forms the upper boundary of the C- and U-protocol blocks. The SCF is positioned at the service boundary in the OSI sense. A lower boundary of the C- and U-protocol blocks will be perceived as the boundary below which C- and U-information flows are seen as a single information flow, just before the service where C- and U-information are passed to a lower layer over a single service access point. Where the lower boundary is perceived depends on how the service is offered.

Figure 5 illustrates the model for the Synchronization and Coordination Function (SCF). This model provides the framework to define the provision of the Network Service (NS) according to Recommendation X.213 to the (N + 1)-Layer at the boundary between the Network Layer of the ISDN and the (N + 1)-Layer. The synchronization and coordination of the Control-plane (C-plane) and User-plane (U-plane) is performed through the interaction between SCF and C-plane network protocol block, and SCF and U-plane network protocol block via the use of service primitives. These primitive interactions involve that the related C-plane and U-plane Network Protocols rely on the underlying services.

The model adopts a concept based on the definition of primitive procedures at three connection endpoints, namely:

- Coordinated Network Connection (NC);
- C-plane Network Connection (N(c)C);
- U-plane Network Connection (N(u)C).

The SCF state machine acts as a coordination process of the three primitive procedures. At the NC endpoint, the SCF provides a Network Service according to Recommendation X.213, while the primitive procedures at the two other connection endpoints depend on the capabilities of the underlying protocol block.

The general syntax of a primitive is *XX-Generic name – Type: Parameters*, where *XX* designates the interface across which the primitive flows, as follows:

<i>Interface</i>	<i>XX</i>
– Coordinated Network Connection	NC N
– C-plane Network Connection	N(c)C N(c)
– U-plane Network Connection	N(u)C N(u)

The SCF state machine provides synchronization and coordination capabilities for different C-plane call control procedures and distinct U-plane Network Services, including confirmed N(u)C release.

The SCF performs the C- and U-plane synchronization on a per NC basis and is not concerned with any functionality which is required, if multiplexing is used within U-plane underlying layers.

This model:

- allows to define the provision of the OSI Network Service in terms of the interrelationship between primitives at the upper and lower boundary of the SCF;
- does not require a particular protocol within the U-plane, but rather relies on SDUs to be exchanged between the SCF as service user and the U-plane as service provider. The SCF does not handle Protocol Data Units (PDUs), thus is independent of elements of a protocol.

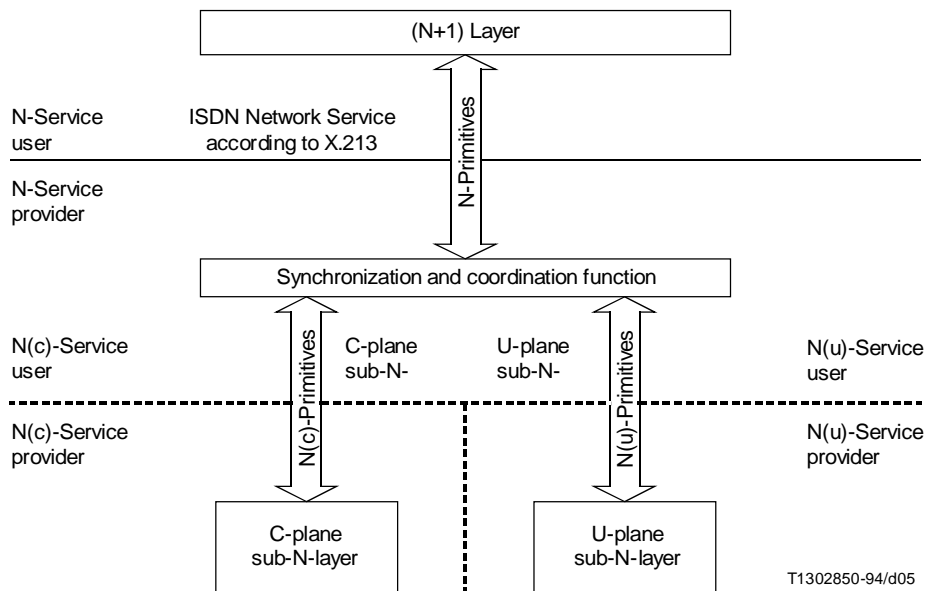


FIGURE 5/.320

Relationship of the Network Service to the service provided by C-plane sub-N-layer and U-plane sub-N-layer

Information in different planes need not be carried by distinct physical/logical means in all cases. For example:

- control and user information may use the same support, e.g. when inband signalling is used, or when user information is carried on D-channel;
- C- and U-plane information of one network may appear as U-plane information in another network. This may be the case when the other network is seen as the stratum infrastructure layer by the first network. In particular, ISPBX to ISPBX control information appears as U-plane information to the ISDN.

3.4 Data flow modelling

For further study.

4 ISDN management

The Plane Management Functions perform management tasks related to a system as a whole. It is similar to the tasks performed by the OSI System Management. These include, for example, SCF and Layer Management Functions.

4.1 SCF (Synchronization and Coordination Function)

The SCF is a measure component of the Plane management function.

The functionality of the SCF is described in 3.3.

4.2 Layer management functions

Layer management performs management functions relating to resources and parameters residing in protocol entities of the protocol blocks. Layer management handles the Operation and Maintenance (OAM) information flows specific to the layer concerned.

5 Interworking

A number of particular interworking situations should be considered:

- internetworking with an OSI network;
- interworking with a non-ISDN terminal;
- interworking between two ISDNs which do not provide the same set of facilities;
- interworking involving a network-provided interworking function to support high-layer and/or low-layer facilities.

5.1 General

All the interworking situations mentioned above are covered by the model illustrated by Figure 6.

The service A may be:

- the initially required telecommunication service (TS), if both networks are able to provide it (F is then empty);
- a telecommunication service resulting from a negotiation process which both networks are able to provide (F is then empty);
- a service which is required to support the telecommunication service to be provided, which is offered by both networks, but by means of different capabilities in the two networks.

The service A is provided:

- by means of functions F1 and protocol(s) P1 in network 1;
- by means of functions F2 and protocol(s) P2 in network 2.

The interworking function (IWF) maps the facilities offered by F1 and F2.

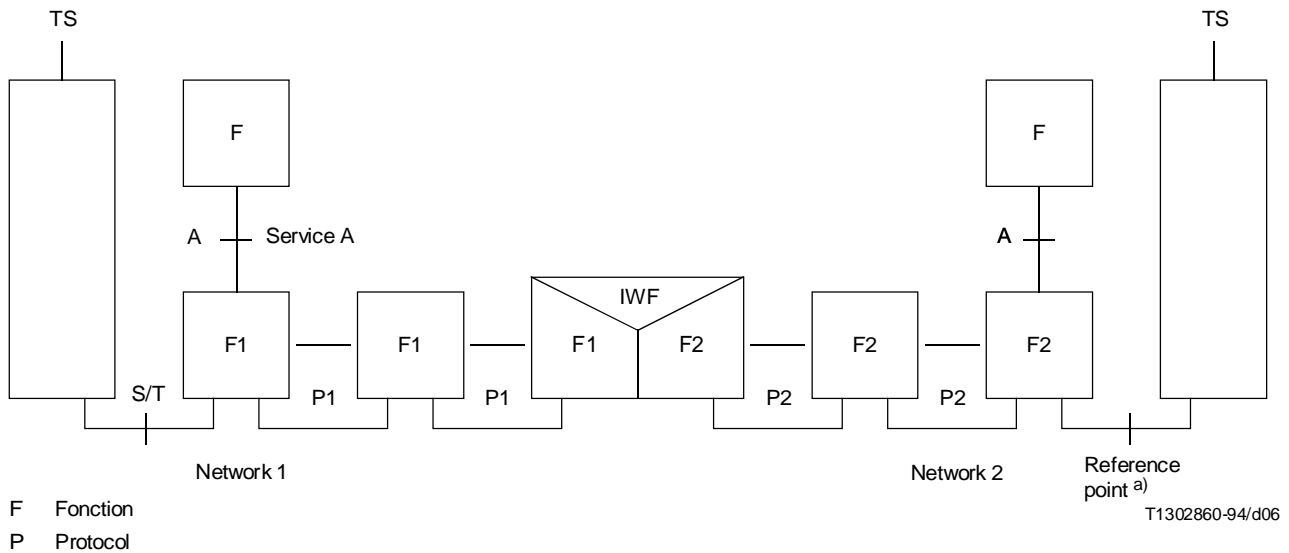


FIGURE 6/I.320
Interworking model

Two kinds of interworking can take place:

- 1) a one-stage interworking, where the calling user is not explicitly aware that an interworking function is required;
- 2) a two-stage interworking, where the calling user has a dialogue with the interworking function prior to exchanging control information with the destination user.

The model applies to both cases.

Interworking may involve the C-plane, and/or the U-plane.

In an interworking situation, the C-plane has to:

- determine the telecommunication service to be provided (agreed telecommunication service): this may imply service negotiation;
- identify the interworking situation, i.e. the fact that more than one network is involved, and that for some service A required to support the telecommunication service, two adjacent networks do not use the same underlying facilities;
- locate and invoke an IWF capable of mapping the facilities in the two networks.

In each network, the C-plane facilities will provide the functions and protocols (Fi and Pi) required to support service A.

In the two-stage interworking case, the C-plane information is “consumed” by the IWF during the first phase, and is forwarded (with or without modification) during the second one.

Whenever interworking in the U-plane is involved the following differences apply in the two cases:

- *One-stage interworking* – In this case only the first three layers (at most) may be involved for the provision of the requested end-to-end service. No HLF is required.
- *Two-stage interworking* – In this case the first stage is the establishment of the U-plane facilities between the calling user and the IWF. High layer functions (HLFs) and protocols may be involved, in which case the IWF acts as a substitute for the called user.

5.2 Relationships with the OSI RM

The OSI RM, seen from the ISDN PRM point of view, appears not to be in contradiction with the latter, but contains some restrictions which stem from the fact that it does not have the same scope:

- 1) The C- and U-planes are not separated, since the C- and U-plane information in one layer (n) always maps onto the U-plane information of the layer below (n - 1).
- 2) The concept of significance does not explicitly appear; however, control informations (e.g. in layer 3) include both “local” information and information which is carried end-to-end transparently or takes part in the definition of the overall service provided to the user (e.g. throughput).
- 3) Most OSI protocols and service definitions restrict facility negotiation to call establishment, and do not provide for facility negotiation during the active phase of a call.

Therefore the C-plane use is restricted to call establishment and facility negotiation before, and call release during, the active phase of a call.

Coexistence between the OSI RM and ISDN PRM takes place in the following situations:

- an ISDN terminal that for its data communication aspects conforms to the OSI RM: OSI RM and ISDN PRM coexist in this terminal;
- internetworking with a specialized network (e.g. PSPDN) which respects the OSI RM: the reference points involved are K/L;
- interworking with an “OSI terminal” via a terminal adaptor: the reference point is then R.

In each case, a mapping of information flows of one model onto information flows of the other has to be defined.

5.2.1 Interworking at reference point K/L

For further study.

5.2.2 Interworking at reference point R

In the case when a user application, running an OSI system, requires network services across the ISDN, the originating user application will address the terminating application as a destination user.

In the OSI system, the application is considered an ISDN user – a communicating functional entity in the PRM.

The C information pertinent to the higher layer OSI application is carried in the U-plane to the destination application. The C information pertinent to the network service required is carried in the control plane.

The OSI system requests the network service from the ISDN by placing a service request to both the C-plane and the U-plane (see Figure 7). The distribution of the information to the appropriate protocol blocks is made by the SCF. The SCF in the Plane Management Function provides support for the OSI Network Service capability.

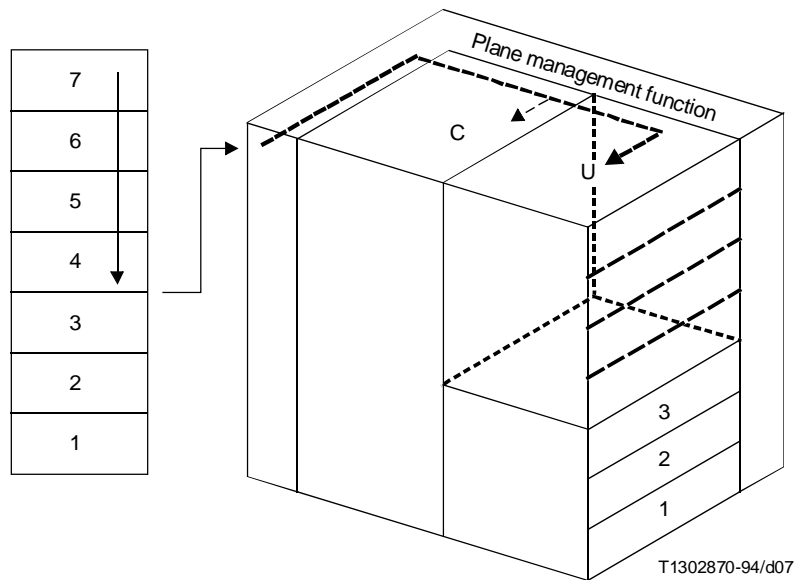


FIGURE 7/I.320
OSI reference model and ISDN protocol reference model

6 Examples

Applications of the PRM to the following examples is for further study.

6.1 Basic call situations (no supplementary service, no interworking)

- Circuit service (see Figure 8);
- packet service;
- multibearer capability;
- database access.

6.2 More elaborate situations

- Supplementary services;
- completion of calls to busy subscribers (CCBS);
- Three-Party Service;
- PABX facilities;
- OAM (operational, administrative and maintenance) applications.

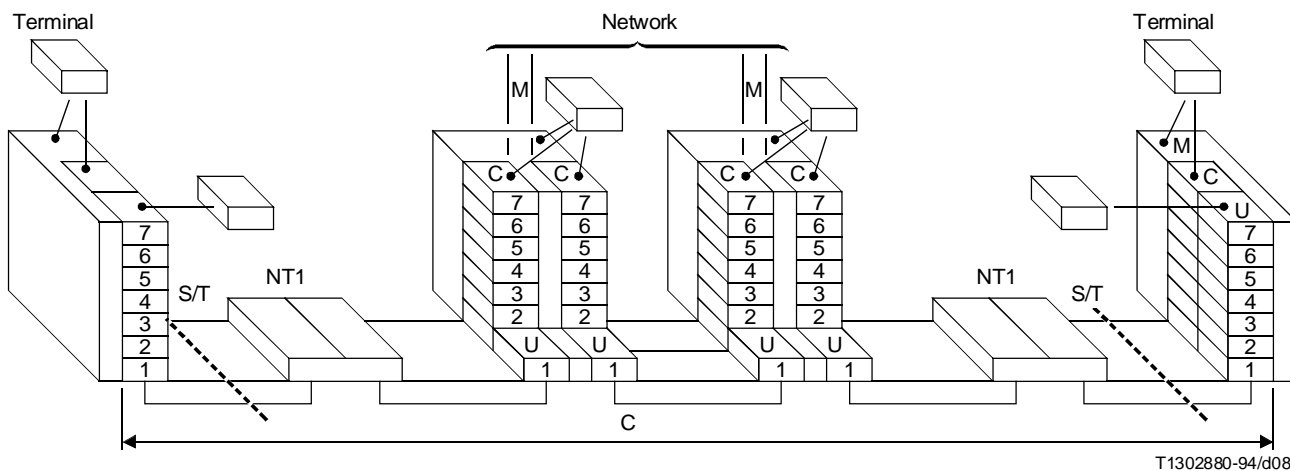


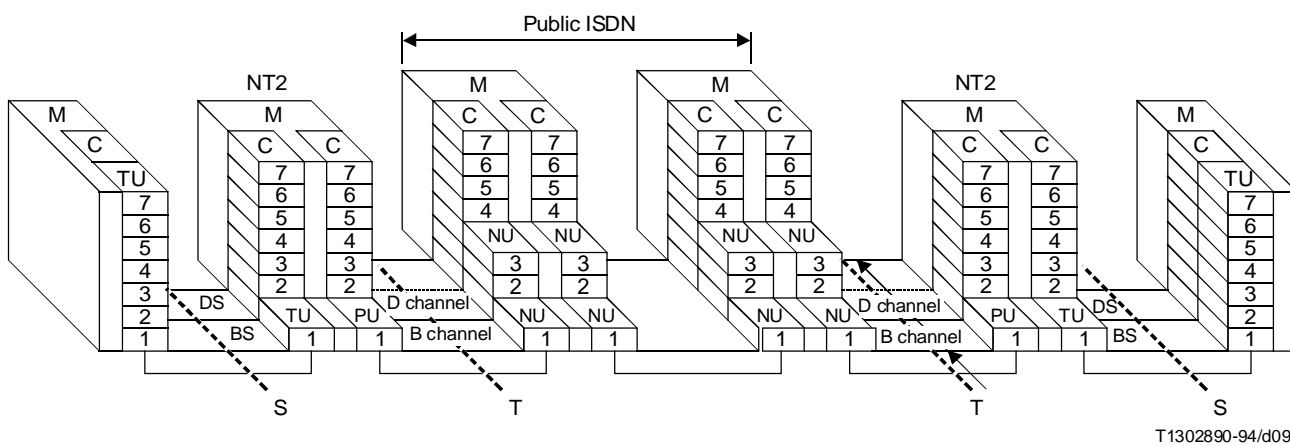
FIGURE 8/I.320

Circuit-switched connections via B-channel

6.3 Interworking

- At reference point R (teletex terminal)
- with a PSTN;
- with a PSPDN (videotex);
- inside an ISDN (provision of an HLF by the network);
- of public ISDN with other networks (a possible example is given in Figure 9).

NOTE - For simplicity reasons, NT1 functional units are not shown.



- C Control plane
- M Plane management function
- NU Network user plane
- PU PSN user plane
- TU Terminal user plane

FIGURE 9/I.320

A protocol reference model example showing the interconnection of public and private ISDNs