THE TRANSPORT LAYER

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1 INTRODUCTION

The concept of a Transport Service and Protocol emerged during the early 1970's. The concept arose from the use of various kinds of data networks which either did not inherently meet application requirements or which possessed particular features which could only be exploited by co-operation between the users.

An example of the first kind is the requirement for a connection oriented service on top of a datagram network. Such a protocol was developed for use on the European Information Network (EIN).

An example of the second kind is the Bridging Protocol designed for use on the early UK Experimental Packet Switched Service which had buffer distribution mechanisms controlled by the users.

More recently, the OSI architectural principles have directed the Service and Protocols of the Transport Layer, particularly with respect to placing network interconnection responsibilities within the Network Layer according to the concept of a 'global' Network Service.

The concept and feasibility of an Open Systems Interconnection environment has stimulated international discussions on standards on an unprecedented scale.

Open Systems Interconnection (OSI) refers to standards for the exchange of information among terminal devices, computers, people, networks, processes etc, that are "open" to one another for this purpose by virtue of their mutual use of the applicable standards.

One of the essential requirements of an Open System is the ability to communicate with another geographically remote open system.

The Transport Layer of the OSI Reference Model (1) has received considerable attention since it is the one and only layer in the architecture with overall responsibility for controlling the transportation of data between the source end-system and the destination end-system.

2 INTERNATIONAL ACTIVITIES

The 3 following organisations are active in producing standards for the Transport Layer:-

European Computer Manufacturers Association - ECMA

Comite Consultative Internationale de Telegraphie et Telephonie - CCITT

International Organisation for Standardisation - ISO

ECMA was the first international standards body to produce and ratify a Transport Protocol which has been published as Standard ECMA-72(2).

The interest from CCITT arises from the requirements to internationally standardise text/graphic and other communications services that could be offered by CCITT member bodies, eg Facsimile, Teletex, Videotex, Message Handling, Electronic Mail etc. These kinds of services are applications and thus, necessarily, require elements of all the layers of the OSI model. The distinction between pure data communications and pure data processing has become less clear. The concepts involved in advanced office automation and the electronic office require both raw communications and processing to be part of the complete 'service' package.

CCITT COM VIII has published Recommendation S.70, a "Network-Independent Basic Transport Service for Teletex". S.70 is compatible with a defined subset of the ECMA - 72 standard (Class 0).

Both ISO and CCITT COM VII are studying the transport layer in the context of wider range of usage than S.70, and see S.70 as a defined subset of the total capabilities. The amount of official liaison is greater than ever before and the personal representation in both CCITT and ISO committees has increased. There is every indication that a single standard will be produced, even though it would appear as separate publications from ISO and CCITT.

The value of the work of ECMA has been acknowledged and as much as possible of the ECMA standard has been included in the CCITT/ISO documents.

Both CCITT and ISO have worked on a single base reference document over the last 2 years. At the recent ISO/TC97/SC16 meeting in Tokyo, Japan, June 1982, the work progressed this document to the status of a Draft Proposal (DP) for balloting amongst ISO member bodies for progression to a Draft International Standard.

3 ARCHITECTURAL ASPECTS

The ISO Basic Reference Model (1) for Open Systems Interconnection defines 7 Layers, see Figure 1. Important architectural relationships have been defined between the Transport Layer and the Network Layer, and Transport Layer and Session Layer. These are as follows:-

a. The highest layer with any responsibility for the transportation of data is the Transport Layer. Thus the Transport Layer relieves higher layer entities from any concern with the means of transportation of data between them.

b. The Transport Layer is OSI End-System oriented. Thus Transport Protocols operate only between OSI End-Systems. Any relay functions or service enhancement protocols used to support the Network Service between the OSI End-Systems are operating below the End-Systems' Transport Layer (see Figure 2).

c. The Transport Layer performs, among others, any functions necessary to enhance the quality of service provided by Network Layer. It includes an addressing function. End-System oriented functions above the Network Layer such as multiplexing or encryption may be performed for cost-related or security-related considerations.

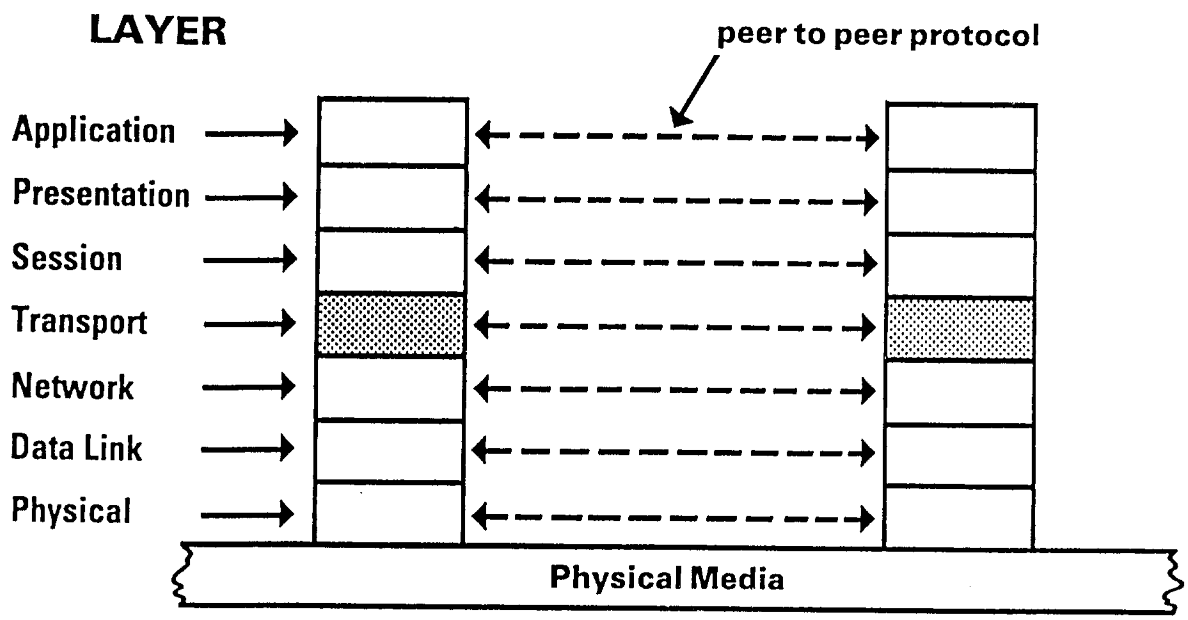


Figure 1

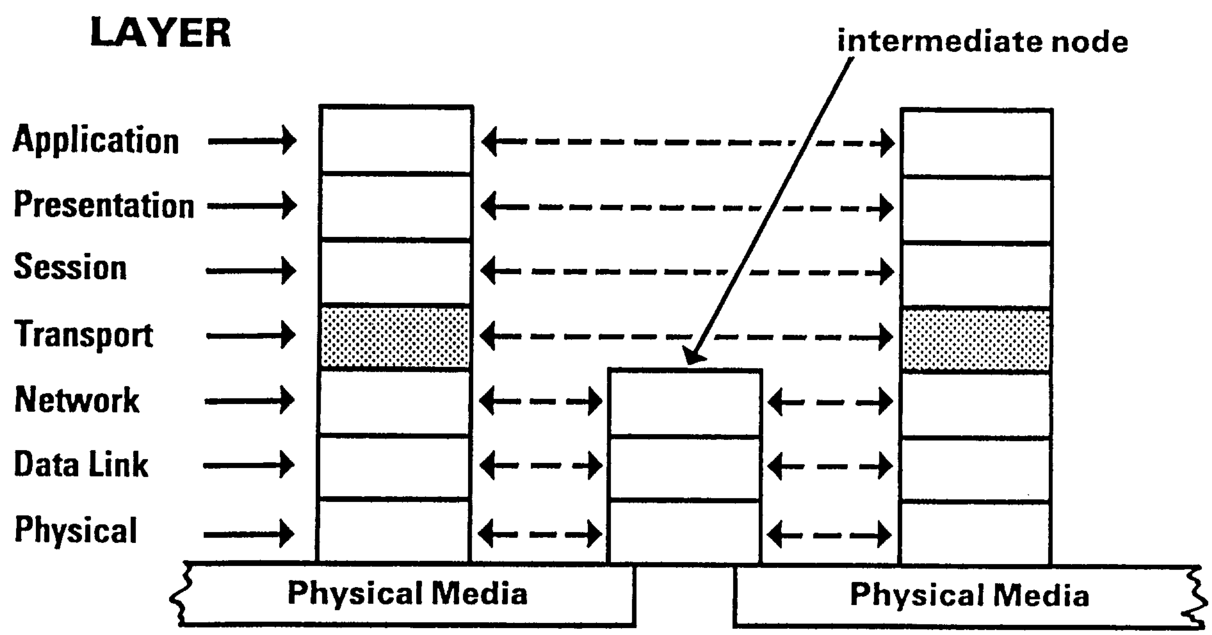


Figure 2

d. The Network Layer provides the Transport Layer with a firm Network/Transport Layer boundary which is independent of the underlying communications media in all things other than quality of service. Thus the Network Layer is assumed to contain functions necessary to mask the differences in the characteristics of different transmission and network technologies into a consistent Network Service.

e. The quality of Network Service is negotiated between the Network Service users and the Network Service provider at the time of establishment of a Network Connection. While this quality of service may vary from one Network Connection to another, it will be agreed for a given Network Connection and will be the same at both Network Connection end-points.

Item (d) implies that when several real networks are connected in tandem the Network Layer must contain the necessary enhancement functions to raise the level of service offered by any real network up to that of the OSI Network Service if the real network is not inherently adequate in this respect. The implications are still under study in relation to precise methods of providing the enhancement function bearing in mind the types of real networks in existence and the possible inter-working schemes.

It should be noted that the terms network and service have special significance to the OSI architecture and are thus distinct from other usage of these terms.

The service of a layer, in the OSI context, is the set of capabilities which it offers to the user in the next higher layer. The service provided to the next higher layer is built upon the service provided from the lower layer, by the addition of appropriate functions. The functional entities themselves communicate by means of the peer-to-peer protocol. This concept is illustrated in Figure 3.

4 OBJECTIVES OF TRANSPORT LAYER

The primary objective of the Transport Layer is to provide to the Session Layer, data transportation at a required quality of service in an optimum manner. The Transport Layer thus 'bridges' the quality of service 'gap' between that required by the Session Layer and that offered by the Network Layer.

The quality of service requirements are expressed in terms of parameters requested by the Session Layer, eg throughput, transit delay, residual error rate, establishment delay, resilience, cost, security, priority etc.

The Transport Layer must provide all the functions to meet the quality of service requirements, and the necessary supporting protocols.

For example, if the throughput requested were in excess of the network access rate it might be necessary to establish more than one Network Connection, and a protocol for line-sharing would be necessary. Conversely one Network Connection might be able to support more than one Transport Connection, in which case a protocol for multiplexing would be necessary.

Extra capabilities for Error Detection and Correction might be necessary.

LAYER CONCEPTS

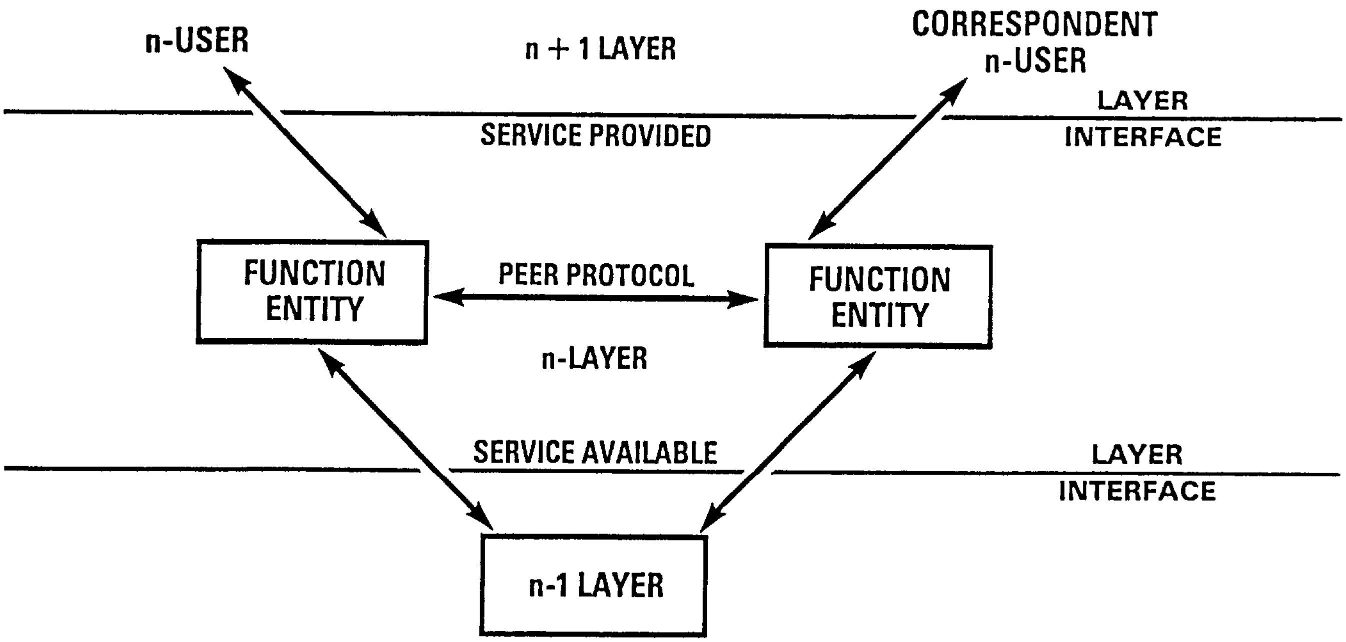


Figure 3

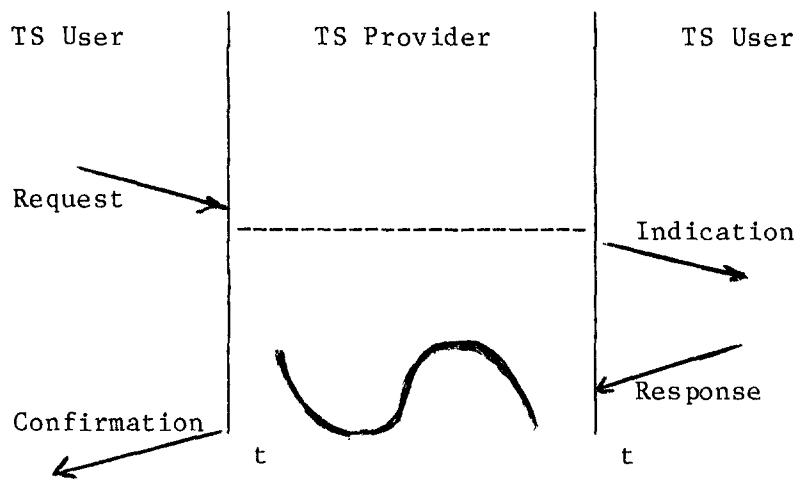
It should also be clear by now that the Transport Layer has to know the quality of service of the Network Connection before it can decide which function will have to be invoked over that Network Connection.

5 TRANSPORT SERVICE (3)

The interaction between the user of the n layer and the provider of the n layer is described by a set of named service primitives. A named service primitive has one or more related parameters and related service primitive events. This method of service definition is accepted by both CCITT and ISO.

Groups of related primitives have similar names and are qualified to indicate their procedural role, eg user generated Requests and Responses, provider generated Indications and Confirmations.

Permissible sequences of primitives are indicated by time sequence diagrams (see Figure 4).



Time Sequence Diagrams - Figure 4.

Necessary sequence relations between the 2 service access points are emphasised by a dotted arrow between the time lines.

Cases where no particular sequence is defined between the service access points are emphasised by a Tilde (~) between the time lines.

5.1 Service Primitives

The following service primitives and associated parameters have been defined:-

Primitive	Parameters
T-CONNECT request	(to transport address, from transport address, options, quality of service, TS-user data)
T-CONNECT indication	(to transport address, from transport address, options, quality of service, TS-user data)
T-CONNECT response	(responding address, options, quality of service TS-user data)
T-CONNECT confirm	(responding address, options, quality of service, TS-user data)
T-DISCONNECT request	(TS-user data)
T-DISCONNECT indication	(Disconnect reason, TS-user data)
T-DATA request	(TS-user data)
T-DATA indication	(TS-user data)
T-EXPEDITED DATA request	(TS-user data)
T-EXPEDITED DATA indication	(TS-user data)

Some example sequences are shown in Figures 5a and 5b

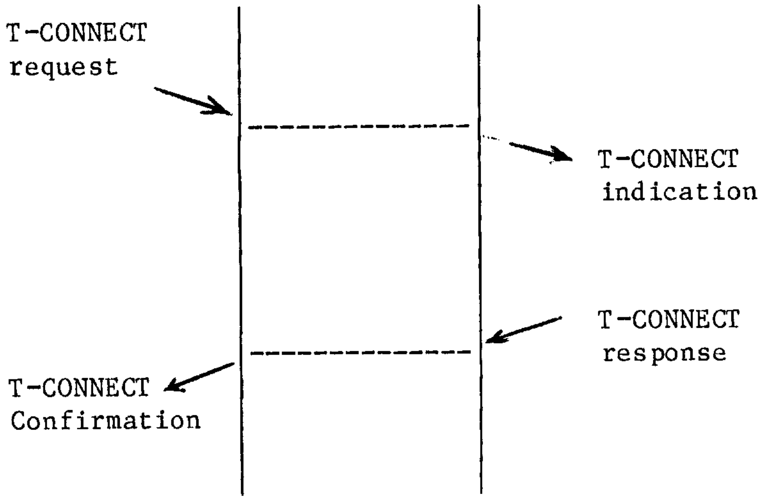


Figure 5a - SUCCESSFUL TC-ESTABLISHMENT

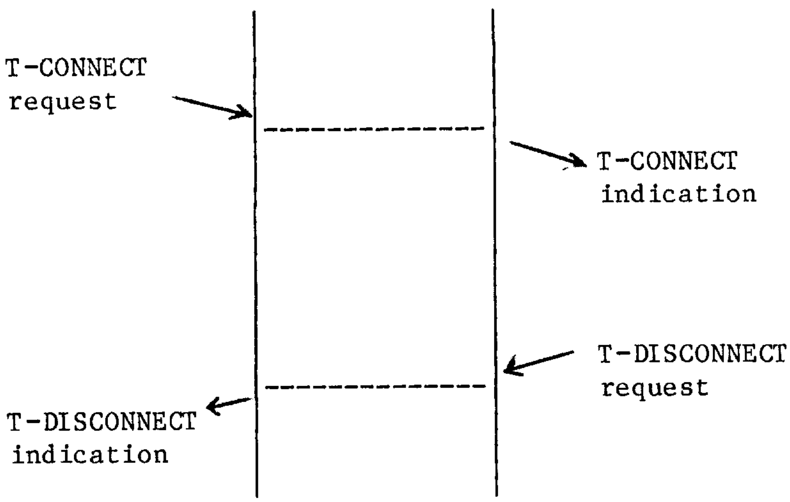


Figure 5b - REJECTION OF TC-ESTABLISHMENT REQUEST BY TS-USER

6 TRANSPORT LAYER FUNCTIONS

Before detailing the protocols under development internationally it is necessary to have an understanding of some of the background issues that have led to the current stage of development.

6.1 Relation between Functions and Protocols

As described in Section 3, functional entities reside within the Transport Layer and intercommunicate with their remote peers by means of the peer-to-peer Transport Protocol.

Thus the protocol is the externally visible representation of the functionality of the Transport Layer. There may be many separate functions within the layer. The issue that arises as a consequence of the relationship between functions and protocols is "what should be the correspondence between protocol elements and functions?".

Two extremes may be postulated:-

a. That for every separate function there should be a separate protocol element (or set of elements).

b. That the protocol always contains sufficient elements for all functions.

This issue is of major importance to the Transport Layer since it has to invoke functions in accordance with a set of parameters tailored to suit the application, over a wide range of Network Service qualities. The number and variety of functions is probably greater in the case of the Transport Layer than for most of the other layers.

The disadvantage of case (a) is the large number of different combinations of parameters and protocols that will result, giving rise to selection and negotiation problems. The disadvantage of case (b) is the inflexibility and the inefficiency of the resulting protocol which accommodates all functions irrespective of whether they are actually required.

A possible solution would be based on a compromise between the 2 extremes. Firstly it is necessary to group related functions together and thus reduce the combinations of resulting protocols, and only parameterise the groups of functions rather than individual functions. Secondly it is necessary to provide scope with each group or within the group structure to permit enough flexibility for evolution.

These considerations have lead to the concept of classes of protocol. The ECMA proposals are based on this concept. Whilst this concept appears desirable there has been considerable difficulty in agreeing the grouping of the functions and agreeing the nature of a group structure. The original ECMA proposals were based on a strict hierarchical set of protocol classes, where protocol class N was always sub-set of class N+1. The consequence of this is that if a particular function only exists in, say, class 3, all the functions of classes 0, 1, 2 are included irrespective of whether they are required.

Both the current studies in ISO and CCITT are based on a variation of the ECMA proposals. There has been a relaxation in the requirement for a strict hierarchy of protocol classes and acceptance of the use of options within classes to overcome the disadvantages described above.

7 CONCLUSIONS

This paper has been a brief introduction into background and main issues that have led to the current status of work on the Transport Layer.

To complete the detail of the Transport Protocol the current ISO document (4) which is subject to the ISO ballot procedures is reproduced in its entirety.

REFERENCES

1 Draft Proposal ISO/DIS 7498, 4 April 1982, "Data Processing - Open Systems Interconnection - Basic Reference Model".

2 Standard ECMA - 72, January 1981, "Transport Protocol".

3 ISO/TC 97/SC 16 N1162 Tokyo June 1982, "Transport Service Definition".

4 ISO/TC 97/SC 16 N1169 Tokyo June 1982, "Transport Protocol Specification".

BIOGRAPHY

Keith G Knightson is Head of Standards and Protocols Group in the Digital Data Networks Division of British Telecom. He has been an active participant in CCITT in the development of the packet switching Recommendations. He also is involved with Open System Interconnection Standards both in CCITT and ISO, and is currently the CCITT SG VII Special Rapporteur for the Transport Service, Transport Layer, and Network Service. He was actively involved with specification and implementation of BT's Packet Switched Service (PSS) and value added services.

Keith holds both an B.Sc and an M.Sc in Computer Science, is a Chartered Engineer, and a Member of the Institute of Electronic and Radio Engineers.