COMPUTER COMMUNICATIONS, TODAY AND TOMORROW - A TUTORIAL

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ABSTRACT

A generalized model of a data communications system is presented. Although this model is applicable to any type of communications system, its use is having a great impact on developments in the field of computer communications. This model has been implemented on the University of Calgary Distributed Communications System (DCS) and examples from this system will be used to illustrate various aspects of the model. The tutorial will conclude with examples illustrating how the adoption of this model is influencing future developments in computer communications.

COMMUNICATIONS PAR ORDINATEUR AUJOURD'HUI ET DEMAIN - UN COURS

RESUME

Un modèle général de système de communication de données est présenté. Même si ce modèle peut être utilisé pour n'importe quel système de communication, son application nous a prouvé très utile. Ce modèle a été mis en oeuvre avec le système de communications distribuées de l'Université de Calgary, (DCS) et nous nous servirons de ce système afin d'illustrer les différents aspects de ce modèle. Enfin nous démontrons comment l'adoption de ce modèle influence les développements futurs dans le domène des communications.

COMPUTER COMMUNICATIONS - A TUTORIAL

INTRODUCTION

In the past five years there have been significant advances in the computer communications field. Many of these advances are in the area of standardization. This paper describes, in the perspective of a layered communication model, the nature and function of the standards under development. An examination of such standards makes it possible to foresee the directions that will be taken in future developments in in computer communications.

MODEL OF LAYERED COMMUNICATION

Communications may be defined as a transfer of information between two end users, where an end user is defined as the person or machine that makes use of the information. An analysis of a communication between end users shows that the transfer of information is actually taking place at more than one level.

As an example, imagine a conversation taking place in a crowded room. The actual physical transfer of information is occurring via sound waves in the air. This first, and lowest, level of communication takes place over the physical medium.

There are actually many sound waves in the air at once due to other conversations, noise, and so on. The ear receives all of these sounds and passes them to the brain which must convert them into words and string the words together to form a portion of a sentence. It is useful to think of the words as being placed in a packet or or envelope in such a way that each packet contains words from only one speaker. This second level of communication thus involves the resolution of sound waves into discrete words. That this second level is independent from the first level may be seen from the fact that the same set of words may be obtained by other means - by lip reading for example.

The person receiving the packet must now decide whether a particular packet (in this case, a part of a conversation) is intended for him. The process by which packets intended for the receiver are extracted from the multitude of packets actually received constitutes the third level of communication. This level may be differentiated from the second level by noting that while the second level deals with many packets containing messages, the third level deals only with packets intended for a single receiver.

At the fourth, and highest, level the information contained within the packet is acted upon. At this level, the manner in which the message was transmitted has no importance. All that counts is the content of the message.

An analysis of the above example reveals several interesting things. First, the useful information transfer was that which occurred at the fourth level, i.e. the message that one person gave to another in the conversation. This same information could have been transferred in other ways such as by telephone, letter, or even a knowing glance. The content of the message did not depend on the medium by which the message was transferred.

Secondly, many other persons in the room may have heard the conversation, but the message itself was (presumably) only acted upon by the intended recipient. The reason that this is so is that the sender of the message used some means to indicate who was to receive the message. The receiver must necessarily have been aware of the 'addressing' technique used by the sender. In other words, a protocol or set of rules is established by which the two participants in the dialogue may send and receive messages. In addition, it may be shown that such a protocol only applies to a single level. In the example of the conversation it is quite apparent that the content of the message (level 4) is not dependent upon the addressing protocol used (level 3).

Recall that the level two portion of the communication is concerned only with the assembly of packets. This level is not concerned with the content of the message or who the recipient of the message is to be. In order to assemble the packets, the receiver and originator of a message must agree on a protocol that describes how the beginning and ending of a packet are to be indicated. For example, in a conversation the ending delimiter usually consists of an inflection in the voice.

At level one, the physical level of communication, there is no concept of a message at all. This level deals only with the physical transmission of data via sound waves, electrical impulses, and so on. A level 1 protocol must exist that describes how the physical medium is to be used. In the example of the conversation, the protocol requires that the recipient's ears convert sound waves to words in the appropriate manner.

In summary, it can be seen that one level of communication is independent of other levels and that a particular level is concerned only with the transfer of information to the corresponding level in a receiver. The four levels of communication may be defined as:

1. The physical link level, which is concerned with the transfer of data over a physical medium,

2. the logical link level, which is concerned with the assembly into packets of the data received from the physical link level,

3. the logical channel level, which extracts from all the packets received only those intended for the reciever, and

4. the end user level, which makes use of the information contained within the packet.

LAYERED COMPUTER COMMUNICATION

The levels of communication described in the above example are present in most, if not all, types of information transfer. The formal recognition of this fact in the computing field has only taken place within the last decade. The major advances now occurring in computer communications are almost exclusively concerned with applications of this model of layered communication. Before describing these advances, it is necessary to formalize the model referred to in the example above as it is applied to computer communication. As shown in Figure 1, the four levels used consist of the physical link level, the logical link level, the logical channel level, and the end user level. As a general rule, each level is distinguished from adjacent levels in that it may be replaced without requiring any modification or alteration to levels above it.

The physical link level is concerned with the actual means of data transfer. In computer communications, the physical link may be wires, satellites, radio, coaxial cable, fiber optic cables, punched cards, and so on. Data is usually transferred over the medium in the form of bits, a bit being a single piece of binary (true/false) information. Before a transfer may take place, both end users must agree on the media to be used , on the speed at which the bits are to be transferred , and on the order of the bits as they are recived in a time sense. Thus, a protocol between the level 1 layers in a communications session must be agreed upon.

The second level, the logical link level, attempts to organize the collection of bits received by the physical level into a packet. The level 2 layers of each communications session have a protocol which

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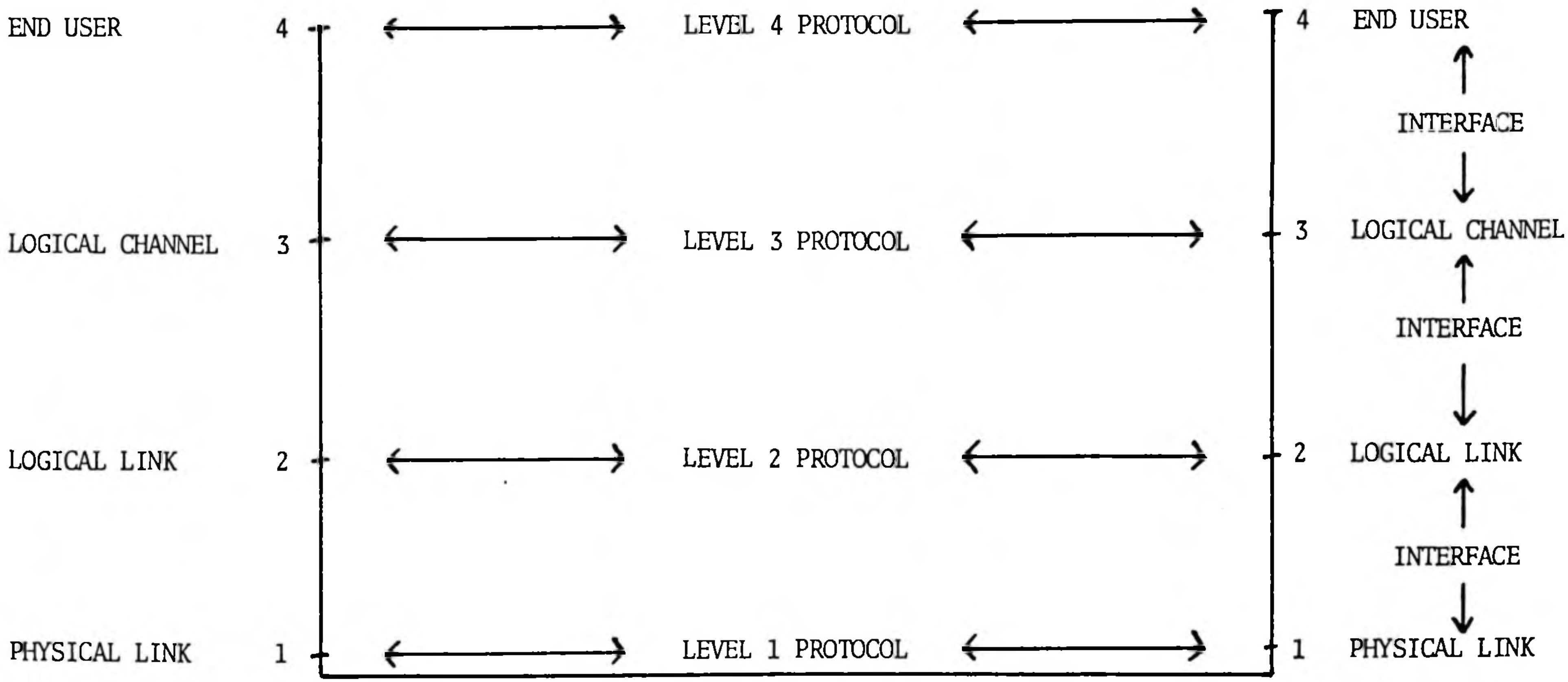

FIGURE 1
LAYERED COMMUNICATIONS SESSION

provides a means for detecting the beginning and and ending of a packet. Many level 2 protocols also provide a means for the detection and correction of any transmission errors which may occur at the physical level.

Once a packet has been created at the logical link level, it is passed upward to level 3, the logical channel level. This level determines which packets are intended for the end user, assembles one or more of these packets into a complete message, and passes the message to the end user level. If the message is not addressed to the correct end user it is ignored by the logical channel level. The protocol governing the operation of the logical channel level thus describes how the address portions of the message are to be encoded and decoded and also provides a means of controlling the rate of message transfer between end users.

Messages accepted by the logical channel level are passed upward to the end user level. In a typical communications session the end user at one end is a person sitting at a terminal while the end user at the other end is a computer program. The terminal user and the computer also use a protocol in order to communicate. Anyone who has used a computer will recall the frustration in determining the protocol that a particular computer requires. No matter what one enters at the ...inal, all that is received in response from the computer is a message such as 'ILLEGAL COMMAND' or the like.

The word 'protocol' has appeared many times in the above text. In the field of computer communications, a protocol may be defined as the set of rules governing the transfer of information between identical levels in a communication link joining two end users.

There are many protocols in existence today and some have become industry wide standards. At the physical level, the protocols most often used for terminals are those that specify that data may be tranferred in an asynchronous mode or in a synchronous mode.

Most of the protocols that are actually commonly referred to as protocols govern data transfer at level 2 or the logical link level. Such protocols include Bisync, 200UT, HDLC, and SDLC. These protocols describe the format of a message in terms of beginning and end characters, the technique to be used for the detection and correction of any transmission errors which occur at the physical level, and the technique to be used for flow control in order to ensure that messages are not transmitted faster than they can be received.

Until recently, level 3 protocols were virtually non-existent in the computer industry. It was assumed that any message received by the logical link could have one and only one destination. Since the level 3 or logical channel protocol is concerned primarily with the origin and destination of a message, no protocol was really required at this level.

In 1974, IBM announced a new communication architecture called SNA or Systems Network Architecture. The concept of levels was introduced at this time and a level 3 or logical channel protocol was defined. With regards to terminals, the impact of the introduction of a level 3 protocol was that a given terminal no longer needed to be dedicated to a particular application. Since the application is now talking at a logical channel level the terminal user is able to specify the application on the computer with which he wishes to communicate by giving the logical channel address of that application.

More recently, the Trans-Canada Telephone System introduced a public offering referred to as DATAPAC. DATAPAC is a packet switched service which is based on internationally defined protocols for both level 2 (HDLC) and level 3 (X.25). A DATAPAC user has the ability to create a connection between himself and another end user at the logical channel level. The logical channel thus created between the user and the computer is referred to as a virtual circuit. The protocol governing the creation and use of a virtual circuit is referred to as X.25 level 3 and was approved as an international standard in 1977.

Currently, there are no standards defined for level 4 protocols, primarily because every computer manufacturer has its own proprietary programs and even programs doing essentially the same thing differ in enough aspects so that the protocol for using them is different.

Thus far, little has been said about the mechanism by which information is passed from one layer to the layer immediately above or below it except to comment that a packet is passed 'up' to an end user or 'down' to the physical link. Although it is not necessary for all communications sessions to use identical mechanisms for inter-layer transfers, there is an important reason for doing so. If there is a standard way, for example, of passing packets from level 2 to level 3, then it is possible to replace one level 2 protocol with another different level 2 protocol. As long as both ends of the session use the same level 2 at any given time, then such changes can be made without affecting level 3 at all. This means that packets arriving at level 3 may be transmitted and created in many different ways. As a result, a computer application may be accessed by many types of terminals with different speeds, different electrical characteristics, and different transmission modes.

The common boundary between two vertical levels is called the interface between the levels. The computer communications industry is concerned with defining standard protocols to govern the horizontal transfer of information between similar levels and with defining standard interfaces which describe the nature of the vertical information transfer up or down between adjacent levels. One well known interface is the RS232 standard interface which defines the interface between the physical link and logical link levels.

Many protocols have been in existence for some time at levels 1 and 2. The significant advance over the past few years has occurred in the area of the definition of standard interfaces as well. By defining the interfaces into and out of a certain level, the nature of the level itself is also defined. Once the function of a level can be described accurately, the protocol describing the communication between such levels is readily achieved. The disadvantage of many of the older protocols is that they tend to incorporate features belonging to more than one level and thus they are not very flexible.

The future of computer communications resolves itself down to the provision for standard protocols and interfaces governing the operation of the four levels of communication. The greatest work required is at level 4, the end user layer, where very few protocols exist and where many, many different interfaces exist. A vigorous adherence to the principle of isolation of layers is necessary if standards are to be developed that are truly transportable between all types of computers and all transmission methods.

EXAMPLE: THE UNIVERSITY OF CALGARY DCS

The Distributed Communications System (DCS) at the University of Calgary operates at all four levels and may therefore be used to illustrate the advantages of a layered communications system.

An end user (level 4) on the DCS can be either a particular program on one of several computers or any of the many terminals attached to the DCS. A logical channel connecting two end users is established when one of the users makes a request for a connection to another end user. For instance, an end user at a terminal may request a connection to the CDC computer, the IBM computer, the Honeywell computer fiber optic cable, or for small local networks, a multi-wire high speed bus. An example of the latter is the IEEE-488 bus for laboratory instruments which has a maxiumum length of 20 metres and a transfer rate of up to 1 million bytes per second.

The thrust of experimental local networks is to replace the usual computer data bus by a local network. In this type of system a processor is not attached to a disk drive directly. Instead, both the processor and the disk controller are treated as 'end users' on the local network. The advantage of this technique is that all end users on such a network, including user terminals, may access the devices as if they were peripherals no different from themselves. The concept itself is not new. A bus architecture incorporating these ideas has been used for many years on the Digital Equipment Corporation PDP11 series of mini-computers. The advance is in the manner in which the local network implements the concept. Instead of the requirement of having very short data busses, of the order of hundreds of feet, a local network may be extended for at least thousands of feet using current technology. In addition, a rigorous compliance with standard level 3 and level 4 protocols in a local network means that all devices on the network may be addressed and used by all other devices.

If one processor on a local network becomes overloaded, more processors may be added at any time without disturbing the rest of the network since a processor is only concerned with level 4 data messages and the location and addresses of other processors (or any other devices) is handled by lower level protocols.

As an example, consider an application of a local network which makes use of an intelligent (micro-processor) based terminal for updating a data base. A user at such a terminal could issue a request on the local network asking to have the data which he wishes to modify transferred to his terminal. The terminal would then store the data into its own memory. This data could then be modified by the user using the micro-processor in his terminal. When the modification is complete, the data can be sent out on the local network for storage or for processing. The terminal user does not have to be concerned about where the data is stored or about the location of the processor that may subsequently make use of the data since the actual tranfer of the data is accomplished at levels lower than that at which the terminal user is operating.

The second area where level four networks are appearing is in global (large geographic area) networks. These networks are the type that are commonly thought of when people discuss networks and they usually involve many user terminals located throughout the country or the continent which are accessing a variety of processors.

Level four versions of global networks will make use of satellite or radio facilities for the physical link. As is the case in local networks, any end user on such a network may establish a logical link (at level 3) to other end users on the same network. Thus a user at a terminal in Vancouver may be able to request that a particular function be performed for him, say examination of a data base, and he will not need to know where the data base is located or even where the computer managing the data base is located. A good illustration of the usefulness of a level four global network is shown in an experiment conducted by the U.S. National Bureau of Standards. This group used the ARPA network, a large network supporting over 100 host computers, as the backbone level 4 network. A data base program was designed that could store and retrieve data from any of five different computers on the ARPA network. A user on the network could request certain data and this would be retrieved from one of the five computers and returned to the user. The user would not be aware of the actual location where the data was stored, nor would he need to be aware of the existence or use of the ARPA network for transporting the data. Obviously to make this type of application possible for many users, standard protocols must be developed to define how one can access the data, how the data must be stored, and so on. These protocols are, of course, level 4 protocols.

In summary, the application of the layered model of communication to computer developments has enabled the content of a data stream to be entirely divorced from the way in which the data is transferred. The result of this separation into layers is that users at terminals can request that computer related services be performed for them without knowing where the computer is located or how messages are transferred to it. For the first time, the user of a computer will be free from the limitation of having to use the particular computer to which his terminal is attached and instead will use the computer best suited to his requirement.

The outcome of this broadened horizon for computer use will be the creation of computer utilities which will provide specific functions and not just time on a computer. Experiments which make use of the Cable TV network are already underway in which users may use their home television sets as computer terminals to request various computer services such as banking, shopping, menu preparation, and printing of news summaries. This is only the beginning. The continued application of the layered model to future developments in computer communications will make computer services available to all and a routine part of everyday life.

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CONCLUSION

The standardization of both protocols and interfaces is enabling rapid advances to take place in the computer communications field. An understanding of the significance and areas of application of such advances may be achieved by viewing them from the perspective of the layered model.

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