

## 20. Communication Networks

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The goal of this newly initiated research program is to determine and demonstrate the principles that should be followed in the design of local communication networks as typified by local area networks, private branch exchanges and internettted collections of such structures.

Two fundamental assumptions distinguish the research from much of the ongoing work in this area. One is that a single integrated system is to provide a set of highly diverse communication services such as interactive terminal service, database access, file transfers, graphics, voice and video. The other is that single mode optical fiber links with very wide bandwidths can be employed economically. These assumptions are not satisfied by the networks now being designed, but based upon the perceived trend toward such integrated diverse services and the declining cost of single mode fiber technology, it is probable that they will be at some time in the future.

The research will involve theoretical, experimental and design activities. The theoretical work will provide the basis for choosing between broad alternative design approaches and will be guided by the existing and projected capabilities of single mode fiber technology. As the basic structure of the network becomes more defined, the feasibility of various design approaches will be evaluated experimentally. A longer term goal will be to design and build a prototype network to verify, and provide an experimental basis for extending, the results of the research.

The broad characteristics of the traffic the network is expected to carry also will provide important guidelines for the work. Those characteristics cannot be anticipated with certainty, but they can be plausibly estimated by conducting experimental studies of the traffic on existing M.I.T. networks and on the network that is being installed to serve the M.I.T. Project Athena.

The assumptions that highly varied information services are to be provided and that very wideband optical fiber technology is to be employed raise two subjective issues that provide some important guidance for the research.

One issue is whether or not all network users are required to employ the same network interface. It

arises because the need for a broad diversity of information services very often will result from a heterogeneous population of users requiring quite different services rather than from a homogeneous population of users all requiring the same broad spectrum of services.

When the network serves a homogeneous population of users it is reasonable to require that all interfaces to it be essentially identical; as do almost all existing and proposed networks. However, as the user requirements become more varied and the link bandwidths become larger it becomes more important to keep the cost of a user's network connection, or interface, roughly less than their other costs. For example, many interfaces that would be economical for a full graphics work station with very high peak data rate requirements would be far too costly for a user whose only requirement is for interactive keyboard traffic. Note that as used here, the interface costs includes both hardware and software.

Of course, if the needs of the most capable user can be met with a network interface that is also economical for the least capable user, that interface should be employed by all. The possibility of developing such a universally capable and economical interface certainly will be explored in the course of this research. However, since such a fortuitous outcome is not to be expected, we will give equal attention to approaches that can accommodate a family of interfaces whose "costs" appear to be monotonically related to the levels of service they can provide.

The other issue relates to the network topology and the means of coupling to it. It arises because, in contrast to the receivers used in lower frequency networks, optical receivers require a significant amount of energy per information bit. This difference is due to the importance of quantum effects at optical frequencies and limits the number of users among whom the available information bearing power can be equally shared. To the degree that such a division of power is made there is a significant limit to the number of users that can be accommodated without repeaters. Stated alternatively, the network topology is severely constrained when many users are to be served without any repeaters.

The determination of network topology that can be used with a family of interfaces and that are well suited to implementation with optical technology will be an important part of the research but the more fundamental issue is whether or not the information bearing power need be shared among users.

Clearly, inactive users should not be coupled to the network in a way that removes power from it. Moreover, once an active user is aware that the information being transmitted is not intended for them there is no reason for them to extract power from the network until the transmission of that information has been completed. Conversely, if they are the intended receiver their coupling to the network can be increased during this same interval so as to extract all of the available power. Thus, in principle, and perhaps in practice, the network can appear to have only one receiver connected to it during the transmission of any given message.

The energy that is used for addressing and/or network control must be shared by all users to determine whether they should reduce or increase their coupling to the network for the next message transmission. But that energy can be increased to accommodate as many users as desired by increasing the time allocated to the transmission of power carrying control and addressing information. Thus the number of users can be increased until the time available for message transmission, as opposed to network control, becomes acceptably small.

It is far too early to say whether or not network interfaces with such controllable coupling can be implemented practically or whether or not the benefits of using them outweigh the additional complexity they introduce. However, the alternatives are sufficiently limited to warrant an exploration of the possibilities. Thus the feasibility and potential merit of using controllable coupling in the network interfaces will be investigated.

In summary, the research will be shaped by the assumptions that a broad spectrum of highly diverse communication services are to be provided by the network and that it is to be implemented with optical fiber technology. These assumptions suggest that the scope of the research should not be limited to networks in which all interfaces are the same and the coupling to the network is fixed but should include networks that employ user interfaces with controllable coupling whose "costs" vary according to the services they must handle.

