The Heralds of Resource Sharing

F.J. CORBATO

There have been two major ideas within the computing community within the last decade. The first was time sharing, which was being advocated very hard in the beginning of the decade.The key thing that was being observed was that there was a lot better way to interact with a computer. The second major idea within the last decade has been the notion that computer networks were not only needed but were valuable and they were gradually coming into production.

J.C.R. LICKLIDER

The computing technology has been moving in a way that nothing else that people have ever known has moved. Here is a field that gets a thousand times as good in twenty years. The communication field hasn't been able to keep pace, but the melding of computers and communication and the switch to digital communication technology, aided and abetted by satellites is doing something pretty good for communication.

LAWRENCE G. ROBERTS

The problem is much like small civilizations or small cities trying to develop separately and not having any of sharing what they learned with other groups. And if that continues to happen you don't have a civilization. So that the necessity was to provide a mechanism so that what was learned in one place could be transferred effectively and directly to other place, without redoing it all and learning it all over again at each place.

The problem was not in the computers, we found out, (computers could talk to one other, even though they were very different) and time sharing systems that existed within each computer were perfectly capable of achieving that.But the real problem that we found was that the communications was inadequate.

ROBERT E. KAHN

And ideally what we wanted to do was to use a common carrying authoring. Unfortunately, there was no wide-band, switched common carrying authoring at the time.

FRANK HEART

Our problem at BBN was to build new kind of digital communication system,employing wide-band leased lines and message switching. Message switching is were each path is not established in advance, and each message carries an address. We wanted this new communication system to support all the various kinds of resource sharing which were so important.

At the same time we wanted to build a data communication system which would stand in its own right as a better, more economical higher performance and faster, and more reliable digital communication system.

KAHN

The underlying concept of that network will have to embody the efficient utilization of communication resources, as well as to provide a system that was both reliable, error free and provide the high-band needed for interactive use of those resources. This means that users sitting at a terminal would be able to hit a key and see a response virtually instantly, almost as if that computer, wherever it were, looked like it was in the same room.

A simple way to interconnect computers into such a network is to place wide-band leased circuits (in the case of the APRAnet 50kb/sec circuits) between each of the computers, and then to interconnect each of the computers to each other to form a fully connected network. As more sites come onto the network, the requirement is than to connect that site to every other one, which that the extension of the network is just not a graceful thing.

And so this naturally leads to the concept of a store and forward technique in order to cut down on the expenses of building such a network. And so let's erase these lines over here to leave ourselves for the moment with a loop network which can be extended. And in this type of network, this computer for example would talk to this computer not by sending it a massage directly, since there is no circuit, but by sending a message first to this

computer which would then store it and forward it toward this computer, thereby acting as a relay.

In order to have a reliable network of this sort, each of these individual computers must be sufficiently reliable to maintain the kinds of communication that's needed. But unfortunately most computer installations are just not reliable enough and this leads to the notion of a small, mini processor to take on the functions of the computers and to allow a single design to then be propagated among all the installations.

So that we would put a little mini processor at each computer, like that, disconnect the 50kb circuits linking the computers themselves, and then interconnect these little mini processors, or IMPs with the wide-band circuits, and then connect the computers to the IMPs, in this fashion.

Now such a network would then operate essentially in the same fashion as the previous one with this computer talking to this computer by first sending a message to its IMP having this IMP relaying it to this IMP and this IMP relaying it to this IMP, and then this IMP delivering it to the final destination.

Now this kind of network can be made to be extremely reliable since an effective control can be placed upon the design of each of these IMPs since there is no large political problem in getting a large number of sites to cooperate in the design and building of the communications part of the system.

HEART

We operate a network control centre here at BBN in Cambridge and each IMP every half second sends us a message telling us how it feels and and how each of its lines are, and how each of its hosts are, and what kind of loading it's got. And we man that centre 24 hours a day and we use those stats-reports from the IMPs to generate statistics about network performance and also to alert the operators to any immediate needs for maintenance, either in circuits of in IMPs.

KAHN

Here is an instance of the ARPAnet as it was recently configured so you can see there are some 25, 30 sites in it. The transmission of a message, say from a node over here, to a node over here might go as follows:tThe computer at this point would send a message to its local IMP which would break it down into thousand bits packets.The packets would then be transmitted from IMP to IMP along a route selected by the IMP themselves. At the destination IMP, the package would be reassembled in the proper order and delivered to the computer.

And then a message would go back along perhaps a different route, to indicate that the original message was received. The whole transmission cycle typically takes no more than a few tenth of a second. The system is completely independent of the ups and downs of small numbers of lines; for example if this circuit over here broke in the midst of the transmission, the message has gotten that far, it might then backtrack to back here and possibly takes some other route until it gets to the destination.

There is error-checking in between each IMPs, so that in the transmission from this node to this node the message that was send would actually be error-checked and an acknowledgment would be send back and then from here to here it would be error-checked and if

it got correctly accepted an acknowledgement would be go back an so forth among each set of IMPs along the path.

HEART

A very unusual feature of this system which I thing is quite new is that it's possible for us to debug any of the running IMPs in the field. We can actually examine core, test and restart them and even reload the program from our Cambridge location.

KAHN

In order to add a new resource into the network, such as this, it would get its own IMP and would require one or two or perhaps three connections to other IMPs in the network. That would be all that would be required the effect that connection. So we could in principle let's say get rid of that connection and the network would work, or we could put in that connection over there to add a little more reliability.

HEART

As soon as the network began working we really had a nation-wide resource complex. And this resource complex was very attractive to many users who had no resource of their own to really contribute. These people wanted direct terminal access to the net, even though they had no host to get that access through.

So we designed a new kind of IMP, we called it a Terminal Interface Message Processor, we called it a TIP, for short. And this machine really includes a very tiny mini-host. With this TIP, many different kinds of terminals can be directly connected to the TIP or can be dialed in through low-speed lines to the TIP, and can provide acces to the nation wide resource pool to users at various kinds of terminals.

KAHN

Let me illustrate such a device down here which can than be connected into the network (nothing more than an IMP), and than terminal devices, some large number of them, can directly connect to that device.

ROBERTS

The most immediate cost-benefit of the network for the users: the hardware and resource sharing being able to getting at large computers time sharing computers and other specialized computer capabilities throughout the country that meets his needs. This eliminates the needs for him to have a medium scaled machine that does everything in a mediocre way.

LICKLIDER

Specialized hardware facilities tend to be expensive, but very efficient. If there isn't any way to distribute their use, to make it available all over the country or all over the world, it may be economically impractical to provide them; because there isn't a large enough need for them in any one place.

On the other hand, if they can be distributed, then specialized hardware facilities can be very effective and can do a lot of things that we couldn't otherwise do.

ROBERTS

In the case of the large superfiles, the ten to the eleventh bit weather files which we're putting on the ELIAC for example, these would never be available without being on the network; because it wouldn't be worthwhile for one person to have it all himself.

LICKLIDER

The thing that makes the computer network communication network special is that it puts the workers, the team members that are geographically distributed, in touch not only with one another, but with the information base with which they work all the time.

So that when they get to developing plans, the blue-prints as it were, don't have to be copied and send all around the country. The blue-prints come out of the database and appear on everybody's scopes and the correlation of coordination of the activity is essentially right there in the computer network itself.

And this is obviously going to make a tremendous difference in how we plan, organize, and execute almost everything of any intellectual consequence.

ROBERTS

The main thing about this data-file sharing is that you don't want to update and maintain it at different places simultaneously. This becomes even very error prone if not very costly.

LICKLIDER

Well it must be amusing to anyone outside the computer field to watch people inside it rewriting and recreating the same old programs over and over and over. And programs are recreated partly because it's fun to program but mainly because it's very difficult to get hold of them and use them if they have been programmed a few hundred or a few thousand miles away for use on different equipment from that which you have. Now, the network idea makes it practical to use those programs on the machines for which they were written and on which they have been debugged and tested and checked out.

ROBERTS

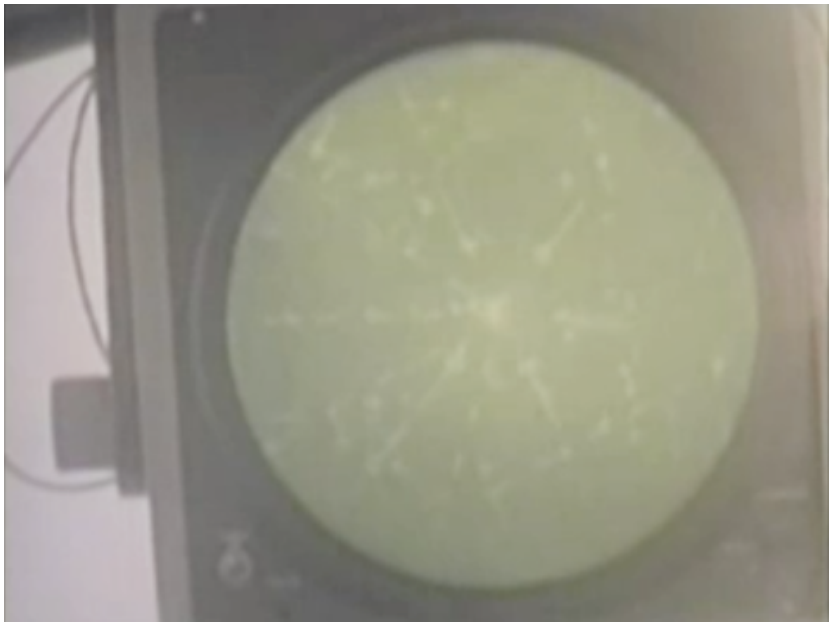
The effect of the network for a user is that now he can start to attack a new problem that he may come up with with any resource that may be available within the net rather than the very limited set of resources that is available through his local computation centre.

This has a tremendously valuable effect because as he starts to look at a problem he can use any language he can use any resource; the reliability is hard because he can choose between several machines for a particular run. And his personal situation is greatly magnifying what he can do. Because he doesn't have to depend on a very limited set of resources to do the job.

WILLIAM R. SUTHERLAND

The ARPA-network provides a new research opportunity for experimenting with computer to computer communication. To make computers talk to each other a number of functions normally performed by human users must be moved into computer programs.

To gain some hands-on, practical experience with computer talking to each other we extended an air-traffic control simulator which we had previously developed. Using this as a model, we partitioned the simulation into a number of air-spaces. Using the ARPA-net as a communication medium, we were able then to couple a number of the independent simulations together making them talk to each other for purposes of handling air crafts off and for changing flight plans and the like.



We were able to dynamically reconfigure one of these multi-computer simulations by ordering the simulation program for one particular area to move into another computer in

the middle of a simulation run. The net effect was an ability to conduct a large simulation exercise involving several autonomous programs in several independent computer. We believe that this is an interesting example of future network capabilities in failure tolerance and in automatic load leveling.

CORBATO

One of the things that is coming out as people begin using networks more and more is that it must have as the node of the network computers which are of a mulitplex class or essentially a major computing utility which is capable of manipulating information, because the network itself doesn't hold information; it doesn't keep information – an important design criterium in fact.

<UNKNOWN SPEAKER>

Research now going on will someday permit a network user to log in and not really care where his computation takes place. With a distributed operating system the user will log in into a network of computers, the system deciding which computer can best perform his job. This development will make possible much more efficient and reliable use of computers.

CORBATO

Now the interesting thing is that as time goes on we find that the powerful nodes also need a network; because as one begins to take on larger and larger problems, one of these systems that one becomes more and more dependent on, which one must be certain of being up and running. And in order to do that, one has to have tremendous reliability agains all kinds of catastrophes.

The user of distributed operating systems will know a new kind of reliability. For example, his files could be backed up on more than one site, so that if one of the sites would go down, he could obtain his files from another site in the network.

LICKLIDER

I'm involved in the ARPA program to develop a speech understanding system. And I think that that program illustrates some potentials of the network. this is a program that involves at present time eight laboratories, some labs will develop some sub-systems and others other sub-systems. Maybe two or three will develop entire speech understanding systems, but even then it's unlikely that one of them will have the best of everything.

RICHARD W. WATSON

A network information centre which is located in Standford Research Institute in California sees the network as this multi-layered experiment in resource sharing where the resource is available for people, computers, data. At one level you've got the technology that is informating (???) the network; the circuits that send the bits from place to place. At another legel you've got the protocols and procedures that allow data to be shared, computers to talk to each other and software. And at other levels you've got the facilities to allow our peoples to get together who are geographically dispersed and allow them to work together, find out information, resources and so forth that they need to do their job and bring them together.

So we see our job is twofold: one, to provide information about resources, about people, about the network that people need; to bring these things together to do their job. And once they've gotten together these things particular groups of people, we like to provide services that will aide their collaboration and their working together.

JOHN R. PASTA

The succes of the network will depend by and large how the user uses them. You have to give the user something more than he gets at present time, otherwise he's not going to be particularly interested in the network. And there are lots of political problems associated with that. He presently has a computer center, That computer center by and large provides some kind of service for him. The people who run the computer center are going to continue to operate them in that mode. As far as the economic aspects are concerned, various computer centers would presumably become expert in some area and provide some kind of resource that would be useful for all the others and they could concentrate on it; they wouldn't have to cut across the whole board and spread out their efforts among many many different kinds of programs.

DONALD D. DAVIES

The ARPA network has been criticized as not being typical what's required for a real commercial network. Well let's look at what present day, commercial networks do. First of all they are only build by very big companies that can afford the expense of the design and have leased long lines and so forth. And secondly they are build around special applications. This schema of private, purpose-build networks is, in my view, a completely false idea of what the future of data communication will be. It seems to me that data communication for a company must evolve in the same way as the company evolves. Organizations change, they merge, they introduce new services; so in principle every terminal on the network, every computer in the company, and computers of different companies, all have to be able interconnect. This means that the subscribers of the network are a great variety of different terminals quite unlike the telephone network. And to my mind, this implies the package-switching principle; it requires that the terminals interconnect at the level of messages and not at particular speed.

Well clearly the public switched network is needed and I don't think many people would now disagree with this. And it must be very versatile and able to connect terminals of very widely different types. In my view, the computer and communication people haven't yet really begun a proper dialog; they're not yet speaking the same language. The thoughts of the communication people are still rooted in the technology of the telephone network. And I think it's necessary, very necessary, for computer people in the future to learn more about the problems of these networks, so they can really join in this dialogue and in this way we can get the kind of data network that we need.

LICKLIDER

Well, it's been hard to share information for years. The printing press of course, was the great step into sharing information, but the printing press didn't essentially handle the problem of distributing it. It handled the problem of copying it. And we have been needing for some time some better way to distribute information than to carry it about. The print on paper form is embarrassing because in order to distribute it you got to move the paper around and lots of paper get to be heavy and bulky and expensive to move about.

GEORGE W. MITCHELL

There are many million checking accounts in the United States. These are in some thirteen thousand banks. And on average there's a cheque written on each one of these accounts every business day. About a hundred million cheques every business day. And that's a hundred million pieces of paper.

LICKLIDER

If we get into a mode in which everything is handled electronically and your only identification is some plastic thing you stick into the machinery, then I can imagine that they wanna get that settled up with your bank account just right now and put it through all the cheques. And that would require a network.

MITCHELL

We have our own network which links the federal reserves offices, all 37 of them. And they in turn are linked with commercial banks and their communities. That linkages is not yet complete.

LICKLIDER

The kind of communication that is required is exactly that provided by a computer communications network. A kind of communication in which you can get in for a tenth of a second or for a hundredth of a second or a thousandth of a second, do your job and be over with it and let somebody else use the facilities.

MICHELL

There is some resistance to changes for people when it happens. Many people like to get currency, they like the feel of it. Other people don't like to have this mechanized and made a matter of record on a bank account because husbands don't want a wife to know what his income is.

LICKLIDER

There isn't any real need to change things just for the sake of changing. But I tend to believe that things are gonna be considerably better for a lot of people. When and if we ever get changed over to an essentially electronic base, it's just fundamental that if one wants

to deal with information you ought to deal with information and not with the paper it's written on.

<UNKNOWN SPEAKER>

The network now costs us one tenth the cost of mail, for moving paper; and this this cost will continue to go down as labour costs go up. So that it's quite clear that material will be moved and handled and stored in computer systems rather than in filing cabinets.

LICKLIDER

Right now, it's possible to buy for about a million dollars an information store that will hold the equivalent of about a hundred thousand books. So one can store – or one can buy the store for a book – for about the same amount as he can buy the book. So that, if everyone had a display console in his home and in his office, he could be reading from electronically stored information instead of from a book. And the difference is, he could have access to anything he wanted to read instead of just what was within reach. Well, it turns out to be surprisingly inexpensive, if you get wide band-width transmission facilities, to send the stuff right when it has to be read instead of sending it to a local bookstore or local library in the hope that it might be read.

RICHARD W. WATSON

The network experiment to be successful has got to include more than just the technology of getting computer A to talk to computer B. It's got to include the human institutions that will bring together these resources for people to solve real problems of real people.

LICKLIDER

The processing and distribution technology and the storage technology are gonna make it possible to get over onto a new technological base for intellectual efforts before our ponderous social processes will let us. And I think more people ought to get in there and think about the social proces.