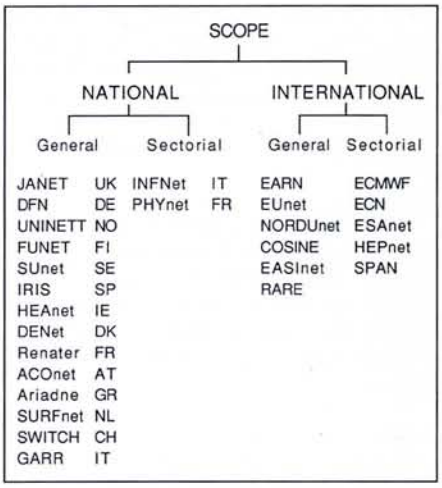
COMPUTER NETWORKS

Spurred on by technical and political developments, the computer networks for the academic and research communities (illustrated on the front cover) are evolving rapidly. However, without some forceful actions, Europe could easily slip behind in abandoning a vital industrial sector. To highlight some of the issues we report here on the applications of networks and their status, developments in a particular discipline of rapidly growing importance, namely climate modelling, US initiatives, European attitudes, expansion towards central and eastern Europe, and EPS proposals.



Academic and research networks in Europe have either a national or a sectorial scope (courtesy of F. Fluckiger, CERN).

EUROPEAN DATA NETWORKS
Is There Coordination?

The computer networks for academic and research staff shown on the front cover are used for the five types of activities detailed in the accompanying box. These activities can be classified according to their scope, both geographical and by the type of community served (see figure). There are no European suppliers of cross-border leased line capacity as this is seen as basic service provided by national PTT's. So each country generally has a national data network, typically based on leased lines supplied by the national PTT and operated by a team reporting to the ministry responsible for research or education. Owing to high leasing costs, it is unusual to find lines with capacities exceeding 64 kbs. The exception is Scandanavia with its regional multidisciplinary NORDUnet linking some six centres.

Sectorial Networks

The pan-European sectorial networks are usually associated with a large organisation such as the Commission of the European Community or a European Treaty Organisation acting as a natural pole for communications. Here we find **HEPnet** connecting CERN to over 20 institutes, ESA with **ESAnet** linking four European Space Agency sites, the European Centre for Medium-Range Weather Forecasts, and eventually a possible European Climate Network (**ECN**, see page 45). These networks collaborate with other networking organisations in sharing leased lines. The trend here is to set up a coordinating body for negotiating lines on the NORDUnet model instead of relying on independent negotiations by participating countries and institutes. Thus, a European HEPnet Consortium is planned.

Y-Net is an European Community Esprit open systems network project which was launched in 1990 to provide participants of all EC R. and D. programmes with improved communications and data exchange. It aims to complement the access to services provided by Cosine's **IXI** pilot network and operation will be sub-contracted to national units. OSI systems installed at a single node in each EC Member State will be accessible by all research organisations. The Y-Net links the nodes and there are two gateways for the exchange of electronic mail to non-OSI based networks. One of these is **EuroKom**, started in 1983 to link researchers in some 20 EC programmes, initially under contract to Esprit but becoming independent last year with 2200 users.

Pan-European Networks

Four networks (Internet, EASInet, EARN, and EUnet) and RARE see themselves as providing a range of services to the entire research and academic community, essentially by sharing international leased lines and some terminal equipment. Steps to create a formal backbone structure based on, for example, a central closed ring, are mainly technically based and will not affect significantly what a user encounters.

Internet

Internet is significant because of its size. It grew out of DARPAnet launched in the USA in 1975 to link defense projects and now encompasses at least 25000 sites, thus connecting some 300000 computers used regularly by 2 million users. It is loosely coordinated by Federal agencies (DARPA, DoE, NASA, NSF) and comprises several national networks operated for specific research communities, together with some 25 regional networks belonging to companies supplying data network services.

Growth of a European equivalent to Internet has been explosive these last few years. There are now 140000 machines connected, making it Europe's largest academic and research network, largely because the open TCP/IP protocol is available for a wide

USING NETWORKS
Many Opportunities

Computer networks are used in a variety of ways, the more technical (data oriented) of which are summarised below. Other types of networking activities such as teleconferencing, videotext, telephony, multi-media networking, *etc.* are not considered.

E-mail includes the exchange of messages with individual users as well as the addressing of so-called list- or mail-servers. Interested persons can receive messages directed to a list, request data files to be sent, and contribute to a list. A trickle server is a specialised type of list server on the EARN network (see main text) where commands to a central point are relayed to the server closest to the user. Helge Steenweg of the Ges. für wissenschaftliche Datenverarbeitung mbH, Göttingen, estimates there are presently about 2700 specialised lists on list servers.

Networks support many *news groups* or *bulletin boards* collecting information daily from essentially every member of a group. Most networks other than EUnet support news services, but in more restricted forms than EUnet.

Remote access enquiries enable access to sources including databases or specialised computer systems designed to perform specific tasks. The TCP/IP Telnet communications protocol is popular, being especially suited for library inquires. Computer protocols are also crucial for *transferring data files*. Using the File Transfer Protocol (FTP) in TCP/IP one can interchange data files and support directory operations (listings of files). Many so-called "anonymous FTP servers" now exist to permit one to logon as an "anonymous" user.

Computing as a utility is fairly speculative. It envisages access to computing resources through a data network "plug in the wall" providing all of today's networking facilities.

range of computers at reasonable cost (see box). Growth has in the main not been planned officially and coordination is handled by the RIPE working group of the European Association of Research Networks (RARE from the French acronym).

EASInet

EASInet belonging to the IBM-sponsored European Academic Supercomputing Initiative has also played an important rôle in promoting the European Internet. In linking roughly 20 supercomputer sites, EASInet employs TCP/IP instead of IBM's proprietary protocol.

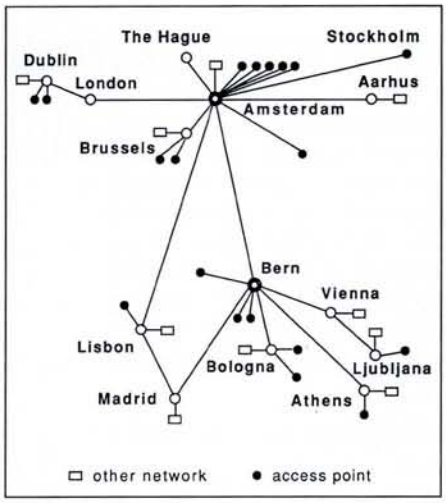
EARN

The European Academic and Research Network (EARN) was sponsored by IBM in 1984 as soon as a similar organisation in the USA (BITNET) was proving a success. It was originally based on having a single national EARN hub with IBM leasing high-speed connections between hubs for the first few years and users leasing low-speed lines to the hubs. The majority of funding now comes from annual fees paid by the 500 or so institutions attached to EARN, and roughly 50% of the more than 600 host machines are non-IBM computers. Robust, old-fashioned technology has facilitated recent extensions into eastern Europe in an IBM-sponsored initiative backed with assistance from the EPS East-West Task Force. The lack of facilities for remote access is a disadvantage.

EARN is an association registered in France with a board of Directors appointed by member countries and a permanent management structure.

EUnet

The European Unix Network (EUnet) is a pan-European R. & D. network run informally by the administrators of national backbone hosts who organise communications and routing within each country. It began as an extension of software and protocols used by the USEnet news network and the UUCP (UNIX Copy Program) network that grew up in the USA with the distribution of the UUCP program. UUCP is based on direct, dial-up communications over modems without an intermediary relay computer so it provides a very decentralised system, at least in the USA (decentralisation in Europe is not as pronounced as a tree-structure of background hosts has evolved). Being independent of direct government support has meant that EUnet can be joined by commercial companies to provide easy access to professionals in many diverse fields. It is well-known for supporting many news groups or bulletin boards collecting information daily from essentially every member of a group. Most other networks also support news services but in more restricted forms.



International links in the EC's pilot Cosine IXI network as of early 1991.

RARE

RARE, founded in 1986, brings together national research networks and several bodies interested in pan-European networking. Up to now it has not seen itself as an operating agency but instead seeks coordination, as for example, converting EARN to open standards and managing Internet through the RIPE (Reseaux IP Européens) working group. This may change as the European Internet continues its rapid expansion. RARE carried out the specification phase of the Cosine project and was involved in IXI.

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Physics Data Exchange Network

The EPS East-West Task Force is presently seeking support for a computer network linking physics departments to make available information on institutes, student exchange, used equipment, and the names of scientists available for carrying out peer reviews. It will also enable access to existing networks, including eventually an EPS Student Mobility Database.

OPEN NETWORKING

A de facto Standard?

The protocols used for transferring data files are complex and evolve as technology changes. Many held high hopes 10 years ago that a single International Standards Organisation (ISO) standard would allow for freely available Open Systems Interconnection (OSI) networking between different types of computers independent of proprietary protocols. This led to implementation of the European Commission's Eureka project **Cosine** in 1990 that aimed to establish pan-European OSI standards for all research activities by coordinating the efforts of national networks. Cosine has set up an interim network called **IXI** (see figure above) as a pilot service based on about 20 national access points connected by 64 kbs trunk lines between Amsterdam and Bern. While useful for some countries with poorly developed networks, the future of Cosine remains uncertain.

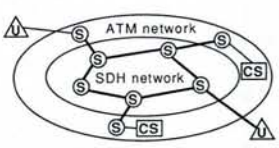
Meanwhile, the TCP/IP suite of protocols lying at the heart of the multidisciplinary **Internet** network in the USA has become widely available in Europe, contributing to the accelerating growth of the European Internet network. So the EC must probably acknowledge *de facto* acceptance of TCP/IP by the computer industry and henceforth support all non-proprietary open networking protocols. Not unsurprisingly, Brian Carpenter who leads CERN's Communications Systems Group believes OSI can no longer be the sole basis for the future expansion of networks.

INTEGRATED SERVICES DIGITAL NETWORK

Is the Emphasis Correct?

European telecommunication companies and national PTT administrations have invested heavily in the concept of an Integrated Services Digital Network (ISDN) to provide a crucial component of Europe's gigabit per second transmission needs for broadband, multimedia communications. A crucial decision was taken in 1988 to switch traffic onto 155 and 622 Mbs lines using the ATM (asynchronous transfer mode) switching technique involving the manipulation of a basic unit (or cell) of data of predetermined length.

Much of the stimulus has come from EC supported (484 MECU for 1990/94) RACE projects which originally aimed to have a Community-wide broadband ISDN network in place by 1995. In focussing on network issues, the criticism is that the vital interplay between between computers, applications and networks has been overlooked. Thus academic and research communities, industry's natural partners in the development process, have little involvement in evaluating products & concepts.



A proposed broadband ISDN network for Europe would use an optical-fibre synchronous digital hierarchy (SDH) network with ATM switches (S) to link users (U) and connectionless servers (SC).

NREN AND FIVE GIGABIT TESTBEDS

Setting the Pace

The National Research and Education Network (NREN) component of the High Performance Computing and Communications (HPCC) Act, signed into law last December, aims to "dramatically expand and enhance" the US portion of Internet by increasing the level of network connectivity and introducing new capabilities into the existing infrastructure. This is because Internet "still falls short of a widespread, uniform and high performance national infrastructure" that would pave the way to a broader, privately owned national information network as well as to new essential capabilities such as digital learning, digital access to libraries and large-scale distributed computing.

The almost 1000 M$US over five years authorised by the Act for the next generation, high speed (initially probably 45 Mbs), high capacity NREN science network with the goal of linking a million computers dwarfs the 16 M$US allocated previously by the National Science Foundation and DARPA over three years for five Gigabit Testbeds which will explore how users can exploit Gbs network speeds (existing gigabit lines are heavily multiplexed so users only operate in the Mbs range). The testbeds form part of NREM's Gigabit R. & D. sub-component which will transfer mature technology to the Interagency Interim NREM sub-component charged with creating a future gigabit NREM network based on existing networks.

SECTORIAL NETWORKS

ECN Envisages Flexibility

Contrary to what might be expected, Europe's main centres for climate modelling do not envisage the creation of a dedicated communications network similar to those used by the space and high energy physics communities. Instead, the European Climate Network (ECN), presently being discussed by working groups reporting to the Directors of national meteorological services, will provide a flexible framework without a formal administrative base to allow the main centres as well as groups and centres in small countries to interchange data and results. This approach stems from the unique character of present-day climate research where the trend is to compare the results of simulations carried out by many groups.

However, the need for interactive, time-critical, terminal sessions will inevitably call for the installation of new links (so-called ECN Links) owing to the general problem of smaller institutes having low-capacity lines to the major research networks. Also, lines between Europe's principal climate research centres have insufficient flexible capacity. These centres are the UK's Hadley Centre for Climate Prediction and Research, Bracknell, France's METEONAT in Toulouse and Hamburg's MPI for Meteorology, each with 50–100 staff members and equipped with a Cray supercomputer.

The bulk of the traffic between the three centres currently involves the activities of the European Centre for Medium-Range Weather Forecasts (ECMWF). Founded in 1973 and located in Reading, UK, the ECMWF is now supported by 18 Member States to develop and disseminate forecasts and other so-called products, to make available computing resources and to implement World Meteorological Organisation (WMO) programmes. The ECMWF communicates to meteorological services in the 18 MS's *via* a dedicated "star" network, with lines to France, Germany, Italy, and Denmark upgraded from 9.6 kbit/s to 64 kbit/s in 1991/2 to facilitate file transfers and interactive access.

The ECMWF is also connected to the Global Telecommunications System (GTS) operated under the World Weather Watch by the WMO. The GTS collects and distributes weather information on a dedicated network: data and forecasts (but no messages) are passed around a 50 to 64 kbs loop in a special format between some eight centres (in Europe, these are located in Bracknell, UK, and Offenbach, Germany).

EUROPE'S FUTURE

Gateways Developing

Instead of speculating on possible developments in international computer network connections for the academic and research communities to east and central Europe (see cover illustration), we shall review what has actually been achieved or is planned. Considerable progress has been made lately, although the situation is still not rosy for eastern Europe as Bulgaria and Romania do not yet have any links.

François Fluckiger, Chairman of the HEPnet Technical Committee, feels a northern Europe gateway is developing in Scandinavia with the installation of a 64 kbs link from the KTH Stockholm to Warsaw to replace an older (1990) 4.8 kbs link *via* Copenhagen. A 64 kbs link from the KTH to the Baltic States has been ordered, NORDUnet plans a link from Helsinki to St. Petersburg, and EARN plans a 9.6 kbs connection from Copenhagen to Moscow.

Moving south, ambitious plans by the German DFN to expand eastwards have been shelved following unification. Nevertheless, DESY in Hamburg established in 1990 a relatively specialised low-speed link to the Lebdev Institute in Moscow, with further routing to the ITEP: there is a similar link to the European Southern Observatory network. CERN in Switzerland operates a 64 kbs HEPnet link to the JINR Dubna, CIS, *via* the Gran Sasso Lab in Italy. HEPnet has also connected CERN to the Institute of Nuclear Physics in Cracow since 1990 and to the KFKI in Budapest since 1991. Extension of HEPnet to Czechoslovakia seems likely now that the country has joined the Organisation. The IXI backbone node in Bern has a IXI link to Ljubljana in Slovenia.

Austria took some significant steps recently towards becoming a gateway to central Europe with a planned upgrading of the 9.6 kbs, 1990 EARN link from the TU Linz to the CTU Prague to 64 kbs and a new 9.6 kbs link from the TU in Vienna to the Institute of Economy, Budapest. These add to older (1985/6) links of 9.6 kbs and less from the TU Linz to the Computer Automation Institute, Budapest (also set for an 1992 upgrade to 64 kbs), and to Belgrade, and from the TU Vienna to Bratislava. A 9.6 kbs leased line from Linz to Bucharest reportedly planned for 1992 may be Romania's first link.

How to Move Ahead?

European network traffic has grown to the point that high speed (2 Mbs) international links are justified. However, with 16 times the generally available 64 kbs capacity, these lines merely represent less than 5% of the capacity of lines forming the NSFnet backbone of Internet in the USA. Introduced in 1986, NSFnet links over 20 regional networks at 45 Mbs. Several countries (the Joint Academic Network — JANET — in the UK, SURFnet in Holland, SWITCH in Switzerland, and the Deutschesforschungsnetz — DFN — in Germany) offer 2 Mbs lines but the only international line is the one connecting Geneva to Bologna.

There appear to be no plans to install long-distance Gbs infrastructure in Europe similar to the Gigabit Testbeds in the USA (see box). The few projects (*e.g.*, BERKOM in Berlin) are national in character and limited in scope, while the EC's 3rd Framework Programme for R. and D. has allocated 484 MECU for communication technologies based on the RACE programme's rather conservative approaches. Commentators, for example CERN's Dr. David Williams, Head of CERN's Computers and Networking Division, view this situation as dangerous as advanced networking must be considered an essential technology.

Several barriers to progress can be cited, including PTT policies, rapidly changing regulations, limits on the networking industry owing to high tariffs for leased lines, the lack of international suppliers of these lines, heavy investment by PTT's in an integrated services digital network (ISDN) in spite of serious problems, and the absence of fully European manufacturers of supercomputers targeting scientific applications — these being the research community's natural partners in advanced networking projects.

How then to move forward? David Williams suggests providing a stronger focus for research computing, a strong emphasis on the service needs of the academic and research communities, improved collaboration between all the parties involved in networking, a merger of EARN and RARE, and the formation of a pan-European operating agency providing leased lines for the entire research community, with the merged body evolving into an agency responsible for planning a vital industry. Rather than yield ground to companies based in the USA, the research community should strive to evolve suitable vehicles for future action.