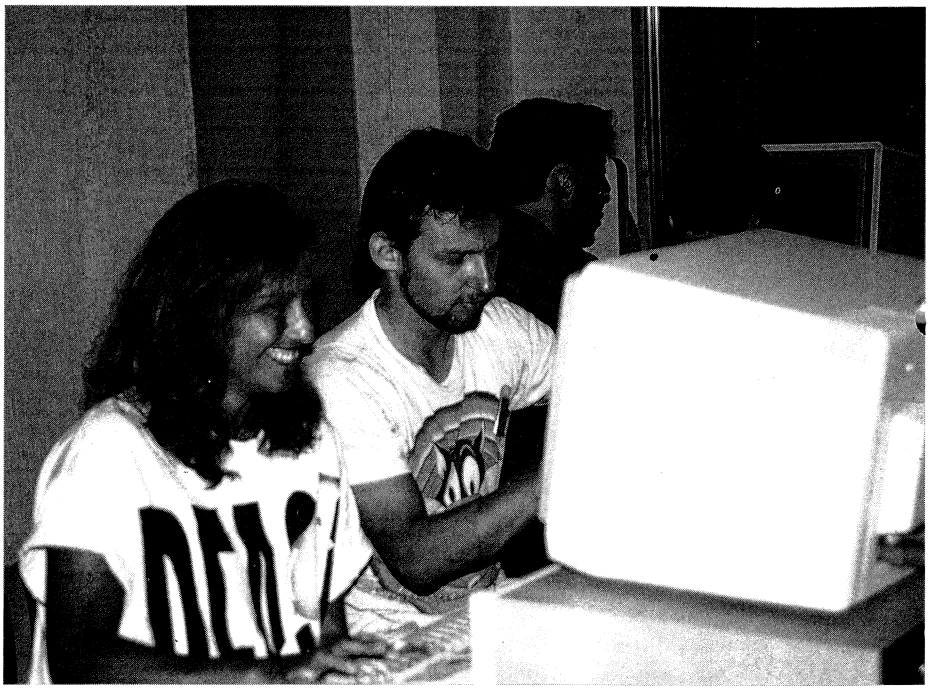
Andy Hamilton from INMOS explains how it's done.

new languages, such as Occam, for parallel processing. Meiko and CERN are collaborating to produce next generation transputer software.

Students were able to keep in touch with their home base via electronic mail using a microVax loaned by Digital Equipment Corporation.

The traditional vital role played by computing in high energy physics is becoming even more pivotal as demands become more intricate and exacting. At the end of the course, students felt better equipped to face the challenges of the future.

From Bob Dobinson



Casting HEPnet

HEPnet is the name used to describe the various computer networking facilities dedicated to high energy physics. HEPnet interconnects some 3000 computers in Europe and some 10000 throughout the world.

Some European countries already have a well-developed national computer network for the academic community (e.g. JANET in the United Kingdom, or more recently DFN in Germany). Where no such network exists, there are active plans to develop one. Furthermore, there are two major international computer networks used by the academic community – EARN and EUNET – as well as plans for centrally-funded links between the national networks within the Eureka COSINE project.

However high energy physics (HEP) has special additional requirements. Experimental facilities are large, expensive, unique, and centralized, while the scientists who use them are spread over at least 200 institutes in Europe, and many more in other continents. There is also a very high level of international collaboration.

The main Laboratories act as large centralized data sources. However many of the smaller institutes generate a lot of data through simulation work. The total data flow is therefore both large and manifold, bringing in its wake a demand for network connectivity between collaborating research centres.

In the near future, it is expected that data analysis will be dominated by the use of powerful graphics workstations working with-

mainframe computers or supercomputers. Such distributed processing over geographical distances clearly requires powerful networks.

The national networks, where they exist, are largely incompatible with one another. HEP, as an international community, requires international compatibility. The current and future international networks are either rather restricted in their functionality (EARN and EUNET), or in their choice of protocols (COSINE) and their performance is limited when judged by the needs of HEP. However in many cases existing infrastructures can be linked at marginal cost to form a wider network capable of meeting evolving needs.

For these reasons and more, the HEP community evolved its own

computer network infrastructure to supplement general-purpose national and international networks.

Over the past five years, coordinated work by the HEP community has led to notable achievements – establishment of an infrastructure of international HEP leased lines; an international private X.25 network with a common addressing scheme; a worldwide DECnet (10,000 nodes); international CBS services; an emerging SNA/RSCS network; an emerging TCP/IP network; and a rich set of gateways and converters.

Leased lines

Today, a total of 20 international leased lines partially or totally dedicated to HEP are in operation over 3 continents (11 lines at 64 Kbps; 9 in the range 9.6/19.2 Kbps) with connection points for France, Germany, Italy, Netherlands, Spain, Sweden (giving also access to Denmark, Finland, Iceland, and Norway), Switzerland and the United Kingdom; the USA and Canada; and Japan.

In France, Italy, Spain, the USA and Japan, the international links connect to a national infrastructure of leased lines dedicated to HEP. In the UK and Scandinavia, they connect to general-purpose leased-line networks (JANET and NORDUNET respectively).

The HEP leased lines form one of the biggest specialized intercontinental communications infrastructures and is complemented in most countries by the PTO (Post Office) public X.25 networks, and by general-purpose research networks such as EARN/BITNET and EUNET/USENET.

Plans are well advanced for additional European and intercontinental links, and for the upgrade of several of them to the range 1.5/2 Mbps.

X.25

The private HEP X.25 network runs on top of the leased line infrastructure, covering France, Italy, CERN/Switzerland and the USA, and has nodes in Germany, the Netherlands and Spain. It is connected to the JANET and NORDUNET general-purpose X.25 services.

It uses the HEP X.25 addressing scheme based on the CCITT X.121 standard. Where the scheme is fully implemented, the connected hosts (DTEs) are fully connected, and any DTE can be called using the same address from anywhere in the network.

DECnet

DECnet is currently the biggest HEP network, with more than 10,000 nodes spread over Austria, Denmark, Finland, France, Germany, Italy, Norway, Portugal, Spain, Sweden and Switzerland in Europe, and in the USA, Canada and Japan.

Except for Austria and Portugal, which are linked via the public X.25 networks, the HEP DECnet runs over HEP leased lines, mostly on top of the HEP X.25 service. The HEP DECnet is coordinated with the Space Physics Analysis Network (SPAN) run by NASA in the USA and ESA in Europe. Additional connections are planned with Belgium and the Netherlands.

SNA/RSCS

International SNA services are now emerging in Europe. Links are currently available between Saclay and Lyon in France and Zürich, Geneva and CERN in Switzerland. In addition RSCS/BSC services are available between Rutherford Appleton in the UK, DESY in Germany, and CERN. However the bulk of the RSCS services between HEP sites is currently provided by the EARN network.

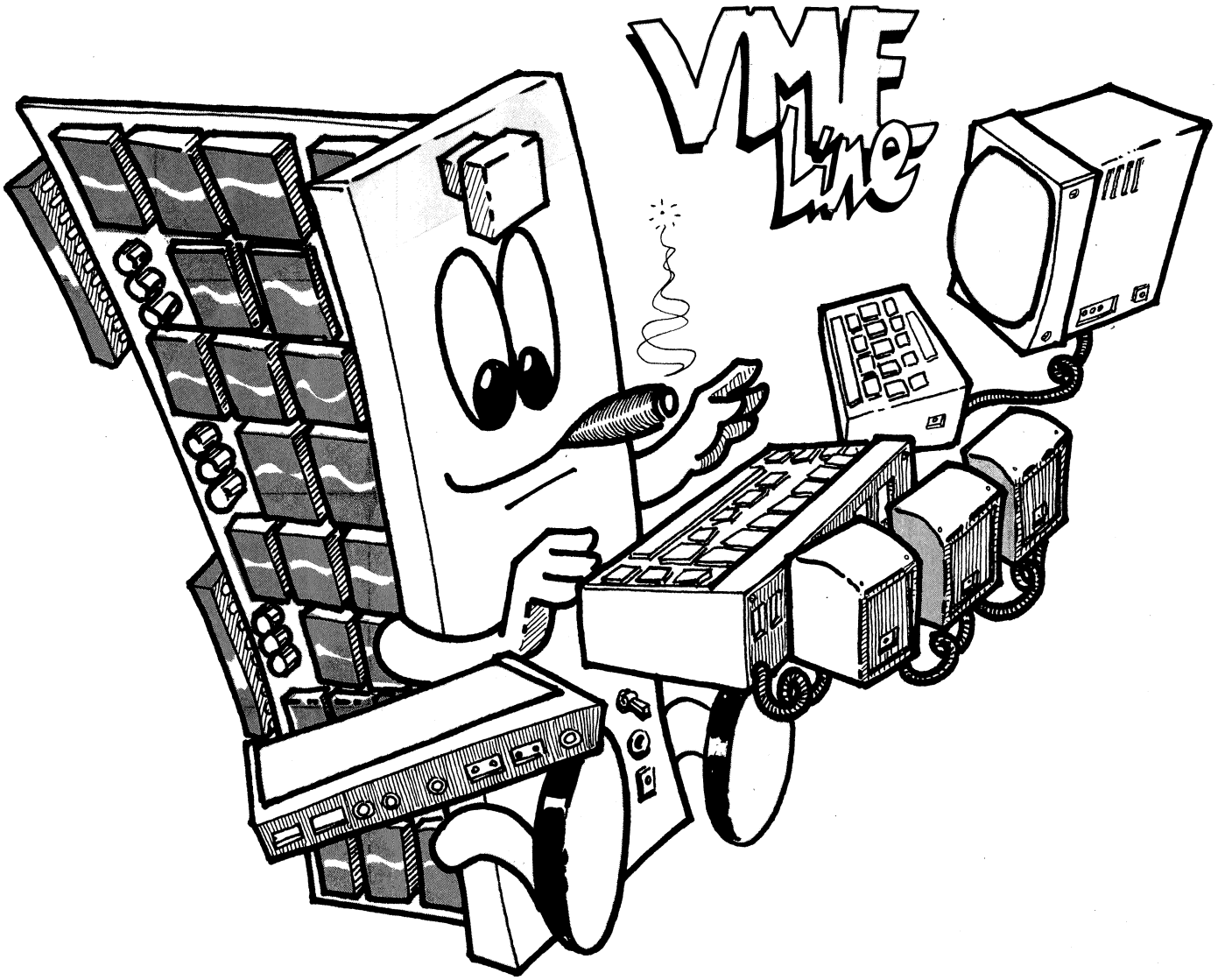
The HEP SNA/RSCS services run currently directly on leased lines (or subchannels via bandsplitters), and not (yet) on top of lower layer facilities such as X.25. Additional SNA connections are being considered between CERN and centres in Italy, the UK, Spain and Germany.

TCP/IP

TCP/IP services have been in use for several years by HEP on a local or regional basis in almost all countries. On the international front, Japan (KEK) and the USA (Berkeley) exploit an IP connection. In Europe, a first international TCP/IP link has been opened between the Netherlands (NIKHEF) and the Nordic countries (especially the Niels Bohr Institute, Denmark). Other international TCP/IP services are planned in the near future in Europe for France, Germany, Italy, Spain and Switzerland. Transatlantic HEP services are also being considered.

Gateways and converters

To improve connectivity, the HEP community has developed and installed a number of converter and gateway facilities: the GIFT system for file transfer, jointly developed



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Mod.	***V 263 (*)***	*16 CHANNEL ECL/TTL DIFFERENTIAL TO NIM TRANSLATOR*
Mod.	***V 264 (*)***	*16 CHANNEL NIM TO ECL/TTL DIFFERENTIAL TRANSLATOR*
Mod.	***V 265***	*16 CHANNEL CHARGE-INTEGRATING ADC*

(*) This module is a CEA-IRF SACLAY design

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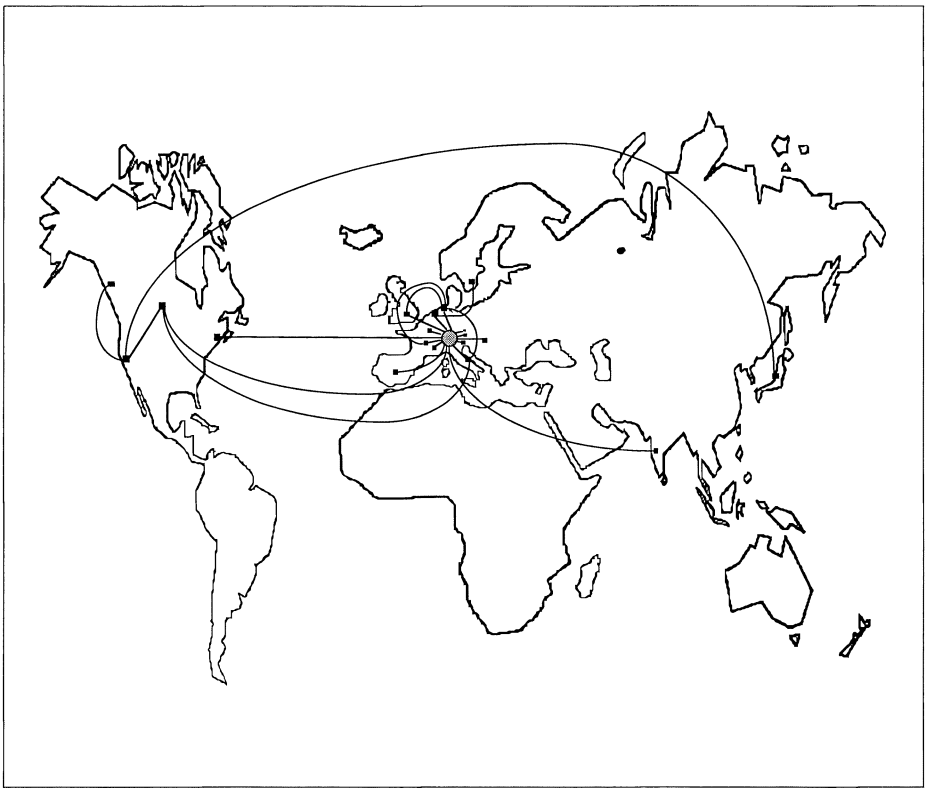
HEPnet – worldwide links.



by several organizations including INFN in Italy, and in operation at CERN.

For electronic mail, a number of sites operate gateways, including INFN Bologna, CIEMAT Madrid, Niels Bohr Institute Copenhagen, and the MINT system at CERN. In addition, commercially available gateways and converters are in use. In several cases, the functionality of the HEP converters (e.g. the GIFT on-the-fly multiprotocol system) is unparalleled.

The GIFT service at CERN is in fact now near the end of its life, but has been further developed at the SARA computer centre in Amsterdam, and is now in use outside HEP.

HEPnet organization

Despite an impressive list of achievements, serious problems remain and more work is needed to improve interfaces, reliabilities, response times, documentation, etc. Higher bandwidths allowing more demanding applications are urgently required.

In some countries physicists are still somewhat underprivileged and vast additional territories need to be covered. A line to India is on order.

The features described so far are mostly funded and operated by individual institutes. Thus, at least until the end of 1988, HEPnet was coordinated, but not designed: it just grew. In Europe, recent growth has been mainly driven by the requirements of the LEP experiments at CERN.

However it became clear that HEPnet's complexity warranted a clarification of its organization. Two committees were set up and have both become operational during the first half of this year.

The HEPnet Requirements Committee (HRC) is constituted by ECFA (European Committee for Future Accelerators) to represent the networking needs of the European HEP community. Its members are mainly physicists designated by their national community and its role is to formulate needs and review how well they are being met. Current chairman is Rob Blokzijl of NIKHEF-H.

The HEPnet Technical Committee (HTC) is constituted by the HEP-CCC (HEP Computer Centre Coordinating committee) and its members are in general the managers responsible from each site or country operating HEPnet leased lines. Its purpose is to coordinate the planning and operation of HEPnet, wherever possible by reaching a consensus rather than by a vote.

All formal agreements remain bilateral. A number of subcommittees handle individual services such as DECnet or SNA/RSCS. The HTC chairman (currently François Flückiger of CERN) sits on the HRC, and vice versa.

For the future, there will be increasing emphasis on tools and procedures for operational network management. Optimistically, some of this work could be delegated to PTOs and the general-purpose networks, particularly for the lower level (data transport) services, but HEP will have to face the prospect of having to do more itself, especially for application services.

An example of ongoing effort is the establishment of the first high-speed link in the 2 Mbit/sec range, now coming into use between INFN (Bologna) and CERN (October, page 17). Others are expected to follow.

US developments

In the US, Fermilab has been chosen by the US Department of Energy to manage HEPnet. Manager Philip DeMar and staff at Fermilab will provide planning and coordination for operations and improvements and will be a focus for the development of network services.

Fermilab already supports over half the US HEPnet users and maintains the majority of HEPnet links to US universities. Fermilab's proposal to provide management was a direct response to a HEPnet Review Committee's report issued in June 1988 which recommended central management.

HEPnet encompasses a wide variety of networks and services including the large international DECnet network with Digital Equipment Corp. VAX and other computer systems in the US, Europe and Japan reaching in all over 17,000 outlets. HEPnet also uses the BITNET and INTERNET educational and research networks.

The HEPnet Manager will represent the technical needs of the high energy physics community to these networks, coordinate with other networks the implementation of new software and standards, and monitor traffic and reliability with a view to introducing new and/or additional features.

The management task is integrated with an overall reorganization of the Fermilab data communications group under Mark Kaletka, covering both on- and off-site networking. HEPnet management is part of the latter, and the HEPnet Manager will also act as the Laboratory's external network Manager.

Links at this speed are comparable in throughput to a Local Area Network (LAN) and will go on to have a dramatic effect on the ability to exploit computers over geographical distances, and will thus noticeably increase the productivity of distributed physics data processing.

The high-speed links must take account of HEPnet's multiple services (DECnet, TCP/IP, SNA, etc.). Several techniques for sharing such links between services have been studied: exclusive use of a single basic protocol such as X.25 or IP; transparent LAN bridging; and intelligent multiplexing. HEPnet has recommended the latter for international 2 Mbit/sec lines, since it is a robust, well-understood technique using off-the-shelf components. Modern intelligent multiplexers allow reallocation of bandwidth, and can be managed remotely, and combinations of protocols can share a line with zero risk of interference.

Hopefully, HEPnet soon will be able to use international links much faster than 2 Mbit/sec, keeping in step with LANs which will then routinely be 100 Mbit/sec. The best techniques for sharing the bandwidth of (say) 140 Mbit/sec international links, or even faster, are still under debate, although the Baden-Würtemberg network has already proven its own technology.

by Brian E.Carpenter and François Flückiger

Glossary

BITNET – American original of EARN

BSC – Proprietary protocol from IBM

CBS – Coloured Book Software, the JANET protocols Converter Device converting one network protocol to another

COSINE – Cooperation for Open Systems Interconnection in Europe

DECnet – Proprietary network architecture from DEC

DFN – Deutsches Forschungsnetz

DTE – Data Terminating Equipment (user of X.25 network)

EARN – European Academic Research Network

EUNET – European Unix Network

Eureka – A European intergovernmental research programme

Gateway – Device connecting two different networks

GIFT – General Internet File Transfer, a converter at CERN

JANET – Joint Academic Network (UK)

MINT – Mail Interchange, a set of converters at CERN

NORDUNET – Nordic University Network

OSI – Open Systems Interconnection, generic standards for networking

PTO – Public telecommunications operator (e.g. a PTT)

RSCS – Proprietary protocol from IBM

SNA – Proprietary network architecture from IBM

SPAN – Space Physics Analysis Network

TCP/IP – De facto standard protocols from America

USENET – American original of EUNET

X.25 – Standard for public data networks