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The European Science Foundation acts as a catalyst for the development of science by bringing together leading scientists and funding agencies to debate, plan and implement pan-European initiatives.

Foreword

The topic covered by this joint statement from the Academia Europaea and the European Science Foundation is one which is becoming fundamental to the future health of the European research effort. High bandwidth networking provides new and exciting opportunities to develop new methods of working and to tackle current research aims in a more efficient and coherent way.

What is important is to recognise that, although the technology involved is constantly changing and improving, there needs to be an underlying commitment from funding authorities at both the European and national levels to long-term support for such a network. Furthermore, the report also draws attention to the need at the regional and local level, particularly in university investment, to ensure the individual researcher can have efficient connectivity.

In addition to research, a high bandwidth network opens up new opportunities for university teaching at a global level, thereby providing Europe's students with access to the very best education, wherever it is located.

I hope that this report will encourage the European Commission and the various national authorities concerned to act rapidly to sustain this important development and to ensure that Europe attains parity with the computing network infrastructure available in North America.

Enric Banda
ESF Secretary General

Joint statement of the Academia Europaea and the European Science Foundation

The role of computer-based networking¹ has grown enormously in the past decade, and has transformed the potential for research and education. This trend is expected to continue in a dramatic fashion. It has led to new ways of working in science which have led, in turn, to the opening up of new lines of investigation. It has also enabled widely dispersed groups to form fully collaborative research communities, breaking down the barriers of distance, and permitting wider and more transparent access to data. In spite of recent improvements to networking in Europe, both within and between countries, Europe continues to lag substantially behind the state of development in the USA.

If this state of affairs is allowed to continue, Europe will be left out of major advances in research and education. The negative impact will fall not only on individual areas of research, but will also affect important improvements in the methods by which research and education are performed.

Advanced research computing has provided an initial "pull" for the development of technology and applications and continuing lag in Europe could also have a negative impact on European industry. Therefore, European governments and institutions must recognise the need to continue to sustain strong long-term investment in and significant increases the bandwidth of their networks and in ubiquitous access to them.

¹ This Joint Statement is mainly concerned with the provision of the network infrastructure needed to carry out research (and education) in all fields. It does not deal directly with the important and related topic of carrying out academic research and industrial R&D in the field of networking

Key points

1. Networking (i.e. world-wide communication between computer systems) has become in recent years a fundamental part of higher education and research. This trend is expected to accelerate rapidly, demanding regular increase in the bandwidth available for electronic transmission.
2. Enhanced networking not only permits an increase in the volume or speed of transmission, but encourages the development of totally new research methods and directions and new developments in the delivery of higher education. This has been recognised in the new Prodi initiative for eEurope and the acceleration of Europe into an "Information Society". This initiative recognises the particular needs of the research and higher education community, which are reflected in the recent discussion document 'Towards a European research area' from EC Research Commissioner Busquin. High bandwidth networking is an essential prerequisite for these concepts.
3. While Europe has made significant advances in its networking capacity, both within and between countries, it continues to lag well behind the facilities available in the major educational and research centres in the United States. If this situation is allowed to continue, Europe could find itself excluded from major new developments in research techniques.
4. As electronic communication comes to play a larger role in many areas of society (for example in e-commerce, business and in the home) evidence is accumulating that healthy networking contributes to many other areas of the economy. At the same time as pressure for bandwidth increases from these sectors, progressive increases in bandwidth must also be provided in order to protect the services available to research and education. Advanced methods of organising distributed computing, known as computational and data "grids" will add further pressure.
5. While the emphasis being placed on access by schools to electronic networking is welcomed, this potentially enormous increase in usage does carry some threat to the capacity available for higher education and research. Steps must be taken to provide the necessary bandwidth required by these two communities while protecting the needs of the research and higher education sector.
6. Congestion and poor network performance may potentially occur at any point on the transmission path invoked. Attention has to be given to the capacity and quality of the network infrastructure at all sites, such as university campuses, where end-users work, as well as to the capacity of the national network and the international connections.
7. European researchers also need good intercontinental network connectivity. For this, a well-organised distributed access to the pan-European network backbone is required which can provide the link to North America and elsewhere.
8. Both national authorities and the EC must recognise the need to secure a long-term commitment to invest in the provision of high bandwidth networks for Europe and to ensure that all regions have full access to them.
9. The current high bandwidth network already in place needs to be maintained and developed. Following the launch of TEN-155, the present European research backbone, planning has already begun for the subsequent expansion, known by the working name of GÉANT. Due to the transition between the EU's Fourth and Fifth Framework Programmes, and various other factors, progress has been delayed. This emphasises the difficulties in operating within the short-term funding approach of the Framework Programme. All parties, and especially the European Commission, must face up to their responsibilities, and reach a definitive conclusion in the coming weeks on the detailed mechanisms by which the transition from TEN-155 to GÉANT will be handled, in order that GÉANT can be fully operational by November 2000.
10. Despite significant falls taking place in the unit cost of bandwidth, the overall level of funding for research and educational networking in Europe still needs to grow for quite some time to come. This is in order to meet the rapidly increasing demands for higher bandwidth and more access points. The potential rewards for research in Europe clearly warrant this investment both for research and the health of the overall economy.

Report of the Expert Group

Research and the pressure for higher bandwidth

The continuous increase in demand for bandwidth is driven by several interrelated factors. If we look at research as a whole we can see that advances in experimental techniques provide dramatic new research opportunities. We are now able to study phenomena from many fields in the life and physical sciences in far finer detail than ever before, to make observations in all three spatial dimensions instead of just in two-dimensional projection, and to keep reducing the time intervals between successive observations.

The possibilities for collaborative working at a distance are also being fundamentally transformed. The combination of person-to-person interaction together with shared access to data and real-time control of highly specialised equipment enables widely dispersed groups to start to form fully collaborative research communities. Emerging new approaches, such as computational and data “grids” (see below), are likely to have very significant impacts in this field, and they are enabled by and increase the demand for higher bandwidth.

In fact, new fields of research spring up when networking of sufficient reliability and capacity becomes widely available. Correlations between sets of related data held by researchers at widely distributed sites can be investigated for the first time. Approaches might involve viewing the same (sets of) objects at multiple points in the frequency spectrum, or coupling data gathered via different observational or scientific techniques. More generally there are several good examples of completely new and fruitful interdisciplinary fields of research being developed. In the USA, this approach is being referred to as a “Collaboratory”. Already there are applications of this mode of working in the investigation of the structure and function of the brain and in neurosciences in general, in “all-sky” surveys in astronomy, in the interactive manipulation of very large datasets of Earth observation data from satellites, in

the linking of major global climate models, and in the developments of high energy physics networks and experiments, especially for the Large Hadron Collider (LHC).

The trend towards world-wide shared access to scientific data should be welcomed as it represents a more efficient use of research results, and enables research programmes to be conducted with less duplication of effort. World-wide cooperation can be thus achieved without the need for additional research facilities. In this context, the costs of providing bandwidth have to be considered against the background of the alternative methods of achieving similar goals.

We can also see that the Internet is rapidly reaching the point where the transmission of audio and video signals will soon become a completely standard facility. This fact lies behind many of the new approaches to collaborative research work just discussed. It also underlies much of the increase in demand for bandwidth from the educational community, where the fields of both initial education and continuous learning will have to confront this fundamental shift. It is also behind the rapidly growing interest in networking from the social sciences, among others, as they anticipate the general availability of video archives opening up completely new opportunities.

High bandwidth networking and economic performance

High bandwidth networking will continue to be an important driver for the development and ever-widening use of the Internet, and hence of the overall European economy. The research and education community are the pioneer users of new networking technology and are usually ahead of the market. They provide a “pull” for the development of both technology and applications, are the most demanding users and are often the leaders in testing the technology and applications. Thus, they pave the way for the introduction of new systems which have been tried first in the research networking environment before being taken into business and society at large, with its consequent economic impact. This pioneering role of research

networking is a further reason for investment in it.

The speed of feedback via the cycle of research, development and deployment leading back to the definition of interesting future R&D is surprisingly rapid. While we do not have the comparable data for Europe, the President's Information Technology Advisory Committee (PITAC) in the USA reported Federal Reserve data showing that 30% of the growth in the American economy during the period 1992-1997 could be attributed to IT, including networking. This rather direct and rapid linkage has been well understood by some of our national governments and their agencies. We recommend that all national governments and the EU should study the strong evidence, incorporate it into their analysis and planning, and take the appropriate action.

High bandwidth networking and education

The potential of high bandwidth networking to change and enhance all stages of the educational system, from the youngest ages upwards, is dramatic. While most European national research networks (NRNs) were initially structured to provide services for some hundreds of universities and research institutes, their role may well have to expand, perhaps even to the point where they become national research and education networks (NRENs). One aspect is the strong push from many governments for their NRNs to provide access at all times for students in higher education, even when they are off campus.

Even more complex issues are raised by the desire to see the NRENs provide service for tens of thousands of schools. There are certainly strong synergies between the different branches of the educational system. Although there is a feeling that the research and higher education communities should welcome the opportunities that this development could bring, this will have implications for the network operation. The high bandwidth network capacity and quality of network services available to research and higher education could be very severely compromised if new missions towards schools are not adequately

resourced and well engineered. This potential evolution of NRNs into NRENs will have to be decided on a national basis, since the assessment of the optimal balance between focusing on the needs of the various groups involved and benefiting from sharing the costs of infrastructure and services, including management and operations, will inevitably depend on many local factors.

Further advanced applications

There are also a number of areas, such as fully automatic world-wide management and processing of distributed data, and remote access to facilities ("caves") which offer fully immersive virtual reality environments, which will have great relevance for research, industry and commerce, and which will consume truly very large amounts of bandwidth.

The end-user view

Networking is a rather complex chain of infrastructures which link two or more users, and chains are only as strong as their weakest links. The research and education communities need to concentrate their attention on the quality of the networking services which are obtained on a daily basis by the real end-user.

The ends of the chain are formed by the local site infrastructures, consisting of the computers available on the desktops or elsewhere, the software environments, the site networks, the support services, and the connectivity to the NRN or NREN. Then the national networks available at both ends extend the chain, introducing some delay and potential packet loss on their backbone and at the points where they connect to international networks such as TEN-155. Additionally, the links between the national networks and the quality of the international network services, especially at their interconnects between countries and at the natural bottlenecks created by the high cost of transmission under the oceans, contribute to the overall level of service perceived by the end-users.

There are two fundamental but related issues. The provision of a good quality of service to the real end-user must always be

emphasised as the goal for all of the suppliers of the individual components of networking for the education and research communities. Until high quality networking services are routinely available on a world-wide basis between all correspondents who themselves have access to good national network services, then the several national and international networking organisations involved will not have completely discharged their joint responsibilities. Secondly, the various funding authorities concerned need to pay attention to the balance between the performance of the site-based, the national, and the international networks.

The goal of uniform and ubiquitous access

It is clear that the research and education communities should support the concept that the access to high bandwidth networking should be fully ubiquitous. There are no *a priori* grounds for accepting lower performance or less reliable services in remote areas, or in economically weak regions.

We recognise that the impact of the telecoms liberalisation, which took effect in much of Europe on 1 January 1998, has been very dramatic in some areas of Europe and much more limited in certain other regions. The construction of several pan-European fibre infrastructures will be completed in the next one to two years, and we can then expect even more widespread competition. However, those infrastructures will link up only the really major cities, and there is some concern that the situation for high bandwidth connections will be far less competitive nationally, especially as we move away from the major cities. All the governments involved need to watch this situation carefully.

From simple networking to computational and data “grids”

Although the concepts of distributed computing have been well-established for some time, we are convinced that a further paradigm shift is taking place, as certain unifying concepts are being identified which will allow the creation of

collaborative systems to handle the computational and data processing needs of diverse disciplines.

Over the next few years we should be able to specify and implement the “middleware” or “glue” which will connect up data repositories, applications software and high bandwidth networks, thereby allowing reliable, resilient fully-distributed systems to be created for various disciplines. Such systems would potentially permit a much broader exploitation of many scientific and educational IT resources (including processor power, mass storage and, more generally, information). These are under-exploited because they are only used, at most, during 12 hours per day and cannot be accessed effectively across the network during off-peak hours. In the USA the name which has become accepted for this new paradigm is that of computational and data “grids”, by analogy with the electrical power grid. Even if the analogy is not perfect, since the provision and transmission of data processing capacity is in several aspects significantly more complex than the provision of electrical power, it would be unwise to try to change the name.

“Grids” provide a good example of how the very existence of more capable networks can lead to unsuspected new applications and even to new scientific approaches. The concept of “grids” was mainly inspired by the gigabit test-bed networks deployed in the USA in the early 1990s. The fast-growing interest of the American scientific community in “grids”, with several projects already under way at U.S. Department of Energy (DoE), NASA and the NSF, is due to the growing confidence of many of their institutions that reliable high bandwidth network connections are indeed here to stay. Our message is that the development of “grids” will be extremely important for the research and education communities in Europe, and that this is an area of software which is so far largely unexplored and which carries both great commercial potential, and opens up new horizons for scientific collaboration, pushing well beyond the limits of existing networks.

Global connections

European researchers need good network connectivity to colleagues, collaborators, and data and information repositories from all over the world, and vice versa. The provision of healthy intercontinental connectivity is part of the basic network requirement of researchers everywhere.

There is a delicate balance to be found in this area. On the one hand a structure is needed with which networks from other countries and continents can easily collaborate, both technically and financially, in order to obtain good connectivity to all European researchers. On the other hand many European NRNs wish to retain direct control of the policy and the cost-optimisation of their most critical international connections.

It is clear that a single point of access is not an appropriate solution for Europe, and that some sort of well-organised but distributed access to the pan-European network backbone is required. We recommend that the parties involved should confirm that a consensus exists for an improved approach in this area, and implement that approach without delay.

Moving from TEN-155 to GÉANT

Building a consensus to create and evolve the pan-European network infrastructure needed by our research and educational communities has never been easy, but the parties concerned have always shown goodwill and the consensus has always been achieved. The process is complex because many different national and pan-European parties are involved, each with their own technical and financial constraints. But the history of TEN-34 (which was based on a 34 Mbit/s core and started in early 1997) and TEN-155 (which was based on a 155 Mbit/s core and started in early 1999) has shown that Europe can build a network which, even if not offering the very highest performance in the world, nevertheless is very solid, bears global comparison in all aspects, and leads in some.

All involved are aware of the relentless progress of aggregate user demand, which typically overwhelms any backbone infrastructure within about 24 months, and the need to catch up on some of the American

lead in the provision of higher bandwidth services. Thus, the parties to TEN-155 started planning for its successor as a pan-European interconnect as soon as it entered service. This proposed successor is known by the working name of GÉANT².

This has been helped by the political recognition from the EU Council of Ministers that research networking infrastructure is the responsibility of governments nationally, and the joint responsibility of the EC and national governments at the European level. Subsequently, the strong commitment given to research networking in the text of the Fifth Framework Programme, significantly increases the allocated funding, and recognises that high bandwidth networking is primarily an infrastructure project for the whole research community, which should not be handled as a research activity in itself. At the same time the creation of a separate Research Networking Unit in the Information Society Directorate General of the EC is a recognition of the importance of this topic.

Unfortunately the consensus for a rapid push towards GÉANT has not yet led to concrete results. Some changes in EC staffing, the interregnum until the Prodi Commission was installed, and some slight legal differences between the Fourth and the Fifth Framework Programmes, all coming at a time when important decisions were needed, have combined to make for extremely slow progress during 1999. It is vital that a formal Commission Decision on how to proceed be published by May 2000, in order that GÉANT can be fully operational by November 2000.

At the same time, we are aware that the EU funding for TEN-155, which comes from the Fourth Framework Programme and which covers some 30% of the total expenditure, with the remainder being paid by the NRNs, is due to terminate in May 2000. It is inconceivable that TEN-155 be allowed to stop before a successor has become operational, and we strongly support the request which has been made for an extension. We cannot emphasise too strongly how much the European research community depends on continuing good network connectivity, and how relentlessly

² It is neither feasible nor appropriate to provide a sensible summary of the technical and financial characteristics of GÉANT in this document. An overview of GÉANT is available at <http://www.dante.net/geant>. A Draft specification of the high-level requirements for broadband interconnection of national research, education and training networks can be found at <http://nicewww.cern.ch/~davidw/public/ragfinal.doc>

the underlying user demands will continue to grow.

All parties, and especially the European Commission, must face up to their responsibilities, and reach a definitive conclusion in the coming weeks on the detailed mechanisms by which the transition from TEN-155 to GÉANT will be handled.

Funding

Providing sensible advice about budget planning for high bandwidth networking is far from trivial, since the underlying costs of bandwidth provision are falling quickly, at the same time as the user requirements are exploding and completely new fields of research and educational use of networking are opening up.

If we look at the underlying networking technologies we can see that the price-performance of bandwidth supply is now improving at least as fast as that of processor power, if not even faster, and that this state of affairs appears likely to prevail for at least the next decade. The main caveat has to be the worry that the variable-speed transition from the old quasi-monopoly situation to a truly competitive supply of fibre (and other) high capacity infrastructures might mean that there are long delays before affordable bandwidth becomes available in all of the less-populated areas or countries of Europe.

The past three to four years provide good evidence that research traffic in Europe has grown by a factor of 2-3 times each year, and there seems to be little reason to believe that this rate of increase will fall off. Should we wish to increase the present level of service, in order to help European research and education at large to become more competitive on the world scale, we ought to be planning for an annual increase by a factor of at least 4-5 for several years to come. At the same time we would expect the overall price of bandwidth provision (which is a very major component of the cost of research and education networking, but not the only one) to decrease by a factor of roughly 2-3 times per year. Taking account of all of these factors, the conclusion has to be that if national and regional governments and the relevant European

institutions wish to have a network infrastructure for their research and education communities, which is competitive on the global scale, then they must still plan to devote increasing resources to this field over time.

In this context we highlight the need for Europe to plan coherently at all levels. The European Union's Fifth Framework Programme emphasised the need for good networking as a vital infrastructure for research in all fields, and budgeted for a significant increase in expenditure with respect to the Fourth Framework Programme, in line with the arguments given in the previous paragraph. As we have already pointed out, the end-user's perception of the performance of a network is only as strong as its weakest link. It is therefore necessary that all other funding bodies, at the national and site level, also make appropriate provisions.

At least one European NRN has recently obtained a tripling of its annual budget, following an external review by an internationally respected firm of consultants, in order to provide for the predicted growth in demand for its services.

On-campus investment

Because of its historically high cost, Europe has often seen international bandwidth as the most critical bottleneck in networking for education and research. But there are now signs that the quality of the local infrastructure on many campuses is starting to become an equally important limitation. To give an indication of the scale, during recent years many American universities have made one-off investments in their campus networking infrastructure, including the cabling and the routers, at the level of some 10% of their annual operational budget. Shared 10 Mbps Ethernet is no longer adequate for many tasks. Soon a very wide availability of switched gigabit service to all desktops would be highly advantageous. This modernisation should not only cover some significant investment in hardware, but also ideally a review of the level of operational and technical IT support available to end-users.

Conclusion

In summary, we conclude that continued investment in research and education networks at all levels – pan-European, national and local – will be important for our research communities, for our education, and for the future health of our economies. The level of funding needs to grow for quite some time to come in order to meet the rapidly increasing demands for higher bandwidth and more access points, but the likely rewards clearly warrant this investment. We also urge that decisions are taken by the European Commission by May 2000 both to protect the existing European networking arrangements and to move forward with the procurement of the next stage of this development.

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Presentations given at the meeting (November 1999) of the Academia Europaea/European Science Foundation Expert Group may be accessed at: [http://nicewww.cern.ch/~davidw/public/hibeer/ \(insert name\).ppt](http://nicewww.cern.ch/~davidw/public/hibeer/(insert name).ppt) for the names ellisman, linglin, messina, canarie, warren-smith, williams

Information concerning the network provision and developments in the United States of America may be accessed at the web site of the National Partnership for Advanced Computational Infrastructures (NPACI) at: <http://npaci.edu>

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