Report on the networking needs of users in the European research community

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Study into European Research and Education Networking As Targeted by *e*Europe

SERENATE

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1. Executive summary

1.1. Introduction and conclusions

- This report describes an assessment of the future networking needs of members of the European research community over the next five years or so. Its conclusions have been derived primarily by analysing the views of active researchers from a large range of subject disciplines and geographical locations. Those views were obtained by a questionnaire and by discussions at two workshops.

- The responses to the questionnaire and the experiences of those at the workshops show that there has been great progress during the past five years such that researchers have a reasonable environment of research and education networking in many parts of Europe. But we cannot be complacent since the situation in several regions in Europe is far from satisfactory, and arguably getting worse in relative terms.

- Satisfactory network performance for the end-user depends on a healthy infrastructure in three areas: on the campus, nationally and internationally. For many European researchers the major source of limited network performance is primarily at the campus.

- The current NREN (National Research and Education Network) model, in which one NREN is necessary and sufficient for each European country with international connectivity being provided between NRENs remains appropriate. But there will be a need for the NRENs to provide enhanced services, and that means that all NRENs will need to engage in a deeper dialogue with campuses and the bodies responsible for their IT infrastructure.

- International connectivity is of particular importance in internationally collaborative research. Most researchers collaborate with a small number of distant collaborators: 50% have five or less. Very large collaborations come from experimental particle physics; the earth sciences and nuclear science can involve quite large collaborations in the 30-50 range; collaborations in the 20-30 range cover a wide range of subjects from the physical and life sciences and sociology.

- There are a significant number of researchers (14%) who are regularly transmitting rather large files, say of more than 100 Megabyte, over the network, and there are a small number who are moving very large files of up to 1 Terabyte.

- SERENATE is impressed by the evidence of growing network requirements from all areas of research. The needs will grow dramatically over the next 5-10 years, in all disciplines and in all countries. Examples are given where the research would become much more efficient if network speeds were increased by one or two orders of magnitude. Examples were also given where there is the possibility of starting completely new research activities that were prohibited until now by lack of very high performance networking facilities. There is a remarkable interest and involvement in Grid computing. It is clear that Grid computing with all its related resources is something that on a five-year timescale will be demanded by all European researchers if they are to contribute to their subject.

- User expectations have evolved beyond the provision of pure bandwidth towards the supply of more complex services. There are concerns about security, privacy and confidentiality and there is likely to be demand for so-called AAA services (authentication, authorisation and accounting) in the research and education area, which will require new expertise in the NRENs. There will be growing demand for the researcher to be able to access networks wherever he or she happens to be.

- NRENs should become more involved in initiatives aimed at reducing “spam” and protecting against viruses and hacking.

- SERENATE further recommends that the NRENs, and DANTE, co-operate to put in place a service that, when a user believes there is unusual bad network performance, would determine whether the performance was indeed worse than normal, and if so, take responsibility for correcting the situation.

- The growing development of globally distributed sets of facilities will require flexibility not just in connection with communication hardware but in all NREN services.

- SERENATE feels that the NRENs should increase the flow of information, including road-maps of likely future service developments, to their end-user communities, and make more educational material available.

- In stressing a move to services, it should not be forgotten that there is a demand for more bandwidth from a significant number of research end-users. Two areas given as examples of the broad demand for increased bandwidth are visualisation and the use of videoconferencing.

- Networking involves real money, and some feel that some form of charging the end-user might be acceptable, particularly where there is heavy use or special needs. Certainly, end-users should be made aware of the true cost of the service being provided, which may also demonstrate to the user community where investment is needed, especially on the campus. However, SERENATE feels that any move in the direction of explicit charging for heavy or special use must be treated with great care. Up-front charging can stifle progress and advanced applications. It should not be considered until both the financial and technical issues are well-understood and stable.

- We are far from "equality of networking opportunities" for researchers in all countries of the European Research Area. Yet, researchers all over the Area wish to do similar work. The reduced network resources in the economically weaker countries of Europe and their consequent reduced contribution to European research imply that an intellectual force is being seriously under-utilised. Provision of good IT infrastructures is also an important factor that can influence the migration of high-quality researchers. The dramatic nature of this internal "digital divide" in Europe must be drawn to the attention of politicians.

- Regulatory liberalisation in the EU-15 countries played a major role in reducing prices and improving services. SERENATE believes that the elimination of telecommunications monopolies and the rapid introduction of effective competition among several operators will be crucial factors if this digital divide is to be eliminated in the next say five years. However, any attempt to implement equal opportunities across the European Research Area within five years will depend on strong political commitment, and spending significant sums of money.

- The report lists a number of specific recommendations.

1.2. Recommendations

Relevant to universities

- A major source of limited network performance is at the campus, and this fact must be drawn to the attention of senior management in the university and similar sectors.

Relevant to NRENs

- NRENs should increase the flow of information, including road-maps of likely future service developments, to their end-user communities, and make more educational material available.

- NRENs should devote more resources to listening to the needs of users.

- NRENs should explicitly explore the problems arising from research collaboration between universities and for-profit organisations such as SMEs[1] and give advice to the relevant stakeholders.

- NRENs must take account of the growth in user expectations in the form of more complex services.

- The NRENs should plan for good broadband remote access for researchers at the office, laboratory, home or away on a mission.

- NRENs should recognise that a greater demand for AAA services will in most cases require new expertise.

[1] Small and Medium-size Enterprises

- It is important for academic and education users that the deployment of AAA (or similar) services is handled in a compatible manner across Europe.

- NRENs and universities should together establish appropriate licensing arrangements for the research community.

- NRENs should become more involved in initiatives aimed at reducing "spam" and protecting against viruses and hacking.

- NRENs, and DANTE, should co-operate to put in place a service that when triggered by the user, would determine whether the performance obtained was indeed worse than normal, and if so, take responsibility for correcting the situation.

Particularly relevant to the European Commission and national funding bodies

- Basic research networking should be regarded as a public good.

- Any move in the direction of explicit charging for heavy or special use must be treated with great care. It must not be considered until both the financial and technical issues are well-understood and stable.

- We are far away from "equality of networking opportunities" for researchers in all countries of the European Research Area. There is a European internal "digital divide". To implement equal opportunities requires strong political commitment, and spending significant sums of money.

- Elimination of telecommunications monopolies and the rapid introduction of effective competition among several operators are crucial.

- The regular reports on each Accession State's progress towards accession should be required to specifically address the extent to which their Research and Education Network has been brought up to EU levels.

2. Introduction

This report is part of the project SERENATE (Study into European Research and Education Networking as Targeted by *e*Europe). SERENATE is a series of strategic studies into the future of research and education networking in Europe. The project aims to contribute to European policies, social objectives and economic development by providing inputs to the development of policies by the European Commission and also to national governments and funding bodies, the management of universities, and the national research and education networking organisations.

In the past years, Europe has taken up the challenge of Gigabit networking. Gigabit networks have been implemented by a number of National Research and Education Networks (NRENs), and in other countries plans for such networks are being developed. At the European level, the GÉANT interconnect network has been a significant step forward, introducing 10 Gb/s in the core of the network and offering a wide coverage of 2.5 Gb/s capacity. It is possible that GÉANT will deploy some links with speeds at or above 100 Gb/s during its lifetime, and even more ambitious longer-term numerical targets may now be appropriate. Similar developments are to be expected at the national and local levels of research networking.

SERENATE contributes to achieving these networking goals by investigating the strategic aspects of the development of such "superfast" networks, looking into the technical, organisational and financial aspects, the market conditions and the regulatory environment. As a result, by the end of the project relevant policy makers, funding bodies and managers of research networks in Europe will have at their disposal a set of recommendations and background materials that will enable them to set their policies for the further development of European research networking.

This report describes the SERENATE assessment of the future networking needs of members of the European research community over the next five years or so. Its conclusions have been derived primarily by analysing the views of active researchers from a large range of subject disciplines and geographical locations. Those views were obtained by a questionnaire and by discussions at two workshops. The first workshop was the SERENATE Initial Workshop at La Hulpe on 17-18 September 2002, to which a small number of research end-users of networks were invited; discussions with and amongst these guided the development of the questionnaire. The second workshop at Montpellier on 17-19 January 2003 was explicitly targeted at research end-users. The main analysis of the questionnaire was available there and could therefore inform the discussion that led to the conclusions given in this report.

A detailed analysis of the answers to the 21 questions that made up the questionnaire is provided in Annex II. However, the main body of this report is rather short and focuses on the conclusions that were drawn from the answers to the questionnaire and the discussions at the Montpellier workshop.

During the preparation of the questionnaire and workshops, actual or potential users of European research and education networks who are not using them in connection with research were also considered; however, such users are not discussed here but in SERENATE deliverable D15.

3. The questionnaire and the Montpellier workshop

The questionnaire (see Annex I) was posted on the Web and invitations to reply were sent by email to more than 4,000 named individuals who were likely to be using research and education networks. There were almost 500 replies coming from a wide range of disciplines and sub-disciplines and with a good geographical distribution over the totality of Europe.

Of those who responded, 73% came from the European Union, 9% from Accession States, 3% came from EFTA, 3% from Candidate States, 7% from other European countries and 5% from non-European states or where the location is unclear.

The detailed distribution by discipline and sub-discipline can be found in Annex II. The distribution by general discipline areas is given in Figure 1.

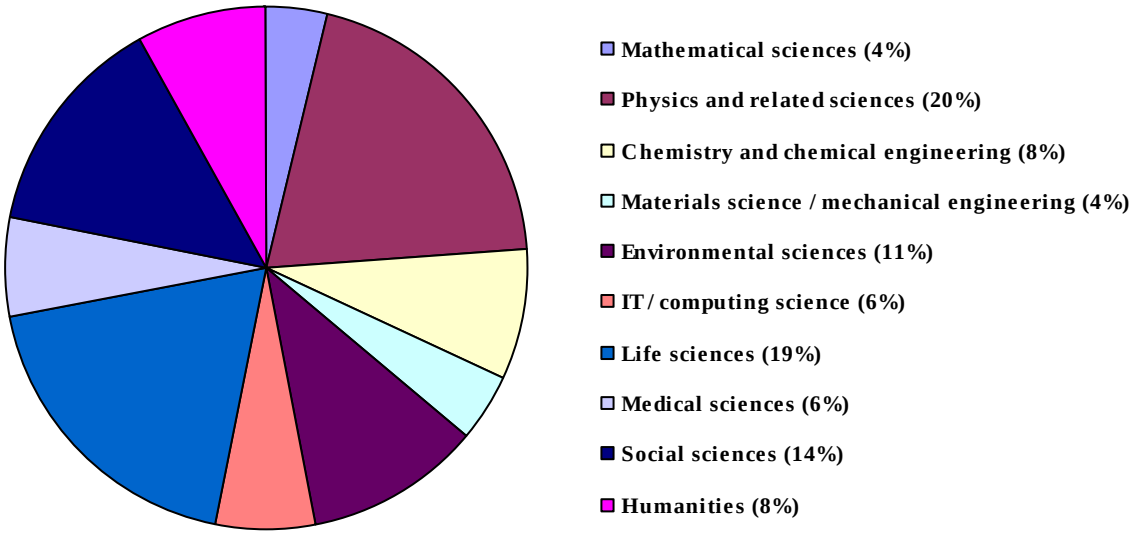

Figure 1. Distribution of discipline areas of questionnaire respondents

The Montpellier workshop was kept small: although there were some ten introductory talks in order to initiate discussion, the main purpose of the workshop was to have real interaction involving all the participants. The programme is given in Annex III.

The invited presentations and some of the contributions to the discussion can be found in the annexes to this report, together with the immediate conclusions determined at the final session of the workshop. These were co-ordinated by SERENATE Steering Committee chairman David Williams.

4. The overall networking environment in Europe

The responses to the questionnaire and the experiences of those at the Montpellier workshop suggest a first conclusion that can be drawn, namely that there has been great progress during the past five years such that researchers have a reasonable environment of research and education networking in many parts of Europe.

One piece of evidence that this is the case comes from the fact that good networking is essential for international collaborative projects and the survey shows the large degree of international collaboration that is now taking place. Almost 60% of those replying to the questionnaire said that 25% or more of their research budget is committed to international collaborative projects. This is markedly different from the situation some five years ago[2]. (Interestingly, collaboration is mainly within Europe: almost half of respondents (46%) said that 20% or less of their collaborators were outside Europe. In the same way, when asked what fraction of their network traffic, coming in or going out, involved other European institutions and what involved institutions outside Europe, 53% felt that traffic with European institutions is the greatest, 21% felt traffic with non-European institutions is the greatest and 26% felt it was equal).

There are therefore many reasons to be grateful to governments and the many different organisations involved in funding and providing the networking services. But we cannot be complacent since the situation in several regions in Europe is far from satisfactory and arguably getting worse in relative terms. The speed of overall developments in the networking field is so rapid that very great efforts have to be made in these weaker regions if they are not to slip relative to the rest of Europe.

[2] See ETAN Working Paper Transforming European Science through ICT, European Commission, 1999, ISBN 92-828-7308-0

5. Satisfactory network performance

Satisfactory network performance for the end-user depends on a healthy infrastructure in three areas[3]:

- on the campus
- nationally
- internationally.

5.1. Campus-related issues

Of the researchers who replied to the question what, if anything, was limiting their use of the research network, 57% felt there was such a limitation. Of these, 40% felt there was a limitation at the campus or institution. These compare with the 20% who felt there was a limitation at the national level and 23% who felt there was a limitation at the international level. In short, there is serious evidence that for many European researchers the major source of limited network performance is local – primarily at the campus. This problem must be drawn to the attention of senior management in the university and equivalent sectors.

There is another issue that universities and possibly the national research and education networks should address, namely that a significant number of researchers, particularly in the humanities and social sciences, traditionally do much or some of their work from home and from there they are currently unable to access the network in a fully satisfactory way.

5.2. The National Research and Education Networks

Both in the questionnaire and in the workshops, end-users recognised that the current NREN model in which one NREN is necessary and sufficient for each European country with international connectivity being provided between NRENs has served them well and remains appropriate. Indeed, minor changes to the model were not considered even where, for example, an end-user might be geographically closer to the networks provided in a neighbouring country.

When in the questionnaire end-users were asked to comment on the NREN in their own country quite a number chose not to reply. Of those that did, 43% were neutral and there is an equal number of respondents who are positive or critical of the service of their NREN: 28% and 29%. There are two countries (in the European Union) where end-users feel they are getting poor service, an observation that cannot be explained by the countries' economic status. Not surprisingly, many of those critical of the NREN service felt they had insufficient say in the policy relating to the NREN (and 6% who were neutral or positive still would have liked to have more say).

SERENATE certainly feels that NRENs should consult with end-users. As will be seen below, there will be a need for the NRENs to provide enhanced services, rather than simply communication bandwidth and that means that **all** NRENs will need to engage in a deeper dialogue with campuses and with their national body or bodies responsible for their IT infrastructure. There is no evidence that end-users want in any way to control the NREN organisations, which in most cases are regarded as operating efficiently and effectively. But they do want to influence policy and feel that NRENs should devote more resources to listening to their needs.

At the final session of the Montpellier workshop, the question was addressed whether the model of multiple interconnected NRENs would still be optimal in say ten years' time. Would it not be better to move to a single, ubiquitous, European Research and Education Network? Issues that might complicate such an approach include the different national political, funding and regulatory regimes and the question of local languages. Some argued that there might be problems about scaling and that the structure of networks tends to be inherently tiered. It was suggested that the correct approach is probably to examine the functionality required at various levels of the network, and a study along that line might follow on from SERENATE. This possibly implies returning to this topic at later workshops.

It is an assumption in the planning for the Information Society Technologies research activities within the European Union's 6th Framework Programme that participation by industrial partners, primarily SMEs, is

[3] Unless indicated otherwise, in this report the word "infrastructure" should be understood in a broad sense – not just cabling and transmission capacity but also the software and services required by the end-user.

essential. Indeed most national research programmes encourage such collaboration and many SMEs seek to collaborate with a local university. One would therefore expect that where there was such collaboration, networking through the NREN would be possible and easy. In practice, answers to the questionnaire show that this is far from being the case. Of the respondents who are actually collaborating or contemplating collaboration with a partner from the for-profit sector, slightly more than 50% reported difficulties.

The main problem (50% of comments) is that the commercial partner has stricter rules as regards security or confidentiality, e.g. firewalls are inhibiting mutual communication or data transfer even when it is recognised as necessary. (In one case the problems are sufficiently severe that the partners simply do not communicate via the network).

The second problem (20% of comments) is that the SME has poorer network facilities than the academic partner. Although conversely, an academic partner collaborating with a large company may have difficulty accessing its better facilities, e.g. virtual-reality caves.

(Although it is not an issue for SERENATE, it is interesting to note that 17% of the problems relate to dispute or potential dispute over intellectual property rights on the results of collaborative research).

SERENATE recommends that NRENs explicitly explore the problems arising from research collaboration between universities and for-profit organisations such as SMEs and give advice to the relevant stakeholders.

5.3. International connectivity

International connectivity is of particular importance in internationally collaborative research, and therefore a number of the questions posed to end-users were aimed at exploring the current nature of collaborations. Thus users were asked if their research involves distant collaborators and if so with how many. Figure 2 shows the distribution of the answers.

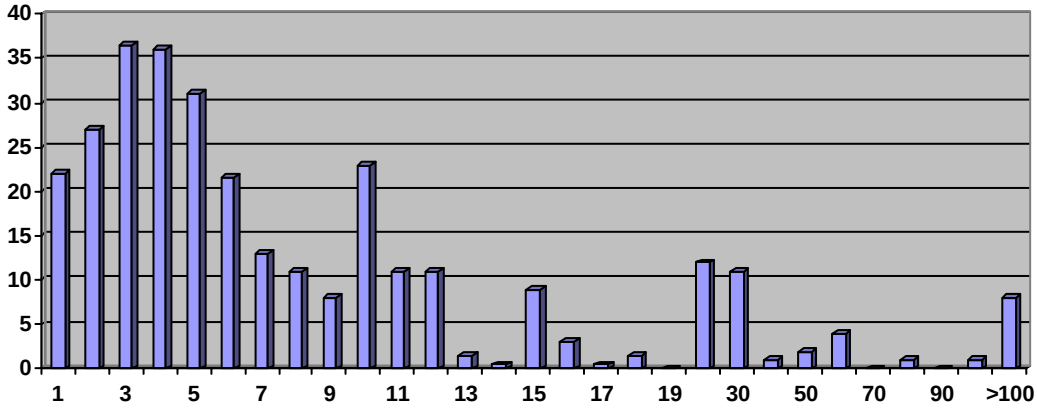

Figure 2. Number of distant collaborators.

It is seen that the large majority of respondents collaborate with a comparatively small number of distant collaborators: 50% have five or less distant collaborators, and 77% have ten or less distant collaborators. The very large collaborations come from experimental particle physics. As one might expect, the earth sciences such as climate research or oceanography can involve quite large collaborations in the 30-50 range, as does nuclear science. Collaborations in the 20-30 range cover a wide range of subjects from the physical and life sciences and sociology.

Respondents were also asked about the typical file size that they transport over the network. Figure 3 shows the distribution.

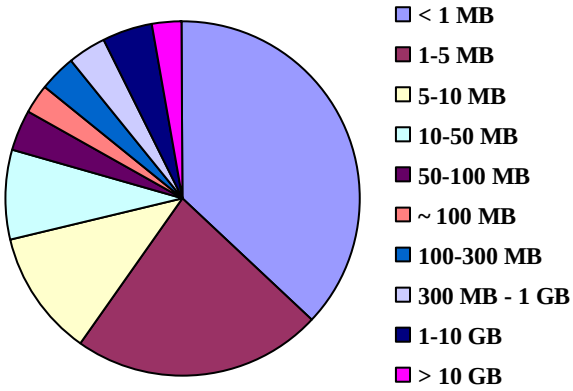

Figure 3. Distribution of typical file size transported over the network

Thus though 37% of researchers currently transfer rather small files (smaller than 1 MB), there are a significant number (14%) who are regularly transmitting rather large files, say more than 100 MB. Several respondents stress that the size of files in use is increasing.

There are a small number who are moving very large files, primarily from the astronomy and particle physics areas. Typical answers are:

> *"Hundreds of GB -> TB files"* (radio astronomy)
>
> *"Sizes vary between some 100 MB to 100 GB and are increasing steadily (for LOFAR, Low Frequency Array, a typical processed observational unit will be 0.9 TB)"* (radio astronomy)
>
> *"We will have large data sets, 10-100 Tbytes in 2003-2005. These are transferred every month or so. The "small" analysis data sets are 0.1-1 Tbyte, and these are transferred several times a week"* (experimental particle physics)

There are some where it is not wholly clear how large the files are: *"1-2 TB per year"* (materials science). Or where a tar compressed 40 GB tape is transferred (environmental science).

6. Growth in requirements from the research community

6.1. Overview

SERENATE is impressed by the evidence of growing network requirements from all areas of research. The needs will grow dramatically over the next 5-10 years, in all disciplines and in all countries. When asked whether their research currently required high-bandwidth networks, 57% of those responding said "yes". Of these, 48% explicitly mention the importance of accessing distant databases, 15% explicitly mention distant processing e.g. at supercomputers. But the best way of seeing the degree to which networking is affecting research is by some of the examples:

Neuronal net modelling with USA colleagues. Optical measurements (VSDs) in neuronal nets. In the very near future use of fMRI data with clinic. (neuroscience)

Grid-computing (Irish CosmoGrid project for Grid-enabled computational physics of natural phenomena) (astrophysics / cosmology)

Simulations and data analysis carried out on the COSMOS supercomputer must sometimes be controlled remotely, and further processing of this data is sometimes done by collaborators at other institutions. This obviously generates a significant amount of traffic. (computational cosmology)

Remote control of job processing. (computational condensed-matter physics and chemistry)

High bandwidth required between UK and CERN for interactive remote applications. (particle physics theory)

Data transfer from Hawaii, Argentina, Namibia, USA. Remote operation of detectors all over the world is beginning to take place. (experimental particle physics)

An experiment based at Stanford, California with partial control from Italy. Data are stored in databases distributed in Stanford, Lyon (F), Padova (I), UK. Data analysis is performed running on big farms with direct database access and transferring reduced datasets to local computing systems. (experimental particle physics)

Databases from different observatories in the world. First the European Southern Observatory (Germany / Chile) and space missions (HST in Baltimore).General databases (catalogues of astronomical objects and observations): CDS in Strasbourg, NED in the States. (astronomy)

Distributed image databases, image delivery, etc. (astronomy)

A lot (few thousands) of large (16MB each) astronomical images from Hawaii and Chile. Databases are in France. Some processing is done in Lisbon. (astronomy)

Access to distant databases; remote control of instruments. (space science)

Access to databanks maintained at international organisations. Shared databanks in networks of small, dedicated teams. Remotely operated research facilities with automatic data analysis. (astrophysics)

Collaboration tools, remote control of d-bases / large repositories, interactive multimedia projects and distributed Virtual Reality. (VR in design)

Molecular Dynamics and Structural Analysis. (proteomics)

The Internet to access structural and sequence databases, as well as remote access tools. (protein modelling)

Remote control of bioreactors by active X Internet applications. (environmental biotechnology)

Data-mining.

Modelling of buildings, including 3D CAD and the effect of fire, CFD. Streaming video of collaborative experiments. (building research)

The data of the main research project is collected in Kazakhstan, then sent to Italy, where it is processed. (human biology)

The numerical relativity work depends crucially on the use of high-bandwidth networks, for distributed computing, transfer of very large datasets and remote visualisation. (astrophysics)

Main research activity at Jefferson Lab (USA): a fast connection to down/up-load data (~100 GB) and online check of installed apparatus during runs. (nuclear physics)

Distributed data processing. (computational chemistry)

Data transfers to/from supercomputer centres. (biophysics)

Passing around MPEG movies of around 100 MB. These movies are transferred to different sites for analysis. (linguistics)

Setting up an international database for analysis of DNA fingerprints including submission of data and online search and analysis of data. (epidemiology)

Remote control of instruments. (forest ecology)

Computer aided surgery.

A "virtual" medical/clinical desktop for users so they can use integrated services from the Web as if they are all provided locally. (medical informatics)

A Virtual Reality project, together with two research centres in Germany, to investigate the use of optical networks (10 Gb/s) for immersive co-operative virtual-reality applications. (virtual reality)

Access to high-level images (up to 30 Gigabytes) and reconstructions (up to 5 Terabytes). (media)

Geography is handling large databases, especially when using satellite images or cartographic data or Geographical Information Systems. More specific use as treatment of large interaction matrices (migration or other interaction flows between local units as 36,000 French communes, or 73,000 European local units for instance) or mapping world population in a 10-km wide grid. Sharing software resources for interactive modelling and visualisation is developing now. (geography)

RealityGrid: remote compute and visualisation at the ultra-high end. Very large scale simulations and the need to render the output, which involves very large datasets (tens to hundreds of Gbytes). Many distributed users can visualise the data, and also use virtual reality and reality centres for such visualisation work. Another feature of RealityGrid is remote control of instruments, including both X-ray micro-tomography within laboratories, or at synchrotron sources such as the ESRF in Grenoble. Use of Access Grid for distributed collaborative meetings. In all cases, minimal bandwidth requirements are at the 100 Mb/s level, and can easily demand Gb/s capacity for full transmission of complex and multiple/concurrent simulation data. (computing science)

Such applications would all be dramatically affected and would lead to more efficient research if network speeds were increased by one or two orders of magnitude. But even more impressively, there is the possibility of starting completely new research activities so far prohibited. Some examples suggested by the answers to the questionnaire could be:

Real-time input from space data to ground observatories. Solar alerts.

The ability to count marine animals optically and transfer the data would revolutionise fishery management.

Remote control of plants and experimental reactors would be possible, including use of machine vision applications.

Slow Internet contacts at the moment stop us from having full collaborations with European researchers. An order of magnitude improvement on network speeds would allow a fully interactive research with the whole European network, adding everybody's expertise to the experiment. It would be a new way of working all together.

Access to archive video and audio would be greatly improved, facilitating content and discourse analysis of broadcasting.

Would allow international collaborations to share primary 3D / 4D volume data rather than just the processed low-resolution results. (developmental molecular biology)

Data collection would be done at remote sites via robotics with remote control from the home lab and data transfer to the home lab. This would diminish the need for frequent travel to synchrotrons.

Science of motion computer simulations of human and animal movement. Co-operative online discussion of motion problems. (biomechanics).

An example of international study on prediction of earthquakes or earthquake hazards clearly shows how high network speed has vital importance.

Could really develop proper European earth system models.

Online, real-time modelling of ecosystem-atmosphere gas-exchange.

Detailed study of global atmospheric electric circuit – permitting prediction of lightning. Significant commercial importance[4].

The Virtual Astronomical Observatories (mega-databases). Remote astronomical observing. Research in astrophysics will undergo a kind of revolution when remote observing will be made possible to the astronomer (so they will not have to travel to distant and isolated sites around the world).

Possibility of ensemble ecosystem simulation by Grid. Online collaborative data mining of simulated complex systems (such as ecosystems) using 3D visualisation.

Ability to respond to Targets of Opportunity (e.g. supernova).

If we had 100 Gb/s we would truly be able to interconnect our computing centres around the globe as if they were "tightly connected" resources and our computing paradigm would change.

6.2. Grid computing

It is remarkable that despite the fact that Grid computing is so new, respondents to the questionnaire from a wide range of disciplines and countries said they were active in Grid computing or have clear plans in this area. The national distribution of these respondents is:

[4] See contribution by M. Füllekrug at the Montpellier workshop.

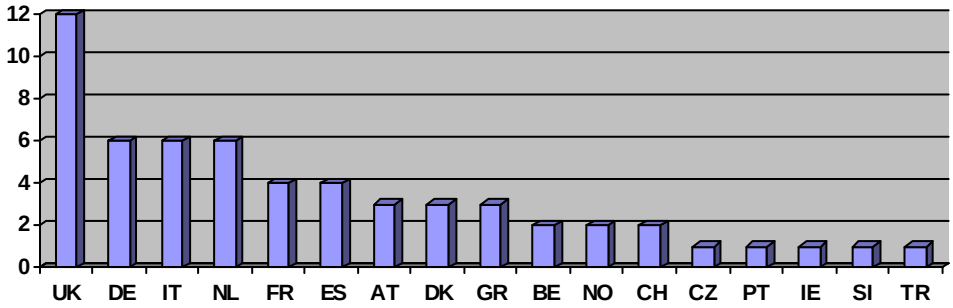

Figure 4. National distribution of respondents involved in Grid computing

They are working in the following areas of research:

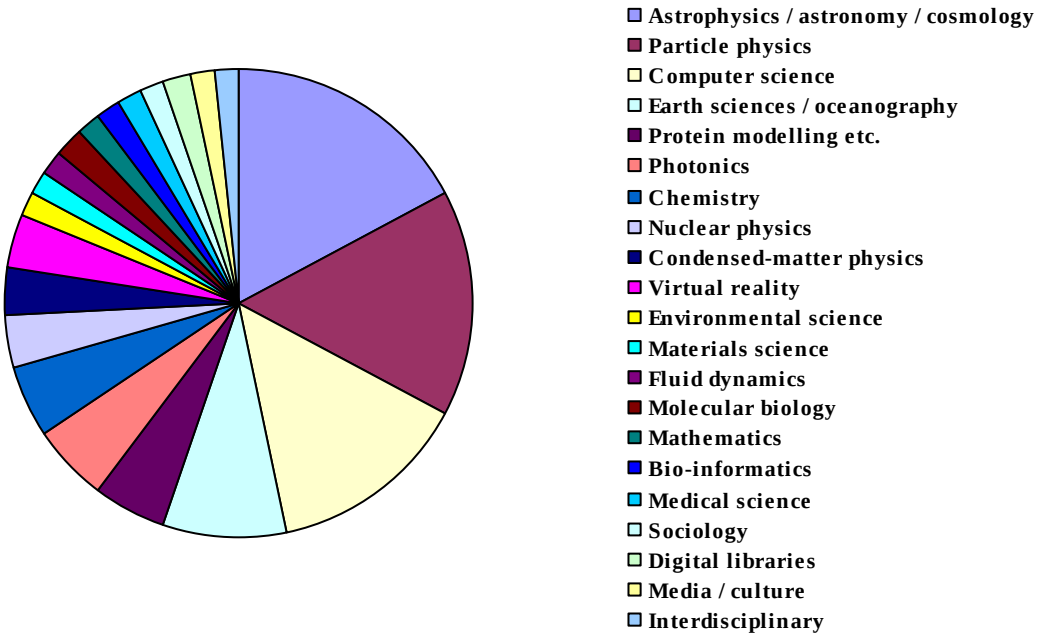

Figure 5. Subject distribution for those involved in Grid computing

It is clear that Grid computing with all its related resources is something that on a five-year timescale will be demanded by all European researchers if they are to contribute to their subject.

7. The move to services

SERENATE has noted that user expectations have evolved beyond the provision of pure bandwidth towards the supply of more complex services. It is important that NRENs take this evolution into account.

A very high percentage of end-users expressed concerns about security (20%), privacy and confidentiality (10%) or both (5%), and some of the actual quoted examples are very worrying. (On the other hand, some point out that excessive and inappropriate security measures can interfere with research efficiency). There are obviously special privacy concerns in medical research, particularly when good networking permits the widespread distribution of photographs of patients and their medical records, and in some aspects of social sciences dealing with personal data.

SERENATE notes that there is likely to be a move towards greater demand for so-called AAA services (authentication, authorisation and accounting) in the research and education community, which will require new expertise in the NRENs. It has been pointed out above that many academics want to work from home, but more generally, there will be growing demand for the researcher to be able to access networks wherever he or she happens to be, at the office, laboratory, home or away on a mission. That implies the need for the deployment of a set of AAA services, or the like, compatible across Europe, and more generally on a global basis. The NRENs will have to plan for good broadband remote access. NREN and university together will have to establish appropriate licensing arrangements for the research community. (And of course for education, but that lies outside the remit of this study).

There is a wide-spread belief that many hackers and virus creators come from universities. This may not be the case, but hackers may work through university networks. It is therefore important not just for the academic community but for the general public that NRENs are sensitive to these problems. Accordingly, SERENATE believes that NRENs should become more involved in initiatives aimed at reducing "spam" and protecting against viruses and hacking.

If an end-user experiences unexpected poor performance, it is normally hard for him or her to understand the reasons and to initiate corrective action. One major complication for the user is the fact that five[5] separate organisations are typically responsible for different components of any international data transfer. SERENATE recommends that the NRENs, and DANTE, co-operate to put in place a service that when triggered by the user, would determine whether the performance obtained was indeed worse than normal, and if so, take responsibility for correcting the situation[6].

In some cases where there is a large infrastructure site such as a radio astronomy array, a large telescope etc. there are special problems in providing last-mile connection to the facility, even when the normal NREN service in that country is perfectly adequate. Since such facilities are usually international facilities, special arrangements should be encouraged between the facility, the local NREN and GÉANT.

But even more demanding are examples where such sites form part of a globally distributed set of facilities, for example the present experiments carried out by GÉANT, several national networks and the radio-astronomy community to combine the signals from the several European radio telescopes[7]. This example, which fundamentally incorporates the networks' long-distance optical fibres into a new scientific instrument, is a very good and successful demonstration of the need for NRENs to be attentive to users' requests and to obtain a flexible approach to service provision. The first ideas of the atmospheric physics community to more-or-less continually monitor lightning on a global basis form another example in the area of data acquisition. It is important to realise that such examples require flexibility not just in connection with communication hardware but in all NREN services.

As the need for services increases, the NRENs have to balance two potentially conflicting end-user requirements:

- to have a highly reliable, always available and easily understood service with hopefully increasing performance and reducing cost – a network which is invisible to the end-user;

[5] The local network at one end, the national network in that country, an international interconnect, and the national network and the local network at the other end.

[6] The monitoring arrangements required for such a service are currently in use by the particle physics community.

[7] See contribution by S. Garrington "High bandwidth data transfer – the future of European radio astronomy" to the Montpellier workshop.

- the need for the end-user to be informed about changes in network technology and services that could have an impact on the way research is carried out.

SERENATE feels that the NRENs should increase the flow of information, including road-maps of likely future service developments, to their end-user communities, and make more educational material available.

8. But still a need for more bandwidth

In stressing a move to services, it should not be forgotten that there is a demand for more bandwidth from a significant number of research end-users. Two areas are given as examples where increased bandwidth is needed.

8.1. Visualisation

Of those answering the question as to whether their research heavily involved visualisation of real or simulated data, 43% answered "yes". Yet, it is clear that even those who use visualisation find serious limitations (90%). The main problem is the size of files, which the user may see as a limitation either locally or in the use of the network, or both, since one can balance one against the other. However, the approach of Grid computing will tend to solve this problem by improved networking – as one user says: *"We can now offer remote visualisation engines on a Grid so that it is no longer necessary for users to have expensive end-user visualisation kit on their site"*.

When asked whether collaborative remote visualisation would change their research, 75% replied "yes" and 25% replied "no". This could be a major driver for higher bandwidth of the research and education networks.

8.2. Videoconferencing

Another driver for improved bandwidth is the wish of the research community to use better videoconferencing facilities. Of those who responded to the questionnaire 16% already use it, and 14% want to do so.

Many of those who do not use videoconferencing give as the reason that it cannot replace a physical meeting and they may fear that funding bodies will use it as an excuse to limit support for travel. In practice, the communities that most use teleconferencing and videoconferencing, like those in particle physics and astrophysics, are the very ones in which the members meet one another frequently and get to know one another since they are funded to go to accelerators, telescopes etc. (Which parallels the observation that those using mobile telephones on trains or buses are invariably communicating with someone they meet frequently). This particular concern about the use of videoconferencing seems groundless.

However, 70% of the regular users find its use is very limited at current bandwidths and with no guaranteed quality of service.

SERENATE concludes that there is potentially a great need for videoconferencing in connection with academic research, but its use implies increased bandwidth and a guaranteed quality of service.

This report is concerned with the needs for future research, but it is important to recognise that there may be a demand for improved network facilities for videoconferencing and related communications for the support of distance learning. Moreover, in the humanities, teaching and research are much more closely integrated than is commonly the case in the sciences[8].

[8] See contributions by P. Goetzen on "The Academy of Humanities and Economics", M. Klimo on "Grid Teaching Challenges" and L.Gallet-Blanchard and M. Martinet on "Humanities end-users: research and teaching" at the Montpellier workshop.

9. Communities beyond those in research and tertiary education

SERENATE was asked to look at how new communities, i.e. other than those in publicly-funded research or tertiary education, might possibly be served by NRENs. This matter is discussed in SERENATE deliverable D15.

Here we simply re-iterate the reasons for having NRENs in the first place. Research and education networking requires a specialised infrastructure, not just hardware but also services, for collaboration among researchers, and this infrastructure is not available as a "standard service" from commercial providers. The research community is tolerant of experimental services at the leading edge and indeed promotes such services. As a result, the last twenty years or so have shown strong economic benefits from using the community as a motor for change. Any extension of the user base for the NRENs must therefore protect research and tertiary education.

10. Charging

SERENATE recognises that there is no such a thing as a “free lunch” – networks do cost money. Currently, in most European publicly funded research institutions there is no charging for networking resources at the point of use, i.e. by the researcher or the research group. Not perhaps surprisingly, a large majority of research end-users (91%) do not wish to see any change from this approach. There is a strong reluctance to charging for standard use at the point of delivery – basic research networking should be regarded as a public good.

However, some (9%) feel that some form of charging might be acceptable, and possibly desirable. This is usually argued as appropriate where there is heavy use or special needs.

For many disciplines the network will become part of the computing resources. The view of SERENATE is, therefore, that any move in the direction of explicit charging for heavy or special use must be treated with great care, even though end users should be made aware of the cost of the service being provided. However, up-front charging if introduced too soon can stifle progress and advanced applications. Any financial contribution expected because of advanced use of the network should not be considered until both the financial and technical issues are well-understood and stable.

11. Closing the gap: the digital divide between European researchers

While we think of most of the EU-15 countries as well connected, we learned at the workshops that there can be unexpected problems at certain research sites where highly specialised instruments or institutes are located off the normal campus. We heard of some dramatic examples of poor connectivity close to, or even within, major cities, but the situation tends to be worst in very rural or mountainous locations, or on islands. The situation is highlighted when wanting to connect such specialised sites with high-performance links – for example as part of a Grid infrastructure. The appropriate NRENs and GÉANT will have to take note of the fact.

But overwhelmingly important is the fact that there is very clear evidence that we are, today, very far away from "equality of networking opportunities" for researchers in all countries of the European Research Area. Indeed, there is a widely held view amongst end-users that the relative situation (for example, the bandwidth available to researchers in the economically weakest countries compared to that available to researchers in the economically strongest countries) is still degrading in relative terms.

Yet, it is obvious from our survey that researchers all over the European Research Area wish to do similar work. The reduced network resources in the economically weaker countries of Europe and their consequent reduced contribution to European research imply that an intellectual force is being seriously under-utilised.

Computing networking and Grids are all about improving human communication and resource sharing. SERENATE feels strongly that the provision of good IT infrastructures – including networking and Grids – is one important factor among others which can influence the migration of high-quality researchers.

One important outcome of the SERENATE project must be to bring the dramatic nature of this gap – Europe's internal "digital divide" – to the attention of politicians.

We note that the regulatory liberalisation in the EU-15 countries played a major role in reducing prices and improving services. SERENATE believes that the elimination of telecommunications monopolies and the rapid introduction of effective competition among several operators will be crucial factors if this gap is to be eliminated in the next say five years.

However, any attempt to implement equal opportunities across the European Research Area within five years will depend on strong political commitment, and the spending of significant sums of money. SERENATE suggests that the annual reports being produced for the Accession States should be required to specifically address the extent to which their Research and Education Network has been brought up to European Union levels.

Annex I. Questionnaire for active research users of research and education networks

The following questionnaire was aimed at active research users of the research and education networks:

1. What is your main research area?

2. Roughly what fraction of your research budget is devoted to high performance computing?

3. Roughly what fraction of your research budget is committed to international collaborative projects?

4. Does your research involve distant collaborators? If so, what is the typical number of distant collaborating researchers with whom you publish? What fraction of them are a) at other institutions in your own country, b) in a different European country, c) outside Europe?

5. Does your research require use of high-bandwidth networks, for example to obtain access to distant databases, remote control of instruments, interactive remote applications, distributed data processing or modelling etc? If so, sketch details.

6. In such use, what fraction of your network traffic, coming in or going out, involves other European institutions and what fraction involves institutions outside Europe?

7. Does your current or foreseen research involve digital libraries?

8. Does your research currently involve file transfer over the research network? If so, what is the typical size of such files?

9. Does your research heavily involve visualisation of real or simulated data? What is limiting its use? Would collaborative remote visualisation change your research?

10. Are you able to identify research issues in your subject area that are currently being limited by the available network facilities? Can you identify ones that are not currently limited, but which will become so in 5 years?

11. What would be the most important network development for your research in the next 3, 5 and 10 years?

12. Is Grid computing being considered in your research area? If so, please sketch what is being planned.

13. What dramatic changes to the nature of your research would result if network speeds were increased by an order of magnitude, or by two orders of magnitude? (International connection at say to 10 Gb/s or to 100 Gb/s).

14. Do you use videoconferencing or other forms of remote conferencing in your research? If so, what are the current limitations?

15. Is your use of the research network currently limited by international connections, the national network, the regional or metropolitan network, or by the campus network?

16. Are there any aspects of the use of networking in your current or proposed research that gives you concern in connection with a) privacy or confidentiality, b) proof of authenticity of data or communications or c) security of data or resources against accident or attack? If so, please give details.

17. Have you any comments to make about your National Research and Education Network? Are you happy with their policy as regards access etc.? Do you feel that end-users have sufficient say in how network policy evolves?

18. Is your research likely to involve collaboration between groups that come partially from the non-profit public sector and partially from the commercial for-profit sector? If the answer is yes, what problems might there be as regards networking?

19. This questionnaire is concerned with your research, but are you also involved in the use of networking for distance education? If so sketch details.

20. Do you have any general concerns about the future development of research and education networks? For example, should there be protected high-performance networks linked to centres of research excellence or is it more important to extend networking more widely?

21. Who should be paying for research and education networks and how? Currently, in most European public institutions there is no charging for networking resources at the point of use, i.e. by the research group. Can such an approach be maintained? Should it be?

The questionnaire was posted on the Web and invitations to reply were sent by email to more than 4,000 named individuals who were likely to use research and education networks. They were identified as: all members of ESF Standing Committees; members of ESF exploratory workshops, programmes and networks; members of the Academia Europaea; AE Burgen Scholars; members of ERCIM workshops; being on the EURESCO list; all members of the Scientific Advisory Committees of CERN, ESA, ESO, EMBO, ILL. (There were other lists of non-research users). There were almost 500 replies. Those replying came from a wide range of disciplines and sub-disciplines and with a good geographical distribution over the totality of Europe.