Networking Spatial Information Systems

REVISED EDITION

Edited by
P. W. Newton, P. R. Zwart
and M. E. Cavill

WILEY

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FOREWORD

This book represents a bringing together of ideas between two exciting fields of technology; telecommunications and spatial information systems. Both these fields of applied technology have been powerfully changed by advances in computing systems - more powerful hardware and software to enable us to crunch bigger problems, to massage data more quickly in even larger data bases, and to display the results more attractively and comprehensively through impressive screen displays. Even better, the more flexible, distributed architectures of modern computing systems facilitate our ability to share the cost and usage of databases, and to provide simultaneous access to many potential users of vital information systems.

In addition, the capabilities of modern telecommunications have progressed through the ability of optical fibre technology to deliver very large bandwidths of information quite cost-effectively from point to point. New network developments enable us to bring together the high bandwidth capabilities of modern telecommunications with the distributed architecture and power of modern computing systems, to enable spatial and other important information systems to be implemented or shared or readily updated in a distributed as well as centralised manner - leading to considerable economies for potential users.

My colleagues and I in Telecom Australia see great potential in bringing together spatial information systems technology and telecommunications technology to provide benefits not only for private industry and large public sector service organisations, but also their customers - the community at large. By ensuring that these two new technologies - spatial information systems and broadband telecommunications - are researched and developed jointly, new and creative service applications are possible: applications which could lead to greater efficiencies in the use of information, enable significant cost savings and lead to greater accessibility of a diverse range of information to the public. It is for this reason that Telecom Australia provides significant funds for research work on Geographical Information Systems, as well as on new network technologies, at its Research Laboratories in Melbourne.

Networking Spatial Information Systems is clearly a timely subject for the 1990s. The applications areas of GIS, LIS, CAD and remote sensing will continue to be growth areas into the 1990s, and along with it will come the opportunity to develop innovative networking solutions made possible by the emergence of new broadband network services.

Several distinct market sub-groups were kept in mind when developing the book outline, recruiting authors and determining the technical level for papers:

- **practitioners** involved in establishing GIS, LIS, CAD and remote sensing operations within their particular organisations and needing to keep abreast of the latest developments being undertaken by their counterparts in leading edge organisations;
- **vendors** of GIS, CAD, LIS, etc., who need to be aware of MAN and WAN

issues and the types of applications capable of being developed around such networks in order to be able to better market their systems to clients;

- **academics** involved in teaching and research in these areas. Most universities now have a number of departments where the subject-matter of this book would represent a key component of the curriculum, either at senior undergraduate or postgraduate levels. Typical departments which could be expected to have a significant interest are: surveying and land information; geography, earth sciences; civil engineering; planning and environmental science. Additionally, many universities now have key centres in either geographic information systems, remote sensing, spatial information systems and the like, where subject matter of the type contained in this book will increasingly become the focus for more intensive research and study during the 1990s;
- **telecommunications companies**, whose new network services will be required to provide the capability for networking the spatial information systems community in the 1990s.

I would like to give credit to the many initiatives taking place in the design of spatial information systems in Australia today - not only in our own Research Laboratories, but also at the the Federal and State government level and within private industry and academia.

Perhaps the publication of this inaugural book on Networking Spatial Information Systems is even overdue - but then, the best ideas always seem obvious, to people other than the originators, with the benefit of hindsight.

I congratulate the editors for their initiative and efforts in initiating the original research in this area, for organising conferences and workshops on the topic and recruiting contributions for this book from leading workers in their respective fields throughout Australia and overseas.

Peter Gerrand,
General Manager - Forward Network Planning
Telecom Australia
Melbourne.

CONTENTS

Chapter 1

INTRODUCING THE NEXT WAVE: NETWORKING SPATIAL INFORMATION SYSTEMS

P.W. Newton, P.R. Zwart and M.E. Cavill

INTRODUCTION

Spatial information systems technology, defined here as encompassing geographical information systems (GIS), land information systems (LIS), imaging and computer aided design (CAD) has largely grown out of an "end user computing" environment catering for the immediate needs of relatively small independent groups of specialist professions and applications. These applications and the supported technology have now reached a level of maturity where management attention is shifting from data collection concerns to those of effectively utilizing, maintaining and enhancing their new-found and expensive information resources. Making this information available to a wider community and gaining added returns and benefits has become an important objective.

Most spatial information networks currently in operation are primarily concerned with the transfer of textual data from dedicated host computers to remote terminals. Land information systems represent a typical example (Sedunary, 1988; Forrest). Only recently have some networks begun transferring large volumes of vector and image data as well (Bennett *et al.*, 1988; Chapman, 1991; Webb). Crosswell (1986) reported that most North American GIS organisations surveyed at that time were transferring spatial data via magnetic tape or diskette. A more recent study indicated that Australian organisations involved in geoprocessing activities still transfer much of their spatial data files to remote users and/or outside customers in the same manner (Newton *et al.*, 1990). Due to relatively slow transmission rates and narrow bandwidths, bulk file transfer of spatial information, graphics and image data across dedicated telecommunication lines have been prohibitively expensive.

The introduction of higher speed telecommunications systems, however, are expected to significantly change the way organisations transfer and utilise their data.

Networking spatial information systems, by the end of the 1990s, will have moved from the status of field trial to that of established practice. Multi-user, multi-media databases will be interactively accessed via regional, national and global broadband networks. Large textual and graphics files will be electronically couriered as routine practice. Videotelephony and videoconferencing will be enhancing the wide area networking of spatial information systems. In short, organisations will have the **technological freedom**, as never before, to re-shape

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the geography of their operations, to determine which activities are undertaken where. Clearly in this environment there are a range of technological economic and applications drivers which will encourage or discourage the networking of spatial information systems. Such is the case with most innovation. Discussion of these elements under the general headings of market pull and tech push in the evolution-diffusion process of networked spatial information systems constitute the two principal segments of this book.

This division, however, tends to represent more the environment in which the authors are working and the perspective from which they are writing, than any suggestion that the factors driving the networking of spatial information systems are relatively independent of one another. For example: data collection is being significantly aided via technologies such as scanning, global positioning systems (GPS), and remote sensing. The larger volumes of (digital) data emerging as a result are stretching storage technologies. In turn these larger volumes and higher collection costs of data, coupled with the complex array of problems for solution in contemporary society are encouraging moves towards data sharing and data integration. Together these compound to further stimulate R & D in areas such as networking, database technologies, image processing software and telecommunications. These investigations have identified yet another series of problems to be overcome such as standards for data definition, data exchange and data models, before real time, interactive, 'seamless' graphic interchange and analysis can become a reality.

The gradual resolution of these technical and human issues is producing a wave of innovation that provides the platform for the networking of spatial information systems. A number of the more significant key factors influencing the introduction and use of these networks are outlined below as a precursor to the more detailed discussions contained in the remainder of the book.

THE NEED FOR BETTER CONNECTIVITY

Growth in Applications, Data Integration and Data Sharing

Evidence from organisations in Australia, North America and UK (see contributions in Part 2 of this volume) indicate that once the basic data sets become available, the applications of spatial information systems multiply rapidly. The impetus derives from a number of sources:

- capitalising on the opportunity for deriving value-added products and services (Forrest); especially in an interactive environment, where information can be accessed when needed. Kohli advances the proposition that demand will grow for all classes of user, but that growth will be most spectacular for what could be currently termed the "occasional" user, whose demand will surge with the availability of simplified off-the-shelf query tools and a more diverse and integrated database.
- once data inventories grow, attention begins to focus on the cost of duplicated data; attempts at coordination and **integration** increase for economic and performance reasons (for example, working through a

common database ensures that everyone is operating on the same information, accuracy is enhanced and repetitive re-entry/re-drafting is reduced or eliminated entirely). Also, attention begins to turn to more imaginative applications which need data from a variety of sources.

Since the prospect of developing integrated systems from scratch is not feasible in most instances, ways must be found to integrate existing heterogeneous data systems (Orlowska *et al.*) and to develop applications software to more fully exploit an information base which is often geographically dispersed (Pretty, Camarata, Lee and McLaughlin). When this is achieved there is demonstrable **added utility** for data hitherto held in separate information systems; enhancing business performance by making better use of the integrated information (Webb).

Growth in Volumes of Spatial Data

Recent surveys of practitioners in the spatial information systems community indicate that data volumes through the 1990s will continue to increase dramatically. While data capture and maintenance have typically represented the most expensive components of spatial information systems (Frank, for example, estimates the ratio of hardware : software : data costs to be of the order of 1:10:100), price-performance shifts through satellite, scanning and storage technologies are likely to result in increased data flows, viz:

- remote sensing communities will be in receipt of data volumes in excess of 1000 Gigabits per day (a combination of new satellites, more reception dishes, increased image resolutions). High resolution Landsat images (of the order of 6 Mbytes) can be compressed by a factor of 10 to 20 with little loss of resolution; but while compression reduces storage requirements and information transfer time, processing time involved in decompressing the image increases (Kirton);
- for the LIS community, decisions to include the spatial dimension through raster scanning the plans of subdivision, for example, will dramatically increase size of files (previously limited to textual data);
- in the design and drafting community the increasing availability of commercial product data in CAD format (for example, libraries of construction details running to items in tens of thousands); also automated specifications for building and construction.
- CD-ROM/optical disk systems with capacities in the Gigabyte range now provide capacity for image archives or databases across a wide range of imaging applications such as natural resource inventories.

THE ACHIEVING OF BETTER CONNECTIVITY

In the past decade, spatial information systems have undergone a dramatic change in their technology and their applications. They now almost universally embrace high performance 32-bit workstations and servers, running enhanced operating systems with new generations of graphic user interfaces, advanced data base technologies operating on mixed data media, connected across near transparent local area networks. At the same time there has also been growing awareness of the importance of spatial information systems in supporting planning, design, engineering and strategic decision-making applications. The availability of high speed networking solutions will allow both the spatial information systems community as well as the users of its information to take full advantage of these technological and applications related developments (see Figure 1).

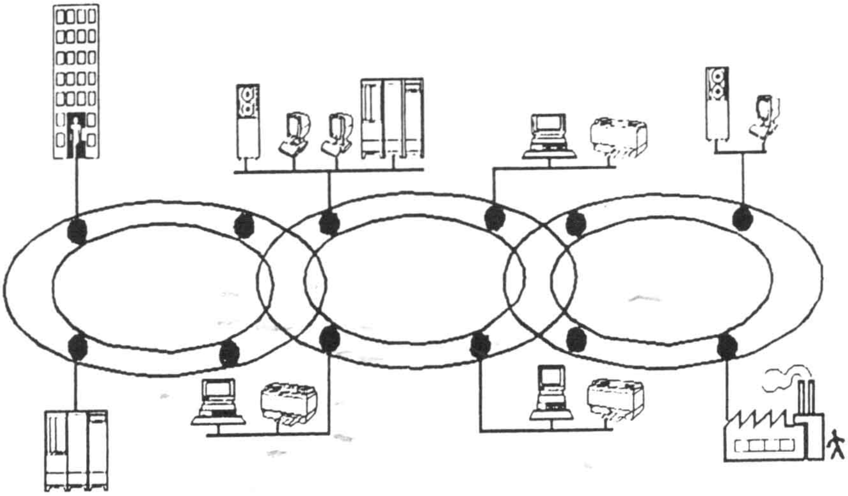


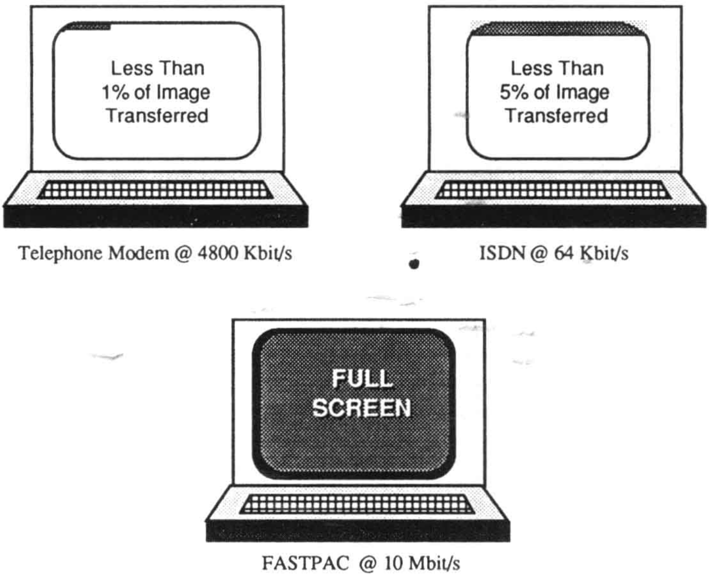
Figure 1. Wide Area and Metropolitan Area Networking

High Speed Digital Telecommunication

This push towards integrating data, together with the realisation that the collection and maintenance of data represents the major item of expense for organisations involved in spatial information systems, makes the ability to share data in real time an important issue. In situations where system response speeds are critical to user acceptance (Webb, for example, argues that response times over 10 seconds are considered unacceptable to most end users), the shift to higher speed public packet switched networks enhances the throughput of data. Figure 2 indicates the radical improvement in performance as one moves from the public switched telephone network (with modem) to ISDN to broadband ISDN (B-ISDN)-type networks. With a basic rate of 155 Mbps, B-ISDN represents almost a thousand-fold increase in information-carrying capacity compared to the basic ISDN user rate of 144 Kbps. Other key features of these broadband networks include (after Kirton):

Service	Speed Range	Speed of Example	Transmission Time to Fill Sun 360 Workstation Screen
Telephone Modem	300 - 9600 bit/s	4800 bit/s	1.4 hours
ISDN	64 K bit/s	64 K bit/s	6.3 minutes
FASTPAC	2-34 M bit/s	10 M bit/s	2.5 seconds

Comparative Times Required to Display a 24 Mb. Image on a Sun 360 Workstation Screen



Comparative Portions of 24 Mb. Image which can be Displayed on a Workstation Screen in 15 Seconds

Figure 2. Comparison of Transmission Speeds Using Alternative Communication Technologies (Source: Zwart and Newton, 1991)

- their ability to take advantage of the high capacity fibre optic transmission networks that are becoming well established at metropolitan and inter-metropolitan levels. Advances in VLSI technology will also make possible the development of very fast, multi-million packet-per-second switches;
- their ability to support a mixture of services such as video, voice and bursty

data. The latter is especially relevant to the spatial information systems community where bit rates may vary considerably during transmission; for example: image retrieval requires high peak bit rates in order to provide screen retrieval delays of less than one second, but average rates will be well below that peak as users engage in the more passive activities (from a telecommunications perspective) such as thinking, reading manuals to check procedures, keyboarding, etc.;

- their connectivity. As a public switched network, broadband technologies will be capable of servicing the requirements of a geographically dispersed organisation or user community with greater reliability and reduced cost than most dedicated links as redundancy is shared among many users. The dramatic growth in local area networks (LAN) has stimulated the need for such interconnection. LANs are typically established within a building or campus-type environment and represent local sources of information. High speed telecommunications, such as fast packet switching and B-ISDN, will provide interconnection of LANs at speeds of 10 Mbps and beyond. From an organisational perspective this creates a single 'enterprise-wide' LAN allowing the flexible connection of workstations to hosts, facilitating distributed applications.

Distributed Information Systems

Given the developments in network capacity and speed, the era in which data was required to be held at the workstation site where interactive graphics analyses were to be undertaken may well be coming to an end. The drivers for this change have been identified as due not only to the emergence of these new high speed communications which permit real time transfer, but to what Orlowska *et al.* suggest as the desire by organisations to **integrate** data for their enterprise, not necessarily centralise it but to make it '..appear as if the information in the component systems are stored and maintained in a single centralised database'. In other words, integration without centralisation; logical rather than physical integration. To achieve this level of integration requires a range of developments and controls related to:

- **security.** One of the major stumbling blocks to electronically linking databases has been the security of the host data. In order to ensure such security, only legitimate users should be able to access the data and only select users update databases. In the specific case of networking legal documents like land titles, the means to authenticate the document is also seen as a problem. The new high speed telecommunication services offer a high degree of security by encrypting the data, even on the public switched network. Indeed, such transactions are much more secure than using a traditional mail service. Once this principal has been understood and enshrined in legislation, we are likely to see a dramatic increase in the number of transactions carried out electronically;
- **ownership.** This issue needs to be clearly identified for reasons relating to maintenance responsibilities, legal responsibilities and costing (Clarke, Calkins). Issues related to degree of local autonomy are also bound to arise

(viz: decisions whether the system is to be homogeneous, that is, composed of the same DBMS at all sites);

- **data quality**: There are several issues here related to standards, viz:
  - (i) commonality of the **data model** (that is, the concepts used to describe data in the database). Are the concepts or meanings associated with a data cover consistent between different user groups? It is not uncommon for information recorded and stored at different sites to exhibit mutually incompatible data structures,
  - (ii) there needs to be a means of assessing the **accuracy** of information held in different databases, across time, space and theme, viz: scales, projections and transformations, spatial precision and density, feature definition, system of classification and so on. Sites may vary in their data quality requirements — utilities engineering versus strategic planning, for example — and this will be reflected in the data held at various sites (for example, locational definitions required for the linkage of data may be coordinates in one system, street address in another, phone number in yet another),
  - (iii) **completeness** of data may vary between sites and users. Some fields may not be mandatory, others may not be verified. Databases may have been established for a particular reason (for example, billing/accounts) which do not support wider functions (marketing, strategic planning),
  - (iv) **currency** of data; regularity of updating;
- **network support and location of expertise**. Expertise is normally not available in sufficient numbers in specialist areas to distribute key EDP, communications or spatial information systems staff across all sites. Head office hubs or key centres will normally provide network-wide services such as fault diagnosis, software maintenance and upgrading and remote user support, drawing upon experts located at a particular site — with telepresence capability (fax, videotelephony, etc.), see Newton *et al.* (1991).

The momentum towards distributed information systems, even in the face of the types of problem outlined above, is growing however, for the following types of reason:

- the advantages of data integration and data sharing already discussed;
- the positive (as well as negative) elements associated with local data ownership and control (Dale, 1989; Nicholson, 1989);
- with distributed systems, computing power can be incrementally added to a network as needs arise, in contrast to the high entry cost of centralised mainframe computing (Pretty);
- distributed systems are also more robust during emergencies where telecommunication links are prone to failure (local data can continue to be drawn upon; Webb);
- new technologies are emerging to assist with multi-media data in spatial

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