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Sandia's Network for Supercomputing '94: Linking the Los Alamos, Lawrence Livermore, and Sandia National Laboratories using Switched Multimegabit Data Service

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Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550
for the United States Department of Energy
under Contract DE-AC04-94AL85000

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Abstract

Supercomputing '94, a high-performance computing and communications conference, was held November 14th through 18th, 1994 in Washington D.C. For the past four years, Sandia National Laboratories has used this conference to showcase and focus its communications and networking endeavors. At the 1994 conference, Sandia built a Switched Multimegabit Data Service (SMDS) network running at 44.736 megabits per second linking its private SMDS network between its facilities in Albuquerque, New Mexico and Livermore, California to the convention center in Washington, D.C. For the show, the network was also extended from Sandia, New Mexico to Los Alamos National Laboratory and from Sandia, California to Lawrence Livermore National Laboratory. This paper documents and describes this network and how it was used at the conference.

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1 Introduction

During the week of November 14th through the 18th, the seventh annual Supercomputing Conference was held in Washington, D.C. This conference is organized by volunteers from academia, government, and industry with a vested interest in high-performance computing and communications. The purpose of the conference is to advance applications of computing technology [9]. In existence for seven years, the conference continues to bring together the leaders in high-performance computing and provides a showcase for new technology. The conference draws a spectrum of professionals from industry, government, and academia. The conference is sponsored by the Association of Computing Machines (ACM) Special Interest Group on Computer Architecture (SIGARCH) and the Institute for Electrical and Electronics Engineers (IEEE) Computer Society Technical Committee on Supercomputing Applications and Computer Architectures. Participants gather to share knowledge, arrange future partnerships, and discover the needs and requirements of potential customers. For the past four years, Sandia has extended its enterprise network to the show floor.

Each year, as part of the conference, a team of volunteers constructs a local area network, called *SCInet*, to interconnect the computing resources in the vendor and research exhibits on the showroom floor. Sandia always participates in this endeavor and expands the network to include wide area connections. Sandia's network extensions demonstrate the frontiers of what is currently possible in high-performance networking and communications for the wide area. Volunteers from Sandia have played major roles in designing and building *SCInet*¹ since its inception at the Albuquerque show in 1991 [1, 7].

This paper describes and documents Sandia's participation at this year's conference. The history of Sandia's participation along with goals and objectives for this year's participation are discussed in sections 2 & 3. The Switched Multimegabit Data Service (SMDS) and Synchronous Optical Network (SONET) extension of Sandia's private network are described in section 4 and the network performance is detailed in section 5. Finally, lessons learned are discussed in section 6 while other network demonstrations undertaken during the year are highlighted in section 7.

¹Tan Chang Hu and Patrick Torrez, Sandia National Laboratories, played instrumental roles in designing and building 1994's *SCInet*.

2 History of Sandia's Participation

Sandia's networking and communications departments have participated in the conference since 1991 when it was held in Albuquerque, New Mexico. Sandia's participation in that show included providing three DS3 (44.736 megabits per second) circuits over an Optical Carrier circuit running at 155.52 megabits per second (OC-3). Sandia also used a High Performance Parallel Interface (HIPPI) gigabit extension over U S WEST provided dark fiber² between Sandia's Massively Parallel Computing Research Laboratory (MPCRL) and its booth at the Albuquerque Convention Center [4]. At the following year's conference in Minneapolis, Sandia demonstrated the prototype technology it was planning to use in its Supercomputing consolidation that was planned for the following spring [8][6]. The network consisted of SMDS based on prototype AT&T BNS-2000 switches with DS3 (44.736 megabits per second) access [5]. This network provided the longest, fastest, private implementation of the technology at the time of the conference [1][2]. The following year at *Supercomputing '93* in Portland, Oregon, Sandia built three high-performance networks [7][3]. The networks encompassed an SMDS network running at DS3, an Asynchronous Transfer Mode (ATM) network running on a SONET circuit at the OC-3 rate, and a High Performance Parallel Interface (HIPPI) network running over a 622.08 megabits per second SONET circuit (OC-12). The SMDS and ATM networks extended from Albuquerque, New Mexico to the showroom floor in Portland, Oregon, while the HIPPI/SONET network extended from Beaverton, Oregon to the showroom floor.

3 Goals and Objectives For This Year's Conference

The conference draws a spectrum of professionals from industry, government, and academia. Participants experience a setting to share knowledge, arrange future partnerships, and to discover the needs and requirements of potential customers. Therefore, Sandia, and in particular the Networking Departments, participate in the conference for several reasons:

- to focus current networking activities and projects for a highly visible and noteworthy demonstration,

²Fiber without any transmission equipment attached so that no light is present and no service is being offered.

- to challenge the capacity and capability of emerging technologies to perform in the high-performance computing and communications environment,
- to encourage partnerships with a variety of vendors and to demonstrate the synergies that standards and partnerships enable,
- to provide a showcase where various other Sandia departments in California and New Mexico can demonstrate their capabilities and ongoing projects in an environment closely coupled to their computer resources at Sandia,
- to encourage interactions and sharing of knowledge between Sandia experts and their professional peers at other research facilities and in private industry,
- to clearly demonstrate Sandia's skills with networking and communications technologies.

This year in Washington, D.C. Sandia elected to:

- demonstrate the utility of SMDS by building a network linking Sandia, Los Alamos, and Lawrence Livermore National Laboratories to their respective booths at the trade show;
- demonstrate the power of DS3 and SONET communications for enterprise network extension;
- provide a network linking the three laboratories so that their collaborative efforts on a number of Department of Energy initiatives could be demonstrated in a real high-performance wide area network;
- demonstrate the application of advanced routing and local network switching technologies;
- and, provide a testbed for actual measurements of throughput for high volume data sets expected in real seismic applications.

4 The Network

Utilizing private SMDS network facilities at Sandia combined with an AT&T FTS2000 DS3 circuit terminated in an SMDS Cisco router in Washington, D.C., a transcontinental SMDS network was constructed (see Figure 1). This network

linked the advanced supercomputing environments of Sandia National Laboratories (SNL), Los Alamos National Laboratories (LANL), and Lawrence Livermore National Laboratories (LLNL) to the show floor at *Supercomputing '94*. A series of demonstrations allowed the Laboratories to showcase the capabilities being jointly developed to support a variety of Department of Energy initiatives.

SMDS is a technology which assigns one or more ten digit numbers (similar to a phone number) to each end point or Subscriber Network Interface (SNI). To transmit IP traffic, a router will map an IP address into an associated SMDS address, encapsulate the IP packet, and transmit it to a SMDS switch, in this case the AT&T BNS-2000. The SMDS switch then transmits the packet to the desired location or router. The receiving router then removes the SMDS encapsulation and forwards the IP packet.

One feature of SMDS is that it allows the sharing of expensive network resources such as DS3 lines by many customers without sacrificing bandwidth or security. Another feature is that SMDS addresses can be combined into groups. This facilitates the construction of the 'virtual LAN' enabling users to be grouped together without regard to their location.

The unique combination public and private network was fully connected at DS3 (44.736 Mbps) rates utilizing AT&T BNS-2000 switches located at Sandia's New Mexico and California sites and an AT&T³ extension to Washington, D.C. (see Figures 2, 3, and 4). The AT&T BNS-2000 switches provided connectionless SMDS functionality via ATM cell switching. Sandia's private SMDS network, extending between California and New Mexico over a private DS3 link, was extended temporarily to LANL (approximately 90 miles) over a DS3 circuit provided by U S WEST. Similarly, Sandia's California network was temporarily extended to LLNL via FDDI. AT&T provided the DS3 interexchange carrier (IEC) circuit to Washington, D.C. from Albuquerque, New Mexico allowing Sandia to place an SMDS router⁴ on the show floor in Washington, D.C. The DS3 link was extended to the *SCInet '94* booth by Metropolitan Fiber Service (MFS). An AT&T DDM2000 multiplexer was used to extend the DS3 circuit from the *SCInet '94* booth to Sandia's booth (see Figure 5). *SCInet '93* provided the dark fibers that allowed an FDDI ring to connect the research booths of LANL, LLNL and SNL. Conference attendees could use LAN-attached workstations at the individual booths to access the Massively Parallel Computing Laboratory (MPCRL) and other computing resources at the National Laboratories including Sandia's California Heterogeneous Environment and Testbed (HEAT).

³Via the FTS2000 public network.

⁴The router was provided by Cisco Systems Inc.

Figure 1: Sandia's *Supercomputing '94* Transcontinental SMDS Network

5 Network Performance

The SMDS network was capable of measured sustained throughputs of 12.5 megabits per second for a single TCP/IP session. Multiple simultaneous sessions are frequently supported up to the limits of the DS3 trunk. These throughputs are dominated by the effects of disk speeds and by the delays on TCP/IP based communications [11]. In the local environment SMDS network we have measured 29 megabits per second throughput (memory to memory) for a session [10]. The ease of construction and robustness over the duration of the conference highlighted the potential U.S. competitive advantage that the national telecommunications infrastructure brings to bear on today's problems. There were no failures or errors in the telecommunications circuits and switches during the network's operation.

Over the duration of the conference, the applications generated the traffic tabulated⁵ in Table 1. These numbers are significantly (approximately 4 times) larger than recorded at *Supercomputing '93* [7] due primarily to the size of seismic data sets being moved between the booth and Sandia, California as part of a Gas and Oil demonstration and the lack of an OC-3 circuit this year. Concurrently, video conferences were being conducted between the booth and California using an application called DAVE, while Los Alamos and Lawrence

⁵These statistics were gathered and compiled by J. P. Brenkosh, Sandia National Laboratories, Department 13216, using a Starkeeper network management system with Sandia developed enhancements located in Albuquerque, NM.

Figure 3: Sandia's *Supercomputing '94* SMDS Network in New Mexico

- a well developed plan should be presented at an early *SCInet* meeting to allow the committee time to react,
- the temptation to modify and expand the plan should be avoided as the conference draws near,
- applications should be planned that will utilize the network so that the effort and expense of building the network is justified for everyone concerned,
- SMDS is an excellent wide area technology,
- the existing Sandia SMDS networks can be extended to support demanding remote demonstrations without degrading production services.

Sandia National Laboratories Booth Network

Figure 4: Sandia's SMDS Network Extension for *Supercomputing '94*

7 Other Demonstrations This Year

The Sandia Enterprise Network is a heterogeneous collection of computers and networking components assembled and managed in order to enable customers to solve problems and develop applications in the national interest. As Sandia continues to focus outward, it becomes increasingly important to the mission of the Advanced Networking Integration Department to take special interest in demonstrating unique, Sandia capabilities and applications throughout the United States by partnering with the telecommunications industry local and interexchange carriers to extend our very capable local infrastructure to a variety of conference locations in order to support the Laboratories' ability to interest others in its capabilities.

Through Enterprise Network Extension, Sandia has been able to demonstrate its unique contributions to the fields of agile manufacturing, robotics, interactive concurrent manufacturing, and advanced networking technologies. The ability to extend, manage, and recreate the campus environment at remote locations is crucial to the successful demonstration of Sandia capabilities. In order to achieve these successes, Sandia has partnered with U S West and

Figure 5: Details of Sandia's *Supercomputing '94* Booth Network

AT&T for communications infrastructure and bandwidth and with Cisco Systems Inc., Digital Equipment Corporation, FORE, and SynOptics for local area and advanced ATM switching technologies. In Enterprise Network extension, Sandia leverages expertise in merging advanced networking technologies, local and wide area networking standards, and network management tools to create the customer network environment required to seamlessly demonstrate its unique capabilities remotely. Network management utilizing mapping, monitoring and alarms, and utilization statistics is an integral part of assuring successful applications demonstrations.

Key enabling technologies include the use of both ATM and SMDS platforms, the use of SONET physical layer transport as well as traditional shared media local area network technologies such as Ethernet and Fiber Distributed Data Interface (FDDI).

Besides *Supercomputing '94*, Sandia has extended its Enterprise Network to support the following demonstrations and applications in the past year:

Table 1: Sandia's ATM/SMDS Network Traffic in Megabytes at *SC '94*

Date	NM to D.C.	D.C. to NM
12 Nov. 93	8,602	13,432
13 Nov. 93	13,185	21,424
14 Nov. 93	8,740	12,684
15 Nov. 93	6,873	3,910
16 Nov. 93	27,225	8,595
17 Nov. 93	51,751	3,803
Trunk Totals	116,376	63,848
Grand Total	180,224	

- Supercomputing '93, Portland, OR.; state-of-the-art demonstrations of ATM over long haul 155 Mbps telecommunications circuits;
- FTS2000 Users Conference, Kansas City, MO.; Interactive Collaborative Environment (ICE);
- Advanced Manufacturing Engineering Technologies, Austin, TX.; Smart Weld, ICE, TIE-IN;
- Advanced Manufacturing Technology, Chicago, IL.; Advanced manufacturing applications;
- Advanced Manufacturing Engineering Forum, Washington, D.C.; Technology demonstrations;
- Ideas in Science and Industry, Albuquerque, NM.; Applications.

8 Conclusion

The network built for *Supercomputing '94* was a success. It met all of its objectives and was heavily utilized. The network was the culmination of work accomplished by many Sandia departments and their industrial partners. In order to meet the challenging goals presented by building a transcontinental network, many people, crossing several corporate and organizational boundaries, had to accomplish a lot in a short time. Once again the conference challenged its participants to take stock of their individual projects and to bring them to a point for the demonstration. By accomplishing all of this, Sandia benefited from its participation in *Supercomputing '94*.

9 Acknowledgements

The networks built for *Supercomputing '94* involved the work of many individuals working together as a team. The following individuals played major roles: Thomas Pratt (project leader and LANL extension), Joseph Maestas (SONET multiplexor support) and Steven Gossage (advisor); Joseph Brenkosh (SMDS network configuration and Starkeeper network management); Bruce Whittet, Richard Gay and Tom Archuleta (LAN and router configuration and network management); Roger Adams (single mode cable to support the DDM2000 extension from the *SCInet* booth to Sandia's research booth); Frank Castelluccio, and George Yonek (intersite circuits). Oscar Suarez⁶, Linda Thue⁷, David Boyer⁸, Mark Wilcop⁹, Kristi Wegman¹⁰, and Dennis MacDonald¹¹ were instrumental in mobilizing their individual corporations in supporting the construction of Sandia's networks. DDM2000 OC-3 multiplexers were provided by Arnold Neal¹². Cassandra Shaw organized and coordinated Sandia's booth for *Supercomputing '94*.

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⁶AT&T

⁷AT&T

⁸AT&T FTS2000

⁹U S WEST

¹⁰U S WEST

¹¹Cisco Systems Inc.

¹²AT&T

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