NETWORK DESIGN FOR A DISTRIBUTOR

JACK HYMER
NETWORK CONSULTANT
HEWLETT-PACKARD
15815 S.E. 37TH STREET
BELLEVUE, WA 98006
(206) 643-4000

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This paper describes the business needs analysis, traffic study, network design and alternative options analysis used at AMFAC Distribution to consolidate three separate operating divisions' data communications requirements in one network of approximately 120 machines.

Bisync autodial DS, X.25 private network and terminal/multiplexer solutions integration methods are presented. Network management and operation problems are discussed. Use of commercially available network design software in the design of this network is discussed. Analog and digital cost models are covered.

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Section I. The Opportunity

A. AMFAC Distribution Group

AMFAC, Incorporated is a New York stock exchange listed diversified service company with interests in wholesale distribution, food processing, retailing, hotels and resorts, sugar and land development and management.

AMFAC Distribution Group is the largest of the AMFAC, Incorporated core business, generating revenues of more than 1.3 billion dollars in 1985 from three specialized segments of the US wholesaling sector. AMFAC Distribution Group is located in Folsom California, 15 miles east of Sacramento.

AMFAC Electric Supply has 87 branches in 16 states marketing a full line of wire, cable, conduit lighting, switchgear and other electrical products to the residential and commercial construction industry, dealers, utilities and government customers. AMFAC Electric ranks fourth in sales within the US electric wholesaling industry.

The AMFAC Electric Supply business is organized as 7 regions located in California(2), Hawaii, Washington, Utah and Texas(2), serving branch locations in up to 5 states from each region office.

AMFAC Industrial and Plumbing Supply (I & P) serves 24 states through 156 branches distributing pipe, valves, fittings, plumbing supplies, building materials, fluid power and industrial supplies to construction, utility industrial and government customers. AMFAC I & P has the largest geographical coverage of any US mechanical supplies distributor.

The AMFAC I & P business is organized as 5 regions located in California(2), Colorado, Texas and Washington serving 18 geographical Market Areas composed of branches located in up to 4 states per Market Area.

AMFAC Health Care serves 47 states through 57 branches distributing ethical pharmaceuticals and selected over-the-counter items to independent drug stores, retail drug chains and hospital pharmacies.

The AMFAC Health Care business is organized as 4 regional accounting centers located in California, Indiana, Texas and Washington serving the individual branch offices and reporting to Folsom.

B. Application Support

Application software system selected by AMFAC for distribution control were Hewlett-Packard's Systems For Distributors (SFD) for the Mechanical division, Management Technology Incorporated (MTI) for the Electric Division and American Data Industries (ADI) for the Health Care division. These applications differ in their terminal handling characteristics in that character mode (Health Care's ADI software), V/Plus Block mode (Health Care's ADI software and Electric's MTI software) and Data Entry Library (DEL) Block mode (Mechanical's SFD and Electric's MTI software) are used.

The significant limitation in the terminal handling methods to be used is that DEL Block mode is not supported in an X.25/Packet Assembler/Disassembler (PAD) environment, eliminating X.25 as a consideration in terminal connection for the Mechanical and Electric divisions.

Analysis of the actual screens used by the three applications showed CPU character counts ranging from 4 to 7055 characters and CPU input character counts of 1 to 609 characters.

As CPU output character counts exceed about 400 characters, delays encountered in the communications link can cause perceptible screen-writing time degradation. Above about 2000 characters these delays may render screen-writing time unacceptable.

For example, a 2000 character screen requires 2000/80=25 ENQ/ACK handshakes. At 9600 BPS direct connect this screen would require:

$$\frac{\text{2000 data characters + 25 ENQs + 25 ACKs}}{\text{960 characters/second}} = \frac{2050}{960} = 2.14 \text{ seconds}$$

For a single user, a statistical time division multiplexer (STATMUX) with a terrestrial 9600 BPS composite link rate and no ENQ/ACK spoofing generates a maximum screen-writing time of approximately:

$$T(in) = \frac{2025}{960} = 2.11 \text{ sec}$$

Time to put characters into CPU side MUX at 9600 BPS.

$+$

$$T(xmit) = \frac{2300}{1200} = 1.92 \text{ sec}$$

Time to transmit characters to remote MUX with 10 overhead characters per MUX frame.

$+$

$$T(out) = \frac{2025}{960} = 2.11 \text{ sec}$$

Time to move characters from remote MUX to remote terminal at 9600 BPS.

$+$

$$T(acki) = \frac{25}{960} = 0.03 \text{ sec}$$

Time to move ACK from remote terminal to remote MUX

$+$

$$T(ackx) = \frac{275}{1200} = 0.23 \text{ sec}$$

Time to move ACKs from remote MUX to CPU MUX with 10 overhead characters per frame

$+$

$$T(acko) = \frac{25}{960} = 0.03 \text{ sec}$$

Time to move ACKs from CPU mux to CPU

$=6.41$ seconds

While use of a STATMUX with a terrestrial 9600 BPS composite link rate and ENQ/ACK spoofing might theoretically produce a screen-writing time close to that of the direct attached terminal with one user, measurements indicated a screen-writing time of 3.1 to 4.4 seconds could be expected with real multiplexers, modems and lines.

Due to the large screen requirements, a primary design goal was to implement terminal links with minimum delays.

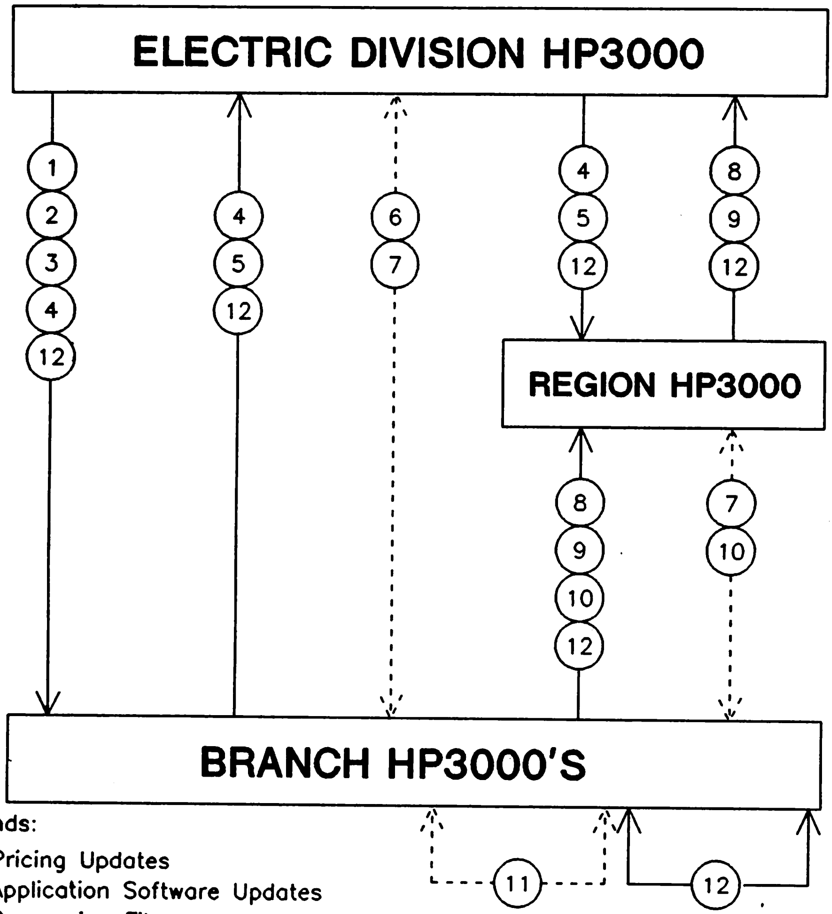
AMFAC expressed interest in using HPDESKMANAGER in the Distribution Group, creating an all-systems interconnection requirement to be considered during the network design process.

C. Information Flow and Traffic Volumes.

Figure 1 is a pictorial summary of the communications requirements for AMFAC Electric Supply division.

Figure 2 is a pictorial summary of the communications requirements for AMFAC I & P division.

Figure 3 is a pictorial summary of the communications requirements for AMFAC Health Care division.

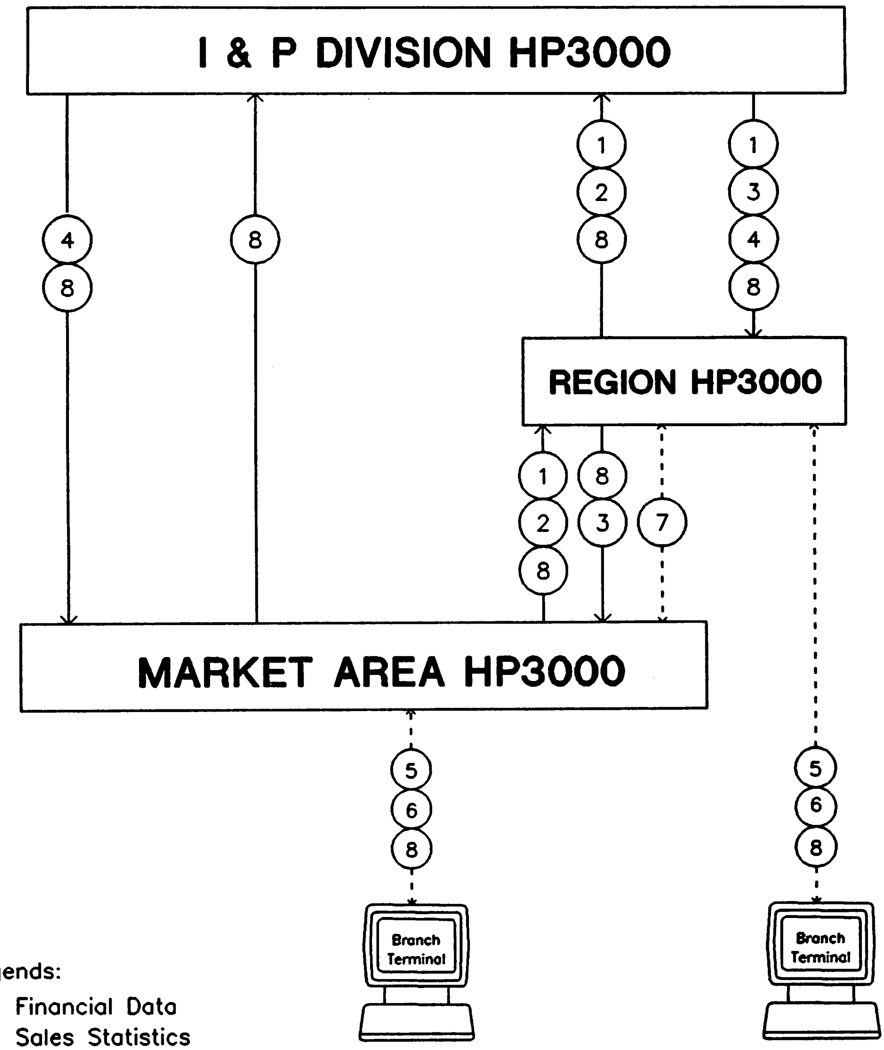


Legends:

1 Pricing Updates
2 Application Software Updates
3 Conversion Files
4 Consolidated Purchasing
5 EIC Summary
6 Central Item Number Assignment
7 Stock Status Inquiries
8 General Ledger Account Balance Summary
9 Summary Database
10 Regional Accounting
11 Inter-Branch Ordering
12 Electronic Mail

——— Batch File Transfer
- - - - - - Interactive

Figure 1

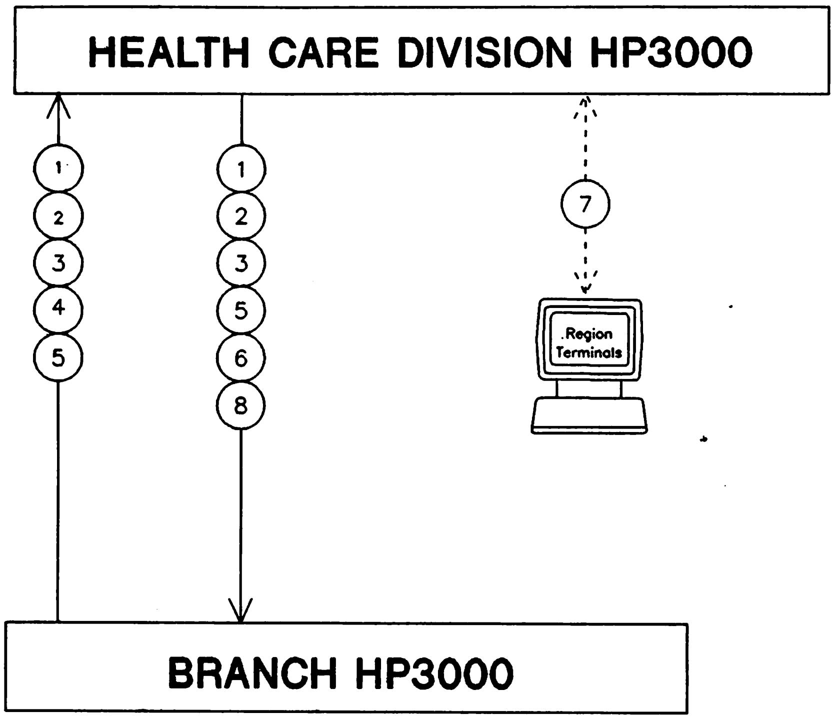


Legends:

1 Financial Data
2 Sales Statistics
3 Pricing Updates
4 Software Updates
5 SFD Application
6 Credit Manager Access
7 Regional Accounting
8 Electronic Mail

Figure 2

——— Batch File Transfer
- - - - - - Interactive



Legends:

1 Centralized Payables
2 Centralized Purchasing
3 Marketing Data
4 Journal Entries
5 Inventory Management
6 Software Updates
7 Regional Accounting
8 Electronic Mail

Figure 3

______ Batch File Transfer
\- - - - - - Interactive

Traffic volumes were collected for the information flow paths shown in the figures (where available) and were estimated where data was not available. collection techniques varied form obtaining AMFAC-prepared detailed information, to interview and data collection via prepared forms, to character counting with an HP4951A data analyzer on active applications terminals. Traffic volume information is quite extensive and will not be presented here unless pertinent to the network design activity being discussed.

D. Restraints and Requirements.

As in any real network, several restraints and requirements were imposed on the network design by the customer, AMFAC Distribution, Inc.
These restraints/requirements were:

1. Industrial and Plumbing
   Restraints:
   a. All CPU locations were pre-determined.
   b. Region, Market Area and Branch connectivity were predetermined.

   These restraints limited the application of network design algorithms which produce minimum cost networks.

   Requirements:
   a. Terminal response time less than 3 seconds average, less than 9 seconds 95th percentile.
   b. Batch communications complete overnight.

2. Electric
   Restraints:
   a. On topology - minimal within a region. Some small, terminal only branches were pre-determined.
   b. Region locations are pre-determined.

   Requirements:
   a. Terminal response time less than 3 seconds average, less than 9 seconds 95th percentile.
   b. Branches should have the capability to do inter-branch ordering
   c. Batch traffic completes overnight.

3. Health Care
   Restraints:
   a. CPU per branch.
   b. Region accounting locations pre-determined (no CPUs).

   Requirements:
   a. Batch traffic completes overnight.

Section II.

A. Topologies

Topology considerations were quite simple.

I & P:

I & P restraints and requirements dictated a terminal network with point-to-point lines and multiplexers for a supported configuration with minimal link delays and Region-to-Division batch links (dialup bisync DS).Many Region and Market Area HP3000's were co-located dictating a direct connection for DS between these machines. The only topology consideration, then, was the Region-to-Market Area cases where the Market Area HP3000 and the Region HP3000 were not co-located. The interactive regional accounting traffic dictated a leased line between these sites but the volume did not support 24 hour connectivitiy. A design goal of facility sharing between I & P and Electric networks was developed to permit I & P use of existing Electric leased facilities where possible to permit low volume interactive traffic for I & P regional accounting.

Health Care:

Health Care requirements and restraints dictated a dialup network using bisync autodial DS at all branch locations. The traffic analysis study indicated that communications for the largest branch would require 92 minutes per day and the smallest branch 21 minutes per day at 4800 BPS, half-duplex, 150 ms. turnaround delay or 143 and 33 minutes respectively at 2400 BPS, full-duplex, no turnaround delay on lines with an error rate of 1 in 10^5 bits. Daily and monthly data transfer costs were determined based on 11 PM to 8 AM AT&T direct dialing rates to do comparative costing of the two speed choices. Results were $7268 per month at 2400 BPS and $4699 at 4800 BPS, a difference of $2569 per month. For the 41 sites considered, a modem cost differential of $1500 per site could thus be accommodated for a 24 month purchase price payback from line cost savings. (24*$2569/41=$1503). A 4800 BPS Bell 208B compatible MODEM and Bell 801C compatible autodialer that met this cost criteria were selected and, to further increase savings, WATS lines were installed and 50 ms. turnaround was selected at central site MODEMS to be used with sites within 100 miles per the Bell PUB41211 paragraph 2.2 recommendation.

To verify the estimated transfer times for the largest branch, multiple tests at 2400 and 4800 BPS were performed with actual data. Results agreed to within 4 percent at 240 BPS and were exact at 4800 BPS.

Electric:

For the Electric division, 4 topologies were considered:

1. 1 or 2 Central CPUs within a region (large HP3000/Series 48 or small HP3000/Series 68) with point-to-point terminal multiplexer links to branch locations.

2. 1 or 2 Central CPUs within a region (large HP3000/Series 48 or small HP3000/Series 68) with multidrop links to terminal locations.

3. Distributed HP3000/Series 37s at branches, HP3000/Series 42 or 48 at Region locations. Non-cpu branches (twigs) connected via point-to-point multiplexer links. Fully interconnect CPUs within a region via private or public X.25 networks to limit INP requirements at each site.

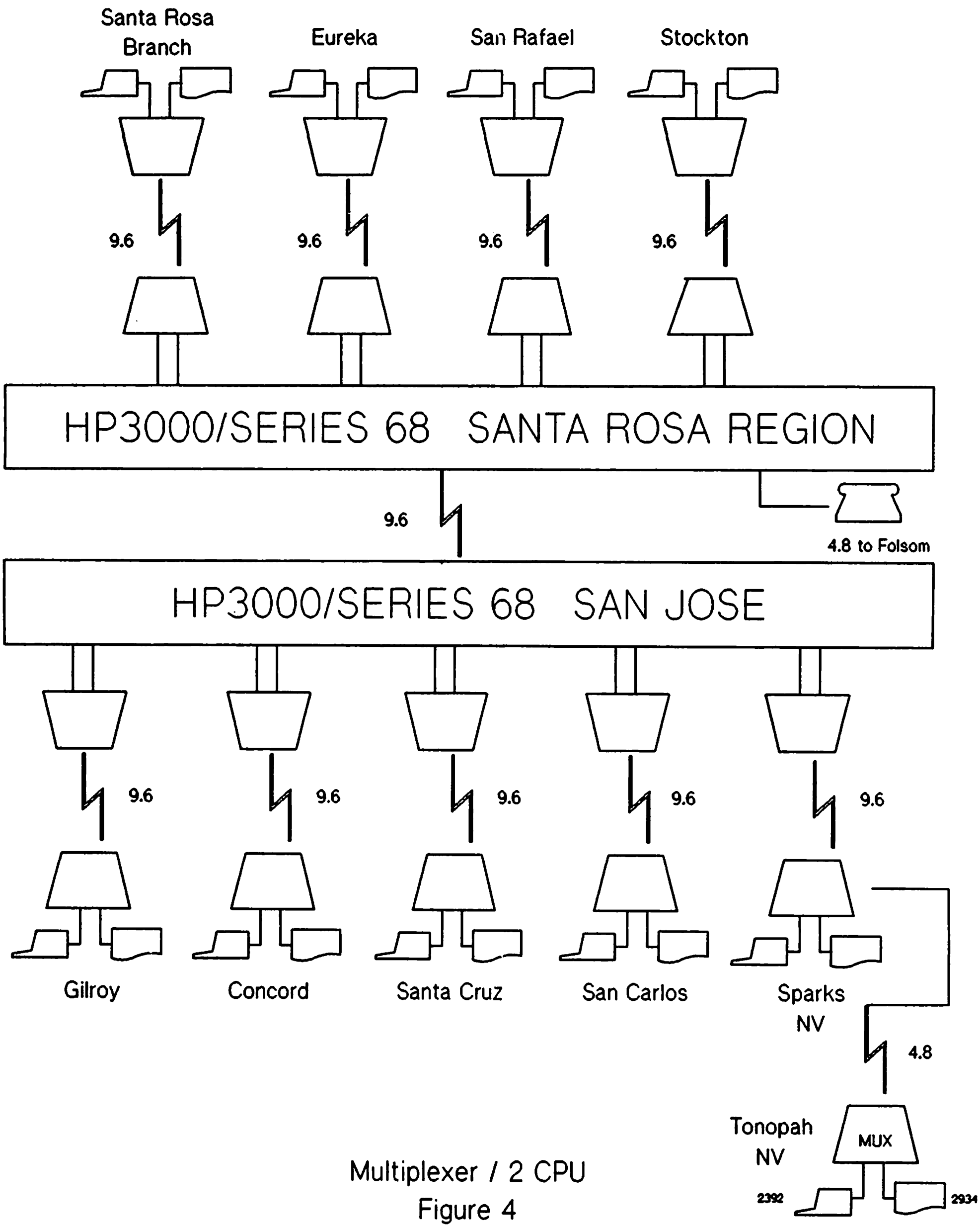
4. Autodial DS between systems.

Item 4 was discarded immediately due to the 1 to 2 minute delay in establishing connection with another branch plus the CPU overhead associated with session establishment and deletion.

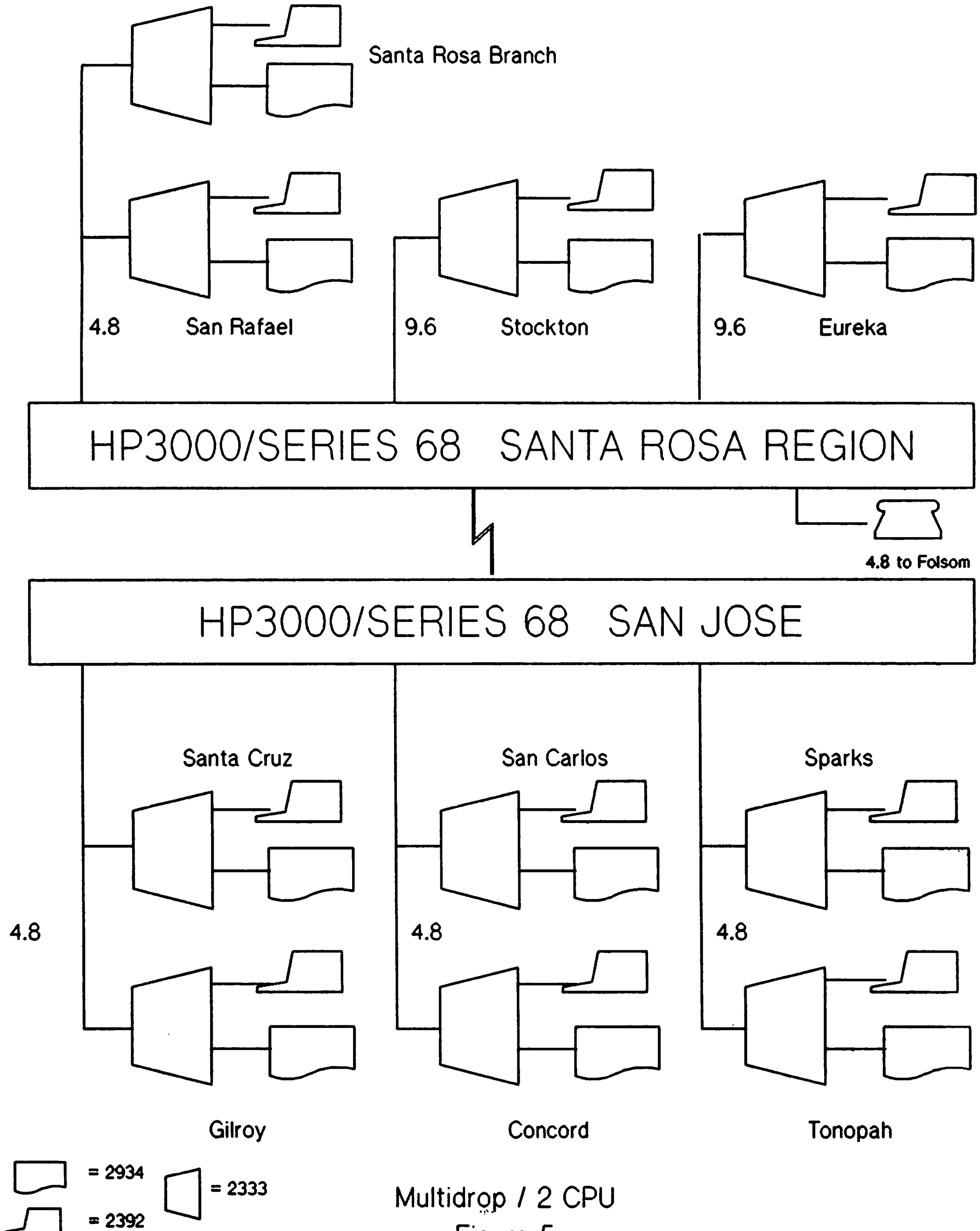
Topologies 1, 2 and 3 were then modeled for response time and cost using the techniques described in Section IIB. All three topologies met the 3 second average and 9 second 95th percentile response time requirements with an assumed host response time of 2 seconds with exponential variation. Topologies 1 and 2 failed to meet the response time objectives when remote site printing requirements were imposed on the links.

More importantly, and contrary to the modeler's intuition, the cost comparison of these 3 topologies revealed that a private X.25 network with analog links was 29.65% less expensive than a point-to-point terminal/multiplexer network with 2 central CPUs and 24.26% less expensive than a multidrop network with 2 central CPUs.

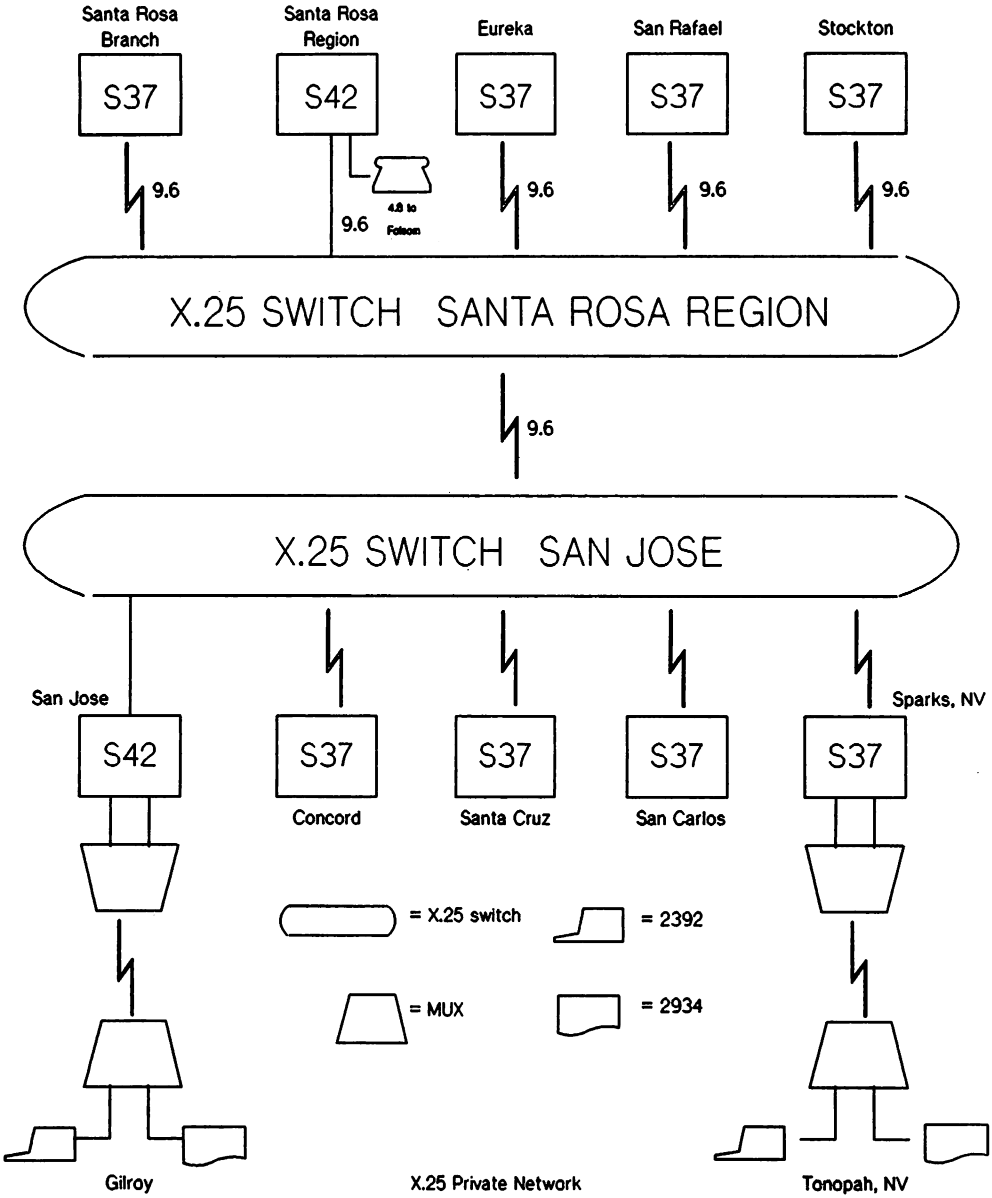
Diagrams of the actual topologies modeled are included as Figures 4, 5 and 6.



Multiplexer / 2 CPU
Figure 4



Multidrop / 2 CPU
Figure 5



X.25 Private Network
Figure 6

B. Response Time Modeling.

Of the tools available for network design and analysis, two were considered applicable at AMFAC: MNDS (Multipoint Network Design Software) from Connections, Inc. and MIND (Modular Interactive Network Designer) from CONTEL Information Systems. MNDS was selected on a cost, speed and ease of use basis. MNDS runs on an IBM PC/XT and was considered suitable for long-term use at AMFAC designing, pricing and verifying networks of the AMFAC region size.

1. CONNECTIONS Software.

MNDS provides the user with the capability of performing 2 primary functions:

1. Predictive performance analysis of multipoint networks. Point-to-point links are simply multipoint links with only 2 points.

2. Topological optimization and alternative price comparison for data communications.

MNDS uses the Esau-Williams algorithm for network optimization which produces a minimum cost conectivity but is not exact (i.e. link drops/adds may produce a lower cost solution).

A. Input Data.

Data required to model a network is provided to MNDS in the following categories:

1. The message file (MF) contains the details of each of the applications which operate in the network. MNDS can consider up to 50 separate application types.

2. The protocol file (PF) is already prepared with 4 default protocols. If these are acceptable, the designer only has to review them and save them in the network database. If the designer is using non-default or customized protocols to do performance analysis (such as when DS or MTS are considered), then the PF must be completed for each of them.

3. The network file (NF) is used to enter the design default values. These are not necessary if the designer is only doing optimum routing and pricing. The NF is also not needed if the designer chooses to enter all of the performance criteria directly into the response model (RM).

4. The site file (SF) contains the specifics of each physical location in the network. MNDS can accommodate up to 200 locations, 10 host computer sites and 20 concentrator/multiplexer sites. A total of 230 sites in each unique network can be handled.

5. The traffic file (TF) contains the number of times each application occurs at each sit in the site file (SF) during the period specified by the designer.

B. Tariffs.

MNDS uses FCC tariffs 9,10 and 11 for pricing. FCC tariff 9 covers Interoffice channels, tariff 10 covers the location of offices and services for serving central offices and tariff 11 covers access rates on a state average basis. Since a large portion of AMFAC's network is located in California, a California specific pricing diskette was obtained for intra-LATA and inter-rate-center channel pricing.

C. Output.

MNDS has 4 modeling programs:

1. Response Model (RM) allows calculation of response time and line utilization for a selected set of network characteristics.

2. Distribution Model (DM) graphically depicts the RM results.

3. Link Model (LM) provides the least cost network layouts and pricing.

4. Operator model (OM) approximates the number of terminals, operators and telephone trunks required at a site.

2. Results.

Modeling was performed on 4 branch sizes in the Electric Supply division's Northern California Region for multipoint and point-to-point multiplexer lines considering each MTI application without screen changes (i.e. data and separator characters only). The results were used to determine a network topology for the Electric supply division. These results showed that neither multipoint (of even 1 drop) or point-to-point multiplexer links could meet the stated goal of 3 seconds average response time when printing was taking place.

C. Considerations.

Of the many items considered during the network design, probably the most taxing areas centered around using digital or analog communications links for leased lines and whether to use public or private x.25 networks for CPU interconnection.

1. Analog vs Digital lines.

Analog lines have the following benefits:

a. Widespread availability
b. Modem availability from 1200 to 19200 BPS
c. Well developed testing methods
d. Moderate costs
e. MODEM based network management systems are available.

Analog lines have the following disadvantages:

a. Comparatively high error rates (1 in 10^5 bits worst case, 1 in 10^6 bits expected with some currently available MODEMS)
b. High speed MODEMS have relatively high cost
c. Timing considerations in large networks may be difficult.

Digital lines have the following benefits:

a. Low error rates. Do not confuse the expected error rate of 1 in 10^7 bits with the expected 99.5% error-free seconds which can be translated into a bit error rate of .5 in 10^2 or 5 in 10^3 which is not very good.
b. Low DCE (Data Communications Equipment) cost.
c. Automatic circuit rerouting to alternate path.

Digital lines have the following disadvantages:

a. Higher cost than analog lines. Cost analysis of the model region and of the entire network revealed that on the average a digital line costs 1.92 times as much as an analog line. Comparisons were also done in California alone using both the AT&T and CPUC pricing which showed that digital cost 1.85 times as much as analog.
b. Limited availability.
c. Limited variety of DCE speed. Present offerings are 2.4, 4.8 9.6 and 56000 BPS.
d. Limited customer testing options.
e. Limited network management options.

For cost comparison a 9600 BPS circuit was chosen. Costs were:

DIGITAL	ANALOG
2ea CSU/DSU @ $800 = $1,600	2ea MODEM @ $5,900 = $11,800
line at $960 / month	line at $500 / month

Neglecting the error rate differences, it can be seen that the analog investment can be paid off in ($11,800-$1600) / ($960-$500) = 23 months. On a 5-year cost of ownership basis the difference is:

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 Digital=$1,600 + (60*$960) = $59,200
-Analog=$11,800 + (60*$500) = $41,800
                              -------
                              $17,400
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Amplifying factors such as the non-availability of digital service at many of the sites in the network and the long digital installation lead times plus the lack of network management options for digital solidified the choice of analog circuits for AMFAC's network.

2. Private vs X.25 networks.

Comparison of the cost of public vs private X.25 networks was relatively straightforward. Using public data networks (GTE TELENET chosen for comparison) the cost of CPU interconnect for Electric and I & P was $154,209 per month. Acquisition cost of the private X.25 network was computed at $261,000 for switches plus monthly MODEM and line lease costs of $81,877 (AT&T Total Service Offering). Comparison shows a payback of:

$261,000/ ($154,209-$81,877) = 4 months!!

III. Recommendations.

Recommendations to Amfac took the following forms:

A. General:

1. Use analog lease lines.
2. Use analog MODEMS with network management capability (Codex 2600 series)
3. Use multiplexers with ENQ/ACK spoofing, with a buffering scheme which will allow termtype 19 remote spooled printers to be used and with HP line, page and user-controlled block mode support (Codex 6002 series)

B. Electric Supply Division:

1. Use an X.25 Private network for CPU interconnect.

C. I & P:

1. Use a Point-to-point multiplexer terminal network.
2. Connect CPU's via leased facilities using x.25 DS and share facilities with Electric when possible.
3. Use time division multiplexing (TDM) for minimum delay times to build multidrop-like lines to minimize mileage costs. (4 and 6 channel TDMs are available as a low cost option to the Codex 2600 series MODEMS)

D. Health Care:

1. Use dialup bisync DS at 4800 BPS.
2. Use OUTWATS lines
3. Use Codex 5208R MODEMS and 2207 autocall units

E. Independent Verification

Toward the end of the network design process AMFAC Distribution group secured the services of Network Strategies Inc. (NSI) to perform 6 tasks:

1. Review all documentation relative to the network design
2. Resolve open issues and interview AMFAC staff
3. Develop network requirements
4. Develop Major network architecture components
5. Develop detailed architecture report
6. Develop a 2-year phased implementation plan

The results of NSI's first 5 tasks is presented in Figure 7. Examination of the the least cost solution column shows agreement with the HP designed solution.

Architecture Cost Comparison

		Dial	Leased Line	Public X.25	Private X.25	StatMux (Leased Line)	Least Cost
Electric	Host-Host	2	Too Few INP Slots	3	1	Too Few INP Slots	Private X.25
	Host-Terminal (Twig)	3	2	No PAD Support	No PAD Support	1	StatMux
I&P	Host-Host	4	2	3	1	No Collocation of Hosts	Private X.25
	Host-Terminal	3	2	No PAD Support	No PAD Support	1 (6002)	StatMux
Health Care	Host-Host	1	(High)	(High)	(High)	(High)	Dial ex. where collocated w/ other sol'ns
	Host-Terminal (Regions)	4	3	5	1 (PAD)	2	PAD to X.25 Switch
Consolidation Problems		None	Can't Handle Electric	Can't Handle I&P Terminals	Can't Handle I&P Terminals	Can't Handle Electric	
Consolidation Configuration		All Dial	Need X.25 For Electric	Need StatMux For I&P Terminals	Need StatMux For I&P Terminals	Need X.25 For Electric	

Figure 7

Section IV Network Management

A. Available types

1. Analog lines

Analog MODEMS are available which provide network management by using part of the available channel bandwidth for an independent communications path (side channel). These systems provide error statistics, modem configuration control, individual modem identification, set-point alarming, management reporting, etc. Features vary from front panel access to multiple node, multiple operator control and costs range from a few hundred dollars per MODEM to over $100,000 per system. The Codex 2600 Series MODEMS support Codex Distributed Network Control System (DNCS).

2. Digital lines.

Only two systems were evaluated for digital link network management systems. One system, AT&T's DATAPHONE II LEVEL 4 provided most of the features noted above but was limited to a non-distributed controlling environment. An alternative offering, Customer Test Service, available from AT&T on a line-by-line basis and requiring only a terminal and 1200 BPS MODEM for access was evaluated but proved to be extremely limited in its testing and problem resolution capacity. Since the anticipated direction was to have an all analog network, these two solutions were not exhaustively evaluated.

3. Multiplexers.

The multiplexers chosen for the AMFAC network have a control port from which the multiplexer may be configured and statistics obtained. The minimum requirement is to set the control port baud rate via front panel switches. Remote access to multiple units is accomplished via a Telematics programmable selector switch and a 1200BPS dialup modem.

4. X.25 Switches

Dynapac Model 8 and 12 X.25 switches chosen for this network based on HP hardware and software support availability for the Model 8 and the connectivity and throughput of the Model 12. Access to these devices for configuration and statistics will be vial a PAD at Folsom.

Section V Summary

During 1985 86 CPU and 56 terminal/multiplexer sites were installed. Current HP activities include the completion of the design of the network management. AMFAC activities include continued installation of sites and implementation of an X.25 pilot region.

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Jack Hymer has been with Hewlett-Packard for 10 years and is currently engaged in network design activities for HP customers as a Network Consultant. Mr.Hymer obtained a BSEE degree from the University of Washington in 1973 after working as a communications technician for 6 years.