

Carnegie Mellon University Computing Services

Voice over Internet Protocol (VoIP) Project

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Executive Summary

The first phase of Carnegie Mellon's Voice over IP (VoIP) project in 2001 was an investigation of the state of IP telephony technologies and a lab test using Cisco's AVVID system. In 2002 a Phase II production trial was implemented in the Computing Services division. Ninety telephone users were converted from Centrex to the Cisco AVVID using an IP phone or their existing analog phone through an analog gateway. During the trial various measurements were taken on call quality, staff effort expended, trouble calls reported, and overall satisfaction with the new system.

User documentation, conversion procedures, and a system administration FAQ were written. An evaluation was performed comparing the VoIP features against the existing Centrex features. A financial and organizational model was developed.

The VoIP system was successful at meeting users' basic telephone needs. The organizational convergence was exciting as different parts of the division worked together. VoIP focused the division efforts to eliminate the remaining shared hubs and to complete the cable plant conversion to Category 5e. A lot of data including cost information was captured during the trial experience. Lastly, we did not return any user's telephone line back to the Centrex.

Other parts of Phase II were less successful. The simple telephone configurations in the division did not test the more complex arrangements needed across campus. Several of the network issues were not addressed such as security, directories, authentication, and new service development. While power backup was deliberately omitted from the trial, two power outages highlighted the importance of power reliability. A few network outages identified gaps in the network architecture that did not affect data but interrupted voice communications. Significant strides were made in staff training and documentation during the trial, but they were not enough to support a sufficiently reliable telephone service.

Computing Services chose to not deploy the Cisco AVVID system campus wide at this time. The priority was to finish converting the remainder (40%) of the cable plant to Category 5e and the remainder (50%) of the edge network to switched connections before VoIP was viable. While we believe that the Cisco VoIP technology is very good, we do not think it is mature enough to deploy enterprise-wide at this time. Lastly, we could not identify a compelling "win" that justified the VoIP solution. Please visit the VoIP project web pages at <http://www.cmu.edu/computing/project/voip>

Project Team and Configuration

The VoIP core team gave overall project direction and consisted of the following team members:

- **Chuck Bartel, Director of Operations**
- **Mark Poepping, Technical Director**
- **Russell Yount, Manager of Network Development**
- **Mary L. Pretz-Lawson, VoIP Project Manager**

The VoIP working group included representatives from all parts of the division and worked through specific issues like power, security, support, and feature functionality. The existing operational groups provided resources to port the 90 telephone lines and sets from Centrex to VoIP. Dan McCarriar provided overall project management from Phase I through the conversion process in Phase II.

The VoIP production system used in Phase II consisted of the following equipment.

- **Two Cisco CallManager servers (version 3.2) operating in a cluster configuration, one primary server running all services and one backup.**
- **Cisco WS-X6608-T1 Gateway for PSTN connectivity, with 2 Verizon Primary Rates Interface trunks (PRIs) (one DID/DOD, one Centrex intercom).**
- **Cisco VG248 analog gateway for connecting analog telephone users and other analog devices (fax machines, modems, voicemail, etc.)**
- **Cisco 7960 IP telephone sets. This is Cisco's high-end telephone set and was deployed to division members that previously used Meridian digital business sets and had a need for multiple line appearances. (approx. 20 users)**
- **Cisco 7940 IP telephone sets. The 7940 is Cisco's mid-range IP telephone set and was deployed to some trial users as a potential replacement for the analog set that Telecom currently offers. (approx. 30 users)**
- **"Existing analog telephone sets (mostly Nortel 9316 enhanced single line set) over the VoIP network via the Cisco VG248 analog gateway. (approx. 40 users)**
- **In addition to the equipment listed above, the IP telephony system relied on certain pieces of the current data and telecommunications network, including the Cisco 3524-PWR closet switches, Cisco 6509 building routers, and the Octel 250 voicemail system.**

Trial Results

The project team wanted to answer six questions by the end of the trial.

1. Can we provide an IP telephony service, as an alternative to our current Centrex service, that is as feature-rich and reliable as our customers demand?

We learned that voice traffic can be carried on the network with decent quality as long as the network is healthy. Users rated call quality midway between Excellent to Good in six sets of surveys. The primary complaints were about accessing the user web pages for the IP phone features, losing the Centrex distinctive ring for internal/external calls, the awkwardness of the IP phones, and quality problems on the analog phones. Several users only recommended VoIP if there was a clear advantage, it was easier to use, or provided some new feature that was lacking in the Centrex system.

The division has basic, single-user telephone configurations except for the front desk and directors arrangement. The feature testing showed that common features such as call coverage, advanced call forwarding, hunt groups, multiple call arrangements, and intercoms were not available. The dial plan in the Phase II Cisco VoIP system was simplistic. We did not test the more complex network classes of service for authorization codes, time of day routing, restrictions to local or campus calling only.

However, more complex telephone configurations that are widespread across campus could not be provided with the Cisco VoIP system. The division trial was fairly reliable but clearly dependent upon the health of the network and power feed. The surveys showed that users often found no difference between the Centrex and VoIP systems. A network outage in August 2002 and the CallManager upgrade in September 2002 highlighted the reliability problems to the project team and users. To meet user's expectations with telephony, a significant increase in redundancy and reliability would need to be deployed throughout our campus network.

2. What types of new products and services will the deployment of IP telephony enable us to offer to the campus?

Carnegie Mellon already had an extensive 802.11b wireless network. During the trial, we evaluated wireless phones from Symbol and SpectraLink. We were unable to get the Symbol phones to work but were more successful with the SpectraLink sets. Field technicians found the SpectraLink phones reached areas previously unavailable via cell phones and pagers. However, cell phones and pagers were more reliable than the wireless phones.

We did not deploy any other new services during Phase II. The quality survey only identified the IP phone ringer options and large screen as "new services." The exit survey reported that the IP phone soft keys and information keys were most frequently used. Users had the most problem with speed dial, call forwarding, and other features accessed via the user web pages. More user documentation on using the web page was needed.

No additional resources were put towards Carnegie Mellon XML services for the trial. The directory services on the IP phones were provided from the CallManager rather than through the campus LDAP service. VoIP niche applications like unified messaging, call centers, user mobility and personal assistants were not tested during the trial.

3. What are the cost/benefit projections for a campus-wide deployment of IP telephony?

We developed a financial model that mirrors the way Telecom tracked its current costs. The financial model assumed a base case of Centrex retention compared to a VoIP case with a three-year conversion period. The model showed between a four to six year breakeven and an annual savings on VoIP over

Centrex of \$.5M annually. It should be noted that the model did not include costs to upgrade the cabling system or to harden the data network for VoIP.

The model proved to be a dynamic, evolving tool both in exploring a campus wide deployment as well as targeted opportunities like the new dormitory under construction. We believe that successive iterations of the model could capture the true costs of a VoIP system against Centrex costs.

4. What are the security issues involved in an IP telephony environment?

Security issues were not sufficiently addressed during the division trial due to limited resources. Items identified for further study include implementing filters in the CallManager and/or the Catalyst 6509s, moving the IP devices to nonroutable addresses, and improving security and authentication on the user and administrative web pages.

5. To what extent can the CiscoCallManager product be integrated with our existing enterprise systems?

Integration with our existing enterprise systems such as email and calendar was not sufficiently explored during Phase II. Initial discussions were held on integration with LDAP for authentication and directory but resources were not available to pursue this during the trial.

Cable plant and network infrastructure - Half of the desktop connections on campus are still served by IBM Category 3 cabling and/or 10 Mbit shared bandwidth served by hubs. Due to the shortcomings of the IBM cabling (baluns, power injectors, etc.), it was impractical to put VoIP on IBM outlets. Given the latency and jitter problems of voice over the network, 10 Mbit shared connections could not support VoIP. A tentative three-year schedule was outlined for Cat 5e cabling installation followed by hub replacement followed by VoIP implementation.

Power infrastructure - Power backup was expressly omitted from the trial. We experienced power failures in May (planned) and July 2002 (unplanned). Land-line phones as backup phones in an emergency were designated on each floor. We did financial power estimates but did not understand the full costs of power backup and maintenance in closets for IP phones and in telecom aggregation points for VG248s. It should be noted that at the time Cisco used a proprietary scheme for sending power over Ethernet that limited the selection of IP phones.

Telemangement database - While the VoIP lines and sets were reflected in the telemangement database, no billing for VoIP was established.

6. What are the transition issues related to an IP telephony deployment?

Official trouble calls -Thirty percent of the trouble calls were No Trouble Found, or no cause determined and the problem fixed itself. Twenty percent of the troubles were fixed in the Call-Manager. Most of the other troubles involved voicemail or network/Network Registration issues.

Analog gateway - the VG248 analog gateway worked amazingly well. Seventy-five percent of Carnegie Mellon's 9000 telephone lines are analog. Given the high price of IP telephones, we wanted to retain the analog base in our assumptions for VoIP conversion. Survey responses showed that many users could not tell the difference between VoIP over the Centrex on their analog phones. However, several users complained of poor call quality. We did not systematically test other analog devices like FAXs, modems, or pagers. We did not consider ring equivalency numbers (REN) to verify that multiple analog extensions would work through the VG248. Feature complaints with analog sets included Caller ID, speed lists, and automatic redial.

Telephone number retention - the trial proved that retaining old telephone numbers was possible. Reusing existing telephone numbers made the change more transparent to the end users but required

some downtime in the Centrex to VoIP conversion process with Verizon.

Feature transparency - the feature comparison between the Centrex and VoIP showed that the basic features between the two systems work satisfactorily. The primary transparency problem was in successfully transferring calls from the Centrex to the VoIP system. We did not address E911 issues in the trial. It should be noted that E911 on the Centrex today does not comply with new FCC guidelines.

Post-Trial Phase III Operational and Tactical Initiatives

Phase III of the VoIP project focused on remedies to the Phase II operational problems and identification of future tactical plans. Due to lack of resources, minimal new work was initiated in 2003. An operational vulnerability for the trial occurred during the Call Manager upgrade in September 2002. Despite assistance from Cisco, the upgrade resulted in a loss of redundancy between the subscriber and publisher Call Managers. In the event of a failure in the subscriber, the publisher could not seamlessly take over. This problem was fixed in March 2003 by rebuilding the Call Manager with Cisco's assistance. Additional reliability was provided by adding AVVID device monitoring to the division's automated monitoring system.

Feature functionality was enhanced for Caller ID on the analog phones by an upgrade to the VG248 analog gateway in February 2003. The feature transfer problem for calls from the Centrex to the VoIP system was fixed by a Verizon central office upgrade and Nortel patch to the DMS100 switch in May 2003. The difficulty in using advanced call forwarding features at the division central answering point was not resolved. The administrative personnel requested conversion back to their Centrex phones that better met their call answering needs.

The last operational work was done on call usage billing from the Call Manager. The intent was to poll calls from the Call Manager and bill them through Telecom's billing database. We were unable after ten person-days to obtain billable call records from the Call Manager. While we stopped our own efforts, we verified with peer universities that they had successfully pulled billing data from their Call Managers.

Several tactical initiatives were pursued in Phase III. The financial model was used to determine the voice solution for a new 250-bed residential hall that opened in May 2003. A VoIP solution was not chosen because the analysis did not show a cost savings and the VoIP system was not reliable enough for a residential facility. For the same reliability reasons, we did not pursue replacement of expensive OPX lines with a VoIP solution for an off campus business unit.

VoIP trials often expose network vulnerabilities. Network hardening alternatives were explored in Computing Services to enhance the reliability of a potential campus-wide VoIP system. The primary recommendation for better reliability was power back-up in the wiring closets feeding the edge switches to which the IP phones were connected. Based on the experience from the VoIP trial, voice requirements were incorporated into the network architecture three year upgrade plan.

While the network architecture plan had a hefty price tag at \$3M, the conversion of the cable plant infrastructure from the remaining Category 3 IBM Cabling System to Category 5e was estimated at \$13M. Neither cost was factored into the VoIP financial model. Both initiatives were presented to the university capital funding body as priorities for network upgrades.

Lastly, we elected to extend the contract for Centrex services from Verizon through 2006. While we built flexibility into the contract terms for VoIP migration, we do not believe that a VoIP solution campus-wide will be feasible for several more years.

Conclusions

Computing Service chose to not deploy the Cisco AVVID system campus-wide at this time. We removed the VoIP system and returned the 90-lines back to the Centrex in summer 2003. We expect to revisit the VoIP solutions in late 2004.

The priority was to finish converting the remaining 40% of the cable plant to Category 5e and the remaining 50% of the edge network to switched connections before VoIP was viable. We must harden the network to assure reliability in a VoIP solution. The reliability requirements of the phone system for a residential campus differ from a more typical corporate business campus.

Costs for a reliable power backup to the VoIP system must be better understood. We believe that the Cisco VoIP technology is very good but not mature enough to deploy enterprise-wide. We experienced difficulties with the Call Manager upgrade and the call billing records even with Cisco assistance. The features on the Call Manager version 3.2 were not sufficient to support complex calling configurations. These conclusions may not be valid for other VoIP products but we did not explore other vendors.

The financial analysis did not show sufficient savings of the VoIP system over the Centrex. We could not identify a compelling "win" that justified the VoIP solution. While we believe that converged communications networks are promising technology that are inevitable, we do not think the time is right to deploy this technology today at Carnegie Mellon.