Integrating Industry with Senior Project Research: Open-Source VoIP Design Project for Medical Sector

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Abstract: Voice over IP (VoIP) has been widely implemented by many organizations within industry over recent years. This technology has revolutionized the voice telephony field and significant research has been conducted in this area. Therefore, it becomes critical to implement the latest developments of this technology into academic programs associated with technology, in order to provide adequate training and education to students and professionals.

In this paper, we present the drawing and implementation of a senior design project, Asterisk VoIP in a Commercial Environment, which is associated with developing and testing an open-source VoIP solution for a small medical institution. This project consists of building a test environment that emulates the participating institution's network and designing an open-source VoIP system, where its end result will be compared against the institution's current commercial VoIP solution. This design will incur both technical and economical analysis

This project's purpose is to provide students an opportunity to apply their technical knowledge and skill on a project that is associated with a VoIP design and analysis within industry. Student's who participated in this project received a comprehensive understanding for VoIP, while gaining confidence that their knowledge can be successfully transformed into industry.

I. Introduction

The growth of the Internet, and related computer networks, has inspired many changes in consumer and business operations. More and more people are turning to computer networks to handle their news, entertainment, education and communications. One technology that has seen its acceptance grow significantly in recent years from industry is VoIP. As a result, considerable developments have been made to improve this technology. Therefore, training students and professionals with the latest developments of VoIP becomes critical in academic programs associated with this technology.

Michigan Technological University's Computer Network & System Administration (CNSA) program [1] is designed to offer students an innovative combination of core courses that are each associated with an intensive lab component that prepares students for positions in network engineering, optical engineering, e-commerce development, security analysis, and systems engineering. One course offered at the senior level requires students to complete a capstone senior design project. This permits students an opportunity to apply their knowledge and skills to industry-related projects, where they can further develop communication, teamwork and problem-solving skills.

In this paper, we present the design and implementation of a senior design project, *Asterisk VoIP in a Commercial Environment*, which is associated with developing and testing an open-source VoIP solution for a small medical institution. This project consists of building a test environment that emulates the participating institution's network and designing an open-source VoIP system, where its end result will be compared against the institution's current commercial VoIP solution. This design incurs both technical and economical analysis.

The project's purpose is to provide students an opportunity to apply their technical knowledge and skill on a project that is associated with a VoIP design and analysis within industry. Students who participated in this project received a comprehensive understanding for VoIP, while gaining confidence that their knowledge can be successfully applied to an industry environment.

II. Background

VoIP has become an effective technology in transferring voice traffic over the Internet. However, this technology is subject to various types of delay, jitter, and packet loss, which can translate to a degradation of sound quality or even dropped calls [2]. As a result, it is imperative that those associated with the design and maintenance of a network that incorporates VoIP, fully understand this technology, along with its current solutions and limitations. In addition, it is also critical to accurately assess the economics of integrating this technology within the network.

This project involves designing and assessing the reliability and cost effectiveness of an open-source VoIP solution, Asterisk [3], as a possible viable alternative to the medical institution's current commercial VoIP solution.

III. Project Design and Implementation

This project was categorized into five phases.

The first phase consisted of emulating the medical institution's network to permit a legitimate analysis when comparing an open-source VoIP solution to the organization's current commercial infrastructure. To accomplish this, similar layer two, layer three, and

wireless access point (AP) devices were used to further extend the validity of the analysis. Figure 1 illustrates the network architecture that was used for this project.

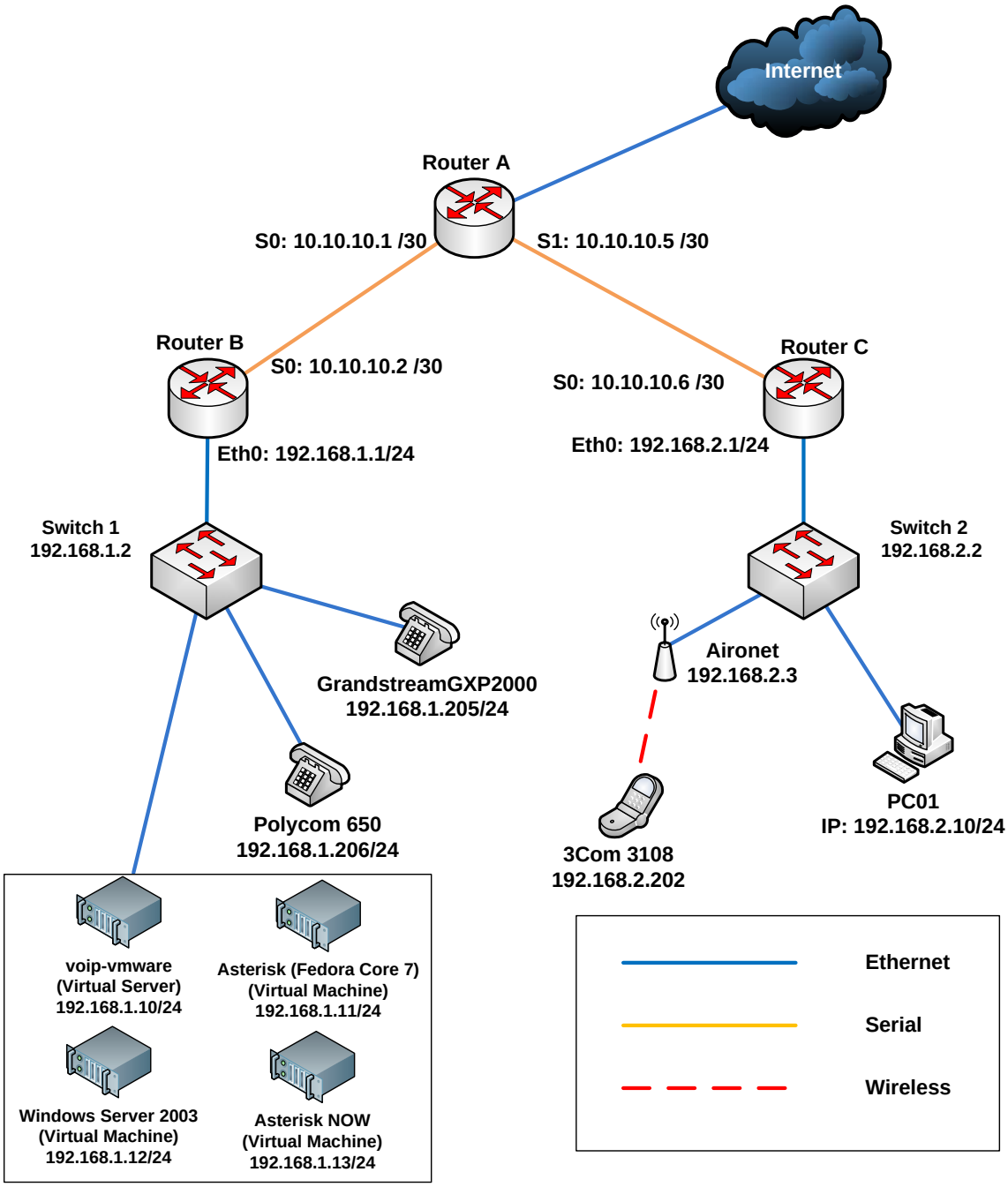

Figure 1

The second phase consisted of the design and development of the open-source Asterisk servers, which is a PC-based VoIP private branch exchange (PBX) that is use to administer and receive voice traffic. The Asterisk platform was placed on two servers to

demonstrate possible hardware limitations associated with flooded traffic. The first server used an AMD XP 2600+ processor (1.83GHz) with 512MB of RAM, and two 40GB ATA 100 hard drives. While the second server was a Power Edge from Dell, equipped with an Intel Pentium 4 2.26GHz processor, 512BM of dual channel RAM, and two 40GB SCSI hard drives. One server was designed with the Asterisk platform's traditional command line interface (CLI), while the other was configured with AsteriskNOW, a GUI format of the Asterisk platform to allow for simpler management.

Both Asterisk PBX systems were configured to include all of the regular features of a commercial PBX, along with added features that were not placed into the organization's current commercial solution due to incurred expense or lack of functionality. The Asterisk platform used within this project included features such as voicemail, call waiting, call-parking, music on hold, text-to-speech, and conference calls.

With the network architecture created to emulate the organization's current design and the implementation of the Asterisk platform solidified, the third phase entailed configuring VoIP-based telephones to function with the Asterisk PBX. To complete this phase, the senior project design group utilized the manufacturer and model of the medical organization's current VoIP solution, while also querying other vendors in the VoIP telephony market to provide a more extensive test analysis. VoIP telephony providers who participated in this research by donating VoIP telephony devices were Avaya, Cisco, Grandstream, 3Com, Polycom, and Mitel.

Testing of Asterisk's open-source VoIP solution, along with the multiple-vendors' telephony devices was the fourth phase of this project. Within this phase, critical areas of performance and security were highlighted.

The Asterisk PBX platform and voice telephony devices included within this project were tested for performance. The Nsauditor [4] traffic generator was implemented to place provisional TCP traffic on the network. This was used to ensure that quality of service (QoS) settings were accurate in giving precedence to voice-related traffic. In addition, since the medical institution was using session initiation protocol (SIP) for call-signaling, the SIPp [5] application was used to simulate large number of SIP calls entering the system.

To test security of the VoIP network, traffic sniffing tools such as Wireshark [6] and Kismet [7] were implemented. Also, attacks in VoIP such as man-in-the-middle, which can be seen in Figure 2, were also tested by spoofing MAC addresses and poisoning IP addresses with the common hacking application of Ettercap [8] and Cain & Abel [9].

The fifth and final phase presented a cost-benefit analysis between the organization's current commercial VoIP solution and the proposed open-source implementation. This phase focused on costs of four main areas; PBX, VoIP hardphones, telecommunications line costs, and maintenance contracts. Current costs incurred by the organization's current VoIP solution were compared against the training and maintenance costs

associated with the open-source Asterisk PBX solution along with a variety of other VoIP-based hardphones.

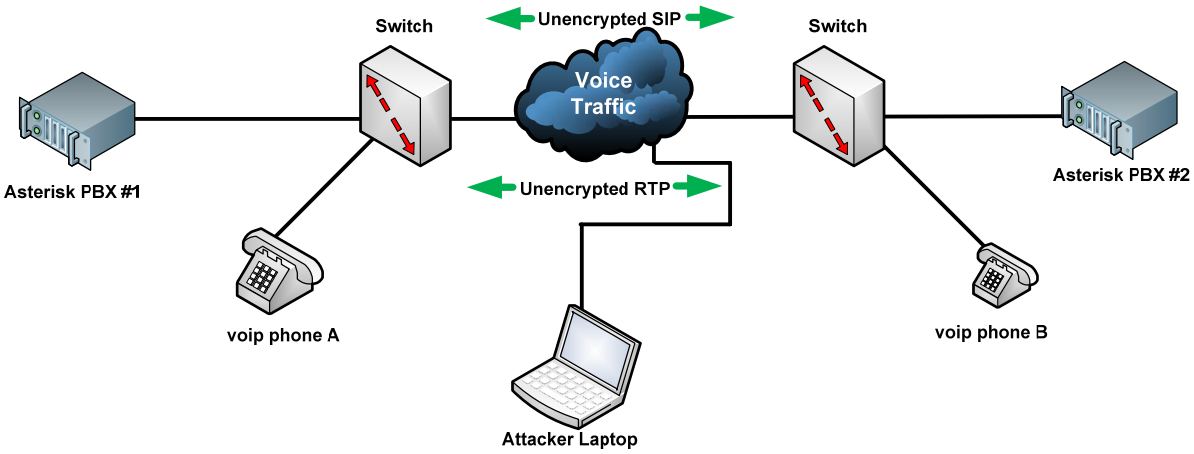

Figure 2

IV. Research Results

The conclusion of the testing associated with the project introduced interesting results to both the students and the medical institution associated with the project. Testing the interoperability of the VoIP phones affiliated with this project, along with the sound quality they produced, provided a subjective yet important analysis. The results of this test are illustrated in Figure 3 and document each phones' ranking when compared with others included on the list. Results that stem from the flooding of SIP calls on the Asterisk server, using SIPp, illustrated Asterisk's stability when the clock rate between the Asterisk server and the test server was changed to determine the amount of bandwidth was required to maintain 20 calls per second (CPS). The custom server could handle 25 CPS before it would fail, while the commercial server would fail at 30 CPS. The network stress test showed to maintain 20 CPS you would need to implement 800 kbps link

Testing the network and its devices for vulnerabilities resulted in producing a series of best practices for the medical institution that applied to both the open-source and commercial VoIP solutions. Recommendations such as separating voice and data over virtual local area networks (VLANs), MAC address lock, VoIP server authentication, dial-plan security, and IP security (IPsec) tunnels were all placed within the best practice list with a detailed explanation to each respective recommendation. In addition, other methods such as using the Zfone [10] to encrypt reliable transport protocol (RTP) traffic or implementing OpenVPN [11] to encrypt both the voice signal and RTP stream were developed and documented for the organization.

Custom Server												
Caller Values			What Caller Hears of the Other phone									
	M1	M2	P1	P2	G1	G2	C1	C2	3Com	Outside	Reciever	Totals
M1	x	2	3	3	3	3	3	3	3	3		26
M2	3	x	3	3	3	3	3	3	3	3		27
P1	2	2	x	3	3	3	3	3	3	3		25
P2	2	2	3	x	3	3	3	3	3	3		25
G1	2	2	3	3	x	3	3	3	2	2		23
G2	2	2	3	3	3	x	3	2	3	3		24
C1	2	2	3	3	2	2	x	2	2	2		20
C2	2	2	2	3	3	3	3	x	2	2		22
3Com	2	2	3	3	3	3	3	3	x	3		25
Outside	2	2	3	3	3	3	3	3	3	x		25
Caller												
Totals	19	18	26	27	26	26	27	25	24	24		
Reciever Values			What Reciever Hears of the other Phone									
	M1	M2	P1	P2	G1	G2	C1	C2	3Com	Outside	Reciever	Totals
M1	x	2	2	2	3	2	2	2	3	2		20
M2	2	x	2	2	2	2	2	2	2	2		18
P1	3	3	x	3	3	3	3	3	3	3		27
P2	3	3	3	x	3	3	3	3	3	3		27
G1	2	2	3	3	x	3	3	3	2	2		23
G2	3	3	3	3	3	x	3	3	3	3		27
C1	2	2	3	3	2	2	x	2	2	3		21
C2	2	2	2	2	3	3	3	x	2	2		21
3Com	3	3	3	3	3	3	3	3	x	3		27
Outside	3	3	3	3	3	3	3	3	3	x		27
Caller												
Totals	23	23	24	24	25	24	25	24	23	23		
Scale												
0	No audio											
1	Bad Audio											

Figure 3

The financial research focused on a comparison between implementing an open-source Asterisk PBX solution and the current commercial PBX solution installed. Cost-benefit analysis was taken on a 1, 3, and 5 year outcome and also incurred a break-even discussion between implementing open-source Asterisk to the current VoIP solution. The result, which can be viewed in Figure 4, shows that the blue line represents the break even point if the maintenance contract cost for the commercial solution is $100,000 for 4 years. The pink line represents the break even point if the maintenance contract cost is $114,400 for 4 years. The break even point for both lines is near 3 years, with the $100,000 maintenance contract cost at 7 years 5 months and the $114,400 maintenance contract cost at 5 years 4 months.

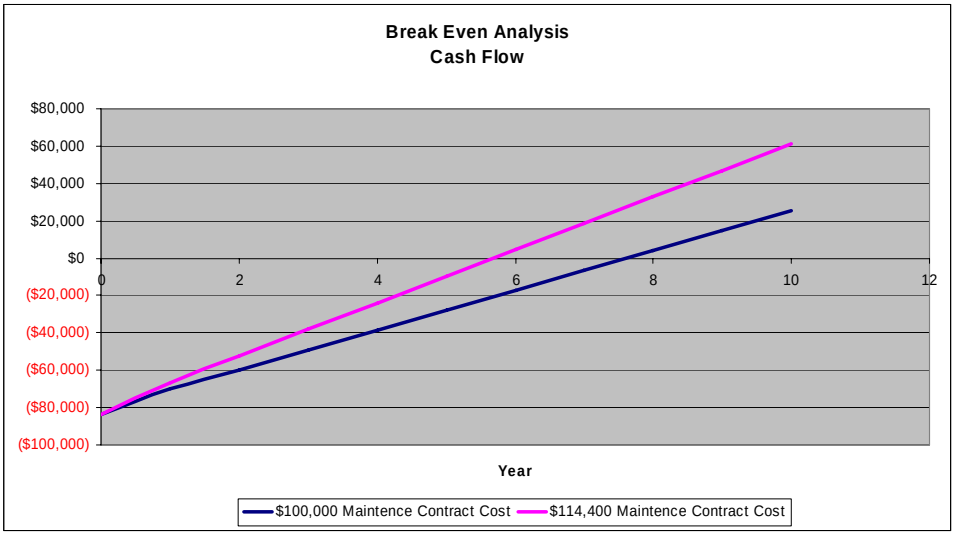

Figure 4

V. Project Organization

This project was designed for four senior students; however it can have a smaller or larger number depending on the project requirements and expectations from the industry organization(s) associated with the project. The project requires that students meet with their group at dedicated times each week, as well as with their senior project advisor once a week. Students are expected to update their group project's wiki with updated information regarding design architecture, configuration files, project budget information, etc. As can be seen in Figure 5, our senior projects utilize the Moin-Moin wiki [12]. In addition, students are required each month to give a presentation of their project's progress to other peers involved in senior project research and advisors. All presentations are recorded and provided to the students for review. The presentations helps students better articulate their research project, while also granting them additional public speaking experience. The feedback from the recorded presentations provides a tool that can be used to help evaluate and improve a student's presentation skills. An oral project defense to industry, faculty, and peers, along with a final project paper in IEEE format is required at the end of the academic year.

Figure 5

VI. Project Assessment

Since the senior project courses are designed as a capstone class within the CNSA program, the department uses these projects a method to evaluate a student's academic progression and accomplishments within the program. Final grades awarded to students within this course are based on the following criteria:

Weekly Submitted Reports displaying progress	10%
Group Web Page and Wiki Maintenance	10%
Monthly Group Presentation	10%
Peer Review	20%
Final project oral presentation	20%
IEEE Format Project Report	25%
Course Project Poster	5%

Results of senior project assessment have been very beneficial and resulted in becoming a significant contributor to improving the CNSA curriculum. Demonstrated technical knowledge regarding the students' respective project is assessed from the group's final oral presentation, project report and weekly submissions/meetings. Although students complete the research project within a group environment, individual responsibilities are delegated to each student. This permits the assessment process to focus on individual performances, as well as the group effort.

Findings of the senior project assessments have been conclusive and encouraging thus far. Preliminary results have shown that students, who have displayed weaknesses on specific

technical subjects, have displayed a significant improvement in these selected areas when related to the content of their senior project. Other technical areas of weakness that encompass content that is not related to a student's senior project display much less improvements. In addition, non technical yet critical areas of financial knowledge and presentation skills also demonstrate improvement. Senior students who are tested before leaving the university have displayed a much more comprehensive knowledge-base regarding financial subjects due to the extensive budgetary inclusions and return on investment (ROI) analysis that is required by the project. Students' final presentations are compared to those that took place within the first semester of the academic year, which show a dramatic increase in the student's ability to articulate the various aspects of the research project to their audience.

VII. Conclusion

VoIP continues to become a significant technology within organizations. Its vulnerability to delay, jitter and packet loss requires a comprehensive understanding of network design to implement successfully. Therefore, it becomes critical to include VoIP's latest developments within the academic realm in order to properly train individuals on this technology. A senior-project that incorporates industry elements, such as the open-source VoIP project, also yields many benefits to both parties. Students are able to apply their knowledge within an industry environment, which provides motivation and gained confidence through project completion. By associating the project with industry, students are also introduced to industry dynamics that are difficult to replicate within an academic lab environment and help better prepare the students for the field. Industry associated with the project also benefit from individuals researching alternative methods or solutions to problems affecting their organization.

In this paper we developed an open-source Asterisk solution for a small medical institution. The organization responded favorably to the research and recommendations given within this project. As a result they are implementing the open-source solution as a backup VoIP PBX with continuing discussions on eventually making it the primary VoIP solution for their institution.

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