The Telecommunications Interoperability Laboratory

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Abstract

The University of Oklahoma has developed a Telecommunications Interoperability Laboratory to enhance the educational and research experience of students in the Telecommunications Systems program. The Interoperability Lab is a collection of five interconnected technology islands: the Internet Protocol (IP), Asynchronous Transfer Mode (ATM), Optical, Wireless, and Legacy. Each island is designed as an entity in its own right, but also provides the interconnection capability with any combination of other islands to create a fully functional end-to-end networking environment. This paper describes the architecture of the Interoperability Lab, as well as how it will impact the education of our students.

1. Introduction

The education of engineering students in the area of telecommunications systems is of growing importance as society becomes increasingly dependent on telecommunications technologies and services. Despite its beginnings from electrical engineering and the broader base of electrical sciences, telecommunications today is strongly rooted as an independent academic discipline. Although the telecommunications industry has well-equipped laboratories for its R&D, such laboratories at universities are usually lacking and often treated as incremental additions over those of the allied disciplines like electrical and computer engineering. The University of Oklahoma is one of a select group of universities that offers a graduate degree in Telecommunications Systems out of the School of Electrical and Computer Engineering. In recognition of the need to have a well-equipped laboratory as an integral component of any engineering program, the University of Oklahoma established, in 2001, an Interoperability Laboratory to provide the best possible educational opportunities and research experience in telecommunications for our students and faculty.

The Interoperability Lab is a collection of five interconnected technology islands: the Internet Protocol (IP), Asynchronous Transfer Mode (ATM), Optical, Wireless, and Legacy. Each island is designed as an entity in its own right, but also provides the interconnection capability with any combination of other islands to create a fully functional end-to-end networking environment, as illustrated in Figure 1. Later sections of this paper address the architecture of each of the islands.

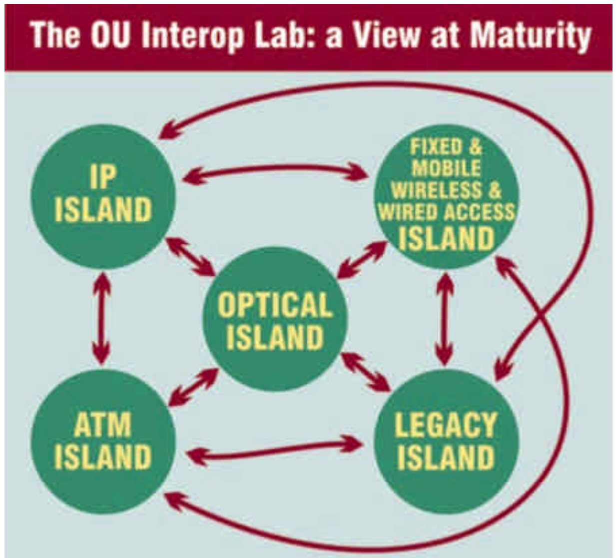

Figure 1 – The interconnection of the five technology islands comprising the Interoperability Lab.

We have developed a laboratory course in telecommunications that allows students to explore issues associated with various facets of IP and ATM networking, as well as their interconnection. We are presently developing a complementary laboratory course in optical networking which, among other topics, will explore interconnection of the Optical island with other islands in the Interoperability Lab. The Wireless island is used to bring in the factor of mobility as well as free space optical communication that can constitute the fringes of a complex end-to-end telecommunications environment. This paper describes the architecture of the Interoperability Lab, examples of how it is being used, and how it will impact the education of our students.

2. The IP Island

The heart of the Interoperability Laboratory is the IP Island which provides the overall end-to-end connectivity that accommodates the edge translation services required by each separate technology island. Although many technologies allow direct connections to the underlying transport layers, the network and data link layers still provide the greatest amount of communication between the applications, protocols, and end-to-end transport media. The island is centered on a main distribution frame containing the junction points of all physical layer transport connections, the majority of which are fiber and copper cables. In addition to providing interconnection among the technology islands, transport connections originating outside the network also enter into the core and can be distributed to a particular island, PC lab, and/or server farm. The core contains the aggregation points for Ethernet connectivity and provides the IP routing capabilities for ingress and egress traffic control. The IP Island is also the containment facility for the traffic impairment and generation equipment. This equipment performs traffic emulation based on predefined and customized parameters, allowing students to observe and analyze real world network behavior in a non-production setting. Students can explore dramatic fluctuations in network behavior in an innocuous setting, facilitating deeper understanding of evolving network anomalies. This provides an avenue for applying theoretical hypotheses to a real-life environment and maintaining control of that environment for deriving conclusive results that support research activities. Figure 2 provides an example of some of the interconnections and that are supported by the IP Island during routine laboratory testing.

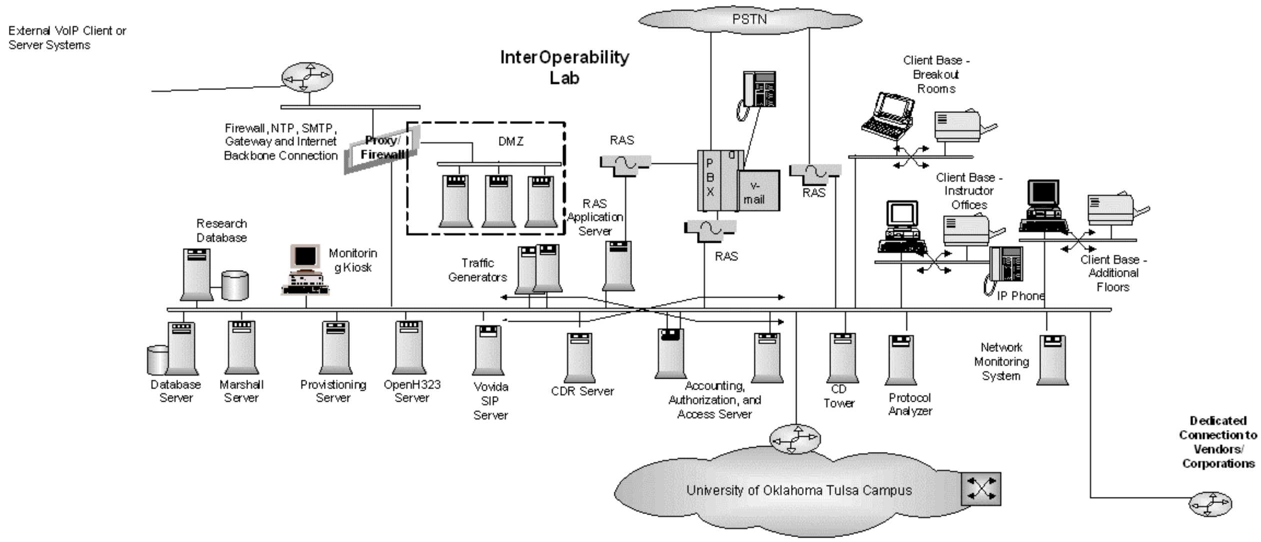

Figure 2 – A typical testing configuration utilizing the IP Island.

3. The ATM Island

The ATM Island is comprised of a fully functional set of ATM switches that promote the testing of several different functional areas. Application traffic can be characterized from both the local and wide area network perspective in a mixed or single service scenario. The ATM switches provide all three rate components – constant, available, and unspecified bit rate – as well as both network node interfaces (NNIs) and user-network interfaces (UNIs). The quality of service (QoS) capabilities of ATM allow the specific request of constant bit rate traffic with bandwidth and delay variation guarantees. The use of virtual channel (VC) queues allows each traffic stream to be treated uniquely. In the case of voice traffic, priority can be given for its transmission. The use of small fixed size cells reduces queuing delay and the delay variation associated with variable sized packets. This capability provides for additional opportunities for student investigation as conversions from one protocol to another can be made while measuring the resulting effects on end-to-end application performance and quality.

The ATM Island ties directly into the IP and Legacy Islands, thus to enabling testing beyond just ATM. Multiple interfaces exist to tie local network traffic to wide area and circuit switched networks. This creates an environment that is capable of testing simple application and end user traffic and also allows complex analysis of carrier-type backbone and circuit switched network traffic.

4. The Legacy Island

The Legacy Island provides the lab with a carrier grade circuit switched network facility capable of delivering circuits with speeds up to the digital signal 3 (DS3) rate of 44.736 Mbps. The capability to partition circuits from DS0 to DS3 allows the lab to connect the latest technology and equipment to current, real-world telecommunication service offerings. The crossover from circuit switched analog voice traffic to packetized voice traffic can be tested with two voice-over-IP (VoIP) gateways that tie into the Legacy and IP Islands. DS1 multiplexing in this island helps test both data and voice services emanating from the IP and ATM Islands, allowing service and traffic aggregation into larger bandwidths. This traffic can then be handed off to the Optical Island for further testing.

5. The Optical Island

New communications services (voice, video and data) have triggered a global appetite for bandwidth. Currently, optical networks utilizing dense wavelength division multiplexing (DWDM) provide the among highest achievable transport bandwidth[1]. However, for efficiency there are additional requirements to be met, such as bandwidth elasticity and service protection[2]. The Optical Island, utilizing DWDM, is presently in the process of being constructed. The Optical Island will provide a flexible platform for both teaching and researching advanced optical technology and networks. Teaching employs both theoretical concepts and experimentation that effectively links physics with components, components with systems, and systems with networks. Research involves both model simulation and network verification. Model simulation is already under way. Network verification will be accomplished with using the Optical Island, which is based on a flexible and easily reconfigurable platform. This platform may be described as a set of devices interconnected with fiber via an optical patch panel. Thus, multiplexers and demultiplexers, amplifiers, and add-drop devices may be interconnected to comprise a network under evaluation. This platform is under current development. Figure 3 illustrates the fundamental functionality of a point-to-point DWDM link that will be accommodated by the Optical Island.

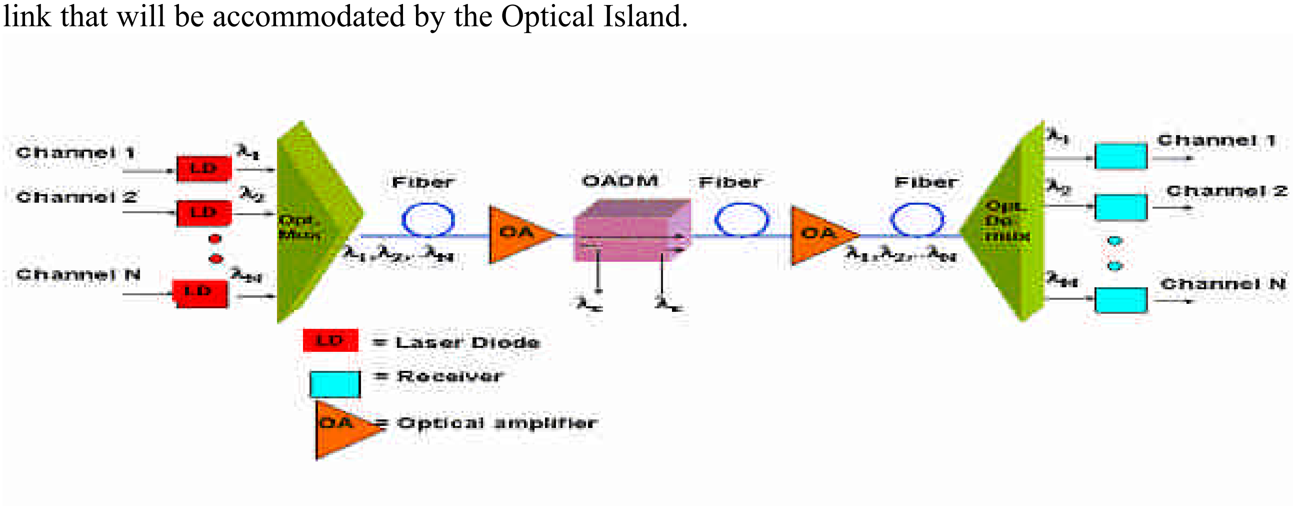

Figure 3 - A DWDM point-to-point optical link with Add-drop multiplexing and amplifiers.

6. The Wireless Island

Two major wireless technologies comprise the hardware infrastructure of the Wireless Island; cellular technology and wireless local area network (WLAN) technology. The cellular technology provides time division multiple access (TDMA) and code-division multiple access (CDMA) connectivity through a base station and is characterized by large coverage area and low data rate. Examples of this technology are TDMA and CDMA. The WLAN connectivity is obtained via access points wired on the same local area network. This technology is characterized by its smaller coverage area and high data rate. Examples of WLAN technology are those that utilize the IEEE802.11 a/b/g and Bluetooth standards. Figure 4 depicts the logical view of the hardware platform, illustrating a mobile unit equipped with laptop, cell phone, drive tester and global positioning system (GPS) receiver as part of the hardware configuration. The mobile unit is used for mobile IP projects and for collecting power measurements to develop propagation models for cellular coverage. Student projects focus on the integration of different wireless technologies into one heterogeneous environment in which wireless terminals use one or multiple WLAN technologies to connect to the internet.

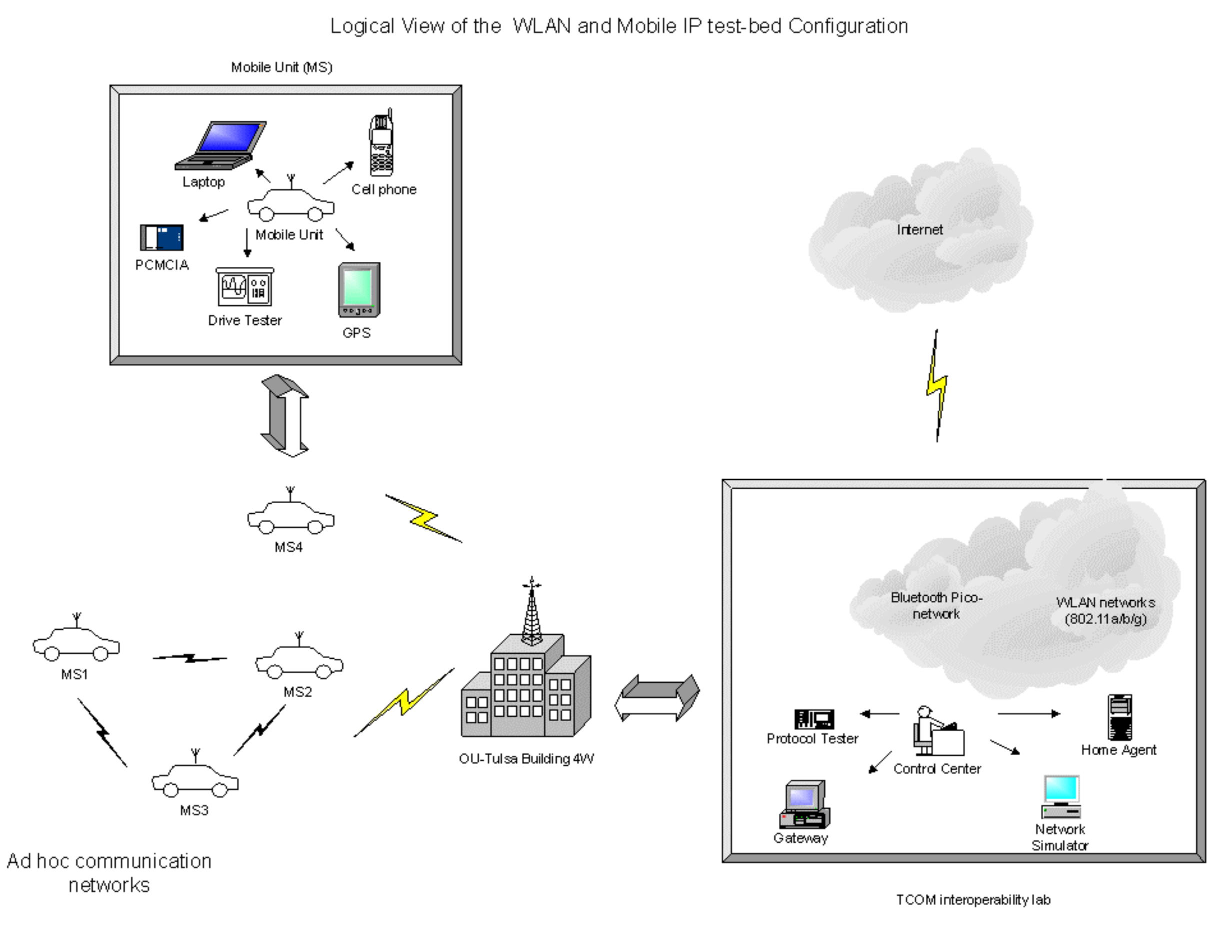

Figure 4 – A view of the functionality of the Wireless Island.

7. Example projects

Several projects are underway using the IP Island, the focus of which has been in the area of packetized voice, or voice- over-IP (VoIP). VoIP has evolved into a viable solution for both telecommunications carriers and enterprise networks alike[3]. While new technologies are evolving and taking shape in the academic communities, students focus on ways to lower costs and enable new solutions with the existing protocols and applications for voice communications. Data networks and telephone networks were designed and implemented with differing objectives, but with the convergence of voice and data, VoIP has become a prevalent contender for low cost voice services. Every network needs addressing, routing, and signaling, no matter the size of the transport medium. Although voice primarily has a low bandwidth requirement, "best effort" data networks must contend with latency, jitter, and loss. The lab recently produced two papers on these topics. The first paper analyzed the most basic component of any call, signaling. Session Initiation Protocol, one of many signaling protocols, was observed and characterized based on call completion ratios and packet loss as a function of link utilization[4]. The second paper, in the area of routing, quality of service (QoS) in the local area network (LAN) for VoIP focused on the delay, jitter, and loss requirement for acceptable voice quality by testing two widely used queuing policies[5].

An activity complementary to the Wireless Island is the use of simulation and development software. The software provides a platform to improve student understanding of textbook materials and to allow them to quickly simulate and model new technologies. One of the software development packages used in the Telecommunications Systems program is CellPlanner Suite from CelPlan[6]. CellPlanner is a cell engineering software package used to predict performance in wireless cellular networks. It facilitates student understanding of the concepts involved in designing a cellular network by exposing to those concepts though projects. One such project is, for example, given demographic and morphology data, coverage area, and the available frequency spectrum, the students are asked to design a cellular network for that service the area. Students are required to use the minimum needed number of towers and antennas, to optimally place the towers, to evaluate the co-channel and adjacent channel interferences, to evaluate the frequency reuse and allocation, and many more cellular related issues. Another software package being used in the program is OPNET from OPNET Technologies, Inc.[7]. OPNET Modeler provides a strong simulation development platform for existing and future technologies. Students are required to build models of existing technologies, such as the MAC layer model for IEEE 802.11b standard or the physical layer model for Bluetooth wireless system. Then, using the hardware infrastructure afforded by the Wireless Island, students enhance their learning experience by configuring the different technologies to implement their design and interoperate it with different vendor equipment.

8. Interoperability Testing and Its Role in an Educational Institution

Interoperability testing can be formally defined as the verification of user-level functionalities in an end-to-end configuration[8]. The elements being tested for interoperability in an end-to-end environment need not necessarily have architectural consistency. Interoperability testing commonly includes interconnected systems that are functionally disparate but are interconnected using a common interface. Further, interoperability testing is usually conducted using field-grade equipment with the aim of discovering and resolving not only functional issues but also issues related to operations, administration and management. The environment being created in the Interoperability Laboratory addresses these requirements.

As the number of systems and sub-systems produced by manufacturers, truly at a global level, proceeds at an unprecedented pace, the importance of interoperability for users, as well as manufacturers and service providers, continues to increase. The authors believe that it is important for students of telecommunications systems to be adept in working with real-life equipment in an environment characterized by architectural and functional diversity. The conventional focus in institutions of higher education is on depth and specialization, leaving little scope in the curriculum for experience in a complex end-to-end environment. An interoperability lab fulfills this gap.

As developers of complex systems reduce their development risks and time-to-market constraints, interoperability testing techniques will continue to offset parts of the traditional development processes. Working in an interoperability testing lab will thus give students a first hand experience at what they would face in the real world.

9. Conclusion

This paper has presented a description of the architecture of the Interoperability Lab at the University of Oklahoma. The Lab is being used in conjunction with class projects and research to enhance the educational experience of students in the Telecommunications Systems program. Examples of representative projects have been presented, along with a brief discussion of the impact the Lab is having on student learning. We conclude that experience in an interoperability lab will offer students a first hand experience at what they would face in the real world, thus preparing them better for the workforce.

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Biographical Information

Dr. James Sluss is a Professor of Computer Engineering in the Telecommunications Systems program at the University of Oklahoma, Tulsa. His research and teaching interests are in the areas of fiber optics, photonics, and telecommunications. He has been awarded seven U. S. patents and has authored/co-authored numerous journal and conference publications. He is a member of the IEEE Education Society, IEEE Communications Society, OSA, and ASEE.

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Dr. Pramode Verma is Director of the Telecommunications Systems program and Professor of Computer Engineering at the University of Oklahoma, Tulsa. He has held management positions with Lucent Technologies/Bell Laboratories for over twenty years. He is the author/coauthor of over 50 publications and several books in telecommunications and computer communication.