The Wisconsin Advanced Internet Laboratory

Overview

The purpose of this note is to provide a summary description of the Wisconsin Advanced Internet Laboratory (WAIL). The intended audience is anyone with general interest in the motivation, design and goals of the lab. Further details and current status are available by contacting the lab's director Paul Barford at pb@cs.wisc.edu.

Motivation and Introduction

Research in any scientific discipline is in many ways limited by the tools available for experimental study. In the networking community, experimental tools can be classified generally into three categories: analytical modeling, simulation and empirical measurement. Two recent reports point to new directions in experimental network research. First, a 2001 National Research Council report on the state of research in networking came to a number of important conclusions related to tools and methods employed by the community. Principal among these was the danger of ossification in network research due to past success and the strictures of the experimental systems that have been developed to date. To address this risk, the report advocates new measurement and empirical evaluation capability in the network research community. Second, a recent NSF report recommends similar initiatives. Specifically, that report calls for the development of new testbed infrastructures as a means for expanding the scope of experimental network research.

There are, however, significant challenges to empirical/experimental study in computer networking. Most significantly these include limited access to in-situ environments due to practical concerns of IPSs, and the lack of availability of large scale laboratory environments due to prohibitive cost and difficult design, management and technical issues.

WAIL is a one-of-a-kind environment designed to provide solutions for both in-situ and laboratory-based network research. The vision of WAIL is a large collection of commercial systems (end hosts, routers, switches, etc. such as would typically be found along any end-to-end path in the Internet) located in a lab, and configured to enable the capability to recreate different "instances" of the Internet (NOTE: WAIL also manages a large set of general purpose systems distributed around the Internet for in-situ measurement, but these systems are not the focus of this note). In addition to a variety of topological configurations, the lab will also have the ability to recreate a range of application level behavior and traffic conditions. The combination of these capabilities results in a unique experimental environment.

Two of the principle advantages of the WAIL environment are the ability to measure and monitor the entire system as well as the ability to deploy and evaluate new prototypes in a controlled testbed. Clearly, neither of these abilities is available in operational networks for practical reasons. At a lower level, the ability to use networking hardware running actual networking protocols (as opposed to an emulated environment) in a broad range of configurations enables a variety of experiments such as:

1. Network measurement - Determining how accurately to probe and monitor the network for information such as delays, loss rates and bandwidths.
2. Protocol interaction – Understanding how protocols affect each other (such as routing and transport) or how a protocol interacts with itself (such as BGP)
3. Benchmarking – Developing test harnesses to test issues of performance, security, and interoperability.
4. Management – Determining how measurements can be matched with control systems to affect adaptive traffic management.
5. Anomaly Detection/Security – Understanding how effectively to detect intrusions and anomalies and prevent attacks in a controlled environment.
6. Testbeds – Using the networking substrate as a platform for distributed systems research in storage, grid computing, caching, streaming, overlay network, etc.
7. Model and simulation validation – Results from models and simulations can be compared one-to-one with results of similar configurations in the lab.

Objectives and Design

Over the past 18 months a team from both Wisconsin and Cisco Systems has developed the basic design features of WAIL. The most fundamental design objectives were to create a lab environment that is flexible, scalable, representative, and openly available to the research community. A number of challenges had to be considered during the design process including the following:

1. Basic components – What systems are required in order to maximize flexibility of configurations and enable the widest variety of experiments?
2. Layout, configuration and management – Once the equipment is acquired, how should it be laid out in the lab (eg. rack, wiring and power layout)? Once assembled, how should it be configured and managed to allow open access and to maximize efficiency in use of resources?
3. Propagation delay – wide area delays are fundamental to most experiments envisioned in WAIL. Other than purchasing miles of cable, how can propagation delay between systems only a few feet apart be realized accurately and efficiently?
4. Traffic generation – the ability to generate a wide variety of traffic conditions which are representative of both ON/OFF and streaming sources also fundamental to most experiments. How can this be realized accurately, scalably and efficiently?
5. Validation – How can the greater networking community be convinced to embrace this new approach to experimental research?

Our solutions to most of these challenges are embodied in different aspects of WAIL's design. The basic components of the lab consist of ~50 routers (configured with T1 through OC12 line cards), ~20 switches, ~120 general purpose end hosts and a variety of additional equipment. Flexibility is achieved through programmable patching and heavy use switching hardware. Configuration management is achieved through the development of a new system specific to WAIL – WAILworks. Propagation delay and traffic generation are also the subject of system development efforts – WAILnet and Harpoon respectively (see status for further information on each of these projects).

Validation in the networking community is clearly a process of education, making the lab available to others and successful completion of projects in the lab. All of these are being addressed.

To make the lab available and useable by researchers outside of UW, WAILworks will eventually include a GUI similar to what is currently available in EMULAB. In the meantime, WAILworks will feature a set of canonical configurations that researchers can use as a baseline for conducting experiments or building their own configuration. A number of canonical configurations are being developed at present (eg. an IGP configuration, a BGP configuration, and multiple end-to-end-through-core configurations).

Partners

At this point, WAIL development has been completely funded by UW and our industrial partners. Our primary partner is Cisco Systems through the support of the TOSA foundation. Other partners who have made generous contributions include EMC, Intel, Sun Microsystems, Spirent Communications and Fujitsu Labs America. Applications for funds from federal agencies in support of this work are currently underway. We have also received strong support from Internet2 which has provided significant access to external systems, and who is our primary partner in our external measurement efforts.