

DEVELOPING A REMOTE ACCESS HARDWARE-IN-THE-LOOP SIMULATION LAB

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**NATIONAL INSTITUTE FOR ADVANCED TRANSPORTATION TECHNOLOGY
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TABLE OF CONTENTS

Executive Summary	1
Approach and methodology	1
Introduction.....	1
Background.....	1
Hardware-in-the-Loop Simulation.....	2
Objective.....	4
Website Access	4
Secure Computer Connections.....	5
Database.....	6
Operation.....	6
Results.....	7
Conclusion	8
References.....	9

EXECUTIVE SUMMARY

The development of an Internet-based remote access hardware-in-the-loop simulation system is presented. Traffic controllers, controller interface devices, and computers to run microscopic traffic simulations are available in the local laboratory for remote users to run simulations remotely via the Internet. A web site has been created that can be used for scheduling the use of the system, to manage users and to manage the system as a whole.

Remote access capabilities laboratory capabilities were implemented to facilitate training and applications for traffic control systems for a variety of geographically dispersed end users. The tools allow traffic engineering students and professionals to remotely use the traffic controllers and controller interface devices located at NIATT's Traffic Operations and Control Laboratory. They are able to test traffic control strategies and to learn about how to do traffic signal timing using real-time hardware-in-the-loop simulation techniques.

APPROACH AND METHODOLOGY

Introduction

The evolution of Intelligent Transportation Systems (ITS) technologies promises new tools for integrated traffic signal systems, including centralized control and the provision for real-time adaptive control. Many states and metropolitan areas have already deployed integrated centralized signal control systems to assure optimal control. These often consist of an extensive network of detection, surveillance and information dissemination devices, strategically located along the roadway network and connected to centralized control software located in a traffic management center. These developments in sensing and communication technologies, however, have not been accompanied by corresponding developments in evaluation and decision-making tools that can take advantage of real-time data to produce more efficient control strategies. This is mainly due to the lack of appropriate hardware and software testing tools in a controlled lab environment.

The National Institute for Advanced Traffic Technology at the University of Idaho developed a state-of-the-art hardware-in-the-loop traffic controller laboratory for testing advanced traffic signal systems. TCLAB-II boasts a collection of hardware and software tools that might not all be available in one place elsewhere.

This report describes the design of a remote-access system to make the unique lab resources accessible by remote users over the Internet for both educational or research activities. These resources can now be used remotely for undergraduate or graduate laboratory instruction or for conducting research on traffic signal operation.

Background

Traffic simulation models have been used to develop, optimize and test control plans for traffic signal systems. Microscopic simulation models simulate the behavior of individual vehicles throughout the transportation network and their response to different traffic control devices. These models use traffic controller emulators to replicate the performance of actual

traffic controllers. The introduction of a device called the Controller Interface Device (CID) allowed engineers to simulate traffic networks with the signals in the simulation being controlled by a real traffic controller. This hardware-in-the-loop simulation, or HILS (1) (2) (3) (4), produces more realistic results than using the software emulator. Engineers can also perform simulations with networked traffic controllers using a device called controller interconnection network (CIN) (5).

Hardware-in-the-Loop Simulation

Microscopic simulation models, such as CORSIM, Federal Highway Administration's (FHWA) simulation model, simulates a real-world traffic network by moving individual vehicles across a combined surface street and freeway network using accepted vehicle and driver behavior models and simulating various traffic control devices. It contains both the algorithms to track vehicles through a prescribed highway network and the algorithms necessary for implementing a coordinated actuated signal system (6).

Hardware-in-the-loop Simulation (HILS) is different in that instead of having CORSIM simulate controller features, the CORSIM traffic model only simulates the vehicle detector signals, but the control strategy is run on an actual traffic controller that will be used in the field. A controller interface device (CID) is used to provide the real-time linkage between CORSIM and the traffic signal controller (3) (4).

The CID is a USB-based device that relays detector information from the simulation software to the traffic controller and phase information from the traffic controller to the simulation software as shown in Fig. 1, and makes hardware in the loop simulation possible.

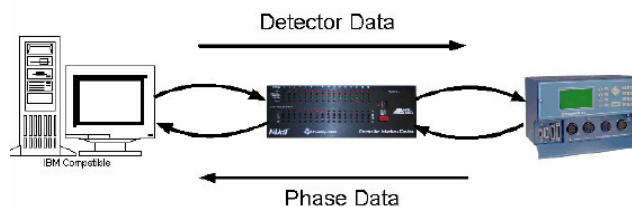


FIGURE 1 Hardware-in-the-Loop simulation with CID

The lab setup requires a PC dedicated for HILS and another PC dedicated to traffic controller software used to upload and download traffic controller data to and from the traffic controller. The latter computer can also be used to control a Controller Interconnection Network (CIN) device which can be used to change the network configurations between traffic controllers when the simulation involves more than one intersection (5).

The CIN is a GUI (graphical user interface) driven microprocessor-based device that allows networking of traffic controllers in different configurations with a typical control architecture shown in Fig. 2. One CIN can be used to interconnect up to five traffic controllers and one

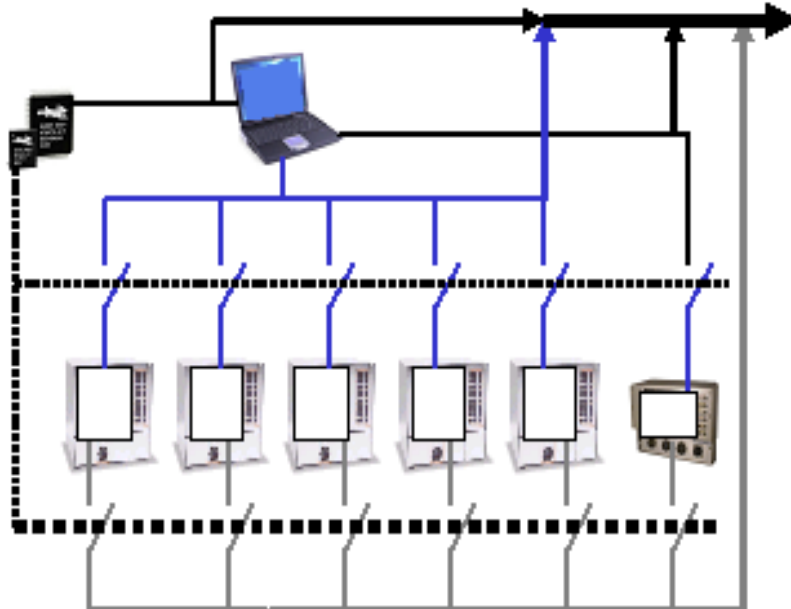


FIGURE 3 CIN Control

master controller and can be used to emulate isolated, master-based and closed-loop network configurations. The CIN eliminates the need for manual connection or disconnection of the cables when the controllers are connected to the CIN. In addition to interconnecting up to the five traffic controllers, the CIN can establish a connection to a neighboring CIN and its traffic controllers. The GUI supports the interconnection of up to four CINs for a total of 20 connections to traffic controllers at simulated intersections.

Objective

The main objective of the project was to develop a secure system to make HILS accessible to enable remote users to run hardware in the loop simulations via the Internet. This requires giving the remote user controlled access to the two computers used for simulations. By accessing the computers, the remote user is able to conduct any kind of simulation, limited only by the Internet bandwidth available to them and the lab. A freely available open-source software package called Real Virtual Network Connection (VNC) is used to access the computers. VNC allows a user access to the remote computer across a network as if the user was sitting in front of the remote computer (7).

Website Access

A web site is used to manage the both system and its use. New users are required to register by providing personal and contact information before then can be authorized to use the system. The administrator authorizes the user to use the system. When a user is authorized, PHP and Perl scripts automatically create a user account for the user to access the computers in the RAHILS network domain. The authorized user is also given disk space in the RAHILS server that can be used to store input files for the simulation and the resulting output files from their simulations. This file storage space is mapped as a network drive on the network computers when the user is logged in. The user can transfer files to or from their own local computers using any secure file transfer software package.

An authorized user is able to view the schedule for the available banks and schedule a time on the system that fits their schedule. The user is also assigned two port numbers to be used as connecting ports on VNC, one port for each computer in the bank they are accessing. The assignment of specific port numbers to each user allows more than one user to use the system (each uses different banks) at the same time. When a time is scheduled, the user's ID, port numbers, start time, end time, and the IP address of the computers in the bank of interest are stored in the database.

General users and the administrator see different menu options when they log in. The general user's menu contains the following options:

- a. Home
- b. Member Profile
- c. Change Password
- d. Lab Schedule

The administrator's menu contains the following options:

- a. Home
- b. Admin profile
- c. Change password
- d. Authorize users
- e. Manage users
- f. Manage lab schedule
- g. Manage banks

Emails are sent automatically by PHP scripts to the administrator and/or the user whenever:

- a. User registers for an account.
- b. User is authorized, suspended or deleted.
- c. User schedules a time.

The system administrator can use the web site to manage users, that is: grant or deny access to new users, edit or remove existing users, manage number of banks and update information. The administrator reserves the right to cancel any scheduled times, remove or suspend users and to remove banks as required.

Secure Computer Connections

The server keeps track of which user is scheduled to use what bank during what time. All that information is stored in the database. A Perl script is set to execute every fifteen minutes (the resolution of the schedule is set at thirty minutes) as a time and date specific "cron" job in the Unix operating system. The script, when executed, checks the schedule database against the current time and determines if any connections need to be established or terminated.

If a user is scheduled, then they should be connected to the computers of interest. This is done by routing incoming connections on the ports assigned to the user on authorization to the computers through the server. These connections are established or terminated by the Perl script by adding or deleting iptables rules. Iptables rules act as the firewall and only allow restricted traffic in and out of the RAHILS domain (9).

Database

The PostgreSQL database system is used to store information for RAHILS. The database is a crucial part of the system because it stores all the information needed to run the system properly. Tables store users' information, authentication information, schedule times, IP addresses of the computers in different banks and so on. PHP scripts constantly store and retrieve information from the database to perform functions such as log-in authentication, user information update, and time scheduling and display. Perl scripts use the database to determine if any incoming connections need to be routed to any of the RAHILS computers.

Operation

An authorized user has to follow the following steps to successfully use the system.

1. Log in and check schedule for bank of interest.
2. Choose a time period that does not conflict with other users already scheduled or with other computers for the same user (otherwise, error messages are shown).
3. During their scheduled periods, use VNC and the assigned port numbers to access the computers (the remote user can only connect to one computer in RAHILS lab per computer at the user's end). VNC authentication requires a password, which is provided to the user. This password is different from the user's RAHILS password. If the authentication is successful, the remote desktop will appear in a window in the local desktop.
4. Logs i to the RAHILS computers using their RAHILS username and password.
5. Use a secure file transfer program to transfer simulation input files to their directory on the server. The home directory will appear as a network drive in the computers and this directory will contain the files previously transferred by the

user. The user does not have to schedule a time to do this.

6. Use the simulation or traffic controller software and hardware installed on the computers as required for simulation or other purposes.
7. Transferred back to the user's computer using file, output files after simulations are completed.

Results

The web site has been successfully tested for user registration, authorization, and management and bank management. The Perl scheduling scripts have also been tested. The computers in RAHILS domain have been accessed from an external computer using VNC during scheduled times periods and the remote users were not able to access the system outside of that time window. The transfer of files and the use of to run simulation in CORSIM has also been tested successfully.

The type of Internet connection and the available bandwidth of the user has a significant effect on how the simulation is viewed in the remote computer. The complexity of the network being simulated and simulations settings such as the update rate, number of vehicles in the network etc. also affects the quality of the simulation viewed at the remote end. But this does not affect the accuracy of the simulation and its output files, which can be transferred back to the remote computer.

CONCLUSION

This report describes a system implemented to allow a hardware-in-the-loop system to be accessed remotely via the Internet. This system can be implemented easily using basic web programming, database and simple Linux functions as described in this report. Most of the software used is free (open-source), which makes the system fairly inexpensive. It is hoped that this kind of system will prove very useful for researchers and educators who have the required skill but limited resources to achieve their goals.

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