A WiFi Virtual Laboratory

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Abstract

The Internet lies at the heart of today's social, educational and business worlds. Computer networking technology has hitherto provided the infrastructure to facilitate inter-personal pan-global communication on an unprecedented scale. The next logical development for such communicative pathways is the extension of access to this global mesh from individual static workstations to a multiplicity of mobile agents. Convenience of access will be greatly increased by the use of such agents, underpinned in turn by wireless network technology. The WiFi Virtual Laboratory project seeks to enhance our learning and teaching of such technology. This paper describes the educational goals of the project, the technological requirements implied by those goals, the architecture developed to satisfy these goals, observations made during preliminary evaluations, and plans for future development.

Keywords

Virtual Laboratory, 802.11, WiFi, Learning Object

1. Aims of the WiFi Virtual Lab

The aims of the WiFi Virtual Laboratory (WiFiVL) project are to widen access to, increase the availability of, and improve the quality of teaching and learning about the widely deployed IEEE 802.11 protocols, often referred to as "WiFi". Those high level aims are being addressed through the design, implementation and evaluation of a set of reusable learning objects which provide a number of desirable generic educational attributes:

- real world or realistic input;
- anytime anywhere access;
- student-centred hands-on exploratory approach to learning;
- easy access to support materials for the learning context and links for conducting further study;
- reusability of learning resources.

Learning objects in this project are manifest as static web pages, interactive Flash animations, simulation scenarios and a virtual laboratory service.

Reusability in this context has three aspects:

i) all the learning objects are made available via a public web site;
ii) the underlying software architecture is modular and its separate large-grain components can be re-used in different simulation developments;
iii) specific scenarios which have been created by users (lecturers or students) can be stored and re-used.

The domain-specific goals of the WiFiVL project are:

- to provide background and context for the IEEE 802.11 protocols;
- to provide an introduction to various WiFi scenarios with relevant descriptions;
- to produce a Virtual Laboratory that allows users to create scenarios, to run them on an underlying simulator and display the results in a meaningful format;
- to make access to, and use of, the Virtual Laboratory as user friendly as possible;
- to provide an interesting and engaging approach to learning about wireless networking
- to create visual and tangible practical artefacts which will illuminate an otherwise abstract protocol.

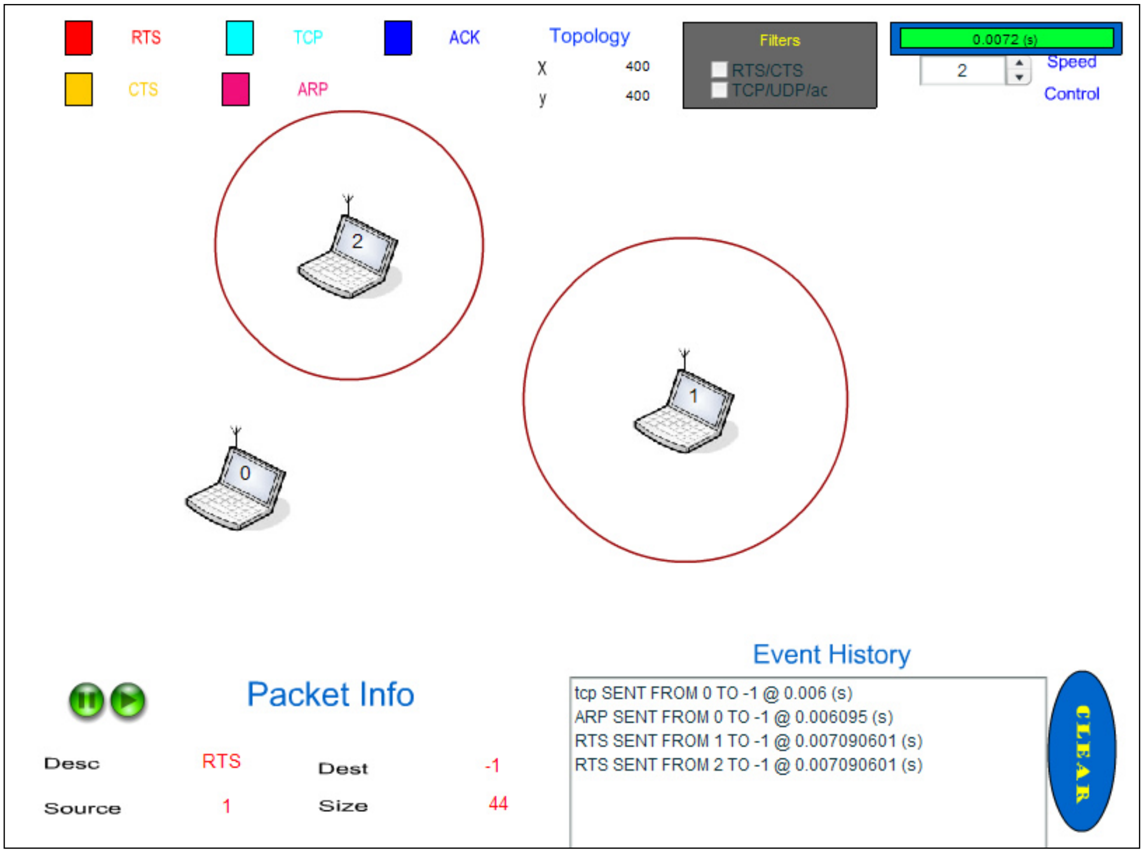

Figure 1: A screenshot of the WiFiVL running a user's simulation

2. DESIGN OF THE WIFI VIRTUAL LAB

In order to provide a reasonable degree of accessibility to the WiFiVL (anytime, anywhere) it is designed to be accessible via the Web using common browsers and plug-ins and have an intuitive, visual, user interface (see Fig.1).

One of the trade-offs is between having to be connected to the Internet in order to generate a simulation, and downloading the simulation engine itself, possibly as a plug-in, to the client computer, allowing for offline use. The former approach was chosen as it was felt that the complexity of installing a simulation engine on a client could deter a large class of potential users. In addition, by having the simulations generated on a server, it is possible for the server to store, re-use, and share simulations between multiple users.

However, once a simulation has been generated, in the scheme adopted, it (an XML file) can in principle be stored on a client computer for offline use.

In order to be reusable beyond simply being available via the Web, a modular architecture has been adopted (see Fig. 2). The main components are described next.

2.1 ns-2: the network simulator

ns-2 is a mature and respected network simulator that is widely used in non-commercial research.

> "*ns is a discrete event simulator targeted at networking research. Ns provides substantial support for simulation of TCP, routing, and multicast protocols over wired and wireless (local and satellite) networks. ns began as a variant of the REAL network simulator in 1989 and has evolved substantially over the past few years. In 1995 ns development was supported by DARPA through the VINT project at LBL, Xerox PARC, UCB, and USC/ISI. Currently ns development is supported through DARPA with SAMAN and through NSF with CONSER, both in collaboration with other researchers including ACIRI. ns has always included substantial contributions from other researchers, including wireless code from the UCB Daedelus and CMU Monarch projects and Sun Microsystems.*" [1]

While there is no doubt about the power and capabilities of ns-2 in a research context, it is not particularly suitable for use as a general educational resource. With reference to Fig. 2, ns-2 only accepts simulations specified in Object TCL (OTCL), a variation on Ousterhout's Tool Command Language Toolkit, TCL/TK [2]. The output from ns-2 is a Network Animation (NAM) type file. Nam is a TCL/TK based animation tool for viewing ns simulation traces.

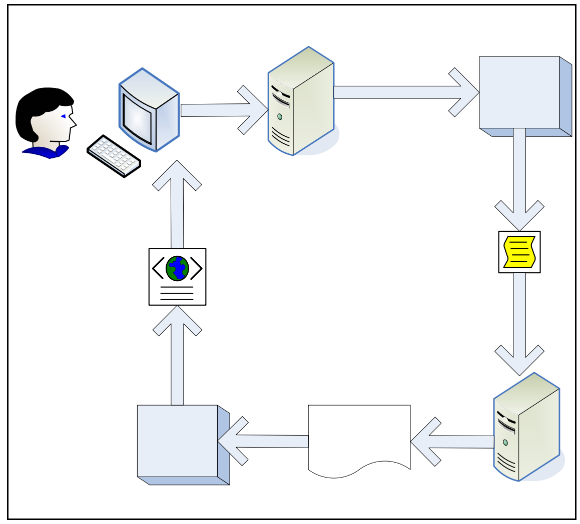

Figure 2: WiFiVL architecture showing flow of execution

2.2 Web Technologies

The normal environment for working with ns-2 involves creating a simulation in OTCL and then using the Linux *namplayer* application to see the execution, typically via an X11 based Linux GUI.

One task for the WiFiVL is how to make an ns-2 802.11 simulation module accessible via an easy-to-use Web interface.

An overview of the architecture is shown in Fig.2. WiFiVL users start by going to a web page and specifying coordinates for the network nodes in their scenario. A user may add as many nodes as they choose. Once nodes have been added the user may schedule communications between arbitrary pairs of nodes for any specified times. The web page makes use of JavaScript to store the user's parameters. When the user is finished specifying the scenario a request string is sent to the WiFiVL servlet (on the Tomcat server in Fig. 2).

The WiFiVL servlet invokes an OTCL script builder which returns a URL pointing to the generated script. The URL is also used to enable the student to retrieve the created OTCL script to further their comprehension of OTCL if required.

The URL of the OTCL file is sent to a custom ns-2 server (which can be run on a separate node); the server retrieves the OTCL file then runs it. The result of a successful simulation is the generation of a trace file bearing the same name as the OTCL file with ".nam" appended. This NAM file provides an event by event view of what happens during the simulation. This file is also made available via a

URL to enable users to run their simulations on custom players.

The NAM trace file is then converted to a format that can be understood by ActionScript 2.0, the Flash scripting language, to enable the display of the simulation. The format that seemed most applicable was XML. The main drawback to using XML is the verbosity involved. If each event is represented in its entirety with multiple attributes the XML file would grow very large. However the compression of these XML files is currently at around 98% which can allow for deployment across slower platforms.

Once converted, the URL of the XML file is passed back to the user's browser and loaded through Flash using ActionScript 2.0.

2.3 Scheduling in Flash

The particular combination of Flash and ActionScript was chosen because it is available cross-platform, it is commonly bundled and/or installed with popular browsers, and it is capable of displaying high quality animations. However, ActionScript, unlike Java, does not provide threads with "sleep" or timing capabilities, which are necessary for switching between events in simulations. This challenge has led to an innovation, the development of a scheduled execution stack written in ActionScript.

The scheduler is implemented as an ActionScript class that controls the execution of simulation events in Flash. The scheduler processes a list of events that are to be executed in the future. This has been implemented as an XML file. The events list is checked with every new frame to see if any events need to be animated and thus removed from the list. The architectural model here is the well known "producer-consumer" situation. The producer is the XML file reader and the consumer is the animation at a specific time event.

The producers' pointer indicates the current progress through the XML file. This pointer can be increased by the scheduler or whenever the execution list drops below a certain value. When increased the pointer progresses through the file and returns a set number of objects until the end of the file.

The animation of a sequence involves mapping real time to simulation time. While the Flash animation is being displayed to the user a new frame is called periodically. This interval and event are used as a slice of execution time in the system. The speed of animation can be around 50 frames per second, each frame is considered to be 1/35000 (s) of simulation time. This divisor can be changed by the user in the animation to control the speed of playback.

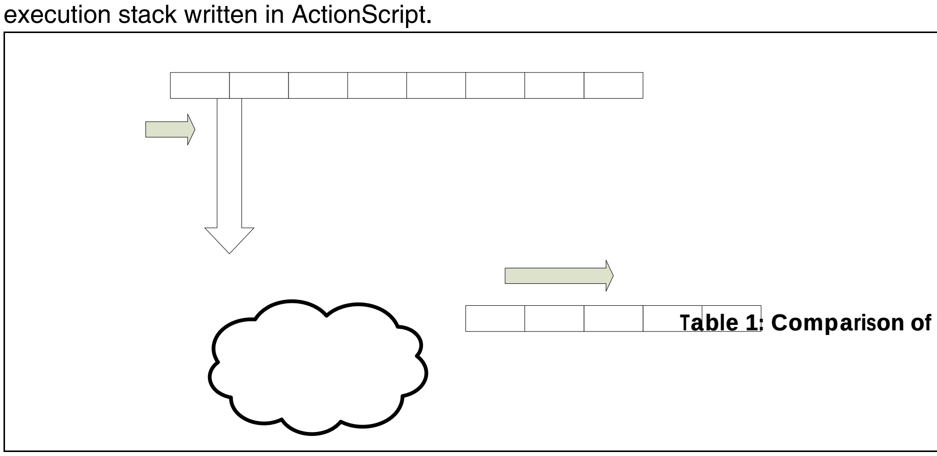

Figure 3: Event switching in Flash

3. EVALUATION

The evaluation presented here is preliminary and based upon the use of the WiFiVL in the BSc honours level Networking and Communications Systems module at St Andrews University. Further and more systematic evaluation is planned for next year.

To date evaluation of three types has been conducted: i) the system has been tested for robustness and its ability to simultaneously serve lab groups of fifty students; ii) observation of users has been conducted and informal feedback solicited; iii) a statistical comparison of exam results, pre and post, has been undertaken.

The system has been tested on MacOs X, Linux, Windows 2000 and Win XP using Mozilla Firefox and Internet Explorer. Under each environment stress testing for 50 simultaneous users was conducted. This was achieved using a test program which was deployed on each machine in a 50 workstation laboratory. Simultaneous requests for scenarios were then generated. The simulations were more complex and longer than normal usage would require. These tests showed that the server and the management code were robust and able to satisfy requests in a timely manner.

Observation and feedback from an honours undergraduate class was undertaken. Observation of the system in use was both positive and informative. The desirability of the following enhancements, which have since been developed, was also identified:

- filters to show only specified traffic and therebye facilitate focus on areas of interest.
- a point and click interface for simulation set up.
- colour coded signalling to more clearly distinguish between different packet types

A simple statistical analysis of examination results was also undertaken to determine whether they suggest that use of the WiFi laboratory has had a discernable effect on student performance. The results given here should be treated with caution for several reasons including; the small sample size and the imperfection of using examinations to measure learning in general.

In part we guard against these limitations by comparing the results from the 2006 WiFi question both with previous years WiFi questions and with other questions in the 2006 diet. In addition we consider the distribution of results as well as the average scores achieved.

The rubric for this module has been unchanged for the period under consideration. The student is required to answer three out of four equally weighted questions. The exam lasts 2 hours and counts for 60% of the final module grade. For each of the years under consideration the module was delivered by the same lecturer. Although the course underwent revision each year this was quantitative rather than qualitative.

Introduction of the WiFi laboratory has facilitated an increase in the weight attached to this subject in the examination from half of one question to a whole question. We see this as a benefit of the work and as being inline with the increasing importance of the subject.

Table 1 contains summative statistics for exam results in 2003, 2005 and 2006. The first column shows that the proportion of students opting to answer the WiFi question has increased to 94%. This high figure is consistent with students feeling confident that they have a good understanding of the material. The second column shows the average

Year	Uptake	Mark	Weight
2006	94%	71%	33%
2005	69%	67%	17%
2003	78%	56%	20%

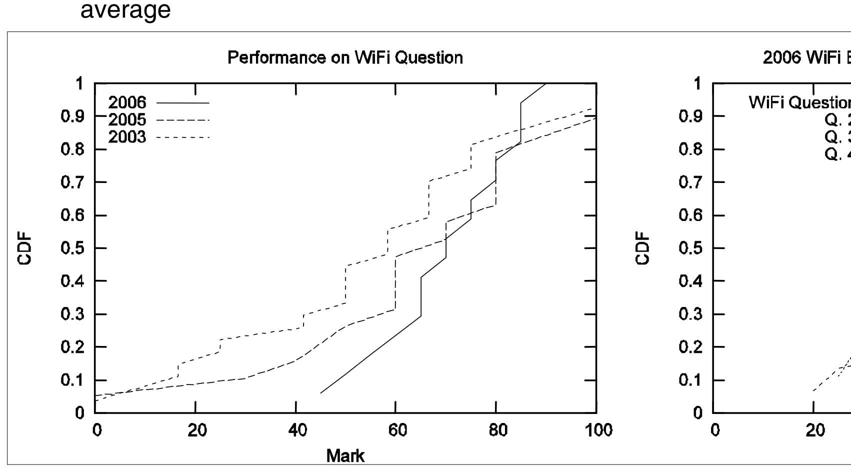

Figure 4: Distribution of Exam marks for WiFi questions in 2003/5/6, and all questions in 2006

mark in each year for the WIFI component of the examination. There is an increase in the average mark from 56% in 2003 to 71% in 2006. Next we discuss the distribution of results. Figure 4 shows two graphs which plot Cumulative Distribution Functions (CDFs). The left hand graph shows the distribution for WiFi questions in 2003/5 and 6. The right hand graph shows the distributions for all questions in the 2006 exam. There are a number of areas of interest.

In 2006 there was a dramatic improvement in the marks achieved by students in the lower quartile. The lowest mark is over 40% and more than three quarters of the students score over 60%. In 2003 and 5 the lowest marks were 0 and the lower quartile was around 40 and 50% respectively. These positive results needs to be balanced as there is little improvement in the upper quartile and the highest grades were higher in 2003/5 than in 2006.

The average normalised mark of 71 for the WiFi question compares with average marks of 67, 58 and 49 for the other questions in 2006. The distribution of marks for the four questions can be seen in the right hand graph of Figure 4. These show higher marks being achieved for the WiFi question across the board with the most significant improvement is again in the lower quartile.

Taken together these results are consistent with our intuition that use of the WiFiVL helps make subject more accessible, less abstract and facilitates explorative learning. They are also consistent with our hope that such an approach would facilitate our students gaining a deeper understanding of the subject.

In summary WiFiVL is capable of classroom deployment, tested for use with 50 students accessing a single server, and has an interface that is fit for purpose. Furthermore our analysis of exam results would suggest that use of the tool makes the subject more accessible, provides an increase in confidence in the subject and allows a deeper understanding of the subject.

4. CONCLUSION

Reusable learning objects have been produced to support learning about, and the teaching of, the widely deployed IEEE 802.11 wireless protocols, often referred to as WiFi. The web site provides two main facilities: a variety of contextual information about WiFi from the historical, technical and standards perspectives, and a Virtual Laboratory where users can create and run WiFi simulations via common web browsers.

The modular design of the WiFiVL software allows for easy adaptation and has opened the door to further exploitation of the ns-2 simulator for educational purposes. In principle, anything that can be run in ns-2 can be broken down into a NAM file and visualised through the Flash animator. This allows for significant code reuse and experimentation with other networking technologies.

Support for scenario re-use, other features of the 802.11 protocols and group learning is planned. The authors welcome feedback on the learning facilities produced to date, which are freely available for non-commercial use at: **`wifi.dcs.st-and.ac.uk`**.

5. REFERENCES

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2. Ousterhout, J.K., *Tcl and the Tk toolkit*. 1994: Addison-Wesley.

ACKNOWLEDGEMENTS

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