ALiCE II:
Cellular Wireless Internet Communication Subsystem for an Autonomous Line-Crawling Robot Designed for Manitoba Hydro

Maciej Borkowski
Christopher Henry
Dan Lockery
James F. Peters, Supervisor
{maciey,chenry,dlockery,jfpeters}@ee.umanitoba.ca
University of Manitoba
Computational Intelligence Laboratory
ENGR E3-576 Engineering & Information Technology Complex
75A Chancellor's Circle
Winnipeg, Manitoba R3T 5V6
Tel.: 204.474.9603
Fax.: 204.261.4639
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Abstract

The is the fifth in a series of research reports from the first phase of the ALiCE II project. This report presents the background and technical details of the cellular wireless internet communication subsystem for the Autonomous Line Crawling Equipment (ALiCE II) robot. ALiCE II is a second generation version of a new family of autonomous line-crawling robotic devices using swarm intelligence system engineering design principles introduced during the past 3 years. Specifically, this report gives the details for the current design of the ALiCE II telecommunication system that includes an implementation using Telus Mobility as a service provider and includes a plan to compare Telus with a similar service offered by Manitoba Telecom Services (MTS). ALiCE II represents the combined efforts of Maciej Borkowski, Christopher Henry and Dan Lockery. The main architect of ALiCE II has been Dan Lockery. ALiCE I was a single line-crawling robot designed by Vitaliy Degetyarov in 1999 as part of his M.Sc. project, which was also funded by Manitoba Hydro. ALiCE II is the focus of Dan Lockery's M.Sc. research project.

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1 Introduction

This report presents the background and technical details of the cellular wireless internet communication subsystem for the Autonomous Line Crawling Equipment (ALiCE II) robot. The motivation for the development of a communication system grew out of a request for email updates from the ALiCE II robot. This idea has evolved into the present implementation which allows for full remote troubleshooting through a secured shell (ssh) connection, updates and communication via email, as well as remote control capabilities through a web based graphical user interface (GUI). It is important to note that the wireless communication system was never designed to supplant the autonomous operation of ALiCE II but to enhance the feature set and desirability of the robot. Furthermore, this reports documents a need to compare the current Telus Mobility implementation with a similar service offered by Manitoba Telecom Services (MTS). An important result of this research has been the introduction of a family of email messages where the subject line a message sent to ALiCE II serves as a command sent to the robot. For example, if a message is sent to ALiCE II with the subject "get image", the robot responds by attaching an image of what it is currently "seeing" to a new email message in reply to the subject-line command. This report is organized as follows. Background definitions and theory is presented in Sect. 2. Sect. 3 presents the details and hardware specifications of the AirCard 580 used in the current ALiCE II design, and Sect. 4 provides a description of the software implemented in the communication system.

2 Background

This section presents the background needed to understand the operations of the cellular wireless internet communication system. Fig. 1 contains the main logistical components of the communication system. The yellow comm link in Fig. 1 represents a Point-To-Point Protocol (PPP) connection to the Telus network[1]. The PPP connection protocol is used to establish a direct connection between two nodes (in this case ALiCE II and the PPP server) [6]. ALiCE II[2] connects to the internet in a manner similar to the traditional modem operating over the telephone lines of a Plain Old Telephone System (POTS). In both cases a connection is made between the modem and a server by establishing a PPP communication link. The only difference between these two cases is the medium in which the connection is made. Specifically, ALiCE II uses the Sierra AirCard 580 Wireless WAN Modem (see, *e.g.*, Fig. 2) to establish the connection to the PPP server over the Telus cellular network. PPP has three main components [5], a method for sending data over the connection between two nodes, a Link Control Protocol (LCP) for maintaining the data link, and a suite of Network Control Protocols (NCPs) used to establish and configure different network-layer protocols. Specifically, the NCP protocol used to establish the IP address is the PPP Internet Protocol Control Protocol (IPCP) which negotiates the IP address only after the data link has been established and tested [5].

An IP address is a unique 32-bit internet address containing a network and host identifier, and is commonly written in the form shown in Eq. 1 [8].

$$130.179.XXX.XXX \tag{1}$$

Furthermore, there are different classes which state the number of bits of the address that represent the network identifier. This identifier is extracted from the address through the use of a subnet mask. A detailed discussion of IP address classification and subnet masks is presented in [2, 3, 8] and is outside the scope of

[1]The term "network" discussed in this report refers to a Wide Area Network which represents a network that covers a large geographical area, involves large arrays of computers, and impart (or completely) consists of circuits provided by a common carrier [8].

[2]The main processing unit of ALiCE II is the TS-5500 compact full-featured PC compatible Single Board Computer based on the AMD Elan520 processor [9].

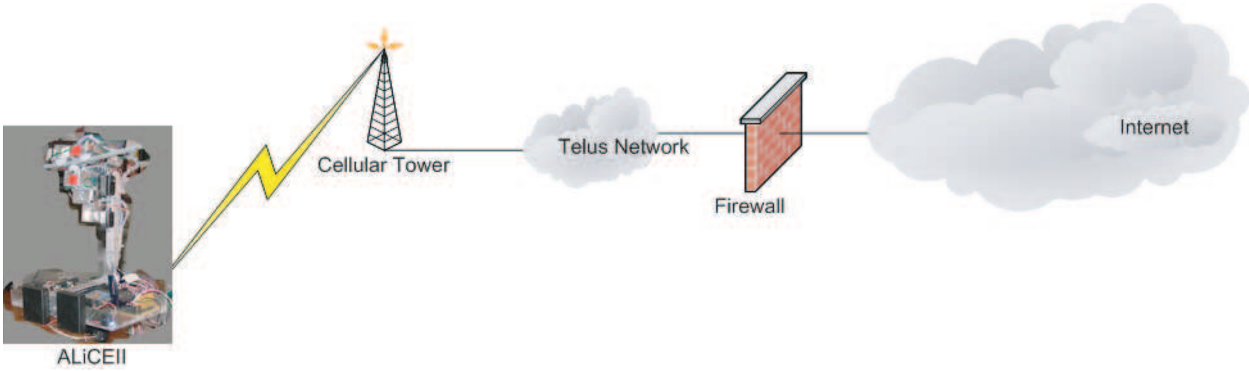

Figure 1: ALiCEII Communications Diagram

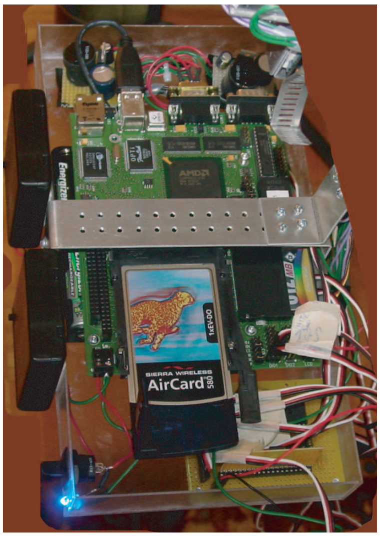

Figure 2: ALiCE II and the Sierra AirCard 580 Wireless WAN Modem

this report. However, it is important to note for our discussion that the term “different network” is used to differentiate between WANs. This means that each network is assigned a different range of IP addresses, for example the addresses in the range $24.79.XXX.XXX$ represent a different network than the one given in Eq. 1.

Sometimes networks are isolated by a firewall. A firewall is a software or hardware entity which restricts access to a network based on a security policy with the ultimate goal of increasing network protection (see, *e.g.*, Fig. 1). Usually a firewall is a single point of defence between two networks and acts to isolate a company's private networks from their public ones [1]. In fact this was the case when we started testing with the AirCard 580. It was observed that we could not access the card from outside the network. As a result we contacted Telus and they confirmed that we should not be able to initiate communication with the IP address from outside the Telus network. Only traffic initiated through the AirCard 580 would be allowed through the firewall.

A Proxy Server is an intermediate point of communication which acts both as a server and a client for the purpose of making requests on behalf of a client (usually because the client is located behind a firewall) [8]. However, in this case the firewall is preventing outside requests to ALiCE II. Here, the general idea is for ALiCE II to initiate a connection to a proxy server accessible on the internet. Then, any party interested in connecting to the protected bot would instead connect to the proxy server (because an attempt to connect directly would fail). From then on all communication is directed through the proxy server.

Finally, this section ends by describing some terms used in the following sections.

Ping: Is a tool used in TCP/IP networks. It is used to test whether a host (a computer connected to a network) is operating correctly, and is reachable from the network where the ping originated [10].

Hypertext Transfer Protocol (HTTP): The protocol considered to be the foundation of the World Wide Web (WWW) [8]. HTTP is mainly implemented between a web browser and a web server and is used for the efficient transfer of data such as text, hypertext, audio, and images.

Secured Shell (SSH): Referees to both a program and a protocol for securely connecting two hosts over an insecure network [10]. The function of the program is to allow users enter commands on a remote networked computer.

3 Sierra AirCard 580 Wireless WAN Modem

Currently, the ALiCE II robot uses the Sierra AirCard 580 Wireless WAN Modem to connect to the internet. Our choices for a wireless internet service provider were Manitoba Telecom Services or Telus Mobility. Currently, the service provider for ALiCE II is Telus Mobility. The service coverage area is anywhere within the city of Winnipeg. This decision was based on the purchase price (without a service contract) of the aircard offered by both companies. We did not want to commit to an extended contract because the card is only for testing purposes and will not be in use for 2 years (minimum contract length). We were quoted $250 by Telus and $799 by MTS to purchase the card. Furthermore, we subscribe to the service on a monthly basis and can cancel at any time. Our current plan is $100 month and includes unlimited data transfer at rates of 40-60 kilo bits per second (kbps). Currently both companies operate on a CDMA network and both have indicated that they will be upgrading to an Evolution-Data Optimized (EVDO) network sometime during Spring 2006. The new network will be capable of achieving data rates of 400-700 kpbs. At present, the AirCard 580 meets our needs. However, as was mentioned in Sect. 2 the Telus network contains a firewall which requires the use of a proxy server. Furthermore, MTS has indicated that the IP address of their cards is not blocked by a firewall and should be accessible without the use of a proxy server. As a result, it is necessary to compare the AirCard 580 offerend by Telus Mobility with the AirCard 555 provided by MTS. This AirCard 555 is also necessary in order to compare signal strength, connection drops, connection duration, and connection speeds.

LED Behaviour	Indicates
Red blinking slowly	The AirCard is powering up, or no service is available.
Green blinking rapidly	An active data session is in progress.
Green blinking slowly	The AirCard has acquired a channel and is in idle mode (no active data session is in progress).
Solid red	An error has occurred.

Table 1: LED Operation

3.1 Hardware

This section presents some of the main hardware specifications of the AirCard 580 [7]. The AirCard 580 has a single red/green LED on the antenna end of the card. The LED operations are given in Table 3.1. The radio frequency and electrical specifications are given in Table 3.1. Finally, the environmental specifications are given in Table 3.1.

4 Software

This section contains descriptions of a software developed for the AirCard 580 card.

4.1 Proxy Server

As described at the beginning of this chapter, the main problem with a point-to-point communication setup is the inability to reach the IP address of the AirCard 580 from the outside of the Telus network. In fact, the AirCard 580 can be seen as hidden behind an firewall, see figure 3. The AirCard 580 can connect to any IP address on the internet, but no client from the outside network can connect directly to the AirCard 580.

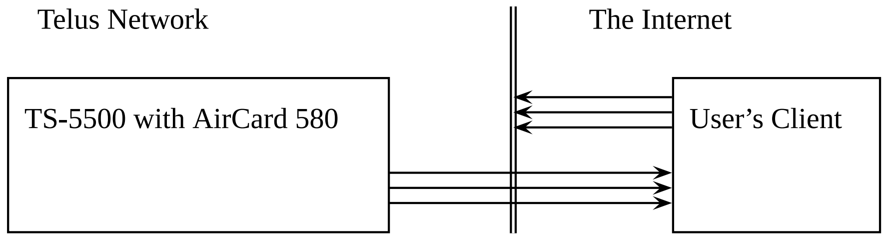

Figure 3: Overview of the point-to-point connection with a firewall between Telus network and the internet.

There are two services, which require the connection from the client's computer to the AirCard 580. These are *http* service and *ssh* service. In order to make these services available from any IP address on the internet a specialized proxy server was designed and implemented. This proxy server runs on a machine, which is visible on the internet. The TS-5500 initializes connection with the server (called *static* connection). After the connection is established, the proxy server has a two way connection with the TS-5500. From this point, all connections from the outside of the Telus network are processed through the proxy server (using *dynamic* connection). Fig. 4 shows the overview of the proxy communication system.

4.1.1 Proxy components

The proxy server consists of two programs. Both programs were written in Java (see [11]) and are easily portable to several operating systems. One server runs on the TS-5500 board and one on the machine visible

Approvals	Compliant with: IS-2000 Release 1.0 (CDMA (1X)) IS-707-A Data, IS-856 (CDMA 1x-EVDO) IS-866, IS-878, IS-890, CDMA Developers Group FCC (ID: PNF-PC3220P) Industry Canada
Voltage	+3.3 Vdc from PCMCIA Slot
Current	Maximum: 950 mA Typical data call current (talk mode): 370 mA (1X) 470 mA (1xEV-DO) Standby: 110 mA (1xEV-DO/IS2000 hybrid mode)
Transmitter Power	200 mW (+24 dBm)
Transmit	PCS: 1805 to 1870 MHz Cellular: 824 to 849 MHz
Receive	PCS: 1715 to 1780 MHz Cellular: 868 to 894 MHz
Channel Spacing	1.25 MHz
Frequency Stability	± 150 Hz

Table 2: Radio Frequency and Electrical Specifications

Operating Temperature **Storage Temperature**	-20 to +60°C (ambient, outside PCMCIA enclosure) -30 to +65°C
Humidity	95%, non-condensing
Vibration	15 g peak 10 to 2000 Hz (non-operating)
Drop	30” (76.2 cm) on to vinyl covered concrete

Table 3: Environmental Specifications

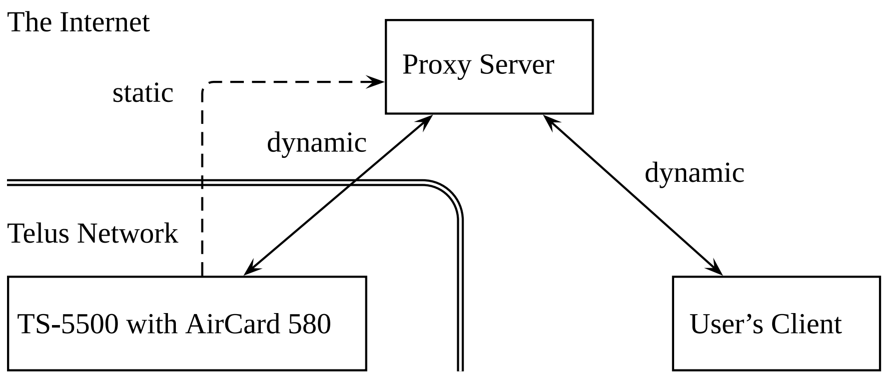

Figure 4: Overview of the point-to-point connection with a firewall between Telus network and the internet.

on the internet, compare with Fig. 6. The server run on the TS-5500 board is called the inside server (since it is located inside the Telus network). The server located on the machine accessible from the internet is called a outside server. Fig. 5 shows the class diagram[3] of a proxy server implemented for ALiCE II.

4.1.2 Connecting sequence

This subsection contains a short description of the sequence of steps required to access the TS-5500 from the internet. The summary of this process is shown in the algorithm 1.

First, the two proxy servers are started. Then the inside server initiates the connection with the outside server. This connection, called a static connection, is used for sending requests for connection to the inside server. After the static connection is created, the servers are ready and waiting incoming connection requests.

Assume that a client wants to open a web page on the TS-5500. The client connects to the outside server using port 80, see step 4. The outside server requests the connection from the inside server using the static connection. The inside server connects to the TS-5500 using the port 80 and closes the connection loop with the client by creating the dynamic connection with the outside server.

Algorithm 1: Connecting sequence

```
1 Start outside proxy server
2 Start inside proxy server
3 Create static connection between proxy servers
4 foreach New client connection do
5     Request inside proxy for connection
6     Connect to the TS-5500
7     Connect to the outside proxy
8 end
```

4.2 Web Server

The TS-5500 board is equipped with the Apache [12] web server. It is capable of running PHP [13] scripts. A web based interface was implemented to allow the user to control remotely the Linux [14] operating system running on the TS-5500. By logging into ALiCE II web page the user can run Linux commands like

[3] Class Diagram created using Altova Umodel software `http://www.altova.com/en/`

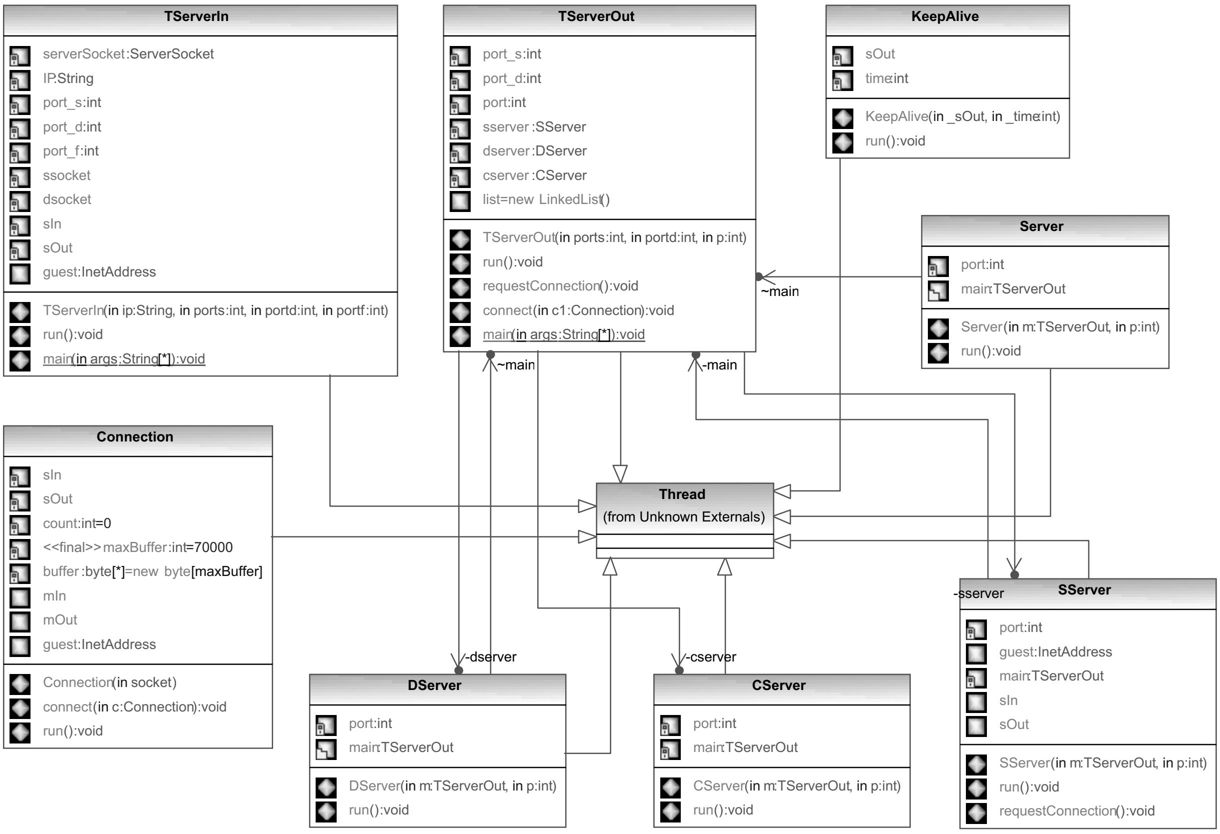

Figure 5: Class diagram of proxy server.

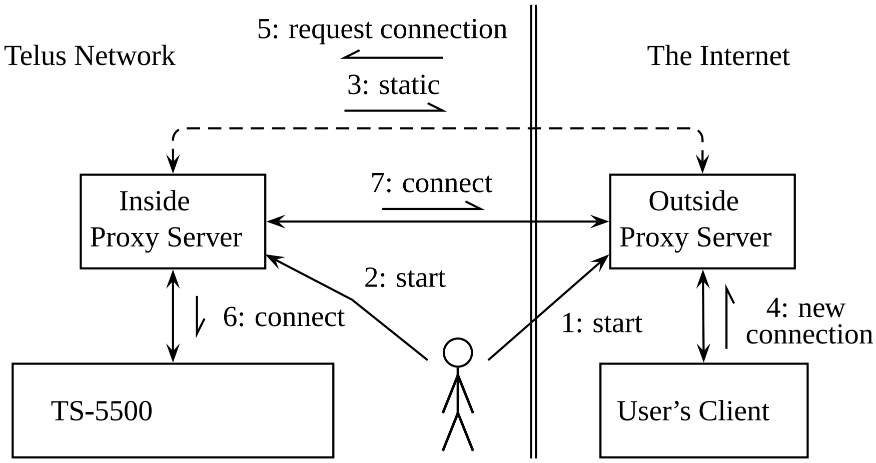

Figure 6: Overview of the point-to-point connection with a firewall between Telus network and the internet.

in terminal window. The commands are executed and the results are shown on the web page. See Fig. 7 for example of checking the up-time on the TS-5500. Several most commonly used scripts were implemented into buttons decreasing the time needed to perform service tasks on TS-5500.

4.3 Email Server

The TS-5500 has ability to receive and send e-mails. A Perl [15] script controls the handling of incoming e-mails, executing of requesting tasks and sending e-mails back with the results. Similarly to the web-based user interface, the user can run any Linux command on the TS-5500 board like in terminal window. The command is run and results are send back to the user. An e-mail can contain several commands, which will be run sequentially. See Fig. 8 for example of checking the up-time on the TS-5500.

Most commonly used actions can be implemented into the script handling the e-mails. As an example, a image acquisition sequence was implemented. If the e-mail's subject contains only words "'get image"', the TS-5500 takes an image and sends it back to the sender in an attachment. See the table 4 for summary of commands recognized by ALiCE II mailing script.

Action	Subject	Body
Run Linux command	run on ALiCE II	run: cmd [run: "cmd1;cmd2;...;cmdN"]
Receive image	get image	

Table 4: Summary of commands recognized by ALiCE II mailing script.

5 Conclusion

At present, the cellular wireless internet communication subsystem for the Autonomous Line Crawling Equipment (ALiCE II) robot has been successfully implemented using the AirCard 580. However, as was mentioned in Sections 2 & 3 the Telus network contains a firewall which requires the use of a proxy server. Furthermore, MTS has indicated that the IP address of their cards is not blocked by a firewall and should be accessible without the use of a proxy server. As a result, it is necessary to compare the AirCard 580 offerend by Telus Mobility with the AirCard 555 provided by MTS. Future work would consist of verifying

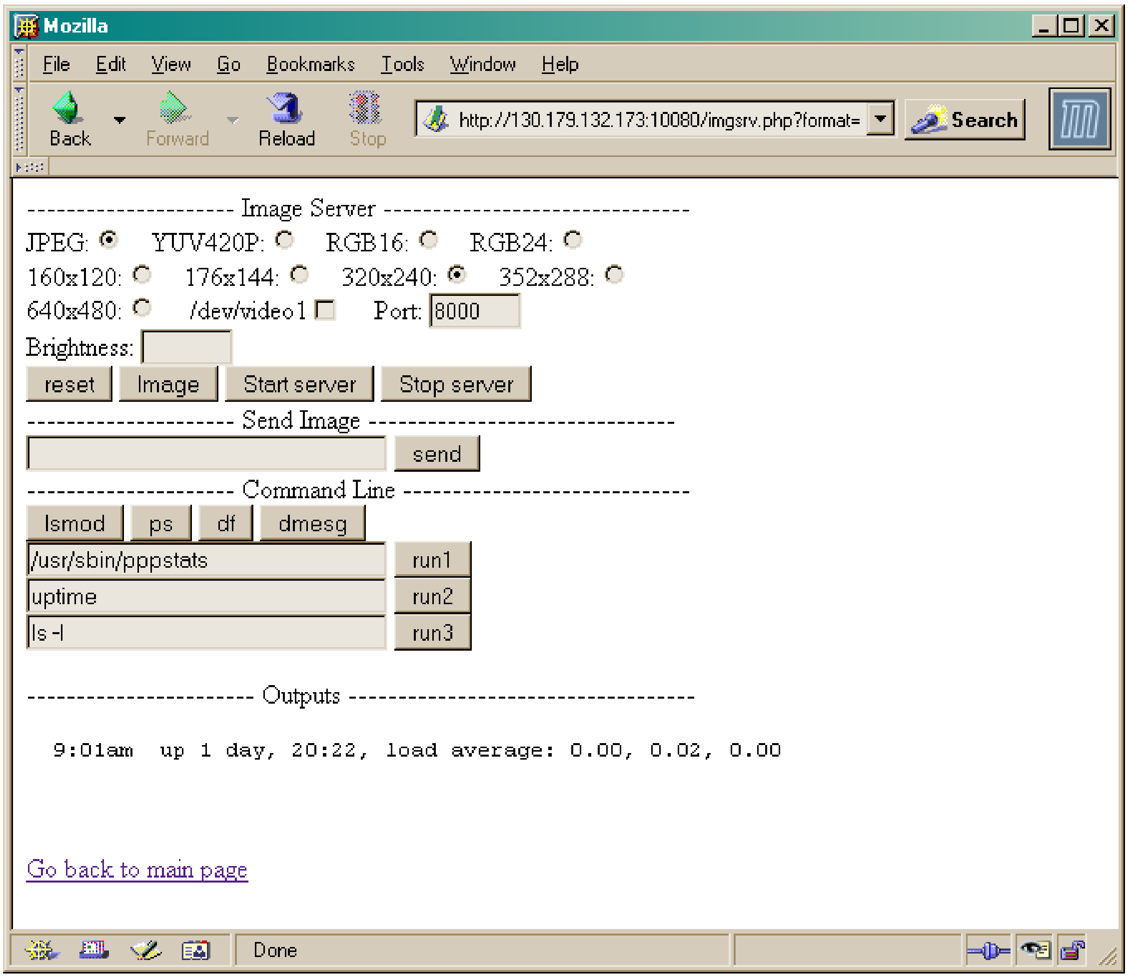

Figure 7: Web-based user interface running on ALiCE II

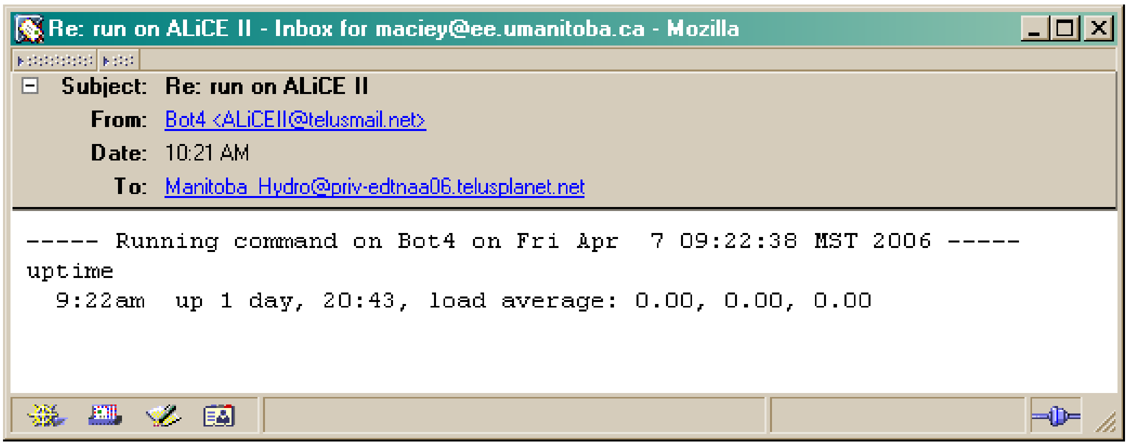

Figure 8: Response from ALiCE II for the up-time request.

that a proxy server is not required when using the AirCard 555 as well as testing to compare signal strength, connection drops, connection duration, and connection speeds.

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