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A framework for collaborative remote experimentation for a physical laboratory using a low cost embedded web server

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ABSTRACT

A TCP/IP-based scientific instrument control and data distribution system have been designed and realized as part of a low cost e-learning strategy to allow an institution of learning to offer remote access to a distant, physical laboratory for collaborative experimentation using a highly embedded web server. In principle a single experimental setup in the remote laboratory can be monitored and logged simultaneously by any number of permitted clients through a simple, custom web browser interface. The system features an IEEE 802.3 compliant full-duplex Medium Access Controller (MAC) and Physical Layer Device connected to actuators and measurement transducers for control, data acquisition, distribution and logging over a local high-speed TCP/IP network. The designed system differs in its approach from most contemporary approaches in that it specifies circuit level components required to set up a low cost collaborative remote experimentation server. The system hardware comprises a server made up of a PIC18f2620 and ENC28j60 and client PC terminals interconnected through a network hub. The software comprises the firmware, written in C and Javascript, and a simple client web browser written in the Visual Basic.NET framework. This custom client browser approach circumvents the restrictions that standard client browsers place on direct file system access while optimizing data acquisition and transport while better handling several exception scenarios and implementing an authentication mechanism for secure client access. The system suggests a simplified external ROM-based client authentication solution to the problem of embedded system security that is of growing global concern. The figures of merit of the system, such as the round-trip times and the inter-sample times, are determined. Finally, typical data outputs of two networked PCs in a collaborative monitoring of temperatures in Newton's law of cooling experiment are presented.

1. Introduction

It is widely accepted that ongoing innovations in the area of embedded systems in education (Wolf and Madsen, 2000; Beetner et al., 2000) coupled with the potential of TCP/IP networks (Woodroffe et al., 2008; Schreier, 2007) are driving the reassessment of the curriculum in the technical subjects. By themselves, embedded Micro-Electro Mechanical System (MEMS) controllers are increasingly being found in standalone experiments dealing with control, data acquisition and communication with a host computer. By integrating MEMS with TCP/IP functionality it is possible to attain high performance to cost ratios, cross-platform compatibility and scalability while observing general ease of development. However, in spite of these indicated benefits, a review of the literature indicates that the potential of TCP/IP networks for the purposes of remote measurement, control and general data acquisition remains largely unexplored. The traditional approach to incorporating TCP/IP functionality has been to use a computer that has hardware input–output interfaces for experiment control and monitoring as an add-on card, and a web interface setup to allow the computer to function as a server. Thereon remote collaboration may be configured. Callaghan et al. (2002, 2006, 2007) and Rodríguez et al. (1999), for example, take this approach.

In the present article we approach collaborative web-based experiments differently through a highly embedded design. A web-enabled controller is integrated at circuit level thereby removing the host computer from the loop and allowing the embedded system to function as the host. It is built on the hardware and software principles of Ocaya and Minny (2010) and demonstrates the feasibility of collaborative remote experimentation using a low cost but highly embedded web server. While the resulting solution appears technically demanding, it is within the grasp of most embedded system designers. Although innovations have made available many low cost high-speed embedded controllers that meet the protocol handling requirements for a networked application, there are still many general

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