Low-Cost Cloud SCADA System Proposed for Education Purposes

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Abstract— Applied Microcontrollers course is a project-based learning (PBL) methodology. The Project Based Learning (PBL) methodology is considered one of the most effective ways for the student to obtain the ability to solve problems. However, these systems infrastructures have a high price and closed architecture, which prevent the student to understand how the system was developed and be just users for them. A prototype based on Cloud SCADA System, CSS, was proposed as an educational tool to be used for entitled Applied Microcontrollers course which can used with Control and Automation Engineering students. This course has project-based learning (PBL) methodology which can be either software programming or building a hardware test rig. This prototype is now used in the discipline mentioned in order to teach practical lessons about embedded systems projects, wireless communication, data acquisition and supervisory systems for students of different Bachelor and Master degrees in engineering at the Faculty of Technology and Education, Helwan University. As all stages of the project were declared to the students in detailed way and its development was performed on a real time application, the students showed a lot of interest about this tool during most of the year. This is due to the fact that the theoretical issues discussed in the lectures are presented and observed in practice. Furthermore, this methodology prepares students for the market, as it promotes the development of leadership skills, decision making, time planning, teamwork, conflict resolution and synthesis of results on students.

Keywords: Project Based Learning (PBL), Cloud SCADA System, real time application, teaching unit.

I. INTRODUCTION

The Microcontrollers Applied to Control Engineering and Automation discipline was created in order to establish the theoretical content seen in the undergraduate course of Control and Automation Engineering through the methodology of project-based learning (PBL). So, the discipline has aroused much interest in the students and contributed to the development of several final course works [1, 2]. A prototype for a PBL system is presented in [1, 3] which has a drive unit and a computer program. This prototype was developed using a PIC18F4550 microcontroller and various electronic components: resistors, capacitors, LEDs, among others. The computer program was developed using programming language C Sharp (C #) In Visual Studio development environment. The interface between the program and the device is performed via USB communication.

Furthermore, the focusing of all information about the process under consideration in a single system will facilitate the analysis to improve the system performances. Research [4] developed SCADA system that was realized on a platform .NET Framework in the C# language. Also, a simple temperature control scheme is developed in [5] using ATMEGA2560 microcontroller and industry standard SCADA software Vijeo Citect v7.2. Which use of MODBUS ASCII protocol to set up a temperature control system which collects real time temperature data, processes the data and performs the desired control action. References [4, 5] also show the development of low-cost SCADA systems. A software architecture presented in [6] for the development of educational laboratories, through industrial virtual plants which models and logic are implemented in Matlab and used within LabVIEW through an appropriate protocol. LabVIEW from National Instruments, a specific purpose software for this kind of applications, was used, since it allows us to provide a friendly interface, to perform communications, data acquisition and the information management. Cloud SCADA systems are used generally to ensure process quality, reducing operating costs and improving production performance. Another research [7], deals with the development of a SCADA system to be used in a flexible manufacturing cell for educational purposes in different automation engineering fields (SCADA development, PLC programming and industrial communications). The application communicates through the internet with four controllers, by means of an OPC server. Also, visualizes fully information about the elements of the cell, using a video streaming of an IP camera, and its features tracking and reporting is capable.

An educational platform for the design of SCADA system for irrigation programming combined with a scale model of a trickle irrigation system is described in [8]. This tool facilitates the students of Agricultural Engineering to testing and simulating different irrigation systems, using this efficient and low-cost tool. Moreover, linking the SCADA system with the LabVIEW program (graphical programming language); complex mathematical models for irrigation, data collection and sampling, and on-line programming through internet are introduced. Also, research [9] describes a lightweight implementation of a SCADA system for process monitoring and control using

eLab SCADA Master Tool Kit. The system provides a modular architecture and can be used for a variety of different processes or devices of scientific and educational nature. In research [10], a design and development of a SCADA course has been presented in which, starting from description of the course, a design of an undergraduate level course in terms of lecture materials, laboratory experiments, student projects, assessments, and, finally, an overall teaching experience. In research [11], make a serious effort to achieved the required knowledge/skill in academia and institutions of higher education to protect Industrial Control Systems, ICS, against cyber-attacks.

II. PROPOSED SYSTEM

On RSS as shown in Figure 1, there are two main points to deal with, the latency of the request and security of the system. The proposed system is used to improve these two parameters to obtain the needed values. Nowadays all systems need to be online and remotely controlled by cross-platform applications like RSS, so let's start to get more details about it. The encryption algorithms used in RSS are RSA and CBC block cipher encryption system. It is a mixed way to prevent any attacker from breaking the cipher. Each two transceiver sides have private key for RSA, public key for RSA, initialization vector for CBC, and encryption key for CBC. With this combination, the speed of symmetric encryption system and the security of asymmetric encryption system have been achieved. On the other hand, the level of security firewalls needed to be Brocken by the attacker to brock the cipher has increased.

Features of the Proposed CSS

Figure 2 shows CSS features which are stated as follows:

- CSS is user friendly program that requires no pre-knowledge just go to site and start to use.

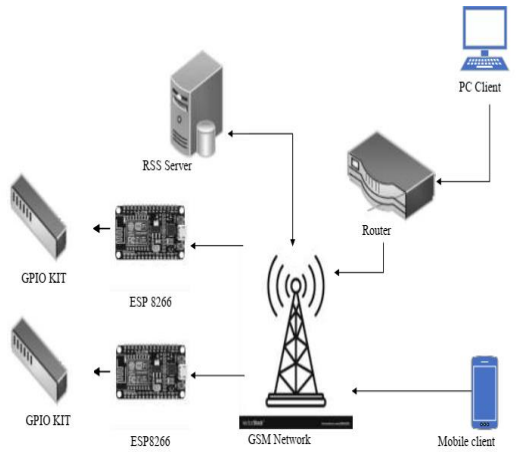

Figure 1 Cloud SCADA System (CSS) Block Diagram

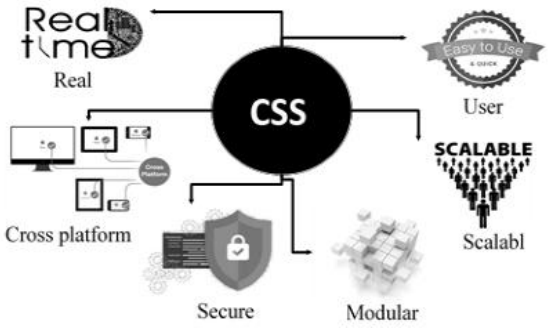

Figure 2 Cloud SCADA System (CSS) features

- CSS is a scalable program which can easily control larger and larger number of nodes on other hand; there is no limit for number of nodes connected to it.
- CSS is based on modular code which simplifies development in the future.
- CSS application is a cross platform application which can be open in any browser on android, IOS, PC or MAC, because it based on responsible page content to modify containers to screen width.
- CSS is a very secure program that has 4 security levels, authentication, authorization, RSA and CBC encryption system.
- CSS provides a real-time response to changes in order to get rid of timing error in emergency cases. Its latency depends only on the speed of the internet access.

2.1 Proposed Hardware

ESP8266: it is used as a simple hardware construction of a Remote Terminal Unit, RTU, for CSS. ESP8266 is used as a microcontroller with integrated WIFI module to connect the node to global network in order to receive and transmit data to the RSS server remotely. This WIFI module has a variety of GPIOs which can be used in reading analog signal, reading and writing digital signals and PWM signals to control motors and other PWM-controlled devices. The schematic and PCB layout for the used card are given in Figure 3, 4 respectively.

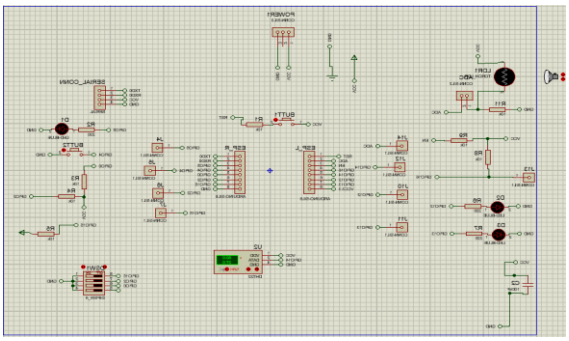

Figure 3 Schematic circuit for interfacing ESP8266-12E.

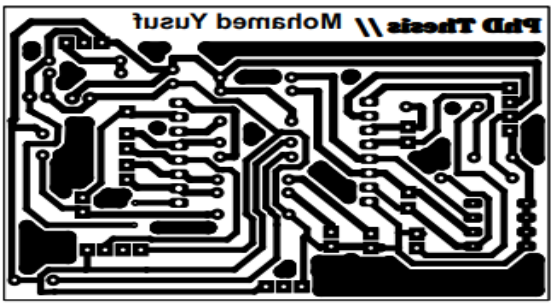

Figure 4 PCB layout for interfacing ESP8266-12E.

Router: it is used as a WIFI hotspot connected to global network in order to remotely access the node from anywhere.

Server: A Server is a computer or a device on the network that manages network resources. Servers are single-tasks device, which perform only their own server tasks. A server in this case could be a program which managing resources rather than the entire computer.

2.2 Proposed Software

Block diagram of program cycle

As indicated in Figure 5 the RTU Node start to send a handshaking request command to the server which start to verify that is that Node Address exists in our TRU's or not. When the server verified the Node, it starts to send its configuration and the Node start to configure its GPIO modes of operation according to the server configuration. When any changes to any of the Node GPIO status occurs, it sends another request to the server, if not, it send frequently request to the server each 500 msec. also, if there any changes in the Node configuration the server send changes request to the Node.

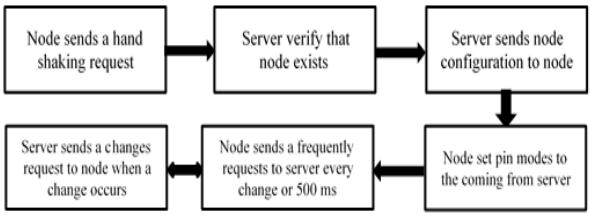

Figure 5 Block Diagram of Proposed system Program Cycle

Arduino Codes

Sample of Arduino Codes are illustrated in Figures 6, 7 for the function used to connect to Wi-Fi and the function used to send Get-Request respectively:

```
void connectToWIFI(const char *ssid, const char *password)
{
  WiFi.mode(WIFI_STA);
  delay(1000);
  WiFi.begin(ssid, password);
  Serial.println("");
  Serial.print("Connecting");

  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }
}
```

Figure *6 C*onnect to WIFI function

```
String sendGetRequest(String host,String msg){
  String payload;
  HTTPClient http;
  String link = host + "nodeData?nodeId="+String(ID)+"&msg=" + msg;
  http.begin(link);
  int httpCode = http.GET();
  if (httpCode > 0) {
  payload = http.getString();
  //Serial.println(payload);
  }
  http.end();
  delay(REFRESH_RATE);
  return payload;
}
```

Figure 7 Send get request function

More details for Arduino Code flowchart can be done as shown in Figure 8.

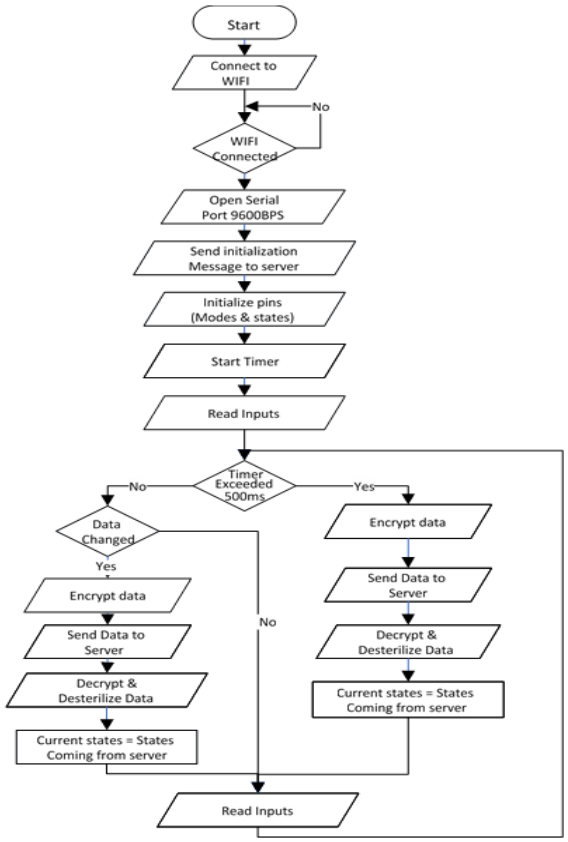

Figure 8 Arduino Code flowchart

3. Proposed CSS GUI Interface

Figure 9 show a screen shot for administrator user in proposed CSS GUI interface. This administration options are create new user, create new admin, monitoring current users, delet user, create nodes, monitoring and control current nodes, delet node and change password.

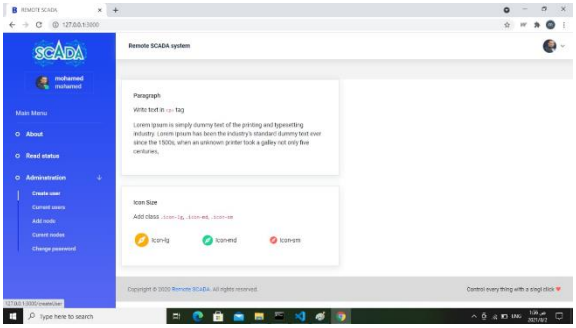

Figure 9 Adminstration Options

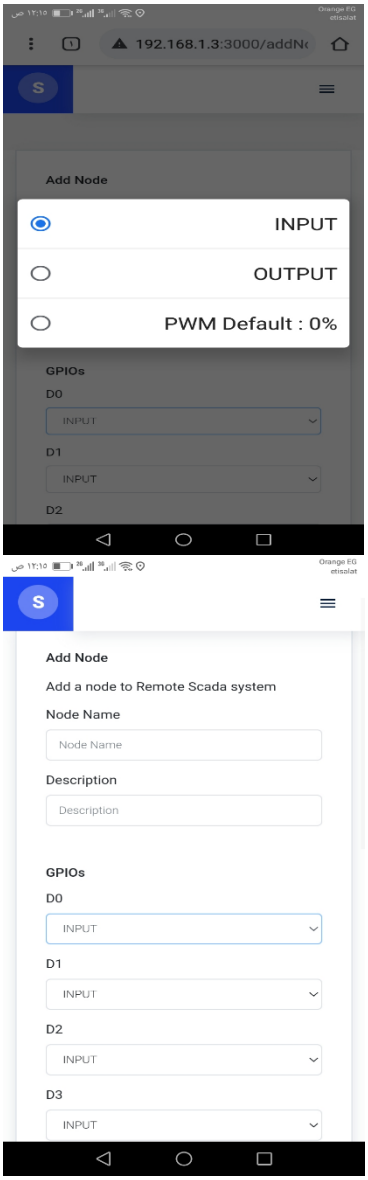

Figure 10 Add New Node and choose its Options windows under Android

Figure 10 shows how to add a new node and how to classify its Input/Output options with the proposed RSS runing under Android Cell Phone.

4. Results for the Teaching Unit

The stability of the note card was calculated for a sample of students of the fourth year at the College of Technology and education majoring in electronics technology and the number of students reached (10) students and the observation are recorded after introducing the teaching unit in Chart 1. Observation stability was calculated by applying the observation card by three specialists in the field of electronics technology. The correlation coefficient was calculated by using Pearson's equation, where the correlation coefficient between (x-y) was 0.982, Table 1. The correlation coefficient between (x - p) reached (0.960), and the correlation coefficient between (p - y) reached (0.970), which is considered a high value for the correlation factor, and this indicates the high stability of the card.

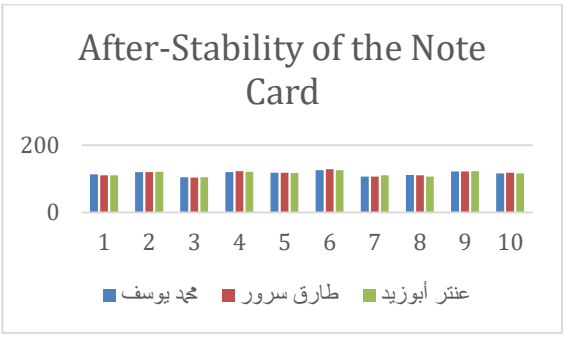

Chart 1 - After-Note Card Observation

Table 1 - Sample of Note Card Measurement for Persons (x, y)

Correlations			
		Person(x)	Person(y)
Person(x)	Pearson's Correlation	1	.982**
	Sig. (1-tailed)		.000
	N	10	10
Person(y)	Pearson's Correlation	.982**	1
	Sig. (1-tailed)	.000	
	N	10	10

****. Correlation is significant at the 0.01 level (1-tailed).**

Pre-Application for the Achievement Test

The researcher clarified the objective of the research for the research sample, and then the achievement test was pre-applied, which deals with the cognitive aspect related to measurement skills in implementing practical training on (30) students from the fourth-year students majoring in electronics technology at the College of Technology and

Education on Sunday 11/14/2020 Inside the electronics and communications laboratories at the Faculty of Technology and Education, Helwan University and the aim of this experiment was determine the following:

(1) The test stability calculation: The test stability was calculated using the retest method within (21) days, the correlation coefficient was calculated, and the reliability coefficient was extracted according to the "Pearson" equation. The test reliability coefficient was (0.828), which is a suitable stability factor for the test.

(2) Calculating the achievement test time:
Average time of fastest three students = 27 + 30 + 33/3 = 45 minutes
Average time of the three slowest students = 37 + 40 + 43/3 = 40 minutes
The average test time = (45 + 40)/2 = approximately 45 minutes, and (5 minutes) was added to reading the test instructions, and thus the final time for the exam reached (50 minutes).

The researcher prepared a table of the final scores in the achievement test before and after the educational unit is trained by them, and the chart for these results are listed in Chart 2. The researcher used the computer program known as the "Statistical Package for the Social Sciences "SPSS" Data, in calculating the average scores of the students in the pre and post application of the note card and calculate the value of (T) and calculate the mean of the scores and the standard deviation, as shown in Table 2.

Chart 2 - Student Marks for Pre and Final Exam

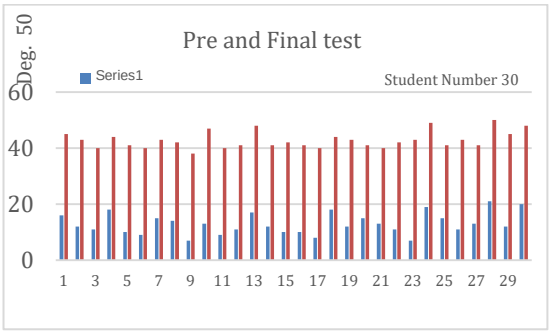

Table 2 Value of (T) of observation card for experimental group

Application	Average	standard deviation	number of students	Degree of freedom	calculated value (T)	Significance level	ETA box
Tribal	27.26	4.91	30	29	52.152	0,01	0,95
Posttest	115.36	8.18					

5. Conclusion

The proposed Remote SCADA System (CSS) is a smarter, faster and more reliable way to control high power machines and monitor their sensors, data, and failures. It's mainly based on standard communication techniques between remote nodes and single server-side application that talk to each node with its own ID and modify its instant database so that every time to access this web app you get a real-time access to these nodes data and a virtual control room control each GPIO in the selected node. When a new event happened in server-side program it will be broadcasted to all related nodes to this event. Each unit of the Remote Terminal Unit, RTU, was implemented using an ESP 8266-EXUnits. The interfacing to the ESP unit is carried through some of its GPIO's for monitoring and controlling the low-level devices. Also, an analog input can be connected through the ADC channel of the ESP and analog output can be output through its PWM channels. Multi-Points of the RMU (ESP's) can be added to the cloud SCADA system, and the MTU of the system can handle all of them for monitoring and controlling. Comparing the cost of our system with pervious work, it's lower than Arduino + WI-FI method by five times and 13 times lower than Raspberry-PI method. On Cloud SCADA System, CSS there are two main points to deal with, the latency of the request and security of the system. These two pointes are covered also here to ensure a higher-level security system. The proposed CSS, is a very secure program that have 4 security levels, authentication, authorization, RSA and CBC encryption system. Also, the encryption algorithms used in RSS are RSA and CBC block cipher encryption system. It is mixed way to prevent any attacker from breaking the cipher.

6. References

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