Design and Implementation of IoT Based Smart Laboratory

M. Poongothai
Department of ECE
Coimbatore Institute of Technology
Coimbatore, India
e-mail: poongothai@cit.edu.in

P. Muthu Subramanian
Department of ECE
Coimbatore Institute of Technology
Coimbatore, India
e-mail: muthusubramanian@cit.edu.in

A. Rajeswari
Department of ECE
Coimbatore Institute of Technology
Coimbatore, India
e-mail: rajeswari@cit.edu.in

Abstract—**Internet of things (IoT) provides a platform that allows devices to be connected, sensed and controlled remotely across a network infrastructure. This work aims to develop a smart laboratory system in CIT campus based on IoT and mobile application technologies to monitor the overall activities of the lab including energy consumption and utilization of devices, environmental parameters via sensors, thereby providing a smart environment to CIT with energy efficiency and comfort. IoT smart hardware kits are designed using ESP8266, Arduino UNO, relays, current transformers, Raspberry Pi3 and sensors. The proposed work controls and monitors the devices of the CIT IoT lab using the dashboard developed in Node-RED or ANDROID STUDIO Mobile Application. Devices in laboratory are connected to IoT smart hardware kit. Dashboard and Mobile Application has been developed for interfacing IoT smart hardware kit & MQTT broker. Node MCU is also coded to monitor and update the temperature, humidity and light intensity inside laboratory. A database has been created for a prototype switch to view status history. From the results of implementation, it is observed that the appliances in our lab are remotely monitored and controlled, thereby reducing their energy consumption considerably.**

Keywords-Internet of Things (IoT); Embedded Computing System; MQTT; ESP 8266; Arduino board; Smart systems

I. INTRODUCTION

More than 85% of systems are unconnected, and do not share data with each other or the cloud. One such technology that facilitates the interconnection is the INTERNET OF THINGS [6]. The Internet of things is a communication paradigm that refers to the idea of connecting the objects of everyday life to the internet. These objects are assembled with microcontrollers, transceivers to enable communication, and configured with protocol stacks that will realize the interaction of the objects with one another to reach to common goals without human intervention

This paradigm gained its strength from the fact that it is interacting with a wide variety of devices such as: robots, drones, heating and air-conditioning systems, security alarms, household appliances, power generation systems, office equipment, and so on, which generate a massive amount of data to provide new services to people and both public and private sectors [8, 10].

As campus grows every year, new management problems and energy issues appear. Managing the resources in the campus has become a real problem. Monitoring and controlling the unused devices that consume power during human absence is also a major inability. In addition to this, coordinating the people participating in the daily activities of the laboratory is tedious when population of the usage of the space out numbers a manageable threshold. Another problem is power management. It is difficult to monitor all sub-systems such as lighting, projecting and air conditioning system. But if these are left indiscriminately, energy will be wasted. People cannot check the status of the sub-system at ease. In order to resolve these problems, IoT technology is a suitable method [5].

Smart devices of IoT can be used to replace some traditional devices so that sub-system devices will connect to each other for better access to construct an IoT network. Human efforts are reduced when things gets automated. The need for the work is to reduce manual effort by automating laboratory resources thereby achieving a futuristic model of Laboratory using IoT and Efficient use of the laboratory resources and power management.

Internet of things Laboratory (www.citeceiot.in) was inaugurated at CIT on January 2018. It enables researchers to exploit the potential applications of Internet of Things for multidisciplinary research with more end-user interactions. The aim of proposed work is to implement a smart laboratory at CIT by replacing electrical appliances by smart IoT hardware kits (Test bed) which is designed for our IoT lab. All the electronic devices are networked to give the real-time data thereby providing the accessibility of the devices through a hand-held device. The proposed test bed facilitates management of energy utilization.

To achieve such aims, the IoT Lab focuses its research and development of the following objectives:

- To create an environment for research, design, development and testing of IoT solutions, in the field of energy management, communication systems, distributed sensor devices and advanced user interfaces.

- To provide a large-scale IoT system for the collection of information from the environment and its transfer to a server, as well as the skills necessary for the development of control logics, processing and display of data.
- To this end, IoT Laboratory is equipped with devices for the monitoring of energy consumption of electrical appliances, sensors for the monitoring of environmental parameters such as temperature and humidity and the communication infrastructure necessary to deliver the acquired information to a server.

The rest of the paper is structured as follows: Section II discusses the related works for the usage of IoT on smart campus. Section III explains the system design of proposed work. Section IV deals with implementation of the proposed system. Section V shows the results and discussion. Finally the conclusion and future work in section VI.

II. RELATED WORKS

Several works have been done with various approaches deployed towards realizing automation in various environments. Shopan Dey et.al [1] proposed a home automation system which is implemented using Smart sensor together with communication technologies such as Wi-Fi, Bluetooth etc. supported by cloud computing. The model proposed in this paper is quite economical and secure as the whole network consists of only a single admin to access all the nodes. They model developed in this paper provides a virtual connection between hub and electronic and electrical objects and control locate & track the connected objects.

Jianli Pan & Raj Jain [2] proposed IoT framework with smart location-based automated and networked energy control using smartphone platform and cloud-computing technologies. They suggested the central idea to generalize the smartphone and location-based energy control and include policies of multiple levels of organizations. This will enable not only multi-scale energy proportionality, but also create an intelligent home space which is an important part of the future smart world.

Hu Yin [3] proposed smart lab system for managing several types of subsystems of a university, including lighting, air conditioning, heating, audio/video, control switches, and security and highlighted the benefits for university and students of using the smart lab system.

Hafsa Tahir et al [4] presented the overview of IoT and its enabling technologies such as RFID, bluetooth, Wi-Fi and wireless sensor networks which have led IoT from its infancy to the verge of fully renovating the current internet. Some of the security issues involved in deployment of IoT are also presented with possible counter measures, but still a further research is needed to meet the demands of users.

Mary Cherian et al [5] proposed a Secure and Smart Lab with Wireless Sensor Network. Smart lab implementation based on Ambient lighting module and Security module by using Passive infrared sensor (PIR) and environment sensor (ES). But the drawback is that the WSN have limited computation, communication resources, limited battery power, limited storage, computation capabilities, prone to the security attacks and have limited bandwidth to communicate.

Ala Al-Fuqaha et al [6] presented a detailed view of the different protocols-MQTT, AMQP, XMPP, DDS to deliver desired IoT services. In addition, they provided a good foundation for researchers and practitioners who are interested to gain an insight into the technologies and protocols that constitutes the IoT. They illustrated by exploring the relation between IoT and other emerging technologies including data analytics and cloud computing.

From the literature survey it is observed that the existing systems suffer lack of graphical user interface (GUI) for easy operation and also due to failure of mobile operators, a message can be delayed. Hence, the solutions suggested in the literature survey are not suitable for real-time monitoring as well as long distance data logging. The integration and optimization of the hardware and software resources need to be realized within laboratory, which are highly controllable and coordinate, realize the intelligent of laboratory [9]. The Internet of things (IoT) is one of the technical areas of rapid development in recent years, and its technology can provide strong support for the realization of laboratory of intelligence.

III. SYSTEM ARCHITECTURE

Fig. 1 shows the IoT based smart laboratory layout at our Institute. All the appliances in the lab are connected to the smart IoT hardware kit which is unique board exclusively designed for CIT IoT lab.

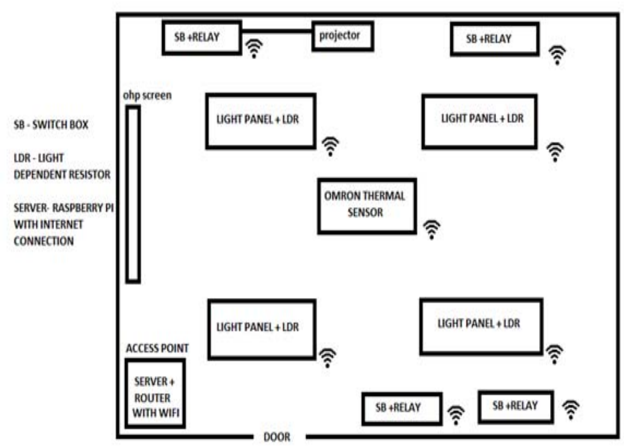

Figure 1. Lay out of smart laboratory at CIT

Fig. 2 shows the hardware setup of the proposed system. Devices are connected to IoT kits which has Arduino UNO, ESP 8266(Wi-Fi module), current transformer and Relays. Each IoT kit can connect to three devices. All the IoT kits, Raspberry Pi3 [12] and end users should be connected in same network to gain control over individual appliances. All the sensors like temperature, humidity and LDR are also connected to ESP8266 module which is present in the IoT hardware kit. In this work, the daylight intensity is sensed using LDR and it is compared with the set threshold value and a light is controlled. Based on the light intensity, the lights also get turned on inside the room. The sensed values are reported in real time and can be viewed in dashboard.

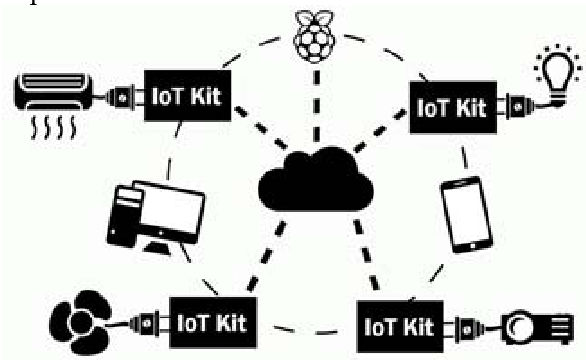

Figure 2. Block diagram of the proposed system

All the devices in laboratory use Message Queuing Telemetry Transport protocol (MQTT) for communication [11]. MQTT is a machine- to- machine/ internet of Things connectivity protocol. It is designed as an extremely lightweight publish / subscribe messaging transport. The electrical appliances and sensors are connected to ESP 8266 and those are act as MQTT clients which helps in accessing the devices connected to common network so that it can transmit data via MQTT protocol. Here, all those Wi-Fi modules act as MQTT clients and Node-RED (Raspberry Pi 3) acts as MQTT broker (Server). Node-RED is a programming tool for wiring hardware devices [12]. It provides a browser-based editor that makes it easy to wire wide range of nodes in the palette that can be deployed to its runtime in a single click. Node-RED application aids in creating the interactive user interface dash boards.

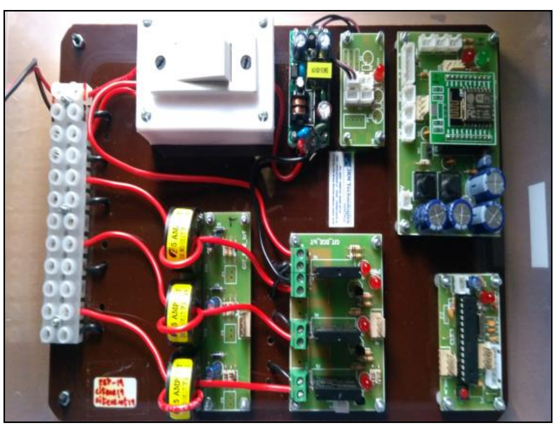

Figure 3. Hardware components of CIT_IoT development kit

Fig. 3 shows the hardware components of CIT_IoT development kit. The main components used are

- ESP8266- It is a low-cost Wi-Fi microchip with full TCP/IP stack and microcontroller capability. Here, it acts as an MQTT client.
- Arduino UNO- It is a microcontroller board based on the ATmega328P. Here, it sends the status of the devices to client.
- Current Transformer- It is a transformer that measures the AC current of the circuit. It senses the current flowing through it and the values are in analog.
- Relay- It acts as a protective switch. It uses an electromagnetic switch operated by a small electric current that can turn on or off a much larger current.

IV. IMPLEMENTATION

The 220v that comes from the main power supply is reduced to 5v by step down transformer. It is then regulated and given to the Arduino UNO and ESP8266. If user wants to turn on/off devices, command is sent from mobile phone to MQTT server. The server then publishes the command to the respective ESP8266 module present in an IoT kit to which that the particular device is connected. After the reception of the command by ESP8266 relay gets turned on, thereby providing the supply to that device and the device gets turned on. Current transformer is used in the IoT kit which checks the actual flow of current. It sends the actual status of device (ON/OFF) to the Arduino which is determined by the amount of current flow. Arduino, then sends that device status to ESP8266 through serial port. ESP8266 sends that data to MQTT server and actual device status can be viewed in Node-RED dash board. So, the Node-RED dashboard acts as an output window that shows the actual status of all devices, provides access to the devices and shows the temperature , humidity and light intensity of the lab.

Raspberry pi 3 is connected to a network, and run this application in it. An online server (test.mosquito.org) [15] act as an MQTT broker. The control signals can be sent from any device connected in the network to the broker. And, clients publish the status of the devices and energy consumed by individual appliance to the broker and can be viewed in the dashboard. Thus all devices can be controlled universally, and the status of the devices can be visualized.

Our Contributions:

- IoT based smart lab has been designed and implemented in our department
- Application code written for interfacing IoT smart hardware kit & MQTT broker, and for monitoring temperature, humidity and light intensity inside the laboratory
- Developed Dashboard and mobile application using Node-RED and ANDROID STUDIO
- A database has been created for a prototype switch to view status history

V. RESULTS AND DISCUSSION

The proposed smart laboratory system is implemented using Arduino Programming Language and the devices are controlled using node-RED and RPi Libraries [15]. After the collection of the data for further processing and transmission of the data, ThingSpeak IoT platform's server is needed. ThingSpeak is an IoT analytics platform service that allows to aggregate, visualize and analyze live data streams in the cloud. ThingSpeak provides instant visualizations of data posted by the devices.

In our ECE lab, three different boards of IoT hardware are used to monitor and control the 4 lights, 1 projector, 1 fan and 1 air conditioner. This was implemented and tested successfully. After successful testing, this same setup was installed in IoT lab to monitor and control the 3 lights and 3 fans. Fig 4 and 5 show the dash board which is used to control and monitor the device status and able to view temperature and humidity values inside the lab.

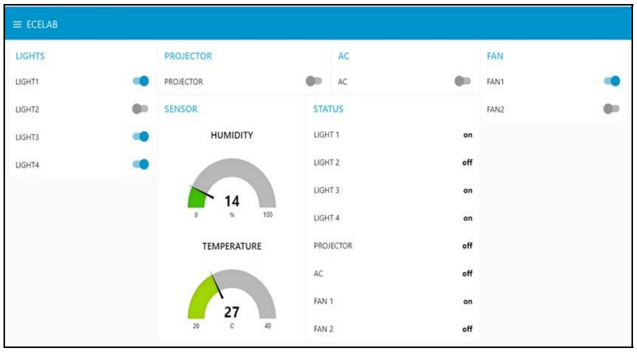

Figure 4. Real time monitoring and controlling Dashboard for ECE lab

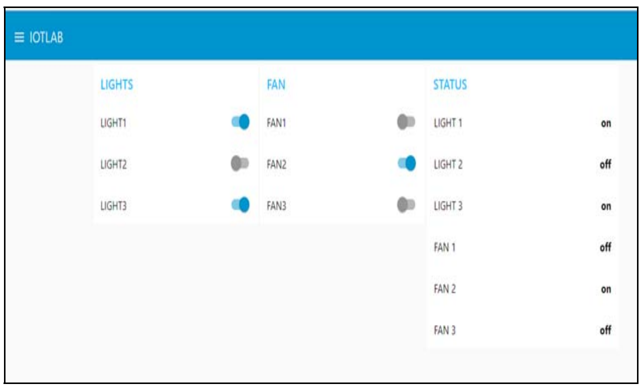

Figure 5. Real time monitoring and controlling Dashboard for IoT lab

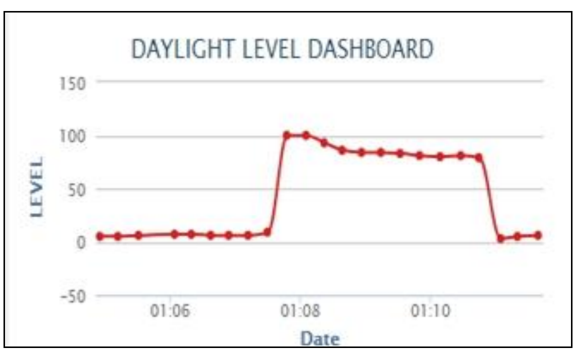

Figure 6. Daylight level dash board

Fig. 6 & 7 shows the light intensity level and bulb status inside the lab. The proposed system is tested during the day time. The output is affected by surroundings light sources. Hence, the bulbs light intensity is reduced causing a directly proportional effect to the power consumption. This system can provide optimized light intensity for the surrounding and reduces the electrical power consumption during daytime.

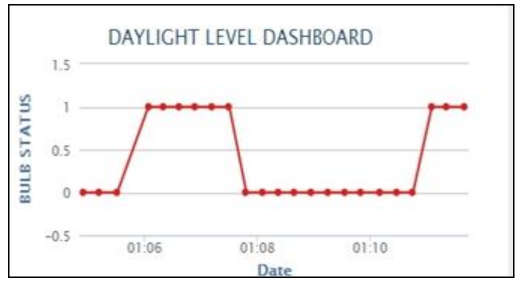

Figure 7. Daylight level dash board for displaying the Status of the light

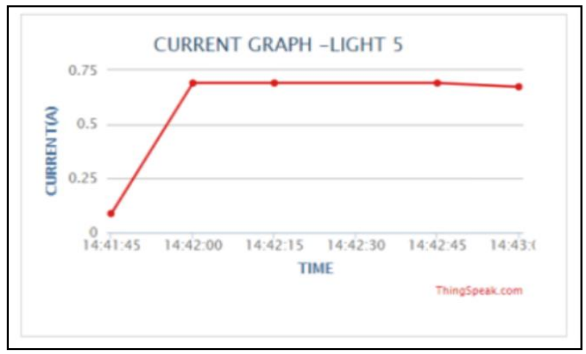

Figure 8. Hourly current consumption graph at the device level

Fig. 8. Shows the graph for variation of current consumption over time interval. From the figure, it is observed that the parameters such as status of the bulb and the current consumption are plotted in the form of a graph and can be viewed on the dashboard and is updated in real time.The proposed system enables user to monitor the current consumption at the device level and upload it to the server and establish remote control of any appliances from anywhere thereby reducing the wastage of energy. Thus, the proposed system helps in energy conservation.

Table 1. Contains information stored in database by smart system. Date: 24th July - 25th July 2017.

TABLE I. TEMPERATURE , HUMIDITY AND DEW POINT INFORMATION STORED IN DATABASE

IoT Lab

Export as CSV

(CIT-CBE-M102-GF-IoT Lab)

Pressure

HOME

Temperature,Humidity,Dewpoint Sensor readings

Timestamp	Temperature 1	Moisture 1	Dew Point 1
2017-07-24 20:12:17	31	35	14
2017-07-24 20:07:14	31	34	13
2017-07-24 20:02:10	31	33	13
2017-07-24 19:57:07	31	33	13
2017-07-24 19:52:04	31	34	13
2017-07-24 19:47:01	31	34	13
2017-07-24 19:41:58	31	34	13

E-Remote is a locally developed interactive application for android users. This application has been developed in ANDROID STUDIO [14] using JAVA programming language. It is a digital remote to monitor and control the appliances of IoT Lab and ECE Lab which is shown in Fig. 9. This has been coded to function as an MQTT CLIENT which publishes control signals to an MQTT BROKER (Online Server).

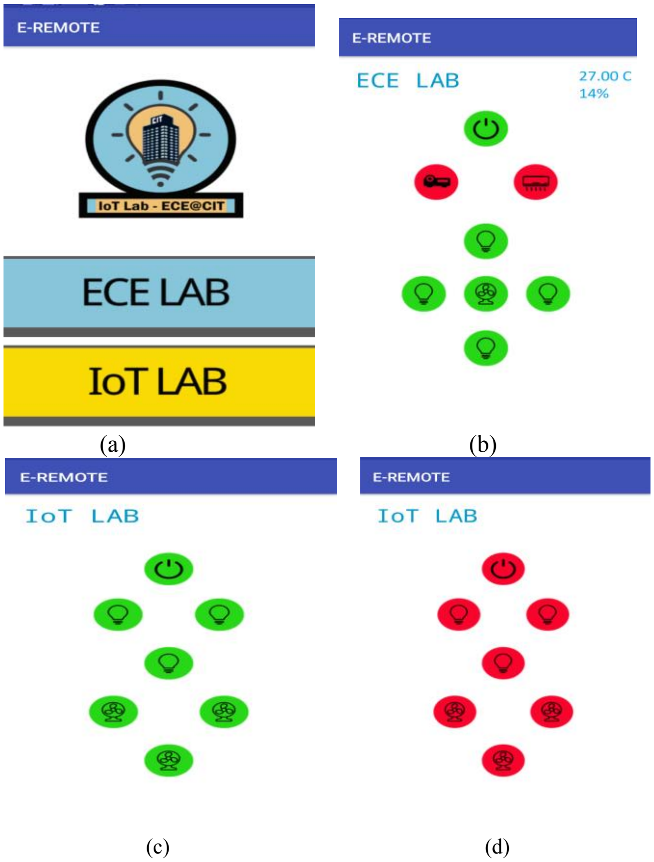

Figure 9. Interacive EREMOTE APP page for mobile users

VI. CONCLUSION

Internet of things reduces the human intervention by introducing device to device interaction. This work has been designed to implement smart laboratory system using IoT technology for remote energy monitoring and control appliances inside the lab. By employing the proposed system, the total energy consumption can be reduced in our campus. On a whole in a year up to 30 percent of energy can be saved in our campus by implementing smart laboratory system through IoT. Node-RED dashboard and Mobile Application has been developed for communication between client and server by establishing Remote Procedure Calls between client and server [13]. This kind of a system with respective changes can be implemented in the homes, hospitals for real time monitoring of newborn babies in the incubator/disable people or in industries and environment monitoring [7]. In future, 38.5 billion devices are expected to be connected to the internet by the year 2020.

Thus the emerging huge scope for doing research work in IoT. The issues need to be addressed are interoperability of multiple systems, data security, standards and government policies for IoT, increasing computing power to handle the huge amount of data generated by sensors, increasing availability of sensors and actuators to connect things in IoT.

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REFERENCES

[1] Shopan Dey, Ayon , Sandip Das,(2016), “Home Automation Using Internet of Thing”, IEEE Annual conference on Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON), vol.4, no.5.

[2] Jianli Pan, Raj Jain, (2015), “An Internet of Things Framework for Smart Energy in Buildings: Designs, Prototype, and Experiments”, IEEE Internet of Things Journal 2.6 , vol.2, no.6.

[3] Hu Yin (2015), “Smart Lab Technologies”, Handbook of Mobile Teaching and Learning, Springer-Verlag Berlin Heidelberg, pp.1–11.

[4] Hafsa Tahir, Ayesha Kanwer and M. Junaid, (2016), “Internet of Things (IoT): An Overview of Applications and Security Issues Regarding Implementation”, International Journal Of Multidisciplinary Sciences and Engineering, , Vol. 7, No. 1.

[5] Mary Cherian , Hitesh Kumar P,(June 2014), “Implementation of a Secure and Smart Lab with Wireless Sensor Network”, International Journal of Science and Research, Vol.3, No. 6.

[6] Ala Al-Fuqaha, Mohsen Guizani, Mehdi Mohammadi, Mohammed Aledhari, (2015), “Internet of Things: A Survey on Enabling Technologies, Protocols and Applications”, IEEE Communications Surveys & Tutorials, vol.3, no.5.

[7] M. A. Razzaque, M. Milojevic-Jevric, A. Palade and S. Clarke, "Middleware for Internet of Things: A Survey," in IEEE Internet of Things Journal, vol. 3, no. 1, pp. 70-95, Feb. 2016

[8] J.ChandraMohan, R.Nagarajan, K.Satheeshkumar, N.AjithKumar, P.A.Gopinath, S.RanjithKumar(2017) “Intelligent Smart Home Automation and Security System using Arduino and Wi-Fi” , International Journal of Engineering and Computer Science, vol 6,issue 3,pp.20694-20698.

[9] Chunsheng Zhu, Victor C.M. Leung, Lei Shu (2015) “Green Internet of Things for Smart World”, IEEE, Volume : 3,Issue : 2, pp.2151-2162.

[10] Vinay sagar K N, Kusuma S M, (2015), “Home Automation Using Internet of Things”, International Research Journal of Engineering and Technology, vol.2, no.3.

[11] https://www.ibm.com/developerworks/library/iot-mqtt-why-good-for-iot/index.html

[12] https://www.raspberrypi.org/documentation/.../RPI-CM-DATASHEET-V1_0.pdf

[13] https://httpd.apache.org

[14] https://www.wemos.cc

[15] https://pythonschool.net