

Building connected home scenarios (IoT) using computers

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Abstract. The construction of scenarios showing the operation of real communication networks is useful not only for industry but also for academia. The fast development of the Internet of Things (IoT) and its use in the most diverse human – computer interaction activities have motivated universities all over the world to organize courses in order to train and make students familiar with the use of this technology. The use of tools that simulate IoT networks functioning is crucial to facilitate the teaching and training of future engineers in this area.

This contribution shows two scenarios which have been used in a seminar of IoT for undergraduate students of Computer Engineering at the Universidad Francisco de Vitoria in Madrid and Computer Engineering and Telecommunications at the Universidad Anáhuac México Norte in Mexico, both related to the application of IoT to create smart building. One scenario is the design and simulation of the networks of a smart building; the second one is the use of an Arduino board to create a small and simple IoT system connected to the cloud.

The software used in the simulation was Cisco Packet Tracer, a multiplatform tool from Cisco System Inc. that allows the “construction” of networks without using hardware and/or physical network. The board used to develop a real IoT system was the Arduino Nano 33 IoT connected by Internet to Arduino IoT Cloud via wireless network.

The scenarios presented were successfully used with undergraduate students in both universities.

Keywords: Internet of Things, CISCO Packet Tracer, Network Simulation, Smart Buildings, Arduino Boards, Cloud, Educational Tools.

1 INTRODUCTION

The term Internet of Things (IoT) first coined by Kevin Ashton in 1999 [1] is consequence of Internet evolution. The IoT refers to the use of intelligently connected devices and systems of heterogenic technologies to leverage data gathered by embedded sensors and actuators in machines and other physical objects. It makes the objects themselves identifiable, intelligent, convey information about them and can access

information gathered by other things. IoT lets us connect with people and things anytime and anywhere [2].

The use of IoT offers many advantages by enabling the deployment of new services by creating smart cities, buildings, and factories among many other applications [3]. The use of data obtained through IoT devices would generate significant revenues. The 2021 Gartner Report [4] predicted that wireless communications will be of key importance for Industry 4.0 and smart factories. Some analyses refer to the integration of 5G technology with IoT applications, and address aspects related to improving some communications functions [5] [6]. Other investigations refer to security issues, suggesting solutions helping to preserve privacy in IoT environments [7] [8]. They also refer to the application of IoT in buildings in order to save energy and increase the comfort of residents [9].

This paper describes the development of two scenarios: an IoT network simulation and a simple real IoT system connected to the cloud. Their purpose was to employ them as educational tools helping students of our universities to learn and understand the benefits of IoT. Both scenarios are intentionally very simple because during the seminars they would be modified by the students themselves, creating more complex networks which will meet the requirements of more realistic environments. During seminars students acquired deeper knowledge about IoT meanwhile developing skills using simulation and developing tools.

2 TOOL

2.1 Simulation

The tool selected for network simulation was Cisco Packet Tracer, a Cisco System Inc. proprietary multi-platform tool that enables students to create networking and IoT simulations without need of hardware and/or existing network. The tool can be downloaded freely by students and runs on the principal operating systems.

Cisco Packet Tracer offers a wide variety of standard network components that can be connected and configured to simulate real networks (see Fig. 1). The release of the version 7.0 of the tool [10] introduced IoT network simulation capabilities.

Working with Cisco Packet Tracer is highly intuitive. Components used to build networks are selected among sets of different kind of components which are then placed in the working area of the main window. IoT components include smart devices (those that can connect directly to network's servers or gateways through their own network interfaces), non-intelligent components (some sensors and actuators) and processing boards named MCU (microcontroller unit) and SBC (single board computer) which simulate the popular and well known Arduino and Raspberry Pi boards. Once the devices are selected, they are connected and configured.

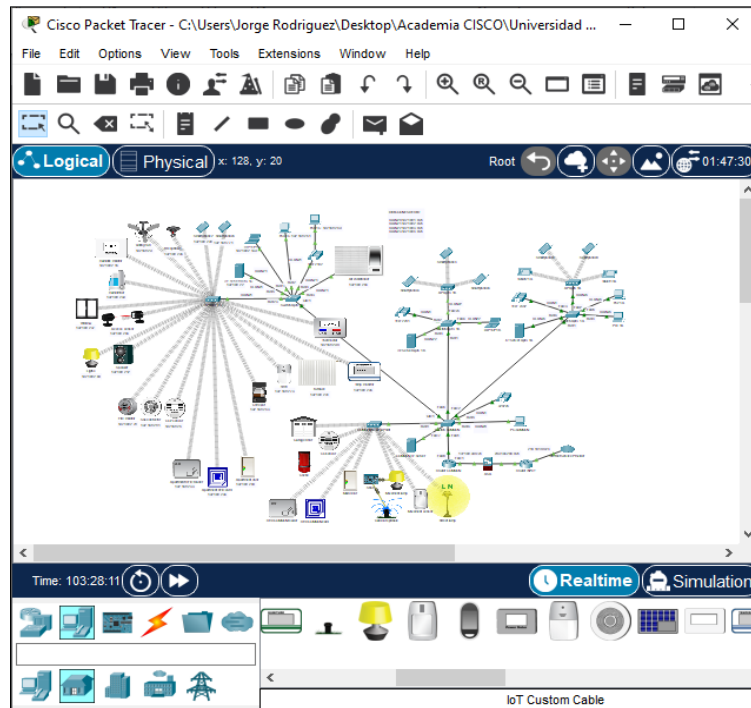


Fig. 1. Building network

In addition to the logical simulation, Cisco Packet Tracer allows the simulation of networks at physical level creating different environments: cities, buildings, physical containers and wired cabins. It is possible to setup the values of environmental variables at different times of the day to simulate the behavior of many IoT devices.

2.2 Arduino Development Platforms

Arduino Nano 33 IoT board was selected because it is a cheap but very powerful board specially designed to be used in IoT applications. It has a powerful ARM processor, a BLE-WiFi module and an inertial unit which, working together the traditional I/O lines and communication ports of Arduino boards, make this board an excellent choice to be used in academic environments.

Arduino IDE, the open source develop environment was used to develop the software running on the Arduino Nano 33 IoT board [11]. It makes it easy to write code and upload it to Arduino compatible boards.

Arduino IoT Cloud [12] is an open-source platform based on easy-to-use hardware and software. It can be used for free with low cost Arduino compatible boards. Its friendly interface facilitates students to learn and train the development of IoT applications on the cloud. Arduino IoT Cloud facilitates students to get familiar with developments of IoT projects on the cloud.

3 NETWORK STRUCTURE

3.1 Network backbone

The network backbone is shown in Fig. 2. It is composed by several conventional network devices which connect the Internet Service Provider (ISP) with subnets of apartments and common areas. The building network backbone includes:

- Router INPUT: which connects the building network to the ISP;
- ASA (Adaptive Secure Appliance) firewall: that enables a secure connection of the building network with the ISP, protecting it from access by intruders and penetration of viruses and malware that may affect its operation;
- Router COMMON: which permits: (1) IP telephony devices configuration to provide telephony services, including the creation of Virtual Local Area Networks (VLANs) to separate data and voice traffics; (2) isolation of data traffic between apartments and common areas networks by creating four VLANs; (3) developing a dynamic and static routes to communicate subnets, including an extended Access Control Lists to control traffic between subnets; (4) Quality of Service strategies to provide optimal use of network: bandwidth, latency, jitter and packet loss.
- Switch COMMON: that separates apartments and common areas subnets.

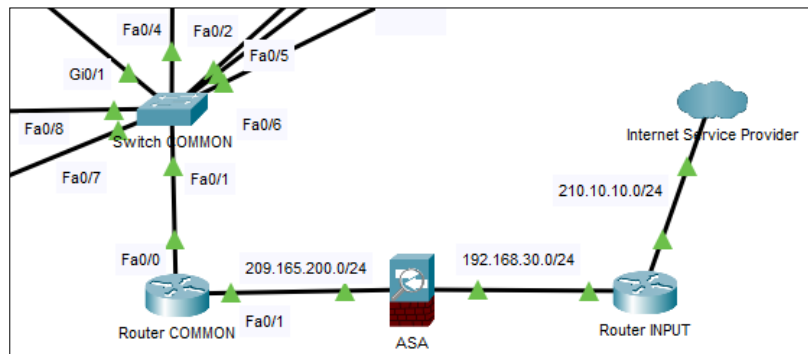


Fig. 2. Network backbone

3.2 Common areas network

Include standard network devices (PC COMMON, IP phone, COMMON IoT Server and COMMON Access Point) and some IoT devices (Garage Door, CO sensor, Main door, RFID COMMON reader, RFID COMMON card, Movement sensor, Outdoor sprinkler, SBC0, Movement lamp and Street lamp) as shown in Fig. 3. All devices used in the common areas network are connected to the VLAN20.

The IoT devices connected to the common areas permit to create several systems to automate areas like garage access, illumination, garden irrigation and building access. SBC0 running a simple java program is used to illustrate how connect a low-cost actuator (outdoor sprinkle) which doesn't have a network interface.

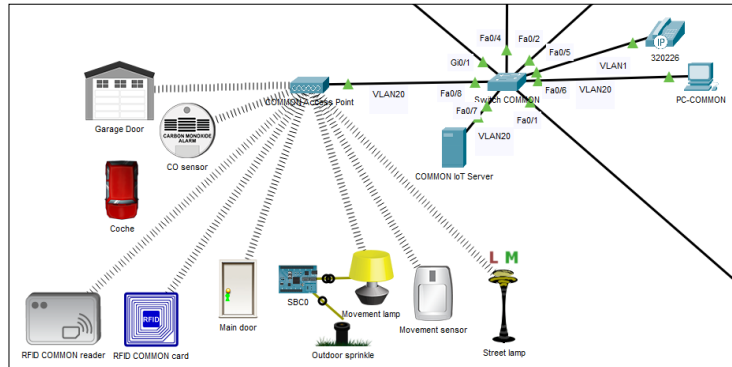


Fig. 3. Common areas network

3.3 Apartment networks

All apartment networks are connected to different VLANs but have very similar configurations. They have several standard network devices and IoT devices connected to the IoT Server which permits to create the control algorithm of the different systems.

3.3.1 Apartment network standard devices

Standard network devices include the apartment switch which connects standard devices like IP phones, smartphones, PC, laptops, server and access point (see Fig. 4). Eventually the apartment switch could connect some IoT wired devices (for example the air conditioner device in our simulation).

The apartment access point is used to provide communication to the IoT devices and also to the wireless standard devices used by residents like smartphones, laptops, notebook, etc.

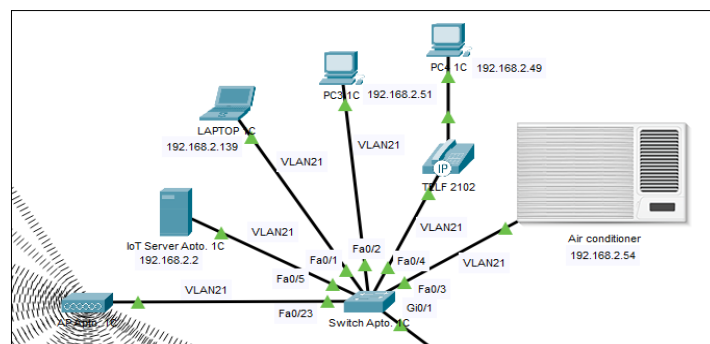


Fig. 4. Apartment network standard devices

3.3.2 Apartment network IoT devices

IoT network devices include a wide variety of devices which permit the functioning of several systems: climate, access, fire-protection, illumination and stand-alone electro domestic and recreational devices as shown in Fig. 5.

- Access control: It controls the access by the apartment door and windows. Apartment door is controlled (locked and unlocked) by the IoT server by using a RFID reader and RFID cards. Windows access is detected by an IR sensor access; thus the IoT server turns ON the alarm siren and sends an alarm message.
- Climate control (temperature & humidity): Temperature control includes the air conditioner, the furnace and a thermostat. Thermostat read and inform the IoT server about local temperature and then air conditioner and furnace are remote controlled from the IoT server. Temperature is maintained within comfort limits. By alternating the operation of air conditioner and furnace (turning them NO and OFF with a proper hysteresis algorithm), the room temperature is adjusted. Ceiling fan will be turned ON and OFF helping to reach faster a comfort temperature. Humidity is controlled by the IoT server with the support of the humidity monitor and the humidifier.
- Fire control: includes fire and smoke detectors, CO₂ sensor, ceiling fan, fire sprinkler and an alarm siren controlled by the IoT server. If a fire is detected, the water sprinkles located on the ceiling are put into operation, the door and windows are opened, the fan is turned on and the alarm siren sounds.
- Household and recreational devices (smart TV, watching machines, refrigerators and many others) could be included on the systems or remotely controlled to increase the comfort of the residents.

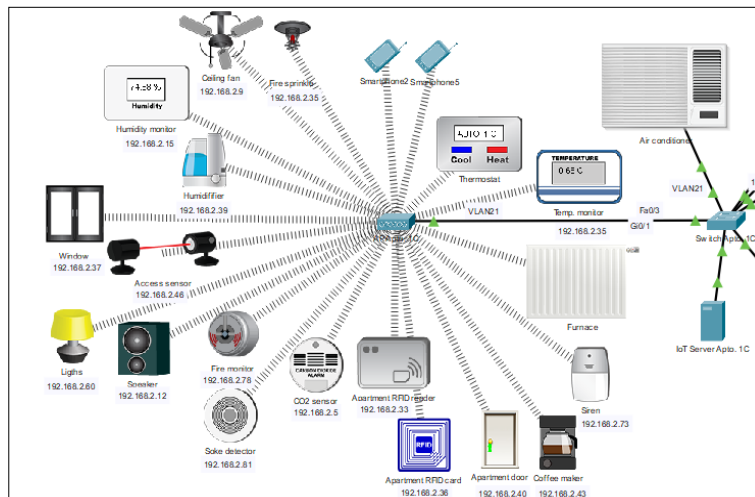


Fig. 5. Apartment IoT network devices

4 EXAMPLE OF A REAL IoT SYSTEM

To complement the scenarios created for teaching purposes, a real IoT system was developed based on the Arduino Nano 33 IoT board that collects data from temperature and acceleration sensors and sends them to a dashboard created in the cloud.

The dashboard allows the exchange of information between the system and an external user by internet connection on any place outside the system under control. Fig. 5 shows the breadboard with the components used to develop the real IoT system.

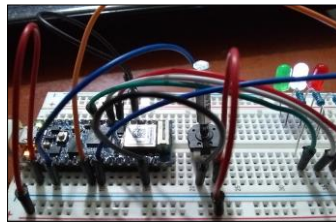


Fig. 6. IoT systems developed with Nano 33 IoT

Fig. 6 shows the dashboard SENSORS created in the cloud. This includes some analog data (ROOM TEMPERATURE and X, Y, Z ACCELERATION) obtained from the environment and a Boolean output used to activate a fan motors.

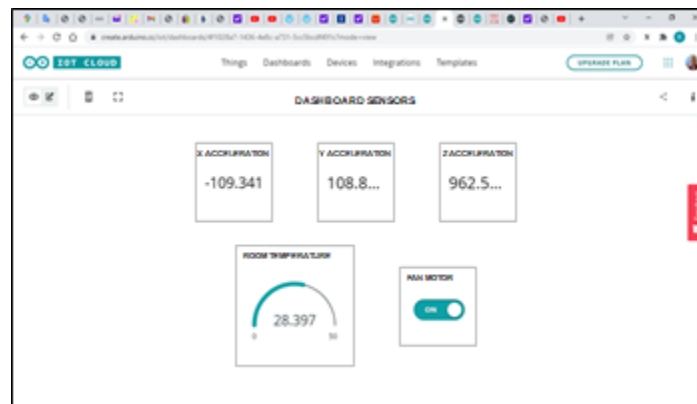


Fig. 7. Dashboard of the IoT systems developed with Nano 33 IoT

The use of the real IoT system developed as an example that can be extrapolated not only to a smart building, but to any other IoT application.

5 CONCLUSIONS

The simulation described in this paper allowed undergraduate students of Computer Engineering at Universidad Francisco de Vitoria in Madrid and Information Technol-

ogy and Telecommunications Engineering at Universidad Anáhuac México Norte in Mexico, to reinforce the knowledge and skills acquired during the IoT seminars.

During the seminars students created, designed and simulated IoT more complex networks letting them to work in scenarios with new requirements closer to real requirements of apartment buildings.

The experience gained will allow professors to improve the educational tools developed to be used in other future IoT courses or seminars.

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