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Design and Simulation of IoT Systems Using the Cisco Packet Tracer

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Abstract: *Nowadays, the term IoT (internet of things) have become extremely important in our life. This technology is used in many fields such as education, health, industries, agriculture and infrastructures. In order to learn and understand how this technology works, many practical learning tools are used.The tool used is Cisco packet tracer which is a software developed by Cisco that is used to create and simulate a virtual network, basically a wireless network, without the need for any network hardware. Design and implementation of Internet of Things (IoT) systems require platforms with smart things and components. Two dominant architectural approaches for developing IoT systems are mashup-based and model-based approaches. Mashup approaches use existing services and are mainly suitable for less critical, personalized applications. Web development tools are widely used in mashup approaches. Model-based techniques describe a system on a higher level of abstraction, resulting in very expressive modelling of systems. The article uses Cisco packet tracer 7.2 version, which consists of four subcategories of smart things home, smart city, industrial and power grid, to design an IoT based control system for a fertilizer manufacturing plant. The packet tracer also consists of boards microcontrollers (MCU-PT), and single boarded computers (SBC-PT), as well as actuators and sensors. The model facilitates flexible communication opportunities among things machines, databases, and Human Machine Interfaces (HMIs). The model developed focuses on three process plants; steam raising, nitric acid, and ammonium nitrate plants. The parameters need to be monitored in order to ensure quality, safety, and efficiency. Through the Cisco packet tracer platform, a use case, physical layout, network layout, IoT layout, configuration, and simulation interface were developed.*

Keywords: Internet of Things (IoT), Smart Sensors, Wireless Sensors, Process Control,Cisco Packet Tracer, Smart Factory.

I. Introduction

Internet of things (IoT) technologies will ensure systems established in Industry 4.0 are of low cost and have lean operating systems. These interconnected things and services enable modern smart factories and integrated value chains to function optimally. IoT and Internet of Services (IoS) concepts are a major part of the broad industry 4.0 technologies. Cisco packet tracer is a powerful software created by Cisco Company for simulating virtual networks, especially wireless networks. Cisco packet tracer gives an environment where devices look what they do in reality, and this is very important for users especially students. They can monitor and interact with different wireless and IoT devices in virtual environment before working in real time. Working with simulation tools to learn how networks work give us both time and materials advantages and help decreasing the costs in education.

Industry players must be prepared for unprecedented changes that IoT brings IoT technologies such as RFID, wired and wireless sensor networks, and embedded systems enable the digitization and virtualization of shared resources and capabilities in the services and manufacturing industries for access through the cloud. The cloud is mainly categorized as private cloud, community cloud, public cloud and hybrid cloud.

Organizations that use IoT, digitization, and big data technologies have been evaluated as having a higher level of logistic service, more efficient processes with their partners, improved cooperation between certain logistic functions, and higher market and financial performance and competitiveness. Countries that promote the use of high technology achieve more efficient production processes, which lead to better productivity and economies of scale.

IoT infrastructure and ecosystem should promote reusability, interoperability integration, modular programming, better flexibility, agility and, ease of maintenance. “Any Thing” and “Every Thing” should be interconnected with the global information and communication infrastructure. This can be achieved through network accessibility (getting on a network) and compatibility (common ability to consume and produce data) . Although the internet protocol version 6 (IPv6) was introduced to solve the problem of the shortage of IP addresses experienced with IPv4, its global implementation has challenges. Each connected device and “being” requires a unique IP address, which makes the network complex and difficult to manage, all the connected sensors need to be powered, and parallel management of different protocols and legacy assets during the transition period is a complex task. The main objective of the article is to advance research in the development and implementation of IoT systems. The research is a case study of a fertilizer manufacturing plant. Needs requirements for an IoT platform were established and a Visual Programming Language (VPL) platform for design and simulating the solution was identified. Several solutions that use VPLs for developing IoT-based systems exist, but a section criterion was used to select the most suitable platform. Cisco Packet Tracer 7.2. The tool offers a variety of IoT functionalities, accommodates smart devices, components, sensors, actuators, and can simulate micro-controllers such as Arudino or Raspberry Pi .

1.1 IoT Definition

Internet of things or internet of everything refer to the idea of thing (object), that are readable, recognizable, addressable through information sensing devices (sensor) and controllable via internet. Things are physical objects with unique identifiers that are able to transfer data over the network. Examples of physical objects include vehicles, smart phones, home appliances, toys, cameras, medical instruments and industrial systems, animals, people, buildings, etc.

Internet of Things is a new revolutionary and advanced technology where any object becomes smart object, and where they can communicate information about themselves without human intervention. The Internet of Things is expected to make a huge change in our lives; it will help us to perform our tasks and duties in a better way.

1.2 Cisco Packet Tracer Definition

Cisco Packet Tracer as the name suggests, is a tool built by Cisco. This tool provides a network simulation to practice simple and complex networks. The main purpose of Cisco Packet Tracer is to help students learn the principles of networking with hands on experience as well as develop Cisco technology specific skills. Since the protocols are implemented in software only method, this tool cannot replace the hardware Routers or Switches. Interestingly, this tool does not only include Cisco products but also many more networking devices.

II. IoT(Internet of Things) Applications

Internet of things is the technology that will make a big impact in our life. This technology is utilizing in many sector for instance agriculture, energy healthcare, transports, and many more.

2.1 Industrial Internet of Things (IIoT)

Internet of things is used in the industry field to improve the productivity and performance. For example, the internet of things devices can be used to monitor and control the process of the factory and for maintenance; it can be used to detect corrosion inside a refinery pipe, or to predict about the malfunctions of some equipment in order to provide maintenance services before it get too late. The use of internet of things in the industries will help variety of industries including manufacturing, food industries, automotive industries, etc. to get work done easily.

2.2 Internet of Medical Things (IoMT)

The medical sector will be the one to benefit the internet of things technology the most. Internet of things in healthcare give the possibility to the doctors possible to control patient conditions anywhere anytime over network in order to provide monitoring, analysis and remote configurations through smart devices such as heart monitors and pace makers. Many others internet of things devices can be used to control our health such as fitness trackers and smart watches etc.

2.3 Smart Cities

Smart cities refer to a city where internet of things devices are used to control and monitor the transportations and infrastructures in the city. Internet of things devices can also be used in smart city to control others sectors or activities in the cities rather than transportations or infrastructures such as controlling the quality of the water, or analyzing and monitoring the energy system, and many more.

2.4 Smart Homes

Smart home refer to a home equipped with smart appliances, fridge, air conditions, light, camera, fan, smart thermostats, door locks etc. that can be remotely control and manage through internet using smart phone or computer. The possibility to manage to manage the home equipment from distance offer homeowner security, comfort and convenience. Smart home help saving energy and avoids some accidents, homeowner can remotely monitor the camera, home alarm system, and detection system to check if there is any violations for security reason.

2.5 Smart Cars

Smart car is a system where all the functionalities of the car can be remotely control by a computer or a smart smartphone with the use of different sensors. With This particular internet of things application, we can check the car oil level, radiator water, and even being capable to drive the car from distance.

III. Literature Review

This section reviews literature on standard definitions for IoT, associated technologies, layered architecture, extended view of IoT, i.e. IoE, and lastly visual programming languages (VPLs).

3.1 Internet of Things (IoT) Definition and Technologies

IoT defined as a system of interrelated computing devices, mechanical and digital machines, objects, animals, or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. Cisco coins its definition of IoT as, "the intelligent connectivity of smart devices, expected to drive massive gains in efficiency, business growth and quality of life". IoT represents electrical or electronic devices, of varying sizes and capabilities, which are connected to the Internet. The scope of the connections has grown beyond just machine-to-machine communication (M2M) to broadly focused machine-to-people (M2P), and people-to-people (P2P) communications. M2M is mainly being utilized to implement "smart factories" using IP networks to inter-connect physical infrastructure with sensors, which results in extra capabilities such as analytics and monitoring using technologies such as radio frequency identification (RFID). M2P is used to capture and analyze consumer data to be used in designing products and services such as mobile marketing to push the manufacture-consumer relationship as close to the consumer as possible. P2P utilizes converged network services such as real-time video collaboration tools with "Bring Your Own Device" (BYOD) capabilities.

Things in "IoT" can refer to anything which possesses smart characteristics, such as sensors, embedded chip, automobile, people, animal, agricultural produce or anything in the value chain, road infrastructure, building or anything in the built environment, consumer goods, plant equipment or machinery, and many others. When these "Things" are provided with unique identifiers (UIDs), they gain the ability to transfer data over a network with no need for human-to-human or human-to-computer interaction. IoT helps private and public enterprises to find more operating efficiencies, deliver greater value to customers, employees, and citizens in general, and enable new business models. Each IoT device provides capabilities features or functions it can use on its own or in conjunction with other IoT and non-IoT devices to achieve one or more goals. LiteOS supports smartphones, intelligent manufacturing applications, smart homes and Internet of Vehicles (IoV). The operating system also serves as a smart device development platform. AMQP (Advanced Message Queuing Protocol) is an open-source published standard for asynchronous messaging by wire. The protocol is used in client/server messaging and in IoT device management. The broad range of enabling technologies for the IoT can be grouped into three categories: 1) technologies that enable "Things" to acquire contextual information, 2) technologies that enable "Things" to process contextual information, and 3) technologies to improve security and privacy.

3.2 Internet of Things (IoT) Architecture

Several architectures have been proposed since the inception of the IoT concept, which evolved from the 3-layered to the 5-layered architecture, service-oriented IoT-A architecture to the special purpose Be TaaS, Open IoT and IoT@Work architectures. IoT architecture serves to illustrate how various technologies relate to each other and to communicate the scalability, modularity and configuration of IoT deployments in different scenarios. The 3-layer architecture model is considered as a primary model for IoT work, which consists of the application layer, network layer, and perception layer. The task of Perception layer is to identify objects along with the collection of information. The 5-layer architecture is a more well-defined architecture and highly recommended for the IoT use. It consists of 2 additional layers as compared to 3-layer architecture that are Processing and Business layers. The processing layer is used to store all the data received from the transport layer (also called network layer) and process it. The processing layer uses technologies like cloud computing, and ubiquitous computing. Management of tasks is performed in the business layer. Figure 1 shows the detailed five (5) layer IoT architecture. The architecture is pyramid shaped to resemble the plant automation pyramid.

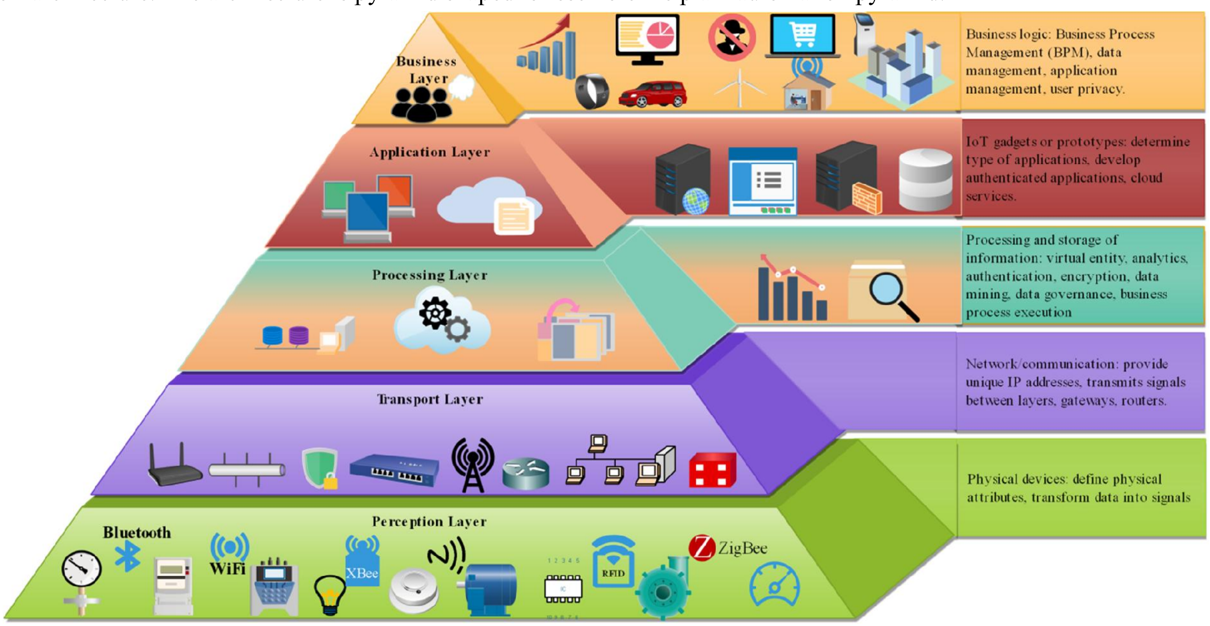

Figure 1: Five (5) layer IoT architecture.

3.3 Internet of Everything (IoE)

The term "Internet of Everything" was used by Cisco since the year 2012, but later on dropped at the dominance of IoT as the preferred term. The Inter-net of Everything (IoE) brings together people, process, data, and things to make networked connections more relevant and valuable than ever before turning information into actions that create new capabilities, richer experiences, and unprecedented economic opportunity for businesses, individuals, and countries. Some popular terms in use today are the Industrial IoT (IIoT), Consumer IoT (CIoT), Web of Things (WoT), and many others. Figure 2 depicts the combined IoE, IIoT, and CIoT.

Many modern consumer electronic devices, which are also present in organizations' facilities, are now connected IoT devices kitchen appliances (refrigerators, microwave ovens, cooking stoves, etc), thermostats, home security cam- eras, door locks, light bulbs, and TVs. CIoT is used to refer to applications and uses cases to track personal "assets"(asset tracking), such as pets, and skate- boards, connected "smart home appliances" such as connected refrigerators, washing machines, light bulbs, etc. Industrial Internet of Things (IIoT) describes typical industry use cases across a range of sectors such as manufacturing industries or utilities, smart cities and smart metering. Web of Things (WoT) has been used to describe approaches to facilitate services offered at Open Systems Interconnection model (OSI)'s application layer.

3.4 Visual Programming and Deployment of IoT

A combined IoT framework with a cloud at the center, gives the flexibility of dividing associated costs in the most logical manner and is also highly scalable. In the combined framework, sensing service providers can join the network and offer their data using a storage cloud; analytic tool developers can provide their software tools; artificial intelligence experts can provide their data mining and machine learning tools useful in converting information to knowledge and computer graphics designers can offer a variety of visualization tools. Cloud computing (CC) can offer these services through various models- Infrastructure as a Service (IaaS), Platform as a Service (PaaS), or Software as a Service (SaaS). This allows the full potential of human creativity to be tapped. Major players in the CC marketplace and related products are IBM, HP, Intel (Intel IoT Solution Alliance), Microsoft (Azure, NET, Node.js, Java, PHP), Google (Google App Engine Python, Java, Go), Amazon (Elastic Cloud Compute EC2, AWS, Simple Storage Service S3), Cisco, ThingSpeak, and many others. A variety of low cost programmable hardware platforms have gained popularity, enabling communities and individuals to fast track their learning in IoT development and deployment. Most popular and cheapest platforms are Raspberry PI, Arduino Uno, Intel Galileo, Particle, NXP, Android Things, and others.

Availability of IoT application specific frameworks for rapid creation of applications and their deployment on cloud infrastructures is the key for achieving rapid development. Using such a framework, the developer of IoT applications will be able to the power of CC without knowing low-level details of creating reliable and scale applications. These platforms are modular and flexible tools for not only real world applications but also educational purposes. Several visual programming languages (VPLs) have been developed to help people start programming without immense knowledge about programming languages (i.e., expression, statement, loop clause, and functional orientation). A VPL is any programming language that lets the user create programs by manipulating program elements graphically rather than by specifying them textually. VPLs are key tools for further enhancement, progress, and motivation towards developers in this field of IoT while reducing time-to-market in product (IoT-software/hardware) development life cycle. VPL solutions are mostly distinct, having a different focus, set of features and base themselves in different paradigms. Examples of VPLs for IoT are Cisco Packet Tracer, Node-RED, Flogo, NETLab Toolkit (NTK), and many other tools. Device heterogeneity is an intrinsic characteristic of any IoT system. Designers of IoT applications should be relieved of most of heterogeneity and specifics (wide range of hardware and software entities running on specific platforms, middleware specific features, computing resources and protocols). They need to use an integrated development environment (IDE) based on domain specific high level language which in its entities would abstract most of these intricacies and specifics. VPLs should have capability to support large scale design of IoT systems by combining several design blocks and saving them in application libraries, importing, and setting parameters with ease for new tags and locations, enabling reusability and scalability.

Figure 2: Internet of everything (IoE), industrial IoT (IIoT) and consumer IoT (CIoT).

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IV. Methodology

Cisco packet tracer enables developers to view the flow of data packets and carry out analysis on the data packets transmitted in the IoT network. The article seeks to explore short development life cycle for IoT projects using a set of cloud based platforms and VPLs. A practical use case for a fertilizer manufacturing company was chosen. The company was commissioned in 1969 and since then, the technology for production of ammonium fertilizer evolved to include new technologies. The focus of the study is to automate the factory process systems and implement an IoT system to help manage the process for better process control and monitoring of key parameters through the use of smart wireless sensors which are able to communicate to the internet. Cisco Packet Tracer 7.2 was used for developing the IoT platform because it offers a variety of network components that simulate a real network. All the IoT devices on Cisco Packet Tracer can be run on standard programs or can be customized by programming them with Java, Python or Blockly.

4.1. Company Process Flow

The Key process plants that need to be interlinked together are the steam raising plant (boiler house for producing dry steam at 13 bars using coal fired boilers), nitric acid plant (produces 57% nitric acid for use in the production of ammonium nitrate), and ammonium nitrate plant (exothermic neutralization of nitric acid and ammonia). Major process parameters that need to be monitored for the three plants are saturated steam temperature, converter head temperature, and neutralisation temperature respectively.

V. IoT System Development

The network for the IoT system is logically separated into three areas: factory (shopfloor sensors), ISP servers (main control centre) and streets (end user devices). All IoT devices for the smart factory are connected to the router in the control centre. Factory floor sensors are wired to the microcontroller, which is in turn wirelessly connected to the home gateway. The home gateway broadcasts the data to the cloud via a DSL modem. The data is archived in servers and can be accessed by end user devices through the cell tower and wireless connections.

Internet settings in the router were the wireless Service Set IDentifier (SSID) and password. The same SSID, password and Dynamic Host Configuration Protocol (DHCP) default settings were used across all wireless devices, whilst the local server used static IP. Static IP addresses ensure that, in the event that the WLAN router is rebooted, the server IP remains the same, and there won't be any need to reconfigure the devices assigning new IoT server IPs. The central office server provides DHCP services, IoT and DNS functionalities. These functionalities ensure that there is backend intelligence to the IoT simulation as well as facilitating hosting of the IoT homepage where end users could connect and interact with the smart factory. The DNS service helps in translating the IoT homepage URL into the IoT server IP.

The smart devices are remotely connected to the IoT backend server. The IoT connection enables the users to check the status of the IoT devices from an IoT browser homepage. The IoT browser homepage shows a list of the smart devices, allows visualization of their status, and also permits remote interaction with the devices. Logical interaction between smart devices can also be set while connected to the IoT main homepage. Interactions between devices are based on set conditions, such as starting the chiller when temperature of a particular unit needs to be lowered, or reducing oxygen supply to the boiler in order to reduce the fire tube temperatures. The central control PC, manager smartphones and tablets, also connected to the local central office wireless LAN (WLAN), can connect to the dedicated IoT homepage via a browser in order to monitor all connected IoT devices.

Cisco Packet Tracer has a feature with the possibility to switch from a real time to a simulation mode. However, only in the simulation mode, it was possible to validate that the network communication layer really happened between the devices. In the simulation mode it was in fact possible to simulate packet traffic between nodes and devices in order to check the connectivity, routing protocols and other network logic.

VI. Conclusion

The article reviewed the literature on IoT under the headings: standard definitions, IoT technologies, layered architecture, Internet of Everything (IoE), visual programming and deployment of IoT, Cloud Computing, and fast track learning in the field of IoT. I choose cisco packet tracer because it offers a simulation environment with devices that look like devices in real life, also within the new version of the packet tracer we can find many internet of things devices, actuator and other sensors, which make the cisco packet tracer the suitable simulator for internet of things. An industrial use case for an IoT based smart fertilizer manufacturing plant was implemented using Cisco Packet Tracer 7.2 a visual tool for IoT modeling. The simulation only focused on process parameters for monitoring saturated steam temperature, converter head temperature, and neutralisation temperature respectively. The network side can also be expanded to incorporate different levels of access control, allowing PCs in the office network to access the IoT homepage, and creating mobile applications for access on mobile devices.

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