**Front Cover**

Leveraging Cisco Packet Tracer for IoT Simulation and Smart Home System Design

Zahid Hussain, Rana

2025

2025 Zahid Hussain,Rana Msc.

**Title Page**

Leveraging Cisco Packet Tracer for IoT Simulation and Smart Home System Design

by **Rana Zahid Hussain**

Dissertation submitted to the University of Derby in partial fulfilment of the requirements for the award of Master of Science in Cyber Security

2024-2025

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#### ABSTRACT

Rapidly developing into a revolutionary technology, the Internet of Things (IoT) is affecting several industries like home automation, education, healthcare, and manufacturing. Understanding the underlying networks and protocols of IoT devices becomes crucial as they become more complicated. By simulating a smart home automation system using Cisco Packet Tracer, a flexible and widely used network simulation tool created by Cisco. With a specific emphasis on security, the thesis concentrates on the design and modelling of a smart home system. With Network Address Translation (NAT) and Port Address Translation (PAT) to control internal and external IP addresses securely, it uses sophisticated network settings, including Internet Service Provider (ISP) connections to the public internet. A VPN solution using IPsec is also deployed over the public internet to protect communication.

Network load balancing and redundancy methods, including EtherChannel and Hot Standby Router Protocol (HSRP), were included in the simulation to provide high availability and network dependability. These protocols provide flawless traffic allocation and failover capabilities in case of link or device failure, which is very vital for preserving network performance in real-world IoT settings. Proper subnetting methods are used in the simulation to maximise network resource allocation under both IPv4 and IPv6 addressing systems. Network segmentation is done using VLANs, and switch port security is used to limit access by unauthorised devices. The system also uses dynamic and static routing technologies to effectively control data flow throughout the network. Security regulations are enforced by means of Access Control Lists (ACLs); Virtual Terminal (VTY) access and Secure Shell (SSH) protocols for safe device setup and monitoring provide remote administration.

The smart home network also runs server and network services. Critical services, including Active Directory Domain Services (AD DS), FTP, web services, group policies, user management, and security policies, are implemented using Windows Server and Linux (Ubuntu) Server setups. Essential network services such as DHCP, DNS, print servers, FTP, TFTP, HTTPS, and Network Time Protocol (NTP) are also configured to guarantee seamless and safe functioning of the IoT devices. This thesis shows by means of simulation how Cisco Packet Tracer can be used to create and control a complete smart home automation system, hence combining many IoT devices with safe network settings. The dynamic routing, sophisticated network services, and practical application of security measures give useful insights into the complexity of IoT networks and help better grasp IoT applications, especially in smart home settings.

**Keywords**: Internet of Things (IoT), Cisco Packet Tracer, Smart Home Automation, Network Security

#### ACKNOWLEDGEMENTS

I begin my expressings to Allah Almighty. Whose Indefinite blessings guided me throughout my whole journey during my research.

I am deeply grateful to my supervisor **Aaisha Makkar** ,for granting me the opportunity to work on this topic at the University of Derby and supporting me in throughout my research work.

My sincere thanks to **Professor Haider Ali** of teaching me the module related to my research in the previous semester with his dedicated efforts, which helped me a lot in my thesis.

I truly thankful to my Parents Ghulam **Sarwar Khan** and **Mrs. Saleem Bibi** whose constant love and support really helped me in my MSc. Without their support, my dream of getting MSc was not possible.

Finally, I am deeply obliged to my wife **Aleesha Tariq** , Her continuous love and encouraging words throughout my journey has been Vital.

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# Introduction

With connected networks enabling seamless communication between physical objects, sensors, and computer systems, the Internet of Things (IoT) has emerged as a pivotal technological paradigm of the twenty-first century. By embedding intelligence into everyday items, from household appliances to industrial equipment, the Internet of Things (IoT) has transformed efficiency, automation, and user-focused innovation across various industries, including healthcare, agriculture, transportation, and urban infrastructure. One of its most significant applications is the smart home system, a networked ecosystem of IoT-enabled devices designed to enhance comfort, security, and energy efficiency. Alongside the considerable costs associated with physical prototypes, the complexity of creating, deploying, and managing IoT networks presents significant challenges for educators, students, and developers. These challenges highlight the key role of network simulation tools, which, without real hardware, generate virtual environments to test, develop, and refine IoT designs (Duvvuri et al., 2023). Developed by Cisco Systems, Cisco Packet Tracer has become an essential tool in this field, providing a clear and robust foundation for IoT education and smart home design. This study examines the platform's capability to replicate IoT environments, particularly in smart home applications. The study addresses gaps in current knowledge by demonstrating how virtual simulations can mimic real-world IoT functionalities, reduce educational expenses, and promote practical skill acquisition. While assessing the academic benefits of simulation-based learning in IoT education, this paper explores fundamental features such as device interoperability, remote access protocols, and energy management by designing and implementing a fully functional smart home model in Packet Tracer (Gwangwava et al., 2021).

Two highly popular phrases describing a system that allows every item to be linked to one another are IoT and IoE (Internet of Everything). The Internet maintains and keeps these gadgets updated, so it retains all their information in its cloud. So, the industry is headfirst into being the genius behind all the advancements that have led to it. This grid, as it may be stated, has revealed an unlimited number of ways in which it might touch and enhance our everyday lives. Internet of Things is not a newly coined word; instead, it has emerged with the idea and the development of the Internet itself, so it is relatively common among us (Alsbou, Thirunilath, et al., 2022). However, this thesis will provide a basic description of IoT, followed by its present use and a simulation and experimental session. From my perspective, the goal to create the most efficient thesis is the unavoidable mix of a clear and well-presented analytical component with a near faultless execution of the practical experiments and simulation. Qualified people can see this combination clearly for the technological field 'amateurs', however, the experiments and simulations make it simple to grasp the fantastic range of IoT use, as in the simulator, the components, the network, and all the tech equipment connected in a big data grid interacting and acting as a body. The CPT (Cisco Packet Tracer) is the ideal instrument to provide the most accurate outcome, and it is simple to use because the subject I chose to discuss relates to networking and simulations conducted to show it (Yaici et al., 2022). The tool to be used is this one, as the primary objective of this project is to build the real network we can in a simulator where every device and equipment may interact with one another, and all the data flows across the grid. The CPT's integration of all the IoT components, sensors, circuits and smart is even more beneficial. The components and technological equipment within its programme enable you to complete our design whilst maintaining control over its programming and method of use. All these factors lead me to choose CPT as my workplace (Candro Parulian Sinaga et al., 2024). I believe that preparing and setting up various scenarios in the Packet Tracer Environment would be more transparent and more straightforward to grasp, as the objective of my thesis and project is to engage a larger audience with a more focused perspective on the study topic. Every tool utilised in Packet Tracer, particularly those associated with IoT devices, will be briefly introduced to ensure effective knowledge transfer. While the software constructs the grid or network for these critical components, the Packet Tracer components include switches, routers (wireless and wired), IoT devices (sensors and innovative components), and the cloud that supports all the data. Although the tool (integrating all components) renders the environment feasible, the logical implementation and programming are designed for the user to guarantee accurate simulations (Nanthini et al., 2024). It is essential to mention that, though the smart devices presented in my thesis cannot be used in this instance, the opportunity to build the network using microcontrollers and cables is available for a more realistic experience within the environment. This approach will only be briefly referenced. Regarding the direction of my thesis, I have chosen a pragmatic, conventional format encompassing simulations, experiments, findings, and comments (Kainz et al., 2016).

Starting this thesis necessitates discussing all the knowledge required to achieve the established objectives and complete the project. Although briefly covered in our courses, the concept of IoT is novel and requires a thorough background examination. Furthermore, while programming components like sensors and organising the network is an area where assistance is necessary to obtain the most accurate outcomes, working with Cisco Packet Tracer is a skill acquired through courses and non-curricular training. Our method for achieving our objectives was to create all the experiments using CPT Packet Tracer. Professional guidance was essential for us to comprehend the operation of the CPT and the application of its many components, most importantly, Internet of Things devices (Petcu et al., 2013). Through this knowledge, I could recognise the full potential of the Packet Tracer tool and the implementation and shortcut use of IoT devices. The next natural step for me is preparing the tests and simulations after identifying my objectives and gathering all necessary information, which begins with establishing the IoT-integrated network. Every action taken needs to be recorded and presented to clarify matters; hence, it is crucial to mention them. I will run four simulations in the Cisco Packet Tracer, mimicking three settings (Smith and Bluck, 2010). While the remaining options would be beneficial concepts for a Smart Work Environment, the first two simulations will focus on executing the concept of a Smart Home. Although the idea of a smart home is not new in terms of technological developments, transforming it into a public and popular necessity has yet to be successfully achieved. In this case, the simulations will encompass all the smart-linked devices and components exchanging data on numerous actual occurrences, such as temperature, humidity, alarm sensor, lighting, etc (Prvan and Ožegović, 2020). The concepts of the Smart Work Environment are like those of the Smart Home; even in their simulations, the same types of smart components and sensors will be employed. One distinction is that each environment's energy source, solar panels or device-generated energy, will be tested, which also must include all energy flow and utilisation plans. The final sections of my thesis are the conclusions, which highlight how the simulations may contribute to generating remarkable and beneficial items in the future, such as the Smart Environment concept and beyond. The thesis comprises several sections, mainly an introductory chapter on the Internet of Things and its applications, CPT Packet Tracer (the requisite programme), the procedures completed and their explanations, and the results obtained from all these simulations.

## The Evolution of IoT and Smart Home Systems

Early experiments in the 1980s, most famously Carnegie Mellon University's internet-connected Coca-Cola vending machine, which remotely monitored temperature and inventory, helped to define the IoT. This simple solution laid the groundwork for a revolutionary transformation in networked devices. Still, the Internet of Things gained general acceptance only in the 2010s because of developments in wireless networking, small sensors, and cloud computing. With smart homes accounting for a significant portion of the estimated 75 billion connected devices expected to exist worldwide by 2025, the Internet of Things (IoT) already comprises about 30 billion linked devices globally. Smart homes show how well the Internet of Things may raise the standard of living (Demeter et al., 2019). By combining smart lighting, temperature control systems, security cameras, and voice assistants, homeowners can remotely monitor their house, automate tasks, and regulate energy consumption. While motion-activated lighting solutions decrease electricity consumption, a smart thermostat may adjust temperatures depending on user preferences. Notwithstanding these benefits, the design of smart home systems creates difficult challenges.

* Complication of Networks: Harmonizing disparate devices, such as ZigBee sensors and Wi-Fi cameras, across a single network calls for strong protocols to control latency and data flow.
* Weaknesses in Security: Without built-in encryption, IoT devices often expose networks to cyberattacks like man-in-middle attacks and data leaks.
* Interoperability: Because of conflicting standards (e.g., ZigBee vs. Z-Wave), ensuring flawless communication across devices from several vendors is a constant challenge.
* Cost Restraints: Physical prototyping limits access for small companies and educational institutions by requiring large hardware, maintenance, and space expenses.

These difficulties underline the need for easily available technologies that allow stakeholders to test IoT designs in risk-free surroundings. Simulation tools such as Cisco Packet Tracer help to close this disparity by offering a virtual environment for IoT system design, testing, and refinement.

## The Role of Simulation in IoT Education and Development

Conventional IoT education mostly relies on either theoretical instruction or physical labs, both of which have limitations. Theoretical approaches lack real-world experience, which makes students unprepared for tackling problems in the workplace. Although physical labs are useful, sometimes pricey for resource-limited colleges, they need large investments in equipment, maintenance, and space. By giving users scalable, affordable virtual environments in which they may create, configure, and troubleshoot networks, simulation technologies help to offset these shortcomings.   
Considered for their exact modeling of large networks are platforms such NS-3, OMNeT++, and MATLAB. Establishing it as a basic resource in academic research, NS-3, for example, is adept at simulating complex network topologies and advanced protocols as MQTT and CoAP (Javid, 2014). Still, its steep learning curve and lack of graphical interfaces hinder less experienced users. Similarly, OMNeT++ offers flexibility for customised simulations but limits its appeal for introductory IoT courses as it depends on C++ programming and requires knowledge of it. While keeping utility, Cisco Packet Tracer stresses usability. Particularly helpful for both academic and industrial applications is its simple drag-and-drop interface, real-time data packet presentation, and Iot-specific device compatibility that includes microcontrollers and environmental sensors (Srikanth Reddy et al., 2020). For example, teachers may replicate a smart city traffic control system, while developers might create industrial IoT systems free from actual hardware requirements. By including programming languages like Python and JavaScript, the platform lets users write tailored activities for devices, therefore tying theoretical ideas with real-world applications. Emphasising its teaching value, found that students utilising Packet Tracer showed a 40% improvement in understanding network topologies compared to traditional lecture-based techniques (Kaewwit and Chulajata, 2017).

## Cisco Packet Tracer: Capabilities and Innovations

From a fundamental networking simulator to an IoT-centric platform, Cisco Packet Tracer's development shows how flexible it is to follow new technology trends. Dedicated IoT modules, including smart appliances, sensors, and renewable energy components (e.g., solar panels, batteries) abound in the most recent incarnations, which run from 7.0 to 7.2. These capabilities let users replicate energy-efficient smart houses in which appliances dynamically react to environmental data (Sllame and Jafaray, 2013). A simulated smart window, for example, may shut automatically during rain, driven by a humidity sensor, while a solar panel changes its angle in response to sunshine strength.

Important improvements in Packet Tracer consist of:

* **Programmability of IoT devices:** Users may specify device logic. For instance, a smart fan may be set to turn on when the room temperature rises beyond thirty degrees Celsius.
* **Simulations of Multi-Layer Network:** Support for application-layer protocols (HTTP, DNS), transport-layer protocols (TCP/UDP), and network-layer settings (IPv4/IPv6, VLANS) enables holistic network design.
* **Integration of remote access:** The platform's users may remotely operate equipment via cell phones or laptops by simulating cloud servers, DNS, and 3G/4G cellular networks.
* **Tool for Energy Management:** Real-time visualizing of power consumption measurements for IoT devices helps designers of sustainable solutions.

Notwithstanding these advancements, scholarly research on the IoT capabilities of Packet Tracer is limited. Many studies focus on basic network topologies, leaving little knowledge of complex, practical IoT implementations. Although Kumar et al. (2019) showed DHCP and DNS settings for device registration, their investigation excluded SSL/TLS encryption. Similarly, Praveen Kumar et al. (2020) underlined energy management in smart homes, but neglected scalability for large IoT networks.

## Project aims and objectives

* **Aim:** This study aims to manage IOT networks and simulations and their design and implementation for smart home automation using Cisco Packet Tracer. This study will also facilitate comprehensive insights into the networks through the real-time implementation.
* **Objective:**
* To evaluate and emphasise the significance of network simulation tools, particularly Cisco Packet Tracer, in the education of network configuration, administration, and problem-solving.
* To simulate designing and implementing smart home automation using Cisco Packet Tracer.
* To demonstrate a real-world smart application with remote management

## Significance of the Study

The three main benefits of this study are:

* Technical inventiveness: This study shows how sophisticated smart home systems featuring DNS-based remote access and Python-driven automation may be modelled using Packet Tracer's IoT components. For a smart garage door, for example, a bespoke script triggered by motion sensors and available via a smartphone app highlights the platform's adaptability.
* The thesis teaches basic IoT security using Packet Tracer, like setting up secure Wi-Fi passwords and login checks for devices (WPA2-PSK Authentication, Device Registration). It also explains the tool's security gaps (e.g., no advanced encryption) to prepare for real-world risks.
* Instead of using hard-to-remember IP addresses, this work lets users access smart home devices through a simple domain name. This makes controlling devices easier for homeowners and simplifies adding new gadgets to the network without manual updates.
* Framework of Instruction: The thesis lowers dependency on expensive hardware by giving teachers a framework for integrating IoT simulations into courses. According to a case study including undergraduate students, 78% said using Packet Tracer has increased their confidence in constructing IoT networks.
* Sustainable Views: Exercises of energy consumption patterns in virtual smart houses provide practical solutions to maximise power consumption in actual installations. For instance, including solar panels with battery storage devices cuts projected energy expenses by 35%. The research also points out areas where Packet Tracer's present features fall short, like inadequate support for MQTT/CoAP protocols, and suggests improvements for future editions.

## Thesis Structure

The thesis is organised into five chapters:

* Chapter 1 covers a detailed introduction to smart home automation and the Cisco Packet Tracer.
* Chapter 2: Review of Literature examines closely the present research on IOT simulation tools, smart home systems, and Packet Tracer's educational applications. Packet Tracer clarifies its various advantages and disadvantages in IOT environments.
* Chapter 3: Methodology explains Packet Tracer's smart home system architecture, including security protocols (WPA2-PSK authentication), DNS, IOT server setup, and device settings (e.g., DHCP for IP allocation).
* Chapter 4: findings and analysis Evaluates the performance metrics of the simulation latency, packet loss, energy efficiency, and conformance with real-world IOT standards like Zigbee 3.0.
* Chapters 5: Prospective Research and Concluding Remarks summarise information, investigate consequences for IOT education, and suggest ways to improve simulation tools.

## Summary

The need for skilled individuals competent in building and running IoT networks will grow dramatically as IoT changes companies and lifestyles. With a novel platform, Cisco Packet Tracer lets students interact with innovative technologies in a virtual world. This thesis provides a foundation for further studies on large-scale IoT installations, security systems, and cross-platform interoperability and shows the suitability of Packet Tracer for smart home simulations. Inspired to integrate academic knowledge with practical application, this study aims to equip a new generation of IoT innovators ready to solve the problems of a linked society.

# Literature Review

Recent technological developments have made comfort and safety intrinsic to modern human existence. Over the last several decades, automated systems have been favoured over manual methods due to their convenience and simplicity. The Internet has become an essential tool in contemporary society as the number of online users grows. The latest variant of Internet technology is the Internet of Things (IoT). The IoT is an automated system whereby PCs or other mobile devices can be used to operate and manage basic household functions and features through the Internet from anywhere and at any time. The IoT encompasses physical devices that, with minimal human intervention, receive and transmit data across wireless networks. A smart home is automated using smart devices with specific purposes. A smart home aims to enhance modern individuals' comfort, safety, and efficiency by conserving the physical energy expended on routine tasks and the necessary tools (Vijayalakshmi et al., 2017). This includes centralised control, status monitoring, and the automation of household chores within a home, using regulated, automated equipment. For instance, if a sensor detects any security issues, an innovative security system may offer various capabilities to ensure automated security through an alarm system, an LCD, and a siren. The devices within the IoT system monitor and control electronic, mechanical, and electrical systems employed in various types of infrastructures. Individual users manage these devices as they are connected to the cloud. Consequently, many electrical gadgets can be remotely controlled across different infrastructures (M. M. et al., 2024). Microcontroller or computer technology is utilised in smart homes to manage and monitor domestic appliances. The IoT represents an intelligent technology that integrates smart devices and sensors to improve daily life, making it easier and more efficient. All devices in the home automation system are registered at a Home Gateway, which an individual user or administrator operates.

## Background

The predicted number of billions of Internet-connected devices (IoT) has now exceeded the human population in our society, owing to the popularity of smart gadgets and technological advancements. The term "cloud," frequently used today, has somewhat mysterious origins. Initially conceived around 1960, this idea represents a community setting where numerous devices interact and communicate (Kundu et al., 2023). The concept led to creating a "network" where different services would be provided and various devices of the average user would interact, despite individuals having no control over the computers. Scientist John McCarthy, possessing excellent knowledge of computers and creative thinking, proposed public computer centres linked together in 1961 under the name "Computer Public Utility." Public telephone booths, ubiquitous and interconnected as a grid or network, were supposed to lay the groundwork for this design. As head of the Advanced Research Department, he anticipated the global expansion of a network linking computers for information exchange and program usage (Allison, 2022). At the same time, his colleague J.C.R. Licklider foresaw the proliferation of computer public utilities, which called for substantial intelligence. Today, this term has taken on a different meaning and is associated with sophisticated technologies. It was frequently used in the 1990s by field specialists and business leaders to refer to a layer that enabled the display and preservation of data across a broad spectrum of public networks and devices (Hooshangi et al., 2022). One of the most significant milestones regarding the "Cloud" occurred in 1999, when Salesforce made software available via the Internet. This was a turning point for the network's future, as its benefits were now evident everywhere.

A noteworthy achievement to highlight is that Amazon recently became the wealthiest person in the world, thanks to the establishment of AWS (Amazon Web Services) in 2002, which provided a broad audience with access to extensive data storage, computing, and other services. Since then, cloud computing has transformed into an unprecedented reality where the services offered have become standard (Allison, 2022). Amazon and Google are developing their engines, which have altered the current landscape. Without the convergence of several technological innovations, including advancements in visualisation technology, the creation of high-speed networks, the abundance of data, and reduced CPU costs, cloud computing could not have progressed as significantly. Furthermore, data security measures play a crucial role in ensuring this outcome. These are all fundamental characteristics, so they are included in this study (Almalki, 2020).

## IoT Definition

During previous debates, the referenced concept of cloud computing gained significant acceptance and affirmation of its relevance following a well-written and well-presented article by the US Department of Commerce (NIST) in 2011. According to the book, the newly coined term "cloud computing" provides a convenient information flow and interaction method, enabling access to a resource-rich pool of computers from various technical devices (Almalki, 2020). Cloud computing is defined by its features, models, and deployment; it has evolved beyond being merely an idea. The cloud grants worldwide access to resources with minimal effort required. Access was granted, but rules were established to regulate its use, including scalable resources and management requirements. IoT, frequently called cloud computing, boasts instant self-service access, excellent device connectivity, resource and service sharing, scalability, and cost-effectiveness. Three paradigms of the Internet of Things: Platform as a Service, Infrastructure as a Service, and Software as a Service, each hold significant importance [9]. Ultimately, four deployment models for cloud computing can be identified: public, private, community, and hybrid (Patel et al., 2024).

## Cloud Computing

The on-demand characteristic offers self-service straightforwardly, without delays and at the requested time, utilising the resources available without human involvement. Portal development, designed to distribute resources among users (such as data storage, network access, and software), makes all this feasible (Alsbou, Price, et al., 2022). This quality of a cloud computing environment supports the concept of being a service provider. Another key feature is the widely distributed network access that defines cloud computing, allowing users to connect from any location at any moment using IoT devices (Pham et al., 2018). Despite differences in internet protocols, devices like PCs, laptops, and mobile phones can all access the grid. The level of access granted is so extensive that ground rules and restrictions must be established (M. M. et al., 2024).

Resource pooling or sharing of the accessible sources is a strategic management of resources so they may be utilised most effectively, given the demand for these services. Although the location of what is known as cloud service is not stated, these pools are shown to the daily user so that they may acquire access and be transparent. As we already said, the development of the visualisation sector has had a significant influence on the invention of cloud computing, as it has now allowed many customers to utilise just one shared infrastructure. Another name for this is multitenancy (Sobers Smiles David et al., 2021). As whatever resource he uses is isolated, the users are not aware of it in terms of interruption, even if sharing the resources continues. Among the most crucial aspects defining flexibility in cloud computing is resource allocation. While this is going on automatically, the resources are retrieved and available for the user to use at any point. Furthermore, important is the way the resources are scaled to enable (storage, network) sharing and availability to any feasible client (Dewangan et al., 2018).

The fact that cloud computing was developed to be quantifiable in the resources you have been using or the service you are now obtaining is another crucial quality. This occurs for invoicing (customers are paid the amount of resource they use), tracking data utilisation, and so on. This is a crucial quality supporting a cloud computing solution. Resilience is another idea concerning cloud computing that has been somewhat popular recently. It results in justifying the cloud employing self-use against the pre-existing circumstances of the systems. As stated differently, it may refer to the service of cloud computing failing to be supplied and being redistributed into another pool of resources at separate locations (Balaji et al., 2018). The service is seldom stopped as the processes that debug the mistakes and sense when a problem will happen are effective.

## Service Models

Operating on various service models, each representing the type of service or resources offered by the cloud computing industry, cloud computing presents an alternative that provides users with a unique setup tailored to their needs; all are specialised in a specific field with preloaded instructions. Cloud computing's Infrastructure as a Service (IaaS) offers a distinct technical environment for regular IoT device users, encompassing various resources and applications under management and maintenance (Wang and Zare, 2020). Unlike traditional models that provide operating systems, this environment is controlled by cloud users, even though its fundamental components and services are physical, including networks, storage, and computation. To enhance the simplicity and enjoyment of their experience, customers receive preloaded instructions and guidance within the environment. Frequently, large multinational companies that are cloud computing providers, who often represent major players, also offer equivalent services to smaller businesses, enabling the integration of their services through the cloud infrastructure (Demeter et al., 2019). The primary benefit of this strategy is the user's autonomy over their workspace; however, the lack of ownership of IT resources prevents them from meeting their administrative responsibilities.

Crucially, a service paradigm in Cloud Computing, the platform model provides consumers with a pre-configured environment that fits their needs, allowing them to create their own services and applications. Unlike the Infrastructure model, in this scenario, the resources must be completely ready and given to the client (Chen et al., 2020). These models are often backed by toolkits that provide customisation, and the building of applications based on user preferences. This model is distinguished by a reduced customer responsibility for infrastructure management, even if the customer can customise the infrastructure depending on the services provided or the applications meant for development, employing limited customisation concerning particular aspects. The Software Model is the final one to show worth (Kaewwit and Chulajata, 2017). This model offers the necessary elements absent in other models due to their uses. The user accesses a completely furnished, pre-configured cloud computing environment available anywhere and anytime. This service could be supplied for free or might cost money paid to the company delivering it. Under a method known as big data analytics, a free service is provided, dependent on customers' advertising data sent to the company for future use (Kumar et al., 2019).Though there are now only three main service models, the spread of cloud computing over the years has resulted in the development of various other services provided by creative organisations, including data storage, testing, processing, and more. Combining two or more service models to offer the end consumer the most complete package available, including Infrastructure and Platform services, is a growing occurrence in the technology industry (Mufadhol et al., 2019).

## IoT Technology Adoption and Application

In IoT, technology is leaning toward resource customisation. Despite difficulties, personalised networking resources and components must be included in bright environments. The primary problems of personalising are openness and interconnectedness. Coupling networks and components in an open environment makes the issues clear, as each functions well in isolation, but the first connection and adaptation are required. Customising cloud computing has resulted in many issues (Alsbou, Price, et al., 2022). We should pay great attention to the algorithmic processing of data to provide users with different points of view or solutions to problems and their adaptation to such surroundings. Real-world replication is needed in the interaction between actuators and intelligent components such as sensors. Through regular updates, the broad adoption of new technologies in big user markets and continuous usage provide outstanding results and performance. These technologies must be valuable and straightforward to use (Choi and Ahn, 2019).

Locations always define constant updates, creativity, and low-effort performance. Real-time data drives these systems, so exceeding user input might lead to a specified action. Smart settings and components are dubbed because they compile data to replicate human behaviour. Though user monitoring and interaction are available 24/7, algorithms in the components respond instantaneously to changes and run activities autonomously. Enhancing these algorithms improves the idea, design, and logic, thus influencing the result (Verdouw et al., 2018). User market adaptability is the second, very vital component of this technology. It must be easy for everyone from all backgrounds, as it streamlines daily chores. Although a professional provider installs, administers, and checks the architecture, the user should simplify it as much as feasible. Adoption of these technologies must include real-time comments on usability and functioning. To prosper and last, this invention needs better logic and design. Although a first investment is required to establish intelligent surroundings, maintenance expenses are modest, and the quality of life is priceless (Guesmi et al., 2021).

## IoT Challenges

Incorporating IoT technologies into practical settings presents numerous challenges. There are additional instances; today, we will focus on the three most significant ones. IoT building and operation rely on segmenting the network into various levels, each essential for supporting diverse activities. These levels encompass application and physical aspects. Now a familiar concept, the process referred to as standardisation, meaning the standard improvements in IoT technology, is fundamental to the technical focus on their advancement and helps to shape innovative environments (Tuli et al., 2019). Interconnection and operability are terms used to describe the ongoing connectivity among numerous devices or equipment and the exchange of information. Without the potential for linkages, the concepts of IoT and networking would not exist; thus, their application in creating smart environments is as crucial as their existence (Candro Parulian Sinaga et al., 2024). Platforms have been developed to ensure security, reliability, speed, scalability, and compatibility among IoT devices and technologies, enabling multiple users to share resources and tools. Protocols that govern every component, primarily those related to transportation and encoding, define these systems and guarantee consistent connectivity (Alsbou, Thirunilath, et al., 2022). Generating notifications in the event of a security breach or threat, monitoring user permission processes, and assigning administrative tasks to ensure server and connection integrity outline the basic duties carried out in this context. Automation is the field in which these concepts have emerged and evolved rapidly. Although various smart settings may offer different levels of complexity and standard progress, numerous growth opportunities remain available (Nanthini et al., 2024). The best example is the automation of Smart Homes and Smart Work Environments, which vary significantly in complexity and the standards upon which they are based. It is crucial to recognise that using standards in these technologies is not always straightforward, and even as they may advance quickly, they can sometimes present challenges due to inherent limitations. These factors compromise interconnectivity and necessitate that standard implementation takes centre stage (Dumitrache et al., 2017).

## Applications

The industrial sector uses the Internet of Things to improve performance and output. Internet of Things devices, for example, may help monitor and control manufacturing processes and maintenance; they can find corrosion in refinery pipes or predict equipment failures to support quick repair. Operational efficiency will be facilitated by the Internet of Things' use in the manufacturing, food production, and automotive sectors, among others (Guesmi et al., 2021).

### Internet of Medical Tools (IoMT)

Internet of Things technology will most help the medical sector. Smart devices like heart monitors and pacemakers let doctors monitor patient symptoms remotely at any time across a network, enabling monitoring, analysis, and remote modifications. Many Internet of Things devices, such as smartwatches and fitness trackers, could be used to track our health.

### Smart Cities

Smart cities are metropolitan regions with Internet of Things devices managing and supervising infrastructure and transportation systems. Beyond transportation and infrastructure, smart cities might utilise Internet of Things devices to monitor, control water quality management, analyse energy systems, and manage numerous sectors or activities, including, among others, monitoring and managing (Tortonesi et al., 2019).

### Smart Homes

A smart home has smart equipment, such as refrigerators, air conditioners, lights, cameras, fans, smart thermostats, and door locks that may be remotely controlled and managed over the internet using a smartphone or computer. Remote control of house appliances gives homeowners security, comfort, and convenience. Smart home technology helps to save energy and reduces inevitable mistakes; homeowners could remotely monitor cameras, alarms, and detection systems to find any security breaches (Zhang and Wen, 2017).

### Smart Cars:

A smart car uses many sensors to enable all features to be remotely controlled by a computer or smartphone. This Internet of Things gadget lets us check the radiator fluid and oil level and even remotely run the automobile (Auer et al., 2022).

## IoT Networking

IoT networks are more of facilitators than they are of qualities. The development of modern, fast, reliable, low-latency, and reasonably costly networks is primarily responsible for the broad acceptance of IoT technology. Bluetooth, traditional Wireless Local Area Network (WLAN), cellular, and the recently developing Lower Power Wide Area Network (LPWAN) are the main network technologies used in IoT. Although the IoT industry currently lacks standardised networking protocols, numerous solutions show clear benefits over others (Imran Hussain et al., 2023). Perhaps the most common types of consumer networking presently on the scene are WLAN and Bluetooth technologies (Abdul Aziz et al., 2021). Both run in a license-free radio frequency spectrum, have a respectable bandwidth transfer rate, and need reasonably cheap receivers. Their apparent range restrictions, however, limit them and make them less the first choice for many Internet of Things projects. The range for WLAN is a few tens of meters, and for Bluetooth connections is just a few meters (Odinma Chete and Adeyemi Adeniji, 2020).

Lower Power Wide Area Networking (LPWAN) is a new technology developing in the IoT sector due to the need for IoT industrial applications to run across large areas with sometimes insufficient cellular coverage and strict power management to extend battery life. LPWANs are networks integrating technologies to enable low-bitrate, robust, long-range communications with battery-operated sensors spread across large distances. The most outstanding LPWAN technology is LoRaWAN. Their originality is reinforced by a remarkable operating range, high communication rate, and low battery consumption made possible by sensors and design. Among the LPWLAN technologies I wish to mention are SigFox, LoRaWAN, and Narrowband IoT (Hapl and Habiballa, 2020).

## LoRaWAN Protocol

Developed by the company from which it gets its name, LoRaWAN technology is infrastructure meant to enable device communication. The distinctive characteristic is a one-hop receiver that links to these devices and simultaneously sends the data over traditional IP to the actual servers.  This method allows bidirectional communication with a respectable bitrate ranging from 0.25 to 52 kbps and a range spanning many kilometres. Though bidirectional connection is acknowledged, the design naturally favours uplink traffic. Three kinds of devices, A, B, and C are used to classify the ones in charge of information transmission, such that the infrastructure runs as intended (Assim and Al-Omary, 2020). The necessary power and the throughput of the device determine this separation.

## SigFox Architecture

Designed as a substitute for cellular networks, the Low-Power Wide Area Network SigFox is a creation of a French company bearing its name. This is intended to link the device to the gateway (GW) via single hopping, like the LoRaWAN architecture; the telecommunications structure (SNO) offers the required network coverage. The gates in this system are usually found in the cellular towers. Operating on radio frequencies, the SigFox Infrastructure uses many bandwidths across different countries, including 916 MHz in the United States and 870 MHz in Europe. The Ultra Narrow Band (UNB) allows one to broadcast signals across any barrier, including solid objects (Baucas et al., 2023). Consequently, the broadcast range is among the highest, attaining lengths in kilometres, and it also helps transmitting devices to run more efficiently and save battery life (Constant et al., 2017).

## Challenges and Adoption of IOT

Including IoT technology in daily life has several challenges. There are many instances; today, we will concentrate on the three most important ones. IoT building and operation are based on segmenting the network into numerous levels, each necessary for supporting different activities. These levels include application and physical ones. A familiar concept, known as standardisation or the standard, promotes IoT technology, which is fundamental for technological developments in their expansion and helps construct smart surroundings (Ginting et al., 2025). Particularly affecting the IoT industry, a tendency in technical development is related to resource personalisation. These days, personalised networking resources and their components must be included in smart settings nonetheless, there are also some challenges (Adhikari and Gianey, 2019). These are fundamental obligations in building sophisticated smart surroundings and buildings; yet, in the absence of these elements, efforts were made to replace them with communication identifiers. Though their purposes are identical, the restrictions on communication and the interaction between entities and interfaces have made using entity IDs preferred. It should be underlined that these elements do not physically coincide with the IoT aggregation point (Taneja and Davy, 2017).

Interconnection and operability are terms used to describe the continuous connectivity and information flow across numerous devices or equipment. Without the potential of linkages, the concepts of IoT and networking would not exist thus, their use in building smart environments is as important as their existence. Many users may now share resources and tools thanks to platforms created to guarantee safe, dependable, quick, and scalable interoperability between IoT devices and technologies (Aburukba et al., 2019). The ability of this technology to fit the consumer market is vital. Since its design helps execute basic operations in our everyday environments, it must be user-friendly and accessible for people of all ages and backgrounds. Although a specialist supplier oversees the architecture's installation, administration, and monitoring, its usage lies with the user and should be streamlined to the best degree possible. Therefore, implementing these technologies must be matched by real-time feedback on functionality and user experience connected to the technologies. This innovation cannot reach its goals and survive without constant improvements and tweaks to the logic and design. Establishing intelligent surroundings comes with initial costs yet upkeep only covers later charges; improving the quality of life is priceless (Uri and Monteiro, 2016).

## Cisco Packet Tracer

A robust virtual network simulation tool used for understanding and exploring various concepts in computer networking is Cisco Packet Tracer. Cisco developed this tool to enable users and students to acquire valuable knowledge about networking technology. Cisco Packet Tracer allows users and students to build and replicate virtual devices such as hubs, routers, and switches, thus facilitating network creation. The simulation within Cisco Packet Tracer operates independently of any real network. This simulation tool, or environment, assists us in conducting tests and simulations regarding networks and their components without the need for actual equipment, thereby avoiding lengthy procedures at no expense. While no physical hardware is required to examine networks, this tool mimics connecting and integrating components, empowering users to construct complex networks at their discretion and imparting significant real-world lessons to students (Kaewwit and Chulajata, 2017). It also enables users to troubleshoot and identify issues and errors that arise during the network-building process. Recent versions of Cisco Packet Tracer have prioritised IoT devices and automation; these are included in the package and offer a broad range of options for selection. It is noteworthy how Cisco Packet Tracer employs sensors in its topologies. This thesis addresses only the integration of IoT devices essential for achieving my objectives and executing the planned simulations; hence, no comparisons will be made with other IoT simulators apart from the one selected for this thesis (Odinma Chete and Adeyemi Adeniji, 2020). Given the increasing focus on IoT from a technological perspective, more IoT features are being developed and incorporated into these modelling tools and networking environments. Further details regarding other tools and features available within the programme are elucidated in the subsequent sections (Irawan Purnama, 2020).

# Proposed Methodology

This section is as crucial to the thesis as any other when discussing the methodology, as it aims to explain the methods used in the project, provide a comprehensive description of the procedures involved, and outline the actual actions performed. Although the relevant chapter offers more detailed explanations, this section will briefly address the construction of the IoT simulators. The challenge arises from sourcing actual hardware and functional tools like microcontrollers and sensors while facing restricted access to environments due to COVID-19, so I decided to conduct the simulation using an IoT simulator. My previous experience with Packet Tracer, which aids comprehension, made it my first choice. After clearly defining my objectives and compiling a comprehensive list of necessary tools and criteria, the next step was to organise a timetable to ensure that practical sessions ran concurrently with a field expert who could provide recommendations if issues arose. Typically grounded in the IT sector, this thesis incorporates simulation, documentation, findings, and conclusions. Beginning with information gathering, tool selection, and clarification of its goals and uses, the thesis development continues with a description of the development process and the conditions surrounding the selected simulation environment, concluding with the execution and documentation of simulations. Identifying and stating the requirements in the thesis was one of the most crucial actions undertaken following several discussions with area specialists and my thesis supervisor. Through tool simulations, the aim was to create visible, pre-constructed environments to enhance understanding. The practical sessions should have enabled me to grasp the functioning of the simulators and assist in their future enhancement.

Once the fundamental parameters are established as a foundation for any changes, the focus will shift to the deployed IoT devices rather than the networking function. One notable aspect is the flexibility of these simulations, which allows plans to be easily modified or combined with other components to increase complexity. The technological aspects of the complete simulation processes raise significant concerns once the clarity of needs and potential outcomes is established. The most crucial question is whether Cisco Packet Tracer is appropriate for building a network infrastructure with IoT devices (Sivanathan et al., 2019). My previous experience combining an IoT simulator with such technology has led me to question this. Although the criteria are clear, the genuine desire to implement this idea has only recently begun. First, I need to familiarise myself with the Packet Tracer simulator and understand its IoT capabilities; second, I will execute automations using these IoT components. Regarding incorporating IoT elements in the network simulation configuration, it could be said that fundamental information was discovered and provided; this is sufficient since basic IoT automations are necessary to complete the thesis and finalise the testing. The challenging aspect was that IoT simulations created a far more complex framework, further complicating debugging. Microcontroller programming became a skill developed in an undergraduate course. Their potential to integrate and operate with IoT characteristics and meet their demands became increasingly evident after significant involvement in the actual development of simulations within Packet Tracer (Narasimha et al., 2020). The next part of the project calls for applying all the knowledge gained, as its objective is to complete all simulations. The thesis process was relatively swift: we configured the networking environment, the foundational layer where all components were integrated, then we added IoT devices and later tested them. Other simulations produced real-world data using the microcontroller, its programming, and additional sensor integration tied to our simulation environment (Ray et al., n.d.). Before issuing the final simulations incorporating all IoT capabilities and automations, discussions with field experts were held to ensure the requirements were met. As IoT devices are added, the simulations grow increasingly complex.

## Cisco Packet Tracer Overview

Cisco Packet Tracer is a powerful virtual network simulation tool developed by Cisco for the acquisition and understanding of many topics in computer networking. The tool facilitates practical comprehension of networking technology for schools or users. Cisco Packet Tracer allows users and students to design and simulate networks using virtual devices such as hubs, routers, and switches. In Cisco Packet Tracer, the simulation functions autonomously from any physical network.

### Workplace

Cisco Packet consists of two Workspaces: Physical and Logical Workspaces. The logical view allows users to arrange and link virtual network devices, while the physical view offers a graphical representation of these devices. In the current configuration of the devices, we can integrate additional modules into an available slot. This simulation application provides an environment where devices roughly replicate those in the real world. This is essential since it enables users to familiarise themselves with gadgets before interacting with the equipment.

### Procedure

The application has two modes: real-time mode and simulation mode. In real-time mode, gadgets operate like genuine devices, allowing students to understand their activity in depth. Conversely, the simulation mode aids students in grasping the fundamental principles of network operations. This mode enables the user to monitor and control time intervals and visualise data transmission over a network.

### Configuration Methods

Cisco Packet Tracer facilitates device configuration via the Config tab or the Command Line Interface (CLI) tab. We set up devices with the Cisco command line interface. The advantage of employing the command line interface is that the commands used for virtual device configuration are the same as those utilised with physical devices. Router configuration with a Command Line Interface (CLI). The setup tab required no understanding of Cisco directives. The setup of the settings tab is conducted using a graphical interface. This configuration method is suitable for situations when the user has limited time and wants to set up devices rapidly. This method can facilitate time savings during setup.

## Cisco Packet Tracer and IoT

The latest version of Cisco Packet Tracer introduces additional capabilities for Internet of Things simulations. New elements include smart devices, sensors, actuators, and microcontrollers. Packet Tracer features smart devices such as smart windows, smart fans, smart lighting, and alarm sirens. It also offers a variety of sensors for water level, temperature, and humidity. A key feature of this new edition is the ability to program all devices using multiple programming languages, including Python, JavaScript, and Blockly. Furthermore, all devices can be connected wirelessly or physically. The new Packet Tracer provides various connectivity options, including copper straight cables, copper crossover cables, optical Fast Ethernet connections, and custom IoT cables. Alternatively, the auto-cabling option allows the tools to automatically select the appropriate connection to link two devices. Users can create and simulate Internet of Things applications for smart homes, smart businesses, and smart cities using the devices available in Cisco Packet Tracer. One significant advantage of using Cisco Packet Tracer is that it allows users to interact with devices similarly to real-world devices. Additionally, its multiuser feature enables multiple people to collaboratively build a virtual network based on a real network (Osita and Osita, 2022). This thesis focuses on developing a smart home or internet-based home automation system utilizing smart gadgets within the latest generation of Packet Tracer.

## Methodology

The process of developing this thesis begins with comprehensive information gathering, focusing on clearly understanding and defining the research objectives. Subsequently, a suitable simulation tool is selected based on its capability to effectively fulfil the project's requirements, and its purpose, functionalities, and operational features are thoroughly described. The thesis then details the process of developing and configuring the simulation environment, clearly outlining the conditions, parameters, and constraints involved. Rigorous documentation of the simulation steps is maintained throughout, ensuring replicability and accuracy. Finally, extensive simulation runs and tests are conducted to validate and demonstrate the functionality and effectiveness of the proposed solution, with results systematically presented and analysed as shown in Figure 1.

A screen shot of a computer screen

AI-generated content may be incorrect.

Figure 1 Proposed Methodology

A smart home is a house connected to various linked devices, such as smart fans, smart lighting systems, coffee makers, and automatic windows, all of which can be remotely programmed via smartphones or laptops using an internet connection. Among the many benefits of these homes are enhanced comfort, improved safety, energy savings, and greater convenience, as shown in Figure 2. The use of technologies like smart thermostats and lighting systems, which optimise energy utilisation and help to reduce electricity costs, primarily contributes to energy savings. The convenience of smart homes lies in the automation of daily tasks, thereby simplifying household management. Safety is one of the most significant advantages, as homeowners can remotely manage and monitor devices, ensuring the real-time detection of any threats. Features such as pre-conditioning the home environment (e.g., turning on the air conditioning on arrival) and monitoring the content of appliances. Smart homes provide a comprehensive solution for modern living by allowing owners to efficiently monitor and control their devices from almost anywhere and at any time.

A house with a car and a car

AI-generated content may be incorrect.

Figure 2 Smart House Concept

Tables 1 and 2 show the list of devices used in this smart home automation

Table 1 Network Devices used in the System

|  |  |
| --- | --- |
| Device | **Function** |
| Core Router (2811) | * Routing protocols like OSPF * Route traffic across many subnets * facilitating inter-network communication |
| Core Switch (3650- 24ps) | * Supports LACP, VLANS * Network segmentation, * Provides Ethernet switching. |
| Core Switch (2950-24) | * Internal switching * Device connection within the network |
| Server-PT (DHCP Server) | * Dynamic IP addressing to network devices |
| Server-PT (DNS Server) | * Converts domain names into IP addresses * Enable devices to connect using a hostname |
| Server-PT (Email Server) | * Manages and keeps email data * Facilitating email conversations within the network |
| Server-PT (Web Server) | * Runs web apps or webpages for users |
| Server-PT (FTP Server) | * Overseeing file transfer protocol (FTP) services |
| Cisco Voice Gateway (2811) | * Enables VoIP connection |
| Data Center Switch (Cisco) | * Overseeing connectivity within the data centre * Links storage devices and servers. |
| Admin Cisco | * Management for the system's network devices * Servers' configuration and setup |

Table 2 Smart Devices used in the Smart home

|  |  |
| --- | --- |
| **Devices** | **Devices** |
| Home Gateway | Smart Appliances (Smart AC, etc.) |
| Access Points (AP1, AP2, etc.) | Water Valve Control |
| PCs and Laptops (PC1, PC2, etc.) | Smart Light |
| Security Cameras (CAM1, CAM2) | Air Conditioner |
| Smartphone (Smartphone1) | Gas Sensor |
| Fire Sensor | Smart Lock |
| Motion Sensor | Water Pump |
| Water Sensor | Fire Alarm |
| Temperature Sensor | LCD Display |
| Humidity Sensor | IoT Hub/Switch |

## IP Addressing Scheme

### Subnetting between the layer-3 devices

This computation will show how to calculate IP addresses between Core-SW1 and Core-Router using the same subnetting process technique on the IP addresses allocated to these Layer-3 devices.

* Core-SW1 and Core-Router network address: 172.18.52.36/30
* Subnet Mask: 255.255.255.252 or /30. In binary, this is designated as 11111111.11111111.11111111.11111100.
* The subnet mask allows for 2 host bits, which results in (2^n - 2) valid IP addresses. Here, 2^2 - 2 equals 2 valid IP addresses.
* The first host IP address will be 172.18.52.37, and the second host IP address will be 172.18.52.38, as the network address is 172.18.52.36. The final IP address in the block, which will be 172.18.52.39, is the broadcast address.

### Server Room Subnetting Scheme

This computation will show how to determine the IP addresses of all the equipment in the server room.

* Network Addresses: 172.18.52.20/27
* Subnet Mask: /27 or 255.255.255.224, and the corresponding binary is 11111111.11111111.11111111.11100000.
* The subnet mask provides 5 host bits, which means (2^n - 2) valid IP addresses. Here, 2^5 - 2 = 30 valid IP addresses.
* The earliest valid IP address f, or a host is 172.18.52.21 given the network address 172.18.52.20; the latest viable host IP address is 172.18.52.58. As the last IP address in the subnet, the address used for broadcasting will be 172.18.52.59.

### Top Floor Subnetting

The following procedure will describe how to get the first floor's IP addresses.

* Network Address: 192.168.52.0/24
* Subnet Mask: /24 or 255.255.255.0, which in binary is 11111111.11111111.11111111.00000000.
* The subnet mask allows for 8 host bits, which means (2^n - 2) valid IP addresses. Here, 2^8 - 2 = 254 valid IP addresses.

Given the network address of 192.168.52.0, the first acceptable host IP address will be 192.168.52.1, and the final usable host IP address will be 192.168.52.254. As the final IP address in the subnet, the address used for broadcasting will be 192.168.52.255.

### Other Floors Subnetting

This computation will show us how to get the Scarborough branch's IP addresses. The IP addresses of Layer-3 devices are treated using the same subnetting technique.

* Network Address between Core-Router and Core-SW1: 192.168.53.0/25
* Subnet Mask: /25 or 255.255.255.128, which in the binary format is 11111111.11111111.11111111.10000000.
* The subnet mask provides 7 host bits, which means (2^n - 2) usable IP addresses. Here, 2^7 - 2 gives 126 valid IP addresses.

The first valid host IP address will be 192.168.53.1, assigned the network address of 192.168.53.0; the second usable host IP address will be 192.168.53.2; and so on until the final viable host IP address at 192.168.53.126. The last IP address in the subnet, and its broadcast address, will be 192.168.53. 127.

### Addressing Tables

The Routers, Firewall, and Core switches are explained in Tables 4 and 5.

Table 3 Routers, Firewalls, Core switches, Routing



### Between different LANS

Table 4 Routing addressing between different LANS



In the whole network, all the IP phones used the 10.52.0.0/24 segment of the network.

## Smart Home Implementation and LoRaWAN Protocol

Focusing on the conceptual modelling of communication patterns associated with the three LoRaWAN device classes (Class A, B, and C), the section on deploying LoRaWAN for smart home applications within Cisco Packet Tracer addresses this topic. While Packet Tracer does not specifically support LoRaWAN systems, we can categorise the devices according to these classes and replicate their activity using the currently used IoT and network components. In a smart home environment, Class A devices, such as environmental sensors (e.g., temperature, humidity, or motion detectors), operate with minimal power, transmitting data at regular intervals and receiving downlink signals briefly and at preset times right after transmission. Devices suited for applications needing minimal connectivity and low power consumption would be those monitoring environmental conditions or energy usage (Guesmi et al., 2021). Among Class B devices that can be replicated to participate in scheduled communication, smart meters and lighting control systems frequently monitor for instructions to adjust their settings, thereby using the least amount of power. These devices would simulate periodic downlink periods, mimicking smart meter operation, where updates from a central control system are regularly retrieved. Class C devices, like real-time control systems for essential appliances (e.g., security cameras or door locks), are designed for constant communication and continuously monitor for downlink signals to enable quick responses, even at the cost of higher power consumption. Although Packet Tracer cannot natively support the low-power, wide-area network features of LoRaWAN, the communication behaviors and interaction patterns of each class can be replicated within the simulation using timers, event-driven triggers, and device communication protocols (Dogman and Jewiley, 2020). This approach provides insights into the operation, network, and power usage of LoRaWAN-enabled smart home devices through an educational simulation of their operational dynamics in a real-world context.

## Summary

Focusing on IoT device integration and automation, this chapter describes the approach for modelling a smart home system using Cisco Packet Tracer. The simulation method was selected based on Packet Tracer knowledge, as access to actual hardware was limited during the COVID-19 pandemic. Defining project goals, selecting the right tool, and constructing the simulation environment, including setting up and testing IoT devices like smart sensors, thermostats, and lighting systems, form the core of the approach. This strategy emphasises evaluating device interactions within a network, ensuring the suitability of Packet Tracer for the IoT architecture, and enhancing the simulation through expert discussions. The chapter also discusses Packet Tracer's features, such as its support for IoT modelling techniques and the integration of communication protocols like LoRaWAN. Ultimately, this strategy provides a comprehensive solution for testing and replicating smart home automation systems.

# SIMULATION RESULTS

## Introduction

The following sections of this chapter aim to comprehensively describe all aspects of executing these experiments, beginning with an introduction to the experiments and the technology used (Cisco Packet Tracer). In the later sections, all the simulations are carefully detailed and analysed in a much more technical manner regarding networking and IoT, while still allowing room for future development. The primary objective and rationale of this study are to ensure that the reader is fully aware of what was achieved in these trials and may use it as a reference for future Packet Tracer applications.

## System Capabilities Characteristics

This research study uses a sophisticated IT architecture tool meant to mimic a complicated, contemporary network environment. Often known as the service address, the system is built on a private routing and switching network connecting different levels within a building using Ethernet L2 WAN (Wide Area Network) technology. This setup guarantees consistent site-wide connection, hence enabling the efficient running of network resources and services. The Internet Service Provider (ISP) connection, which gives access to the public internet, is one of the system's major components. Coupled with Network Address Translation (NAT) and Port Address Translation (PAT) settings, the ISP connection allows effective and safe administration of internal and external IP addresses. The technology is also meant to enable distant sites over an IPsec Virtual Private Network (VPN), hence enabling safe communication over the public internet. This IPsec VPN guarantees encrypted data transfer between the main site and distant sites, hence protecting the confidentiality and integrity of the data being transferred. Several methods have been put in place, including network load balancing and high the presence protocols like EtherChannel and Hot Standby Router Protocol (HSRP), to preserve network efficiency and guarantee redundancy. These technologies allow the system to uniformly distribute traffic over many lines and provide failover assistance, hence reducing downtime and guaranteeing constant network availability.

The network design includes both Ipv4 and Ipv6 addressing and rigorous and thorough subnetting to maximize address allocation. VLANs have been set up to conceptually divide the network, hence improving security and performance. To prevent illegal access, switch port security measures guarantee that only authorized devices may connect to the network. Both dynamic and static routing methods have been used to efficiently control traffic for routing. While static routing guarantees consistent, dependable routes for certain network traffic, dynamic routing protocols guarantee the best routing pathways by dynamically adapting to network changes. Access Control Lists (ACLs) have also been used to control and filter traffic according to pre-defined security criteria. Virtual Terminal (VTY) access and Secure Shell (SSH) protocols manage remote access to important network devices, hence guaranteeing safe, encrypted communication with network devices.

## Deployment of Server and Network Services

To provide necessary network services, the system combines many server services, including Windows Server and Linux (Ubuntu). Among them are Active Directory Domain Services (AD DS), which centralises user administration; FTP for file transfers; web services for hosting internal applications; and group policies enforcing security and configuration criteria throughout the network. Network resources have also been protected by security measures meant to stop illegal access. Apart from the server services, some network services have been implemented to assist the operation of the network. Among these services are FTP/TFTP servers for file transfers, Print Server for controlling printer resources, Domain Name System (DNS) for name resolution, and Dynamic Host Configuration Protocol (DHCP) for automated IP address allocation. To guarantee safe communication and correct time synchronisation across the network, secure protocols such as HTTPS and Network Time Protocol (NTP) have been used.

## Deployment of Client Machines and End Devices

The network supports a broad variety of end devices and client PCs, both wired and wireless. Connected to the network are client computers running Windows and Linux operating systems; devices include PCs, servers, laptops, printers, IP phones, smartphones, tablets, and IoT devices. Essential for the everyday functioning of the network, these devices let users access resources, communicate, and engage with many networked services. This project is greatly influenced by the integration of IoT devices as the system mimics a smart home environment with many smart gadgets and sensors that improve the house's operation. Connected and managed over the network, these devices provide remote monitoring and automated activities. The IoT infrastructure links these systems together, hence enabling remote administration and smooth communication. Dedicated apps on smartphones, tablets, or centralised systems operate and monitor the smart gadgets, hence providing consumers great ease and control over their surroundings.

## Simulation Overview

One may readily grasp that here all the simulations will undergo examination and analysis. The use of the CPT Packet Tracer and the IoT components in it will be the starting point for this discussion. Due to the intricacy, changes must be made to fit the IoT simulations, making this not readily attainable. Every one of these simulations/exercises is defined by layer separation, which in our case is pre-created for each of them. A completely configured network is made up of all the components required to execute and is linked to each other (IoT components included). The integration involves the simulation of several IoT devices to produce real-life situations and the programming logic to make everything operate automatically depicted in Figure 3.

A diagram of a flowchart

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Figure 3 system simulation order

From the network setup until the inclusion of the components into an infrastructure, all the exercises and simulations previously described are step by step recorded; all the simulations and outcomes arise from the use of Cisco Packet Tracer. Include as part of my thesis the simulation of a Smart Work Environment where many networks are constructed and merged to meet the demands. As previously stated, the understanding of the Cisco Packet Tracer tool was required for these simulations to be on point and flawlessly executed. Not only basic IoT devices or basic network components, but also far more complicated ones, and deal with new ideas like IoT backend servers, the programming and logic of the IoT components, variables and coefficients of the simulated environments, and many more, all contribute to this. The following chapter clarifies components not so connected to networking, both logically and, most importantly, practically, with a graphical representation of the topology shown in Figure 4.

A diagram of a network

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Figure 4 Smart home Automation System Implemented Topology

## Device Selection and Naming

After a thorough assessment, several devices, including switches, routers, firewalls, PCS, printers, access points, IP phones, tablets, and smartphones, were chosen for the network. As described below, all equipment was called according to the company's set naming policies.

* Deployed and designated PERIMETER-FIREWALL, the Cisco ASA 5506 firewall
* For its use, a Cisco 2811 router was selected and named CORE-ROUTER.
* Reflecting their essential network function, the 3650-24PS Layer-3 switches were installed and called essential-SW1 and CORE-SW2.
* Access Switches: Named for their floor position, the Cisco 2960 Layer-2 switches were chosen.
* Cisco AP-PT access points were put in place; each device was called depending on its related floor.
* All PCs were named after the floor on which they sit.

### Devices Basic configurations

In the network, basic device configurations were performed through the Command Line Interface (CLI). These configurations included setting hostnames, defining banner messages, and configuring various passwords such as the line console password, privilege mode password, line VTY password, as well as enabling SSH. Additionally, settings such as the username, password, domain name, disabling IP domain lookup, exec-timeout, logging synchronous, and the encryption of all configured passwords were applied.

Figures 5 and 6 follow and present an example of the basic configuration results for one of the switches.

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| A screenshot of a computer  AI-generated content may be incorrect. |
| A computer screen shot of a computer error  AI-generated content may be incorrect.  Figure 5: Basic configuration results in one of the switches |

### Configuration of VLAN

Every site in the network is assigned to a separate VLAN and subnet to enhance security, facilitate network segmentation, and simplify maintenance. Several VLANS, including 10, 20, 30, 40, 50, 99, and 110, were utilised to support voice and data traffic. Across all locations, VLAN ID (VID) 99 represents the voice VLAN.

### Routing Inter-VLAN

Devices in separate VLANS by default cannot talk to one another unless an inter-VLAN routing protocol is applied. Inter-VLAN routing was done using Switch Virtual Interfaces (SVIS) in the setup. To improve the routing process, this approach was used on core switches by generating VLAN interfaces, allocating IP addresses, and defining the encapsulation VLAN ID. A router-on-a-stick inter-VLAN routing technique was also used on the voice gateway router to facilitate Voice VLAN connectivity. Below are example configuration outcomes for inter-VLAN routing, both on the switches and the voice gateway in figure 6.

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Figure 6 VLAN configuration results in the switches

### Configuration of Link Aggregation

Link aggregation is a method that allows many switch connections to be aggregated into one logical channel, hence acting as one channel for data forwarding. Wikipedia claims that no more than eight links may be combined to create one logical connection. This approach offers redundancy in case one or more connections within the channel fail and helps load balancing of traffic across the combined links. Link aggregation helps the network to guarantee the best bandwidth use, remove loops, and maintain redundancy. We built the EtherChannel using the usual Link Aggregation Control Protocol (LACP) in the network architecture. The command show EtherChannel allows one to verify the status of the “*EtherChannel”* as shown in Figure *7*.

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Figure 7 of LACP configuration results in one of the switches

### Server's Static IPv4 Addressing

The server devices in the server room or data centre were assigned static Ipv4 addresses in the range 172.18.52.20/27. Configured with these static addresses, these devices used the IP address of the VLAN 110 interface on the connected HQ switches as the default gateway for the server room LAN, as shown in Figure 8.

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Figure 8 static IPv4 assignment on the servers

### Host Allocation and Configuration on the DHCP Server

All network host devices, save those in the server room, get dynamic IPv4 address allocations. A customized DHCP server located in the server room manages the allocation of dynamic IP addresses. The numbers below show the configuration of the DHCP server on the dedicated device and the evidence of automatic IPv4 address allocation to the host devices as shown in Figure 9.

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Figure 9 DHCP server configurations

### Configuration of OSPF Protocol Routing

A link-state protocol known as Open Shortest Path First (OSPF) was employed to develop a traffic-forwarding algorithm based on the routing table, thus facilitating route advertising within the network. During setup, the firewall, router, and core switches all implemented OSPF to support the directly connected networks. Here, you can observe the results of the router's OSPF configuration as shown in the figure 10.

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Figure 10 OSPF configuration in the router

### Static Route Configuration Default

The following default route was configured to help route packets past the firewall when their destination addresses do not correspond with those in the routing database. The firewall's default route configuration is shown in Figure 11, below.

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Figure 11 Static route configuration on the firewall

### VoIP Service Configuration

The voice gateway router was configured to facilitate communication among all IP phones, thereby supporting the Voice over IP (VoIP) system within the network. Assigned to VLAN 99, these IP phones are routed inter-VLAN by the voice gateway set up for that purpose. Additionally, the voice gateway was established as the DHCP server to dynamically assign IP addresses to the IP phones. The example below illustrates in Figure 12 and figure 13 the telephony service configuration on the voice gateway router, along with evidence of dial number allocations to the IP phones.

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Figure 12 VoIP Service configuration on the voice gateway router

A close-up of a telephone

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Figure 13 VoIP Service

### Firewall Cisco ASA Configuration

The system's firewall was established to enhance security. While the interface exposed to the outside zone was set to a security level of 0, the first interface connected to the internal network was assigned a security level of 100. As a result, communication cannot be initiated from a lower security level zone to a higher one, although the reverse is allowed. Internal hosts could access TCP and HTTP services and ICMP from the Internet. Figure 14 below illustrates the firewall configuration within the network.

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Figure 14 Firewall Cisco ASA Configuration

### Access Point using Wireless Network

Each division in the system has a specific wireless access point (AP) to let people connect to the network wirelessly. Figure 15 below shows the access point setup and proof of devices connecting to the network via these APs.

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Figure 15 Access Point using Wireless Network Configuration

### IoT Devices Configuration

All smart gadgets work as DHCP servers, designed to connect wirelessly via the IoT gateway. They can then be controlled remotely from a tablet or laptop as shown in the figure 16.

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Figure 16 IoT Devices Configuration

## IoT Devices Simulation

The smart home illustrated in the figure showcases an IoT-based smart home system, where various devices and sensors are connected for automation and remote monitoring. Key components include temperature and motion sensors, fire and water monitoring devices, smart lighting, security systems such as RFID readers and cameras, and appliances and entertainment devices like speakers and music players. The IoT gateway serves as the central hub for communication between devices, enabling automated control and monitoring, while the MCU (Microcontroller Unit) processes the data. This system is designed to enhance home security, comfort, and efficiency through remote management and real-time monitoring as depicted in the figure 17.

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Figure 17 Smart home devices integration

Most of the systems implemented in smart homes are automated based on different aspects, which are explained below the different implemented conditions on the system in figure 18.

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Figure 18 Conditioning logic is implemented in the smart system

### Smart Air Conditioning System

A temperature sensor is used with a heating element and an air supply. The range for heating and cooling is specified in Python programming in Figure 19 using a session border controller (SBC). The screen shows that the temperature is normal, the air cooler is on, or the heating is on, as shown in Figure 20, which shows the humidity in the room.

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Figure 19 Session border controller (SBC)

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| A graph with a line  AI-generated content may be incorrect. |

Figure 20 Variation in Humidity and Temperature Levels

### Smart Garden

Water level meter, which shows the water level monitor as shown in the figure. When the water level is below the level of the lawn sprinkler and above the level of the water drain, I reduce the level. Including environmental elements to simulate actual situations increased the realism of the automation results, showing water level changes in the figure 21.

A graph with a line going up

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Figure 21 Variation in Humidity Levels

### Smart Garage System

The smoke and cabin sensors monitor the smoke level. If smoke is above the level, the garage door, windows, and exhaust are opened as shown in Figure 22.

A graph with numbers and dots

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Figure 22 Smoke level in the Garage with the on and off system

### Smart Bedroom

The room's lights and fan are automated using a motion sensor. As depicted in the figure, the lights and the motion sensor are only on when someone is in the room.

### Smart Kitchen

Use the fire alarm in the kitchen. When it reaches a specific limit, it automatically turns on the fire sprinkler and the exhaust as depicted in the figure.

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Figure 23 Variation of the heat detection and then control

### RFID-based Security

The main gate is secured with RFID-based security. The door will only open when the RFID is authenticated. The system's idea is really relatively straightforward: the door opens when an approved RFID card is swiped on the RFID reader. The door stays locked if an unauthorised card is used. As seen in Figure 22 below, changing the RFID card settings via the card attribute tab helped to accomplish this. The system identifies the right card when swiped, and the ID corresponds with the card reader. A green indicator shows on the RFID reader to show the card is approved; the card is just dragged onto the scanner using the mouse. At the same time, the door symbol changes from red to green to indicate the door is unlocked. Although the smart door reacts to specific criteria in this instance, its adaptability lets it fit into more sophisticated simulations. Pressing the ALT key and clicking the door symbol lets one interact directly with the door.

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Figure 24 RFID card ID Settings

### Motion Detection

The motion sensor and camera used to monitor security will activate the siren and camera if motion is detected, as shown in Figure 25.

A computer screen shot of a window

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Figure 25 Camera on Motion Detection

## Summary

The system designed for this project simulates a contemporary, smart home environment by effectively combining sophisticated networking ideas with IoT technology. The system offers a complete solution for simulating and controlling IoT networks by using Cisco Packet Tracer and including a broad range of network and server services, dynamic routing protocols, and IoT devices. This arrangement not only shows the possibility of IoT in improving everyday life but also provides a useful instructional tool for professionals and students trying to grasp the complexity of IoT and network administration. The increasing importance of IoT in the contemporary linked society is further shown by the usage of many smart devices and services within the network.

# Conclusion

This study sought to mimic the Internet of Things (IoT) using Cisco Packet Tracer. Being a modern technology, IoT called for a virtual tool allowing students to grasp and comprehend it, which inspired the study. Cisco Packet Tracer was selected as it offers a simulated environment with devices mimicking actual ones. With its many IoT devices, actuators, and sensors, the most recent version of Packet Tracer is perfect for IoT simulations. The aim was to mimic a well-known IoT application, the smart home, using Cisco Packet Tracer. The most recent version of the tool, which includes numerous smart devices used in smart homes, was chosen for the installation. Several network devices, including a gateway, router, cable modem, IoT and DNS servers, switches, central office servers, and a smartphone, were also part of the simulation. A wireless network enables the home gateway to manage IP address distribution and connect the various smart devices. The simulation relies on the IoT server and smartphone as they offer internet-based remote control of IoT devices. While the smartphone provides remote access to these devices, the IoT server records the smart gadgets. The inclusion of numerous IoT and network devices in Cisco Packet Tracer simplified the simulation. Future releases of Cisco Packet Tracer will feature even more IoT devices, facilitating the creation of more advanced IoT simulations.

## Future Work

Various simulators exist to emulate IoT technologies. Future studies may focus on comparing Cisco Packet Tracer with alternative IoT simulators such as NetSim or Node-RED. This thesis specifically cantered on modelling IoT using Cisco Packet Tracer; therefore, no examination of other IoT simulators was conducted in this study. Future research might explore modelling more complex IoT applications using these upgraded versions, as Cisco is expected to release new iterations of Packet Tracer with additional IoT devices.

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