

New Design Approaches to Enhance the Internal E-Government Network for an Institution: Applications of Different Scenarios

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ABSTRACT

Although the Iraqi government is seeking to advance the networks of the e-government project, many institutions in Iraq still rely on Wi-Fi technology for their internal networks due to its ease of installation. However, Wi-Fi networks suffer from low capacity and performance, instability, and difficulty scaling, which is due to poor design and failure to follow established standards. In response to the growing demand for higher data rates and more reliable services, many organizations have begun studying how to update or replace their internal networks. In this work, the internal communication network of the Informatics and Telecommunications Public Company (ITPC) was studied and analyzed as an example of one of the networks of the Iraqi institutions that adopt wireless local area networks (WLANs). This research presents a comparative study between an existing real-world network and a simulated model developed using OPNET. The institution's internal network was evaluated and redesigned based on the actual infrastructure, services, applications, and subscriber numbers. Multiple scenarios measured key parameters such as received traffic, throughput, load, and delay. Networks designed and evaluated through simulation yielded significantly better performance. For example, one proposed scenario recorded traffic received of 9 MB with a delay of only 0.0000019 seconds, compared to 5.8 MB in the original network with a delay of 0.00020 seconds. The OPNET-based model enabled thorough examination of various design scenarios, providing insights into optimal hardware selection, transmission media, and topology configuration, reducing implementation costs and improving application performance.

Keywords: E-government; ITPC; Iraq, OPNET; delay; load; traffic received; throughput

INTRODUCTION

An increasing number of national governments are effectively leveraging technology to manage public services and interact with their citizens. Each advancement in information and communication technology (ICT) plays a crucial role in shaping modern life, making it a defining feature of our era (Alshehri & Drew 2010; Zhu & Xu 2023). The term “e-government” carries various interpretations, often influenced by differing policy priorities. Broadly, e-government refers to the use of ICT to deliver government services to individuals, businesses, and non-governmental organizations (Abdulhassan & Al-Hamadani 2012). According to the World Bank (2001), e-government

involves the ownership or operation of ICT by government entities to transform their relationships with citizens, the private sector, and other government agencies. The goal is to empower citizens, enhance service delivery, strengthen accountability, increase transparency, and improve overall government efficiency (M. A. Mohammed et al. 2016; Ndou 2004). E-government can be further categorized into segments such as government-to-citizen (G2C), government-to-business (G2B), government-to-employee (G2E), and government-to-government (G2G), each representing a distinct mode of service interaction (Nkomo, 2012).

Governments around the world face numerous obstacles and challenges in realizing the full potential of

robust e-government systems. These challenges include inadequate ICT infrastructure, concerns over privacy and security, policy and regulatory issues, a shortage of qualified personnel and training opportunities, limited collaboration and partnerships, the digital divide, cultural differences, and insufficient managerial support (Al-Otaibi & Ahmad 2022; Rabaa'i 2018). Elisa et al. (2020) advocate for blockchain-based solutions to enhance security and privacy in e-government platforms, addressing critical vulnerabilities inherent in traditional, centralized systems. Such decentralized systems can greatly increase citizen trust and government transparency (Elisa, Yang, Chao & Cao 2020).

Among these, ICT infrastructure is widely recognized as one of the most critical barriers to effective e-government implementation (Ibrahim, 2014). For e-government to function successfully, a nation must have the necessary technological infrastructure in place, ensuring that services are accessible to all citizens (Jaeger & Thompson 2003). Governments must assess existing gaps and upgrade their e-government networks to meet evolving requirements, adopting solutions that address both current and future needs (Al-Sai & Abualigah, 2017). There are real studies and works in many countries around the world aimed at identifying the factors affecting the interaction between local agencies in the various institutions of those countries to implement a strong e-government.

Due to the growing demand for handling big data, driven by the widespread use of information and communication technology (ICT), particularly during the COVID-19 pandemic across nearly all countries, there has been an urgent need to identify critical gaps in communication networks. This necessity has highlighted the importance of developing or upgrading existing ICT infrastructure to meet essential requirements such as scalability, security, and availability (Bertot & Choi 2013; Hussein 2018; Suh, Vujin, Barac, Bogdanovic & Radenkovic 2015).

Many developing countries, including Iraq, still lack the infrastructure necessary to fully deploy e-government services nationwide (Hussain 2019; A. H. Mohammed, Alhamdani, & Al-Khalidi 2024; United Nations Development 2023; Ziemba, Papaj, Zelazny & Jadamus-Hacura 2016). The delay in building this network will increase the social and technological gap within the Iraqi community and thereby increase the technological gap in all Iraqi institutions. According to another study, Iraq has to improve its technology infrastructure and human resources in order to strengthen its e-governance capabilities. According to the findings of this research, the primary impediments to e-governance adoption have been identified, and it is recommended that immediate attention be paid to removing these obstacles (Ahmad 2019; Yue et

al. 2018). These limitations significantly impede the effective nationwide implementation of e-government initiatives (United Nations Development 2023). Additionally, (Jasim, Hameed, & Jasim 2021) identified major infrastructural and regulatory barriers that continue to hinder Iraq's ability to fully realize robust e-government systems, underscoring the necessity for systemic improvements. "With the support of the United Nations Development Programme (UNDP), the Iraqi government made efforts to establish the foundation for e-government to better benefit from modern information and communication technologies. In June 2004, a Memorandum of Understanding was signed between the Iraqi Ministry of Science and Technology and the Italian Ministry of Innovation and Technology, following a request by the United Nations for Italy's assistance in helping Iraq develop its e-government system (Jameel 2019). However, Iraq still lacks the necessary infrastructure to effectively implement and expand e-government services and applications across the country. This infrastructure remains slow and outdated. Internet access in Iraq is still expensive, unreliable, and slow due to weak network systems (Al-Dabbagh 2011; Q. A. Habash, Sadek, Hussein, & AlZubaidi 2024).

In general, there is a noticeable lack of scientific research that thoroughly examines the challenges facing e-government in Iraq or proposes strong, practical solutions and consistent roadmaps to address them (Al-Taie & Kadry 2013). To accelerate the development of e-government across all Iraqi institutions, it is essential to strengthen the existing communications infrastructure by modernizing, expanding, and connecting it to all necessary sites throughout the country. For Iraq to establish a reliable telecommunications backbone capable of effectively supporting e-government services, the development must encompass the systems and networks of all ministries and institutions. This requires ongoing planning, development, and the comprehensive redesign of a large-scale national project (Al-Dabbagh 2011).

In addition to the studies that examined the situation in Iraq, United Nations surveys on e-government indicators have consistently shown low rankings for the country compared to its neighboring nations, except for a slight improvement in the 2020 survey results. This improvement was primarily due to a notable rise in the telecommunications infrastructure index, while only minor progress was observed in the other indicators. As a result of this improvement, Iraq's ranking moved from 155th place in the 2018 survey to 143rd in the 2020 United Nations survey.

As previously mentioned, the Ministry of Communications in Iraq oversees the General Communications and Informatics Company (ITPC), a state-owned enterprise that provides both wireless and wired internet services across the country. ITPC has

identified last-mile wireless broadband access as a cost-effective solution for improving connectivity. As the primary internet service provider in Iraq, several studies have focused on enhancing and developing the infrastructure of external communication networks to improve performance efficiency. However, in contrast, there has been little to no research aimed at developing the internal networks within the headquarters of institutions—networks that are the focus of this study and are expected to serve as the foundation for the future e-government network connecting all state institutions (Al-Hassani 2013).

Al-Hilfi et al. (Al-Hilfi, Marghescu, & Sahrab 2018a) studied and analyzed methods to enhance the overall network performance of ITPC's WiMAX system in terms of delay, load, and throughput, using the OPNET Modeler for simulation and analysis. Their new design demonstrated that overall performance could be improved by applying the End-to-End Quality of Service (E2E QoS) model. WiMAX was found to deliver better overall performance than Wi-Fi, primarily due to its superior quality of service capabilities (Abdulghafoor, Al-Neami, & Hussein 2025; Ali et al. 2018). Despite this, ITPC selected Wi-Fi for last-mile access. A proposal was made to design and simulate the ITPC Wi-Fi network in Baghdad using the OPNET simulator, based on the company's current internet service delivery sites. The results showed that when ITPC Wi-Fi incorporates the E2E QoS solution, network performance improves significantly—specifically, network delay was reduced by 48%, and throughput increased by 8% (Al-Hilfi, Marghescu, & Sahrab 2018b).

Wireless networks are widely regarded as effective solutions due to their flexibility, ease of use, and portability. Their performance can be analyzed and evaluated using simulation tools such as OPNET, even in heterogeneous environments with diverse applications. The results of such analyses depend on the types of applications involved and the time required for their execution. However, wireless networks are particularly vulnerable to jamming attacks, as they rely on a shared communication medium (Mehta & Baghla, 2015). To study the behavior of these networks under such conditions, OPNET Modeler was used to simulate jamming attacks. The results showed that these attacks can significantly degrade the performance of wireless networks. However, the use of channel switching technology was shown to be an effective countermeasure to mitigate the impact of such attacks (Obaid 2020).

The efficacy of OPNET Modeler 14.5 in optimizing network performance has been well-established across multiple studies. Khalaf and Hasan (2022) demonstrated the critical impact of proper WLAN configuration on performance metrics, including throughput and delay, emphasizing that careful parameter selection can substantially enhance wireless network efficiency (Khalaf

& Hasan 2022). Bensalah et al. expanded on this by examining scalability aspects of VoIP services across MPLS networks, confirming through simulation that optimal configurations significantly reduce latency and packet loss, thereby improving network reliability (Bensalah, El Kamoun, & Bahasse 2017). In (Al-Khraishi & Quwaider 2020), Al-Khraishi and Quwaider (2020) implemented a Virtual Local Area Network (VLANs) using OPNET to manage network traffic by dividing a single physical network into multiple broadcast domains. The results showed a significant reduction in traffic handled by the switch and improved bandwidth utilization, security, and overall network efficiency. Additionally, Rhaif et al. (2020) employed OPNET Modeler to simulate a fiber-optic-supported Wi-Fi network within a fixed local area network. The simulation results indicated that the baseline configuration exhibited greater delay compared to the fiber-based setup.

Network working relies on various types of routing protocols, such as EIGRP, OSPF, RIP, and IGRP, which directly impact overall performance through factors such as convergence activity and duration, average throughput, end-to-end delay, and point-to-point communication. To study these effects, network designs were simulated using the OPNET Modeler in studies (Q. Habash, Al-Neami, & Hussein 2024; Mahmood 2020; Noman & Hamad 2017), and the results demonstrated that routing protocols significantly improve network performance. Today, networks primarily depend on the Transmission Control Protocol (TCP) to manage data flow between all types of connected devices. The proposed network design for Salahuddin University in Iraq was tested using OPNET to highlight the importance of the Transmission Control Protocol (TCP) in network architecture and to develop an efficient and reliable computer network capable of avoiding potential deadlocks in the future. The simulation results confirmed that the proposed design, along with the selected devices, ensures service delivery while maintaining quality of service across key performance metrics, including delay, throughput, bandwidth, data transfer, packet transmission, and packet delivery (Al-Salihi, Ismael, Rashid, & Hasan 2019; Rashid & Barznji 2018). In the same network design, the impact of adding a firewall was tested concerning key performance metrics such as throughput, data transmission, delay, and packet transfer. The results indicated that the addition of a firewall did not negatively affect network speed and had no adverse impact on the VoIP application or its related parameters (Barznji, Rashid, & Al-Salihi 2018; Hasan, Yousif, & Rashid 2017). Furthermore, Ameen and Nourildean (Ameen & Nourildean 2014) demonstrated that while both VPNs and firewalls influence network performance, their results showed a more noticeable impact on throughput than on delay.

Alrammahi & Al Kimgood (Alrammahi & Al Kim, 2018) achieved a good result in network performance by obtaining the best voice quality in transmission and reception and the best performance in VoIP service applications through the application of the OPNET program in enhancement and performance analysis of VoIP algorithms in wireless networks. Lafta et al. (2020) simulated the performance of multimedia broadband wireless networks based on OPNET to obtain QoS in IP networks and effectively employ the available network resources to reduce the delay in network traffic containing multimedia services that contain voice, video, and databases. Given the considerable advantages offered by the OPNET simulator, many institutions and organizations have used it to build, enhance, and develop their communication network infrastructures, whether for small internal networks or large-scale external networks (Al-Bayati, 2018; Jiang et al. 2025).

Based on the literature review in this research, most studies focus on the performance and behavior of various telecommunications networks in general. However, these studies often ignore the requirements of internal e-government networks within each institution. This confirms the findings of a comprehensive survey of most Iraqi institutions, which is the lack of a robust internal network infrastructure for many institutions in Iraq. This is due to several reasons, including random designs, ignorance of economic factors, the inability of the network to expand in the future, the diversity of hardware assets, and the lack of compliance with standard specifications. For these reasons, the performance of current networks is generally low, and consequently, the services they provide are considered unreliable. Currently, this is a major concern for those interested in building and developing networks. Therefore, current networks in Iraq cannot be relied upon for e-government purposes. As demand for secure, high-speed communications increases across government operations, organizations need a network infrastructure capable of handling high data loads, diverse applications, and real-time interactions with citizens. The contributions of this research can be listed as follows:

1. Providing a detailed analysis of the performance of e-government networks within a specific institution by conducting a "field survey" of that institution to identify its internal network infrastructure and critical gaps.
2. Identifying how to develop a more robust, reliable, and scalable internal communications network capable of handling the flow of data between government institutions.
3. Validating the proposed network design and implementation using OPNET Modeler, testing, and evaluating it in realistic scenarios to ensure it achieves the desired objectives and addressing any issues before full implementation.
4. Providing practical, data-backed recommendations to decision-makers to help establish a robust, secure, and advanced communications network infrastructure that enables institutions to benefit from it.

INFORMATICS AND TELECOMMUNICATIONS PUBLIC COMPANY (ITPC) IN IRAQ

The Informatics and Telecommunications Public Company is one of the entities affiliated with the Iraqi Ministry of Communications, located in the center of Baghdad Governorate. The company specializes in various fields, including telecommunications, microwave and optical transmission, communications through ground stations, data transmission, and the provision of internet packages to private sector companies across the country.

The life of this company extends for tens of years; create for it a strong and solid infrastructure that extends to all governorates of Iraq, which is the national optical network, which extends to thousands of kilometers, and the national microwave network, which has dozens of microwave stations in various parts of the country. This company provides landline phone service through more than 280 exchanges and an optical access network of different capacities and types spread throughout the governorates of Iraq and serves more than 2,150,658 subscribers, including five wireless exchanges in Baghdad, Najaf, Karbala, Babylon, and Diyala, with a total capacity of 358,000 lines.

In addition to numerous ground stations for satellite communications and an extensive network of copper, audio, and optical cables spanning thousands of kilometers, the ITPC has also implemented optical access network projects using Fiber to the Home (FTTH) technology. This project has been activated in the Baghdad exchanges (Karkh and Rusafa) as well as in the governorates of Basra, Dhi Qar, Maysan, Najaf, Wasit, Diwaniyah, Kirkuk, Babylon, Salah al-Din, Muthanna, Karbala, Diyala, Nineveh, and Anbar. FTTH services are being expanded across all Iraqi governorates through public-private partnerships and investment projects.

Due to the scale and significance of ITPC's operations, it has been selected as a model institution among Iraqi ministries and public entities for studying and developing

its network in alignment with the current national strategy to connect all ministries and institutions under the e-government framework.

Therefore, the redevelopment of any network's infrastructure must achieve several key objectives. Technically, the initiative aims to enhance electronic services for Iraqi citizens by enabling the smooth and efficient exchange of information and data among federal government entities, local communities, and individuals, thereby improving overall public sector efficiency. It also highlights the importance of adapting and developing applications to meet evolving needs and demands. Furthermore, it promotes the creation of standards and frameworks that support the efficient reuse of data structures and related electronic services.

Economically, the initiative aims to promote competition and maximize the return on investments in information and communication technology (ICT). It encourages the adoption of open standards wherever feasible to foster a competitive environment across all sectors. In cases where open standards are not applicable, the initiative seeks support for private standards from international ICT service and product providers. Additionally, it emphasizes the importance of effective

public-private partnerships in the implementation of ICT projects, with the goal of reducing costs, time, and effort while leveraging the combined expertise and experience of both the public and private sectors.

From a security standpoint, the initiative focuses on bolstering information security by following strict security standards to prevent unauthorized access, interception, or modification of data. This includes implementing network firewall devices and intrusion detection systems, employing encryption systems for data and communications security, deploying antivirus and anti-spyware programs as needed, and enhancing server capacity for daily backups. The initiative also underscores compliance with security-related requirements outlined in the national Information and Communications Strategy, including authentication, licensing, access control, and network access. Moreover, it promotes a culture of responsible information sharing within the boundaries of national security and personal safety, safeguarding the privacy of data and information concerning citizens, government institutions, and the business sector in accordance with constitutional and legal provisions, while strictly regulating legal access to information and publications. Figure 1 shows types of e-Governments delivery models.

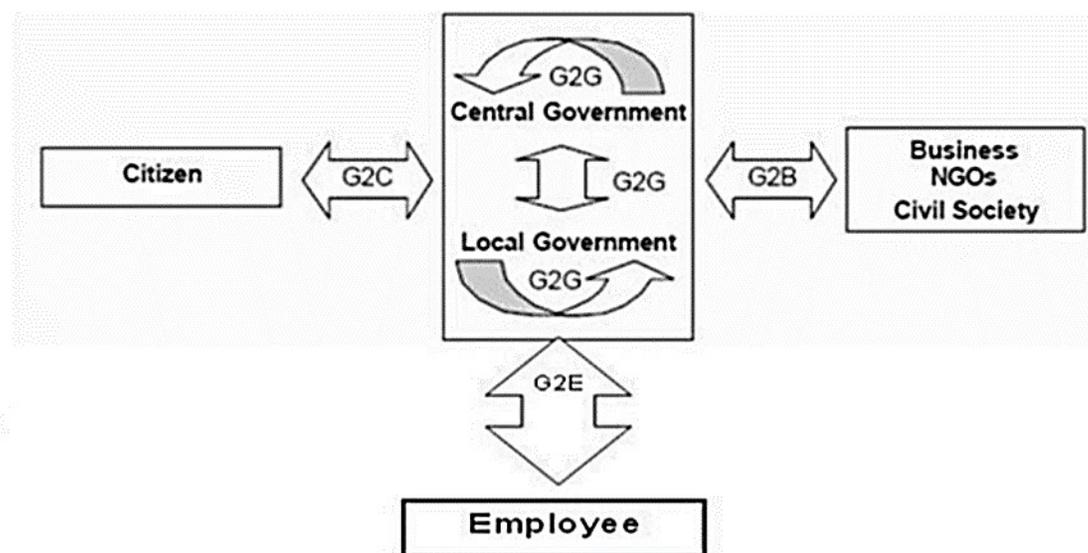


FIGURE 1. Types of e-Governments delivery models

In summary, the concept of service can be understood as a collective effort divided into several key modes. First, the Administration mode focuses on streamlining work processes and enhancing information exchange among various ministries and government agencies. It emphasizes speed, accuracy, cost reduction, the prevention of waste and fraud, and the identification of negligent parties.

Second, the Citizen mode aims to establish effective communication channels between the government and both citizens and the private sector for the exchange of information, documents, and transactions. This mode also plays a crucial role in promoting oversight, ensuring government accountability, supporting democratic governance, and countering the spread of rumors and misinformation.

Lastly, the Society mode seeks to strengthen collaboration between the government, diverse segments of the population, the private sector, and non-governmental organizations. It facilitates information sharing, joint

studies, and inclusive decision-making at the local level—fostering public trust and encouraging private sector participation in economic activities, as illustrated in Figure 2.

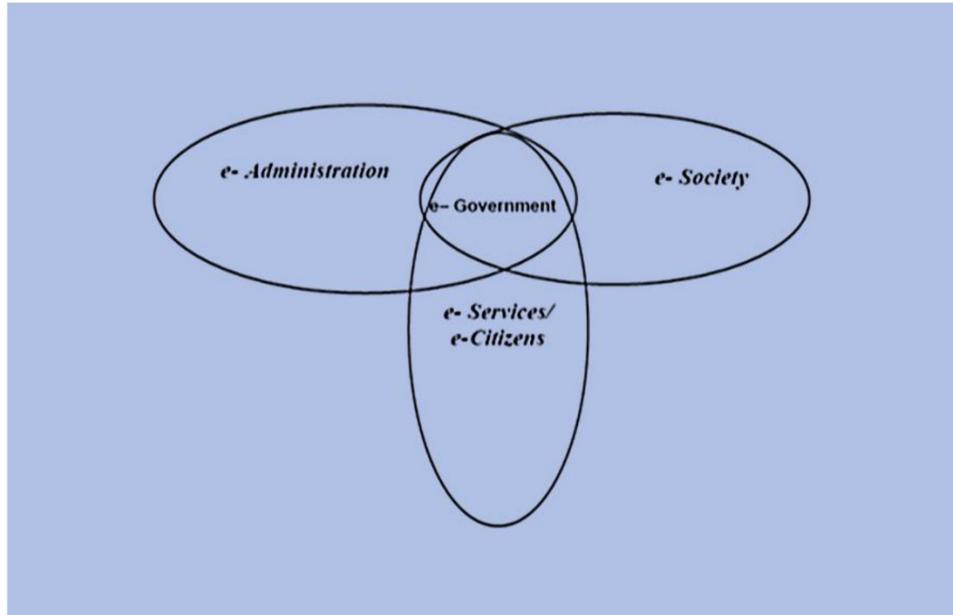


FIGURE 2. The e-Government domains

These three application domains should be viewed as overlapping, with e-government positioned at the intersection where all three converge. To build a robust e-government system capable of meeting the demands of modern life, ten key requirements must be fulfilled (Figure 3). The strategic working plan for e-government is founded

on these ten core elements, each of which has a direct impact on the success of the project. These elements are closely interconnected, offering an opportunity to implement priority areas in a cohesive and integrated manner.

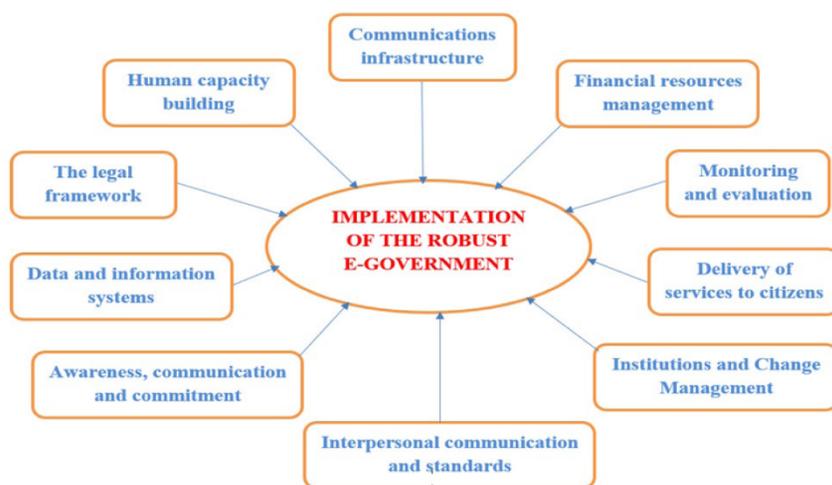


FIGURE 3. The elements of the robust e- government

ITPC BUILDING DESCRIPTION

The ITPC building consists of eleven floors in addition to the ground floor, with each level designated for either technical or administrative functions. The building measures 50 meters in width and 150 meters in length. All floors are identical in design and equal in area; however, they differ in terms of the number of users and the nature of their work, whether technical or administrative. Each floor hosts different applications and accommodates a varying number of employees (network subscribers). The distribution of the institution's floors is outlined as follows:

1. Ground Floor: Houses the Department of Administrative Affairs, Protocols, and other non-technical service units. The number of participants is 50.
2. First Floor: Contains the Cybersecurity Department, a technical division responsible for overseeing and monitoring all company websites, as well as detecting and responding to external threats and violations. The number of participants is 14.
3. Second Floor: Hosts the Legal Affairs Department, with a total of 20 participants.
4. Third Floor: Includes the Exchanges Section, a technical department that supervises and monitors all telephone exchanges across Iraq. The number of participants is 15.
5. Fourth Floor: Occupied by the Planning and Follow-up Department, which handles both administrative and technical responsibilities. It oversees the company's technical projects. The number of participants is 18.
6. Fifth Floor: Contains the Financial Affairs and Auditing Departments, which manage all financial operations of the company. These two departments have a combined total of 60 participants.
7. Sixth Floor: Contains the Information Technology Department, a technical division responsible for distributing internet packages to all other departments. It also handles approvals for purchasing devices and applications for all employees at the company's headquarters. The number of participants is 20.
8. Seventh Floor: Houses the Optical and Copper Networks Section, a technical department tasked with supervising all optical and copper network infrastructure across Iraq, whether operated by ITPC or private sector companies. The number of participants is 21.
9. Eighth Floor: Includes the Data Transmission Department, a technical unit responsible for supervising, monitoring, and maintaining all fiber optic and data transmission stations throughout the governorates of Iraq. The number of participants is 50.
10. Ninth Floor: Contains the offices of the Assistant Director General for both technical and administrative affairs. The number of participants is 12.
11. Tenth Floor: Hosts the General Manager's office and its administrative annexes. The number of participants is 15.
12. Eleventh Floor: Contains the Media Department, which is responsible for promoting and publicizing the company's projects. The number of participants is 12.

ITPC also comprises 17 directorates of communications and informatics—two of which are in Baghdad, while the remaining directorates are distributed across the other governorates of Iraq, with one directorate in each province. In addition, there are five buildings in Baghdad that serve as exchange and data transmission sites.

The current network within this institution is built around a single Mikrotik 1100 main router, which receives the internet connection via fiber optics directly from the service provider, with a total bandwidth capacity of 155 Mb/s. The network also includes a main 24-port Huawei switch. Notably, the network does not include a server or any protection systems such as a firewall or antivirus software. The existing network architecture follows a star topology. Data transmission is handled through Cat 6 and Cat 5 cables, and the network serves approximately 320 users. It supports a range of applications, including HTTP, email, file, and data transfer protocols, and video services. The network infrastructure provides full coverage to all required users across every floor of the building, as illustrated in Figure 4. Each floor is equipped with a switch that connects to the main switch, which in turn is linked to an access point located on the same floor. This access point is connected to a sub-switch, and all computers and other devices are connected through the access point. The access point provides wireless service to all subscribers on each floor.

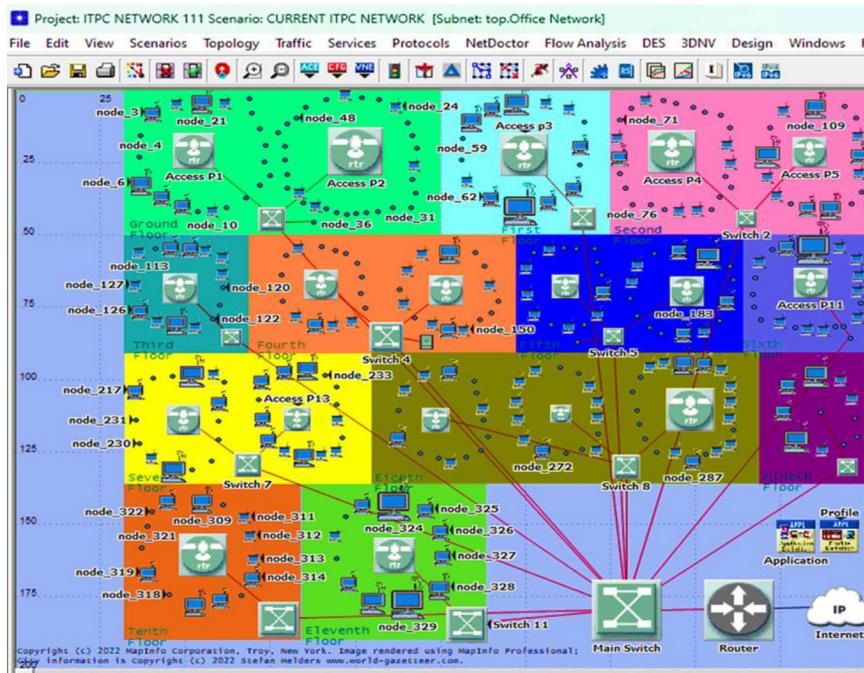


FIGURE 4. The topology for current ITPC network

The network consists of several essential components, including routers, a central (main) switch, floor-specific segment switches, secondary servers, computers, printers, day and night surveillance cameras, security and fire alarm systems, as well as various software systems, cabling, and internet bandwidth. To meet the diverse needs of network users, the design supports a wide range of applications, including: high-load multimedia email; high-load simple multimedia and FTP; high-load user-to-user transfers of mixed content via FTP; medium-load document retrieval

and database access; medium-load database queries and website browsing; medium-load electronic publishing and database activity; medium-load voice communication; medium-load video and videotext; and professional image communication, including color printing and scanning.

The network employs several essential profiles, including Administrator, Technical, Human Resource, Salesperson, Marketing, and Multimedia. These profiles are pivotal for its functionality. Additionally, Table 1 illustrates the current network components and the specific requirements essential for the OPNET simulator.

TABLE 1. Current network simulation requirements

No.	Tools	Requirements
1	Technologies	WLAN
2	Network Scale	Office
3	Range of Network	150m*50m
4	Technology Type	802.11g
5	Data Rate	54 Mbps
6	Number of Access point	19
7	Number of Switches	13
8	Number of sub- Servers	3
9	Number of Workstation	320
10	Router	1
11	Ip-cloud	1
12	Backbone Cable	1000BaseX duplex link (1 Gbps)
13	Link to Ip cloud	PPP T1
14	Support of Application	Data base, Telnet, FTP, HTTP, Email, VoIP, Video, File Print.
15	Profiles	Administrator, Technical, Human Resource, Sale person, Marketing, Multimedia.
16	Simulation Time	10 minutes.

As shown in Table 1, these parameters were chosen based on the available technology (Wi-Fi) in the original institution network, its characteristics, the connections and devices used, their actual number, as well as the profiles and applications available on that network and used in the simulation.

Table 2 includes the number of actual network subscribers, as well as the profiles, applications, and services used based on the actual load on each floor of the institution. These profiles and applications were kept constant in all simulation scenarios and for the original network.

TABLE 2. The applications and profiles used in the network

No. of Floor	No. of Sub.	Profiles	Applications							
			Data base	Email	FTP	File Print	Telnet session	Web browsing	VoIP	Video conference
GROUND	50	Administrator	Light	Light	Light	-	-	-	-	-
		Human Resource	Heavy	Heavy	Heavy	Heavy	-	-	-	-
		Multimedia	-	-	-	-	Heavy	-	PCM	Heavy
1	15	Technical	Heavy	Heavy	Heavy	-	Heavy	Heavy	-	-
2	40	Human Resource	Light	Light	Light	Light	-	-	-	-
		Marketing	Light	Light	-	Light	-	-	-	-
3	15	Sale person	-	Light	-	-	Heavy	Heavy	-	-
		Technical	Light	-	Light	-	-	Heavy	-	-
4	30	Multimedia	-	-	-	-	-	-	PCM	Light
		Human Resource	Heavy	Heavy	Heavy	Heavy	-	-	-	-
		Technical	Light	Light	Light	-	-	-	-	-
5	30	Marketing	Light	Light	-	Light	-	-	-	-
		Sale person	-	Light	-	-	Heavy	Heavy	-	-
		Administrator	Heavy	Light	Heavy	Heavy	-	-	-	-
6	20	Marketing	Light	Light	-	Light	-	-	-	-
		Administrator	Light	-	Light	Light	-	-	-	-
7	30	Technical	Light	Light	Light	-	Heavy	Heavy	-	-
		Administrator	Heavy	-	-	Light	-	-	-	-
		Multimedia	-	-	-	-	-	-	PCM	-
8	50	Administrator	Light	-	-	Light	-	-	-	-
		Technical	Light	Light	Light	-	Heavy	Heavy	-	-
		Multimedia	-	-	-	-	-	-	PCM	Light
9	10	Administrator	Light	Light	-	Light	-	-	-	-
		Multimedia	-	-	-	-	-	-	PCM	Light
10	15	Administrator	Light	Light	-	Light	-	-	-	-
		Multimedia	-	-	-	-	-	-	PCM	Heavy
		Marketing	Light	Light	-	Light	-	-	-	-
11	12	Sale person	-	Heavy	-	-	Heavy	Heavy	-	-
		Multimedia	-	-	-	-	-	-	PCM	Heavy

METHODOLOGY

The proposed study consist of two steps:

1. The first step involved data collection from relevant network stakeholders through a site survey conducted at the intended location. The study population comprised the information and communication technology (ICT) departments located in the centres of institutions or ministries, which are responsible for executing various technical tasks related to network implementation.
2. The second step focused on analyzing and utilizing the collected data using the OPNET Modeler to obtain the required results. The proposed new network design was developed

based on the comprehensive data gathered and aligned with existing resources and requirements. Network architecture and scenarios used in this study are grounded in precise analytical outcomes generated by the OPNET simulation tool.

Additionally, the design incorporates preliminary data collected through on-site surveys or based on specific requirements. Figure (5) below represents a flowchart that describes the study methodology.

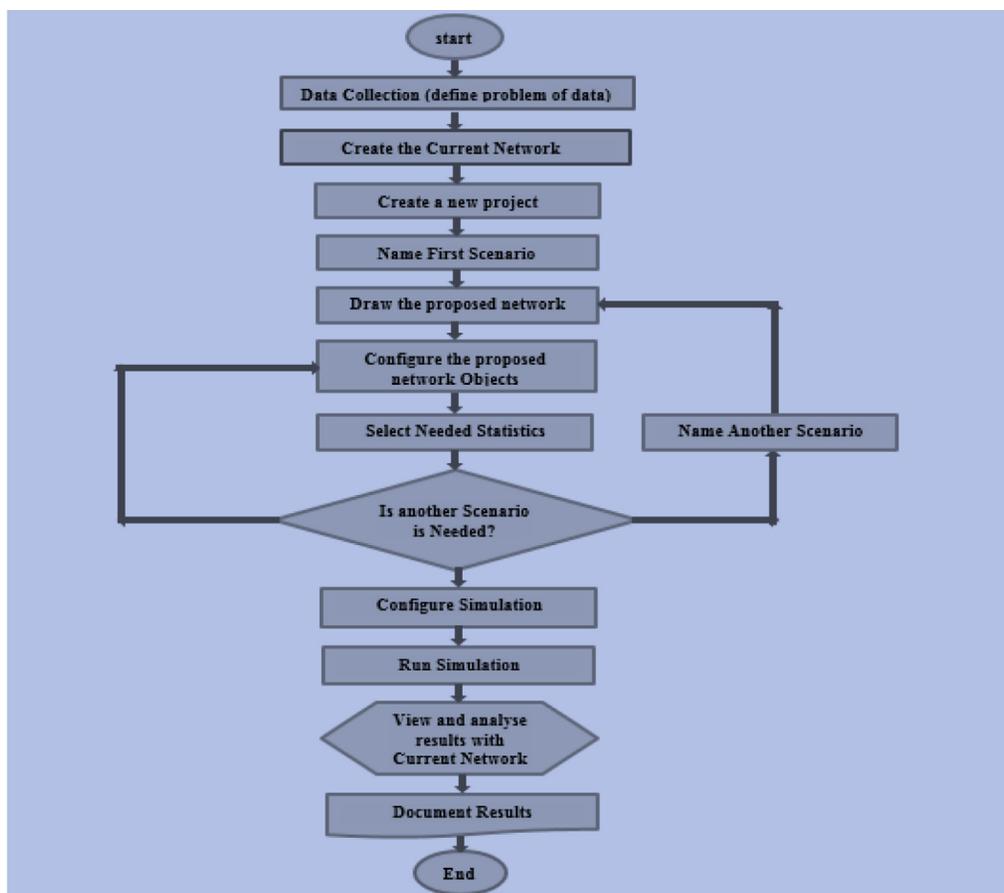


FIGURE 5. Research flow chart

The study focused on the ITPC institution, recognized as the largest telecommunications company in Iraq. The aim is to improve and develop the internal network of the institution to be able to communicate and interact with all other institutions involved in the e-government project, as well as for better accessing Internet services. To achieve this, the institution's building was visited on three separate occasions to conduct a detailed examination of the existing network and gather responses to targeted inquiries posed to technical specialists within the organization. This effort proved valuable in supporting the development of the new network design using the OPNET Modeler. The questions addressed a wide range of topics, including technological aspects, security considerations, and information management. These inquiries are highly relevant to the design of network architectures for institutions of various sizes, highlighting their critical importance (Bolano, Paredes, & Li 2021; Liu 2021; Onah et al. 2020).

Based on the information gathered from network administrators, several key conclusions were drawn. Firstly, the network is classified as a Local Area Network (LAN) due to its limited coverage within a single building, which consists of eleven floors plus a ground floor, and has dimensions of 150 meters in length, 50 meters in width, and 50 meters in height. Internet access is delivered via optical fiber cables with a capacity of 1 STM; however, these optical cables are used exclusively for internet connectivity and not for internal network cabling. Internally, the network operates on Wi-Fi technology (IEEE 802.11) with a star topology and uses Ethernet cables of Cat 6 and Cat 5 types.

The network's specifications include a 1 STM upload/download package capacity (equivalent to 155 Mb/s), supporting approximately 320 subscribers. The maximum cable length from any switch to a workstation is 100 meters, with the total network cable length reaching 1 km. Each

switch or hub connects to a maximum of 25 devices, and the data transfer rate is limited to 8 Mb/s. No bridge devices were used, which could have improved network performance by reducing congestion. Additionally, there's no VLAN technology implementation to fragment the Broadcast Domain, leading to increased congestion and pressure on the network. Other aspects noted involve the lack of consideration for cable transmission speed, maximum length, resistance to interference, and the type of network to be connected. There's no network partitioning, and the institution lacks a main data center but utilizes a second router as a backup for the first one. Security measures are limited, as there are no protection devices (firewalls) or network access control systems, with only basic security administration programs in place.

Furthermore, cable placement near potential sources of electromagnetic interference was not accounted for, which can negatively affect network performance. The network also lacks applications for serving citizens and relies on two internal applications for employees and human resources, supported by a dedicated server. Data storage is done on regular hard disks. The network operates using various protocols, including TCP/IP, SMTP, FTP, SNMP, POP, and HTTP. Approximately 30% of the hardware comprises CISCO devices. The network has a low wired-to-wireless connection ratio of 10%, and it relies entirely on conventional cabling. Notably, there is no existing network connection between the institution and its branch offices located in other governorates. Devices

in the network originate from various sources, and standard specifications are often not met. Some sections still use hubs instead of switches, and the majority of the network comprises wireless Wi-Fi connections. In conclusion, the network appears to have been constructed haphazardly, lacking a systematic approach. This results in several limitations, including subpar network speed, reliability issues, security vulnerabilities, instability, and suboptimal cost-effectiveness, as complete needs were not adequately considered while minimizing costs.

PROPOSED DESIGN

The nature of the building for this institution is suitable for building and designing a typical LAN network. To be able to implement the network, it can be implemented by designing subnets by choosing the type of devices, cables, and applications appropriate for each floor of the building and then linking those subnets with the main point, which will be the main switch, which in turn receives the Internet packet from the main router for the network. It can be done in several ways, depending on what each sub-network requires of us in terms of devices, requirements, and applications, as well as according to the tools available to us in the OPNET programme. Table 3 shows the specifications of the hardware and equipment used in the OPNET Modeler 14.5 program in designing the proposed networks in the scenarios and the original network.

TABLE 3. Specifications of devices and equipment used in network design

No.	Equipment	Part	Model Attributes	Restrictions	General Description
1-	Cables	100BaseT_base duplex link	«Propagation Speed» specifies the medium's propagation speed (in meters/sec). If the link's "delay" attribute is set to "Distance Based," this speed is used to calculate the propagation delay based on the distance between two nodes.	This link cannot be used to connect two Ethernet hubs	Represents an Ethernet connection operating at 100 Mbps. It can connect any combination of the following nodes: Station, Hub, Bridge, Switch, LAN nodes. except Hub-to-Hub, which cannot be connected.
		1000BaseX duplex link	Propagation Speed» specifies the medium's propagation speed (in meters/sec). If the link's "delay" attribute is set to "Distance Based," this speed is used to calculate the propagation delay based on the distance between two nodes.	This link cannot be used to connect two Ethernet hubs	Represents an Ethernet connection operating at 1 Gbps or 1000 Mbps. It can connect any combination of the following nodes: Station, Hub, Bridge, Switch, LAN nodes. except Hub-to-Hub, which cannot be connected

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		10Gbps_Ethernet duplex link	Propagation Speed” specifies the propagation speed (in meters/sec) for the medium. If the “delay” attribute of the link is set to “Distance Based”, this speed is used to calculate the propagation delay based on the distance between two nodes	This link cannot be used to connect to an Ethernet port operating in a half-duplex mode, e.g., hub.	Represents an Ethernet connection operating at 10 Gbps. The connected MACs must always operate in a full-duplex mode as the 802.3ae standard does not support half-duplex operation: Station, workstation, Server, and Routers, Switch, Switched LAN nodes.
		PPP T1	-	-	Connects two nodes running IP. Data Rate T1 (1.544 Mbps).
2-	Workstation	wlan_wkstn_adv node model	Client Custom Application, Client Database Application, Client Email, Client Ftp, Client Remote Login, Client X Windows, Client Video conferencing, Client Start Time: These attributes allow for the specification of application traffic generation in the node.	-	Represents a workstation with client-server applications running over TCP/IP and UDP/IP. Supported Protocols: UDP, IP, Ethernet, Fast Ethernet, Gigabit Ethernet, RIP, TCP, OSPF. Port Interface Description: 1 Ethernet connection at 10 Mbps, 100 Mbps, or 1000 Mbps. Transport Address: This attribute allows for the specification of the address of the node.
3-	Switch	Ethernet64_switch node model	Combination of up to 32 Ethernet ports (10 Mbps, 100 Mbps, or 1000 Mbps).	The switch can only connect LAN’s of the same type (Ethernet to Ethernet, FDDI to FDDI, or Token Ring to Token Ring).	Represents a switch supporting up to 64 Ethernet interfaces. The switch implements the Spanning Tree algorithm in order to ensure a loop free network topology. Switches communicate with each other by sending Bridge Protocol Data Unit (BPDU’s). Protocols: Spanning Tree Bridge Protocol (IEEE 802.1D), Ethernet (IEEE 802.3). Interconnections: 64 Ethernet connections at the specified data rate (10, 100, 1000 Mbps).
		Ethernet32_switch node model	Combination of up to 32 Ethernet ports (10 Mbps, 100 Mbps, or 1000 Mbps).	The switch can only connect LAN’s of the same type (Ethernet to Ethernet, FDDI to FDDI, or Token Ring to Token Ring).	Represents a switch supporting up to 32 Ethernet interfaces. The switch implements the Spanning Tree algorithm in order to ensure a loop free network topology. Switches communicate with each other by sending Bridge

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					<p>Protocol Data Units (BPDU's).</p> <p>Protocols: Spanning Tree Bridge Protocol (IEEE 802.1D), Ethernet (IEEE 802.3).</p> <p>Interconnections: 32 Ethernet connections at the specified data rate (10, 100, 1000 Mbps).</p>
		Ethernet16_switch node model	Combination of up to 16 Ethernet ports (10 Mbps, 100 Mbps, or 1000 Mbps).	The switch can only connect LAN's of the same type (Ethernet to Ethernet, FDDI to FDDI, or Token Ring to Token Ring).	<p>Represents a switch supporting up to 16 Ethernet interfaces. The switch implements the Spanning Tree algorithm in order to ensure a loop free network topology. Switches communicate with each other by sending Bridge Protocol Data Units (BPDU's)</p> <p>Protocols: Spanning Tree Bridge Protocol (IEEE 802.1D), Ethernet (IEEE 802.3).</p> <p>Interconnections: 16 Ethernet connections at the specified data rate (10, 100, 1000 Mbps).</p>
4-	Hub	Ethernet16_hub node model	«Ethernet Hub Sim Acceleration» specifies whether the hub only sends packets to the station to which the packets are destined (Enabled) or broadcasts to all stations (Disabled). When this attribute is "Enabled", the number of simulation events and therefore the simulation run time is decreased.	<p>1- All ports of a hub must be connected to links with the same operating speed.</p> <p>2- Two or more Ethernet hubs cannot be directly connected to each other. An Ethernet bridge may be used to connect hubs.</p>	<p>Represents an Ethernet Hub supporting up to 16 Ethernet connections All the ports should be operating at the same speed (set based on the connected link) The possible link model choices are 10BaseT, 100BaseT, or 1000BaseX. Note that the hub handles deference and collision detection for all the stations connected to it.</p> <p>Protocols: Ethernet, Fast Ethernet, Gigabit Ethernet (IEEE 802.3).</p> <p>Interconnections: Either of the following:</p> <p>1-16 10BaseT connections at 10 Mbps</p> <p>2-16 100BaseT connections at 100 Mbps.</p> <p>3-16 1000BaseX connections at 1000 Mbps.</p>
5-	AccessPoint	wlan_ethernet_router-adv	Physical characteristics: Extended Rate PHY (802.11g) Data Rate (bps):54Mbps.	-	<p>This is a wireless LAN based router with one ethernet interface. Wlan (IEEE 802.11) with 1 port.</p>

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6-	Server	Ethernet_server model	<p>Supported Services: This attribute allows for the specification for various services supported on the node.</p> <p>Server Address: This attribute allows for the specification of the address of the node.</p>	-	<p>Represents a server node with server applications running over TCP/IP and UDP/IP. This node supports one underlying Ethernet connection at 10 Mbps, 100 Mbps, or 1 Gbps. The operational speed is determined by the connected link's data rate.</p> <p>Protocols: RIP, UDP, IP, TCP, Ethernet, Fast Ethernet, Gigabit Ethernet, OSPF.</p> <p>Interconnections: 1 Ethernet connection at 10 Mbps, 100 Mbps, or 1000 Mbps</p>
7-	Gateway	Ethernet2_slip8_gtwy node model	<p>IP Forwarding Rate specifies the rate (in packets/second) at which the gateway can perform a routing decision for an arriving packet and transfer it to the appropriate output interface.</p>	<p>This gateway requires a fixed amount of time to route each packet, as determined by the "IP Forwarding Rate" attribute of the node. Packets are routed on a first-come-first-serve basis and may encounter queuing at the lower protocol layers, depending on the transmission rates of the corresponding output interfaces.</p>	<p>Represents an IP-based gateway supporting up to two Ethernet interfaces and up to 8 serial line interfaces at a selectable data rate. 2 Ethernet connections at 10 Mbps, 100 Mbps, or 1000 Mbps.</p> <p>Protocols: RIP, UDP, IP, Ethernet, Fast Ethernet, Gigabit Ethernet, OSPF.</p> <p>Interconnections: 1- 2 Ethernet connections at a selectable data rate. 2- 8 Serial Line IP connections at a selectable data rate.</p>
8-	Firewall	Ethernet2_slip8_firewall node model	<p>- IP Forwarding Rate specifies the rate (in packets/second) at which the gateway can perform a routing decision for an arriving packet and transfer it to the appropriate output interface.</p> <p>- IP Gateway Function" specifies whether the local IP node is acting as a gateway. Nodes with only one network interface should not act as network gateways.</p> <p>- RIP Start Time specifies the simulation time (in seconds) at which the Gateways start sending routing updates to build the IP routing tables.</p>	<p>The existence of a proxy server for a certain application makes this application acceptable through the firewall. Each forwarded packet may also experience an additional proxy server delay, again based on the configuration of proxy servers.</p>	<p>Represents an IP-based gateway with firewall features and server support. Hence, it can be also called as a multihomed-server firewall node. It supports two Ethernet and eight serials line interfaces at selectable data rates. 2 Ethernet connections at 10 Mbps, 100 Mbps, or 1000 Mbps.</p> <p>Protocols: TCP, RIP, UDP, IP, Ethernet, Fast Ethernet, Gigabit, Ethernet, OSPF, BGP IGRP.</p> <p>Interconnections: 1- 1 Ethernet connection at a selectable data rate. 2- 1 Serial Line IP connections at a selectable data rate.</p>

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9-	Internet	ip32_cloud node model	<ul style="list-style-type: none"> - Packet Latency specifies the delay (in seconds) after which the incoming IP datagrams get transferred through the cloud. - Packet Discard Ratio determines the number of packets to be dropped out of the total packets transferred. 	Packets are routed on a first-come-first-serve basis and may encounter queuing depending on the transmission rates of the corresponding output interfaces.	Represents a IP cloud supporting up to 32 serial line interfaces at a selectable data rate through which an IP traffic can be modeled. Protocols: RIP, UDP, IP, OSPF, BGP, IGRP, TCP. Interconnections: 32 Serial Line IP connections at a selectable data rate.
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Once the institution's local area network (LAN) is fully designed and implemented, it will be ready to connect with the networks of other institutions through its main router. This design aims to upgrade and enhance the existing network infrastructure, enabling the effective use of high-reliability networking components, from endpoints to backbone connections. The new design will allow each segment of the network to deliver the required services at high speeds and with enough bandwidth, minimal delay, and improved support for collaborative operations within the institution.

The proposed design outlines how to implement a modern network infrastructure for ITPC, replacing the outdated, Wi-Fi-based system that supports simple work by using old tools between the floors of the building, with a high delay in the network. The proposed design will show how technologies are selected in the building network. The design will include the strategies that can be used to support the network with up-to-date standards for the systems used to enhance network performance. In addition, it will build a strong Gigabit Ethernet core that can support high-bandwidth and high-speed networks to increase network performance and meet user requirements and applications (Freitag, Tous Liesa, & Navarro Moldes, 2019). After all the above in this research, it can be concluded that the current design of the ITPC network, after analysis, study, and comparison, turned out to be not well suited to serve the e-government network. Therefore, work has been done to propose new designs or update the current design and to analyze and study each proposal or each new design, as shown in the scenarios below. These scenarios were specifically used because they closely resemble the original network design (Star Network), particularly in terms of backbone (Ethernet) architecture and technology. Therefore, we maintained the simplicity of the proposed scenarios, ensuring optimal results at a lower cost.

VLANs or hybrid networks were not used in the proposed scenarios because they were not used in the original network. Although the institution network consists of several subnets (building floor networks), each subnet is isolated from the other subnets and performs different tasks and applications, so there is no need to use VLANs.

SCENARIO 1: ETHERNET DESIGN WITH USING SWITCHES AND HUBS

In this Scenario, a local area network (LAN) is implemented across eleven floors plus the ground floor using an Ethernet star topology. This configuration provides high-speed data transfer through 100BaseT connections for linking devices to sub-switches on each floor. The backbone connections between the sub-switches and the main switch use 1000BaseX cabling. The network layout supports a wide range of applications, including HTTP, email, FTP, databases, video, and audio services. It is designed to serve all users within the building. Figure 6 illustrates the network topology, demonstrating the replacement of wireless technology by using Ethernet, while retaining the existing switches and hubs used in the network. Each floor contains computers and other workstations, all connected to a local switch, which in turn is connected to the central switch. A central switch was selected to allow for future network expansion, making it easy to add or replace devices as needed. This design enables us to put switches instead of hubs, which offer greater scalability and enable simultaneous operation of all connected devices.

The switches used in this design support 16, 32, and 64-bit Ethernet interfaces and are compatible only with networks of the same type, for example, Ethernet to Ethernet, FDDI to FDDI, or Token Ring to Token Ring. They also support various network speeds, including 10 Mbps, 100 Mbps, 1000 Mbps, and 10 Gbps.

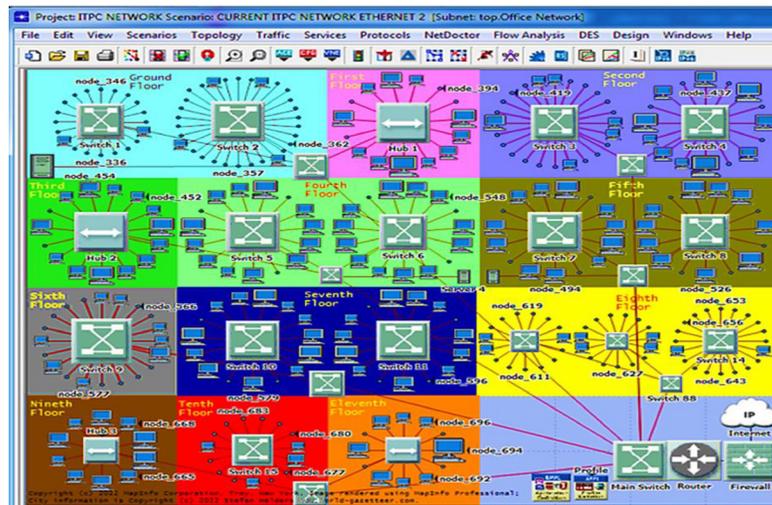


FIGURE 6. Ethernet technology by using switches and hubs.

The cable used to connect each floor’s backbone to the central switch is 1000BaseX (Gigabit Ethernet), an extension of the IEEE 802.3 standard that supports high-speed Ethernet, offering speeds ten times faster than

standard Ethernet. This significantly contributes to reducing latency caused by network applications. Table 4 presents the different types of Gigabit Ethernet cables used in networks (Ferrari, 2018; Nilsson, 2000).

TABLE 4. Types of Gigabit Ethernet

No.	Name	Media Type	Distance (meters)
1	1000 Base-CX	STP Copper cable	25
1	1000 Base-T	CAT 5 UTP copper link	100
2	1000 Base-SX	Short wavelength, 62.5 Mm multimode fiber optic link	275
3	1000 Base-SX	Short wavelength, 50 Mm multimode fiber optic link	550
4	1000 Base-LX	Long wavelength, 62.5 Mm multimode fiber optic link	550
5	1000 Base-LX	Long wavelength, 50 Mm multimode fiber optic link	550
6	1000 Base-LX	long wavelength, 10 Mm single-mode fiber optic link	5000
7	1000 Base-ZX	Non-Standard	70 k

SCENARIO 2: ETHERNET DESIGN WITH USING SWITCHES ONLY

In this scenario, the same applications and user profiles from the original network and the previous scenario were

implemented. Ethernet technology was retained, along with the same cables and devices. The only change involved replacing all hub devices with switches to improve network performance, as illustrated in Figure 7.

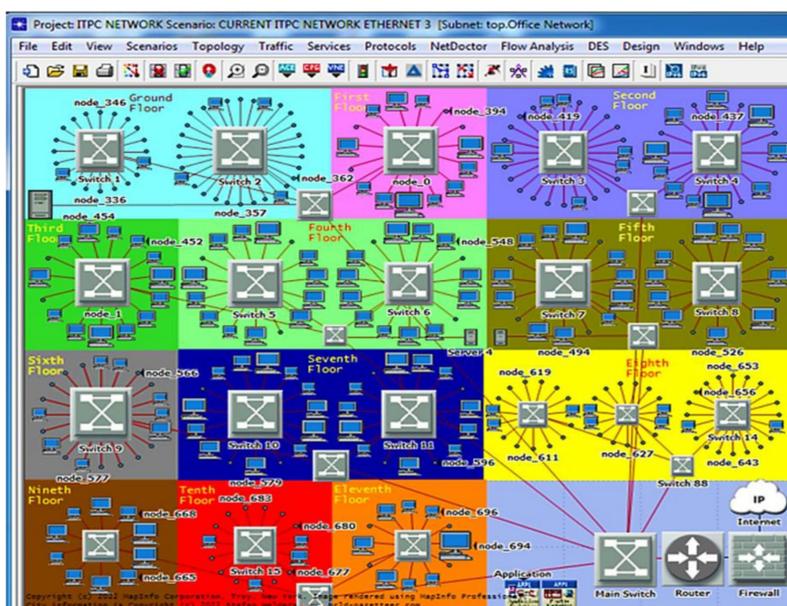


FIGURE 7. Ethernet technology by using switches only

SCENARIO 3: ETHERNET DESIGN BY USING REGROUPING DEVICES

In this scenario, the same Ethernet technology was used with the same applications and profiles used in the original network and previous scenarios, but by replacing the switches with others of the same type but with a larger

capacity. This means that the number of switches used in the network was reduced from 26 to 12 (one switch for each floor). The other change was the use of 1000BaseX cable to connect each of the devices with the sub-switches, as well as the use of 10 Gbps Ethernet cable that was used as a backbone, that is, to connect the sub-switches with the main switch, as shown in Figure 8.

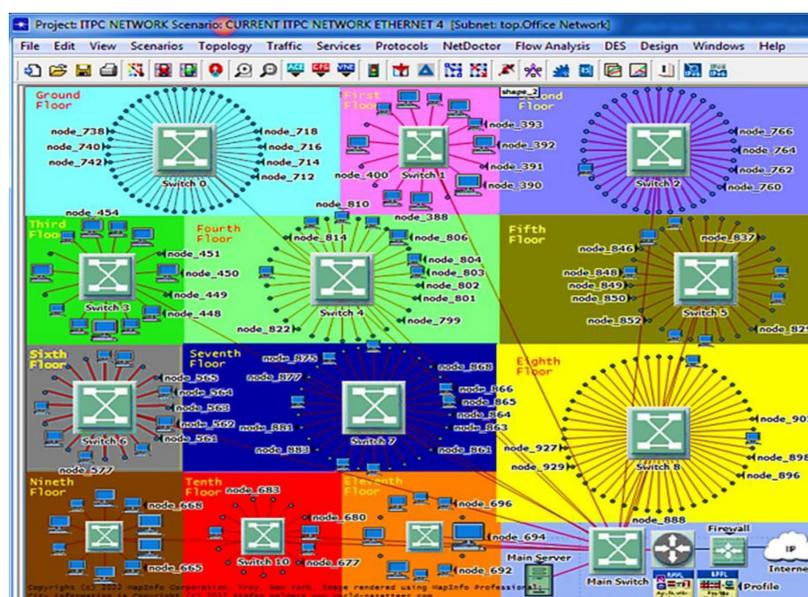


FIGURE 8. Ethernet technology by using regrouping devices

SCENARIO 4: ETHERNET DESIGN BY USING REGROUPING DEVICES AND EXTERNAL SERVER

This scenario is similar to the third scenario, with the only difference being the inclusion of an external server, as

shown in Figure 9. The objective of this scenario is to evaluate the network’s performance, specifically in terms of delay, load, and traffic, when it is connected to other external networks.

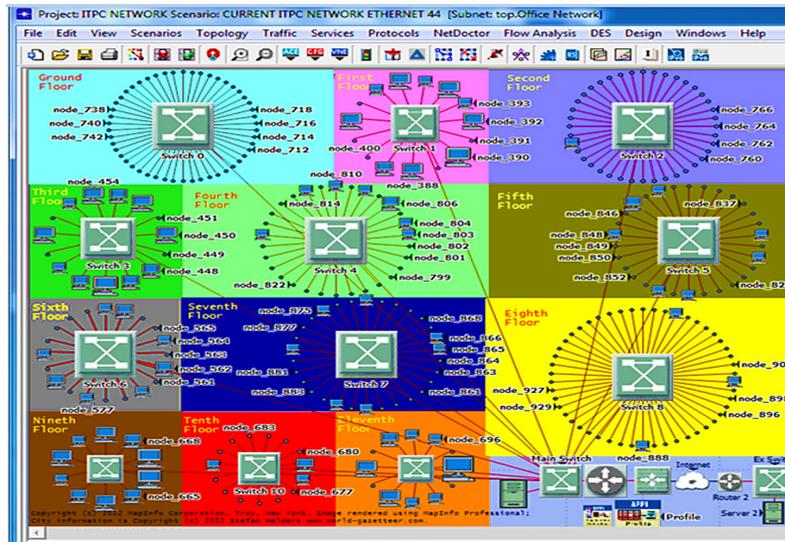


FIGURE 9. Ethernet technology by using regrouping devices and external server

RESULTS AND DISCUSSION

This paper presents several findings regarding the use of OPNET to simulate the ITPC building, including all eleven floors and the range of services and applications utilized within. The simulation involved measuring key network parameters—such as time delay, load, traffic, and throughput—for the original wireless network, and then comparing these metrics with those of the redesigned Ethernet-based network.

The hardware components used in the network design were carefully selected based on cost-effectiveness and technical specifications to enhance reliability and achieve high performance. Once the network models were built, the simulator was used to test the performance of all proposed network scenarios.

The main parameters in this study focused on measuring the delay, load, and throughput to be used as a reference point function that can be compared with different proposed scenarios. Figures 10 to 14 show the results obtained from this network, based on these data.



FIGURE 10. Ethernet delay in the network

This figure 10 presents the end-to-end delay for packets transmitted through the Ethernet-based network. It includes medium access delay, fragment reception time,

and frame transmission time through the Access Point (if enabled). The values reflect stable performance, showcasing Ethernet's low-delay capability under load.



FIGURE 11. Wireless LAN delay in the network

Figure 11 illustrates the global delay in the wireless LAN. It highlights higher end-to-end delays caused by increased medium access contention, fragmented packet

handling, and frame forwarding via APs, revealing the performance limitations of Wi-Fi in dense environments.



FIGURE 12. Wireless LAN load in the network

This figure (12) shows the total data load (in bits/sec) submitted by upper layers in all WLAN nodes of the

network. The increasing load reflects growing user activity, contributing to congestion and delay in wireless networks.

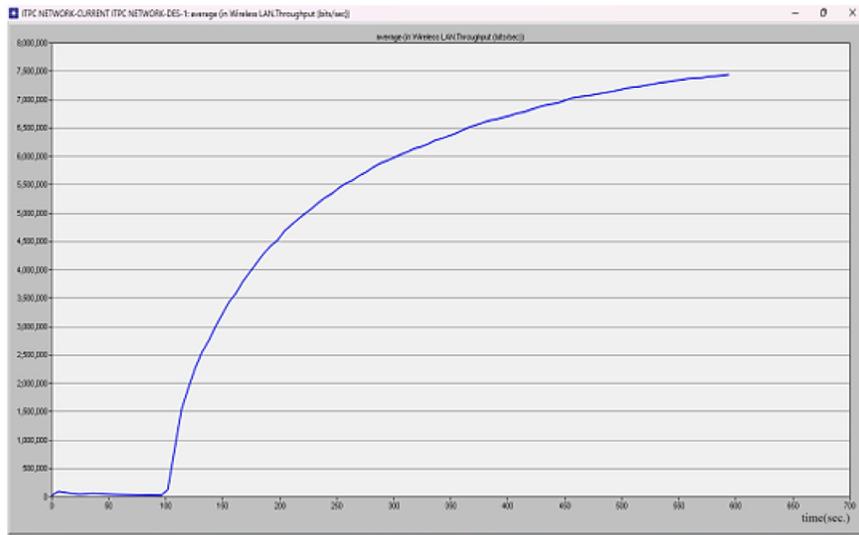


FIGURE 13. Wireless LAN throughput in the network

Figure 13 depicts the effective throughput, measuring how much data is successfully delivered to higher layers.

Despite high load, throughput remains relatively lower, indicating inefficiencies in Wi-Fi transmission under shared access constraints.



FIGURE 14. Traffic received(bits/sec.) in main switch

This figure 14 shows the volume of traffic received at the main switch. The results indicate steady performance,

with the main switch reliably handling traffic aggregation from all floors, peaking at 9.25 Mbps by the tenth minute.

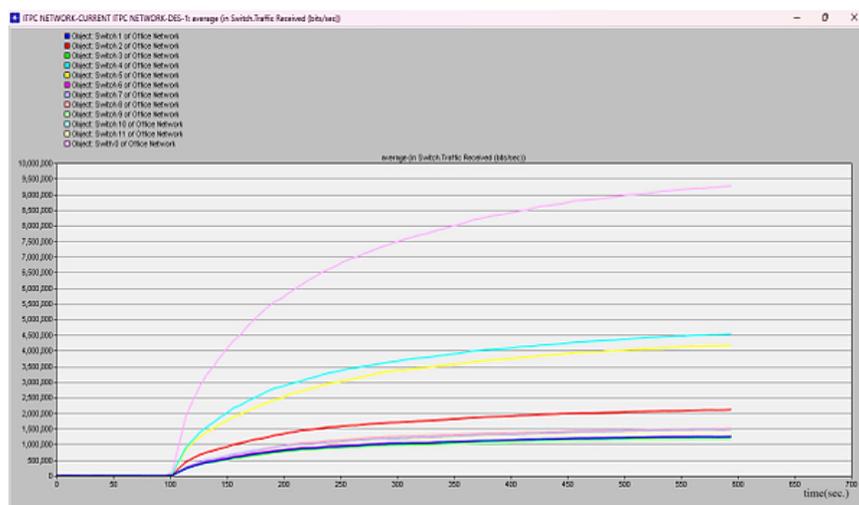


FIGURE 15. Traffic received(bits/sec.) in levels switches

Figure 15 highlights the data traffic received by switches on each floor. The values range from 1.25 Mbps to 9.25 Mbps, reflecting varying user densities and activity levels across floors. The main switch shows a consistent peak load, validating its central role in the topology.

Results show that the current ITPC network is insufficient to meet the needs of all subscribers. This is due to the need for scalability and an increase in the number of users, as well as the need to implement new applications

in the network, such as high-definition video and sound, video conferencing, real-time control via fast email, and interactive design by computers. As a result of these factors and challenges, ITPC must update its network design and update all other network devices and equipment to meet the needs of the institution’s services. The updated network must also be well-designed to be able to communicate with other networks using the right mediums.

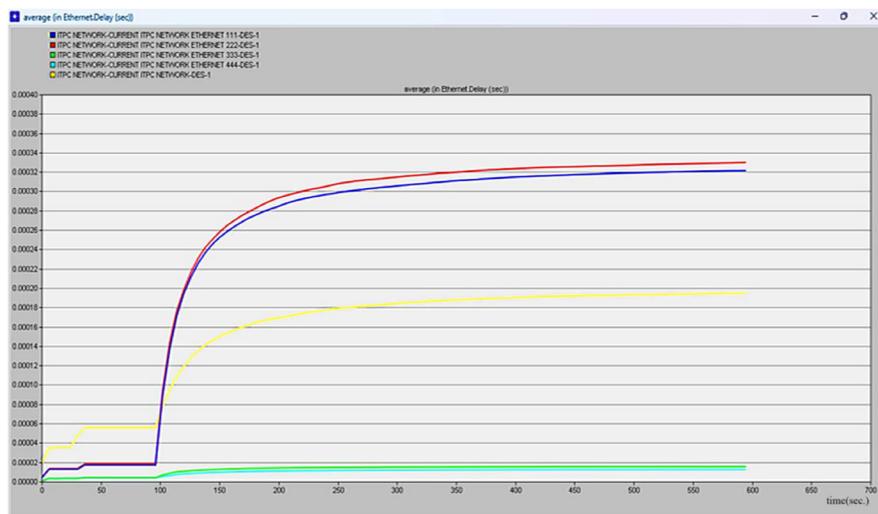


FIGURE 16. Global characteristics average Ethernet delay in the network for all scenarios

The results of a delay comparison of all scenarios are presented in Figure 16. The results show the ratio of the average end-to-end delay. The delay in the Ethernet network represents the end-to-end delay of all packets received by all the stations. In a wireless network, it represents the end-to-end delay of all packets received by the wireless LAN MACs of all WLAN nodes in the network and forwarded to the higher layer. This delay includes a medium access delay at the source MAC, reception of all the fragments individually, and transfer of the frames via AP if access point functionality is enabled. Scenarios 3 and 4 demonstrate superior performance (0.00002 s), even with firewall integration, while Scenarios 1 and 2 show higher delays (0.00032–0.00033 s). The original network falls in between (0.00020 s), revealing the benefits of optimized switch configuration and upgraded cabling.

Although firewalls typically impact several network performance parameters, such as throughput, data transmission, delay, and packet transfer, in this design, the use of a firewall did not negatively affect delay. On the contrary, the network maintained minimal delay while continuing to support the same services and applications, as illustrated in the figure above.

The measurements were recorded after 100 seconds of simulation time. This initial period accounts for the time required by all network components, such as clients, servers, routers, and hosts, to initialize and recognize one another. After this setup phase, the network begins operating normally, and the output curves quickly stabilize and rise to their peak values, indicating full network functionality.

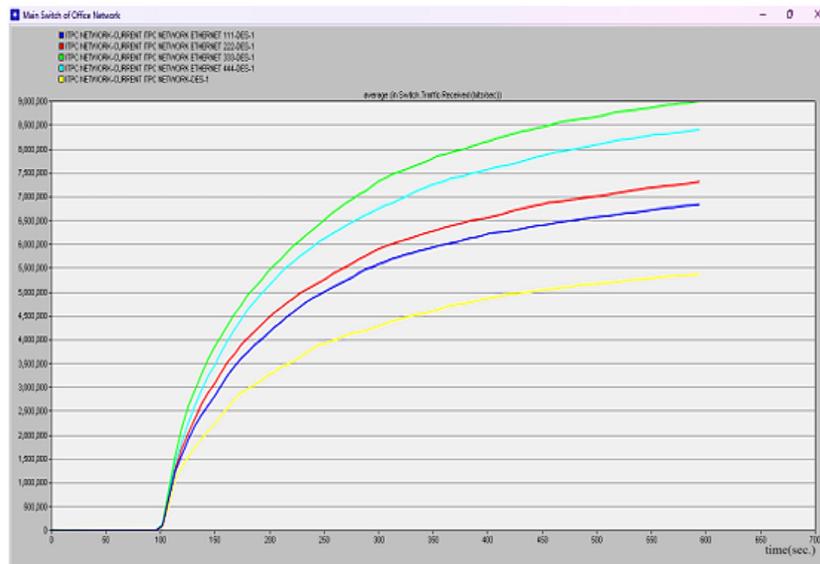


FIGURE 17. Object statistics main switch traffic received in (bits/sec) in the network for all scenarios

Figure 17 presents the traffic volume received at the main switch. Scenarios 1 and 2 reflect suboptimal design with higher device usage but lower throughput; the recorded traffic values were 6.8 Mb and 7.3 Mb, respectively. These relatively low values are attributed to the heavy use of network resources, such as multiple switches and hubs. In contrast, scenario 3 achieved a higher traffic value of 9 Mb, despite utilizing fewer resources—only 13 switches and a single server, indicating efficient handling and reduced congestion, despite fewer hardware components. This outcome is particularly noteworthy, as it was achieved even with the presence of a firewall in the network. Moreover, Scenario 3 recorded a delay of just 0.0000019 seconds, which is significantly lower than the delay observed in the current network as well as in Scenarios 1 and 2. Scenario 4 recorded a traffic value of 8.4 MB and a delay of 0.000018 seconds—one of the

lowest delays among all scenarios, despite the use of a firewall. This scenario differs from the others in that it includes the addition of an external network. Its primary purpose is to evaluate the performance of the proposed network design when data flows between networks over the Internet—in other words, testing the connection between two separate networks through an internet link. The original network maintained a stable traffic reception rate of approximately 5.8 MB. This relatively low value is attributed to the high number of resources used in the network, including 19 access points, 13 switches, 3 servers, and an extensive amount of cabling. As a result, the network is economically costly to build and maintain. In addition to the high resource cost, the recorded delay in this network was 0.00020 seconds.



FIGURE 18. Object statistics main server traffic received in (bits/sec) in the network for scenario 3 and 4.

As it is evident from the proposed scenarios that the main server was utilized only in Scenarios 3 and 4. Figure 18 illustrates the traffic received by the main server, with Scenario 3 recording 1.93 MB, slightly higher than Scenario 4, which recorded 1.53 MB. The lower traffic in

Scenario 4 is attributed to its integration with an external network, which included an additional router, switch, and server. This setup was designed to test inter-network connectivity over the Internet and resulted in the distribution of traffic across more nodes.



FIGURE 19. Object statistics main server load in (bits/Sec) in the network for scenarios 3 and 4

Figure 19 reports the average load on the main server. Scenario 3 shows a higher load (1.94 MB) than Scenario 4 (1.48 MB), consistent with the traffic received. This

reflects efficient server utilization under optimized switch and firewall configurations.

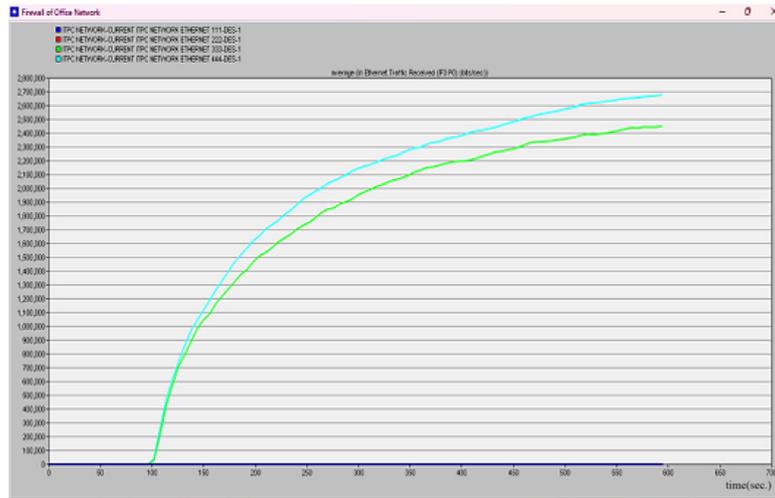


FIGURE 20. Object statistics firewall traffic received in (byte/sec) in the network for scenarios 1,2,3 and 4.

This figure 20 presents the volume of traffic handled by the firewall. Scenario 4 shows the highest value (2.6 MB), demonstrating successful inter-network data

exchange. Scenario 3 follows closely at 2.46 MB. Scenarios 1 and 2 record zero traffic due to the absence of a main server and external connectivity.

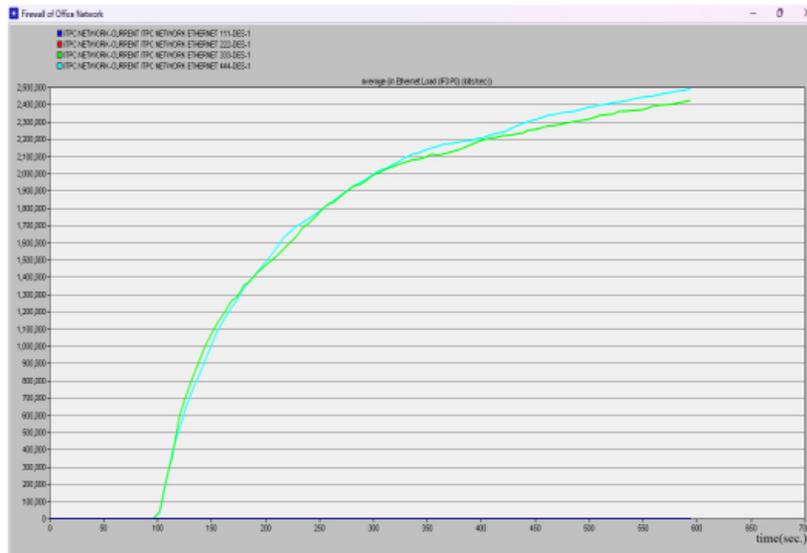


FIGURE 21. Object statistics firewall average load in (byte/sec) in the network for scenarios 1,2,3 and 4.

Figure 21 mirrors the trends in Figure 20. Scenario 4 again records the highest average load, supporting its role in external data routing. Scenario 3 maintains high internal

handling efficiency, while Scenarios 1 and 2 remain inactive in this metric.

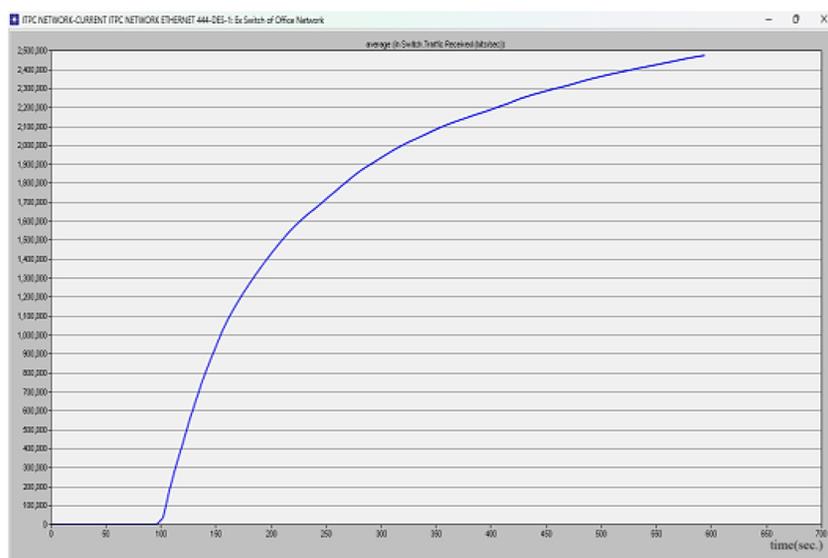


FIGURE 22. Object statistics external switch traffic received in (byte/sec) in the network for scenarios 4.

This figure 22 tracks the traffic received by the external switch in Scenario 4, peaking at 2.49 MB by the tenth minute and continuing to rise. It confirms the success of the network-to-network connection via the Internet, a key goal of Scenario 4. The redesigned scenarios, especially Scenarios 3 and 4, demonstrate significantly improved performance with fewer resources, optimized device configurations, and advanced cabling. This will result in efficient and effective transmission of data and packets across all network nodes.

Although this study offers valuable insights into optimizing institutional internal networks using OPNET simulations, it has some limitations that can be listed as follows:

1. It is primarily based on a single case study and idealized conditions in OPNET; the results may not be fully generalizable to other Iraqi institutions or organizational contexts with varying network infrastructures.
2. Although OPNET simulation software offers a robust environment for network modeling and evaluation, the results are based on idealized simulation conditions, where real-world variables such as environmental interference, hardware malfunctions, or human factors were not fully replicated, which may impact the practical applicability of the results.
3. The research is limited in its technological scope, focusing primarily on improvements using traditional wired alternatives to Wi-Fi; The advanced technologies are not considered, such

as 5G integration, fiber optic, and cloud-managed services.

4. The analysis predominantly centers on technical performance metrics, including delay, throughput, load, and received traffic. Broader organizational, operational, and user-centric factors, such as cybersecurity threats, regulatory compliance, user experience, and maintenance costs, were not thoroughly explored.

Future studies should expand the evaluation scope to include a broader set of Iraqi institutions to verify the feasibility of deploying advanced network technologies to improve the proposed network. It is recommended that simulation-based evaluations be complemented by real-world pilot applications. These efforts will provide valuable insights into the long-term sustainability, maintenance planning, and cost-effectiveness of e-government network deployments.

CONCLUSION

Many institutions in Iraq, including ITPC and others, continue to rely heavily on Wi-Fi technology due to its ease of installation. However, Wi-Fi-based networks often suffer from significant limitations in transmission quality, particularly for voice, video, and data, and generally offer poor quality of service. Network performance in such environments is further hindered by factors such as suboptimal topology design, inadequate hardware specifications, and increased demand driven by the rise in data-intensive applications. These issues are especially

pronounced in IEEE 802.11-based wireless networks, where non-standardized implementation and poor planning have led to shortcomings in speed, reliability, security, stability, and cost-effectiveness.

To address these limitations and keep pace with rapid developments in the telecommunications sector, telecommunications networks must be continuously updated and developed through study and analysis using various network simulation programs.

This study takes a novel approach by building both a prototype of the existing network and a virtual model using OPNET simulation software. We evaluated these models by analyzing the impact of various services, applications, user loads, and network resource allocations. The simulation results

demonstrated a clear performance advantage over the physical network, highlighting the benefits of careful design and validation through modeling. Simulated environments like OPNET enable the creation of optimized enterprise network scenarios, allowing institutions to assess application performance, transmission efficiency, and resource use before actual implementation. This process results in reduced costs, shorter deployment times, and improved data throughput using minimal resources.

Based on the simulation outcomes, we were able to recommend an optimized network design, including the selection of appropriate components and transmission media. The results affirm that a well-planned network architecture significantly enhances data exchange efficiency and overall network performance.

Ultimately, this research contributes practical insights for improving telecommunications infrastructure, as an example of internal networks, as in this research. It underscores the importance of thoughtful network design and simulation in supporting broader initiatives like e-government network development. By aligning technical strategies with real-world challenges, institutions can ensure more reliable, secure, and scalable network solutions.

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DECLARATION OF COMPETING INTEREST

None

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