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Analysis of Optimal Routing Protocol for an Inter-Campus Private Cloud Network System

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***Abstract*: With the need for resources sharing and the integration of cost-effective IT solution across tertiary institution in Nigeria, the need for an inter-campus private cloud network is presented in this project. The inter-campus private cloud network provides a platform for sharing resources across campuses instead of replicating such resources which are in many cases underutilized. This work presents the optimal routing protocol for an inter-campus private cloud network system that connects 5 campuses together within Owerri city in Nigeria. A star-star hybrid network topology was adopted in this project work and was modelled using Packet Tracer simulator. The network was simulated using the three main routing protocols namely RIP (routing information protocol), OSPF (open shortest path first) and EIGRP (enhanced interior gateway routing protocol) which were tested and compared to determine the routing protocol with the shortest convergence time. The connection time of the three routing protocols used on the exchange point network was run at a TTL value of 24 and packet size of 32 bytes. The RIP provided a convergence time that is within 3 and 4 seconds, with slightly varied spikes of not up to 10 seconds, OSPF and EIGRP also tries to maintain a time of between 3 and 4 seconds but is plagued with so many spikes of up 20 seconds for EIGRP and 17seconds for OSPF. The results showed that with a routing protocol like RIP, connections between the campuses via the exchange point will converge faster. As a result, RIP routing protocol was adopted as the optimal routing protocol to be used for the network configuration due to its better convergence time.**

***Keywords*: Internetwork, Routing Protocol, Inter Campus, Cloud Network, RIP.**

1. Introduction

The growing bandwidth power of the Internet has pushed the client/server model one step further towards what is called the "Cloud Computing Model". Cloud computing refers to a model of computing that provides access to a shared pool of computing resources (computers, storage, applications, and services) over an internet protocol driven network. These "clouds" of computing resources can be accessed on an as-needed basis from any connected device and location [1].

An Inter-Campus Private Cloud Network is a cloud installation that is largely controlled from within an organization's premises. Local users of applications hosted on the private cloud-driven infrastructure have access to the facility without need for internet connectivity. Only external users of the facility require some form of internet connectivity to gain access. This installation is modular in nature such that it can be easily replicated and interconnected with each other to form a cluster [2].

Exiting cloud platforms like Amazon Web Services, Google Cloud Platform, Alibaba, Microsoft Azure and IBM Bluemix among others provide ready to use infrastructure or applications that organization leverage on to setup their cloud presence online. Using these cloud platforms, organization rely heavily on the security plugins provided by their cloud providers in addition to their private security instance. This is one major drawback of public cloud as entire organizations data are domicile in cloud providers premises. The need for internet connection and cloud subscription are important considerations when adopting public cloud platforms. On the other hand, aside from providing organizations with more control over sensitive data, a private cloud infrastructure helps to support organizations' data privacy needs by keeping data within company's premises. Organizations that are very concerned about data privacy while needing online presence opt for a hybrid cloud installation that integrates the private cloud facility alongside the public cloud platforms [3].

Adopting private cloud-driven installation can largely minimize cost associated with cloud and internet bandwidth subscription. Investigation into the current approach to application hosting in tertiary institution, shows that most applications run on public hosting platforms with almost nothing running on private facilities The significance of using private cloud computing in education was demonstrated in a case study conducted at Al-Zaytoonah University (Jordan). The case study results indicate that cloud computing can save the cost and resources of university. The main reasons to select the private model for Al-Zaytoonah University were to reduce associated costs, deliver high quality and consistent services, and to ensure a stable system for students. Al-Zaytoonah cloud computing infrastructure is based on OpenStack architecture which is an open-source platform. [4].

A. Research Objectives and Focus

The objective of this project is to determine the optimal routing protocol for an inter-campus private cloud network system.

Specifically, this work will achieve the following objectives:

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1. Empirical review of existing network infrastructure of selected institutions in the South-East.
2. Model an Inter-Campus Private Cloud Network System (ICPCNS) for five (5) institutions.
3. Simulate the model on packet tracer network simulator using the exchange point approach.
4. Simulate selected routing protocols on the network topology model to determine the best routing protocol for the exchange point network.
5. Analyze the output of the simulation using the convergence time for each protocol tested.

The work covers Inter-Campus Private Cloud Network System (ICPCNS) modeling for 5 Major campuses in Nigeria. This work will be limited to providing network experiences with a basis for the choice of a particular routing protocol that is suitable for an intercampus network covering the 5 selected institutions in Imo State. The routing protocols to be analyzed in the network are: RIP (routing information protocol), OSPF (open shortest path first) and EIGRP (enhanced interior gateway routing protocol). The selected institutions are within the Owerri city and they include: Federal University of Technology Owerri (FUTO), Alvan Ikoku Federal College of Education (AIFCE), Federal Polytechnic Nekede (FEDPOLY), University of Agriculture and Environmental Sciences (UAES) and Imo State University (IMSU).

2. Related Literature

Several works have been going on to improve the performance of campus networks. A campus with an internal network is an example of a network domain that requires some level of connectivity to the outside world. Data exchange between campus or corporate domains is facilitated by some actions of a third-party cooperation; these cooperate domains offer, as a service, transmission and switching facilities for data exchange between their customers. Providers usually interconnect at Internet *exchange points* and can vary in the geographical scope of their operations from regional, to national and international [5].

Researchers have over the years have tried to provide design models for campus networks that are optimal using various techniques. What is most common for campus networks are flat designs that do not pay attention to design considerations but rather focus on the campus needs and usage capacity. The use of cloud-based networks due to its scalability has found some level of application in campus networks. Most campus now run a hybrid private cloud and public cloud networks to balance availability, costs, and management [6].

[7] carried out a performance Analysis and Route Optimization: Redistribution between EIGRP, OSPF & BGP Routing Protocols. Their research article focuses on the performance and redistribution of different routing protocols in medium or enterprise IP networks. A simulated network model is established in GNS3 simulator. Five Cisco-7200 series routers and a switch is used in this simulated topology. All these routers are directly connected with each other via serial links. Routing protocols EIGRP, OSPF and BGP are used in this topology and then configured route redistribution on these routers. Their findings revealed that EIGRP is better in convergence and through put whereas OSPF is better in packet delay. The constraint is that with an increasing node scale, the cost of obtaining network state information will increase rapidly, and the network convergence will be slow. [8] researched on routing optimization for cloud services in SDN-based Internet of Things with TCAM capacity constraint. They addressed the routing optimization problem in SDN-based IoT with TCAM capacity constraint. [9] carried out a study on private network optimization. The author noted that optimization was required as the number of devices connected to this network was more. [10] studied the Intrusion detection for network-based cloud computing by custom RC-NN and optimization. Their work was aimed at optimizing custom RC-NN-IDS model thus achieved an improved classification accuracy of 94% and also a decreased error rate of 0.0012. [11] analysed the performance of routing protocols for UAV communication networks. He stressed the challenges associated with designing a routing protocol that can provide efficient and reliable node to node packet transmission.

One method used to maintain communication is by implementing a protocol redundancy system. One or more routers will act as the primary router for load balancing, and some routers are in standby mode if one main router is down. First hop redundancy protocols (FHRP) is a protocol that implements redundancy and load balancing systems. This protocol can transfer access data traffic if one of the routers on the network is down. FHRP is divided into virtual router redundancy protocol (VRRP) and gateway load balancing Protocol (GLBP). This research analyzes the design and implementation to provide information about the quality of VRRP and GLBP services on the main router and the backup router, by using an application graphical network simulator (GNS) simulation 3. In the GNS3 application, a LAN network topology is designed with eight router devices in the form of a ring topology using RIPv2 and OSPF routing protocols, then implemented in protocols VRRP and GLBP. The analysis results show that GLBP can back up the network faster than VRRP [12]. [13] proposed a cloud network that focuses on the total cost of ownership. Their focus was to get organizations to shift their management effort to third parties which is the real concept behind cloud computing. The challenge with this model is that privacy of sensitive information is not guaranteed. [14] focused their research on integrating software as a service cloud solution. In this context, the solution does not factor in other models like infrastructure and platforms that are critical in cloud deployment models especially where it involves private ownership. [15] examined the selection of optimal cluster head that makes the network prompt. Consequently, he develops a new clustering model with optimal cluster head selection by looking at four major criteria such as energy, distance, delay and security.

3. Research Methodology and System Design

A. Research Methodology

The ICPCNS will be analyzed using Prototyping

Methodology. The prototyping steps used in prototyping the ICPCNS System are stated below:

1. Evaluation of the old system: here the existing system is evaluated and noted.
2. Initial setup requirements: here the settings of the initial requirements are done.
3. Design: here the design of the system is developed and implemented.
4. Prototyping: here the prototype is modified based on the comments supplied by the users.
5. Simulation: here the system is simulated as specified using the various routing protocols.
6. Review and update: here the simulated system is reviewed and updated for any additional input.
7. System development: here the system is developed based on the prototype which represents the final product as desired.
8. System testing: here the developed system is tested for compliance and consistency in accordance with the specified values.
9. System maintenance: This is the final step after system testing. This step is designed for the routine maintenance of the system in case of failure.

B. *System Design*

The following campuses are considered for the research work. These institutions are government owned and are faced with the problems listed above. The institutions also cut across the major category of tertiary institutions available in Nigeria; college of education, polytechnic and the university. These institutions are also Managed by the federal government or state government.

The institutions include:

1. Federal University of Technology Owerri (FUTO)
2. Federal Polytechnic Nekede (FEDPOLY)
3. University of Agriculture and Environmental Sciences (UAES) Umuagwo
4. Alvan Ikoku Federal College of Education (AIFCE)
5. Imo State University (IMSU)

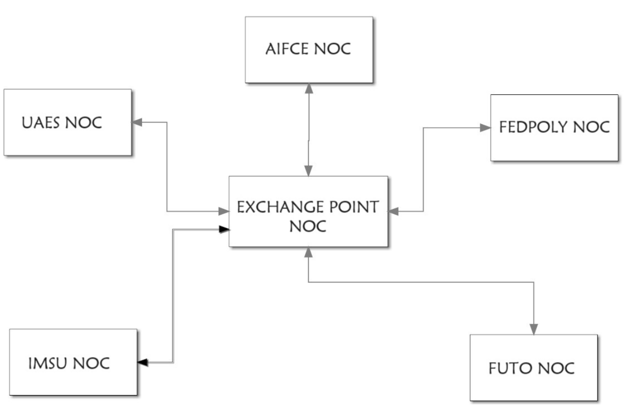

Fig. 1. Block diagram of the ICPCNS

The ICPCNS are made up of two basic modules, the exchange point and the campus unit. The exchange point serves as a connection point for all the campuses subscribed to the exchange point service. For this pilot design, the five campuses in Imo state eastern Nigeria are used (FUTO, IMSU, FEDPOLY, UAES and AIFCE).

Figure 1 shows a block diagram showing how the campuses are connected. Each campus network is connected directly to the exchange point.

Figure 1 shows that the exchange point exchanges traffic between each campus Network Operations Center (NOC) and allow for these campuses to also exchange traffic between each other via the exchange point NOC.

To setup the ICPCNS network, a flow chart showing the algorithm behaviour was adopted as shown in figure 2. The flow chat describes how the network was designed and simulated on the simulated environment. This process is to be replicated for the following protocols to be tested: RIP, OSPF and EIGRP.

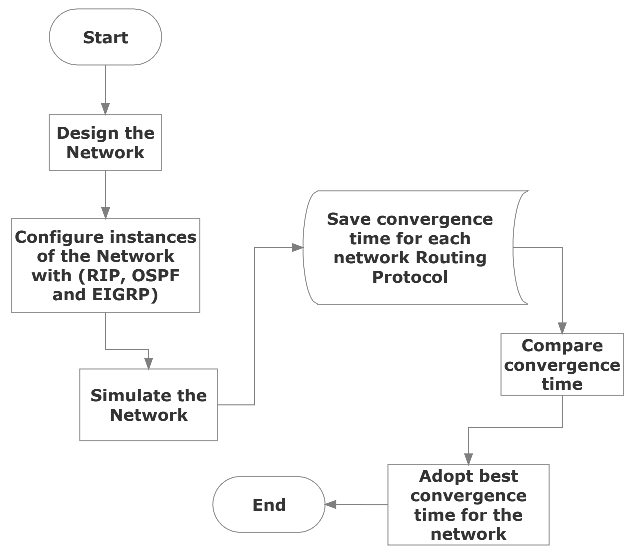

Fig. 2. Flow chat of the design process

The network topology adopted in this project work is a star-star hybrid topology due to the spatial nature of the locations of the campuses. The campuses are connected end router devices communicating via their serial ports. Figure 3 shows the network topology of the design showing edge routers at each location of a campus NOC and three routers at the exchange point for purpose of load balancing and redundancy.

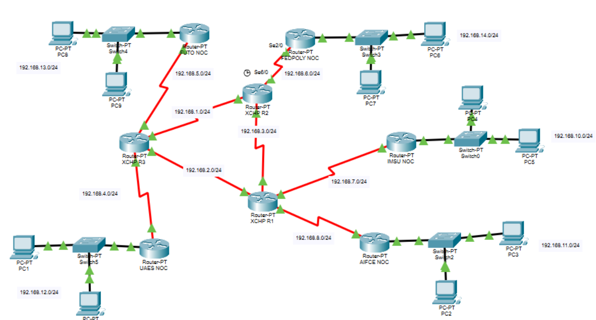

Fig. 3. Network topology of the simulation model

Table 1 shows the IP configuration table of the network in figure 3. Private class C address was used between 1 and 14. Each interface of the router was assigned a whole block of IP for easy administration.

Table 1
IP addressing table for the ICPCNS

Device	Interface	IP address	CIDR value	Subnet mast
XCHP R3	Se 2/0	192.168.1.1	24	255.255.255.0
XCHP R2	Se 2/0	192.168.1.2	24	255.255.255.0
XCHP R3	Se 3/0	192.168.2.1	24	255.255.255.0
XCHP R1	Se 2/0	192.168.2.2	24	255.255.255.0
XCHP R1	Se 3/0	192.168.3.1	24	255.255.255.0
XCHP R2	Se 3/0	192.168.3.2	24	255.255.255.0
XCHP R3	Se 7/0	192.168.4.1	24	255.255.255.0
UAES NOC	Se 3/0	192.168.4.2	24	255.255.255.0
XCHP R3	Se 6/0	192.168.5.1	24	255.255.255.0
FUTO NOC	Se 2/0	192.168.5.2	24	255.255.255.0
XCHP R2	Se 6/0	192.168.6.1	24	255.255.255.0
FEDPOLY NOC	Se 2/0	192.168.6.2	24	255.255.255.0
XCHP R1	Se 7/0	192.168.7.1	24	255.255.255.0
IMSU NOC	Se 2/0	192.168.7.2	24	255.255.255.0
XCHP R1	Se 6/0	192.168.8.1	24	255.255.255.0
AIFCE NOC	Se 2/0	192.168.8.2	24	255.255.255.0
IMSU NOC	Fa 0/0	192.168.10.1	24	255.255.255.0
AIFCE NOC	Fa 0/0	192.168.11.1	24	255.255.255.0
UAES NOC	Fa 0/0	192.168.12.1	24	255.255.255.0
FUTO NOC	Fa 0/0	192.168.13.1	24	255.255.255.0
FEDPOLY NOC	Fa 0/0	192.168.14.1	24	255.255.255.0

4. Results and Discussion

The network is configured using 3 routing protocols (RIP, EIGRP and OSPF) and their time to live is compared with each other to determine the optimal routing protocol that can fit the network topology for the exchange point network. The connectivity between individual NOC is tested using internet control message protocol (ICMP) packets. A sample result is shown in figure 4.

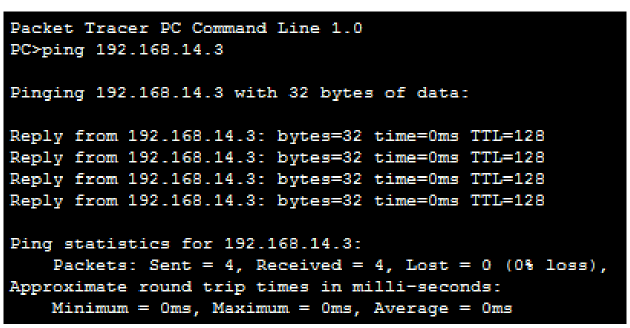

Fig. 4. Connectivity test between PC6- and PC7

Table 2 shows the connection time of the three routing protocols used on the exchange point network at a TTL value of 24 and packet size of 32 bytes. The simulation was monitored over a period of 2 minutes.

The graph shown in figure 5 shows the behaviours of the various routing protocols used for the simulation.

Form the results gotten from the simulation process as shown in table 2 and figure 6, the following can be deduced:

1. RIP as a routing protocol to be used for the exchange point network provides a convergence time that is within 3 and 4 seconds, with slightly varied spikes of not up to 10 seconds.
2. OSPF and EIGRP also tries to maintain a time of between 3 and 4 seconds but is plagued with so much spikes of up 20 seconds for EIGRP and 17seconds for OSPF.
3. From the graph, it can be clearly deduced that with a routing protocol like RIP connections between the campuses via the exchange point will converge faster.

Table 2
Simulation output of connection for RIP, EIGRP and OSPF

Simulation time	Time (ms) [@ TTL=24 and PKT=32]		
	RIP	EIGRP	OSPF
6	5	20	3
12	4	3	9
18	3	4	4
24	3	3	5
30	3	3	13
36	3	4	10
42	5	3	3
48	4	3	3
54	3	4	4
60	7	12	3
66	3	3	17
72	3	11	3
78	3	4	3
84	4	17	16
90	3	5	7
96	3	3	5
102	3	10	4
108	3	10	3
114	6	3	11
120	3	3	3

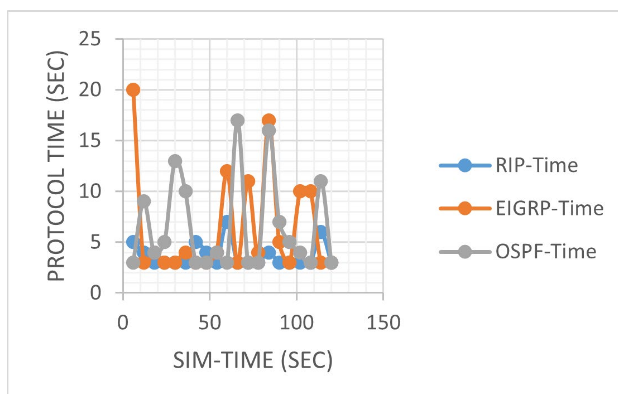

Fig. 5. The Protocol time for RIP, EIGRP and OSPF

5. Conclusion

Implementing a functional internetwork is no simple task. Many challenges must be faced, especially in the areas of configuration, connectivity, reliability, network management, and flexibility. Each area is key in establishing an efficient and effective internetwork.

The challenge when connecting various systems is to support communication among disparate technologies. Different sites, for example, may use different types of media operating at varying speeds, or may even include different types of systems that need to communicate.

Because institutions rely heavily on data communication, internetworks must provide a certain level of reliability. This is an unpredictable world, so many large internetworks include redundancy to allow for communication even when problems occur. Redundancy provided could be an additional link or a special kind of link as proposed in this work; the internet exchange point.

The ICPCNS is a reliable, easy to set up and cost-effective redundant link for institutions. The ICPCNS points simply help the various campuses share resources when it is necessary and also balance load as they are funded from the same source in this case the government.

Furthermore, network management must provide centralized support and troubleshooting capabilities in an internetwork. Configuration, security, performance, and other issues must be adequately addressed for the internetwork to function smoothly.

Because nothing in this world is stagnant, internetworks must be flexible enough to change with new demands.

This work will provide to network engineers a guide for network design and configuration within campus environment, paying attention to network efficiency. It pays attention to equipment, topology and protocol in the design and deployment of network in campuses. This work also provides a guide to institution administrators and the government to help check the quality of infrastructure being deployed by contractors in our tertiary learning environment.

From the results generated it is clear that to get the best out of an inter campus network system connecting campuses with limited number of nodes, RIP is the best bet, with a convergence time ranging mainly between 3 and 4 seconds.

The following are the contribution of this research:

1. The research provided a design model that enables campuses share resources over an inter campus private cloud network thereby minimizing link downtime for developing countries that have issues around stable internet connection.
2. The research provided the best routing protocol for an intercampus network using the convergence time approach.
3. The work introduced the use of an exchange point design for an intercampus wide network thereby minimizing cost for individual campus link and maximizing resources usage.

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