IMPACT OF NETWORK SCALABILITY ON THE PERFORMANCE OF RIP AND IGRP FOR EMAIL SERVICES

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ABSTRACT

Dynamic routing is one of the major areas in computer networks, in which routing protocols are used to automate the process of routing. Routing protocols dynamically determine best path(s) to every network. Routing protocols are classified as distance vector and link-state routing protocols. Routing Information Protocol (RIP) and Interior Gateway Routing Protocol (IGRP) are examples of distance vector while Open Shortest Path First (OSPF) and Intermediate System to Intermediate System (IS-IS) are link-state routing protocols. Both RIP and IGRP are using different metrics to evaluate best route to a destination in the network. RIP uses a simple metric value of hop-count while IGRP uses a composite metric. A composite metric consists of several attributes like bandwidth, delay, reliability, Maximum Transmission Unit (MTU) and load. Usually it is considered that because of the simple metric value, RIP produces better results for any application in simple network architectures. This paper studies the performance of RIP and IGRP in simple networks of different sizes, using email application as evaluation entity. The objective is to find that where, in simple network architectures, RIP with its simple metric will produce better email services or IGRP will win the race with the help of its composite metric. This study also investigates the effect of scalability on both of the routing protocols when the size of the network grows. The behavioural study of RIP and IGRP for email, in different sizes of networks, will also help in evaluating the behaviour of simple and composite metrics. Simulations and experiments results indicate that IGRP produces better results for email services as the size of the network becomes more scalable and the number of hops between source and destination increases, even if simple network architecture is followed. The results also indicate that IGRP consumes relatively less CPU pulses of email server.

KEY WORDS: *Dynamic rovting, IGRP, RIP, Scalaility.*

I. INTRODUCTION

Organizations develop networks to inter-communicate users. Email is one of the most frequently used application that enables users to share text, graphical and audio data with each other. Email uses Simple Mail Transfer Protocol (SMTP)[1] in client-server architecture to transfer data from source to destination mail server. The receiving device uses some kind of pull protocols, like Post Office Protocol V.3 (POP3)[2] or Internet Mail Access Protocol V.4 (IMAP4)[3], to read messages from the mail server. The email messages are segmented at transport layer of OSI model and forwarded to the network layer for routing. The network layer then uses one of the routing protocols to dynamically route the email message toward the destination network.

Routing protocols play a vital role in fast, reliable and secure transmission of data packets. This paper will help network administrators and students to understand the behavior of routing protocols transmission in a scalable network environment, especially in campus area networks.

Some of the most commonly used dynamic routing protocols are RIP[4], IGRP, EIGRP[5], OSPF[6] and IS-IS[7]. RIP and IGRP are classified as distance vector routing protocols, which uses distance and direction as metric to calculate best path(s) to remote networks. Some of the distance vector protocols also use link characteristics for best path(s) selection. Distance vector protocols send both triggered and periodic updates to share the routing information with other routers. Routing updates are only sent to neighbor devices, and hence, distance vector protocols do not have complete information about network topology. Distance vector protocols are considered good choice to be configured in simple and flat networks. At the other hand, link-state protocols create a complete view of network topology. Link-state protocols send only triggered updates when a change in topology is detected. Link-state protocols uses only link characteristics for best path(s) selection to remote networks. Link-state protocols like OSPF are preferred to be used in hierarchical network designs. OSPF has the ability to divide the large network into many smaller sub-networks, called areas. Each area is assigned a

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number, called autonomous number, to uniquely identify a particular area[8]. OSPF uses Shortest Path First (SPF) algorithm to determine the best path to a network by analyzing all the available paths[9].

EIGRP is categorized as hybrid routing protocol which has qualities of both distance vector and link-state algorithms. There are five components for the internet-working of EIGRP protocol: neighbor table, topology tables, route states, route tagging and routing tables[10]. In order to provide loop-free routing, EIGRP uses DUAL algorithm[11,12]. DUAL algorithm encompasses the qualities of both distance vector and link-state algorithms[13].

In our work, we are comparing the performance of RIP and IGRP for email services, using a simple CAN (Campus Area Network). From simple we mean that all the links used to interconnect routers carry same set of characteristics, like bandwidth, delay and background utilization. We are evaluating the parameters of email download and upload response times of email application. We also investigate the behavior of both routing protocols, in terms of scalability. The goal of this work is to investigate that which one of the two routing protocols, RIP and IGRP, provides better email upload and download response times in a simple CAN. Further, we wants to find the factors that make composite metric calculation efficient than simple metric, if both are adopted even in a simple network architecture. We will also investigate the effect on performance of both of the routing protocols by enlarging the size of the network and increasing the number of hops between sources (client hosts) and destination (email server).

II. RELATED WORK

Being a major and popular area of research in computer networks, a lot of work has been done on the performance evaluation and enhancement of Routing Protocols. Performance of routing protocols can be enhanced by using one of the three methods.

- Design new routing algorithm that contain some new features and improves routing efficiency.
- Add some new and efficient features in the already existing algorithm for routing.
- Modify the existing features and characteristics by making some valuable changes in the existing algorithm of a routing protocol.

Researchers have performed many enhancements in routing protocols of different types of networks, given in[14,15,16].

Performance of two or more routing protocols can also be compared for some application(s), to evaluate that which one of these routing protocols can best facilitate a particular application. For performance evaluation, a sample network is designed and configured for all the comparing routing protocols, following similar set of data, configuration and application settings. Then network is executed for some fixed period and responses of performance evaluation parameters are collected and compared. Mostly network simulating software are used for performance evaluation and comparison. In our work, we are performing a comparative study for RIP and IGRP using OPNET IT Guru for simulations configuration.

Choosing a routing protocol for a network, among many, is a critical and equally important task and involves many parameters to be considered. Parameters that are to be considered while making a choice for routing protocol include convergence time, security, CPU and bandwidth requirements and scalability support. EIGRP, OSPF and RIP were checked for these performance parameters and it was concluded that EIGRP compared to RIP and OSPF produces better results for Network convergence activity, Network convergence duration[17]. All the parameters discussed above, helps in providing knowledge about the routing protocols. These parameters do not convey anything regarding an application like File Transfer Protocol (FTP), Hyper Text Transfer protocol (HTTP), and Email etc. In our work we are going to compare the response times of Email Upload and Download obtained for both RIP and IGRP, in a simple network.

The performance comparison of networks having single routing protocol configured in it has also performed with network having multiple routing protocols configured in it simultaneously. Vasudha and Jindal compared the performance of RIP with the combination of RIP and OSPF over a sample network. Simulations are performed in OPNET over a Wide Area Network (WAN) deployment network of two wireless LANs (Local Area Networks) connected with router. The network has two subnets each consisting of two workstations and the subnets has been connected with router via 100BaseT. The network is connected over IP cloud with remote site (wireless network) with FTP and web server over firewall. It was concluded in[18] that the download response time for FTP traffic is much lower with the integration of RIP and IGRP, compared to RIP only. It was also concluded that both "RIP" and "RIP with OSPF" result same for the comparison tests of WLAN (Wireless LAN) load, WLAN throughput, Links utilization, Links throughput, WLAN delays, WLAN media access delay and Queuing delays.

Another comparison study of a low-load campus area hybrid network, using RIP and RIP with IGRP as routing protocols, for the applications of FTP, ATM cell delay and Remote login response time is performed in[22]. The investigations reveal that the integration of RIP&I-GRP routing protocols result in increasing the FTP upload and download response time. It was also concluded that the performance was better for Remote login response time with the integration of two routing protocols. It is also notified in the same study that the ATM cell delay with the two routing protocols was better than using only RIP as routing protocol.

EIGRP is also considered as a hybrid routing protocol because it has the properties of both distance-vector and link-state routing protocols. The comparison of EIGRP has also been performed with pure links-state and pure distance-vector routing protocols. In[19], EIGRP performance for HTTP traffic and Response time of HTTP Server were compared with that of RIP, IGRP and OSPF and it was concluded that EIGRP network on average provides better results for HTTP traffic and response time.

Another performance evaluation study of RIP and IGRP is performed by Sapna, Manju Sharma and Harpreet Kaur in[20]. Simulations are performed in OPNET IT GURU simulator, using a hybrid network topology (combination of both wired and wireless networks). The topology is configured with RIP as routing protocol and the same topology is again deployed by configuring the combination of both RIP and IGRP routing protocols simultaneously. Results from both simulations were collected for the applications of Email Download Response time, WLAN media access delay, WLAN delay, WLAN throughput and FTP Server CPU utilization. This study recommended the use of RIP and IGRP for downloading processes. This study also revealed that Remote Login Response Time with the combination of two routing protocols was better than RIP. Furthermore it was also recorded that FTP server utilization was more in case of RIP and IGRP routing network. A marginal decrease in WLAN utilization is also noticed in the RIP network.

Another hybrid network was investigated for different applications like Email (Upload and Download response time), FTP (Upload and Download response time), Remote login response time, WLAN throughput etc, using EIGRP and OSPF as routing protocols[21]. This investigation recommended the use OSPF routing protocol for Email download rather than EIGRP. It was also concluded that the use of OSPF as routing protocol produced better results for Remote login response time and WLAN throughput, compared to EIGRP.

A Performance comparison study of IEEE 802.3 LAN is performed against the parameters of Network Convergence Time, End to End delay, Delay Variation, Throughput, Utilization, Queuing Delay and IP Processing delay, using IGRP and EIGRP as routing protocols in one study[22]. This work also investigated the performance of both routing protocols for video and voice data transmission. This work has recommended the use of IGRP for small and medium size networks, compared to EIGRP.

The performance of different interior gateway routing protocols for real time transmission were compared in another study[23]. In this work, the performance of RIP, IGRP, EIGRP and OSPF were compared for voice and video transmission against the parameters of Packet Dropping, Traffic Received, End-to-End Delay and Jitter. This work concluded that IGRP performs well for the parameters of End-to-End Delay, Packets Dropping and Traffic Received compared to other routing protocols, while in case of Jitter; RIP performs better than all the remaining protocols.

We have observed that a lot of comparative studies of different routing protocols are performed by researches for different applications. In our study, we also compared the performance of RIP and IGRP routing protocols for Email application. Our focus is on the parameters of Email upload response time and Email download response time. Our study, compared to other comparison studies of routing protocols, has several differences that are listed below.

- **The network architecture:**

The network architecture that we are using in our study is different from those architectures that are followed in the other studies. Our network architecture contains routers, interconnected in a campus area of 10 kilometers in square. No Wireless networks are added to the routers. All the routers are interconnected directly to each other via point-to-point links, rather than using any IP cloud network to connect them.

Second, our network architecture is simple and the complex design of the network is ignored intentionally. We want to compare the performance of RIP and IGRP in a simple network to evaluate that whether the complex metric of IGRP can perform better than RIP in a simple network, which has a simple routing metric of hop-count? None of the other studies has followed or discussed the architecture they used. They have followed an architecture in which different networks are interconnected via few routers only.

• **Scalability:**

We have observed in the other studies that none of the routing protocols is compared for any of the applications, in terms of scalability. No one has evaluated the response of a routing protocol performance, if the size of their network changes. From scalability we mean increase in number of routers and email users, in the network. It is important to note that increase in number of routers will also cause increase in the value of hop-count to reach email server as well as the number of links connected to router(s). We evaluate in our study that which one of the two routing protocols remains stable, if the size of the network is enlarged.

• **Single application evaluation:**

In our investigation, we will configure only the Email application in our sample networks (scenarios). This will be useful in finding true results for the application, because no background traffic will exist. In all the other studies, multiple applications are configured in a network simultaneously. In these types of networks, if we are evaluating performance of a single application, the other applications will also be sending and receiving their traffic in background. This background traffic will affect the response time evaluated for a particular application among many.

III SCENARIOS SETTING

In this section we discuss the scenarios that we have used for evaluating the performance of both routing protocols for email application. We will use multiple scenarios of different sizes, because we are also interested in recording the effect of scalability on performance of both routing protocols for email application.

A. Five Routers Scenario

Our first scenario, depicted in Figure1, consists of five intermediate routers i.e. R1, R2, R3, R4 and R5. A client's network (subnet) is attached to the R1, while the server network subnet is attached to the router5. Both the networks are connected to their corresponding routers, using Ethernet 100BaseT communication links. 100BaseT links are capable of carrying data with speed of 100Mbps.

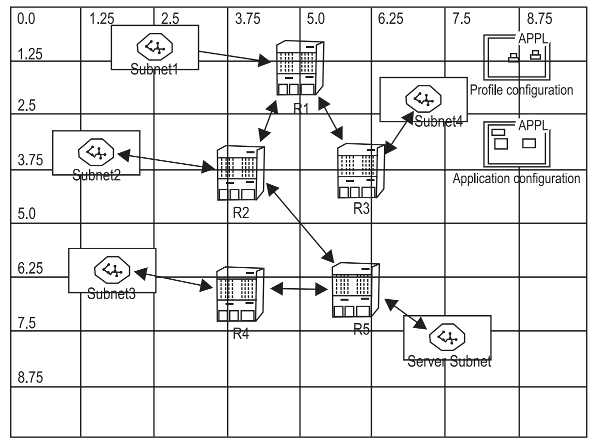

Figure 1. Five Routers Scenario

All the routers are interconnected by using point-to-pint DS1 (PPP DS1) links, which carry speed of 1.54Mbps. We have used the same combination of links (Ethernet and PPP-DS1) in all of the scenarios. The figure shows that it is a very simple scenario and every router has maximum of only three directly connected neighbors. In this scenario, the data generated by subnet1 devices will pass through two hops to access the server subnet. All the remaining subnets, i.e. subnet2, subnet3 and subnet4, are located at distance of only one hop to access the server subnet. Table1 shows hop-count information for every network to reach the server network.

The client network of this scenario is depicted in Figure2, which consist of three sub-networks i.e. Admin Network, Staff Network and Students Network.

Table 1. Hop count information (Fiver Routers Scenario)

Network	Minimum Hop-count to reach Server Network
Subnet1	2
Subnet2	1
Subnet3	1
Subnet4	1

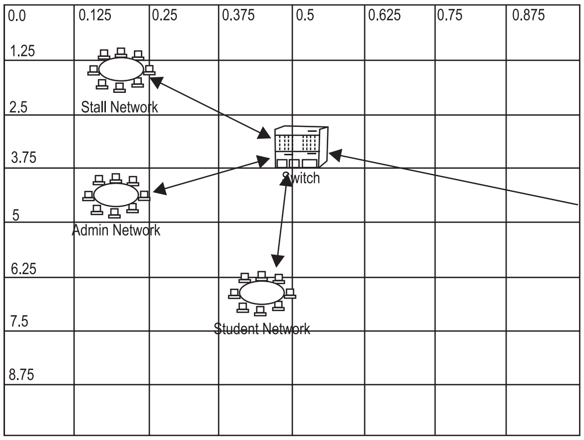

Figure 2. Clients Subnet of Fiver Routers Scenario

Table 2. Clients Subnet Description of Five Routers Scenario

Network Name	Number of Hosts	Application
Admin Network	25	25
Staff Network	25	25
Students Network	50	50

Detail about the number of hosts and currently running applications in the networks inside the client sub-network is given in the Table 2.

The table shows that total of 100 hosts exist in each of the client network subnet. As a total of four client network subnets exist in the five router scenarios, so there exist a total of 400 host computers in the network. All these hosts are configured to send and receive heavy and light email traffic simultaneously. The email traffic must be routed to transfer it between email server and client computers.

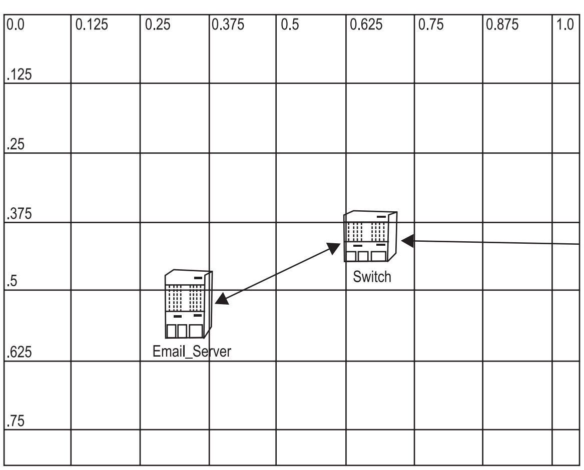

Figure 3. Server Subnet of Five Routers Network

RIP is configured first as routing protocol in the five routers scenario to route traffic from client subnets toward the server subnet. Email server is available in the server subnet and configured to provide services to all the clients in remaining subnets. Figure 3 shows the server subnet of five routers scenario, which will also remain same for other scenarios. After collecting the results for email download and upload response times, RIP is replaced with IGRP as routing protocol. Again the email upload and download response times with IGRP as routing protocol are collected.

B. Ten Routers Scenario

In this scenario, ten routers, R1 through R10, are interconnected using PPP-DS1 links. Again simple network architecture is followed to design this network. Figure 4 depicts the ten routers network.

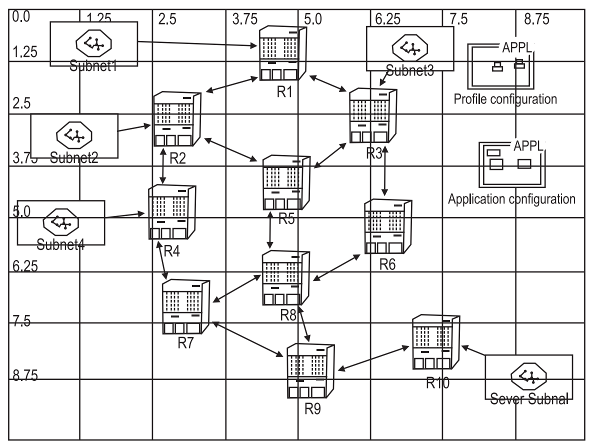

Figure 4. Ten Routers Scenario

Total of four client networks, named Subnet1, Subnet2, Subnet3 and Subnet4 are connected with R1, R2, R3 and R4 respectively, using 100BaseT links. The server network is attached to the R10, which contains the email server. Data of subnet1 devices will pass through minimum of five hops to reach server subnet. Similarly, the devices included in subnet2 and subnet3 has a minimum hop count of four while subnet4 devices can access email server by passing through a minimum hop count of three. We can also observe from the figure that most of the routers are attached to at least three neighbor routers; however, router 8 is attached to four neighbor routers R5, R6, R7 and R9. Table3 shows detail about the hop counts of every network.

We can observe from Figure4 that the number of user networks (subnets) is not increased in this scenario, however to ensure scalability, the size of every subnet is increased by adding more networks and client computers.

Table 3. Subnets Hop-count Information (Ten Routers Scenario)

Network	Minimum Hop-count to reach Server Network
Subnet1	5
Subnet2	4
Subnet3	4
Subnet4	3

Figure 5 shows the changes made to the client networks (subnets), to ensure scalability in ten routers network.

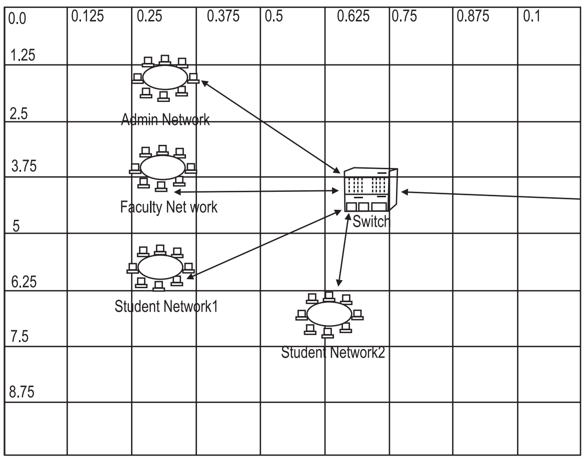

Figure 5. Client Subnet of Ten Routers Scenario

Table 4 shows detail information about all the networks of the subnets, used in ten routers scenario. It is important to note that all client networks (subnets) in the ten routers scenario contain the same characteristics given in the bellow table.

Table 4. Client Subnet Description of Ten Routers Scenario

Network Name	Number of Hosts	Application
Admin Network	25	Emil Heavy, Email Light
Staff Network	25	Email Heavy, Email Light
Students Network1	50	Email Heavy, Email Light
Students Network2	50	Email Heavy, Email Light

It can be observed from the above table that every Client Network (subnet) of ten routers network contains 175 host computers, capable of sending and receiving email traffic (both Heavy and Light) simultaneously. As the ten routers network contains four Client Network subnets, so it contains 700 (4*175) host computers.

Like the five routers network, ten routers network is also configured for using RIP and then IGRP as routing protocol. Here also the email download and upload response times for both of the routing protocols is recorded.

C. Fifteen Routers Scenario

The fifteen routers scenario is depicted in Figure 6. The figure shows that fifteen routers, named R1 through R15, are included in the scenario.

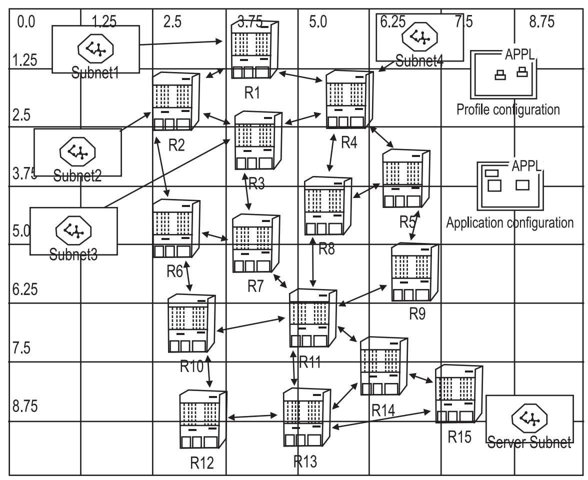

Figure 6. Fifteen Routers Scenario

It can be observed from the fifteen routers network that it also contains four client networks i.e Subnet1, Subnet2, Subnet3 and Subnet4. Devices in subnet1 and subnet2 have a hop count of five, while subnet3 and subnet4 are located at distance of four hop counts to reach server subnet. Here also most of the routers are connected to at least three neighbor routers, however, R4 has four neighbor routers while R11 is connected to six neighbor routers. The hop-count information of fifteen routers scenario is summarized in Table 5.

Table 5. Hop-count information of Fifteen Routers Scenario

Network	Minimum Hop-count to reach Server Network
Subnet1	5
Subnet2	4
Subnet3	4
Subnet4	3

In fifteen routers scenario again, the number of client networks is not increased; however, the size of every client network is increased by adding an extra network of 50 hosts. All the client networks in this scenario encompass the same size and architecture, depicted in Figure 7.

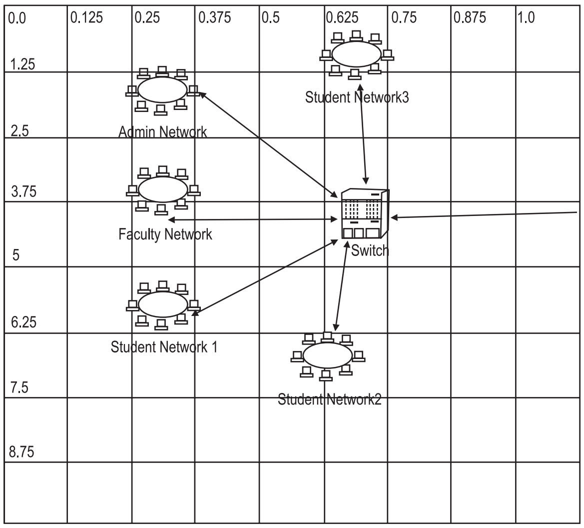

Figure 7. Client subnet of fifteen routers scenario

Table 6 shows detail information of devices and the currently running applications of fifteen routers network scenarios.

Table 6. Client subnet description of fifteen routers scenario

Network Name	Number of Hosts	Application
Admin Network	25	Emil Heavy, Email Light
Staff Network	50	Email Heavy, Email Light
Students Network1	50	Email Heavy, Email Light
Students Network2	50	Email Heavy, Email Light
Students Network3	50	Email Heavy, Email Light

Information of above table shows that every client network has 225 client computers, which are configured to send and receive email messages of heavy and light sizes. So total number of host computers in fifteen routers network is 900 (225*4).

To carry email messages from client computers to email server and vice versa, RIP is configured as routing protocol in the scenario. After collecting results for email download and upload response time, RIP is replaced with IGRP and same results are collected for comparison.

IV. APPLICATION DESCRIPTION AND PARAMETERS SETTING

In this section, we will discuss the parameters that are used for application specification, performance evaluation, scenario configuration and simulation running

Application Configuration

In OPNET IT Guru, Profiles are designed to generate traffic for specific application(s), identified to the profile. The client computers (users) are assigned with some profile to generate traffic on that user. We have designed a profile, named Email Profile, which is configured to generate heavy and light email traffic on the client computers. The email profile is assigned to every client network in all of the scenarios. Detail about the email profile is given in Table 7.

Table 7. Application Configuration Parameters

Profile Name	Application	Operation Mode	Start Time (sec)	Duration	Rpea Tabiliy
Email Profile	Email (Heavy)	Serial (Random)	Uniform (5,10)	End of Simulation	Unlimied
	Email (Light)				

It can be observed from the Table 7 that the profile is designed to generate traffic for email (heavy and light) in serial (random) mode. The serial (random) operation mode enable applications to be started one after each other in a random manner. The start time of the profile is set to Uniform (5,10). The profile is configured to generate traffic until the simulation time is expired. The parameter unlimited, under the attribute of repeatability ensures the execution of the profile for the simulation time. It means that the profile may continue to execute for unlimited number of times, until the simulation time expires.

B. Application Description

Table 8 shows description of the applications that we will evaluate i.e. Email (Heavy) and Email (Light).

D. Application Evaluation Parameters

Table 9 shows the applications and corresponding parameters that we are going to evaluate in this work. We

Table 8. Application Description

Application	Attribute	Value
Email (Heavy)	Send Inter-arrival Time	Exponentia (360)
	Send Group Size	Constant (3)
	Receive Inter-arrival Time	Exponentia (360)
	Receive Group Size	Constant (3)
	Email Size (bytes)	Constant (2000)
	Type of Service (ToS)	Best Effort (0)
Email (Light)	Send Inter-arrival Time	Exponential (360)
	Send Group Size	Constant (3)
	Receive Inter-arrival Time	Exponentia (360)
	Receive Group Size	Constant (3)
	Email Size (bytes)	Constant (500)
	Type of Service (ToS)	Best Effort (0)

will evaluate the following parameters for corresponding applications in all of the scenarios and compare them.

All the remaining parameters related to simulation run, are set to default and no change has been made to them. It means that we have run all the scenarios for the duration of Ten Minutes, and after their execution we collected the results. The obtained results are discussed in the next section, simulation analysis.

Table 9. Application Evaluation Parameters

Application/ Node	Parameters	Unit
Email	Download Res. Time	Seconds
	Upload Res. Time	Seconds
TCP	Delay	Seconds
Email Server	CPU Utilization	Percent

V. SIMULATION ANALYSIS

In this section, we will discuss the simulations results for email download response time, email upload response time and email server CPU utilization for both of the routing protocols, in all of the scenarios. All graphs in this section represents the simulation run time (10 minutes) on X-Axes.

Table 10. Simulation Run Parameters

Entity	Value
Simulation Duration	10 (Minutes)
Seed	128
Values per Statistics	100
Update Interval	100000

A. Email download response time

In this section, the email download response time of all the scenarios is compared for both of the routing protocols.

i. Five routers scenario

Figure 8 shows the email download response time of five routers scenario. The figure shows that initially both RIP and IGRP produces download response time of 0.11 (sec). Then the download response time of both RIP and IGRP starts to increase for a few seconds. The download response time of RIP increases to 0.145 (sec) while the IGRP download response time increases to 0.128 (sec). After that, we observe a constant decrease in RIP download response time and at simulation time 90 seconds, the download response time of RIP decreases to 0.125 (sec). We also observe a variation in increase and decrease of download response time for IGRP and we record download response time of 0.126 (sec) at simulation time of 2 minutes. We can observe from the figure that for the simulation duration between 2 minutes and 4.5 minutes, RIP and IGRP produced download response time of approximately 0.138 (sec) and 0.130 (sec) respectively. The figure also shows that both the RIP and IGRP routing protocols produces same download

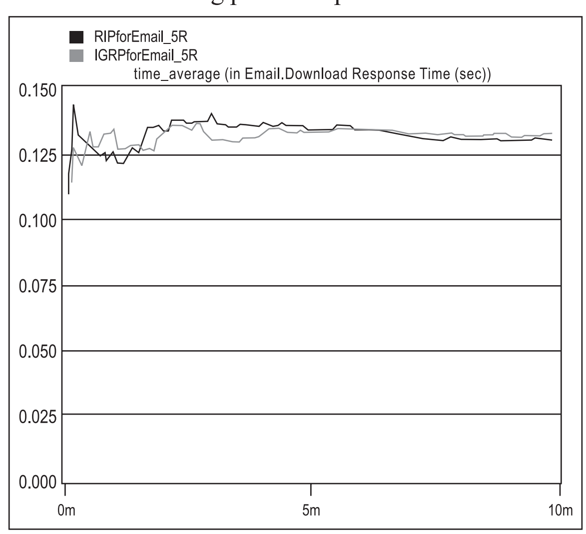

Figure 8. Email download response time in five routers scenario

response time of approximately 0.134 (sec) in simulation duration of 4 minutes to 10 minutes. We can observe from the figure that both RIP and IGRP are producing approximately same download response time for email in a network of five routers.

ii. Ten routers scenario

The email download response time for ten routers network is depicted in Figure 9. We can observe that both RIP and IGRP are producing email download response time of 1.6 (sec) and 2.2 (sec) respectively at the start time of simulation. Then a constant increase in email download response time for both the routing protocols is encountered. At simulation time of 30 seconds, the email download response time for RIP and IGRP increases to 9.4 (sec) and 8.1 (sec) respectively. After that, a constant decrease in email download response time is recorded for both RIP and IGRP. At simulation time of 2.5 minutes, the email download response time for RIP and IGRP decreases to 1.8 (sec) and 1.5 (sec) respectively. After that, A very smaller but constant decrease in email download response time continue and at the end of simulation time, it reaches to 0.6 (sec) for

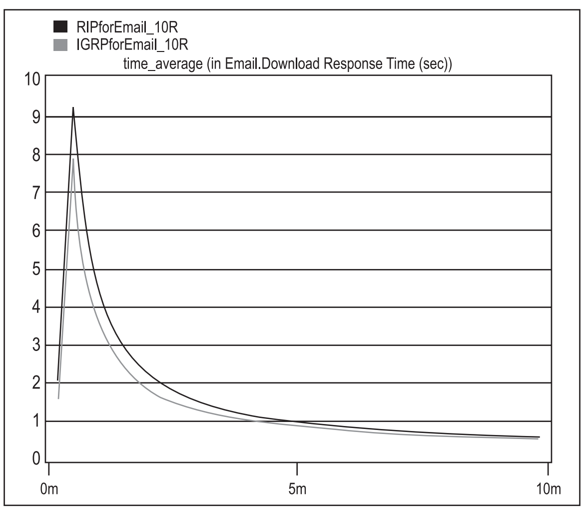

Figure 9. Email download response time in ten routers scenario

both RIP and IGRP routing protocols. It is important to note that for most of the simulation time, IGRP produced lower download response time compared to RIP. We can also examine from the figure that RIP is never succeeded throughout the simulation to produce better email download response time than IGRP.

iii. Fifteen routers scenario

The email download response time of fifteen routers scenario is depicted in Figure 10. We can observe from the figure that initially RIP is producing email download response time of 2.4 sec which rapidly increases to 14.7 sec, at simulation time of 40 seconds. After that, the download response time for RIP start decreasing and it reaches down to 2.5 sec at simulation time of 4 minutes approximately. The gradual decrease in download response time for RIP continues and it reaches to 1.2 sec at the end of simulation time. We can also observe from the same figure that at start of simulation, IGRP produces email download response time of 2.6 sec which rapidly increases to 8.6 sec within 30 seconds of simulation time. After that, download response time for IGRP start decreasing and reaches to

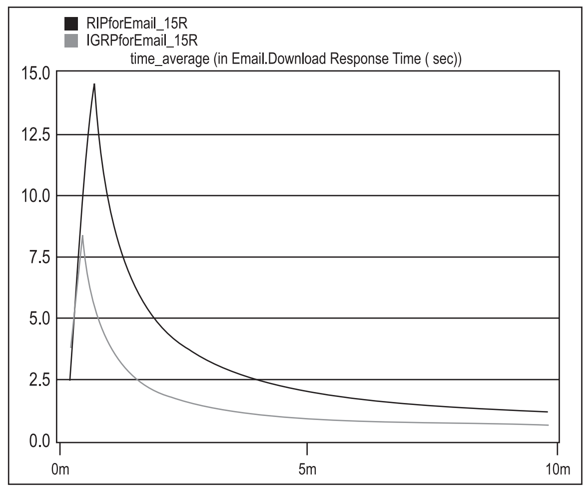

Figure 10. Email download response time of fifteen routers scenario

2.0 sec at simulation time of 2 minutes. After that, we recorded gradual decrease in email download response time and at end of the simulation time, it decreases to 0.6 sec. The figure shows that no overlap performance for downloading process is found and IGRP produced better response time throughout the simulation execution for email download compared to RIP.

VI. EFFECT OF SCALABILITY

The email download response time of all the scenarios is different in several ways from each other. The main differences that are encountered in all of the three scenarios for email download response time using RIP and IGRP are discussed bellow.

- In five routers scenario, both RIP and IGRP are producing overlapping download response times. Means, for some time RIP is producing better email download response time, while for other times; IGRP performs better for email downloading process. A close look to Figure 8 and keeping the effect of overlapping in mind, we can say that email download response time for both RIP and IGRP is same. Opposite to five routers scenario, the ten routers scenario and fifteen routers scenario contains no performance overlapping. In ten and fifteen routers scenarios, IGRP continue to produce better email download response time throughout the simulation time.

- In five routers scenario, RIP is producing email download response time in range of 0.11 sec (minimum) to 0.145 sec (maximum), while for IGRP, the email download response time lies in between 0.11 sec (minimum) and 0.137 sec (maximum). In ten routers scenario, the email download response time for RIP is recorded between 0.6 sec (minimum) and 9.3 sec (maximum), while for IGRP it lies between 0.6 sec (minimum) and 8.0 sec (maximum). In fifteen routers network, the email download response time for RIP is recorded in range of 1.2 sec and 14.6 sec. For IGRP, the email download response time in fifteen routers network is recorded in the range of 0.8 sec and 8.2 sec.

The above differences caused by scalability, are summarized in Table 11.

We have also calculated the total email download response time for the complete simulation time, for all of the three scenarios. This will help us in evaluating the differences in email download response times of different scenarios, caused by the scalability. The total email download response time for five routers scenarios is depicted in Figure 11. The figure shows that both RIP and IGRP produces same results for email downloading process.

Table 11. Differences in email download response time (all scenarios)

Scenario	Routing Protocol	Email Download Res. Time(sec)		Performance Overlapping
		Min	Max	
5 Routers Scenario	RIP	0.11	0.145	Exist
	IGRP	0.11	0.137	
10 Routers Scenario	RIP	0.6	9.4	Not Exist
	IGRP	0.6	8.1	
15 Routers scenario	RIP	1.2	14.7	Not Exist
	IGRP	0.6	8.6	

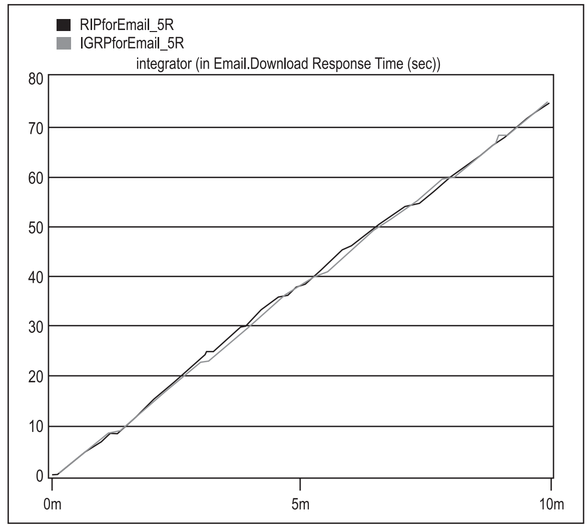

Figure 11. Total email download response time in five routers scenario

The total email download response time for RIP and IGRP in ten routers scenario is shown in Figure 12. We can observe from the figure that initially RIP and IGRP are producing similar total of download response time, but at simulation time of 33 seconds (approximately), the total email download response time for RIP increase to 226 sec while at the same simulation time, the total email download response time for IGRP is 196 sec. The difference in the total email download response time for RIP and IGRP increased very gradually and at the end of simulation, the total download response time for RIP and IGRP are recorded as 342 sec and 308 sec respectively.

The rapid increase at the start of simulations is caused by the relation ship between the type of graph (Integrated) and routing protocols. The integrated graph shows the total time taken for uploading or downloading at a particular simulation run time. Initialy, for few seconds, there is no upload or download response time recorded by the integrated graph because the routing protocols were busy in network learning. Routing protocols take some time to learn the complete topology and record the best and backup paths in its routing tables. These best paths to remote networks are also communicated to the neighbor routers in the network.

Figure 13 shows the total email download response time for RIP and IGRP in fifteen routers scenario. The figure shows that at the end of simulation time, the total email download response time for RIP is 650 sec, while

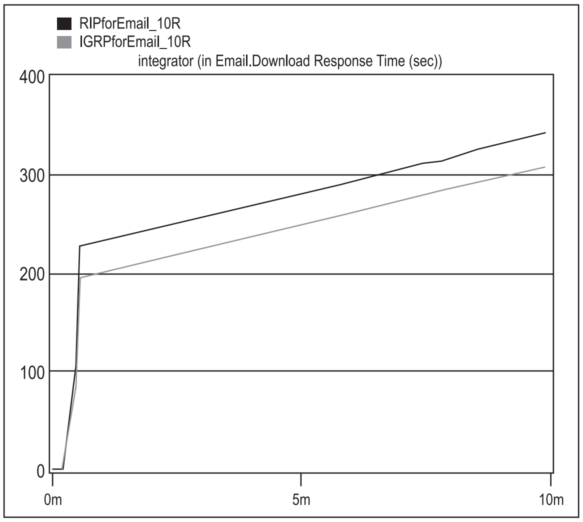

Figure 12. Total email download response time in ten routers scenario

for IGRP it is 325 sec approximately.

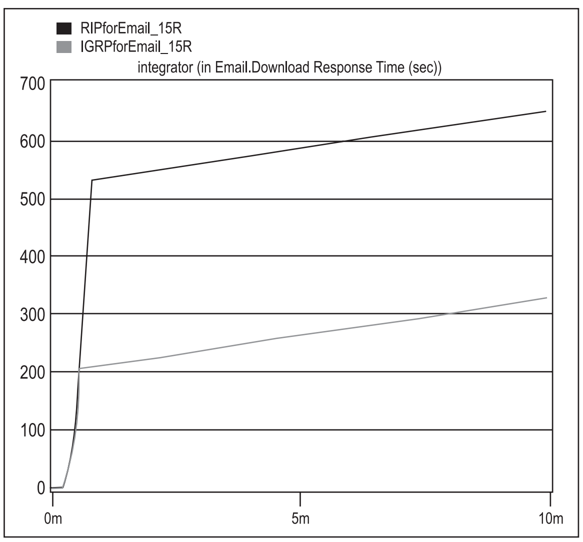

Figure 13. Total email download response time in 15 routers scenario

The difference in total download response time for RIP and IGRP in all the three scenarios is summarized in the Table 12. In this table, we have clearly depicted the total email download response times of RIP and IGRP in all the three scenarios. The first portion of the table shows the total email download response time of RIP networks in all the three scenarios, while the second portion of the table shows the email download response time of IGRP networks for all of the three scenarios.

B. Email upload response time

In this section, the email download response time of all the scenarios is compared for both of the routing protocols.

Table 12. Total email download response time in all scenarios

Routing Protocol	Scenario	Total Email Download Res. Time
RIP	5 Routers Scenario	75 seconds
	10 Routers Scenario	342 seconds
	15 Routers Scenario	650 seconds
IGRP	5 Routers Scenario	76 seconds
	10 Routers Scenario	308 seconds
	15 Routers Scenario	325 seconds

i. Five routers scenario

The graph that shows the email upload response time using RIP and IGRP for five routers scenario is depicted in Figure 14. The figure shows that initially RIP produces email upload response time of 0.09 seconds which rapidly increased to 0.133 seconds. After that some fluctuations in increase and decrease of email upload response time for RIP is recorded and at simulation time 2.7 minutes, it reaches to 0.137 seconds. Like RIP, IGRP also produces an unstable email upload response time of 0.09 seconds at start of simulation and reaches to 0.135 seconds at simulation time of 2.7 minutes. It is important to note that IGRP produced better results for email upload response time compared to RIP in the specified simulation period (i.e start of simulation to 2.7 minutes). It can be observed from the figure that in simulation duration of 2.7 minutes to the end of simulation (10 minutes), RIP continues to produce better results for email upload response time than IGRP. We investigate from the figure that both RIP and IGRP are producing

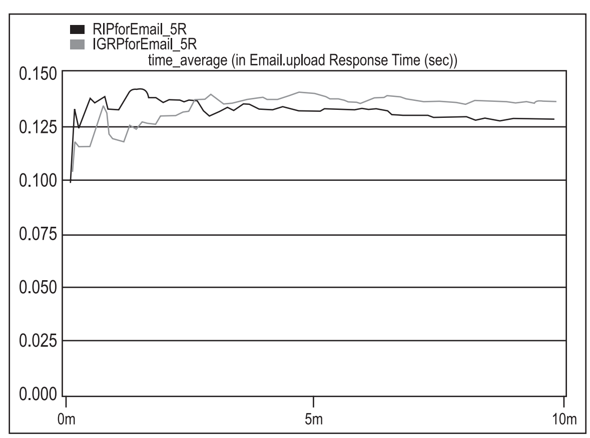

Figure 14. Email upload response time in five routers scenario

email download response times of 0.135 seconds and 0.130 seconds (on average) respectively in the later specified simulation duration.

ii. Ten routers scenario

The email upload response time for RIP and IGRP in ten routers scenario is depicted in Figure 15. We can observe from the figure that initially RIP and IGRP are providing email upload response time of 2.0 and 1.6 seconds respectively which is increased to 9.5 seconds for RIP and 8.0 seconds for IGRP, after the simulation execution for a few seconds. After that we encountered a sudden decrease in email upload response time for both of the protocols. The figure shows that at simulation execution time of 2.3 minutes approximately, the email upload response time for RIP and IGRP decreases to 2.0 seconds and 1.8 seconds respectively. The decrease in email upload response time continues and reaches to 0.7 seconds for both RIP and IGRP at the end of simulation duration.

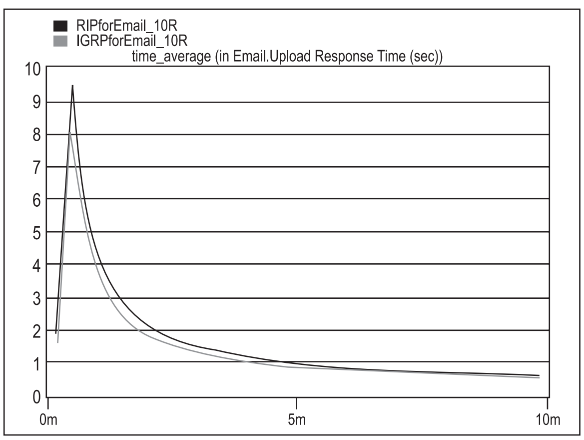

Figure 15. Email upload response time in ten routers scenario

iii. Fifteen routers scenario

Figure 16 shows the email upload response time of fifteen routers scenario. The figure shows that initially both RIP and IGRP are producing email upload response time of 2.5 seconds and 2.8 seconds respectively. After that a sudden increase in email upload response time for RIP and IGRP is recorded and it is evaluated that email upload response time for RIP and IGRP increases to 14.5 and 8.2 seconds respectively at simulation time of 45 seconds approximately. The figure shows that after that a rapid decrease in email upload response time for both RIP and IGRP is recorded. Because of this rapid decrease, the email upload response for RIP and IGRP decreases to 5.0 seconds and 2.2 seconds respectively at simulation duration of 2 minutes. After that a gradual decrease in email download response time for RIP and IGRP is recorded and at the end of simulation duration it reaches to 0.8 seconds for RIP and 1.2 seconds for IGRP.

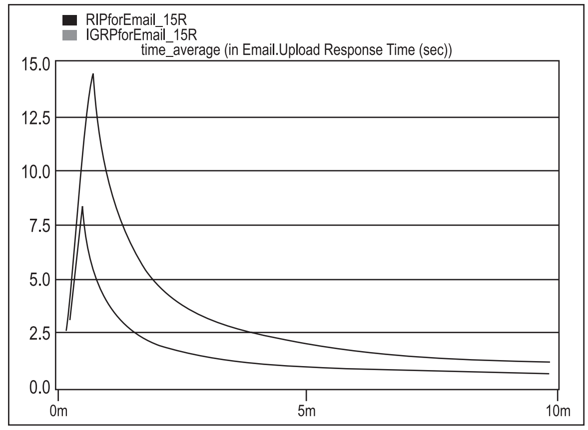

Figure 16. Email upload response time in 15 routers scenario

iv. Effect of scalability

In this section we will discuss the differences in email upload response time for RIP and IGRP routing protocols, caused by scalability. We have observed the following differences in email upload response time in terms of scalability.

- Figure 14 show that RIP and IGRP are providing overlapping performance for the process of email uploading. Initially IGRP is producing better results for email uploading process and letter RIP starts to produce better email upload response time. We also can observe from the Figures 15 and 16 that there exists no overlapping in performance of RIP and IGRP for email upload in ten and fifteen routers networks. For both the ten routers network and fifteen routers network, IGRP continue to produce better email upload response time throughout the simulation duration compared to RIP.
- In five routers network, RIP produced email upload response time in the range of 0.09 seconds to 0.137 seconds while IGRP produced email upload response time in range of 0.09 seconds and 0.135 seconds. In ten routers network, the email upload response time for RIP and IGRP are recorded in the ranges of (0.7 sec – 9.5 sec) and (0.7 sec – 8.0 sec) respectively. Similarly, in fifteen routers scenario, RIP produced email upload response time in the range of 1.2 seconds to 14.5 seconds while

IGRP produced email upload response time in the rage of 0.8 seconds to 8.2 seconds.

All these differences in email upload response time for RIP and IGRP in all the scenarios are summarized in Table 13.

Table 13. Differences in email upload response time (all scenarios)

Scenario	Routing Protocol	Email Upload Res. Time(sec)		Perfor-mance Overlap-ping
		Min	Max	
5 Routers Scenario	RIP	0.09	0.137	Exist
	IGRP	0.09	0.135	
10 Routers Scenario	RIP	0.7	9.5	Not Exist
	IGRP	0.7	8.0	
15 Routers scenario	RIP	1.2	14.5	Not Exist
	IGRP	0.8	8.5	

In order to highlight these differences more efficiently, we have also calculated the total email upload response times for all of the scenarios. Figure 17 represents the total email upload response time for RIP and IGRP protocols in five routers scenarios. The figure shows the total email upload response times in different simulation durations. Initially IGRP was performing well. Then both RIP and IGRP produces similar results for email uploading process. We can observe that at the end of simulation duration, the performance of RIP for email uploading process is better compared to IGRP.

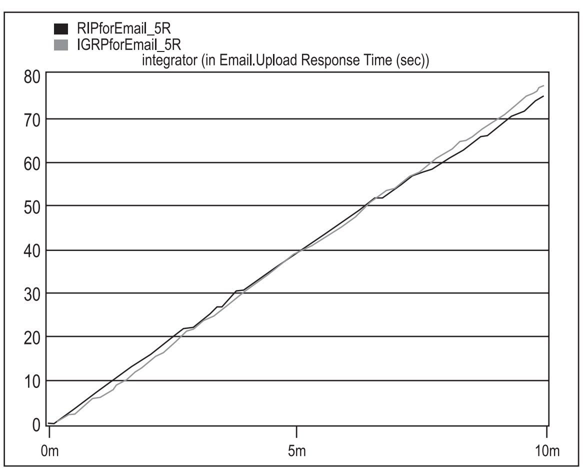

Figure 17. Total email upload response time in five routers scenario

Figure 18 shows the total email upload response time for RIP and IGRP protocols in ten routers scenario. The figure shows that a rapid increase is recorded for both RIP and IGRP protocols at the start of simulation.

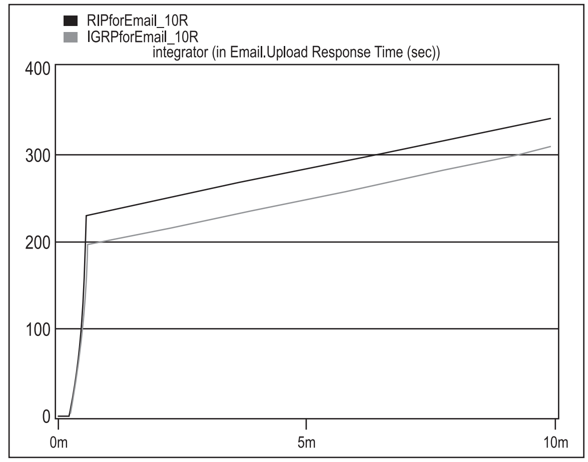

Figure 18. Total email upload response time in ten routers scenario

Initially the email upload response time of RIP increases to 235 seconds while for IGRP it increases to 200 seconds. This difference in RIP and IGRP protocols performance continued till the end of simulation time and we observe that email upload response time for RIP and IGRP increases to 340 seconds and 305 seconds respectively at the end of simulation duration.

Figure 19 shows the total email upload response time for RIP and IGRP in fifteen routers scenario. The figure shows that at start of simulation duration, the email upload response time for RIP and IGRP protocols networks increases to 510 seconds and 205 seconds respectively. This difference in performance of RIP and IGRP continue till the end of simulation duration and we record email upload response times of 640 seconds and 330 seconds for RIP and IGRP respectively at the end of simulation duration.

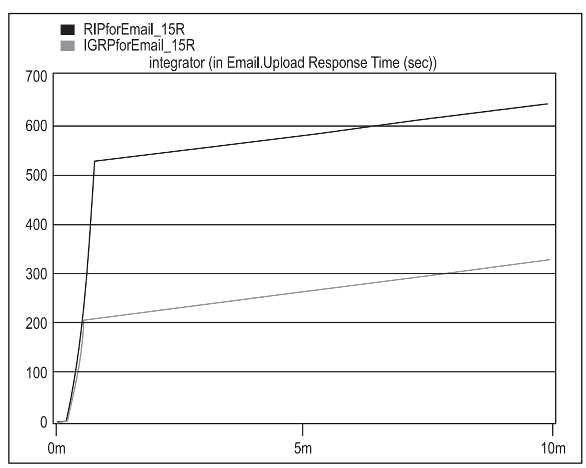

Figure 19. Total email upload response time in 15 routers scenario

The total email upload response times of all the scenarios are summarized in Table 14.

Table 14. Total email upload response time of all scenarios

Routing Protocol	Scenario	Total Email Download Res. Time
RIP	5 Routers Scenario	75 seconds
	10 Routers Scenario	340 seconds
	15 Routers Scenario	640 seconds
IGRP	5 Routers Scenario	78 seconds
	10 Routers Scenario	305 seconds
	15 Routers Scenario	330 seconds

C. Email Kerver CPU Utilization

In this section, we will discuss the CPU utilization of email server in all of the scenarios. We will also discuss the effect of scalability on CPU utilization of email server. The email server used in our scenarios, consist of a single processor.

Figure 20 shows the total CPU utilization of email server in five routers scenario. The figure shows that RIP network's traffic results in less CPU consumption compared to IGRP.

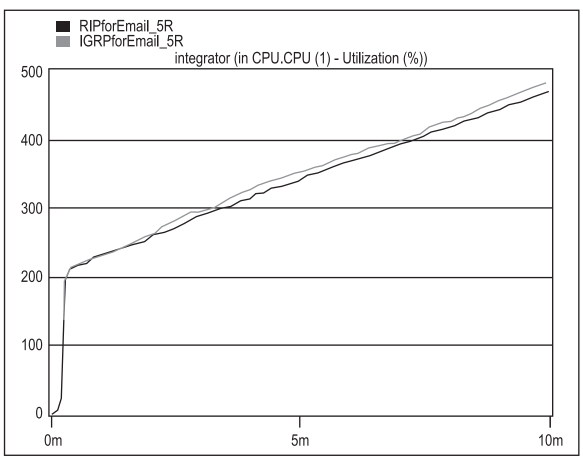

Figure 20. Total email server CPU utilization in five routers scenario

The CPU utilization of email server for RIP and IGRP in ten routers scenario is depicted in Figure 21. The figure shows that initially both RIP and IGRP network's traffic is producing similar utilization of email server's CPU. For simulation duration of 40 seconds to 6 minutes, IGRP traffic results in less consumption of email server's CPU. In simulation duration of 6 minutes to the end of simulation, both RIP and IGRP traffics are resulting in similar CPU consumption of email server.

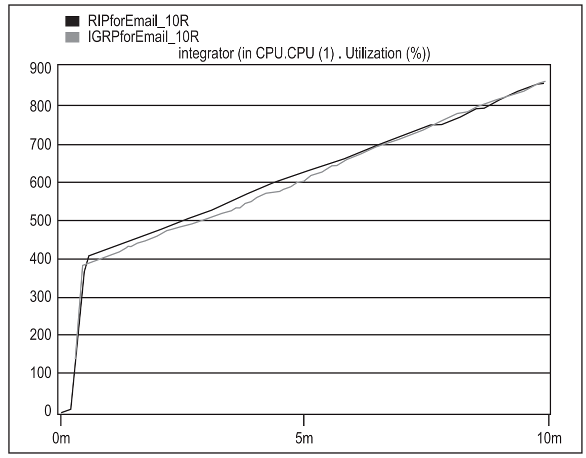

Figure 21. Total email server CPU utilization in ten routers scenario

The total CPU utilization of email server in fifteen routers scenario is depicted in Figure 22. The figure shows that initially RIP is utilizing relatively less CPU pulses of email server compared to IGRP for a few seconds of simulation execution. After that, as depicted in the figure, IGRP traffic results in less CPU utilization of email server till the end of the simulation execution.

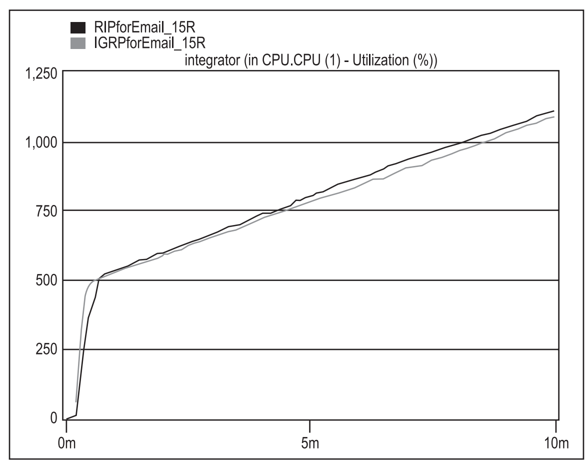

Figure 22. Total email server CPU utilization in 15 routers scenario

II. CONCLUSIONS AND FUTURE WORK

The simulations have shown that both RIP and IGRP are producing approximately same email download and upload response times for simple and small campus area networks. However, the simulations reveal that as the size of the network grows and the number of hops between source and destination devices increases, the IGRP networks produces better performance compared to RIP. It is investigated that scalability also results in increasing the number of possible paths between clients and email server. So on the basis of simulation results, we have concluded that as the number of hops between the email clients and email server as well as the number of routes among which one best route to be selected, increases, IGRP performs better email download and upload response times compared to RIP even if simple network architecture is followed. It means that there exist some scenarios using simple network architecture, where IGRP produces better performance compared to RIP.

Our investigations also reveals that IGRP compared to RIP, results in putting less burden on the mail server in terms of CPU pulses. The results shows that as the scalability in networks increases, IGRP utilizes relatively less CPU pulses of mail server compared to RIP, however, it is also concluded that RIP puts less burden on server CPU if the size of the network is very small.

Our work contributes in the selection process of suitable routing protocol for email services in a simple CAN, if the choice is to be made between RIP and IGRP. This work contributed in the identification of simple network scenarios where IGRP can perform better than RIP. However, our work doesn't show the exact factor to show that how much one routing protocol is better than the other in a particular type of scenario. In future, the exact factor value can be evaluated to measure the reliability of IGRP compared to RIP. The factor based evaluation will involve the combination of total links, total paths and total hop-counts in all of the scenarios. Another enhancement in this work is possible, by comparing the performance of RIP and IGRP in complex scenarios. Apposite to the contribution of this work, we can evaluate if there exist some complex network scenarios where RIP can produce better results compared to IGRP.

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