Packet Tracer as an Educational Serious Gaming Platform

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***Abstract*— Serious gaming is quickly becoming an important trend in education, as it provides an interactive as well as enjoyable environment for learning various technology, business and scientific topics. The main objective of this research is to explore the possibility of using Cisco packet tracer's multiuser capability to develop several interactive, multiuser games for teaching networking topics and assessing students skills in the class. We present a list of primary principles for design of such games, and design two multiuser educational games as in-class activities to showcase the benefits of our approach. We demonstrate how students' skills in important network topics such as routing, remote access and security help them succeed in these games. We also provide test results to evaluate the performance of packet tracer in handling multiuser traffic in this scenario.**

Keywords- Packet Tracer; Serious Gaming; Multiuser; Collaborative; Cisco Networking Academy; Emerging Teaching Methods; Simulation; Online Teaching

I. INTRODUCTION

A. Background

The maturing of the video gaming industry has triggered significant interest in developing simulated and interactive serious gaming platforms. The main advantage of serious gaming platforms is that they combine in-depth educational topics with goal-oriented and realistic scenarios. To date there have been many applications of serious gaming. These games have spanned over many industries, from urban planning to business, military, healthcare training etc. These applications have provided the means to an individual, or a group of individuals, to engage in an artificial conflict, assess, and learn the complexities associated with each of their individual area of work. Some real world applications of serious games include INNOV8 Business Process Management simulator by IBM [1], physical conditioning games for the general public, e.g. Fitness Shape Evolved for the new Microsoft Kinect hardware platform [2], Foldit for biologists [3], and flight simulator applications for the military [4]. Serious gaming has allowed users of the application to attain skills and knowledge related to a specific activity. The subject can be as difficult as addressing physical and physiological disorders or be as simple as promoting physical activity. The main goal of serious gaming is to provide a powerful means of encouraging people to learn and provide them with a more entertaining way to obtain the skills and knowledge addressed by the specific serious gaming activities.

During the research project we focused on creating serious games for the purpose of teaching topics in information networking at the University of Ontario Institute of Technology (UOIT) in Ontario, Canada. UOIT has an undergraduate program in networking and IT security, and also serves as a regional Cisco Network Academy. With growing interest in the networking field and the hands-on nature of the topic, the objective of this project was to make the classroom lecture hours more interactive.

The research team began by analyzing and utilizing the tools available through the Cisco Networking Academy. Cisco Packet Tracer's is most commonly used as an emulation platform for Cisco networking devices and IOS network operating system. The new version includes multiuser capabilities that enable designers to create large group based interactions during classroom hours. The Packet Tracer includes many necessary elements needed for CCNA-level education.

The research team explored the area of using packet tracer as an educational serious gaming platform by developing two gaming activities, Domination & Relay Race. Domination & Relay Race utilize the multiuser capabilities of packet tracer to the greatest extent. The two games provide students with a great educational value and help them hone their networking expertise. Packet Tracer provides a great interface to gain experience with practical configuration scenarios. Our aim was to combine the powerful capabilities of packet tracer with serious gaming in order to provide a simple and entertaining environment for teaching basic and advanced networking topics.

The rest of this paper is organized as follows: In Section II we examine some of the current serious games that focus on networking education. A basic description of the multiuser capability in Packet Tracer and our methodology is presented in Section III. We describe the design and technical details of our serious games in Sections IV and V. Some system performance results, e.g. memory, network and CPU requirements are presented in Section VI. We present our conclusions and future work plan in Section VII.

II. CURRENT NETWORKING SERIOUS GAMES

Cisco has developed a number of serious games for networking education. Most recently, Cisco ASPIRE Beta 3 has been released. This game utilizes the Packet Tracer platform to provide the players a role-playing/SimCity-like serious game focused on the business of networking. Players take on the role of a network engineer who applies his/her entrepreneurial and networking skills to complete several contracts that arise during the game. They must purchase the correct hardware and apply the correct configuration schemes in order to complete the contract. For the correct completion of contracts players receive credits which they can spend toward improving their network. Complete with a mobile device that rings when new

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contracts are available, Cisco's Aspire immerses players into the networking world while providing an entertaining way to practice your networking and entrepreneurial skills.

Cisco Systems has also released Cisco myPlanNet 1.0 [5]. Players are put into the shoes of a service provider CEO. They must direct their business through various technological ages ranging from dial-up all the way up to the broadband/mobile connected ages. Along the way players learn about the various technologies that make the networking world possible. The game provides a SimCity-like overlay where issues arise in the city and must be resolved. There is a credit system that players must use to purchase new technologies to advance their businesses and provide better services to the civilians in their cities. There is also a leaderboard to encourage players to attain higher scores and improve their skills.

Additionally, Cisco provides many smaller serious games that allow users to improve their skills, such as: Wireless Explorer, Unified Communications Simulation Challenge, Cisco Mind Share, and Edge Quest. These serious games provide players with a means to enjoy learning the complicating subjects related to the networking field, albeit on a smaller scale.

III. GAME DESIGN

A. Brief Overview of the PT Multuser environment

One of Packet Tracer's greatest features is the ability to connect two or more lab sessions together, known as a Multiuser Connection. By utilizing Packet Tracer's multiuser capabilities very extensively throughout the term of the research project and within the completed serious gaming activities, the creation of two very unique and interactive Packet Tracer game activities was possible. Packet Tracer allows users to use a simple drag and drop cloud icon to connect to a peer cloud. Each multiuser cloud supports one-to-one, many-to-one and many-to-many peer-connection configurations. The activities that are created operate on a model similar to the client/server architecture observed widely today. The central file with the game scenario is hosted on an instructor PC and the student side file is used by each student to connect to the central Packet Tracer game file hosted on the instructor PC. This instructor/student architecture allows for easy management, control and provides an overall view for the instructor operating the game. The multiuser capabilities of Packet Tracer during testing allowed the connection of up to 60-75 users simultaneously to a single activity over LAN. The number of connections possible is directly limited by the hardware performance of the instructor PC. An in-depth examination of the multiuser environment was conducted and reported in a research paper submit last year, Multiuser Collaborative Practical Learning Using Packet Tracer [7], or refer to the research paper being submitted to ICNS this year, Building Interactive multi-user in-class learning modules for computer networking.

B. Project Objectives

The simulated-based games were created to provide students with a very different approach to networking. Goals and objectives had to be met in order to satisfy the CCNA course's academic requirements and the serious game aspects of the activities. The main objectives include:

- Easy deployment in large user environments
- Scalability to ensure reusability
- Provide an educational experience
- Can be used to assess student progression
- Have to provide a psychological perception of having won or loss

The psychological perception of having won or loss is one of the key elements that make up a serious game. The enthusiasm of a student is very crucial in a serious gaming aspect. It is an emotional driver that encourages students to improve his/her networking abilities in order to better compete against fellow classmates. Ensuring that the perception of having won or loss exist, improves our chances of encouraging students to participate and learn the skills and knowledge needed to complete the activities and course material more efficiently.

C. Methodology

Using the tools and interactive features provided by Packet Tracer 5.3, Domination and Relay Race simulation-based games were created to help teach and observe the students progression in the first year CCNA courses. The games covered topics learned throughout the whole year. Each activity tested the configuration and troubleshooting abilities of the players while providing an educational experience that was novel and entertaining for the students.

Each of the games presented students with artificial conflicts that resembled several real world networking problems that had to be fixed before achieving the game's end goal. DHCP mechanisms were used to provide each connected player with a set of unique IP address ranges for management and game play structure purposes. A detailed explanation of each game follows.

IV. DOMINATION GAME

A. Topology Structure

The game topology is broken down into four sections. Each section consists of layer 3 switches, multiuser clouds, and clusters. The Section switches all connect to a central Main Domination Switch. Each section consists of 15 cluster clouds and 15 multiuser clouds, all of which are connected to a Section Domination Switch. Each cluster cloud contains an identical network topology that presents students with a network problem. Each of the clusters have been assigned a /24 subnet, from which the first host IP is assigned to the default gateway. The DHCP IP addressing scheme has been kept simple, allowing for easy scalability and management. Student side Packet Tracer instances connect into the multiuser clouds assigned to them by the instructor. Multiuser clouds are distinguished by the Peer

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Network Name property within each cloud. The game is initiated by the instructor when all players have obtained a connection to the peer multiuser cloud. Once all students clouds are active students begin by using the telnet protocol to obtain access into their specific cluster. Fig 1 shows an overview of the Domination topology.

B. Game-play

The student's main goal is to fix the network problems presented to them within their clusters. The problems within the cluster can vary in complexity, but initially the clusters have been set up with a basic problem. Once the cluster problems are solved the students must quickly telnet into the directly connected section switch and shutdown all other interfaces except the interface directed toward the main domination switch. Once a student has managed to dominate their sections switch, they must quickly telnet into the Main Domination Switch and shutdown the 3 other ports allowing other section switches to telnet into the main switch. The first person to quickly dominate their section's switch and the main switch is the winner. The other 3 that have managed to dominate only their sections switch are runner up's. It is possible for 1 person to dominate all 5 switches but for that the player will have to be really fast.

C. Domination Technical Details

The domination game comes with only one student side file that will work with all of the Multiuser clouds within the instructor file. The student file consists of a single workstation and a multiuser cloud to allow connectivity to the instructor file.

By providing a standard student file with basic configurations already applied to the workstation allows for easy deployment in large user environments. Furthermore, IP addresses are dynamically assigned by a DHCP located in each cluster. Having DHCP enabled on each cluster eliminates the need for students to configure an initial IP address to their student side Packet Tracer Workstation.

The cluster problems can be increased in complexity easily as needed. Additional devices can be added within a single cluster and be duplicated easily across the clusters because of the easy IP addressing scheme. The EIGRP protocol is running between the 5 switches to allow telnet capabilities to the students. IP addressing schemes were designed to be as simple as possible so to encourage future development within the activity. The number of vty lines available within each switch limits the section sizes to 15.

D. Educational Value

The domination game allows students to experience the pressure sometimes put on network engineers in the real world environment. It forces students to apply all of their learnt networking knowledge to a problem. By gaining the ability to combine the hands-on and theoretical knowledge learnt throughout a Cisco Network Academy course, students will gain a better understanding of how to apply these skills and tools in the networking world. Moreover, the game can also be used as an evaluation tool to see if the students understand the concepts delivered in the course.

V. RELAY RACE GAME

A. Topology Structure

Adapted from the original Relay Race game presented by Cisco, this Relay Race game incorporates new and old features. The topology is broken down into 4 sections, each consisting of 5 Main Line Routers, 4 network clusters and 5 multiuser clouds. The whole topology is brought together at a central Finish Line Router. Each cluster contains problematic network scenarios that students must correct in order to allow a Runner, designated in each team, to move closer to the Finish Line Router. The network scenarios within the clusters progressively become harder the closer the cluster is to the Finish Line Router. The 5 Main Line Routers act as doorways, locked, preventing the runner from moving forward. Fig 2 shows an overview of Relay Race topology.

B. Game-play

Although slightly more complicated, the concept of the game remains somewhat similar to the Domination game. Relay Race consists of 4 Teams each consisting of 5 team members. Each team consists of 1 Runner and 4 members responsible for solving the problematic network clusters. Once the problem within the cluster is solved they must move forward to their Main Line Router and no shutdown their routers Serial 0/0/0 interface. This will allow the runner of the team to telnet into their routers in order to move forward towards the Finish Line Router. Many ACL's have been put in place so that only the appropriate hosts can telnet into the appropriate devices. For example, none of the team members responsible for solving cluster problems can telnet into the Finish Line Router, only the runner will be able to telnet into that router. The ACL's also ensure that telnets to other Main Line Routers will only work from the Runner's Workstation on the student Packet Tracer file. The Goal of the game is to have the fastest team to no shutdown all of their S0/0/0 interfaces within the Main Line Routers. The Runner must then run (telnet) into the Finish Line Router before any of the other teams and shutdown all of the other interfaces allowing the opposing teams access to the Finish Line Router.

C. Relay Race Technical Details

Only one student file is included with this game because DHCP has been implemented in a very unique manner allowing the file to be used among any multiuser peer-connection within the game. The instructor file contains the Relay Race game that students must telnet into. The students connect to the multiuser clouds according to the name of the cloud in correspondence to the role of the student within each team. By providing this instructor/student architecture we ensure easy deployment of the game during play time. The clusters problem can be easily changed if need be.

D. Educational Value

Relay Race pits students together in a team environment where they must communicate and apply their skills to a

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problem. The activity will help hone communication skills and also improve the ability of the students to solve network problems. The game will force students to work rapidly and correctly to solve their problems the fastest in order to win. This environment emulates the fast paced environments of the networking world today, where problems arise quickly and must be solved rapidly. The game can also be used as an evaluation tool to see how far student's configuration and troubleshooting skills have progressed.

VI. PERFORMANCE RESULTS

With Packet Tracers ability to manage and create Multiuser Packet Tracer sessions, it was still unknown to the team whether or not Packet Tracer could handle large scale Multiuser environments that consisted of 60+ Multiuser sessions. We conducted various stress tests to confirm that it could handle the 60+ user load. The tests included: CPU Average Utilization, Memory Utilization, Total Network Utilization, Instruction Offline File Size, Time to Create Offline File, and Memory Utilization by offline File.

A. The Test Bed

Two sets of tests were conducted on each of the two activities instructor files. The first was done using the Domination instructor file and its companion student file. The second was done using the Relay Race instructor file and its companion student file. During the testing procedure for the Domination game a total of 60 multiuser clouds were connected in increments of 5 users to the instructor file. Each time 5 users connected to the game, new data was collected. The Relay Race game has a maximum capacity of 20 users playing at the same time therefore, 20 multiuser clouds were connected to the Relay Race instructor file in increments of 5 users.

B. CPU Utilization

The results for this test were very satisfying for both of the activities. Figure 3 shows both the CPU utilization for Domination and Relay Race. It is evident that the as more hosts connect to the instructor files, the CPU utilization increases in a logarithmic form. This indicates that the packet tracer software is capable of handling higher levels of stress if need be. If we compare the Relay Race and Domination results it's evident that continuous even if we add up to 60 users.

C. Memory Utilization

Test results for both the activities indicated a linear growth rate in memory utilization. Figure 4 shows that growth rate for both the Domination activity and the Relay Race activity is linear as the number of users increases. Although memory is not an issue with 50 users connected to an activity, if we were to connect up to 100 or more users' memory could potentially become an issue. For our university use cases memory does not pose a threat to the functionality of our activities.

D. Network Utilization

The test results indicated that the multiuser environment does not put a huge or rather places a minimal burden on the computers network resources. It indicates that we can have a large number of users connected to a single instructor file without worrying about the burden it puts on the network. The network utilization test increased in a linear fashion and these values are bound to increase as the number of users increase. An important issue to note is that these values are bound to change depending on how actively the students interact with the instructor side network.

E. Offline File Save Tests

Packet Tracer allows the ability to save an offline file. The offline file saves can be described as a snapshot of the entire network at an instance of time. The file consists of all of the peer connected multiuser clouds and each device in that peer cloud. The offline file saves also includes all of the devices current state, configuration, and connection status. The offline file proves to be a great tool to use when assessing the results of an activity or grading students depending on the configuration status of the devices they were responsible for. This gives the instructor the ability to save offline files after the completion of the games and assess the students after the activity is completed.

Offline saving times of greater than 5 minutes for a 30 user Multiuser environment could render useless a 20-minute activity and a class room limited to an 80 minute class. Therefore it is important to test how long it actually takes to create the offline file. The results indicated that for the Domination activity the time to create the offline file grew exponentially. The Relay Race activity indicated a linear growth rate. The exponential growth rate for the Domination file could prove to be troublesome if more than 60 users are connected to the Domination activity. Currently it takes about 25 seconds for a 50 user multiuser environment offline file to save. Although it serves our purpose to provide 60 students a reliable platform to use the activity, connecting more than 100 users to a single instructor file could take much longer. These values are bound to change if the complexities of the problems in each cluster are increased.

VII. CONCLUSION AND FUTURE WORK

By using packet tracer as an educational serious gaming platform we can provide a simple and entertaining solution to present complex networking scenarios to networking students enrolled in our courses. We can train students to not only improve their configuration and troubleshooting skills but also improve communications skills in an IT environment. We can also increase the speed at which they tackle these problems and provide them with the expertise and knowledge to excel in the fast paced networking environments of today.

With Cisco constantly updating their packet tracer platform there is an endless possibility of how many different types of game activities we can create. Currently the activities are limited to only CCNA topics, but future packet tracer improvements by Cisco could allow us to

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cover CCNP topics as well. Cisco has already taken the potential of serious gaming seriously and began with creating their packet tracer based educational serious gaming platforms with Cisco Aspire Passport21 and Cisco myPlanNet.

Using Cisco's Packet Tracer 5.3 as our serious gaming platform, the development of multiuser serious gaming activities was made possible. By utilizing the familiar environment known to all Cisco Network Academy students, we ensured that the activities could be easily understood and collaboration between multiple or groups of students was possible using the multiuser capabilities. Combining the concept of serious gaming with a network simulator allows us to approach teaching methodologies for Cisco network oriented courses in an entirely new light.

With the future for serious gaming looking bright, it can be surmised that we will see the development of many networking educational serious gaming platforms. This research has shown the great potential of the topic and the educational values its holds. Lastly, Cisco's packet tracer has proven to be a power platform that can be used to provide an educational serious gaming platform.

VIII. ACKNOWLEDGMENT

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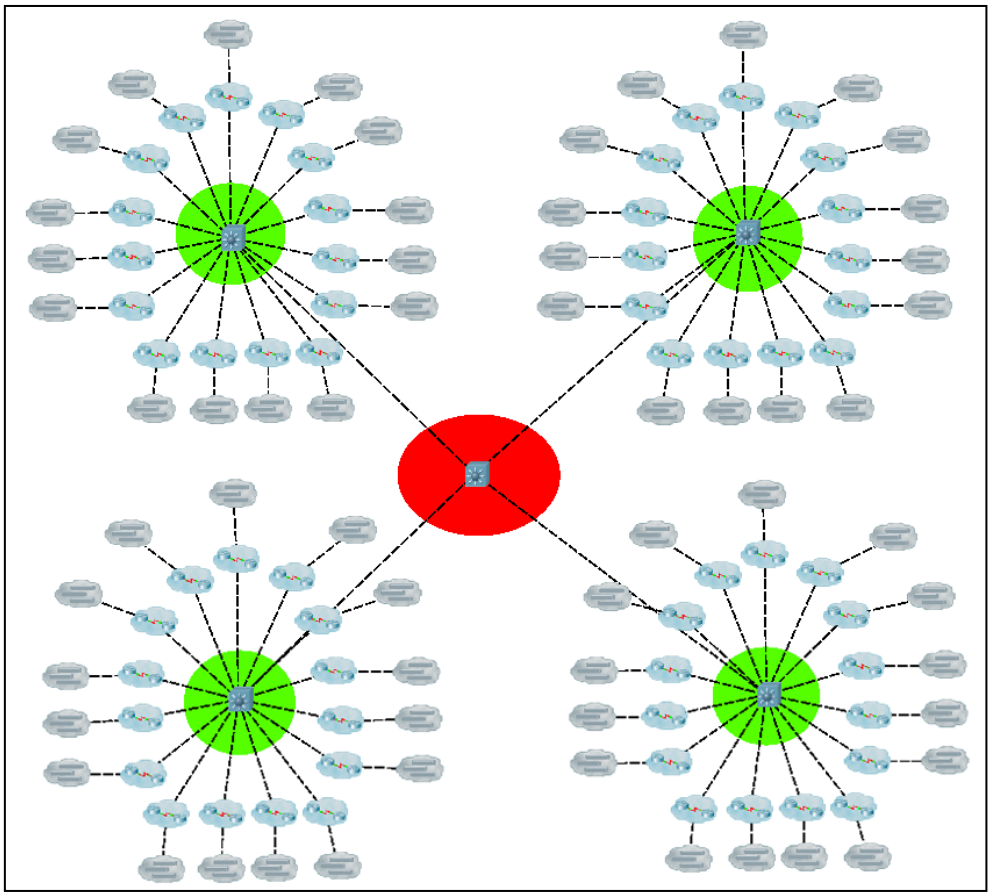

Figure 1. Domination Game Screen Shot

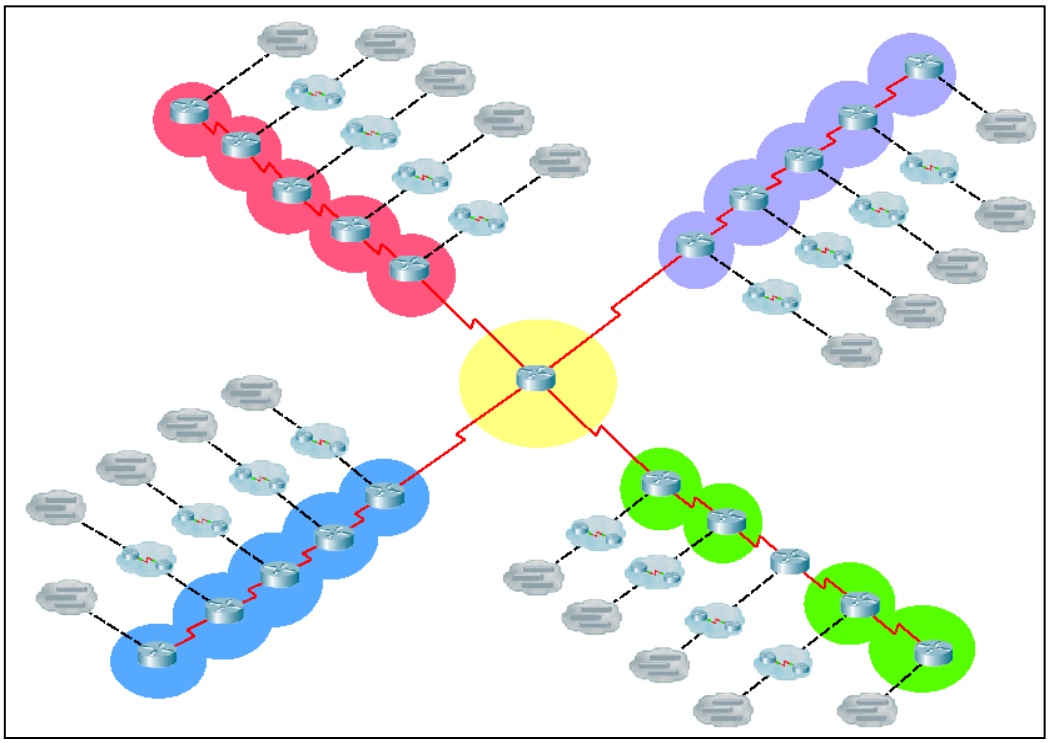

Figure 2. Relay Race Game Screen Shot

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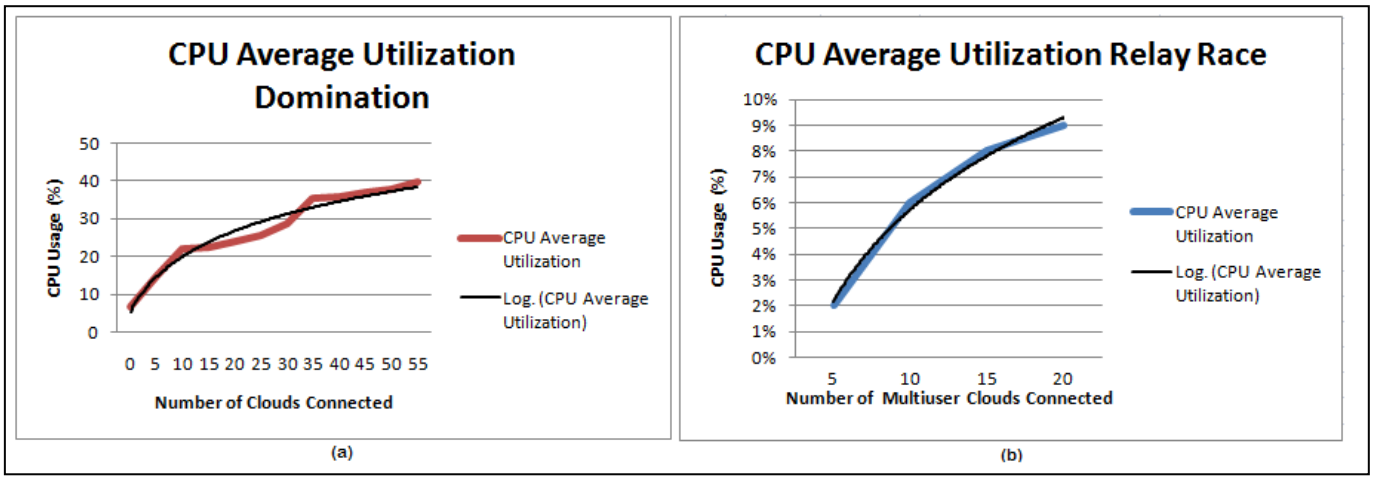

Figure 3. CPU Utilization: (a) Domination CPU Utilization (b) Relay Race CPU Utilization

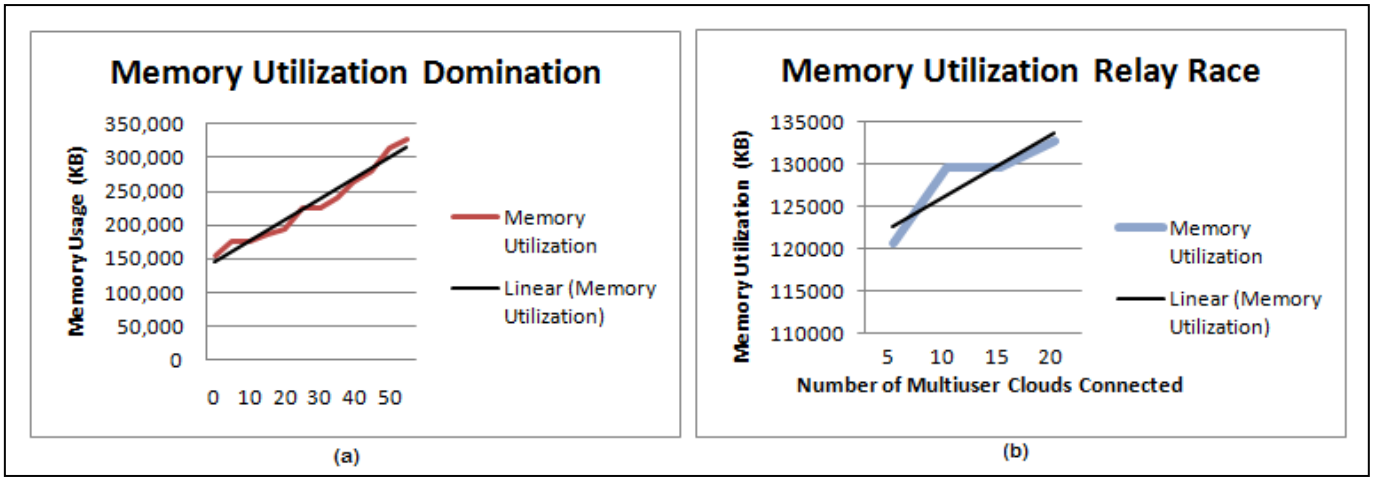

Figure 4. Memory Utilization (a) Domination Memory Utilization (b) Relay Race Memory Utilization

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