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GERASOS—A Wireless Health Care System

Master’s Thesis in Computer System Engineering

T.V.Rajani Kanth
Supervisor: Urban Bilstrup

School of Information Science, Computer and Electrical Engineering
Halmstad University
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School of Information Science, Computer and Electrical Engineering
Halmstad University
Box 823, S-301 18 Halmstad, Sweden

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Abstract

The present development of the demography of elderly people in the western world will generate a shortage of caregiver’s for elderly people in the near future. There are major risk that the lack of qualified caregivers will result in deterioration in the quality of elderly care. One possible solution is the use of modern information and communication technology (ICT) to enable staff to work more efficiently. However, if ICT system is introduced into the elderly care it must done in a way which is acceptable from a humane perspective while at the same time increasing the efficiency of the personal that working in elderly care centers. This thesis investigates the technical feasibility of using a wireless mesh network for a social alarm system, in the elderly care. The System as such is not intended to replace the staff at an elderly care center but instead is intended to reduce staff workloads while providing more time for elderly care.

Keywords: wireless mesh, health care systems, wireless social alarms
Preface

This project is a master’s degree thesis and concludes the program Master of Science in Computer System Engineering at the School of Information Science, Computer and Electrical Engineering at Halmstad University.

I would like to thank my supervisor, Urban Bilstrup. Without whose continuous guidance this work would not have been achieved.

T.V.Rajani Kanth
Halmstad University, June 2007
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1. Introduction

One emergent problem of the society today is the increase in the elderly population; this will generate a shortage of caregiver’s for elderly people in the near future. The lack of qualified caregivers will result in deterioration in the quality of the elderly care. This problem must be solved, in a way which is acceptable from a humanity perspective and at the same time increasing the efficiency of the personal that works at elderly care centers. One possible solution is the use of modern information and communication technology (ICT) to enable staff to work more efficiently. This thesis will investigate the feasibility of such an ICT system from a technology perspective, within the context of making elderly care more efficient and still retaining a commitment to the human integrity. The system as such is not intended to replace the staff at an elderly care center but instead is intended to reduce staff workloads and provide more time for the elderly.

An example of one such an ICT system is the Gerasos system, which is a distributed computer system, based on wireless communication. The system uses a wireless mesh network as a communication infrastructure. This infrastructure is used as a backbone network for a large number of embedded computers, which provide a distributed system for supervision. A number of sensors and alarm trigger devices are attached to the system e.g. bed guard sensors, door guard sensors, alarm bracelets etc. These sensors and alarm triggers are battery powered and must have a very long life time. Therefore they can not be directly connected to the backbone network instead an extremely low power consuming wireless technology is used to communicate with these devices.

1.1. Motivation

The rapidly growing elderly population and the limited number of available caregivers result in a reduction in the quality of the elderly care. The work load on the caregivers must somehow be decreased to reach a feasible working and cost-effective situation. The main motivation of doing this thesis is to investigate an ICT solution that provides cost effective way to monitor the activities of the elderly care center continuously by using a distributed computer system with its communication based on wireless communication.

1.2. Project Goal

In this thesis parts of a modern Information and Communication technology (ICT) system are implemented to assess the feasibility of the cost effective work based on wireless communication to healthcare units. The main task is to implement a software defined switch, for packet switched traffic, which can handle the voice and logical connections of the gerasos health care system. Furthermore the performance should be investigated; the key performance metrics are network capacity, reliability, and possible number of simultaneous voice connection.
2. Related Work

In this section a brief overview of related work are presented.

2.1. Sensor Network for supporting elderly care home

A example of an ICT system used in the elderly care is a system installed in an elderly care center in Tokyo [1]. This system is based on a network of ultrasonic sensors. The goal of the system is to warn the caregivers about dangerous situations and avoid that accident occurrence in the elderly center. The main rationale behind of this System is to remotely monitor the position of elderly people detecting when a person is on his/her way to some hazardous area. If an alarm is triggered the personnel is directly informed about the position of the serious situation and can go there to see whether the support is required or not. According to caregivers in nursing homes, major accidents are classified as two cases [1].

Falls: People fall from beds or fall wheelchairs. The major part of accidents occurs when they transfer from the wheelchair to their bed or to a toilet seat etc.

Wandering around: some people tend to walk around day or night, as a result of medical conditions akin to sleepwalking etc.

Today there are sensors available that can detect this type of behaviour in the n ursing home, but they cannot prevent accidents. If we suppose that elderly people wear to wear some small device and the condition is monitored through that device, then the caregivers would be able to give a much faster support. The problem is that they do not always wear this device due to the fact they are unable to remember the bring the device or taking off. The use of a CCT camera is another possible solution but it unfortunately infringes the privacy.

The system consists of Badges ultrasonic receiver badges, RF transmitters, and network devices for the receiver and host computer. The system activates every badge in periodically and receives ultrasonic pulses from the badge. The system then computes the distance from badge to each receiver from the time of flight date and by acting on this information determine the position the badge.

2.2. Mobile clinical information System

Another type of application is a mobile clinical information system [2]. This comprises a wireless bi-directional portable patient monitoring system, as shown in figure 1. It consists of a communication interface which enables the care givers to receive patient data through a WLAN and transmit parameters to the communication interface of the patient. This portable patient monitor device contains a mobile computer connected to the communications interface to process the patient data and care parameters; this system also contains bedside patient monitors to connect centralized patient monitoring systems to improve efficiency. The advantage of a centralized monitoring system is that a small number of caregivers can monitor a large number of patients. These patient monitor systems are placed in patient rooms to measure heart rate, ECG, respiratory patterns etc.
The Centralized patient monitor (CPM) is connected to servers, which retrieve and store patient data. The CPM also receives telemetry signals through network. This server is directly connected to hospital labs, pharmacy, voice router, and numerous portable monitoring devices (PPM) through wireless local area network (WLAN). Personnel can access real-time information from labs, pharmacy, etc., and send that data to PPMs, furthermore, it will give updated information to caregivers. This server can provide messages from CPM to PPMs; such messages include current patient data, ECG waveforms, and alarm signals. Personnel carry these PPMs and are always wirelessly connected by bi-directional to the patient data server. WLAN access points are connected to the server to judge the signals between server and PPMs.

![Clinical patient information monitoring system](image)

**Figure 1. Clinical patient information monitoring system**

### 2.3. WLAN Architecture for Integrated time-critical and non-time-critical services within medical facilities

Another example of a distributed patient monitoring system is given in [3]. The general intention of this system is for supporting both real-time and non-real time wireless access to a hardwired
network within the medical facility is given. This system consists of multiple access points that are distributed throughout a medical facility, as in figure 2, to provide wireless access to a hardwired network, these access points implements multiple WLAN protocol which includes a real time protocol for real-time patient monitoring and a standard WLAN protocol for general purpose wireless access. All these access points implement WLAN protocols so that all the WLAN and wireless devices share network access resources. All of these access points also contain RF location tracking modules; the main purpose of these modules is to track locations of patients, hospital personnel, capital equipment and disposable medical supplies. To avoid lockstep interference between access points operated in the same channel a TDMA timeslot rotation method is used.

![System installed in hospital](image)

Figure 2. System installed in hospital

In this hospital the system architecture consists of two separate Ethernet LANs, one for real time patient monitoring another for non-real-time applications. This system consists of two types of access points multi-band access point (WMTS/802.11) and single-band (WMTS) access points are required for patient monitoring. These access points are placed in patient areas of the hospital, i.e. step-down units, surgical wards etc. here each access point sets up data connections with a
Related Work

fixed number of patients at a time and multiple access points are placed side by side within more patients roaming areas. Furthermore these multi-access points are placed throughout the hospital providing accesses to the hospital network. The main function of access points are real-time patient monitoring, wireless access to different network resources i.e. hospital information systems (HIS) and clinical information system (CIS) databases, captured ECG data, paging system etc. these access points also contains location-tracking modules the main purpose of which is to track the locations e.g. patients, hospital personnel, capital equipment, disposable supplies etc. furthermore this system also contains T1 interface to view the remote viewing of real-time telemetry data

2.4 Related Applications of Wireless Mesh Networking

Some of applications of mesh networking are deployed in the market, e.g. intelligent transportation systems, public internet access, public safety and the underground mining industry.

2.4.1 Intelligent transportation systems

Wireless mesh networks can be used in intelligent transportation systems due to low cost, flexibility and more secure inter communication. The real-time travel information system (PORTEL) [4] is a system which is provides a city wide public transportation communication network. The main intension of this system is to provide real-time information to passengers. This system support 500 buses and is operated by a wireless mesh technology. The system provides real-time information, when the bus is available in addition to the ultimate destination and arrival schedules.

2.4.2 Public Internet access

Today Internet service provides (ISP’s) can depend on Wi-Fi technology to provide their broadband wireless internet access. It is difficulty to deploy this broadband wireless connectivity [4] in urban, sub-urban and rural environments due to the extremely high cost of network infrastructure. To avoid this problem, a wireless mesh is more suitable. The cost of network installation is very small for a wireless mesh compared to use standard wired access points for wireless internet access.

2.4.3 Public Safety

Today some urban emergency networks are built the principle of the wireless mesh, i.e. used by police department, fire department, emergence department etc. All these departments are depend on good communication facilities, a wireless mesh network can provide this in urban environments due to the fact that they provide good mobile support, flexibility and high bandwidth. For the moment, at least one police department in U.S. use a wireless mesh network [4]. All patrolling cars are equipped with laptops and motorcycle, and bicycle with PDA’s. The communications between these units are conducted over a wireless mesh network.

2.4.4 Underground Mines Industry:
In the underground mining industry operations are very difficult. Today the modern mining industry needs extensive wiring to support general safety procedures.

To increase the safety in underground mines wireless mesh is used for alarm and data transmission systems. It provides good mobility, rapid deployment, and easy scalability in an underground mining environment. The wireless mesh provides embodies redundancy and robustness which is often lacking in standard wireless technologies. It includes voice, control telemetry, tracking of personals, vehicles, location monitoring etc. A wireless mesh is also useful in underground railway systems [5]. Using low power mesh technology it is possible to monitor and control telemetry environments in underground mines, i.e. roof stress, gas monitoring and distributed temperature sensors on belt conveyor drives.

2.5 WLAN Technology

A tremendous growth of the wireless communication industry has taken place in recent years. The use of wireless communication technology provides new features such as mobility and flexibility. Wireless LAN [6] are often more economical to install than wired networks, especially when renovating old buildings or rebuilding old facilities for new activities. The Wireless LAN network can be run in two possible configurations; Ad-hoc mode and Infrastructure mode.

2.5.1. Ad-hoc mode

In ad-hoc mode the mobile stations communicate [6] with each other directly without the use of an access point, all the stations are independent and form an ad-hoc network. In ad-hoc mode there is no need of network infrastructure. Consequently deployment is very easy.

2.5.2. Infrastructure mode

In infrastructure mode the wired network [6] and mobile stations are bridged through access points. This network configuration is the most commonly used, the basic service set (BSS) is connected through a wired LAN and further more the coverage area of BSS overlaps.

2.5.3 Medium Access

The MAC Architecture of IEEE 802.11 LAN is divided into two parts: distributed coordination function (DCF) and point coordination function (PCF). There are two mechanisms which are available for carrier sense: virtual carrier sense and physical carrier sense.

2.5.3.1 Distributed Coordination function (DCF):

The IEEE 802.11 medium access control is a distributed coordinate function (DCF) based on carrier sense multiple access with collision avoidance (CSMA/CA). The DCF method can be used in two configurations, i.e. ad-hoc mode and infrastructure mode. In busy mediums conditions DCF allows medium sharing [7] through CSMA/CA and random back off time. Furthermore it will send positive acknowledgement (ACK frame) to all traffics and if no
acknowledgement has been received retransmission is scheduled by the sender. The main function of CSMA/CA protocol is that if multiple STAs are able to access each other in a medium it will reduce collision because theses multiple STAs are available again waiting for the medium to avoid random back off procedure [7] to resolve contention conflicts in the medium.

2.5.3.2. Point Coordination Function (PCF):

Another centralized method available in the IEEE 802.11 standard [7] is known as the point coordinate function (PCF). This method is only used in infrastructure network mode. This access method uses a point coordinator (PC); this is implemented in BSS access points, to know which STA presently right to transmit.

PCF uses a virtual carrier sense mechanism. In this method STAs set network allocation vector (NAV) to gain control of medium [7] through distributing information within beacon management frames. Furthermore frames transmitted through PCF uses inter-frame space, so called IFS, which is too small when compared to IFS frames transmitted via DCF. Because of smaller (IFS), the point coordinated traffic has maximum preference to access the medium. This PCF access method is used to form a contention free (CF) access method. The main function of this access method is that it can to some extent support real-time traffic.

2.6 Wireless Mesh Networks

In a wireless Mesh network architecture nodes or wireless routers are communicating directly with each other [4], so data can travel from user to user without any access points. The network with wireless routers forms a wireless backbone. Furthermore it gives multi-hop connectivity between users and gateways. Wireless routers and access points create a wireless backhaul communication due to forwarding which provides [4] mobile users with low cost and high bandwidth. The main function of backhaul is it forwards traffic from original node to access point from which it can be distributed over an external network. While in mesh case the traffic is in user’s devices when it traverses the wireless backbone and is distributed over the internet work.

Using wireless mesh network as communication infrastructure is cheap, it does not demand for any wiring on the building; provide good scalability in coverage area and capacity. A wireless mesh network does not need any backhaul instead radio is used to relay messages between the stations so the deployment is very easy. Wireless mesh networks have so far mostly been used in so called citizen networks providing wireless internet access. The capacity of the physical layer of the IEEE WLAN standard has been increasing rapidly last years and the bandwidth of WLAN now reaches 54- mbps and will soon provide a bandwidth far in excess of above 100 mbps.

2.7 Routing Protocols for wireless mesh network

In wireless mesh networks there is no fixed node, nodes suddenly add or delete in a mesh networks. To communicate between these nodes [8] they require specialized protocols which mainly focus on node changing concepts, i.e. new nodes tell to their neighbour node when they are present and relay the information from the neighbour node. The function of routing protocol in mesh network is too choosing an easier route between the nodes to get high throughput, fast
operation. The routing table which is maintained between the nodes maintain smaller connections and update the table with the new nodes when adding or deleting.
3. GERASOS – HEALTH CARE SYSTEM

This section provides a brief overview of the network architecture and software architecture of the Gerasos health care system. The System consists of sensors, sensor hubs, beepers, PDAs and connectors. The main function of sensors is to measure physical force. Every sensor is connected to an sensor hub, sensors send alarm message to the sensor hub. This sensor hub maintains sensor status which is connected to display; this also called the human machine interface (HMI) of the system. In this system handling devices are called beepers; these main functions are to tell which sensor hub has triggered the alarm, an alarm message is showing in the display which is connected to the beepers. When sensor hubs receive an alarm message from any one of the connected sensors, it will send a message to beepers. When an alarm message is received by beeper, the person who is holding that beeper can go to their location of sensor hub and reset the alarm and beeper holding person can also see the display of the sensor hub the sensors of which trigger the alarm.

3.1 The Gerasos system architecture

The Gerasos system architecture is divided into logic layer, Sensor or Interaction layer, and the network layer. In the sensor layer numerous heterogeneous sets of hardware devices are connected such as bed guard sensors, door guard sensors, bracelets alarm button, fire guard etc. In the network layer room/corridors module, WLAN module, WLAN Mesh Router, are present. In the logic layer the soft-switch is placed to control the traffic in the network.
3.1.1 Bed guard sensor

The function of bed guard sensor is to be placed in bed. It will detect when any person sitting in the bed has been injured and sends message to hand unit. This sensor is an equipped with a capacitive wireless pressure sensor to measure the physical force on it. This sensor operates in three modes i.e. non-associated mode, sensing mode and sensing alarm mode. In non-associated mode, the sensors send messages in every minute, sensing mode it will send messages in every twenty seconds, sensing alarm mode it will send messages on physical force change events.
3.1.2 Door guard sensors

These sensors are placed in doors. It will detect if the door is opened and send message to hand Unit.

3.1.3 Hand Unit

The function of a hand unit is carried by the personnel and is a form of beeper that informs the care takers which alarm have been triggered. It furthermore supports voice communication to the bracelet alarm buttons.

3.1.4 Bracelets alarm button

The function of the bracelets is an alarm button which when triggered opens a voice channel to available personnel carrying a hand unit.

3.1.5 Fire guard

The function of fire guard is that it detect if fire occur in a patient’s rooms, corridors etc.

3.1.6 WLAN Mesh Router

The Function of WLAN mesh is that it forms a wireless mesh between all clients and the soft switch. In the router that forms the wireless mesh an open source firmware from freifunk network is running.

3.1.7 Soft-Switch

The function of soft-Switch is it maintains all data given by different hosts. Message switching will take places in soft switch mode i.e. all incoming messages and out going messages switching will be going through the soft-switch.

3.2 Network Architecture

The Gerasos system is to a large extent based on standard hardware and software components. Previously the Gerasos system had a Bluetooth based backbone network; an ongoing work is to convert the backbone to a wireless mesh network instead. The new concept is based on Linksys WRT54GL WLAN routers running open source firmware from freifunk network [10]. The routers form a wireless mesh network where the RKM is working as end nodes, figure 3. The intelligence of the system is centralized in the form of a system computer; a standard PC the communication is based on that serial links which are tunnelled on top of TCP/IP connections which are connected to the system computer, i.e. the soft switch. The system computer works as switch solely implemented in the software. The virtual serial links are represented as TCP/IP
address and port numbers in the application running on the system computer where the application provides the switching functionality of ingoing and outgoing messages. Since the network layer is built upon Ethernet and TCP/IP and standard WLAN it opens up for the use of COTS units, e.g. standard WLAN equipped PALM and cell phones can be used in the system. Furthermore the system scalability becomes much better than the previous network layer based on Bluetooth and it enables the possible use of voice connections over network, e.g. VOIP.

### 3.3 Software architecture

Most logics and functions in the Gerasos system are centralized on the system computer. All databases registers are put there, with some exception for some information that is also mirrored in the RKM’s. The main task for the system computer is to work as software defied switch, the API for the software defined switch for sockets. It also supports the logical topology (i.e. connection set up between RKM and beepers) and handover for migrating units, with the help of a number of registers. The system computer also contains a web based interfaces for configuration and management of the system. A number of registers and databases are used for error logging and so forth. The system computer maintains the databases of all the information. The software architecture is shown in figure 4. The API for the application layer and system computer is in the form of sockets through which the sockets messages are forwarded and setting up logic connection.
Figure 4. Software architecture of Gerosos system

WLAN --- WLAN modules
HMI------Human machine interface
APP---- Application level protocol

Alarm filtering
Networks topology

APP & LANK

Logics layer

Internet connection

Sensor/interactions layer

WLAN MESH

TCP/UDP IP

System computer

Message filtering, network topology, error detection, handover system

APP

WLAN/serial port module

APP

HMI

RKM

Alarm filtering

Networks topology

APP & LANK

Sample

Bed guard

APP & Sample

Door guard

APP &

APP

Hand unit

HMI

Bracelet

APP & LINK

Bed guard, Door guard, Hand guard, Bracelets

Alarm filtering
3.3.1 Soft Switch

In the soft-switch server sockets are created, from the server connections to clients are set up. Each client system will be identified to the server by its individual IP address. The clients send messages to the soft switch; the soft switch forwards those messages to other clients. The soft switch maintains all incoming messages and outgoing messages in its buffer. In the buffer it will maintains all incoming messages and outgoing messages in individual queues for each connection. If the buffer is overflows it will reject messages.

3.3.2 Flowchart for Software Architecture of the soft switch

The soft switch starts to process the data, at the other end the host also starts to send data to the soft switch. The soft switch subsequently receives that data and processes which it then send to another host, the flowchart is shown in figure.5.
Figure 5 Flow chart soft switch

1. Host Starts
2. Soft Switch starts
3. Soft Switch receives data
4. Soft Switch processes data
5. Soft Switch returns results
6. Host sends Data
7. Host reads user command
8. Host sends Data
9. Soft Switch processes data
10. Soft Switch returns results
11. Host reads results
12. Host display results

Gerosos: A Wireless Health Care System
4. Results:

Performances tests are carried out on the soft switch, which is connected with WLAN routers on a wired network. In this test the soft switch running fedora Linux kernel version 2.6., The WRT54GL WLAN Routers is running an open source firmware from freifunk, and the host systems are also running a Linux distribution fedora, kernel version 2.6. These tests measure the throughput and average delay for different connections.

4.1 Test 1

A one hop network consists of two WLAN routers, and two client systems are set up. The soft switch is connected with one of the WLAN routers, second router is connected to the host system. The soft switch and host systems form a WLAN mesh figure 6. In this one hop network, network throughput test is measured.

To measure the network throughput 10000 packets to the soft switch from host systems figure 7. Each packet contains of 128 bytes of data and within time intervals of 10 ms sending data to soft switch from host systems, figure 8. The packet loss is subsequently lost in the host systems with
Results

In this test the packet loss rate is calculated between two host systems. Here one connection means two host systems are connected to the soft switch with two WLAN routers. Figure 9 shows the results of packet loss verses the number of connections. To test the performance, 8 connections were taken.

From the results it would appear that the packet loss rate increases with increasing number of connections, up to certain point and later on it kept at same value, which is due to traffic intensity being high in the network. Because with increasing the number of connections, soft switch becomes overloaded this due to many client systems simultaneously sending messages to soft switch, due to high congestion in packet switched traffic and messages in soft switch are dropping. so packet loss rate increases with increasing number of connections.
Packet loss = \frac{\text{Number of Received packets}}{\text{Number of Sending packets}}

Figure 9. Packet loss versus number of connections.

4.2 Test 2

In this test measurement, the delay was measured in sending 10000 packets to soft switch from host systems. Each packet contains 128 bytes of data and in the intervals of 10 ms sending data to soft switch from host systems, figure 8. Here calculate the average delay in host systems with different connections is calculated.

Results

In this test the average time between two host systems was calculated. Here one connection means that two client systems are connected to the soft switch via two WLAN routers, figure 10 shows the results of the average time delay versus the number of connections. The performance
Results

was tested by taking eight connections. From the results it would appear that the delay increases with an increasing number of connections, up to certain point to keep within the same value, due to traffic intensity being high in the network. Because with increasing the number of connections, soft switch becomes overloaded this due to many client systems simultaneously sending messages to soft switch, due to high congestion in packet switched traffic average delay increases, this is due to high flooding in the network.

Figure 11 shows ping testing results of one hop network, the average time delay versus number of connections. From the results it would appear that the delay gradually increases with an increasing number of connections. After observing result we can say that very less delay with more number of connections. This is due to low network traffic congestion in the network.

![Figure10. Delay versus number of connections.](image)
4.3 Test 3

A two hop network consists of a soft switch, Three WLAN Routers and host systems. Soft switch is connected with one WLAN router and the second router is connected to host systems. In between first and second routers, the third router is placed. The soft switch, host systems and routers form a WLAN mesh figure 12. In this two hop network the network throughput test is measured.
Results

In this test the packet loss rate between two host systems is calculated. Here one connection means that two host systems are connected to the soft switch with two WLAN routers, the graph in figure 13 shows the results of packet loss versus number of connections. Performance was tested by taking 8 connections. From the results it would appear that the packet loss rate increases with increasing number of connections, up to certain point and later on it kept at same value, which is due to traffic intensity being high in the network. Because with increasing the number of connections, soft switch becomes overloaded this due to many client systems simultaneously sending messages to soft switch, due to high congestion in packet switched traffic and messages in soft switch are dropping, this is mainly due to number of router's increases messages are dropping in the network, i.e. the packet loss rate increases with increasing number of connections.

Figure 12 Two-hop Network

This test measures the network throughput, by sending 10000 packets to soft switch from host systems, figure 7. Each packet contains 128 bytes of data and within a time interval of 10 ms, sending data to soft switch from host systems, figure 8. Then calculate the packet loss rate in host systems with different connections. Soft switch and host systems communicate through TCP/IP connections.
This test measures the delay. To measure the delay, 10000 packets have been sent to the soft switch from each host systems. Each packet contains 128 bytes of data, using a time interval 10 ms sending data to soft switch from host systems, figure 8. Here the average delay is calculated in host systems with different connections.

Results

In this test the average time between two host systems is calculated. Here one connection means that two host systems are connected to soft switch with two WLAN routers. Figure 14 shows the results of an average time delay verse number of connections. Performance was tested by setting 8 connections. From the results it would appear that the delay increases with an increasing number of connections, up to certain point to keep within the same value, due to traffic intensity being high in the network. Because with increasing the number of connections, soft switch becomes overloaded this due to many client systems simultaneously sending messages to soft switch, due to high congestion in packet switched traffic average delay increases, this is due to high flooding in the network. The graph in figure 15 shows ping testing results of two hop
network, the average time delay versus number of connections. From the results it would appear that the delay gradually increases with an increasing number of connections. After observing result we can say that very less delay with more number of connections. This delay is mainly due to increases of number of routers and slightly network traffic congestion in the network.

Figure 14. Delay versus number of connections.
Figure 15. Delay versus number of connections.
5. Results and Analysis:

The goal of the measurement is to investigate the performance of the soft switch implementation for which the key measurements are throughput and average delay. To judge the performance different test was conducted with one-hop network and two-hop networks. The goal of these tests has been to determine the performance of gerasos health care systems.

For the one-hop network the packet loss rate is less for less number of connections. Packet loss rate increases with an increasing number of connections up to certain point and later on maintaining the same values. This is due to high traffic intensity in the network. Furthermore for average delay is considerable, the delay increases with the increasing number of connections up to certain point after that it will maintain the same value.

For two-hop network the packet loss rate is high for different connections. Packet loss rate increases with an increasing number of connections up to certain point and later on maintaining the same values. This is due to traffic intensity high in the network; consequently traffic congestion is high in the network. Furthermore for average delay is considers, the delay is high for different connections. Delay increases with increasing number of connections up to certain point after that it will maintaining the same value. This due to traffic congestion is high in the network.

Voice connections are concerned with delay and throughput is less in one-hop network, consequently it is possible to send voice messages in this network. Where as in two hop networks delay and throughput is considerable, it is consequently not possible to send voice messages in this network, ultimately drop will occur in voice messages. This due to congestion in network.

After observing results from one-hop network and two hop networks, Soft switch can't support more connections, which is due to high traffic congestions in the network. Network capacity is increasing then packet loss rate is also increases. This is due to increasing numbers of connections. Furthermore delay is also increases with an increasing number of connections.
6. Conclusion

This thesis investigated the performance of the soft switch implementation leading to the following conclusions.

The performance evaluation of soft switch in terms of throughput and average delay are assessed with one-hop network and two-hop networks by considering different test conditions.

Our measurement indicates that throughput and average delay bound the utilization of soft switch. A bottleneck is forming in the soft switch due to traffic congestion by increasing the number of connections, which leads to an increase in average delay.

The present soft switch implementation on the current hardware platform can not support voice messages due to high throughput and delay.

Future work based on this project is to investigate the performance complicated network architectures with multiple routers, different connections and tedious traffic patterns.
7. References:


[10] Information available at Http://freifunk.net (070615)