SETIT 2007
4th International Conference: **S**ciences of **E**lectronic,
Technologies of **I**nformation and **T**elecommunications
March 25-29, 2007 – TUNISIA

Architectural Infrastructural Issues of Mobile Ad hoc Network Communications For Mobile Telemedicine System

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Abstract: The needs to provide medical services in remote areas have motivated researchers to develop telemedicine systems. In most cases, it is very likely that very remote areas and disaster struck areas lack telecommunication infrastructure. Telemedicine system operating in such areas must have advanced wireless technology supporting it. Our approach is on MANET combined with Mobile IP and MIPV6, is the basis of infrastructure for the mobile telemedicine system. Our evaluation is based on simulating the various codecs of VoIP over MANET and presenting the ideal codec for real world implementation. In our simulations we found that G723.1 worked well in the three performance metrics, packet delivery fraction it delivered 92.4% traffic with 6 connections. For the increasing number of connections, the performance decreased from 62.5% at 12 connections to 24.4% at 30 connections and decreased to 19.4% at 36 connections. For packet delivery fraction, G.723.1 is the best performer against the other two CODECs. The delay suffered for 6 connections is 0.001 seconds and for 12 and 18 connections is 0.002 seconds. For 24 connections, the delay increases steeper than for lower number of connections. The normalized routing load for all CODECs vary within 1.022 to 1.082, hence the performances for all CODECs are almost similar for all connections. The project's primary objective is to create a prototype of mobile telemedicine system including hardware and software that can be rapidly deployed in remote areas or in disaster condition where telecommunication infrastructures are lacking or destroyed

Key words: Mobile Ad-hoc Network (MANET), Mobile IP, WLAN, Telemedicine, Ad-Hoc On Demand Distance Vector (AODV)

INTRODUCTION

Telemedicine is defined as the delivery of medical health care and medical expertise using a combination of telecommunications technologies. Telemedicine systems can support applications ranging from video conferencing to providing diagnostics, high quality image and still-image, and medical database record.

The Tele-emergency project proposed tele-emergency units as mobile telemedicine units. The system is based on three technologies viz., MIPv6, MANET, and WLAN. The integration of the technologies will produce a highly capable system with the ability to be rapidly deployed to support medical services. The integration of MANET with Mobile IP has been introduced [1]-[3].

1. Tele-Emergency Requirements and Applications

The requirements of the Tele-Emergency are:

1. Capable to work in remote areas, which has limited communications infrastructure,
2. Capable of being deployed in emergency condition
3. Capable of managing electronic patient records,
4. Support by real-time multimedia communication and geographical information system (GIS) ,
5. Low operating cost.

Applications in the Tele-Emergency are classified into basic and extended services. Basic services applications are digital electrocardiogram (ECG), oxymeter (spo2 meter), patient database record, and location information based on GPS technologies. Extended services applications are complete multimedia services. All services can be used in rural areas based on wireless communication despite hospitals, which have wired communication.

2. System and Network Architecture

2.1 Mobile Ad Hoc Network Review

Ad hoc literally means "formed or used for specific or immediate problems or needs". Thus, MANET means a mobile network which can be formed or used for specific or immediate problems or needs.

Mobile nodes in a MANET communicate to each other without base station, without the aid of any centralized administration hence it is also known as an infrastructure less wireless network.

MANET employs its mobile nodes as a part of the networking system. Each node in MANET can act as an intermediate node, i.e. as a relay to forward packets of data [4] and do routing functionality. In MANET, mobile nodes are free to move arbitrarily. It leads to an important property of MANET which is dynamic topology.

MANET routing protocols can be classified into demand-driven routing protocols and table-driven routing protocols. Demand-driven protocols create routes only when the source node initiates a route discovery process. Examples of demand-driven protocols are Ad Hoc On-Demand Distance Vector (AODV) [5] and Dynamic Source Routing (DSR) [6]. Table-driven protocols attempt to maintain consistent, up to date routing information in routing tables on every node. Examples of table-driven protocols are Destination Sequenced Distance Vector (DSDV) [7] and Optimized Link State Routing (OLSR) [8].

2.2 Mobile IP Review

The traditional way of IP address assignment to a node is network dependent. It brings problem in a mobile network environment. When a mobile node moves from one wireless network to other network, the IP address must be changed accordingly, while ongoing connection must be maintained and the packets belonging to the connection must be delivered continuously. Mobile IP is the solution to this problem.

Mobile IP users keep the same long-term IP address, i.e. home address, which has the same network prefix as a network called home network. When a Mobile Node determines that it is connected to a foreign network, it acquires a care-of address in addition to its home address. Care-of address is a forwarding address for a roaming mobile node.

In mobile IP, packets destined for the mobile node are always sent to the mobile's home network. When a mobile node moves to a foreign network, it gets the care-of address from a router in the foreign network, called foreign agent. The mobile node then registers the new location to a router in its home network, called home agent. The home agent captures packets meant for the roaming mobile node, encapsulates and forwards it to the foreign agent. The foreign agent then delivers the packets to the mobile node. Packets in the reverse direction from the mobile node can go directly to the corresponding host without going through the home agent.

Mobile IPv6 simplifies the scenario by removing the foreign agent. The mobile node uses IPv6 address auto-configuration procedure to acquire a collocated care-of address [9], [10].

2.3 Network Architecture

The Tele-Emergency network consists of at least one sub network using 2.4 GHz WLAN MANET. Figure 1 shows two MANET based sub networks.

In a sub network, Mobile Nodes (MNs) communicate directly with one another in a peer-to-peer connection, and each MN acts as a router for any other nodes.

The health practitioners use MNs to transmit patient's data to the health care center or mobile ambulance. The mobile ambulance is a Tele-Emergency MN, which is equipped with a local server, several Tele-Emergency MNs, and some

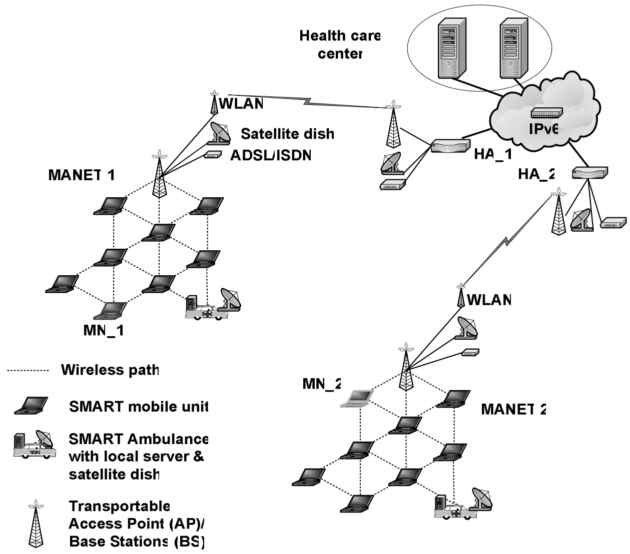

Figure 1. System design

optional communication devices such as satellite dish, ADSL, and ISDN modem. The server in the mobile ambulance functions as a local database when there is no connection to the health care center. However, the optional satellite communication link and wired terrestrial communication in Figure1 are used only if the field condition is making them more feasible than using 2.4 GHz WLAN.

The health care center, e.g. hospitals, has its own wireless LAN based medical systems working in the

2.4 GHz ISM band [11].

2.4 Tele-Emergency's Mobility with MIPv6 and MANET

Every mobile node can route packets within a sub network based on a MANET routing protocol. Since mobile nodes can move arbitrarily, the network topology can change according to the ongoing moves.

In Figure 1, MN_1 is a member of sub network MANET 1. This sub network is the home network of MN_1. The other network, sub network MANET 2, is MN_2's home network and a foreign network for MN_1. The MNs use MIPv6 for addressing. Each Tele-Emergency mobile node (MN) has a home address (HoA) given by the home agent (HA) in the home network. The home network has a network prefix matching that of the MN's home address. When the mobile node is away from home network, it uses the address auto-configuration procedure defined in IPv6 to get a care-of-address (CoA).

When a MN sends packets to another node within the same sub network, the packets will only have to go through a MANET routing protocol.

When MN_1 sends packets to MN_2, which is in a different sub network, the packets go through different types of routing. First, they are sent from MN_1 to the transportable base station in sub network 1 by using a MANET routing protocol, which then forward them to HA_1. HA_1 sends the packets to HA_2 by using IPv6 routing. HA_2 then forwards the packets to the transportable base station in sub network 2. Finally the packets again have to be routed by a MANET routing protocol to go to MN_2.

A mobile node such as MN_1 can move anywhere, anytime in the home network or move into foreign network as shown in Figure 2. When MN_1 is attached to a foreign network, it obtains a care of address (CoA) and registers it with HA_1. The HA_1 will know the current address and location of the MN_1.

When a correspondent node (CN) such as the server in health care center sends packets towards MN_1's home address, the packets are intercepted in MN_1's home network by HA_1 and tunneled to MN_1's care-of address.

When MN_1 sends packets to the CN, it uses its CoA as source address and puts its HoA in the Destination Options (home address options). MN_1 informs the CN of its new CoA so that subsequent data traffic can be sent directly between MN_1 and CN, without tunneling process to the HA_1. Upon the packet receive by CN; the HoA replaces the source address so that the applications in CN perceive that it is still communicating with the MN at its HoA. While the CN sends packets to MN_1, it puts MN_1's CoA in the destination field and the HoA in the type 2 routing header. The same processes are applied to MN_2 when it is moved and attached into a different sub networks.

The macro mobility given by MIPv6 combined with MANET micro mobility within sub network provides seamless mobility for Tele-Emergency MN.

2.5 Telemedicine Protocol Architecture

In order to discuss about the protocol architecture, we need to examine the following case. When MN_1 is attached to its home network and located within coverage area of the AP, it has one hop to HA_1. MN_1 can use MIPv6 mechanism available from HA_1 to communicate with another node. In the mean time,

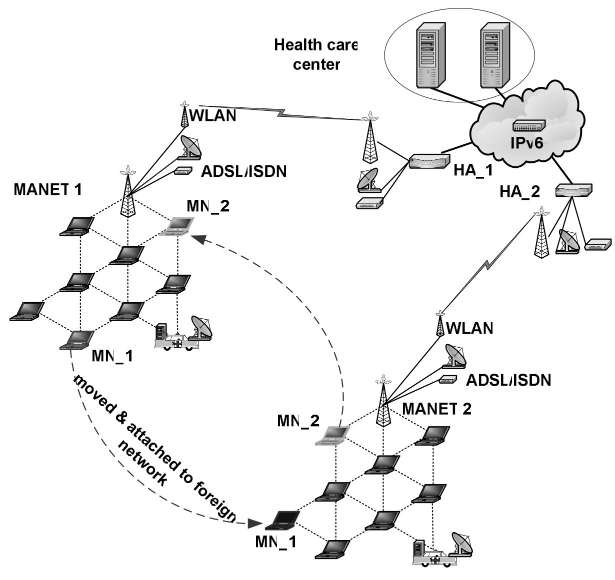

Figure 2. Tele-Emergency mobility with MIPv6

MN_1 can also communicate directly to another node in a peer-to-peer fashion using ad hoc network based on medium access control (MAC) WLAN ad hoc mode.

Therefore, that MN has two mechanism links over MAC WLAN ad hoc mode, namely MIPv6 over ad hoc mode and MIPv6 over ad hoc network. Figure 3 illustrates a simple connection between two MNs and a HA.

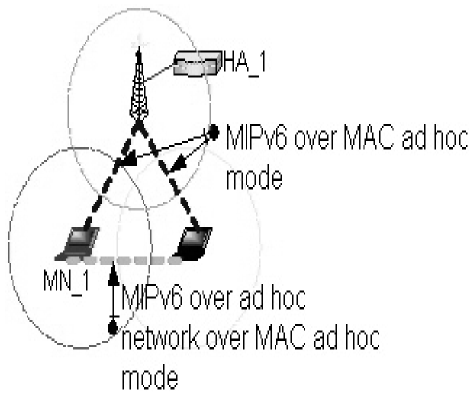

Figure 3. Simple connection of telemedicine network

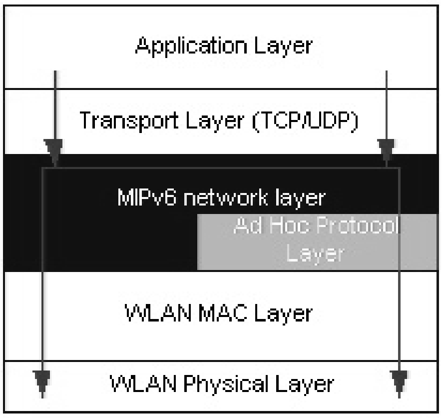

Figure 4. Telemedicine MN protocol architecture

The tele medicine MN specifications are defined in a protocol architecture describing the functionality of all layers. As illustrated in Figure 4, the tele medicine protocol architecture consisting of fourth layer includes ad hoc protocol network within the network layer. If a MN communicates using ad hoc network, the ad hoc network layer is taken to provide ad hoc communications. With this architecture, the MN is able to handle two mechanism links as defined above.

3. SIMULATION

3.1 Simulation of MANET

The simulation integrates WLAN and ad hoc network to form a wireless-cum-wired environment. The selected routing protocol is AODV, and we use an AODV extension called AODV+ [12].

The performance of AODV+ is evaluated by running simulations on ns2 which is a discrete event simulator developed by the University of California at Berkeley and the VINT project [13]. The AODV+ extensions on ns2 can be obtained [12].

In this experiment, a total of 40 nodes with limited mobility, considered as moderate scale network (i.e., 30-100 nodes) [14], were randomly placed across the simulation environment of size 2500m×1000m. This simulation environment is a model of an emergency situation in an area where 40 emergency units are able to communicate to each other without the needs of communication infrastructures. The units in this kind of environment are mobile but the mobility is limited.

Since AODV+ was meant to work in wired-cum-wireless environment, two gateways and a router were deployed to provide connection to the Internet. The gateways and routers formed the wired environment and are within the range of each other. The bandwidth capacity is 1000 Mbps while the delay is 0.1 seconds. It is not the purpose of this project to examine the performance in wired network but in the wireless environment. Therefore, the resources in the wired network are assumed to be abundant and shall not affect the overall performance of the system.

The radio propagation range for each node is 250 meters and channel capacity is 2Mbps. The IEEE 802.11 MAC protocol with Distributed Coordination Function (DCF) is adopted as the MAC layer in this simulation model. DCF is a method for nodes to share the channel capacity. The access scheme is Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA). This scheme uses Ready-to-Send (RTS) and Clear-to-Send (CTS) control packets to reserve the channel and solve the hidden nodes problems. Each correctly received packet is preceded with acknowledgement (ACK) packet to the sender.

The traffic type is CBR (constant bit rate) which is commonly used for voice based applications [15]. In CBR mode, silences are not exploited for other voice or data traffic [16].

Each simulation is executed for 200 seconds. Data rates are selected from VoIP CODECs and are presented in Table 1.

The simulations use different number of traffic sources against performance metrics like packet delivery fraction (PDF), normalized routing overhead and average end-to-end delay. The results are presented in graphs and extensive analysis is provided in the next section. Before proceeding to the next section, we present a summary of the simulation parameters in Table 2.

Table 1. VoIP CODECs

CODECs	ITU-T G.711	ITU-T G.723.1	ITU-T G.729A
Packet size (b)	178	82	68
Data rate (kbps)	193	43	108
Packets per second	66	33	100

3.2 Simulation Results and Analysis

Based on the simulation settings mentioned in previous section, we present the results and analysis in this section. The performance metrics are packet delivery fraction (PDF), average end-to-end delay and normalized routing overhead.

3.2.1 Packet Delivery Fraction:

the ratio of the number of data packets successfully delivered to all destination nodes and the number of data packets generated by all source nodes.

Packet delivery fraction (pdf%) =

*(received packets/sent packets)*100*

3.2.2 Average End-to-End Delay:

The average time interval between the generation of a packet in a source node and the successfully delivery of the packet at the destination node. It counts all possible delays that can occur in the source and all intermediate nodes, including queuing time, packet transmission and propagation, and retransmissions at the MAC layer. The queuing time can be caused by network congestion or unavailability of valid routes.

$$Avg\ end\ to\ end\ delay = \sum_{h=1}^{H} t_{t_h} + t_{d_h} + t_{p_h}$$

t_{t_h} = Time taken for transmission between two nodes.

t_{d_h} = The propagation delay per hop between two nodes

t_{p_h} = The mean processing time in the intermediate nodes

3.2.3 Normalized routing load:

The ratio of the number of routing messages propagated by every node in the network and the number of data packets successfully delivered to all destination nodes. Whenever several nodes propagate a given routing message, the transmission on each hop is counted once in the total number of routing messages. In other words, the routing load means the average number of routing messages generated to each data packet successfully delivered to the destination

Normalized routing load = routing packets sent / received data packets.

Figure 5 presents the packet delivery fraction against various values of number of connections. Based on table 1 and 2, the CODECs introduce tremendous amount of traffic in one second while each nodes are only able to handle 50 packets in their queue. Therefore, we predict that the performance will degrade as the number of connections increase due to limited resources. However, for G.723.1, it is able to deliver 92.4% traffic with 6 connections. For the increasing number of connections, the performance decreased from 62.5% at 12 connections to 24.4% at 30 connections and decreased to 19.4% at 36 connections. G.711 is regarded as the average performer while G.729A is the worst CODEC in this performance metric. As the number of connections increase, more and more packets are being pumped

Table 2. Simulation Parameters

Parameter	Value
Number of nodes	40
Number of gateways	2
Number of router	1
Radio propagation range	250m
Wireless channel capacity	2 Mbps
Wired channel capacity	1000 Mbps
Medium access control protocol	802.11
Mobility/Movement	Limited
Simulation time	200 s
Environment size	2500m × 1000m
Traffic type	CBR
Number of connections	6,12,18,24,30,36
Queue length	50

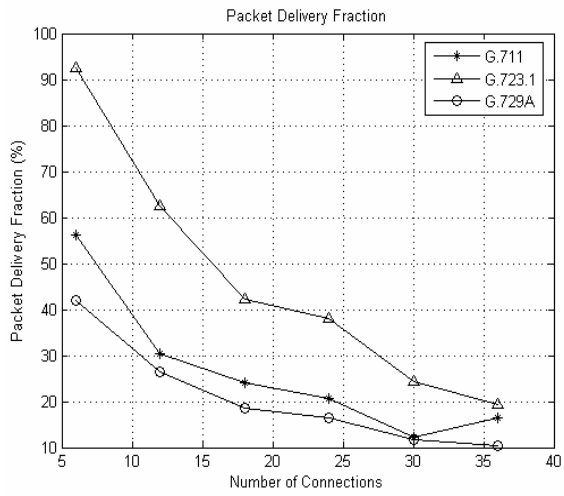

Figure 5. Packet Delivery Fraction

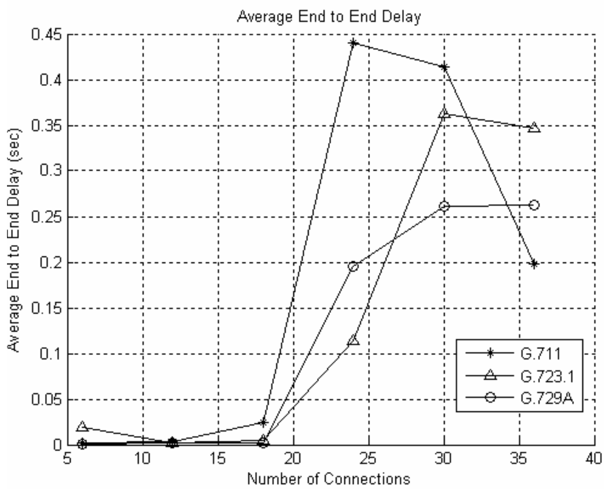

Figure 6. Average End-to-End Delay

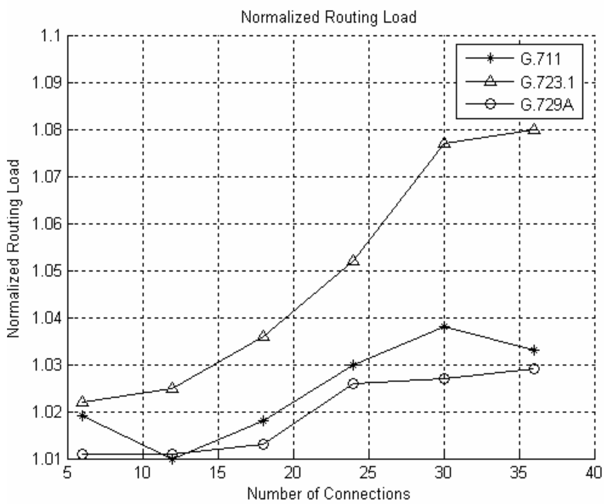

Figure 7. Normalized Routing Load

into the network and thus causing cache overflow in busy nodes. G.723.1 is still able to withstand this effect in small connections because the traffic is slower (33 packets/sec) compared to the others (66 and 100 packets/sec). Another important factor is the route discovery process. While the originator node spends some time to locate a route to destination, the application layer continues to produce packets. When the queue is full and the route is not yet available, packets on the queue will be discarded.

Average end-to-end delay metric is presented in Figure 6. Again G.723.1 is the best performer against the other two CODECs. The delay suffered for 6 connections is 0.001 seconds and for 12 and 18 connections is 0.002 seconds. For 24 connections, the delay increases steeper than for lower number of connections. As for G.711, the delay increases very steep between 6 connections and 12 connections. G.729A recorded a more stable delay rate in all number of connections ranging from 0.001 to 0.263 seconds. The simulations were done in limited mobility environments. The traffics are bound to concentrate on the particular routes because change of routes does not occur except for transmission error. As a result, the traffic is not evenly distributed and the effect of congestion increases as the number of traffic increases. This is clearly shown in G.723.1 and G.729A. One more interesting factor is the packet size. The larger the size, the more time required for processing them. G.711 has the largest packet size (178 bytes) followed by G.723.1 (82 bytes) and G.729A (68 bytes). This is the reason that G.711 suffered higher delay than G.723.1 except with 6 connections. The relatively low packet size and transfer rate makes G.723.1 the ideal CODEC,.

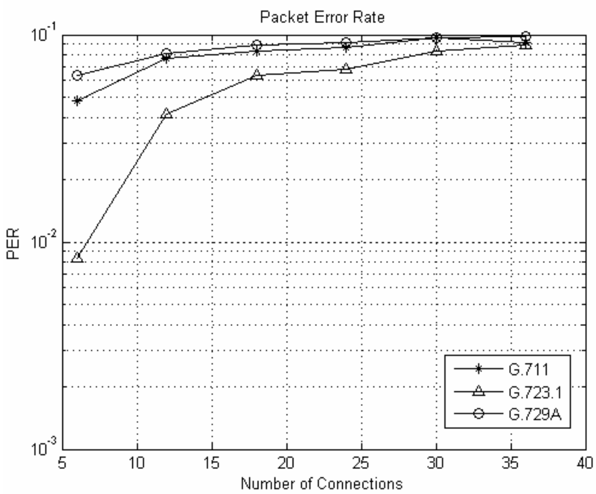

Figure 8. Packet Error Rate

then, the result for normalized routing load is presented in Figure 7. This metric is a measure of ratio between routing packets and number of packets sent. The normalized routing load for all CODECs vary within 1.022 to 1.082, hence the performances for all CODECs are almost similar for all connections. Therefore, we can conclude that in a limited mobility network the amount of routing packets are relative to number of packets sent. With limited mobility the nodes do not need to rediscover routes and inform others about broken links

Finally we check the number of packet reaching the destinations but dropped by the destinations, and we denoted that as packet error rate. In the MANET environment, the interference signal level increases along with the number of connections. This causes the signal to interference ratio to decrease with larger number of connections. Hence, the packet error rate increases as the number of connections is going up. The result is shown in Figure 8, and again G.723.1 performance is the best one.

4. Conclusions

We present the status of the Tele-Emergency project. Our approach in developing the prototype includes MANET- WLAN based simulation using ns2. The performance of delivering voice data in the extended AODV+ protocol is evaluated using ns2 simulator. Out of the three selected CODECs, G.723.1 works best in the simulation environment.

Simulation of various video CODECs on MANET implementation with Mobile IPv6 will be the subject of further works.

5. ACKNOWLEDGMENTS

This work was supported in part by the Intensification of Research in Priority Areas (IRPA) program of The Ministry of Science Technology and Innovation (MOSTI) Malaysia, under Grant 04-02-10-0041-EA0039.

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