Telephone Answering Machine with Embedded Message Forwarding System

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***Abstract*— In this paper, an email capable embedded system is added to a traditional telephone answering machine to turn it into a multi-user automatic message forwarding system. The proposed system utilizes the embedded email technology to automatically forward a voice message left by the caller to the designated recipient via an email. The recipient may, in this regard, listen to the voice message by playing the audio attachment in the mail virtually anywhere in the world where Internet access is possible. By using the proposed system, if users are expecting an incoming message, they will be notified as soon as the message has arrived instead of polling the answering machine repeatedly. In addition, for users who travel a lot, to listen to the voice message attached in emails saves the expenses of long distance calls. Lastly, the privacy of the personal messages can be preserved.**

***Keywords*— Answering machine, Embedded systems, Message forwarding systems, email, telephone**

1. INTRODUCTION

Without doubts, the most frequently seen add-on function on home used telephone sets is the capability of answering a call automatically. Such an answering device, usually called a telephone answering machine (or TAM), is an electronic device that picks up an incoming telephone call, plays a pre-recorded message, and records voice messages that the caller leaves. In addition to the answering function, there are other features that may also be added to TAMs depending on implementations by different manufacturers. For example, most TAMs allow messages to be played back over the telephone network via a remote command issued by an authorized person, whereas some have the capability to dial a predetermined telephone number and play back a recorded message to that number. A TAM has become a very convenient personal communication device in almost every household when people are not convenient to answer a call.

Traditionally, a TAM user may play back the messages left either on site or remotely. If a user can operate the answering machine directly, the voice messages are played out from the speaker of the TAM; otherwise, while being away from home, the user can issue a remote commend to the TAM, and then the messages are played and sent to the user via the telephone network. To listen to the recorded messages remotely takes time. If the signal quality is poor, which frequently happens in the long distance calls, the user may need to play the message more than once. In this regard, the charge of long distance calls could be a burden. In the case when a user is expecting an important message, the user may need to check with TAM over and over again. Moreover, in a household use, where a telephone line is usually shared by all family members, a message left by a caller could be addressed to any one of them. If the privacy and the security issues have to be taken into account, the traditional TAMs are just not good enough.

There are two types of voice messages involved in a TAM operation: a pre-recorded message and messages left by callers. The pre-recorded message, usually called the greeting message, used to inform the caller that the called party is not available to answer the phone. It is automatically played back after a pre-defined number of rings. Both types of the messages are stored in the non-volatile storages, such as tapes or EEPROM. Because the messages stored on tapes can only be sequentially played back, and

the quality of recorded voice messages goes down after several record-and-erase cycles, tapes are rarely used now. Instead, on more recent TAMs, messages are stored in EEPROM in digital formats. This makes further messages manipulations possible, such as delivering the message files over Internet.

In this paper, a new design of TAM called embedded TAM (or e-TAM) is introduced. The e-TAM enhances the traditional TAM by adding an embedded email system into the device. When a voice message has been recorded, it is encoded and saved in an audio file. Afterwards, the e-TAM automatically attaches the message file into an email and delivers it to the recipient that the message is addressed to. The recipient may access the message virtually anywhere in the world where Internet access is possible. By using the e-TAM, if users are expecting an incoming message, they will be notified as soon as the message has arrived instead of polling the answering machine repeatedly. The proposed system not only saves the expenses of listening to the messages remotely but preserves the privacy of personal messages as well. The e-TAM provides a mechanism that allows a user to access only the files addressed to that user.

The remainder of this paper is organized as follows. Section 2 introduces the hardware architecture of the proposed e-TAM. Section 3 discusses the necessary software components to drive the system especially the embedded email system. Section 4 shows the implementation and experimental results of the e-TAM.

2. HARDWARE ARCHITECTURE

Fig. 1 shows the hardware architecture of the proposed e-TAM. There are two systems in the device: a telephone answering machine and an embedded mail system. The major components of the telephone answering machine include a ring detector, a DTMF (Dual Tone Multiple Frequency) decoder [1], and a voice IC. The embedded system contains an MCU, a storage module, an Ethernet [2] module, a voice modem [3], and a numeric keypad. Since Internet connection is indispensable to fulfill the goal of voice message forwarding, inside the e-TAM, there are two connectors for different Internet connection options. One is the Ethernet module, which is used to connect Internet via a local LAN, and the other is the voice modem module, which is used to dialup to Internet when the local LAN connection is not available.

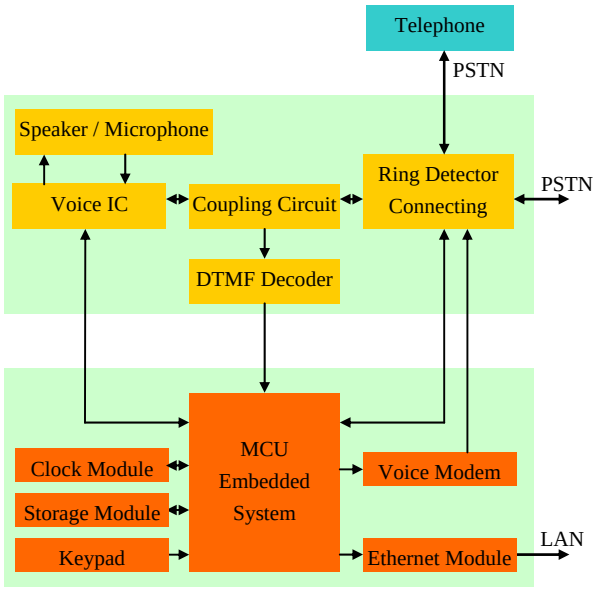
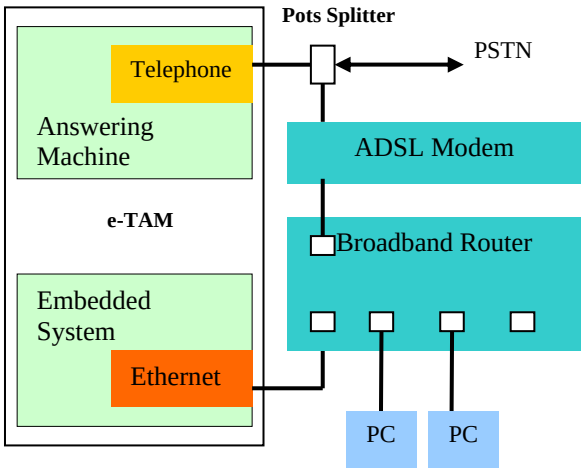


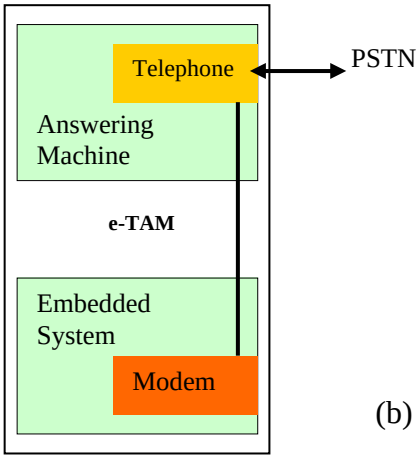
Fig. 1 Hardware architecture of the proposed e-TAM

The e-TAM records and manipulates a voice message by the following procedures:

1. A ring signal is sensed by the ring detector, which informs the MCU an incoming call.
2. The MCU activates the connecting circuit to connect the telephone line after a pre-defined number of rings.
3. The MCU enables voice IC to play the greeting message that was previously recorded and saved in the storage module. In the greeting message, the recipients and their corresponding ID are enumerated.
4. The caller selects the party that the voice message is addressed to by using the keypad on the caller's phone set.
5. The keys pressed are decoded by the DTMF and sent to the MCU. The recipient of the message is determined.
6. The voice IC finishes playing the greeting message and informs the caller to start leaving the voice message.
7. The message left is sampled and digitized by the voice IC and stored in the storage module.
8. The MCU compresses and encodes the voice message into a common audio file format [4], such as WAV, MP3, WMA, and so on.
9. The MCU packs the voice message as an attachment of an email, which is sent to the email address of the recipient.



(a)



(b)

Fig. 2 The e-TAM using (a) LAN-to-Internet, (b) dialup-to-Internet connections

Fig. 2 presents two different Internet connection layout diagrams for the proposed e-TAM: the LAN-to-Internet and the dialup-to-Internet connections. The LAN-to-Internet connection is preferable because the LAN usually provides higher bandwidth and more reliable data transfer than those of the dialup connection. Nowadays, most home users choose ADSL as their primary choice to access Internet. By using a broadband router, ADSL supports multiple users sharing the same bandwidth to get on Internet, if a local LAN is deployed at home. As shown in Fig. 2(a), where an e-TAM is added to the local LAN, a UTP cable is required to connect the Ethernet module to the broadband router. This makes the e-TAM a member of the local LAN and the embedded email system of the e-TAM would use this path to forward voice messages to Internet. In case that the local LAN using non-ADSL connection to Internet, such as a leased line, there will be a LAN switch replacing the broadband router and ADSL modem in Fig. 2(a). Alternatively, as shown in Fig 2(b), if there is no local LAN available, the voice modem inside the embedded system is used to make dialup connection. Although both connection diagrams are appeared differently, the ways they forward messages are basically the same. Since the voice modem shares the same PSTN line with telephone, the message forwarding can only be done while the telephone line is not in use. The MCU controls the time to dialup and make Internet connection, if there are messages pending to be sent. When all the messages have been forwarded, the voice modem disconnects the connection to leave the line ready for next incoming call.

3. SOFTWARE COMPONENTS OF THE E-TAM

Fig 3 shows the software components of the embedded mail system. Among the components, they are interrupt service routines (ISRs), digital signal processor (DSP), TCP/IP protocols [5] and an SMTP [6]-[8] client. The ISRs are a common approach to process unsynchronized events. In the embedded system, ISRs are used to detect the ring signals, enable the answering function and record the messages left. The DSP program module is responsible to process voice signals sent by the voice IC. The processing includes filtering, sampling, compressing and encoding the voice signals.

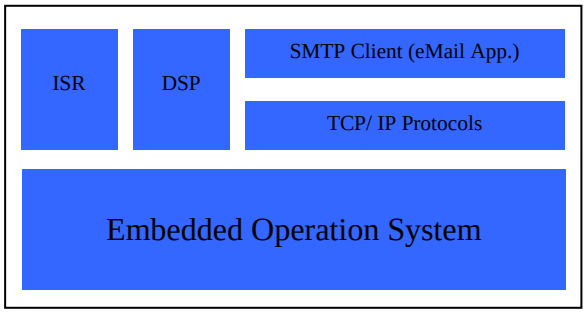


Fig. 3 Software components of the e-TAM

Besides, the e-TAM needs an email module to forward the voice message to the recipient. The easiest way to meet this requirement is to adopt an SMTP client directly. There are a number of open STMP clients, also known as email applications, available and they have been widely used for years. SMTP clients call TCP/IP as

transport and data delivery protocols. Therefore, TCP/IP protocols are also required. The SMTP client packs the voice message as an audio attachment into an email and sends out by calling the TCP/IP protocols underneath.

Before putting the e-TAM to work, an initial configuration setup is necessary. There are three configuration items need to be set in advance: (1) IP address, (2) SMTP server information, (3) user accounting information. An IP address is required for SMTP client application to work. If the LAN-to-Internet connection is used, the IP address of the Ethernet module can be configured in either statically assigned by the e-TAM administrator or dynamically assigned by a DHCP server on the local LAN. On the other hand, if the dialup-to-Internet connection is used, no IP address configuration is necessary. Instead, ISP will automatically assign an IP address while the dialup connection is established.

To setup the SMTP server information is to designate a mail service provider, or a mail server, to deliver the email that the embedded system has prepared to its destination for SMTP client. Assigning any valid mail server as we usually use in our daily email exchanges will do the job.

If a traditional answering machine is shared by multiple home users, messages left by callers could be accessed by any user who knows the access code. Moreover, the actual message recipient cannot be determined prior to the message is being played back. These drawbacks can be overcome by adding a simple accounting mechanism to the proposed e-TAM. The contents of all user accounts are entered in advance by the system administrator from the numeric keypad of the embedded system and saved in the storage module. In most cases, a simple table to store user IDs, names, passwords as well as their email addresses is enough. Since the English letters are inevitable in an email address, the keypad uses a specially designed code-mapping scheme, which could convert a sequence of number keys pressed into English letters. The user names and their corresponding IDs are enumerated and pre-recorded in the greeting message. As the answering function is initiated and the greeting message is played back, the caller may select the exact recipient from the user list before leaving the message. Afterwards, the message left by the caller will be only sent, by the SMTP client, to the designated recipient. On the other hand, if the messages are to be played back on site, the user would need to pass an authentication process first. Since the messages left have been stored for each user independently, the messages playback feature plays only messages that are addressed to the user.

4. RESULTS

To implement the proposed e-TAM, an embedded system chip with a build-in ADC, a voice IC, and a 4x4 keypad were integrated into a traditional TAM. Inside the embedded system, the TCP/IP protocols and an SMTP client were installed. In addition, an open source audio application with MP3 encoder was also installed to record and encode the messages. The user accounting information for testing was entered in advance, as shown in Table 1. There are four fields in the table: names, passwords, numeric IDs and email addresses. The names and the IDs are to be read out while recording the greeting message from which the caller can choose the recipient. The numeric IDs are used to look up the recipient in the table as the caller pressing the keypad.

TABLE 1
USER ACCOUNT INFORMATION

Name	Password	Numeric ID	Email Address
John Smith	********	101	jsmith@mail.lhu.edu.tw
Mary Smith	********	102	msmith@mail.lhu.edu.tw
David Smith	********	211	dsmith@mail.lhu.edu.tw

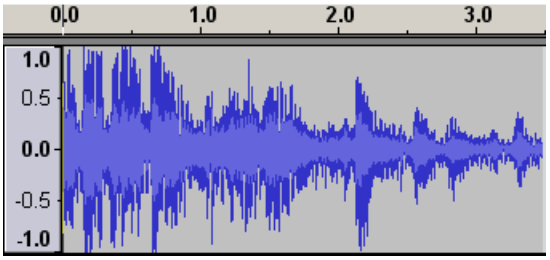


Fig. 4 Waveform of the message left by caller

A test was performed on a local LAN environment with ADSL connection to Internet. As the e-TAM was plugged into the local LAN, a dynamic IP address was assigned to the e-TAM by a DHCP server on the local LAN. A call to initiate the e-TAM was made by one of our lab staff who left a 3.5-second voice message, as the waveform shown in Fig. 4. The message was sampled, recorded and encoded into MP3 file format (about 60KB in size) and stored in EEPROM. Afterwards, the voice message file

was added into an email as an attachment and sent to the designated recipient specified by the caller. Fig. 5 shows the email that had been successfully received.

Fig. 5 Voice message in a received email

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