Fax Over Packet

White Paper

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Introduction

A Fax over Packet application enables the interworking of standard fax machines with packet networks. It accomplishes this by extracting the fax image from an analog signal and carrying it as digital data over the packet network. This paper references a general class of packet networks that are used to transport the fax, including Internet (IP), Frame Relay, and ATM. Currently, the Frame Relay Forum and the International Telecommunication Union (ITU) have defined protocols for transmission of fax over a packet network. However, the principles described are equally applicable to ATM networks.

Traditionally, there have been two approaches for sending Fax over Packet networks: real-time methods and store and forward methods. The primary difference in service between these two approaches is in the delivery and method of receipt confirmation. The Frame Relay Forum has defined a real-time protocol for the transmission of Fax over Frame Relay networks. Likewise, the ITU and IETF are working together to continue to evolve both the real-time Fax over IP network standard (T.38) as well as the store and forward Fax over IP network standard (T.37). Both T.37 and T.38 were approved by the ITU in June, 1998. Furthermore, T.38 is the fax transmission protocol selected for H.323.

In this paper, the principles related to implementing real-time Fax over Packet networks are discussed. An overview of an embedded software architecture is presented, and a system is described for sending fax image data and signaling information over the packet network. Benefits to designers and manufacturers of this embedded approach are lower cost of goods sold, faster time to market, and lower development costs. Customers can gain a considerable advantage in time to market in building their communication systems.

Applications

There are tremendous opportunities for cost savings by transmitting fax calls over packet networks. Fax data in its original form is digital. However, it is modulated and converted to analog for transmission over the PSTN. This analog form uses 64 Kbps of bandwidth in both directions.

The Fax over Packet Interworking Function (IWF) reverses this analog conversion, instead transmitting digital data over the packet network, and then reconverting the digital data to analog for the receiving fax machine. This conversion process reduces the overall bandwidth required to send the fax because the digital form is much more efficient and the fax transmission is half duplex (i.e. only one direction is used at any

time). The peak rate for a fax transmission is 14.4 Kbps in one direction. A representation of this process is shown in Figure 1.

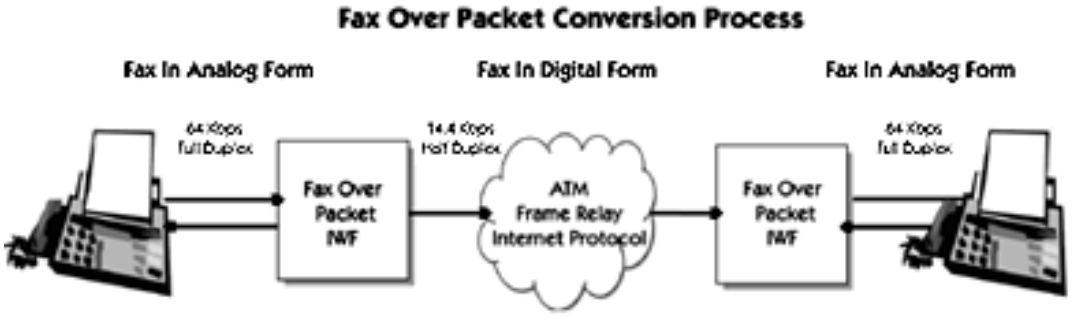

Figure 1

An application for Fax over Packet, shown in Figure 2, is a network configuration of a company with numerous branch offices that wants to use the packet network, instead of the long distance network, to provide fax access to the main office. The IWF is the physical implementation of the hardware and software that enables the transmission of fax over the packet network. The IWF must support analog interfaces that directly interface to fax machines at the branches and to a PBX at the central site. The IWF must emulate the functions of a PBX for the fax machines.

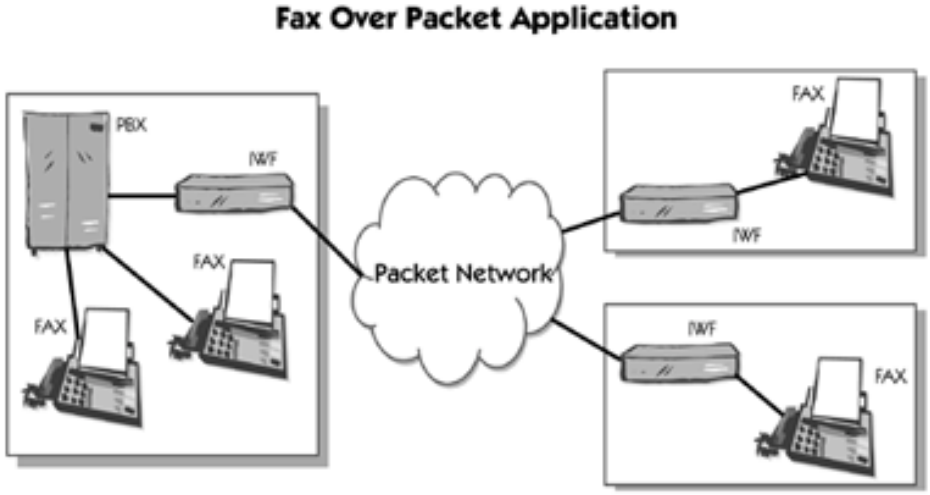

Figure 2

PSTN Fax Call Procedure

This section will describe the stages of a standard fax call over the Public Switched Telephone Network (PSTN) so that the processing required for a reliable fax transmission over a packet network can be explored. Fax machines in common use today implement the ITU recommendations T.30 and T.4 protocols. The T.30 protocol describes the formatting of non-page data, such as messages that are used for capabilities negotiation. The T.4 protocol describes formatting of page image data.

T.30 and T.4 have evolved substantially over time and are now quite complex because they attempt to describe the behavior of an evolving set of fax machines. The timing related to the message interaction and phases of the call is critical and is one of the major causes of problems in the transmission of Fax over Packet networks.

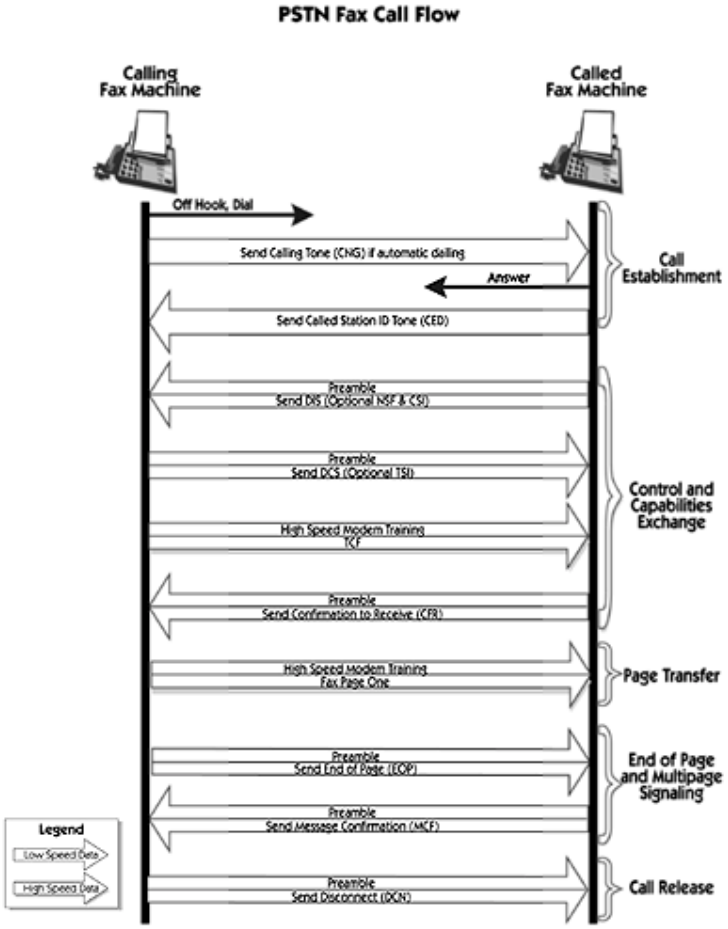

Figure 3

The PSTN fax call is divided into five phases, as shown in Figure 3. This example assumes that the call is accomplished without errors. The procedure becomes somewhat more complicated if errors occur or there is a need for modem retraining. The five phases are:

- Call Establishment
- Control and Capabilities Exchange
- Page Transfer
- End of Page and Multi-Page Signaling
- Call Release

Call Establishment

The fax call is established either through a manual process, where someone dials a call and puts the machine into fax mode, or by automatic procedures, where no human interaction is required. In both cases, the answering fax machine returns an answer tone, called a CED, which is the high pitched tone that you would hear when you call a fax machine. If the call is automatically dialed, the calling station will also indicate the fax call with a calling tone (CNG), which is a short periodic tone that begins immediately after the number is dialed. These tones are generated to allow a human participant to realize that a machine is present on the other end call. These tones are sometimes used to recognize the presence of a fax call, although they are not a very reliable indication.

Control and Capabilities Exchange

The Control and Capabilities Exchange phase of the fax call is used to identify the capabilities of the fax machine at the other end of the call. It also negotiates the acceptable conditions for the call. The exchange of control messages throughout the fax call are sent using the low speed (300 bps) modulation mode. Every control message is preceded by a one second preamble which allows the communication channel to be conditioned for reliable transmission.

The called fax machine begins the procedure by sending a Digital Identification Signal (DIS) message which contains the capabilities of the fax machine. An example of a capability that could be identified in this message is that the V.17 (14000 bps) Data Signaling Rate is supported. At the same time, the Called Subscriber Information (CSI) and Non-Standard Facilities (NSF) messages are optionally sent. Non-Standard Facilities are capabilities that a particular fax manufacturer has built into a fax machine to distinguish their product from others. They are not required to be supported for interoperability.

Once the calling fax machine receives the DIS message it determines the conditions for the call by examining its own capabilities table. The calling machine responds with the Digital Command Signal (DCS), which defines the conditions of the call.

At this stage, high speed modem training begins. The high speed modem will be used in the next phase of the fax call to transfer page data. The calling fax machine sends a Training Check Field (TCF) through the modulation system to verify the training and ensure that the channel is suitable for transmission at the accepted data rate. The called fax machine responds with a Confirmation to Receive (CFR) which indicates that all capabilities and the modulation speed have been confirmed and the fax page may be sent.

Page Transfer

The high speed modem is used to transmit the page data that has been scanned in and compressed. It uses the ITU T.4 protocol standard to format the page data for transmission over the channel.

End of Page and Multi-Page Signaling

After the page has been successfully transmitted, the calling fax machine sends an End of Procedures (EOP) message if the fax call is complete and all of the pages have been transmitted. If only one page has been sent and there are additional ones to follow, it sends a Multi-Page Signal (MPS). The called machine would respond with Message Confirmation (MCF) to indicate the message has been successfully received and it is ready to receive more pages.

Call Release

The release phase is the final phase of the call where the calling machine sends a Disconnect Message (DCN). While the DCN message is a positive indication that the fax call is over, it is not a reliable indication since the fax machine can disconnect prematurely without ever sending the DCN message.

Quality of Service

The advantages of reduced cost and bandwidth savings of carrying fax over packet networks are associated with some quality of service issues which are unique to packet networks and can affect the reliability of the fax transmission. These issues are explored below.

Timing

A major issue in the implementation of Fax over Packet networks is the problem of inaccurate timing of messages caused by delay through the network. The delay of fax packets through a packet network causes the precise timing that is required for many portions of the fax protocol to be skewed and can result in the loss of the call. The Fax

over Packet protocol in the IWF must compensate for the loss of a fixed timing of messages over the packet network so that the T.30 protocol operates without error.

There are two sources of delay in an end-to-end Fax over Packet call: network delay and processing delay.

Network delay is caused by the physical medium and protocols that are used to transmit the fax data and by buffers used to remove packet jitter on the receiving end. This delay is a function of the capacity of the links in the network and the processing that occurs as the packets transit the network. The jitter buffers add delay when they remove the packet delay variation of each packet as it transits the packet network. This delay can be a significant part of the overall delay since packet delay variations can be as high as 70-100 msec in some Frame Relay networks and even higher in IP networks.

Processing delay is caused by the process of demodulating and collecting the digital fax information into a packet for transmission over the packet network. The encoding delay is a function of both the processor execution time and the amount of data collected before sending a packet to the network. Low speed data, for instance, is usually sent out with a single byte per packet since the time to collect a byte of information at 300 bps is 30 msec.

Jitter

Delay issues are compounded by the need to remove jitter, a variable inter-packet timing caused by the network that a packet traverses. An approach to removing the jitter is to collect packets and hold them long enough so that the slowest packets to arrive are still in time to be played in the correct sequence. This approach, however, causes additional delay. In most Fax over Packet protocols, a time stamp is incorporated in the packet to ensure that the information is played out at the proper instant.

Lost Packet Compensation

Lost packets can be an even more severe problem, depending on the type of packet network that is being used. In a Voice over Packet application, the loss of packets can be addressed by replaying last packets and other methods of interpolation. A Fax over Packet application, however, has more severe constraints on the loss of data since the fax protocol can fail if information is lost. This problem varies depending on the type of fax machine used and whether Error Correction Mode is enabled.

Two schemes that are used by Fax over Packet software to address the problems of lost frames are:

- Repeating information in subsequent frames so that the error can be corrected by the receiver's playout mechanism.

- Using an error correcting protocol such as TCP to transport the fax data at the expense of added delay.

Fax over Packet Software Architecture

The Facsimile Interface Unit (FIU) is the software module that resides within a Fax over Packet Interworking Function. It demodulates voice-band signals from an analog interface and converts them to a digital format suitable for transport over a packet network. It also re-modulates data received from the packet network and transmits it to the analog interface. In doing so, the FIU performs protocol conversion between Group 3 facsimile protocols and the digital facsimile protocol employed over the packet network.

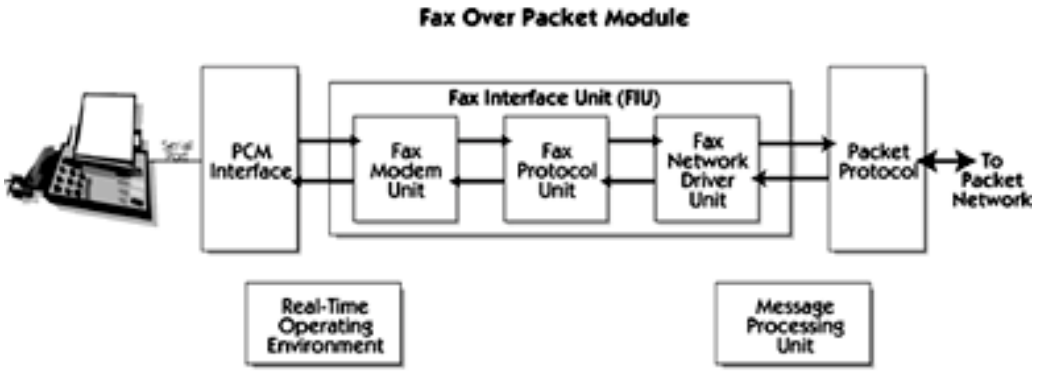

Figure 4

The Fax Interface Unit, shown in Figure 4, consists of the following three units:

Fax Modem Unit (FM): processes PCM samples based on the current modulation mode and supports the following functions:

- V.21 Channel 2 (300 bps) binary signaling modulation and demodulation
- HDLC framing (0 bit insertion/removal, CRC generation/checking)
- V.27 ter (2,400/4,800 bps) high-speed data modulation and demodulation
- V.29 (7,200/9,600 bps) high-speed data modulation and demodulation
- V.17 (7,200/9,600/12,000/14,400 bps) high speed data modulation and demodulation
- V.33 (12,000/14,400 bps) high speed modulation and demodulation
- CED detection and generation

- CNG detection and generation
- V21 Channel 2 detection

Fax Protocol Unit (FP): compensates for the effects of timing and lost packets caused by the packet network. The FP prevents the local fax machine from timing out while waiting for a response from the other end by generating HDLC flags. If, after a time out, the response from the remote fax machine is not received, it also sends a CRP frame (command repeat) to resend the frame. This unit monitors the facsimile transaction timing, the direction of current transmission and the proper modem configuration. It performs:

- Protocol processing (group 3 facsimile)
- Examination/alteration of binary signaling messages to ensure compatibility of the facsimile transfer with the constraints of the transmission channel
- Network channel interface data formatting
- Line state transitions

Fax Network Driver Unit (FND): assembles and disassembles fax packets to be transmitted over the network and is the interface unit between the FP and network modules. The control information packets consist of header and time stamp information. In the direction of the PCM to the packet network, the FND collects the specified number of bytes and transmits the packet to the network. In the receive direction, the FND provides data with the proper timing (as generated on the transmit side and reproduced through the received time stamp information) to the rest of the FIU. The FND formats the network packets for transmission to the network based on the specific network protocol. The FND delays the data in order to remove timing jitter from the packet arrival times and performs:

- Formatting of control information
- Formatting of fax data
- Properly timed playout of data
- Elastic (slip) buffering
- Lost packet compensation

Summary

A Fax over Packet software architecture has been described for the interworking of fax machines and packet networks. Some of the key features enabling this application to function successfully are:

- an approach that addresses the effect of delay through the network
- a process that minimizes the effect of jitter
- features that address lost packet compensation

Though the quality of service issues associated with carrying Fax over Packet networks are significant, the future of this approach will be driven by the substantial cost savings and exciting applications made possible with Fax over Packet software technology.

For More Information

For more information on TI's Voice Over Packet and Fax Over Packet solutions please visit www.ti.com/sc/voip or contact your local TI sales representative.