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White Paper

Adding Reliable Fax Capability to VoIP Networks

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Executive Summary

As businesses move to Voice over IP (VoIP), they often neglect to consider that traditional fax technology was not designed to work on VoIP networks. In addition, IP-PBX vendors, VARs, and Systems Integrators tend to dismiss fax as an obsolete technology, even though studies show that significant growth in the fax market is expected during the next five years. Because fax is not "going away" in the foreseeable future, it is important to implement fax efficiently and reliably on a VoIP network. This white paper will compare the two principal options for implementing fax in a VoIP network today: Fax-Relay (T.38) and Fax Pass-Through (G.711) and will conclude that Fax Relay is superior. Adding a Fax over IP (FoIP) fax server and Multi-Function Peripherals (MFPs) to the IP network infrastructure can also provide gains in productivity and streamlined regulation compliance along with the additional benefit of reducing maintenance and administration.

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White Paper

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Fax in the VoIP Network Today

With IP line shipments exceeding 50% of new PBX and contact center technology since 2005 in some regions, the convergence of voice and data on a single network is obviously moving forward at a healthy pace [Synergy]. But as the adoption of VoIP continues, the fact that traditional fax technology is proving less suitable for implementation on a VoIP network than on a TDM network is often ignored by IP-PBX vendors, VARs, and Systems Integrators. The feeling seems to be that fax will be "going away" soon, and the interim techniques of connecting a few fax machines to a new VoIP network with an Analog Telephone Adaptor (ATA) or maintaining a few POTS lines for fax are sufficient. The common belief seems to be that, for the short term, an 80% to 90% single page success rate for fax transmission can be tolerated, even though the inefficiency resulting from a strategy that provides such a poor success rate can be sizeable, resulting in significantly higher toll charges, lost time and productivity, poor network performance, and a lower level of customer service.

Fax is not conveniently fading away, and studies continue to indicate that fax technology will continue to be a major part of the telecom infrastructure for many years to come. A judicious strategy, then, seems to be to move fax to the IP infrastructure in order to fully realize the financial and administrative benefits of the converged network.

This paper examines and compares the options available for adding fax traffic to a converged voice and data network. In addition, it will consider the benefits of adding a fax server to a converged network as well as those derived from including Multi-Function Peripherals (MFPs).

Interest in Fax over IP and the Fax Market

Discussions of methods for achieving real-time fax transmission over a VoIP network is a topic of interest in the industry, as can be seen repeatedly in the blog of Tom Keating, CTO at TMC [Keating]. At the same time, significant growth is expected in many segments of the fax market in the next five years. For example, the Fax over IP Fax Server segment is expected to show a Compounded Annual Growth Rate (CAGR) of 39.2% through 2011 and be worth $340 million. [Davidson]

Traditional T.30 Fax

Traditional real-time faxing (T.30) is inadequate and unreliable over a VoIP Network for a number of reasons. First, the T.30 fax protocol was designed for a network with relatively smooth and uninterrupted data flows, which is the opposite of the way in which an IP network behaves. In other words, the T.30 fax protocol was not created to tolerate the latency, jitter, and packet loss that are inherent in an IP network.

Second, the compression routinely implemented by VoIP networks works well for speech (based on the limited frequency response of the human ear and the human brain's ability to "fill in the gaps" when certain sounds are missing from a spoken words), but the distortion resulting from compression and packetization can easily cause a T.30 transmission to fail.

Third, the overall variability and unpredictability of an IP network (the internet in particular) makes it nearly impossible to "tune" a T.30 session to deal with IP network behavior. In addition, fax transmissions that complete when an IP network is lightly loaded may fail when the same network is more heavily loaded. The opposite is also true. If a system is tuned to complete faxes successfully when it is heavily loaded, a high fax failure rate may result when the network is lightly loaded.

Fax Solutions for VoIP

To create an environment for more reliable fax transmission over a VoIP network, the industry has adopted two solutions: Fax Pass-Through and Fax Relay.

Fax Pass-Through

Fax Pass-Through is a simple technique for creating a "fax-friendly" environment on a VoIP network. Its biggest drawback is that it makes very little distinction between voice calls and fax calls. Also called Voice Band Data (VBD) by the ITU, Fax Pass-Through refers to the transport of fax or modem signals over a voice channel through a packet network with an encoding appropriate for fax or modem signals. The minimum set of coders for Fax Pass-Through mode is G.711 (μ-law and A-law) with Voice Activity Detection (VAD) and Echo Cancellation (EC) disabled.

Two methodologies are used for implementing Fax Pass-Through. In the first, a dedicated "fax trunk" is created by configuring all ATAs, IADs, and gateways to be locked permanently at G.711 with VAD and EC disabled. While this setup may be acceptable in a small office where a "dedicated fax line" is normally available, having a dedicated fax trunk is far more expensive and severely restricts the ability of

telecom administrators to take advantage of any trunk-sharing capabilities available with the PBX or IP-PBX in their infrastructure.

A second, more elegant methodology is to install gateways that are able to distinguish between a voice call and a fax call in real time by detecting the V.21 preamble, which is part of all fax calls. Once this preamble is detected, the gateway automatically switches to Fax Pass-Through mode [Haynes].

The disadvantage of Fax Pass-Through mode is that it processes fax calls as audio calls. The tones that the sending fax machine generates are transmitted as accurately as possible through the network until they are "heard" by the receiving fax machine; however, no effort is made by the network, or any network element, to interpret the tones. All tone interpretation is left to the endpoint (receiving) fax device. Any distortion or disruption of the tones during transit across the network negatively impacts the quality of the fax transmission.

Fax Relay

Unlike Fax Pass-Through, Fax Relay breaks down the T.30 fax tones into their HDLC frames (known as demodulation) before sending the fax information through the network. This information is sent across the voice network using the T.38 Fax Relay protocol, and is then converted back into T.30 fax tones at the endpoint (known as modulation). The fax machines on either end are sending and receiving tones and are not aware that any demodulation or modulation is occurring.

T.38 is an ITU protocol that is designed to enable fax transmission over IP networks in real time. It was engineered to deal with the characteristics of an IP network, which can make standard T.30 faxing unreliable over IP. In short, the T.38 standard uses a variety of techniques that keep the T.30 communication between two T.30 endpoints from failing when even significant delay, jitter, and packet-loss occur.

Fax Pass-Through vs. Fax Relay

Although it seems obvious that Fax Relay is superior to Fax Pass-Through, have any studies been done to definitively decide the issue? Since delay, jitter, and packet loss are so critical to Quality of Service and VoIP performance, a detailed study was published in 2007 in which the impact of each was recorded and compared. [Aljaz]

For the study, a test environment was set up that consisted of the following:

- Two G3 fax machines
- Two FoIP-capable gateways

All four devices were connected on a network and signals were passed through a TDM Exchange. A packet-based network emulation device was present in the environment.

A one-page fax document was sent between the two fax machines while varying delay, jitter, and packet-loss in the packet network. Tests were made with the gateways in both Fax Pass-Through and Fax Relay modes and also with a variety of packetization speeds. In addition, T.38 was tested in both redundant and non-redundant configurations. The image quality, transmission time, and success rate were measured [Aljaz].

Delay

The effects of fixed delay were nominal on both image quality and success rate. The test page was sent with nearly a 100% success rate in both Fax Pass-Through and Fax Relay mode with no image distortion. Increasing delay did result in measurably longer transmission times (as much as 15% longer transmission times with 500 ms of network delay). Delay increased transmission time more significantly in Fax Relay Mode than it did in Fax Pass-Through mode.

Packet Loss

The effects of packet loss were much more pronounced. At 1% packet loss, single-page success rate fell to below 80% for every configuration except for Fax Relay in redundant mode. The success rate for Fax Relay in redundant mode remained above 80% until packet loss exceeded 4%. While an 80% success rate may be acceptable for a single page, a fax document greater than 20 pages has less than a 1% chance of successful delivery at that throughput level. A 55-page fax theoretically cannot be delivered (statistically to three significant digits).

In Fax Pass-Through mode, no distinction could be made between the effects of random packet loss and bursty packet loss. However, in Fax Relay mode, bursty packet loss (in which more than 10 packets in a row are lost), will significantly impact the success rate even when fax transmission is in redundant mode.

Jitter

The effect of jitter (variable delay) is normally very significant, but introducing jitter into the test network had no effect when sending faxes via Fax Relay. Fax Pass-Through was very different. With a nominal delay of 60 ms and the maximum length of the jitter buffer set to 100 ms, the success rate for faxes sent using Fax Pass-Through fell to below 80% with delay variance of as little as 17 ms in some configurations. Other configurations did stay at about an 80% success rate until the variance reached 25 ms. Success rate in Pass-Though mode increased when the maximum size of the jitter was set equal to the expected nominal delay. Increasing the maximum length of the jitter buffer to match the nominal delay had a negative effect on the quality of the voice conversations carried over the converged network.

Fax Relay Merits Serious Consideration

Taken as a whole, the research cited here indicates that Fax Relay is more reliable than Fax Pass-Through. Because packet loss and jitter are present on most networks, adopting Fax Relay should be given serious consideration, since Fax Pass-Through may not provide the QoS required for many business fax applications.

A Summary of Advantages of Fax Relay vs. Fax Pass-Through

When attempting to send real-time faxes over an IP network that is operating under normal conditions, a success rate of 80% is reasonable for single-page faxes. Unfortunately, an 80% success rate for faxes over four pages may cause them to fail. Fax documents of over 20 pages have less than a 1% chance of successful completion. The implementation of Fax Relay (T.38 protocol) in redundant mode can provide a success rate of upwards of 98% for one-page faxes even with a delay of up to 500 ms, packet loss of up to 4%, and significant jitter. Fax Pass-Through (G.7.11) does not provide an equivalent success rate, partly because G.711 is not a specialized fax protocol, but a voice protocol.

Additional Advantages of Fax Relay over Fax Pass-Through

When deciding between Fax Relay and Fax Pass-Through, two other areas to consider are bandwidth and CODEC support.

Bandwidth

When transmitting the same fax over an IP network, the bandwidth for Fax Relay is 20% of the amount needed for Fax Pass-Through. Fax Relay is a T.38 fax transmission that uses a stream of bits running at an average speed of 14,400 bps. Fax Pass-Through is a G.711 stream of audio samples running at 64,000 bps. Using Fax Relay can result in a bandwidth savings of 80% over Fax Pass-Through.

CODEC Support

When deciding between Fax Relay and Fax Pass-Through, it is important to check whether or not a network provider still supports the older technology of G.711. Because they need to maximize available bandwidth, network providers may choose to drop support for G.711 and may only support T.38 because of its superior bandwidth efficiency.

Fax Servers and MFPs

As they search for the right strategies for reducing costs, increasing productivity, eliminating operational risks, and complying with the rapidly changing regulatory environment, many enterprises are integrating fax servers, MFPs, and fax document management systems as solutions to these challenges.

Fax Servers

Fax servers support centralized faxing services for network-connected nodes. Today's fax servers sit at the center of very busy and complex networks of users, business applications, and communications technologies, and can perform a wide variety of value-added services while automating the time-intensive process of sending and receiving faxes. A central component of document management systems, fax servers provide fax document management services and perform a range of tasks. They can complete simple tasks, such as appending fax cover pages and dialing fax numbers, and more complex ones that include automating fax invoices generated by ERP systems, and routing incoming faxes to recipients and to applications that serve as a conduit for records management and workflow.

MFPs

The addition of MFPs can further enhance the overall value of a fax solution because they allow user documents to be

captured electronically by the fax document management system without requiring modifications to standard work routines. If staff members are comfortable with using traditional fax machines, the introduction of MFPs can maintain standard operating procedures while providing the benefits of a FoIP fax server. For example, users may still enter fax destination numbers into the MFP, scan documents, and receive confirmations after the fax documents are sent, but the MFPs handle the actual documents differently than traditional fax machines. The MFP collects the destination numbers and scanned document images and transfers them to a fax server where the information can be archived and indexed before the faxes are actually sent by the fax server and before the confirmation receipts are printed at the originating MFP.

Advantages of Fax Servers

Using a fax server, with or without MFPs, has several advantages. Management of telecommunications resources and the fax documents themselves is centralized, and fax information flows in an electronic, easily stored format. IT departments can more readily structure how information contained in faxed documents is accepted, routed, audited, and archived while automating labor-intensive and error-prone manual processes, which reduces costs and risk.

Dialogic® Brooktrout® Fax Products and Fax Server Applications

If you are interested in using a fax server, consider Dialogic® Brooktrout® fax products, which deliver time-tested, industry-leading fax technology. Dialogic offers a broad range of fax and FoIP products, which are supported by more than 50 software partners and approved for use in more than 40 countries (as of 2008). The Dialogic® Brooktrout® T.30 Stack has been deployed for more than 20 years and the same T.30 stack has been implemented as part of Dialogic's T.38 Fax Relay solution.

The Dialogic® Brooktrout® TR1034 Fax Board uses the V.34 standard, which enables the transmission and receipt of TDM or IP faxes at speeds of up to 33.6 kbps. Not only can the Brooktrout TR1034 process fax at twice the speed of 14.4 kbps fax boards, but it also supports V.8 fast handshaking and advanced compression, which can cut call setup and session-management time by one-third. A document that can be faxed in one minute with a 14.4 kbps intelligent fax board can be sent in less than 30 seconds with the Brooktrout TR1034. This can translate into significant savings on long-distance toll charges.

Dialogic® Brooktrout® SR140 Fax Software can provide effective options for application developers because Brooktrout SR140 supports the Dialogic® Brooktrout® Bfv API, the same API used throughout the Dialogic® Brooktrout® line of fax products. Developers can choose to write one application to the Bfv API and deploy it on both TDM and IP equipment. This dual-network support also allows developers, who wish to sell into both TDM and IP accounts, to use either a Brooktrout TR1034 or Brooktrout SR140. The SR140 also supports the V.34 standard.

Using Dialogic® Media Gateways in FoIP Solutions

Dialogic® Media Gateways can be used to connect many IP-based applications, including FoIP server applications, with a PSTN/TDM environment, allowing data to flow freely between the two types of networks.

Dialogic® Media Gateway Series are available in a range of densities, work with PSTN and many leading PBX interfaces, and support the T.38 protocol. All are rigorously tested and have been proven compatible with Brooktrout SR140, which can provide a reliable option for deploying FoIP server applications in a hybrid TDM-IP environment. In addition, the high-speed V.34 fax protocol over T.38 is supported (as of 2008) by Brooktrout SR140 and both the Dialogic® 3000 Media Gateway Series and Dialogic® 4000 Media Gateway Series. Support is planned for the Dialogic® 1000 Media Gateway Series and the Dialogic® 2000 Media Gateway Series.

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Acronyms

ATA	Analog Telephone Adaptor
EC	Echo Cancellation
ERP	Enterprise Resource Planning
HDLC	High-level Data Link Control
IAD	Integrated Access Device
IP	Internet Protocol
IP-PBX	PBX for an IP network
FoIP	Fax over IP
ITU	International Telecommunications Union
MFP	Multi-Function Peripheral
PBX	Private Branch eXchange
PSTN	Public Switched Telephone Network
POTS	Plain Old Telephone System
QoS	Quality of Service
TDM	Time Division Multiplex
VAD	Voice Activity Detection
VAR	Value Added Reseller
VBD	Voice Band Data
VoIP	Voice over IP

For More Information

Find the latest information about the Dialogic products mentioned in this paper by visiting the Dialogic website at www.dialogic.com. You can also subscribe to *Dialogic View*, a monthly newsletter that provides the latest news about Dialogic® technology and products.

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