The Fax on IP Networks

White Paper | *February 2011*

MESSAGEmanager Solutions

Contents

Executive Summary

Despite the popularity of e-mail and the Internet, fax continues to be an important technology for business communications. According to fax industry analysts Davidson Consulting an estimated 112 million fax machines are transmitting more than 100 billion fax pages of invoices, purchase orders, legal documents, financial summaries, confidential and mission-critical business documents around the globe on a yearly basis.

By today's standards it is not unreasonable to consider fax a dated technology, it was invented in 1843, over 160 years ago! It was not until the Group 3 standard was published in 1980 by the International Telecommunications Union (ITU), that fax gained a reputation as a popular, universally compatible, inexpensive and reliable technology for business to business communication.

VoIP is the standard for voice communications in most organisations today. But in the rapid transition to VoIP fax is often overlooked or ignored as many organisations presume fax will work just as effectively on IP Networks. But getting fax to work reliably has become one of the biggest challenges facing organisations as they switch from the public switched telephone network (PSTN) to Voice over IP (VoIP).

Fax over an IP Network (FoIP) presents a special problem because the fax protocols rely on very precise timing mechanisms. Circuit switched networks for which Group 3 fax was designed don't have jitter and the modulation techniques and protocols specified in the G3 standard contain no provision for dealing with it.

Group 3 Fax Technology

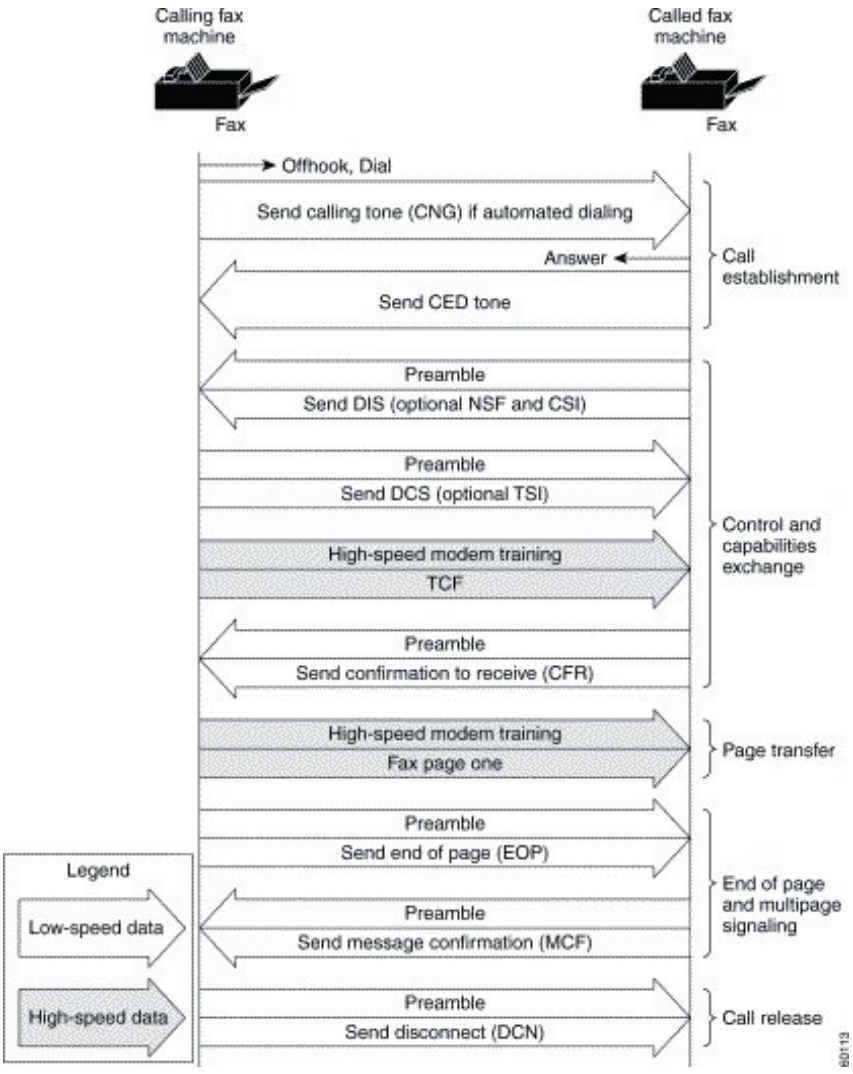
Group 3 is specified in several standards - T.4 specifies the image-transfer protocol and T.30 specifies the session-management procedures.

Fax machines are fundamentally a modem with an image scanner and printer and work by scanning the source image and converting it into a stream of pixels that are transmitted to the remote terminal using the ITU T.30 data protocol. T.30 is an interactive protocol that is composed of commands and responses that allow the terminals to negotiate capabilities at run time and agree on such things such as transmission speed and page size, how the pixel data is compressed and how to attach additional meta-data to the transmission like the source terminal number.

Error detection and correction solve the drop-out and signal noise problems.

T.30 is transmitted over a switched circuit voice line by converting the bit stream into modulated tones. This is the familiar warbling you hear when you accidentally pick up on a fax call. But these tones are merely the modulation technique used to transmit the T.30 data over a fixed bandwidth communications channel. The actual payload is the underlying T.30 fax commands transmitted at baud rates between 300 and 33600 baud. At the conclusion of the fax call, T.30 makes sure that a graceful disconnect occurs between the fax devices.

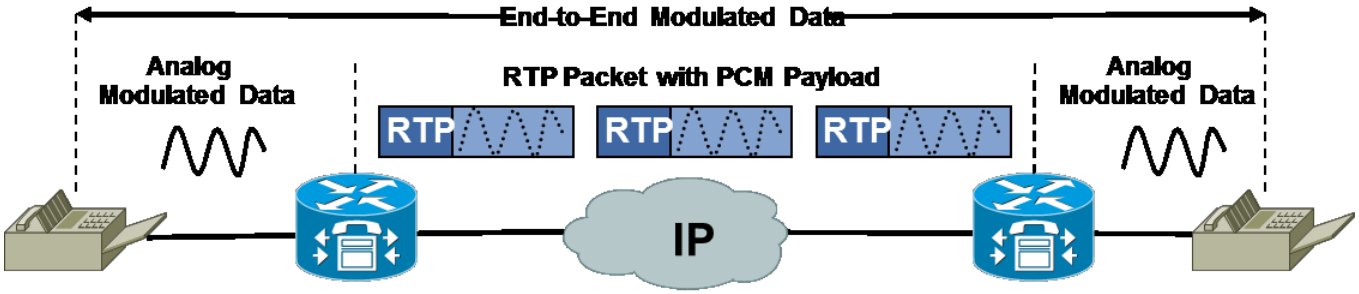
With the exception of certain signals that are nothing but single frequency audio tones, the T.30 messages used in communication between two fax devices consist of binary coded data.



From a high-level overview, this can simply be viewed as a preamble followed by the binary data itself in the form of High-Level Data Link Control (HDLC) frame(s) but a G3 fax preamble occurs every time new information is sent in either direction. The preamble consists of repeated flag sequences that last for about one second. These flags help condition the line so that the ensuing real data can pass without problems. These preamble tones occur quite often because they precede any HDLC frame or group of frames from either the sending or receiving side, usually following short silence periods.

G.711 Fax Pass-through

Modulated fax data information is sampled and encoded as standard PCM (i.e. G.711) and encapsulated in RTP for transport over IP just like a voice codec does for human speech. From the gateway perspective, this is more or less a G.711 voice call, commonly referred to as Voice Band Data (VBD).



When network conditions are perfect in a VoIP deployment, a fax sent in Pass-through mode using the G.711 codec will work exactly like a PSTN-based fax call.

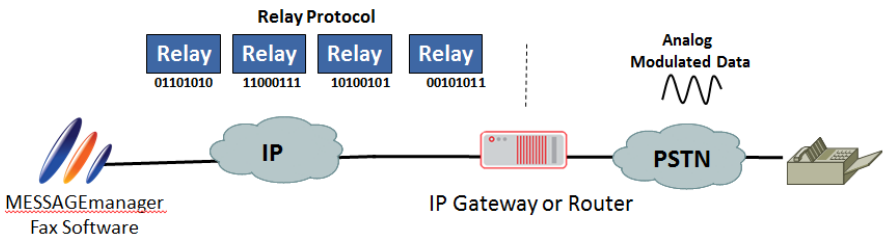
In spite of being similar in nature, Voice and Fax Pass-through calls are affected differently by IP Network impairments. Because Fax Pass-through calls' data cannot be altered during its transport, these calls are more susceptible to IP problems than voice calls. Voice calls may experience some degradation from certain network impairments, and the parties involved on the call might not even realise the degradation is occurring. In addition, there are mechanisms in place for most compressed audio codecs such as predictive algorithms and packet loss concealment techniques that can assist in masking many network problems. These techniques, however, do not protect Fax Pass-through transmissions.

T.38 IP Fax Relay

In 1998 the ITU published the T.38 fax relay standard to enable faxes to be transported across IP Networks between existing Group 3 (G3) fax terminals. T.38 is today the standard for fax transmissions on IP Networks, especially when interoperating with third party devices.

Gateways serve as bridges between the legacy PSTN and IP Networks transforming the PSTN call stream to data packets, and vice versa, isolating the PSTN Fax terminals from the delays, timing jitter and packet loss as far as possible. And by sending fax as image data, rather than digitised audio, they reduce the bandwidth required on the IP Network.

- The analog modulated fax data is demodulated by a DSP on the gateway and the binary information extracted.
- Binary information is passed over IP using T.38 relay protocol.
- A DSP on the destination gateway takes the binary information from the relay packets and re-modulates it into a fax data signal on the telephony side.



Network Design Considerations

Fax Pass-through calls are very sensitive to packet loss, especially when carrying high-speed modem modulations. Lab testing shows that as little as 0.02 percent packet loss can cause Pass-through calls to fail.

T.38 fax calls may use the protocol's redundancy mechanism to handle substantially more packet loss than Pass-through. It has been shown that T.38 calls can succeed with up to 10 percent random packet loss.

Pass-through and T.38 fax calls may also respond differently to certain IP Network impairments. The following table lists specific impairments and descriptions of how each one may impact T.38 and G711 Pass-through calls.

Impairment	Definition	Description
Packet Loss	A relative measure of the number of packets that were not received compared to the total number of packets transmitted.	Fax Pass-through calls are very sensitive to packet loss, especially when carrying high-speed modem modulations. Lab testing shows that as little as 0.02 percent packet loss can cause Pass-through calls to fail. T.38 fax calls may use the protocol's redundancy mechanism to handle substantially more packet loss than Pass-through. It has been shown that T.38 calls can succeed with up to 10 percent random packet loss.
Delay	The finite amount of time it takes a packet to reach the receiving endpoint after being transmitted from the sending endpoint.	The recommendation for voice is to keep the one-way latency (mouth-to-ear) to less than 150 ms. In the case of Fax Pass-through and T.38 calls, delay is not typically as much of an issue as it can be for voice.
Jitter	The delay variation between packets or the difference in the end-to-end delay between packets.	Average one-way jitter of less than 30 ms is the recommendation to ensure voice QoS. With T.38 and Fax Pass-through, average jitter less than 30 ms is not quite as critical.
Clock Skew	The running sum of the differences between when packets actually arrive at a destination and when they were expected.	Synchronisation issues between a voice gateway and an IP endpoint are more critical for Fax Pass-through than for T.38 and voice. When using the Pass-through transport method for long fax calls, there can be issues because of the lack of clock synchronisation between the DSPs on the voice gateway and an IP endpoint. The gateway and endpoint use different clocks, therefore a clocking discrepancy, ever so slight in some cases, will always exist between the rates that packets are generated and consumed. This slight clocking discrepancy can cause playout buffer underrun/overrun on the voice gateway, which can result in bad image lines or PPRs in Error Correction Mode (ECM).

It should also be noted that Voice Activity Detection (VAD) and silence suppression should be disabled for G711 Fax Pass-through calls on gateways that do not already perform this action upon detection of fax signals. This is needed in order to avoid fax signal clipping that can be caused by VAD algorithms that are used to suppress silence in voice calls.

What the Experts Say

According to the paper "The packet-based networks performance requirements for real-time facsimile transmission", *Computer Communications*, "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.

At 80% single page success rate, a fax document of more than 20 pages has less than a 1% chance of success and a 55 page fax statistically cannot be delivered successfully."

The authors concluded “It was not possible to recreate a network condition in the testing environment that the T.38 protocol, in redundant or non-redundant mode, could not have coped with.”

Vonage (NYSE: VG), a technology company that provides voice and messaging services over broadband networks used G.711 Fax Pass-through in an unmanaged network. Vonage users received a very high rate of Fax failures and launched a Class Action Suit. The court determined Vonage made false and misleading statements and concealed material information in the marketing, advertising and sale of Vonage Fax Services by failing to inform consumers that the protocol that Vonage used for the Fax service was unreliable and unsuitable for Fax communications.

David Hanes an engineer in Cisco's Customer Advanced Engineering (CAE) team and co-author of the book Fax, Modem, and Text for IP Telephony, says “for Cisco customers who may want to integrate fax communications with third party products, such as voice gateways and fax servers, T.38 fax relay is a necessity.”

T.38 can result in a bandwidth savings of 80% over 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.

Fax module Rate in bps	Redundancy	T.38-100ms bandwidth (kbps)	G.711-10ms bandwidth (kbps)	Remarks
V.27ter 2400	R0	8.48	126.4	T.38 of 8.48 kbps is 15 times lower than G.711.
	R1	11.36	194.4	
	R3	17.12	328.8	T.38 is 19 times lower.
V.29/V.17 9600	R0	15.68	126.4	
	R1	25.76	194.4	
	R3	45.92	328.8	T.38 is 7 times lower. This is most popular in deployment.
V.17 14400	R0	20.48	126.4	
	R1	35.36	194.4	
	R3	65.12	328.8	T.38 is 5 times lower.
V.34 33600	R0	39.68	126.4	T.38 is at least 2 times better.
	R1	73.76	194.4	
	R3	141.92	328.8	
V.34 33600-40 ms packets	R3	153.2	328.8	T.38 is 2 times lower than G.711 even at 40 ms packets.

MESSAGEmanager IP Fax Software

MESSAGEmanager Solutions supports both T.38 IP Fax and G711 Pass-through.

Pass-through is only supported on managed networks as G711 Pass-through over unmanaged networks can result in significant fax protocol errors which cannot be resolved. T.38 is recommended for all unmanaged networks.

It should be noted that G711 Fax is more prone to the impact of Virtual Machine timing inaccuracies.

MESSAGEmanager IP Fax software will operate on any VoIP network with latency ranges from 250-300 milliseconds or less for each packet. To protect against packet loss, MESSAGEmanager sends redundant packets. Variable timing between packets (jitter) is overcome by adding time stamps to the packets ensuring signals are ‘played’ at the right instance by the gateway.

IP Fax introduces no additional threat to security from network attack. MESSAGEmanager IP Fax sits behind the corporate firewall. If malicious packets get through or a virus is spawned internally:

- Invalid RTP packets are dropped.
- Invalid T.30 messages are dropped.
- Invalid T.4/T.6 image data is dropped.
- Invalid T.30 messages or T.4/T.6 image data for a specific point in the call are dropped.

About the Author

Ivor Livingston is the founder and Chief Executive of MESSAGEmanager Solutions. In this role he is responsible for driving the strategic direction of the company by identifying emerging and powerful technologies that meet industry demands, high-level consulting and international expansion initiatives. Ivor has over 25 years of experience in researching, marketing and delivering computer telephony solutions.

MESSAGEmanager Solutions is a pioneer of computer based telex, fax, voice messaging and communications. The company is credited with developing the world's first Fax Server in 1986 for Australian Carriers Telecom and OTC. Today we are acknowledged as a global leader in IP Fax and voice messaging and communication solutions.

MESSAGEmanager Solutions is a Microsoft Gold Certified Partner, IBM PartnerWorld Member, SAP Certified Solution, HP Development Partner, Dialogic, Nuance, Avaya Gold Partner, Cisco Technology Developer and Audiocodes Partner.

Our technical services have designed and implemented IP solutions on various platforms including Cisco, Avaya, Alcatel, and Audiocodes in USA, UK, Singapore, Canada, South Africa, Israel, Asia and Australia.

MESSAGEmanager Solutions

Level 8, 9 Help Street
Chatswood, NSW 2067 Australia
info@mmanager.com
sales@mmanager.com
www.mmanager.com

Australia Tel: +61 2 8448 8800
Fax: +61 2 8448 8811
Canada: 1877 370 1261
Hong Kong: 800 905 955
Israel: 077 901 1111

New Zealand: 0800 445 308
Singapore: 800 616 3168
South Africa: 011 912 9358
United Kingdom: 0800 169 8226
United States: 1877 884 1664