AudioCodes

V.34 Fax Relay over Packet Networks

December 2011

WHITE PAPER

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Scope

This white paper provides a technical overview of V.34 fax technology and is intended for Fax over IP (FoIP) application and test engineers, FoIP gateway vendors and customers, and FoIP customer support. A brief introduction in V.34 fax relay technology is given with reviewing fax signals exchanged during different phases of V.34 fax call, stimulus signals for transitioning gateways to V.34 fax relay, different methods of V.34 fax communication over the Internet, and optimal methods of T.38 call establishment.

Standard Abbreviations

ANSam	V.8 Answer tone, 2100 Hz, amplitude-modulated
CI	V.8 Call Indicator signal
CJ	V.8 CM terminator
CM	V.8 Call Menu signal
JM	V.8 Joint Menu signal
CFR	T.30 Confirmation to Receive
CNG	T.30 Calling fax tone
CSI	T.30 Called Subscriber Identification
DCN	T.30 Disconnect
DCS	T.30 Digital Command Signal
DIS	T.30 Digital Identification Signal
EOP	T.30 End of Page
ECM	T.30 Error-Correction Mode
HDLC	High-level Data Link Control
MCF	T.30 Message Confirmation
PPS	T.30 Partial Page Signal
SDP	Session Description Protocol
SIP	Session Initiation Protocol
TCF	T.30 Training Check Frame
TSI	T.30 Transmitting Subscriber Identification

Overview

The late 1990s and early 2000s were remarkable for the appearance and widespread proliferation of high-speed faxes based on the V.34 half-duplex modulation system. Faxes featuring V.34 modulation capability are also known as “super G3” faxes. Relative to regular G3 faxes, V.34 faxes significantly reduce the total time of fax image transfer over PSTN. The time saving is achieved thanks to the following V.34 advantages:

- Fax image transfer at higher data rates of up to 33600 bps vs. the regular G3 maximum fax rate of 14400 bps
- Estimation of optimal symbol rate, data signaling rate and other modulation parameters while avoiding using T.30 TCF
- Capability of fast renegotiation of the data signaling rate without restarting T.30 Phase B
- Fast T.30 control at 1200 bps full-duplex vs. 300 bps half-duplex V.21 of regular G3 faxes

The T.38 Recommendation initially published in 1998 defined the regular T.30 fax relay over IP (FoIP). Due to high complexity of V.34 modulation, and due to the T.30 incompatibility of V.34 fax relative to regular fax communication, for several years the T.38 had no support of V.34 fax relay; and the first three versions of T.38 – namely, version 0 (dated 1998), version 1 (dated 2000), and version 2 (dated 2002) – were based on regular fax modulation schemes.

Two alternative methods of transferring V.34 fax calls over packet networks were used and continue to be used today:

- Voice-Band Data (VBD) fax transfer per V.151.1 and V.152
- V.34 fax fallback to regular G3 fax relay at data rates of up to 14400 bps (V.17 modulation)

In VBD mode, all V.34 fax signals are transferred using a low distortion compression, for example, PCM A-/-µ laws. The VBD method is attractive because it is least complex compared to FoIP and it allows a native V.34 operation at fax rates of up to 33600 bps. But VBD transfer may be problematic because:

- The VBD stream cannot be used by fax servers, internet-aware faxes, and other fax relay oriented applications
- Broad bandwidth consumption even without redundancy (≈64 kbps, full-duplex)
- Low immunity to packet loss
- Low tolerance to network jitter and constant delay
- Low tolerance to sampling rate difference (or clock offset) between originate and answer side gateways
- High sensitivity to imperfections of echo canceling

In order to allow FoIP communication between V.34 fax terminals by using T.38 of version 0, version 1 or version 2, a FoIP gateway may need to force the V.34 fax terminals to operate in a fallback mode limited by V.17 modulation at data signaling rates (fax rates) of up to 14,400 bps. Gateways may use different methods to force a V.34-to-V.17 fallback which result in establishing a T.38 session based on regular (non-V.34) modulation at both sides of communication.

A growing usage of V.34 fax terminals required adequate signal processing by FoIP gateways and an adaptation of the FoIP protocol. Accordingly, version 3 of the T.38 (dated 2007) defines an extended FoIP protocol of V.34 fax communication over IP at fax rates of up to 33,600 bps.

The following sections summarize important T.30 definitions for full V.34 fax relay and V.34 fax relay in fallback mode.

V.34 Fax Call over the PSTN

A V.34 fax call may be divided into the following phases (according to ITU-T recommendations T.30 from 09/2005 and V.34 from 02/98):

- Phase A – V.34 Call Establishment
- V.34 Phase 2 – Line probing
- V.34 Phase 3 – Primary channel equalizer training
- Phase B – Pre-message procedures
- Phase C – In-message procedure
- Phase D – Post-message procedure
- Phase E – Call release

Figure 1 and Figure 2 show an example of a single fax call (Phase A through to D).

T.30 Phase A – V.34 Call Establishment

Figure 1 shows a typical signal flow corresponding to T.30 Phase A of V.34 call establishment. Phase A starts with a tonal exchange between calling and answering fax terminals. It includes V.34 Phase 1 beginning with an ANSam tone. During V.34 Phase 1, the fax terminals exchange V.8 CM and JM messages to define the fax call type. If the answering fax does not confirm having V.34 fax capability, then when the V.8 signal exchange is complete, the fax terminals enter regular T.30 Phase B. If the answering fax confirms V.34 capability, the terminals enter proper V.34 fax procedures, shown in Figure 2.

Generally, a more complex scenario is possible when an answering fax terminal uses regular T.30 Phase B for transmission of T.30 capabilities (DIS) before it enters normal V.34 operation. In this case, the calling fax may transmit the V.8 CI signal to initiate V.34 Phase 1.

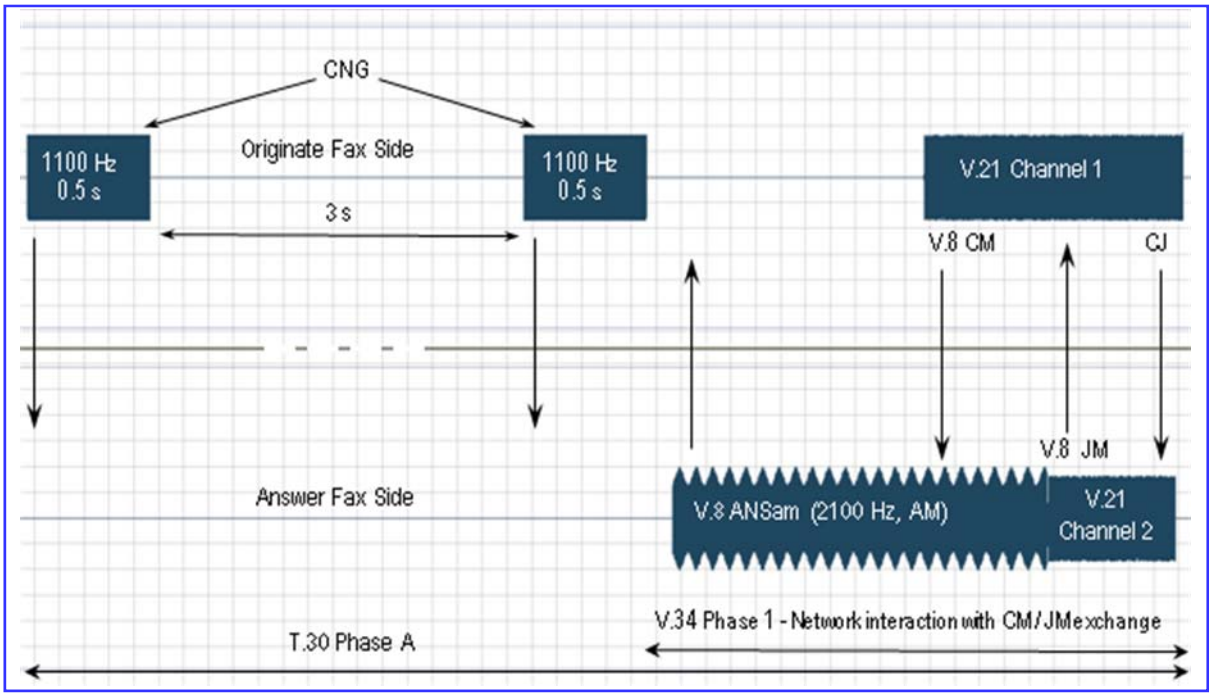

Figure 1: T.30 Phase A – V.34 Call Establishment

V.34 Phase 2 – Line Probing

Entering V.34 Phase 2, fax terminals send full-duplex INFO0c and INFO0a signals at 600 bps to exchange the supported symbol rates and other V.34 capabilities. After a successful exchange by INFO0 sequences, the originating fax modem transmits line probing signals. The answering fax modem receiving the line probing signals analyzes the channel characteristics and selects the optimal symbol rate, carrier frequency, pre-emphasis filter, and power reduction to be used during V.34 Phase 3 and later for every fax page of T.30 Phase C. The selected parameters and requested V.34 TRN duration are forwarded to the originating fax by INFOh sequence. After successfully transferring INFOh, the originating and answering modems enter V.34 Phase 3.

V.34 Phase 3 – Primary Channel Equalizer Training

In this phase, the originating fax modem sends a half-duplex TRN signal. An answering fax modem receiving the TRN trains the primary channel equalizer and precoder coefficients and adapts the other demodulation parameters. When TRN duration expires, the fax modems launch a V.34 control channel (1200 bps, full-duplex) and exchange modulation parameter sequences: The MPh0 sequence of the originating modem and the MPh1 sequence of the answering modem. The MPh modulation parameters contain a maximum data signaling rate and other options offered by the V.34 modem. The MPh1 sequence sent by the answering fax additionally includes the precoder coefficients which should be used by the primary channel transmitter of the originating fax.

After a successful exchange of modulation parameters, the fax terminals continue the full-duplex operation of the control channel and enter T.30 Phase B with transmission of HDLC flags.

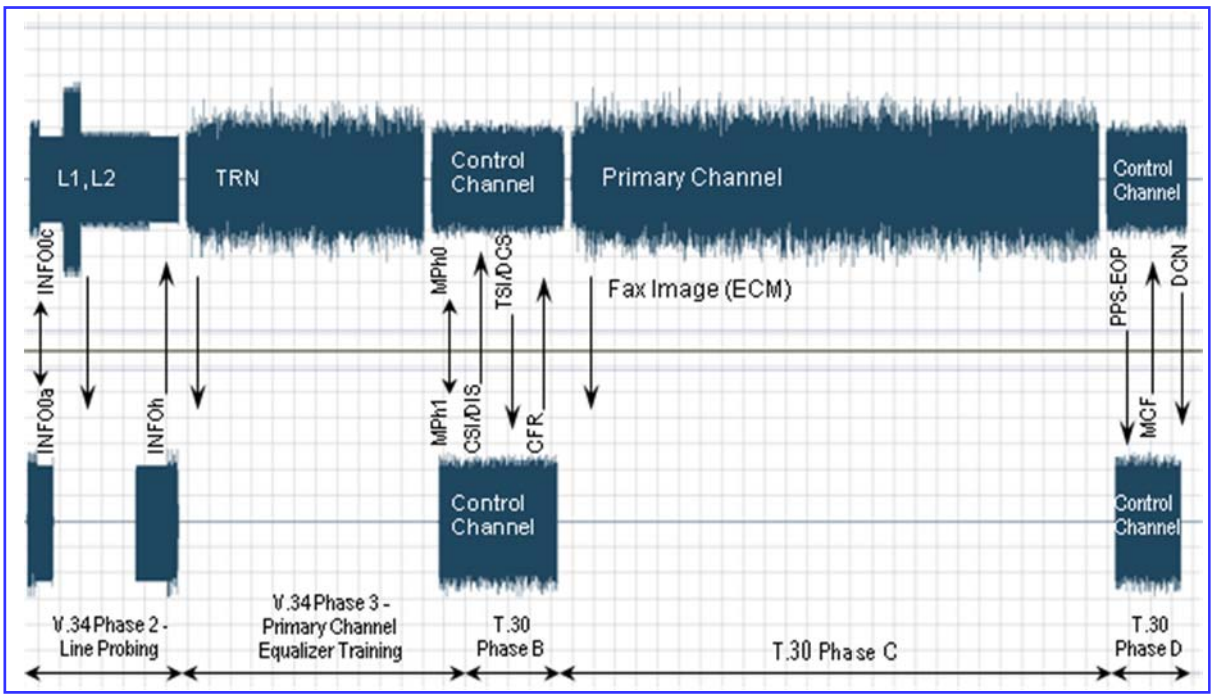

Figure 2: V.34 Fax Procedures

Phase B – Pre-Message Procedures

After Phase B, all pre- and post-message commands and responses of T.30 control are exchanged using the V.34 control channel. The content of T.30 frames exchanged using the V.34 control channel is similar to that of a regular G3 fax session. But the process is much faster relative to regular T.30 control exchange by V.21, because

- The V.34 control channel bit rate is 4 times faster
- HDLC preamble of duration 1.0±0.15 sec is not required. According to T.30, at least two HDLC flags (13.3 msec) are enough to send before the first HDLC frame.

The V.34 fax modulation system does not use TCF defined by T.30 for Phase B of regular G3 fax. In Phase B (see Figure 2), an answering V.34 fax sends T.30 capabilities [CSI/] DIS to the originating fax and waits for a DCS command. On receipt of the DIS from the answering fax, the originating V.34 fax sends a [TSI/] DCS command and waits for CFR confirmation. On receipt of the DCS from the originating fax, the answering fax responds with a CFR. The originating fax, on receipt of the CFR, starts a normal turn-off procedure of the control channel after which both faxes enter T.30 Phase C of fax image transfer.

By analyzing the telephone line for maximum use of line bandwidth and estimating modulation parameters required for optimum image transfer, the V.34 faxes substantially reduce a total duration of phases preceding Phase C relative to regular G3 fax. The highest gain in transmission time preceding T.30 Phase C is achieved when line conditions do not allow transferring a G3 fax at the maximum data rate. Where a regular G3 fax may perform some attempts in Phase B to choose an appropriate data rate and modulation system (V.17, V.29, or V.27), a V.34 fax is capable of entering the image transfer directly after a single attempt of line probing and TRN.

Phase C – In-Message Procedure

The binary data of fax image and Return-to-Control for Partial page (RCP) frames are sent using the half-duplex primary channel. T.30 Error-Correction Mode (ECM) is mandatory for V.34 faxes.

The primary channel signal is transmitted using a symbol rate, carrier frequency, pre-emphasis filter, and power reduction specified by INFOh from the answering fax. The data signaling rate is the maximum rate enabled that is less than or equal to the data signaling rates specified in both modems' MPh sequences. The other modulation parameters of primary channel (types of trellis and non-linear encoders, constellation

shaping, and precoder filter coefficients) are applied according to the values specified by MPh1 of the answering fax modem.

After transmission of the fax image and RCP, the originating fax turns off the half-duplex primary channel and enters T.30 Phase D.

Phase D – Post-Message Procedure

In Phase D, the communicating modems resynchronize the V.34 control channel. Also, instead of resynchronization of the control channel, a fax modem may initiate a control channel start-up followed by modulation parameters MPh exchange. This is useful when a change of MPh is required. For example, an answering fax that received a fax image of Phase C as non-satisfactory, may request a reduction of the data signaling rate. In contrast to regular G3 fax procedures, renegotiation of the data rate is extremely fast and does not require retraining the image type modulation system.

After resynchronization of V.34 control channel or control channel start-up with MPh renegotiation, the modems are ready to exchange a T.30 post-message command of the originating fax, for example, PPS-EOP, and post-message response of the answering fax. If a final partial page is positively confirmed by MCF of the answering fax, the originating fax sends a DCN (see Figure 2).

On completion of Phase D, fax terminals execute a normal turn-off procedure of the control channel. If the fax image transfer is not completed, or a retransmission is required, then the fax terminals return to Phase C. In case of DCN exchanged, the fax modems terminate the fax session via T.30 Phase E.

Phase E – Call release

Fax terminals physically disconnect. Under certain conditions, call release may be irregular, for example, before completion of image transfer.

V.34 Fax Relay Stimulus Signals

Calling Fax Tone (CNG)

A calling fax tone (CNG) is common to regular G3 and V.34 fax calls. Generally, the CNG stimulus tone provides transitioning to fax relay with highest reliability because gateways may switch a voice-over-IP (VoIP) operation mode onto a fax relay during a silence period of CNG. Sometimes, however, fax relay initiated by a CNG tone may be undesirable, for example, if:

- Call progress and/or speech signals exist during CNG
- Called terminal equipment is a regular telephone and not a fax

According to V.150.1, the CNG alone is not enough to indicate that a call is a facsimile and in some cases, the originating fax may not transmit it.

V.8 Answer Tone (ANSam)

As stimulus signals, a called fax tone CED and a V.8 answer tone ANSam allow safe transitioning of gateways from VoIP or VBD to fax relay state. To avoid answer tone irregularities caused by the gateway switching from VoIP to a non-VoIP state, ITU-T V.150.1 recommends blocking the answer tone sent from the answering equipment in the direction of the network, while the gateway determines answer tone type.

As the ANSam signal is common to V.34 fax and modem terminals, using only ANSam as a stimulus of V.34 fax relay may be problematic for modem transport over packet networks, though in environments without modems or in fax server gateways, the ANSam may be a recommended stimulus signal for transitions to V.34 fax relay.

CNG and Answer Tone

AudioCodes gateways performing bi-directional monitoring of fax signals use the following signal combinations as stimuli for safest transitioning to fax relay:

- A CNG detected from the network and an answer tone received from TDM input
- A CNG received from TDM input and an answer tone detected from the network

Out-of-band signaling may be applied as an alternative to monitoring the signals decoded from the network stream.

V.8 CM

A V.8 call menu (CM) sent by a calling fax terminal in response to an ANSam received from an answering fax terminal is definitely a good signal for discriminating V.34 fax calls. But for fax relay call setup, the V.8 CM may be less safe compared to CNG and/or ANSam because transition to fax relay state occurs in the middle of the answer tone and may cause tone irregularities. AudioCodes gateways use the V.8 CM stimulus signal if they're not switched to fax relay at earlier stages.

V.21 Preamble Flags

The V.21 preamble of HDLC flags is common to regular G3 fax and manual V.34 fax calls. It is a good signal for fax call discrimination and is considered a mandatory stimulus for transitioning to fax relay. Sometimes, though, a switch to fax relay - initiated by V.21 preamble flags - may be problematic due to:

- Irregularities in the V.21 signal caused by the switch
- Prolonged gateway negotiation at stage of T.38 call setup, possibly resulting in loss or irregular delay of T.30 data

AudioCodes gateways use the V.21 preamble as a final stimulus signal if they're not switched to fax relay at earlier stages.

V.34 Fax Relay in Fallback Mode

When a V.34 capable fax terminal (super G3) communicates with a regular G3 fax, the fax call is always regular G3:

- A calling V.34 fax terminal cannot start in V.34 Phase 1 because the answering G3 fax terminal cannot transmit an ANSam
- An answering V.34 fax enters regular Phase B after an ANSam because the calling G3 fax terminal cannot transmit a V.8 CM.

For such calls, independently of T.38 version capabilities of communicating gateways, the corresponding fax relay session will be regular G3 fax relay performed at fax data rates up to 14400 bps of V.17. The only non-regular T.38 packet **v8-ansam** may appear at the beginning of fax relay session if both gateways support T.38 version 3.

A more complex scenario takes place when V.34 fax terminals connect through gateways not supporting V.34 fax procedures. For example, if ANSam and V.8 CM signals are transferred in VoIP or VBD mode, then gateways waiting for the V.21 preamble may miss the possibility of entering fax relay because V.34 faxes do not use HDLC protocol during automatic V.8 negotiation.

To resolve this problem, according to T.38 Recommendation, gateways not supporting T.38 version 3 must prevent transferring the fax CM over VoIP or VBD to the answering fax terminals, and avoid V.8 capability to be relayed in V.21 DIS frame to calling fax terminals.

Some gateways may support T.38 version 3 or higher but not be capable to V.34 modulation system, for example, gateways may use high versions of T.38 to allow obsolete V.33 modulation (14400/12000 bps) or/and new methods of T.38 call establishment. Such gateways, alternatively to blocking V.8 interaction, may allow T.38 **v8-cm-message/v8-jm-message** packet exchange, but prevent the relaying V.34 modulation capability.

After avoiding or resolving the V.8 negotiation problem, the gateways may continue regular fax relay which forces V.34 fax terminals to operate in non-V.34 mode at fax data rates of up to 14400 bps of V.17.

V.34 Fax Relay per T.38 Version 3

The following Figure 3 is a schematic block-diagram illustration of a FoIP communication system. System may include, on one communication side, a calling or answering V.34 fax terminal connected to a switched network, and may further include, on another communication side, an IP network connected to a remote gateway or an IP fax device. A FoIP gateway may be connected between the switched network and the IP network. The remote FoIP capable gateway, in turn, may be connected to a fax terminal, which may be an answering or calling fax terminal.

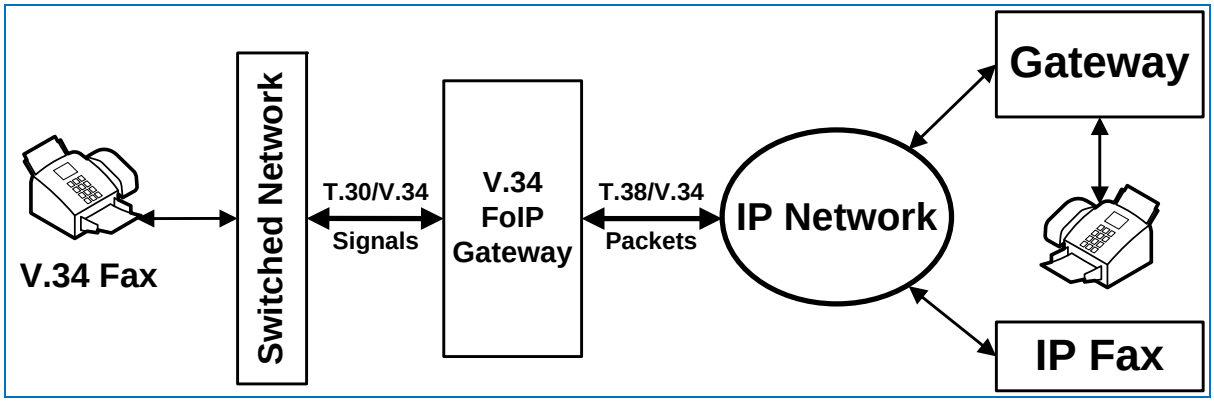

Figure 3: Typical layout of V.34 FoIP communication

A FoIP gateway may receive analog signals from a facsimile terminal, for example the V.34 fax terminal, through the switched network. The FoIP gateway may demodulate or convert the analog fax transmission to a fax data set, may encode and packetize the fax data set according to the T.38 FoIP protocol, and may relay the fax packets over the IP network to the remote gateway or to an Internet-aware fax device, e.g., the IP fax.

Independently of whether a V.34 fax relay call is initiated during automatic or manual T.30 call establishment procedures, the local and remote gateways must finally pass V.34 Phase 1 of V.8 ANSam/CM/JM interaction to enter the main V.34 fax signal processing. A V.34 FoIP gateway receiving a V.34 CM signal from a connected V.34 call fax may send a T.38 **v8-cm-message** packet carrying a T.38 Facsimile Application Profile (FAP). As a response on the **v8-cm-message** packet, the gateway may receive a **v8-jm-message** packet carrying a T.38 acknowledgement (ACK) of a remote gateway or IP fax.

The local and remote FoIP gateways may start the V.34 modulation system if the FAP with V.34 half-duplex is acknowledged by ACK. Otherwise, gateways may perform fallback to regular G3 fax relay, or, if there is no compatible mode, may terminate the FoIP session.

On the successful completion of a **v8-cm-message** and **v8-jm-message** packet exchange, a V.34 FoIP gateway enters V.34 Phase 2. In this phase, each of the communicating gateways locally establishes a symbol rate, data signaling rate and other modulation parameters to be used in T.30 phase C.

At the V.34 signal processing level, two gateways connected in V.34 fax relay mode are highly independent of each other because V.34 modulation parameters, excluding data signaling rate, are not exchanged via IP packet network. The data signaling rate is relayed using a T.38 **v34-pri-rate** data packet from the T.38 receiving gateway (for example, on answering fax side) to the T.38 emitting gateway (for example, on the calling fax side). The emitting gateway is responsible for selecting a data signaling rate not greater than the **v34-pri-rate**. The maximum difference between data signaling rates of V.34 fax relay gateways corresponds to 2400 bps of the emitting gateway and 33600 bps of the receiving gateway.

The T.30 control data are relayed between communicating gateways in T.38 **v34-CC-1200-hdlc-xxx** data packets.

On transitioning from control channel to primary channel, a T.38 emitting gateway sends a **v34-pri-channel** indicator packet to receiving gateway. The fax image data of T.30 phase C are relayed by T.38 **v34-pri-ch:hdlc-xxx** data packets.

The T.38 emitting gateway transiting from T.30 phase C to T.30 phase D of post-message procedure sends a **v34-cntl-channel-1200** indicator packet to receiving gateway. The T.38 receiving gateway, before sending T.30 post-message response data, may re-negotiate the data signaling rate by sending a T.38 **v34-CC-retrain** indicator packet followed by **v34-pri-rate** data packet.

The V.34 FoIP session is normally ended in T.30 phase E on completion of T.30 DCN transfer followed by **v34-CC-1200:hdlc-sig-end** packet.

T.38 Call Setup

To enable T.38 packet exchange over the packet network, communicating gateways exchange T.38 capabilities during SIP/SDP call establishment procedures. The gateway negotiation is done by first offer and answer SDP, using SIP INVITE and 200 OK response. Because the T.30 phase A of V.34 calls is significantly differ relative to T.30 phase A of regular G3 fax calls, the SIP/SDP interaction and gateway operation may have some peculiarities to allow an optimal V.34 fax relay.

A completion of VBD and T.38 capabilities negotiation at call start enables smooth switching between audio RTP to T.38 or audio to VBD codecs on fax and modem detection. For example,

1) OFFER (SIP INVITE):
INVITE sip:101@xx.xx.xx.78;user=phone SIP/2.0
Via: SIP/2.0/UDP xx.xx.xx.70;branch=z9hG4bKac663170125;rport
From: <sip:501@xx.xx.xx.70>;tag=1c662567132
To: <sip:101@xx.xx.xx.78;user=phone>
Call-ID: 66253175228112011195 37@xx.xx.xx.70
CSeq: 1 INVITE
Contact: <sip:501@xx.xx.xx.70:5060>
Content-Type: application/sdp
Content-Length: …
v=0
o=Mediant-800 661883735 661869660 IN IP4 xx.xx.xx.70
s=Phone-Call
c=IN IP4 xx.xx.xx.70
t=0 0
m=audio 6000 RTP/AVP 18 118
a=rtpmap:18 G729/8000
a=fmtp:18 annexb=no
a=rtpmap:118 PCMA/8000
a=gpmd:118 vbd=yes
a=ptime:20
a=sendrecv
m=image 6002 udptl t38
a=T38FaxVersion:3
a=T38MaxBitRate:33600
a=T38FaxMaxBuffer:3000
a=T38FaxMaxDatagram:560
a=T38FaxRateManagement:transferredTCF
a=T38FaxUdpEC:t38UDPRedundancy

2) ANSWER (SIP 200 OK):
SIP/2.0 200 OK
Via: SIP/2.0/UDP xx.xx.xx.70;branch=z9hG4bKac663170125;rport
From: <sip:501@xx.xx.xx.70>;tag=1c662567132
To: <sip:101@xx.xx.xx.78;user=phone>;tag=1c615537688
Call-ID: 66253175228112011195 37@xx.xx.xx.70
CSeq: 1 INVITE
Contact: <sip:101@xx.xx.xx.78:5060>
Content-Type: application/sdp
Content-Length: …
v=0
o= Mediant-800 615608588 615608445 IN IP4 xx.xx.xx.78
s=Phone-Call

```
c=IN IP4 xx.xx.xx.78
t=0 0
m=audio 6000 RTP/AVP 18 118
a=rtpmap:18 G729/8000
a=fmtp:18 annexb=no
a=rtpmap:118 PCMA/8000
a=gpmd:118 vbd=yes
a=ptime:20
a=sendrecv
m=image 6002 udptl t38
a=T38FaxVersion:3
a=T38MaxBitRate:33600
a=T38FaxRateManagement:transferredTCF
a=T38FaxUdpEC:t38UDPRedundancy
```

With this configuration, the gateways will support simultaneously the voice calls (for example, G.729 encoded), modem calls by using VBD codec (G.711 PCM A-law), and fax calls by using T.38 version 3. Because the VBD and T.38 capabilities are known since call start, the communicating gateways are able to perform autonomous transitioning between audio, VBD, and T.38 gateway states according to VBD and T.38 stimuli signals. Such type of call establishment is optimal for V.34 fax relay.

If other party doesn't support the negotiation of T.38 codec at call start, it is possible to negotiate T.38 capabilities by using SIP REINVITE message sent by gateway on detecting fax signal. This REINVITE will contain a single media with T.38 parameters in its SDP. For V.34 fax relay, it is important for gateway to enter the T.38 state as fast as possible, for example, on detecting CNG, or ANSam, or on detecting a combination of CNG from one direction and ANSam from opposite direction. A complete suppression of answer fax tone or/and V.8 CM is not desirable, because it disables the T.30 automatic operating method of V.34 fax call setup, forces the T.30 manual call establishment, and as a result, extends a duration of V.34 fax call.

If a remote side does not support the suggested T.38 version 3, then the inviting or re-inviting gateway may apply an appropriate lower T.38 version with forcing V.34-to-V.17 fallback for regular G3 fax relay or, alternatively, apply the VBD transfer method to fax call.

Why Choose AudioCodes?

AudioCodes fax relay technology has been widely deployed for more than 10 years and serves thousands of organizations worldwide. AudioCodes fax technology is known for its vast interoperability with hundreds of fax machine models from various vendors, and considered by customers as most stable and reliable.

AudioCodes gateways terminate V.34 fax (Super G) arriving over TDM and support multiple modes to transport it over VoIP. Best way is through the use of full V.34 fax relay according to T.38 version 3. Alternately, for peer gateways which do not support T.38 version 3, V.34 can be transferred using Voice Band Data or downgraded to regular G3 with T.38.

In addition, AudioCodes Session Border Controllers, allow IP to IP translation of T.38 packets carrying either G3 or V.34 faxes into Voice Band Data packets. This facilitates interoperability between SIP endpoints that do not share the same fax relay capabilities.

References

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About AudioCodes

AudioCodes Ltd. (NasdaqGS: AUDC) designs, develops and sells advanced Voice over IP (VoIP) and converged VoIP and Data networking products and applications to Service Providers and Enterprises. AudioCodes is a VoIP technology market leader focused on converged VoIP & data communications and its products are deployed globally in Broadband, Mobile, Enterprise networks and Cable. The company provides a range of innovative, cost-effective products including Media Gateways, Multi-Service Business Gateways, Session Border Controllers (SBC), Residential Gateways, IP Phones, Media Servers and Value Added Applications. AudioCodes' underlying technology, VoIPerfectHD™, relies on AudioCodes' leadership in DSP, voice coding and voice processing technologies. AudioCodes High Definition (HD) VoIP technologies and products provide enhanced intelligibility and a better end user communication experience in Voice communications. For more information on AudioCodes, visit http://www.audiocodes.com

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