GL Insight™ Fax Analysis Training

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ITU - T Standards

- T Series: Terminals for Telematic Services - T.0 to T.870
- V Series: Data communication over the telephone network - V.1 to V.399

Supported Protocols

- GL Insight Supports the following protocols:
  - Start-up Protocols - V.8, V.8bis, and V.8 short
  - Fax Protocols - T4/T6, T.30 ,T.38
  - Modulations - V.92, V.90, V.34, V.32bis/V.32, V22bis/V.22, V.21, V.23, and Bell 103/ Bell 212
  - Error Correction and Data Compression Protocols - V.42, V.42bis, V.44, MNP2-4, MNP5, and V.14

Standards applicable in GL Insight™

Description	Standard
General	V.1 – V.9
Interfaces and modems	V.10– V.34
Wideband modems	V.35–V.39
Error Control	V.40 –V.49
Transmission quality and maintenance	V.50 – V.59
Simultaneous transmission of data and other signals	V.60– V.99
Internetworking with other networks	V.100 – V.199
Interface layering specifications for data communications	V.200 – V.249
Control procedures	V.250 – V.299
Modems on Digital circuits	V.300 – V.399

Overview of Standards

Standard	Description
V.8	Procedures for starting sessions of data transmission over the public switched telephone network Part of the capabilities exchange during the modem and fax answering procedures
V.14	Transmission of start-stop characters over synchronous bearer channels
V.17	High speed data transmission, used for high transfer rates of High Speed (HS) fax page data (9600 to 14400 bps).
V.21	Low Speed (LS) data transmission, used for the fax control information (300 baud).
V.22bis	Medium speed data transmission, used for low transfer rates of High Speed (HS) fax page data (1200 to 2400 bps).
V.23	600/1200-baud modem standardized for use in the general switched telephone network
V.29	High speed data transmission, used for medium transfer rates of High Speed (HS) fax page data (4800 to 9600 bps).
V.32	A family of 2-wire, duplex modems operating at data signaling rates of up to 9600 bit/s for use on the general switched telephone network and on leased telephone-type circuits
V.32bis	A duplex modem operating at data signaling rates of up to 14 400 bit/s for use on the general switched telephone network and on leased point-to-point 2-wire telephone-type circuits
V.33	High speed data transmission, fax page data (1200 to 1440bps). Used for synchronous data transmission
V.34	High speed data transmission, fax page data (1200 to 2880 bps). Used for Sync/Async data transmission

Signals

Signals

Data

GL Communications

Overview of Standards…

Standard	Description
V.42	Error-correcting procedures for DCEs using asynchronous-to-synchronous conversion
V.42bis	Data compression procedures for data circuit-terminating equipment (DCE) using error correction procedures
V.44	Data compression procedures
V.90	Adopted in 1998, V.90 improves upon V.34 by using pulse-code modulation (PCM) for the downstream link, achieving speeds of up to 56,000 bps when connected to a digital modem, sending G.711 signals with a symbol rate of 8000 baud.
V.92	Adopted in 1999, V.92 improves upon V.90 by adding 'Quick Connect', 'Modem on Hold', 'V.PCM upstream' and 'V.44 compression' features.

Fax Standards

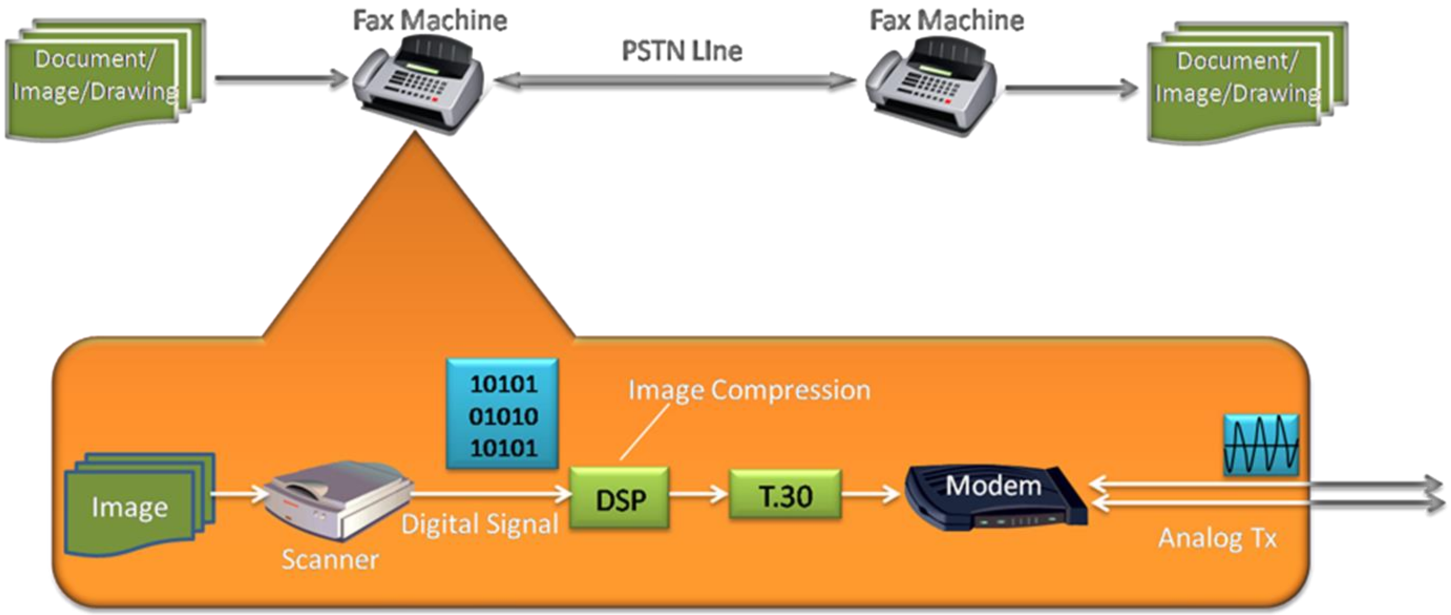
Standard	Description
T.4	Defines the encoding of printed information (content) into a digital stream ready for modulation (defines algorithms used for one-dimensional and two-dimensional data compression)
T.6	Defines algorithms used for error correction mode (ECM)
T.30	Defines the handshaking protocol and capabilities exchange that takes place during fax transmission.
T.30Annex A	Defines Error Correction Mode (ECM) facilities.
T.38	IP-Fax protocol for real time transmission of FoIP networks

Fax Transmission Overview

- A fax machine uses a scanner to convert the paper image into digital bits, a single-chip microprocessor called a digital signal processor (DSP) to reduce the number of bits, and a modem to convert the bits into an analog signal for transmission over an analog dial-up phone line.

- Facsimile (fax) transmission is the sending of an image, drawing, or document over a distance by converting it into coded electrical signals at the originating end, passing the signals from the originator to the receiver over a transmission medium, and converting the signals into a replica of the original at the receiving end.

- The protocol for sending or receiving a fax image and exchanging associated messages is defined in the International Telecommunications Union (ITU) Recommendation T.30.



Basic Standards

- Group 1 standard for transmission that was introduced by the International Telegraph and Telephone Consultative Committee (CCITT) in 1968 took for a single-page letter about six minutes to send over public phone lines.

- Group 2 standard, introduced in 1976, reduced the time to send a page to three minutes, but still could not provide transmission at a dense enough resolution for the clear reproduction of small print.

- Group 3 standard introduced in 1980 improved fax scanning resolution and introduced digital transmission techniques to enable transmission rates of 14400 bits per second (bps). Group 3 fax machines are the most common today by far.

- Group 4 is a standard for digital phone lines such as ISDN, and it operates at 64 kbps.

- Each standard specifies special tones that identify calls as fax calls and enable handshaking to define fax capabilities at both ends of the call.

- All the fax standards have evolved with a goal of sending more data faster over the public switched telephone network (PSTN).

Fax Traffic Modulation

Fax traffic consists of digital data modulated onto high-frequency carrier tones. There are various ways to modulate this information, such as

- Amplitude Modulation (AM),
- Frequency Modulation (FM) or Frequency Shift Keying (FSK),
- Phase Modulation (PM) or Phase Shift Keying (PSK).

In order to get higher bit rates (more information) across the same carrier circuit, these modulation techniques are often combined into forms of modulation called Quadrature Amplitude Modulation (QAM) or Trellis-Coded modulation.

Fax Transmission Through PSTN

Phase	Description
Phase A—Establishing a Voice Call	The calling party picks up a handset or prepares a fax and then dials a destination phone or fax machine.
Phase B—Identifying Facilities and Capabilities	Facilities and capabilities are identified and negotiated between the calling and called parties.
Phase C—Transmitting Content	The message or page is sent.
Phase D—Signaling End of Transmission and Confirmation	The end of transmission and confirmation are signaled between the calling and called parties.
Phase E—Releasing the Call	The call is released when a phone or fax machine hangs up.

Phase A-Establishing a Voice Call (Pre-Image Handshake Sequence)

- The call originator A prepares a fax and dials a destination number
- The destination fax device picks up the call.
- The originator and the destination are now connected in a voice call, but to transition to fax transmission one party must signal that it is a fax device.
- Either device can send its signal first, using one of the following methods:

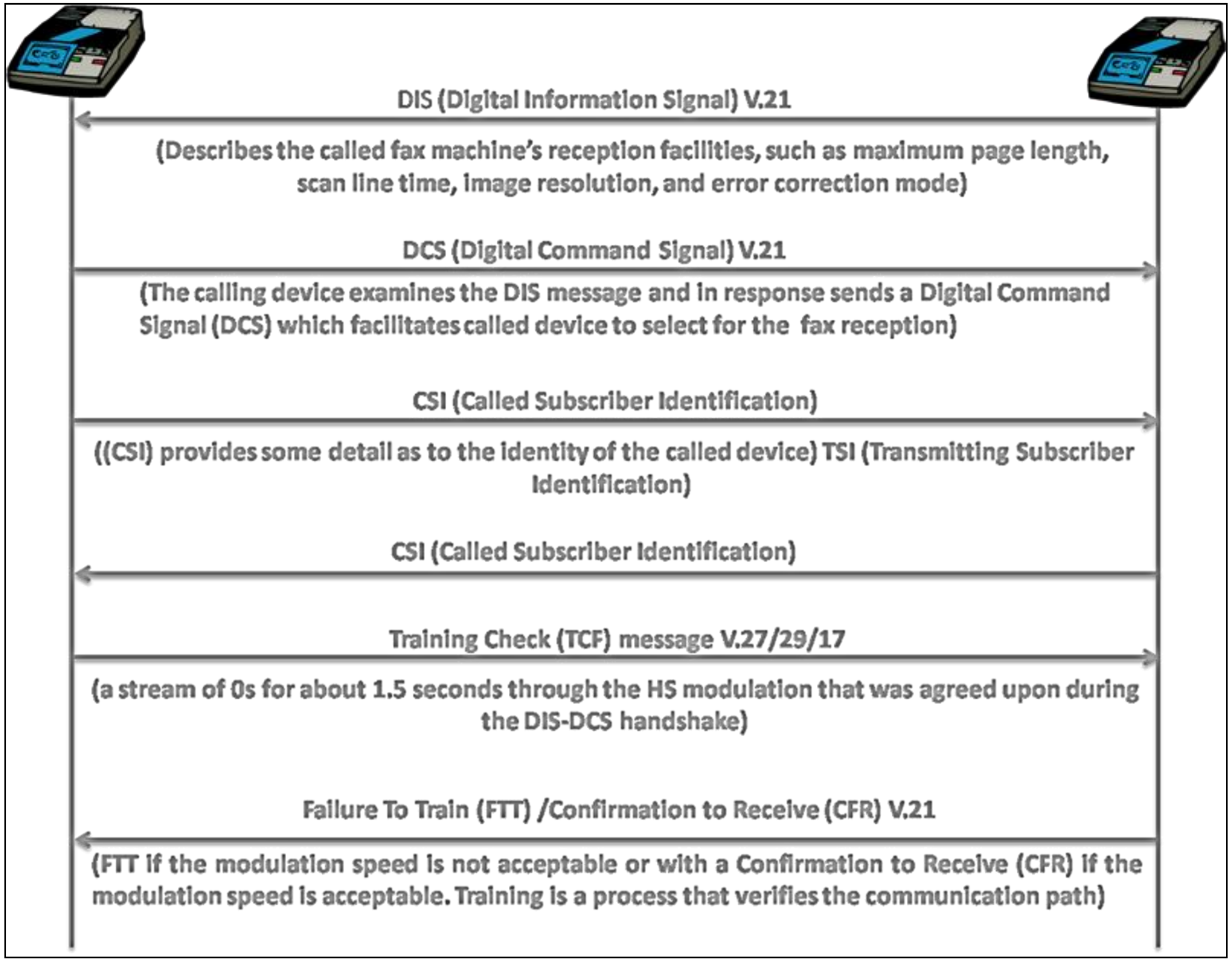
Send 1100 Hz CNG tone sent

- ➢ The Calling Unit Announcing tone identifies the calling device as a fax machine.
- ➢ (The Calling tone is a repeating 1100-Hz tone that is on for 0.5 seconds and then off for 3 seconds)

Send 2200 Hz CED tone sent

- ➢ Called Station Identifier (CED) tone identifies the called device as a fax machine
- ➢ (CED is a 2100-Hz tone that is on for 2.6 to 4 seconds)

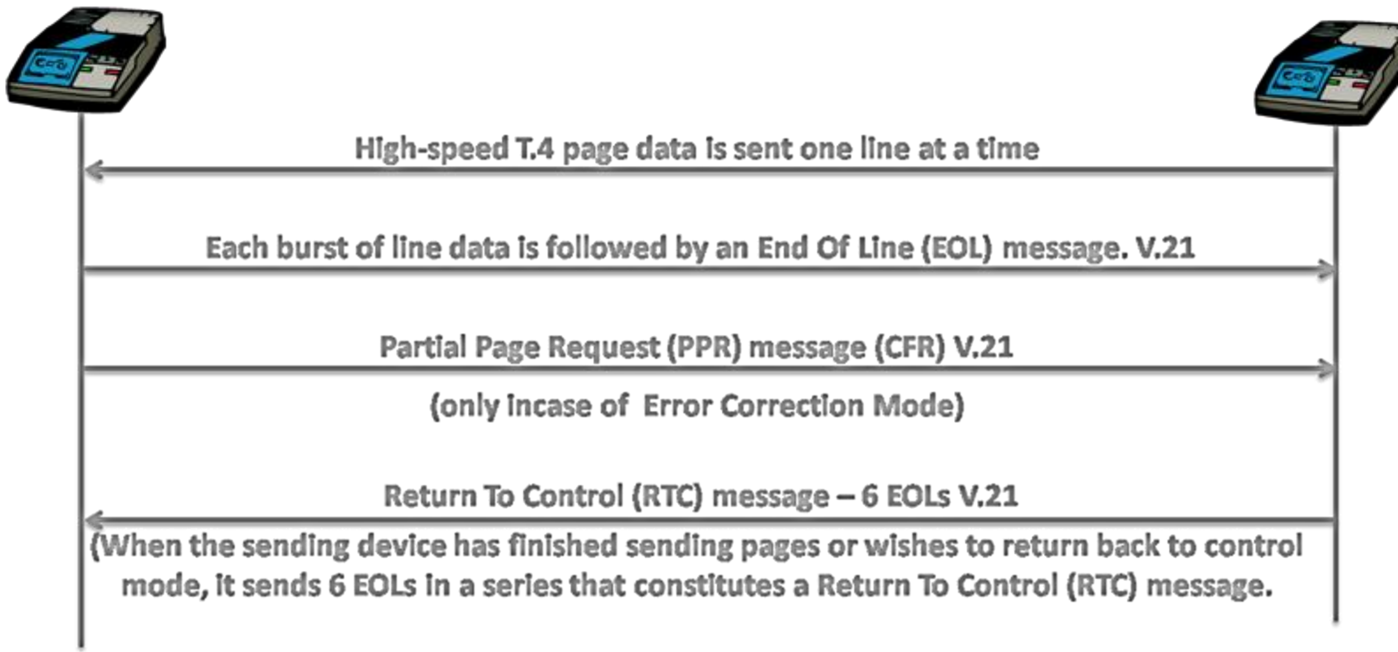
Phase B—Identifying Facilities and Capabilities (DIS and DCS handshakes)



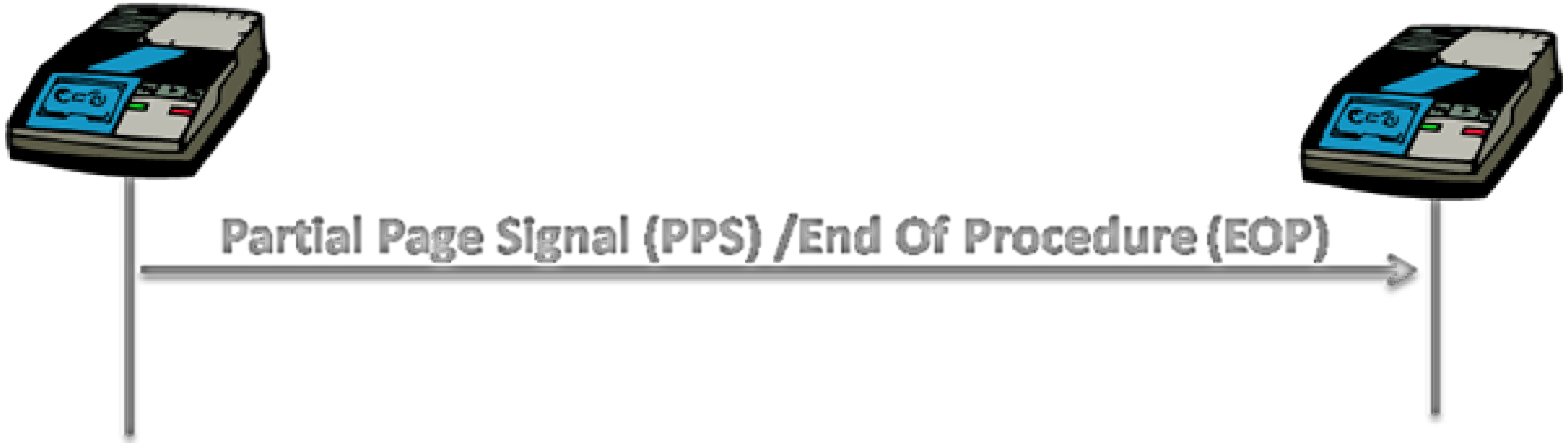
Phase C-Transmitting Content

- The RTC message indicates the end of phase C, and the call progresses to phase D. Since the EOL information is sent as T.4 data, it would not necessarily be seen in a T.30 trace.

- With ECM, the T.4-page data is grouped into high-level data link control (HDLC) frames rather than being sent in a raw stream. This means that if the HDLC blocks of T.4-page data are not received error-free, a Partial Page Request (PPR) message can be sent, listing the frames that were not received and asking for them to be resent.



Phase D-Signaling End of Transmission & Confirmation



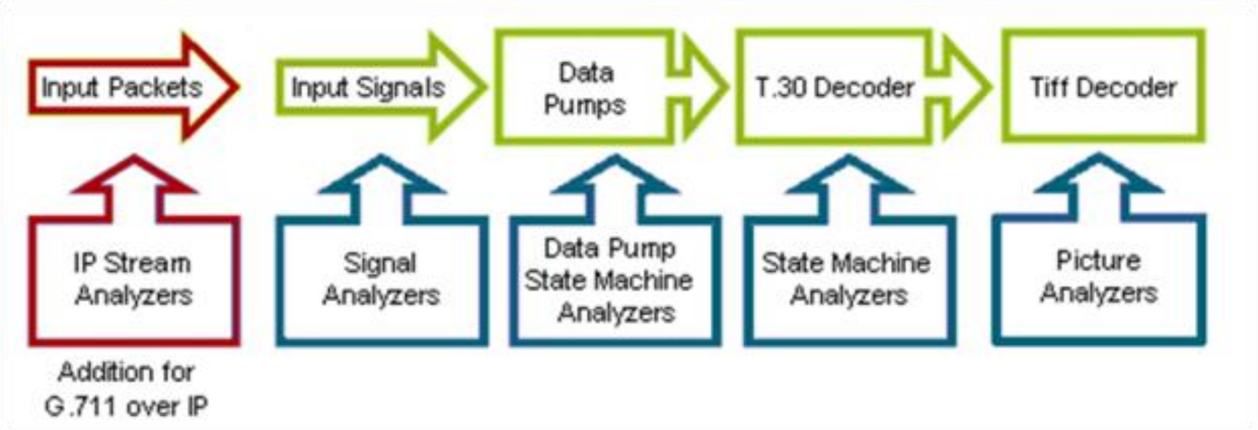
After the T.4 transmission and the subsequent return to control mode, the sending device must send one of the following signals:

- (PPS)—Devices that send faxes with ECM can send a PPS, which must be acknowledged by a Message Confirmation (MCF) signal from the receiving device.
- (EOP)—This signal indicates that transmission of pages is complete and that there are no more pages to send. The EOP must be acknowledged with an MCF from the receiving device, after which the devices can move to phase E.

Phase E-Releasing the Call

- Following the fax transmission and the post message transactions, either the calling device or the called device can send a Disconnect (DCN) message, at which point the devices tear down the call, and the telephony call control layer releases the circuit.
- DCN messages do not require a response from the opposite device.

Fax Decoding and Analysis Information



Signal Analyzers

- Unstable signal detector
- Signal overflow detector
- No-signal on single-sided indication

Data Pump State Machine Analyzers

- Fax phase changes, data rates, symbol rate
- Structure's interchange (rate sequences, MP, Info) and complete connection parameters
- PDSNR (post detection signal quality measurement) improper quality drop detector
- V.8 incompatibility indication

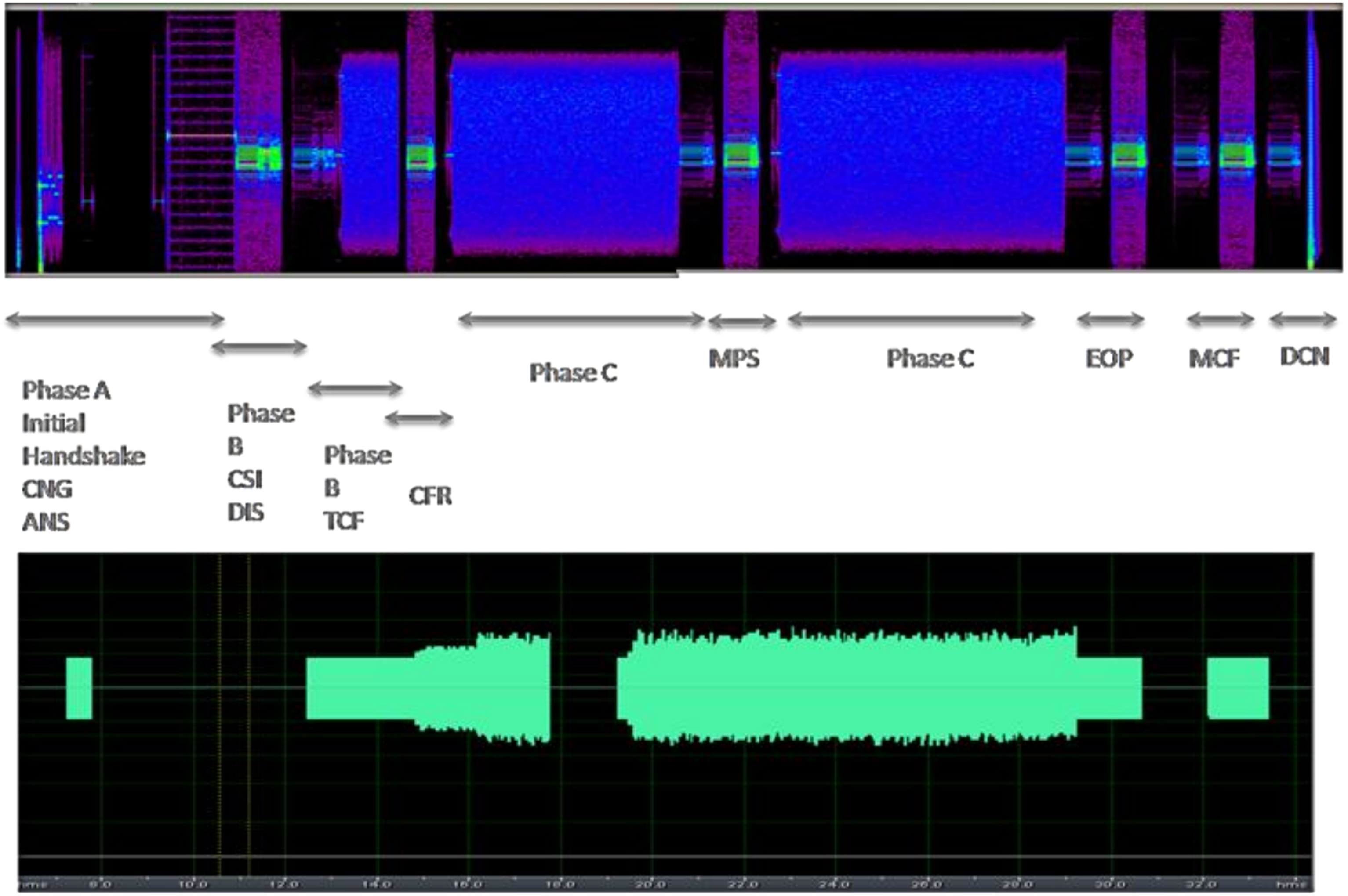
T.30 Decoder Analyzers

- T.30 raw data
- T.30 frames and information
- T.4/T.6-page coding information
- CRC error detector in V.21
- Repetitive T.30 frames detector
- T.4/T.6 bad-line statistics
- ECM failure to correct error frames indication
- Unexpected end of Fax indication
- Improper T.30 protocol flow indication

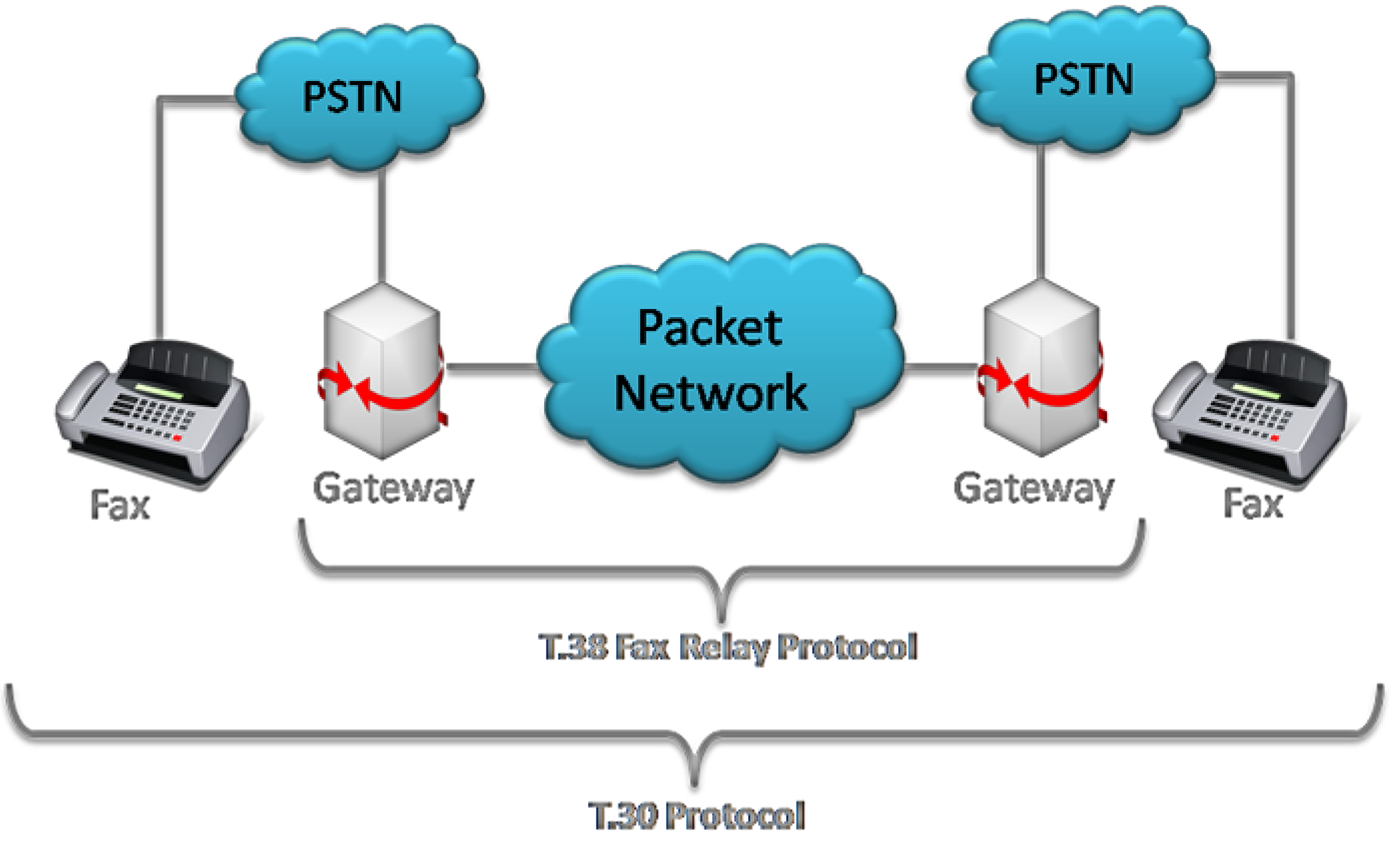
GL Insight Decoded Files

a_ls_bits.bin **b_ls_bits.bin**	The a_ls_bits file contain all the lowspeed bits decoded in the fax call. (It is similar to the hs_bits file which contains the High Speed bits)
ans_rx_pdsnr_lo.pcm **org_rx_pdsnr_lo.pcm**	Post Detection Signal to Noise Ratio) files should be opened as 8000samples/sec, mono, 16 bit linear. Lo is low resolution (133.3 measurements per second) and Shows the value in dB (/100) of the Signal-to-Noise ratio of the answer side training data signal respectively
ans_level.pcm **org_level.pcm**	The ans_level and org_level files are similar to the PDSNR files. Each provides the value of the signal power of the direction denoted by the name of the file. Divide the value by a 100 to get the signal power in the recording.
jitter.bin	The Jitter.bin file is relevant in T.38 files and contains the network jitter of the recorded analyzed packets.
equalizer.pcm	The equalizer file describes the equalizer values used when entering the data in the hs portion. They serve as to distinguish between the highspeed sections
t30_bytes.bin	Contains T.30 signal bits
hs_bits.bin	High speed (page transmitting side) bits decoded in the fax call
symbols.pcm	Demodulated 2-dimensional symbols
sym_err.pcm	Estimated demodulated 2-dimensional symbol errors (noise)

Spectrogram view of ECM_v17_14400_ans.pcm



Fax over IP



- T.38 is the real-time FAX over IP protocol.
- It is an ITU recommendation for allowing transmission of fax over IP networks in real time

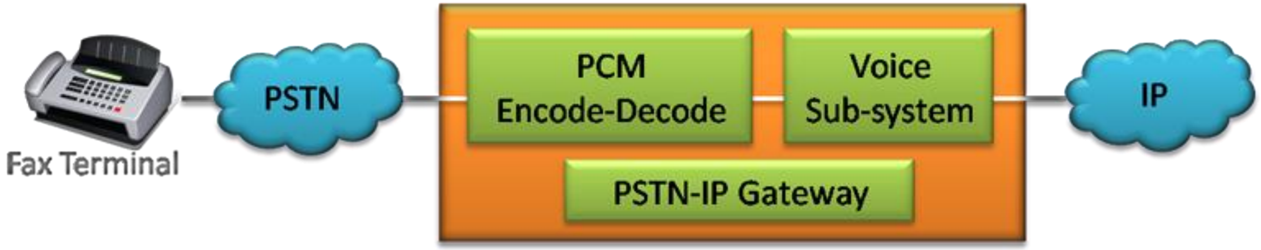
Fax over IP…

- The T.38 fax relay standard was devised in 1998 to permit faxes to be transported across IP networks between existing Group 3 (G3) fax terminals.
- T.30 fax device sends a fax over PSTN to a T.38 Fax gateway which converts or encapsulates the T.30 protocol into T.38 data stream. This is then sent either to a T.38 enabled end point such as fax machine or fax server or another T.38 Gateway that converts it back to PSTN PCM or analog signal and terminates the fax on a T.30 device.
- The T.38 recommendation defines the use of both TCP and UDP to transport T.38 packets.
- Implementations tend to use UDP, due to TCP's requirement for acknowledgement packets and resulting retransmission during packet loss, which introduces delays.
- When using UDP, T.38 copes with packet loss by using redundant data packets.
- T.38 is not a call setup protocol; thus the T.38 devices need to use standard call setup protocols to negotiate the T.38 call, e.g., H.323, SIP & MGCP.

Why do we need T.38 ?

- It is common for each packet to contain a copy of the main data in the previous packet. This forward error correction scheme makes T.38 far more tolerate of dropped packets
- Loosing a packet in a T.38 stream does not cause the modems to lose sync. This means two successive lost packets should only corrupt a section of an image. If the optional FAX error correction (ECM) mode is used, there is a good chance that with a retry or two, a perfect image will be transferred. Not ideal, but functional.
- T.38 gateway can start sending a page as soon as it gets some data, without performing any jitter buffering
- A special protocol is needed for real-time fax over IP (Internet Protocol) since existing fax terminals only supported PSTN connections, where the information flow was generally smooth and uninterrupted, as opposed to the jittery arrival of IP packets
- Missing packets will often cause a fax session to fail at worst or create one or more image lines in error at best.
- It will also correct for network delays with so-called spoofing techniques and missing or delayed packets with fax-aware buffer-management techniques.
- Spoofing refers to the logic implemented in the protocol engine of a T.38 relay that modifies the protocol commands and responses on the TDM side to keep network delays on the IP side from causing the transaction to fail. This is done, for example, by padding image lines or deliberately causing a message to be re-transmitted to render network delays transparent to the sending/receiving fax terminals.

T.38 Subsystem



- A T.38 gateway is comprised of two primary elements: the fax modems and the T.38 subsystem.
- The fax modems modulate and demodulate the PCM samples of the analog data, turning the sampled-data representation of the fax terminal's analog signal to its binary translation, and vice versa.
- The PSTN network samples the analog signal of a voice or modem signal (it doesn't know the difference) 8,000 times per second (SPS), and encodes them as 8-bit data bytes
- This means 8000 samples-per-second times 8-bits per sample, or 64,000 bits per second (bit/s) to represent the modem (or voice) data in one direction.
- However, the typical modem in a fax terminal transmits the image data at 14,400 bit/s, so if the analog data are first converted to the digital content they represent, only 14,400 bits (plus network overhead of a few bytes) are needed.
- And since T.30 fax is a half-duplex protocol, the network is only needed for one direction at a time.
- T.38 provides facilities to eliminate the effects of packet loss through data redundancy.
- When a packet is sent, either zero, one, two, three, or even more of the previously sent packets are repeated.
- This increases the network bandwidth required (it's still much less than not using T.38) but it allows the receiving gateway to reconstruct the complete packet sequence, even with a fairly high level of packet loss.

SIP T.38 Call with QoS Enabled Output

GW1 -----INV-----> GW2
GW1 <--100 Trying- GW2
GW1 <--183 QoS --- GW2
GW1 ----PRACK----> GW2
GW1 <--200/PRACK-- GW2
GW1 ----COMET----> GW2
GW1 <--200/COMET-- GW2
GW1 <--183SesProg- GW2
GW1 ----PRACK----> GW2
GW1 <--200/PRACK-- GW2
GW1 <---200OK----- GW2
GW1 -----ACK-----> GW2
GW1 <-reINVITE/FAX GW2
GW1 ----200OK----> GW2
GW1 <----ACK------ GW2

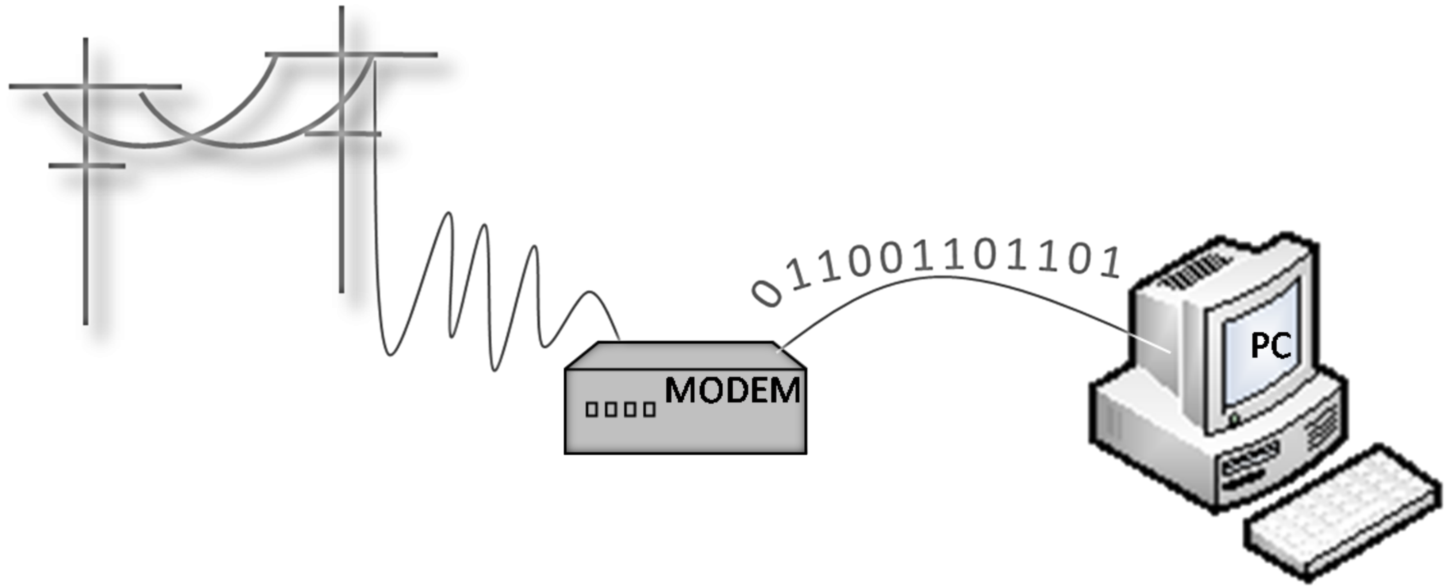
Fax Transmission

GW1 -----BYE-----> GW2
GW1 <---200OK----- GW2

```
INVITE sip:1000@172.18.193.196:5060;user=phone SIP/2.0
Via: SIP/2.0/UDP 172.18.193.135:5060
From: <sip:2000@172.18.193.187;user=phone>;tag=14B968AC-2668
To: "1000"<sip:1000@172.18.193.196>;tag=14B99A90-269E
Date: Mon, 14 May 2001 17:43:11 GMT
Call-ID: F8C02D00-47BE11D5-805FE64C-BD156232@172.18.193.196
Supported: 100relCisco-Guid: 4143344000-1203638741-2153637452-
3172295218
User-Agent: Cisco-SIPGateway/IOS-12.x
CSeq: 101 INVITE
Max-Forwards: 6
Timestamp: 989858591
Contact: <sip:2000@172.18.193.135:5060;user=phone>
Expires: 180
Content-Type: application/sdp
Content-Length: 403
v=0
o=CiscoSystemsSIP-GW-UserAgent 5201 1829 IN IP4 172.18.193.135
s=SIP Call
c=IN IP4 172.18.193.135t=0 0
m=image 18036 udptl t38
a=T38FaxVersion:0
a=T38MaxBitRate:14400
a=T38FaxFillBitRemoval:0
a=T38FaxTranscodingMMR:0
a=T38FaxTranscodingJBIG:0
a=T38FaxRateManagement:transferredTCF
a=T38FaxMaxBuffer:200
a=T38FaxMaxDatagram:72
a=T38FaxUdpEC:t38UDPRedundancy
a=qos:optional sendrecv
```

MODEM

What are they ?



- Short for modulator-demodulator. A modem is a device or program that enables a computer to transmit data over, for example, telephone or cable lines. Computer information is stored digitally, whereas information transmitted over telephone lines is transmitted in the form of analog waves. A modem converts between these two forms.

Characteristics distinguishing Modems

Following characteristics distinguish one modem from another:

- **bps : How fast the modem can transmit and receive data.**
  - At slow rates, modems are measured in terms of baud rates. The slowest rate is 300 baud (about 25 cps). At higher speeds, modems are measured in terms of bits per second (bps). The fastest modems run at 57,600 bps, although they can achieve even higher data transfer rates by compressing the data.
- **voice/data:**
  - Many modems support a switch to change between voice and data modes. In data mode, the modem acts like a regular modem. In voice mode, the modem acts like a regular telephone.
- **data compression :**
  - Some modems perform data compression, which enables them to send data at faster rates. However, the modem at the receiving end must be able to decompress the data using the same compression technique.

Asymmetric Digital Subscriber Line (ADSL)

DSL signifies a modem, not the line !

- using symmetric signals in many pairs within a cable significantly limit the data rate and the length of the line

- solution: asymmetric transmission.

- ADSL uses:
  - high speed downstream channel: 1.5-6.1 or even 9 Mbps
  - low speed duplex channel: 16-640 kbps
  - each channel can be sub multiplexed to form multiple, lower rate channels

- ADSL is used for many types of applications (video, data, and others) with different needs (bandwidth, error correction, delay, etc. concurrently.

Thank you

GL Communications