Information on Sage's Fax Emulator

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1 Introduction

Sage's Fax Emulator (SFE) is a test feature that emulates both a realistic FAX transmitter and a FAX receiver. By FAX transmitter, we mean the FAX machine that originates a call, and sends the FAX pages. By FAX receiver, we mean the FAX machine that answers the call, and receives the FAX pages. The FAX transmitter emulator is available on Sage's 925 with analog 2-wire POTS interface. Sage's 960, with digital DS1 (T1/E1 and PRI-ISDN access capable) interface, has both FAX transmitter and FAX receiver emulators.

To use SFE, one normally originates a call from Sage's FAX transmitter to another FAX machine or Sage's FAX receiver across the network under test. Sage's FAX transmitter will then communicate with the destination FAX machine or Sage's FAX receiver with the protocols specified in ITU-T T.30 [1]. Two test pages will be sent from the transmitter to the receiver. The test pages are encoded according to formats documented in ITU-T T.4 [2]. While the test is going on, Sage's FAX emulators will report in real time the test progress, such as what signal is being sent; what signal is being received; whether or not a certain stage is being retried; whether or not an unexpected invalid protocol packet is received; whether or not certain timing errors have occurred (certain protocol packet is not received within allowable time frame), and whether or not the page transmission has succeeded etc.

Although Sage's FAX emulators can be used to trouble-shoot any FAX call problems across all types of telephone networks, the primary use might be to verify the "modern" FAX-gateways' (or FAX-capable voice gateways and IADs etc) capability to handle a normal FAX call across a packetized network, the so-called Fax over IP (FoIP) application as specified in ITU-T T.38 [3]. For FoIP test, Sage's FAX emulators have obvious advantages over an actual FAX machine:

1. Sage's FAX emulators are far more portable. The 925, for example, is a small hand-held unit. Even Sage's 960 is more portable than a real FAX machine. For the situation where the access interface is digital DS1, Sage's FAX emulators on 960 are the only solution as a regular FAX machine normally does not have DS1 interface.
2. Sage's FAX emulators provide far more diagnostic information. When a FAX call fails, a regular FAX machine usually just prints some mysterious generic error information such as "A communication error occurred during the fax transmission. Error code 283". Sage's FAX emulators, on the other hand, will provide real-time progress report. When a problem occurs, the FAX emulators will provide precise description as to what the problem is. By looking at the progress report log-file, one can also deduce which stage or how far the FAX call has progressed.

3. For FoIP testing with Sage's 960, one can easily generate "massive" number of FAX calls to test-load the FAX-gateways under test. Such load testing can never be achieved with an actual FAX machine.

4. Sage's FAX emulators also allow a user to adjust the transmitted signal power level as well as the specific modem type to be used for transmitting the FAX pages. Sage's FAX emulators support all 3 mandatory modem types: V.17 [6] at 7200, 9600, 12000 and 14400 bps; V.29 [5] at 7200 and 9600 bps; V.27ter [4] at 2400 and 4800 bps. Support for V.34 modem (SuperG3 FAX) will be added through future SW upgrade.

2 A typical FAX call signal exchange sequence

A successful FAX call should follow the signal exchange sequence shown in Figure 1.

3 Signal description

Descriptions of the signals shown in Figure 1 are as follows:

1. Tonal signals. These include two straight tone signals, CNG and CED.

   CNG: , CNG (Calling tone) is sent by the calling fax terminal (FAX transmitter) to indicate that this calling device is a fax (data) device, and ready to transmit on receipt of the DIS explained below) from the receiving fax terminal. It is a 1100 Hz tone with cadence of 0.5s on and 3s off.

   CED: , CED (Called terminal identification) is an answer tone used by the called device (FAX receiver) to indicate that it is a fax machine. This is a continuous 2100 Hz tone with a duration between 2.6s and 4.0s.

2. Protocol control messages. The fax protocol control messages include the DIS, DCS, CFR, MPS, EOP, MCF, DCN and other signals that will be explained later. All these binary messages are framed with an HDLC structure, and then modulated using the V.21 [7] FSK scheme (1750 Hz center frequency with 100 Hz frequency deviation). The HDLC frame structure implies that the binary message payload is preceded by control field, address field and flags (0x7e), and followed by CRC bytes and flags. The HDLC transparency check (transmitter inserts extra zero bit following 5 consecutive ones and receiver shall remove the extra zero bit after 5 consecutive ones) is also applied to the data payload and CRC bits.

   DIS: This DIS (digital identification signal) is used by the called fax machine to indicate its capabilities on scanning and printing resolutions and modem capabilities etc. The DIS packet sent by Sage's FAX receiver will indicate that is capable of 1-D coding scheme with vertical resolution of 3.85 lines/mm and horizontal resolution of 1728 picture elements per line, and it can handle all 3 types of modems V.17 [6], V.29 [5] and V.27 [4].

   DCS: This DCS (digital command signal) is the calling terminal's response to the DIS. It informs the called terminal what type of modem and what type of coding and resolution will be used. The DCS packet sent by Sage's FAX transmitter will inform the receiving fax machine that it will use the standard 1-D coding scheme with vertical resolution of

3.85 lines/mm and horizontal resolution of 1728 picture elements per line, and modem to be used will be one of the selections from V.17 at 7200, 9600, 12000, 14000bps, or V.29 at 7200, 9600 bps or V.27ter at 2400, 4800bps.

CFR: This CFR (confirmation to receive) is transmitted by the called terminal to indicate whether or not the entire pre-message signals (DCS, training signal and TCF (described later)) have been successfully received.

MPS: This multipage signal is sent from FAX transmitter to FAX receiver to indicate the end of the current page transmission. But more page(s) are to come.

EOP: Like MPS, this EOP (end of procedure) is sent from FAX transmitter to FAX receiver to indicate the end of the current page transmission. But no more page is coming (that's all).

MCF: This MCF (message confirmation) is a positive response to the MPS and EOP message from FAX receiver to FAX transmitter to indicate the successful reception of the current page transmission.

DCN: This DCN (disconnect) is sent from FAX transmitter to FAX receiver to indicate call disconnection.

3. Fax data messages. These include the training sequence, TCF and actual fax message sequences. All these sequences are modulated through the modem type selected by the user (V.17, V29 or V27ter at various rates).

   Training sequence is specific to each modem type. Basically it contains various segments of known signal to help the receiver equalize out the static and linear communication channel distortions.

   TCF: This is the training check sequence that is formed by feeding continuous zero bits into the modem scrambler and modulating the output bits for 1.5s.

   Fax message: the black-and-white line-by-line image from the "scanner" is encoded into a sequence of "raw" bits according to the 1-D encoding scheme specified in T.4 [2]. Each line of bits are preceded with EOL (end-of-line) pattern and followed by fill bits (all zero bits) to guarantee minimum transmission time per line, and then modulated according to the modem type.

4 Typical progress report at the FAX transmitter for a successful FAX call

For a successful FAX call, the FAX transmitter should sequentially show the following call progress messages:

1. FAX_TX started.
2. Send CNG, await CED.
3. CED received.
4. CED off, await DIS.
5. DIS received, send DCS.

6. Send training and TCF.
7. Await CFR.
8. CFR received, send page 1.
9. Page 1 ends. Send MPS.
10. Await MCF.
11. MCF received, send page 2.
12. Page 2 sends. Send EOP.
13. Await MCF.
14. MCF received, send DCN.
15. FAX_TX success.

5 Typical progress report at the FAX receiver for a successful FAX call

For a successful FAX call, the FAX receiver should sequentially show the following call progress messages:

1. FAX_RX started.
2. Send CED.
3. Send DIS.
4. Await DCS.
5. DCS received, check TCF.
6. TCF OK, send CFR.
7. Receive page 1.
8. Page 1 ends. Await MPS.
9. MPS received, send MCF.
10. Receive page 2.
11. Page 2 ends. Await EOP.
12. EOP received, send MCF.
13. Await DCN.
14. FAX_RX success.

6 Non-fatal errors reported by the FAX transmitter

Sage's FAX transmitter will report some non-fatal messages when one of the following conditions is true:

1. FAX transmitter received an unexpected or unrecognizable protocol control message while waiting for a specific control message.
2. FAX transmitter received FTT (Failure-To-Tain) signal from the FAX receiver requesting retransmitting the DCS and ensuing training signal and TCF.
3. After page transmission, FAX transmitter received RTN (retrain negative) signal, instead of the positive MCF, which will cause the transmitter to re-transmit the current page.

These non-fatal messages do not cause the FAX test to halt. If an invalid packet is received, the packet will be ignored until a valid packet is received, or until timeout, which will fall into the fatal-error category that will be explained later. When retry message is received (FTT or RTN), Sage's FAX transmitter will proceed with the retry according to T.30 [1]. If a specific retry exceeds 3 times, a fatal error (Retry Time Out) will be reported as explained later.

The non-fatal error messages can be ignored. But if these errors occur quite frequently, the channel or device under test may be problematic or unstable. In summary, the following non-fatal error messages may show up on the FAX transmitter:

1. Received invalid DIS.
2. Received FTT, re-send DCS and training.
3. Received invalid CFR.
4. Received RTN, re-send the current page.
5. Received invalid MCF.

7 Non-fatal errors reported by the FAX receiver

When unexpected or unrecognizable protocol control messages are received, the FAX receiver will also report some non-fatal messages. These messages are:

1. Received invalid DCS.
2. Received invalid MPS or EOP.

8 Fatal errors reported by the FAX transmitter

Fatal error messages will be reported by the FAX transmitter if one of the following conditions is true:

1. Obvious violation of T.30 protocol is detected.
2. Expected signal is not received and detected within allowable time period.
3. Retry has exceeded more than 3 times for a specific signal retransmission.
4. The disconnect DCN signal is received prematurely and unexpectedly (in middle of FAX protocol negotiation and page transmission etc.).

The fatal errors will cause the FAX transmitter to halt (or abort) the test, and the test fails, and the call is disconnected. When appropriate, a DCN message will be sent to the other end.

The following fatal error messages are likely to occur at the FAX transmitter:

1. No CED. The FAX transmitter receives no CED tone within 60 seconds after call connection (in 960) or after call origination (in 925).
2. CED tone too short. The CED tone is less than 1s. Valid CED tone should be between 2.6 and 4 s.
3. CED tone too long. CED tone is longer than 6 s.
4. Modem mismatch. The FAX receiver's modem capability does not match the modem type selected by the user at the FAX transmitter side.
5. Received DCN. The disconnect DCN message is received unexpectedly and prematurely.
6. NO DIS. A valid DIS signal has not been received within 15 seconds after CED was off.
7. Retry time out. After receiving retry request from the other end, the FAX transmitter has performed the same retry for more than 3 times. Time out error.
8. No CFR. A valid CFR has not been received within 10 seconds after the end of the training signal.
9. No MCF. A valid MCF has not been received within 10 seconds after the end of the MPS or EOP signal.

9 Fatal errors reported by the FAX receiver

At the FAX receiver side, the following fatal error messages may occur:

1. Received DCN. The disconnect DCN message is received unexpectedly and prematurely.
2. No DCS. A valid DCS signal has not been received within 10 seconds after the end of the just-sent DIS signal.
3. No TCF. A valid training sequence has not been received.
4. No page transmission. A valid page transmission has not been received.
5. No MPS or EOP. A valid MPS or EOP message has not been received within 10 seconds after the end of the current page transmission.

References

[1] "Procedures for document facsimile transmission in the general switched telephone network," *ITU-T Recommendation T.30*, April, 1999.

[2] "Standardization of Group 3 facsimile terminals for document transmission," *ITU-T Recommendation T.4*, April, 1999.

[3] "Procedures for real-time Group 3 facsimile communication over IP networks," *ITU-T Recommendation T.38*, June 1998.

[4] "4800/2400 bits per second modem standardized for use in the general switched telephone network," *ITU-T Recommendation V2.7 ter*, 1993.

[5] "9600 bits per second modem standardized for use on point-to-point 4-wire leased telephone-type circuits," *ITU-T Recommendation V.29*, 1993.

[6] "A 2-wire modem for facsimile applications with rates up to 14400 bit/s," *ITU-T Recommendation V.17*, 1991.

[7] "300 bits per second duplex modem standardized for use in the general switched telephone network," *ITU-T Recommendation V.21*, 1993.

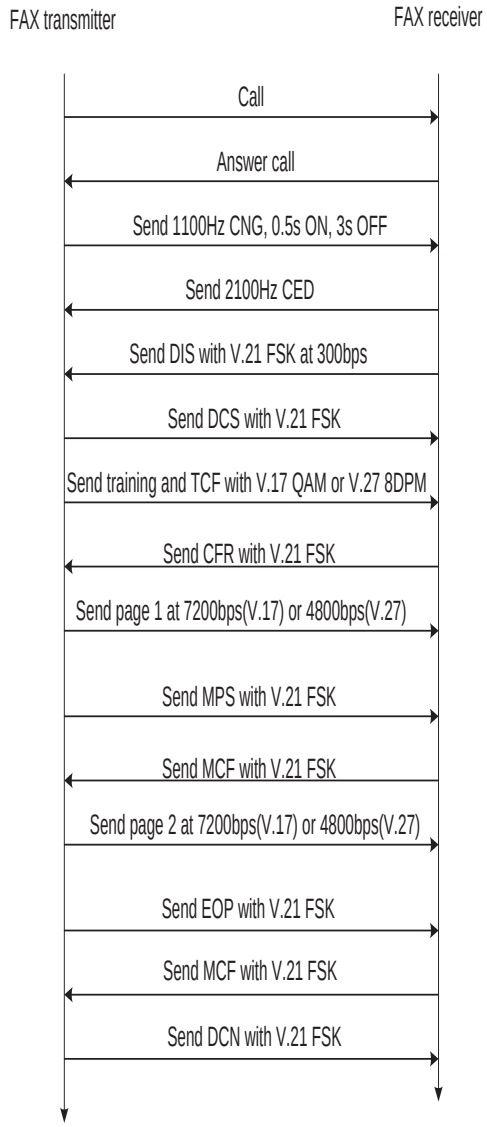

Figure 1: A typical FAX call signal exchange sequence. If Sage's FAX transmitter is used, two FAX pages will be sent, as shown in this figure. Page 1 has a pattern "SAGE FACS TEST I", and page 2 has a pattern "SAGE FACS TEST II".