Scenarios for Testing Reliable Transmission of Provisional Responses in SIP User Agent

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Summary
In this paper, we present testing scenarios for reliable transmission of provisional responses in SIP user agent. Several test scenarios for different functionalities of SIP user agent have been presented by European Telecommunications Standards Institute (ETSI). However, no scenarios have been given for reliable transmission of provisional responses. Scenarios in this paper are got from the finite state machines designed in the paper for both SIP user agent server and user agent client. State machines are designed according to the behavior of SIP user agent client and server. These behaviors are observed from the functionalities and conditions adopted from accredited RFCs and standards of SIP protocol. A major characteristic of this set of scenarios is that it is optimum in terms of the number, since the designed state machines are minimal in terms of the states. Finally, these tests are executable in a real lab environment as are to be executed in Iran Telecommunication Research Center (ITRC)'s Next Generation Network (NGN) Pilot lab.

Key words:
SIP, test, finite state machine, user agent client, user agent server

1. Introduction

In order to provide useful services, internet telephony requires a set of control protocols for connection establishment, capabilities exchange, and conference control. Currently, two protocols exist to meet this need. One is ITU-T H.323 and the other is IETF Session Initiation Protocol (SIP). H.323 is a rather complex protocol. It defines hundreds of elements, while SIP has only 37 headers each with a small number of values and parameters. H.323 uses a binary representation for its messages. SIP, on the other hand, encodes its messages as text, similar to HTTP; this leads to simple parsing and generation. Also, extensibility is a key metric for measuring an IP telephony signaling protocol. SIP is more extensible than H.323. For these reasons, nowadays SIP application in communication networks is more common.

SIP is a text-based protocol similar to Hyper Text Transport Protocol (HTTP) [1], used for web browsing, and also the Simple Mail Transport Protocol (SMTP) [2], used for email transferring on the Internet. SIP was developed by the IETF Multiparty Multimedia Session Control (MMUSIC) Working Group as part of the Internet Multimedia Conferencing Architecture [3], but found its own working group within the IETE and has also generated new related working groups, SIPPING, SIMPLE, and PINT. As the name implies, the primary function of SIP is session initiation or setup, but it also has other important applications and functions, such as presence leveraging, instant messaging, [4] and delivering Servlet APIs [5], etc. SIP is used for peer-to-peer communications in which both parties of the call are considered at the same level, no master or slave exists. However, SIP uses a client-server transaction model similar to HTTP. The SIP client generates a SIP request in a predefined message format. The SIP server responds to the request by generating a response using the predefined format.

There are two main elements in a SIP network: server and user agent. User agent plays two roles in the network, i.e. User Agent Client (UAC) and User Agent Server (UAS). A user agent client is the part of the user agent that initiates requests, while the user agent server is the part of the user agent that generates responses to received requests. Every SIP user agent contains both a UAC and a UAS. during the SIP session an endpoint will switch between client and server depending on whether it is initiating or responding to a request. User agents are the end devices in a SIP network. They originate SIP requests to establish media sessions and send/receive media, i.e. voice, video, data. A user agent might be a SIP phone or a SIP software client running on a PC.

Although outstanding progresses have been yielded up to now, little has been done in regards to the design and implementation of automated network tools for end-to-end testing of networks and their services [6]. The reason is the fact that studying network protocols and distributed applications in real networks can be difficult due to the need for complex topologies, hard to find physical channels, and conditions beyond the control of a researcher [7].

Considering SIP as the dominant control protocol in the forthcoming future, testing its functions and features is posed as a critical issue. In this paper, testing one of the most important SIP functions, i.e. reliable transmission of provisional responses in the user agent is followed.

The rest of the paper is organized as follows. Section 2 presents a short description of SIP functionality. In section 3, the mechanism of reliable transmission of provisional responses is discussed. The FSM for user agent client and server is designed in section 4. Tests description and

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scenarios are presented by section 5. Finally section 6 concludes the paper and gives some guides for future works in this line of research.

2. SIP Functionality

SIP functionality is different from most other client/server architectures, such as web browsing. SIP user agents are usually assumed to be intelligent in the sense they are part of a fully qualified Internet host as defined in RFC 1121 [8] and RFC 1122 [9]. These agents support many other basic Internet protocols including DHCP, DNS, and IMCP. SIP is based on request/response transactional model. Each transaction includes a request, which calls a special method or function in the server, and at least one response. SIP message are divided into two categories, requests sent from the client to the server and responses sent from the server to the client. Both types use the template defined in RFC 2822 [10]. Two types of response are defined in SIP, provisional response and final response. The former indicates progress of the request process and includes some information about this processing. These responses are sent non-reliably according to SIP protocol standard [11]. The latter indicates final result of request processing and they are always sent reliably.

The reliability is an important issue in SIP messages transmission, especially in interoperation with PSTN. In PSTN networks, a mechanism is used for reliable message transmission. In this mechanism, different responses are retransmitted periodically until reception of the acknowledgement.

SIP tests can be divided into four categories, i.e. functional, conformance, performance, and interoperability. Most documents concerning SIP tests discuss on conformance of the protocol implementation with the RFC 3261 [11].

The objective of the functional tests is to check whether the system can generate proper output according to its input. In fact, there is no concern of the internal implementation of the system and hence this type of test is called black-box test. SIP functional tests include the tests of the user agents and the test of the servers, i.e. proxy, redirect, and registrar servers.

Main part of SIP functional tests relates to user agent tests for which no standards have been delivered yet. In this paper, we propose SIP user agent test scenarios for one the significant mechanisms of this protocol, viz. reliable transmission of provisional responses. The scenarios have been generated according to the recommendations of IETF SIP RFCs and are executable in a real test environment. The procedure of tests generation is as follows. At first, mandatory features and functions required for user agent implementation in SIP were specified [12], [13]. One of these functions is reliable transmission of provisional responses. Then the tests necessary to ensure support of this function were determined. In order to generate the scenarios of these tests the Finite State Machine (FSM) was designed for both user agent client and user agent server. The FSM is optimum in terms of the number of states and transitions. Afterwards, scenarios have been adopted according to the FSMs. All states of the machine and the transitions between the states have been regarded in extraction of scenarios. Therefore, scenarios consider all aspects in the mechanism of reliable transmission of provisional responses and make a comprehensive set of tests. Furthermore, the set is minimal in terms of the number of tests due to the optimism of the FSM.

3. Reliable transmission of provisional responses

Final responses which are always sent reliably include the final result of a request process. For example, when a UAS sends the 2xx successful response to a UAC, it will continue to send the same response periodically until it receives the acknowledgment from the UAC. However, provisional responses indicate request reception and process continuation.

According to the fact that network evolution is now in the migration period, interworking with the current networks seems to be critical. Reliable transmission of SIP responses is considerable in many issues such as interworking with circuit-switched networks. Missing provisional responses causes problems in the interworking. For example, the "180" provisional response in SIP is converted to ACM message in ISUP in related gateways. ACM generates a one-way path for transmission of different announcements such as "The dialed number has changed." In such cases, if a provisional response is missed the circuit-switched network will not find the reason of call tear-down. Reliable transmission for provisional responses is necessary due to further reasons. One of the important reasons occurs in the transactions of "INVITE" message, the message used for session establishment request. It may take a long time from "INVITE" message transmission to final response reception. Thus, UAS requires sending provisional responses to request development of x and extra time for transaction processing. Due to the probability of packet loss, these responses should be retransmitted in every time interval.

Reliable transmission of provisional responses is similar to final responses [14]. Reliable provisional responses are retransmitted with an exponential backoff until reception of PRACK response. PRACK request in provisional responses is similar to ACK in final responses; however there is a key difference: although PRACK is used for notification of message reception, it is an ordinary message like BYE and a response is sent for this message.

In contrast, ACK is not an ordinary message and does not require a response.
If the client requires reliable transmission of provisional responses the "INVITE" message sent by UAC includes the "Require" header field in which there is a tag called "Option" equal to "100rel". In this case, UAS should send any non-100 provisional responses reliably. This response should also include the "Require" header field with the "OPTION" tag equal to 100rel. On the other hand, if the first request includes the "Supported" header with the "Option" tag equal to 100rel it indicates that the client supports reliable transmission of provisional responses and UAS can send these responses reliably. It is worth mentioning that UAS should not send "100" responses reliably and this is only "101" to "199" responses that can be sent so.

4. Proposed state machine for SIP user agent in reliable transmission of provisional response

In this section, we design a state machine for SIP user agent in reliable transmission of provisional response. This state machine includes two sub-machines: server state machine and client state machine. These machines are useful for describing test scenarios to evaluate functionality of SIP user agents in reliable transmission of provisional response.

4.1. Proposed user agent client state machine

In client state machine, user agent sends the "INVITE" request after reception of that from the SIP client. If the "Require" header field in this request contains the "OPTION" tag equal to "100rel" user agent client will wait for provisional response reception of this request. After reception UAC sends an acknowledgment (PRACK) for the provisional response and go to waiting mode for final response. In this mode, UAC will send an acknowledgment after final response reception, i.e. 200. If the server does not support reliable transmission of provisional responses, user agent client will retransmit the "INVITE" request without the header mentioned above after reception of the unsuccessful response "420" and will stay in waiting mode for provisional and final responses of this request. In this case, it does not send PRACK for provisional response. Figure 1 shows the state machine of client user agent.

4.2. Proposed User agent server state machine

As it is observed in figure 2, user agent decides based on "Require" header field of "INVITE" request, in user agent server state machine. If this header field contains the "OPTION" tag equal to 100rel and server supports reliable transmission of provisional response, the transmission will begin and the server will go to waiting mode for response acknowledgment reception (PRACK); otherwise the error response "420" will be sent and user agent will stay in waiting mode for further "INVITE" reception without the feature mentioned above. Receiving the "INVITE" request UAS will send provisional and final responses and will wait for acknowledgment. User agent server state machine is illustrated in figure 2.

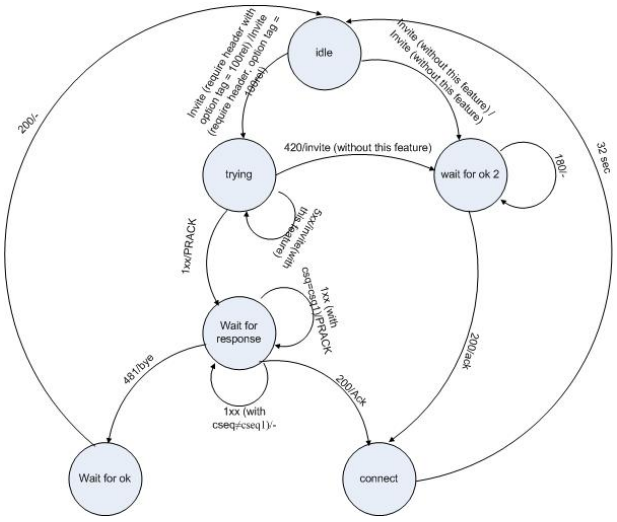

Fig. 1 SIP User Agent Client State Machine

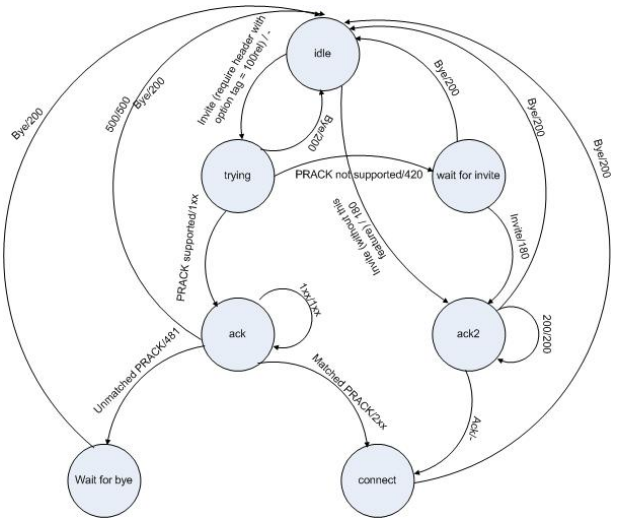

Fig. 2 SIP User Agent Server State Machine

In the next section, these state machines are used to define functional test scenarios.

5. Tests Description

Testing is one of the most important issues in setting up a network, especially when the network is not still mature, e.g. a SIP network. We implemented a Pilot for Next Generation Networks (NGN) and tested different vendors' devices supporting SIP protocol [15]. In this pilot we observed that a considerable number of tests failed due to the mentioned immaturity, especially in interoperability between distinct vendors' network elements in a multi-vendor environment. For example, some SDP parameters used by a call server might be unknown for another call server; there might be some problems in route recording in SIP header; "REINVITE" messages might not have SDP body; etc [16]. This indicates the great importance and necessity of describing tests in each field of network implementation. A SIP test plan can have a structure as figure 3 illustrates.

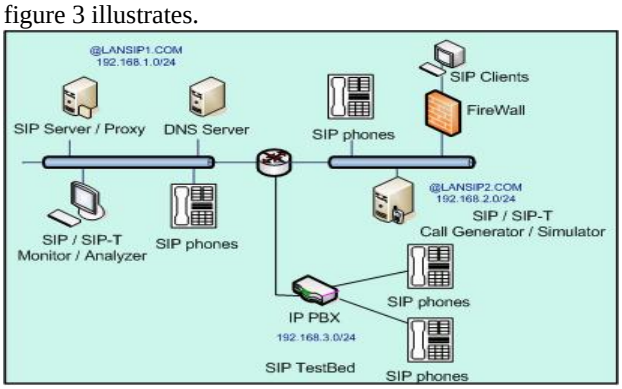

Fig. 3 SIP Test Plan

In this section, complete description of user agent tests in reliable transmission of provisional responses is mentioned. Objectives, presumptions, assumptions, and steps of each test are mentioned in this section. UAC, UAS, or both are examined in these tests. These scenarios are comprehensive according to the designed state machines. However, the number of tests in the set is minimum.

Table 1: Test scenario #1

Test ID	SIP-UA-FU-PR-01
Topic	Normal transmission
Goal	Investigating message exchange for reliable transmission of provisional responses
DUT	UAS, UAC
Test settings	-
Test steps	UAC sends "INVITE" request with "Require" header field containing tag "OPTION" equals to "100rel" to UAS. It is expected that UAS resends provisional response until PRACK reception. Tag "OPTION" in "Require" header field is equal to 100rel in this response. Time interval for provisional response resend is equal to T_1 which is doubled in each transmission. The presumption for T_1 is 500 ms. It is expected that UAC acknowledges this provisional response by PRACK. It is expected that UAS produces 2xx final response for this request. It is expected that the final response is acknowledged by UAC.

Table 2: Test scenario #2

Test ID	SIP-UA- FU-PR-02
Topic	No supporting reliable transmission of provisional responses
Goal	Verification of this point that if the server does not support reliable transmission of provisional responses, INVITE request will be returned
DUT	UAC
Test settings	Server should be configured in the way that does not support reliable transmission of provisional responses
Test steps	UAC sends "INVITE" request with "Require" header field containing tag "OPTION" equals to "100rel" to UAS. UAS responses by "420". It is expected that UAC resends request without the header mentioned above. It is expected that UAS accepts this request and send final response for it. It is expected that UAC acknowledges this response.

Table 3: Test scenario #3

Test ID	SIP-UA-FU-PR-03
Topic	Incompatible PRACK with provisional response
Goal	Verification of this point that a PRACK incompatible with provisional response has been returned with error, compatibility with PRACK includes compatibility of "Method", "Cseq-num", and "Response-num" header fields with corresponding fields in provisional response.
DUT	UAS
Test settings	-
Test steps	UAC sends "INVITE" request with "Require" header field containing tag "OPTION" equals to "100rel" to UAS. UAS resends provisional response until receiving acknowledgement. UAC sends a PRACK incompatible with provisional response. It is expected that UAS answers with "481". It is expected that UAC transmits "BYE" request and terminates the session.

Table 4: Test scenario #4

Test ID	SIP-UA-FU-PR-04
Topic	Not reception of PRACK
Goal	If PRACK request is not received, failure answer will be returned.
DUT	UAS
Test	-

settings	
Test steps	UAC sends "INVITE" request with "Require" header field containing tag "OPTION" equals to "100rel" to UAS. UAS sends provisional response, reliably. UAC does not send PRACK request until the timer in the server ends, i.e. reaches to $64*T_1$. It is expected that UAS sends 5xx answer. It is expected that UAC sends "INVITE" request again.

Table 5: Test scenario #5

Test ID	SIP-UA-FU-PR-05
Topic	Sending final response for the request before receiving PRACK for all provisional responses
Goal	Investigating conditions in which final response can be sent for all provisional responses before receiving PRACK
DUT	UAS
Test settings	Server is configured such that these conditions are removed: final response is equal to 2xx and at least one of provisional responses has session description.
Test steps	UAC sends "INVITE" request with "Require" header field containing tag "OPTION" equals to "100rel" to UAS. UAS generates more than one response. These responses do not have session description. UAS sends final response for the request before receiving PRACK for all provisional responses. It is expected that UAS does not resend provisional responses, but processes PRACK for them.

Table 6: Test scenario #6

Test ID	SIP-UA-FU-PR-06
Topic	Sending final response for the request before receiving PRACK for all provisional responses
Goal	Investigating conditions in which final response cannot be sent before receiving PRACK for all provisional responses
DUT	UAS
Test settings	Server is configured such that final response will be 2xx and at least one of provisional responses has session description
Test steps	UAC sends "INVITE" request with "Require" header field containing tag "OPTION" equals to "100rel" to UAS. UAS generates more than one response one of which has session description. It is expected that UAS does not generate final response for the request until receiving acknowledgement for all provisional responses.

Table 7: Test scenario #7

Test ID	SIP-UA-FU-PR-07
Topic	In-order provisional responses
Goal	Ensuring that reliable provisional responses are sent in-order.
DUT	UAC
Test	-
settings	
Test steps	UAC sends "INVITE" request with "Require" header field containing tag "OPTION" equals to "100rel" to UAS. UAS generates more than one response. RSeq in the second response is not one more than RSeq in the first answer. It is expected that PRACK is not sent for the second provisional response by UAC.

Table 8: Test scenario #8

Test ID	SIP-UA-FU-PR-08
Topic	Receiving offer in PRACK
Goal	Investigating exchange of massages during offer reception in PRACK
DUT	UAS
Test settings	-
Test steps	UAC sends "INVITE" request with "Require" header field containing tag "OPTION" equals to "100rel" to UAS. UAS sends provisional response reliably. UAC places "Offer" in PRACK and sends it. It is expected that UAS places "Answer" in final response to this PRACK.

Table 9: Test scenario #9

Test ID	SIP-UA-FU-PR-09
Topic	Unreliable transmission of provisional response
Goal	Acknowledging that if the "Required" or "Supported" header field does not include the "Option" tag equal to "100rel", the server must not reliably send the provisional response
DUT	UAS
Test settings	-
Test steps	UAC sends "INVITE" request without "Require" header field containing tag "OPTION" equals to "100rel" to UAS. It is expected that UAS sends provisional response for this request unreliably. This response does not have the "Require" header field including "Option" tag equal to 100rel.

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