                    Problems Identified Associated with the
           Session Initiation Protocol's (SIP) Non-INVITE Transaction

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Abstract

   This document describes several problems that have been identified
   with the Session Initiation Protocol's (SIP) non-INVITE transaction.

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1. Problems under the Current Specifications

   There are a number of unpleasant edge conditions created by the SIP
   non-INVITE transaction (NIT) model's fixed duration. The negative
   aspects of some of these are exacerbated by the effect that
   provisional responses have on the non-INVITE transaction state
   machines as currently defined.

1.1. NITs must complete immediately or risk losing a race

   The non-INVITE transaction defined in RFC 3261 [1] is designed to
   have a fixed and finite duration (dependent on T1). A consequence of
   this design is that participants must strive to complete the
   transaction as quickly as possible. Consider the race condition
   shown in Figure 1.

```
                        UAC              UAS
                         |    request    |
                  ---    |---.           |
                   ^     |    `---.      |
                   |     |        `--->|   ---
                   |     |             |    ^
                   |     |             |    |
              64*T1 |    |             |    |
                   |     |             |    |
                   |     |             | 64*T1
                   |     |             |    |
                   |     |             |    |
                   v     |             |    |
       timeout <=== ---  |    200 OK   |    |
                         |        .---|    v
                         |    .---'    |   ---
                         |<--'         |
```
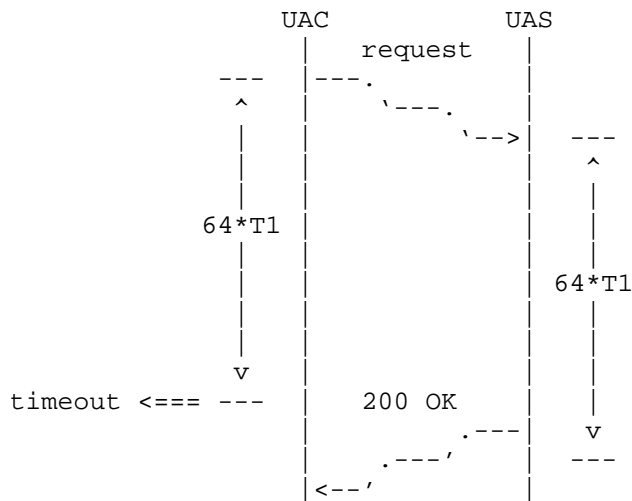
                   Figure 1: Non-Invite Race Condition

   The User Agent Server (UAS) in this figure believes it has responded
   to the request in time, and that the request succeeded. The User
   Agent Client (UAC), on the other hand, believes the request has
   timed-out, hence failed. No longer having a matching client
   transaction, the UAC core will ignore what it believes to be a
   spurious response. As far as the UAC is concerned, it received no
   response at all to its request. The ultimate result is that the UAS
   and UAC have conflicting views of the outcome of the transaction.

Therefore, a UAS cannot wait until the last possible moment to send a
final response within a NIT. It must, instead, send its response so
that it will arrive at the UAC before that UAC times out.
Unfortunately, the UAS has no way to accurately measure the
propagation time of the request or predict the propagation time of
the response. The uncertainty it faces is compounded by each proxy
that participates in the transaction. Thus, the UAS's only choice is
to send its final response as soon as it possibly can and hope for
the best.

This result constrains the set of problems that can be solved with a
single NIT. Any delay introduced during processing of a request
increases the probability of losing the race. If the timing
characteristics of that processing are not predictable and
controllable, a single NIT is an inappropriate model for handling the
request. One viable alternative is to accept the request with a 202
and send the ultimate results in a new request in the reciprocal
direction.

In specialized networks, a UAS might have some reliable knowledge of
inter-hop latency and could use that knowledge to determine if it has
time to delay its final response in order to perform some processing
such as a database lookup while mitigating its risk of losing the
race in Figure 1. Establishing this knowledge across arbitrary
networks (perhaps using resource reservation techniques and
deterministic transports) is not currently feasible.

1.2. Provisional responses can delay recovery from lost final responses

The non-INVITE client transaction state machine provides reliability
for NITs over unreliable transports (UDP) through retransmission of
the request message. Timer E is set to T1 when a request is
initially transmitted. As long as the machine remains in the Trying
state, each time Timer E fires, it will be reset to twice its
previous value (capping at T2) and the request is retransmitted.

If the non-INVITE client transaction state machine sees a provisional
 response, it transitions to the Proceeding state, where
retransmission continues, but the algorithm for resetting Timer E is
simply to use T2 instead of doubling at each firing. (Note that
Timer E is not altered during the transition to Proceeding.)

Making the transition to the Proceeding state before Timer E is reset
to T2 can cause recovery from a lost final response to take extra
time. Figure 2 shows recovery from a lost final response with and
without a provisional message during this window. Recovery occurs
within 2*T1 in the case without the provisional. With the
provisional, recovery is delayed until T2, which by default is 8*T1.

In practical terms, a provisional response to a NIT in currently
deployed networks can delay transaction completion by up to 3.5
seconds.

```
               UAC        UAS                  UAC        UAS
                |          |                    |          |
      ---     |----.      |           ---     |----.      |
       ^      |    '-->|              ^      |    '-->|
     E = T1   |          |          E = T1   |    .-----|(provisional)
       v      |          |            v      |<--'      |
      ---     |----.      |           ---     |----.      |
       ^      |    '-->|              ^      |    '-->|
       |      | X<----|(lost final)   |      | X<-----|(lost final)
       |      |          |            |      |          |
     E = 2*T1 |          |            |      |          |
       |      |          |            |      |          |
       |      |          |            |      |          |
       v      |          |            |      |          |
      ---     |----.      |            |      |          |
              |    '-->|              |      |          |
              |    .-----|(final)     |      |          |
              |<-'      |              |      |          |
              |          |            |      |          |
       \/\       /\/              /\/ /\/        /\/
                            E = T2
       \/\       /\/              /\/ /\/        /\/
        |          |              |    |          |
        |          |              |    |          |
        |          |              v    |          |
        |          |             ---  |----.      |
        |          |              |    |    '-->|
        |          |              |    |    .-----|(final)
        |          |              |    |<--'      |
        |          |              |    |          |
        |          |              |    |          |
        |          |              |    |          |
```
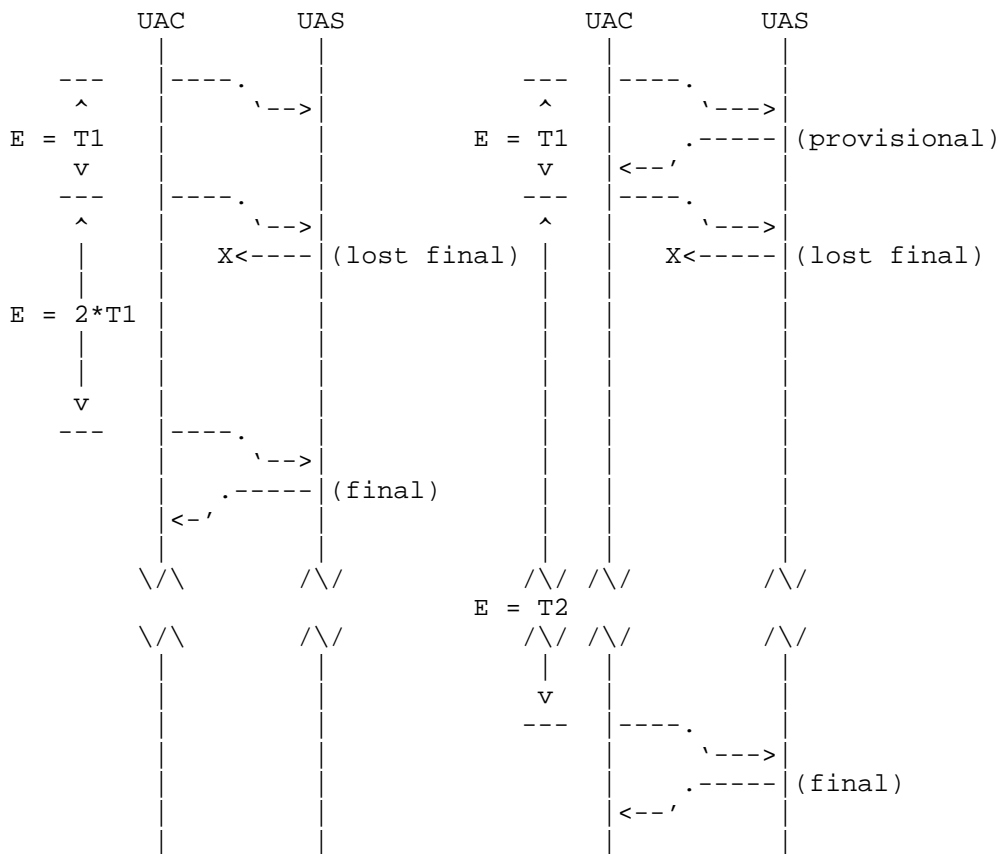
Figure 2: Provisionals Can Harm Recovery

No additional delay is introduced if the first provisional response
is received after Timer E has reached its maximum reset interval of
T2.

1.3. Delayed responses will temporarily blacklist an element

A SIP element's use of DNS Service Record Resource Records [3] is
specified in RFC 3263 [2]. That specification discusses how SIP
ensures high availability by having upstream elements detect failure
of downstream elements. It proceeds to define several types of
failure detection and instructions for failover. Two of the
behaviors it describes are important to this document:

o Within a transaction, transport failure is detected either through
   an explicit report from the transport layer or through timeout.
   Note specifically that timeout will indicates transport failure
   regardless of the transport in use. When transport failure is
   detected, the request is retried at the next element from the
   sorted results of the SRV query.

o Between transactions, locations reporting temporary failure
   (through 503/Retry-After, for example) are not used until their
   requested black-out period expires.

The specification notes the benefit of caching locations that are
successfully contacted, but does not discuss how such a cache is
maintained. It is unclear whether an element should stop using
(temporarily blacklist) a location returned in the SRV query that
results in a transport error. If it does, when should such a
location be removed from the blacklist?

Without such a blacklist (or equivalent mechanism), the intended
availability mechanism fails miserably. Consider traffic between two
domains. Proxy pA in domain A needs to forward a sequence of non-
INVITE requests to domain B. Through DNS SRV, pA discovers pB1 and
pB2, and the ordering rules of [2] and [3] indicate it should use pB1
first. The first request to pB1 times out. Since pA is a proxy and
a NIT has a fixed duration, pA has no opportunity to retry the
request at pB2. If pA does not remember pB1's failure, the second
request (and all subsequent non-INVITE requests until pB1 recovers)
are doomed to the same failure. Caching would allow the subsequent
requests to be tried at pB2.

Since miserable failure is not acceptable in deployed networks, we
should anticipate that elements will, in fact, cache timeout failures
between transactions. Then the race in Figure 1 becomes important.
If an element fails to respond "soon enough", it has effectively not
responded at all and will be blacklisted at its peer for some period
of time.

(Note that even with caching, the first request timeout results in a
timeout failure all the way back to the original submitter. The
failover mechanisms in [2] work well to increase the resiliency of a
given INVITE transaction, but do nothing for a given non-INVITE
transaction.)

1.4. 408 for non-INVITE is not useful

   Consider the race condition in Figure 1 when the final response is
   408 instead of 200. Under the current specification, the race is
   guaranteed to be lost. Most existing endpoints will emit a 408 for a
   non-INVITE request 64*T1 after receiving the request if they have not
   emitted an earlier final response. Such a 408 is guaranteed to
   arrive at the next upstream element too late to be useful. In fact,
   in the presence of proxies, these messages are even harmful. When
   the 408 arrives, each proxy will have already terminated its
   associated client transaction due to timeout. Therefore, each proxy
   must forward the 408 upstream statelessly. This, in turn, is
   guaranteed to arrive too late. As Figure 3 shows, this can
   ultimately result in bombarding the original requester with spurious
   408s. (Note that the proxy's client transaction state machine never
   enters the Completed state, so Timer K does not enter into play.)

```
                 UAC          P1          P2          P3          UAS
                  |           |           |           |           |
          ---  ===---.        |           |           |           |
           ^   |     '-->===---.          |           |           |
           |   |           |   '-->===---.            |           |
           |   |           |           |   '-->===---.            |
        64*T1  |           |           |           |   '-->===    |
           |   |           |           |           |           |  |
           |   |           |           |           |           |  |
           v   |           |           |           |           |
    (timeout) --- ===       |           |           |           |
                  |     .-408===        |           |           |
                  |<--'      |      .-408===         |           |
                  |     .-408-|<--'       |      .-408===        |
                  |<--'      |     .-408-|<--'        |      .-408===
                  |     .-408-|<--'      |     .-408-|<--'       |
                  |<--'      |     .-408-|<--'        |           |
                  |     .-408-|<--'      |           |           |
                  |<--'      |           |           |           |
                  |          |           |           |           |
```
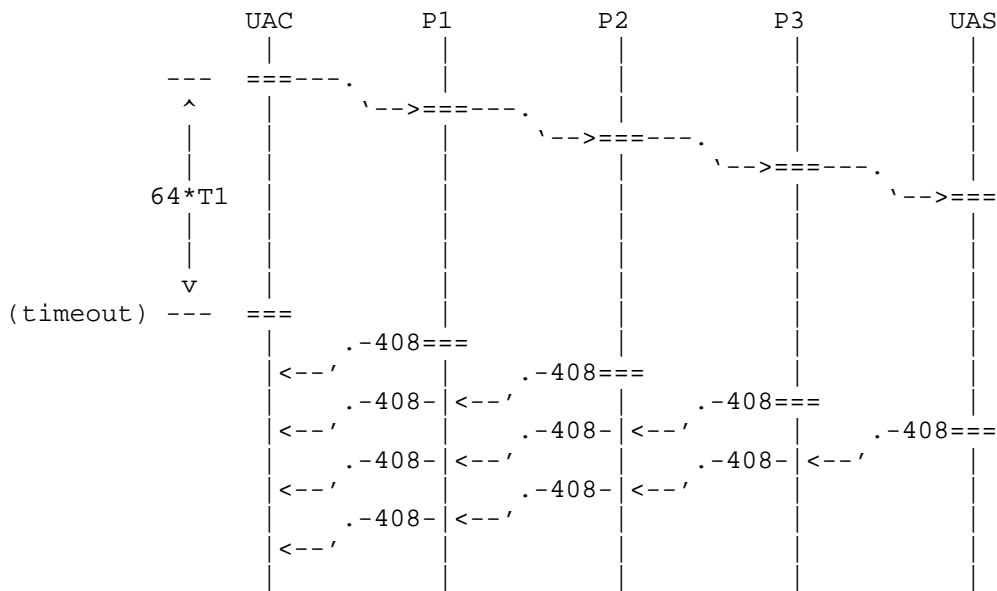
                  Figure 3: Late 408s to Non-INVITEs

   This response bombardment is not limited to the 408 response, though
   it only exists when participating client transaction state machines
   are timing out. Figure 4 generalizes Figure 1 to include multiple
   hops. Note that even though the UAS responds "in time" to P3, the
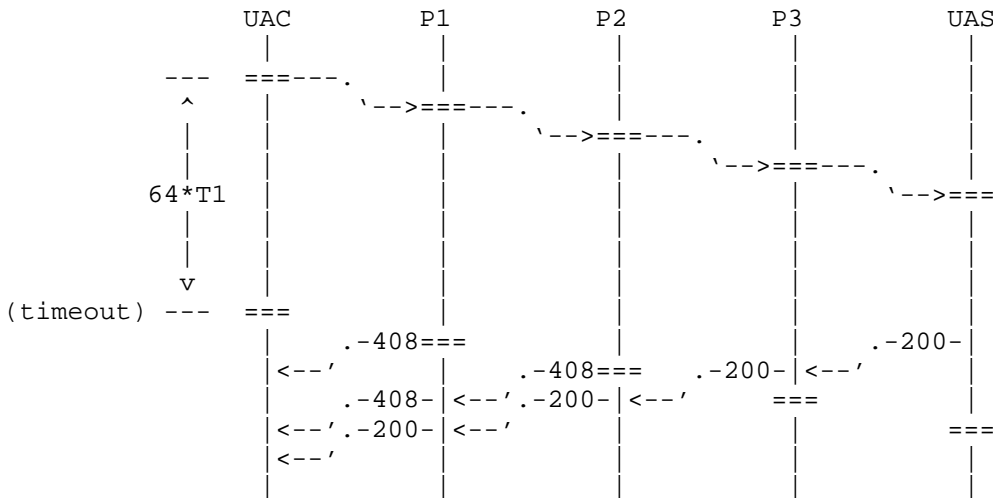   response is too late for P2, P1, and the UAC.

```
              UAC         P1          P2          P3          UAS
               |           |           |           |           |
        --- ===---.        |           |           |           |
         ^     |    '-->===---.        |           |           |
         |     |           |    '-->===---.        |           |
         |     |           |           |    '-->===---.        |
       64*T1   |           |           |           |    '-->===
         |     |           |           |           |           |
         |     |           |           |           |           |
         v     |           |           |           |           |
(timeout) --- ===          |           |           |           |
               |       .-408===        |           |        .-200-|
               |<--'       |       .-408===    .-200-|<--'       |
               |       .-408-|<--'.-200-|<--'       ===          |
               |<--'.-200-|<--'       |           |           ===
               |<--'       |           |           |           |
               |           |           |           |           |
```

                  Figure 4: Additional Timeout-Related Error

1.5. Non-INVITE timeouts doom forking proxies

   A single branch with a delayed or missing final response will
   dominate the processing at proxy that receives no 2xx responses to a
   forked non-INVITE request. This proxy is required to allow all of
   its client transactions to terminate before choosing a "best
   response". This forces the proxy's server transaction to lose the
   race in Figure 1. Any response it ultimately forwards (a 401, for
   example) will arrive at the upstream elements too late to be used.
   Thus, if no element among the branches would return a 2xx response,
   failure of a single element (or its transport) dooms the proxy to
   failure.

1.6. Mismatched timer values make winning the race harder

   There are many failure scenarios due to misconfiguration or
   misbehavior that the SIP specification does not discuss. One is
   placing two elements with different configured values for T1 and T2
   on the same network. Review of Figure 1 illustrates that the race
   failure is only made more likely in this misconfigured state (it may
   appear that shortening T1 at the element behaving as a UAS improves
   this particular situation, but remember that these elements may trade
   roles on the next request). Since the protocol provides no mechanism
   for discovering/negotiating a peer's timer values, exceptional care
   must be taken when deploying systems with non-defaults to ensure that
   they will never directly communicate with elements with default
   values.

2. Security Considerations

   This document describes some problems in the core SIP specification
   [1] related to the SIP non-INVITE requests, the messages other than
   INVITE that begin transactions. A few of the problems lead to
   flooding or forgery risk, and could possibly be exploited by an
   adversary in a denial of service attack. Solutions are defined in
   the companion document [4].

   One solution there prohibits proxies and User Agents from sending 408
   responses to non-INVITE transactions. Without this change, proxies
   automatically generate a storm of useless responses. An attacker
   could capitalize on this by enticing User Agents to send non-INVITE
   requests to a black hole (through social engineering or DNS
   poisoning) or by selectively dropping responses.

   Another solution prohibits proxies from forwarding late responses.
   Without this change, an attacker could easily forge messages which
   appear to be late responses. All proxies compliant with RFC 3261 are
   required to forward these responses, wasting bandwidth and CPU and
   potentially overwhelming target User Agents (especially those with
   low speed connections).

3. Acknowledgements

   This document captures many conversations about non-INVITE issues.
   Significant contributers include Ben Campbell, Gonzalo Camarillo,
   Steve Donovan, Rohan Mahy, Dan Petrie, Adam Roach, Jonathan
   Rosenberg, and Dean Willis.

4. Informative References

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   [3] Gulbrandsen, A., Vixie, P., and L. Esibov, "A DNS RR for
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   [4] Sparks, R., "Actions Addressing Identified Issues with the
        Session Initiation Protocol's (SIP) Non-INVITE Transaction", RFC
        4320, January 2006.

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