Detecting Forged TCP Reset Packets

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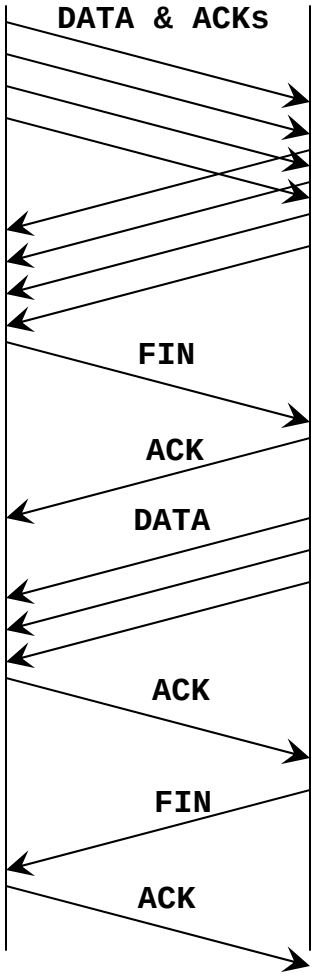
Outline:

- Injected TCP Reset (RST) packets can be used for many purposes.
  - Our goal is ***not*** to judge their use but to make their use ***transparent***
- TCP 101: TCP Reset (RST) Packets
  - Network Management 101: Injected RSTs
- Injected Packets: Constraints and Freedoms
- Detecting Injected Packets: Race Conditions
- Fingerprinting Packet Injectors
- What sources did we see?
  - TCP Packet Injectors and their uses
  - Non-injected sources

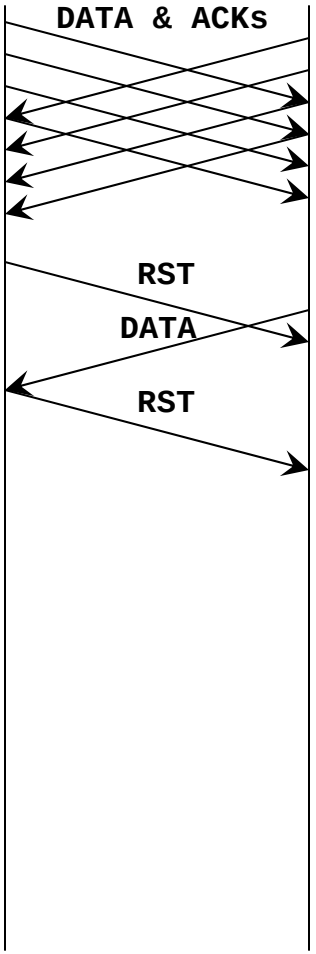
TCP 101: Connection Termination

- A side sends a TCP Finish (FIN) to indicate that it is done sending but not receiving
  - Resulting connection is “half-closed”
- Connection is only closed when the other side sends a FIN of its own
  - Until then, the other side can keep sending data



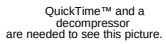
TCP 101: Connection Aborting

- But what if a side does not want to send ***or receive*** any more data:
  - Program closed
  - Abort the connection
  - Deny the connection after first accepting it
- A TCP Reset (RST) tells the other side of the connection:
  - There will be no more data from this source on this connection
  - This source will not accept any more data, so no more data should be sent
- Once a side has decided to abort the connection, the ***only*** subsequent packets sent on this connection may be RSTs in response to data
  - Once a side accepts a RST, it will no longer send data or accept any more data
- Yet RSTs are quite common, 10-15% of ALL flows are terminated by a RST rather than a FIN
  - For HTTP, it can be over 20%



Network Management 101: Connection Blocking

- Many reasons to terminate a connection:
  - Required network censorship (the “Great Firewall” of China)
  - Blocking “undesirable” protocols (blocking P2P traffic)
  - Stopping spam and network attacks
- Can build either an in-path device or an out-of-path device
  - In path devices can just drop traffic:
    But they are dangerous! They add points-of-failure and can slow down the network
- An out-of-path device is simpler to build, but you have to terminate the flow somehow:
  - Tell an in-path device to block a flow (ACL injection)
  - Send bogus TCP data or FINs
    - May result in packet storms
  - Send bogus TCP RSTs
    - If ***one*** side accepts the packet, the connection will terminate
    - Injecting RSTs is the generally most preferred method by network engineers



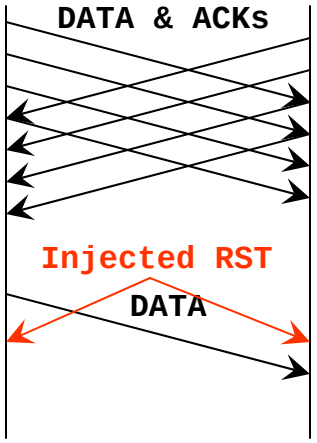
From Comcast’s FCC Filings

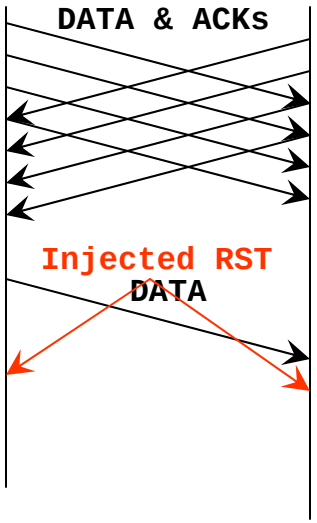
What Can an Injected TCP RST Look Like?

- The 5-tuple (source and destination ports and IP addresses) must be correct
  - Can send to both directions, to ensure that one side accepts the RST
- The packet must have ***consistent*** sequencing:
  - Many TCP stacks will accept any RST ***in window***
  - Paranoid stacks will only accept RSTs ***in sequence***
    - Prevents blind TCP RST injection
- Almost complete freedom elsewhere
  - TTL may be different (because the injected packet took a different path)
    - But TTL can be highly variable on normal RSTs too
  - The ACK field is not checked
  - IPID, other TCP flags (ACK flag, ECN, etc)
- Yet we'd expect an end host or injector to be ***consistent*** in how it creates packets

RST Injection Race Conditions

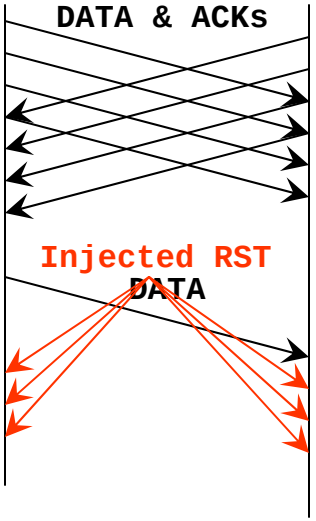
- An injected reset is an ***additional*** packet, it can't remove a packet from the network
- Unavoidable race conditions which create detectable out-of-spec packet flows:
- DATA_SEQ_RST:
  - A data packet immediately following a RST packet where data packet (seq + len) > RST seq
  - Caused by a subsequent data packet in flight
- RST_SEQ_DATA:
  - A RST packet immediately following a data packet where RST seq < data packet (seq + len)
  - Caused because the injector was too slow in sending the packets





Race Conditions Cause RSTs to be ignored

- RST_SEQ_DATA creates RSTs that are ignored
  - So countermeasure is to send multiple RSTs with increasing sequence number
    - Thus the second or third RST should be in-window
  - Best increment: size of last packet
  - Second-best increment: standard MTU
- RST_SEQ_CHANGE:
  - Back to back RST packets where the second RST seq != first and
    RST seq > maximum sent sequence
    RST seq > maximum received ACK
    - (In case we missed a packet or the other side is not following the specification)
- Non-robust injectors can only be detected when the race conditions occur
- Injectors robust the the RST_SEQ_DATA race condition can ***always*** be detected



RST Injectors Also Create "Interesting" Aborts

- SYN_RST:
  - A RST packet immediately following a SYN packet
    - Note that web browsers and SMTP authentication clients do this for benign reasons:
      For example, the user misclicks on a bookmark and then immediately hits "STOP"
- SYN_ACK_RST:
  - A RST packet immediately following the SYN/ACK from the server
    - Note that web servers and SMTP servers do this for benign reasons:
      For example, accept a connection and ***then*** check for presence on a blacklist
- RST_ACK_CHANGE:
  - Back to back RST packets where the second one's ACK != the first one's ACK and the ack doesn't make sense (greater than any seen packet in the other direction, not equal to the SEQ, not equal to zero)
    - An identified injector does this

The High Level Procedure

- A ***click*** element to ***passively*** detect suspicious RST packets as they occur
  - Either as a live network monitor or on packet traces
  - Extract ***context*** around every suspicious packet for further analysis
- Postprocess captured packets to remove private information
  - Strip the payload from the packets
  - Perform hostname and GeoIP lookups
  - Optional anonymization
- Place alerts in a database and look for fingerprints and other commonalities between alerts
  - Fingerprints generated by manual examination of clusters of alerts

More Details

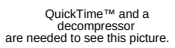
- The click module used a small (256k entry) flow cache
  - 32 way associative, evict-oldest policy
  - Time window is ***not*** a problem: injected RSTs must be close to the associated packet to be effective
    - RST_SEQ_DATA, DATA_SEQ_RST, RST_SEQ_CHANGE, and RST_ACK_CHANGE are set with a threshold of 2 seconds
    - SYN_RST and SYN_ACK_RST are set with a threshold of .1 seconds
- Buffer 256K packets and isolate any “interesting” host-pairs in the buffer
  - Allows a one-pass procedure to capture the context of an alert
- Associate reverse name lookup and GeoIP information with each IP
- Optional anonymization pass:
  - replace IP with random ID, remove hostname from FQDN
- Place all alerts and all packet headers -200 to +100 around each alert into the database for analysis
- Ran on 4 networks in early 2008:
  - Operationally at ICSI for months,
    19 hours at UC Berkeley, 24 hours at Columbia CS, 5 hours at George Mason University

The Comcast Sandvine Injector

- A multiple-packet RST injector with a distinct fingerprint:
  - First RST packet: ipid += 4
  - Second RST packet: ipid += 1
    sequence += 12503
    - Large increment is a known bug to Sandvine, it should be smaller
- Numerous alerting IP addresses
  - 106 communicating with ICSI, 30 communicating with Berkeley, 36 communicating with Columbia, 2 communicating with GMU
    - Most of the ICSI alerts correspond to known incidents of unauthorized P2P usage
- Comcast is ***not*** the only user of this tool
  - Cox: 35 at ICSI, 262 at Berkeley, 3 at Columbia
  - Unknown Korean ISP: 1 at ICSI, 50 at Berkeley, 4 at Columbia
  - 2 other alerts with no reverse name lookup

Is Comcast Only Blocking Leeches?

- Comcast made public statements that they were only blocking uploads from Comcast peers ("Seeding" and "leeches")
  - Blocking leeches and incidental seeding directly benefits Comcast's customer (although hurts BitTorrent overall)
  - Blocking deliberate seeding penalizes Comcast's customer
    - Problem of transparency: if you ***know*** the policy is "no seeding" there are easy workarounds for legal content
- Looked at flows at ICSI where we see the SYN and blocking RST
  - All but 7% are clear seeds/leeches
  - For remaining 7%, Sandvine supports recognizing pure seeds by looking at the initial BitTorrent message



The Bezeq International and IPID 256 Injectors on P2P traffic

- Bezeq International (Israeli Telecom/Cable company) disrupting P2P traffic
  - Common at ICSI (25 alerting IPs), seen at Columbia (2 alerting IPs)
  - Multiple RST packets with a distinct fingerprint:
    - Always IPID = 16448 (0x4040)
    - Second and successor packets increment ***ack*** field, not the ***seq*** field
      - Assume to be a bug
- Korean IPID 256 injector
  - Single packet injector, IPID = 256
    - Single packet injectors are less robust but somewhat less detectible
  - 9 alerting IPs seen at ICSI, 90 alerting IPs to Berkeley, 16 alerting IPs to Columbia
    - Plus 5 alerts at Berkeley to other Asian countries

Gummadi et al Report on BitTorrent Blocking

- Gummadi et al built and used a Java test-client
  - Java client emulates a BitTorrent transfer, checks for some seeding/blocking policies
    - Requires transferring almost 30 MB of data for the full test
- They discovered three ISPs performing significant blocking: Comcast, Cox, and StarHub (Singapore)
- We can confirm StarHub (maxonline.com.sg) was blocking P2P traffic
  - We see 4 alerting IPs from this ISP at ICSI which appear to be a multipacket injector:
    - Second RST's sequence increment is equal to the last data packet's length
    - 34 flows show interference
  - But we were unable to develop a better fingerprint for this injector

Spam and Virus Blocking with RST injection

- yournet.ne.jp: Apparently blocking Spam Bots
  - 29 IPs generating SYN_RST alerts on port 25 to ICSI
    - >30% of ***all*** IPs generating SYN_RST alerts for SMTP to ICSI
    - TTL is usually +5, but not always. IPID appears unrelated
  - Appears to be a dynamic spam-blocking system
    - Rather than just block outbound port 25:
      Heuristically detect spam bots and then block their messages with RST packets
- UVic.ca: Apparently blocking viruses
  - One smtp server attempting to forward a MyDoom bounce message back to ICSI:
    Message is blocked with a series of RST packets
    - ~10 RST packets, increment sequence by 1500, IPID = 305, TTL 38 higher
    - Mail server then retries a few hours later, and the same thing occurs
      - Timed out after several days

The Great Firewall of China

- Appears to be multiple injectors with distinct fingerprints:
  - IPID 64: Multiple packets, IPID always 64
  - IPID -26: IPID is 26 less than previous packet
  - SEQ 1460: Multiple packets, always increments by 1460, unrelated IPID
  - RAE: Single packet, sets both ACK bit and ECN Nonce bit!?!
- Multiple injectors can be seen on the same flow!
  - 102 hosts at ICSI show multiple chinese fingerprints: redundant devices along the path?!
    - Although the RAE injector appears to be distinct, only 2 overlaps at ICSI
  - One web request from columbia shows:
    - IPID 64 injector RSTs, then (probably) the 1460 injector, then a RST from the host, then a series of RSTs from the IPID -26 injector ***whose IPID seems derived from the 1460 injector's RST packet!?!?***
      - Or perhaps our fingerprints are too specific: a single injector could have mulitple fingerprints?

But Not All "Suspicious" RSTs are Injected!

- NATs can generate spurious RSTs
  - And bad ones too, in active flows…
- Google and Yahoo' load balancers occasionally generate RST_SEQ_DATA and DATA_SEQ_RST alerts
- Planetlab is awful: generates RST_SEQ_DATA and DATA_SEQ_RST errors ***all the time***
  - We excluded Planetlab from our datasets, after a 1 hour trace at Columbia generated 300 alerts on Planetlab communication!
- Random out-of-sequence RSTs with IPID=0 in the middle of traffic
  - Including internal hosts. Bad NATs? Bad Endhosts?
- Common SYN_RST behavior with no geographic commonality
  - TTL > 128 higher or IPID = 65259
  - Bad NATs? Bad Endhosts?
- Thus until the alerts are correlated in a database and fingerprinted, just alerting is insufficient to conclude interference

Conclusions

- Can ***detect*** injected TCP RST packets
  - The same technique can be used for other packet-injection attacks: we have such an IDS detector for DNS attacks
- Can ***fingerprint*** many sources of injected TCP RST packets
- Many ***benign*** sources of seemingly injected RST packets
  - Without fingerprints or correlation, can't conclude that suspicious RSTs are actually injected by a network management process
- Email nweaver@icsi.berkeley.edu if you desire a copy of the source code

Backup: All Fingerprints

QuickTime™ and a
decompressor
are needed to see this picture.

Backup: Identified Sources

QuickTime™ and a
decompressor
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Backup: Identified Benign Sources

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