Denial of Service Attacks

Denial of Service (DoS) Attacks

- Attack availability
- No direct benefit to the attacker, except for the victim's pain
- (But there are some exceptions)
- Major problem on today's Internet

History

- Most viruses and worms simply perpetrate DoS attacks
- The phone system has experienced prank DoS attacks
- Must distinguish attacks from "flash crowds", also known as the "Slashdot Effect"

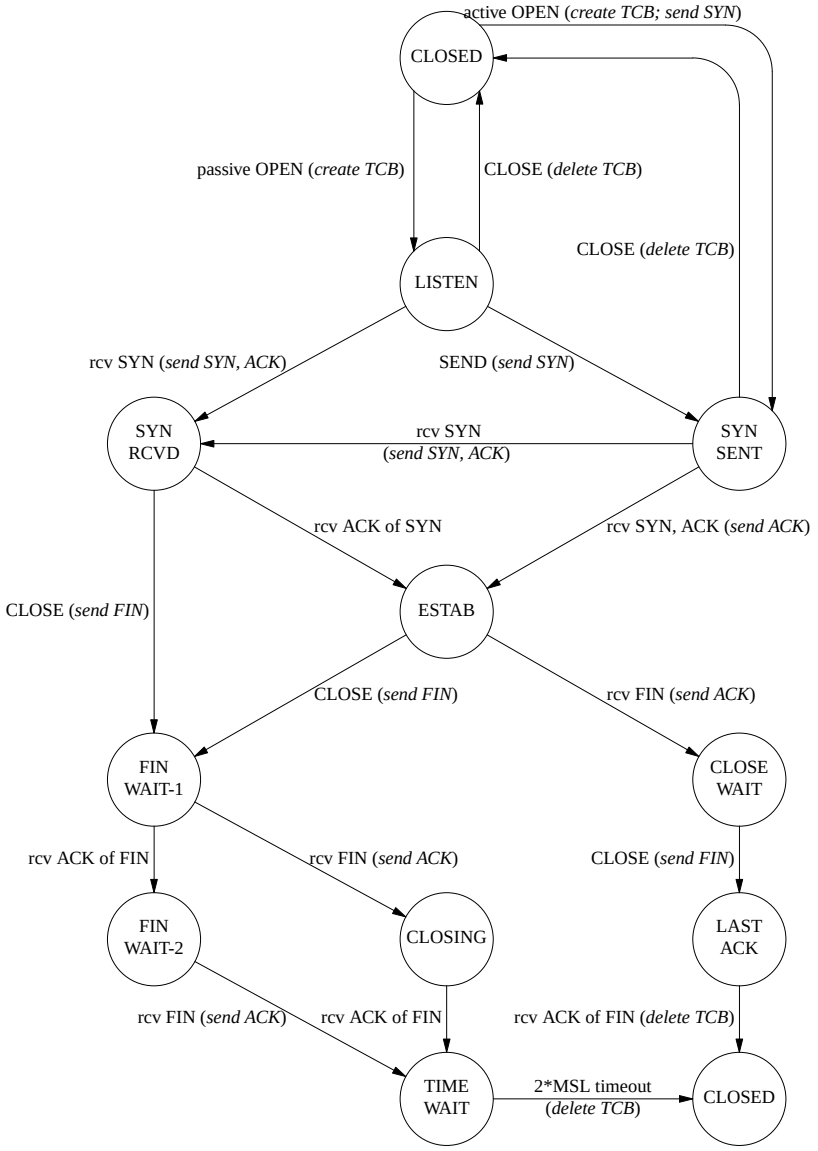
What Can be DoSed?

- Bandwidth — clog the link
- CPU time — make someone do expensive calculations
- Memory — tie up system state
- More generally, DoS can occur any time it costs less for an attacker to send a message than it costs the recipient to process it

First Internet DoS Attack

- Attacker sends many SYN packets from a forged source address
- The SYN+ACK packets go nowhere
- No ACK to them ever arrives; the connection stays half-open
- Why is this a DoS?

The TCP State Diagram



SYN Flooding

- An arriving SYN sends the "connection" into `SYN-RCVD` state
- It can stay in this state for quite a while, awaiting the acknowledgment of the SYN+ACK packet, and tying up memory
- For this reason, the number of connections for a given port in `SYN-RCVD` state is limited
- Further SYN packets for that port are dropped
- The trick is the address forgery — if the attacker impersonates a non-existent host, neither the SYN+ACK nor a RST will ever arrive
- The port is thus blocked

Defenses

- Anti-spoofing
- Better data structures
- SYN cookies

Anti-Spoofing

- Conceptually simple, but requires wide-scale deployment
- Get most — all? — ISPs to filter outbound packets, to prevent spoofing
- Very hard — ISPs don't want to do that; it's expensive for some
- Can still have local spoofing
- But — can blacklist entire site if necessary

Better Data Structures

- No reason to allocate full protocol control block for just a SYN packet
- Allocate something *much* more compact, and raise the limit on half-open connections
- Can handle many more, but the attacker can still win

Attacking Compact Data Structures

- Bare minimum to store: 32-bit address, 16-bit port number, at least part of initial sequence number — call it 64 bits
- (Actually, must be higher)
- Allocate 256MB to connection table
- Assume each entry can persist for 10 seconds
- Attacker can keep it filled with bandwidth of about 200M bps — not a lot for a large site

Generic Solution

- Don't create state until necessary
- In particular, don't create connection state until you know that the far end is there
- General idea: encode (and cryptographically seal) state into some value sent from the server to the client
- The client returns the state in its third message
- The server unseals the state, makes sure it's authentic, and then creates the connection

SYN Cookies

- Generally credited to Dan Bernstein (though there's some evidence that others had the idea (but didn't publish widely) first
- Basic idea: generate the server's ISN from a time counter, the client's MSS, and a 24-bit cryptographic function of the time counter and the connection four-tuple
- When the client's ACK message comes in, validate the connection data from the 24-bit function, and create the connection control block using the data in the ACK packet

It's Not Perfect

- Certain TCP features can't be handled, or are handled imperfectly
- Solution: fall back to this if and only if under attack
- It's better than no connection at all

CPU Denial of Service

CPU Denial of Service

- Using SYN cookies requires CPU time for a cryptographic calculation
- Suppose the attacker wants to exhaust CPU time
- Better yet, think of TLS — RSA calculations are very expensive
- Need a way to rate-limit requests from compromised clients

Puzzles

- General solution: create a puzzle that's expensive to solve but cheap to verify
- Puzzle difficulty should be tunable, in response to server load
- Before doing any expensive work, challenge the client to solve the puzzle
- Not a serious problem for legitimate clients; should pose a considerable burden for attackers

Hash Puzzle

- Generate n, a difficulty metric, and a random value x
- Send the client $\langle n, h(x), x' \rangle$, where x' is x with the low-order n bits set to zero and h is a cryptographic hash function
- Client must find x
- Client's guesses – and its answer — are validated by calculating $h(x)$ and seeing if it matches the server's value; that's easy

Why it Works

- Since h is a cryptographic hash function (i.e., SHA-1), there is no faster way to find x from $\langle n, h(x), x' \rangle$ than brute force
- This takes 2^{n-1} operations on average
- A guess is easy to validate; it takes just 1 operation

Why it Doesn't Work

- Attackers have *lots* of machines
- It's easier for the attacker to throw more machines at the problem than it is for the defender
- (If the server increases n too much, it's difficult for legitimate clients)

History

- Attack not (yet?) seen in the wild
- Similar to anti-spam technique ("hash cash") proposed in 1992
- Merkle used puzzles in an early approach to public key-like key distribution
- Laurie and Clayton showed why it doesn't work against spam

Distributed Denial of Service Attacks (DDoS)

Distributed Denial of Service Attacks (DDoS)

- Most common form of DoS today
- Exhaust network bandwidth
- Uses large network of compromised "zombies" or "bots"
- "Command and control" node tells bots what to do
- IRC frequently used for control channels
- Newer ones use peer-to-peer meshes

History

- First seen in late 1999
- Comments in the code suggested that a massive attack was scheduled for December 31 — just in time to exacerbate possible Y2K troubles
- Fortunately, neither happened

Address-Spoofing

- Early versions used address-spoofing — make it harder to trace or filter bots
- As a result, early defense attempts focused on traceback
- Most newer attacks don't bother with address-spoofing — because traceback and filtering don't work

Too Many of Them!

- A defender can't do much with a list of 10,000 bots
- Tracing down the person responsible is time-consuming and sometimes futile
- Most routers can't handle a filter list with 10,000 entries

Building Botnets

- Get someone to run the bot software
- Use "come and get it" with infected "free" software (today's lure: "free" anti-virus software)
- Use web pages with nasty ActiveX controls (plus trickery to make users accept them) — "drive-by downloads"
- Use exploits to penetrate machines, possibly via worms
- Buy or rent them
- Steal them!

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Bot-Jacking

- Bot-jacking — stealing botnets from other bad guys
- To prevent this, some bots patch other security holes on "their" machines
- One recent one includes current anti-virus software!

State of the Art

- Modern bots are fully updatable by the botherd
- Download new software to them for bug fixes or new functions: spam, DDoS, scanning, etc.
- Many bots use encrypted communications channels

Uses of Botnets

- Primary uses: DDoS and spamming
- (Spamming is a denial of service attack on mailers!)
- DDoS primarily used for extortion, especially against sports-betting sites
- "Hacktivism" — attack a target for ideological reasons (Estonia, Georgia, India vs. Pakistan, Israel vs. Palestine, more)
- They have a time-sensitive product and can't outwait the bad guys
- (Occasional use: revenge against other bad guys)

Combination Attacks

- DDoS can be used as part of other attacks
- Example: interrupt communication to SecurID servers
- Example: divert people to "backup" bank site as part of phishing attack

Defenses

Defending Against DDoS

It's Not Quite that Bad...

- No comprehensive defenses
- Some heuristic defenses
- Still an active research area

Heuristic Defenses

- Overprovision
- Black-hole routing
- Filter anomalies
- Replication

Overprovisioning

- Design DDoS-proof site with really big pipes
- Ideally, ride out multi-gigabit attack
- Of course, there are really big botnets, too

Black-Hole Routing

- Set up ISP routing to make it really easy to divert all traffic for the victim to a sinkhole
- The ISP takes the victim site off the air!
- But — it avoids collateral damage to other sites
- Most DDoS attacks have been relatively short-lived

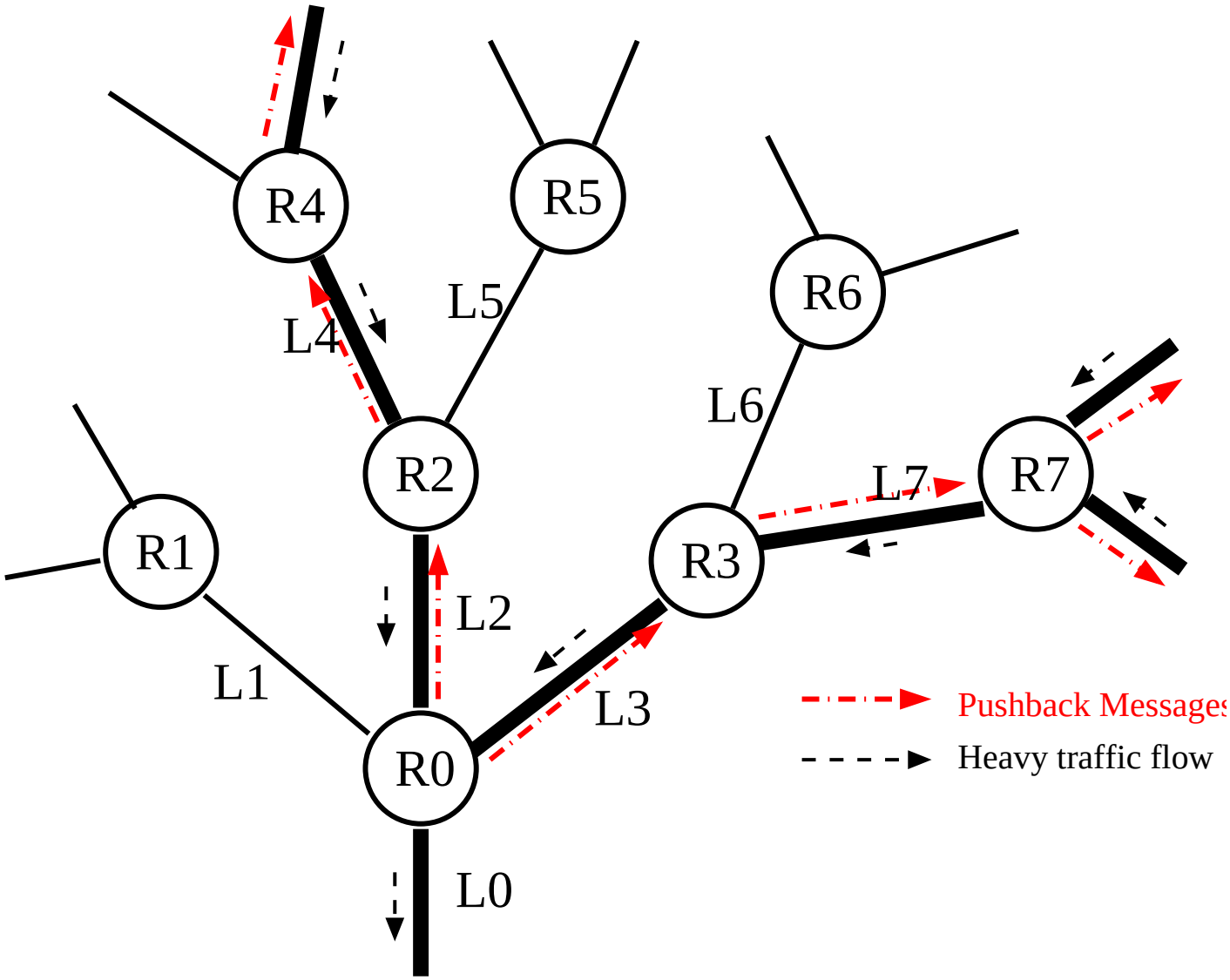
Anomaly Filtering

- DDoS traffic usually isn't perfectly "normal"
- TTLs, protocols, etc., are often unusual
- Route traffic through filtering boxes; filter based on these anomalies
- Imperfect, but frequently good enough

Pushback

- When a router output link is overloaded, see which input links the packets are coming from
- Tell the upstream nodes to rate-limit packets to this router
- Apply the algorithm recursively

Data Flow



Other DoS Attacks

Other DoS Attacks

- Bayesian filter
- Program availability
- Reflector attacks

Bayesian Filter

- Bayesian filters are used for anti-spam
- Spammers have sometimes sent email carefully crafted to consume most CPU cycles on Bayesian filters
- Result: sites turn off the filters to let email go through
- Consequence: spam gets through, too

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Reflector Attacks

- Attacker sends a small packet with a forged source address to some service, especially the DNS
- The packet generates a much larger response
- This response is sent to the forged source address
- Attacker gets a *multiplier effect*, and hides, too

Program Availability

- Find bugs and exploit them, to crash some programs
- Persistent worry: is there a penetration exploit, too?
- If you see lots of core dumps on your system, worry...