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# Normal Failures and Automatic DDoS Mitigation

(Where's the Red Button?)

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# Considerations for designers of network dependent systems



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# The Impact

- History indicates that the growth in damage from worms and DDoS is a result of increased computerization and dependence on network systems.
- Often the simplest worms cause the most damage.
  - SQL slammer was a good example
    - Spread via a single UDP packet, 376 bytes application.
    - Caused disruption to Bank Of America Teller Machine network.



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# Can we fix this by adding layers of security?

- Virtual Private Data Networks(VPNs)
- Stateful and Application level Firewalls
- Intrusion Detection Systems



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# Up to a point adding layers works

- Security, like safety, suffers from diminishing followed by negative returns on investment.
- At a certain point additional attempts to make things more secure result in steadily eroding security.
- Concept of “Normal Failures” (William Langwieche) & “Interactive complexity” (Charles Perrow)



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# Examples of Normal Failure in complex systems

- The lessons of Flight 592
  - <http://www.theatlantic.com/issues/98mar/valuejet1.html>
- The Three Mile Island Incident
  - [http://www.acsh.org/publications/reports/island\\_0399.html](http://www.acsh.org/publications/reports/island_0399.html)



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# The implication for system designers

- We are not attempting to discourage attempts to leverage economies nor to suggest that security is intractable but to point out that, despite our best effort, “stuff” does and will continue to happen.
- As Nation-States get into the act of Worm and DDoS tool development, these systems will be come weaponized.
- These tools will be tailored to attack network based command and control, they will target Force-Net type systems.



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# The implications, cont.

- Designers of systems must not presume that network presence will always be possible.
- With the right attack the network will fail.
- Maintain a lower tech backup plan.
  - The example of the financial institution that had no fax machines.



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# What can be done?

1. Make sure you have backup plan that does NOT depend on the network.
2. Install and run only what is required
3. Authenticate and encrypt where possible.
4. Avoid software monoculture.
5. Demand Critical Quality software (avoid temptation to blindly use CoTS systems)
6. Keep an eye on emerging threats.
7. Know who is writing the software running on your network (and what's in that software)



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# Cautionary tales

- Remotely causing hardware failure in a MM\*C Plus FDDI switch, without administrator access?
- Mistaken cut and paste of router BGP config causing segmentation of a Tier-1 US backbone.



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# Automatic DDoS Mitigation

- Motivation  
(Why it would be nice)
- Technical and Political Issues  
(Why we don't have it)
- Potential Solutions  
(What might work)



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# Motivation

- The tools we've examined involve *analysis* and *reporting* but not *automatic control*
- These tools allow engineers to detect and locate an ongoing DDoS
- They do not offer any automatic protection from the effects of a DDoS attack
- We have no “fire and forget” system



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# Why Not Automatic?

- Some of the tools we've looked at even output filtering code for major routers
- Why not apply these filters automatically?
- Wouldn't this provide excellent response time?



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# Why Network Engineers Say “No”

- Engineers are generally very conservative within their field
- *Proven* carries a lot more weight than *promising*
- Their mission is to keep the network running, and they don't like to experiment with it



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# Once Bitten, Twice Shy

- A large proportion of network downtime is related to bugs in routing software
- Because of the complexity of modern routers and economic factors, engineers are often given immature code
- Result: network engineers do not trust the work of software engineers



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# Is This Reasonable?

- Estimates of Code Quality (in bugs per thousand lines of code):
  - Standard SW: 25 bugs / kLOC
  - Good SW: 2 bugs / kLOC
  - Critical SW: 0.1 bugs / kLOC  
(think Space Shuttle)



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# Is This Reasonable?

- A modern router OS may have 5,000,000 lines of code
- Estimated number of bugs:
  - Standard SW: 125,000 bugs
  - Good SW: 10,000 bugs
  - Critical SW: 500 bugs
- Engineers' fear is not just superstition



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# Issues to Bear in Mind

- Any automatic system must prove itself before being accepted
- Resistance will be strong if there are large demands on engineer time
- False positives undermine system credibility



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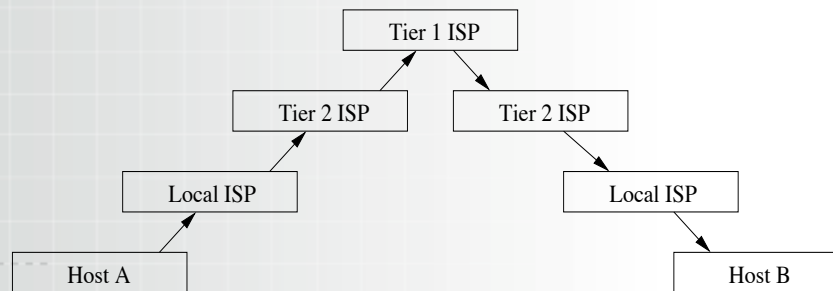
# Administrative Domains

- Remember that the Internet is a collection of many interconnected networks
- For routing, the Internet is broken up into *autonomous systems (ASes)*
  - Each AS has responsibility for some portion of the Internet address space
  - This includes routing configuration, security, and preventative techniques



# Hierarchy in Routing

- The AS system is not hierarchical.
- While there are “Tier 1” and “Tier 2” ISPs, traffic between host A and host B generally does not travel like this:





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# Why Doesn't It Look Like That?

- There are lateral connections between ASes at each “level” of this path
- This is especially true of Tier 1 ISPs
- Traffic is likely to pass through direct competitors when going from A to B



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# Example Routing Paths

1. Bowman Capital
2. Verio
3. SprintLink
4. GHS, Inc.
5. RUNNET
6. Trident
7. RUSNET

(from the Route Views Project at U. Oregon)



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# Example Routing Paths

1. Yuma Proving Ground
2. AT&T
3. DREN
4. UUNet
5. DISAUN

(from the Route Views Project at U. Oregon)



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# Example Routing Paths

1. Hewlett-Packard
2. ERX-SingNet
3. Singapore Telecom
4. Genuity
5. SprintLink
6. Sprint
7. Sprint-CA

(from the Route Views Project at U. Oregon)



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# Features of Routing Paths

- Between two edge networks, there are often multiple ASes of various tiers
- These peering connections are critical to the Internet and will continue to be around, even with IPv6
- The forward and reverse paths may transit different sets of ASes



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# What Does This Mean for DDoS?

- DDoS mitigation requires at least the involvement of the AS closest to the target
- If traffic is spoofed, finding the source of the attack requires the involvement of every AS in the path
- For distributed attacks, there may be multiple AS paths for the attack traffic



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# So What is “Involvement”?

“Involving” the next AS in the chain means gathering sufficient proof; calling the NOC for that AS (assuming you can find accurate contact information); hoping the person on the phone speaks English and has authority to act; explaining the problem; and hoping that they believe you, that they have the expertise to do something, and that they’ll actually do it.



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# Consequences

- For locating the attack source, this must happen between every pair of ASes
- This “human engineering” time can easily become the largest component in incident response time
- Also remember that DDoS attacks rarely consider or care about international boundaries



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# Another Problem: Spoofed IPs

- Anti-spoofing filters are now common
- Edge networks should not allow packets onto the Internet with addresses not in their local address space (*egress* filtering)
- This is not difficult to accomplish
- But we *still* see randomly spoofed IP addresses in current attacks



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# Why Does That Matter?

- Tracing the source of the attack is much more difficult with fully spoofed addresses
- Each AS can really just hope to find the next AS in the chain, not the whole path
- In practice, a complete trace is unlikely to happen



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# Ingress Filtering

- Use routing information to prevent spoofed address from *entering* your network
- This is possible for transit ASes
- This saves you from having to trust that everyone is doing proper egress filtering



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# Does This Fix Things?

- The problem is a lot smaller
- Attackers can still spoof within the local address space
- Identifying the source AS is fairly straightforward
- Within that AS, large switched campus networks can make finding the exact source difficult



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# What do ISPs do about DDoS?

- The standard practice is to combine a “blackhole route” and a DNS name change:
  - Customer changes address of server under attack.
  - ISP updates DNS with the new address.
  - ISP discards all traffic to the old address.



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# Problems with this Approach

- This doesn't remove all effects of the attack; some systems cache DNS lookups
- If attackers begin to target hostnames rather than addresses, the technique won't work
- The DNS entries for the server may be an integral part of load-sharing



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# Automating DDoS Defenses

- Suppose that ISPs can trust all routes received from peers
  - (This is a big “suppose”)
- Suppose also that a QoS infrastructure exists to give preference to BGP traffic
  - (This is less of a “suppose”)



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# Automating DDoS Defenses

- We could use BGP to propagate blackhole routes across AS boundaries
- Pushing the blackhole route toward the traffic source reduces network impact
- Single-homed customers could either run minimal BGP or still contact their ISP directly



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# Additional Benefits

- When routers send traffic to a blackhole, this can be reported to a management system
- The management system can use this data as an indication of a ingress point for attack traffic
- This allows better tracing of the origin of a DDoS attack



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# Why Can't This Be Done Now?

- If ISPs blindly accept blackhole routes from peers, the routing infrastructure has a DDoS vulnerability
- An attacker could introduce a blackhole route for an address over which they have no authority
- The network would also be vulnerable to accidental misconfiguration



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# What Needs to Happen?

1. All Tier-1 ISPs must adopt an infrastructure for per-prefix routing policy.
2. Standards organizations (NANOG/IETF) must agree on the BGP extensions for propagating blackhole routes.
3. A shared infrastructure must be developed for backtracing analysis.



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# Per-Prefix Routing Policy

- This involves the use of a Routing Registry.
- RRs have existed in the past, but a number of Tier-1 ISP refuse to use them.
  - UUNet and Sprint are examples
- Automatic blackhole propagation is too dangerous without RR infrastructure
- Attitudes must change for this to work



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# Standards Organizations

- Solution must work across international boundaries
- BGP extensions introduced by a single vendor are unlikely to be accepted
- Network engineers will resist any system not adopted by a standards organization (IETF in particular)



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# Shared Infrastructure

- Accurate backtracing requires data from ASes around the Internet
- Many ASes are direct competitors
- Some ASes cross international borders
- Some pairs of ASes are in mutually unfriendly nations
- Only a neutral party can be given this data



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# Making This Happen

- The greatest challenges are personal and political, not technical
- Network engineers are very hesitant to use automated systems
  - Loss of autonomy
  - Experience with buggy beta-test code
  - Lack of faith in software engineering



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# Making This Happen

- Any successful system must satisfy these fears
  - Cannot threaten network infrastructure
  - Cannot compromise information felt to be proprietary
  - Every false positive or mistaken blackhole is itself a DoS attack



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# Open Issues

- When and how do blackhole routes go away?
  - The same infrastructure that propagates them needs to be able to recall them as well
  - At the end of the AS path, we can't tell if the attack is continuing
  - We must rely on either time or the judgment of the AS closer to the attacker



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# Open Issues

- What if attackers focus on names rather than addresses?
  - This makes the blackhole routing defense ineffective
  - There is *no technical barrier* to this sort of attack appearing on the Internet tomorrow
  - If it can happen, it will happen