Recent Advances in IPv6 Security

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About...

- Security researcher and consultant for SI6 Networks
- Have worked on security assessment on communications protocols for:
  - UK NISCC (National Infrastructure Security Co-ordination Centre)
  - UK CPNI (Centre for the Protection of National Infrastructure)
- Active participant at the IETF (Internet Engineering Task Force)
- More information available at: http://www.gont.com.ar

Agenda

- Disclaimer
- Motivation for this presentation
- Recent Advances in IPv6 Security
  - IPv6 Addressing
  - IPv6 Fragmentation & Reassembly
  - IPv6 First Hop Security
  - IPv6 Firewalling
  - Mitigation to some Denial of Service attacks
- Conclusions
- Questions and Answers

Disclaimer

- This talks assumes:
  - You know the basics of IPv4 security
  - You now the basics about IPv6 security
  - (i.e. I'm not doing an “IPv6 primer” in this presentation, sorry)
- Much of this is “work in progress” → your input is welcome!

Motivation for this presentation

Motivation for this presentation

- Sooner or later you will need to deploy IPv6
  - In fact, you have (at least) partially deployed it, already
- IPv6 represents a number of challenges: What can we do about them?

Option #1

Option #2

Option #3

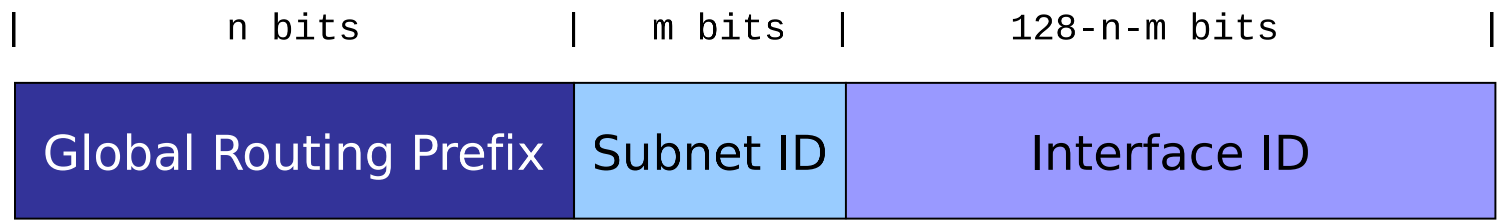
SI6 NETWORKS

Motivation for this presentation (II)

- We have been doing a fair share of IPv6 security research
  - Identification of problems
  - Proposals to mitigate those problems
- Part of our research has been taken to the IETF
- This talk is about our ongoing work to improve IPv6 security

Advances in IPv6 Addressing

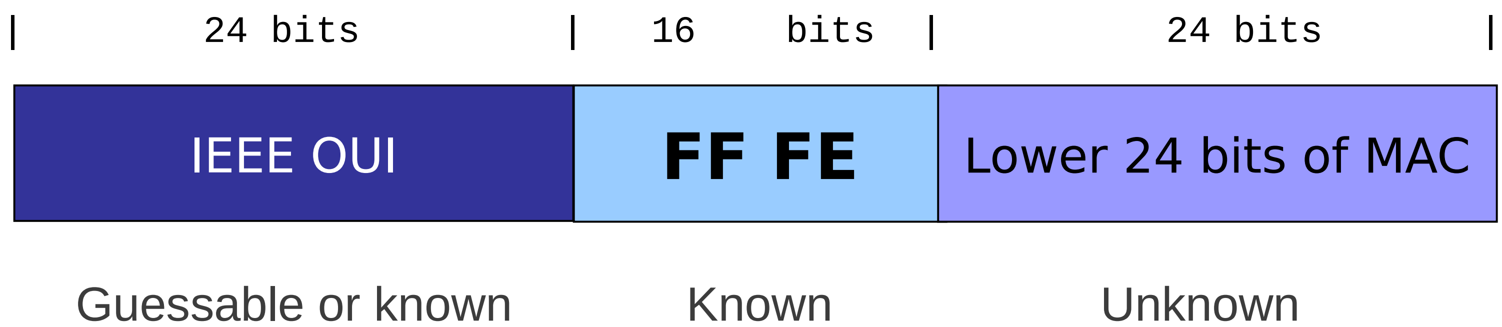
IPv6 Global Addresses format



- Traditional auto-configuration (SLAAC) addresses embed the MAC address in the Interface ID
- Originally considered convenient for auto-configuration
- But turned out to be a bad idea

Problem #1: Host-scanning attacks

- Search space for host-scanning considered to be 2^{64} bits and IPv6 host-scanning deemed infeasible – **really?**
- Modified EUI-64 format identifiers are created as:



- In practice, the search space is ~2^{24} bits – **feasible!**

Problem #2: Host-tracking attacks

- Modified EUI-64 IIDs are constant for each interface
- As the host moves, the prefix changes, but the IID doesn't
  - the 64-bit IID results in a super-cookie!
- This introduces a problem not present in IPv4: **host-tracking**
- Example:
  - In net #1, host configures address: 2001:db8:1::1111:2222:3333:4444
  - In net #2, host configures address: 2001:db8:2::1111:2222:3333:4444
  - The IID “1111:2222:3333:4444” leaks out host “identity”.

“Mitigation” to host-tracking

- RFC 4941: privacy/temporary addresses
  - Random IIDs that change over time
  - Generated **in addition** to traditional SLAAC addresses
  - Traditional addresses used for server-like communications, temporary addresses for client-like communications
- Operational problems:
  - Difficult to manage!
- Security problems:
  - They mitigate host-tracking **only partially**
  - They **do not** mitigate host-scanning attacks

Industry mitigations for scanning attacks

- Microsoft replaced the MAC-address-based identifiers with (non-standard) randomized IIDs
  - Essentially RFC 4941, but they don't vary over time
- Certainly better than MAC-address-based IIDs, but still not “good enough”
- They mitigate host-scanning, but **not** host tracking – constant IIDs are still present!

Auto-configuration address types

	Stable	Temporary
Predictable	Mod. EUI-64 IIDs	None
Unpredictable	**NONE**	RFC 4941

- We lack stable privacy-enhanced IPv6 addresses
  - Used to replace MAC-derived addresses
  - Pretty much orthogonal to privacy addresses
  - Probably “good enough” in most cases even without RFC 4941

Stable privacy-enhanced addresses

- draft-gont-6man-stable-privacy-addresses proposes to generate Interface IDs as:

  F(Prefix, Modified_EUI64, Network_ID, secret_key)

- Where:
  - F() is a PRF (e.g., a hash function)
  - Network_ID could be e.g. the SSID of a wireless network
  - the rest should be obvious ;-)
- This function results in addresses that:
  - Are stable within the same subnet
  - Have different Interface-IDs when moving across networks
  - For the most part, they have “the best of both worlds”

Work in progress

- Proposal presented at IETF 83 (Paris, March 2012)
- 6man wg **currently** being polled about adoption of this document
- Hopefully, host-scanning attacks will become unfeasible, and host tracking less trivial ;-)

IPv6 Fragmentation and Reassembly

IPv6 fragmentation

- IPv6 fragmentation performed only by hosts (never by routers)
- Fragmentation support implemented in “Fragmentation Header”
- Fragmentation Header syntax:

8 bits	8 bits	13 bits	2b	1b
Next Header	Reserved	Fragment Offset	Res	M
Identification				

Fragment Identification

- Security Implications of predictable Fragment IDs well-known from the IPv4 world
  - idle-scanning, DoS attacks, etc.
- Situation exacerbated by larger payloads resulting from:
  - Larger addresses
  - DNSSEC
- But no worries, since we learned the lesson from the IPv4 world... – **right?**

Fragment ID generation policies

Operating System	Algorithm
FreeBSD 9.0	Randomized
NetBSD 5.1	Randomized
OpenBSD-current	Randomized (based on SKIPJACK)
Linux 3.0.0-15	Predictable (GC init. to 0, incr. by +1)
Linux-current	Unpredictable (PDC init. to random value)
Solaris 10	Predictable (PDC, init. to 0)
Windows 7 Home Prem.	Predictable (GC, init. to 0, incr. by +2)

GC: Global Counter   PDC: Per-Destination Counter

At least Solaris and Linux patched in response to our IETF I-D – more patches expected!

IPv6 Fragment Reassembly

- Security implications of overlapping fragments well-known (think Ptacek & Newsham, etc,)
- Nonsensical for IPv6, but originally allowed in the specs
- Different implementations allow them, with different results
- RFC 5722 updated the specs, forbidding overlapping fragments
- Most current implementations reflect the updated standard
- See http://blog.si6networks.com

IPv6 Fragment reassembly (II)

- ICMPv6 PTB < 1280 triggers inclusion of a FH in all packets to that destination (not actual fragmentation)
- Result: IPv6 atomic fragments (Frag. Offset=0, More Frag.=0)
- Some implementations mixed these packets with “normal” fragmented traffic
- draft-ietf-6man-ipv6-atomic-fragments fixes that:
  - IPv6 atomic fragments required to be processed as non-fragmented traffic
  - Document ready for WGLC

Handling of IPv6 atomic fragments

Operating System	Atomic Frag. Support	Improved processing
FreeBSD 8.0	No	No
FreeBSD 8.2	Yes	No
FreeBSD 9.0	Yes	No
Linux 3.0.0-15	Yes	**Yes**
NetBSD 5.1	No	No
OpenBSD-current	Yes	**Yes**
Solaris 11	Yes	**Yes**
Windows Vista (build 6000)	Yes	No
Windows 7 Home Premium	Yes	No

At least OpenBSD patched in response to our IETF I-D – more patches expected!

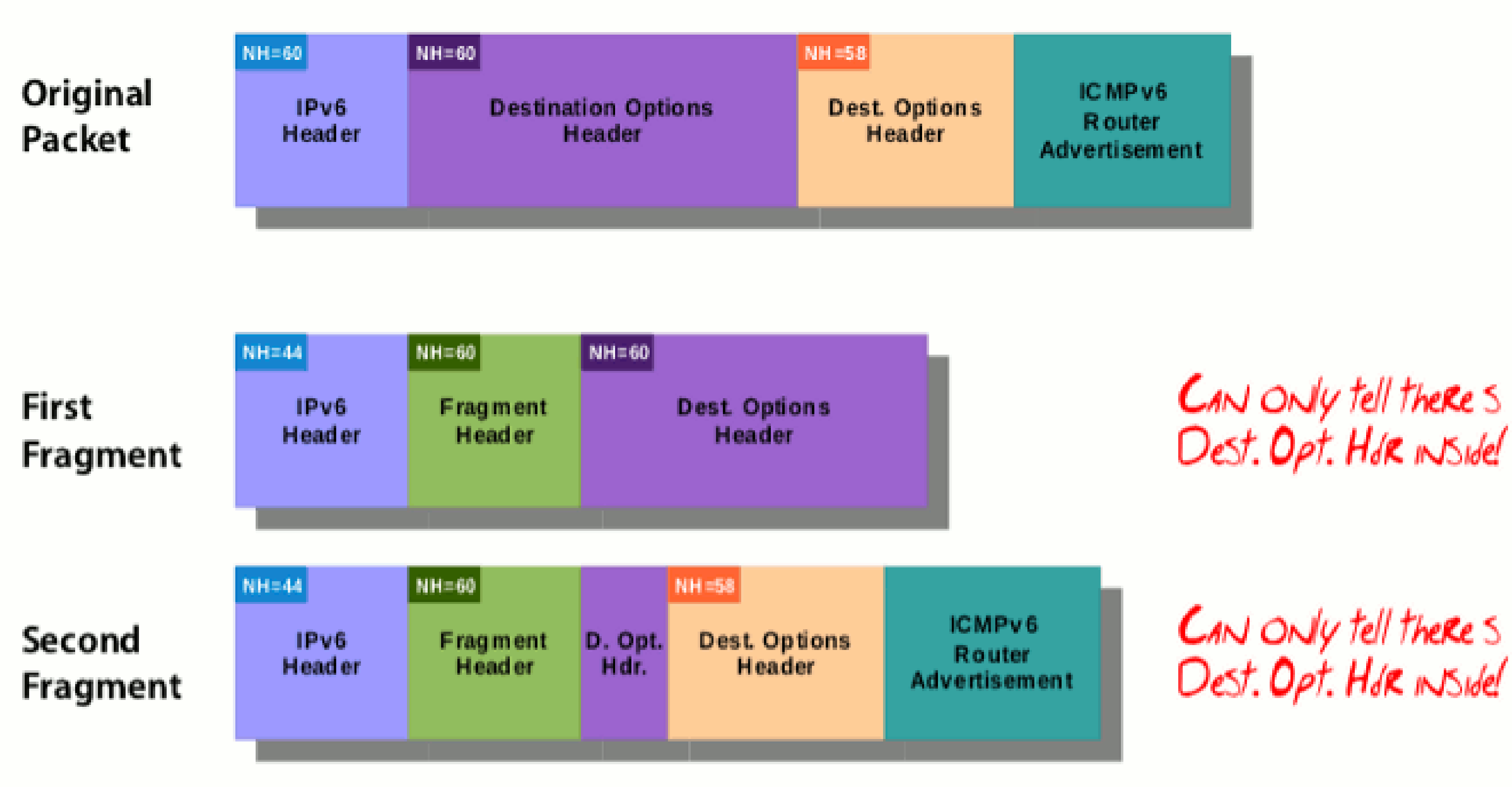
IPv6 First Hop Security

IPv6 First Hop Security

- Security mechanisms/policies employed/enforced at the first hop (local network)
- Fundamental problem: lack of feature-parity with IPv4
  - arpwatch-like Neighbor Discovery monitoring virtually impossible
  - DHCP-snooping-like RA blocking trivial to circumvent

IPv6 First-Hop Security (II)

- Fundamental problem: complexity of traffic to be "processed at layer-2"
- Example:



Bringing “sanity” to ND traffic

- draft-gont-6man-nd-extension-headers forbids use of fragmentation with Neighbor Discovery
  - It makes ND monitoring feasible
  - Turns out it is vital for SEND (or SEND could be DoS'ed with fragments)
- Work in progress:
  - Discussed last year
  - Presented at IETF 83 (Paris, March 2012)
  - 6man wg to be polled about adoption shortly

RA-Guard

- Meant to block RA packets on “unauthorized” switch ports
- Real implementations trivial to circumvent
- draft-gont-6man-ra-guard-implementation contains:
  - Discussion of RA-Guard evasion techniques
  - Advice to filter RAs, while avoiding false positives
- Can only be evaded with overlapping fragments
  - But most current OSes forbid them
  - And anyway there's nothing we can do about this :-)
- Work in progress: to be WGLC'ed soon.

IPv6 firewalling

First step away from “insanity”

- Specs-wise, state-less IPv6 packet filtering is impossible
- draft-gont-6man-oversized-header-chain tries to improve that:
  - The entire IPv6 header chain must be within the first PMTU bytes of the packet
  - i.e. packets with header chains that span more than one fragment may be blocked – don't send them!
- Work in progress:
  - Presented at IETF 83 (Paris, March 2012)
  - To be discussed on the 6man wg mailing-list
- There's an insanely large amount of work to be done in the area of IPv6 firewalling

Mitigation to some DoS attacks

IPv6 Smurf-like Attacks

- IPv6 is assumed to eliminate Smurf-like attacks
  - Hosts are assumed to not respond to global multicast addresses
- **But**,
  - Options of type 10xxxxxx require hosts to generate ICMPv6 errors
  - Even if the packet was destined to a multicast address
- Probably less important than the IPv4 case (since it requires multicast routing)
- But might be an issue if multicast routing is deployed
- draft-gont-6man-ipv6-smurf-amplifier addresses this issue:
  - Discusses the problem
  - Recommends that multicasted packets must not elicit ICMPv6 errors

Some conclusions

Some conclusions

- Many IPv4 vulnerabilities have been re-implemented in IPv6
  - We just didn't learn the lesson from IPv4, or,
  - Different people working in IPv6 than working in IPv4, or,
  - The specs could make implementation more straightforward, or,
  - **All of the above?** :-)
- Still lots of work to be done in IPv6 security
  - We all know that there is room for improvements
  - **We need IPv6, and should work to improve it**

Questions?

Thanks!

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IPv6 Hackers mailing-list

http://www.si6networks.com/community/

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