Recent Advances in IPv6 Security

Fernando Gont

SI6 NETWORKS

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About...

- Security researcher and consultant at 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!
- No “0-days”, sorry.

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

Motivation for this presentation (II)

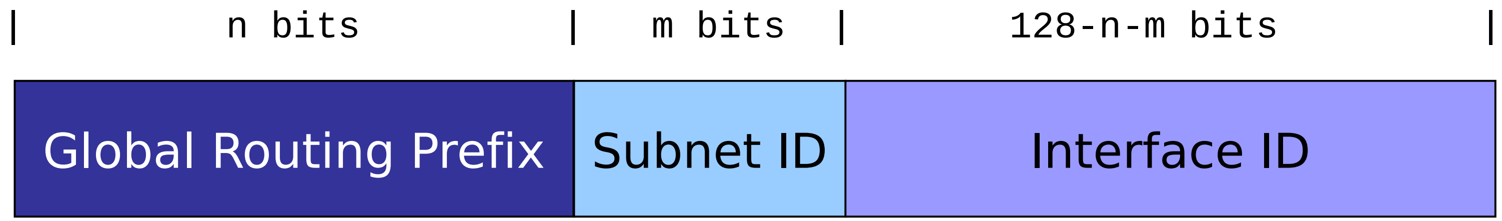
- We have been doing a fair share of IPv6 security research
  - Identification of problems
  - Proposals to mitigate those problems
- Part of our research has been taken to the IETF
- This talk is about our ongoing work to improve IPv6 security

Advances in IPv6 Addressing

Brief overview

- Main driver for IPv6 deployment
- Employs 128-bit addresses
- Address semantics similar to those of IPv4:
  - Addresses are aggregated intro “prefixes”
  - Several address types
  - Several address scopes
- Each interface typically employs more than one address, of different type/scope:
  - One link-local unicast address
  - One or more global unicast addresses
  - etc.

Global Unicast Addresses



- The “Interface ID” is typically 64-bit long
- Can be selected with different criteria:
  - Modified EUI-64 Identifiers
  - Privacy addresses
  - Manually configured
  - As specified by transition/co-existence technologies

IPv6 Addressing

Implications on host scanning attacks

IPv6 host scanning attacks

"Thanks to the increased IPv6 address space, IPv6 host scanning attacks are unfeasible. Scanning a /64 would take 500.000.000 years"

– Urban legend

Is the search space for a /64 really 2^{64} addresses?

IPv6 addresses in the real world

- Malone measured (*) the address generation policy of hosts and routers in real networks

Address type	Percentage
SLAAC	50%
IPv4-based	20%
Teredo	10%
Low-byte	8%
Privacy	6%
Wordy	<1%
Others	<1%

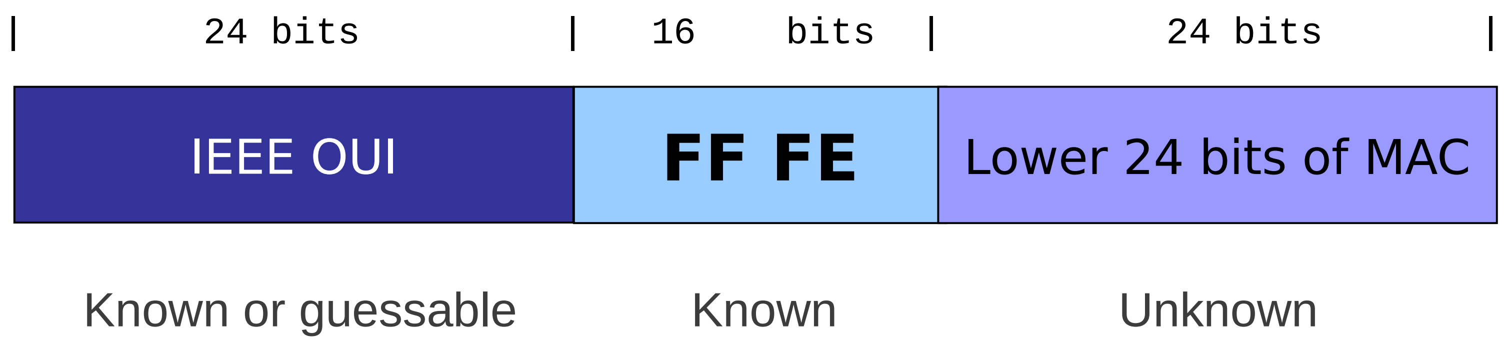
Hosts

Address type	Percentage
Low-byte	70%
IPv4-based	5%
SLAAC	1%
Wordy	<1%
Privacy	<1%
Teredo	<1%
Others	<1%

Routers

Malone, D., "Observations of IPv6 Addresses", Passive and Active Measurement Conference (PAM 2008, LNCS 4979), April 2008, <http://www.maths.tcd.ie/~dwmalone/p/addr-pam08.pdf>.

IPv6 addresses embedding IEEE IDs



- In practice, the search space is at most ~2^{24} bits – **feasible!**
- The low-order 24-bits are not necessarily random:
  - An organization buys a large number of boxes
  - In that case, MAC addresses are usually consecutive
  - Consecutive MAC addresses are generally in use in geographically-close locations

IPv6 addresses embedding IEEE IDs (II)

- Virtualization technologies present an interesting case
- Virtual Box employs OUI 08:00:27 (search space: ~2^{24})
- VMWare ESX employs:
  - Automatic MACs: OUI 00:05:59, and next 16 bits copied from the low order 16 bits of the host's IPv4 address (search space: ~2^{8})
  - Manually-configured MACs:OUI 00:50:56 and the rest in the range 0x000000-0x3fffff (search space: ~2^{22})

IPv6 addresses embedding IPv4 addr.

- They simply embed an IPv4 address in the IID
  - e.g.: 2000:db8::192.168.0.1
- Search space: same as the IPv4 search space

IPv6 "low-byte" addresses

- The IID is set to all-zeros, except for the last byte
  - e.g.: 2000:db8::1
  - There are other variants..
- Search space: usually 2^8 or 2^{16}

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!

Conclusions about scanning attacks

- IPv6 host scanning attacks are **feasible**, but typically harder than in IPv4
- They require more "intelligence" on the side of the attacker
- It is **possible** to make them infeasible
- It is likely that many other scanning strategies/techniques will be explored

IPv6 Addressing
Implications on privacy

Problem statement

- 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

IPv6 addressing

Mitigating scanning and privacy issues

Auto-configuration address/ID types

	Stable	Temporary
Predictable	IEEE ID-derived	None
Unpredictable	**NONE**	RFC 4941

- We lack stable privacy-enhanced IPv6 addresses
  - Used to replace IEEE ID-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, Interface_Index, Network_ID, Secret_Key)

- Where:
  - F() is a PRF (e.g., a hash function)
  - Prefix SLAAC or link-local prefix
  - Interface_Index is the (internal) small number that identifies the interface
  - Network_ID could be e.g. the SSID of a wireless network
  - Secret_Key is unknown to the attacker (and randomly generated by default)

Stable privacy-enhanced addresses (II)

- As a host moves:
  - Prefix and Network_ID change from one network to another
  - But they remain constant within each network
  - F() varies across networks, but remains constant within each network
- This 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”
- Document already accepted as a 6man wg item

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.
- Amount of fragmented traffic will probably increase as a result of:
  - 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!

Fixing predictable Fragment IDs

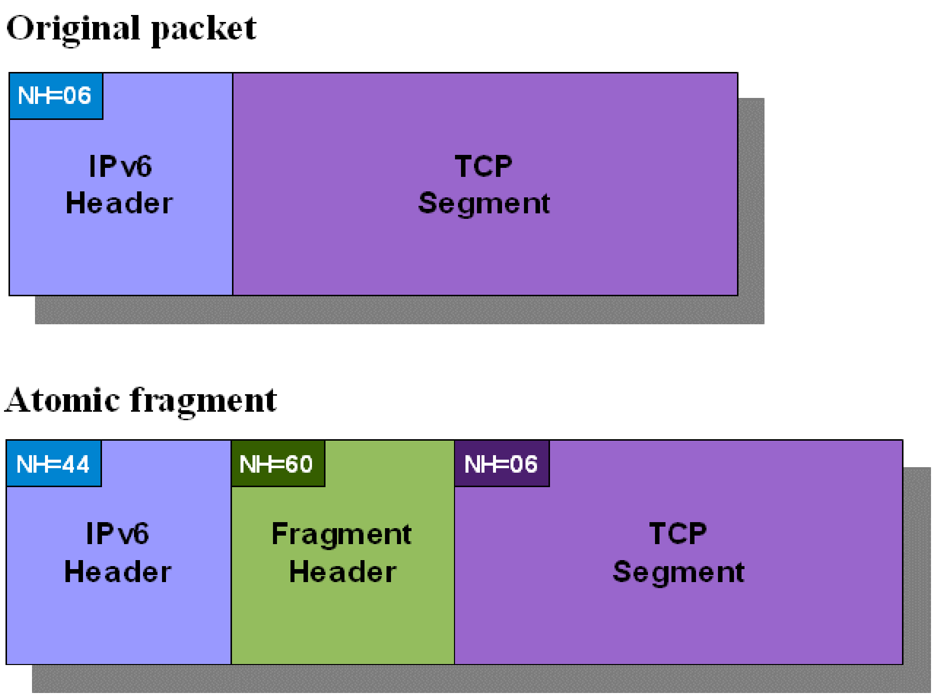
- draft-gont-6man-predictable-fragment-id:
  - Discussed the security implications of predictable Fragment ID
  - Proposes a number of algorithms to generate the Fragment ID
- Ongoing work at the 6man wg
  - The wg should be polled about adoption of this document

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 “atomic” fragments

- 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)



IPv6 “atomic” fragments (II)

- draft-ietf-6man-ipv6-atomic-fragments fixes the problem:
  - IPv6 atomic fragments required to be processed as non-fragmented traffic
- Document has passed WGLC
  - Should be published as an RFC this year

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!

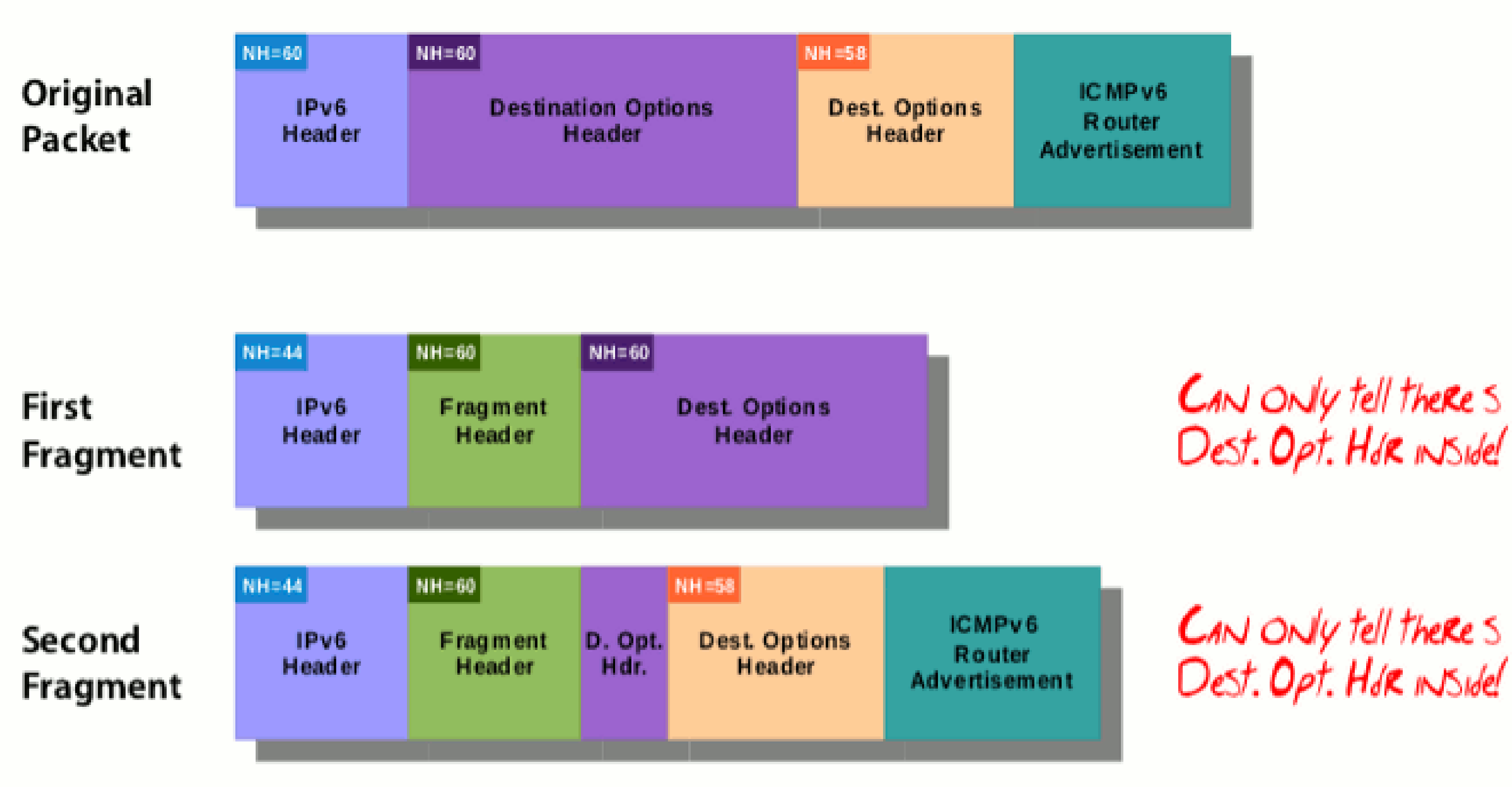
IPv6 First Hop Security

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-ietf-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:
  - Has been adopted as a 6man wg item
  - Should be published as an RFC this year

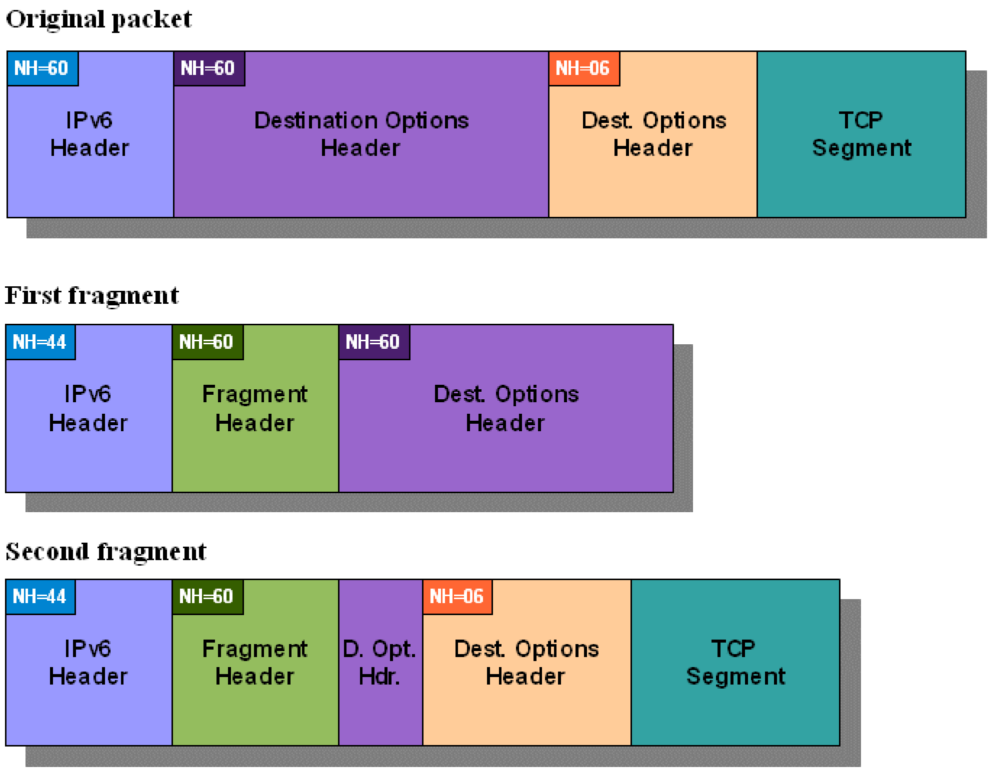
RA-Guard

- Meant to block RA packets on “unauthorized” switch ports
- Real implementations trivial to circumvent
- draft-ietf-v6ops-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 :-)
- Should be published as an RFC this year.

IPv6 firewalling

Problem statement

- Specs-wise, state-less IPv6 packet filtering is impossible:
  - The IPv6 header chain can span multiple fragments
  - This makes state-less firewalling impossible



First step away from “insanity”

- draft-ietf-6man-oversized-header-chain fixes this problem:
  - The entire IPv6 header chain must be contained in the first fragment
  - i.e. packets with header chains that span more than one fragment may be blocked – don't send them!
- Work in progress:
  - Recently adopted by the 6man WG
  - Should be published as an RFC this year
- 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

Tools

IPv6 security tools

- For ages, THC's IPv6 attack suite was the only IPv6 security tools publicly available
- We've produced “IPv6 toolkit” – a brand-new set of tools
- Runs on Linux and *BSD
- Available at: http://www.si6networks.com/tools

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!

Fernando Gont

fgont@si6networks.com

IPv6 Hackers mailing-list

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

www.si6networks.com