The IPv6 Snort Plugin

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Context

- Diploma thesis
- 2011 at Potsdam University
- part of “attack prevention and validated protection of IPv6 networks”

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EANTC

STRATO

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State ∼ 1994

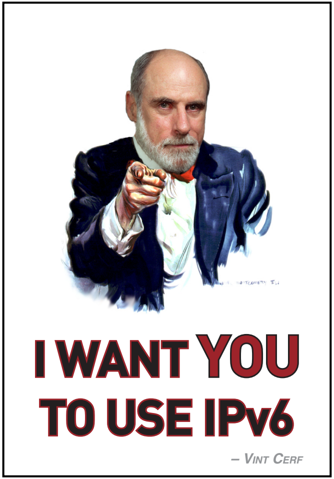
IPv4 Internet:

- Research and Academic Networks
- Known design & implementation errors
- Little experience with protocol security
- No urgency for improvement

State ∼ today

IPv6 Internet:

- Research and Academic Networks
- Known design & implementation errors
- Little experience with protocol security
- No urgency for improvement (?)



www.cs.brown.edu/~adf/cerf/

IPv6 Security Issues

- Main IPv6 RFCs from 1995/1998

⇒ many years of IPv4 security experience to catch up with

- Many accompanying RFCs and Internet Drafts (IPsec, SEND, RH0 deprecation, RA Guard, …)
- Few (yet already old) implementations
- Very little in end user devices
- Uncertainty hinders deployment

Attacks Against IPv6

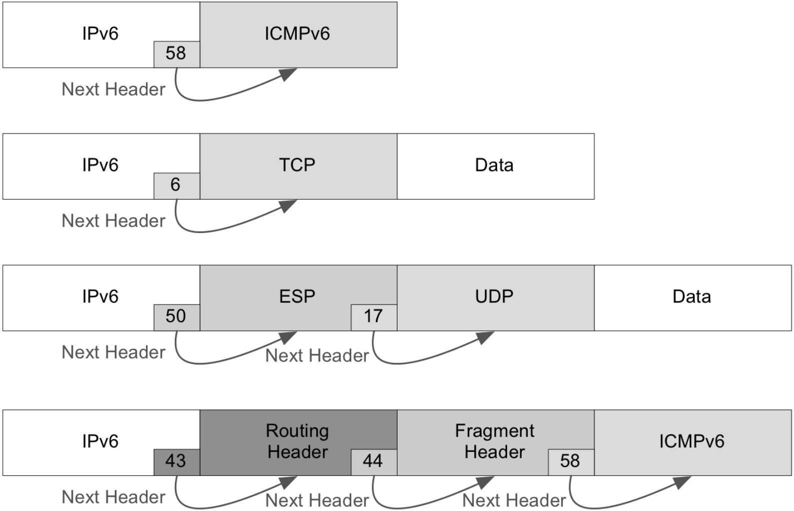
The usual:

- Value ranges
- Fragmentation
- Denial of Service
- Portscans
- Errors in Application Layer

IPv6 specific:

- Variable headers
- Multicast
- Routing
- v4/v6 Transition
- **Autoconfiguration**
- **Neighbor Discovery**

Header Chaining



Design Flaw

Designed in 1994,
same premise as IPv4: secure and trustworthy LAN
$\Rightarrow$ cable LAN in organizational hierarchy

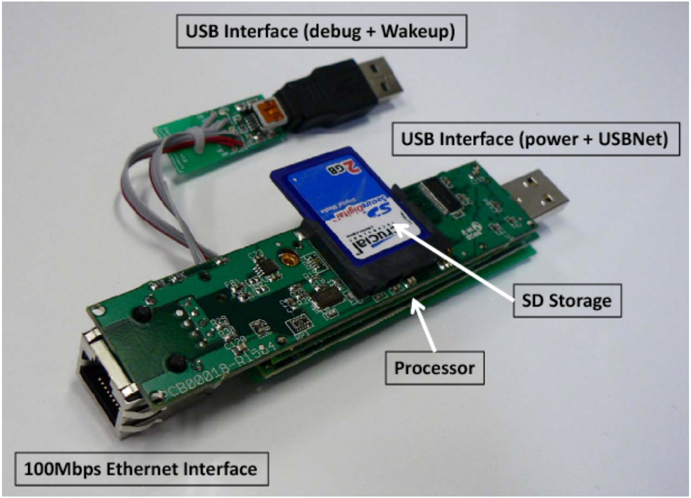
No consideration of:

- WiFi
- mobile usage
- anonymous users

Workstation ∼ 1990s

by Mike Chapman

Network Device ∼ today



gumstix-based Somniloquy prototype, Yuvraj Agarwal et al.

Local Attacks

Simple Denial of Service:

1. Host Alice starts *Duplicate Address Detection*:
   "Anyone using IP *X*?"
2. Host Eve answers "I have IP *X*."
3. `goto 1`

Routing/Man in the Middle:

1. Host Eve sends ICMPv6 Redirect:
   "This is router Bob, for *google.com* please use router Eve."

Remote Attacks

- Denial of Service
  - Neighbor Cache Exhaustion
  - Oversized IPv6 Header Chains
  - Excessive Hop-by-Hop Options
- Routing
  - RH0 source routing
  - Loop using IPv6 Automatic Tunnels

Attack Collections: THC Toolkit and SI6 Networks' IPv6 Toolkit

Tools/Attacks/Tests for:

- Autoconfiguration DoS
- Neighbor Cache
- Routing/Redirect
- Flood-Attacks
- Multicast Listener Discovery
- DHCPv6
- `implementation6`

Honorable Mention: Scapy

```
p = Ether(src='00:15:2c:c8:b8:80', dst='33:33:00:00:00:01')
 / IPv6(src='fe80::215:2cff:fec8:b880', dst='ff02::1')
 / ICMPv6ND_RA(M=0L, O=0L, routerlifetime=1800)
 / ICMPv6NDOptSrcLLAddr(lladdr='00:15:2c:c8:b8:80')
 / ICMPv6NDOptMTU(mtu=1500)
 / ICMPv6NDOptPrefixInfo(prefix='2001:638:807:3a::', prefixlen=64)

wrpcap('mypacket.pcap', p)

a = rdpcap('autoconf_winxp.pcap')
a[5].psdump('scapy_na.ps', layer_shift=1)
```

Scapy `psdump()`

Ethernet	
dst	00:e0:81:75:c2:b8
src	00:24:1d:a9:76:51
type	0x86dd

IPv6	
version	6L
tc	0L
fl	0L
plen	32
nh	ICMPv6
hlim	255
src	2001:db8:12:ab:bd50:f2b8:77e0:4469
dst	2001:db8:12:ab:217:9aff:fe3a:7ca6

ICMPv6 Neighbor Discovery - Neighbor Advertisement	
type	Neighbor Advertisement
code	0
cksum	0x578
R	0L
S	1L
O	1L
res	0x0L
tgt	2001:db8:12:ab:bd50:f2b8:77e0:4469

ICMPv6 Neighbor Discovery Option - Destination Link-Layer Address	
type	2
len	1
lladdr	00:24:1d:a9:76:51

```
00 e0 81 75 c2 b8 00 24 1d a9 76 51 86 dd
                                       60 00
00 00 00 20 3a ff 20 01 0d b8 00 12 00 ab bd 50
f2 b8 77 e0 44 69 20 01 0d b8 00 12 00 ab 02 17
9a ff fe 3a 7c a6
                  88 00 05 78 60 00 00 00 20 01
0d b8 00 12 00 ab bd 50 f2 b8 77 e0 44 69
                                       02 01
00 24 1d a9 76 51
```

Countermeasures

- Filter known-bad packets
- Show anomalous network activity
- Collect data for correlation and detection

Where to Monitor

Placement at:

- Routers
- Switches
- Packet Filters
- Hosts

Implementation as:

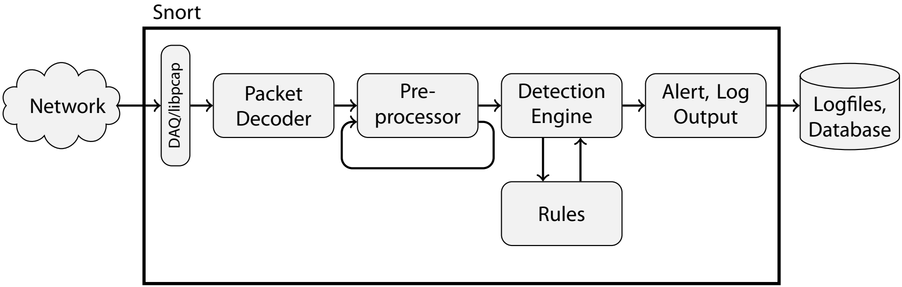
- Stand-alone tool (cf. ndpmon)
- Add-on for existing application
- Operating System module

$\Rightarrow$ High versatility: Intrusion Detection Systems

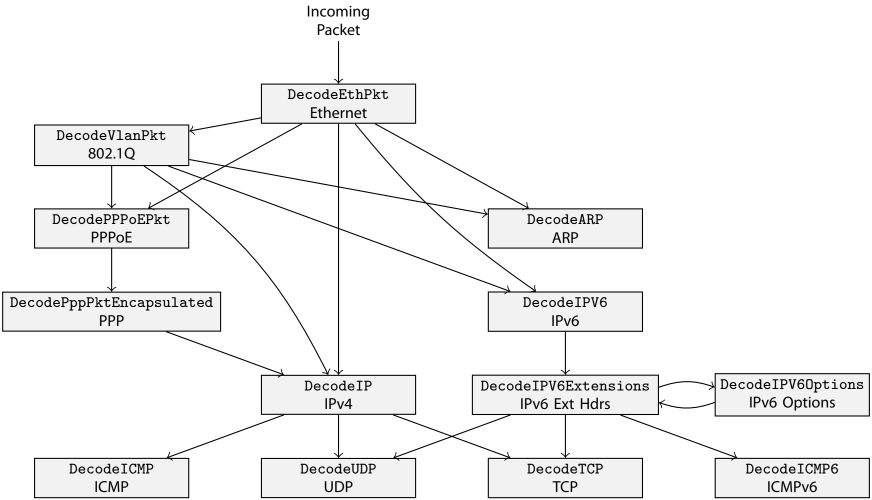
Target System: Snort 2.9

- Widely used Open Source NIDS
- Filter/inline mode
  (*Intrusion Prevention System*)
- Plugin APIs
- Decoder for common
  tunnel protocols

Snort Packet Processing Overview



Decoding


Incoming
Packet
DecodeEthPkt
Ethernet
DecodeVlanPkt
802.1Q
DecodePPPoEPkt
PPPoE
DecodeARP
ARP
DecodePppPktEncapsulated
PPP
DecodeIPV6
IPv6
DecodeIP
IPv4
DecodeIPV6Extensions
IPv6 Ext Hdrs
DecodeIPV6Options
IPv6 Options
DecodeICMP
ICMP
DecodeUDP
UDP
DecodeTCP
TCP
DecodeICMP6
ICMPv6

Decoding Result: `struct _Packet`

```
typedef struct _Packet
{
    const DAQ_PktHdr_t *pkth;          // packet meta data
    const uint8_t *pkt;                // raw packet data

    EtherARP *ah;
    const EtherHdr *eh;                /* standard TCP/IP/Ethernet/ARP headers */
    const VlanTagHdr *vh;

    const IPHdr *iph, *orig_iph;       /* and orig. headers for ICMP_*_UNREACH */
    const IPHdr *inner_iph;            /* if IP-in-IP, this will be the inner  */
    const IPHdr *outer_iph;            /* if IP-in-IP, this will be the outer  */

    uint32_t preprocessor_bits;        /* flags for preprocessors to check */
    uint32_t preproc_reassembly_pkt_bits;

    uint8_t ip_option_count;           /* number of options in this packet */
    uint8_t tcp_option_count;
    uint8_t ip6_extension_count;
    uint8_t ip6_frag_index;

    IPOptions ip_options[MAX_IP_OPTIONS];
    TCPOptions tcp_options[MAX_TCP_OPTIONS];
    IP6Extension ip6_extensions[MAX_IP6_EXTENSIONS];

    // ...
} Packet;
```

Rule Engine

Example detection rule:

```
var EXTERNAL_NET any
var SMTP_SERVERS [192.0.2.123, 2001:db8:12:ab::123]

alert tcp $EXTERNAL_NET any -> $SMTP_SERVERS 25 (
  flow:to_server,established;
  content: "|0A|Croot|0A|Mprog";
  metadata:service smtp;
  msg:"SMTP sendmail 8.6.9 exploit";
  reference:bugtraq,2311;reference:cve,1999-0204;
  classtype:attempted-user;
  sid:669; rev:9;
)
```

IPv6 Support

technically yes, but …

All major IDS have IPv6 support.

What does that mean?

- Fragment reassembly
- TCP & UDP decoding ⇒ upper-layer checks
- Decoder-warning on severe protocol errors

Not:

- check extensions (Routing Headers, Jumbograms)
- support all rule options (`fragbits`)
- IPv6 specific detection (ICMPv6/Neighbor Discovery)

IPv6 Signatures

Existing rules work for IPv4 and IPv6

No keywords for IPv6-only fields, no IPv6-only rules provided

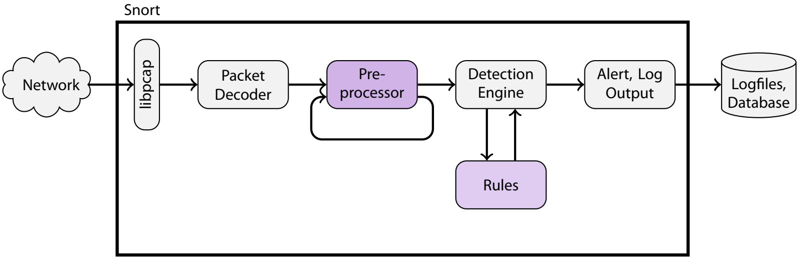
```
alert ip icmp any -> any any                              \
    (msg:"IPv6 ICMP Echo-Request?"; itype:128;            \
    classtype:icmp-event; sid:2000001; rev:1;)
```

Good for application layer checks
Bad for protocol layer detection

⇒ need to develop a IPv6-Plugin

Snort Customizations

- Writing rules
- Dynamic Detection API: compiled rule evaluations
- Dynamic Preprocessor API:
  - add rule options
  - do something with a packet



New IPv6 Rule Options

Goal: Provide IPv6 access for signatures

- Basic Header
- Extension Headers
- Neighbor Discovery Options

Functionality:

- Handler for option parsing on config (re-)load
- Callbacks for option keywords
- Called with rule parameter and current packet
- Return `match/no_match`

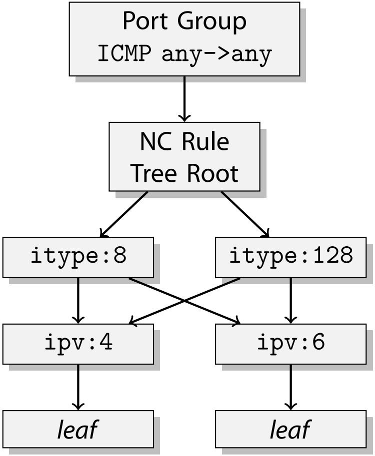
Implementation

```
// IPv6_Rule_Init() reads rule "ipv: 6;" into IPv6_RuleOpt_Data

int IPv6_Rule_Eval(void *raw_packet, const u_int8_t **cursor, void *data)
{
    SFSnortPacket *p = (SFSnortPacket*) raw_packet;
    struct IPv6_RuleOpt_Data *sdata = (struct IPv6_RuleOpt_Data *) data;

    switch (sdata->type) {
        case IPV6_RULETYPE_IPV: {
            uint_fast8_t ipv = GET_IPH_VER(p);
            if (checkField(sdata->op, ipv, sdata->opt.number))
                return RULE_MATCH;
            else
                return RULE_NOMATCH;
    // ...
    }
}
```

IPv6 Rule Options

```
alert icmp any any -> any any (itype:8;   ipv: 4; \
  msg:"ICMPv4 PING in v4 pkt"; sid:1000000; rev:1;)
alert icmp any any -> any any (itype:8;   ipv: 6; \
  msg:"ICMPv4 PING in v6 pkt"; sid:1000001; rev:1;)

alert icmp any any -> any any (itype:128; ipv: 4; \
  msg:"ICMPv6 PING in v4 pkt"; sid:1000002; rev:1;)
alert icmp any any -> any any (itype:128; ipv: 6; \
  msg:"ICMPv6 PING in v6 pkt"; sid:1000003; rev:1;)
```

Resulting Evaluation Tree



Rule Options of the IPv6-Plugin

`ipv`	IP version
`ip6_tclass`	Traffic Class
`ip6_flow`	Flow Label
`ip6_exthdr`	Extension Header
`ip6_extnum`	Num. of Ext Hdrs.
`ip6_ext_ordered`	Ext Hdrs. correctly ordered (bool)
`ip6_option`	Destination-/HbH-Option
`ip6_optval`	Destination-/HbH-Option Value
`ip6_rh`	Routing Header
`icmp6_nd`	Neighbor Discovery (bool)
`icmp6_nd_option`	Neighbor Discovery Option

(Most rules accept comparison operators = ! < >)

More Examples

```
alert ip  any any -> any any (ip6_rh: !2;             \
  msg:"invalid routing hdr";                          \
  sid:1000004; rev:1;)

alert ip any any -> any any (ip6_option: 0.0xc2;      \
  msg:"ip6 option: Jumbo in HBH hdr";                 \
  sid:100066; rev:1;)

# event threshold
alert icmp any any -> any any (icmp6_nd;              \
  detection_filter: track by_dst, count 50, seconds 1; \
  msg:"ICMPv6 flooding";                              \
  sid:100204; rev:1;)

# log only one flooding event per second:
event_filter gen_id 1, sig_id 100204,                 \
  type limit, track by_src,                           \
  count 1, seconds 1
```

Preprocessor for Neighbor Discovery Tracking

Goal: monitor network changes

- new hosts
- new routers
- basic extensions/options check

Functionality:

- Reads ICMPv6 messages
- Follows network state, i. e. (MAC, IP) tuple of:
  - On-link routers
  - On-link hosts
  - Ongoing DADs
- Alert on change

Configuration

in `snort.conf`, all optional

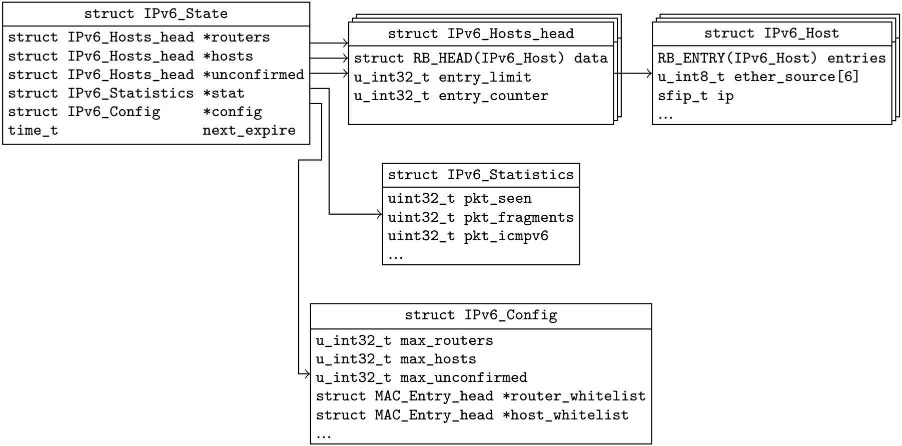
`net_prefix`	subnet prefixes
`router_mac`	known router MAC addresses
`host_mac`	known host MAC addresses
`max_routers`	max routers in state (default: 32)
`max_hosts`	max hosts in state (default: 8 K)
`max_unconfirmed`	max unconfirmed nodes in state (default: 32 K)
`keep_state`	remember nodes for *n* minutes (default: 180)
`expire_run`	clean memory every *n* minutes (default: 20)
`disable_tracking`	only rules & stateless checks (default: false)

Configuration

"normal use"

```
preprocessor ipv6:                                   \
    net_prefix 2001:0db8:1::/64                      \
    router_mac 00:16:76:07:bc:92
```

Preprocessor State at Runtime



Implementation of NS Processing

```
static void IPv6_Process_ICMPv6_NS(const SFSnortPacket *p, struct IPv6_State *context)
{
    struct nd_neighbor_solicit *ns = (struct nd_neighbor_solicit *) p->ip_payload;
    sfip_t *target_ip;
    struct IPv6_Host *ip_entry;

    target_ip = sfip_alloc_raw(&ns->nd_ns_target, AF_INET6, &rc);
    // ..

    ip_entry = get_host_entry(context->hosts, target_ip);
    if (ip_entry) {
        DEBUG_WRAP(DebugMessage(DEBUG_PLUGIN, "Neighbour solicitation from known host\n"););
        return;
    }

    /* this is the expected part: the IP is yet unknown --> put into DAD state */
    ip_entry = create_dad_entry_ifnew(context->unconfirmed,
                                   &p->pkt_header->ts,
                                   p->ether_header->ether_source,
                                   target_ip);
    if (!ip_entry) {
        DEBUG_WRAP(DebugMessage(DEBUG_PLUGIN, "create_dad_entry_ifnew failed\n"););
        return;
    }
    DEBUG_WRAP(DebugMessage(DEBUG_PLUGIN, "%s DAD started by %s / %s\n",
              pprint_ts(ip_entry->last_adv_ts),
              pprint_mac(ip_entry->ether_source),
              sfip_to_str(&ip_entry->ip)););
    _dpd.alertAdd(GEN_ID_IPv6, SID_ICMP6_ND_NEW_DAD, 1, 0, 3, SID_ICMP6_ND_NEW_DAD_TEXT, 0 );
}
```

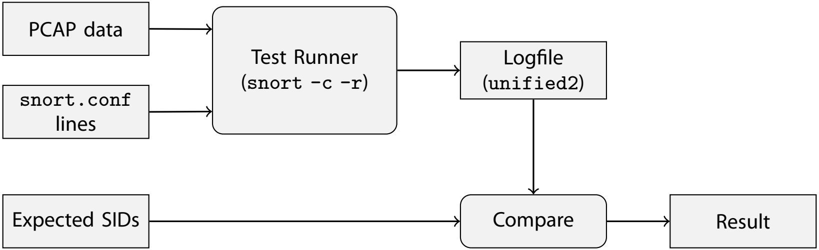
Snort IPv6 Alerts: ND Tracking

SID	Message
1	RA from new router
2	RA from non-router MAC address
3	RA prefix changed
4	RA flags changed
5	RA for non-local net prefix
6	RA with lifetime 0
7	new DAD started
8	new host in network
9	new host with non-allowed MAC addr.
10	DAD with collision
11	DAD with spoofed collision

Snort IPv6 Alerts: Packet Attributes

SID	Message
12	mismatch in MAC/NDP src ll addr.
13	extension header has only padding
14	option lengths $\neq$ ext length
15	padding option data $\neq$ zero
16	consecutive padding options

tester.pl

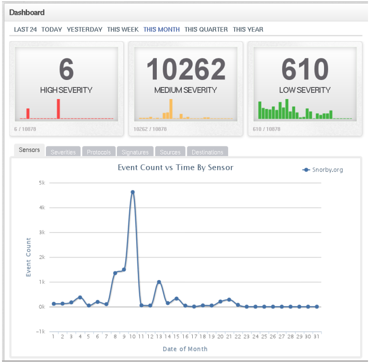


Extremely useful for development.

Verify intended results for given packet samples.

Output/Visualization

- Big Problem
- `barnyard2` tool for Snort log processing (e. g. write SQL)
- Few Open Source frontends (BASE & Snorby)
- All using old SQL Schema, without IPv6 field



Performance

Theory:

- Stateless checks require processing
- ND Tracking requires memory $\Rightarrow$ DoS risk

Practice:

- Snort’s packet decoding does 90 % of the work
- Configurable memory limit ~ 8 Mb
- TCP stream reassembly is much more expensive

Bugs Found in Snort 2.9.0

or: *Real-World Problems of Major Commercial Security Products*

- Ping of Death, cannot process > 40 extension headers
- wrong Endianness in `GET_IPH_VER()`
- fragmentation breaks ICMP/UDP checksums
- Routing Headers break ICMP/UDP checksums
- `fragbits` rules not supported

Extension Header Parsing in Snort 2.9.0

fixed in 2.9.1

```
void DecodeIPV6Options(int type, const uint8_t *pkt, uint32_t len, Packet *p)
{
    uint32_t hdrlen = 0;

    if(p->ip6_extension_count < IP6_EXTMAX) {
        switch (type) {
            case IPPROTO_HOPOPTS:
                hdrlen = sizeof(IP6Extension) + (exthdr->ip6e_len << 3);
        }
    }
    /* missing else => hdrlen=0 => infinite mutual recursion */

    DecodeIPV6Extensions(*pkt, pkt + hdrlen, len - hdrlen, p);
}

void DecodeIPV6Extensions(uint8_t next, const uint8_t *pkt, uint32_t len, Packet *p)
{
    switch(next) {
        case IPPROTO_HOPOPTS:
        case IPPROTO_DSTOPTS:
        case IPPROTO_ROUTING:
        case IPPROTO_AH:
            DecodeIPV6Options(next, pkt, len, p);
            return;
    }
}
```

Conclusion

- It works!

- Dynamic Library (no need to recompile Snort)
- Enables IPv6-specific detection signatures
- Snort & IPv6-Plugin detects THC attacks

- Cannot solve fundamental problems: DoS and insecure Ethernet
- **Can** raise visibility and awareness of network threat situation

Contact

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Project Page: http://mschuette.name/wp/snortipv6/
Source Code: https://github.com/mschuett/spp_ipv6

Questions?