IPv6 in Wireshark

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IPv6 in Wireshark

- IPv6 – a bit more than basics
- Wireshark basics
- Wireshark color rules, display filters, columns and configuration profiles
- IPv6 in Wireshark

IPv6 – a bit more than basics

- Quick IPv6 history
- IPv6 Address basics
- IPv6 Address Autoconfiguration
- IPv6 in applications

IPv6 Brief History

- Fall 1992 – IPv4 addresses will run out someday
- Oct 1993 – DHCP – RFC 1531 – easier IPv4 address management
- Dec 1993 – IPng – RFC 1550 – basic specification for next version IP
- May 1994 – NAT – RFC 1631 – temporary solution before IPng available
- Dec 1995 – RFC 1883 – Basic specifications of IPv6
- Feb 1996 – RFC 1918 – Private Iv4 addresses
- Dec 1998 – RFC 2460 – Full IPv6 defined
- May 2005 – RFC 3927 – APIPA (IPv4)

Comparing IPv4 & IPv6 Addresses

- IPv4 addresses 2^{32} = 4,294,967,296
- IPv6 addresses 2^{128} = 340,282,366,920,938,463,463,374,607,431,768,211,456
  - which is 340 undecillion
    - 340 trillion trillion trillion
  - 79,228,162,514,264,337,593,543,950,336 times more v6 addresses than v4
- If IP addresses weighed one gram each:
  - IPv4 = half the Empire State Building
  - IPv6 = 56 billion earths

What is an IPv6 Address?

- IPv6 addresses are very different than IPv4 addresses in the size, numbering system, and delimiter between the numbers
  - 128bit -vs- 32bit
  - colon-hexadecimal -vs- dotted-decimal
  - colon and double colon -vs- period (or “dot” for the real geeks)

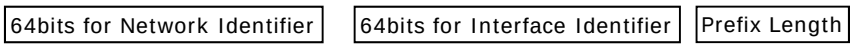
Valid IPv6 addresses are comprised of hexadecimal numbers (0-9 & a-f), with colons separating groups of four numbers, with a total of eight groups

(each group is known as “quibble” or “**hextet**”)

- 2001:0db8:1010:61ab:f005:ba11:00da:11a5

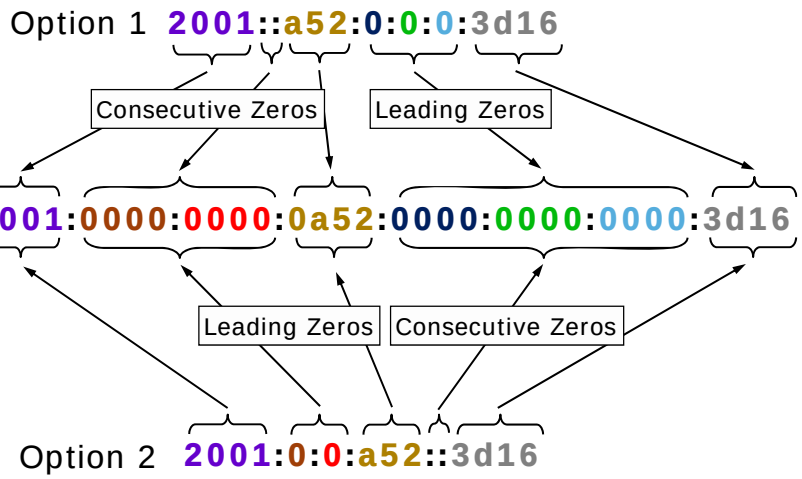
IPv6 default for subnet

- Based on the default definition an IPv6 address is logically divided into two parts: a 64-bit network prefix and a 64-bit interface identifier (IID)
- Therefore, the default subnet size is /64
- 2001:0db8:1010:61ab:f005:ba11:00da:11a5/64

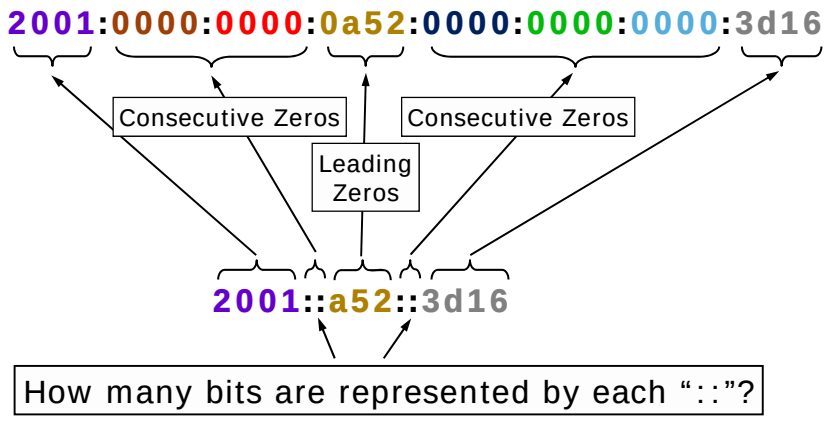


- A single /64 network yields 18 billion-billion possible addresses

IPv6 shorthand notation



Incorrect shorthand notation



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Address types

Address Type	IPv4	IPv6
Unicast - One-to-one communication	Yes	Yes
Broadcast - One-to-many communication local	Yes	No
Multicast - One-to-many communication local/remote	Yes	Yes
Anycast - One-to-many communication nearest	Yes	Yes

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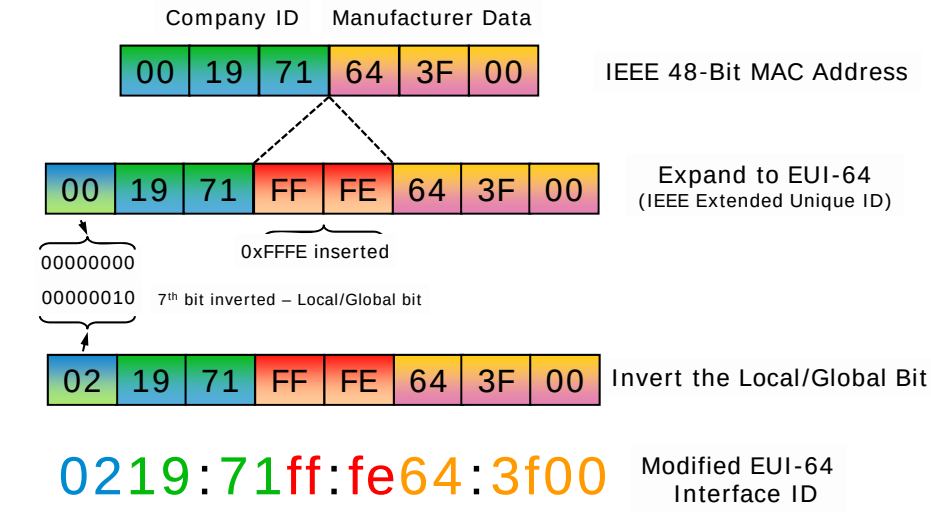
Address scopes

Address Scope	IPv4	IPv6
Link-Local - Not routable	Yes (is temp, APIPA)	Yes
Global Unicast - Routable to Internet	Aka public	Yes
Unique Local - Routable only within domain	Aka private RFC 1918	RFC 4193

Interface ID from MAC address



0219:71ff:fe64:3f00 Modified EUI-64 Interface ID

Interface ID from Random Number

- RFC4941 - Privacy Extensions for Stateless Address Autoconfiguration in IPv6
- Initial IID is derived based on mathematical computation to create a “random 64bit number” and appended to prefix to create a GUA
- An additional but different 64bit number is computed, appended to prefix, and tagged “temporary” for a 2nd GUA
- Temporary GUA should be re-computed on a frequent basis
- Temporary GUA is used as primary address for communications, as it is considered “more secure”

IPv4/IPv6 special addresses

Address Type	IPv4	IPv6
Default Route	0.0.0.0/0	::/0
Unspecified	0.0.0.0/32	::/128
Loopback	127.0.0.1/8	::1/128
Multicast	224.0.0.0/4	ff00::/8
Link-Local	169.254.0.0/16	fe80::/10
Global Unicast	All others	2000::/3
Unique Local	10.0.0.0/8 172.16.0.0/12 192.168.0.0/16	fc00::/7
Documentation	192.0.2.0/24 198.51.100.0/24 203.0.113.0/24	2001:db8::/32

IPv6 well known multicast addresses

Address	Description	Scope
ff01::1	All nodes address	Interface-local
ff02::1	All nodes address	Link-local
ff01::2	All routers address	Interface-local
ff02::2	All routers address	Link-local
ff05::2	All routers address	Site-local
ff02::4	DVMRP routers	Link-local
ff02::5	OSPF drothers	Link-local
ff02::6	OSPF designated routers	Link-local
ff02::9	RIPng routers	Link-local
ff02::a	EIGRPv6 routers	Link-local
ff02::d	All PIM routers	Link-local
ff02::16	ALL MLDv2 routers	Link-local
ff02::1:2	DHCPv6 servers/agents	Link-local
ff02::1:3	DHCPv6 servers/agents	Site-local
ff02::1:ffxx:xxxx	Solicited node address	Link-local

Comparing IPv4 & IPv6 Neighbor Discovery Protocols

IPv4	IPv6
ARP Request	Neighbor Solicitation
ARP Reply	Neighbor Advertisement
Router Solicitation	Router Solicitation
Router Advertisement	Router Advertisement
Gratuitous ARP	Duplicate Address Detection
ARP Cache	Neighbor Cache

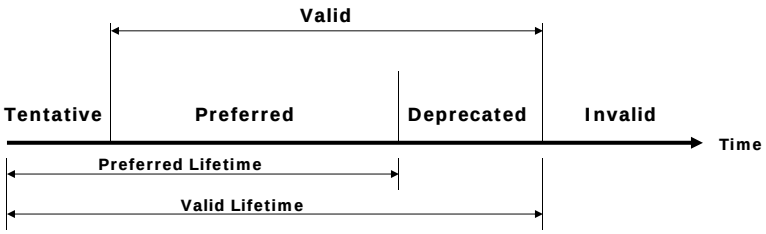
IPv6 Neighbor Discovery Protocol

- Neighbor Discovery Protocol (NDP) is defined in RFC 4861
- NDP provides the following basic IPv6 functions per node
  - Discover what link they are one
  - Learn link prefix addresses
  - Discover the on-link router
  - Discover on-link neighbors
  - Keep track of active neighbors

NDP ICMPv6 message types

- ICMPv6 type 133 - Router Solicitation (RS)
- ICMPv6 type 134 - Router Advertisement (RA)
- ICMPv6 type 135 - Neighbor Solicitation (NS)
- ICMPv6 type 136 - Neighbor Advertisement (NA)

Lifetime states of an IPv6 address



- Tentative – address is in process of verification for uniqueness and is not yet available for regular communications
- Valid – address is valid for use in communication based on Preferred and Deprecated status
- Preferred – address is usable for all communications
- Deprecated – address can still be used for existing sessions, but not for new sessions
- Invalid – an address is no longer available for sending or receiving

Duplicate Address Detection (DAD)

- When a node initially assigns an IPv6 address to its interface, it must check whether the selected address is unique
- If unique, the address is configured on interface
- To verify uniqueness, the node sends a multicast Neighbor Solicitation message with the:
  - dest MAC of 33:33:<last 32bits of IPv6 mcast addr>
  - dest IPv6 addr of ff02::1:ff<last 24bits of proposed IPv6 addr>
  - source IPv6 of "::" (IPv6 unspecified addr)

IPv6 autoconfiguration options

Address Autoconfiguration Method	ICMPv6 RA (Type 134) Flags M Flag	O Flag	ICMPv6 RA (Type 134) ICMPv6 Option Prefix Info A Flag	L Flag	Prefix Derived from	Interface ID Derived from	Other Configuration Options	# of IPv6 Addr
Link-Local (always configured)	N/A	N/A	N/A	N/A	Internal (fe80::)	M-EUI-64 or Privacy	Manual	1
Manual	Off	Off	Off	On	Manual	Manual	Manual	2 (LL, Manual)
SLAAC	Off	Off	On	On	RA	M-EUI-64 or Privacy	Manual	3 (LL, IPv6, IPv6 temp)
Stateful (DHCPv6)	On	N/R	Off	On	DHCPv6	DHCPv6	DHCPv6	2 (LL, DHCPv6)
Stateless DHCPv6	Off	On	On	On	RA	M-EUI-64 or Privacy	DHCPv6	3 (LL, IPv6, IPv6 temp)
Combination Stateless & DHCPv6	On	N/R	On	On	RA and DHCPv6	M-EUI-64 or Privacy and DHCPv6	DHCPv6	4 (LL, IPv6, IPv6 temp, DHCPv6)

IPv6 address autoconfiguration

- Assigning an IPv6 address:
  - **Link-Local** (automatically assigned when IPv6 is enabled)
    - Based on prefix fe80::/10, assigned as fe80::/64
    - Interface ID (64 bit host portion) derived from either:
      - Modified IEEE EUI-64 format (RFC 4291)
        - Derived from MAC address
      - Privacy format (RFC 4941)
        - Derived from random number generator

❖NOTE: Requires no routers, no DHCPv6 servers, no additional network systems support

Link-Local address basics

- Each interface must have one (and only one) link-local address (generally autoconfigured by OS)
- Can/may be same on any/all interfaces
- Zone ID or Scope ID is used to differentiate which interface is to be used for outbound communications
- Zone ID is appended to link-local address when used for outbound communications

ping fe80::22c:8a5c:12ab:370f%vlan1 - switch

ping fe80::22c:8a5c:12ab:370f%12 - Windows

ping fe80::22c:8a5c:12ab:370f%eth0 - Linux

^destination host to ping ^intf to go out

Link-Local address status (Win7)

Windows 7 example:

```
C:\>ipconfig /all |more

Ethernet adapter Local Area Connection:
   Connection-specific DNS Suffix  . : example.com
   Description . . . . . . . . . . . : Intel(R) 82579LM Gigabit Network Connection
   Physical Address. . . . . . . . . : 00-9C-02-8F-61-F4
   DHCP Enabled. . . . . . . . . . . : Yes
   Autoconfiguration Enabled . . . . : Yes
   Link-local IPv6 Address . . . . . : fe80::a120:9e8f:ac0a:69b2%12(Preferred)
   IPv4 Address. . . . . . . . . . . : 10.1.1.105(Preferred)
   Subnet Mask . . . . . . . . . . . : 255.255.255.0

C:\>netsh int ipv6 show address interface=12

   Address fe80::a120:9e8f:ac0a:69b2%12 Parameters
   ---------------------------------------------
   Interface Luid     : Local Area Connection
   Scope Id           : 0.12
   Valid Lifetime     : infinite
   Preferred Lifetime : infinite
```

Link-Local neighbors (Win7)

- Windows 7 example:

```
C:\>netsh int ipv6 show neighbors interface=12

Interface 12: Local Area Connection
Internet Address                              Physical Address   Type
--------------------------------------------  -----------------  -----------
2001:470:1f0f:ee7::1                          00-09-0f-db-04-d3  Stale (Router)
fe80::209:fff:fedb:4d3                        00-09-0f-db-04-d3  Stale (Router)
ff02::1                                       33-33-00-00-00-01  Permanent
ff02::2                                       33-33-00-00-00-02  Permanent
ff02::c                                       33-33-00-00-00-0c  Permanent
ff02::16                                      33-33-00-00-00-16  Permanent
ff02::fb                                      33-33-00-00-00-fb  Permanent
ff02::1:2                                     33-33-00-01-00-02  Permanent
ff02::1:3                                     33-33-00-01-00-03  Permanent
ff02::1:ff00:1                                33-33-ff-00-00-01  Permanent
ff02::1:ff07:101                              33-33-ff-07-01-01  Permanent
ff02::1:ff0a:69b2                             33-33-ff-0a-69-b2  Permanent
ff02::1:ff15:d7a3                             33-33-ff-15-d7-a3  Permanent
ff02::1:ffdb:4d3                              33-33-ff-db-04-d3  Permanent
```


Link-Local usage (Win7)

- Windows 7 example:

```
C:\>ping fe80::209:fff:fedb:4d3%12

Pinging fe80::209:fff:fedb:4d3%12 with 32 bytes of data:
Reply from fe80::209:fff:fedb:4d3%12: time<1ms
Reply from fe80::209:fff:fedb:4d3%12: time<1ms
```

Link-Local address status (Mac)

- Mac OS X 10.9.1 example:

```
mac:~ jcarrell$ ifconfig -L en0
en0: flags=8963<UP,BROADCAST,SMART,RUNNING,PROMISC,SIMPLEX,MULTICAST> mtu
   1500
      options=27<RXCSUM,TXCSUM,VLAN_MTU,TSO4>
      ether 00:23:32:c9:f3:c4
      inet6 fe80::223:32ff:fec9:f3c4%en0 prefixlen 64 scopeid 0x4
      inet 192.168.1.199 netmask 0xffffff00 broadcast 192.168.1.255
      inet6 2001:5c0:1506:ef00::119 prefixlen 64 pltime 138 vltime 251
      nd6 options=1<PERFORMNUD>
      media: autoselect (100baseTX <full-duplex,flow-control>)
      status: active
```


Link-Local neighbors (Mac)

- Mac OS X 10.9.1 example:

```
mac:~ jcarrell$ ndp -an - show IPv6 neighbors
Neighbor                        Linklayer Address  Netif Expire    St Flgs Prbs
2001:5c0:1506:ef00::119         0:23:32:c9:f3:c4     en0 permanent R
fe80::1%lo0                     (incomplete)         lo0 permanent R
fe80::223:32ff:fec9:f3c4%en0    0:23:32:c9:f3:c4     en0 permanent R
fe80::a00:27ff:fe3f:556e%en0    8:0:27:3f:55:6e      en0 2s        R  R
```

Link-Local usage (Mac)

- Mac OS X 10.9.1 example:

```
mac:~ jcarrell$ ping6 fe80::a00:27ff:fe3f:556e%en0
PING6(56=40+8+8 bytes) fe80::223:32ff:fec9:f3c4%en0 -->
  fe80::a00:27ff:fe3f:556e%en0
16 bytes from fe80::a00:27ff:fe3f:556e%en0, icmp_seq=0 hlim=64 time=0.366 ms
16 bytes from fe80::a00:27ff:fe3f:556e%en0, icmp_seq=1 hlim=64 time=0.630 ms
^C
--- fe80::a00:27ff:fe3f:556e%en0 ping6 statistics ---
2 packets transmitted, 2 packets received, 0.0% packet loss
round-trip min/avg/max/std-dev = 0.366/0.498/0.630/0.120 ms


mac:~ jcarrell$ ping6 fe80::a00:27ff:fe3f:556e
PING6(56=40+8+8 bytes) fe80::223:32ff:fec9:f3c4%en0 -->
  fe80::a00:27ff:fe3f:556e
ping6: sendmsg: No route to host
ping6: wrote fe80::a00:27ff:fe3f:556e 16 chars, ret=-1
```


Link-Local address status (HP)

- HP ProVision Layer3 switch example:

```
HP3500# show ipv6

 Internet (IPv6) Service

  IPv6 Routing    : Enabled
  ND DAD          : Enabled
  DAD Attempts    : 3

                                    VLAN Interfaces
  Interface Name  : vl2-client-vlan
  IPv6 Status     : Enabled
  Layer 3 Status  : Enabled

  Address    |                                          Address
  Origin     | IPv6 Address/Prefix Length               Status
  ---------- + ---------------------------------------- -----------
  manual     | 2001:470:c9:1692::f254/64                preferred
  manual     | fe80::9/64                               preferred
```

Link-Local usage (HP)

- HP ProVision Layer3 switch example:

```
HP3500# show ipv6 neighbors

 IPv6 ND Cache Entries
 IPv6 Address                              MAC Address   State Type    Port
 ----------------------------------------- ------------- ----- ------- ----
 fe80::2cab:3680:143d:603a%vlan2           000c29-34478a STALE dynamic 8
 2001:470:56:1ff9::1                       4001c6-a6aa81 REACH dynamic 1


HP3500# ping6 fe80::2cab:3680:143d:603a%vlan2
fe80::2cab:3680:143d:603a is alive, time = 5 ms


HP3500# ping6 fe80::2cab:3680:143d:603a [I did not supply vlan-id,
                                          I simply pressed <ENTER>]
Specified address must include an interface scope. For example, to specify
the link-local address "fe80::1" on VLAN 1, use: fe80::1%vlan1.
```


Link-Local address status (Cisco)

- Cisco Layer3 switch example:

```
Cisco3750#show ipv6 interface vlan 2
Vlan2 is up, line protocol is up
  IPv6 is enabled, link-local address is FE80::5
  Global unicast address(es):
    2001:470:56:1652::F254, subnet is 2001:470:56:1652::/64
  Joined group address(es):
    FF02::1
    FF02::2
    FF02::5
    FF02::6
    FF02::1:2
    FF02::1:FF00:5
    FF02::1:FF00:F254
  MTU is 1500 bytes
  ICMP error messages limited to one every 100 milliseconds
  ICMP redirects are enabled
  ND DAD is enabled, number of DAD attempts: 1
```


Link-Local usage (Cisco)

- Cisco Layer3 switch example:

```
Cisco3750#show ipv6 neighbors

IPv6 Address                              Age Link-layer Addr State Interface
FE80::250E:BB04:9D92:370E                   0 000c.2997.60e8  STALE Vl2
2001:470:56:1652::102                       1 000c.2997.60e8  STALE Vl2
FE80::F254                                  0 4001.c6a6.aa81  STALE Vl1

Cisco3750#ping ipv6 fe80::250e:bb04:9d92:370e
Output Interface: vlan 2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to FE80::250E:BB04:9D92:370E, timeout is 2
  seconds:
Packet sent with a source address of FE80::5
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 0/0/0 ms

Cisco3750#ping ipv6 fe80::250e:bb04:9d92:370e
Output Interface:  [I did not supply vlan-id, I simply pressed <ENTER>]
% Interface required
```


IPv6 autoconfiguration options

Address Autoconfiguration Method	ICMPv6 RA (Type 134) Flags M Flag	O Flag	ICMPv6 RA (Type 134) ICMPv6 Option Prefix Info A Flag	L Flag	Prefix Derived from	Interface ID Derived from	Other Configuration Options (DNS, domain, time, tftp, etc) Derived via	# of IPv6 Addr
Link-Local (always configured)	N/A	N/A	N/A	N/A	Internal (fe80::)	M-EUI-64 or Privacy	Manual	1
Manual	Off	Off	Off	On	Manual	Manual	Manual	2 (LL, Manual)
SLAAC	Off	Off	**On**	**On**	RA	M-EUI-64 or Privacy	Manual	3 (LL, IPv6, IPv6 temp)
Stateful (DHCPv6)	On	N/R	Off	On	DHCPv6	DHCPv6	DHCPv6	2 (LL, DHCPv6)
Stateless DHCPv6	Off	On	On	On	RA	M-EUI-64 or Privacy	DHCPv6	3 (LL, IPv6, IPv6 temp)
Combination Stateless & DHCPv6	On	N/R	On	On	RA and DHCPv6	M-EUI-64 or Privacy and DHCPv6	DHCPv6	4 (LL, IPv6, IPv6 temp, DHCPv6)

IPv6 address autoconfiguration

- Assigning an IPv6 address:
  - **SLAAC** (Stateless address autoconfiguration), generally a /64
    - Uses prefix information from Router Advertisement
    - Interface ID (64 bit host portion) derived from either:
      - Modified IEEE EUI-64 format (RFC 4291)
        - Derived from MAC address
      - Privacy format (RFC 4941)
        - Derived from random number generator
        - Generally creates 2 global addresses
      - Cryptographically generated (RFC 3971 & 3972)
        - Secure/unique interface ID

IPv6 SLAAC process

- A node sends a multicast Router Solicitation message to the “all-routers” address ff02::2
- Router(s) respond with Router Advertisement message containing A & L flags “on” and prefix(es) for stateless autoconfiguration
- The node configures its own IPv6 address(es) with the advertised prefix(es), plus a locally-generated Interface ID
- Node checks whether the selected address(es) is(are) unique (Duplicate Address Detection)
- If unique, the address(es) is(are) configured on interface
- Note – no DNS automatically configured

ICMPv6 - Router Advertisement

- Router Advertisement (RA) [key components]
  - M flag – managed address configuration flag
    (for stateful (DHCPv6) autoconfig)
  - O flag – other configuration flag
    (for stateless DHCPv6 autoconfig)
  - Prf flag – router preference flag (ska priority)
  - Router Lifetime – lifetime associated with the default router
  - Prefix Length – number of bits in the prefix
  - **A flag – autonomous address-configuration flag** (for SLAAC)
  - **L flag – on-link flag**
  - Valid Lifetime – length of time the address is valid for use in preferred and deprecated states
  - Preferred Lifetime – length of time the address is valid for new communications
  - Prefix – IPv6 address prefix
  - **For additional info, see RFC 4861**

Router Advertisement packet (Stateless)

```
No.   Delta    Time          Source                  Destination             Protocol Length Info
  267 52.815 14:38:24.440 fe80::21b:3fff:fedb:1d00 ff02::1                 ICMPv6   110    Router Advertisement

Frame 267: 110 bytes on wire (880 bits), 110 bytes captured (880 bits)
Ethernet II, Src: Procurve_db:1d:00 (00:1b:3f:db:1d:00), Dst: IPv6mcast_00:00:00:01 (33:33:00:00:00:01)
Internet Protocol Version 6, Src: fe80::21b:3fff:fedb:1d00 (fe80::21b:3fff:fedb:1d00), Dst: ff02::1 (ff02::1)
Internet Control Message Protocol v6
   Type: Router Advertisement (134)
   Code: 0
   Checksum: 0x5293 [correct]
   Cur hop limit: 64
   Flags: 0x00
     0... .... = Managed address configuration: Not set
     .0.. .... = Other configuration: Not set
     ..0. .... = Home Agent: Not set
     ...0 0... = Prf (Default Router Preference): Medium (0)
     .... .0.. = Proxy: Not set
     .... ..0. = Reserved: 0
   Router lifetime (s): 0
   Reachable time (ms): 0
   Retrans timer (ms): 0
   ICMPv6 Option (Source link-layer address : 00:1b:3f:db:1d:00)
   ICMPv6 Option (Prefix information : 2001:db8:1ab:ba5e::/64)
     Type: Prefix information (3)
     Length: 4 (32 bytes)
     Prefix Length: 64
     Flag: 0xc0
       1... .... = On-link flag(L): Set
       .1.. .... = Autonomous address-configuration flag(A): Set
       ..0. .... = Router address flag(R): Not set
       ...0 0000 = Reserved: 0
     Valid Lifetime: 0
     Preferred Lifetime: 0
     Reserved
     Prefix: 2001:db8:1ab:ba5e:: (2001:db8:1ab:ba5e::)
```

IPv6 autoconfiguration options

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Manual	Off	Off	Off	On	Manual	Manual	Manual	2 (LL, Manual)
SLAAC	Off	Off	On	On	RA	M-EUI-64 or Privacy	Manual	3 (LL, IPv6, IPv6 temp)
Stateful (DHCPv6)	**On**	N/R	Off	**On**	DHCPv6	DHCPv6	DHCPv6	2 (LL, DHCPv6)
Stateless DHCPv6	Off	On	On	On	RA	M-EUI-64 or Privacy	DHCPv6	3 (LL, IPv6, IPv6 temp)
Combination Stateless & DHCPv6	On	N/R	On	On	RA and DHCPv6	M-EUI-64 or Privacy and DHCPv6	DHCPv6	4 (LL, IPv6, IPv6 temp, DHCPv6)

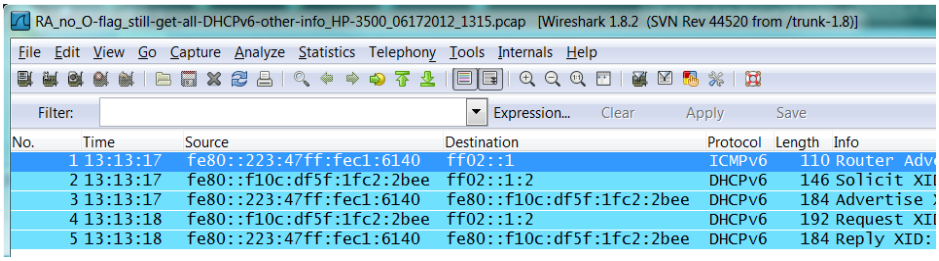
IPv6 address autoconfiguration

- Assigning an IPv6 address:
  - **Stateful** (DHCPv6), generally a /64
    - DHCPv6 (RFC 3315)
    - Uses prefix information defined in scope
    - Interface ID (64 bit host portion) derived from scope pool
    - Reply includes “other” information
      - DNS, domain, time server, tftp or download server, etc

IPv6 Stateful (DHCPv6) process

- A node sends a multicast Router Solicitation message to the "all-routers" address ff02::2
- Router(s) respond with Router Advertisement message containing M flag for stateful autoconfiguration
- The node sends a multicast Solicit message to the "all-DHCP relay agents and servers" address ff02::1:2
- DHCPv6 server(s) responds with Advertise message(s) containing IPv6 address and lifetimes
- The node sends a Request message to confirm and seeking other information
- DHCPv6 server responds with Reply message
- Node checks whether the selected address is unique (Duplicate Address Detection)
- If unique, the address is configured on interface

IPv6 Stateful (DHCPv6) process



- DHCPv6**S**olicit = DHCP**D**iscover (IPv4)
- DHCPv6**A**dvertise = DHCP**O**ffer (IPv4)
- DHCPv6**R**equest = DHCP**R**equest (IPv4)
- DHCPv6**R**eply = DHCP**A**ck (IPv4)

ICMPv6 - Router Advertisement

- Router Advertisement (RA) [key components]
  - **M flag – managed address configuration flag**
    (for stateful (DHCPv6) autoconfig)
  - O flag – other configuration flag
    (for stateless DHCPv6 autoconfig)
  - Prf flag – router preference flag (ska priority)
  - Router Lifetime – lifetime associated with the default router
  - Prefix Length – number of bits in the prefix
  - A flag – autonomous address-configuration flag (for SLAAC)
  - **L flag – on-link flag**
  - Valid Lifetime – length of time the address is valid for use in preferred and deprecated states
  - Preferred Lifetime – length of time the address is valid for new communications
  - Prefix – IPv6 address prefix
  - **For additional info, see RFC 4861**

Router Advertisement packet (Stateful/DHCPv6)

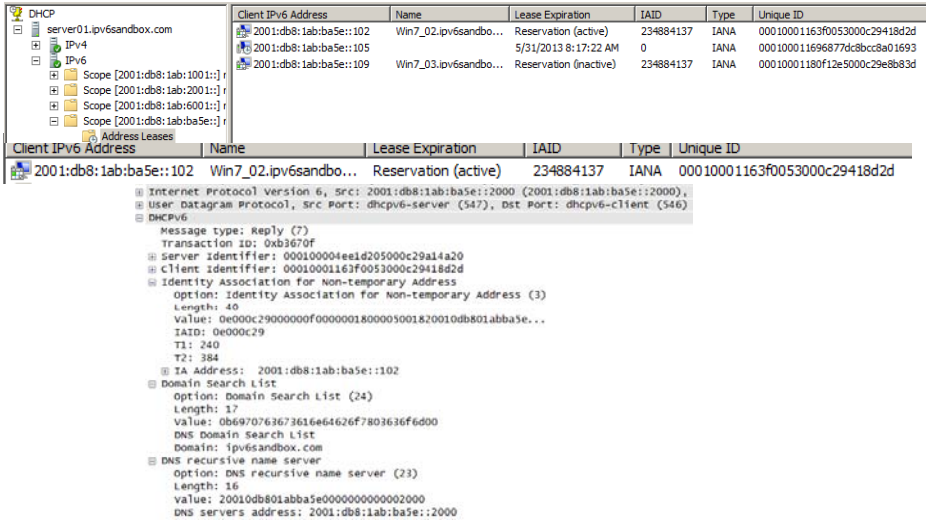
```
No.     Time        Source                Destination           Protocol Length Info
   1282 12:18:21    fe80::20c:29ff:fe35:e8c1 ff02::1               ICMPv6   110 Router Advertisement

Frame 1282: 110 bytes on wire (880 bits), 110 bytes captured (880 bits) on interface 0
Ethernet II, Src: Vmware_35:e8:c1 (00:0c:29:35:e8:c1), Dst: IPv6mcast_00:00:00:01 (33:33:00:00:00:01)
Internet Protocol Version 6, Src: fe80::20c:29ff:fe35:e8c1 (fe80::20c:29ff:fe35:e8c1), Dst: ff02::1 (ff
Internet Control Message Protocol v6
   Type: Router Advertisement (134)
   Code: 0
   Checksum: 0xe3c1 [correct]
   Cur hop limit: 64
   Flags: 0xc0
     1... .... = Managed address configuration: Set
     .1.. .... = Other configuration: Set
     ..0. .... = Home Agent: Not set
     ...0 0... = Prf (Default Router Preference): Medium (0)
     .... .0.. = Proxy: Not set
     .... ..0. = Reserved: 0
   Router lifetime (s): 540
   Reachable time (ms): 0
   Retrans timer (ms): 0
   ICMPv6 Option (Prefix information : 2001:db8:1ab:ba5e::/64)
     Type: Prefix information (3)
     Length: 4 (32 bytes)
     Prefix Length: 64
     Flag: 0x80
       1... .... = On-link flag(L): Set
       .0.. .... = Autonomous address-configuration flag(A): Not set
       ..0. .... = Router address flag(R): Not set
       ...0 0000 = Reserved: 0
     Valid Lifetime: 300
     Preferred Lifetime: 240
     Reserved
     Prefix: 2001:db8:1ab:ba5e:: (2001:db8:1ab:ba5e::)
   ICMPv6 Option (Source link-layer address : 00:0c:29:35:e8:c1)
     Type: Source link-layer address (1)
     Length: 1 (8 bytes)
     Link-layer address: Vmware_35:e8:c1 (00:0c:29:35:e8:c1)
```

Key difference in DHCP/DHCPv6

- Default gateway
  - DHCP – configurable Router option in scope
  - DHCPv6 – no configurable Router option in scope
    (possible future, but no client OS support yet)

- An IPv6 node derives its default gateway from the router's Link-Local address when the L flag is set in the Prefix information field of an RA
  (! not from the network prefix !)

W2K8-R2 DHCPv6 server operation



DHCPv6 Unique Identifier - DUID

- Each DHCPv6 client and server has a DUID
- DHCPv6 servers use DUIDs to identify clients for the selection of configuration parameters and in the association of IAs with clients
- DHCPv6 clients use DUIDs to identify a server in messages where a server needs to be identified

(ref RFC 3315)

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Cloning clients and DUID

- When a client machine is cloned, all the clones have the same DUID
- When 2 clients with the same DUID request an IPv6 address, the DHCPv6 server provides the same address to both clients
- When the 2nd client performs DAD, it detects an IPv6 address conflict, and will not go “on link”

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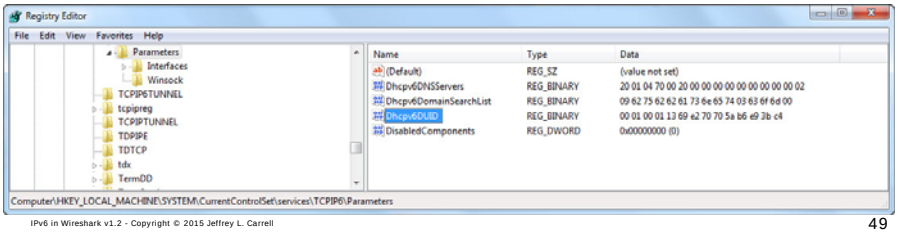
Cloning clients and DUID

- For cloned Microsoft Windows clients, the DUID is in the Windows Registry and can be removed with a manual operation (regedit)
- This should be done before creating a clone, so that when the clones clients are booted, new and unique DUIDs will be created

- reg delete HKLM\SYSTEM\CurrentControlSet\Services\Tcpip6\Parameters /f /v Dhcpv6DUID



IPv6 autoconfiguration options

Address Autoconfiguration Method	ICMPv6 RA (Type 134) Flags M Flag	O Flag	ICMPv6 RA (Type 134) ICMPv6 Option Prefix Info A Flag	L Flag	Prefix Derived from	Interface ID Derived from	Other Configuration Options (DNS, domain, time, tftp, etc) Derived via	# of IPv6 Addr
Link-Local (always configured)	N/A	N/A	N/A	N/A	Internal (fe80::)	M-EUI-64 or Privacy	Manual	1
Manual	Off	Off	Off	On	Manual	Manual	Manual	2 (LL, Manual)
SLAAC	Off	Off	On	On	RA	M-EUI-64 or Privacy	Manual	3 (LL, IPv6, IPv6 temp)
Stateful (DHCPv6)	On	N/R	Off	On	DHCPv6	DHCPv6	DHCPv6	2 (LL, DHCPv6)
Stateless DHCPv6	Off	**On**	**On**	**On**	RA	M-EUI-64 or Privacy	DHCPv6	3 (LL, IPv6, IPv6 temp)
Combination Stateless & DHCPv6	On	N/R	On	On	RA and DHCPv6	M-EUI-64 or Privacy and DHCPv6	DHCPv6	4 (LL, IPv6, IPv6 temp, DHCPv6)

IPv6 address autoconfiguration

- Assigning an IPv6 address:
  - **Stateless DHCPv6**
    - Uses prefix information from Router Advertisement
    - Interface ID (64 bit host portion) derived from either:
      - Modified IEEE EUI-64 format (RFC 4291)
        - Derived from MAC address
      - Privacy format (RFC 4941)
        - Derived from random number generator
      - Cryptographically generated (RFC 3971 & 3972)
        - Secure/unique interface ID
    - Uses DHCPv6 for "other" information
      - DNS, domain, time server, tftp or download server, etc

IPv6 Stateless DHCPv6 process

- A node sends a multicast Router Solicitation message to the "all-routers" address ff02::2
- Router(s) respond with Router Advertisement message containing A & L flags "on" and prefix(es), and O flag "on" for stateless DHCPv6 autoconfiguration
- The node configures its own IPv6 address(es) with the advertised prefix(es), plus a locally-generated Interface ID
- The node sends a multicast Information-Request message to the "all-DHCP relay agents and servers" address ff02::1:2
- DHCPv6 server responds with Reply message
- Node checks whether the selected address is unique (Duplicate Address Detection)
- If unique, the address is configured on interface

ICMPv6 - Router Advertisement

- Router Advertisement (RA) [key components]
  - M flag – managed address configuration flag
    (for stateful (DHCPv6) autoconfig)
  - **O flag – other configuration flag**
    (for stateless DHCPv6 autoconfig)
  - Prf flag – router preference flag (ska priority)
  - Router Lifetime – lifetime associated with the default router
  - Prefix Length – number of bits in the prefix
  - **A flag – autonomous address-configuration flag** (for SLAAC)
  - **L flag – on-link flag**
  - Valid Lifetime – length of time the address is valid for use in preferred and deprecated states
  - Preferred Lifetime – length of time the address is valid for new communications
  - Prefix – IPv6 address prefix

– **For additional info, see RFC 4861**

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Router Advertisement packet (Stateless/DHCPv6)

```
6000  5.346 09:33:22.152 fe80::2                ff02::1                ICMPv6   118 Router Advertisement
Frame 6000: 118 bytes on wire (944 bits), 118 bytes captured (944 bits) on interface 0
Ethernet II, Src: Cisco_54:4b:c0 (00:11:21:54:4b:c0), Dst: IPv6mcast_00:00:00:01 (33:33:00:00:00:01)
Internet Protocol Version 6, Src: fe80::2 (fe80::2), Dst: ff02::1 (ff02::1)
Internet Control Message Protocol v6
   Type: Router Advertisement (134)
   Code: 0
   Checksum: 0x8df9 [correct]
   Cur hop limit: 64
   Flags: 0x40
     0... .... = Managed address configuration: Not set
     .1.. .... = Other configuration: Set
     ..0. .... = Home Agent: Not set
     ...0 0... = Prf (Default Router Preference): Medium (0)
     .... .0.. = Proxy: Not set
     .... ..0. = Reserved: 0
   Router lifetime (s): 1800
   Reachable time (ms): 0
   Retrans timer (ms): 0
   ICMPv6 Option (Source link-layer address : 00:11:21:54:4b:c0)
   ICMPv6 Option (MTU : 1500)
   ICMPv6 Option (Prefix information : 2001:db8:1ab:ba5e::/64)
     Type: Prefix information (3)
     Length: 4 (32 bytes)
     Prefix Length: 64
     Flag: 0xc0
       1... .... = On-link flag(L): Set
       .1.. .... = Autonomous address-configuration flag(A): Set
       ..0. .... = Router address flag(R): Not set
       ...0 0000 = Reserved: 0
     Valid Lifetime: 35
     Preferred Lifetime: 15
     Reserved
     Prefix: 2001:db8:1ab:ba5e:: (2001:db8:1ab:ba5e::)
```


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IPv6 autoconfiguration options

Address Autoconfiguration Method	ICMPv6 RA (Type 134) Flags M Flag	O Flag	ICMPv6 RA (Type 134) ICMPv6 Option Prefix Info A Flag	L Flag	Prefix Derived from	Interface ID Derived from	Other Configuration Options (DNS, domain, time, tftp, etc) Derived via	# of IPv6 Addr
Link-Local (always configured)	N/A	N/A	N/A	N/A	Internal (fe80::)	M-EUI-64 or Privacy	Manual	1
Manual	Off	Off	Off	On	Manual	Manual	Manual	2 (LL, Manual)
SLAAC	Off	Off	On	On	RA	M-EUI-64 or Privacy	Manual	3 (LL, IPv6, IPv6 temp)
Stateful (DHCPv6)	On	N/R	Off	On	DHCPv6	DHCPv6	DHCPv6	2 (LL, DHCPv6)
Stateless DHCPv6	Off	On	On	On	RA	M-EUI-64 or Privacy	DHCPv6	3 (LL, IPv6, IPv6 temp)
Combination Stateless & DHCPv6	**On**	N/R	**On**	**On**	RA and DHCPv6	M-EUI-64 or Privacy and DHCPv6	DHCPv6	4 (LL, IPv6, IPv6 temp, DHCPv6)

Combination Stateless and DHCPv6

- This is typically an undesired configuration
- Generally a result of enabling RA flags for one type of address autoconfiguration requirement, and not disabling other flags not required
- Result is too many/unwanted IPv6 GUA's
  - SLAAC – up to two possible GUA's
  - Stateful (DHCPv6) – one GUA
  - Even a manual configured GUA

❖ Remember, if there is a "Temporary" GUA, it will be used for outbound communications

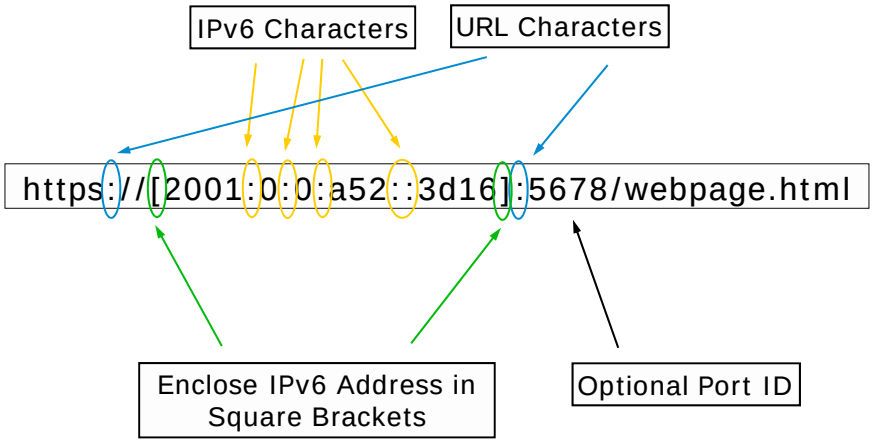
IPv6 autoconfiguration options

Address Autoconfiguration Method	ICMPv6 RA (Type 134) Flags M Flag	O Flag	ICMPv6 RA (Type 134) ICMPv6 Option Prefix Info A Flag	L Flag	Prefix Derived from	Interface ID Derived from	Other Configuration Options (DNS, domain, time, tftp, etc) Derived via	# of IPv6 Addr
Link-Local (always configured)	N/A	N/A	N/A	N/A	Internal (fe80::)	M-EUI-64 or Privacy	Manual	1
Manual	Off	Off	Off	**On**	Manual	Manual	Manual	2 (LL, Manual)
SLAAC	Off	Off	On	On	RA	M-EUI-64 or Privacy	Manual	3 (LL, IPv6, IPv6 temp)
Stateful (DHCPv6)	On	N/R	Off	On	DHCPv6	DHCPv6	DHCPv6	2 (LL, DHCPv6)
Stateless DHCPv6	Off	On	On	On	RA	M-EUI-64 or Privacy	DHCPv6	3 (LL, IPv6, IPv6 temp)
Combination Stateless & DHCPv6	On	N/R	On	On	RA and DHCPv6	M-EUI-64 or Privacy and DHCPv6	DHCPv6	4 (LL, IPv6, IPv6 temp, DHCPv6)

Manual configured IPv6 addresses

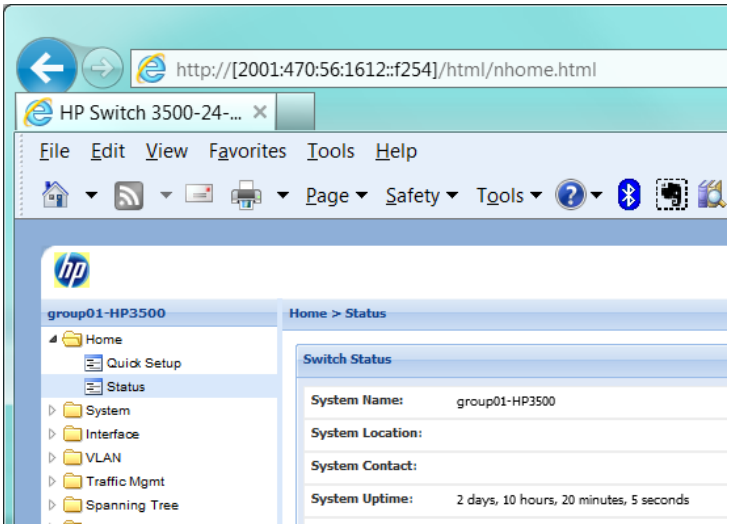
- In Windows operating systems (server and client), does not over-ride DHCPv6 functions (like it does in IPv4)
- If don't want SLAAC or DHCPv6 addresses on network segment, must disable A, M, and O flags in RA
- Do not need to configure default gateway, but can
  - Remember, how does an IPv6 node derive a router ???
- May be able to manually configure Link-local address, handy for routers so configuration is "portable"
  - Generally not possible on client OSs

IPv6 notation in URL



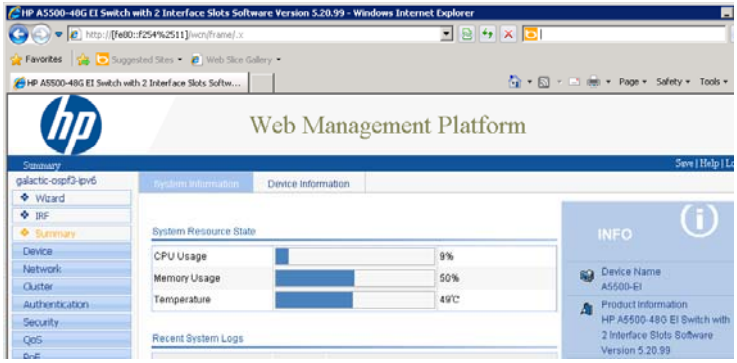
For additional info, see RFC 5952

IPv6 GUA in URL

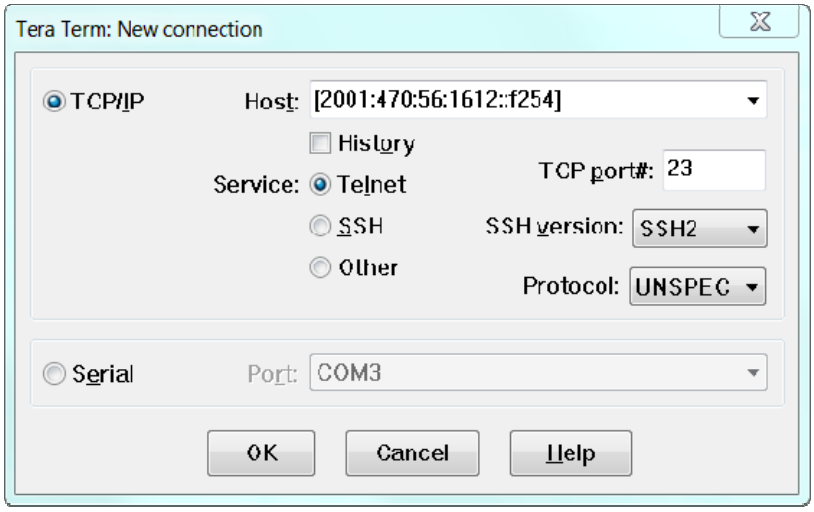


IPv6 Link-local in URL

- http://[fe80::f254%2511]
  - fe80::f254 is destination, %11 is the outbound interface – but specified as %2511 where the %25 is hex converted to the % symbol
    - ❖Note, this does not work in all browsers



Telnet/SSH over IPv6

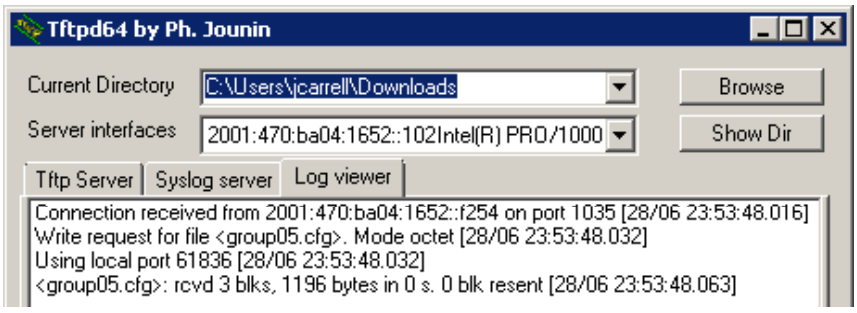


Telnet/SSH over IPv6

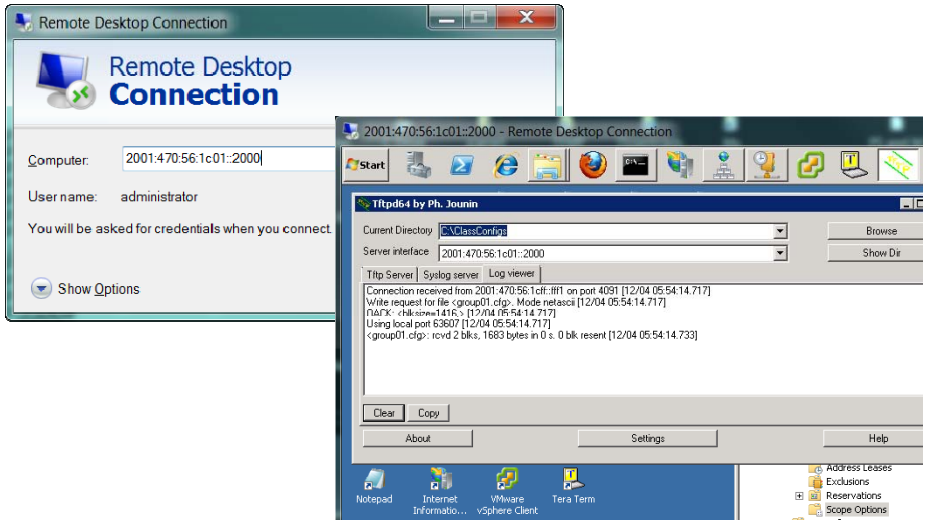
```
group05-NetIron#show telnet
Console connections:
        established, privilege super-user
        you are connecting to this session
        4 seconds in idle
Telnet server status: Enabled
Telnet connections (inbound):
 1      established, client ip6 address
2001:470:1f0f:ee7::7:100, privilege super-user
        using vrf default-vrf.
```


TFTP over IPv6

```
group05-NetIron#copy running-config tftp ipv6
  2001:470:ba04:1652::102 group05.cfg
```



RDP over IPv6



IPv6 and DNS

- Bind forward and reverse resolution

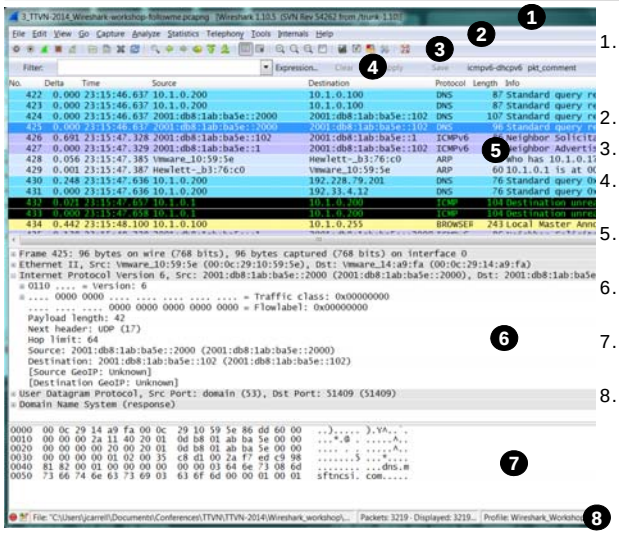
```
; 4to6labs.com Dumped
<snip>
www.4to6labs.com.     3600    IN      AAAA    2607:f2f8:a6d0:0:0:0:0:2


; 0.0.0.0.0.d.6.a.8.f.2.f.7.0.6.2.ip6.arpa Dumped ;
  2.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.d.6.a.8.f.2.f.7.0.6.2.ip6.arpa.
  86400 IN PTR www.4to6labs.com.
```

Wireshark

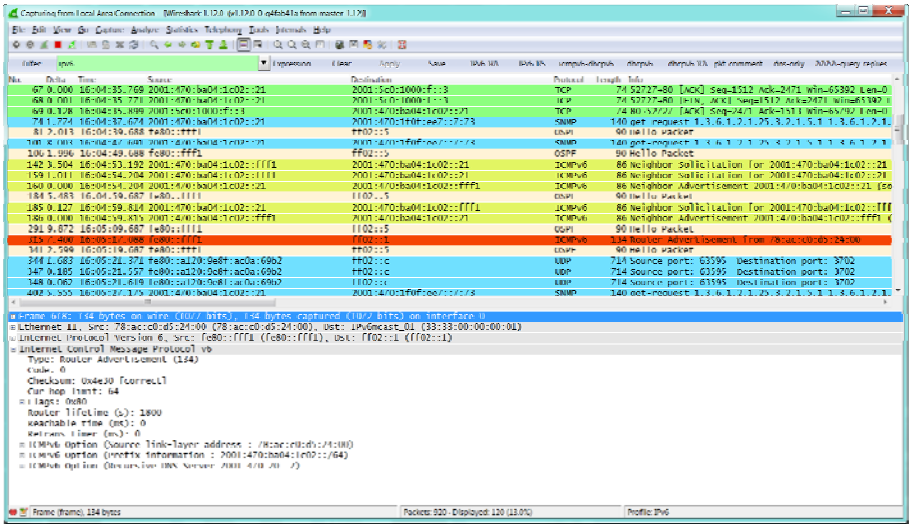
- Wireshark basics
- Wireshark
  - color rules
  - display filters
  - columns
  - configuration profiles
- Wireshark labs!!!

Wireshark main view



1. Title bar — trace file name or capture device name, and Wireshark version number
2. Main menu — standard menu
3. Main toolbar — quick access
4. Display filter area — reduce the amount of traffic you see
5. Packet List pane — summary of each frame
6. Packet Details pane — dissected frames
7. Packet Bytes pane — hex and ASCII details
8. Status Bar — access to the Expert, annotations, file location, packet counts, and profiles

Jeff's IPv6 Wireshark

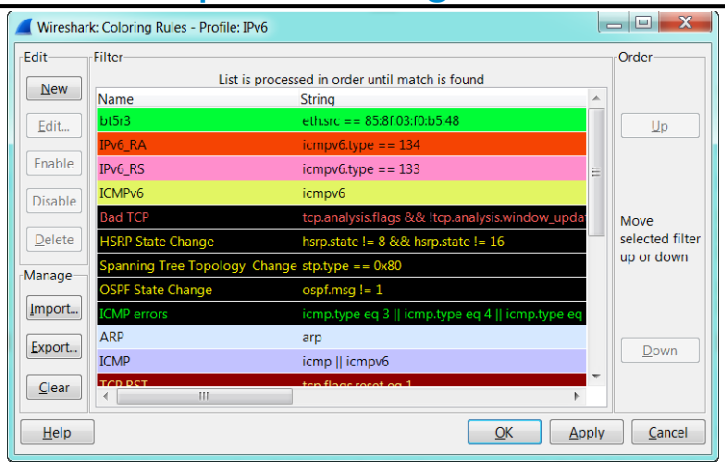


Coloring rules

446	0.000	23:15:51.638	10.1.0.200	10.1.0.100	DNS	87 Standard query response 0x
447	0.000	23:15:51.638	10.1.0.200	10.1.0.100	DNS	87 Standard query response 0x
448	0.000	23:15:51.638	10.1.0.100	10.1.0.200	ICMP	115 Destination unreachable (P
449	0.000	23:15:51.638	2001:db8:1ab:ba5e::2000	2001:db8:1ab:ba5e::102	DNS	96 Standard query response 0x
450	0.000	23:15:51.639	2001:db8:1ab:ba5e::102	2001:db8:1ab:ba5e::2000	ICMPv6	155 Destination Unreachable (P
451	0.959	23:15:52.599	Hewlett-_b3:76:ec	LLDP_Multicast	LLDP	282 Chassis Id = 00:16:35:b3:7
452	1.266	23:15:53.865	fe80::1	ff02::1	ICMPv6	110 Router Advertisement from
453	0.287	23:15:54.152	10.1.0.100	239.255.255.250	SSDP	175 M-SEARCH * HTTP/1.1
454	1.045	23:15:55.198	Hewlett-_b3:76:c0	HP_00:00:67	HP	110 HP Switch Protocol
455	1.130	23:15:56.328	Vmware_14:a9:fa	Vmware_10:59:5e	ARP	60 Who has 10.1.0.200? Tell
456	0.000	23:15:56.329	2001:db8:1ab:ba5e::102	2001:db8:1ab:ba5e::2000	ICMPv6	86 Neighbor Solicitation for
457	0.001	23:15:56.330	Vmware_10:59:5e	Vmware_14:a9:fa	ARP	60 10.1.0.200 is at 00:0c:29:
458	0.000	23:15:56.331	2001:db8:1ab:ba5e::2000	2001:db8:1ab:ba5e::102	ICMPv6	86 Neighbor Advertisement 200
459	0.810	23:15:57.141	10.1.0.100	239.255.255.250	SSDP	175 M-SEARCH * HTTP/1.1
460	2.999	23:16:00.141	10.1.0.100	239.255.255.250	SSDP	175 M-SEARCH * HTTP/1.1
461	3.012	23:16:03.153	10.1.0.100	239.255.255.250	SSDP	175 M-SEARCH * HTTP/1.1

- Colors help you focus on specific address, protocols, events, and possibly find errors quickly

Color rule processing order



- Color rules read like a router ACL or firewall rule
  - First color rule that matches wins

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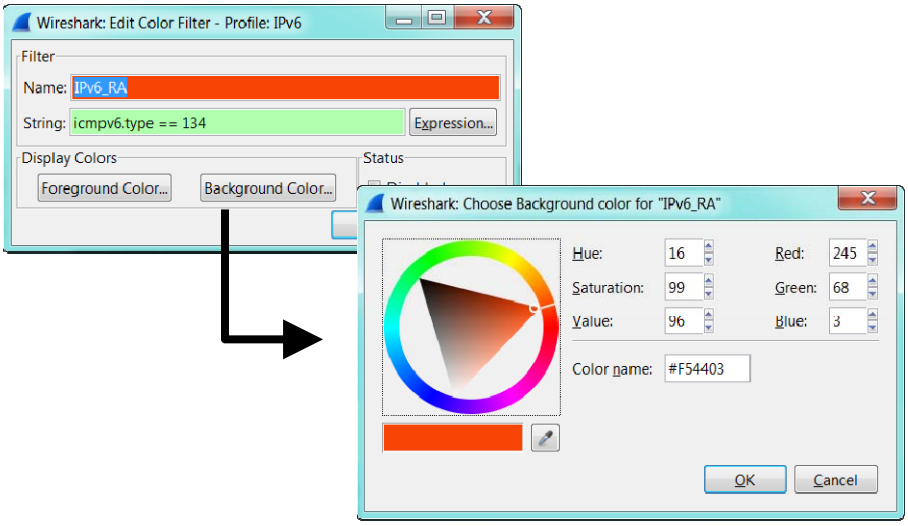
Color rule creation



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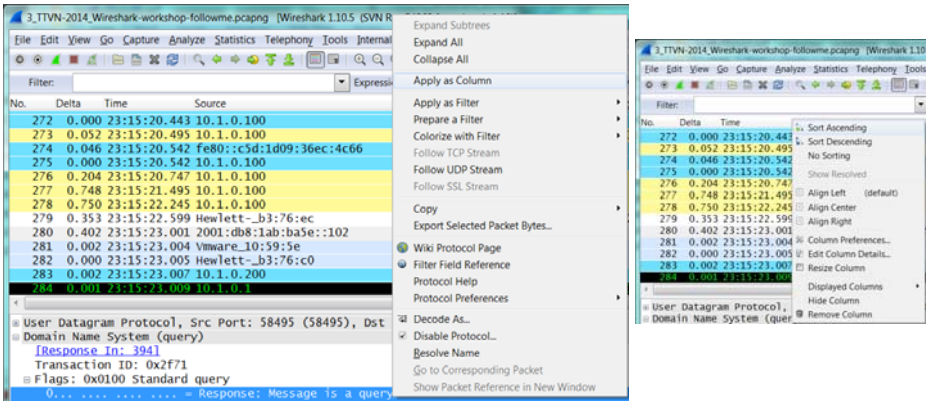
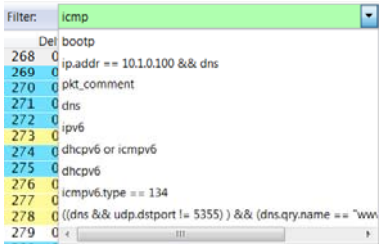
Columns



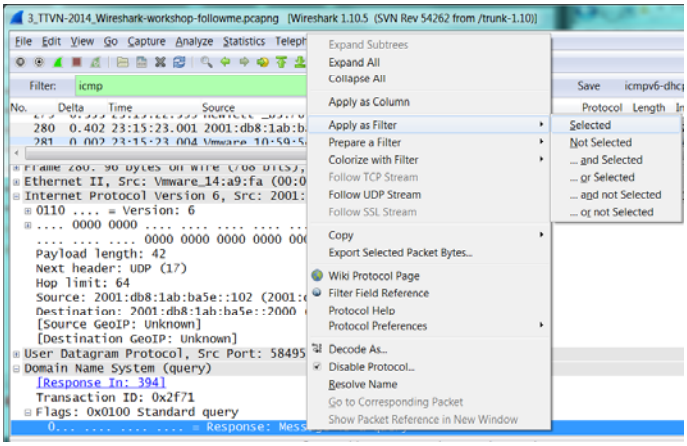
- In the Packet Details view, right-click on a specific field to Apply as Column
- Right-click column headings to sort, rename, align, etc

Display filters – option 1



- The Filter bar will change colors as you type to signify correct syntax for the filter
  - Green – syntax is correct
  - Red – syntax is correct
  - Yellow – syntax is suspect
- The Filter dropdown will show last 10 filters used
- You can save Filter definitions for frequent use

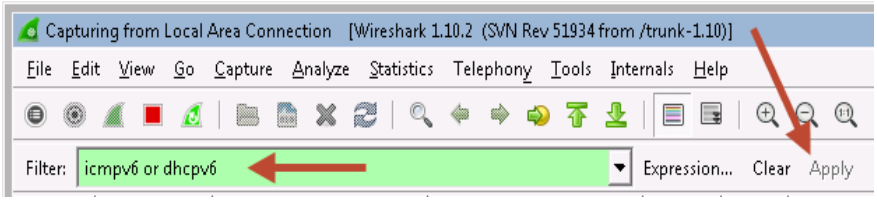
Display filters – option 2



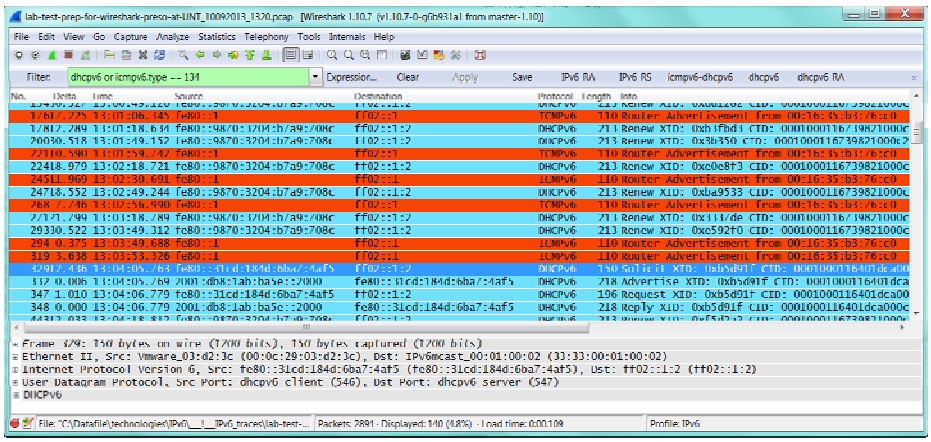
- In the Packet Details view, right-click on a specific field to build a filter

Using Wireshark to view IPv6 pkts

- IPv6 display filter families
  - ipv6
  - icmpv6
  - dhcpv6
- IPv6 related display filters:
  - http://www.wireshark.org/docs/dfref/i/ipv6.html

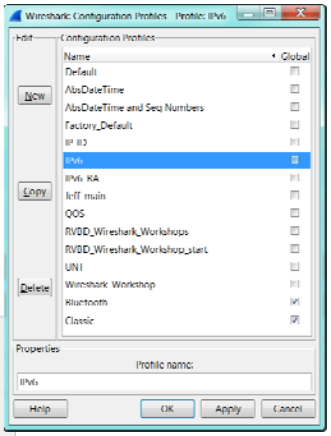


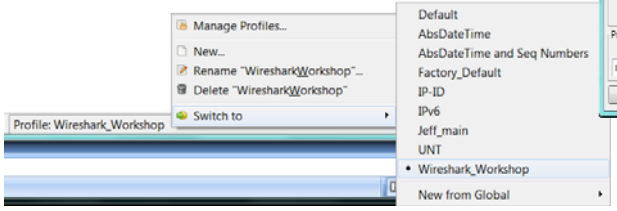
Using Wireshark to view IPv6 pkts



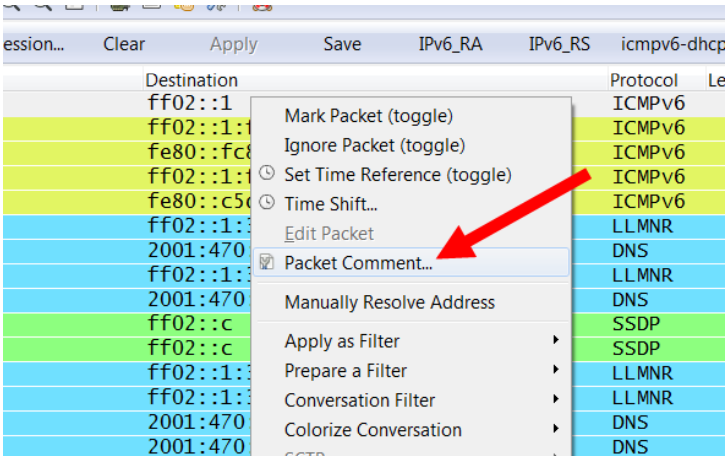
Configuration profiles

- What they are
- Why/how you use them
- What they contain
- How to share





Packet annotation



- Right click packet, select Packet Comment

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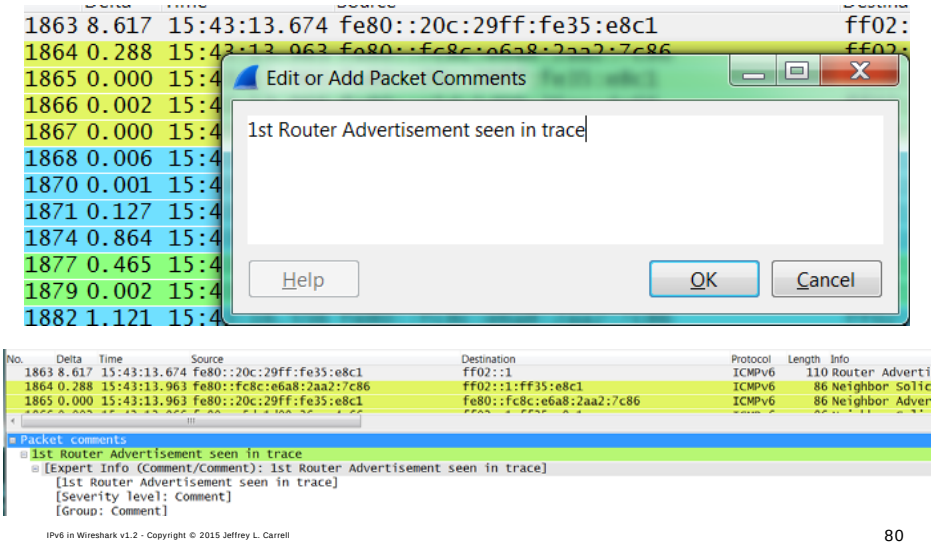
Packet annotation



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Wireshark demo #1 – watch me

- Discussion about various IPv6 operations and viewing them in Wireshark

Wireshark demo #2 – follow me

- Open:
  "Troopers2015_Wireshark-workshop.pcapng"
  - Watch and follow me on this one
    - Telnet
    - SSH
    - HTTP
    - DNS
- Now it's your turn…next slide please

Wireshark lab #1

- Create your own named profile
- Add delta time column
- Change time/date to time (only) and in milliseconds
- Create/save pkt_comment filter

Wireshark lab #2

- Find 1st pkt with dns.qry.name == "www.ipv6sandbox.com"
  - make a note as to which pkt this is
- Find 1st pkt with AAAA DNS query response for www.ipv6sandbox.com
  - make a note as to which pkt this is
  - what is the IPv6 address in the answer section

Wireshark lab #3

- Find pkt with http.host == "www.ipv6sandbox.com"
  - make a note as to which pkt this is
- Find pkt with an http response code of 200
  - make a note as to which pkt this is
- Find pkt with comment of 'this is the secret pkt with the most important comment!'

Wireshark lab #4 – IPv6-RA

- Inspect RA packets
  - configure a display filter as "icmpv6.type == 134"
  - select an RA pkt, which flags are set to "1":
    M ___ O ____ L ____ A ____
  - which IPv6 address autoconfiguration option is this RA configured for?
    SLAAC __ Stateful(DHCPv6) __ Stateless DHCPv6 __

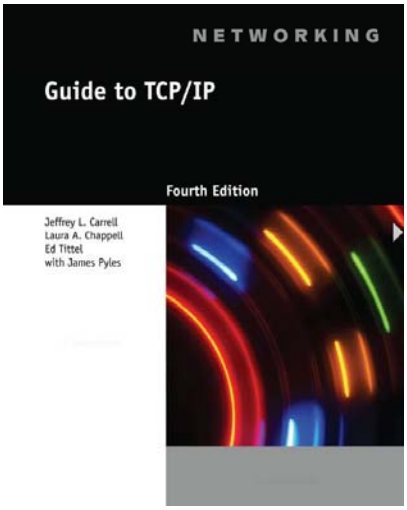
Wireshark lab #5 – DHCPv6

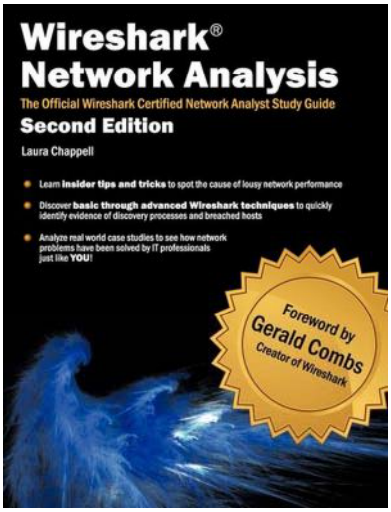
- Inspect DHCPv6 packets
  - configure a display filter as “dhcpv6”
  - pick a specific client
  - find the first of each of its DHCPv6 process pkts
    - what is the dhcpv6 server’s v6 addr?
    - what are the pkt numbers for:

      Solicit ____ Advertise ____ Request ____ Reply ____
  - what v6 addr did the client get assigned?

    _____

Resources





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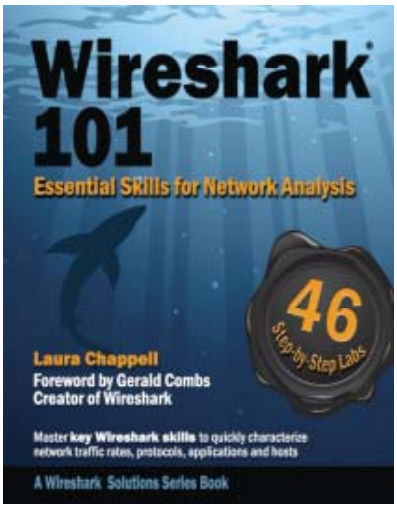

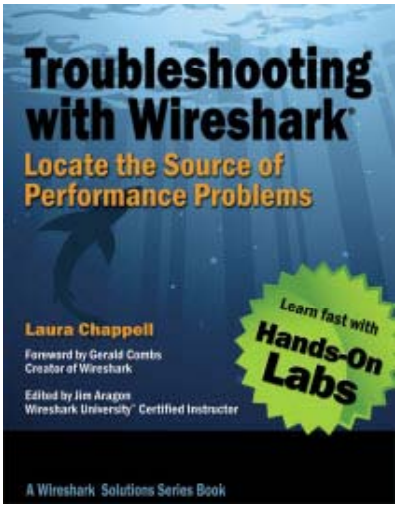

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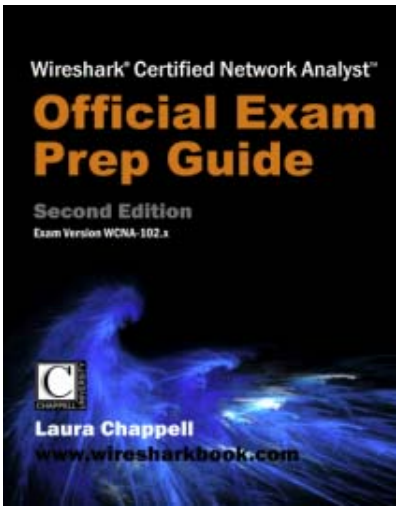

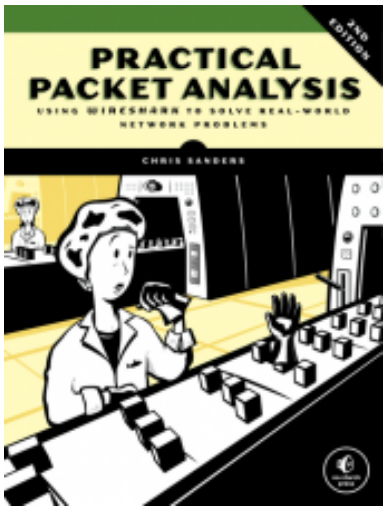

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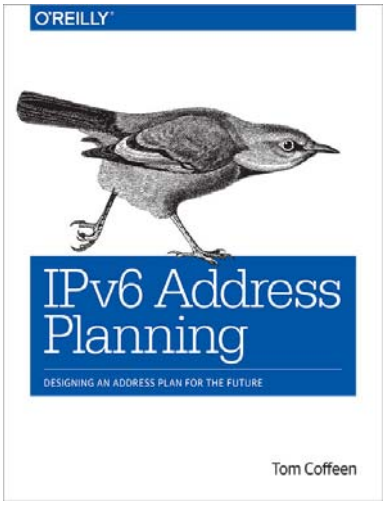

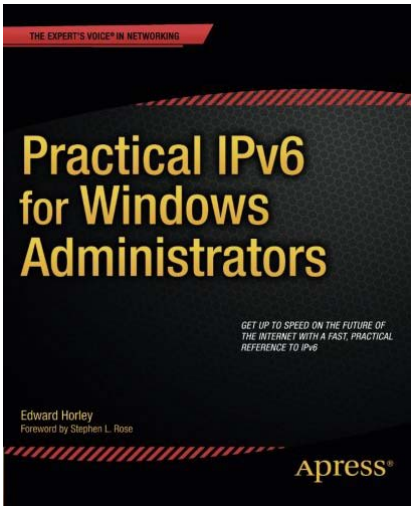

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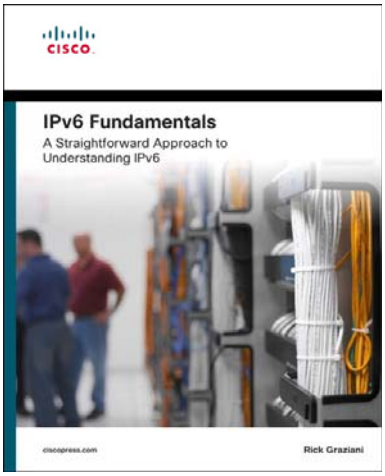
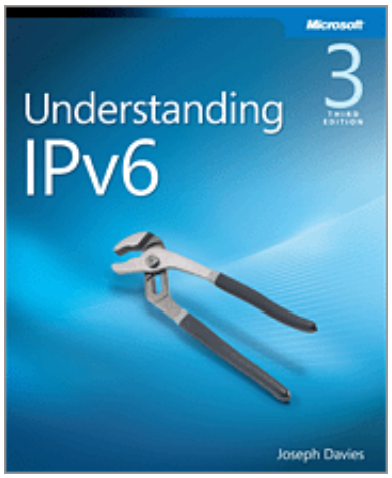
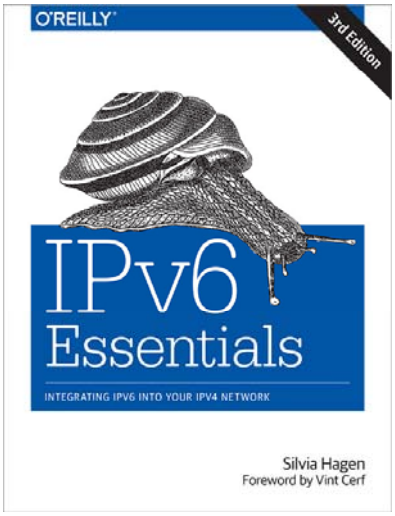




Resources



Thank You for Attending!

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- Twitter: @JeffCarrell_v6