Enhanced IP

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This is Research

- We're going to demonstrate an extension to the IPv4 protocol
- EnIP is aimed at mobile devices and mobile device operator networks initially as we believe they have the most incentive.
- EnIP could also be adopted on a wider scale for the home/enterprise user but not initially.
- The ideas we present compete with IPv6
- EnIP has had limited peer review. It might have glaring holes. You are the peers.

This is Research (cont.)

- How should we encourage spirited debate in this session or afterwards?
- Our process: we're going to hit the highlights on IPv6 deployment issues as we see them. After describing EnIP we'll also hit on it's problems.
- IPv6 has had a spirited debate over the years as have many other protocols. If EnIP suffers a fatal flaw, we will withdraw it. If people are interested in the concept and the ideas continue to have technical merit, the research will continue.

Talk Outline

- 1992-1994: A Time Period of Significance to Today
- IPv6 Problems summarized in 3 slides
- Enhanced IP

Some Important R&D 1992-1994

- Nov 1992 - publication of EIP as RFC 1385
- Jan 1993 - original ACM SIGCOMM paper describing NAT
- 1992 - 1994 - Robert Ullman's IPv7 in 1992 became known as TP/IX in 1993. TP/IX proposed changes to IP and TCP at the same time. IP would use 64-bit addresses, 3 bytes for administrative domain, 3 bytes for network address, and 2 bytes for host. In 1994 proposal evolved into a completely new design called CATNIP but also keeping IPv7 name. CATNIP was about universal interoperability for IP, CLNP, and IPX.
- Dec 1993 - publication of RFP by IPng working group. Received proposals on SIP, CATNIP, & TUBA. EIP did not submit a proposal. SIP proposed increase of IP space from 32-bit to 64-bit addresses. TUBA and CATNIP used 160-bit ISO CLNP addresses. Later SIP merged with PIP and became SIPP.

Some Important R&D 1992-1994

- Mar 1994 - Brian Carpenter suggested use of IP options in protocol called AEIOU. In the Mar 1994 IETF meeting minutes, Steve Deering "noted that AEIOU should go into the same status as EIP: honored, revered, unimplemented."
- Jul 1994 - SIPP is chosen by the IPng Directorate to become IPv6 after changing address size from 64-bit to 128-bit

Brian E. Carpenter's response

- "AEIOU is fairly simple to explain. I was still new to the IETF at the time, and by the time I came up with the idea, the IPng process was well launched and there was no mood in the IETF to consider quick fixes. You need to remember that in 1994, although WWW was taking off, the Internet was still at least a year from becoming commercially significant, and we didn't feel a need for a quick fix. Also there were two good technical arguments against AEIOU, both of which were important in the BOF at IETF 29 (Seattle):"

- AEIOU BOF, Seattle IETF, 28 March, 1994. 1.30pm

- **“It is pointed out that it is dangerous to assume that new options will survive passage across the Internet, Rob Ullman has done some investigation on what routers and hosts do to options.”**
- **“Brian presents a matrix where OLD and AE cannot talk to each other.”**
- **“Deployment of AEIOU requires that all routers within a site be upgraded.”**

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- **“Summary discussion focused on whether or not AEIOU was too much effort for the return, in light of IPng efforts. Many felt that this would hamper IPng efforts and Eric Fleischman asked if we did AEIOU wouldn't it cause several people to think that they did not have to worry about deploying IPng.”**

Rob Ullman

- Couldn’t find his study on certain IP options not passing.
- Robert passed away last year
- There is a 2005 study by some UC Berkeley researchers with some details.

Summary of UC Berkeley Options Study

- Paper: IP Options are not an Option
- Title of paper and conclusions do not match
- 160 machines used to traceroute to each other. 139 machines usable. 160x139 = 22240 paths
- They were able to get traceroutes for 21,051 of the possible pairs or 94.65%
- Experienced some routers that had problems forwarding SYN packets with IP options
- They sent standard ICMP traceroutes, and traceroutes containing NOP, Timestamp, and Record Route options.

What about IP Options?

- "However, as we will show in this paper, IP options are not well supported in the Internet."
- Between 85% and 92% of the drops occur at edge ASs
- "A surprising result of our study was that approximately 90% of option-enabled packet drops occurred at the edges of the network, not in the core, and that a small fraction of the ASes are responsible for a vast majority of the drops."
- "Surprisingly, our findings indicate that it is feasible to restore support for options in the wide-area. We discovered that the core of the network drops very few options packets, with the vast majority of those drops occurring in edge AS networks. Furthermore, these drops are concentrated in a minority of the ASes."

EIP: Comments from Jon Scowcroft

"briefly, we worked on EIP .... we did an implementation, but only a proof of concept, and it would have needed a lot more hard work:) - however, the main guy behind the idea (Zheng Wang) moved to Bell Labs and changed priorities- but also, I had just taken on Paul Francis to do a PhD which turned into PIP, which was a significant input in to the IPng process (effectively a merge of PIP (Paul's IP) and SIP (Simple, or Steve's IP) turned into IPv6....although some key cool bits of PIP were too ATM like (designed to support superfast switching) to stay in there (alas:)

Jon Scowcroft on Fast and Slow Path

- “However, most routers for most the 1980s and 1990s and 2000s (but less so now) had a notion of "fast path" and "slow path". The fast path was highly optimised s/w and h/w that targeted the most common packet structures - typically, around the time of Cisco 7000 series routers on, this meant packets got processed on line cards (input to decide on output, and output for queuing)”

IPv6 Implementation Problems

- The Peering Problem
- As of 4/11/2012 according to bgpmon.net
  - Count of IPv4 Routes = 336072
  - Count of IPv6 Routes = 3948
  - Stats extracted from routing table rr03.ripe.net

IPv6 Implementation Problems

- The CPE Problem
- From Brian E. Carpenter's 2010 IPv6 Task Force talk
  - Billing Systems, Handsets, management interfaces and systems, DSLAMs, Routers, Traffic mgmt boxes, load balancers, VPN boxes, SIP boxes, firewalls
- End to End principle violated to support LTE needs
  - NAT64 to support IPv6 LTE subscribers reachability to legacy IPv4

IPv6 Implementation Problems

- "Deploying IPv6 in the Google Enterprise Network. Lessons learned." It's hard for Google. They're working with vendors as problems arise.
- Geoff Huston's Nanog 53 Talk on IPv4 Address Exhaustion and how we're presently running IPv4, IPv6, tunnelling, CGNs, CDNs, ALGs and how market forces are driving transitions or lack of transitions.
- The reality is all these things are happening at the same time. Now we'll propose adding Enhanced IP into the market. The market will decide.

Enhanced IP

Enhanced IP Outline

- Protocol Details
- Working code between University of Maryland and University of Delaware over Internet 2 link. (over 7 router hops)
- Demonstrated Enhanced IP running in an LTE system (details later)
- Demonstrated Enhanced IP running on an Android (Alpha state)
- The transition plan
- Positive and Negative viewpoints

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- Routing of Enhanced IP packets are sent over the wide area using IPv4 routing table.
- We use IP options, so data plane forwarding issues exist

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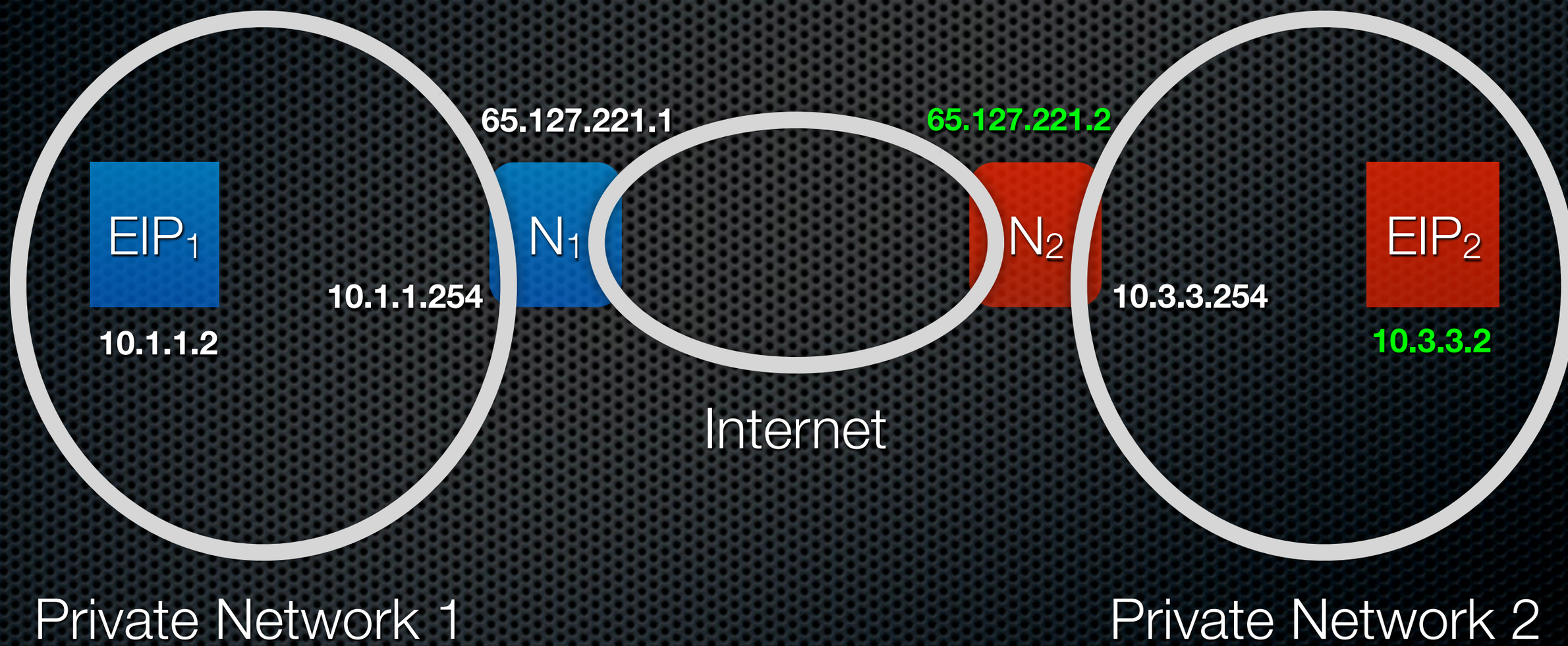
- **Host address: 10.3.3.2**, used to route packets to a node behind the router/NAT that has the outside address of 65.127.221.1

Enhanced IP Network



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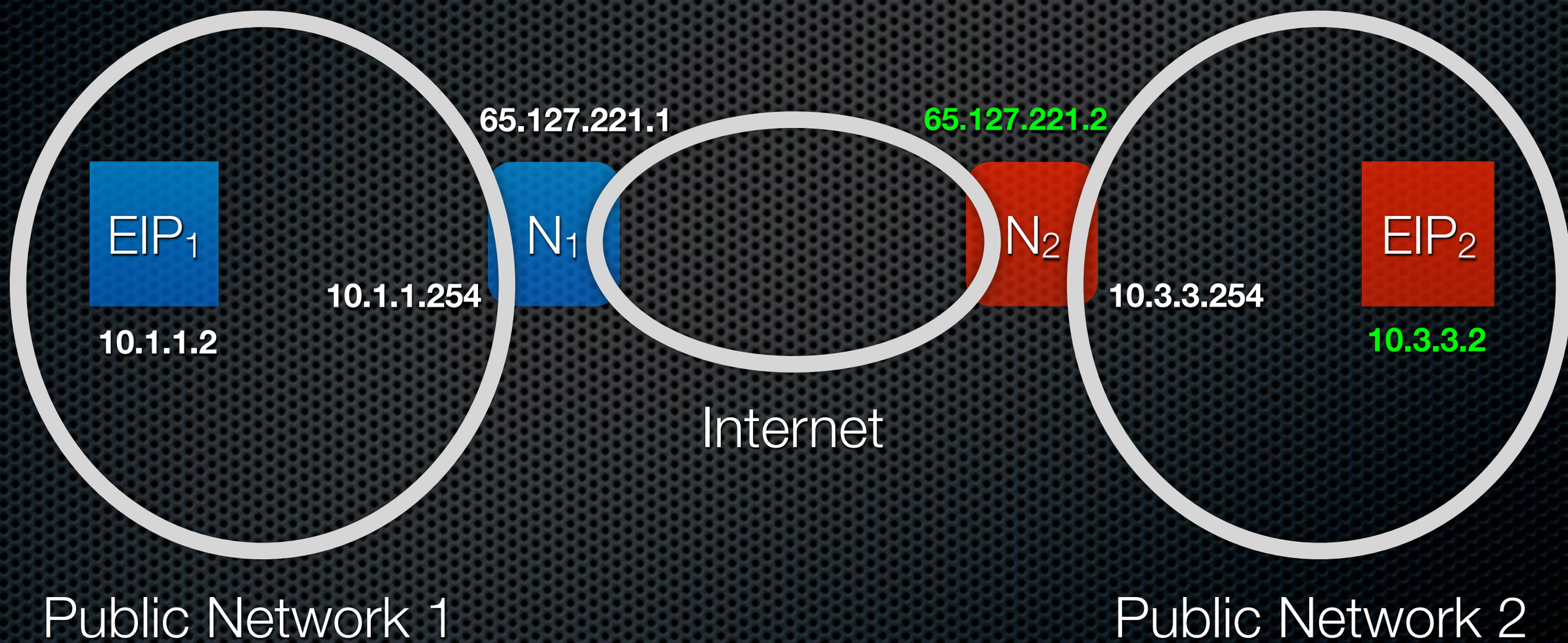

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  - does not replace ARP, DHCPv4, routing protocols
- Uses IP Option 26 to extend the length of the IP header, 12 bytes per packet
- The NAT functionality used in Enhanced IP is stateless as opposed to the stateful nature of IPv4 NAT.

IPv4 Header

<table>
<tr><td>Version</td><td>IHL</td><td>ToS</td><td colspan="2">Total Length</td></tr>
<tr><td colspan="3">Identification</td><td>Flag</td><td>Fragment Offset</td></tr>
<tr><td colspan="2">Time to Live</td><td>Protocol</td><td colspan="2">Header Checksum</td></tr>
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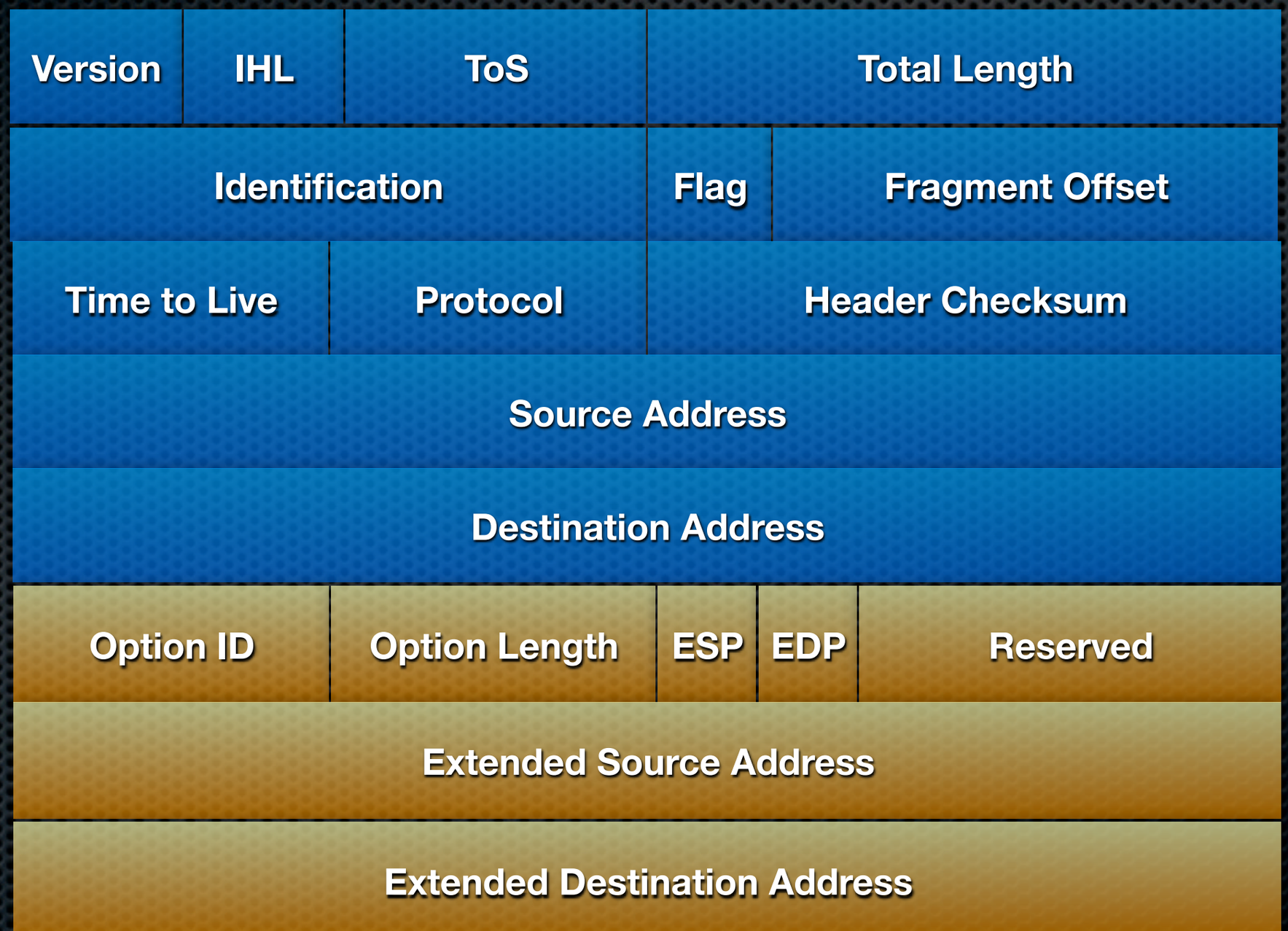

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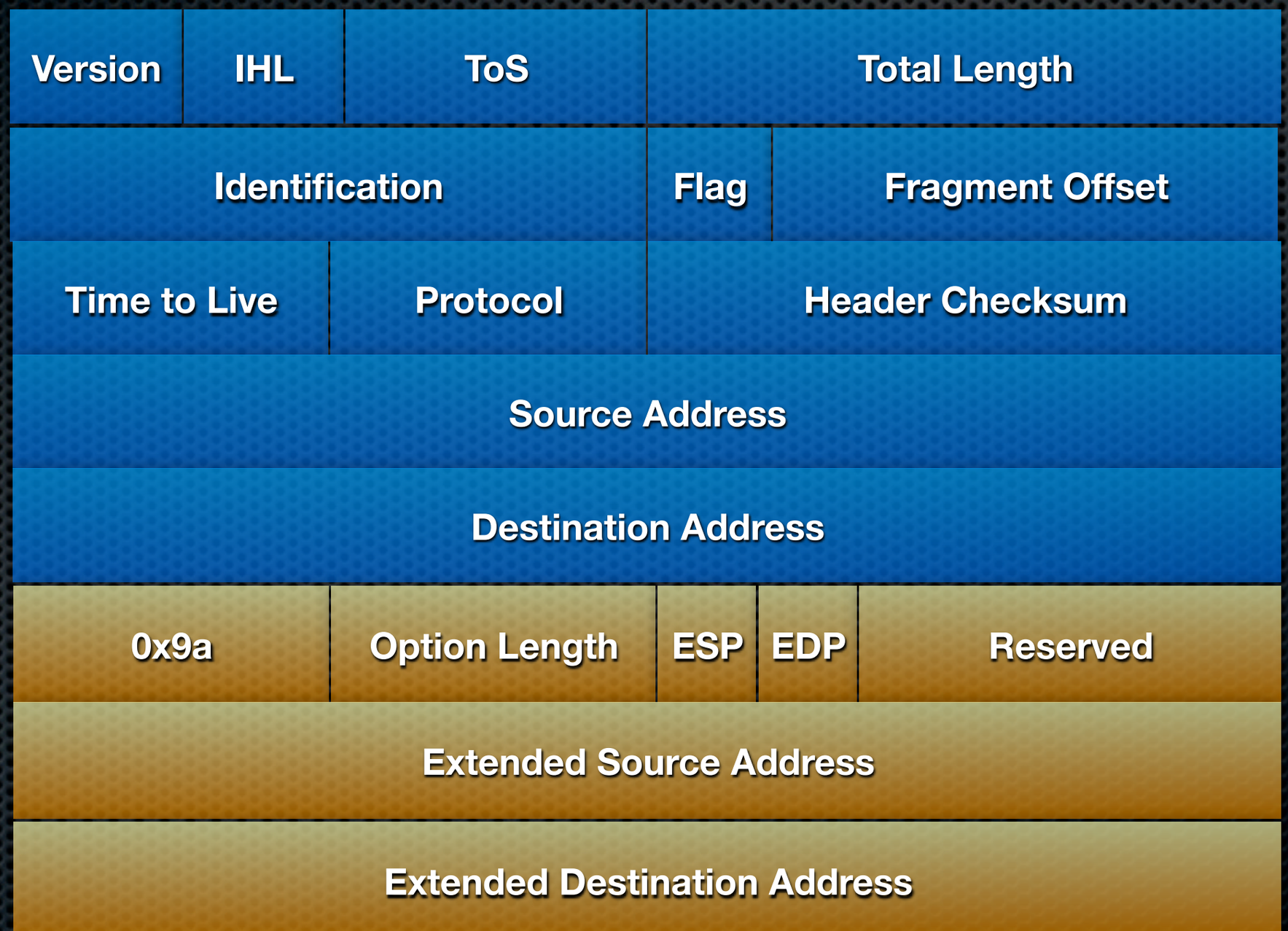

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<tr><td colspan="6">Source Address</td></tr>
<tr><td colspan="6">Destination Address</td></tr>
<tr><td>0x9a</td><td>12</td><td>ESP</td><td>EDP</td><td colspan="2">Reserved</td></tr>
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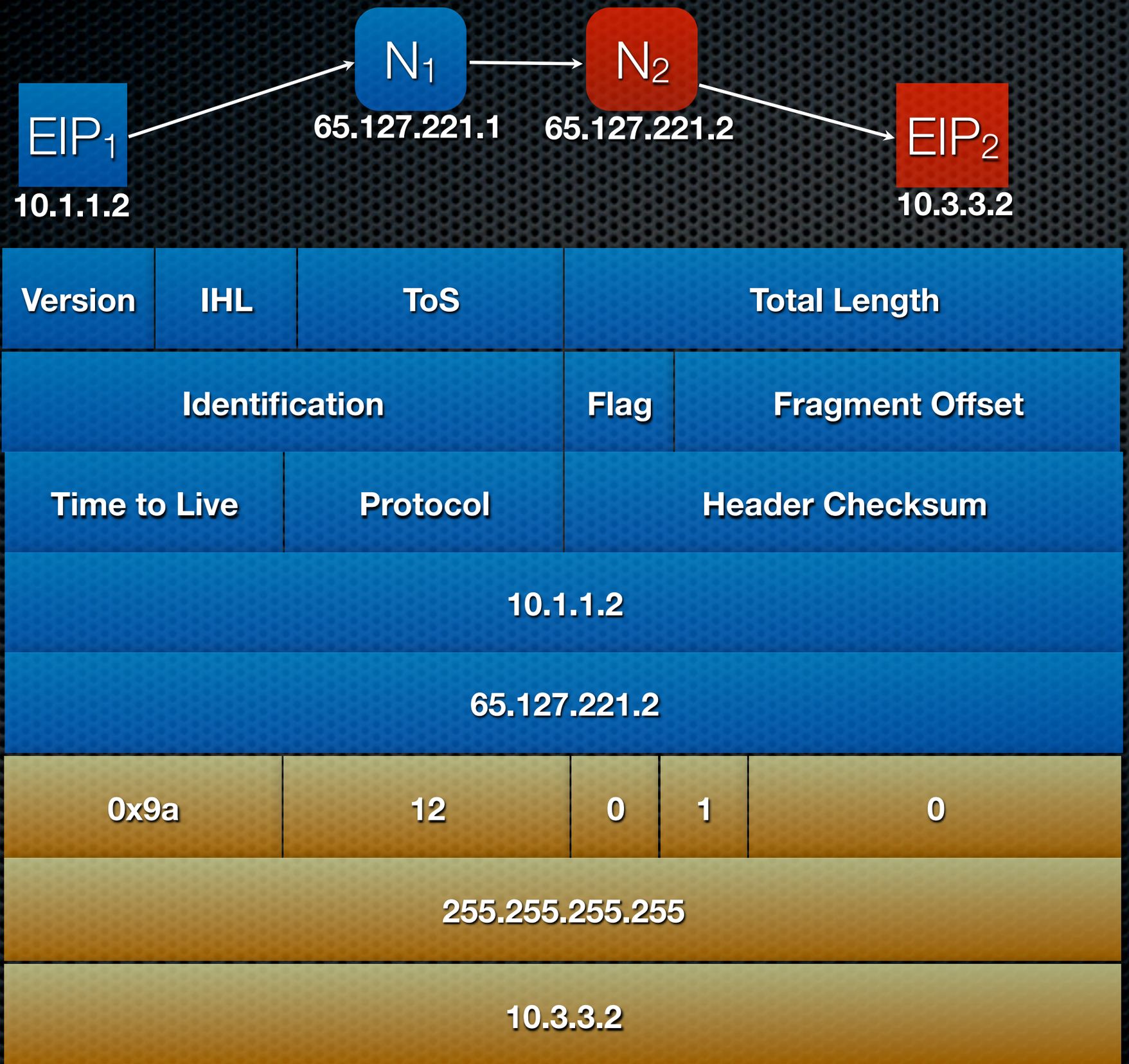
EIP1
10.1.1.2
N1
65.127.221.1
N2
65.127.221.2
EIP2
10.3.3.2
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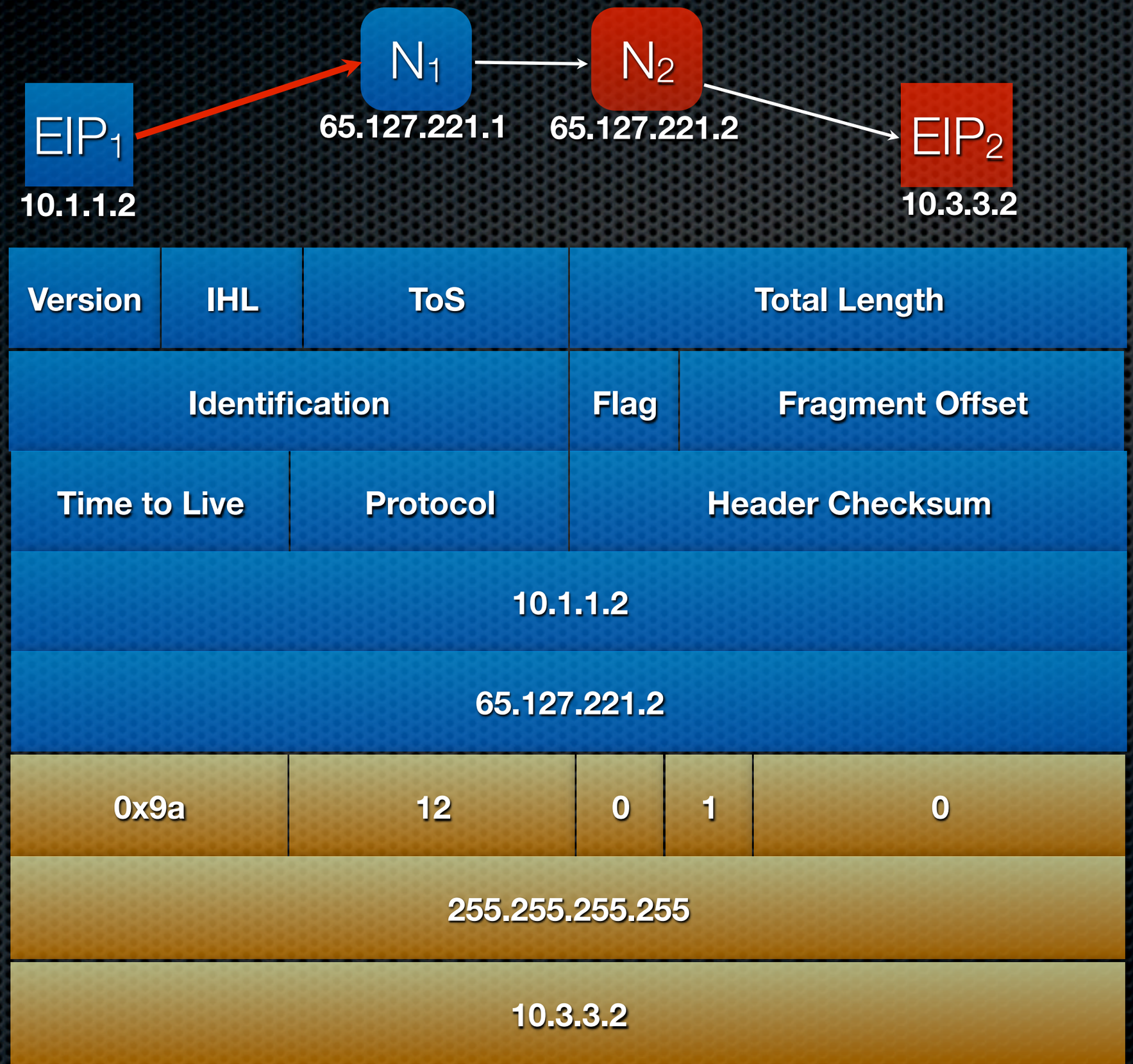
12
0
1
0
255.255.255.255
10.3.3.2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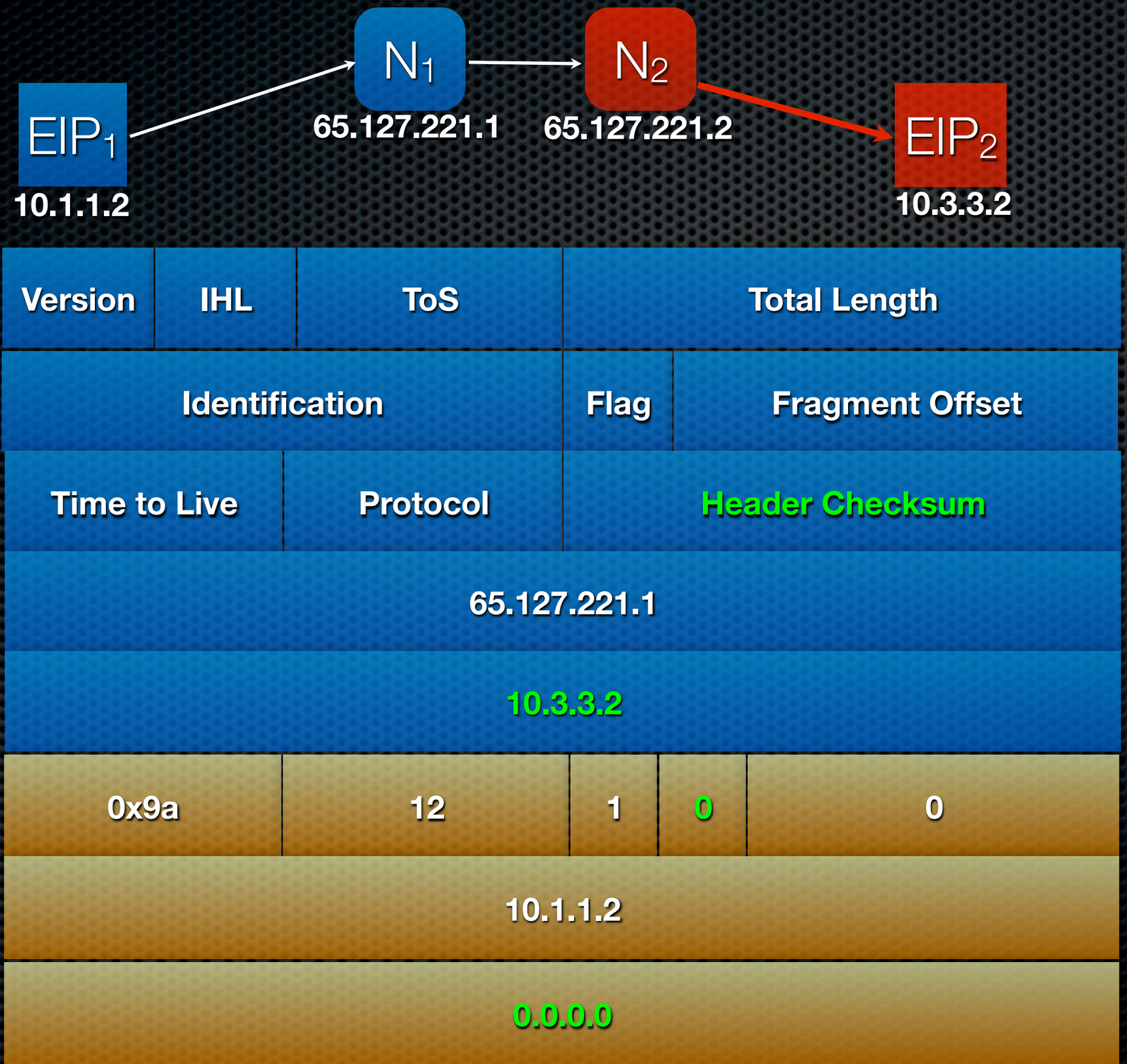
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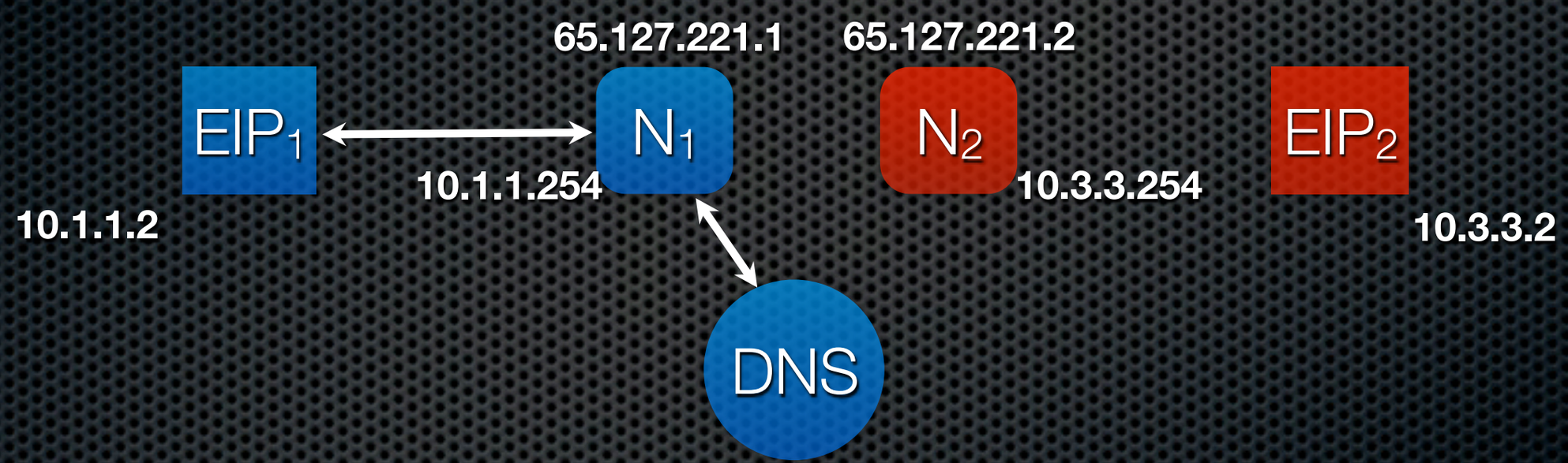
DNS: Using AAAA to lookup 64 bits



- EIP1 sends a AAAA request for eip2.somesite.com and receives back 2001:0101:417F:DD02:0a03:0302::0

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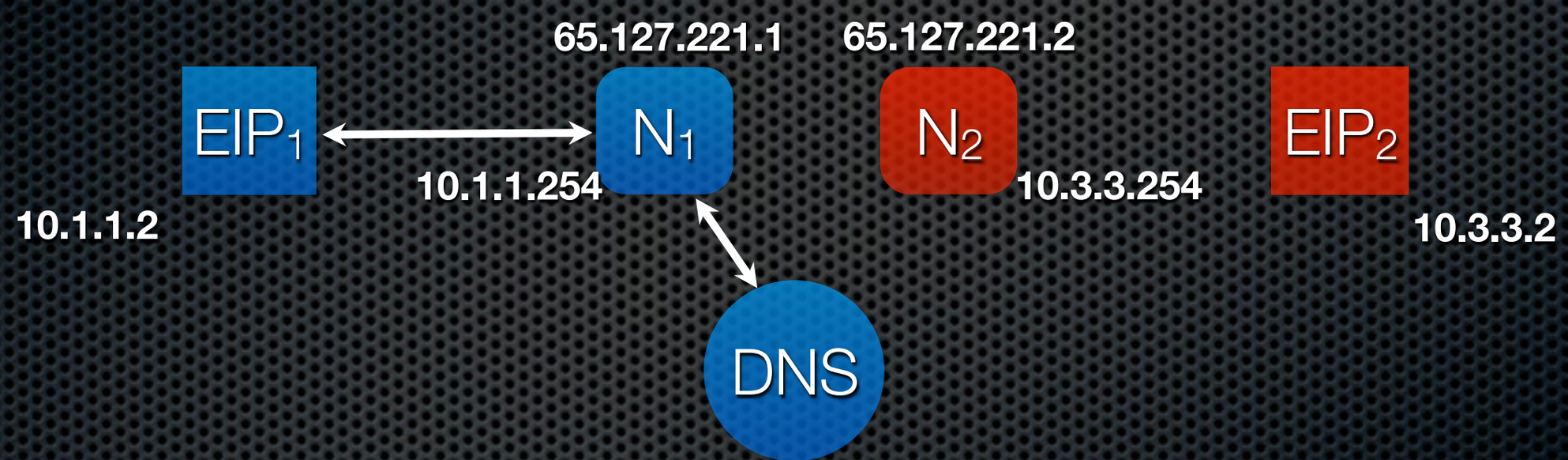
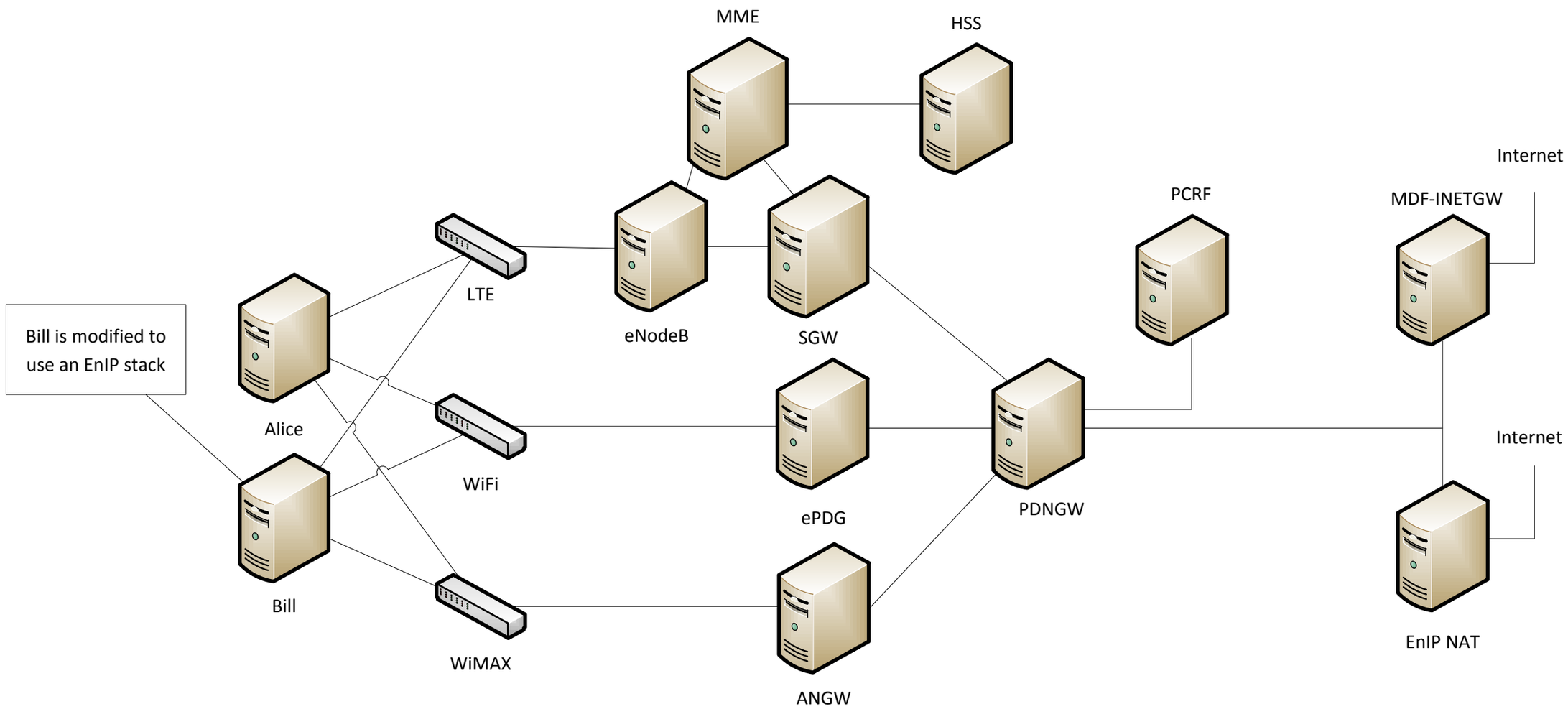


- 2001:0101:417F:DD02:0a03:0302::0 is really 65.127.221.2.10.3.3.2

EnIP Proposed Architecture



Enhanced IP: Transition

Transition Plan

- Phase 1: Motivated by end to end addressing and simpler deployment model, Mobile Voice Providers and Mobile industry lead fast path role out of EnIP. This would include IP transit providers.
- Phase 2: Content Providers may selectively upgrade servers to ease load on Mobile provider NATs.
- Phase 3: Home users are upgraded as needed. For example, a Mobile provider may wish to offload voice calls from cell towers to a wired connection within the home via the home's wifi network.

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- What will different vintages of router tolerate in terms of passing lots of packets with options?

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- ASICs, FPGAs, NPUs, CPUs. The fast path can be designed any number of ways. For ASICs, how many are running a custom instruction set designed towards cost and performance for executing route table most specific match? If this is so, is a fast path upgrade a firmware update as opposed to new hardware? Testing cost is an issue.

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- Or would we be looking at another hardware refresh cycle?

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- Drawback: According to Router Architectures Tutorial at Networking 2004: Fast Path upgrade is expensive.
- What if router vendors made changes to their fast path today to pass certain IP options and over the next N years these changes are deployed?

Thoughts on a transition?

- What if we had done this ten years ago and we were giving the EnIP talk today? E.g. you type 'show fastpath' and it lists the IP options it treats as fast as opposed to slow.
- The fast path was upgraded to support IPv6. The hardware is out there but peering is an issue. What if the vendors as a fail-safe started passing a few IP options on the fast path.
- In fact, suppose we find a fatal flaw in Enhanced IP. Even if we do we would still be ahead because we'd be buying other engineering options in our future. E.g. some future Nanog person might design something based on these options. The engineering cost is very low. If IPv6 works out, we'd forget about these options. If we think we might need some new ideas these might be deployed by that time.

Or.....

- NAT continues to be used to expand the Internet
- Layers of NAT becomes ubiquitous because of IP scarcity
- The original IPv6 designers all retire
- IPv6 continues to have the CPE and peering issues

Or.....

- Someone comes up with a workable solution to IPv6 peering and CPE problems.
- Someone comes up with IPtg. The argument of extending IPv4 versus new IP datagram structure takes us back to issues being researched during 1992-1994

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- Firewall software is not presently aware of Enhanced IP addresses. IPv4 functions still work just not filtering of specific EnIP addresses. This is probably workable in many situations.
- Enhanced IP NAT devices must only forward packets to networks that are directly connected (e.g. 10.0.0.0/8)

What people might like about EnIP

- The 8 byte address scheme is familiar
- Each 4 byte part of the address is still addressable as an IPv4 node
- Enhanced IP addresses can talk to legacy IPv4 addresses
- With a single public IP address it's possible to address a 10.0.0.0/8 network.
- Logical extension to NAT design

What people might not like about EnIP

- Dependence on IP options and fast path issues
- Legacy IPv4 nodes can still reach an Enhanced IP node through use of existing NAT port forwarding mechanisms. Beauty is in the eye of the beholder. To some this might be clever and some ugly.
- Enhanced IP is not 2^128. You get to use RFC 1918 addresses behind public IPs you already own.
- In the early days, the fast path wouldn't need to be in place. Experiments on interconnectivity could start. We built special version of ping that can detect fast path versus slow path issues.

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- Forward lookups for DNS are implemented. (reverse not)
- Enhanced IP NAT extensions are implemented to demonstrate interoperation with IPv4 NAT
- Demonstrated ssh, samba file sharing, and firefox+apache web server over Enhanced IP sockets. No modifications to ssh, scp, samba, firefox, or apache software.

Development and Test Environment

- Gentoo Linux running as Virtualbox guest OS
- 2.6.38 Kernel
- 4 virtual machines: **EIP1, N1, N2, EIP2**

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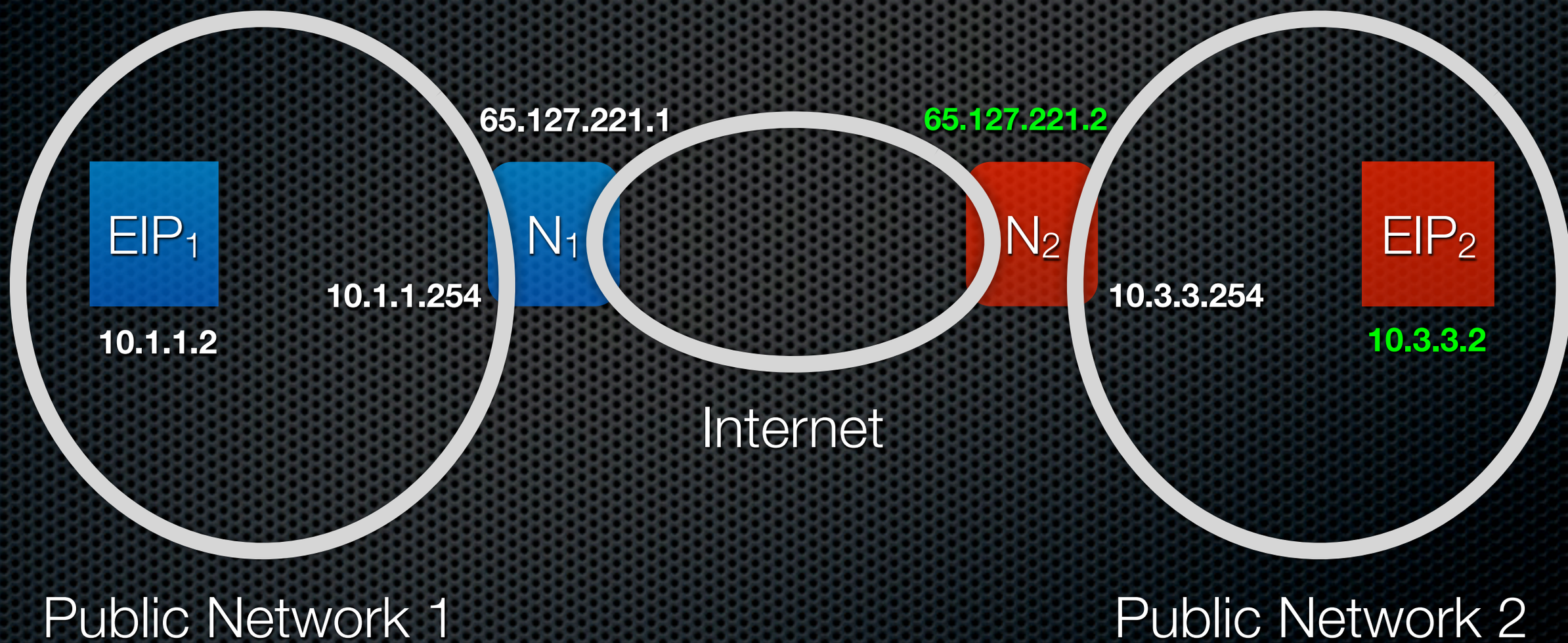

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  - ~200 lines in the kernel, ~500 lines in user-space
- edge device (SOHO router)
  - ~450 line driver, 8 line patch to NAT code
- Linux Utilities
  - ~3500 lines: ping, traceroute, netcat-like program, measurement programs

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- Any comments about passing an agreed on IP option in the fast path? Today, 1 year, 5 years, 10 years from now?
  - Perhaps IP options 26-30 become fast?

Requests for Comments

- Are there players from the mobile device and networking industry who might want to discuss Enhanced IP and LTE?
- Is there any interest in turning the Enhanced IP paper into a Draft RFC?
- Any interest in help on Linux kernel implementation? E.g. ICMP would be nice.

Project Info

- enhancedip.project@gmail.com
- http://enipproject.sourceforge.net/

Conclusion

- In our opinion certain conditions were in place to enable the Enhanced IP research. These conditions were not in place in the 1992-1994 period when IP options were last considered. IPng was the focus.
- NAT became pervasive
- In 2012, Peering and CPEs are two problem areas in IPv6 deployment. Multiple layers of NAT are easier to deploy as a fix today.

Conclusion

- We came up with the 64-bit format, the IP swapping technique used in the EnIP NAT and found a way to overload the AAAA record to avoid addition of a new DNS record. The EnIP focus is on mobile devices and infrastructure. Home/enterprise is optional. Less of a CPE problem, still have a core routing issue with the fast path. IPv4 reachability of IP options is already better than IPv6 route reachability. The slow path is the issue. Presume providers would de-ossify the edge if they wanted to pass certain IP options.
- IP options are processed in the slow path. Picking a few free option numbers and starting to pass them in the fast path might be one way to buy future protocol options.

Conclusion

- Current EnIP R&D focuses heavily on mobile space. In the EnIP model Home and enterprise adoption could come later or not at all. EnIP protocol could only live in mobile. Mobile is viewed as the industry that could make it happen.
- Does the community think we need a IPtg RFP to see what we would get?
- This is research. There might be glaring holes. Aside from this presentation, there is a detailed paper.
- If you think the EnIP research is interesting or you have other ideas about the future of networks we'd love to hear them.

Questions?

Extra Slides

Some Facts about Each

	Address Length	Requires Fast Path Upgrade to Core Internet	Config-Free Core Router Upgrades	Uses Existing L2, ICMP, and Routing Protocols	Slows Growth of Routing Table	Capable of transiting the slow path	Requires CPE Upgrades
Enhanced IP	64	Yes	Yes	Yes	Yes	Yes	Yes
IPv6	128	Yes	No	No	No	No	Yes

Routers and IP Options

	Passes IP options by Default	Config Option to drop all packets with options	Config option to route all packets as if they contain no options	ACLs to block/allow options	ACLs to block options processed in fast path	Processes Option 26 in the Fast Path
Cisco	Yes	Yes	Yes	Yes	?	No
Juniper	Yes	No	No	Yes	?	No
Vendor N	-	-	-	-	-	-

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- TEST 2: Is it possible to perform TCP and UDP connections to an Enhanced IP server using the router's default settings?
- TEST 3: Is it possible to perform TCP and UDP connections to an Enhanced IP server after changing some settings on the router?

Test Results

	TEST 1	TEST 2	TEST 3
Netgear	PASS	FAIL	PASS
DLink	FAIL	FAIL	FAIL
Linksys	PASS	PASS	PASS
Belkin	PASS	FAIL*	FAIL*
Linux Router	PASS	PASS	PASS
OpenWRT	PASS	FAIL	FAIL
OpenWRT + EnhancedIP	PASS	PASS	PASS