



# Transition to IPv6 on the Internet: Threats and Mitigation Techniques

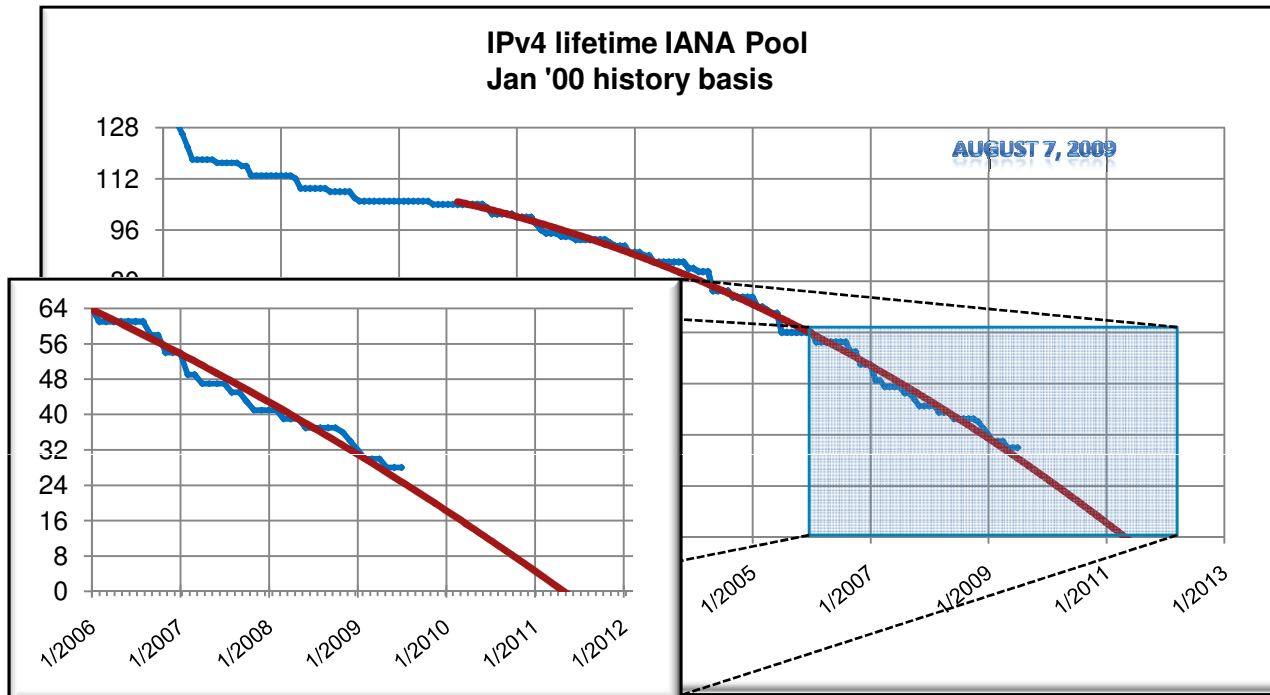


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# Agenda

- Why IPv6? What is IPv6?
- Shared Issues by IPv4 and IPv6
- Specific Issues for IPv6
  - IPsec everywhere, dual-stack, tunnels
- Enforcing a Security Policy in IPv6

# Remaining IANA IPv4 pool



Update to: [http://www.cisco.com/web/about/ac123/ac147/archived\\_issues/ipj\\_8-3/ipj\\_8-3.pdf](http://www.cisco.com/web/about/ac123/ac147/archived_issues/ipj_8-3/ipj_8-3.pdf)

Tony Hain

Day 2011-12-24 Last RIR depleted

**Whatever happens, today's IPv4 Internet will continue to run – *It just stops growing* (OECD report <http://www.oecd.org/dataoecd/7/1/40605942.pdf>)**

**Make your own IPv4 exhaustion estimate.**

Developed by Stephan Lagerholm

<http://www.lagerholm.com/~stephan/cgi-bin/ipv6/predict.cgi>

[http://www.infoweapons.com/pdfs/When Will IPv4 Addresses Run Out ver00 rev06.pdf](http://www.infoweapons.com/pdfs/When_Will_IPv4_Addresses_Run_Out_ver00_rev06.pdf)

# IPv4 Address Fractal Map Jan-2000

000 Reserved	001 Reserved	014 PDN	015 HP	016 DEC	019 Ford	020 CsC	021 US DoD	234 Multicast	235 Multicast	236 Multicast	239 Multicast	240 Class E	241 Class E	254 Class E	255 Class E
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005 Reserved	006 US DoD	009 IBM	010 Private	031 Reserved	028 US DoD	027 Reserved	026 US DoD	229 Multicast	228 Multicast	227 Multicast	224 Multicast	245 Class E	246 Class E	249 Class E	250 Class E
058 Reserved	057 SITA	054 Merck	053 Cap Debis	032 AT&T	035 MERIT	036 Reserved	037 Reserved	218 Reserved	219 Reserved	220 Reserved	223 Reserved	202 APnic	201 Reserved	198 Various	197 Reserved
059 Reserved	056 US Postal	055 US DoD	052 EI duPONT	033 US DoD	034 Halliburton	039 Reserved	038 PSI	217 Reserved	216 ARIN	221 Reserved	222 Reserved	203 APnic	200 Reserved	199 ARIN	196 AfrNIC
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063 ARIN	062 RIPE	049 Reserved	048 Prudential	047 Bell North	044 Radio	043 Inet	042 Reserved	213 RIPE	212 RIPE	211 APnic	208 ARIN	207 ARIN	206 ARIN	192 RIPE	192 Various
064 ARIN	067 Reserved	068 Reserved	069 Reserved	122 Reserved	123 Reserved	124 Reserved	127 Loopback	218 Various	219 Various	210 Various	209 Various	186 Reserved	187 Reserved	188 Reserved	191 Various
065 Reserved	066 Reserved	071 Reserved	070 Reserved	121 Reserved	120 Reserved	125 Reserved	126 Reserved	219 Various	218 Various	217 Various	216 Various	185 Reserved	184 Reserved	189 Reserved	190 Reserved
078 Reserved	077 Reserved	072 Reserved	073 Reserved	118 Reserved	119 Reserved	114 Reserved	113 Reserved	212 Various	211 Various	210 Various	209 Various	182 Reserved	183 Reserved	178 Reserved	177 Reserved
079 Reserved	076 Reserved	075 Reserved	074 Reserved	117 Reserved	116 Reserved	115 Reserved	112 Reserved	213 Various	212 Various	211 Various	210 Various	181 Reserved	180 Reserved	179 Reserved	176 Reserved
080 Reserved	081 Reserved	094 Reserved	095 Reserved	096 Reserved	097 Reserved	110 Reserved	111 Reserved	214 Various	213 Various	212 Various	211 Various	160 Various	161 Various	174 Reserved	175 Reserved
083 Reserved	082 Reserved	093 Reserved	092 Reserved	099 Reserved	098 Reserved	109 Reserved	108 Reserved	217 Various	216 Various	215 Various	214 Various	163 Various	162 Various	173 Reserved	172 Various
084 Reserved	087 Reserved	088 Reserved	091 Reserved	100 Reserved	103 Reserved	104 Reserved	107 Reserved	218 Various	217 Various	216 Various	215 Various	164 Various	167 Various	168 Various	171 Various
085 Reserved	086 Reserved	089 Reserved	090 Reserved	101 Reserved	102 Reserved	105 Reserved	106 Reserved	219 Various	218 Various	217 Various	216 Various	165 Various	166 Various	169 Various	170 Various

Fractal map: Layout by Randall Munroe, Time Sequence by Tony Hain, Highlighted by Jeff Apcar

# IPv4 Address Fractal Map Jan-2001

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004 L3	007 ARIN	008 L3	011 US DoD	030 US DoD	029 US DoD	024 Reserved	025 UK Defense	230 Multicast	231 Multicast	226 Multicast	225 Multicast	244 Class E	247 Class E	248 Class E	251 Class E
005 Reserved	006 US DoD	009 IBM	010 Private	031 Reserved	028 US DoD	027 Reserved	026 US DoD	229 Multicast	228 Multicast	227 Multicast	224 Multicast	245 Class E	246 Class E	249 Class E	250 Class E
058 Reserved	057 SITA	054 Merck	053 Cap Debis	032 AT&T	035 MERIT	036 Reserved	037 Reserved	218 APnic	219 Reserved	220 Reserved	223 Reserved	202 APnic	201 Reserved	198 Various	197 Reserved
059 Reserved	056 US Postal	055 US DoD	052 El duPONT	033 US DoD	034 Haliburton	039 Reserved	038 PSI	217 RIPE	216 ARIN	221 Reserved	222 Reserved	203 APnic	200 Reserved	199 ARIN	196 AfrNIC
060 Reserved	061 APnic	050 Reserved	051 UK DSS	046 Reserved	045 Interop	040 Eli Lilly	041 Reserved	214 US DoD	215 US DoD	210 APnic	209 ARIN	204 ARIN	205 ARIN	194 RIPE	195 RIPE
063 ARIN	062 RIPE	049 Reserved	048 Prudential	047 Bell North	044 Radio	043 Inet	042 Reserved	213 RIPE	212 RIPE	211 APnic	208 ARIN	207 ARIN	206 ARIN	192 RIPE	192 Various
064 ARIN	067 Reserved	068 Reserved	069 Reserved	122 Reserved	123 Reserved	124 Reserved	127 Loopback	218 Various	219 Various	210 Various	209 Various	186 Reserved	187 Reserved	188 Reserved	191 Various
065 ARIN	066 ARIN	071 Reserved	070 Reserved	121 Reserved	120 Reserved	125 Reserved	126 Reserved	219 Various	210 Various	211 Various	208 Various	185 Reserved	184 Reserved	189 Reserved	190 Reserved
078 Reserved	077 Reserved	072 Reserved	073 Reserved	118 Reserved	119 Reserved	114 Reserved	113 Reserved	212 Various	211 Various	210 Various	209 Various	182 Reserved	183 Reserved	178 Reserved	177 Reserved
079 Reserved	076 Reserved	075 Reserved	074 Reserved	117 Reserved	116 Reserved	115 Reserved	112 Reserved	213 Various	212 Various	211 Various	208 Various	181 Reserved	180 Reserved	179 Reserved	176 Reserved
080 Reserved	081 Reserved	094 Reserved	095 Reserved	096 Reserved	097 Reserved	110 Reserved	111 Reserved	214 Various	213 Various	212 Various	209 Various	160 Various	161 Various	174 Reserved	175 Reserved
083 Reserved	082 Reserved	093 Reserved	092 Reserved	099 Reserved	098 Reserved	109 Reserved	108 Reserved	215 Various	214 Various	213 Various	210 Various	163 Various	162 Various	173 Reserved	172 Various
084 Reserved	087 Reserved	088 Reserved	091 Reserved	100 Reserved	103 Reserved	104 Reserved	107 Reserved	216 Various	215 Various	214 Various	211 Various	164 Various	167 Various	168 Various	171 Various
085 Reserved	086 Reserved	089 Reserved	090 Reserved	101 Reserved	102 Reserved	105 Reserved	106 Reserved	217 Various	216 Various	215 Various	212 Various	165 Various	166 Various	169 Various	170 Various

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060 Reserved	061 APnic	050 Reserved	051 UK DSS	046 Reserved	045 Interop	040 Eli Lilly	041 Reserved	214 US DoD	215 US DoD	210 APnic	209 ARIN	204 ARIN	205 ARIN	194 RIPE	195 RIPE
063 ARIN	062 RIPE	049 Reserved	048 Prudential	047 Bell North	044 Radio	043 Inet	042 Reserved	213 RIPE	212 RIPE	211 APnic	208 ARIN	207 ARIN	206 ARIN	192 RIPE	192 Various
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078 Reserved	077 Reserved	072 Reserved	073 Reserved	118 Reserved	119 Reserved	114 Reserved	113 Reserved	212 Various	213 Various	216 Various	217 Various	203 Reserved	200 Reserved	199 Reserved	196 Reserved
079 Reserved	076 Reserved	075 Reserved	074 Reserved	117 Reserved	116 Reserved	115 Reserved	112 Reserved	213 Various	214 Various	215 Various	218 Various	204 Reserved	205 Reserved	194 Reserved	195 Reserved
080 RIPE	081 RIPE	094 Reserved	095 Reserved	096 Reserved	097 Reserved	110 Reserved	111 Reserved	214 Various	215 Various	210 Various	209 Various	204 Reserved	205 Reserved	194 Reserved	195 Reserved
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083 Reserved	082 RIPE	093 Reserved	092 Reserved	099 Reserved	098 Reserved	109 Reserved	108 Reserved	247 Various	246 Various	257 Various	256 Various	163 Various	162 Various	173 Reserved	172 Various
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060 APnic	061 APnic	050 Reserved	051 UK DSS	046 Reserved	045 Interop	040 Eli Lilly	041 Reserved	214 US DoD	215 US DoD	210 APnic	209 ARIN	204 ARIN	205 ARIN	194 RIPE	195 RIPE
063 ARIN	062 RIPE	049 Reserved	048 Prudential	047 Bell North	044 Radio	043 Inet	042 Reserved	213 RIPE	212 RIPE	211 APnic	208 ARIN	207 ARIN	206 ARIN	192 RIPE	192 Various
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078 Reserved	077 Reserved	072 ARIN	073 Reserved	118 Reserved	119 Reserved	114 Reserved	113 Reserved	213 Various	212 Various	211 Various	208 Various	207 Reserved	206 Reserved	192 Reserved	192 Reserved
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064 ARIN	067 ARIN	068 ARIN	069 ARIN	122 Reserved	123 Reserved	124 APnic	127 Loopback	128 Various	131 Various	132 Various	133 Various	186 Reserved	187 Reserved	188 Various	191 Various
065 ARIN	066 ARIN	071 ARIN	070 ARIN	121 Reserved	120 Reserved	125 APnic	126 APnic	129 Various	130 Various	135 Various	134 Various	185 Reserved	184 Reserved	189 LACnic	190 LACnic
078 Reserved	077 Reserved	072 ARIN	073 ARIN	118 Reserved	119 Reserved	114 Reserved	113 Reserved	142 Various	141 Various	136 Various	137 Various	182 Reserved	183 Reserved	178 Reserved	177 Reserved
079 Reserved	076 ARIN	075 ARIN	074 ARIN	117 Reserved	116 Reserved	115 Reserved	112 Reserved	143 Various	140 Various	139 Various	138 Various	181 Reserved	180 Reserved	179 Reserved	176 Reserved
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083 RIPE	082 RIPE	093 Reserved	092 Reserved	099 Reserved	098 Reserved	109 Reserved	108 Reserved	147 Various	146 Various	157 Various	156 Various	163 Various	162 Various	173 Reserved	172 Various
084 RIPE	087 RIPE	088 RIPE	091 RIPE	100 Reserved	103 Reserved	104 Reserved	107 Reserved	148 Various	151 Various	152 Various	155 Various	164 Various	167 Various	168 Various	171 Various
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060 APnic	061 APnic	050 Reserved	051 UK DSS	046 Reserved	045 Interop	040 Eli Lily	041 AFRNic	214 US DoD	215 US DoD	210 APnic	209 ARIN	204 ARIN	205 ARIN	194 RIPE	195 RIPE
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065 ARIN	066 ARIN	071 ARIN	070 ARIN	121 APnic	120 Reserved	125 APnic	126 APnic	129 Various	130 Various	135 Various	134 Various	185 Reserved	184 Reserved	189 LACnic	190 LACnic
078 RIPE	077 RIPE	072 ARIN	073 ARIN	118 Reserved	119 Reserved	114 Reserved	113 Reserved	142 Various	141 Various	136 Various	137 Various	182 Reserved	183 Reserved	178 Reserved	177 Reserved
079 RIPE	076 ARIN	075 ARIN	074 ARIN	117 Reserved	116 Reserved	115 Reserved	112 Reserved	143 Various	140 Various	139 Various	138 Various	181 Reserved	180 Reserved	179 Reserved	176 Reserved
080 RIPE	081 RIPE	094 Reserved	095 Reserved	096 ARIN	097 ARIN	110 Reserved	111 Reserved	144 Various	145 Various	158 Various	159 Various	160 Various	161 Various	174 Reserved	175 Reserved
083 RIPE	082 RIPE	093 Reserved	092 Reserved	099 ARIN	098 ARIN	109 Reserved	108 Reserved	147 Various	146 Various	157 Various	156 Various	163 Various	162 Various	173 Reserved	172 Various
084 RIPE	087 RIPE	088 RIPE	091 RIPE	100 Reserved	103 Reserved	104 Reserved	107 Reserved	148 Various	151 Various	152 Various	155 Various	164 Various	167 Various	168 Various	171 Various
085 RIPE	086 RIPE	089 RIPE	090 RIPE	101 Reserved	102 Reserved	105 Reserved	106 Reserved	149 Various	150 Various	153 Various	154 Various	165 Various	166 Various	169 Various	170 Various

Fractal map: Layout by Randall Munroe, Time Sequence by Tony Hain, Highlighted by Jeff Apcar

# IPv4 Address Fractal Map Jan-2008

000 Reserved	001 Reserved	014 PDN	015 HP	016 DEC	019 Ford	020 CsC	021 US DoD	234 Multicast	235 Multicast	236 Multicast	239 Multicast	240 Class E	241 Class E	254 Class E	255 Class E
003 GE	002 Reserved	013 Xerox	012 AT&T	017 Apple	018 MIT	023 Reserved	022 US DoD	233 Multicast	232 Multicast	237 Multicast	238 Multicast	243 Class E	242 Class E	253 Class E	252 Class E
004 L3	007 ARIN	008 L3	011 US DoD	030 US DoD	029 US DoD	024 Cable	025 UK Defense	230 Multicast	231 Multicast	226 Multicast	225 Multicast	244 Class E	247 Class E	248 Class E	251 Class E
005 Reserved	006 US DoD	009 IBM	010 Private	031 Reserved	028 US DoD	027 Reserved	026 US DoD	229 Multicast	228 Multicast	227 Multicast	224 Multicast	245 Class E	246 Class E	249 Class E	250 Class E
058 APnic	057 SITA	054 Merck	053 Cap Debis	032 AT&T	035 MERIT	036 Reserved	037 Reserved	218 APnic	219 APnic	220 APnic	223 Reserved	202 APnic	201 LACnic	198 Various	197 Reserved
059 APnic	056 US Postal	055 US DoD	052 EI duPONT	033 US DoD	034 Halliburton	039 Reserved	038 PSI	217 RIPE	216 ARIN	221 APnic	222 APnic	203 APnic	200 LACnic	199 ARIN	196 AFRnic
060 APnic	061 APnic	050 Reserved	051 UK DSS	046 Reserved	045 Interop	040 Eli Lily	041 AFRnic	214 US DoD	215 US DoD	210 APnic	209 ARIN	204 ARIN	205 ARIN	194 RIPE	195 RIPE
063 ARIN	062 RIPE	049 Reserved	048 Prudential	047 Bell North	044 Radio	043 Inet	042 Reserved	213 RIPE	212 RIPE	211 APnic	208 ARIN	207 ARIN	206 ARIN	192 RIPE	192 Various
064 ARIN	067 ARIN	068 ARIN	069 ARIN	122 APnic	123 APnic	124 APnic	127 Loopback	128 Various	131 Various	132 Various	133 Various	186 LACnic	187 LACnic	188 Various	191 Various
065 ARIN	066 ARIN	071 ARIN	070 ARIN	121 APnic	120 APnic	125 APnic	126 APnic	129 Various	130 Various	135 Various	134 Various	185 Reserved	184 Reserved	189 LACnic	190 LACnic
078 RIPE	077 RIPE	072 ARIN	073 ARIN	118 APnic	119 APnic	114 APnic	113 Reserved	142 Various	141 Various	136 Various	137 Various	182 Reserved	183 Reserved	178 Reserved	177 Reserved
079 RIPE	076 ARIN	075 ARIN	074 ARIN	117 APnic	116 APnic	115 APnic	112 Reserved	143 Various	140 Various	139 Various	138 Various	181 Reserved	180 Reserved	179 Reserved	176 Reserved
080 RIPE	081 RIPE	094 RIPE	095 RIPE	096 ARIN	097 ARIN	110 Reserved	111 Reserved	144 Various	145 Various	158 Various	159 Various	160 Various	161 Various	174 Reserved	175 Reserved
083 RIPE	082 RIPE	093 RIPE	092 RIPE	099 ARIN	098 ARIN	109 Reserved	108 Reserved	147 Various	146 Various	157 Various	156 Various	163 Various	162 Various	173 Reserved	172 Various
084 RIPE	087 RIPE	088 RIPE	091 RIPE	100 Reserved	103 Reserved	104 Reserved	107 Reserved	148 Various	151 Various	152 Various	155 Various	164 Various	167 Various	168 Various	171 Various
085 RIPE	086 RIPE	089 RIPE	090 RIPE	101 Reserved	102 Reserved	105 Reserved	106 Reserved	149 Various	150 Various	153 Various	154 Various	165 Various	166 Various	169 Various	170 Various

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# IPv4 Address Fractal Map Jan-2009

000 Reserved	001 Reserved	014 Reserved	015 HP	016 DEC	019 Ford	020 CsC	021 US DoD	234 Multicast	235 Multicast	236 Multicast	239 Multicast	240 Class E	241 Class E	254 Class E	255 Class E
003 GE	002 Reserved	013 Xerox	012 AT&T	017 Apple	018 MIT	023 Reserved	022 US DoD	233 Multicast	232 Multicast	237 Multicast	238 Multicast	243 Class E	242 Class E	253 Class E	252 Class E
004 L3	007 ARIN	008 L3	011 US DoD	030 US DoD	029 US DoD	024 Cable	025 UK Defense	230 Multicast	231 Multicast	226 Multicast	225 Multicast	244 Class E	247 Class E	248 Class E	251 Class E
005 Reserved	006 US DoD	009 IBM	010 Private	031 Reserved	028 US DoD	027 Reserved	026 US DoD	229 Multicast	228 Multicast	227 Multicast	224 Multicast	245 Class E	246 Class E	249 Class E	250 Class E
058 APnic	057 SITA	054 Merck	053 Cap Debis	032 AT&T	035 MERIT	036 Reserved	037 Reserved	218 APnic	219 APnic	220 APnic	223 Reserved	202 APnic	201 LACnic	198 Various	197 AFRINic
059 APnic	056 US Postal	055 US DoD	052 EI duPONT	033 US DoD	034 Halliburton	039 Reserved	038 PSI	217 RIPE	216 ARIN	221 APnic	222 APnic	203 APnic	200 LACnic	199 ARIN	196 AFRnic
060 APnic	061 APnic	050 Reserved	051 UK DSS	046 Reserved	045 Interop	040 Eli Lily	041 AFRNIC	214 US DoD	215 US DoD	210 APnic	209 ARIN	204 ARIN	205 ARIN	194 RIPE	195 RIPE
063 ARIN	062 RIPE	049 Reserved	048 Prudential	047 Bell North	044 Radio	043 Inet	042 Reserved	213 RIPE	212 RIPE	211 APnic	208 ARIN	207 ARIN	206 ARIN	192 RIPE	192 Various
064 ARIN	067 ARIN	068 ARIN	069 ARIN	122 APnic	123 APnic	124 APnic	127 Loopback	128 Various	131 Various	132 Various	133 Various	186 LACnic	187 LACnic	188 Various	191 Various
065 ARIN	066 ARIN	071 ARIN	070 ARIN	121 APnic	120 APnic	125 APnic	126 APnic	129 Various	130 Various	135 Various	134 Various	185 Reserved	184 ARIN	189 LACnic	190 LACnic
078 RIPE	077 RIPE	072 ARIN	073 ARIN	118 APnic	119 APnic	114 APnic	113 APnic	142 Various	141 Various	136 Various	137 Various	182 Reserved	183 Reserved	178 Reserved	177 Reserved
079 RIPE	076 ARIN	075 ARIN	074 ARIN	117 APnic	116 APnic	115 APnic	112 APnic	143 Various	140 Various	139 Various	138 Various	181 Reserved	180 Reserved	179 Reserved	176 Reserved
080 RIPE	081 RIPE	094 RIPE	095 RIPE	096 ARIN	097 ARIN	110 APnic	111 APnic	144 Various	145 Various	158 Various	159 Various	160 Various	161 Various	174 ARIN	175 Reserved
083 RIPE	082 RIPE	093 RIPE	092 RIPE	099 ARIN	098 ARIN	109 Reserved	108 ARIN	147 Various	146 Various	157 Various	156 Various	163 Various	162 Various	173 ARIN	172 Various
084 RIPE	087 RIPE	088 RIPE	091 RIPE	100 Reserved	103 Reserved	104 Reserved	107 Reserved	148 Various	151 Various	152 Various	155 Various	164 Various	167 Various	168 Various	171 Various
085 RIPE	086 RIPE	089 RIPE	090 RIPE	101 Reserved	102 Reserved	105 Reserved	106 Reserved	149 Various	150 Various	153 Various	154 Various	165 Various	166 Various	169 Various	170 Various

Fractal map: Layout by Randall Munroe, Time Sequence by Tony Hain, Highlighted by Jeff Apcar

# IPv4 Address Fractal Map - Today

000 Reserved	001 Reserved	014 Reserved	015 HP	016 DEC	019 Ford	020 CsC	021 US DoD	234 Multicast	235 Multicast	236 Multicast	239 Multicast	240 Class E	241 Class E	254 Class E	255 Class E
003 GE	002 Reserved	013 Xerox	012 AT&T	017 Apple	018 MIT	023 Reserved	022 US DoD	233 Multicast	232 Multicast	237 Multicast	238 Multicast	243 Class E	242 Class E	253 Class E	252 Class E
004 L3	007 ARIN	008 L3	011 US DoD	030 US DoD	029 US DoD	024 Cable	025 UK Defense	230 Multicast	231 Multicast	226 Multicast	225 Multicast	244 Class E	247 Class E	248 Class E	251 Class E
005 Reserved	006 US DoD	009 IBM	010 Private	031 Reserved	028 US DoD	027 Reserved	026 US DoD	229 Multicast	228 Multicast	227 Multicast	224 Multicast	245 Class E	246 Class E	249 Class E	250 Class E
058 APnic	057 SITA	054 Merck	053 Cap Debis	032 AT&T	035 MERIT	036 Reserved	037 Reserved	218 APnic	219 APnic	220 APnic	223 Reserved	202 APnic	201 LACnic	198 Various	197 AFRINic
059 APnic	056 US Postal	055 US DoD	052 EI duPONT	033 US DoD	034 Halliburton	039 Reserved	038 PSI	217 RIPE	216 ARIN	221 APnic	222 APnic	203 APnic	200 LACnic	199 ARIN	196 AFRnic
060 APnic	061 APnic	050 Reserved	051 UK DSS	046 Reserved	045 Interop	040 Eli Lily	041 AFRNIC	214 US DoD	215 US DoD	210 APnic	209 ARIN	204 ARIN	205 ARIN	194 RIPE	195 RIPE
063 ARIN	062 RIPE	049 Reserved	048 Prudential	047 Bell North	044 Radio	043 Inet	042 Reserved	213 RIPE	212 RIPE	211 APnic	208 ARIN	207 ARIN	206 ARIN	192 RIPE	192 Various
064 ARIN	067 ARIN	068 ARIN	069 ARIN	122 APnic	123 APnic	124 APnic	127 Loopback	128 Various	131 Various	132 Various	133 Various	186 LACnic	187 LACnic	188 Various	191 Various
065 ARIN	066 ARIN	071 ARIN	070 ARIN	121 APnic	120 APnic	125 APnic	126 APnic	129 Various	130 Various	135 Various	134 Various	185 Reserved	184 ARIN	189 LACnic	190 LACnic
078 RIPE	077 RIPE	072 ARIN	073 ARIN	118 APnic	119 APnic	114 APnic	113 APnic	142 Various	141 Various	136 Various	137 Various	182 APnic	183 APnic	178 RIPE	177 Reserved
079 RIPE	076 ARIN	075 ARIN	074 ARIN	117 APnic	116 APnic	115 APnic	112 APnic	143 Various	140 Various	139 Various	138 Various	181 Reserved	180 APnic	179 Reserved	176 Reserved
080 RIPE	081 RIPE	094 RIPE	095 RIPE	096 ARIN	097 ARIN	110 APnic	111 APnic	144 Various	145 Various	158 Various	159 Various	160 Various	161 Various	174 ARIN	175 APnic
083 RIPE	082 RIPE	093 RIPE	092 RIPE	099 ARIN	098 ARIN	109 RIPE	108 ARIN	147 Various	146 Various	157 Various	156 Various	163 Various	162 Various	173 ARIN	172 Various
084 RIPE	087 RIPE	088 RIPE	091 RIPE	100 Reserved	103 Reserved	104 Reserved	107 Reserved	148 Various	151 Various	152 Various	155 Various	164 Various	167 Various	168 Various	171 Various
085 RIPE	086 RIPE	089 RIPE	090 RIPE	101 Reserved	102 Reserved	105 Reserved	106 Reserved	149 Various	150 Various	153 Various	154 Various	165 Various	166 Various	169 Various	170 Various

Fractal map: Layout by Randall Munroe, Time Sequence by Tony Hain, Highlighted by Jeff Apcar

# IPv4 Address Fractal Map Jan-2010

000 Reserved	001 Reserved	014 Reserved	015 HP	016 DEC	019 Ford	020 CsC	021 US DoD	234 Multicast	235 Multicast	236 Multicast	239 Multicast	240 Class E	241 Class E	254 Class E	255 Class E
003 GE	002 Reserved	013 Xerox	012 AT&T	017 Apple	018 MIT	023 Reserved	022 US DoD	233 Multicast	232 Multicast	237 Multicast	238 Multicast	243 Class E	242 Class E	253 Class E	252 Class E
004 L3	007 ARIN	008 L3	011 US DoD	030 US DoD	029 US DoD	024 Cable	025 UK Defense	230 Multicast	231 Multicast	226 Multicast	225 Multicast	244 Class E	247 Class E	248 Class E	251 Class E
005 Reserved	006 US DoD	009 IBM	010 Private	031 Reserved	028 US DoD	027 Reserved	026 US DoD	229 Multicast	228 Multicast	227 Multicast	224 Multicast	245 Class E	246 Class E	249 Class E	250 Class E
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060 APnic	061 APnic	050 Reserved	051 UK DSS	046 Reserved	045 Interop	040 Eli Lily	041 AFRNIC	214 US DoD	215 US DoD	210 APnic	209 ARIN	204 ARIN	205 ARIN	194 RIPE	195 RIPE
063 ARIN	062 RIPE	049 Reserved	048 Prudential	047 Bell North	044 Radio	043 Inet	042 Reserved	213 RIPE	212 RIPE	211 APnic	208 ARIN	207 ARIN	206 ARIN	192 RIPE	192 Various
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079 RIPE	076 ARIN	075 ARIN	074 ARIN	117 APnic	116 APnic	115 APnic	112 APnic	143 Various	140 Various	139 Various	138 Various	181 Reserved	180 APnic	179 Next	176 Next
080 RIPE	081 RIPE	094 RIPE	095 RIPE	096 ARIN	097 ARIN	110 APnic	111 APnic	144 Various	145 Various	158 Various	159 Various	160 Various	161 Various	174 ARIN	175 APnic
083 RIPE	082 RIPE	093 RIPE	092 RIPE	099 ARIN	098 ARIN	109 RIPE	108 ARIN	147 Various	146 Various	157 Various	156 Various	163 Various	162 Various	173 ARIN	172 Various
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Fractal map: Layout by Randall Munroe, Time Sequence by Tony Hain, Highlighted by Jeff Apcar



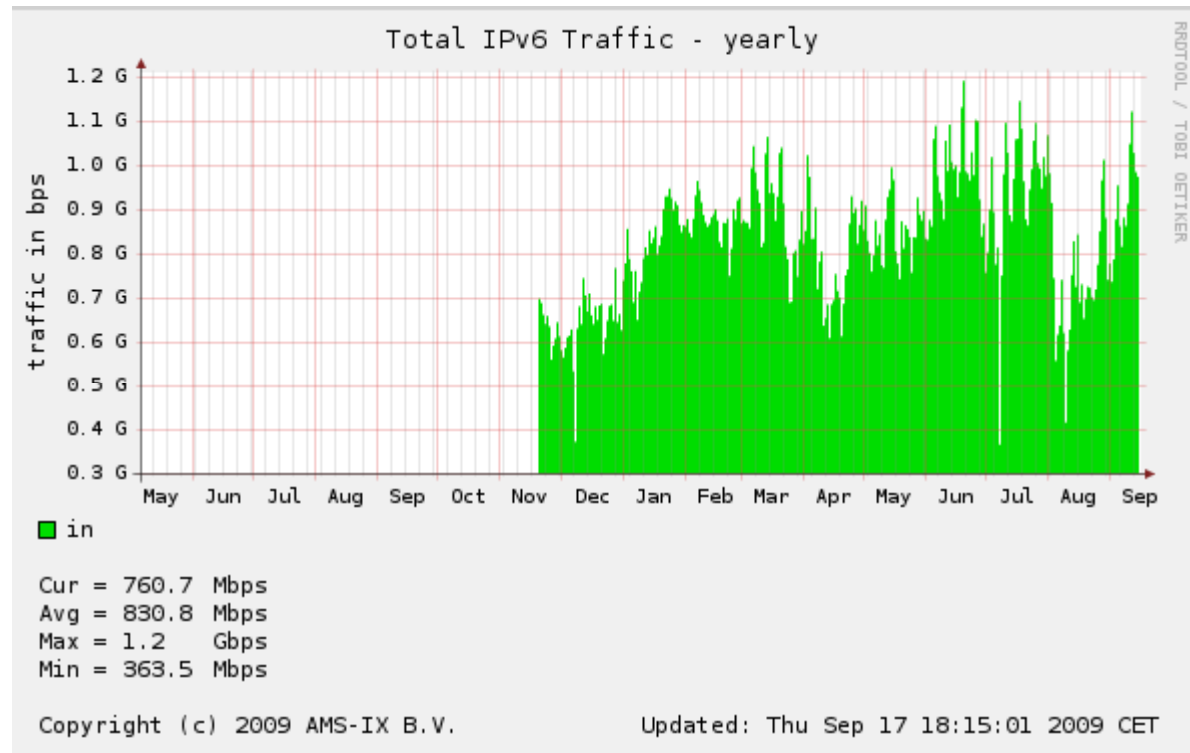
# IPv4 Address Fractal Map Jan-2011

000 Reserved	001 Reserved	014 Next	015 HP	016 DEC	019 Ford	020 CsC	021 US DoD	234 Multicast	235 Multicast	236 Multicast	239 Multicast	240 Class E	241 Class E	254 Class E	255 Class E
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004 L3	007 ARIN	008 L3	011 US DoD	030 US DoD	029 US DoD	024 Cable	025 UK Defense	230 Multicast	231 Multicast	226 Multicast	225 Multicast	244 Class E	247 Class E	248 Class E	251 Class E
005 Next	006 US DoD	009 IBM	010 Private	031 Next	028 US DoD	027 Next	026 US DoD	229 Multicast	228 Multicast	227 Multicast	224 Multicast	245 Class E	246 Class E	249 Class E	250 Class E
058 APnic	057 SITA	054 Merck	053 Cap Debis	032 AT&T	035 MERIT	036 Next	037 Next	218 APnic	219 APnic	220 APnic	223 Next	202 APnic	201 LACnic	198 Various	197 AFRINic
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060 APnic	061 APnic	050 Next	051 UK DSS	046 Next	045 Interop	040 Eli Lily	041 AFRNc	214 US DoD	215 US DoD	210 APnic	209 ARIN	204 ARIN	205 ARIN	194 RIPE	195 RIPE
063 ARIN	062 RIPE	049 Next	048 Prudential	047 Bell North	044 Radio	043 Inet	042 Next	213 RIPE	212 RIPE	211 APnic	208 ARIN	207 ARIN	206 ARIN	192 RIPE	192 Various
064 ARIN	067 ARIN	068 ARIN	069 ARIN	122 APnic	123 APnic	124 APnic	127 Loopback	128 Various	131 Various	132 Various	133 Various	186 LACnic	187 LACnic	188 Various	191 Various
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078 RIPE	077 RIPE	072 ARIN	073 ARIN	118 APnic	119 APnic	114 APnic	113 APnic	142 Various	141 Various	136 Various	137 Various	182 APnic	183 APnic	178 RIPE	177 Next
079 RIPE	076 ARIN	075 ARIN	074 ARIN	117 APnic	116 APnic	115 APnic	112 APnic	143 Various	140 Various	139 Various	138 Various	181 Next	180 APnic	179 Next	176 Next
080 RIPE	081 RIPE	094 RIPE	095 RIPE	096 ARIN	097 ARIN	110 APnic	111 APnic	144 Various	145 Various	158 Various	159 Various	160 Various	161 Various	174 ARIN	175 APnic
083 RIPE	082 RIPE	093 RIPE	092 RIPE	099 ARIN	098 ARIN	109 RIPE	108 ARIN	147 Various	146 Various	157 Various	156 Various	163 Various	162 Various	173 ARIN	172 Various
084 RIPE	087 RIPE	088 RIPE	091 RIPE	100 Next	103 Next	104 Next	107 Next	148 Various	151 Various	152 Various	155 Various	164 Various	167 Various	168 Various	171 Various
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# Current IPv6 Traffic Amsterdam Internet Exchange



<http://www.ams-ix.net/technical/stats/sflow/?type=ipv6>

# IPv6 is not that different than IPv4

- Layer 2 (Ethernet, Wifi) and below: **unchanged**
- Layer 4 and above (TCP, UDP, ...): **unchanged**
- **Same** routing protocols: RIP, BGP, OSPF
- Only **FOUR** big changes

Larger addresses: 128 bits vs. 32 bits

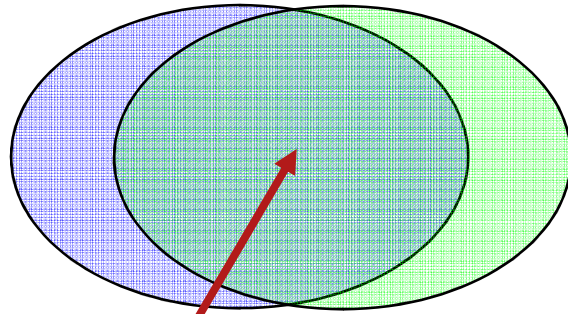
Multiple addresses per node (correlation more difficult)

Optional extension headers (complexity for ACL)

ARP is replaced by Neighbor Discovery Protocol



IPv4 Vul.



IPv6 Vul.

Shared Issues



Security Issues Shared by IPv4 and IPv6

# Reconnaissance in IPv6

## Scanning Methods Are Likely to Change

- Default subnets in IPv6 have  $2^{64}$  addresses
  - 10 Mpps = more than 50 000 years
- Public servers will still need to be DNS reachable
  - ⇒ More information collected by Google...
- Increased deployment/reliance on dynamic DNS
  - ⇒ More information will be in DNS
- Administrators may adopt easy-to-remember addresses (`::10`, `::20`, `::F00D`, `::C5C0` or simply IPv4 last octet for dual stack)
- By compromising hosts in a network, an attacker can learn new addresses to scan

# Scanning Made Bad for CPU

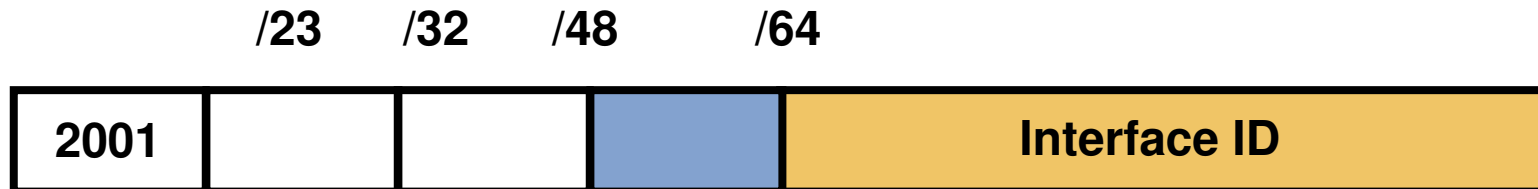
- Potential router CPU attacks if aggressive scanning
  - Router will do Neighbor Discovery... And waste CPU and memory
  - Built-in rate limiter but no option to tune it
- Using a /64 on point-to-point links => a lot of addresses to scan!
- Using infrastructure ACL prevents this scanning
  - iACL: edge ACL denying packets addressed to your routers
  - Easy with IPv6 because new addressing scheme can be done 😊

# Viruses and Worms in IPv6



- Viruses and email, IM worms: IPv6 brings no change
  - Other worms:
    - IPv4: reliance on network scanning
    - IPv6: not so easy (see reconnaissance) => will use alternative techniques
- Worm developers will adapt to IPv6
  - IPv4 best practices around worm detection and mitigation remain valid
  - Potential router CPU attacks if aggressive scanning
    - Router will do Neighbor Discovery...

# IPv6 Privacy Extensions (RFC 3041)



- Temporary addresses for IPv6 host client application, e.g. web browser
  - Inhibit device/user tracking
  - Random 64 bit interface ID, then run Duplicate Address Detection before using it
  - Rate of change based on local policy

**Recommendation: Use Privacy Extensions for External Communication but not for Internal Networks (Troubleshooting and Attack Trace Back)**



# ICMPv4 vs. ICMPv6

- Significant changes
- More relied upon

ICMP Message Type	ICMPv4	ICMPv6
Connectivity Checks	X	X
Informational/Error Messaging	X	X
Fragmentation Needed Notification	X	X
Address Assignment		X
Address Resolution		X
Router Discovery		X
Multicast Group Management		X
Mobile IPv6 Support		X

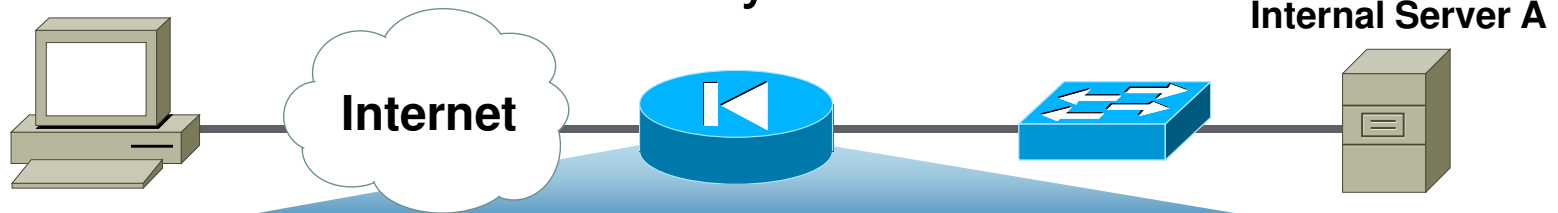
- => ICMP policy on firewalls needs to change

# Equivalent ICMPv6

## Border Firewall Transit Policy\*



For Your Reference



Action	Src	Dst	ICMPv6 Type	ICMPv6 Code	Name
Permit	Any	A	128	0	Echo Reply
Permit	Any	A	129	0	Echo Request
Permit	Any	A	1	0	No Route to Dst.
Permit	Any	A	2	0	Packet Too Big
Permit	Any	A	3	0	Time Exceeded— TTL Exceeded
Permit	Any	A	4	0	Parameter Problem

\*RFC 4890

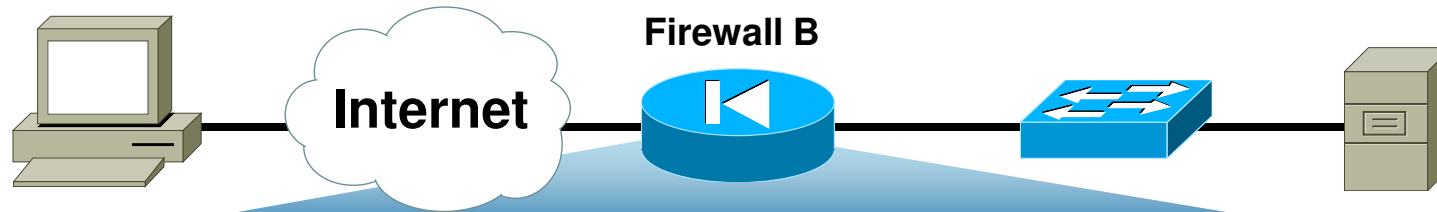
# Potential Additional ICMPv6

## Border Firewall Receive Policy\*



For Your Reference

Internal Server A



Action	Src	Dst	ICMPv6 Type	ICMPv6 Code	Name
Permit	Any	B	2	0	Packet too Big
Permit	Any	B	130–132	0	Multicast Listener
Permit	Any	B	133/134	0	Neighbor Solicitation and Advertisement
Permit	Any	B	4	0	Parameter Problem

\*RFC 4890

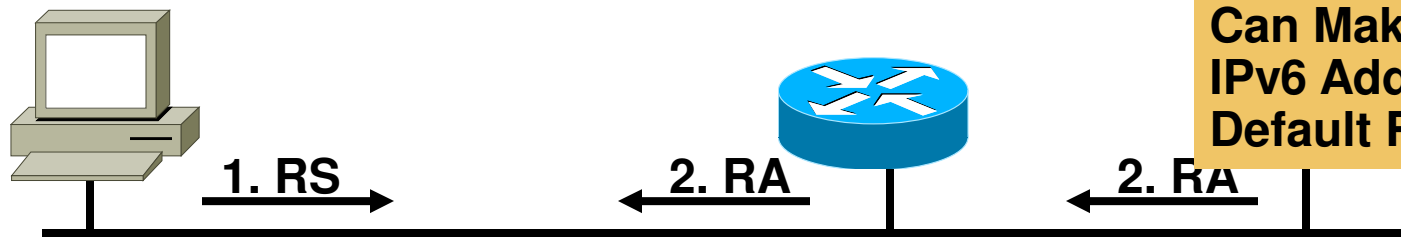
# Neighbor Discovery Issue#1 Stateless Autoconfiguration

**Router Solicitations** Are Sent by Booting Nodes to Request Router Advertisements for Stateless Address Auto-Configuring

RA/RS w/o Any Authentication Gives Exactly Same Level of Security as ARP for IPv4 (None)

Attack Tool:  
**fake\_router6**

Can Make Any IPv6 Address the Default Router



## 1. RS:

Src = ::

Dst = All-Routers  
multicast Address

ICMP Type = 133

Data = Query: please send RA

## 2. RA:

Src = Router Link-local  
Address

Dst = All-nodes multicast  
address

ICMP Type = 134

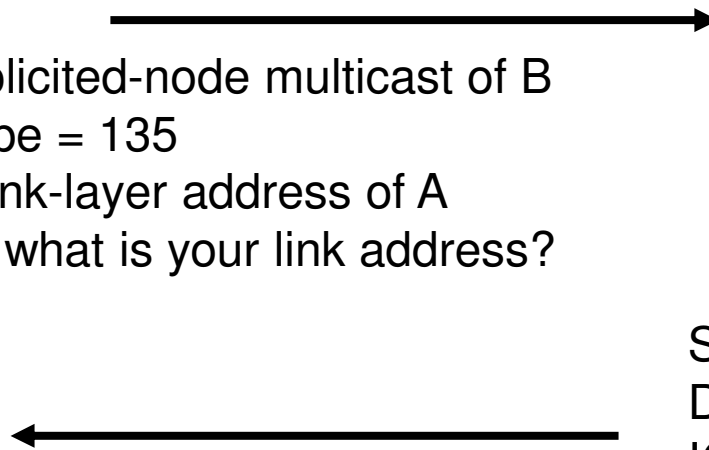
Data= options, prefix, lifetime,  
**autoconfig** flag

# Neighbor Discovery Issue#2

## Neighbor Solicitation



Src = A  
Dst = Solicited-node multicast of B  
ICMP type = 135  
Data = link-layer address of A  
Query: what is your link address?



Src = B  
Dst = A  
ICMP type = 136  
Data = link-layer address of B



**A and B Can Now Exchange  
Packets on This Link**

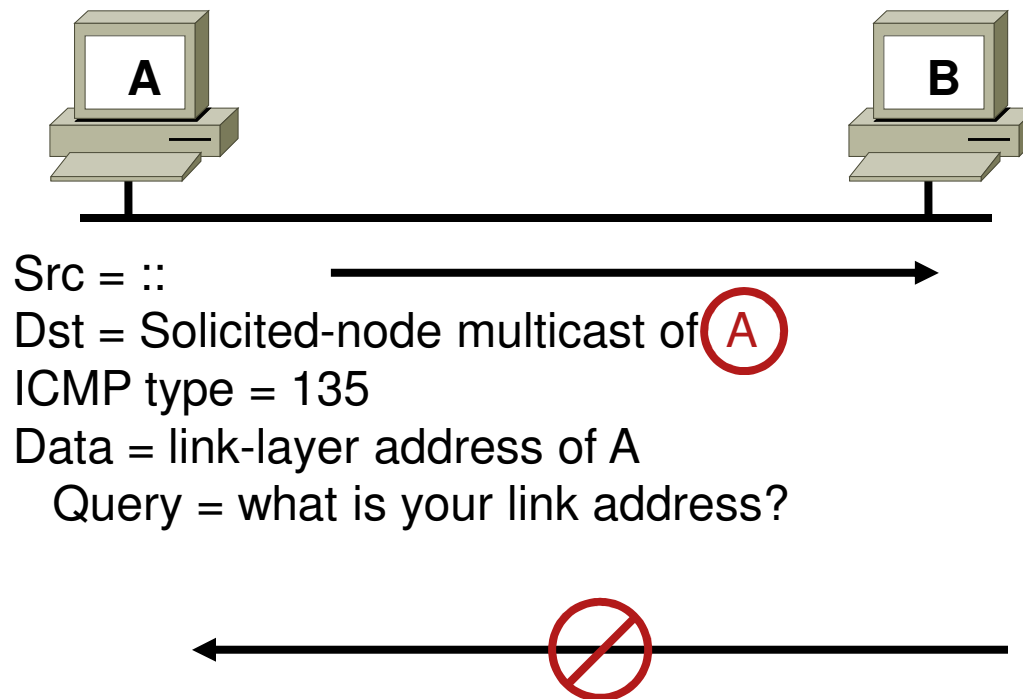
**Security Mechanisms  
Built into Discovery  
Protocol = None**

**=> Very similar to ARP**

**Attack Tool:  
Parasite6  
Answer to all NS,  
Claiming to Be All  
Systems in the LAN...**

# Neighbor Discovery Issue#3 Duplicate Address Detection

Duplicate Address Detection (DAD) Uses Neighbor Solicitation to Verify the Existence of an Address to Be Configured



From RFC 2462:  
« If a Duplicate @  
Is Discovered...  
the Address Cannot  
Be Assigned to the  
Interface»

⇔ What If: Use MAC@  
of the Node You Want  
to DoS and Claim Its  
IPv6 @

Attack Tool:  
**Dos-new-ipv6**

# ARP Spoofing is now NDP Spoofing: Mitigation

- **BAD NEWS:** nothing like dynamic ARP inspection for IPv6
  - Will require new hardware on some platforms
  - Not before mid-2010...
- **GOOD NEWS:** Secure Neighbor Discovery
  - SEND = NDP + crypto
  - IOS 12.4(24)T
  - But not in Windows Vista, wait for next Windows version...
  - Crypto means slower...
- Other **GOOD NEWS:**
  - Private VLAN works with IPv6
  - Port security works with IPv6
  - IEEE 802.1X 802.1AE work with IPv6

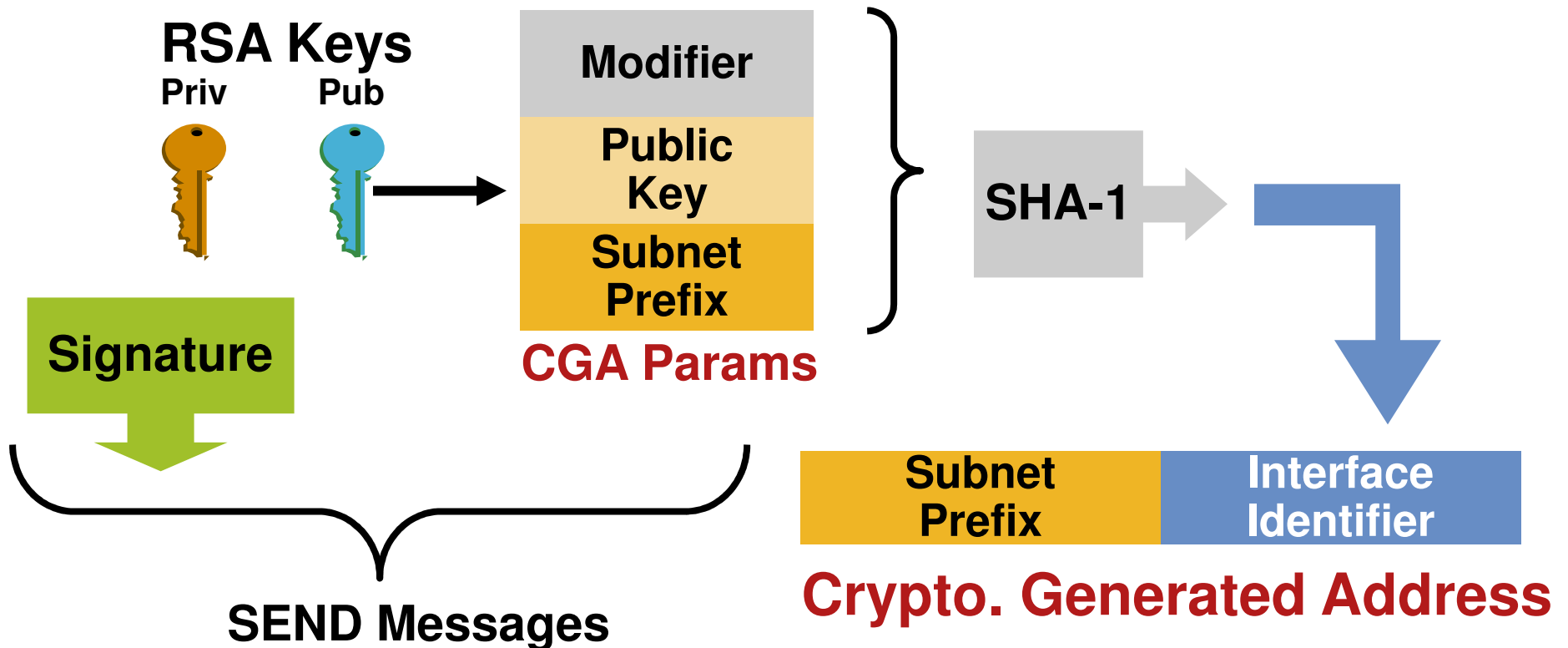
# Secure Neighbor Discovery (SEND) RFC 3971

- Certification paths
  - Anchored on trusted parties, expected to certify the authority of the routers on some prefixes
- Cryptographically Generated Addresses (CGA)
  - IPv6 addresses whose interface identifiers are cryptographically generated
- RSA signature option
  - Protect all messages relating to neighbor and router discovery
- Timestamp and nonce options
  - Prevent replay attacks
- Requires IOS 12.4(24)T



# Cryptographically Generated Addresses CGA RFC 3972 (Simplified)

- Each devices has a RSA key pair (no need for cert)
- Ultra light check for validity
- Prevent spoofing a valid CGA address



# IPv6 Attacks with Strong IPv4 Similarities

- **Sniffing**

Without IPsec, IPv6 is no more or less likely to fall victim to a sniffing attack than IPv4

- **Application layer attacks**

Even with IPsec, the majority of vulnerabilities on the Internet today are at the application layer, something that IPsec will do nothing to prevent

- **Rogue devices**

Rogue devices will be as easy to insert into an IPv6 network as in IPv4

- **Man-in-the-Middle Attacks (MITM)**

Without IPsec, any attacks utilizing MITM will have the same likelihood in IPv6 as in IPv4

- **Flooding**

Flooding attacks are identical between IPv4 and IPv6

# IPv6 Stack Vulnerabilities

- IPv6 stacks are new and could be buggy
- Some examples

CVE-2008-2476	Oct 2008	FreeBSD OpenBSD NetBSD and others	Lack of validation of NDP messages
CVE-2008-2136	May 2008	Linux	DoS caused by memory leak in IPv6 tunnels
CVE-2008-1153	Mar 2008	IOS	Cisco IOS dual-stack router IPv6 DoS
CVE-2007-4689	Nov 2007	Apple Mac OS X	Packet processing double-free memory corruption
CVE-2007-3038	Aug 2007	Microsoft	Microsoft Windows Vista Teredo interface firewall bypass

# By the Way: It Is Real ☹️

## IPv6 Hacking Tools

Let the Games Begin

- Sniffers/packet capture

Snort

TCPdump

Sun Solaris snoop

COLD

Wireshark

Analyzer

Windump

WinPcap



**The Hacker's Choice**

- Scanners

IPv6 security scanner

Halfscan6

Nmap

Strobe

Netcat

- DoS Tools

6tunneldos

4to6ddos

Imps6-tools

- Packet forgers

Scapy6

SendIP

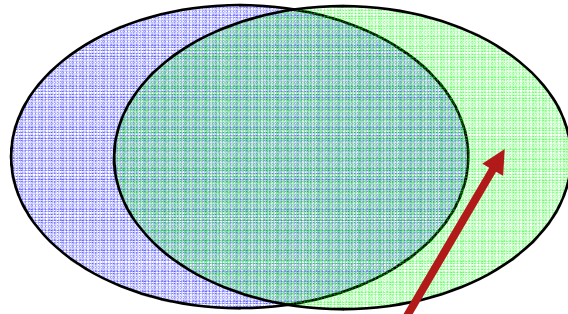
Packit

Spak6

- Complete tool

<http://www.thc.org/thc-ipv6/>

IPv4 Vul.



IPv6 Vul.

## Specific IPv6 Issues



Issues Applicable only to IPv6

# The IPsec Myth: IPsec End-to-End will Save the World

- IPv6 mandates the implementation of IPsec
- IPv6 does not require the use of IPsec
- Some organizations believe that IPsec should be used to secure all flows...

Interesting **scalability** issue ( $n^2$  issue with IPsec)

Need to **trust endpoints and end-users** because the network cannot secure the traffic: no IPS, no ACL, no firewall

IOS 12.4(20)T can parse the AH

Network **telemetry is blinded**: NetFlow of little use

Network **services hindered**: what about QoS?

**Recommendation:** do not use IPsec end to end within an administrative domain.

**Suggestion:** Reserve IPsec for residential or hostile environment or high profile targets.

# IPv4 to IPv6 Transition Challenges

- 16+ methods, possibly in combination
- Dual stack
  - Consider security for both protocols
  - Cross v4/v6 abuse
  - Resiliency (shared resources)
- Tunnels
  - Bypass firewalls (protocol 41 or UDP)
  - Can cause asymmetric traffic (hence breaking stateful firewalls)

# Dual Stack Host Considerations

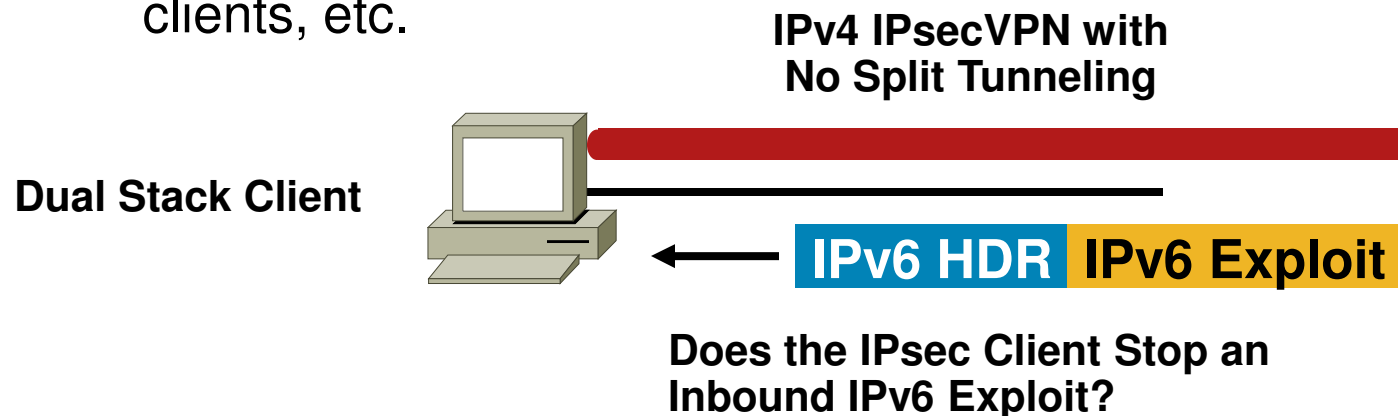
- Host security on a dual-stack device

Applications can be subject to attack on both IPv6 and IPv4

**Fate sharing:** as secure as the least secure stack...

- Host security controls should block and inspect traffic from both IP versions

Host intrusion prevention, personal firewalls, VPN clients, etc.



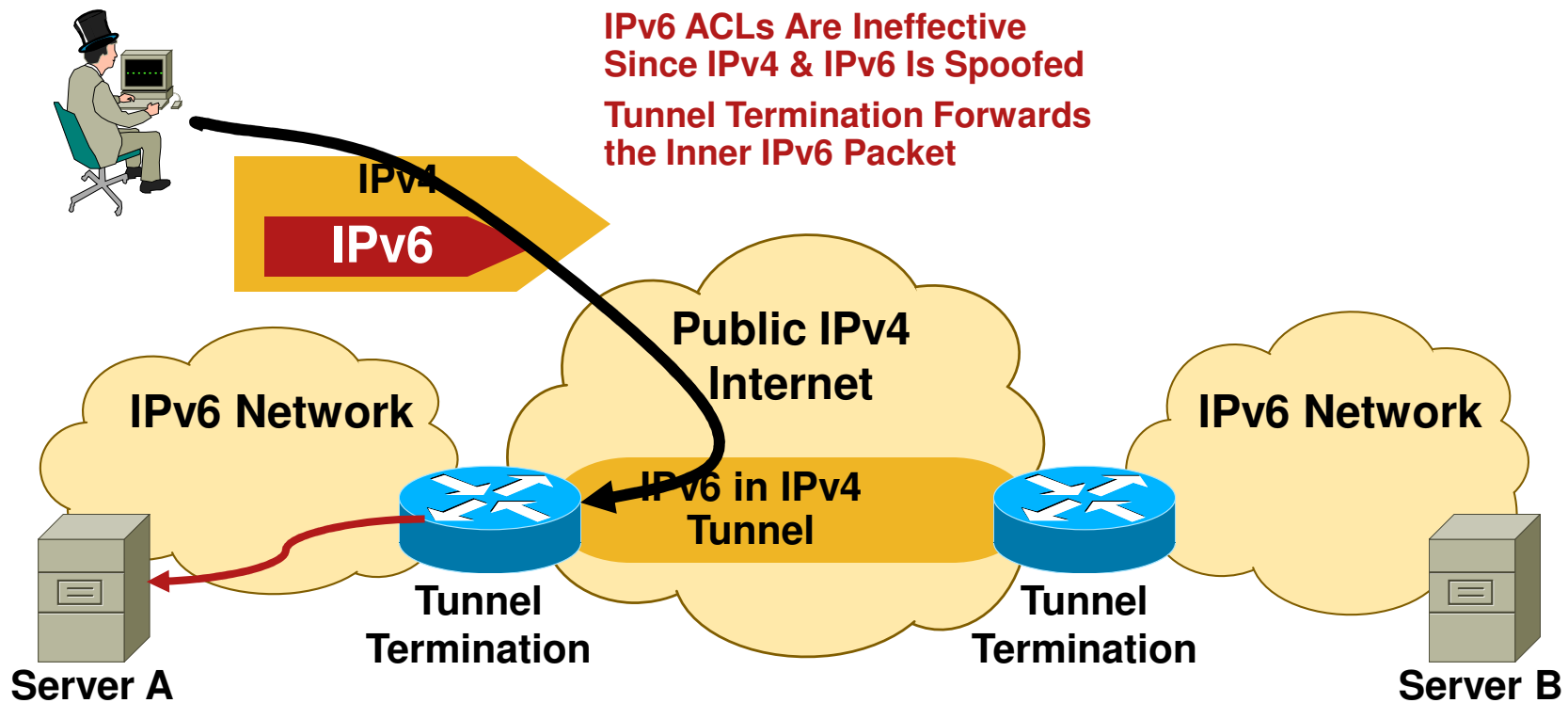


# Dual Stack with Enabled IPv6 by Default

- Your host:
  - IPv4 is protected by your favorite personal firewall...
  - IPv6 is enabled by default (Vista, Linux, Mac OS/X, ...)
- Your network:
  - Does not run IPv6
- Your assumption:
  - I'm safe
- Reality
  - You are **not** safe
  - Attacker sends Router Advertisements
  - Your host configures silently to IPv6
  - You are now under IPv6 attack
- => **Probably time to think about IPv6 in your network**

# L3-L4 Spoofing in IPv6 When Using IPv6 over IPv4 Tunnels

- Most IPv4/IPv6 transition mechanisms have no authentication built in
- => an IPv4 attacker can inject traffic if spoofing on IPv4 and IPv6 addresses



# TEREDO?

- **Teredo navalis**  
A shipworm drilling holes in boat hulls
- **Teredo Microsoftis**  
IPv6 in IPv4 punching holes in NAT devices

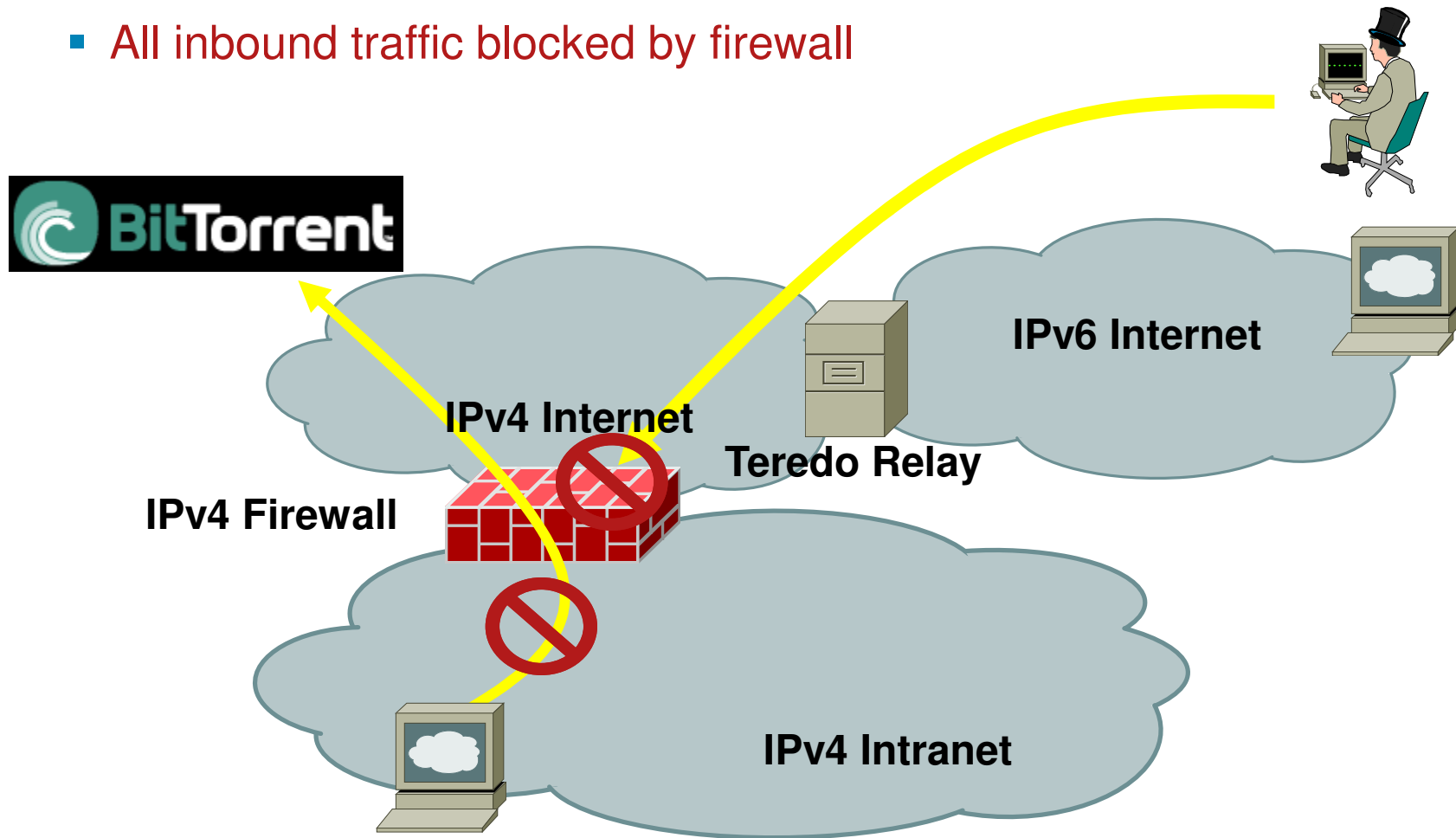


Source: United States Geological Survey

# Teredo Tunnels (1/3)

## Without Teredo: Controls Are in Place

- All outbound traffic inspected: e.g., P2P is blocked
- All inbound traffic blocked by firewall

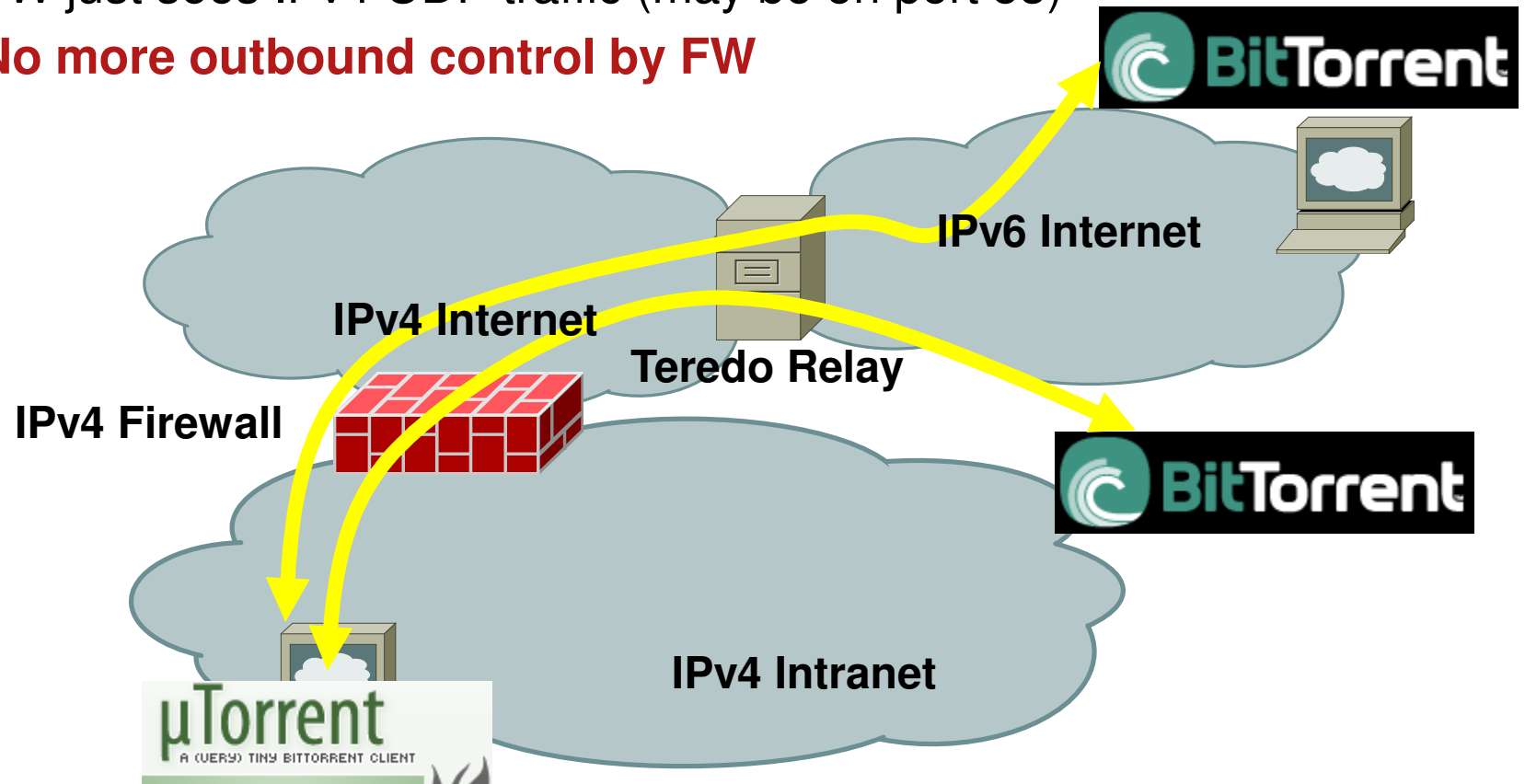


# Teredo Tunnels (2/3)

## No More Outbound Control

Teredo threats—IPv6 over UDP (port 3544)

- Internal users want to get P2P over IPv6
- Configure the Teredo tunnel (already enabled by default!)
- FW just sees IPv4 UDP traffic (may be on port 53)
- **No more outbound control by FW**

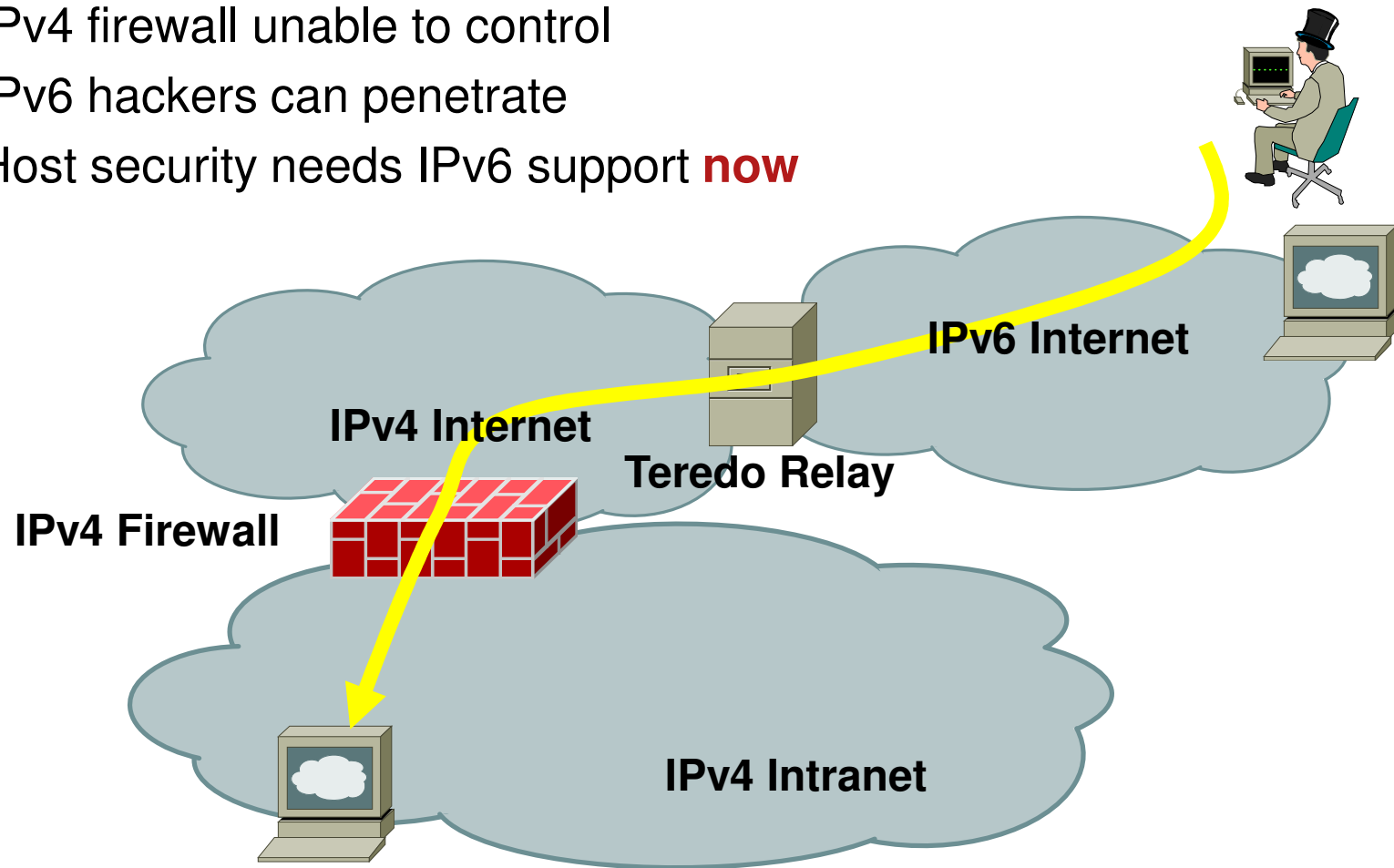


# Teredo Tunnels (3/3)

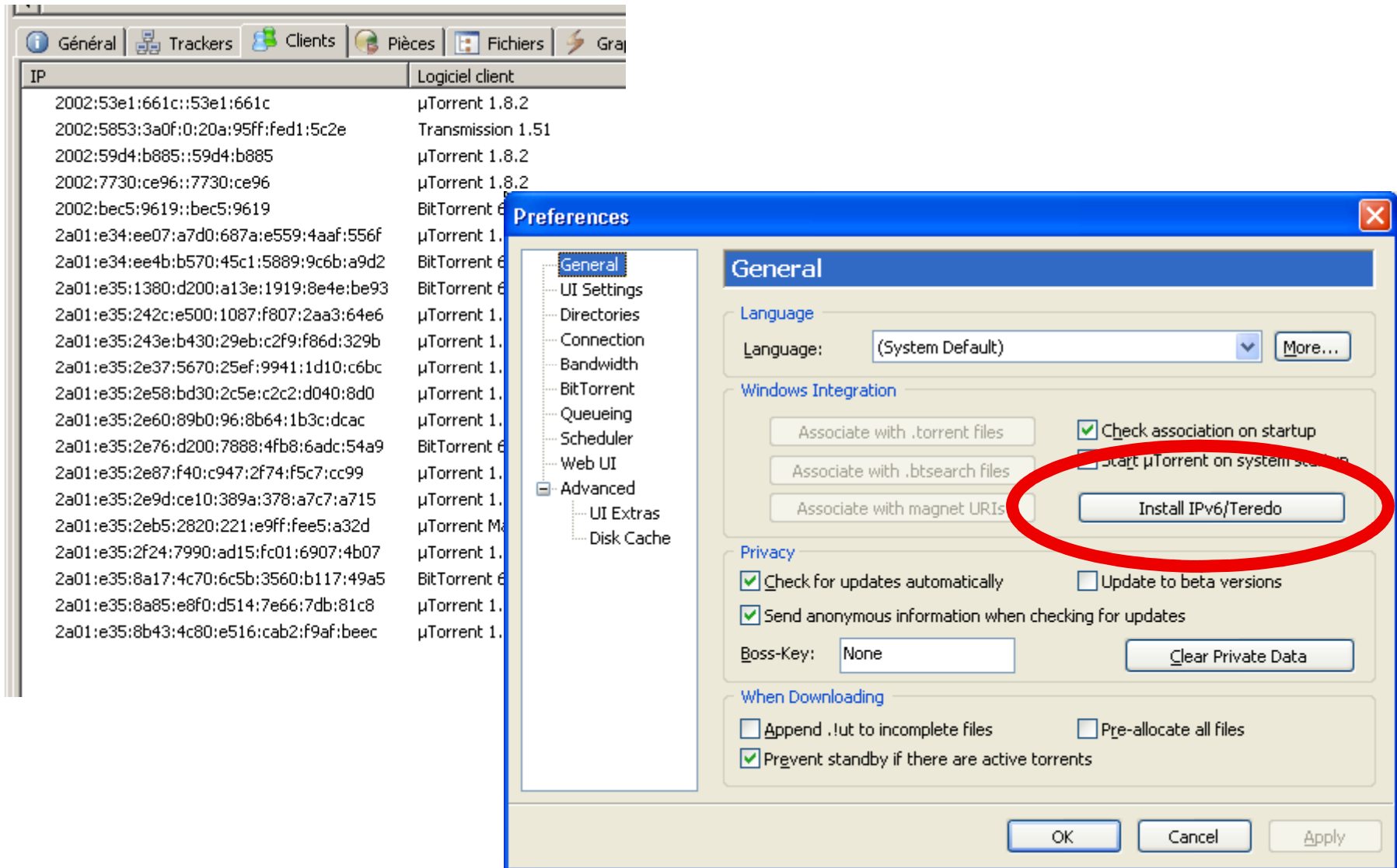
## No More Outbound Control

Once Teredo Configured

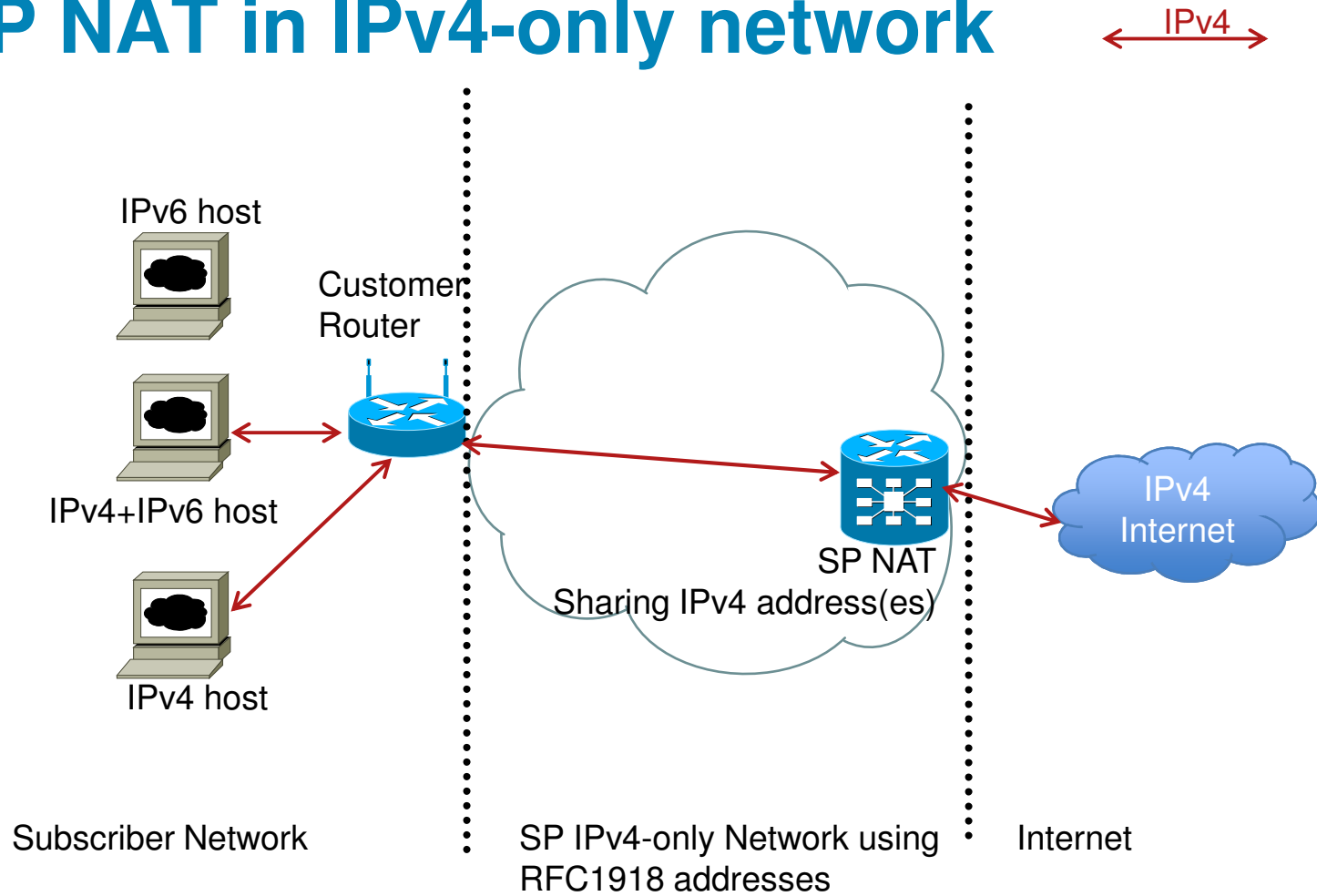
- **Inbound** connections are allowed
- IPv4 firewall unable to control
- IPv6 hackers can penetrate
- Host security needs IPv6 support **now**



# Is it real? May be uTorrent 1.8 (released Aug 08)



# SP NAT in IPv4-only network





# Translation Issues

- NAT-PT specifics (and other stateful translations)

  - DoS: IPv4-pool exhaustion

  - Single point of failure (redundancy has scalability issues)

- Whether NAT-PT or NAT444 or Address Family Translation

  - Shared IPv4 address among different subscribers

  - Per-IP address reputation, one bad behavior => multiple subscribers impacted

  - Sending ICMP Packet-too-big to common server => bandwidth reduction for all subscribers

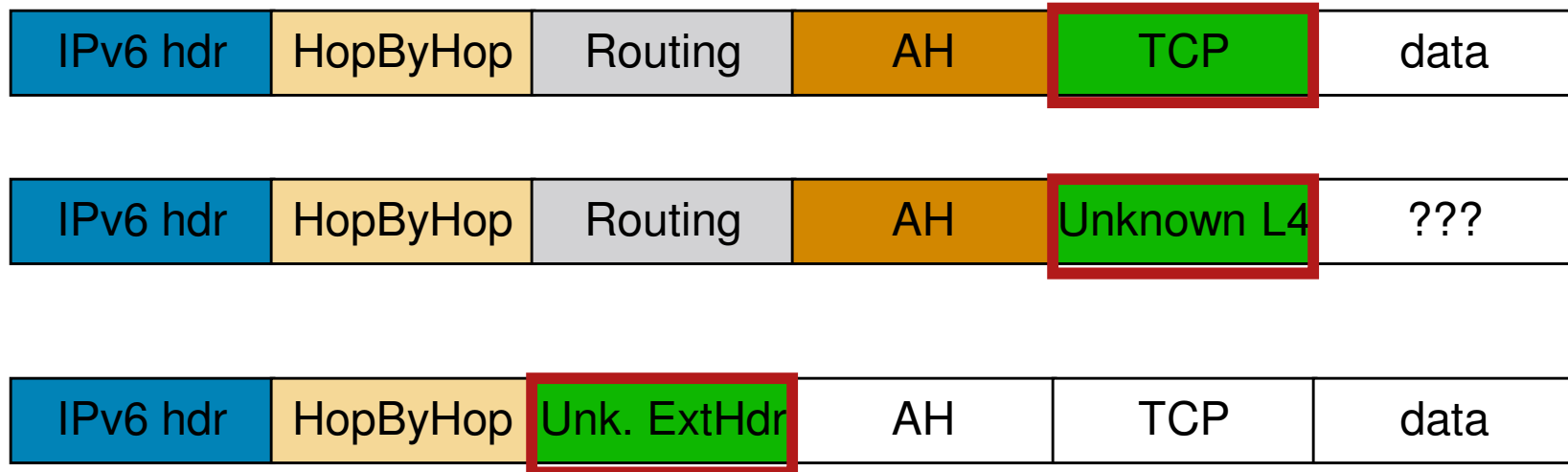
  - Huge amount of log for LI (but there are other ways to keep track)

# Enforcing a Security Policy



# Parsing the Extension Header Chain

- Finding the layer 4 information is not trivial in IPv6
  - Skip all known extension header
  - Until either known layer 4 header found => **SUCCESS**
  - Or unknown extension header/layer 4 header found... => **FAILURE**



Note: if chain is too long on HW routers, packet is process switched...

# Cisco IOS IPv6 ACL

## A Trivial Example

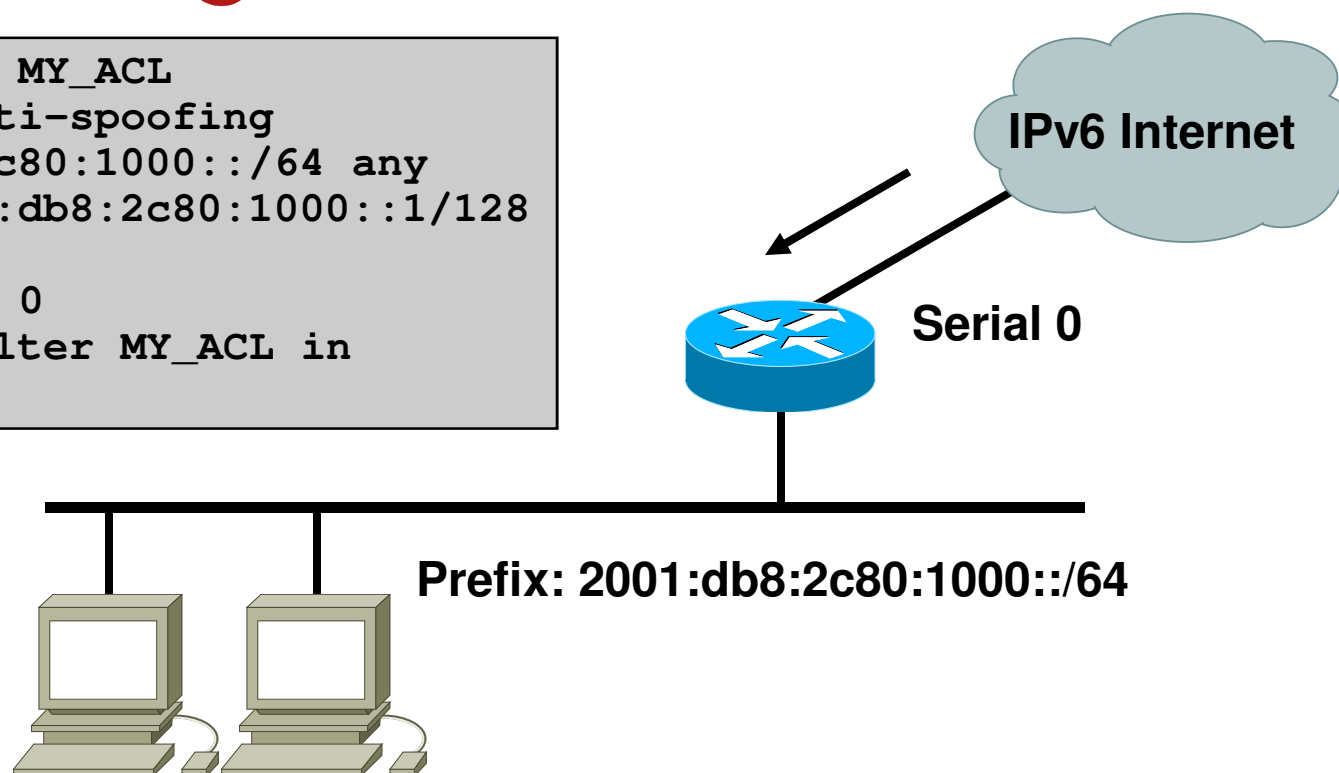
Filtering inbound traffic to one specific destination address

✓ 2001:db8:2c80:1000::1

⊘ others

```
ipv6 access-list MY_ACL
remark basic anti-spoofing
deny 2001:db8:2c80:1000::/64 any
permit any 2001:db8:2c80:1000::1/128

interface Serial 0
ipv6 traffic-filter MY_ACL in
```



# Summary of Cisco IPv6 Security Products

- ASA Firewall

  - Since version 7.0

  - Flexibility: Dual stack, IPv6 only, IPv4 only

  - SSL VPN for IPv6 (ASA 8.0)

  - No header extension parsing, no stateful-failover (coming)

- FWSM

  - IPv6 in software...

- Cisco Security Agent

  - Since version 6.0.1 for IPv6 network protection

- IPS

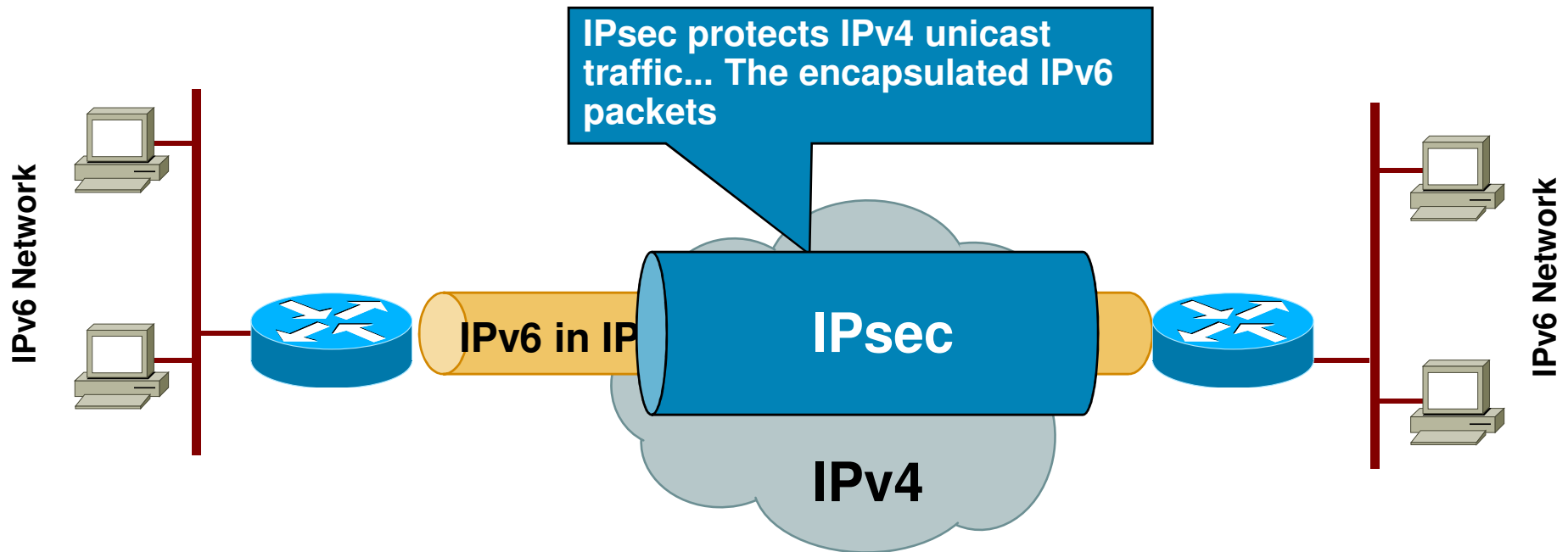
  - Since 6.2 (November 2008)

# Secure IPv6 over IPv4/6 Public Internet

- No traffic sniffing
- No traffic injection
- No service theft

Public Network	Site 2 Site	Remote Access
IPv4	<ul style="list-style-type: none"><li>■ 6in4/GRE Tunnels Protected by IPsec</li><li>■ DMVPN 12.4(20)T</li></ul>	<ul style="list-style-type: none"><li>■ ISATAP Protected by RA IPsec</li><li>■ SSL VPN Client AnyConnect</li></ul>
IPv6	IPsec VTI 12.4(6)T	N/A

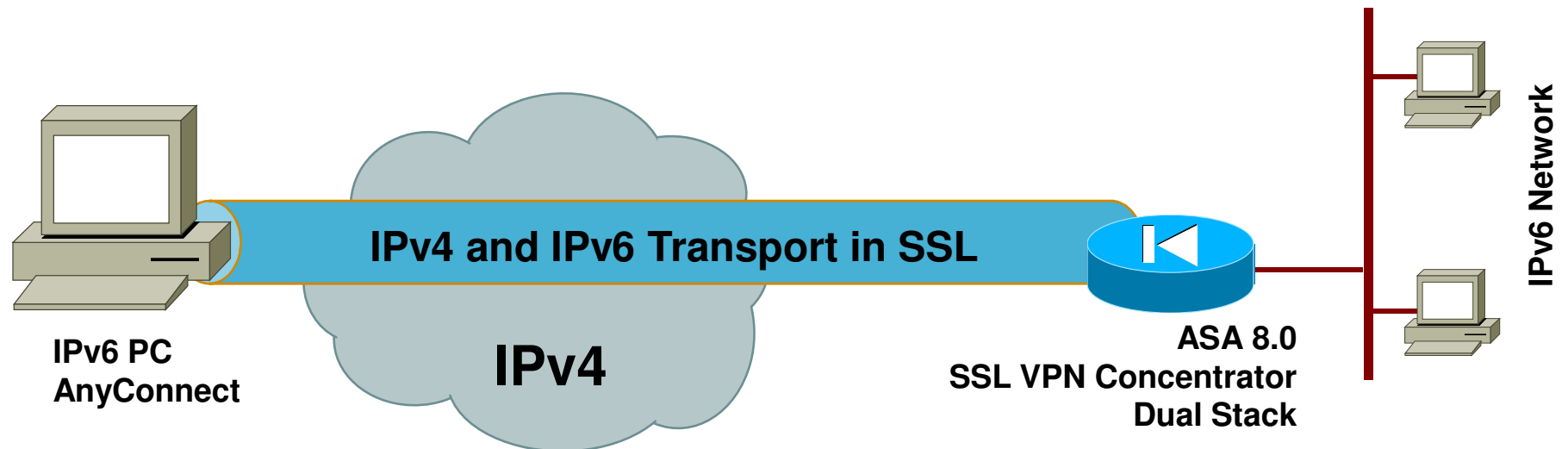
# Secure Site to Site IPv6 Traffic over IPv4 Public Network with GRE IPsec



GRE tunnel can be used to transport both IPv4 and IPv6 in the same tunnel

*See reference slides for more details*

# Secure RA IPv6 Traffic over IPv4 Public Network: AnyConnect SSL VPN Client





# IPv6 Security Best Common Practice



# Candidate Best Practices



For Your  
Reference

- **Train your network operators and security managers on IPv6**
- **Selectively filter ICMP** (RFC 4890)
- Implement RFC 2827-like filtering
- Block Type 0 Routing Header at the edge
- Determine what extension headers will be allowed through the access control device
- Deny IPv6 fragments destined to an internetworking device when possible
- Use traditional authentication mechanisms on BGP and IS-IS
- Use IPsec to secure protocols such as OSPFv3 and RIPng
- Document procedures for last-hop traceback

# Candidate Best Practices (Cont.)



For Your  
Reference

- Implement privacy extensions carefully
- Filter internal-use IPv6 addresses & ULA at the border routers
- Filter unneeded services at the firewall
- Maintain host and application security
- Use cryptographic protections where critical
- Implement ingress filtering of packets with IPv6 multicast source addresses
- Use static tunneling rather than dynamic tunneling
- Implement outbound filtering on firewall devices to allow only authorized tunneling endpoints

# Conclusion



# Key Take Away

- So, nothing really new in IPv6
- Lack of operation experience may hinder security for a while: **training is required**
- Security enforcement is possible
  - Control your IPv6 traffic as you do for IPv4
- Leverage IPsec to secure IPv6 when suitable

# Is IPv6 in My Network?

- Easy to check!
- Look inside NetFlow records
  - Protocol 41: IPv6 over IPv4 or 6to4 tunnels
  - IPv4 address: 192.88.99.1 (6to4 anycast server)
  - UDP 3544, the public part of Teredo, yet another tunnel
- Look into DNS server log for resolution of ISATAP
- Beware of the IPv6 latent threat: ***your IPv4-only network may be vulnerable to IPv6 attacks NOW***

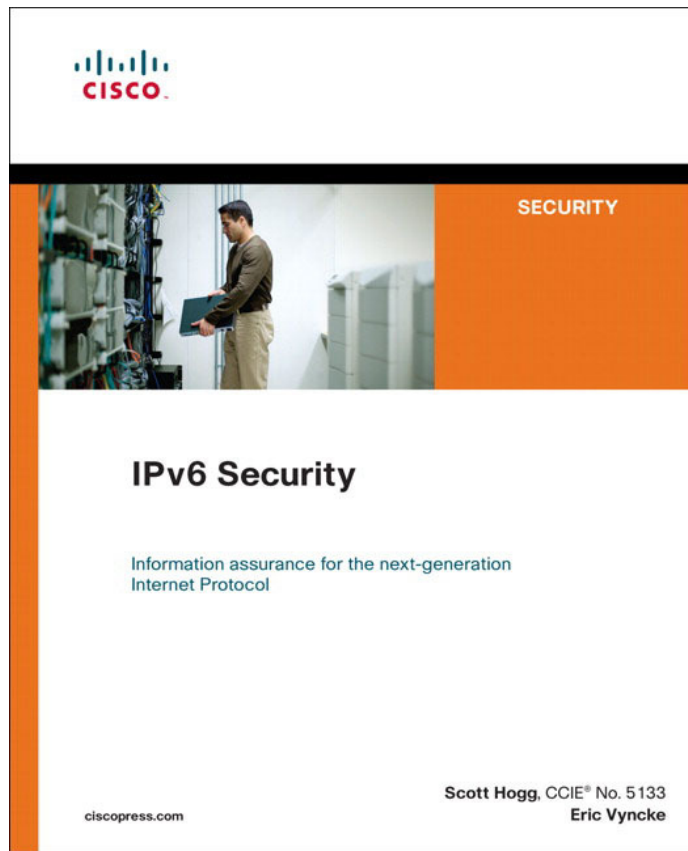
# Kudos to the Brucon IPv6 Team!

- Kristoff Bonne
  - Marc Neuckens
  - Filip Waeytens
  - Patrice Devemy
  - Sven Van Den Steene
  - Patrick Uyttersprot
  - And others
- 
- Try is on SSID 'Surfhouse ipv6'



*IPv6 is best experimented with a Belgian beer*

# Recommended Reading



<http://www.networkworld.com/community/blog/9269>



# Q and A

