Modernizing FTP with IPv6

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Agenda

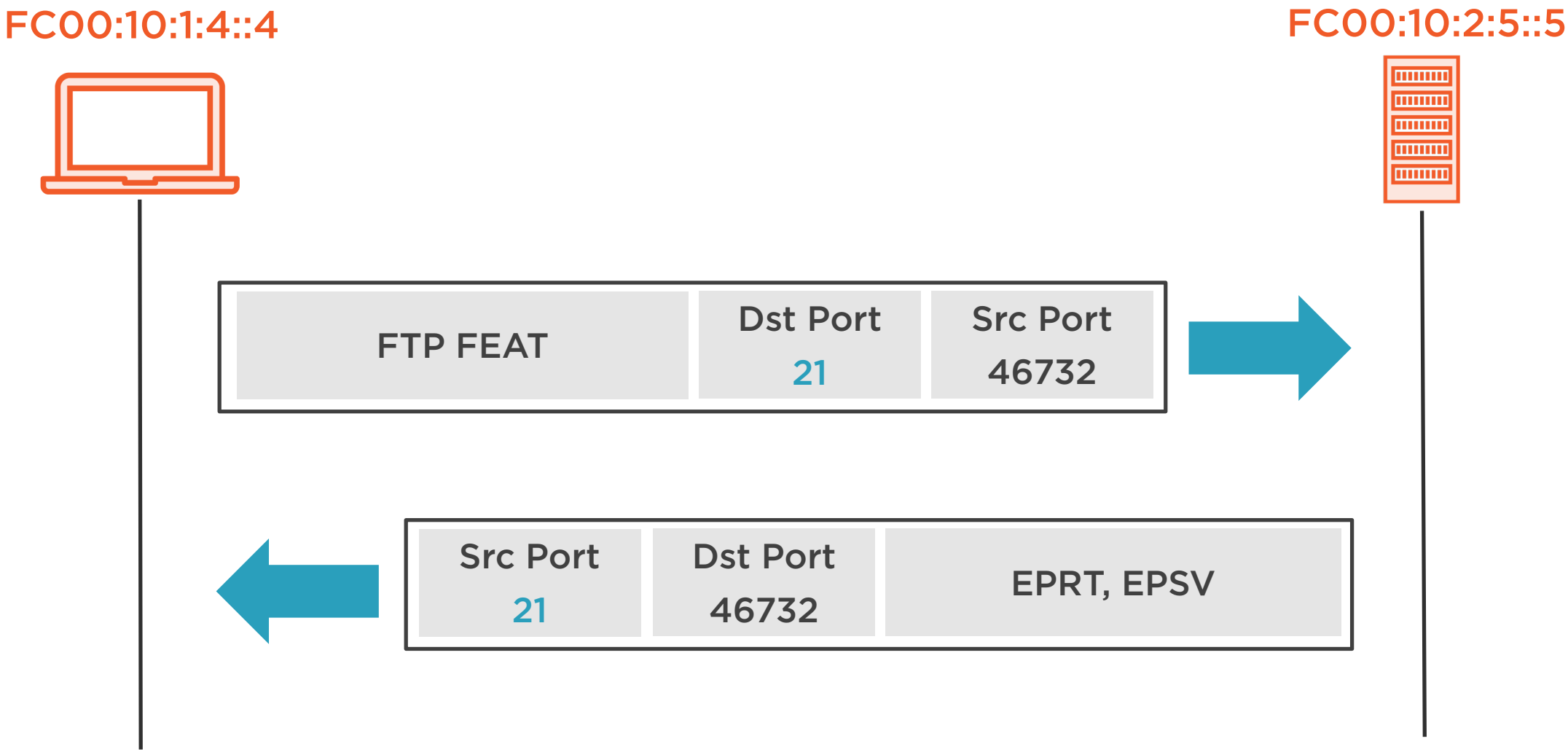
New message types in classic FTP

Changes to FTPS and SFTP

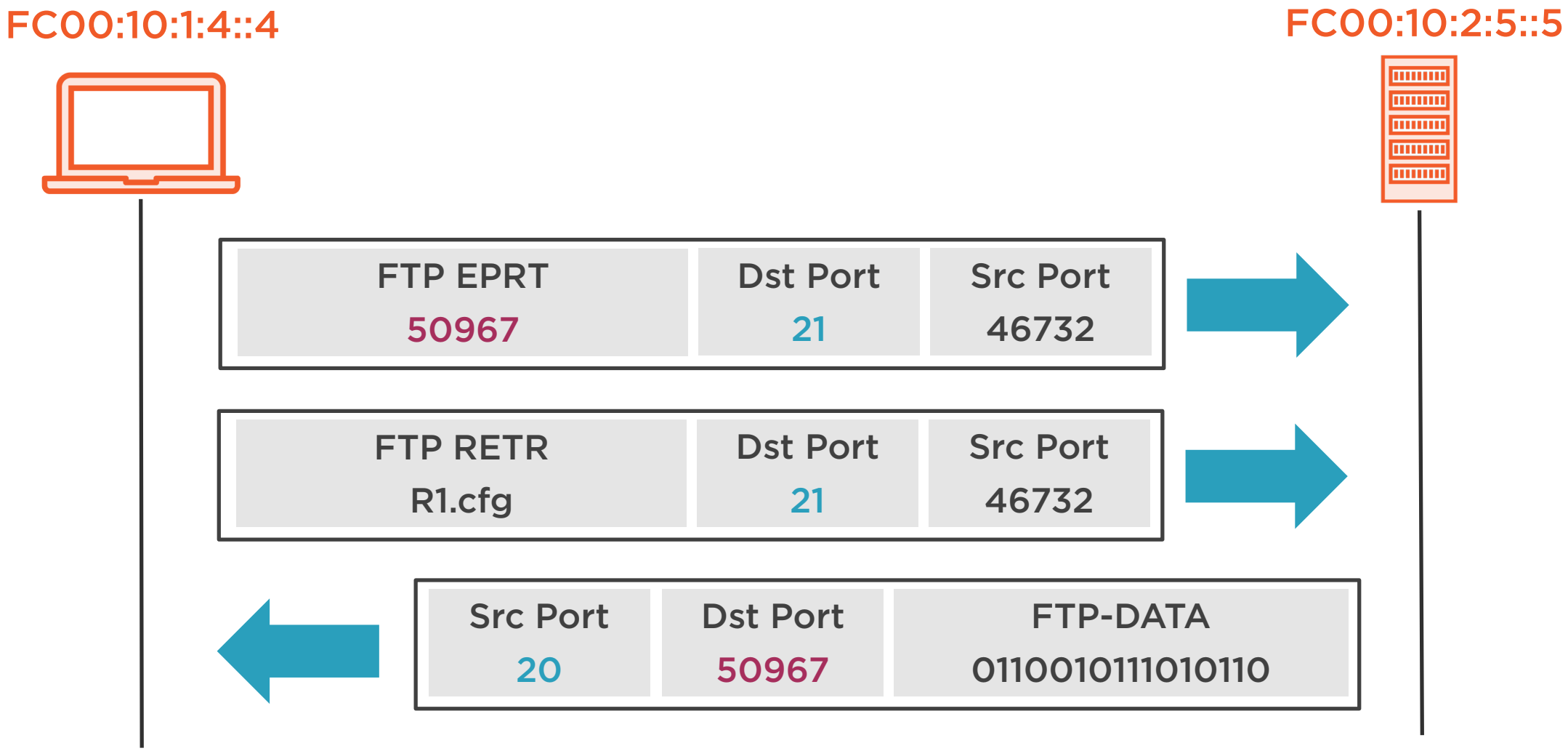
TFTP; simple and strong

Security summary

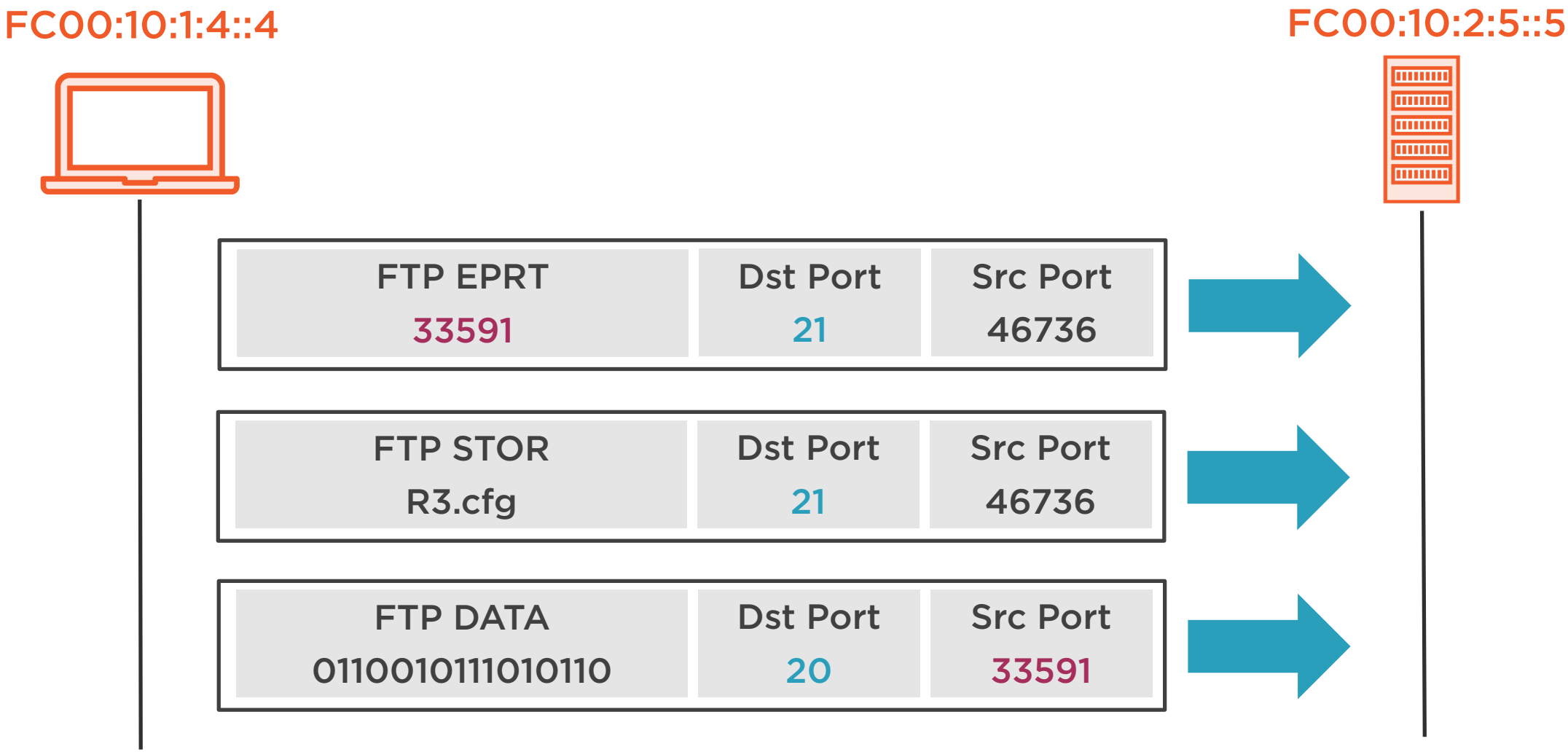
New FTP Features



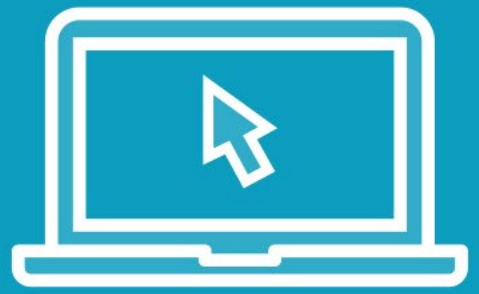
IPv6 FTP Active Mode Download



IPv6 FTP Active Mode Upload



Demo



Exploring IPv6 FTP active mode

IPv6 FTP Required Features

No.	Source	Destination	Proto	Src Port	Dst Port	Info
1	fc00:10:1:4::4	fc00:10:2:5::5	TCP	46732	21	46732→21 [SYN] Seq=0 Win=2880
2	fc00:10:2:5::5	fc00:10:1:4::4	TCP	21	46732	21→46732 [SYN, ACK] Seq=0 Ack
3	fc00:10:1:4::4	fc00:10:2:5::5	TCP	46732	21	46732→21 [ACK] Seq=1 Ack=1 Wi
4	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46732	Response: 220 (vsFTPd 3.0.3)
5	fc00:10:1:4::4	fc00:10:2:5::5	TCP	46732	21	46732→21 [ACK] Seq=1 Ack=21 W
6	fc00:10:1:4::4	fc00:10:2:5::5	FTP	46732	21	Request: FEAT
7	fc00:10:2:5::5	fc00:10:1:4::4	TCP	21	46732	21→46732 [ACK] Seq=21 Ack=7 W
8	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46732	Response: 211-Features:
9	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46732	Response: EPRT
…	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46732	Response: EPSV
…	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46732	Response: MDTM
…	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46732	Response: PASV
…	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46732	Response: REST STREAM
…	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46732	Response: SIZE
…	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46732	Response: TVFS
…	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46732	Response: 211 End

IPv6 FTP Active Mode Download

No.	Source	Destination	Proto	Src Port	Dst Port	Info
32	fc00:10:1:4::4	fc00:10:2:5::5	FTP	46732	21	Request: EPRT |2|fc00:10:1:4::4|50967|
33	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46732	Response: 200 EPRT command successful. Consider using EPSV.
34	fc00:10:1:4::4	fc00:10:2:5::5	FTP	46732	21	Request: RETR R1.cfg
35	fc00:10:2:5::5	fc00:10:1:4::4	TCP	20	50967	20→50967 [SYN] Seq=0 Win=28800 Len=0 MSS=1440 SACK_PERM=1 TSv
36	fc00:10:1:4::4	fc00:10:2:5::5	TCP	50967	20	50967→20 [SYN, ACK] Seq=0 Ack=1 Win=28560 Len=0 MSS=1440 SACK
37	fc00:10:2:5::5	fc00:10:1:4::4	TCP	20	50967	20→50967 [ACK] Seq=1 Ack=1 Win=28800 Len=0 TSval=918594362 TS
38	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46732	Response: 150 Opening BINARY mode data connection for R1.cfg
39	fc00:10:2:5::5	fc00:10:1:4::4	FTP-DATA	20	50967	FTP Data: 38 bytes
40	fc00:10:2:5::5	fc00:10:1:4::4	TCP	20	50967	20→50967 [FIN, ACK] Seq=39 Ack=1 Win=28800 Len=0 TSval=918594
41	fc00:10:1:4::4	fc00:10:2:5::5	TCP	50967	20	50967→20 [ACK] Seq=1 Ack=39 Win=28672 Len=0 TSval=63721491 TS
42	fc00:10:1:4::4	fc00:10:2:5::5	TCP	50967	20	50967→20 [FIN, ACK] Seq=1 Ack=40 Win=28672 Len=0 TSval=637214
43	fc00:10:2:5::5	fc00:10:1:4::4	TCP	20	50967	20→50967 [ACK] Seq=40 Ack=2 Win=28800 Len=0 TSval=918594365 T
44	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46732	Response: 226 Transfer complete.

IPv6 FTP Active Mode Upload

No.	Source	Destination	Proto	Src Port	Dst Port	Info
28	fc00:10:1:4::4	fc00:10:2:5::5	FTP	46736	21	Request: EPRT |2|fc00:10:1:4::4|33591|
29	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46736	Response: 200 EPRT command successful. Consider using EPSV.
30	fc00:10:1:4::4	fc00:10:2:5::5	FTP	46736	21	Request: ALLO 48
31	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46736	Response: 202 ALLO command ignored.
32	fc00:10:1:4::4	fc00:10:2:5::5	FTP	46736	21	Request: STOR R3.cfg
33	fc00:10:2:5::5	fc00:10:1:4::4	TCP	20	33591	20→33591 [SYN] Seq=0 Win=28800 Len=0 MSS=1440 SACK_PERM=1 TS
34	fc00:10:1:4::4	fc00:10:2:5::5	TCP	33591	20	33591→20 [SYN, ACK] Seq=0 Ack=1 Win=28560 Len=0 MSS=1440 SAC
35	fc00:10:2:5::5	fc00:10:1:4::4	TCP	20	33591	20→33591 [ACK] Seq=1 Ack=1 Win=28800 Len=0 TSval=918683781 T
36	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46736	Response: 150 Ok to send data.
37	fc00:10:1:4::4	fc00:10:2:5::5	FTP-DATA	33591	20	FTP Data: 48 bytes
38	fc00:10:1:4::4	fc00:10:2:5::5	TCP	33591	20	33591→20 [FIN, ACK] Seq=49 Ack=1 Win=28672 Len=0 TSval=63810
39	fc00:10:2:5::5	fc00:10:1:4::4	TCP	20	33591	20→33591 [ACK] Seq=1 Ack=49 Win=28800 Len=0 TSval=918683784
40	fc00:10:2:5::5	fc00:10:1:4::4	TCP	20	33591	20→33591 [FIN, ACK] Seq=1 Ack=50 Win=28800 Len=0 TSval=91868
41	fc00:10:1:4::4	fc00:10:2:5::5	TCP	33591	20	33591→20 [ACK] Seq=50 Ack=2 Win=28672 Len=0 TSval=63810910 T
42	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46736	Response: 226 Transfer complete.

The EPRT Command

No.	Source	Destination	Proto	Src Port	Dst Port	Info
32	fc00:10:1:4::4	fc00:10:2:5::5	FTP	46732	21	Request: EPRT |2|fc00:10:1:4::4|50967|
33	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46732	Response: 200 EPRT command successful. Consider using EPSV.
34	fc00:10:1:4::4	fc00:10:2:5::5	FTP	46732	21	Request: RETR R1.cfg
35	fc00:10:2:5::5	fc00:10:1:4::4	TCP	20	50967	20→50967 [SYN] Seq=0 Win=28800 Len=0 MSS=1440 SACK_PERM=1 T
36	fc00:10:1:4::4	fc00:10:2:5::5	TCP	50967	20	50967→20 [SYN, ACK] Seq=0 Ack=1 Win=28560 Len=0 MSS=1440 SA
37	fc00:10:2:5::5	fc00:10:1:4::4	TCP	20	50967	20→50967 [ACK] Seq=1 Ack=1 Win=28800 Len=0 TSval=918594362

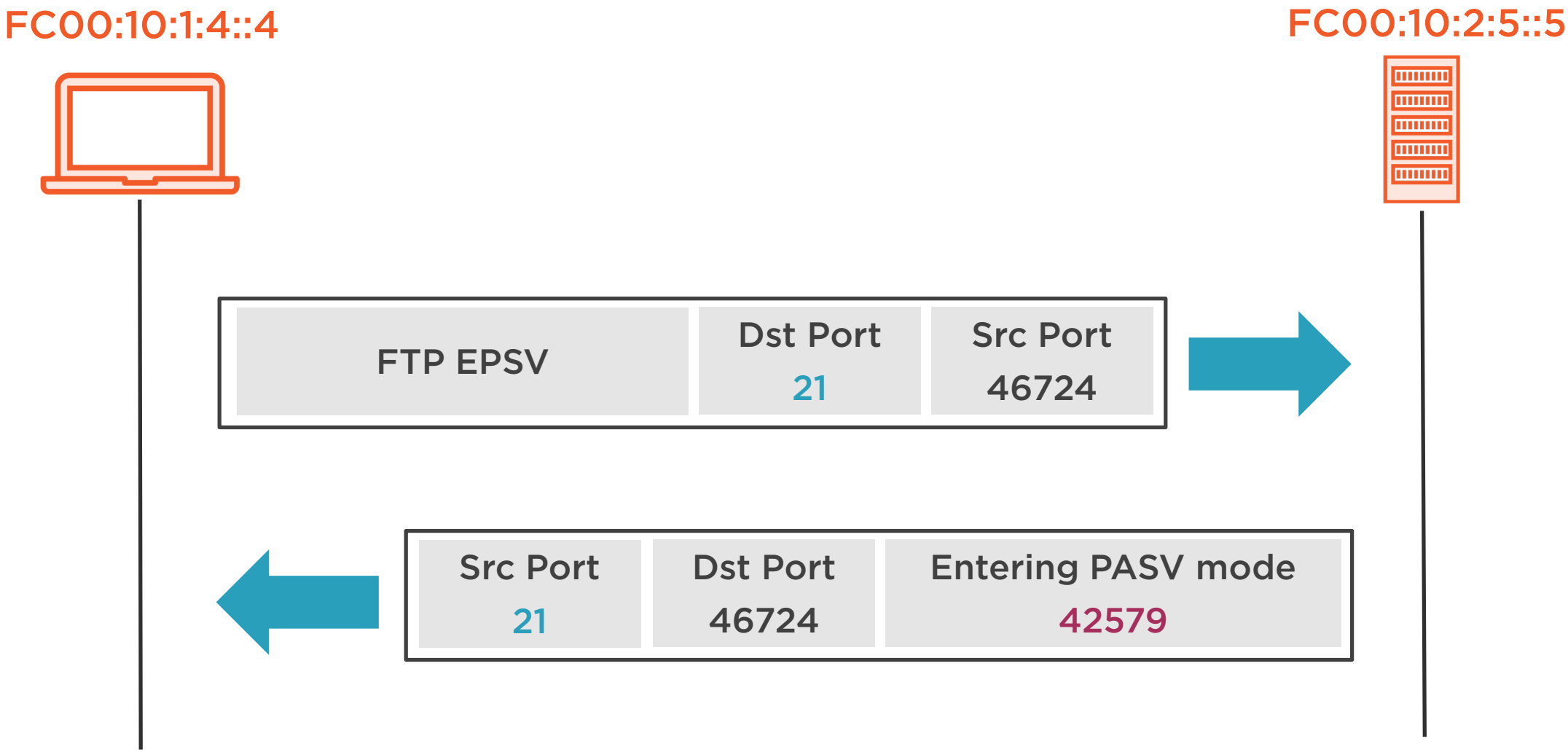
```
▶ Frame 32: 117 bytes on wire (936 bits), 117 bytes captured (936 bits) on interface 0
▶ Ethernet II, Src: 00:0c:29:9e:6d:dd, Dst: 00:00:a6:16:00:01
▶ Internet Protocol Version 6, Src: fc00:10:1:4::4, Dst: fc00:10:2:5::5
▶ Transmission Control Protocol, Src Port: 46732, Dst Port: 21, Seq: 84, Ack: 305, Len: 31
▼ File Transfer Protocol (FTP)
  ▼ EPRT |2|fc00:10:1:4::4|50967|\r\n
      Request command: EPRT
      Request arg: |2|fc00:10:1:4::4|50967|
      Extended active address family: IPv6 (2)
      Extended active IPv6 address: fc00:10:1:4::4
      Extended active port: 50967
```

1: IPv4
2: IPv6

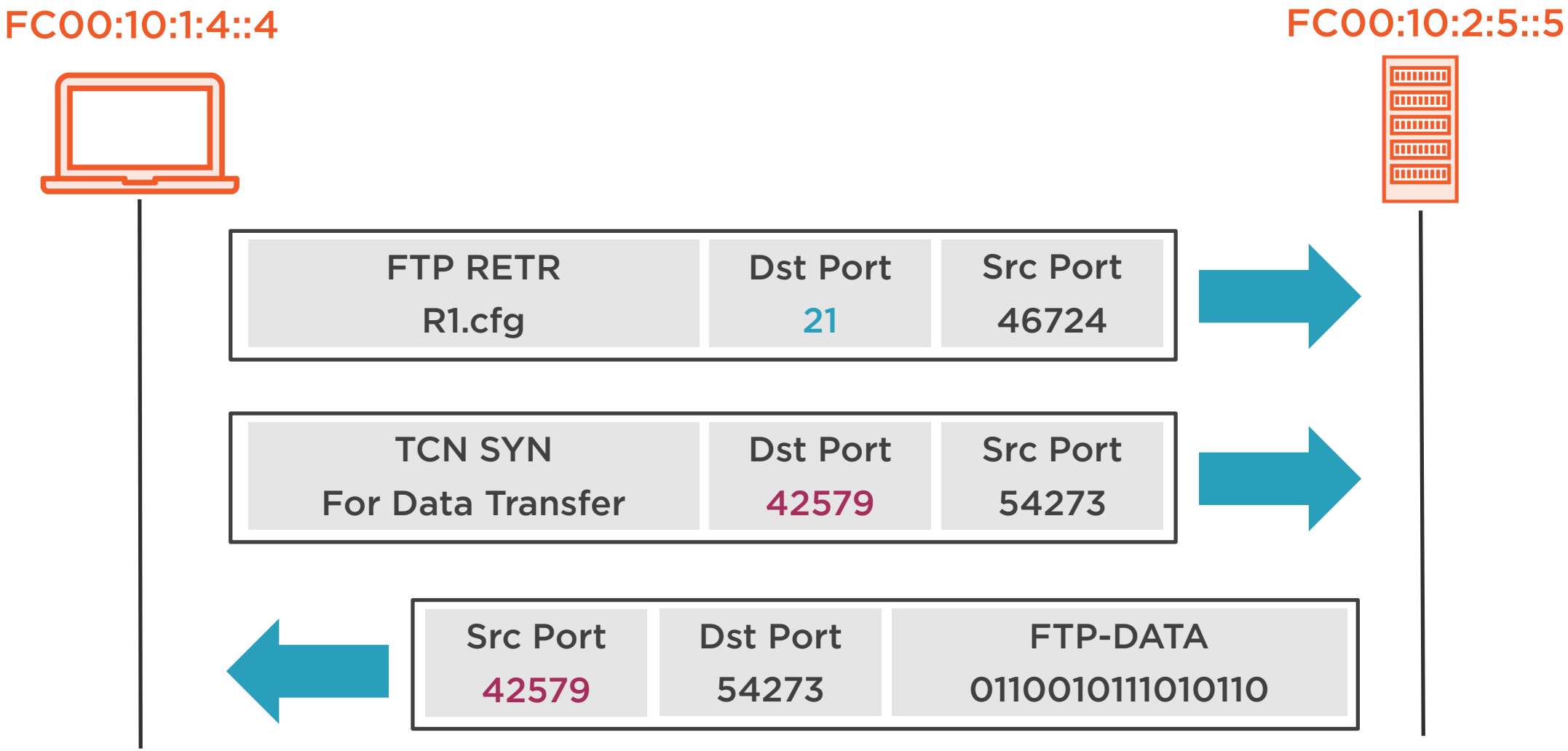
Old PORT example:
10,2,5,5,180,32

Easy to read

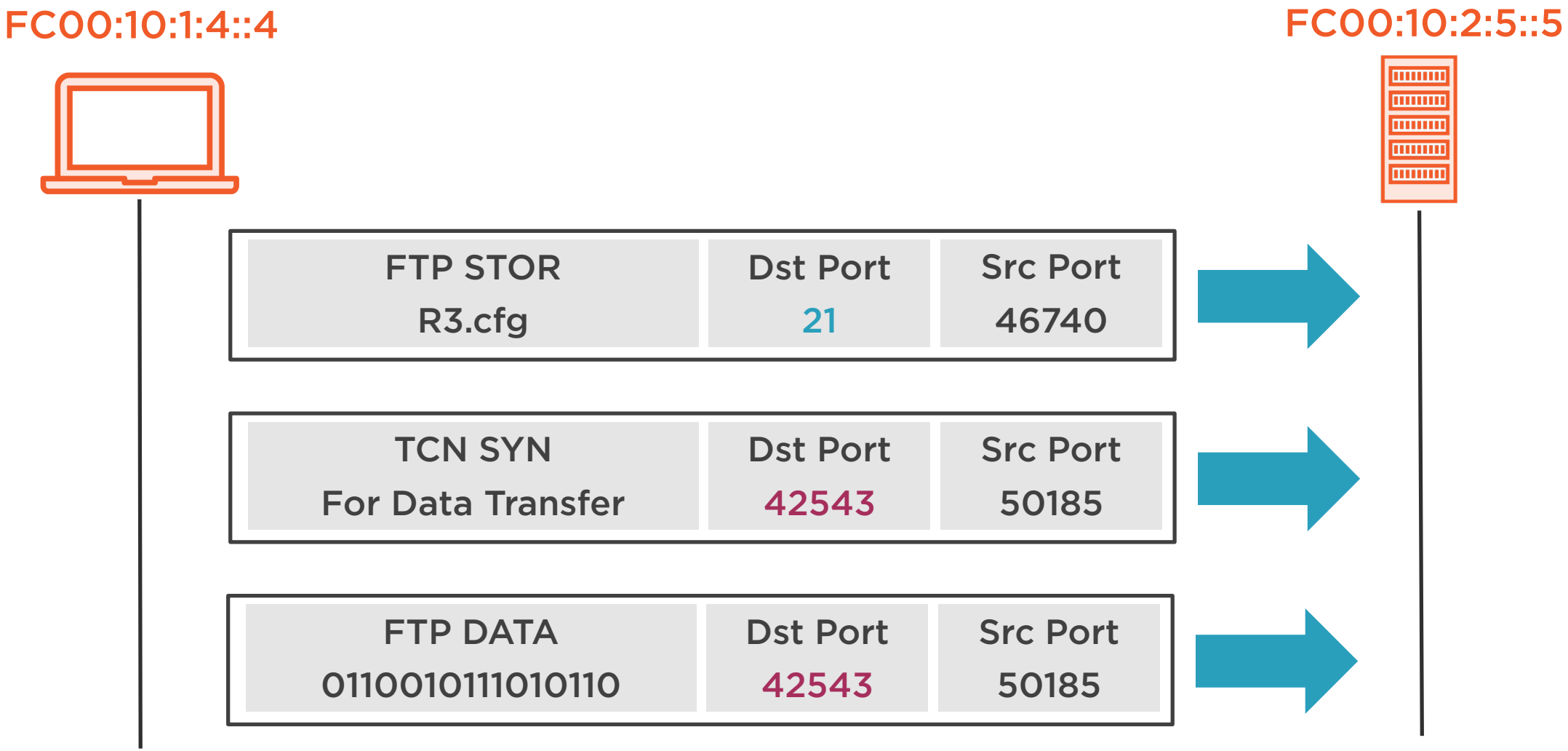
The EPSV Command



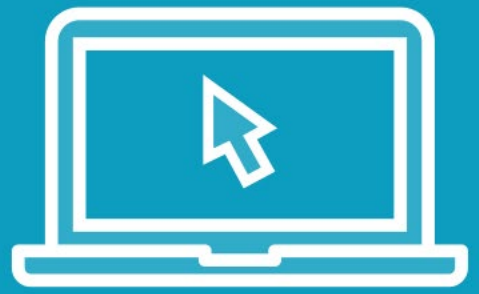
IPv6 FTP Passive Mode Download



IPv6 FTP Passive Mode Upload



Demo



Retesting IPv6 FTP with passive mode

IPv6 FTP Passive Mode Download

No.	Source	Destination	Proto	Src Port	Dst Port	Info
33	fc00:10:1:4::4	fc00:10:2:5::5	FTP	46724	21	Request: EPSV
34	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46724	Response: 229 Entering Extended Passive Mode (|||42579|)
35	fc00:10:1:4::4	fc00:10:2:5::5	TCP	54273	42579	54273→42579 [SYN] Seq=0 Win=28800 Len=0 MSS=1440 SACK_PERM=1
36	fc00:10:2:5::5	fc00:10:1:4::4	TCP	42579	54273	42579→54273 [SYN, ACK] Seq=0 Ack=1 Win=28560 Len=0 MSS=1440 S
37	fc00:10:1:4::4	fc00:10:2:5::5	TCP	54273	42579	54273→42579 [ACK] Seq=1 Ack=1 Win=28800 Len=0 TSval=63604830
38	fc00:10:1:4::4	fc00:10:2:5::5	FTP	46724	21	Request: RETR R1.cfg
39	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46724	Response: 150 Opening BINARY mode data connection for R1.cfg
40	fc00:10:2:5::5	fc00:10:1:4::4	FTP-DATA	42579	54273	FTP Data: 38 bytes
41	fc00:10:2:5::5	fc00:10:1:4::4	TCP	42579	54273	42579→54273 [FIN, ACK] Seq=39 Ack=1 Win=28672 Len=0 TSval=918
42	fc00:10:1:4::4	fc00:10:2:5::5	TCP	54273	42579	54273→42579 [ACK] Seq=1 Ack=39 Win=28800 Len=0 TSval=63604832
43	fc00:10:1:4::4	fc00:10:2:5::5	TCP	54273	42579	54273→42579 [FIN, ACK] Seq=1 Ack=40 Win=28800 Len=0 TSval=636
44	fc00:10:2:5::5	fc00:10:1:4::4	TCP	42579	54273	42579→54273 [ACK] Seq=40 Ack=2 Win=28672 Len=0 TSval=91847770
45	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46724	Response: 226 Transfer complete.

IPv6 FTP Passive Mode Upload

No.	Source	Destination	Proto	Src Port	Dst Port	Info
29	fc00:10:1:4::4	fc00:10:2:5::5	FTP	46740	21	Request: EPSV
30	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46740	Response: 229 Entering Extended Passive Mode (|||42543|)
31	fc00:10:1:4::4	fc00:10:2:5::5	TCP	50185	42543	50185→42543 [SYN] Seq=0 Win=28800 Len=0 MSS=1440 SACK_PE
32	fc00:10:2:5::5	fc00:10:1:4::4	TCP	42543	50185	42543→50185 [SYN, ACK] Seq=0 Ack=1 Win=28560 Len=0 MSS=1
33	fc00:10:1:4::4	fc00:10:2:5::5	TCP	50185	42543	50185→42543 [ACK] Seq=1 Ack=1 Win=28800 Len=0 TSval=6388
34	fc00:10:1:4::4	fc00:10:2:5::5	FTP	46740	21	Request: ALLO 48
35	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46740	Response: 202 ALLO command ignored.
36	fc00:10:1:4::4	fc00:10:2:5::5	FTP	46740	21	Request: STOR R3.cfg
37	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46740	Response: 150 Ok to send data.
38	fc00:10:1:4::4	fc00:10:2:5::5	FTP-DATA	50185	42543	FTP Data: 48 bytes
39	fc00:10:1:4::4	fc00:10:2:5::5	TCP	50185	42543	50185→42543 [FIN, ACK] Seq=49 Ack=1 Win=28800 Len=0 TSva
40	fc00:10:2:5::5	fc00:10:1:4::4	TCP	42543	50185	42543→50185 [ACK] Seq=1 Ack=49 Win=28672 Len=0 TSval=918
41	fc00:10:2:5::5	fc00:10:1:4::4	TCP	42543	50185	42543→50185 [FIN, ACK] Seq=1 Ack=50 Win=28672 Len=0 TSva
42	fc00:10:1:4::4	fc00:10:2:5::5	TCP	50185	42543	50185→42543 [ACK] Seq=50 Ack=2 Win=28800 Len=0 TSval=638
43	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46740	Response: 226 Transfer complete.

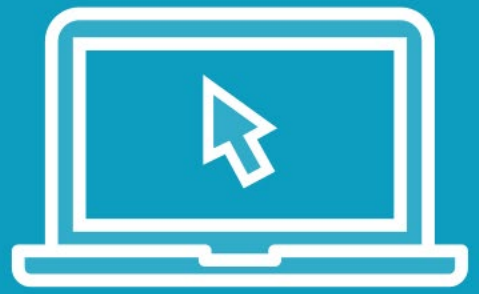
The EPSV Command

No.	Source	Destination	Proto	Src Port	Dst Port	Info
33	fc00:10:1:4::4	fc00:10:2:5::5	FTP	46724	21	Request: EPSV
34	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46724	Response: 229 Entering Extended Passive Mode (|||42579|)
35	fc00:10:1:4::4	fc00:10:2:5::5	TCP	54273	42579	54273→42579 [SYN] Seq=0 Win=28800 Len=0 MSS=1440 SACK_PE
36	fc00:10:2:5::5	fc00:10:1:4::4	TCP	42579	54273	42579→54273 [SYN, ACK] Seq=0 Ack=1 Win=28560 Len=0 MSS=14
37	fc00:10:1:4::4	fc00:10:2:5::5	TCP	54273	42579	54273→42579 [ACK] Seq=1 Ack=1 Win=28800 Len=0 TSval=63604

```
▶ Frame 34: 134 bytes on wire (1072 bits), 134 bytes captured (1072 bits) on interface 0
▶ Ethernet II, Src: 00:00:a6:16:00:01, Dst: 00:0c:29:9e:6d:dd
▶ Internet Protocol Version 6, Src: fc00:10:2:5::5, Dst: fc00:10:1:4::4
▶ Transmission Control Protocol, Src Port: 21, Dst Port: 46724, Seq: 305, Ack: 90, Len: 48
▼ File Transfer Protocol (FTP)
  ▼ 229 Entering Extended Passive Mode (|||42579|)\r\n
      Response code: Entering Extended Passive Mode (229)
      Response arg: Entering Extended Passive Mode (|||42579|)
      [Extended passive IPv6 address: fc00:10:2:5::5]
      Extended passive port: 42579
```

This may be carried in EPSV replies later

Demo



Can FTPS work with IPv6?

IPv6 FTPS Active Mode

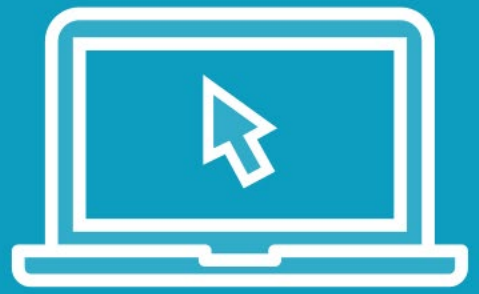
No.	Source	Destination	Proto	Src Port	Dst Port	Info
40	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46704	Response: \027\003\003\000K\373\016k\
41	fc00:10:1:4::4	fc00:10:2:5::5	FTP	46704	21	Request: \027\003\003\000\036\000\000
42	fc00:10:2:5::5	fc00:10:1:4::4	TCP	20	36373	20→36373 [SYN] Seq=0 Win=28800 Len=0
43	fc00:10:1:4::4	fc00:10:2:5::5	TCP	36373	20	36373→20 [SYN, ACK] Seq=0 Ack=1 Win=2
44	fc00:10:2:5::5	fc00:10:1:4::4	TCP	20	36373	20→36373 [ACK] Seq=1 Ack=1 Win=28800
45	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46704	Response: \027\003\003\000?\373\016k\
46	fc00:10:1:4::4	fc00:10:2:5::5	FTP-DATA	36373	20	FTP Data: 485 bytes
47	fc00:10:2:5::5	fc00:10:1:4::4	TCP	20	36373	20→36373 [ACK] Seq=1 Ack=486 Win=2995
48	fc00:10:2:5::5	fc00:10:1:4::4	FTP-DATA	20	36373	FTP Data: 141 bytes

IPv6 FTPS Passive Mode

No.	Source	Destination	Proto	Src Port	Dst Port	Info
36	fc00:10:1:4::4	fc00:10:2:5::5	FTP	46706	21	Request: \027\003\003\000\036\000\000\00
37	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46706	Response: \027\003\003\000H\224\272\362\
38	fc00:10:1:4::4	fc00:10:2:5::5	TCP	34487	42568	34487→42568 [SYN] Seq=0 Win=28800 Len=0
39	fc00:10:2:5::5	fc00:10:1:4::4	TCP	42568	34487	42568→34487 [SYN, ACK] Seq=0 Ack=1 Win=2
40	fc00:10:1:4::4	fc00:10:2:5::5	TCP	34487	42568	34487→42568 [ACK] Seq=1 Ack=1 Win=28800
41	fc00:10:1:4::4	fc00:10:2:5::5	FTP	46706	21	Request: \027\003\003\000\036\000\000\00
42	fc00:10:2:5::5	fc00:10:1:4::4	FTP	21	46706	Response: \027\003\003\000?\224\272\362\
43	fc00:10:1:4::4	fc00:10:2:5::5	TCP	34487	42568	34487→42568 [PSH, ACK] Seq=1 Ack=1 Win=2

Also true for IPv4

Demo



How about SFTP with IPv6?

IPv6 SFTP Initial Setup

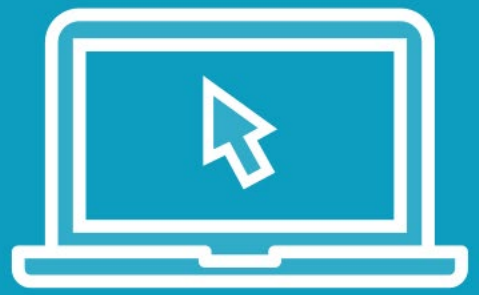
No.	Source	Destination	Proto	Src Port	Dst Port	Info
1	fc00:10:1:4::4	fc00:10:2:5::5	TCP	48842	22	48842→22 [SYN] Seq=0 Win=28800 Len=0 MSS=1440 SACK_PE
2	fc00:10:2:5::5	fc00:10:1:4::4	TCP	22	48842	22→48842 [SYN, ACK] Seq=0 Ack=1 Win=28560 Len=0 MSS=1
3	fc00:10:1:4::4	fc00:10:2:5::5	TCP	48842	22	48842→22 [ACK] Seq=1 Ack=1 Win=28800 Len=0 TSval=6261
4	fc00:10:1:4::4	fc00:10:2:5::5	SSHv2	48842	22	Client: Protocol (SSH-2.0-OpenSSH_7.6p1 Ubuntu-4ubunt
5	fc00:10:2:5::5	fc00:10:1:4::4	TCP	22	48842	22→48842 [ACK] Seq=1 Ack=42 Win=28672 Len=0 TSval=917
6	fc00:10:2:5::5	fc00:10:1:4::4	SSHv2	22	48842	Server: Protocol (SSH-2.0-OpenSSH_7.6p1 Ubuntu-4ubunt
7	fc00:10:1:4::4	fc00:10:2:5::5	TCP	48842	22	48842→22 [ACK] Seq=42 Ack=42 Win=28800 Len=0 TSval=62
8	fc00:10:2:5::5	fc00:10:1:4::4	SSHv2	22	48842	Server: Key Exchange Init
9	fc00:10:1:4::4	fc00:10:2:5::5	TCP	48842	22	48842→22 [ACK] Seq=42 Ack=1122 Win=30976 Len=0 TSval=
10	fc00:10:1:4::4	fc00:10:2:5::5	SSHv2	48842	22	Client: Key Exchange Init
11	fc00:10:2:5::5	fc00:10:1:4::4	TCP	22	48842	22→48842 [ACK] Seq=1122 Ack=1402 Win=31488 Len=0 TSva
12	fc00:10:1:4::4	fc00:10:2:5::5	SSHv2	48842	22	Client: Diffie-Hellman Key Exchange Init
13	fc00:10:2:5::5	fc00:10:1:4::4	TCP	22	48842	22→48842 [ACK] Seq=1122 Ack=1450 Win=31488 Len=0 TSva
14	fc00:10:2:5::5	fc00:10:1:4::4	SSHv2	22	48842	Server: Diffie-Hellman Key Exchange Reply, New Keys,
15	fc00:10:1:4::4	fc00:10:2:5::5	SSHv2	48842	22	Client: New Keys

IPv6 SFTP Data Transfer

No.	Source	Destination	Proto	Src Port	Dst Port	Info
19	fc00:10:2:5::5	fc00:10:1:4::4	SSHv2	22	48842	Server: Encrypted packet (len=44)
20	fc00:10:1:4::4	fc00:10:2:5::5	SSHv2	48842	22	Client: Encrypted packet (len=68)
21	fc00:10:2:5::5	fc00:10:1:4::4	SSHv2	22	48842	Server: Encrypted packet (len=52)
22	fc00:10:1:4::4	fc00:10:2:5::5	SSHv2	48842	22	Client: Encrypted packet (len=372)
23	fc00:10:2:5::5	fc00:10:1:4::4	SSHv2	22	48842	Server: Encrypted packet (len=52)
24	fc00:10:1:4::4	fc00:10:2:5::5	SSHv2	48842	22	Client: Encrypted packet (len=148)
25	fc00:10:2:5::5	fc00:10:1:4::4	SSHv2	22	48842	Server: Encrypted packet (len=28)
26	fc00:10:1:4::4	fc00:10:2:5::5	SSHv2	48842	22	Client: Encrypted packet (len=112)

All data is private

Demo



Last but not least … IPv6 TFTP

IPv6 TFTP Download

No.	Source	Destination	Proto	Src Port	Dst Port	Opcode	Info
1	fc00:10:1:4::4	fc00:10:2:5::5	TFTP	57705	69	1	Read Request, File: R1.cfg,
2	fc00:10:2:5::5	fc00:10:1:4::4	TFTP	47609	57705	3	Data Packet, Block: 1 (last)
3	fc00:10:1:4::4	fc00:10:2:5::5	TFTP	57705	47609	4	Acknowledgement, Block: 1

```
▶ Frame 2: 107 bytes on wire (856 bits), 107 bytes captured (856 bits) on interface 0
▶ Ethernet II, Src: 00:00:a6:16:00:01, Dst: 00:0c:29:9e:6d:dd
▶ Internet Protocol Version 6, Src: fc00:10:2:5::5, Dst: fc00:10:1:4::4
▶ User Datagram Protocol, Src Port: 47609, Dst Port: 57705
▼ Trivial File Transfer Protocol
    Opcode: Data Packet (3)
    [Source File: R1.cfg]
    Block: 1
▼ Data (41 bytes)
    Data: 68656c6c6f20776f726c640d0a746869732069730d0a5231...
    [Length: 41]
```

← Nothing IP-specific here!

```
0000  00 0c 29 9e 6d dd 00 00  a6 16 00 01 86 dd 60 04   ..).m... ......`.
0010  26 d9 00 35 11 3d fc 00  00 10 00 02 00 05 00 00   &..5.=.. ........
0020  00 00 00 00 00 05 fc 00  00 10 00 01 00 04 00 00   ........ ........
0030  00 00 00 00 00 04 b9 f9  e1 69 00 35 a8 b3 00 03            i 5
0040  00 01 68 65 6c 6c 6f 20  77 6f 72 6c 64 0d 0a 74   ..hello  world..t
0050  68 69 73 20 69 73 0d 0a  52 31 27 73 20 63 6f 6e   his is.. R1's con
0060  66 69 67 20 66 69 6c 65  21 0d 0a                  fig file !..
```

IPv6 TFTP Upload

No.	Source	Destination	Proto	Src Port	Dst Port	Opcode	Info
1	fc00:10:1:4::4	fc00:10:2:5::5	TFTP	46552	69	2	Write Request, File: R3.cfg,
2	fc00:10:2:5::5	fc00:10:1:4::4	TFTP	39893	46552	4	Acknowledgement, Block: 0
3	fc00:10:1:4::4	fc00:10:2:5::5	TFTP	46552	39893	3	Data Packet, Block: 1 (last)
4	fc00:10:2:5::5	fc00:10:1:4::4	TFTP	39893	46552	4	Acknowledgement, Block: 1

```
▶ Frame 3: 117 bytes on wire (936 bits), 117 bytes captured (936 bits) on interface 0
▶ Ethernet II, Src: 00:0c:29:9e:6d:dd, Dst: 00:00:a6:16:00:01
▶ Internet Protocol Version 6, Src: fc00:10:1:4::4, Dst: fc00:10:2:5::5
▶ User Datagram Protocol, Src Port: 46552, Dst Port: 39893
▼ Trivial File Transfer Protocol
    Opcode: Data Packet (3)
    [DESTINATION File: R3.cfg]
    Block: 1
▼ Data (51 bytes)
    Data: 68656c6c6f20776f726c640d0a523327732066696c652069...
    [Length: 51]
```

Nothing IP-specific here!

```
0000  00 00 a6 16 00 01 00 0c  29 9e 6d dd 86 dd 60 08   ........ ).m...`.
0010  84 be 00 3f 11 40 fc 00  00 10 00 01 00 04 00 00   ...?.@.. ........
0020  00 00 00 00 00 04 fc 00  00 10 00 02 00 05 00 00   ........ ........
0030  00 00 00 00 00 05 b5 d8  9b d5 00 3f dd 65 00 03              ? e
0040  00 01 68 65 6c 6c 6f 20  77 6f 72 6c 64 0d 0a 52   ..hello  world..R
0050  33 27 73 20 66 69 6c 65  20 69 73 0d 0a 6d 75 63   3's file  is..muc
0060  68 20 6d 6f 72 65 20 69  6e 74 65 72 65 73 74 69   h more i nteresti
0070  6e 67 21 0d 0a                                    ng!..
```

Security Advice for IPv6 FTP

Ports and flows are identical

Account for new IPv6 addressing

Don't forget ICMPv6 Neighbor Discovery (ND)

```
ipv6 access-list ACL_INSIDE_FTP_ACTIVE_IN_V6
 permit tcp FC00:10:1:4::/64 host FC00:10:2:5::5 eq ftp
 permit tcp FC00:10:1:4::/64 host FC00:10:2:5::5 eq ftp-data
 permit icmp FE80::/10 FE80::/10 <-- Allows neighbor discovery
 deny ipv6 any any log

ipv6 access-list ACL_OUTSIDE_FTP_ACTIVE_IN_V6
 permit tcp host FC00:10:2:5::5 eq ftp FC00:10:1:4::/64
 permit tcp host FC00:10:2:5::5 eq ftp-data FC00:10:1:4::/64
 permit icmp FE80::/10 FE80::/10 <-- Allows neighbor discovery
 deny ipv6 any any log
```

Cisco Access-list Example

Template for IPv6-based rules for allowing FTP

Final Thoughts on IPv6 FTP

EPRT and EPSV

Easy migration

Security for IPv6 similar to IPv4

Course Summary

Active vs. passive

Secure vs. unsecure

Thank you!