

Tecnologías Wi-Fi

Area de Ingeniería Telemática
<http://www.tlm.unavarra.es>

Grado en Ingeniería en Tecnologías de
Telecomunicación, 3º

802.11: Nivel físico

Wi-Fi 1, 2 y 3

Nivel físico 802.11

802.11b

- 2.4 GHz, unos 11-14 canales, 3 sin solape (canales 1, 6 y 11)
- Hasta 11 Mb/s (1, 2, 5.5 Mb/s)

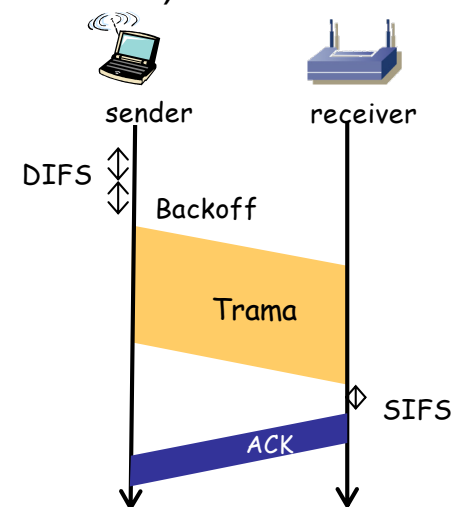
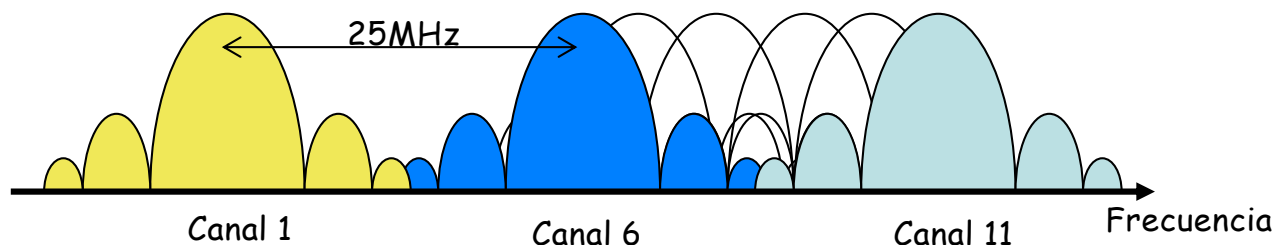
802.11a

- 5 GHz, unos 23 canales, 12 sin solape
- Añade a las velocidades de 802.11b: 6, 9, 12, 18, 24, 36, 48 y 54 Mb/ss



802.11g

- 2.4 GHz como 802.11b, calanes iguales, compatible
- Añade las modulaciones de 802.11a a la banda de 2.4GHz
- (Esto son tasas de transmisión, a nivel MAC aproximadamente un 65%)



802.11: Nivel físico

Wi-Fi 4



802.11n



- La modificación es grande
- Al incorporarla (en 2009) se duplicó el tamaño del estándar
- 802.11-2007 tenía unas 1200 páginas
- 802.11-2012 tiene 2793
- **Con muchas características opcionales**
- Eso quiere decir que seguramente muchos equipos no implementen todas
- Además la electrónica ha tenido que ir añadiéndolas

IEEE STANDARDS ASSOCIATION



IEEE Standard for Information technology—
Telecommunications and information exchange between systems
Local and metropolitan area networks—
Specific requirements

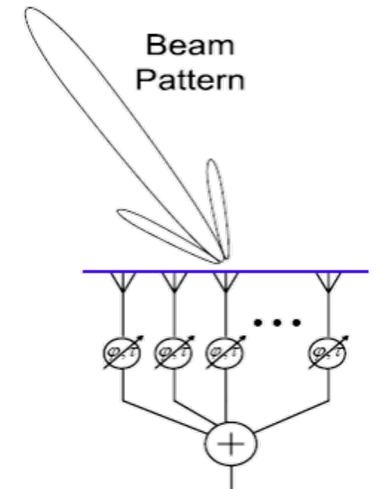
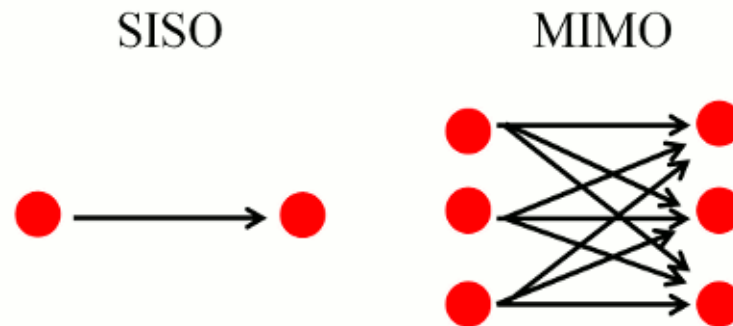
**Part 11: Wireless LAN Medium Access Control
(MAC) and Physical Layer (PHY) Specifications**



802.11n



- Tanto en 2.4 GHz como 5 GHz
- Compatible con 802.11a/b/g
- Canales de diferente BW (20MHz, 40 MHz)
- En 2.4GHz hasta 3 canales que no se solapan (solo uno de 40MHz)
- En 5GHz hasta 21 (unos 9 si son de 40MHz)
- MIMO
 - *Multiple Input Multiple Output*
 - Hasta 4 *streams* espaciales
 - No confundir con *antenna diversity*, es decir, tener múltiples antenas y emplear la que reciba mayor potencia (esto ya en equipos 802.11a/b/g)
- Permite *beamforming* (baja compatibilidad entre fabricantes)
- No solo trae mejoras en el nivel físico sino también en MAC





802.11n



- Hay 10 páginas en 802.11-2012 con tablas sobre las velocidades posibles según el ancho de banda, la codificación, el nivel de corrección de errores...
- En canal de 40 MHz con 4 streams espaciales, 64-QAM y codificación 5/6 podrían alcanzarse los 540 Mbps (esto es lo máximo)
- Hoy en día lo normal es hasta 3 streams con lo que máximos de 450Mbps

Table 20-44—MCS parameters for optional 40 MHz, $N_{SS} = 4$, UEQAM

MCS Index	Modulation				R	N_{BPSC}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
	Stream 1	Stream 2	Stream 3	Stream 4								800 ns GI	400 ns GI
53	16-QAM	QPSK	QPSK	QPSK	1/2	10	108	6	1080	540	1	135	150
54	16-QAM	16-QAM	QPSK	QPSK	1/2	12	108	6	1296	648	1	162	180
55	16-QAM	16-QAM	16-QAM	QPSK	1/2	14	108	6	1512	756	1	189	210
56	64-QAM	QPSK	QPSK	QPSK	1/2	12	108	6	1296	648	1	162	180
57	64-QAM	16-QAM	QPSK	QPSK	1/2	14	108	6	1512	756	1	180	210

802.11: Nivel físico

Wi-Fi 5



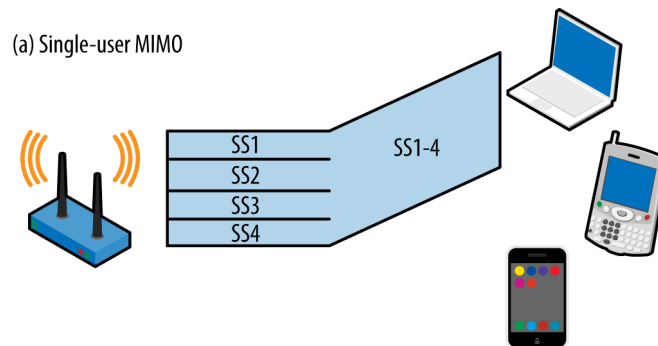
802.11ac



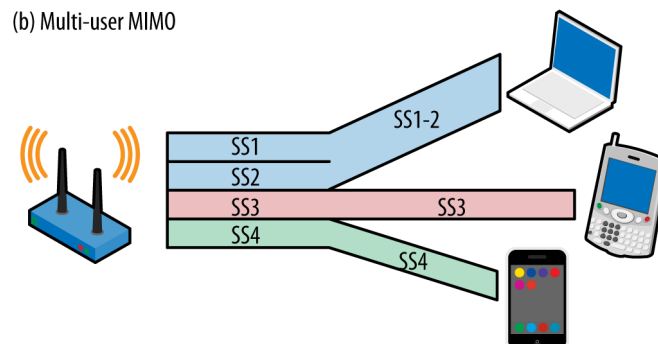
- Estándar IEEE de 2013; solo 802.11ac ya son 425 páginas
- En 5 GHz, canales de 20, 40, 80 ó 160 MHz
- 2 canales de 80 MHz o 1 canal de 160 MHz (no caben en la banda de 2.4 GHz)
- Se puede enviar hasta a 4 receptores simultáneamente (Multi-User MIMO o MU-MIMO)
- Los dispositivos suelen a la vez soportar 802.11n

Generational name	Technology supported
Wi-Fi 7	802.11be (in development)
Wi-Fi 6	802.11ax
Wi-Fi 5	802.11ac
Wi-Fi 4	802.11n

(a) Single-user MIMO



(b) Multi-user MIMO





802.11ac



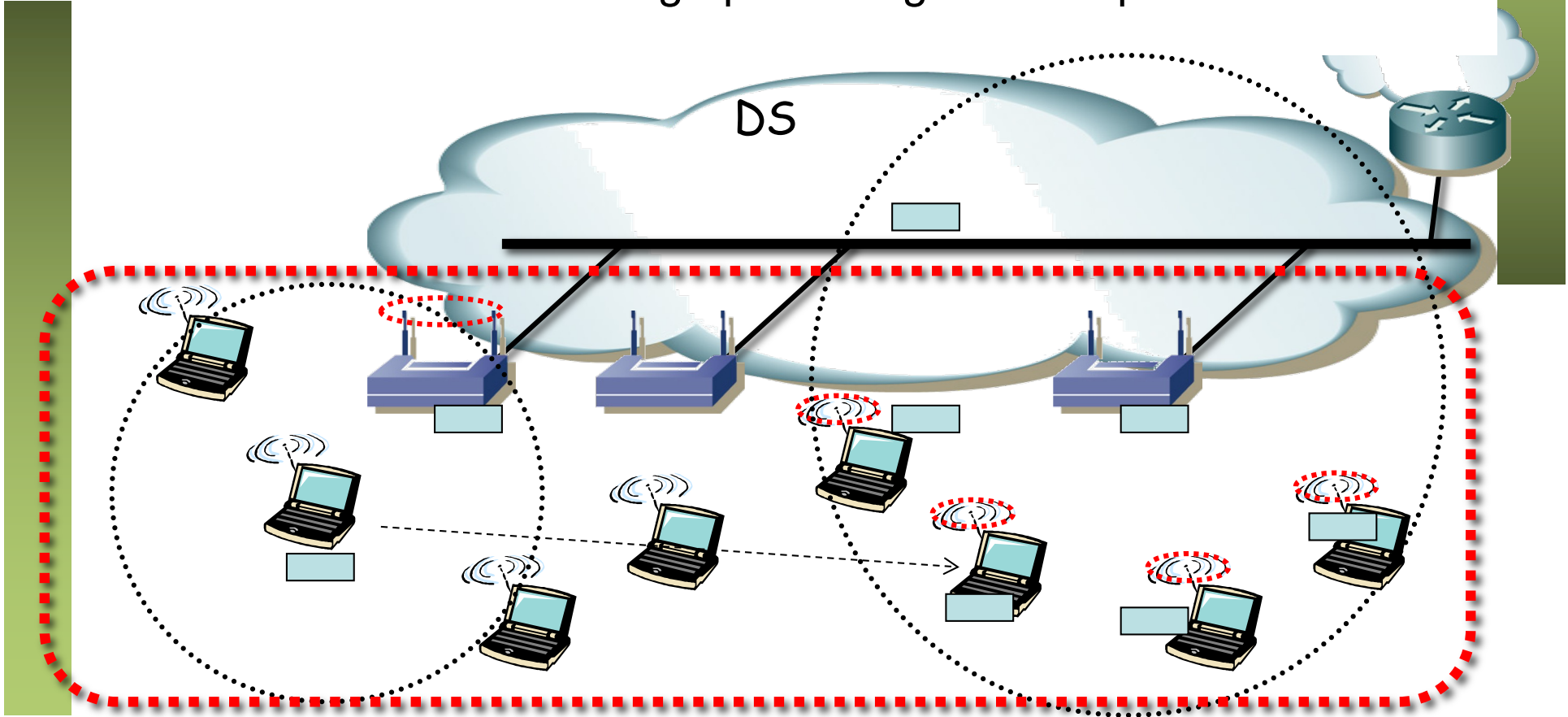
- Hay 16 páginas en 802.11ac con tablas sobre las velocidades posibles
- En canal de 160 MHz con 8 streams espaciales, 256-QAM y codificación 5/6 podrían alcanzarse los 6.9 Gbps (esto es lo máximo)
- Hoy en día lo normal es (al menos) hasta canal de 80 MHz con 3 streams y eso da hasta 1.3Gbps compartidos (“wave 1”)
- En canal de 80 MHz se podría esperar hasta 500Mbps a una estación
- En general no hay cambios al nivel MAC
- Equipos por “oleadas” (wave 1 y wave 2)

Technology	20 MHz ^[a]	40 MHz	80 MHz	160 MHz
802.11b	11 Mbps			
802.11a/g	54 Mbps			
802.11n (1 SS)	72 Mbps	150 Mbps		
802.11ac (1 SS)	87 Mbps	200 Mbps	433 Mbps	867 Mbps
802.11n (2 SS)	144 Mbps	300 Mbps		
802.11ac (2 SS)	173 Mbps	400 Mbps	867 Mbps	1.7 Gbps
802.11n (3 SS)	216 Mbps	450 Mbps		
802.11ac (3 SS)	289 Mbps	600 Mbps	1.3 Gbps	2.3 Gbps ^[b]
802.11n (4 SS) ^[c]	289 Mbps	600 Mbps		
802.11ac (4 SS)	347 Mbps	800 Mbps	1.7 Gbps	3.5 Gbps
802.11ac (8 SS)	693 Mbps	1.6 Gbps	3.4 Gbps	6.9 Gbps

802.11: Nivel de enlace

Topologías

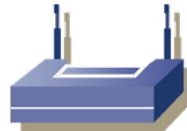
- Topologías:
 - *Independent Basic Service Sets (IBSSs)* o *Ad Hoc BSS*
 - *Basic Service Sets (BSSs)* o *Infraestructure BSS*
 - *Extended Service Sets (ESSs)*
- Un *Service Set* es una agrupación lógica de dispositivos



Wi-Fi: Tráfico en un *ping* entre dos terminales inalámbricos

Ping entre dos terminales WiFi

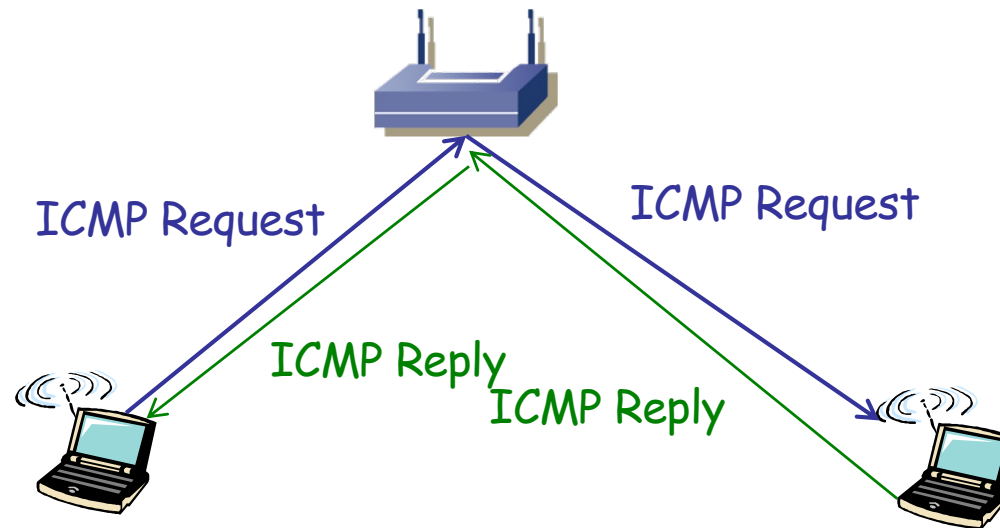
No.	Time	Arrival Time	Source	Destination	Length	Data rate	Transmitter address	Receiver address	Source address	Receiver address	Info
1	0.000000000	0.000000000	192.168.1.100	192.168.1.101	134	12	00:13:f7:54:32:01	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,...
2	0.000016446	0.000016446		SmcNetwo_54:32:01 ...	28	12		00:13:f7:54:32:01			Acknowledgement, Flags=.....
3	0.000270064	0.000253618	192.168.1.100	192.168.1.101	134	48	00:13:10:92:a8:60	00:13:f7:54:33:53	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,...
4	0.000287857	0.000017793		Cisco-Li_92:a8:60 ...	28	24		00:13:10:92:a8:60			Acknowledgement, Flags=.....
5	0.000314591	0.000026734	192.168.1.101	192.168.1.100	134	54	00:13:f7:54:33:53	00:13:10:92:a8:60	00:13:f7:54:33:53	00:13:f7:54:32:01	Echo (ping) reply id=0x099a,...
6	0.000390506	0.000075915		SmcNetwo_54:33:53 ...	28	24		00:13:f7:54:33:53			Acknowledgement, Flags=.....
7	0.000728395	0.000337889	192.168.1.101	192.168.1.100	134	54	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	00:13:f7:54:32:01	Echo (ping) reply id=0x099a,...
8	0.000745338	0.000016943		Cisco-Li_92:a8:60 ...	28	24		00:13:10:92:a8:60			Acknowledgement, Flags=.....



Ping entre dos terminales WiFi

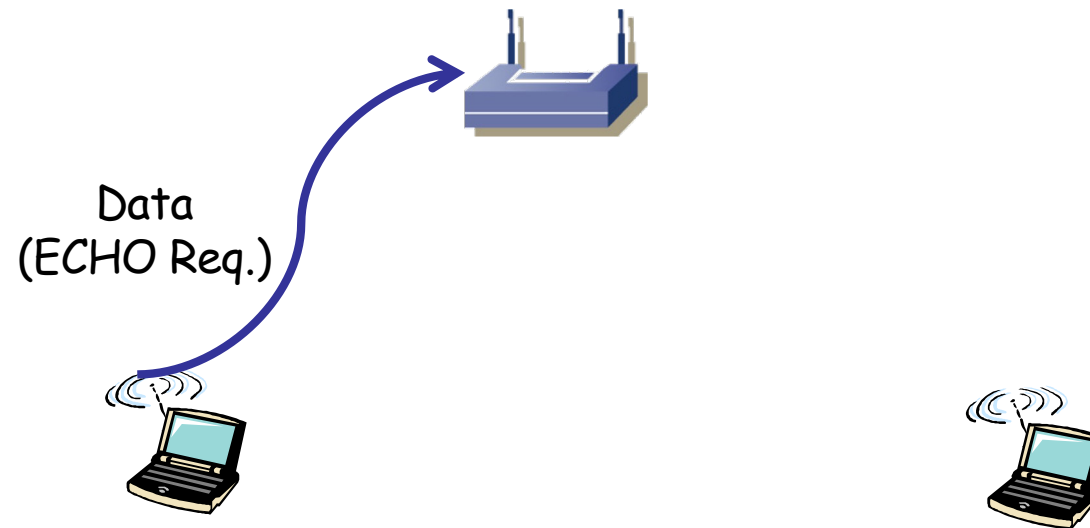
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Si miramos solo las tramas de datos tenemos esto:



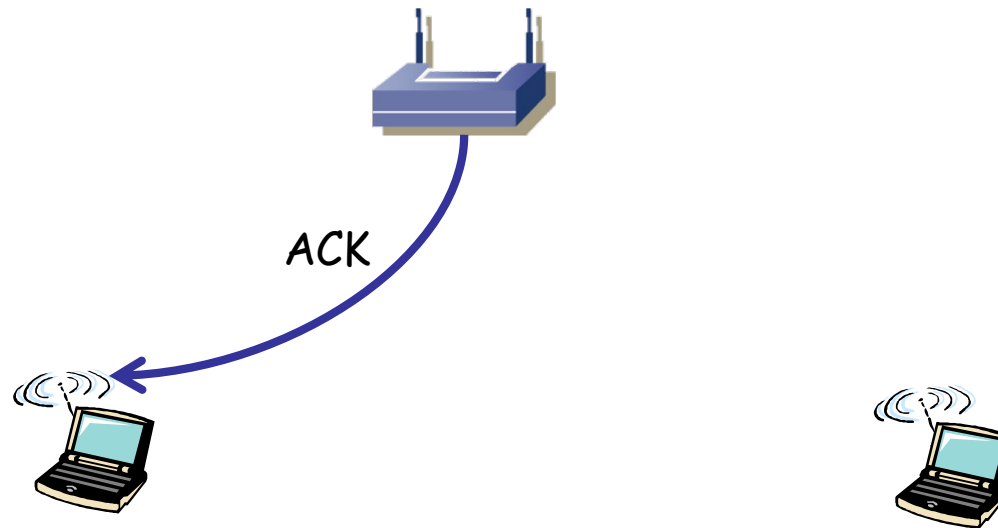
Incluyendo tramas de control

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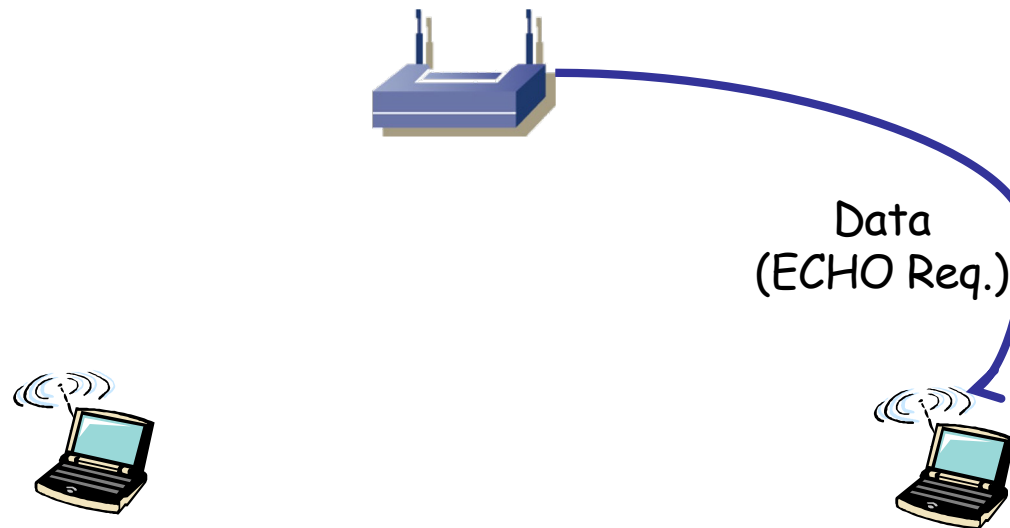
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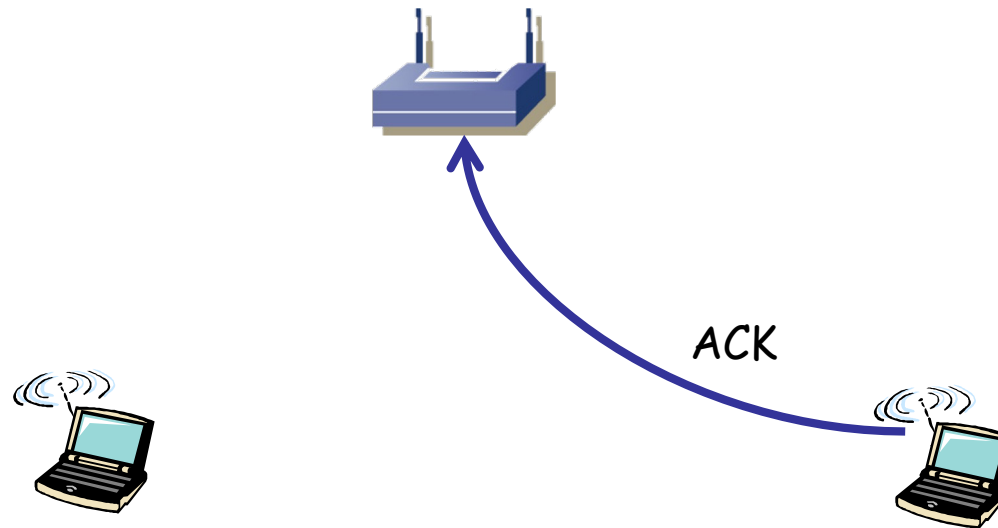
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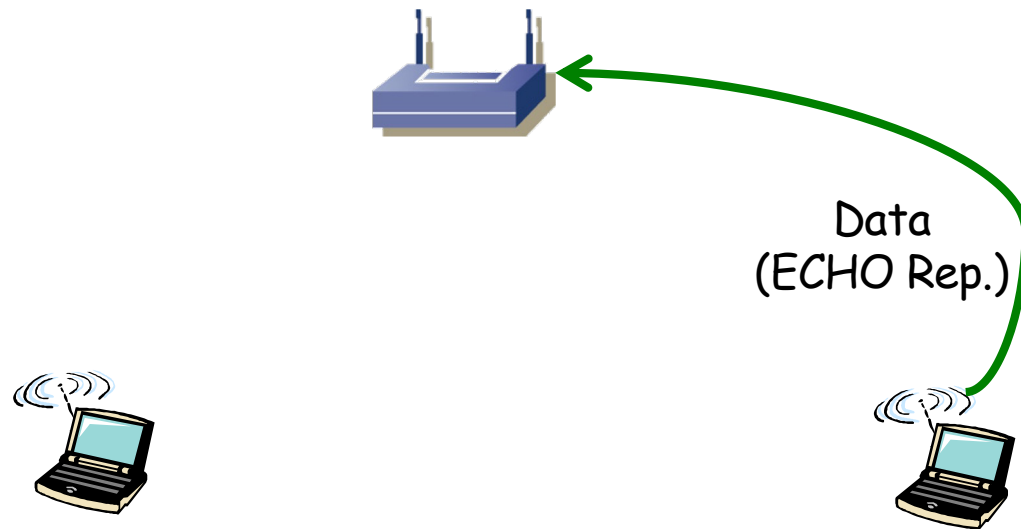
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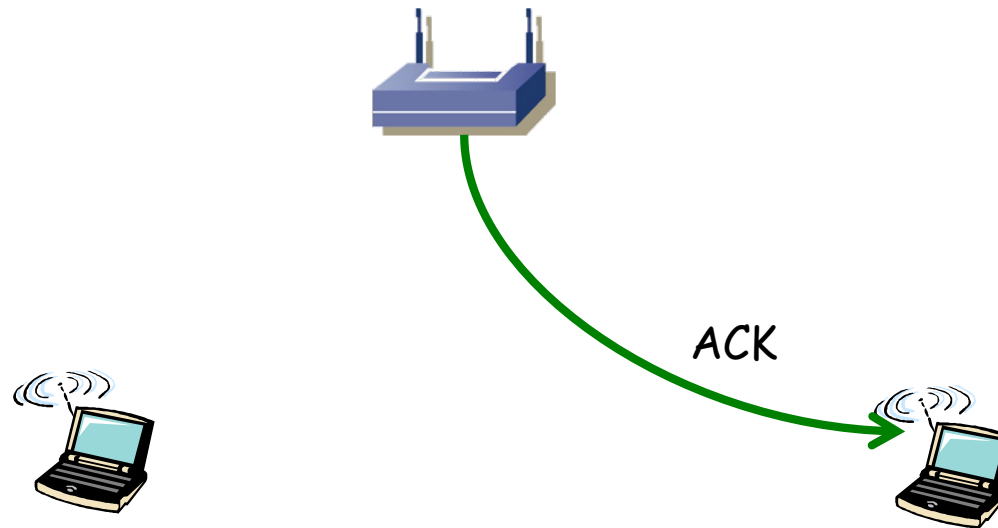
Incluyendo tramas de control

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Incluyendo tramas de control

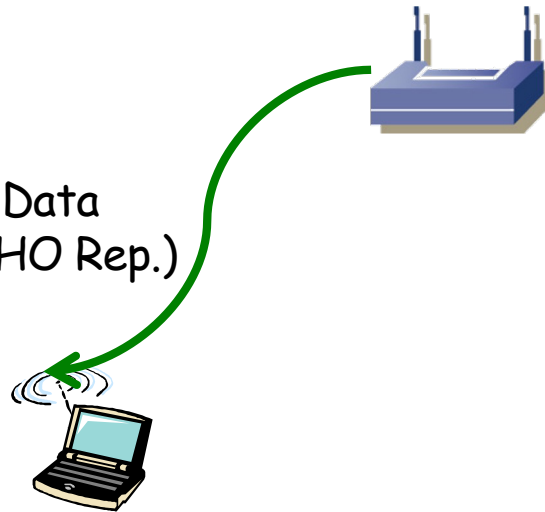
No.	Time	Arrival Time	Source	Destination	Length	Data rate	Transmitter address	Receiver address	Source address	Receiver address	Info
1	0.000000000	0.000000000	192.168.1.100	192.168.1.101	134	12	00:13:f7:54:32:01	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,...
2	0.000016446	0.000016446		SmcNetwo_54:32:01 ...	28	12		00:13:f7:54:32:01			Acknowledgement, Flags=.....
3	0.000270064	0.000253618	192.168.1.100	192.168.1.101	134	48	00:13:10:92:a8:60	00:13:f7:54:33:53	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,...
4	0.000287857	0.000017793		Cisco-Li_92:a8:60 ...	28	24		00:13:10:92:a8:60			Acknowledgement, Flags=.....
5	0.000314591	0.000026734	192.168.1.101	192.168.1.100	134	54	00:13:f7:54:33:53	00:13:10:92:a8:60	00:13:f7:54:33:53	00:13:f7:54:32:01	Echo (ping) reply id=0x099a,...
6	0.000390506	0.000075915		SmcNetwo_54:33:53 ...	28	24		00:13:f7:54:33:53			Acknowledgement, Flags=.....
7	0.000728395	0.000337889	192.168.1.101	192.168.1.100	134	54	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	00:13:f7:54:32:01	Echo (ping) reply id=0x099a,...
8	0.000745338	0.000016943		Cisco-Li_92:a8:60 ...	28	24		00:13:10:92:a8:60			Acknowledgement, Flags=.....



Incluyendo tramas de control

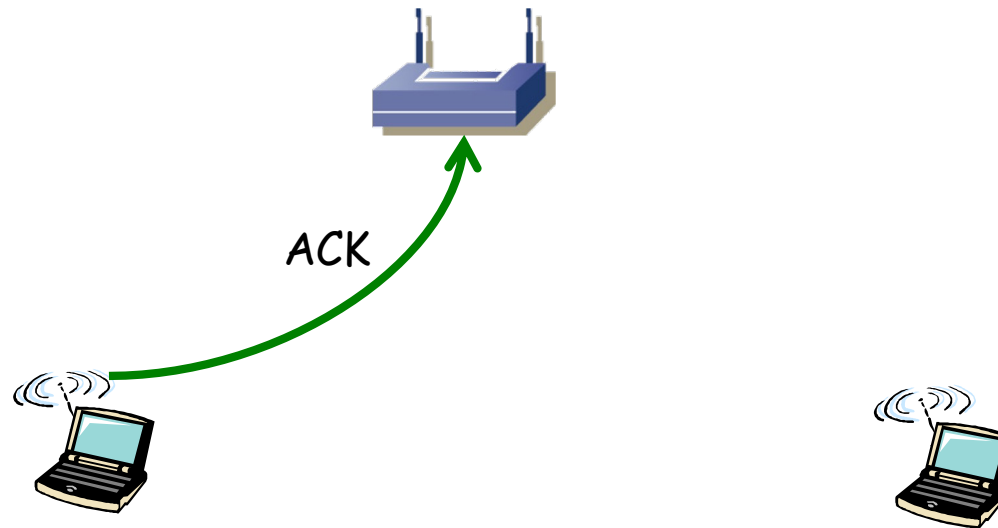
No.	Time	Arrival Time	Source	Destination	Length	Data rate	Transmitter address	Receiver address	Source address	Receiver address	Info
1	0.000000000	0.000000000	192.168.1.100	192.168.1.101	134	12	00:13:f7:54:32:01	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,...
2	0.000016446	0.000016446		SmcNetwo_54:32:01 ...	28	12		00:13:f7:54:32:01			Acknowledgement, Flags=.....
3	0.000270064	0.000253618	192.168.1.100	192.168.1.101	134	48	00:13:10:92:a8:60	00:13:f7:54:33:53	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,...
4	0.000287857	0.000017793		Cisco-Li_92:a8:60 ...	28	24		00:13:10:92:a8:60			Acknowledgement, Flags=.....
5	0.000314591	0.000026734	192.168.1.101	192.168.1.100	134	54	00:13:f7:54:33:53	00:13:10:92:a8:60	00:13:f7:54:33:53	00:13:f7:54:32:01	Echo (ping) reply id=0x099a,...
6	0.000390506	0.000075915		SmcNetwo_54:33:53 ...	28	24		00:13:f7:54:33:53			Acknowledgement, Flags=.....
7	0.000728395	0.000337889	192.168.1.101	192.168.1.100	134	54	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	00:13:f7:54:32:01	Echo (ping) reply id=0x099a,...
8	0.000745338	0.000016943		Cisco-Li_92:a8:60 ...	28	24		00:13:10:92:a8:60			Acknowledgement, Flags=.....

Data
(ECHO Rep.)



Incluyendo tramas de control

No.	Time	Arrival Time	Source	Destination	Length	Data rate	Transmitter address	Receiver address	Source address	Receiver address	Info
1	0.000000000	0.000000000	192.168.1.100	192.168.1.101	134	12	00:13:f7:54:32:01	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,...
2	0.000016446	0.000016446		SmcNetwo_54:32:01 ...	28	12		00:13:f7:54:32:01			Acknowledgement, Flags=.....
3	0.000270064	0.000253618	192.168.1.100	192.168.1.101	134	48	00:13:10:92:a8:60	00:13:f7:54:33:53	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,...
4	0.000287857	0.000017793		Cisco-Li_92:a8:60 ...	28	24		00:13:10:92:a8:60			Acknowledgement, Flags=.....
5	0.000314591	0.000026734	192.168.1.101	192.168.1.100	134	54	00:13:f7:54:33:53	00:13:10:92:a8:60	00:13:f7:54:33:53	00:13:f7:54:32:01	Echo (ping) reply id=0x099a,...
6	0.000390506	0.000075915		SmcNetwo_54:33:53 ...	28	24		00:13:f7:54:33:53			Acknowledgement, Flags=.....
7	0.000728395	0.000337889	192.168.1.101	192.168.1.100	134	54	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	00:13:f7:54:32:01	Echo (ping) reply id=0x099a,...
8	0.000745338	0.000016943		Cisco-Li_92:a8:60 ...	28	24		00:13:10:92:a8:60			Acknowledgement, Flags=.....



Contenido de las tramas

No.	Time	Arrival Time	Source	Destination	Length	Data rate	Transmitter addr
1	0.000000000	0.000000000	192.168.1.100	192.168.1.101	134	12	00:13:f7:54:
2	0.000016446	0.000016446		SmcNetwo_54:32:01 ...	28	12	
3	0.000270064	0.000253618	192.168.1.100	192.168.1.101	134	48	00:13:10:92:
4	0.000287857	0.000017793		Cisco-Li_92:a8:60 ...	28	24	
5	0.000314591	0.000026734	192.168.1.101	192.168.1.100	134	54	00:13:f7:54:
6	0.000390506	0.000075915		SmcNetwo_54:33:53 ...	28	24	
7	0.000728395	0.000337889	192.168.1.101	192.168.1.100	134	54	00:13:10:92:
8	0.000745338	0.000016943		Cisco-Li_92:a8:60 ...	28	24	

▶ Frame 1: 134 bytes on wire (1072 bits), 134 bytes captured (1072 bits) on interface 0
▶ Radiotap Header v0, Length 18
▶ 802.11 radio information
▶ IEEE 802.11 Data, Flags:T
▶ Logical-Link Control

▼ Internet Protocol Version 4, Src: 192.168.1.100, Dst: 192.168.1.101
0100 = Version: 4
.... 0101 = Header Length: 20 bytes (5)
▶ Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
Total Length: 84
Identification: 0xc38b (50059)
▶ Flags: 0x02 (Don't Fragment)
Fragment offset: 0
Time to live: 64
Protocol: ICMP (1)
Header checksum: 0xf303 [validation disabled]
[Header checksum status: Unverified]
Source: 192.168.1.100
Destination: 192.168.1.101
[Source GeoIP: Unknown]
[Destination GeoIP: Unknown]

▶ Internet Control Message Protocol

0000 00 00 12 00 2e 48 00 00 00 18 6c 09 c0 00 cc 01H.. .l.....
0010 00 00 08 01 34 00 00 13 10 92 a8 60 00 13 f7 544... ..T
0020 32 01 00 13 f7 54 33 53 40 9b aa aa 03 00 00 00 00 2.....T3S @.....
0030 08 00 45 00 00 54 c3 8b 40 00 40 01 f3 03 c0 a8 ..E..T.. @.@.....
0040 01 64 c0 a8 01 65 08 00 99 b0 09 9a 02 1f 2f 61 .d...e../a
0050 f0 59 00 00 00 00 6a 08 0a 00 00 00 00 10 11 .Y....j.
0060 12 13 14 15 16 17 18 19 1a 1b 1c 1d 1e 1f 20 21 12 13 14 15 16 17 18 19 1a 1b 1c 1d 1e 1f 20 21
0070 22 23 24 25 26 27 28 29 2a 2b 2c 2d 2e 2f 30 31 "#\$%&'()*+,-./01
0080 32 33 34 35 36 37 234567

No.	Time	Arrival Time	Source	Destination	Length	Data rate	Transmitter
1	0.000000000	0.000000000	192.168.1.100	192.168.1.101	134	12	00:13:f7:54:
2	0.000016446	0.000016446		SmcNetwo_54:32:01 ...	28	12	
3	0.000270064	0.000253618	192.168.1.100	192.168.1.101	134	48	00:13:10:92:
4	0.000287857	0.000017793		Cisco-Li_92:a8:60 ...	28	24	
5	0.000314591	0.000026734	192.168.1.101	192.168.1.100	134	54	00:13:f7:54:
6	0.000390506	0.000075915		SmcNetwo_54:33:53 ...	28	24	
7	0.000728395	0.000337889	192.168.1.101	192.168.1.100	134	54	00:13:10:92:
8	0.000745338	0.000016943		Cisco-Li_92:a8:60 ...	28	24	

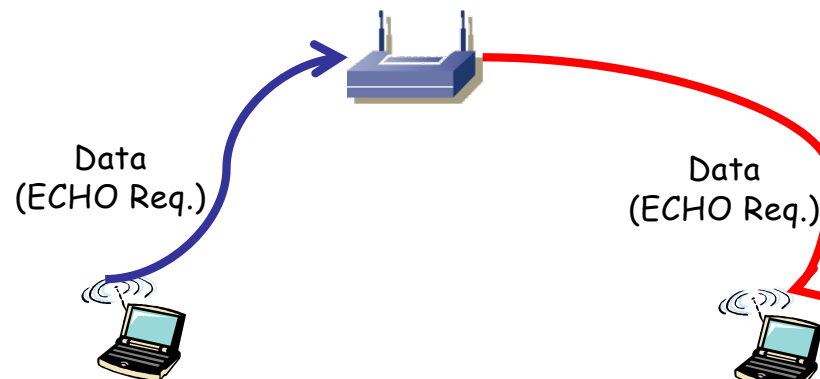
▶ Frame 3: 134 bytes on wire (1072 bits), 134 bytes captured (1072 bits) on interface 0
▶ Radiotap Header v0, Length 18
▶ 802.11 radio information
▶ IEEE 802.11 Data, Flags:T
▶ Logical-Link Control

▼ Internet Protocol Version 4, Src: 192.168.1.100, Dst: 192.168.1.101
0100 = Version: 4
.... 0101 = Header Length: 20 bytes (5)
▶ Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
Total Length: 84
Identification: 0xc38b (50059)
▶ Flags: 0x02 (Don't Fragment)
Fragment offset: 0
Time to live: 64
Protocol: ICMP (1)
Header checksum: 0xf303 [validation disabled]
[Header checksum status: Unverified]
Source: 192.168.1.100
Destination: 192.168.1.101
[Source GeoIP: Unknown]
[Destination GeoIP: Unknown]

▶ Internet Control Message Protocol

0000 00 00 12 00 2e 48 00 00 00 18 6c 09 c0 00 df 01H.. .l.....
0010 00 00 08 02 2c 00 00 13 f7 54 33 53 00 13 10 92T3S....
0020 a8 60 00 13 f7 54 32 01 a0 6d aa aa 03 00 00 00 00 ..T2.. .m.....
0030 08 00 45 00 00 54 c3 8b 40 00 40 01 f3 03 c0 a8 ..E..T.. @.@.....
0040 01 64 c0 a8 01 65 08 00 99 b0 09 9a 02 1f 2f 61 .d...e../a
0050 f0 59 00 00 00 00 6a 08 0a 00 00 00 00 10 11 .Y....j.
0060 12 13 14 15 16 17 18 19 1a 1b 1c 1d 1e 1f 20 21 12 13 14 15 16 17 18 19 1a 1b 1c 1d 1e 1f 20 21
0070 22 23 24 25 26 27 28 29 2a 2b 2c 2d 2e 2f 30 31 "#\$%&'()*+,-./01
0080 32 33 34 35 36 37 234567

Idéntico hacia y desde el AP
(bridging)



Contenido

No.	Time	Arrival Time	Source	Destination	Length	Data rate	Transmitter addr
1	0.000000000	0.000000000	192.168.1.100	192.168.1.101	134	12	00:13:f7:54:
2	0.000016446	0.000016446		SmcNetwo_54:32:01 ...	28	12	
3	0.000270064	0.000253618	192.168.1.100	192.168.1.101	134	48	00:13:10:92:
4	0.000287857	0.000017793		Cisco-Li_92:a8:60 ...	28	24	
5	0.000314591	0.000026734	192.168.1.101	192.168.1.100	134	54	00:13:f7:54:
6	0.000390506	0.000075915		SmcNetwo_54:33:53 ...	28	24	
7	0.000728395	0.000337889	192.168.1.101	192.168.1.100	134	54	00:13:10:92:
8	0.000745338	0.000016943		Cisco-Li_92:a8:60 ...	28	24	

▶ Frame 1: 134 bytes on wire (1072 bits), 134 bytes captured (1072 bits) on interface 0
 ▶ Radiotap Header v0, Length 18
 ▶ 802.11 radio information
 ▶ IEEE 802.11 Data, Flags:T
 ▶ Logical-Link Control

▼ Internet Protocol Version 4, Src: 192.168.1.100, Dst: 192.168.1.101

0100 = Version: 4
 0101 = Header Length: 20 bytes (5)

▶ Differentiated Services Field
 Total Length: 84
 Identification: 0xc38b (5005)
 ▶ Flags: 0x02 (Don't Fragment)
 Fragment offset: 0
 Time to live: 64
 Protocol: ICMP (1)
 Header checksum: 0xf303 [valid]
 [Header checksum status: Unchecked]
 Source: 192.168.1.100
 Destination: 192.168.1.101
 [Source GeoIP: Unknown]
 [Destination GeoIP: Unknown]

▶ Internet Control Message Protocol

0000	00 00 12 00 2e 48 00 00	00 18 6c 09 c0 00 cc 01	H.. .l.....
0010	00 00 08 01 34 00 00 13	10 92 a8 60 00 13 f7 54	4... ..T
0020	32 01 00 13 f7 54 33 53	40 9b aa aa 03 00 00 00	2....T3S @.....
0030	08 00 45 00 00 54 c3 8b	40 00 40 01 f3 03 c0 a8	..E..T.. @.@.....
0040	01 64 c0 a8 01 65 08 00	99 b0 09 9a 02 1f 2f 61	.d...e../a
0050	f0 59 00 00 00 00 6a 08	0a 00 00 00 00 00 10 11	.Y....j.
0060	12 13 14 15 16 17 18 19	1a 1b 1c 1d 1e 1f 20 21	 !
0070	22 23 24 25 26 27 28 29	2a 2b 2c 2d 2e 2f 30 31	"#%&'()*+,-./01
0080	32 33 34 35 36 37		234567

No.	Time	Arrival Time	Source	Destination	Length	Data rate	Transmitter
1	0.000000000	0.000000000	192.168.1.100	192.168.1.101	134	12	00:13:f7:54:
2	0.000016446	0.000016446		SmcNetwo_54:32:01 ...	28	12	
3	0.000270064	0.000253618	192.168.1.100	192.168.1.101	134	48	00:13:10:92:
4	0.000287857	0.000017793		Cisco-Li_92:a8:60 ...	28	24	
5	0.000314591	0.000026734	192.168.1.101	192.168.1.100	134	54	00:13:f7:54:
6	0.000390506	0.000075915		SmcNetwo_54:33:53 ...	28	24	
7	0.000728395	0.000337889	192.168.1.101	192.168.1.100	134	54	00:13:10:92:
8	0.000745338	0.000016943		Cisco-Li_92:a8:60 ...	28	24	

▶ Frame 3: 134 bytes on wire (1072 bits), 134 bytes captured (1072 bits) on interface 0
 ▶ Radiotap Header v0, Length 18
 ▶ 802.11 radio information
 ▶ IEEE 802.11 Data, Flags:F.
 ▶ Logical-Link Control

▼ Internet Protocol Version 4, Src: 192.168.1.100, Dst: 192.168.1.101

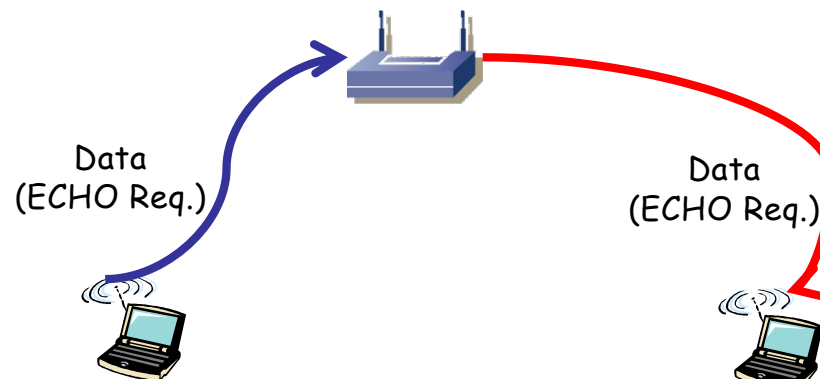
0100 = Version: 4
 0101 = Header Length: 20 bytes (5)

[Source GeoIP: Unknown]
 [Destination GeoIP: Unknown]

▶ Internet Control Message Protocol

0000	00 00 12 00 2e 48 00 00	00 60 6c 09 c0 00 df 01	H.. .l.....
0010	00 00 08 02 2c 00 00 13	f7 54 33 53 00 13 10 92	T3S....
0020	a8 60 00 13 f7 54 32 01	a0 6d aa aa 03 00 00 00	T2.. .m.....
0030	08 00 45 00 00 54 c3 8b	40 00 40 01 f3 03 c0 a8	..E..T.. @.@.....
0040	01 64 c0 a8 01 65 08 00	99 b0 09 9a 02 1f 2f 61	.d...e../a
0050	f0 59 00 00 00 00 6a 08	0a 00 00 00 00 00 10 11	.Y....j.
0060	12 13 14 15 16 17 18 19	1a 1b 1c 1d 1e 1f 20 21	 !
0070	22 23 24 25 26 27 28 29	2a 2b 2c 2d 2e 2f 30 31	"#%&'()*+,-./01
0080	32 33 34 35 36 37		234567

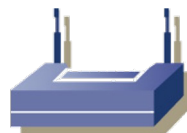
Solo ha cambiado la cabecera 802.11.
 Cambian las direcciones MAC y que primero
 va hacia el DS y luego viene del DS



Direcciones MAC

No.	Time	Arrival Time	Source	Destination	Length	Data rate	Transmitter address	Receiver address	Source address	Receiver address	Info
1	0.000000000	0.000000000	192.168.1.100	192.168.1.101	134	12	00:13:f7:54:32:01	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,...
2	0.000016446	0.000016446		SmcNetwo_54:32:01 ...	28	12		00:13:f7:54:32:01			Acknowledgement, Flags=.....
3	0.000270064	0.000253618	192.168.1.100	192.168.1.101	134	48	00:13:10:92:a8:60	00:13:f7:54:33:53	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,...
4	0.000287857	0.000017793		Cisco-Li_92:a8:60 ...	28	24		00:13:10:92:a8:60			Acknowledgement, Flags=.....
5	0.000314591	0.000026734	192.168.1.101	192.168.1.100	134	54	00:13:f7:54:33:53	00:13:10:92:a8:60	00:13:f7:54:33:53	00:13:f7:54:32:01	Echo (ping) reply id=0x099a,...
6	0.000390506	0.000075915		SmcNetwo_54:33:53 ...	28	24		00:13:f7:54:33:53			Acknowledgement, Flags=.....
7	0.000728395	0.000337889	192.168.1.101	192.168.1.100	134	54	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	00:13:f7:54:32:01	Echo (ping) reply id=0x099a,...
8	0.000745338	0.000016943		Cisco-Li_92:a8:60 ...	28	24		00:13:10:92:a8:60			Acknowledgement, Flags=.....

00:13:10:92:a8:60



00:13:f7:54:32:01



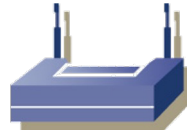
00:13:f7:54:33:53

Direcciones MAC

No.	Time	Arrival Time	Source	Destination	Length	Data rate	Transmitter address	Receiver address	Source address	Receiver address	Info
1	0.000000000	0.000000000	192.168.1.100	192.168.1.101	134	12	00:13:f7:54:32:01	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,...
2	0.000016446	0.000016446		SmcNetwo_54:32:01 ...	28	12		00:13:f7:54:32:01			Acknowledgement, Flags=.....
3	0.000270064	0.000253618	192.168.1.100	192.168.1.101	134	48	00:13:10:92:a8:60	00:13:f7:54:33:53	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,...
4	0.000287857	0.000017793		Cisco-Li_92:a8:60 ...	28	24		00:13:10:92:a8:60			Acknowledgement, Flags=.....
5	0.000314591	0.000026734	192.168.1.101	192.168.1.100	134	54	00:13:f7:54:33:53	00:13:10:92:a8:60	00:13:f7:54:33:53	00:13:f7:54:32:01	Echo (ping) reply id=0x099a,...
6	0.000390506	0.000075915		SmcNetwo_54:33:53 ...	28	24		00:13:f7:54:33:53			Acknowledgement, Flags=.....
7	0.000728395	0.000337889	192.168.1.101	192.168.1.100	134	54	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	00:13:f7:54:32:01	Echo (ping) reply id=0x099a,...
8	0.000745338	0.000016943		Cisco-Li_92:a8:60 ...	28	24		00:13:10:92:a8:60			Acknowledgement, Flags=.....

Interfaz WiFi que envía la trama

00:13:10:92:a8:60



00:13:f7:54:32:01



00:13:f7:54:33:53

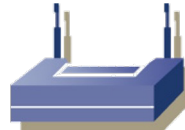
Direcciones MAC

No.	Time	Arrival Time	Source	Destination	Length	Data rate	Transmitter address	Receiver address	Source address	Receiver address	Info
1	0.000000000	0.000000000	192.168.1.100	192.168.1.101	134	12	00:13:f7:54:32:01	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,...
2	0.000016446	0.000016446		SmcNetwo_54:32:01 ...	28	12		00:13:f7:54:32:01			Acknowledgement, Flags=.....
3	0.000270064	0.000253618	192.168.1.100	192.168.1.101	134	48	00:13:10:92:a8:60	00:13:f7:54:33:53	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,...
4	0.000287857	0.000017793		Cisco-Li_92:a8:60 ...	28	24		00:13:10:92:a8:60			Acknowledgement, Flags=.....
5	0.000314591	0.000026734	192.168.1.101	192.168.1.100	134	54	00:13:f7:54:33:53	00:13:10:92:a8:60	00:13:f7:54:33:53	00:13:f7:54:32:01	Echo (ping) reply id=0x099a,...
6	0.000390506	0.000075915		SmcNetwo_54:33:53 ...	28	24		00:13:f7:54:33:53			Acknowledgement, Flags=.....
7	0.000728395	0.000337889	192.168.1.101	192.168.1.100	134	54	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	00:13:f7:54:32:01	Echo (ping) reply id=0x099a,...
8	0.000745338	0.000016943		Cisco-Li_92:a8:60 ...	28	24		00:13:10:92:a8:60			Acknowledgement, Flags=.....

Interfaz WiFi que envía la trama

Interfaz WiFi que debe leer la trama

00:13:10:92:a8:60



00:13:f7:54:32:01



00:13:f7:54:33:53

Direcciones MAC

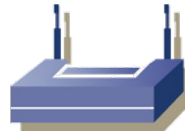
No.	Time	Arrival Time	Source	Destination	Length	Data rate	Transmitter address	Receiver address	Source address	Receiver address	Info
1	0.000000000	0.000000000	192.168.1.100	192.168.1.101	134	12	00:13:f7:54:32:01	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,...
2	0.000016446	0.000016446		SmcNetwo_54:32:01 ...	28	12		00:13:f7:54:32:01			Acknowledgement, Flags=.....
3	0.000270064	0.000253618	192.168.1.100	192.168.1.101	134	48	00:13:10:92:a8:60	00:13:f7:54:33:53	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,...
4	0.000287857	0.000017793		Cisco-Li_92:a8:60 ...	28	24		00:13:10:92:a8:60			Acknowledgement, Flags=.....
5	0.000314591	0.000026734	192.168.1.101	192.168.1.100	134	54	00:13:f7:54:33:53	00:13:10:92:a8:60	00:13:f7:54:33:53	00:13:f7:54:32:01	Echo (ping) reply id=0x099a,...
6	0.000390506	0.000075915		SmcNetwo_54:33:53 ...	28	24		00:13:f7:54:33:53			Acknowledgement, Flags=.....
7	0.000728395	0.000337889	192.168.1.101	192.168.1.100	134	54	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	00:13:f7:54:32:01	Echo (ping) reply id=0x099a,...
8	0.000745338	0.000016943		Cisco-Li_92:a8:60 ...	28	24		00:13:10:92:a8:60			Acknowledgement, Flags=.....

Interfaz WiFi que envía la trama

Interfaz origen de la trama de datos

Interfaz WiFi que debe leer la trama

00:13:10:92:a8:60



00:13:f7:54:32:01



00:13:f7:54:33:53

Direcciones MAC

No.	Time	Arrival Time	Source	Destination	Length	Data rate	Transmitter address	Receiver address	Source address	Receiver address	Info
1	0.000000000	0.000000000	192.168.1.100	192.168.1.101	134	12	00:13:f7:54:32:01	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,...
2	0.000016446	0.000016446		SmcNetwo_54:32:01 ...	28	12		00:13:f7:54:32:01			Acknowledgement, Flags=.....
3	0.000270064	0.000253618	192.168.1.100	192.168.1.101	134	48	00:13:10:92:a8:60	00:13:f7:54:33:53	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,...
4	0.000287857	0.000017793		Cisco-Li_92:a8:60 ...	28	24		00:13:10:92:a8:60			Acknowledgement, Flags=.....
5	0.000314591	0.000026734	192.168.1.101	192.168.1.100	134	54	00:13:f7:54:33:53	00:13:10:92:a8:60	00:13:f7:54:33:53	00:13:f7:54:32:01	Echo (ping) reply id=0x099a,...
6	0.000390506	0.000075915		SmcNetwo_54:33:53 ...	28	24		00:13:f7:54:33:53			Acknowledgement, Flags=.....
7	0.000728395	0.000337889	192.168.1.101	192.168.1.100	134	54	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	00:13:f7:54:32:01	Echo (ping) reply id=0x099a,...
8	0.000745338	0.000016943		Cisco-Li_92:a8:60 ...	28	24		00:13:10:92:a8:60			Acknowledgement, Flags=.....

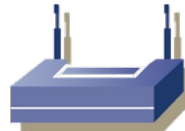
Interfaz WiFi que envía la trama

Interfaz origen de la trama de datos

Interfaz WiFi que debe leer la trama

Interfaz destino de la trama de datos

00:13:10:92:a8:60



00:13:f7:54:32:01



00:13:f7:54:33:53

Direcciones MAC: Ejemplo

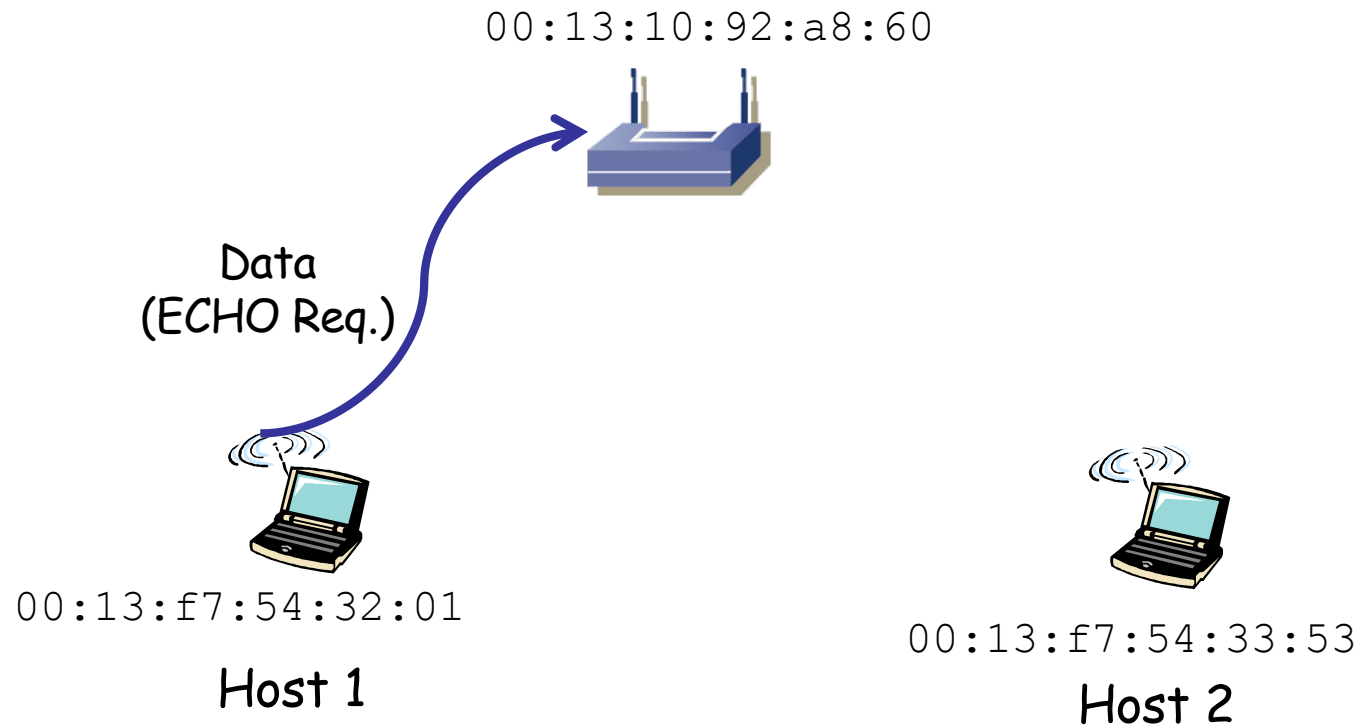
No.	Time	Arrival Time	Source	Destination	Length	Data rate	Transmitter address	Receiver address	Source address	Receiver address	Info
1	0.000000000	0.000000000	192.168.1.100	192.168.1.101	134	12	00:13:f7:54:32:01	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,...
2	0.000016446	0.000016446		SmcNetwo_54:32:01 ...	28	12		00:13:f7:54:32:01			Acknowledgement, Flags=.....
3	0.000270064	0.000253618	192.168.1.100	192.168.1.101	134	48	00:13:10:92:a8:60	00:13:f7:54:33:53	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,...
4	0.000287857	0.000017793		Cisco-Li_92:a8:60 ...	28	24		00:13:10:92:a8:60			Acknowledgement, Flags=.....
5	0.000314591	0.000026734	192.168.1.101	192.168.1.100	134	54	00:13:f7:54:33:53	00:13:10:92:a8:60	00:13:f7:54:33:53	00:13:f7:54:32:01	Echo (ping) reply id=0x099a,...
6	0.000390506	0.000075915		SmcNetwo_54:33:53 ...	28	24		00:13:f7:54:33:53			Acknowledgement, Flags=.....
7	0.000728395	0.000337889	192.168.1.101	192.168.1.100	134	54	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	00:13:f7:54:32:01	Echo (ping) reply id=0x099a,...
8	0.000745338	0.000016943		Cisco-Li_92:a8:60 ...	28	24		00:13:10:92:a8:60			Acknowledgement, Flags=.....

Transmite el interfaz del host 1

Recibe el Punto de acceso

El origen de la trama es el host 1

El destino es el host 2



Direcciones MAC: Ejemplo

No.	Time	Arrival Time	Source	Destination	Length	Data rate	Transmitter address	Receiver address	Source address	Receiver address	Info
1	0.000000000	0.000000000	192.168.1.100	192.168.1.101	134	12	00:13:f7:54:32:01	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,...
2	0.000016446	0.000016446		SmcNetwo_54:32:01 ...	28	12		00:13:f7:54:32:01			Acknowledgement, Flags=.....
3	0.000270064	0.000253618	192.168.1.100	192.168.1.101	134	48	00:13:10:92:a8:60	00:13:f7:54:33:53	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,...
4	0.000287857	0.000017793		Cisco-Li_92:a8:60 ...	28	24		00:13:10:92:a8:60			Acknowledgement, Flags=.....
5	0.000314591	0.000026734	192.168.1.101	192.168.1.100	134	54	00:13:f7:54:33:53	00:13:10:92:a8:60	00:13:f7:54:33:53	00:13:f7:54:32:01	Echo (ping) reply id=0x099a,...
6	0.000390506	0.000075915		SmcNetwo_54:33:53 ...	28	24		00:13:f7:54:33:53			Acknowledgement, Flags=.....
7	0.000728395	0.000337889	192.168.1.101	192.168.1.100	134	54	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	00:13:f7:54:32:01	Echo (ping) reply id=0x099a,...
8	0.000745338	0.000016943		Cisco-Li_92:a8:60 ...	28	24		00:13:10:92:a8:60			Acknowledgement, Flags=.....

▶ Frame 1: 134 bytes on wire (1072 bits), 134 bytes captured (1072 bits) on interface 0

▶ Radiotap Header v0, Length 18

▶ 802.11 radio information

▼ IEEE 802.11 Data, Flags:T

Type/Subtype: Data (0x0020)

▼ Frame Control Field: 0x0001

.... ..00 = Version: 0

.... 10.. = Type: Data frame (2)

0000 = Subtype: 0

▼ Flags: 0x001

.... ..01 = DS status: Frame from STA to DS via an AP (To DS: 1 From DS: 0) (0x1)

.... .0.. = More Fragments: This is the last fragment

.... 0... = Retry: Frame is not being retransmitted

...0 = PWR MGT: STA will stay up

..0. = More Data: No data buffered

.0.. = Protected flag: Data is not protected

0... = Order flag: Not strictly ordered

.000 0000 0011 0100 = Duration: 52 microseconds

Receiver address: Cisco-Li_92:a8:60 (00:13:10:92:a8:60)

Destination address: SmcNetwo_54:33:53 (00:13:f7:54:33:53)

Transmitter address: SmcNetwo_54:32:01 (00:13:f7:54:32:01)

Source address: SmcNetwo_54:32:01 (00:13:f7:54:32:01)

BSS Id: Cisco-Li_92:a8:60 (00:13:10:92:a8:60)

STA address: SmcNetwo_54:32:01 (00:13:f7:54:32:01)

.... 0000 = Fragment number: 0

1001 1011 0100 = Sequence number: 2484

▶ Logical-Link Control

▶ Internet Protocol Version 4, Src: 192.168.1.100, Dst: 192.168.1.101

▶ Internet Control Message Protocol

0000 00 00 12 00 2e 48 00 00 00 18 6c 09 c0 00 cc 01H.. .l....

0010 00 00 08 01 34 00 00 13 10 92 a8 60 00 13 f7 54 ...4... ..T

0020 32 01 00 13 f7 54 33 53 40 9b aa aa 03 00 00 00 2....T3S @.....

0030 08 00 45 00 00 54 c3 8b 40 00 40 01 f3 03 c0 a8 ..E..T.. @.@.....

0040 01 64 c0 a8 01 65 08 00 99 b0 09 9a 02 1f 2f 61 .d...e../a

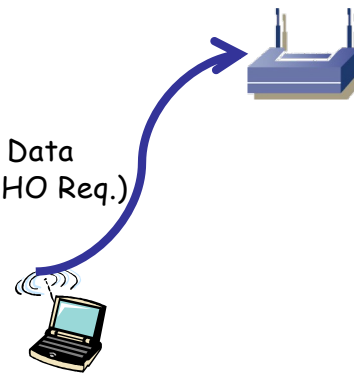
0050 f0 59 00 00 00 0a 08 0a 00 00 00 00 00 10 11 .Y....j.

0060 12 13 14 15 16 17 18 19 1a 1b 1c 1d 1e 1f 20 21 !

0070 22 23 24 25 26 27 28 29 2a 2b 2c 2d 2e 2f 30 31 "##&'()*+,-./01

0080 32 33 34 35 36 37 234567

Data
(ECHO Req.)



Direcciones MAC: Ejemplo

No.	Time	Arrival Time	Source	Destination	Length	Data rate	Transmitter address	Receiver address	Source address	Receiver address	Info
1	0.000000000	0.000000000	192.168.1.100	192.168.1.101	134	12	00:13:f7:54:32:01	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,...
2	0.000016446	0.000016446		SmcNetwo_54:32:01 ...	28	12		00:13:f7:54:32:01			Acknowledgement, Flags=.....
3	0.000270064	0.000253618	192.168.1.100	192.168.1.101	134	48	00:13:10:92:a8:60	00:13:f7:54:33:53	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,...
4	0.000287857	0.000017793		Cisco-Li_92:a8:60 ...	28	24		00:13:10:92:a8:60			Acknowledgement, Flags=.....
5	0.000314591	0.000026734	192.168.1.101	192.168.1.100	134	54	00:13:f7:54:33:53	00:13:10:92:a8:60	00:13:f7:54:33:53	00:13:f7:54:32:01	Echo (ping) reply id=0x099a,...
6	0.000390506	0.000075915		SmcNetwo_54:33:53 ...	28	24		00:13:f7:54:33:53			Acknowledgement, Flags=.....
7	0.000728395	0.000337889	192.168.1.101	192.168.1.100	134	54	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	00:13:f7:54:32:01	Echo (ping) reply id=0x099a,...
8	0.000745338	0.000016943		Cisco-Li_92:a8:60 ...	28	24		00:13:10:92:a8:60			Acknowledgement, Flags=.....

► Frame 1: 134 bytes on wire (1072 bits), 134 bytes captured (1072 bits) on interface 0
 ► Radiotap Header v0, Length 18
 ► 802.11 radio information

▼ IEEE 802.11 Data, Flags:T

Type/Subtype: Data (0x0020)

▼ Frame Control Field: 0x0001

.... ..00 = Version: 0

.... 10.. = Type: Data frame (2)

0000 = Subtype: 0

▼ Flags: 0x01

.... ..01 = DS status: Frame from STA to DS via an AP (To DS: 1 From DS: 0) (0x1)

.... ..0.. = More Fragments: This is the last fragment

.... 0... = Retry: Frame is not being retransmitted

...0 = PWR MGT: STA will stay up

..0. = More Data: No data buffered

.0.. = Protected flag: Data is not protected

0... = Order flag: Not strictly ordered

.000 0000 0011 0100 = Duration: 52 microseconds

Receiver address: Cisco-Li_92:a8:60 (00:13:10:92:a8:60)

Destination address: SmcNetwo_54:33:53 (00:13:f7:54:33:53)

Transmitter address: SmcNetwo_54:32:01 (00:13:f7:54:32:01)

Source address: SmcNetwo_54:32:01 (00:13:f7:54:32:01)

BSS Id: Cisco-Li_92:a8:60 (00:13:10:92:a8:60)

STA address: SmcNetwo_54:32:01 (00:13:f7:54:32:01)

.... ..0000 = Fragment number: 0

1001 1011 0100 = Sequence number: 2484

► Logical-Link Control

► Internet Protocol Version 4, Src: 192.168.1.100, Dst: 192.168.1.101

► Internet Control Message Protocol

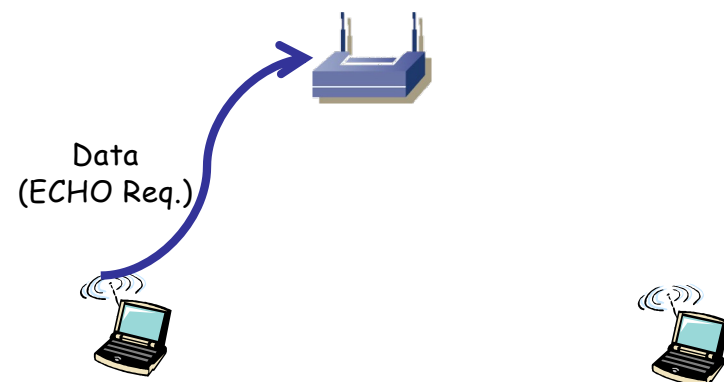
```

0000 00 00 12 00 2e 48 00 00 00 18 6c 09 c0 00 cc 01 .....H..l....
0010 00 00 08 01 34 00 00 13 10 92 a8 60 00 13 f7 54 ...4...T
0020 32 01 00 13 f7 54 33 53 40 9b aa aa 03 00 00 00 2....T3S @.....
0030 08 00 45 00 00 54 c3 8b 40 00 40 01 f3 03 c0 a8 ..E..T.. @. ....
0040 01 64 c0 a8 01 65 08 00 99 b0 09 9a 02 1f 2f 61 .d...e.. ..../a
0050 f0 59 00 00 00 0a 08 0a 00 00 00 00 00 10 11 .Y....j. ....
0060 12 13 14 15 16 17 18 19 1a 1b 1c 1d 1e 1f 20 21 ..... ..!
0070 22 23 24 25 26 27 28 29 2a 2b 2c 2d 2e 2f 30 31 "##&'()*+,-./01
0080 32 33 34 35 36 37 234567
  
```

Trama de datos

Va de una estación (STA) al Distribution System (DS). La funcionalidad de bridge del AP es parte del DS.

Duración, para que el resto de STAs sepan el tiempo que va a estar ocupado el medio. Incluye al ACK.



Direcciones MAC: Ejemplo

- ▶ Frame 1: 134 bytes on wire (1072 bits), 134 bytes captured (1072 bits) on interface 0
- ▶ Radiotap Header v0, Length 18
- ▶ 802.11 radio information

▼ IEEE 802.11 Data, Flags:T

Type/Subtype: Data (0x0020)

▼ Frame Control Field: 0x0801

.... ..00 = Version: 0

.... 10.. = Type: Data frame (2)

0000 = Subtype: 0

▼ Flags: 0x01

.... ..01 = DS status: Frame from STA to DS via an AP (To DS: 1 From DS: 0) (0x1)

.... .0.. = More Fragments: This is the last fragment

.... 0... = Retry: Frame is not being retransmitted

...0 = PWR MGT: STA will stay up

..0. = More Data: No data buffered

.0.. = Protected flag: Data is not protected

0... = Order flag: Not strictly ordered

.000 0000 0011 0100 = Duration: 52 microseconds

Receiver address: Cisco-Li_92:a8:60 (00:13:10:92:a8:60)

Destination address: SmcNetwo_54:33:53 (00:13:f7:54:33:53)

Transmitter address: SmcNetwo_54:32:01 (00:13:f7:54:32:01)

Source address: SmcNetwo_54:32:01 (00:13:f7:54:32:01)

BSS Id: Cisco-Li_92:a8:60 (00:13:10:92:a8:60)

STA address: SmcNetwo_54:32:01 (00:13:f7:54:32:01)

.... 0000 = Fragment number: 0

1001 1011 0100 = Sequence number: 2484

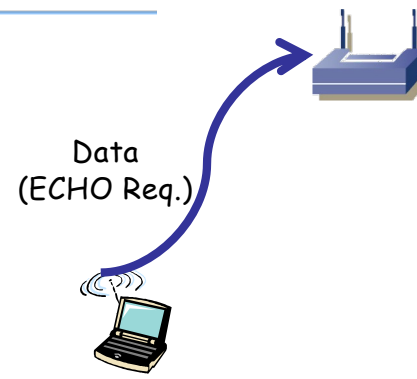
▶ Logical-Link Control

▶ Internet Protocol Version 4, Src: 192.168.1.100, Dst: 192.168.1.101

▶ Internet Control Message Protocol

```
0000 00 00 12 00 2e 48 00 00 00 18 6c 09 c0 00 cc 01 .....H.. ..l.....
0010 00 00 08 01 34 00 00 13 10 92 a8 60 00 13 f7 54 ....4... ..\...T
0020 32 01 00 13 f7 54 33 53 40 9b aa aa 03 00 00 00 2....T3S @.....
0030 08 00 45 00 00 54 c3 8b 40 00 40 01 f3 03 c0 a8 ..E..T.. @.@.....
0040 01 64 c0 a8 01 65 08 00 99 b0 09 9a 02 1f 2f 61 .d...e.. ..../a
0050 f0 59 00 00 00 00 6a 08 0a 00 00 00 00 00 10 11 .Y....j. ....
0060 12 13 14 15 16 17 18 19 1a 1b 1c 1d 1e 1f 20 21 ..... !
0070 22 23 24 25 26 27 28 29 2a 2b 2c 2d 2e 2f 30 31 "#$%&'()*+,-./01
0080 32 33 34 35 36 37 234567
```

¡ No hay 5 direcciones en la trama !
Hay solo 3

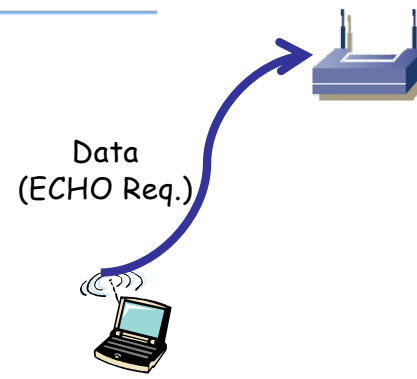


Direcciones MAC: Ejemplo

```
► Frame 1: 134 bytes on wire (1072 bits), 134 bytes captured (1072 bits) on interface 0
► Radiotap Header v0, Length 18
► 802.11 radio information
▼ IEEE 802.11 Data, Flags: .....T
  Type/Subtype: Data (0x0020)
  ▼ Frame Control Field: 0x0801
    .... ..00 = Version: 0
    .... 10.. = Type: Data frame (2)
    0000 .... = Subtype: 0
  ▼ Flags: 0x01
    .... ..01 = DS status: Frame from STA to DS via an AP (To DS: 1 From DS: 0) (0x1)
    .... .0.. = More Fragments: This is the last fragment
    .... 0... = Retry: Frame is not being retransmitted
    ...0 .... = PWR MGT: STA will stay up
    ..0. .... = More Data: No data buffered
    .0.. .... = Protected flag: Data is not protected
    0... .... = Order flag: Not strictly ordered
    .000 0000 0011 0100 = Duration: 52 microseconds
    Receiver address: Cisco-Li_92:a8:60 (00:13:10:92:a8:60)
    Destination address: SmcNetwo_54:33:53 (00:13:f7:54:33:53)
    Transmitter address: SmcNetwo_54:32:01 (00:13:f7:54:32:01)
    Source address: SmcNetwo_54:32:01 (00:13:f7:54:32:01)
    BSS Id: Cisco-Li_92:a8:60 (00:13:10:92:a8:60)
    STA address: SmcNetwo_54:32:01 (00:13:f7:54:32:01)
    .... .... 0000 = Fragment number: 0
    1001 1011 0100 .... = Sequence number: 2484
► Logical-Link Control
► Internet Protocol Version 4, Src: 192.168.1.100, Dst: 192.168.1.101
► Internet Control Message Protocol
```

En una trama que va de una STA al DS el trasmisor y el origen son el mismo

```
0000 00 00 12 00 2e 48 00 00 00 18 6c 09 c0 00 cc 01 .....H.. ..l.....
0010 00 00 08 01 34 00 00 13 10 92 a8 60 00 13 f7 54 ....4... ..\...T
0020 32 01 00 13 f7 54 33 53 40 9b aa aa 03 00 00 00 2....T3S @.....
0030 08 00 45 00 00 54 c3 8b 40 00 40 01 f3 03 c0 a8 ..E..T.. @.@.....
0040 01 64 c0 a8 01 65 08 00 99 b0 09 9a 02 1f 2f 61 .d...e.. ..../a
0050 f0 59 00 00 00 00 6a 08 0a 00 00 00 00 00 10 11 .Y....j. ....
0060 12 13 14 15 16 17 18 19 1a 1b 1c 1d 1e 1f 20 21 ..... !
0070 22 23 24 25 26 27 28 29 2a 2b 2c 2d 2e 2f 30 31 "#$%&'()*+,-./01
0080 32 33 34 35 36 37 234567
```



Direcciones MAC: Ejemplo

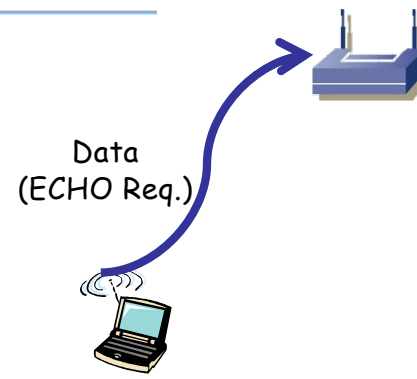
```

▶ Frame 1: 134 bytes on wire (1072 bits), 134 bytes captured (1072 bits) on interface 0
▶ Radiotap Header v0, Length 18
▶ 802.11 radio information
▼ IEEE 802.11 Data, Flags: .....T
  Type/Subtype: Data (0x0020)
  ▼ Frame Control Field: 0x0801
    .... ..00 = Version: 0
    .... 10.. = Type: Data frame (2)
    0000 .... = Subtype: 0
    ▼ Flags: 0x01
      .... ..01 = DS status: Frame from STA to DS via an AP (To DS: 1 From DS: 0) (0x1)
      .... .0.. = More Fragments: This is the last fragment
      .... 0... = Retry: Frame is not being retransmitted
      ...0 .... = PWR MGT: STA will stay up
      ..0. .... = More Data: No data buffered
      .0.. .... = Protected flag: Data is not protected
      0... .... = Order flag: Not strictly ordered
      000 0000 0011 0100 = Duration: 52 microseconds
      Receiver address: Cisco-Li_92:a8:60 (00:13:10:92:a8:60)
      Destination address: SmcNetwo_54:33:53 (00:13:f7:54:33:53)
      Transmitter address: SmcNetwo_54:32:01 (00:13:f7:54:32:01)
      Source address: SmcNetwo_54:32:01 (00:13:f7:54:32:01)
      BSS Id: Cisco-Li_92:a8:60 (00:13:10:92:a8:60)
      STA address: SmcNetwo_54:32:01 (00:13:f7:54:32:01)
      .... ..0000 = Fragment number: 0
      1001 1011 0100 .... = Sequence number: 2484
▶ Logical-Link Control
▶ Internet Protocol Version 4, Src: 192.168.1.100, Dst: 192.168.1.101
▶ Internet Control Message Protocol

```

En una trama que va de una STA al DS el SSID es la dirección MAC del receptor, ya que es el Access Point

0000	00 00 12 00 2e 48 00 00 00 18 6c 09 c0 00 cc 01	H.. ..l.....
0010	00 00 08 01 34 00 00 13 10 92 a8 60 00 13 f7 54	4... ..\....T
0020	32 01 00 13 f7 54 33 53 40 9b aa aa 03 00 00 00	2....T3S @.....
0030	08 00 45 00 00 54 c3 8b 40 00 40 01 f3 03 c0 a8	..E..T.. @.@.....
0040	01 64 c0 a8 01 65 08 00 99 b0 09 9a 02 1f 2f 61	.d...e../a
0050	f0 59 00 00 00 00 6a 08 0a 00 00 00 00 00 10 11	.Y....j.
0060	12 13 14 15 16 17 18 19 1a 1b 1c 1d 1e 1f 20 21	 !
0070	22 23 24 25 26 27 28 29 2a 2b 2c 2d 2e 2f 30 31	"#\$%&'()*+,-./01
0080	32 33 34 35 36 37	234567

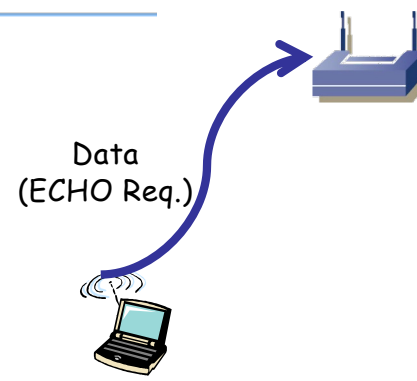


Direcciones MAC: Ejemplo

```
► Frame 1: 134 bytes on wire (1072 bits), 134 bytes captured (1072 bits) on interface 0
► Radiotap Header v0, Length 18
► 802.11 radio information
▼ IEEE 802.11 Data, Flags: .....T
  Type/Subtype: Data (0x0020)
  ▼ Frame Control Field: 0x0801
    .... ..00 = Version: 0
    .... 10.. = Type: Data frame (2)
    0000 .... = Subtype: 0
  ▼ Flags: 0x01
    .... ..01 = DS status: Frame from STA to DS via an AP (To DS: 1 From DS: 0) (0x1)
    .... .0.. = More Fragments: This is the last fragment
    .... 0... = Retry: Frame is not being retransmitted
    ...0 .... = PWR MGT: STA will stay up
    ..0. .... = More Data: No data buffered
    .0.. .... = Protected flag: Data is not protected
    0... .... = Order flag: Not strictly ordered
  .000 0000 0011 0100 = Duration: 52 microseconds
  Receiver address: Cisco-Li_92:a8:60 (00:13:10:92:a8:60)
  Destination address: SmcNetwo_54:33:53 (00:13:f7:54:33:53)
  Transmitter address: SmcNetwo_54:32:01 (00:13:f7:54:32:01)
  Source address: SmcNetwo_54:32:01 (00:13:f7:54:32:01)
  BSS Id: Cisco-Li_92:a8:60 (00:13:10:92:a8:60)
  STA address: SmcNetwo_54:32:01 (00:13:f7:54:32:01)
  .... .... 0000 = Fragment number: 0
  1001 1011 0100 .... = Sequence number: 2484
► Logical-Link Control
► Internet Protocol Version 4, Src: 192.168.1.100, Dst: 192.168.1.101
► Internet Control Message Protocol
```

Y finalmente tenemos la dirección del host destino

```
0000 00 00 12 00 2e 48 00 00 00 18 6c 09 c0 00 cc 01 .....H.. ..l.....
0010 00 00 08 01 34 00 00 13 10 92 a8 60 00 13 f7 54 ....4... ..\...T
0020 32 01 00 13 f7 54 33 53 40 9b aa aa 03 00 00 00 2....T3S @.....
0030 08 00 45 00 00 54 c3 8b 40 00 40 01 f3 03 c0 a8 ..E..T.. @.@.....
0040 01 64 c0 a8 01 65 08 00 99 b0 09 9a 02 1f 2f 61 .d...e.. ..../a
0050 f0 59 00 00 00 00 6a 08 0a 00 00 00 00 00 10 11 .Y....j. ....
0060 12 13 14 15 16 17 18 19 1a 1b 1c 1d 1e 1f 20 21 ..... ..!
0070 22 23 24 25 26 27 28 29 2a 2b 2c 2d 2e 2f 30 31 "#$%&'()*+,-./01
0080 32 33 34 35 36 37 234567
```

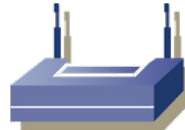


Data rate

No.	Time	Arrival Time	Source	Destination	Length	Data rate	Transmitter address	Receiver address	Source address	Receiver address	Info
1	0.000000000	0.000000000	192.168.1.100	192.168.1.101	12	12	00:13:f7:54:32:01	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,...
2	0.000016446	0.000016446		SmcNetwo_54:32:01 ...	12	12		00:13:f7:54:32:01			Acknowledgement, Flags=.....
3	0.000270064	0.000253618	192.168.1.100	192.168.1.101	48	48	00:13:10:92:a8:60	00:13:f7:54:33:53	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,...
4	0.000287857	0.000017793		Cisco-Li_92:a8:60 ...	24	24		00:13:10:92:a8:60			Acknowledgement, Flags=.....
5	0.000314591	0.000026734	192.168.1.101	192.168.1.100	54	54	00:13:f7:54:33:53	00:13:10:92:a8:60	00:13:f7:54:33:53	00:13:f7:54:32:01	Echo (ping) reply id=0x099a,...
6	0.000390506	0.000075915		SmcNetwo_54:33:53 ...	24	24		00:13:f7:54:33:53			Acknowledgement, Flags=.....
7	0.000728395	0.000337889	192.168.1.101	192.168.1.100	54	54	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	00:13:f7:54:32:01	Echo (ping) reply id=0x099a,...
8	0.000745338	0.000016943		Cisco-Li_92:a8:60 ...	24	24		00:13:10:92:a8:60			Acknowledgement, Flags=.....

La velocidad de transmisión no es la misma para todas las tramas

00:13:10:92:a8:60



00:13:f7:54:32:01

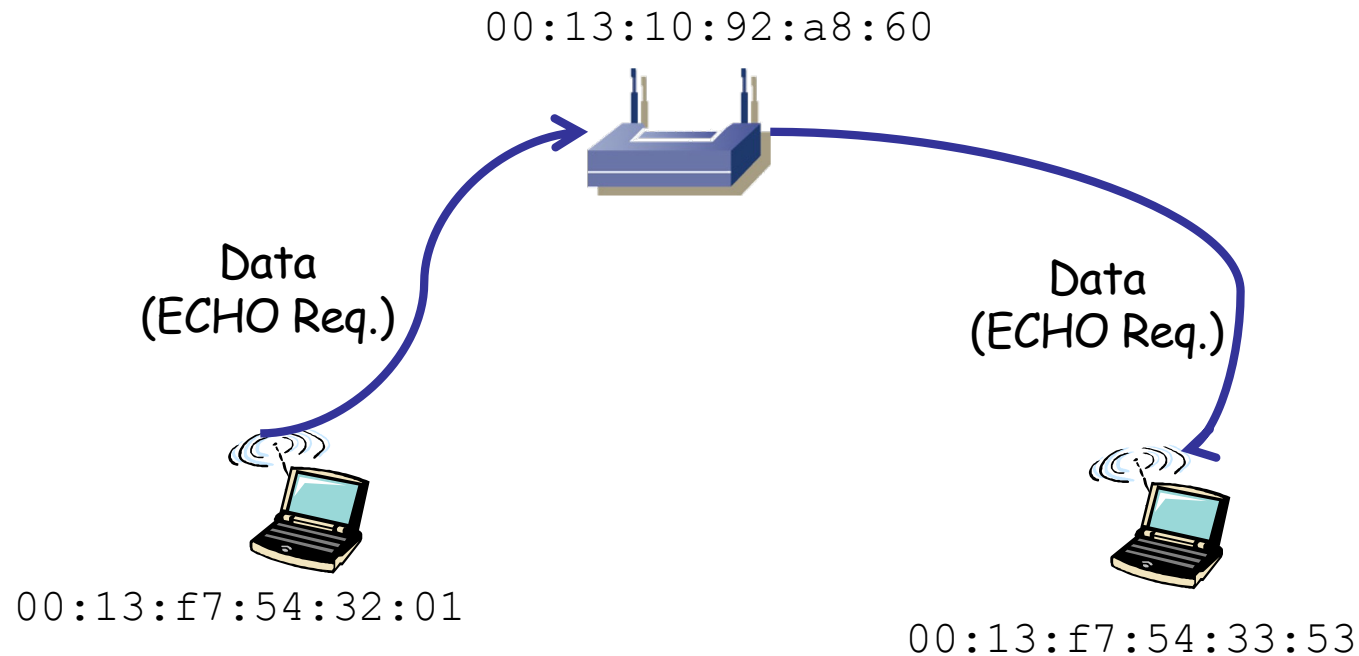


00:13:f7:54:33:53

Data rate

No.	Time	Arrival Time	Source	Destination	Length	Data rate	Transmitter address	Receiver address	Source address	Receiver address	Info
1	0.000000000	0.000000000	192.168.1.100	192.168.1.101	134	12	00:13:f7:54:32:01	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,...
2	0.000016446	0.000016446		SmcNetwo_54:32:01 ...	28	12		00:13:f7:54:32:01			Acknowledgement, Flags=.....
3	0.000270064	0.000253618	192.168.1.100	192.168.1.101	134	48	00:13:10:92:a8:60	00:13:f7:54:33:53	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,...
4	0.000287857	0.000017793		Cisco-Li_92:a8:60 ...	28	24		00:13:10:92:a8:60			Acknowledgement, Flags=.....
5	0.000314591	0.000026734	192.168.1.101	192.168.1.100	134	54	00:13:f7:54:33:53	00:13:10:92:a8:60	00:13:f7:54:33:53	00:13:f7:54:32:01	Echo (ping) reply id=0x099a,...
6	0.000390506	0.000075915		SmcNetwo_54:33:53 ...	28	24		00:13:f7:54:33:53			Acknowledgement, Flags=.....
7	0.000728395	0.000337889	192.168.1.101	192.168.1.100	134	54	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	00:13:f7:54:32:01	Echo (ping) reply id=0x099a,...
8	0.000745338	0.000016943		Cisco-Li_92:a8:60 ...	28	24		00:13:10:92:a8:60			Acknowledgement, Flags=.....

Ni siquiera tiene que ser la misma entre que se entrega al AP y él la entrega al destino



Acknowledgement

No.	Time	Arrival Time	Source	Destination	Length	Data rate	Transmitter address	Receiver address
1	0.000000000	0.000000000	192.168.1.100	192.168.1.101	134	12	00:13:f7:54:32:01	00:13:10:92:a8:60
2	0.000016446	0.000016446		SmcNetwo_54:32:01 ...	28	12		00:13:f7:54:32:01
3	0.000270064	0.000253618	192.168.1.100	192.168.1.101	134	48	00:13:10:92:a8:60	00:13:f7:54:32:01
4	0.000287857	0.000017793		Cisco-Li_92:a8:60 ...	28	24		00:13:10:92:a8:60
5	0.000314591	0.000026734	192.168.1.101	192.168.1.100	134	54	00:13:f7:54:33:53	00:13:10:92:a8:60
6	0.000390506	0.000075915		SmcNetwo_54:33:53 ...	28	24		00:13:f7:54:33:53
7	0.000728395	0.000337889	192.168.1.101	192.168.1.100	134	54	00:13:10:92:a8:60	00:13:f7:54:33:53
8	0.000745338	0.000016943		Cisco-Li_92:a8:60 ...	28	24		00:13:10:92:a8:60

- ▶ Frame 2: 28 bytes on wire (224 bits), 28 bytes captured (224 bits) on interface 0
- ▶ Radiotap Header v0, Length 18
- ▶ 802.11 radio information

▼ IEEE 802.11 Acknowledgement, Flags:

Type/Subtype: Acknowledgement (0x001d)

▼ Frame Control Field: 0xd400

.... ..00 = Version: 0

.... 01.. = Type: Control frame (1)

1101 = Subtype: 13

▼ Flags: 0x00

.... ..00 = DS status: Not leaving DS or network is operating in AD-HOC mode (To DS: 0 From DS: 0) (0x0)

.... .0.. = More Fragments: This is the last fragment

.... 0... = Retry: Frame is not being retransmitted

...0 = PWR MGT: STA will stay up

..0. = More Data: No data buffered

.0.. = Protected flag: Data is not protected

0... = Order flag: Not strictly ordered

.000 0000 0000 0000 = Duration: 0 microseconds

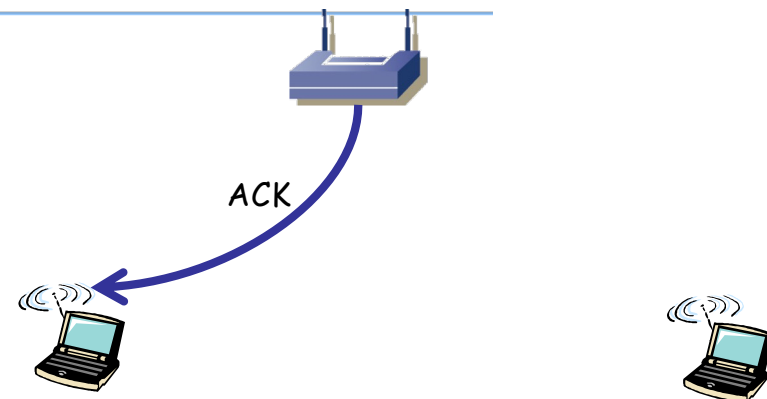
Receiver address: SmcNetwo_54:32:01 (00:13:f7:54:32:01)

Trama de confirmación (subtipo de tramas de control)

No pasa por el DS

```
0000 00 00 12 00 2e 48 00 00 00 18 6c 09 c0 00 dd 01 .....H.. ..l.....
0010 00 00 d4 00 00 00 00 13 f7 54 32 01 .....T2.
```

Solo incluye la dirección MAC del receptor (el que envió la de datos)



Router WiFi SOHO

Router WiFi SOHO

- Tipo de equipo muy popular hoy en día
- Aglutina una gran cantidad de funciones



- Complies with 802.11 g and 802.11 b (2.4 GHz) Standards
- Unsurpassed Wireless Security with Wi-Fi Protected Access™ 2 (WPA2)
- Enhanced Internet Security Management Functions including Internet Access Policies with Time Schedules
- All LAN Ports Support Auto-Crossover (MDI/MDI-X) — No Need for Crossover Cables

Standards

IEEE 802.3, IEEE 802.3u, IEEE 802.11g, IEEE 802.11b

Ports

Internet: One 10/100 RJ-45 Port

Ethernet: Four 10/100 RJ-45 Switched Ports

One Power Port

Buttons

One Reset Button

LEDs

Power, DMZ, WLAN, Ethernet (1, 2, 3, 4), Internet

Cabling Type

CAT 5

RF Power (EIRP) in dBm

18

UPnP able/cert

Able

Security Features

Stateful Packet Inspection (SPI) Firewall, Internet Policy

Wireless Security

Wi-Fi Protected Access™ 2 (WPA2), WEP, Wireless MAC Filtering

Router WiFi SOHO

Puertos “LAN”

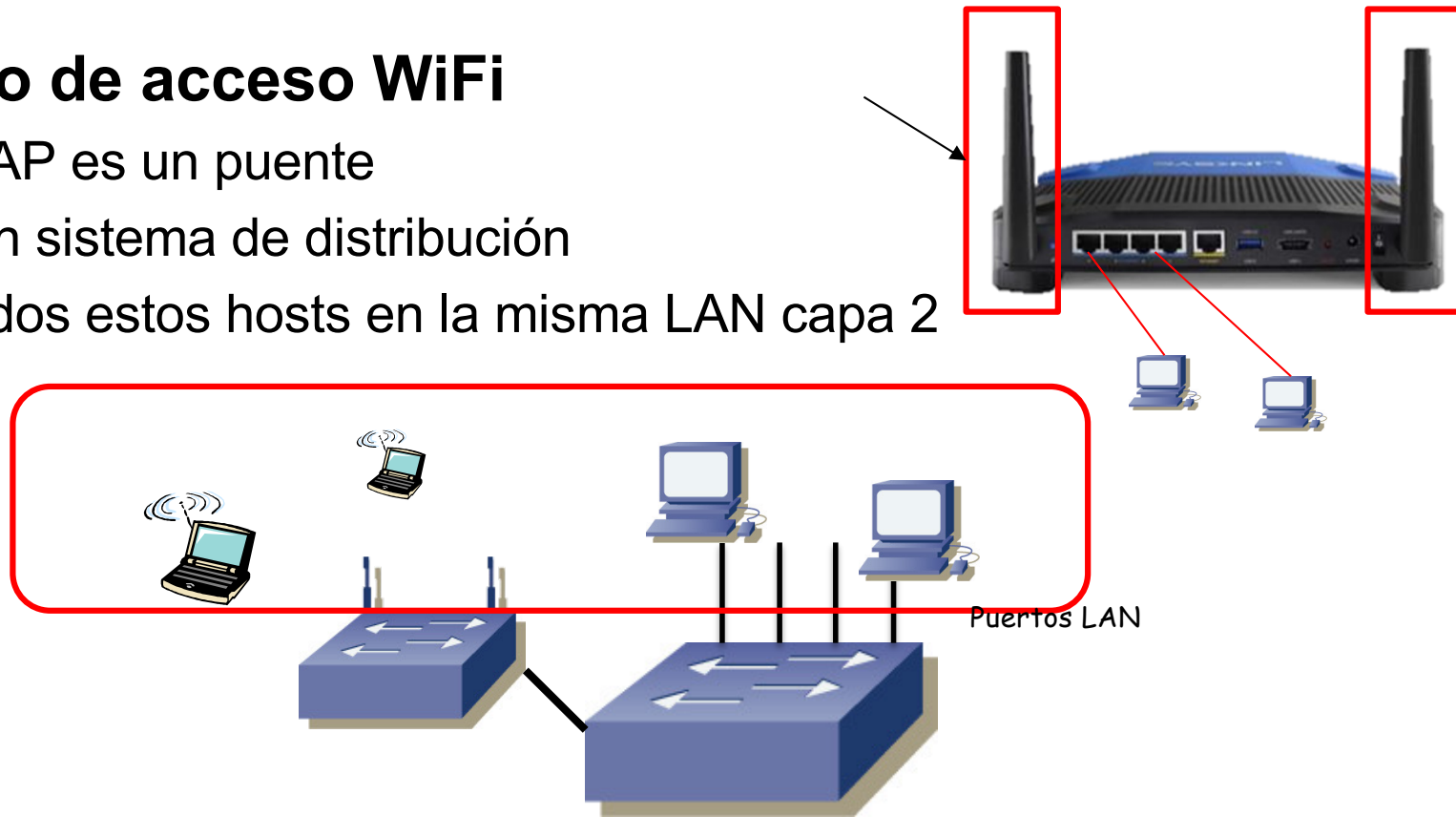
- Son puertos puenteados/conmutados



Router WiFi SOHO

Punto de acceso WiFi

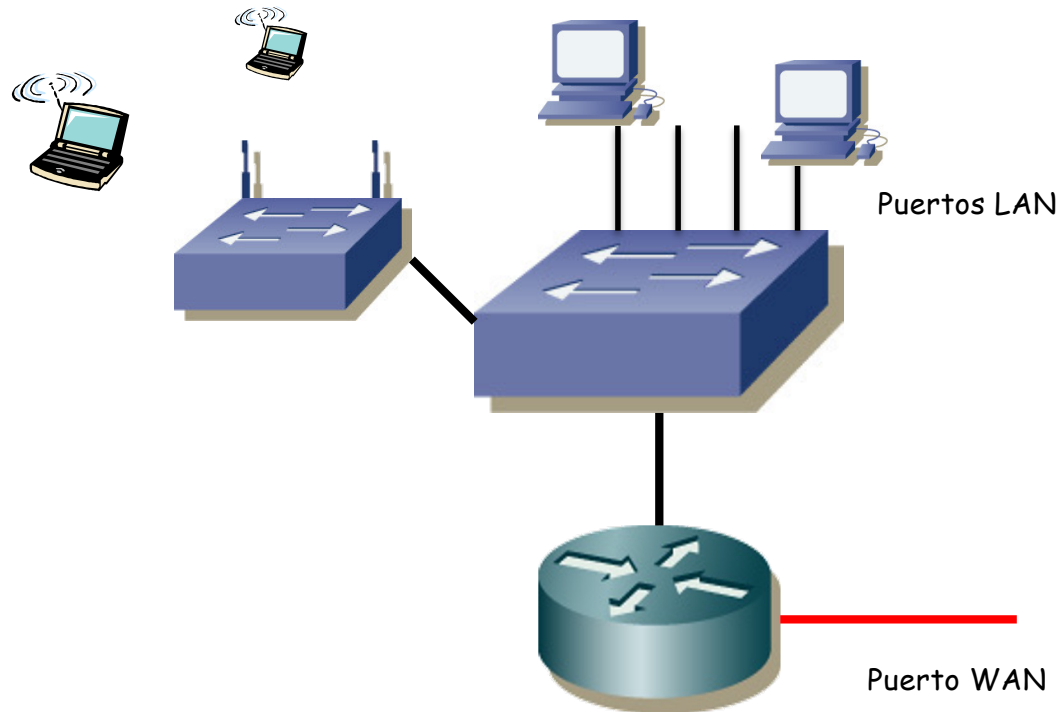
- El AP es un puente
- Con sistema de distribución
- Todos estos hosts en la misma LAN capa 2



Router WiFi SOHO

Puerto “WAN”

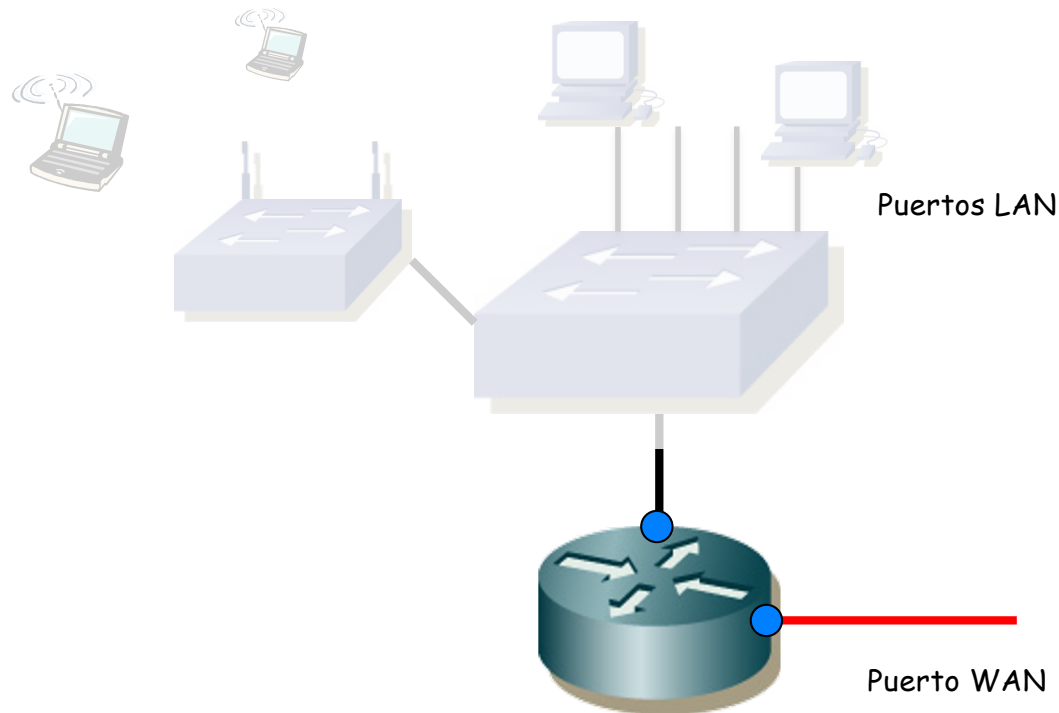
- Ethernet, ADSL, PON, etc
- Normalmente enrutado
- Comunicación entre hosts LAN no pasa por la funcionalidad de router



Router WiFi SOHO

Visión capa 3 (IP)

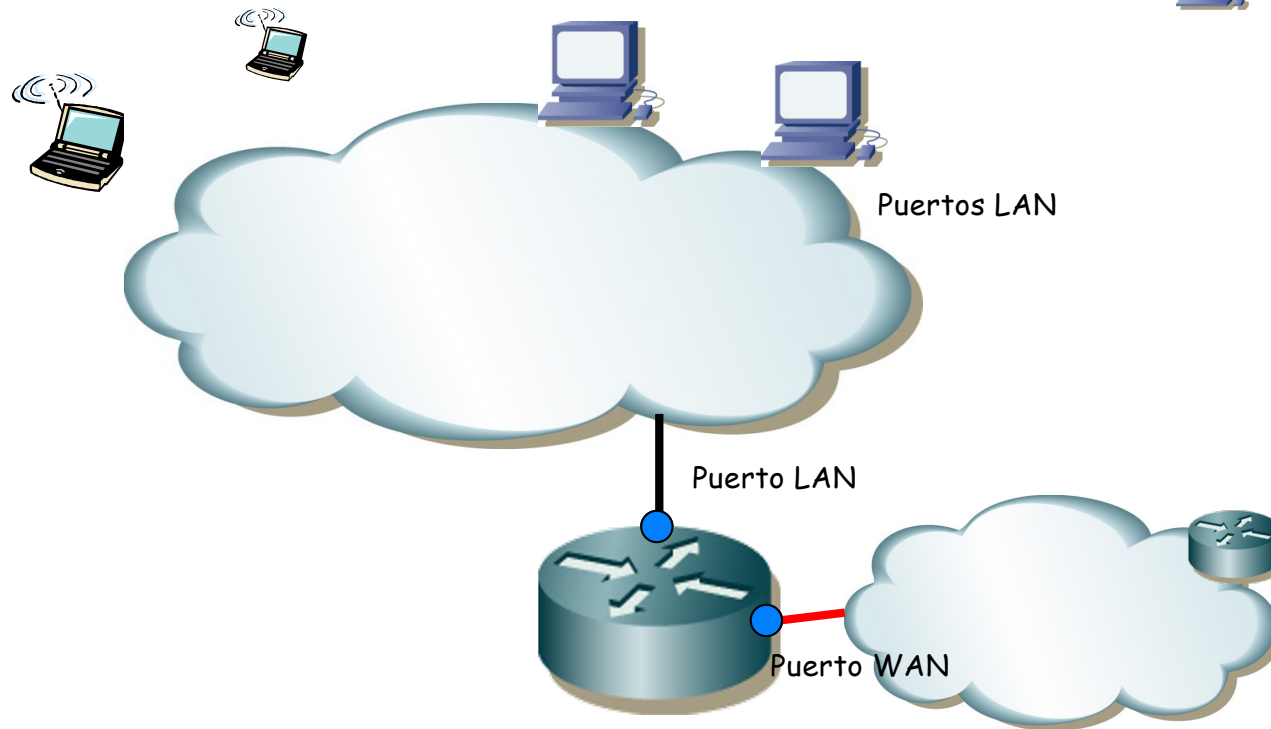
- Los puentes no son hosts IP
- El router sí tiene 2 interfaces IP
- Uno de ellos en la LAN (puerto lógico)



Router WiFi SOHO

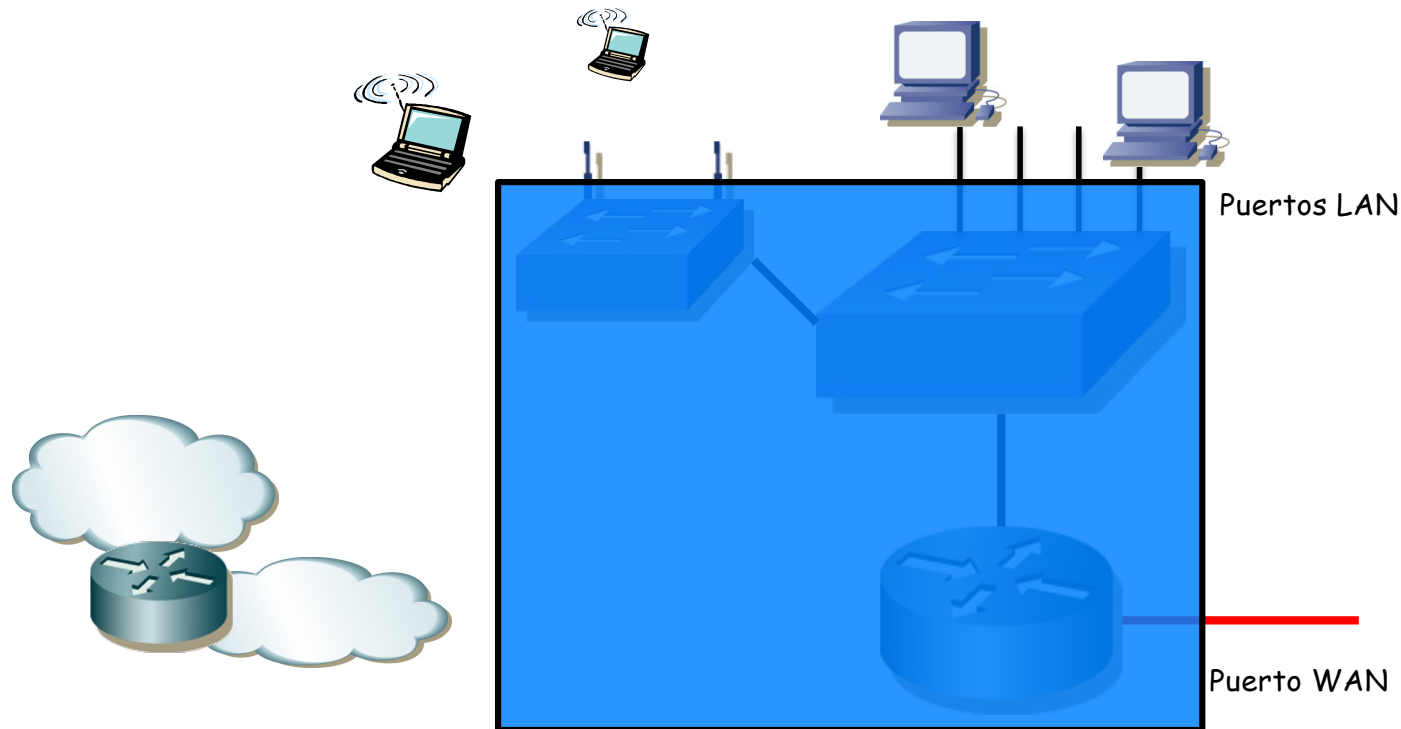
Visión capa 3 (IP)

- Es decir, hay 2 subredes IP
- El router tendrá su tabla de rutas
- Normalmente (usuario doméstico) default-route



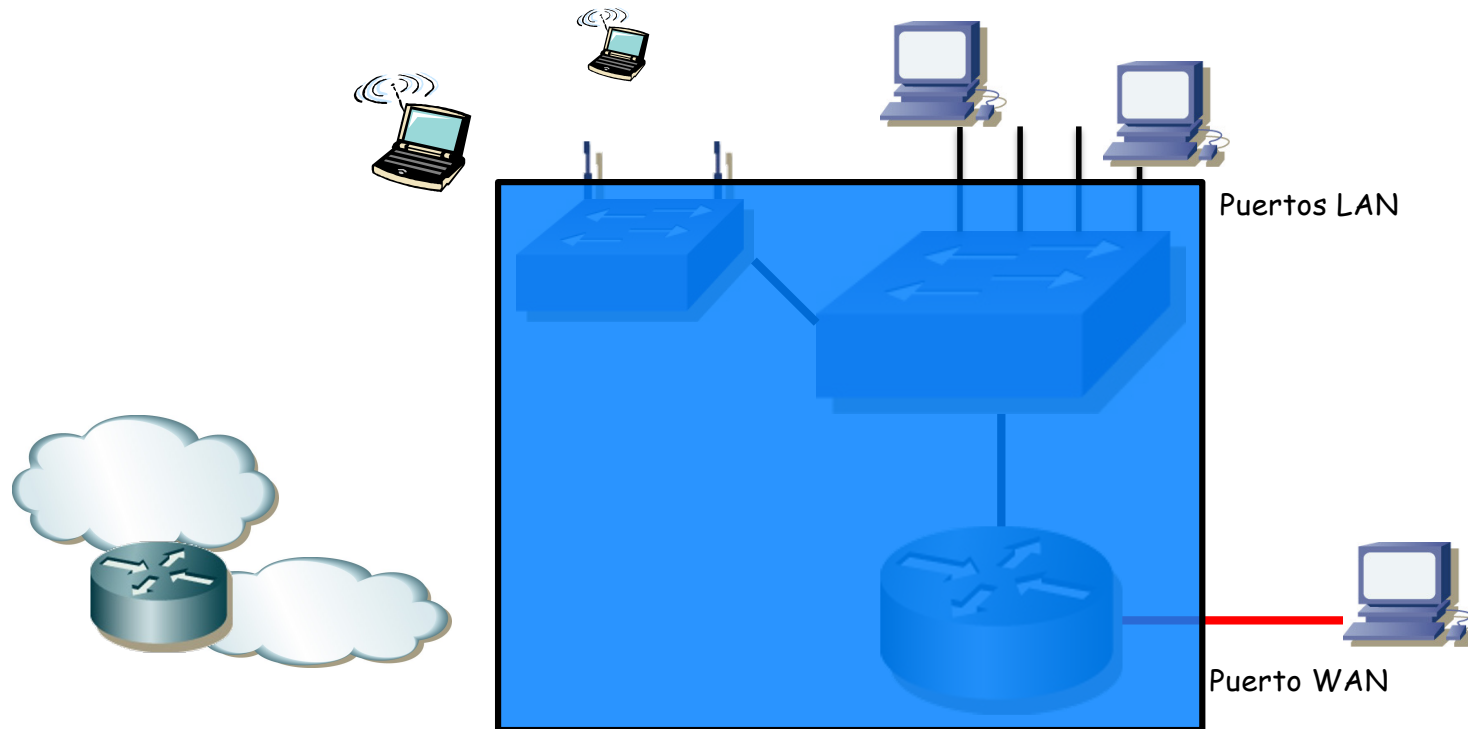
Router WiFi SOHO

- Recordemos cómo es el equipo
- Vemos los puertos LAN, WAN y antenas



Router WiFi SOHO

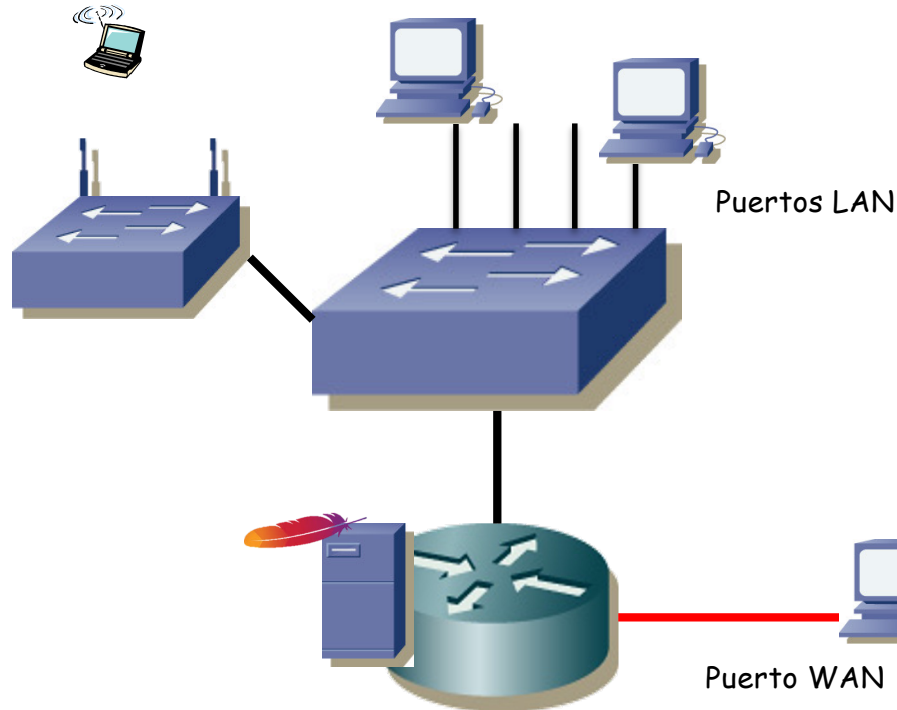
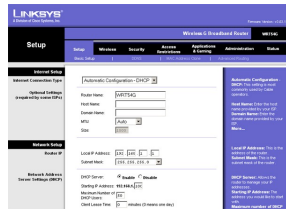
- El puerto WAN está lógicamente al otro lado del router
- PCs que conectemos a puertos LAN y al WAN no pueden estar en la misma subred IP
- No va a funcionar la comunicación si los configuramos en la misma subred IP



Router WiFi SOHO

Configuración del equipo

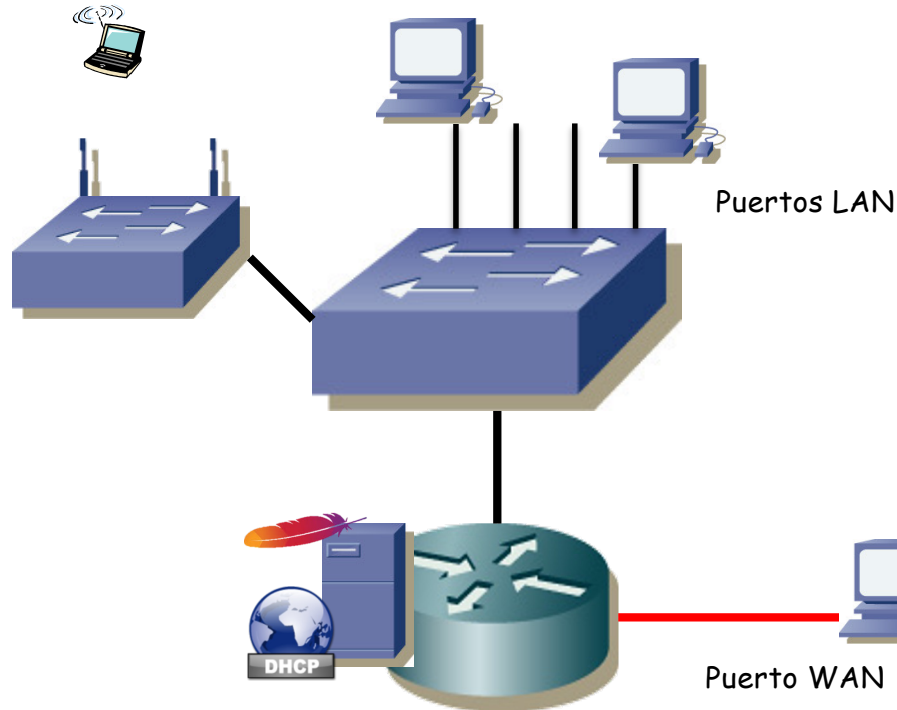
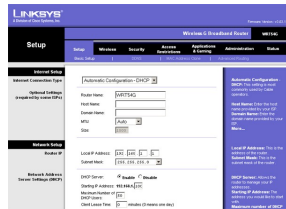
- El router tiene una CPU, corre un S.O. y en él suele tener corriendo un servidor web
- Es muy común que el router sea un kernel Linux
- El servidor es accesible por esos interfaces



Router WiFi SOHO

Otras opciones: servidor DHCP

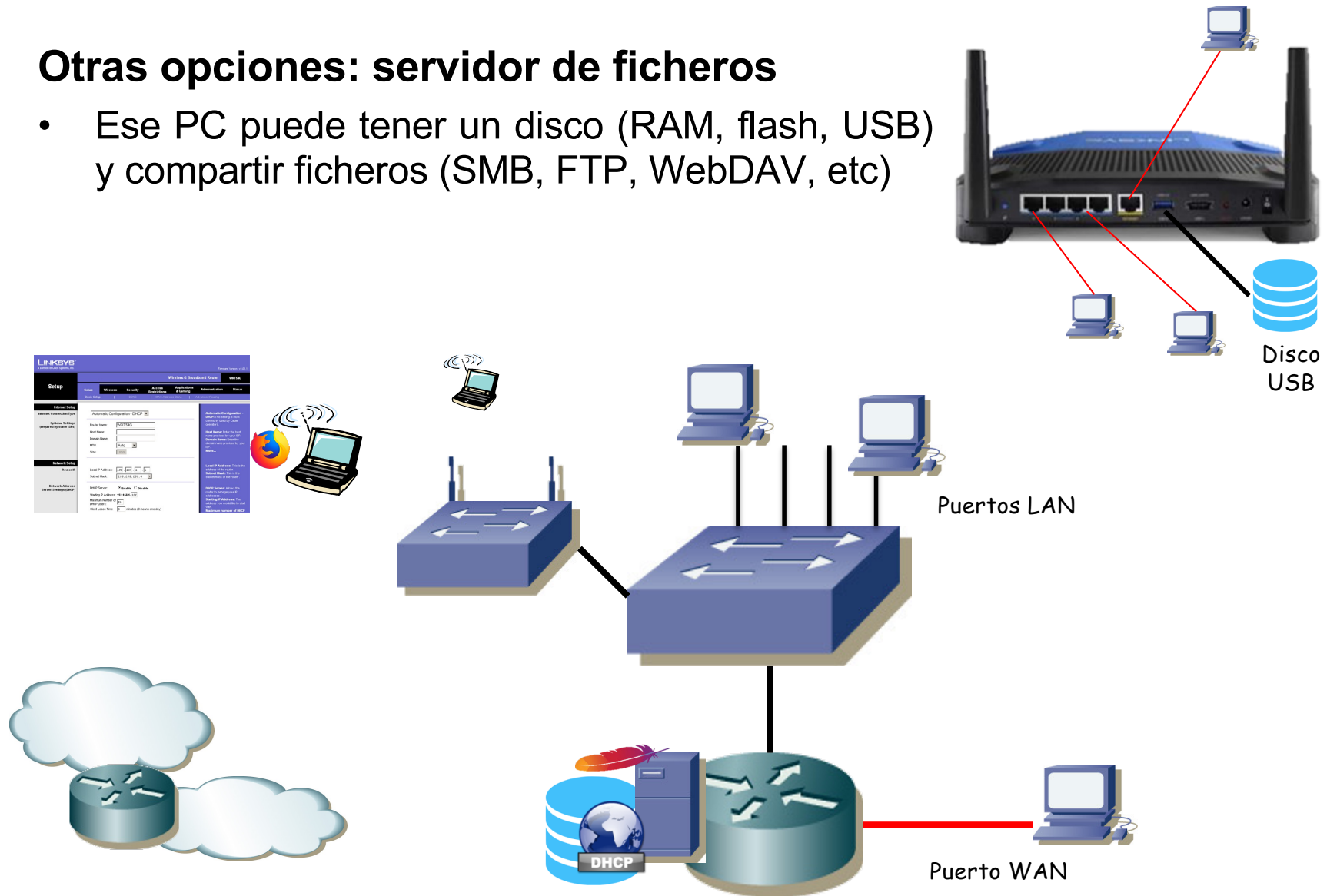
- Ese PC puede tener un servidor de DHCP
- Normalmente para entregar direcciones IP a hosts en la sección “LAN”



Router WiFi SOHO

Otras opciones: servidor de ficheros

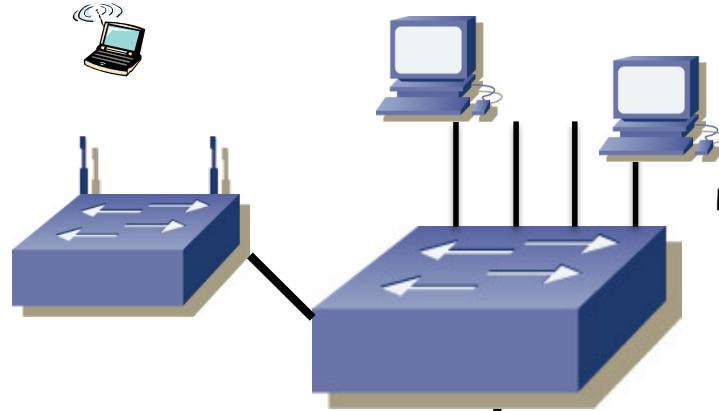
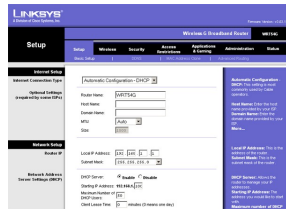
- Ese PC puede tener un disco (RAM, flash, USB) y compartir ficheros (SMB, FTP, WebDAV, etc)



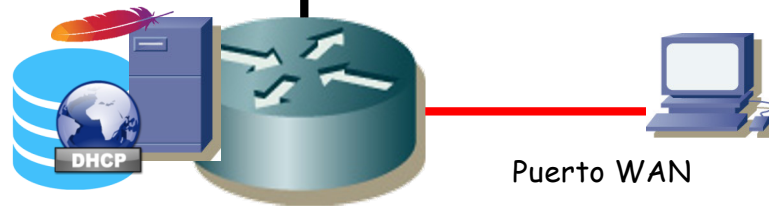
Router WiFi SOHO

Otras opciones: interfaz móvil

- Ese PC puede tener un interfaz USB 3G/4G



Puertos LAN

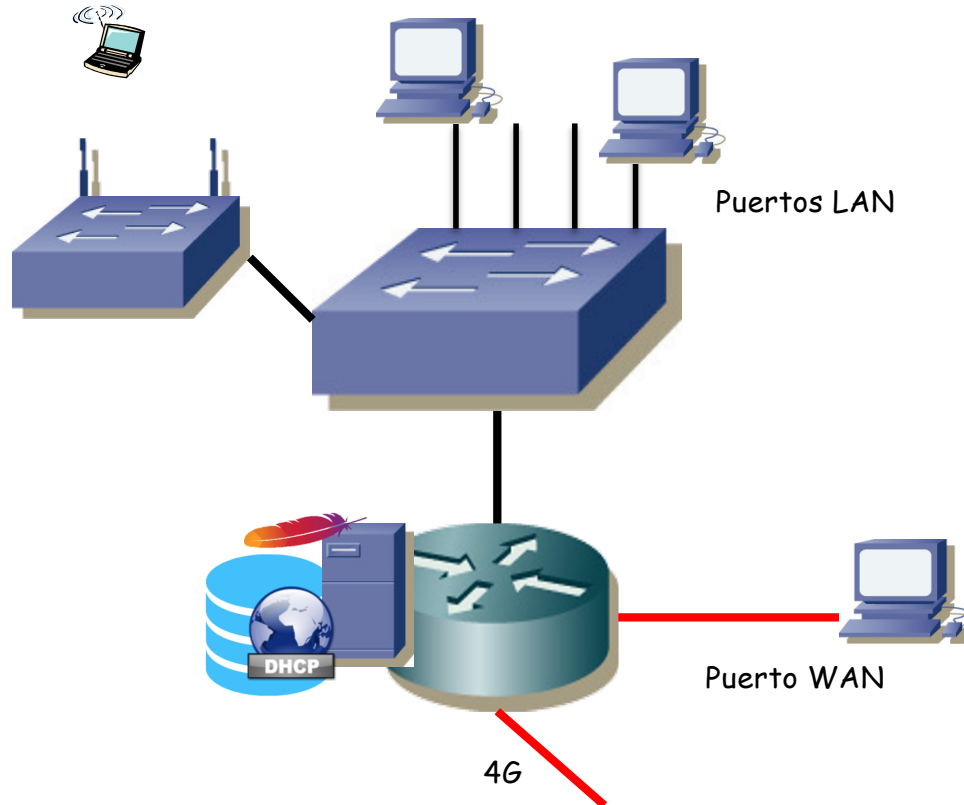
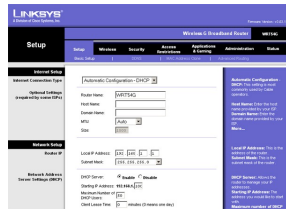


Puerto WAN

Router WiFi SOHO

Otras opciones: interfaz móvil

- Ese PC puede tener un interfaz USB 3G/4G
- Normalmente es un nuevo interfaz enrutado



100

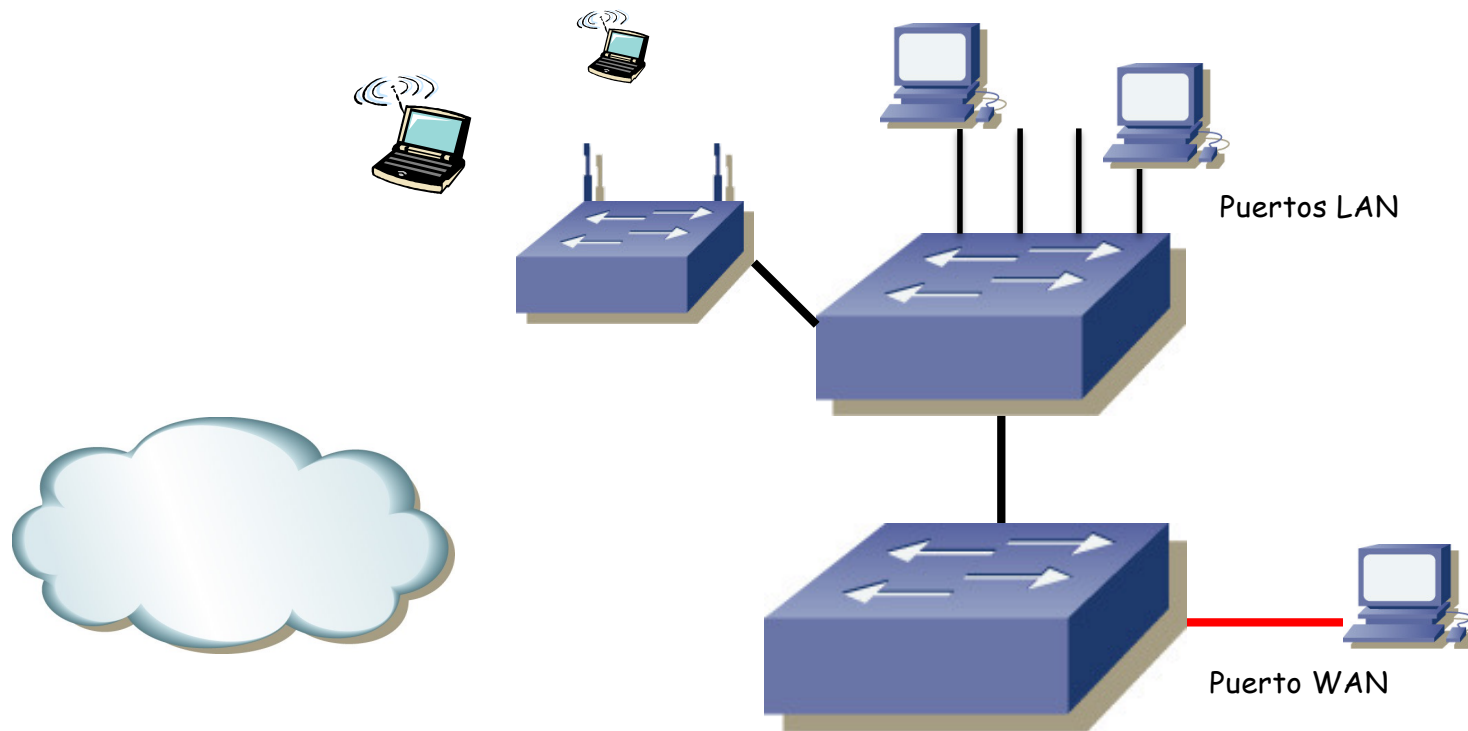
A diagram of a black wireless router with two antennas. Three red lines represent Ethernet cables connecting three blue laptop icons to the router's ports. One laptop is connected to the yellow WAN/Internet port, and two laptops are connected to the four white LAN ports.



Router WiFi SOHO

Otras opciones: bridging

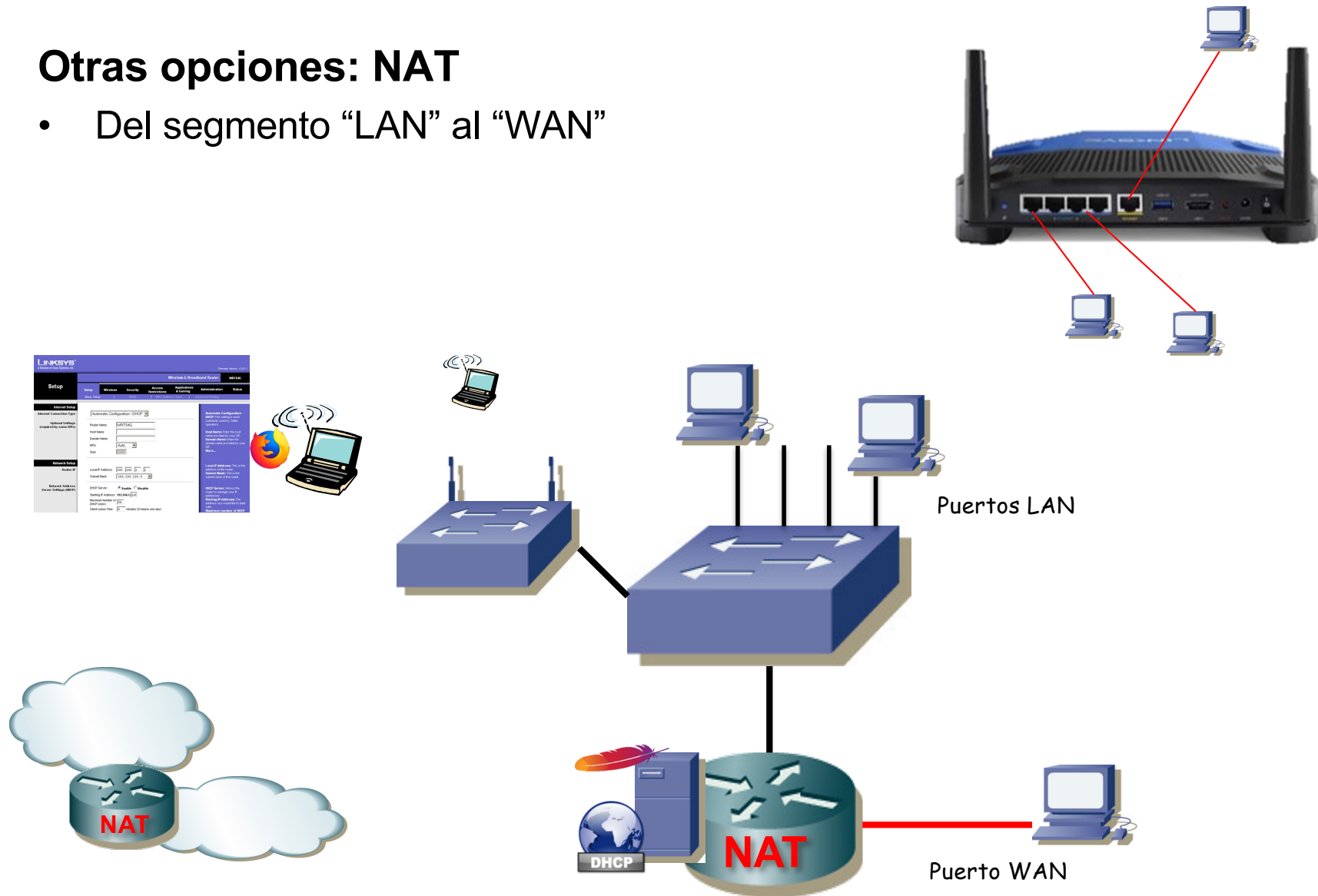
- En lugar de actuar como switch capa 3 (router) con el interfaz WAN actúa en capa 2 (bridge)
- Todos los hosts en el mismo dominio capa 2



Router WiFi SOHO

Otras opciones: NAT

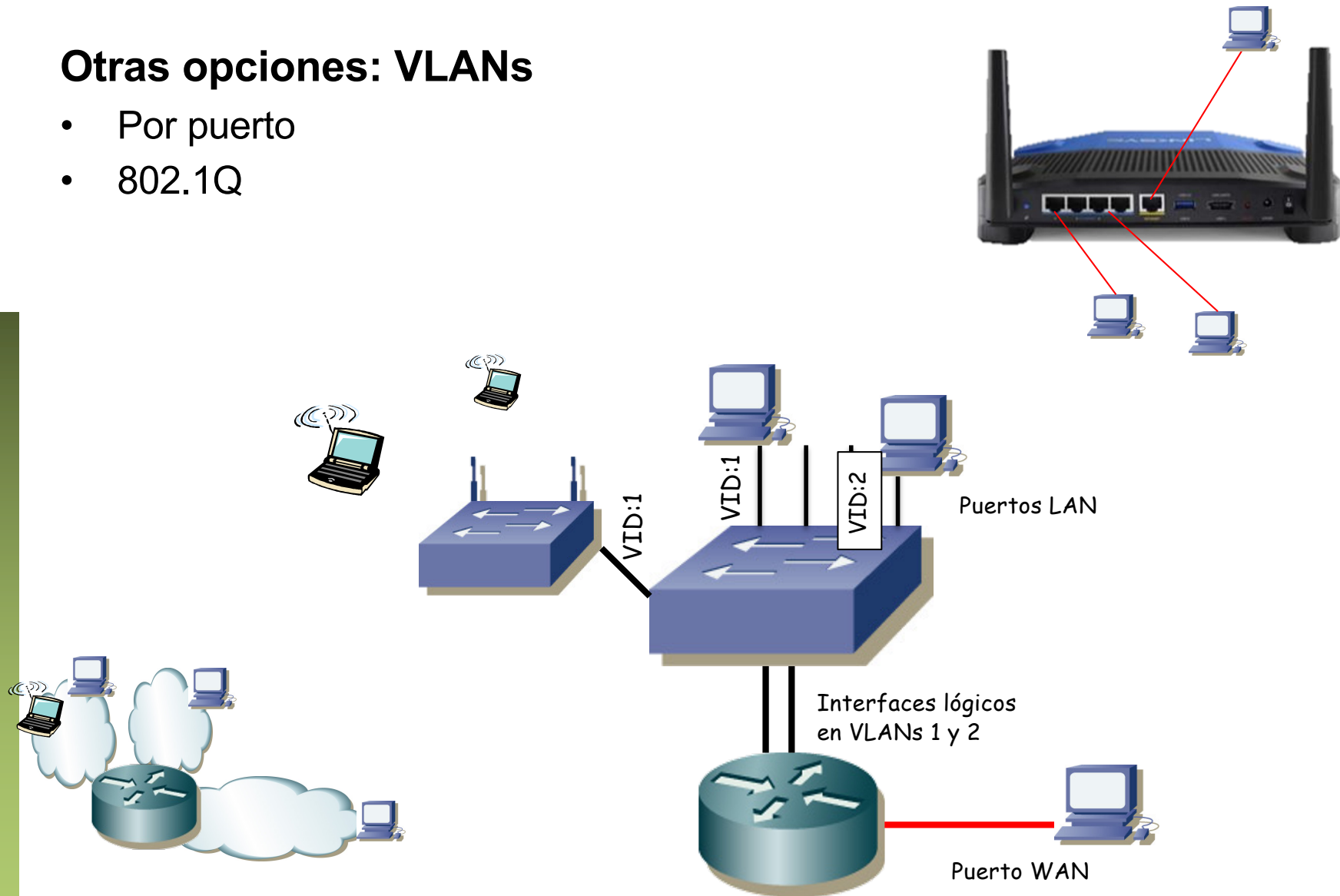
- Del segmento “LAN” al “WAN”



Router WiFi SOHO

Otras opciones: VLANs

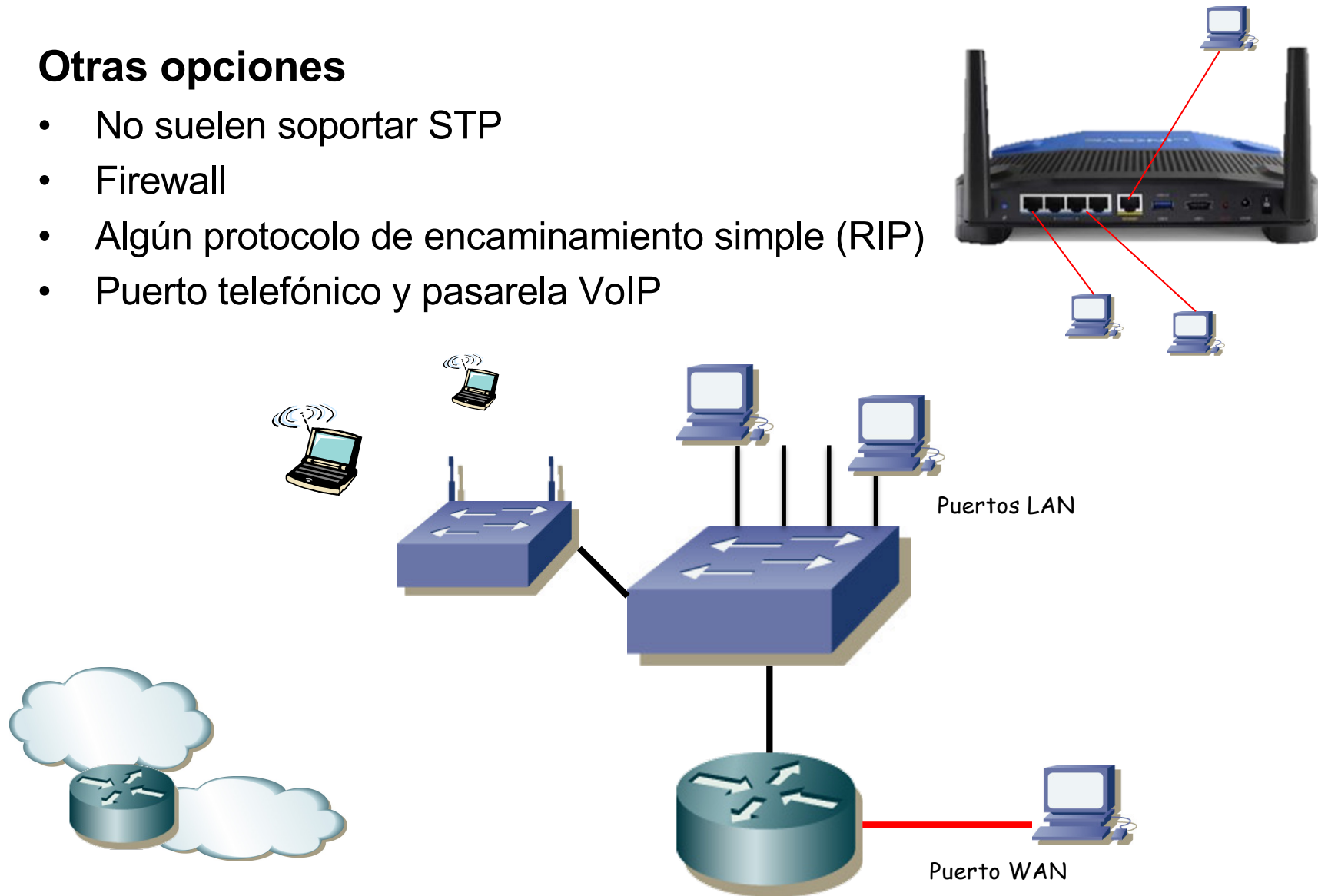
- Por puerto
- 802.1Q



Router WiFi SOHO

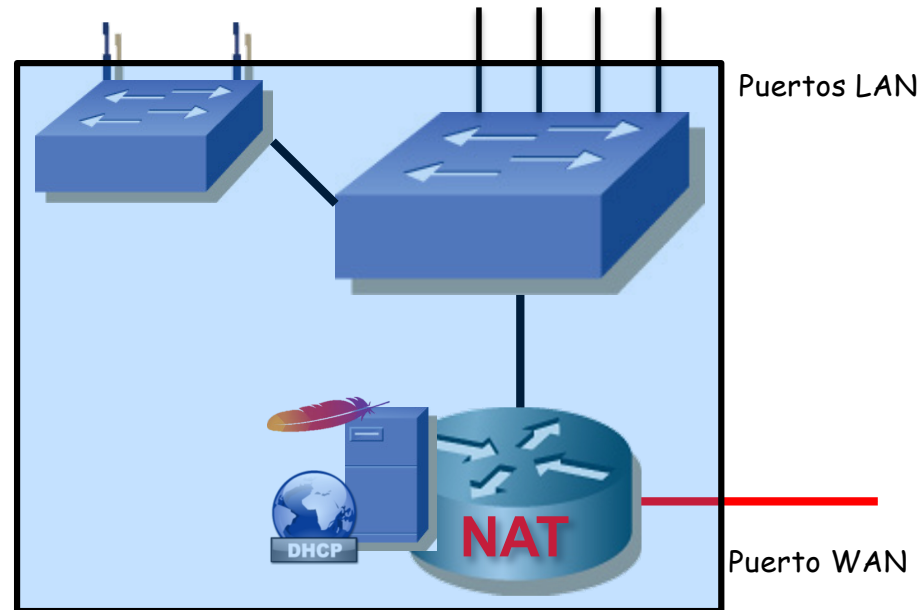
Otras opciones

- No suelen soportar STP
- Firewall
- Algún protocolo de encaminamiento simple (RIP)
- Puerto telefónico y pasarela VoIP



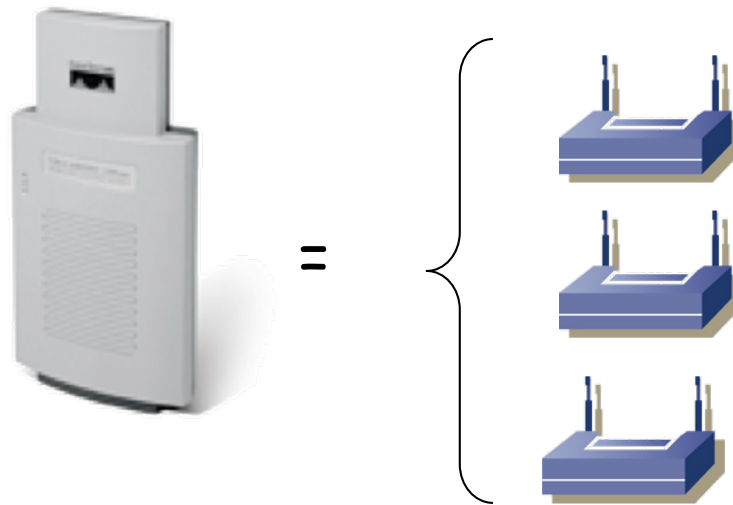
Router WiFi SOHO

- No todos los puertos son iguales (aunque tengan el mismo conector)
- Al llevar una pequeña CPU (y comúnmente un kernel Linux) puede hacer mucho de lo que podría hacer un PC
- Parte está implementado en hardware pero gran parte es software



Multi-BSS APs

- Circuitos integrados para 802.11 originalmente soportaba un solo BSS
- Hoy en día son capaces de gestionar más de uno, con diferente SSID
- *Virtual Access Points*



Tecnologías Wi-Fi

Area de Ingeniería Telemática
<http://www.tlm.unavarra.es>

Grado en Ingeniería en Tecnologías de
Telecomunicación, 3º