Tecnologías Wi-Fi

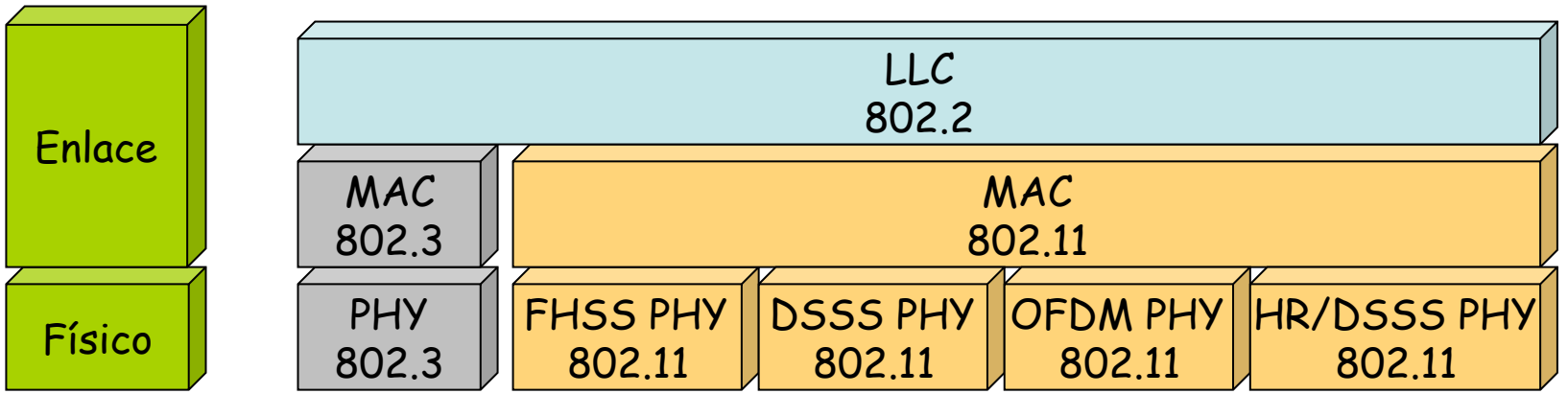
Area de Ingeniería Telemática
http://www.tlm.unavarra.es

Grado en Ingeniería en Tecnologías de Telecomunicación, 3º

802.11: Nivel físico

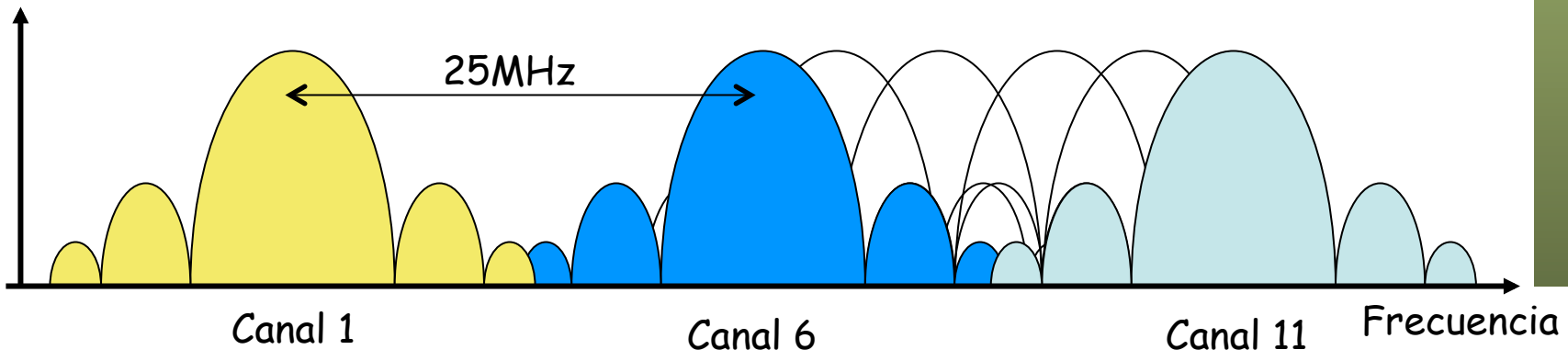
Estándar Wireless LANs

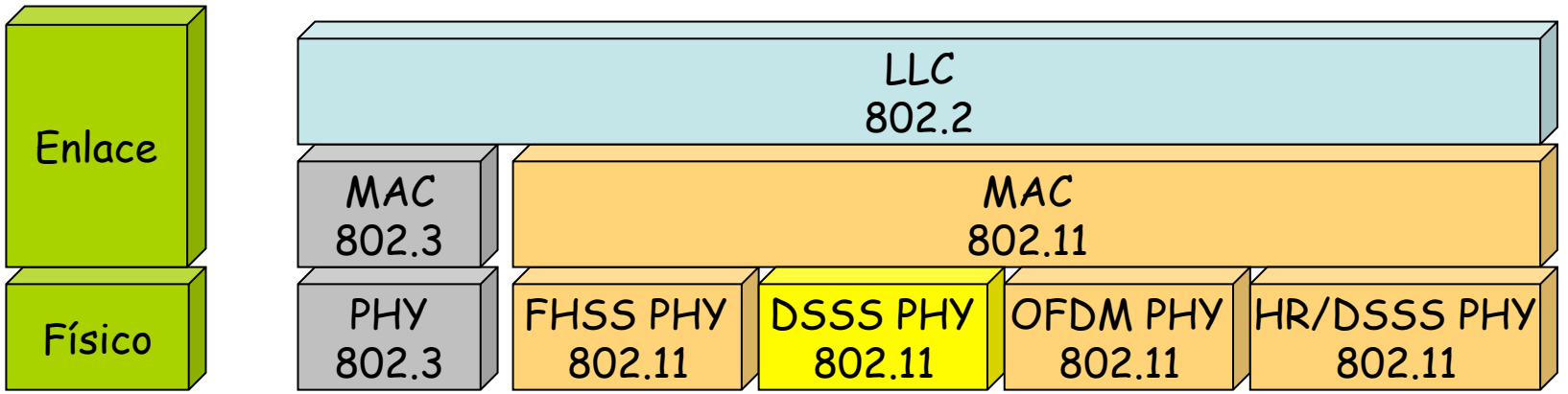
- IEEE 802.11 (1999)
- LAN basada en medio inalámbrico
- Certificación de la Wi-Fi Alliance
  - http://www.wi-fi.org/
  - Fundada en 1999 por 3com, Intersil, Lucent Tech, Nokia y Symbol Tech
  - Hoy más de 350 compañías miembro
- Hay diferentes niveles físicos posibles
- MAC 802.11 es común a todos ellos
- MAC intenta ofrecer un acceso justo al medio
- El nivel físico está dividido en dos subniveles:
  - PLCP: Physical Layer Convergence Procedure
  - PMD: Physical Medium Dependent



802.11b

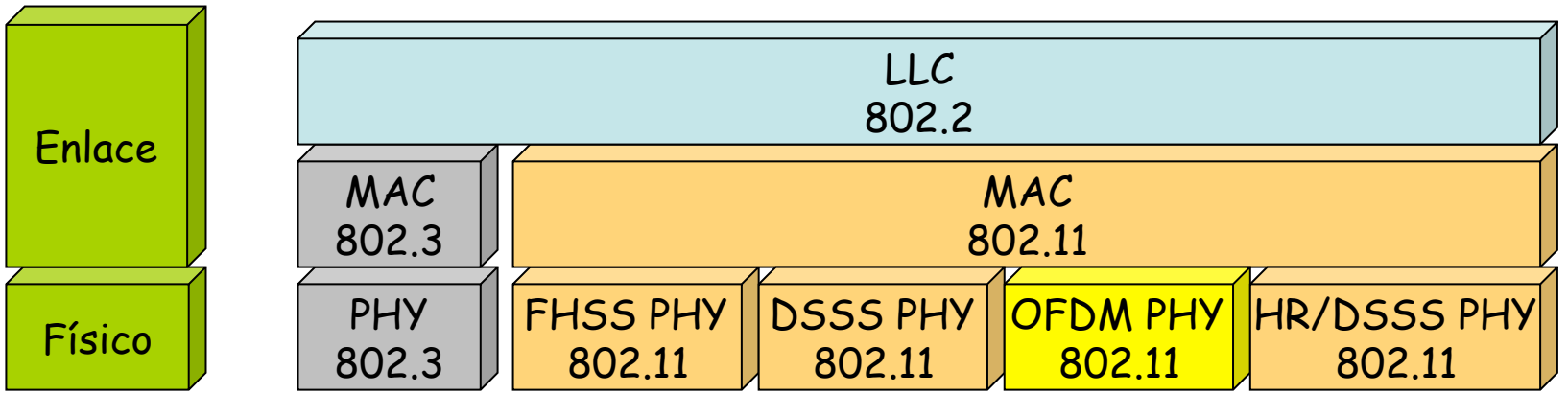
- Banda de 2.4GHz
- HR/DSSS = *High Rate Direct-Sequence Spread Spectrum* (hasta 11Mbps)
- En EEUU 11 canales (14 en Japón, 13 en Europa-ETSI)
- BW aprox. de un canal menor de 25MHz (atenuación mayor de 30dB)
- Separación entre canales de 5MHz
- Canales 1-6-11 tienen ya escasa interferencia





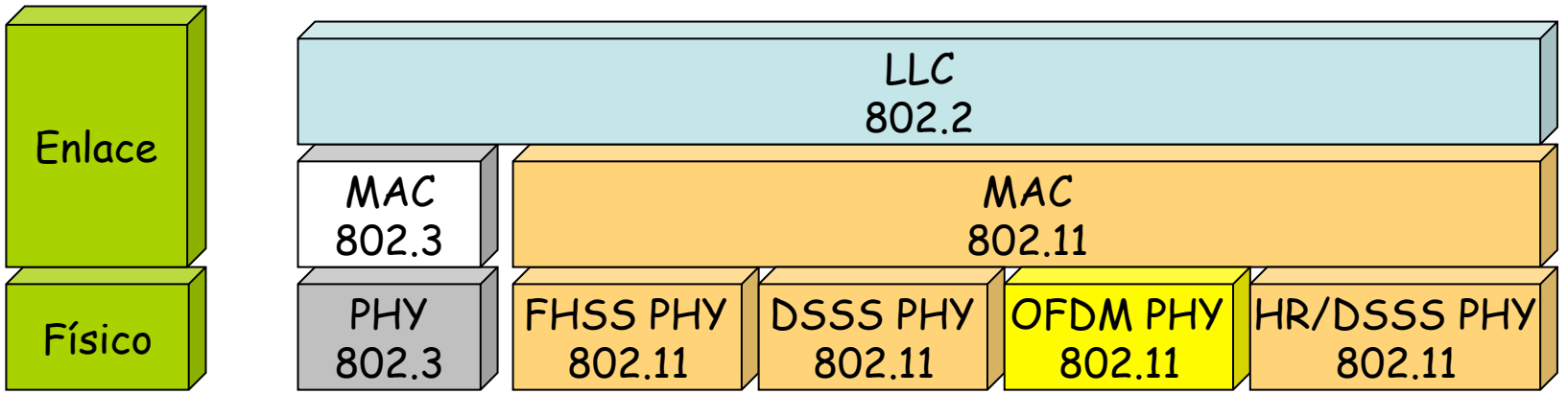
802.11a

- Banda de 5GHz
- OFDM = *Orthogonal Frequency Division Multiplexing*
- En torno a 23 canales (unos 12 que no se solapan)
- Añade a las velocidades de 802.11b: 6, 9, 12, 18, 24, 36, 48 y 54 Mbps



802.11g

- 2.4GHz compatible con 802.11b
- Añade OFDM con velocidades como 802.11a (hasta 54Mbps)
  Mismos canales que 802.11b
- Lo mejor es seleccionar uno de entre 1-6-11 que comparta con menor número de otras WLANs



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

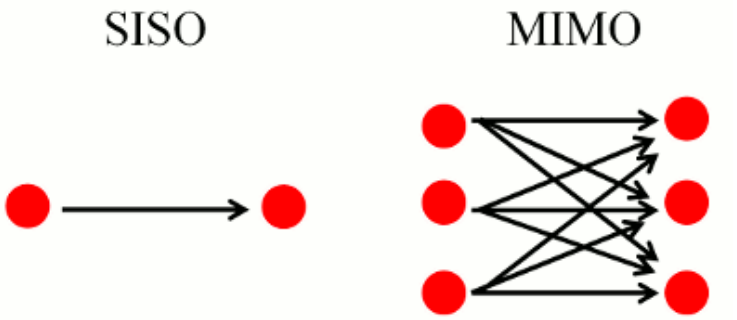
IEEE STANDARDS ASSOCIATION IEEE

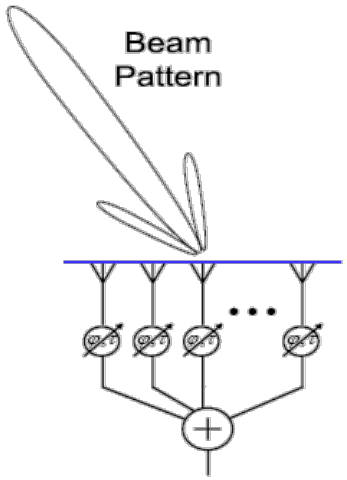
IEEE Standard for Information technology—
Telecommunications and information exchange between systems
Local and metropolitan area networks—
Specific requirements

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

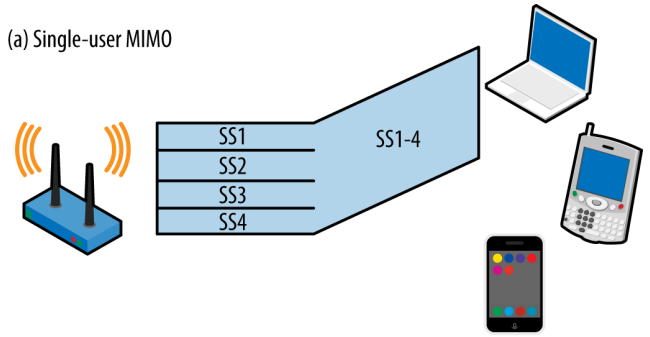
- Hay 10 páginas en 802.11-2012 con tablas sobre las velocidades posibles según el ancho de banda, la codificación, el nivel de corrección de errores...
- En canal de 40 MHz con 4 streams espaciales, 64-QAM y codificación 5/6 podrían alcanzarse los 540 Mbps (esto es lo máximo)
- Hoy en día lo normal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

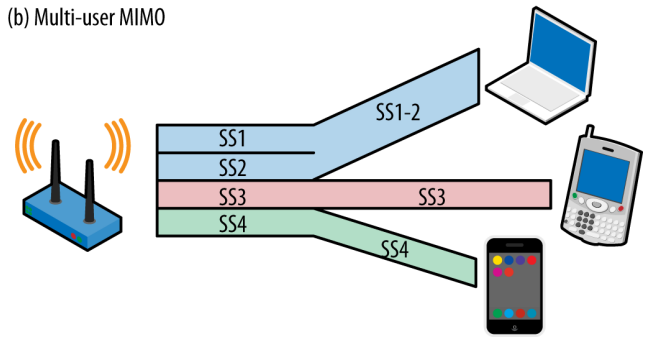
Table 20-44—MCS parameters for optional 40 MHz, N_{SS} = 4, UEQM

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-	16-	QPSK	QPSK	1/2	14	108	6	1512	756	1	189	210

802.11ac

- Estándar IEEE de 2013, solo 802.11ac 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 simultaneamente (Multi-User MIMO o MU-MIMO)
- Los dispositivos suelen a la vez soportar 802.11n





http://chimera.labs.oreilly.com/books/1234000001739/ch01.html#beamforming_and_multiuser_mimo_mumimo

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 hasta canal de 80 MHz con 3 streams y eso da hasta 1.3Gbps compartidos
- 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

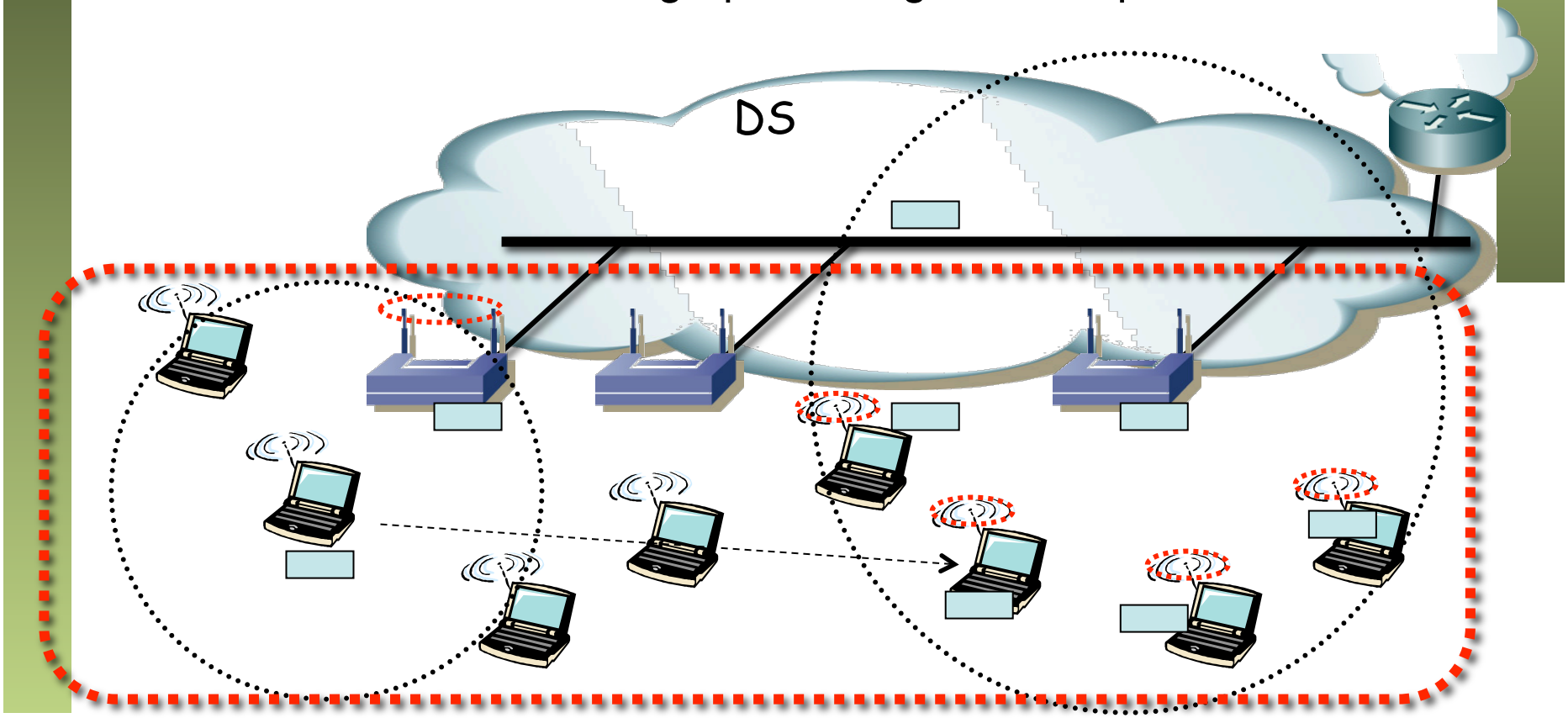
http://chimera.labs.oreilly.com/books/1234000001739/ch02.html#ac_data_rate_matrix

802.11: Nivel de enlace

802.11: *Service Sets* y movilidad

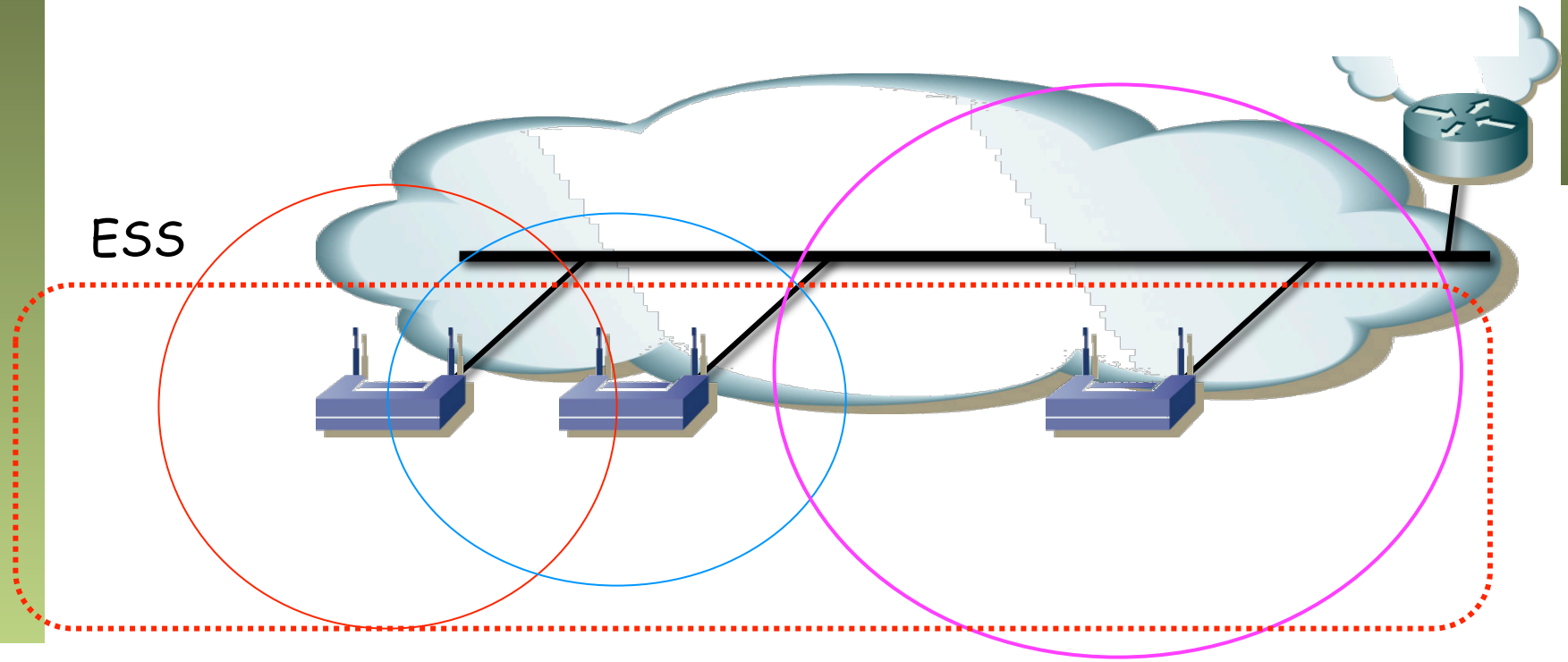
Topologías

- 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



Movilidad

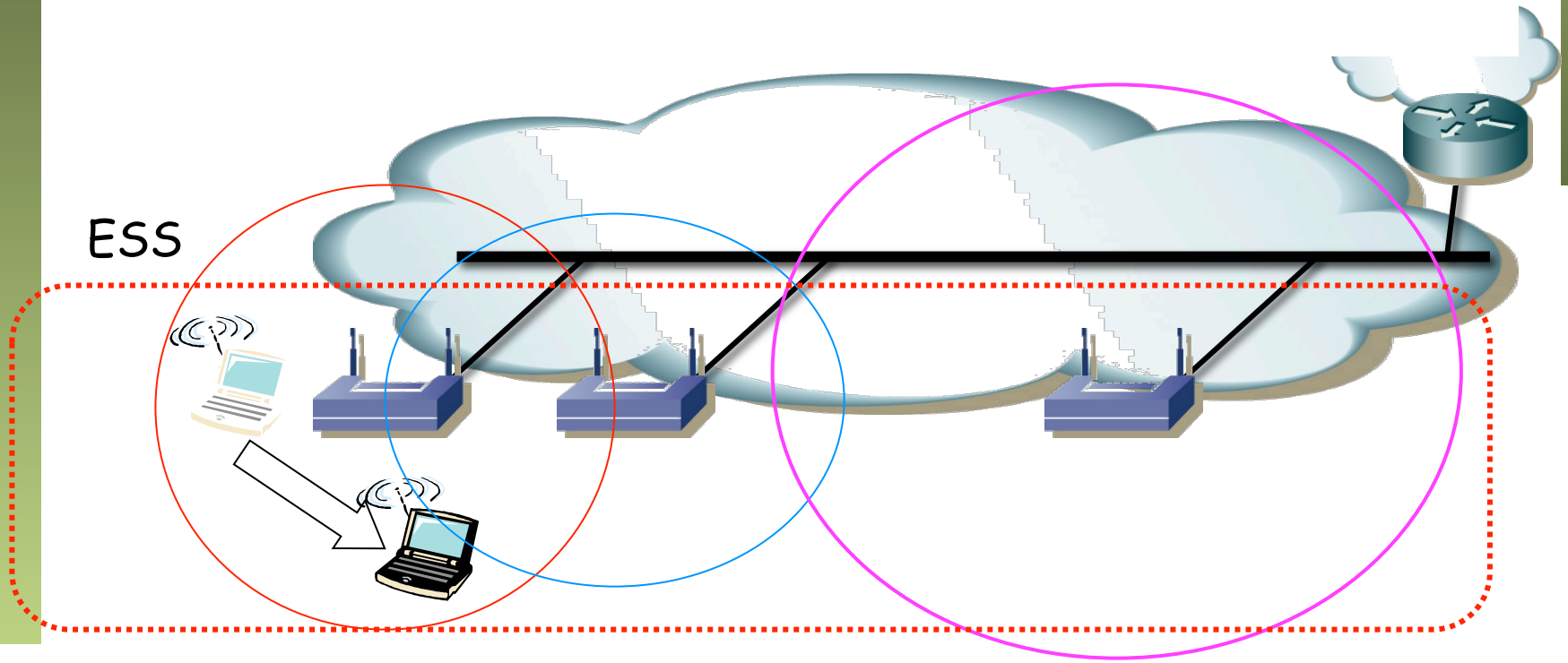
- 802.11 ofrece movilidad en el subnivel MAC
- Transparente para los niveles superiores (para LLC parece una LAN cableada)
- Todo el contenido de un ESS es la misma LAN
- El ESS sabe hacer llegar una trama a donde esté el destino



Movilidad

Sin transición

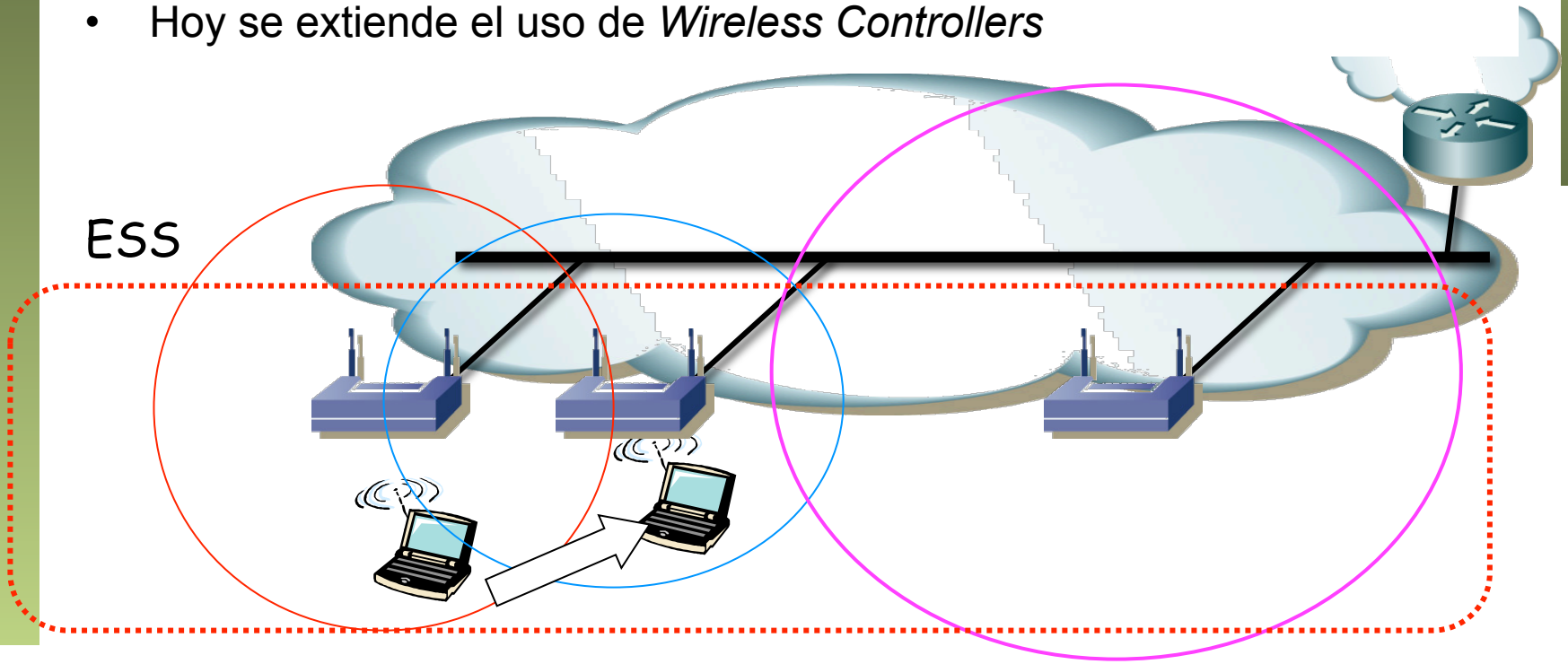
- Estaciones se mueven dentro del área de cobertura de un mismo AP



Movilidad

Transición BSS

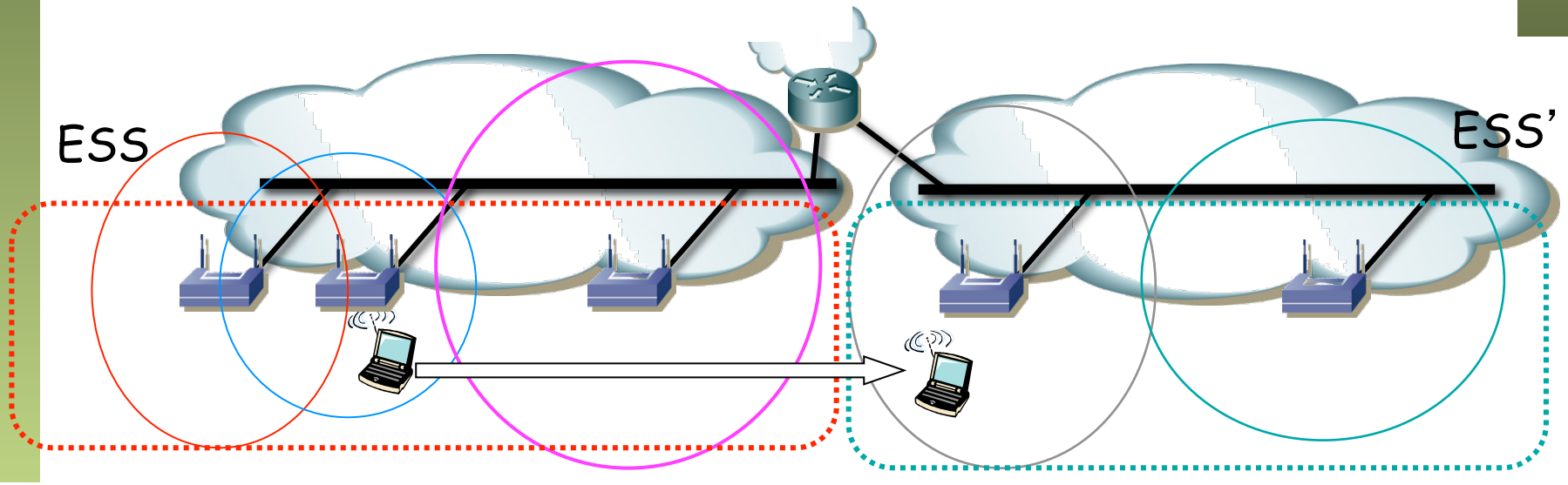
- Estaciones se mueven dentro de un mismo ESS cambiando de AP
- Reasociación, normalmente al detectar otro AP con más potencia
- Requiere cooperación entre los APs para conocer a cuál se encuentra asociado el usuario
- Durante bastante tiempo esa cooperación no estuvo estandarizada (802.11F pero retirado en 2006)
- Hoy se extiende el uso de *Wireless Controllers*



Movilidad

Transición ESS

- De un ESS a otro distinto
- No soportado por 802.11
- Comunicación de capas superiores se ve interrumpida
- Se creará una nueva asociación y nueva configuración de red
- Para TCP/IP existe la posibilidad de *Mobile IP*

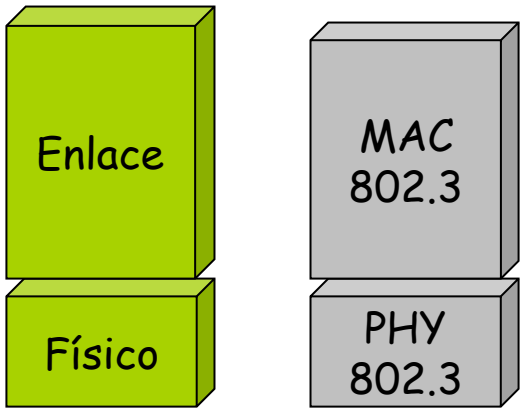


802.11: MAC tradicional

Subnivel MAC

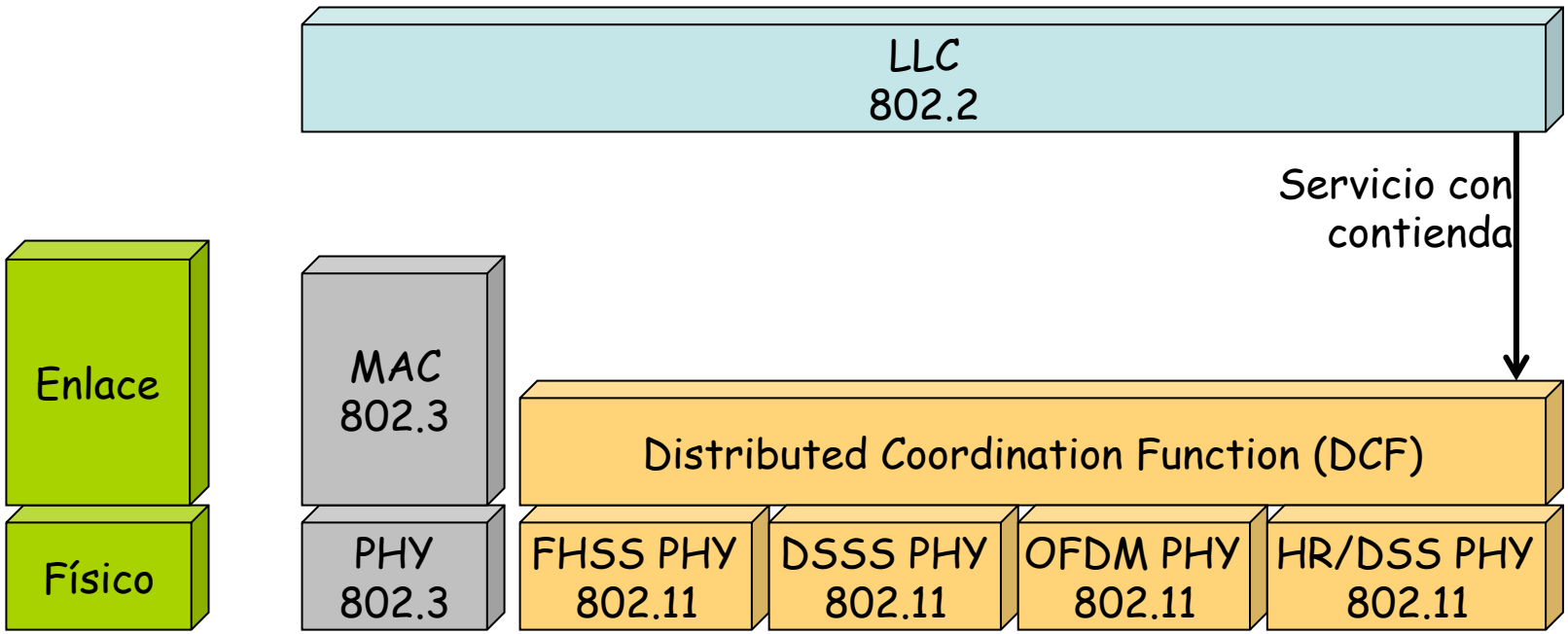
Conveniente un cierto conocimiento en detalle:

- Para comprender las diferentes soluciones para hacer la red segura
- Para solucionar problemas de red (*packet sniffing*)
- Para poder optimizar parámetros de la misma
- Para ajustar parámetros de los drivers
- Para comprender las mejoras que se van ofreciendo en nuevos productos y estándares



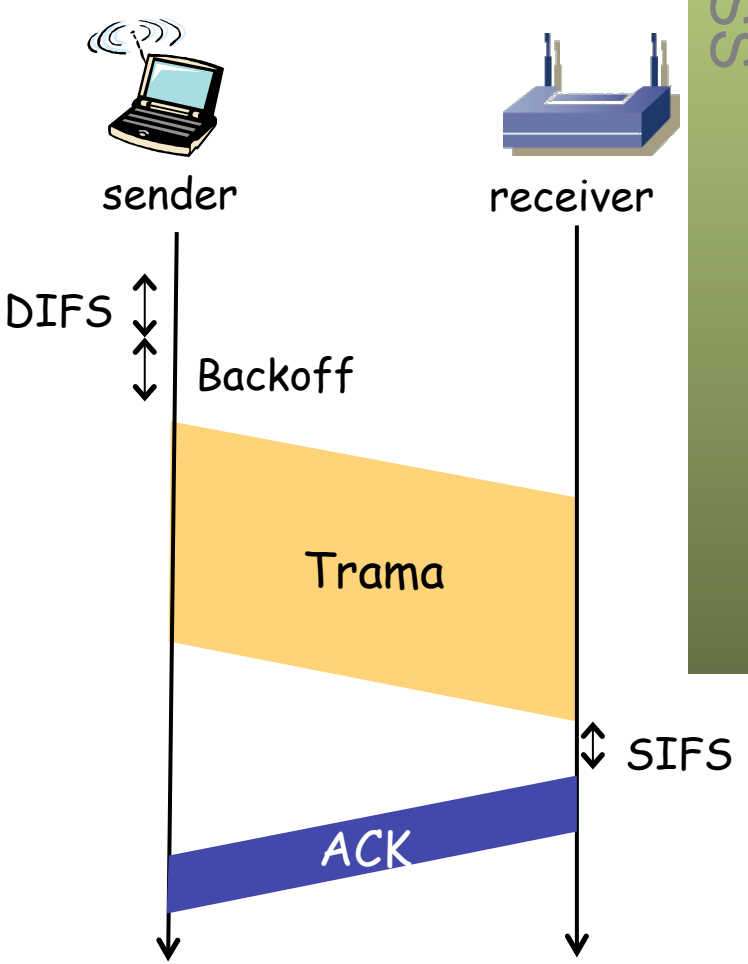
Subnivel MAC

- IEEE 802.3 (Ethernet) usa CSMA/CD
- IEEE 802.11 (Wi-Fi):
  - DCF = *Distributed Coordination Function*
    - CSMA/CA = *Carrier Sense Multiple Access / Collision Avoidance*
    - *Mandatory*
    - Modo infraestructura o *ad-hoc*
    - Emplea confirmaciones positivas (ACKs)



CSMA/CA

- ***Carrier Sense*:** Si se detecta el medio inactivo durante el tiempo suficiente (DIFS) la estación puede enviar una trama
- ***Random Backoff***: Si durante el DIFS el medio está activo, espera a que esté libre, espera un DIFS y genera un valor al alzar de tiempo que espera (entre CW_{min} y CW) (*collision avoidance*)
- Si el medio sigue libre envía la trama
- Destinatario espera un tiempo (SIFS, con SIFS<DIFS) y envía una confirmación
- Si no recibe ACK duplica CW, genera un nuevo backoff aleatorio, espera y retransmite

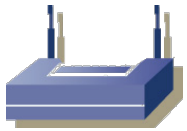


DIFS = *DCF Interframe Space*
SIFS = *Short Interframe Space*

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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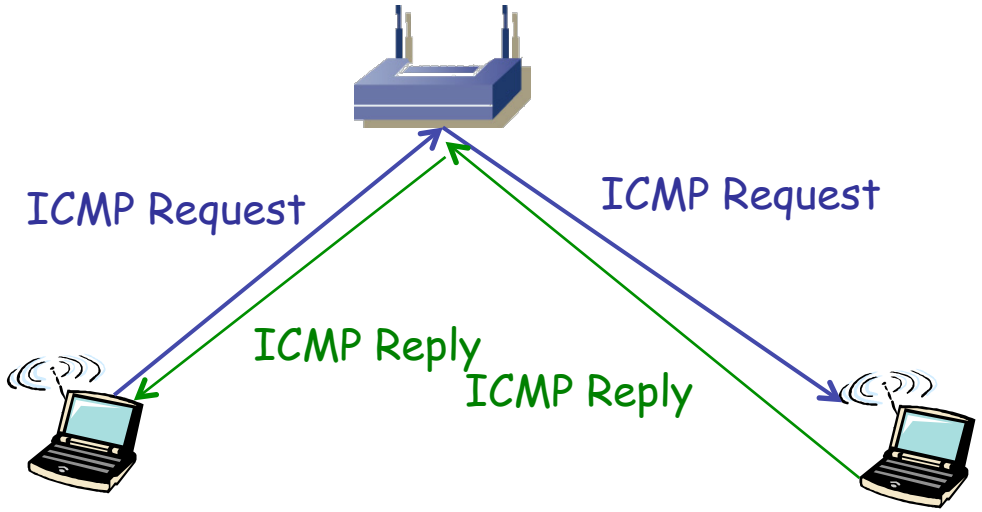
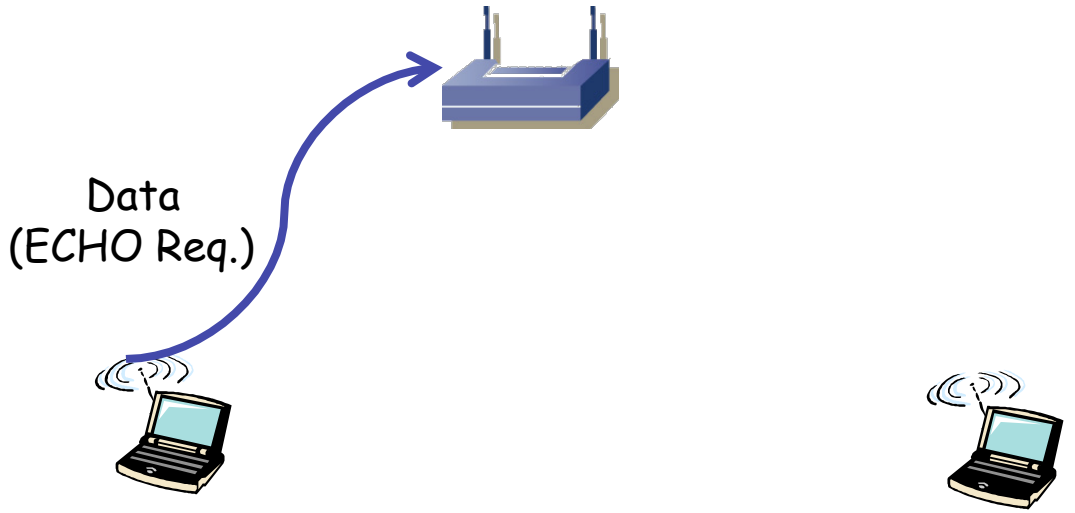
1	0.000000000	0.000000000	192.168.1.100	192.168.1.101	134	12	00:13:f7:54:32:01	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,…
2	0.000016446	0.000016446		SmcNetwo_54:32:01 …	28	12		00:13:f7:54:32:01			Acknowledgement, Flags=.....
3	0.000270064	0.000253618	192.168.1.100	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=.....

Si miramos solo las tramas de datos tenemos esto:



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=.....



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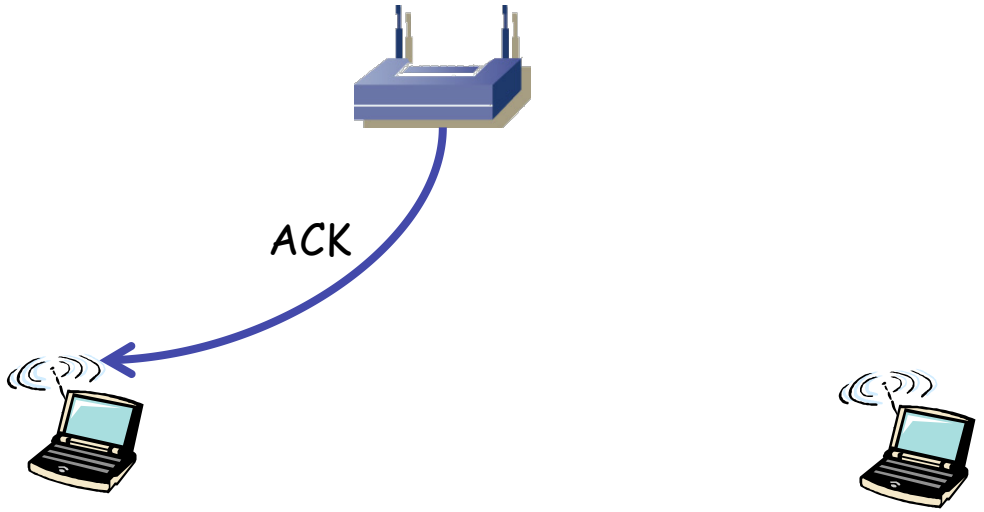
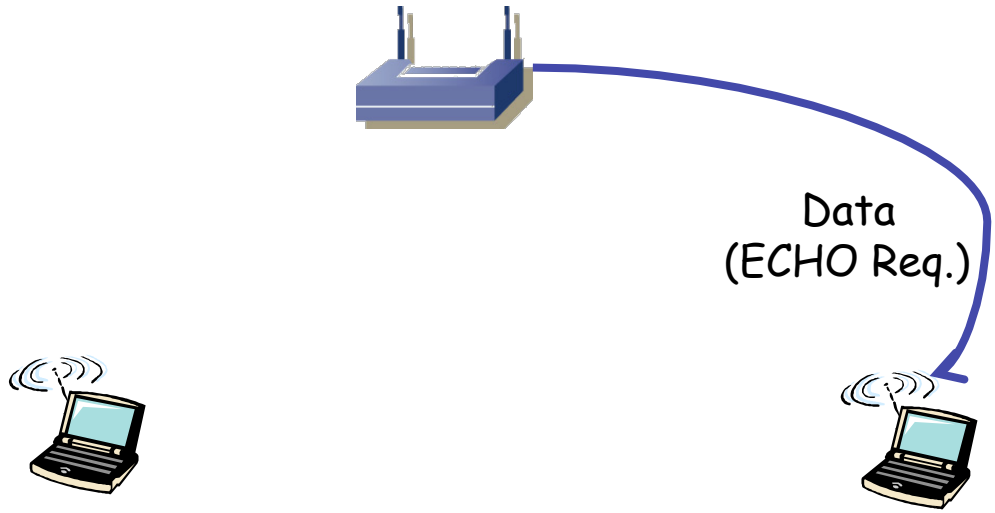
No.	Time	Arrival Time	Source	Destination	Length	Data rate	Transmitter address	Receiver address	Source address	Receiver address	Info
1	0.000000000	0.000000000	192.168.1.100	192.168.1.101	134	12	00:13:f7:54:32:01	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,…
2	0.000016446	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=……..



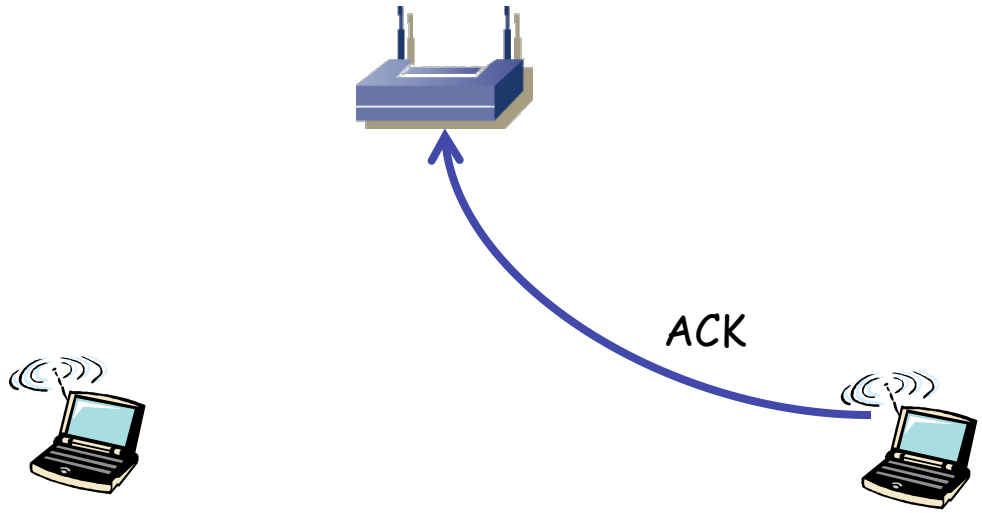
Incluyendo tramas de control

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=……..



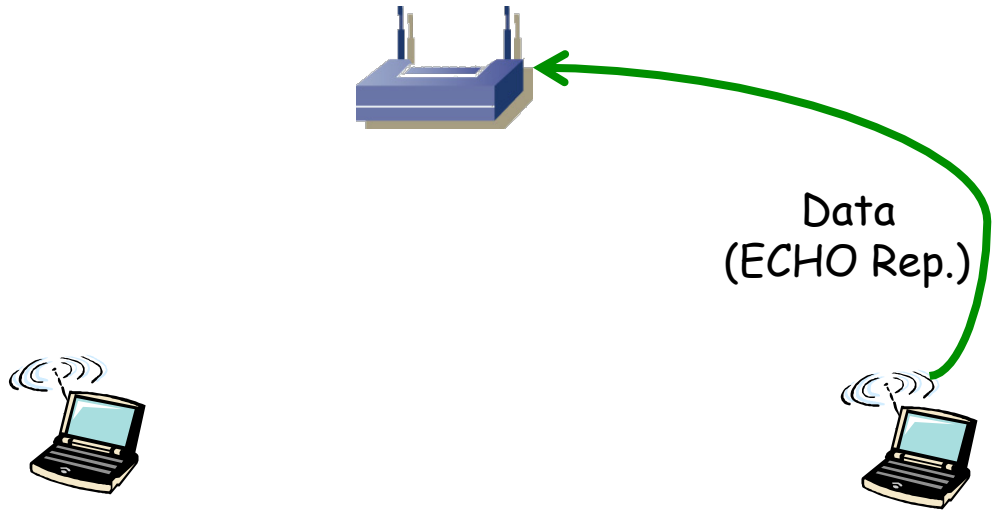
Incluyendo tramas de control

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=.....



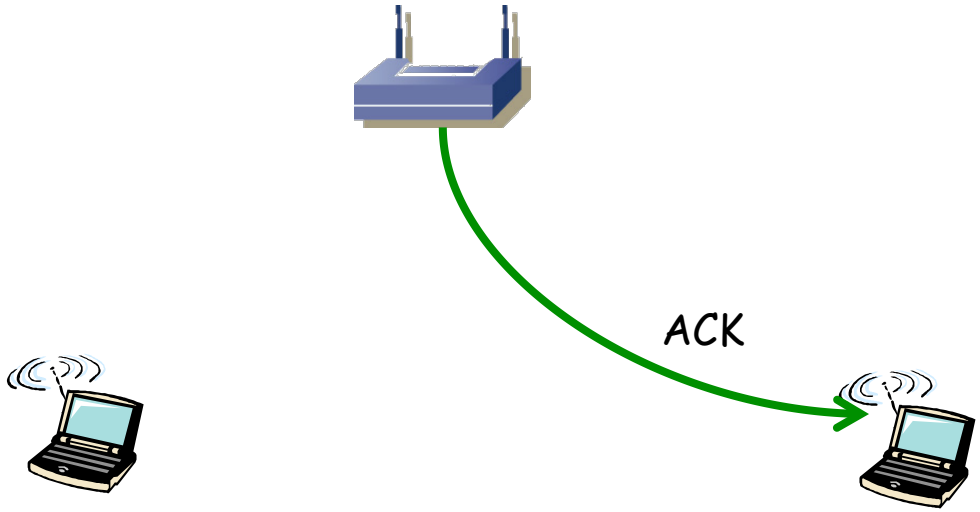
Incluyendo tramas de control

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=……..



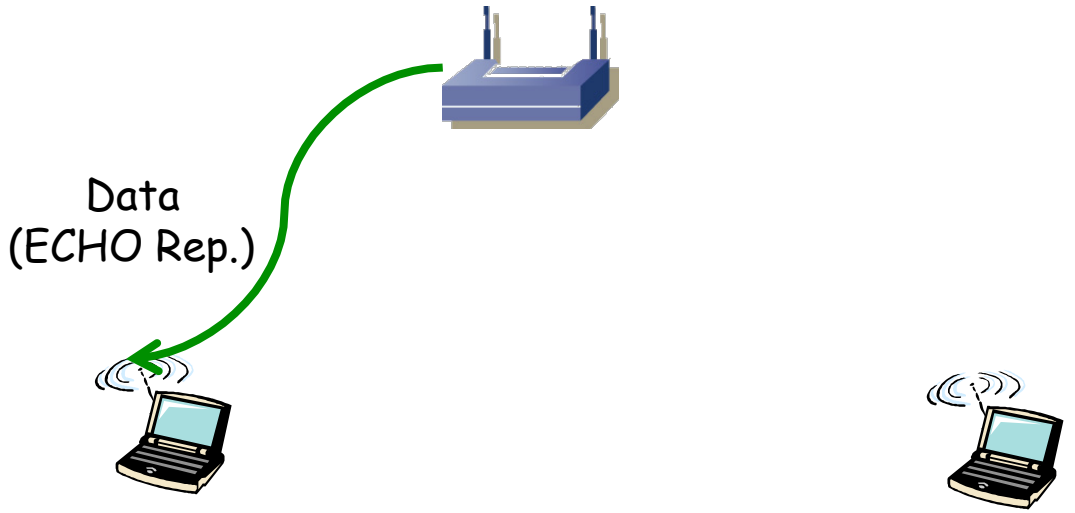
Incluyendo tramas de control

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=........



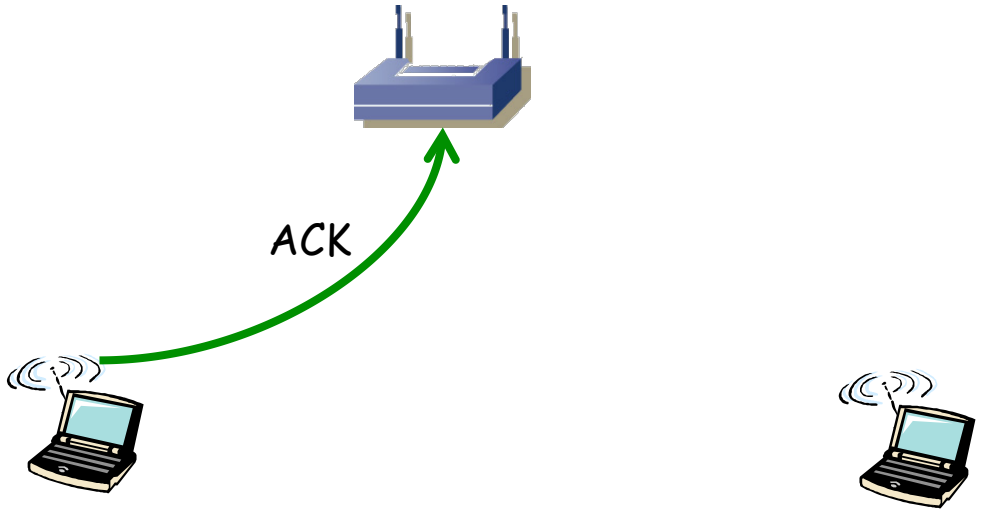
Incluyendo tramas de control

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=……..

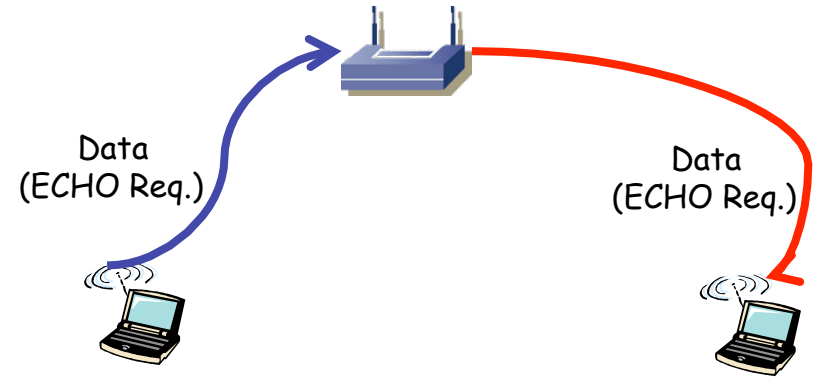


Incluyendo tramas de control

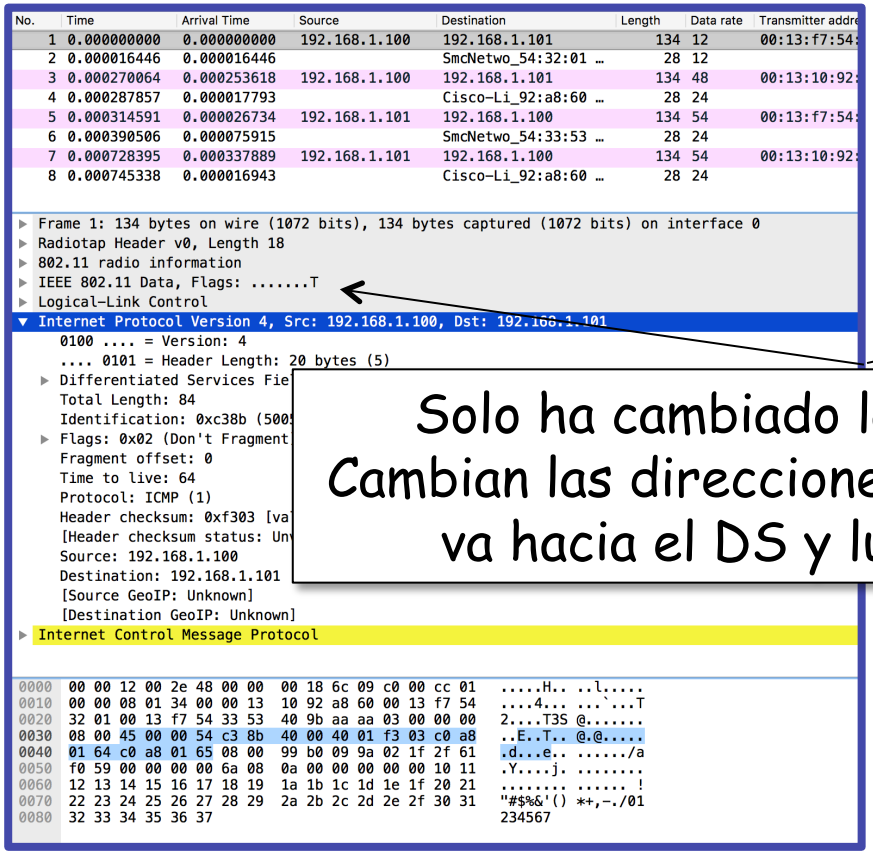
No.	Time	Arrival Time	Source	Destination	Length	Data rate	Transmitter address	Receiver address	Source address	Receiver address	Info
1	0.000000000	0.000000000	192.168.1.100	192.168.1.101	134	12	00:13:f7:54:32:01	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,…
2	0.000016446	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=……..

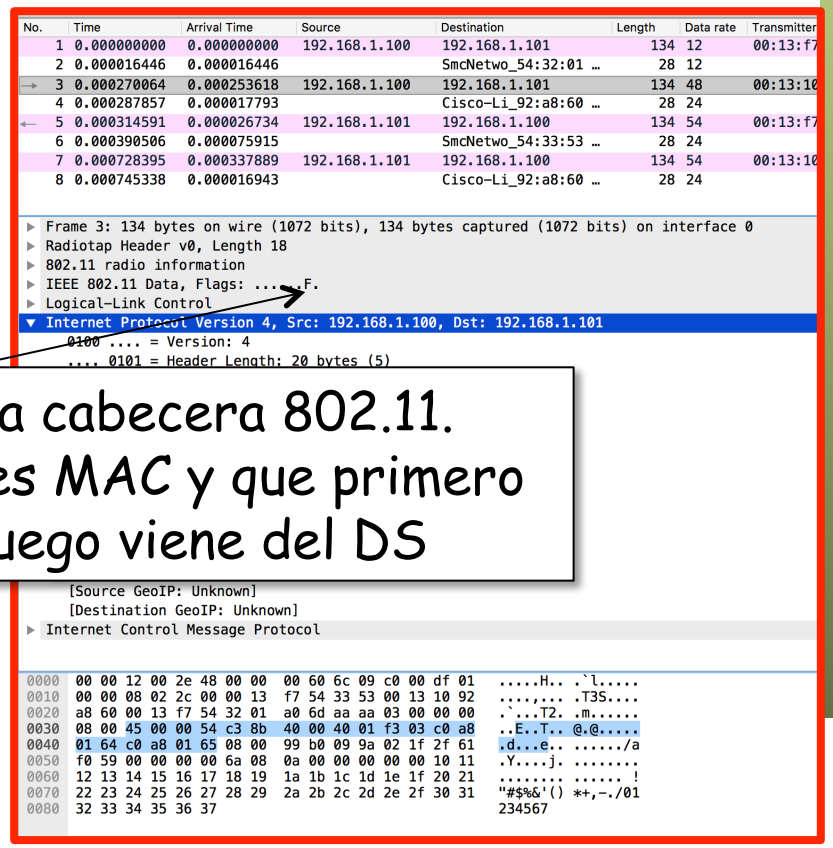


Contenido de las tramas

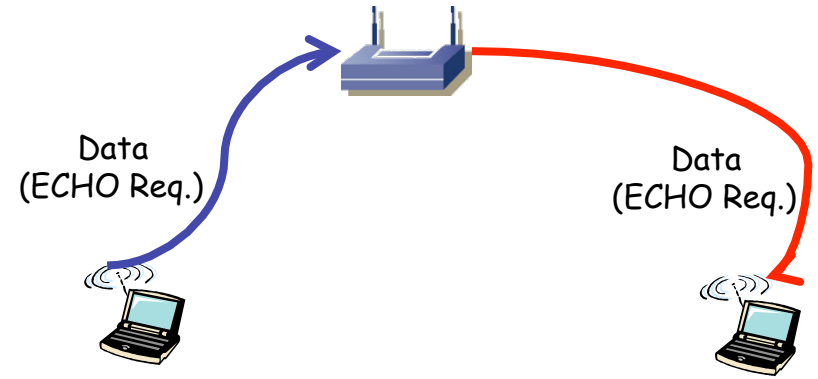


Contenido





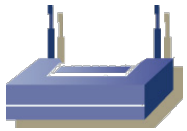
Solo ha cambiado la cabecera 802.11.
Cambian las direcciones MAC y que primero va hacia el DS y luego viene del DS



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

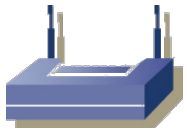
00:13:f7:54:33:53

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

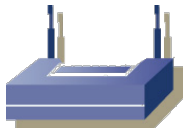
Direcciones MAC

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

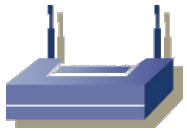
No.	Time	Arrival Time	Source	Destination	Length	Data rate	Transmitter address	Receiver address	Source address	Receiver address	Info
1	0.000000000	0.000000000	192.168.1.100	192.168.1.101	134	12	00:13:f7:54:32:01	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,…
2	0.000016446	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 WiFi que debe leer la trama

Interfaz origen 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

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=……..

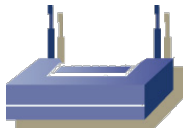
Interfaz WiFi que envía la trama

Interfaz WiFi que debe leer la trama

Interfaz origen de la trama de datos

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

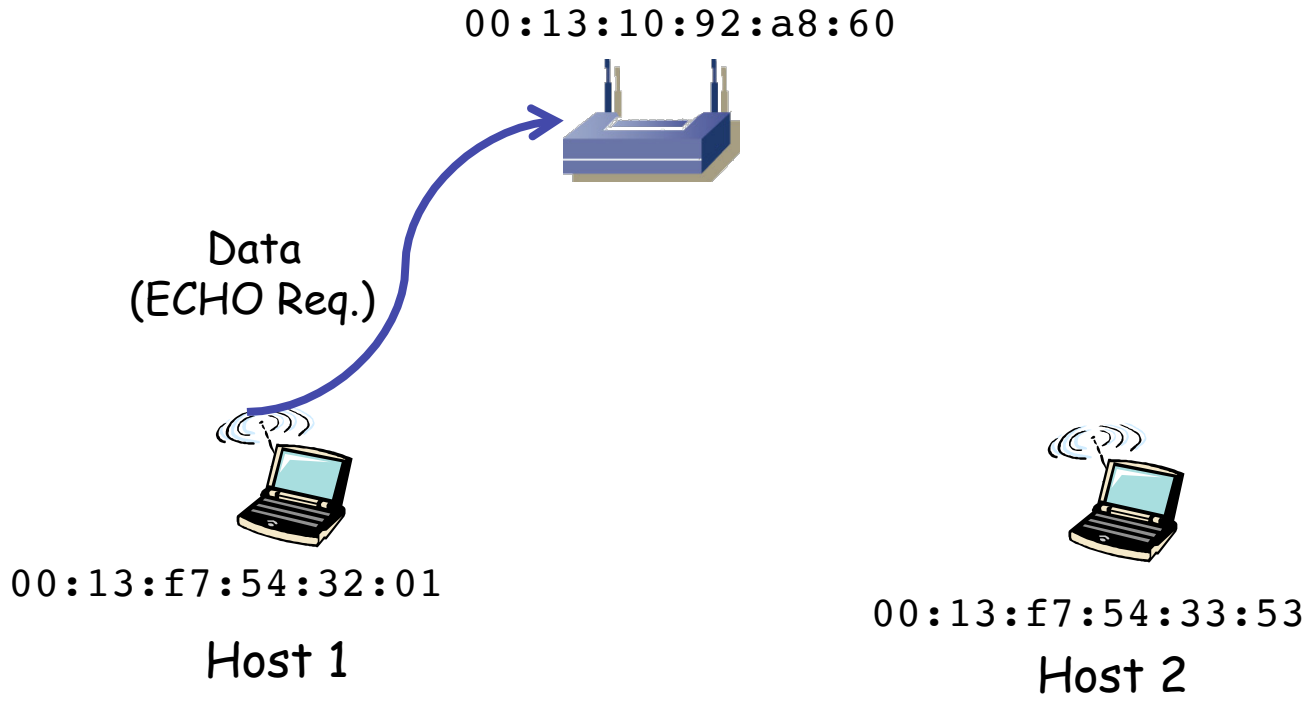
No.	Time	Arrival Time	Source	Destination	Length	Data rate	Transmitter address	Receiver address	Source address	Receiver address	Info
1	0.000000000	0.000000000	192.168.1.100	192.168.1.101	134	12	00:13:f7:54:32:01	00:13:10:92:a8:60	00:13:f7:54:32:01	00:13:f7:54:33:53	Echo (ping) request id=0x099a,…
2	0.000016446	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:f7:92: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

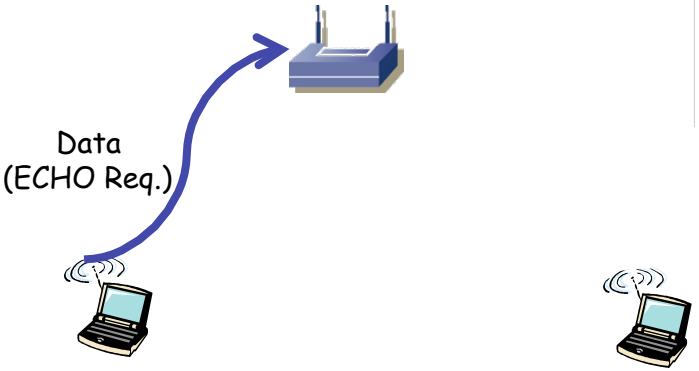


Direcciones MAC: Ejemplo

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: 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
```



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: 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
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▶ Logical-Link Control
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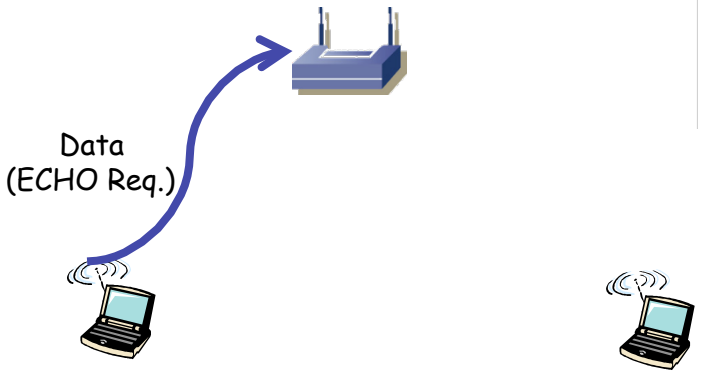
```
0000  00 00 12 00 2e 48 00 00  00 18 6c 09 c0 00 cc 01   .....H.. ..l.....
0010  00 00 08 01 34 00 00 13  10 92 a8 60 00 13 f7 54   ....4... ...`...T
0020  32 01 00 13 f7 54 33 53  40 9b aa aa 03 00 00 00   2....T3S @.......
0030  08 00 45 00 00 54 c3 8b  40 00 40 01 f3 03 c0 a8   ..E..T.. @.@.....
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
```

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

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  ▼ Frame Control Field: 0x0801
      .... ..00 = Version: 0
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        ...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
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▶ Logical-Link Control
▶ Internet Protocol Version 4, Src: 192.168.1.100, Dst: 192.168.1.101
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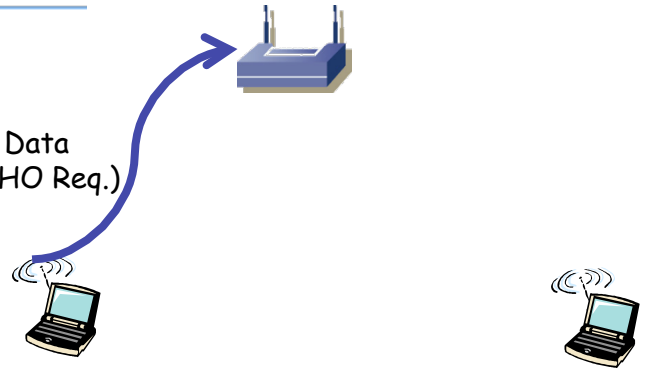
0020  32 01 00 13 f7 54 33 53  40 9b aa aa 03 00 00 00   2....T3S @.......
0030  08 00 45 00 00 54 c3 8b  40 00 40 01 f3 03 c0 a8   ..E..T.. @.@.....
0040  01 64 c0 a8 01 65 08 00  99 b0 09 9a 02 1f 2f 61   .d...e.. ....../a
0050  f0 59 00 00 00 00 6a 08  0a 00 00 00 00 00 10 11   .Y....j. ........
0060  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

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  ▼ Frame Control Field: 0x0801
      .... ..00 = Version: 0
      .... 10.. = Type: Data frame (2)
      0000 .... = Subtype: 0
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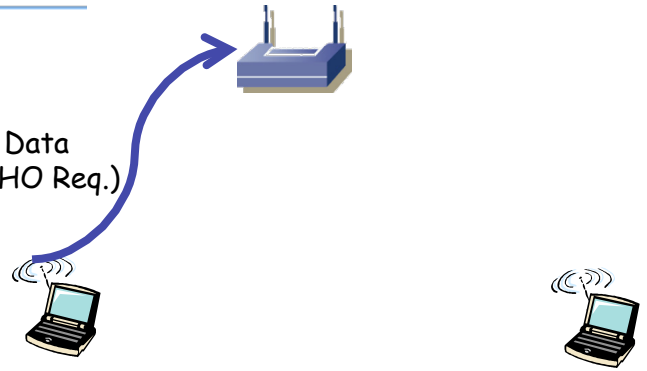
        .... .0.. = More Fragments: This is the last fragment
        .... 0... = Retry: Frame is not being retransmitted
        ...0 .... = PWR MGT: STA will stay up
        ..0. .... = More Data: No data buffered
        .0.. .... = Protected flag: Data is not protected
        0... .... = Order flag: Not 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
```

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

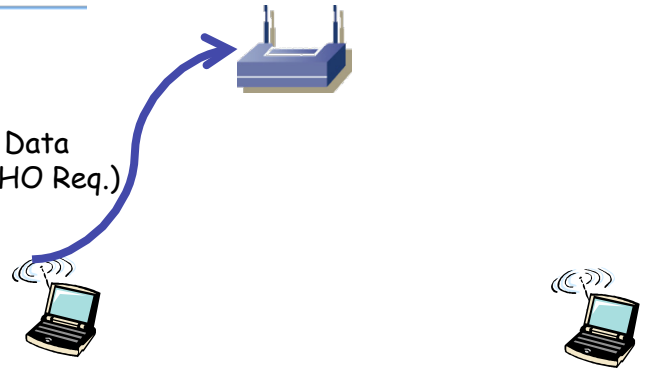


Direcciones MAC: Ejemplo

```
▶ 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
```

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

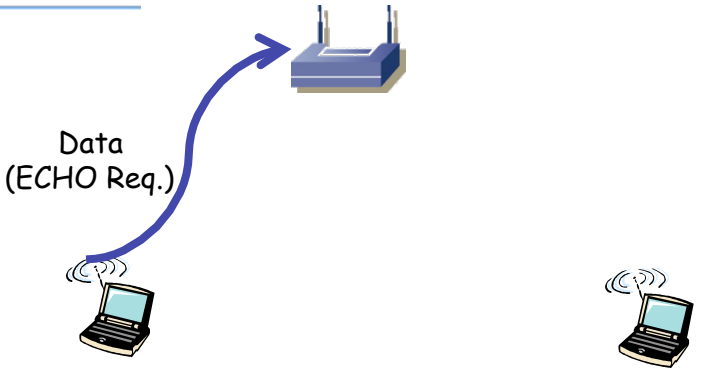


Direcciones MAC: Ejemplo

```
▶ 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
```

Y finalmente tenemos la dirección del host destino

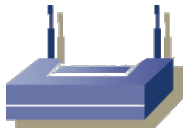


Data rate

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=.....

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

00:13:10:92:a8:60



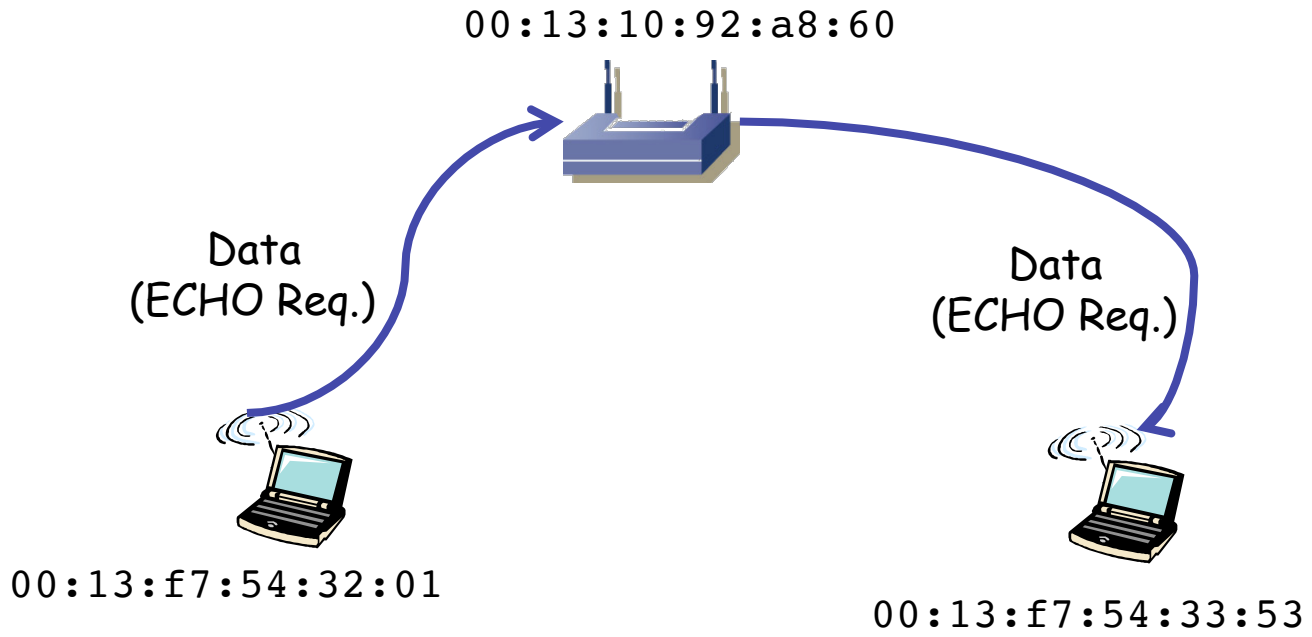
00:13:f7:54:32:01

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:a
2	0.000016446	0.000016446		SmcNetwo_54:32:01 …	28	12		00:13:f7:54:3
3	0.000270064	0.000253618	192.168.1.100	192.168.1.101	134	48	00:13:10:92:a8:60	00:13:f7:54:3
4	0.000287857	0.000017793		Cisco-Li_92:a8:60 …	28	24		00:13:10:92:a
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:a
6	0.000390506	0.000075915		SmcNetwo_54:33:53 …	28	24		00:13:f7:54:3
7	0.000728395	0.000337889	192.168.1.101	192.168.1.100	134	54	00:13:10:92:a8:60	00:13:f7:54:3
8	0.000745338	0.000016943		Cisco-Li_92:a8:60 …	28	24		00:13:10:92:a

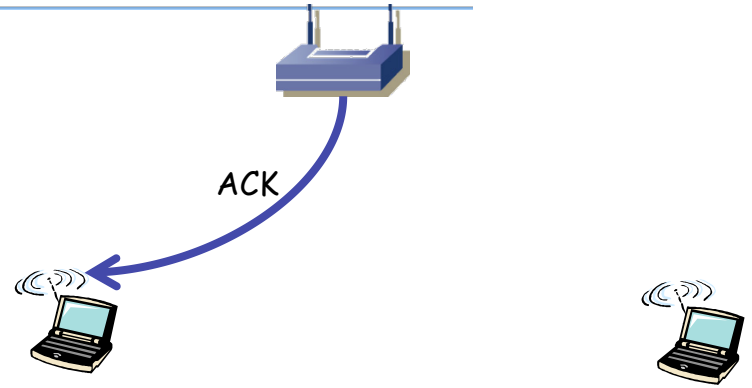
```
▶ Frame 2: 28 bytes on wire (224 bits), 28 bytes captured (224 bits) on interface 0
▶ Radiotap Header v0, Length 18
▶ 802.11 radio information
▼ IEEE 802.11 Acknowledgement, Flags: ........
    Type/Subtype: Acknowledgement (0x001d)
  ▼ Frame Control Field: 0xd400
      .... ..00 = Version: 0
      .... 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)

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.
```

Trama de confirmación (subtipo de tramas de control)

No pasa por el DS

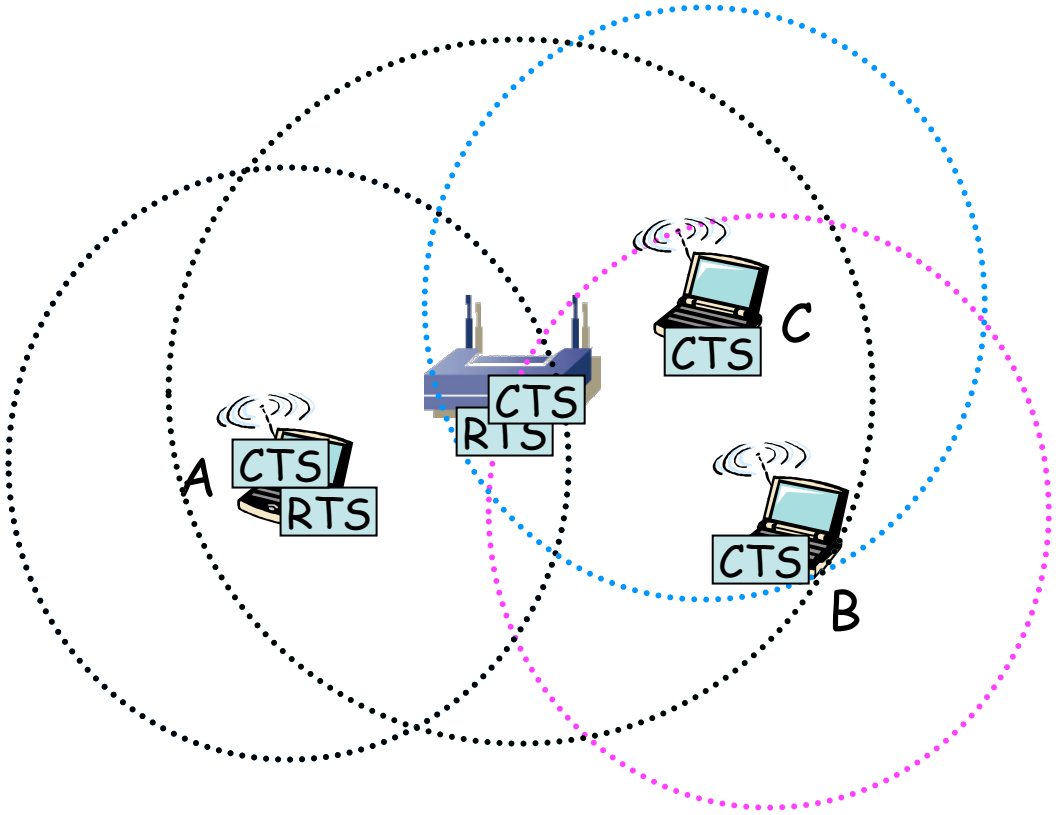
Solo incluye la dirección MAC del receptor (el que envió la de datos)



Terminal oculto

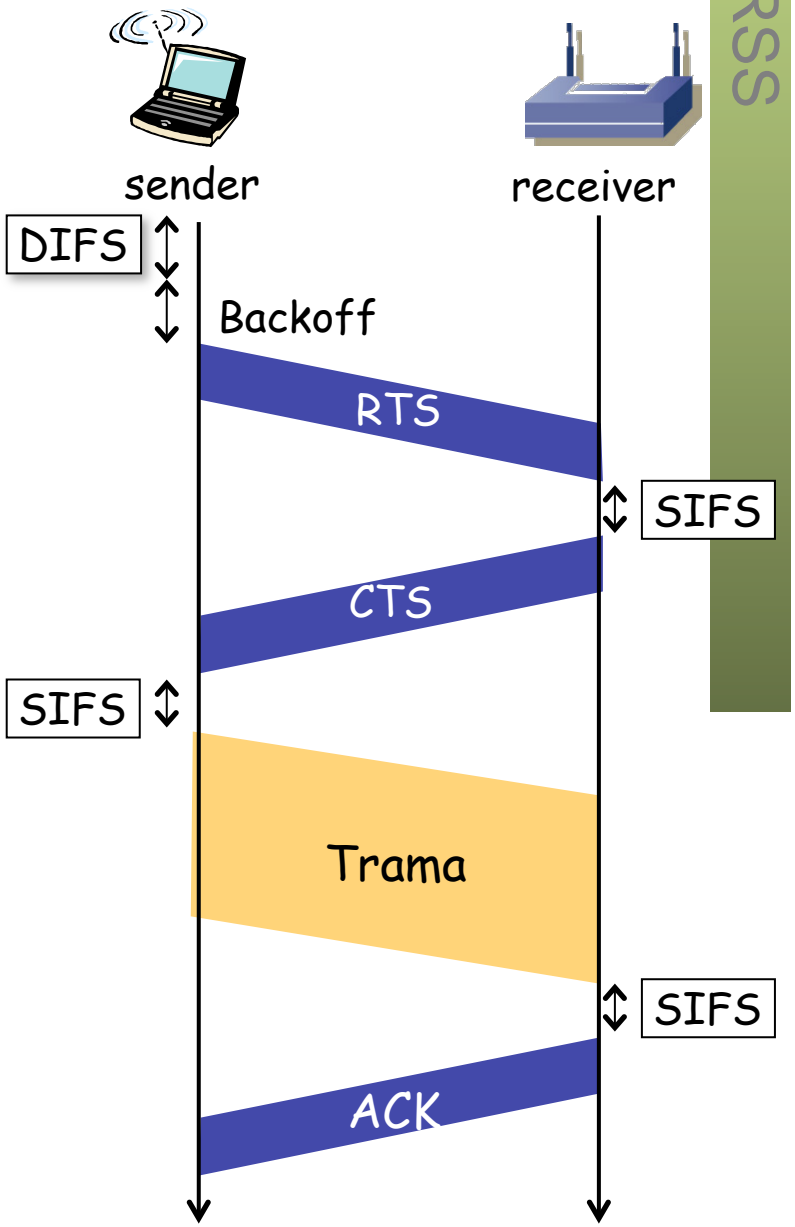
Queremos evitar las colisiones

- Reservar previamente el canal con una trama corta (menor probabilidad de colisión)
- *Request-To-Send* (RTS) (puede colisionar) (…)
- *Clear-To-Send* (CTS) (nadie más transmite) (… …)



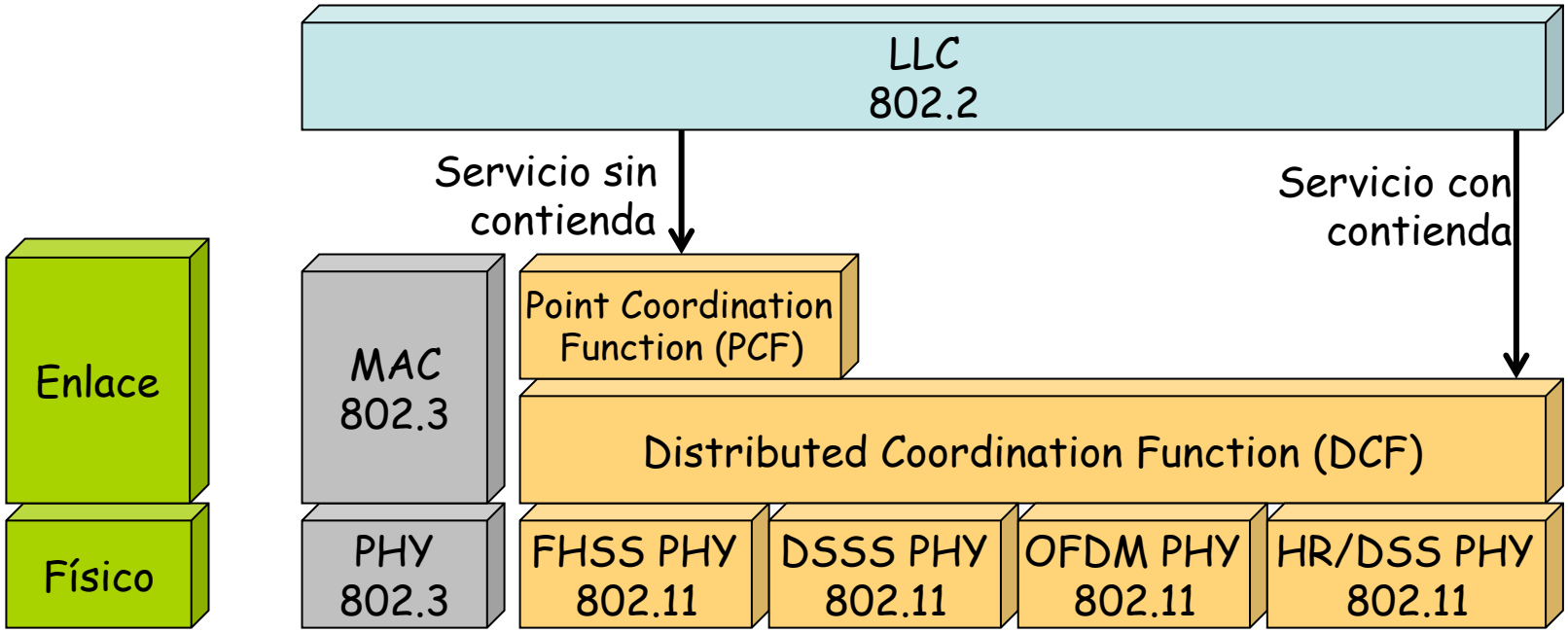
CSMA/CA

- DIFS > SIFS
- RTS/CTS consume capacidad
- Utilizado en entornos con frecuente contienda
- Generalmente solo para tramas grandes
- Throughput obtenible limitado
- Unos 4-6Mbps en 802.11b a 11Mbps
- Unos 30Mbps en 802.11g y 802.11a a 54Mbps
- En un AP b/g si hay terminales de ambos se anuncia esto en los beacons y se usa RTC/CTS



Subnivel MAC

- IEEE 802.3 (Ethernet) usa CSMA/CD
- IEEE 802.11 (Wi-Fi):
  - PCF = *Point Coordination Function*
    - Solo para modo infraestructura
    - Sin contienda (hay un coordinador)
    - Poco implementada



802.11: MACs nuevos

Subnivel MAC

- IEEE 802.3 (Ethernet) usa CSMA/CD
- IEEE 802.11 (Wi-Fi):
  - HCF = *Hybrid Coordination Function*
  - QoS sin los requisitos rigurosos de PCF
  - Obligatorio para QoS STAs
  - 802.11e (parte de 802.11-2007)

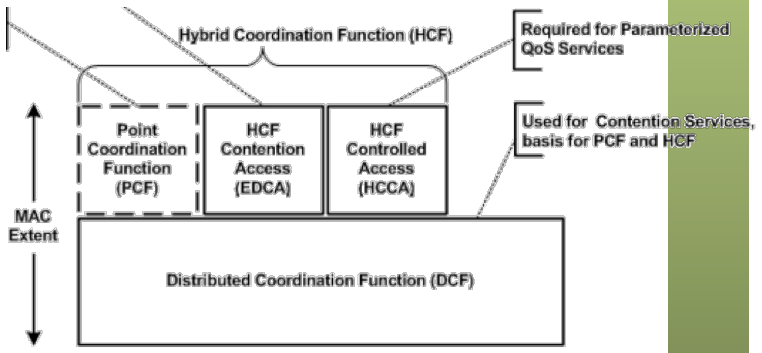
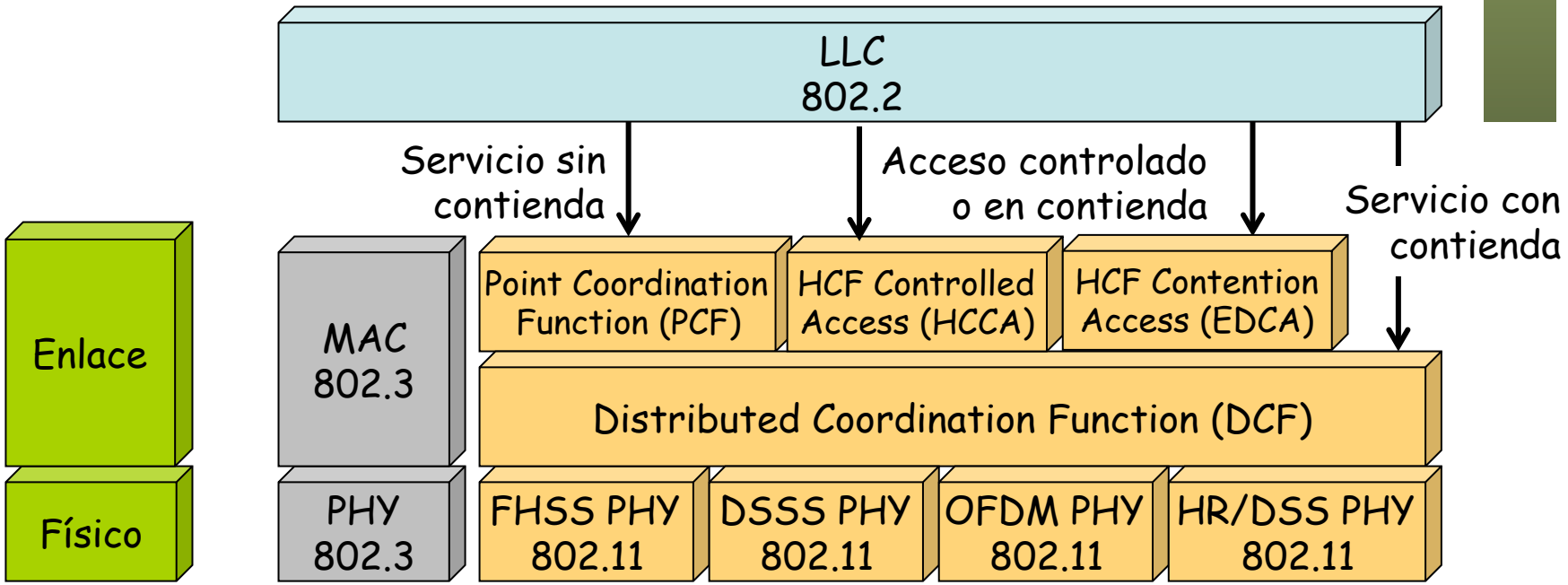


Figure 9-1—MAC architecture

IEEE 802.11-2007

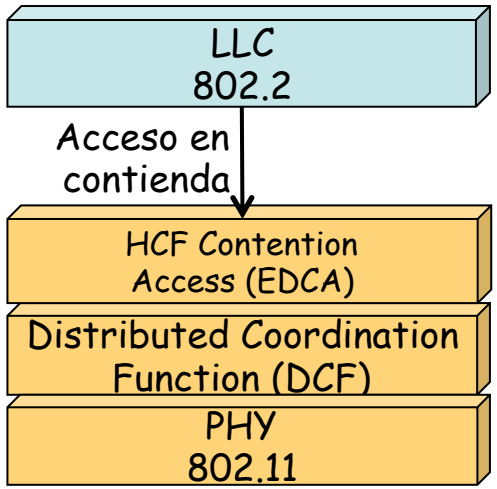


HCF

- Debe ser implementada en todas las QoS STAs
- Dos métodos de acceso posibles:
  - En contienda: *Enhanced Distributed Channel Access (EDCA)*
  - Controlado: *HCF Controlled Channel Access (HCCA)*
- WMM (...)

WMM®

- Wi-Fi Multimedia™ (Wi-Fi Alliance)
- Un subconjunto (*profile*) de 802.11e
- Emplea la EDCA
- 4 *Access Categories (ACs):* voz, vídeo, best effort y background (no necesariamente)

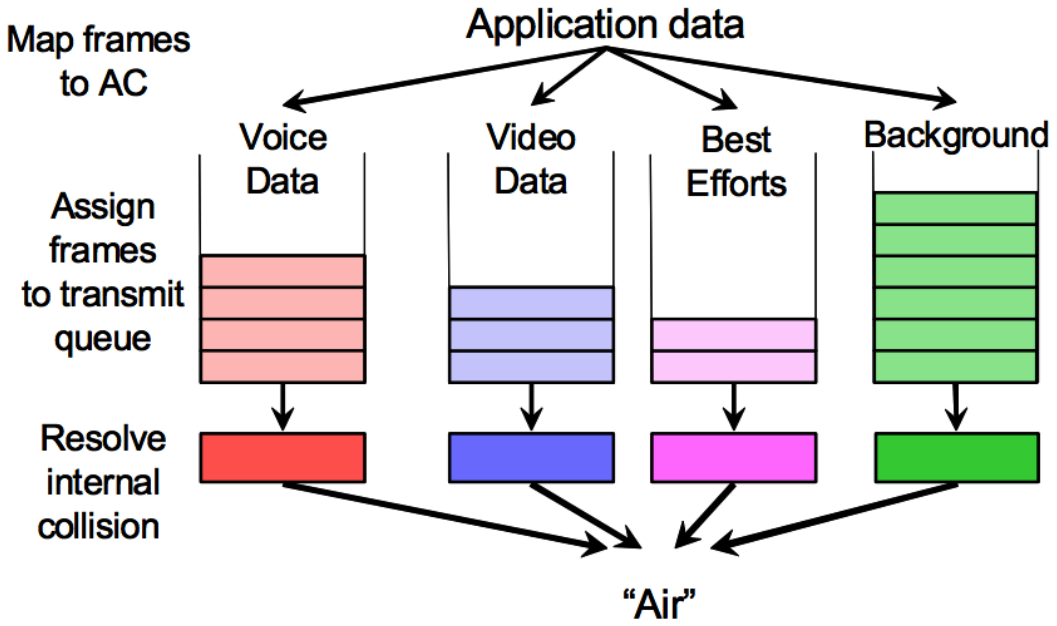


Access Category	Description	802.1d Tags
WMM Voice Priority	Highest priority Allows multiple concurrent VoIP calls, with low latency and toll voice quality	7, 6
WMM Video Priority	Prioritize video traffic above other data traffic One 802.11g or 802.11a channel can support 3-4 SDTV streams or 1 HDTV streams	5, 4
WMM Best Effort Priority	Traffic from legacy devices, or traffic from applications or devices that lack QoS capabilities Traffic less sensitive to latency, but affected by long delays, such as Internet surfing	0, 3
WMM Background Priority	Low priority traffic (file downloads, print jobs) that does not have strict latency and throughput requirements	2, 1

http://www.wi-fi.org/files/wp_1_WMM%20QoS%20In%20Wi-Fi_9-1-04.pdf

WMM

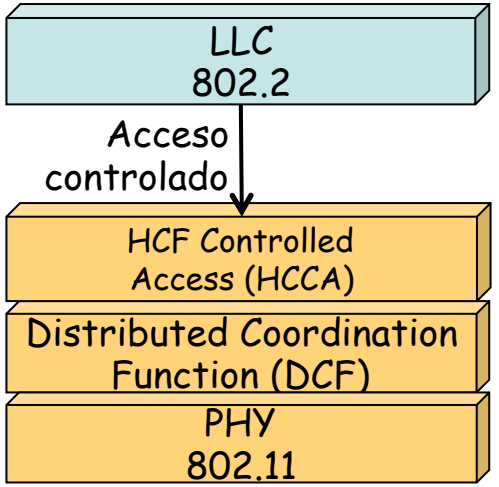
- Las aplicaciones asignan cada paquete a una AC
- Se añaden a una de las cuatro colas independientes
- El algoritmo para determinar de qué AC se transmite o qué cliente inalámbrico transmite es probabilístico
- Para ello se emplean diferentes valores de IFS y de CW según la AC (menores para mayor prioridad)
- Cuando una AC logra una oportunidad de transmisión, el tiempo que tiene reservado depende de la clase y de la tasa de transmisión física



http://www.wi-fi.org/files/wp_1_WMM%20QoS%20In%20Wi-Fi_9-1-04.pdf

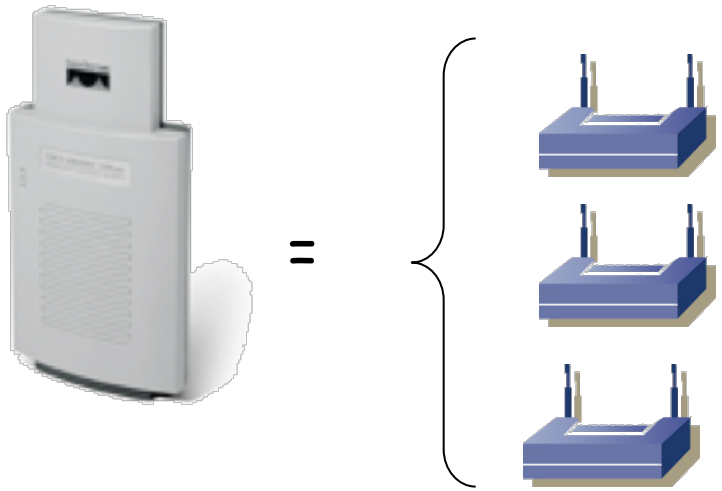
Scheduled Access

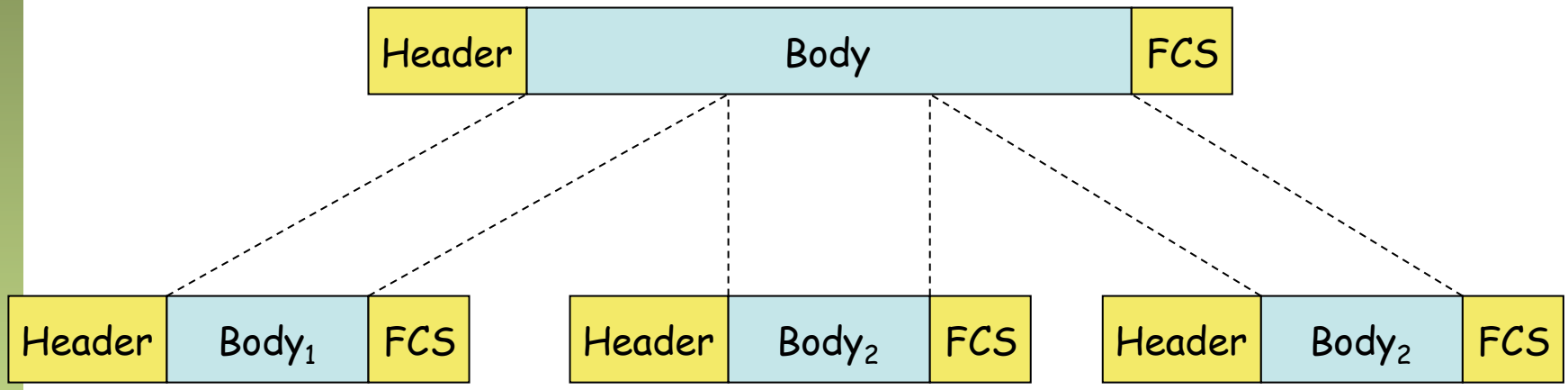
- Wi-Fi Scheduled Multimedia (WSM)
- Opcional en la certificación WMM
- Similar a la PCF
- Permite que las aplicaciones reserven recursos en base a las características de su tráfico
- Para ello envían solicitudes al AP
- Se llama el *Hybrid Coordinator (HC)*
- Emplea la HCCA
- Un planificador centralizado haciendo *polling*
- Logra reducir la latencia en la red



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*



Fragmentación

- Servicio ofrecido en el nivel de enlace
- Divide trama grande en más pequeñas
- Cada fragmento es confirmado por separado
- El transmisor no libera el medio hasta enviar todos los fragmentos
- Aumenta la fiabilidad en la transmisión
- Solo se aplica a tramas *unicast*
- Atención a las diferencias con la fragmentación en el nivel de red