WLAN Security and Analysis

April 1, 2008

Thomas d'Otreppe de Bouvette
Aircrack-ng

SHARKFEST **'08**
Foothill College
March 31 - April 2, 2008

Agenda

- Who Am I?
- Wireless networks
  - Timeline
  - Overview of 802.11 networks
  - Wireless packets
  - Encryption
  - Interactions with networks
  - Capture files analysis
- OSdep
- Demo

SHARKFEST '08

Who Am I?

- Started Aircrack-ng ~2 years ago.
- Graduated from Brussels High School in June 2006
- Currently work as IT consultant
- Created Offensive-Security WiFu course

SHARKFEST '08

CACE TECHNOLOGIES

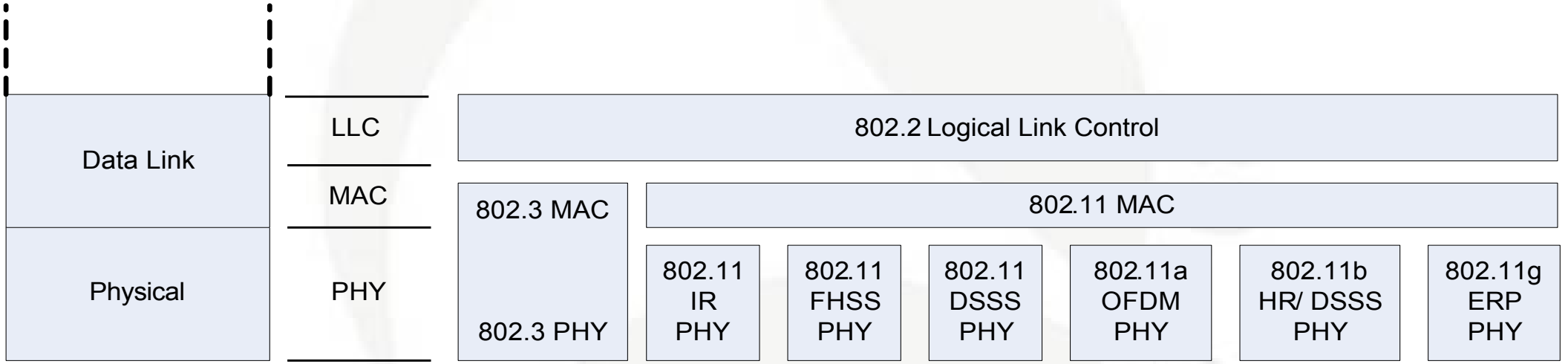
www.wiresharkU.com WIRESHARK UNIVERSITY

Overview of 802.11 networks - Timeline

- 802.11: ’97
- 802.11a: ‘99
- 802.11b: ’99
- 802.11g: 2003
- 802.11n: Group started in January 2004
  - D1.0 (1.06): November 2006
  - D1.1: January 19, 2007
  - D2.0: March 2007
  - D3 (3.02): January 2008

SHARKFEST '08

Overview of 802.11 networks - OSI



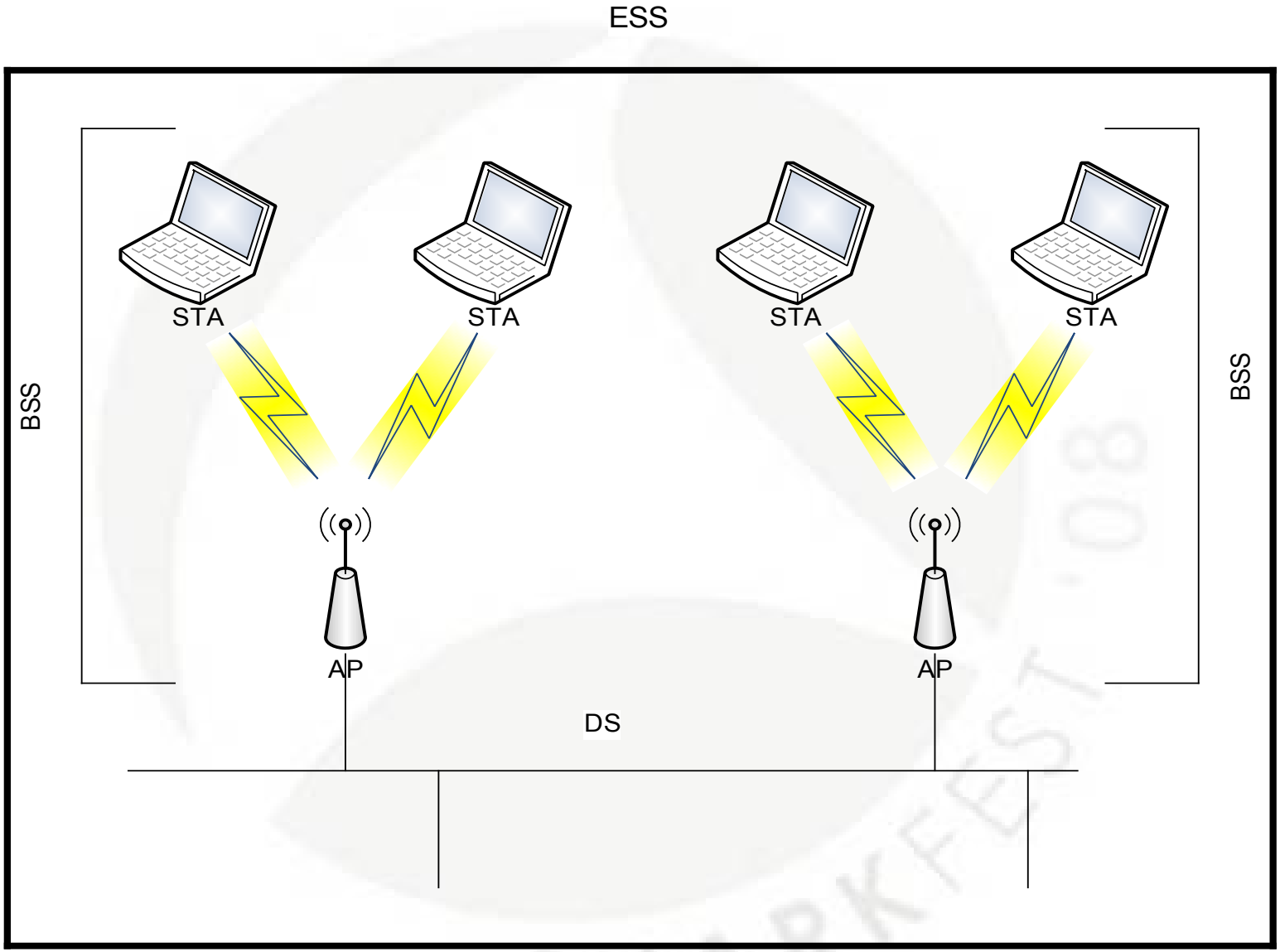
CACE TECHNOLOGIES
www.wiresharkU.com WIRESHARK UNIVERSITY

Overview of 802.11 networks – Operating Modes

- Infrastructure
- Ad hoc

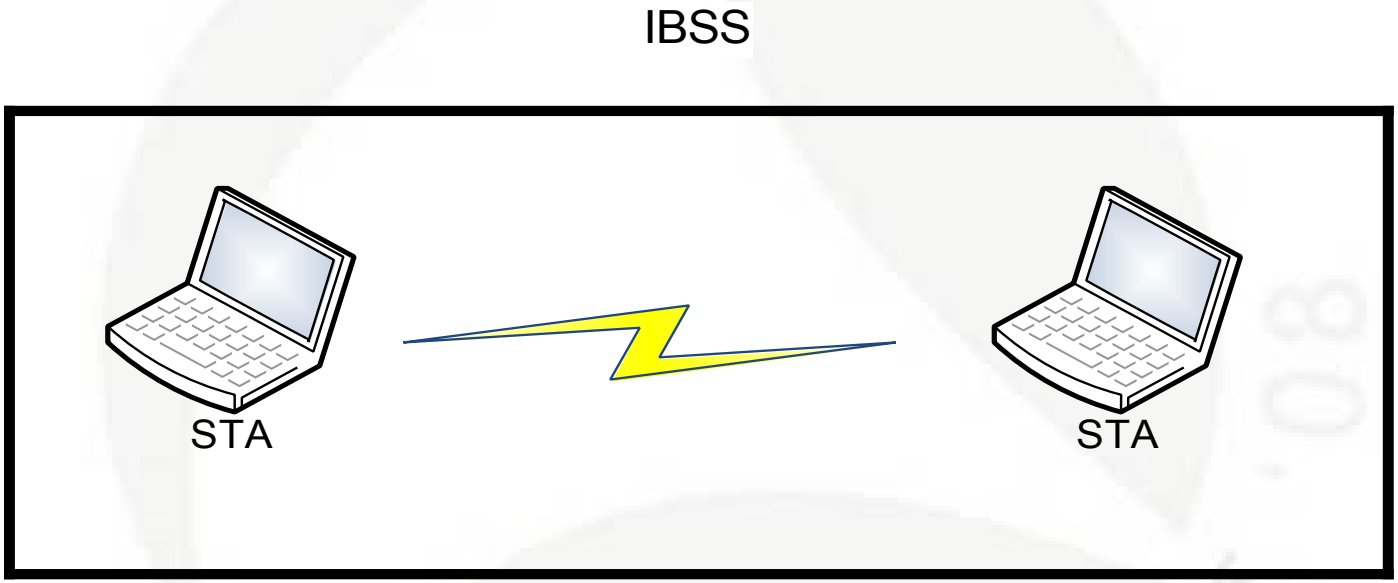
SHARKFEST '08

Overview of 802.11 networks - Infrastructure



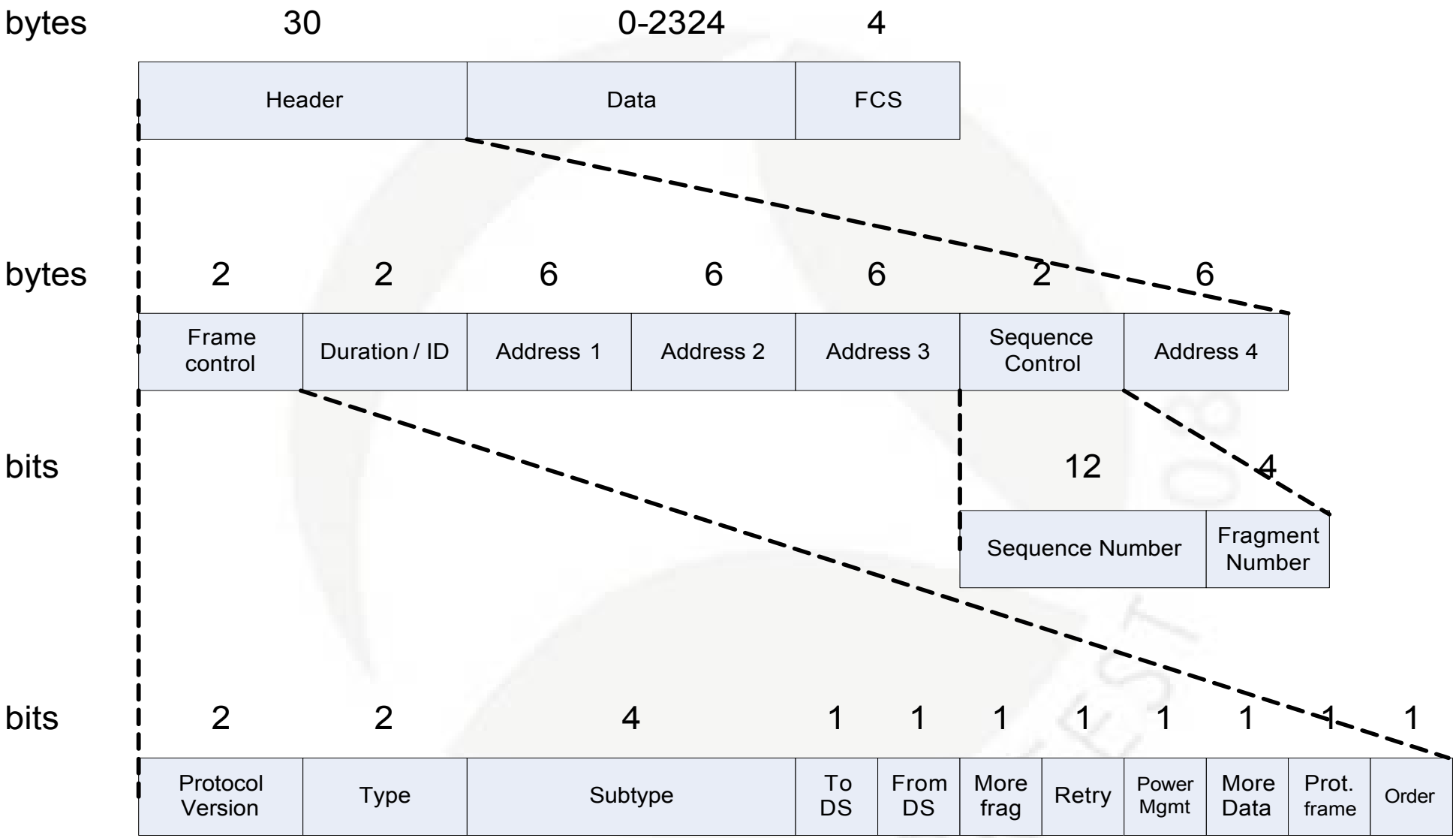
CACE TECHNOLOGIES
www.wiresharkU.com
WIRESHARK UNIVERSITY

Overview of 802.11 networks – Ad hoc



SHARKFEST '08

Wireless packets – Frame structure



CACE TECHNOLOGIES
www.wiresharkU.com WIRESHARK UNIVERSITY

Wireless packets – Frame structure Addresses

FromDS bit	ToDS bit	Address 1	Address 2	Address 3	Address 4	Mode
0	0	DA	SA	BSSID		IBSS
0	1	BSSID	SA	DA		AP
1	0	DA	BSSID	SA		AP
1	1	RA	TA	DA	SA	WDS

CACE TECHNOLOGIES
www.wiresharkU.com WIRESHARK UNIVERSITY

Wireless packets – Frames types

- Management frames
- Control frames
- Data frames

SHARKFEST '08


mister@m200: ~
CH 1][BAT: 2 hours 2 mins][Elapsed: 1 min][2008-03-30 14:19
BSSID PWR RXQ Beacons #Data, #/s CH MB ENC CIPHER AUTH ESSID
0A:ED:9D:E5:17:D4 -1 0 10027 406 0 1 11 OPN hpsetup
BSSID STATION PWR Rate Lost Packets Probes
0A:ED:9D:E5:17:D4 00:16:CF:28:03:33 0 0- 0 30 5063
0A:ED:9D:E5:17:D4 00:1D:4F:09:6F:E2 0 0- 0 25 5488
(not associated) 00:1B:77:05:93:71 0 0- 0 0 146 TELENETHOTSPOT,CK-AP-Y-1,co_presidents_club,tmobile,concourse,pcswifi,attwifi,hhonors,CLTNET,f4
m200
Sun 30 Mar
CPU
1200 MHz
116 procs
3 users
Proc
hda 38.0C
0:00


root@nx6110:~# nmap -sS 169.254.21.35
Starting Nmap 4.50 (http://insecure.org) at 2008-02-14 13:01 CET
Interesting ports on 169.254.21.35:
Not shown: 1709 filtered ports
PORT STATE SERVICE
139/tcp open netbios-ssn
445/tcp open microsoft-ds
MAC Address: 00:1F:3A:1E:9D:58 (Unknown)
Nmap done: 1 IP address (1 host up) scanned in 30.868 seconds
root@nx6110:~# nmap -sO 169.254.21.35
Starting Nmap 4.50 (http://insecure.org) at 2008-02-14 13:03 CET
Interesting protocols on 169.254.21.35:
Not shown: 255 open|filtered protocols
PROTOCOL STATE SERVICE
1 open icmp
MAC Address: 00:1F:3A:1E:9D:58 (Unknown)
Nmap done: 1 IP address (1 host up) scanned in 22.005 seconds
root@nx6110:~# nmap -sO -O 169.254.21.35
WARNING: Disabling OS Scan (-O) as it is incompatible with the IPProto Scan (-sO)
Starting Nmap 4.50 (http://insecure.org) at 2008-02-14 13:04 CET
root@nx6110:~# nmap -sS -O 169.254.21.35
Starting Nmap 4.50 (http://insecure.org) at 2008-02-14 13:04 CET
Interesting ports on 169.254.21.35:
Not shown: 1709 filtered ports
PORT STATE SERVICE
139/tcp open netbios-ssn
445/tcp open microsoft-ds
MAC Address: 00:1F:3A:1E:9D:58 (Unknown)
Warning: OSScan results may be unreliable because we could not find at least 1 open and 1 closed port
Device type: general purpose
Running: Microsoft Windows 2000
OS details: Microsoft Windows 2000 Server SP3 or SP4
Network Distance: 1 hop
OS detection performed. Please report any incorrect results at http://insecure.org/nmap/submit/ .
Nmap done: 1 IP address (1 host up) scanned in 56.240 seconds
root@nx6110:~#

Wireless packets – Management frames

- **Definition**: used to negotiate and control the relationship between the AP and the station.

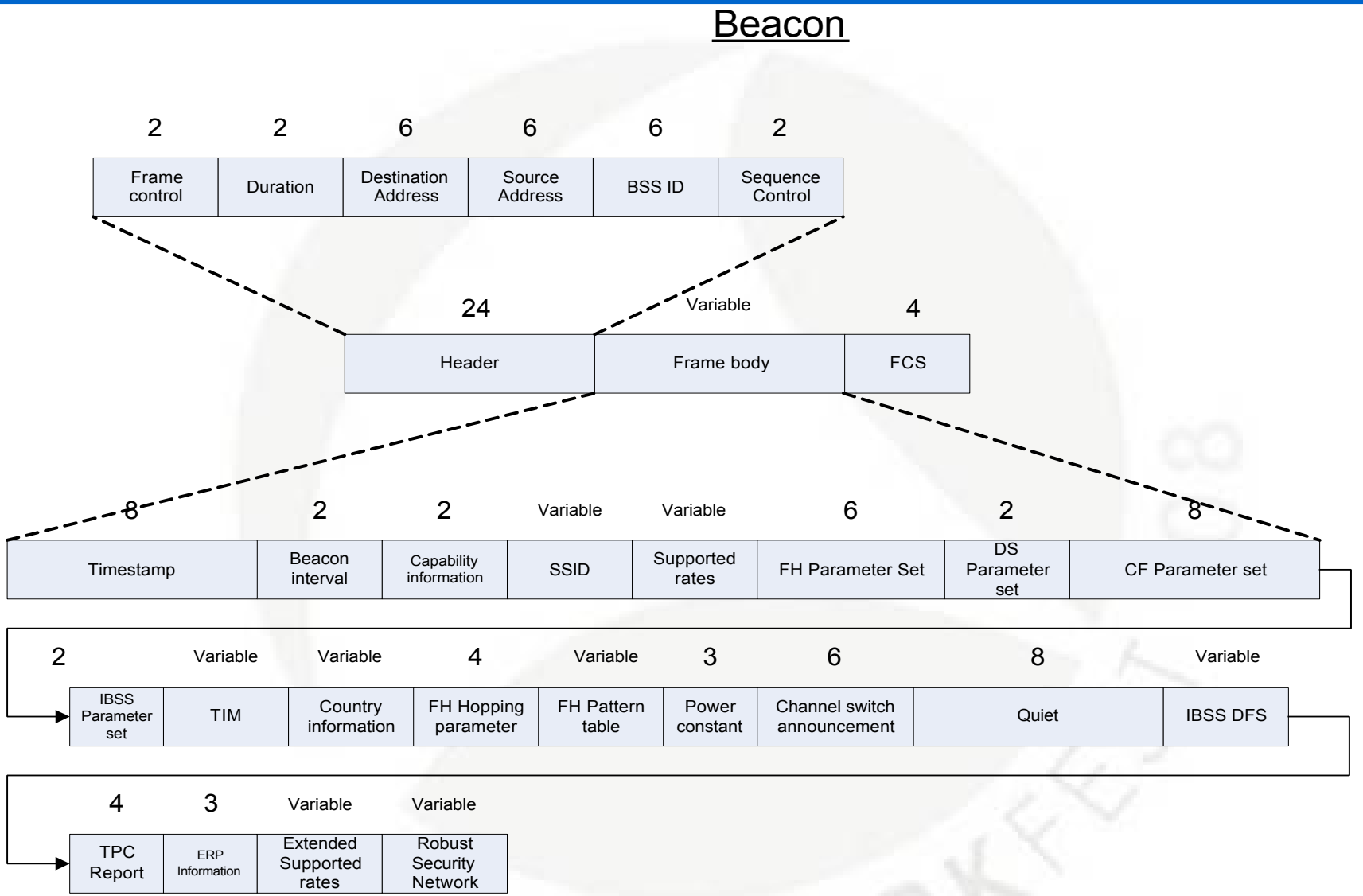
- Type field value: 0

Subtype field value	Description
0	Assoc. request
1	Assoc. response
2	Reassoc. req.
3	Reassoc. resp.
4	Probe request
5	Probe response
6	Meas. Pilot

Subtype field value	Description
7	Reserved
8	Beacon
9	ATIM
10	Disassociation
11	Authentication
12	Deauthentication
13	Action
14	Action No ACK
15	Reserved

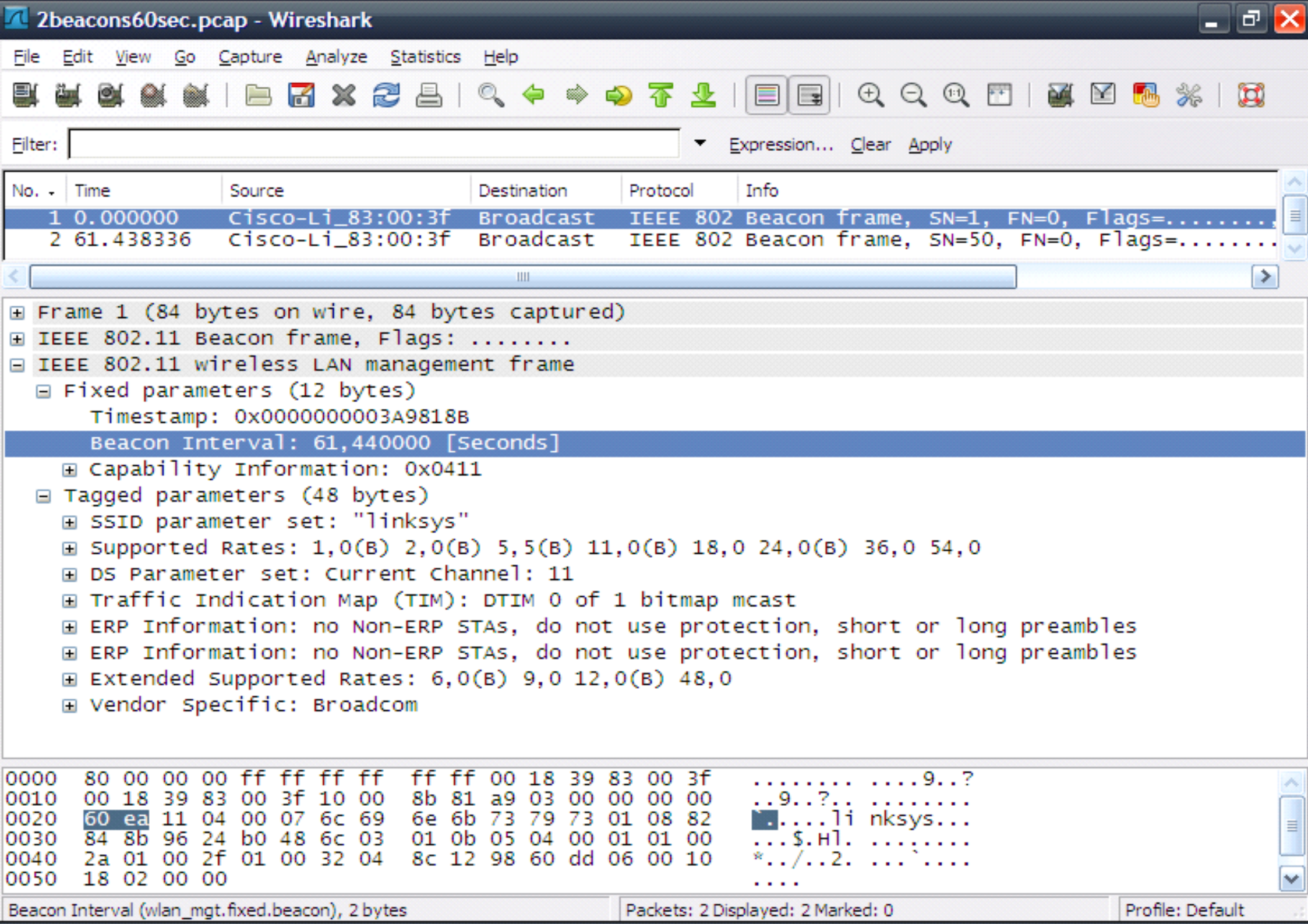
CACE TECHNOLOGIES
www.wiresharkU.com WIRESHARK UNIVERSITY

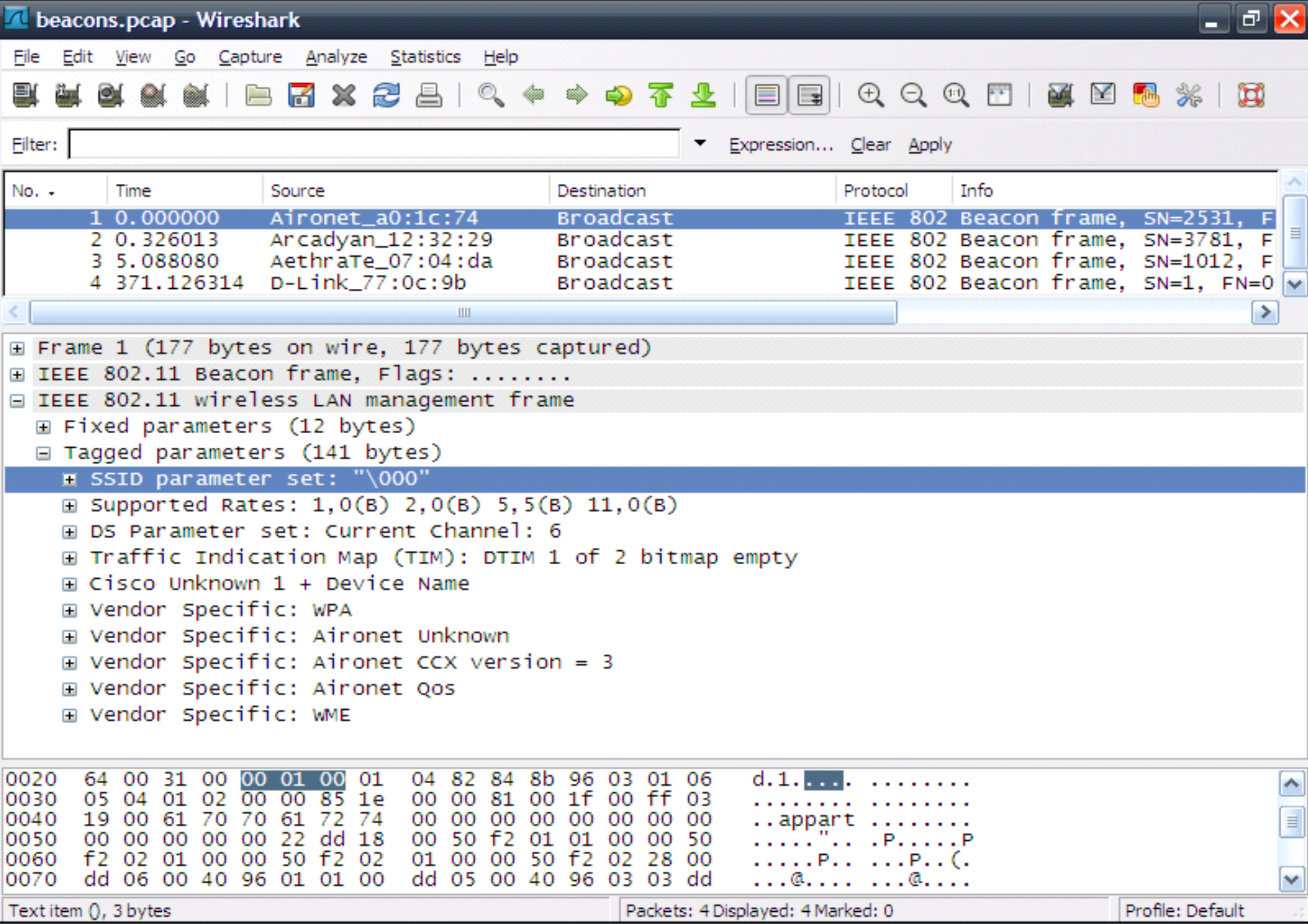
Wireless packets – Management frames (1)

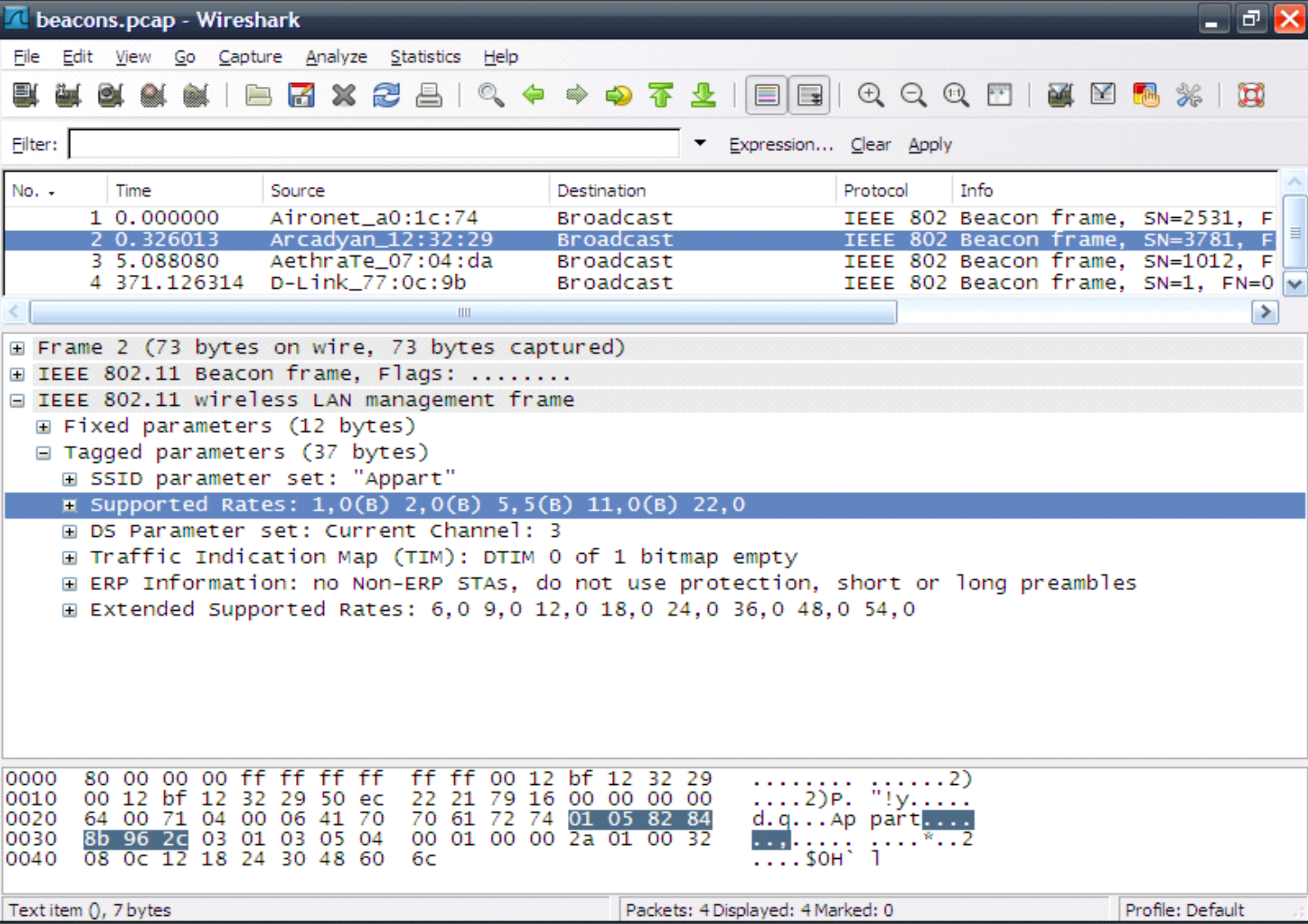


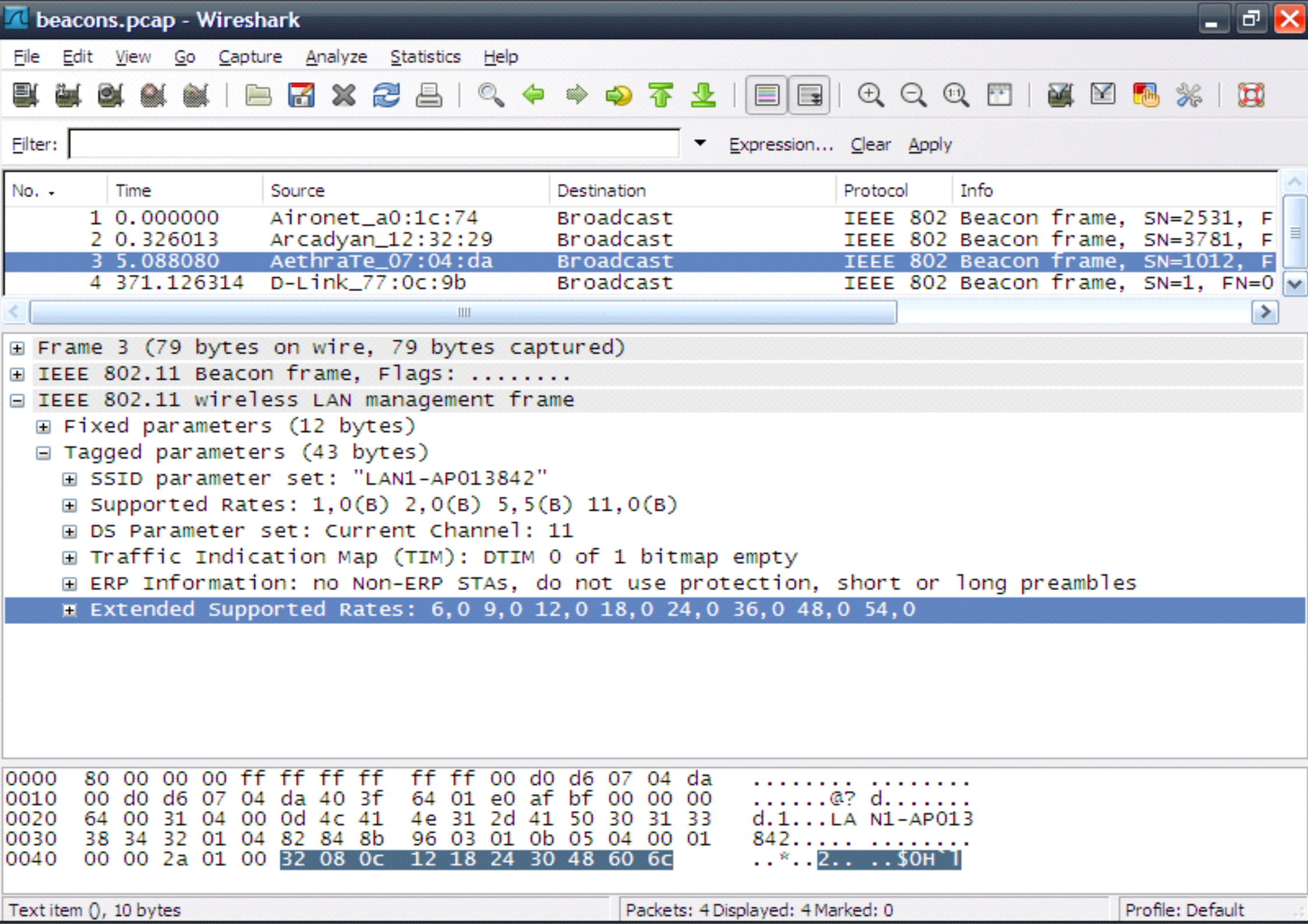
CACE TECHNOLOGIES

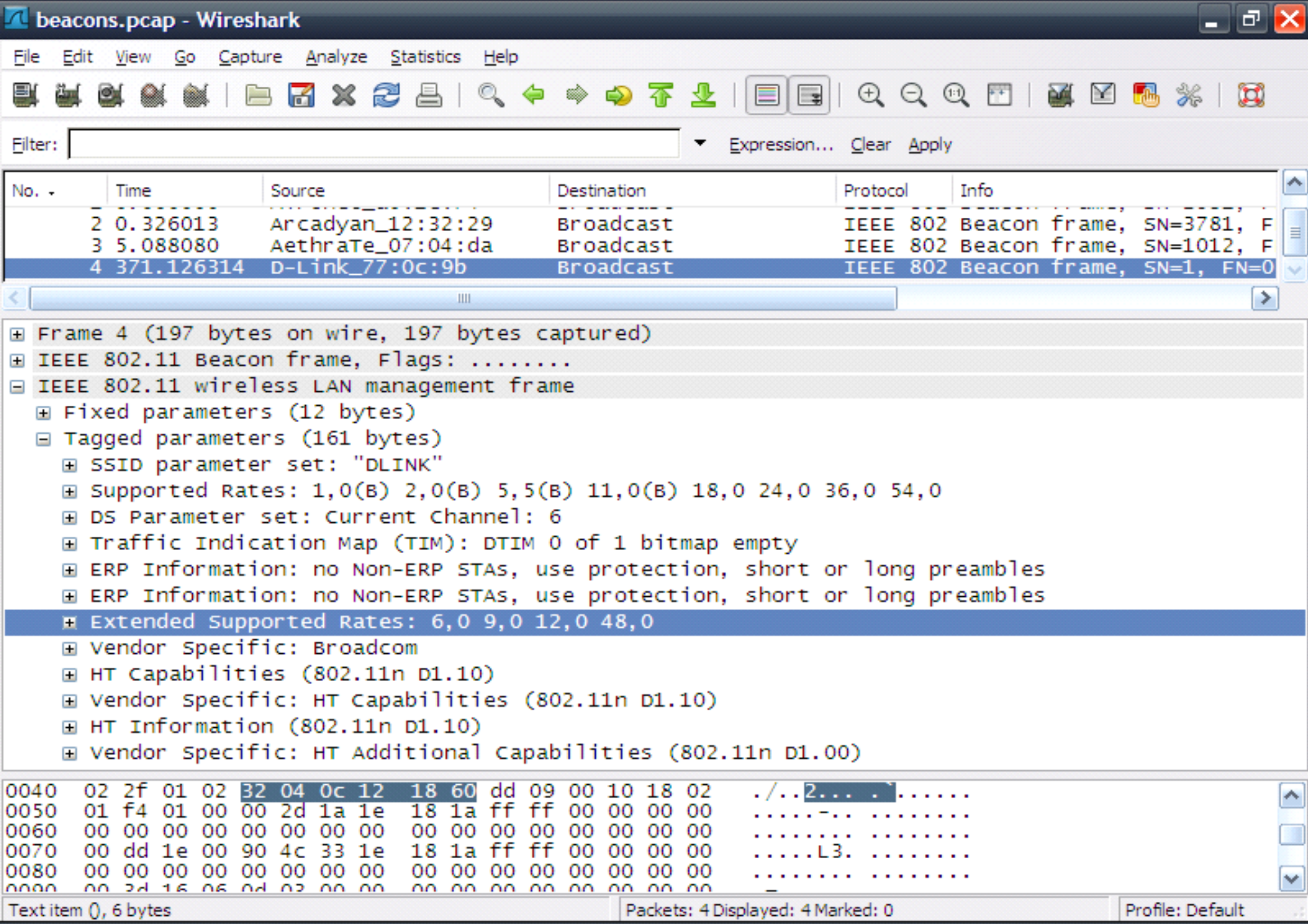
www.wiresharkU.com
WIRESHARK UNIVERSITY


2beacons60sec.pcap - Wireshark
File Edit View Go Capture Analyze Statistics Help
Filter: Expression... Clear Apply
No. Time Source Destination Protocol Info
1 0.000000 Cisco-Li_83:00:3f Broadcast IEEE 802 Beacon frame, SN=1, FN=0, Flags=.....
2 61.438336 Cisco-Li_83:00:3f Broadcast IEEE 802 Beacon frame, SN=50, FN=0, Flags=.....
Frame 1 (84 bytes on wire, 84 bytes captured)
IEEE 802.11 Beacon frame, Flags: .....
IEEE 802.11 wireless LAN management frame
Fixed parameters (12 bytes)
Timestamp: 0x0000000003A9818B
Beacon Interval: 61,440000 [Seconds]
Capability Information: 0x0411
Tagged parameters (48 bytes)
SSID parameter set: "linksys"
Supported Rates: 1,0(B) 2,0(B) 5,5(B) 11,0(B) 18,0 24,0(B) 36,0 54,0
DS Parameter set: Current Channel: 11
Traffic Indication Map (TIM): DTIM 0 of 1 bitmap mcast
ERP Information: no Non-ERP STAs, do not use protection, short or long preambles
ERP Information: no Non-ERP STAs, do not use protection, short or long preambles
Extended Supported Rates: 6,0(B) 9,0 12,0(B) 48,0
Vendor Specific: Broadcom
0000 80 00 00 00 ff ff ff ff ff ff 00 18 39 83 00 3f
0010 00 18 39 83 00 3f 10 00 8b 81 a9 03 00 00 00 00
0020 60 ea 11 04 00 07 6c 69 6e 6b 73 79 73 01 08 82
0030 84 8b 96 24 b0 48 6c 03 01 0b 05 04 00 01 01 00
0040 2a 01 00 2f 01 00 32 04 8c 12 98 60 dd 06 00 10
0050 18 02 00 00
Beacon Interval (wlan_mgt.fixed.beacon), 2 bytes
Packets: 2 Displayed: 2 Marked: 0
Profile: Default

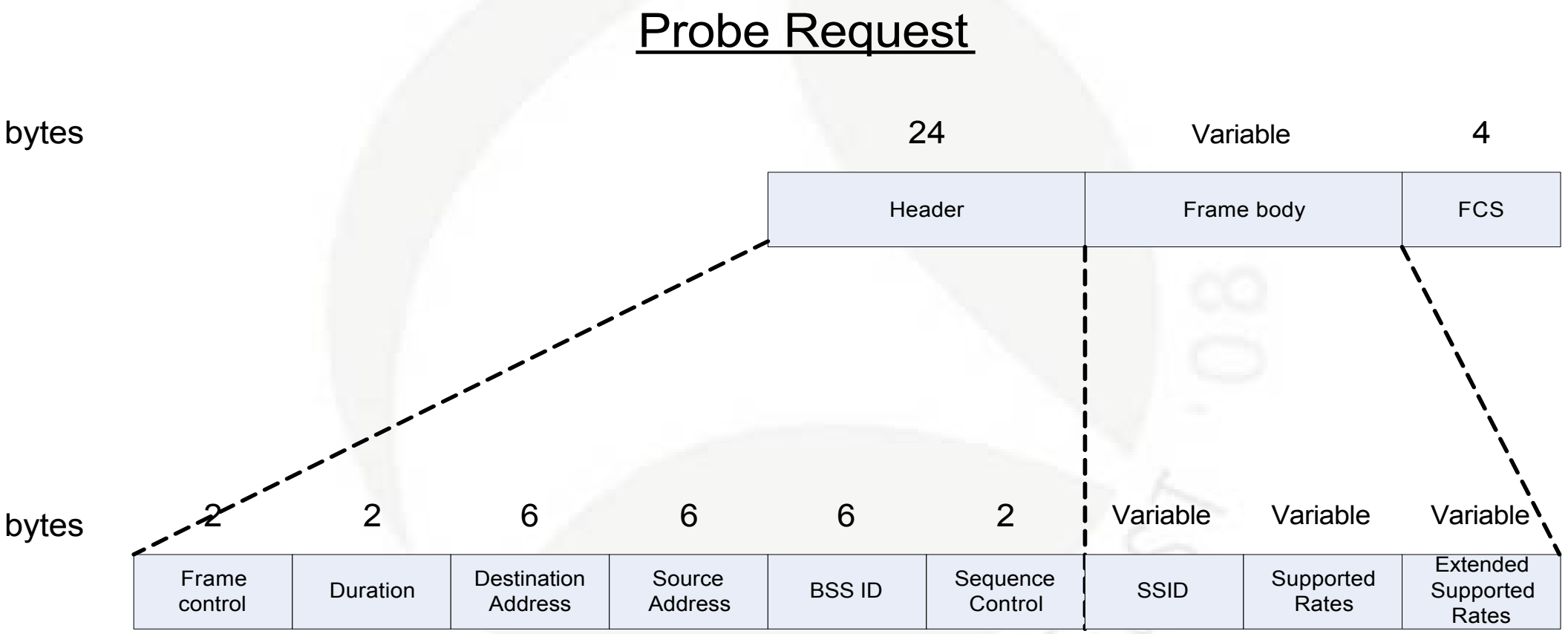

beacons.pcap - Wireshark
File Edit View Go Capture Analyze Statistics Help
Filter: Expression... Clear Apply
No. Time Source Destination Protocol Info
1 0.000000 Aironet_a0:1c:74 Broadcast IEEE 802 Beacon frame, SN=2531, F
2 0.326013 Arcadyan_12:32:29 Broadcast IEEE 802 Beacon frame, SN=3781, F
3 5.088080 AethraTe_07:04:da Broadcast IEEE 802 Beacon frame, SN=1012, F
4 371.126314 D-Link_77:0c:9b Broadcast IEEE 802 Beacon frame, SN=1, FN=0
Frame 1 (177 bytes on wire, 177 bytes captured)
IEEE 802.11 Beacon frame, Flags: ....
IEEE 802.11 wireless LAN management frame
Fixed parameters (12 bytes)
Tagged parameters (141 bytes)
SSID parameter set: "\000"
Supported Rates: 1,0(B) 2,0(B) 5,5(B) 11,0(B)
DS Parameter set: Current Channel: 6
Traffic Indication Map (TIM): DTIM 1 of 2 bitmap empty
Cisco Unknown 1 + Device Name
Vendor Specific: WPA
Vendor Specific: Aironet Unknown
Vendor Specific: Aironet CCX version = 3
Vendor Specific: Aironet Qos
Vendor Specific: WME
0020 64 00 31 00 00 01 00 01 04 82 84 8b 96 03 01 06 d.1. ....
0030 05 04 01 02 00 00 85 1e 00 00 81 00 1f 00 ff 03 ....
0040 19 00 61 70 70 61 72 74 00 00 00 00 00 00 00 00 ..appart ....
0050 00 00 00 00 00 22 dd 18 00 50 f2 01 01 00 00 50 ....".. .P....P
0060 f2 02 01 00 00 50 f2 02 01 00 00 50 f2 02 28 00 ....P.. ...P..(.
0070 dd 06 00 40 96 01 01 00 dd 05 00 40 96 03 03 dd ...@.... ...@....
Text item (), 3 bytes
Packets: 4 Displayed: 4 Marked: 0
Profile: Default


beacons.pcap - Wireshark
File Edit View Go Capture Analyze Statistics Help
Filter: Expression... Clear Apply
No. Time Source Destination Protocol Info
1 0.000000 Aironet_a0:1c:74 Broadcast IEEE 802 Beacon frame, SN=2531, F
2 0.326013 Arcadyan_12:32:29 Broadcast IEEE 802 Beacon frame, SN=3781, F
3 5.088080 AethraTe_07:04:da Broadcast IEEE 802 Beacon frame, SN=1012, F
4 371.126314 D-Link_77:0c:9b Broadcast IEEE 802 Beacon frame, SN=1, FN=0
Frame 2 (73 bytes on wire, 73 bytes captured)
IEEE 802.11 Beacon frame, Flags: ....
IEEE 802.11 wireless LAN management frame
Fixed parameters (12 bytes)
Tagged parameters (37 bytes)
SSID parameter set: "Appart"
Supported Rates: 1,0(B) 2,0(B) 5,5(B) 11,0(B) 22,0
DS Parameter set: Current Channel: 3
Traffic Indication Map (TIM): DTIM 0 of 1 bitmap empty
ERP Information: no Non-ERP STAs, do not use protection, short or long preambles
Extended Supported Rates: 6,0 9,0 12,0 18,0 24,0 36,0 48,0 54,0
0000 80 00 00 00 ff ff ff ff ff ff 00 12 bf 12 32 29
0010 00 12 bf 12 32 29 50 ec 22 21 79 16 00 00 00 00
0020 64 00 71 04 00 06 41 70 70 61 72 74 01 05 82 84
0030 8b 96 2c 03 01 03 05 04 00 01 00 00 2a 01 00 32
0040 08 0c 12 18 24 30 48 60 6c
Text item (), 7 bytes
Packets: 4 Displayed: 4 Marked: 0
Profile: Default


beacons.pcap - Wireshark
File Edit View Go Capture Analyze Statistics Help
Filter: Expression... Clear Apply
No. Time Source Destination Protocol Info
1 0.000000 Aironet_a0:1c:74 Broadcast IEEE 802 Beacon frame, SN=2531, F
2 0.326013 Arcadyan_12:32:29 Broadcast IEEE 802 Beacon frame, SN=3781, F
3 5.088080 AethraTe_07:04:da Broadcast IEEE 802 Beacon frame, SN=1012, F
4 371.126314 D-Link_77:0c:9b Broadcast IEEE 802 Beacon frame, SN=1, FN=0
Frame 3 (79 bytes on wire, 79 bytes captured)
IEEE 802.11 Beacon frame, Flags: ....
IEEE 802.11 wireless LAN management frame
Fixed parameters (12 bytes)
Tagged parameters (43 bytes)
SSID parameter set: "LAN1-AP013842"
Supported Rates: 1,0(B) 2,0(B) 5,5(B) 11,0(B)
DS Parameter set: Current Channel: 11
Traffic Indication Map (TIM): DTIM 0 of 1 bitmap empty
ERP Information: no Non-ERP STAs, do not use protection, short or long preambles
Extended Supported Rates: 6,0 9,0 12,0 18,0 24,0 36,0 48,0 54,0
0000 80 00 00 00 ff ff ff ff ff ff 00 d0 d6 07 04 da
0010 00 d0 d6 07 04 da 40 3f 64 01 e0 af bf 00 00 00
0020 64 00 31 04 00 0d 4c 41 4e 31 2d 41 50 30 31 33
0030 38 34 32 01 04 82 84 8b 96 03 01 0b 05 04 00 01
0040 00 00 2a 01 00 32 08 0c 12 18 24 30 48 60 6c
Text item (), 10 bytes
Packets: 4 Displayed: 4 Marked: 0
Profile: Default


beacons.pcap - Wireshark
File Edit View Go Capture Analyze Statistics Help
Filter: Expression... Clear Apply
No. Time Source Destination Protocol Info
2 0.326013 Arcadyan_12:32:29 Broadcast IEEE 802 Beacon frame, SN=3781, F
3 5.088080 AethraTe_07:04:da Broadcast IEEE 802 Beacon frame, SN=1012, F
4 371.126314 D-Link_77:0c:9b Broadcast IEEE 802 Beacon frame, SN=1, FN=0
Frame 4 (197 bytes on wire, 197 bytes captured)
IEEE 802.11 Beacon frame, Flags: ....
IEEE 802.11 wireless LAN management frame
Fixed parameters (12 bytes)
Tagged parameters (161 bytes)
SSID parameter set: "DLINK"
Supported Rates: 1,0(B) 2,0(B) 5,5(B) 11,0(B) 18,0 24,0 36,0 54,0
DS Parameter set: Current Channel: 6
Traffic Indication Map (TIM): DTIM 0 of 1 bitmap empty
ERP Information: no Non-ERP STAs, use protection, short or long preambles
ERP Information: no Non-ERP STAs, use protection, short or long preambles
Extended Supported Rates: 6,0 9,0 12,0 48,0
Vendor Specific: Broadcom
HT Capabilities (802.11n D1.10)
Vendor Specific: HT Capabilities (802.11n D1.10)
HT Information (802.11n D1.10)
Vendor Specific: HT Additional Capabilities (802.11n D1.00)
0040 02 2f 01 02 32 04 0c 12 18 60 dd 09 00 10 18 02 ./..2... .`......
0050 01 f4 01 00 00 2d 1a 1e 18 1a ff ff 00 00 00 00 .....-.. ....
0060 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ....
0070 00 dd 1e 00 90 4c 33 1e 18 1a ff ff 00 00 00 00 .....L3. ....
0080 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ....
Text item (), 6 bytes
Packets: 4 Displayed: 4 Marked: 0
Profile: Default

Wireless packets – Management frames (2)

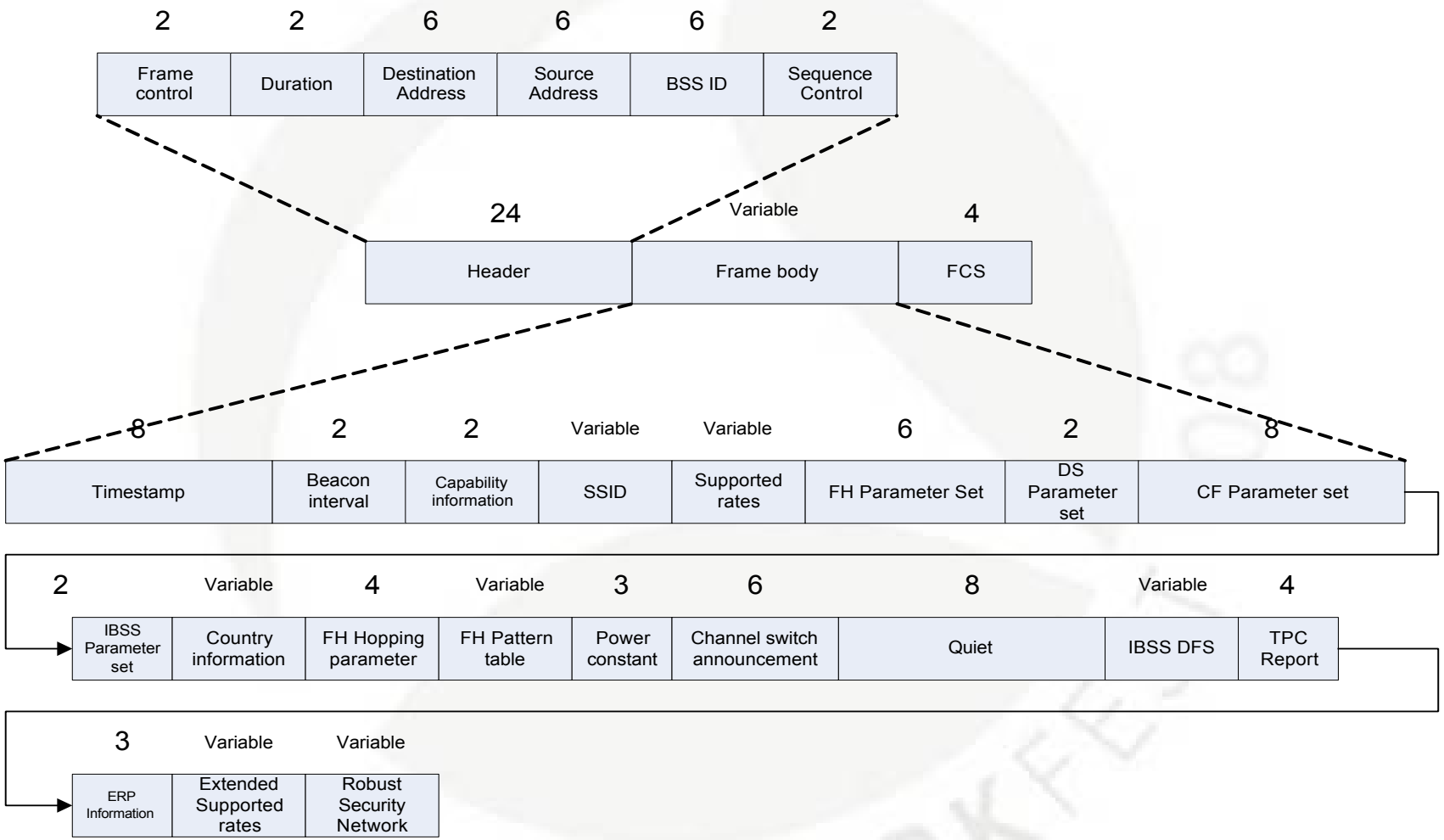


CACE TECHNOLOGIES

www.wiresharkU.com WIRESHARK UNIVERSITY

Wireless packets – Management frames (3)

Probe response

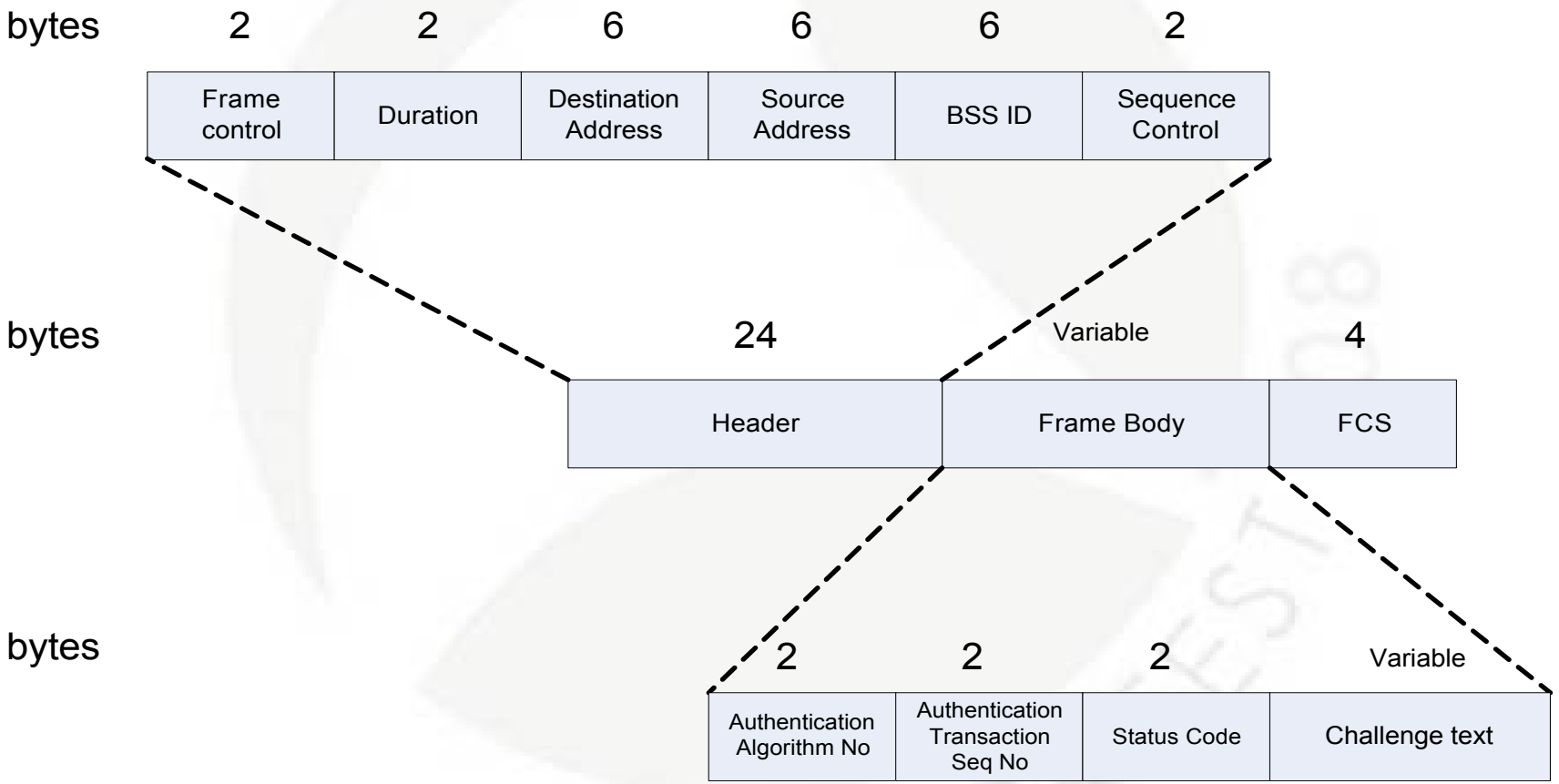


CACE TECHNOLOGIES

www.wiresharkU.com
WIRESHARK UNIVERSITY

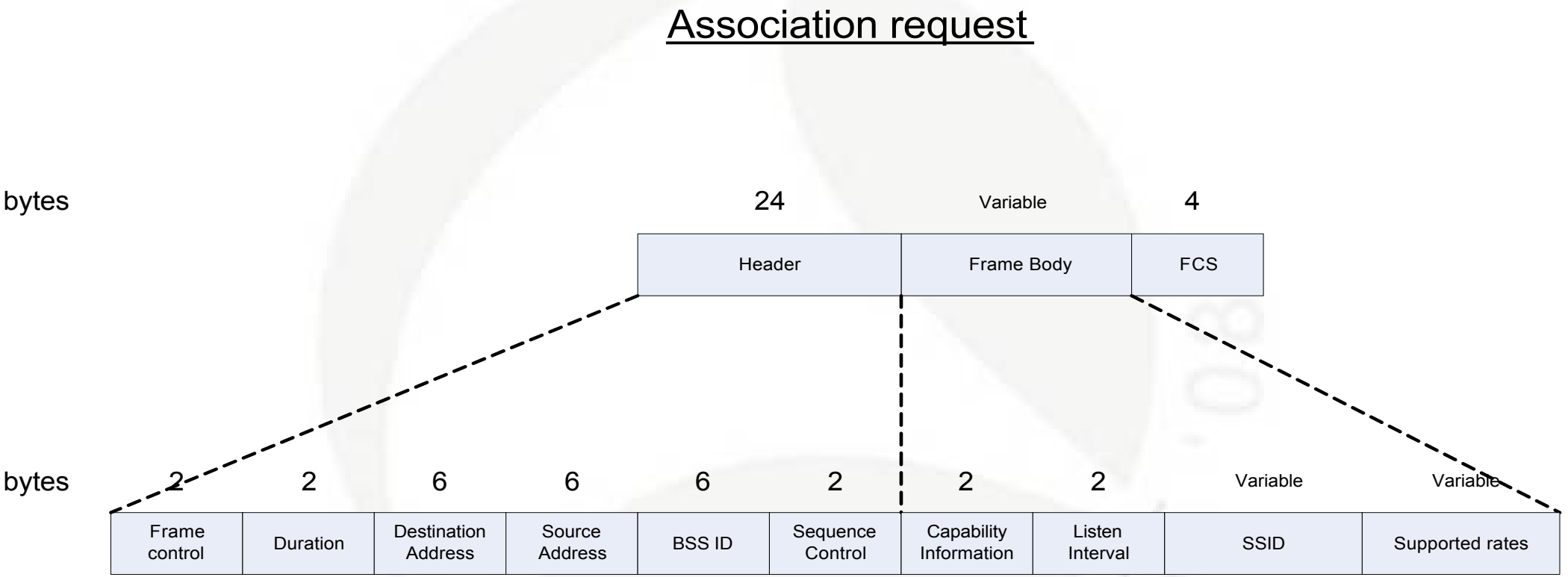
Wireless packets – Management frames (4)

Authentication



CACE TECHNOLOGIES
www.wiresharkU.com WIRESHARK UNIVERSITY

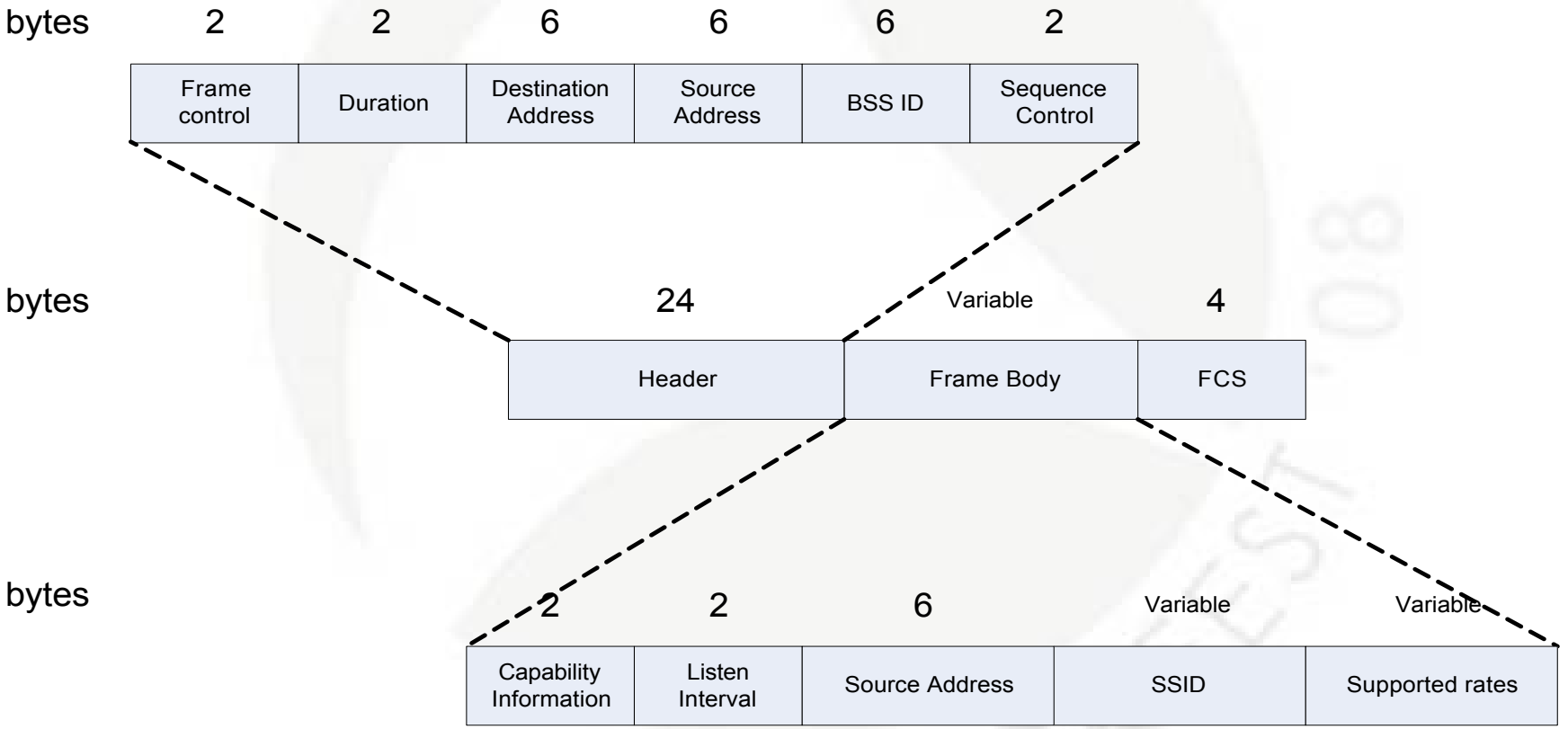
Wireless packets – Management frames (5)



CACE TECHNOLOGIES
www.wiresharkU.com
WIRESHARK UNIVERSITY

Wireless packets – Management frames (6)

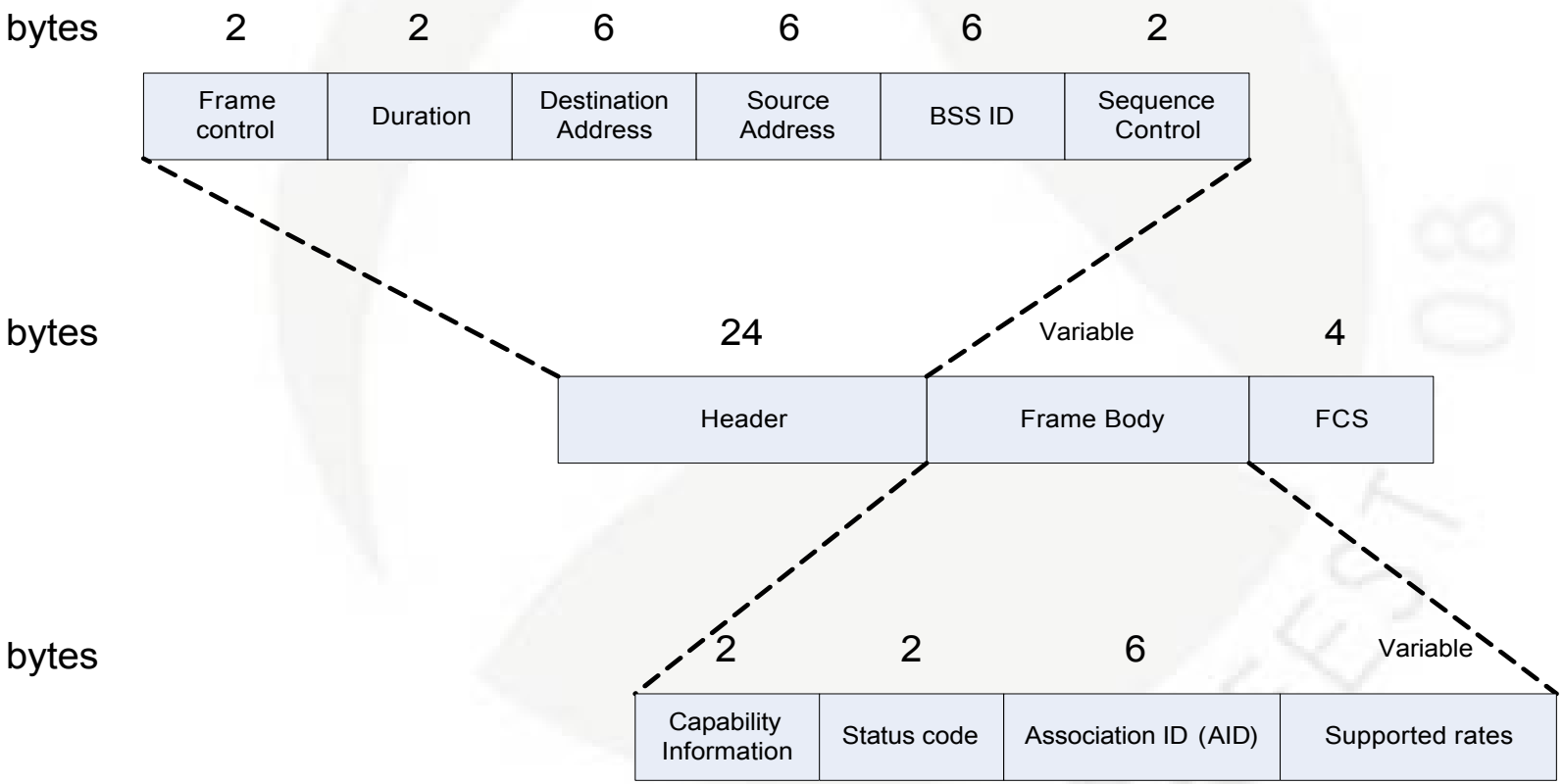
Reassociation request



CACE TECHNOLOGIES
www.wiresharkU.com WIRESHARK UNIVERSITY

Wireless packets – Management frames (7)

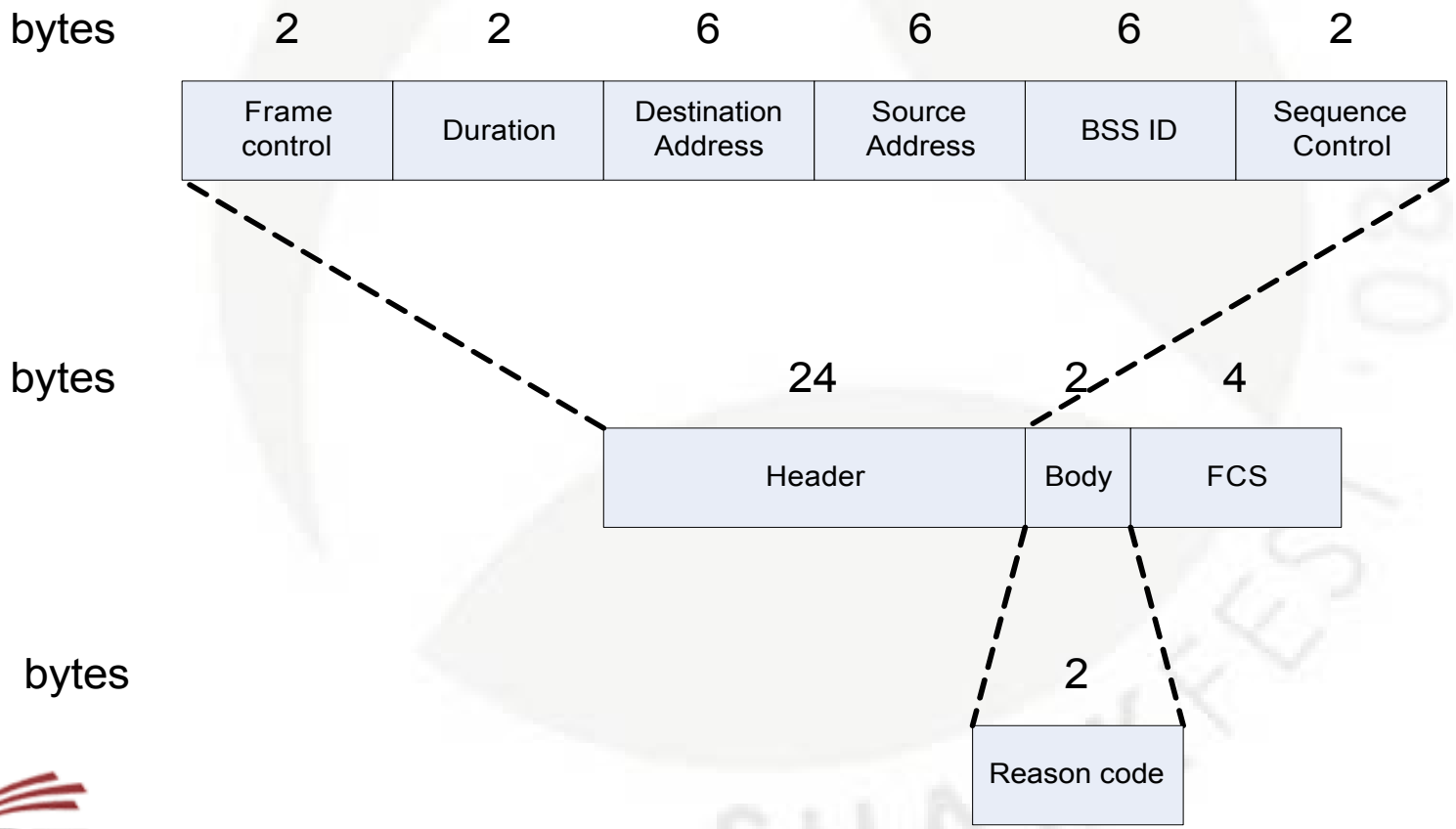
Association/Reassociation response



CACE TECHNOLOGIES
www.wiresharkU.com WIRESHARK UNIVERSITY

Wireless packets – Management frames (8)

Disassociation / Deauthentication frame



CACE TECHNOLOGIES

WIRESHARK UNIVERSITY www.wiresharkU.com

Wireless packets – Control frames

- **Definition**: Assist in the delivery of management and data frames.
- Type field value: 1

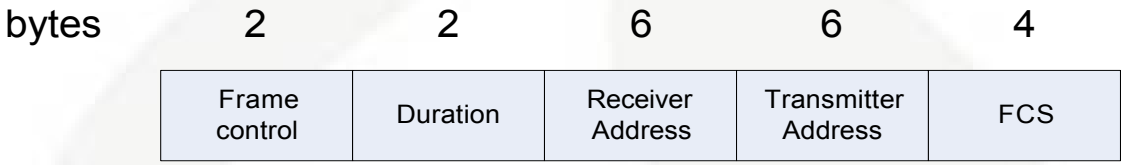
Subtype field value	Description
0-6	Reserved
7	Control Wrapper
8	Block ACK request
9	Block ACK
10	PS-Poll

Subtype field value	Description
11	RTS
12	CTS
13	ACK
14	CF End
15	CF-End + CF-ACK

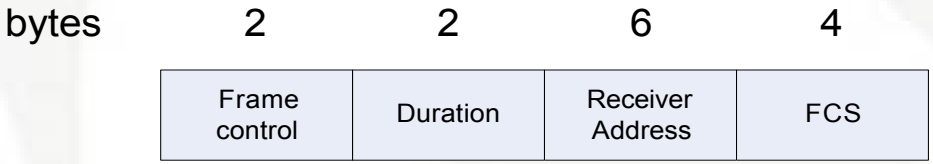
CACE TECHNOLOGIES
www.wiresharkU.com WIRESHARK UNIVERSITY

Wireless packets – Control frames (2)

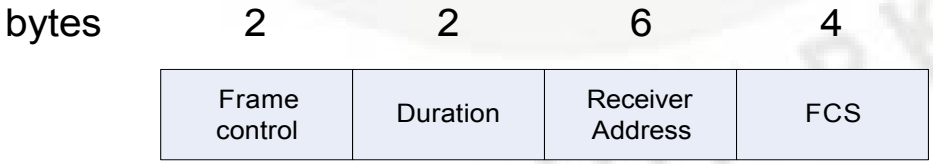
RTS



CTS



ACK



CACE TECHNOLOGIES

www.wiresharkU.com WIRESHARK UNIVERSITY

Wireless packets – Data frames

- **Definition**: Carry higher level protocol data in the frame body

- Type field value: 2

Subtype field value	Description
0	Data
1	Data + CF ACK
2	Data + CF Poll
3	Data + CF ACK + CF Poll
4	Null function
5	CF ACK
6	CF Poll

Subtype field value	Description
7	CF ACK + CF Poll
8	QoS data
9	QoS data + CF-ACK
10	QoS data + CF-Poll
11	QoS data + CF-ACK + CF-Poll
12	QoS Null (no data)
13	Reserved
14	QoS CF-Poll (no data)
15	QoS CF-ACK + CF-Poll (no data)

CACE TECHNOLOGIES
www.wiresharkU.com WIRESHARK UNIVERSITY

Interactions with networks – Encryption

- Open network
- WEP
- WPA

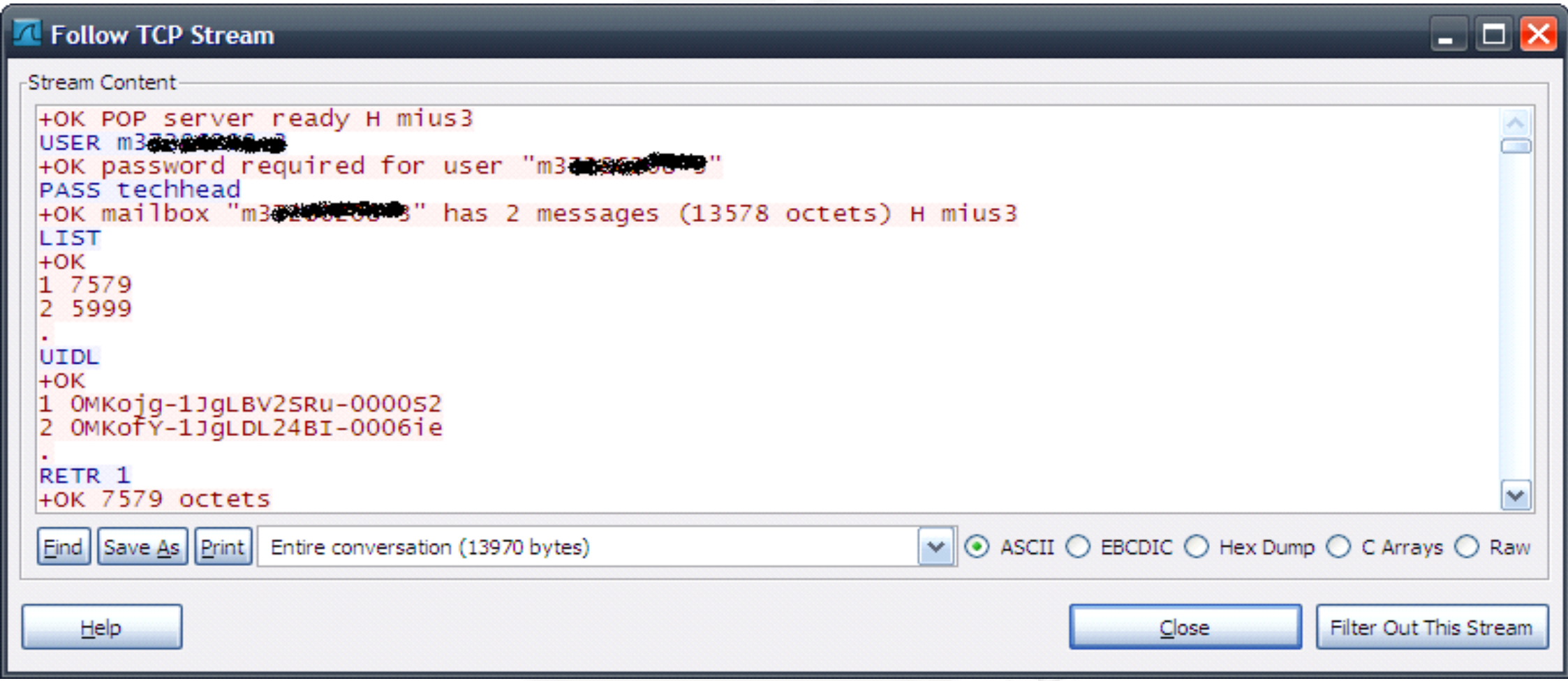
SHARKFEST '08

Interactions with networks – Encryption - Open networks

- No encryption
- Hotspot, mesh networks

SHARKFEST '08

Thanks for your passwords ;)



CACE TECHNOLOGIES

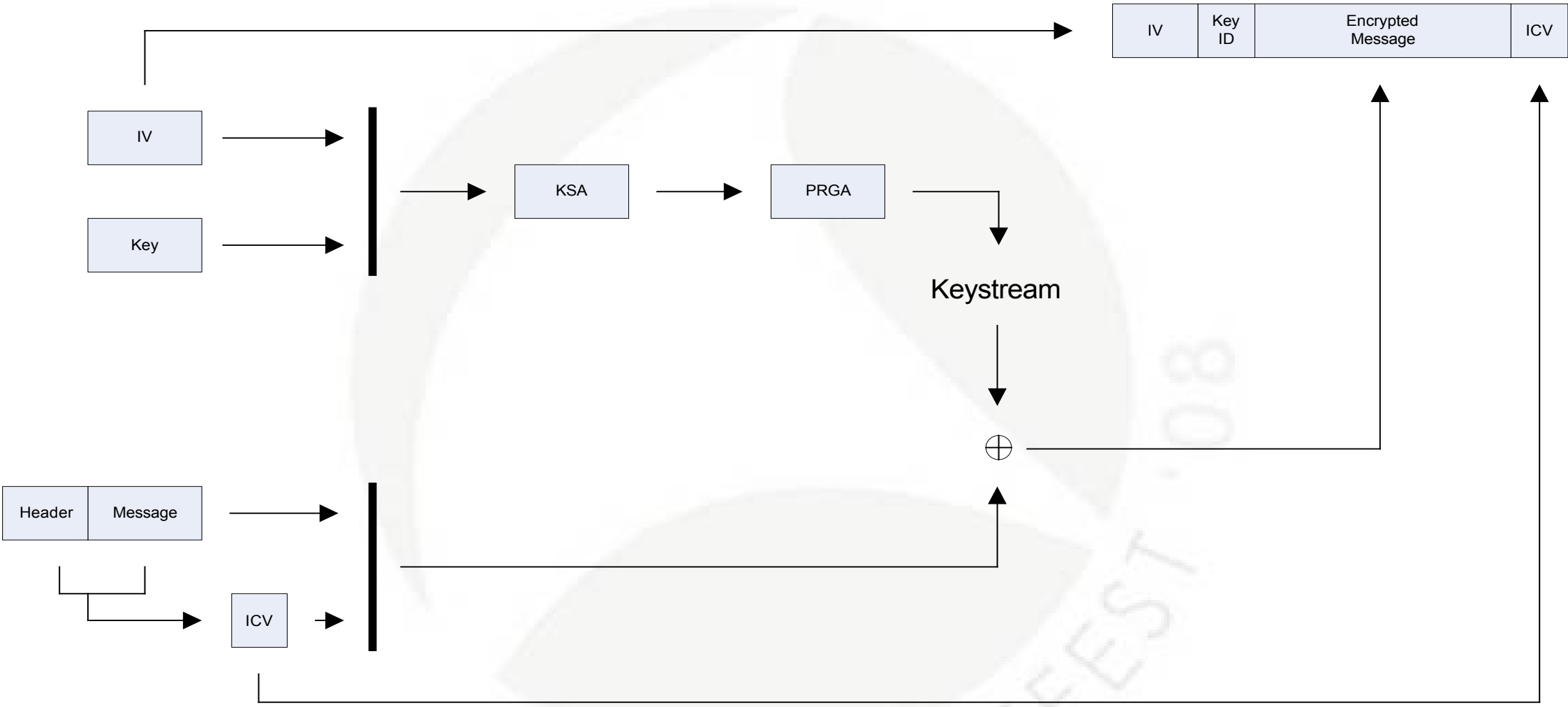
WIRESHARK UNIVERSITY
www.wiresharkU.com

Interactions with networks – Encryption - WEP

- Wired Equivalent Privacy
- Part of 802.11
- RC4
- 24 bit IV
- CRC32 (ICV) for message integrity

CACE TECHNOLOGIES
www.wiresharkU.com WIRESHARK UNIVERSITY

Interactions with networks – Encryption - WEP (2)

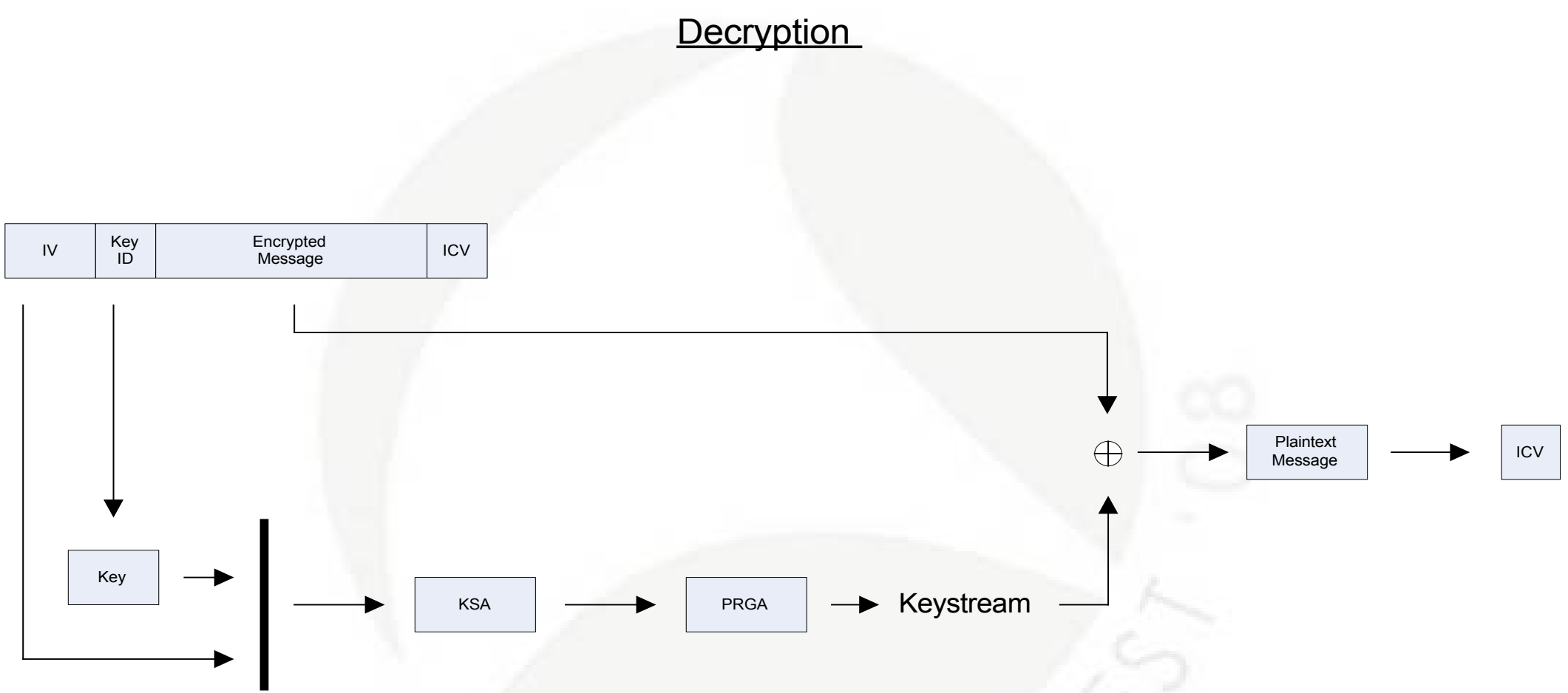


SHARKFEST '08

CACE TECHNOLOGIES

www.wiresharkU.com WIRESHARK UNIVERSITY

Interactions with networks – Encryption - WEP (3)



CACE TECHNOLOGIES
www.wiresharkU.com
WIRESHARK UNIVERSITY

Interactions with networks – Encryption - WEP (4)

```
function KSA()
   for i from 0 to 255
     S[i] := i
   endfor
   j := 0
   for i from 0 to 255
     j := (j + S[i] + key[i % keylength]) % 256
     swap(S[i], S[j])
   endfor
endfunction
```

CACE TECHNOLOGIES

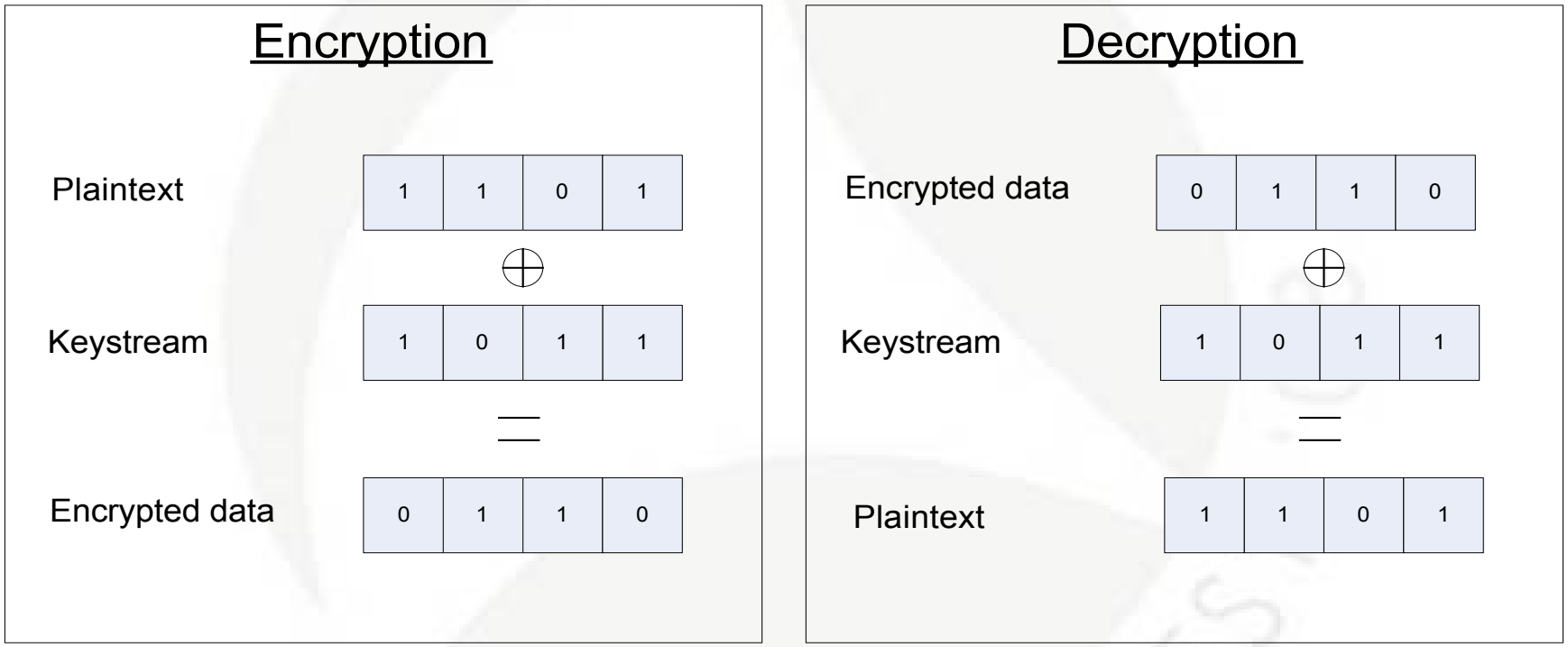
WIRESHARK UNIVERSITY www.wiresharkU.com

Interactions with networks – Encryption - WEP (5)

```
function PRGA()
   i := 0
   j := 0
   while GeneratingOutput:
     i := (i + 1) % 256
     j := (j + S[i]) % 256
     swap(S[i], S[j])
     output S[(S[i] + S[j]) mod 256]
   endwhile
endfunction
```

CACE TECHNOLOGIES
www.wiresharkU.com WIRESHARK UNIVERSITY

Interactions with networks – Encryption - WEP (6)



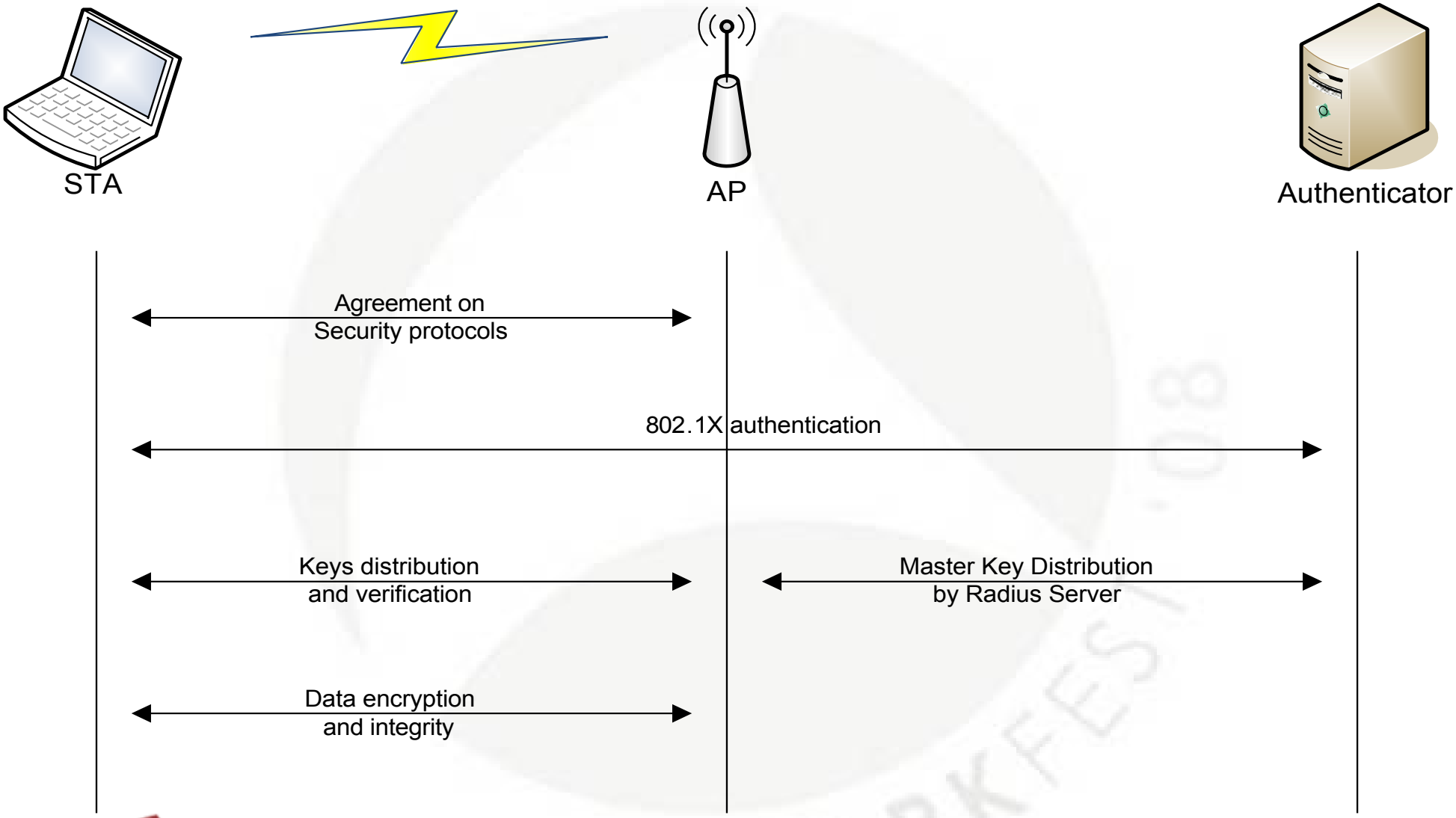
CACE TECHNOLOGIES
www.wiresharkU.com WIRESHARK UNIVERSITY

Interactions with networks – Encryption - WPA

- 802.11i group
- Developped two link-layer protocols:
  - TKIP – WPA1: Draft 3 of 802.11i group (backward compatible with legacy hardware).
  - CCMP – WPA2: final 802.11i standard
- Two flavors:
  - Personal: PSK
  - Enterprise: MGT

SHARKFEST '08

Interactions with networks – Encryption - WPA (2)



CACE TECHNOLOGIES
www.wiresharkU.com
WIRESHARK UNIVERSITY

Interactions with networks – Encryption - WPA (3)

Agreement on security protocols

- Beacons and probe
- Authentication: PSK or Radius server
- Encryption suite for unicast and multicast/broadcast: TKIP, …

CACE TECHNOLOGIES
www.wiresharkU.com WIRESHARK UNIVERSITY

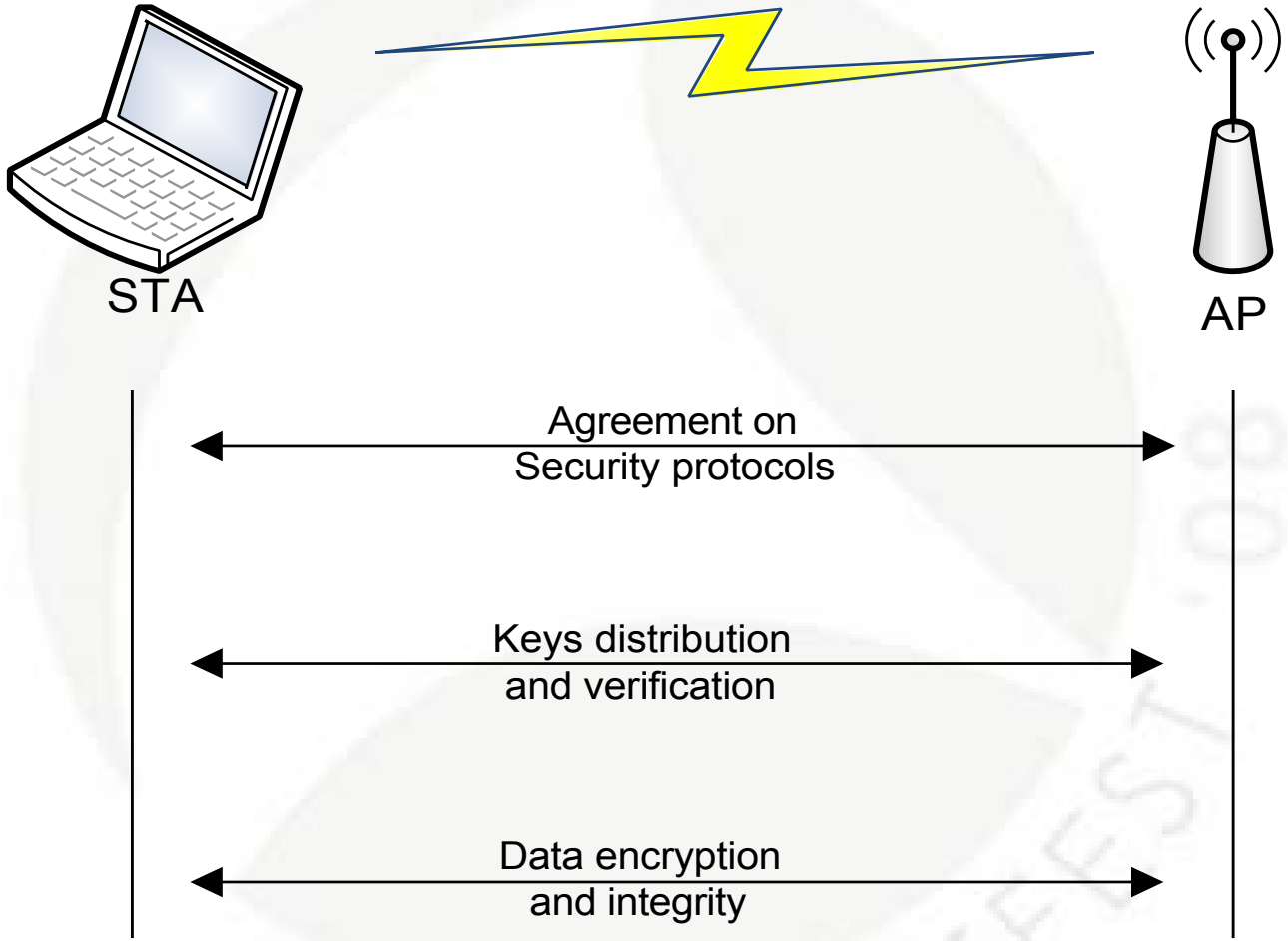
Interactions with networks – Encryption - WPA (4)

802.1X Authentication

- Not done with PSK
- Use EAP
- When successfully authenticated:
  - ACK sent to the client
  - Generated Master Key sent to the AP

SHARKFEST '08

Interactions with networks – Encryption - WPA (5)



CACE TECHNOLOGIES
www.wiresharkU.com
WIRESHARK UNIVERSITY

Interactions with networks – Encryption - WPA (6)

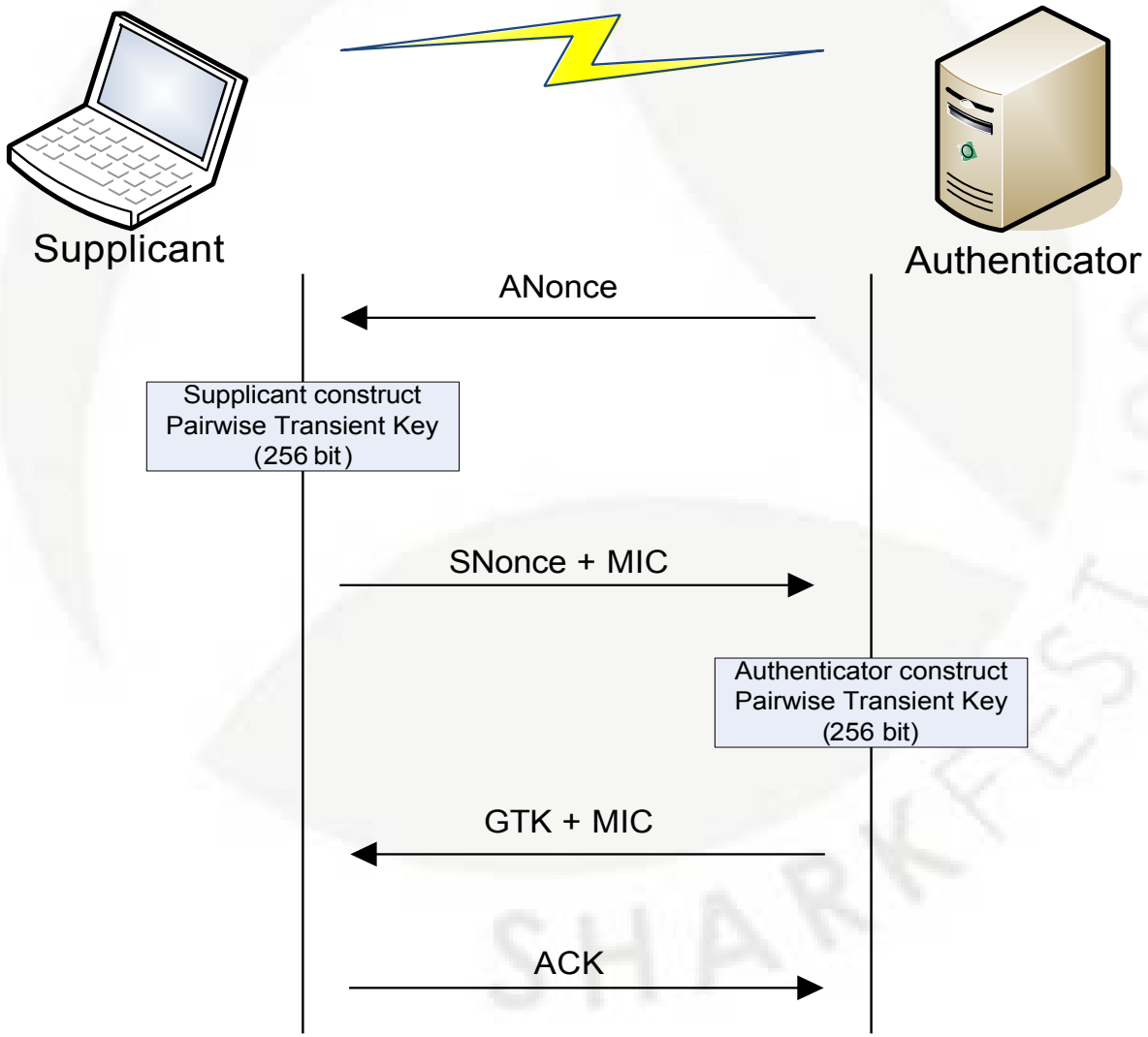
Key distribution and verification

- Confirmation of the cipher suite used
- Confirmation of the PMK knowledge
- Installation of the integrity and encryption keys
- Send GTK securely

CACE TECHNOLOGIES
www.wiresharkU.com WIRESHARK UNIVERSITY

Interactions with networks – Encryption - WPA (7)

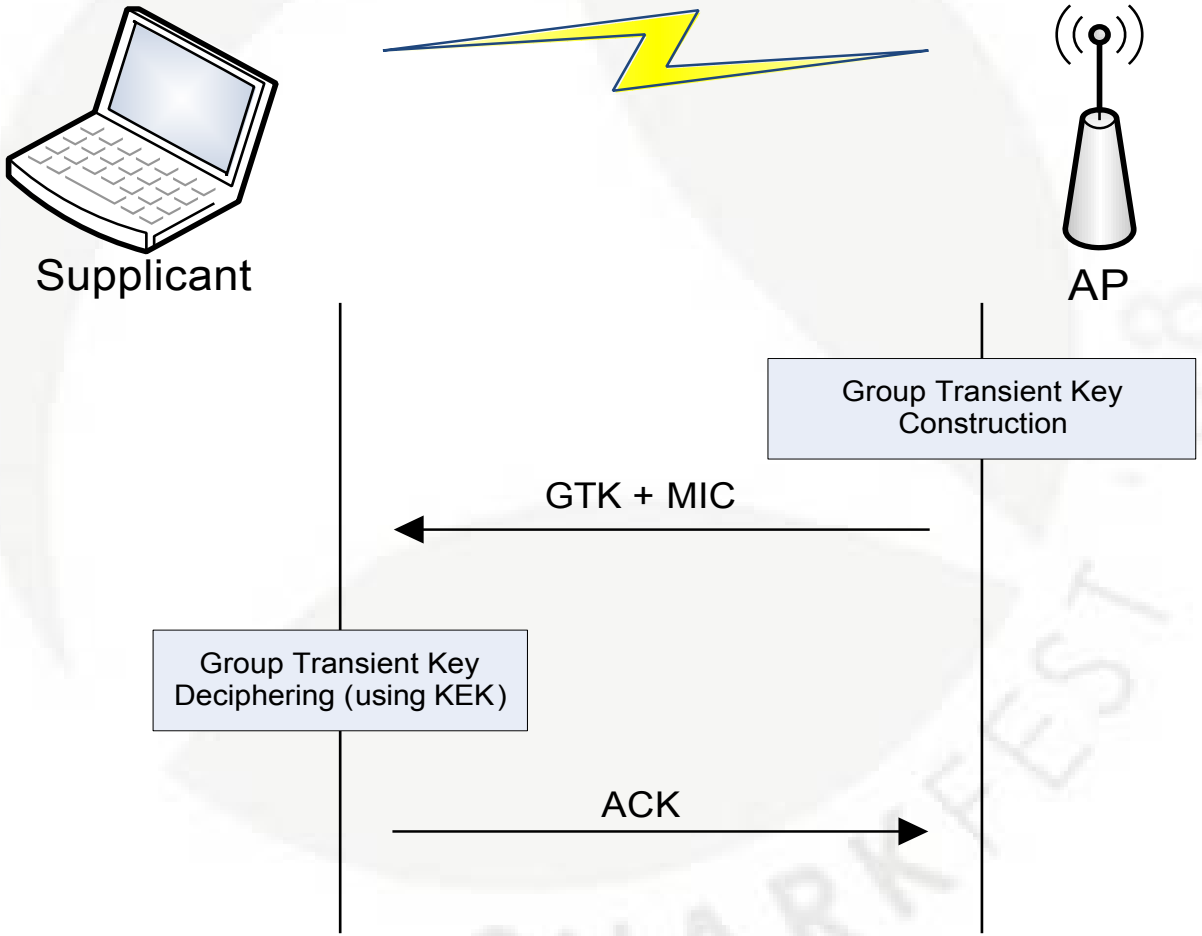
WPA Key distribution and verification 4-way handshake



CACE TECHNOLOGIES
www.wiresharkU.com WIRESHARK UNIVERSITY

Interactions with networks – Encryption - WPA (8)

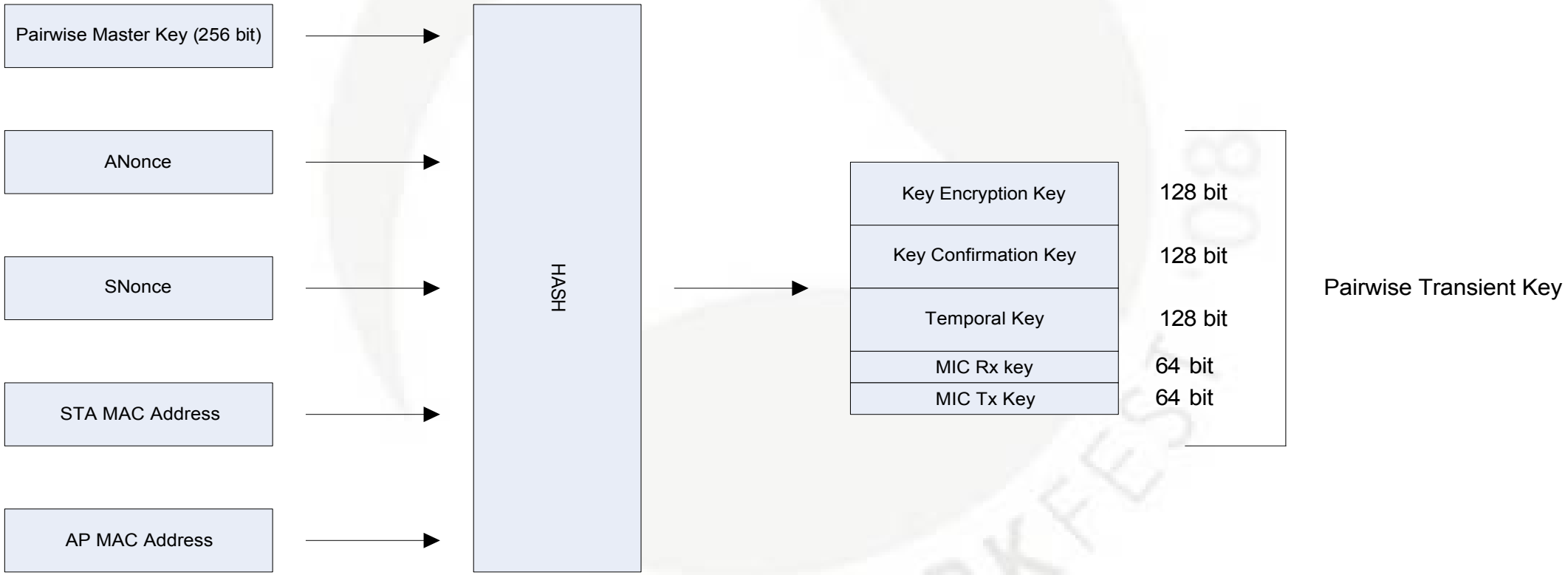
Group key handshake



CACE TECHNOLOGIES
www.wiresharkU.com WIRESHARK UNIVERSITY

Interactions with networks – Encryption - WPA (9)

WPA Key exchange and verification
PTK Generation



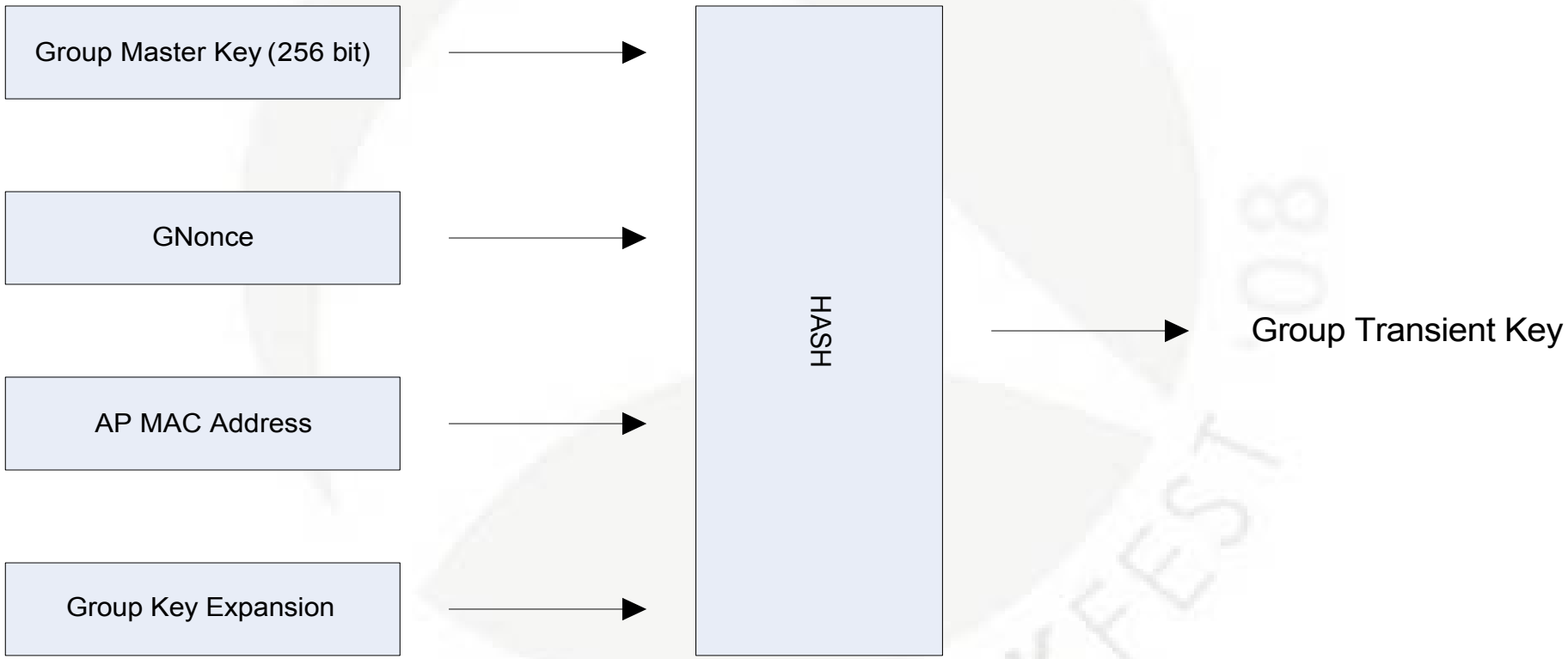
SHARKFEST'08

CACE TECHNOLOGIES

www.wiresharkU.com WIRESHARK UNIVERSITY

Interactions with networks – Encryption - WPA (10)

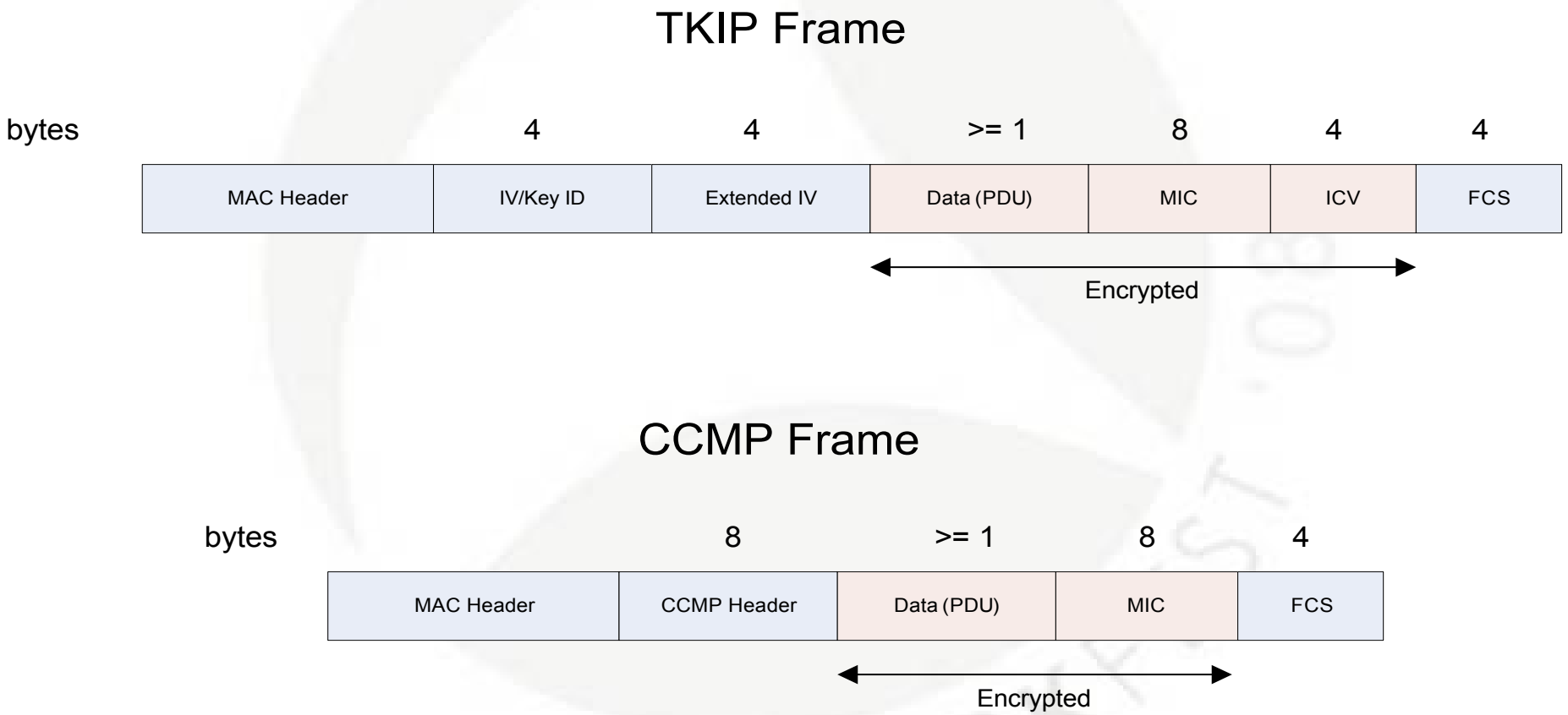
WPA Key exchange and verification
GTK Construction



SHARKFEST '08

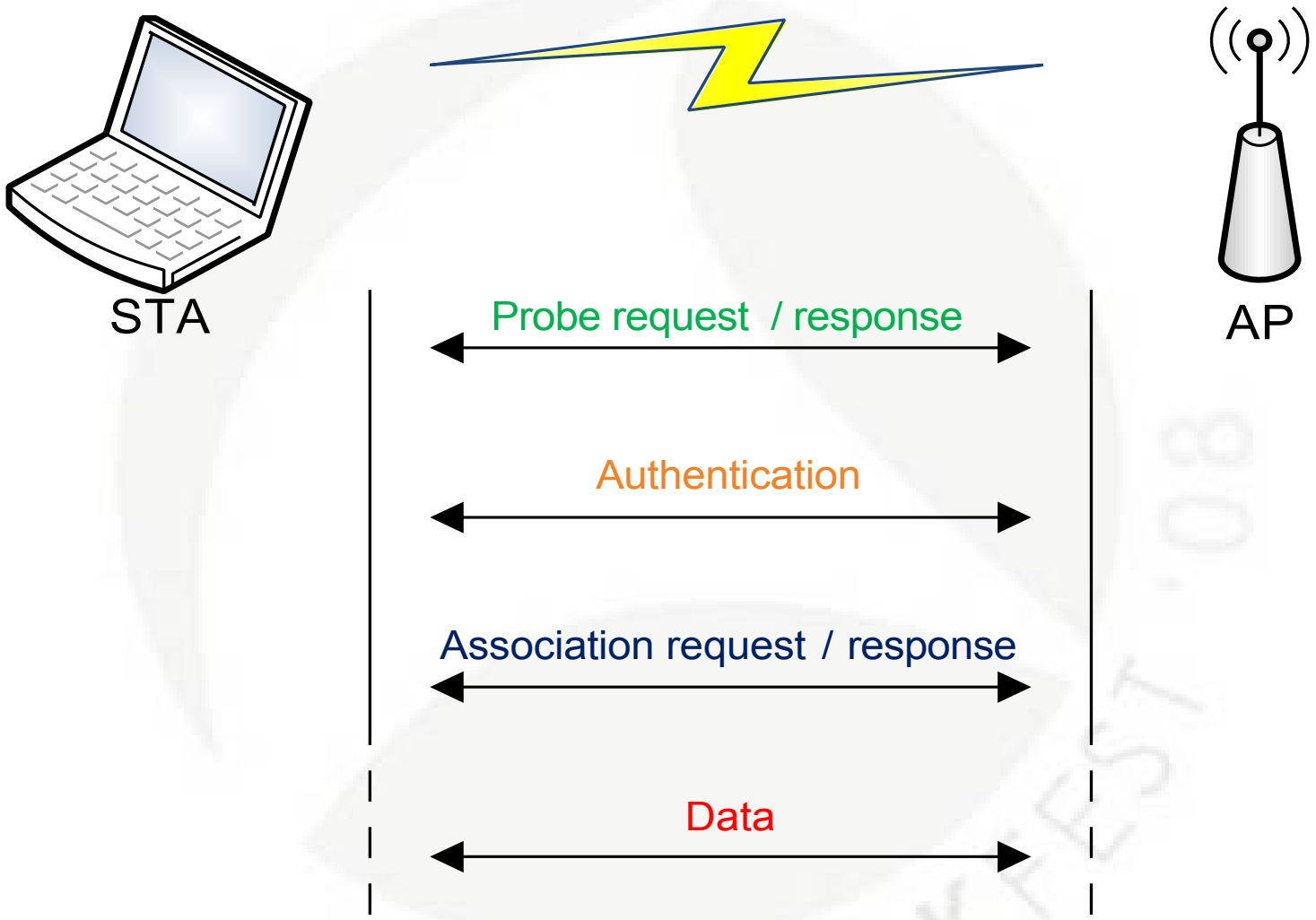
Interactions with networks – Encryption - WPA (11)

Data Encryption and Integrity



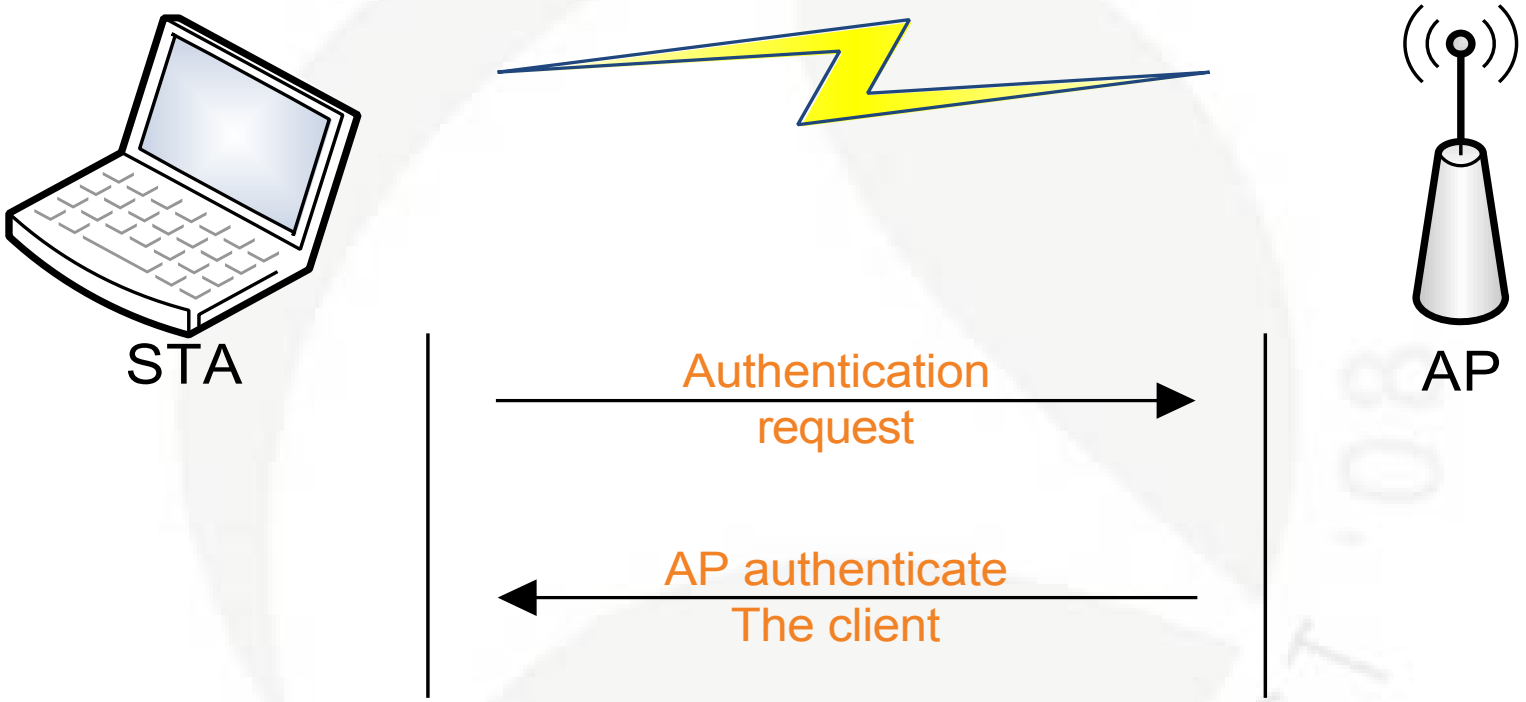
CACE TECHNOLOGIES
www.wiresharkU.com
WIRESHARK UNIVERSITY

Interactions with networks



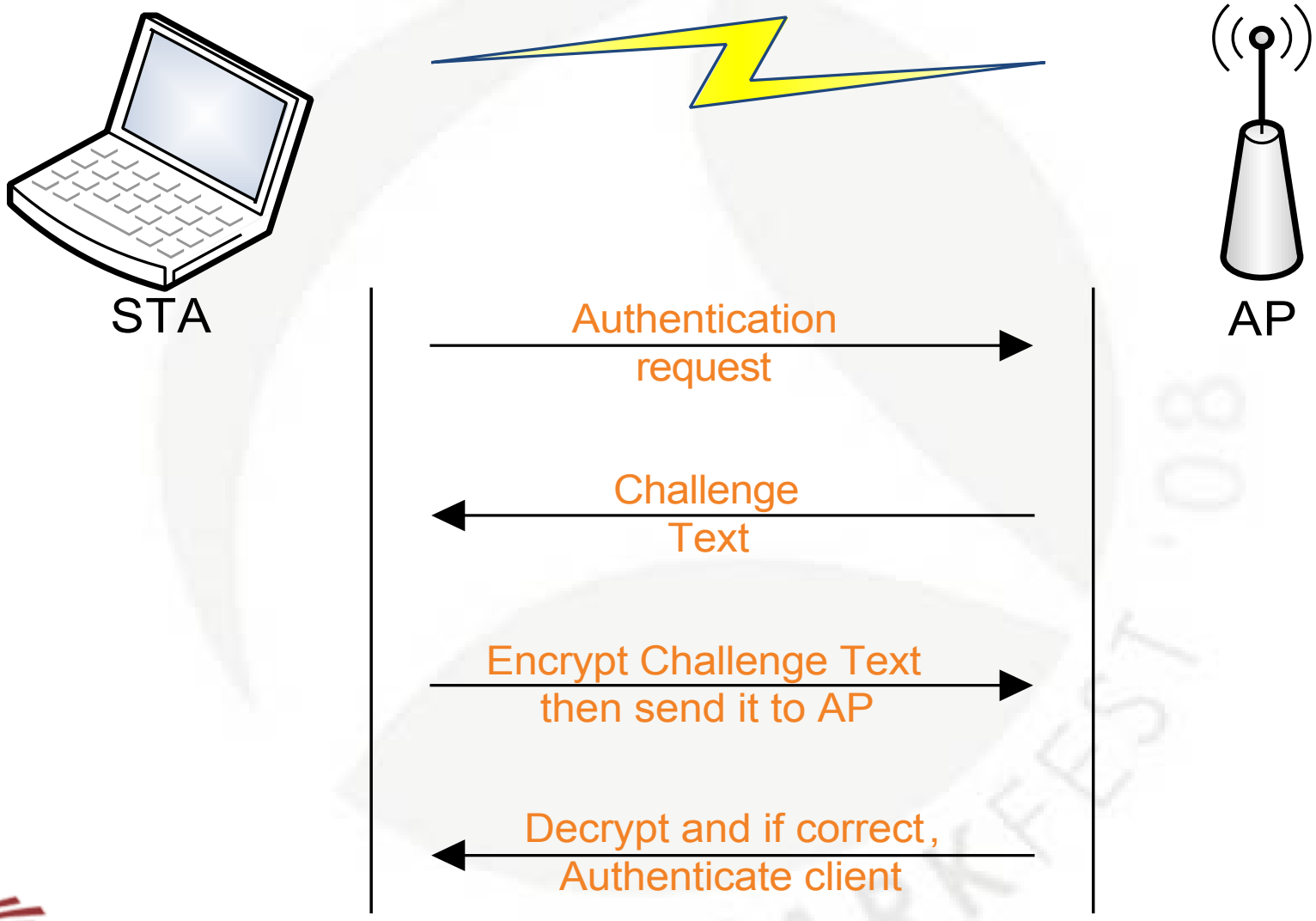
CACE TECHNOLOGIES
www.wiresharkU.com
WIRESHARK UNIVERSITY

Interactions with networks – Authentication - Open



SHARKFEST '08

Interactions with networks – Authentication - Shared



CACE TECHNOLOGIES
www.wiresharkU.com WIRESHARK UNIVERSITY

Capture file analysis

- Hotspot / Open network
- WEP network (Shared authentication)
- WPA network

SHARKFEST '08

OSdep

- Similar to LORCON
- OS supported: Linux, *BSD, Windows
- Automatic recognition of the interface / driver
- Sniffing capabilities

CACE TECHNOLOGIES
www.wiresharkU.com WIRESHARK UNIVERSITY

OSdep (2)

- Control interfaces
  - Get and set MAC address
  - Get and set Channel
  - Get and set rate
- Networking
- Create your own DLL to interact with special drivers on windows

SHARKFEST '08

OSdep - Applications

- Existing tools:
  - Aircrack-ng 1.0
  - MDK3
- Sample application:

  www.aircrack-ng.org/wifiping.tar.gz

SHARKFEST '08

Questions?

SHARKFEST '09