Show Me The Data
Protocol and Spectrum Analysis Basics for 802.11 Wireless LAN

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Eight·O·Two TECHNOLOGY SOLUTIONS

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Agenda

- Common Troubleshooting Methodology
- The OSI Model (A Quick Review)
- OSI Model – The Wireless Element
- The IEEE 802.11 Frame
- Common IEEE 802.11 Frame Exchanges
- Wireless LAN Troubleshooting Tools for Layer 2 (Data Link)
- Protocol Analysis
- Wireless LAN Troubleshooting Tools for Layer 1 (Physical)
- Spectrum Analysis

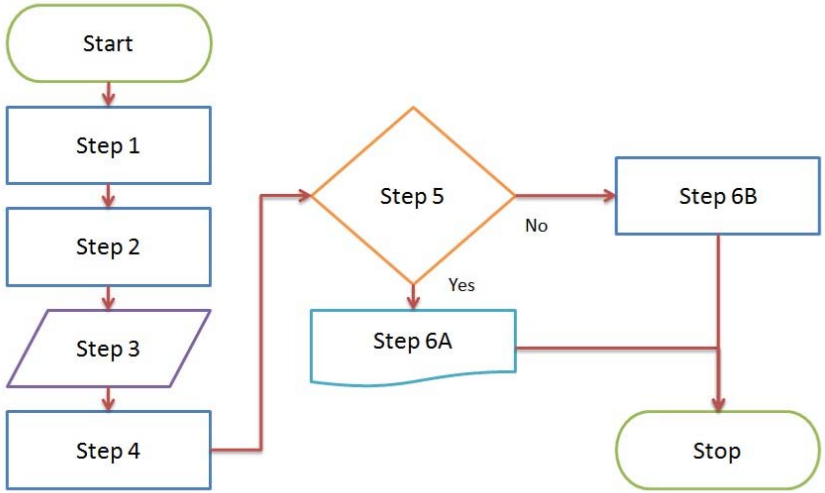
This is a no lollygagging session

lol·ly·gag
ˈlälēˌgag/
*verb*North American*informal*
gerund or present participle: **lollygagging**
spend time aimlessly; idle.
"he sends her to Arizona every January to lollygag in the sun"

Common Troubleshooting Methodology

Steps in a common troubleshooting methodology

1. Identify the problem
2. Determine the scale of the problem
3. Possible causes
4. Isolate the problem
5. Resolution or escalation
6. Corrective action / verify solution
7. Document, document and document



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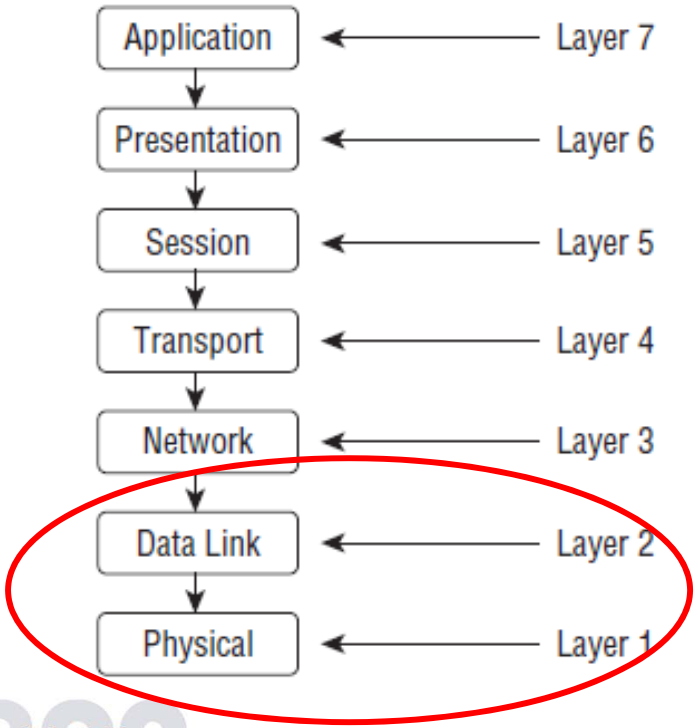
The OSI Model

The OSI Model (A Quick Review)

Open Systems Interconnection (OSI)



- The basic concept of communications in the computer network environment
- Consists of seven layers
- Each layer is made up of many protocols and serves a specific function
- Data is encapsulated at some layers
- WLAN technology operates at the two lowest layers

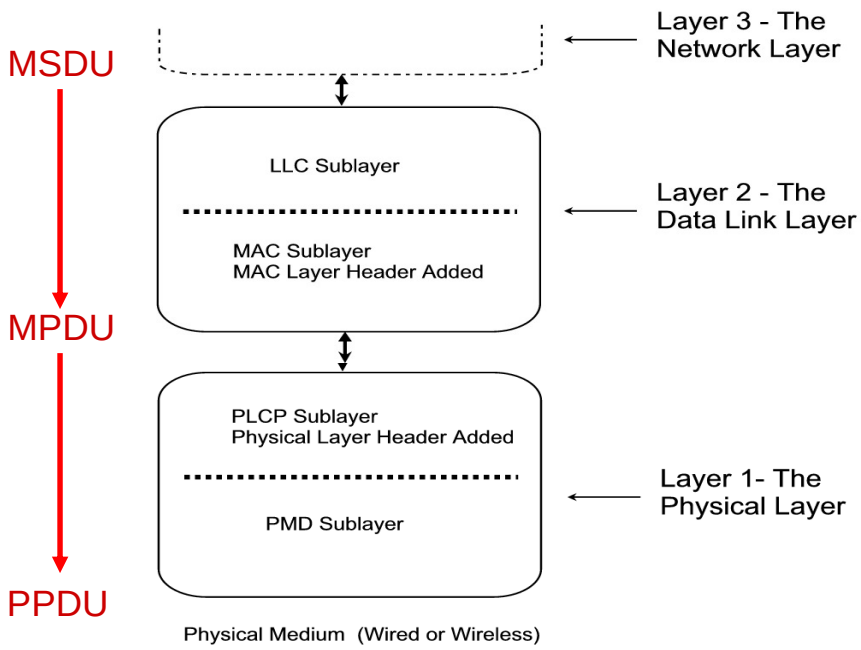
OSI Model – The Wireless Element

Layer 2 – Data Link Layer (MAC)

- Two sublayers
- Responsible for organizing the bit-level data for communications (frames)
- Detecting and correcting Physical layer errors

Layer 1 – Physical Layer (PHY)

- Two Sublayers
- Bit-level data streams and computer network hardware connecting the devices together



The Media Access Control Service Data Unit (MSDU) is upper layer data that is encapsulated at the MAC and PLCP sublayers

Show Me The Data

The IEEE 802.11 Frame

Famous Quotation #1

“SHOW ME THE MONEY”

Tom Cruise as Jerry Maguire
in Jerry Maguire (1996)

Famous Quotation #2

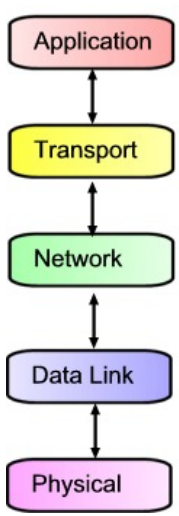
“SHOW ME THE DATA”

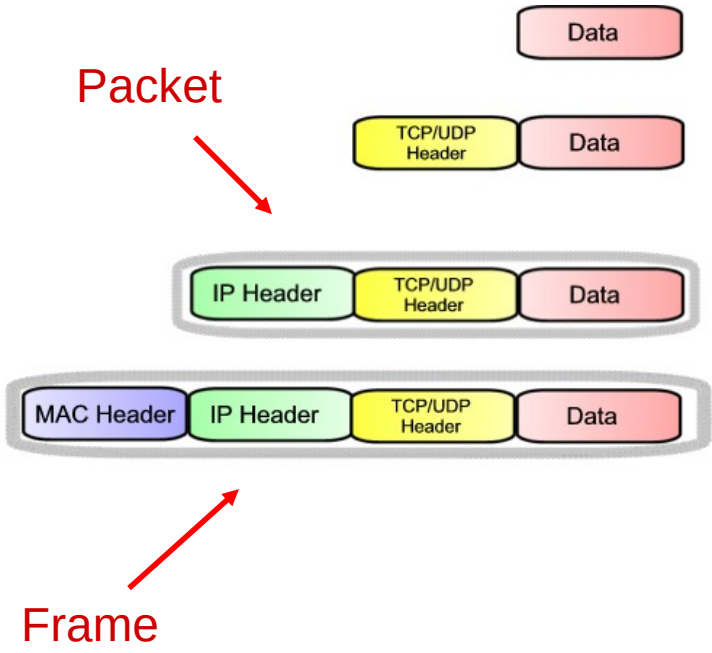
Robert Bartz as himself
BICSI Fall Conference & Exhibition
Las Vegas, Nevada (2019)

The IEEE 802.11 Frame

Packets and Frames

- Packets are at layer 3
  - Packets encapsulate data
- Frames are at Layer 2
  - Frames encapsulate packets





The IEEE 802.11 Frame

IEEE 802.11 - General Frame Format

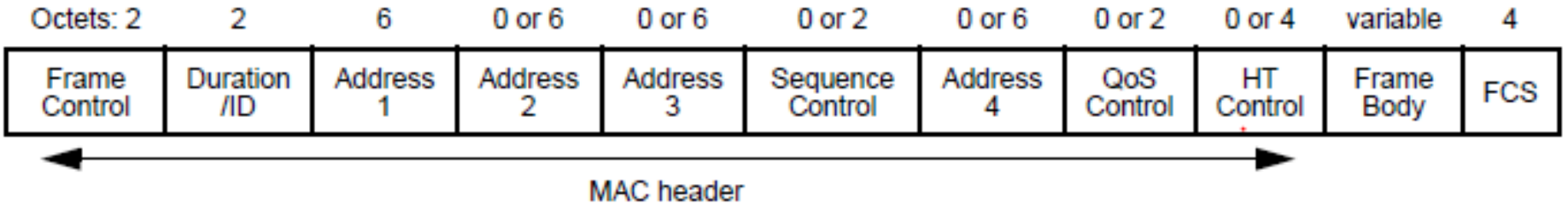
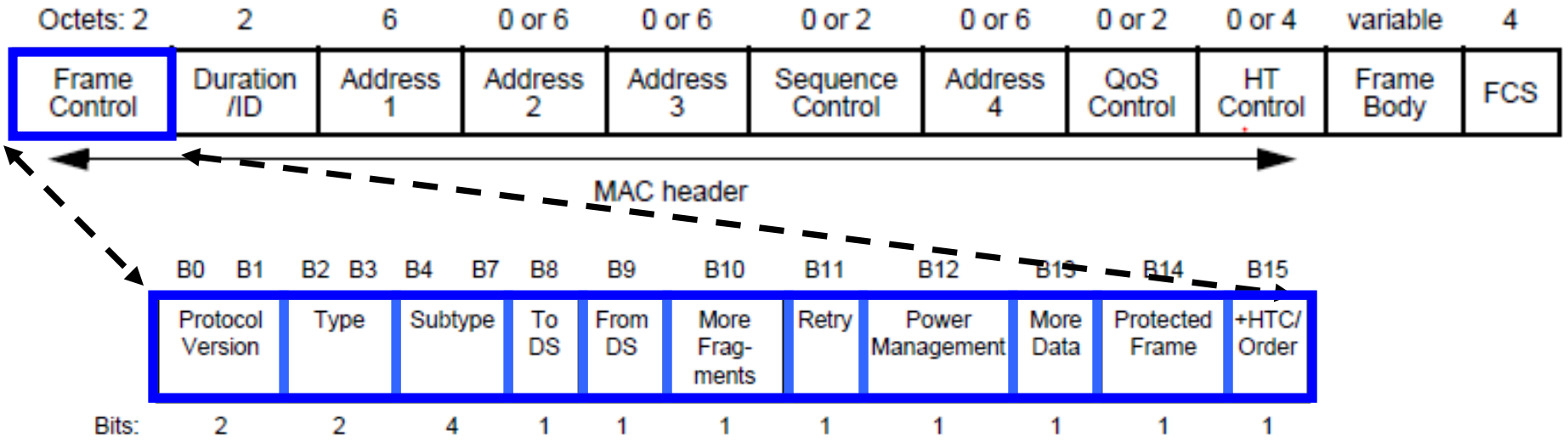


Image provided by IEEE Std 802.11™-2016

The IEEE 802.11 Frame

Frame Control Field



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Every IEEE 802.11 Frame Has a Frame Control Field

The IEEE 802.11 Frame

The Three IEEE 802.11 Frame Types

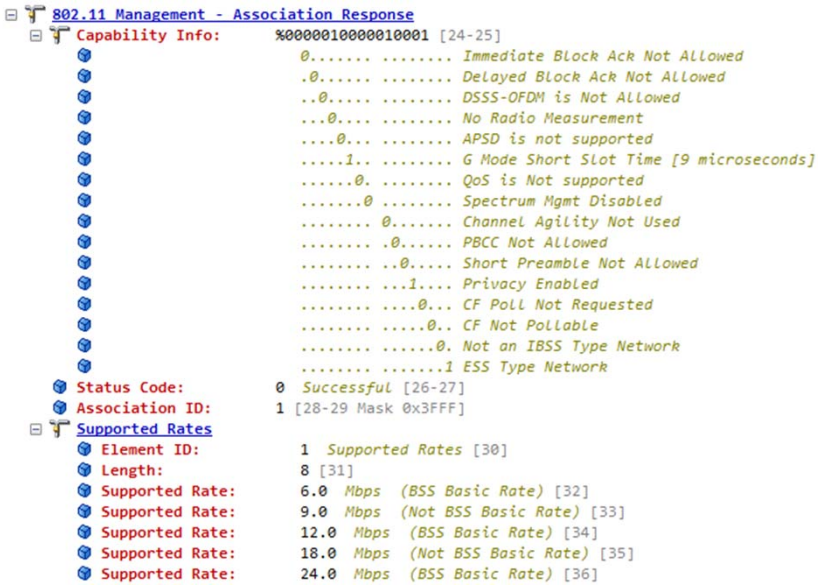
- Management Frames
- Control Frames
- Data Frames

Source	Destination	BSSID	Protocol
A8:BD:27:87:D7:F1	Ethernet Broadcast	A8:BD:27:87:D7:F1	802.11 Beacon
A8:BD:27:87:D7:F1	Ethernet Broadcast	A8:BD:27:87:D7:F1	802.11 Beacon
A8:BD:27:87:D7:F1	Ethernet Broadcast	A8:BD:27:87:D7:F1	802.11 Beacon
A8:BD:27:87:D7:F1	Ethernet Broadcast	A8:BD:27:87:D7:F1	802.11 Beacon
A8:BD:27:87:D7:F1	Ethernet Broadcast	A8:BD:27:87:D7:F1	802.11 Beacon
A8:BD:27:87:D7:F1	Ethernet Broadcast	A8:BD:27:87:D7:F1	802.11 Beacon
Intel:5F:5A:B0	Ethernet Broadcast	Ethernet Broadcast	802.11 Probe Req
Intel:5F:5A:B0	Ethernet Broadcast	Ethernet Broadcast	802.11 Probe Req
A8:BD:27:87:D7:F1	Intel:5F:5A:B0	A8:BD:27:87:D7:F1	802.11 Probe Rsp
Intel:5F:5A:B0	A8:BD:27:87:D7:F1		802.11 Ack
A8:BD:27:87:D7:F1	Intel:5F:5A:B0	A8:BD:27:87:D7:F1	802.11 Probe Rsp
Intel:5F:5A:B0	A8:BD:27:87:D7:F1		802.11 Ack
ProximWire:CA:48:2C	F0:1F:AF:3E:AE:21	A8:BD:27:87:D7:F0	802.11 Encrypted ...
ProximWire:CA:48:2C	F0:1F:AF:3E:AE:21	A8:BD:27:87:D7:F0	802.11 Encrypted ...
ProximWire:CA:48:2C	F0:1F:AF:3E:AE:21	A8:BD:27:87:D7:F0	802.11 Encrypted ...
ProximWire:CA:48:2C	F0:1F:AF:3E:AE:21	A8:BD:27:87:D7:F0	802.11 Encrypted ...
ProximWire:CA:48:2C	F0:1F:AF:3E:AE:21	A8:BD:27:87:D7:F0	802.11 Encrypted ...
ProximWire:CA:48:2C	F0:1F:AF:3E:AE:21	A8:BD:27:87:D7:F0	802.11 Encrypted ...

The IEEE 802.11 Frame

Management Frame Types in IEEE 802.11 Networking

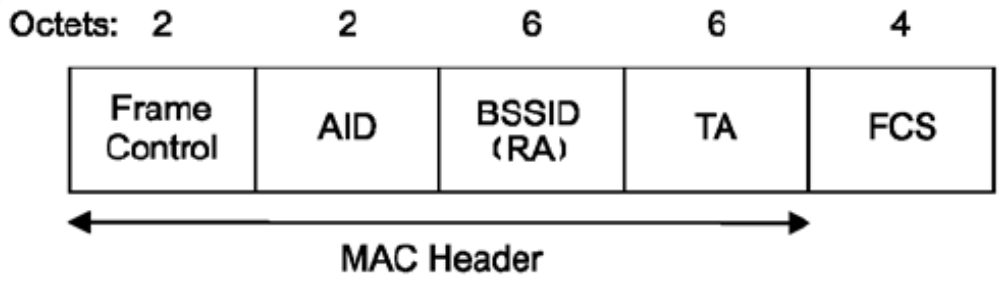
- Common Management Frames
  - Beacon
    - Passive Scanning
  - Probe Request / Response
    - Active Scanning
  - IEEE 802.11 Authentication
    - Open System
  - IEEE 802.11 Association Request / Response
    - Capabilities



The IEEE 802.11 Frame

Control Frame Types in IEEE 802.11 Networking

- Common Control Frames
  - RTS – Request to Send
    - Reserves the medium
  - CTS – Clear to Send
    - Response to an RTS
  - IEEE 802.11 ACK
    - Acknowledges unicast frames
  - PS Poll
    - Legacy power save mode



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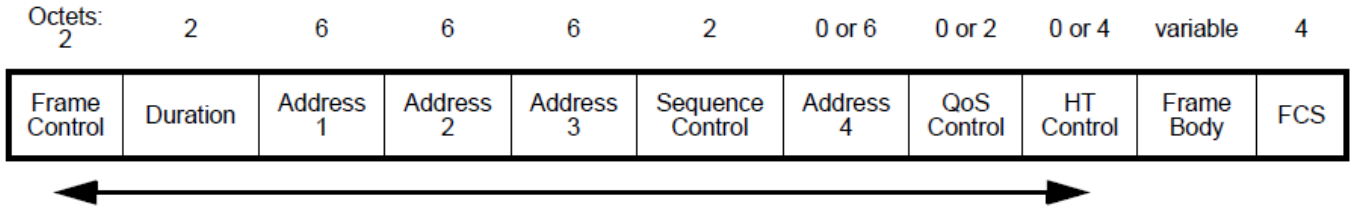
The IEEE 802.11 Frame

Data Frame Types in IEEE 802.11 Networking

- Two Types of Data Frames
  - Data
  - Null Data



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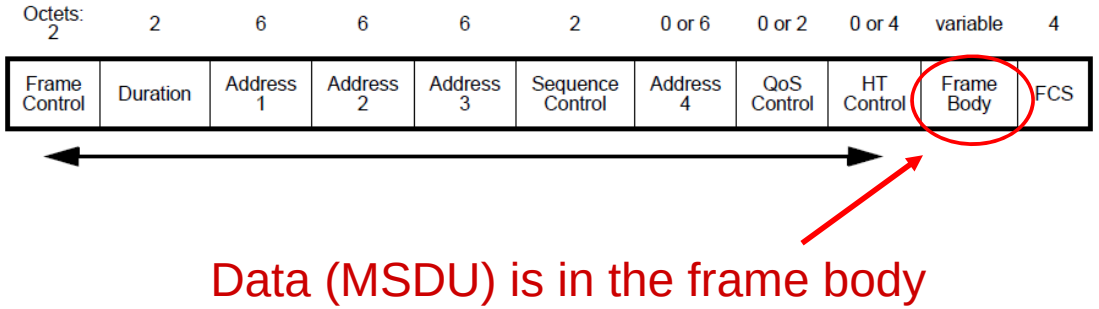
The IEEE 802.11 Frame

Data Frames Types in IEEE 802.11 Networking

- Data
  - Carry data payload



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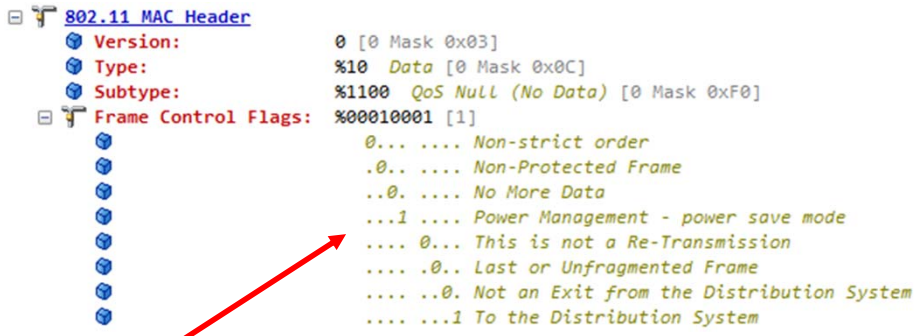
The IEEE 802.11 Frame

Data Frames Types in IEEE 802.11 Networking

- Null Data
  - Does not carry data payload
  - Power management
  - Channel scanning
  - Maintaining an association



Power Management Bit

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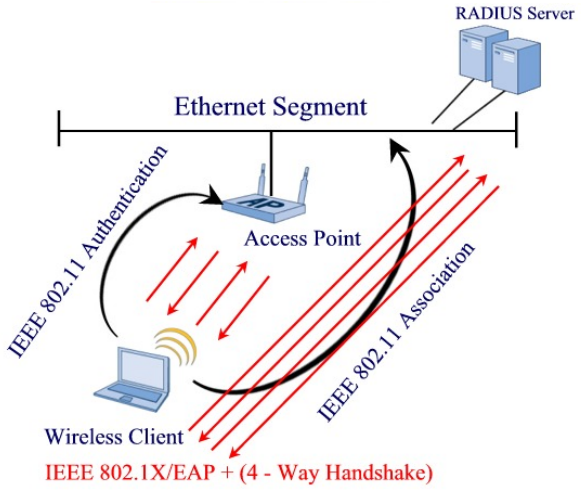
Common IEEE 802.11 Frame Exchanges

IEEE 802.11 Frame Types

Common IEEE 802.11 Frame Exchanges

- IEEE 802.11 Authentication and Association
- IEEE 802.11 Pre-Shared Key Authentication
- IEEE 802.1X/EAP Authentication



IEEE 802.11 Frame Types

IEEE 802.11 Authentication and Association

Packet	Source	Destination	BSSID	Protocol
9	Intel:5F:5A:B0	Ethernet Broadcast	Ethernet Broadcast	802.11 Probe Req
10	A8:BD:27:87:D7:F0	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	802.11 Probe Rsp
11	Intel:5F:5A:B0	A8:BD:27:87:D7:F0		802.11 Ack
12	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	A8:BD:27:87:D7:F0	802.11 Auth
13	A8:BD:27:87:D7:F0	Intel:5F:5A:B0		802.11 Ack
14	A8:BD:27:87:D7:F0	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	802.11 Auth
15	Intel:5F:5A:B0	A8:BD:27:87:D7:F0		802.11 Ack
16	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	A8:BD:27:87:D7:F0	802.11 Assoc Req
17	A8:BD:27:87:D7:F0	Intel:5F:5A:B0		802.11 Ack
18	A8:BD:27:87:D7:F0	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	802.11 Assoc Rsp
19	Intel:5F:5A:B0	A8:BD:27:87:D7:F0		802.11 Ack

IEEE 802.11 Frame Types

IEEE 802.11 Pre-Shared Key Authentication

Packet	Source	Destination	BSSID	Protocol
1	Intel:5F:5A:B0	Ethernet Broadcast	Ethernet Broadcast	802.11 Probe Req
2	Intel:5F:5A:B0	Ethernet Broadcast	Ethernet Broadcast	802.11 Probe Req
3	A8:BD:27:87:D7:F0	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	802.11 Probe Rsp
4	*Intel:5F:5A:B0*	A8:BD:27:87:D7:F0		802.11 Ack
5	A8:BD:27:87:D7:F0	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	802.11 Probe Rsp
6	*Intel:5F:5A:B0*	A8:BD:27:87:D7:F0		802.11 Ack
7	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	A8:BD:27:87:D7:F0	802.11 Auth
8	*A8:BD:27:87:D7:F0*	Intel:5F:5A:B0		802.11 Ack
9	A8:BD:27:87:D7:F0	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	802.11 Auth
10	*Intel:5F:5A:B0*	A8:BD:27:87:D7:F0		802.11 Ack
11	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	A8:BD:27:87:D7:F0	802.11 Assoc Req
12	*A8:BD:27:87:D7:F0*	Intel:5F:5A:B0		802.11 Ack
13	A8:BD:27:87:D7:F0	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	802.11 Assoc Rsp
14	*Intel:5F:5A:B0*	A8:BD:27:87:D7:F0		802.11 Ack
15	A8:BD:27:87:D7:F0	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	EAPOL-Key
16	*Intel:5F:5A:B0*	A8:BD:27:87:D7:F0		802.11 Ack
17	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	A8:BD:27:87:D7:F0	EAPOL-Key
18	*A8:BD:27:87:D7:F0*	Intel:5F:5A:B0		802.11 Ack
19	A8:BD:27:87:D7:F0	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	EAPOL-Key
20	*Intel:5F:5A:B0*	A8:BD:27:87:D7:F0		802.11 Ack
21	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	A8:BD:27:87:D7:F0	EAPOL-Key
22	*A8:BD:27:87:D7:F0*	Intel:5F:5A:B0		802.11 Ack
23	Intel:5F:5A:B0	Ethernet Broadcast	A8:BD:27:87:D7:F0	802.11 Encrypted ...

IEEE 802.11 Frame Types

IEEE 802.1X/EAP Authentication

35	Intel:5F:5A:B0	Ethernet Broadcast	Ethernet Broadcast	802.11 Probe Req
36	A8:BD:27:87:D7:F0	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	802.11 Probe Rsp
37	Intel:5F:5A:B0	A8:BD:27:87:D7:F0		802.11 Ack
38	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	A8:BD:27:87:D7:F0	802.11 Auth
39	A8:BD:27:87:D7:F0	Intel:5F:5A:B0		802.11 Ack
40	A8:BD:27:87:D7:F0	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	802.11 Auth
41	Intel:5F:5A:B0	A8:BD:27:87:D7:F0		802.11 Ack
42	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	A8:BD:27:87:D7:F0	802.11 Assoc Req
43	A8:BD:27:87:D7:F0	Intel:5F:5A:B0		802.11 Ack
44	A8:BD:27:87:D7:F0	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	802.11 Assoc Rsp
45	Intel:5F:5A:B0	A8:BD:27:87:D7:F0		802.11 Ack
46	A8:BD:27:87:D7:F0	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	802.11 Assoc Rsp
47	Intel:5F:5A:B0	A8:BD:27:87:D7:F0		802.11 Ack
48	A8:BD:27:87:D7:F0	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	EAP Request
49	Intel:5F:5A:B0	A8:BD:27:87:D7:F0		802.11 Ack
50	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	A8:BD:27:87:D7:F0	EAPOL-Start
51	A8:BD:27:87:D7:F0	Intel:5F:5A:B0		802.11 Ack

Packet	Source	Destination	BSSID	Protocol
93	A8:BD:27:87:D7:F0	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	EAP Request
94	Intel:5F:5A:B0	A8:BD:27:87:D7:F0		802.11 Ack
95	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	A8:BD:27:87:D7:F0	EAP Response
96	A8:BD:27:87:D7:F0	Intel:5F:5A:B0		802.11 Ack
97	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	A8:BD:27:87:D7:F0	EAP Response
98	A8:BD:27:87:D7:F0	Intel:5F:5A:B0		802.11 Ack
99	A8:BD:27:87:D7:F0	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	EAP Request
100	Intel:5F:5A:B0	A8:BD:27:87:D7:F0		802.11 Ack
101	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	A8:BD:27:87:D7:F0	EAP Response
102	A8:BD:27:87:D7:F0	Intel:5F:5A:B0		802.11 Ack
103	A8:BD:27:87:D7:F0	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	EAP Success
104	Intel:5F:5A:B0	A8:BD:27:87:D7:F0		802.11 Ack
105	A8:BD:27:87:D7:F0	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	EAPOL-Key
106	Intel:5F:5A:B0	A8:BD:27:87:D7:F0		802.11 Ack
107	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	A8:BD:27:87:D7:F0	EAPOL-Key
108	A8:BD:27:87:D7:F0	Intel:5F:5A:B0		802.11 Ack
109	A8:BD:27:87:D7:F0	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	EAPOL-Key
110	Intel:5F:5A:B0	A8:BD:27:87:D7:F0		802.11 Ack
111	Intel:5F:5A:B0	A8:BD:27:87:D7:F0	A8:BD:27:87:D7:F0	EAPOL-Key
112	A8:BD:27:87:D7:F0	Intel:5F:5A:B0		802.11 Ack
113	Intel:5F:5A:B0	Ethernet Broadcast	A8:BD:27:87:D7:F0	802.11 Encrypted ...
114	A8:BD:27:87:D7:F0	Intel:5F:5A:B0		802.11 Ack

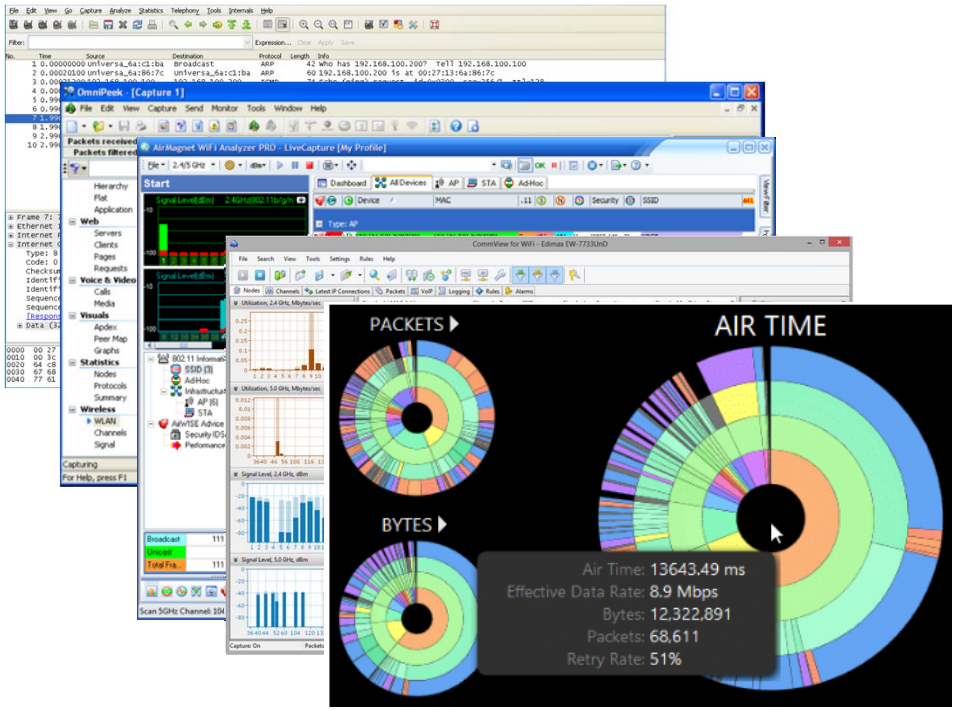
Show Me The Data

Common Layer 2 Data Link aka (MAC Layer)
Troubleshooting Tools

Layer 2 Data link Layer (MAC) - Troubleshooting Tools

Protocol (Packet) Analyzers

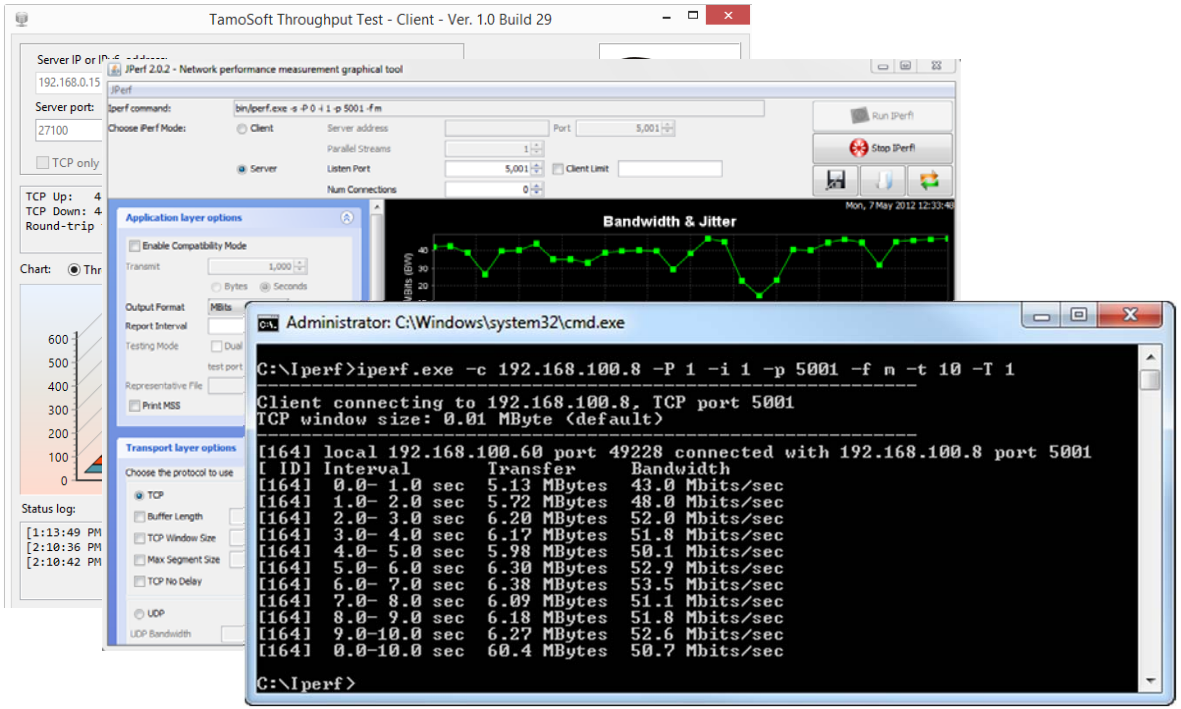
- Wireshark
- LiveAction Omnipeek
- Netscout Wi-Fi Analyzer
- Tamosoft CommView for Wi-Fi
- MetaGeek Eye P.A.



Layer 2 Data link Layer (MAC)- Troubleshooting Tools

Throughput Test Tools

- Tamosoft - Free
- jPerf - Free
- iPerf - Free



Layer 2 Data link Layer (MAC) - Troubleshooting Tools

Throughput test tools are not just for throughput testing

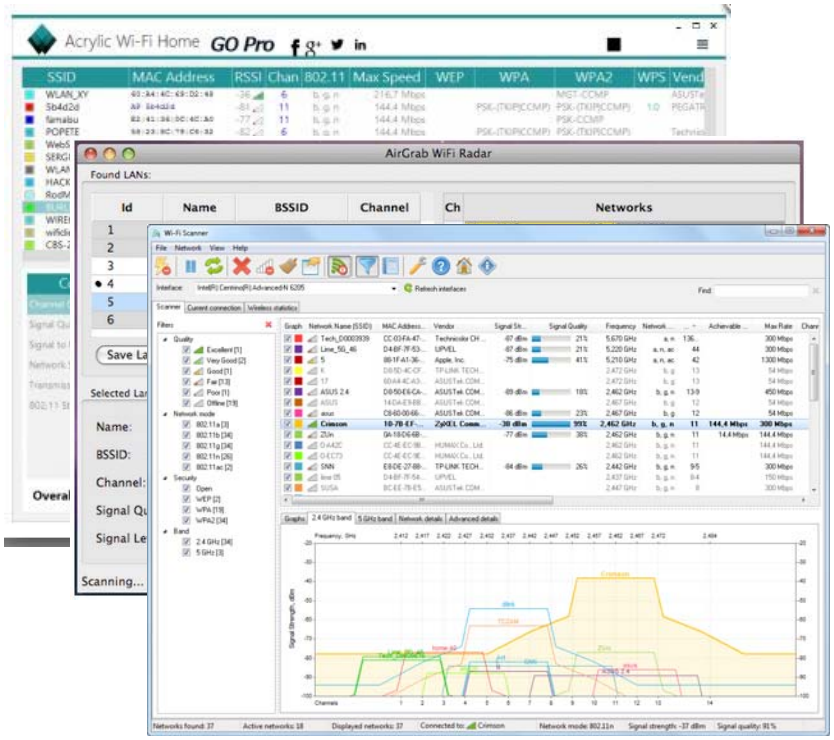
- Get data moving for various testing purposes

	Protocol	Summary
27:87:D7:F0	802.11 Encrypted ...	
27:87:D7:F0	802.11 WEP Data	
27:87:D7:F0	802.11 Encrypted ...	
27:87:D7:F0	802.11 Encrypted ...	
27:87:D7:F0	802.11 Encrypted ...	
27:87:D7:F0	802.11 Encrypted ...	
27:3B:1C:12	802.11 Encrypted ...	
27:87:D7:F0	802.11 Encrypted ...	
27:87:D7:F0	802.11 Encrypted ...	
27:87:D7:F0	802.11 Encrypted ...	
27:87:D7:F0	802.11 Encrypted ...	
	802.11 BA	FC=........
	802.11 Ack	FC=........
27:87:D7:F0	802.11 Encrypted ...	FC=.F....W.,SN=3215,FN= 0
	802.11 BA	FC=........
27:87:D7:F0	802.11 Encrypted ...	
27:87:D7:F0	802.11 Encrypted ...	
AF:3E:AE:21	802.11 Encrypted ...	
27:87:D7:F0	802.11 Encrypted ...	
27:87:D7:F0	802.11 Encrypted ...	
27:87:D7:F0	802.11 Encrypted ...	
27:87:D7:F0	802.11 Encrypted ...	
27:87:D7:F0	802.11 Encrypted ...	
27:87:D7:F0	802.11 Encrypted ...	
27:87:D7:F0	802.11 Encrypted ...	

Additional Software Troubleshooting Tools

Wi-Fi Discovery Tools

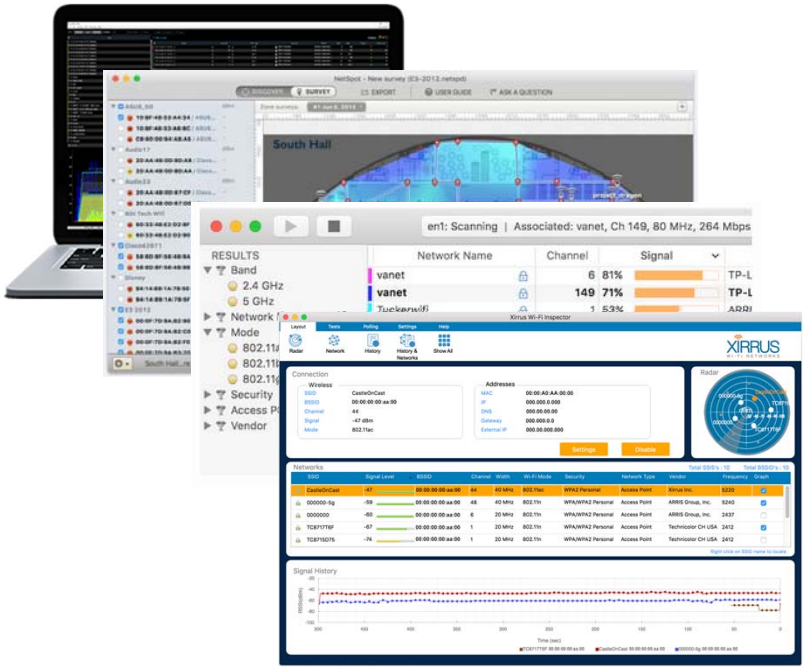
- Acrylic WiFi Home (Windows) - Free
- AirGrab WiFi Radar (Mac OSX) - Free
- LizardSystems Wi-Fi Scanner (Windows) Free and purchase version



Additional Software Troubleshooting Tools

Wi-Fi Discovery Tools

- MetaGeek InSSIDer Office - Purchase
- NetSpot (Windows and Mac)
- WiFi Explorer (Mac) – Free and purchase version
- Xirrus (Riverbed) W-Fi Inspector (Windows and Mac) - Free



Hardware Troubleshooting Tools

Wi-Fi Test Tools

- Netscout LinkSprinter
- Netscout AirCheck G2
- Berkeley Varitronics Yellowjacket-BANG
- Netscout OptiView XG

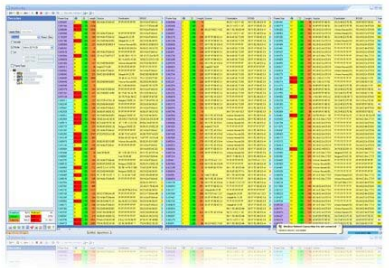
Show Me The Data

Protocol Analysis

Troubleshooting Tools – Protocol Analyzers

Types of Protocol Analyzers

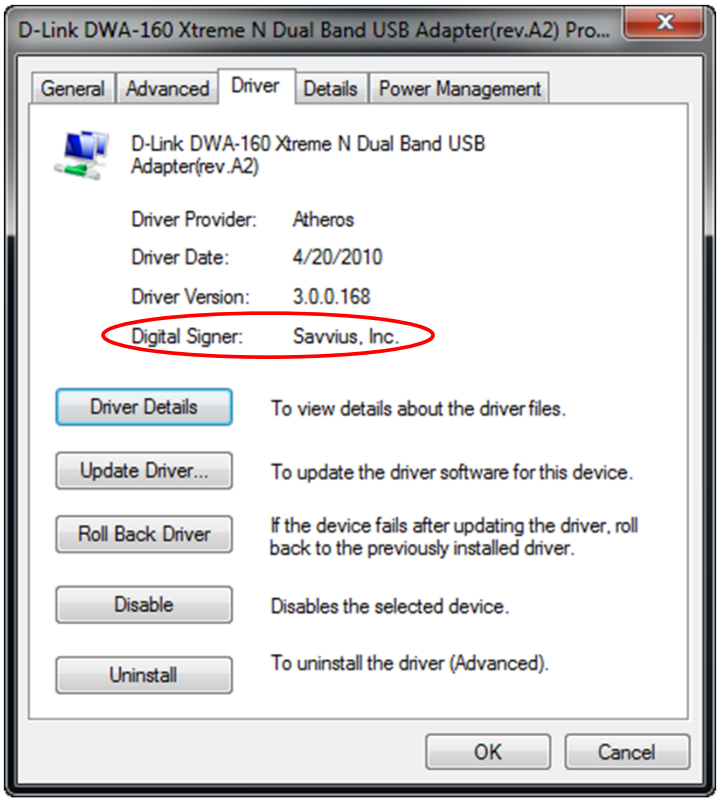
- Portable (Laptop)
- Infrastructure (Access Points)
- Distributed (Sensors)



Troubleshooting Tools – Protocol Analyzers

Network Adapter and Operation Modes

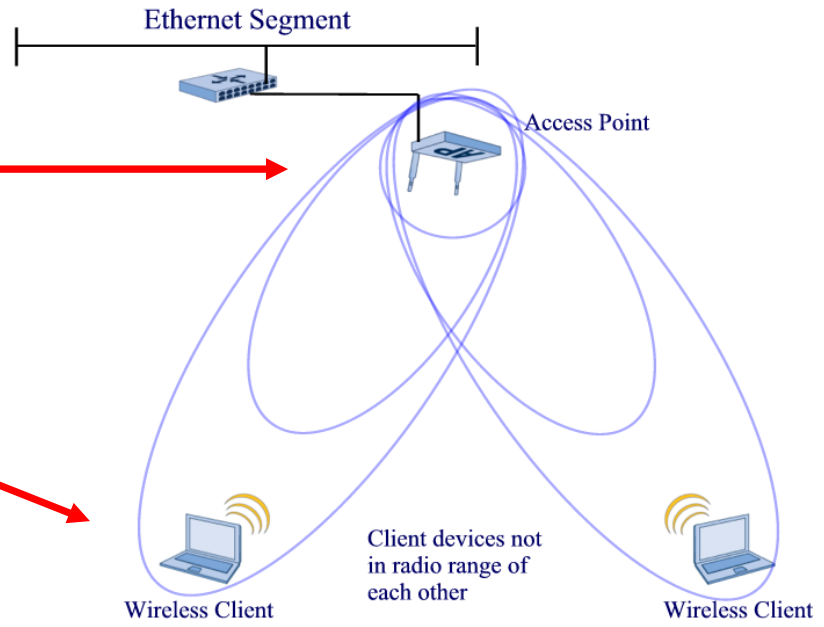
- Monitor vs Promiscuous Mode
- Supported Adapters
- Adapter Capabilities



Troubleshooting Tools – Protocol Analyzers

Protocol Analyzers Placement

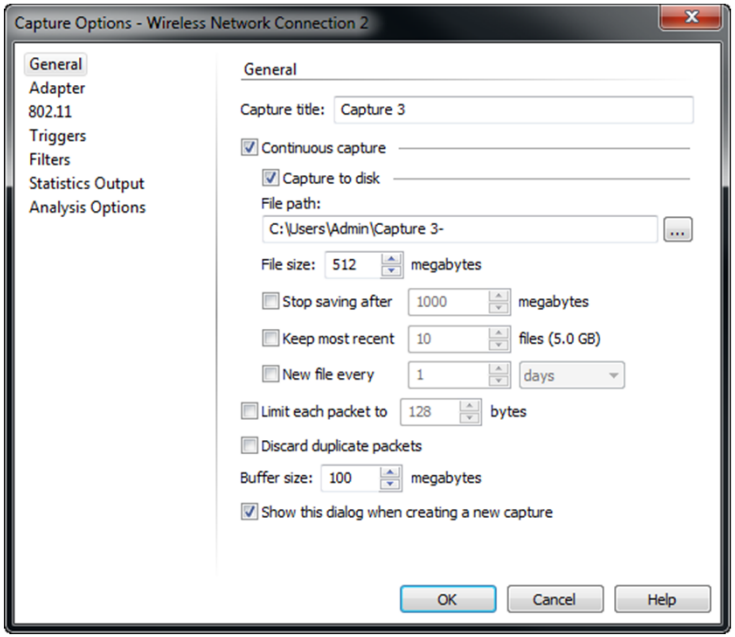
- Near Access Point?
- Near User?
- Moving?



Troubleshooting Tools – Protocol Analyzers

Common Protocol Analyzers Settings

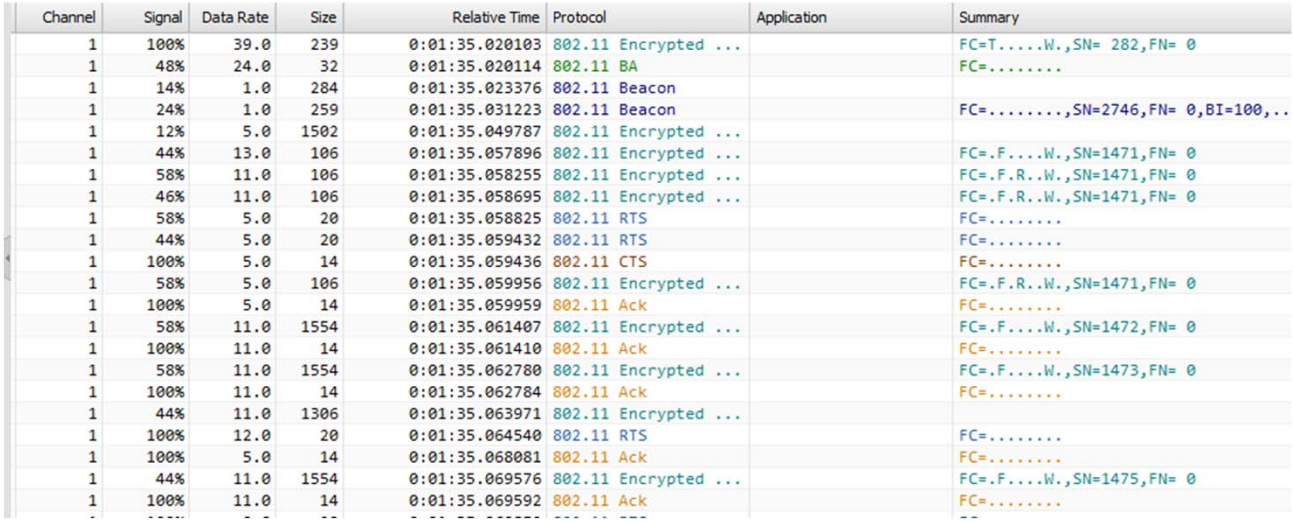
- Filters
- RF Channel / Transitioning
- Save to Disk
- Naming



Troubleshooting Tools – Protocol Analyzers

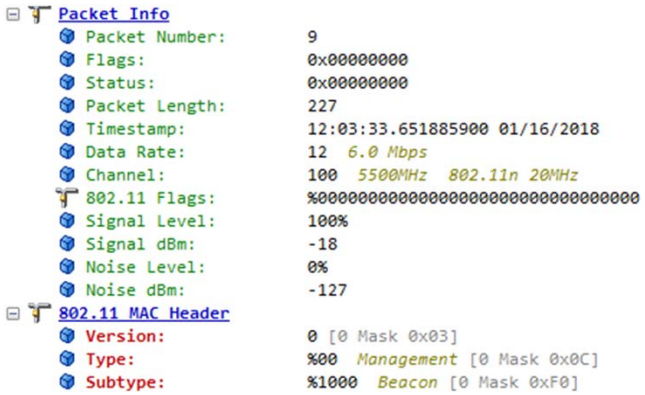
Protocol Analyzers Packet List

- MAC Address Information
- Protocol Types
- Timing



Channel	Signal	Data Rate	Size	Relative Time	Protocol	Application	Summary
1	100%	39.0	239	0:01:35.020103	802.11 Encrypted ...		FC=T.....W.,SN= 282,FN= 0
1	48%	24.0	32	0:01:35.020114	802.11 BA		FC=........
1	14%	1.0	284	0:01:35.023376	802.11 Beacon		
1	24%	1.0	259	0:01:35.031223	802.11 Beacon		FC=........,SN=2746,FN= 0,BI=100,..
1	12%	5.0	1502	0:01:35.049787	802.11 Encrypted ...		
1	44%	13.0	106	0:01:35.057896	802.11 Encrypted ...		FC=.F....W.,SN=1471,FN= 0
1	58%	11.0	106	0:01:35.058255	802.11 Encrypted ...		FC=.F.R..W.,SN=1471,FN= 0
1	46%	11.0	106	0:01:35.058695	802.11 Encrypted ...		FC=.F.R..W.,SN=1471,FN= 0
1	58%	5.0	20	0:01:35.058825	802.11 RTS		FC=........
1	44%	5.0	20	0:01:35.059432	802.11 RTS		FC=........
1	100%	5.0	14	0:01:35.059436	802.11 CTS		FC=........
1	58%	5.0	106	0:01:35.059956	802.11 Encrypted ...		FC=.F.R..W.,SN=1471,FN= 0
1	100%	5.0	14	0:01:35.059959	802.11 Ack		FC=........
1	58%	11.0	1554	0:01:35.061407	802.11 Encrypted ...		FC=.F....W.,SN=1472,FN= 0
1	100%	11.0	14	0:01:35.061410	802.11 Ack		FC=........
1	58%	11.0	1554	0:01:35.062780	802.11 Encrypted ...		FC=.F....W.,SN=1473,FN= 0
1	100%	11.0	14	0:01:35.062784	802.11 Ack		FC=........
1	44%	11.0	1306	0:01:35.063971	802.11 Encrypted ...		
1	100%	12.0	20	0:01:35.064540	802.11 RTS		FC=........
1	100%	5.0	14	0:01:35.068081	802.11 Ack		FC=........
1	44%	11.0	1554	0:01:35.069576	802.11 Encrypted ...		FC=.F....W.,SN=1475,FN= 0
1	100%	11.0	14	0:01:35.069592	802.11 Ack		FC=........

Troubleshooting Tools – Protocol Analyzers



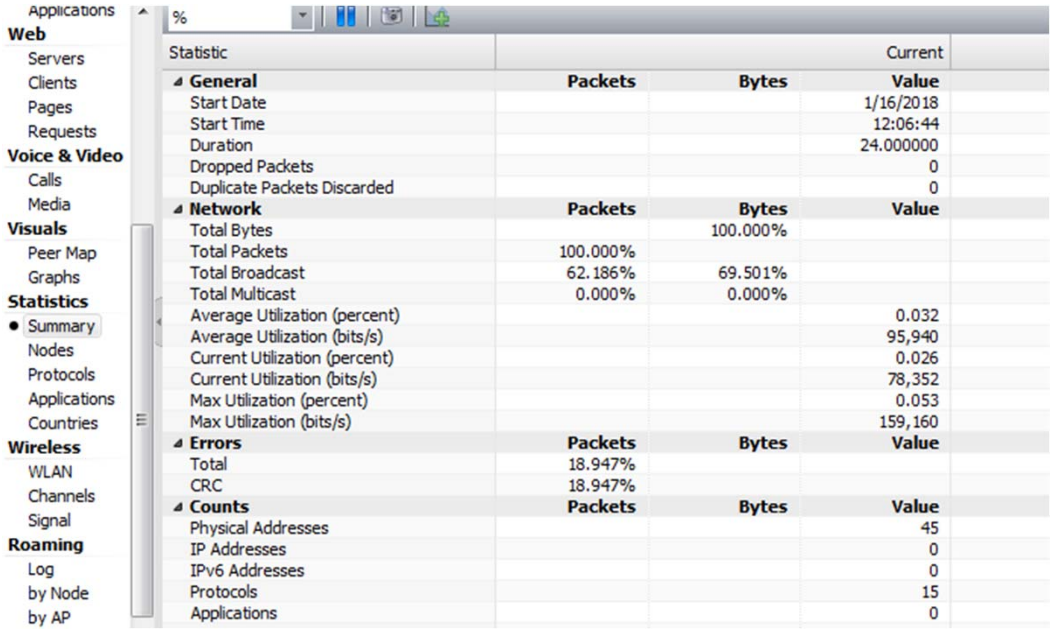
Protocol Analyzers Decodes

- Radiotap Header / Packet Info
- Not Layer 2 Information
- Derived from Physical Layer Header or Driver

Troubleshooting Tools – Protocol Analyzers

Protocol Analyzers General Information

- Channel Information
- Statistics



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So, Let's Get Physical

Wireless LAN Troubleshooting Tools

Common Layer 1 Physical Layer (aka The PHY) Troubleshooting Tools

Layer 1 Physical Layer (PHY) - Troubleshooting Tools

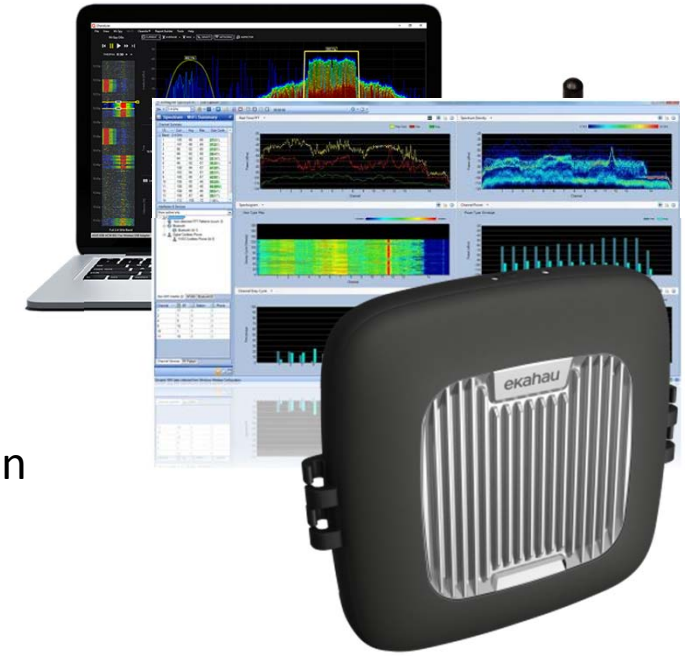
Instrumentation Spectrum Analyzers

- Tektronix
- Rohde & Schwarz
- RF Explorer

Layer 1 Physical Layer (PHY) - Troubleshooting Tools

Wi-Fi Centric Spectrum Analyzers

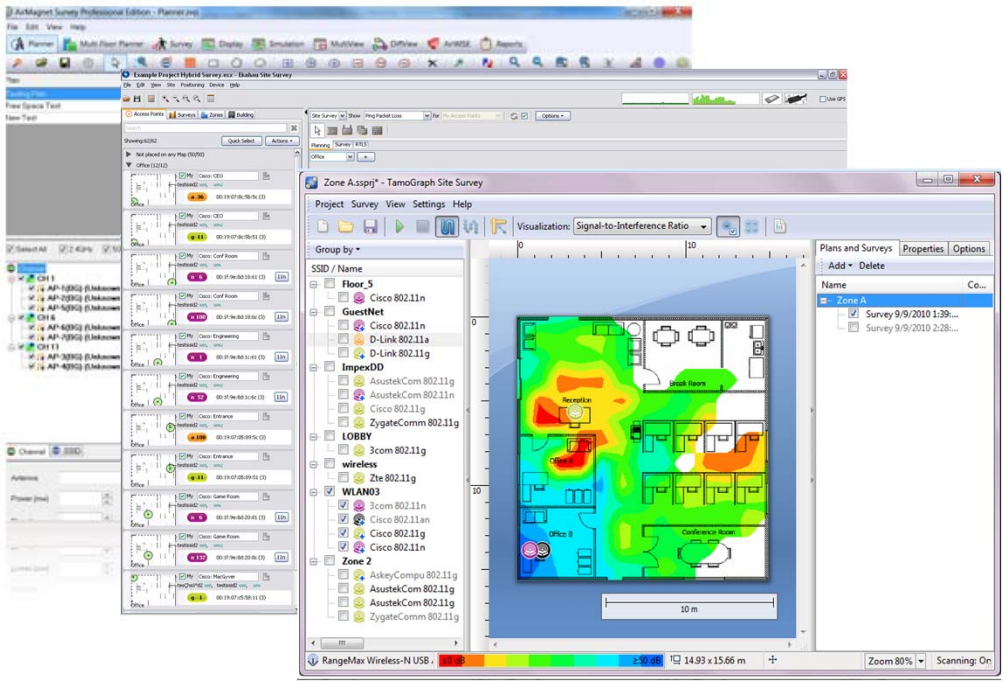
- MetaGeek Chanalyzer + Wi-Spy DBx
- Netscout Spectrum XT
- Ekahau Sidekick
- Not just for troubleshooting
  - Spectrum analyzers are also used with design



Layer 1 Physical Layer (PHY) - Troubleshooting Tools

Site Survey / Design Software

- Netscout Survey Pro
- Ekahau Site Survey
- Tamosoft TamoGraph



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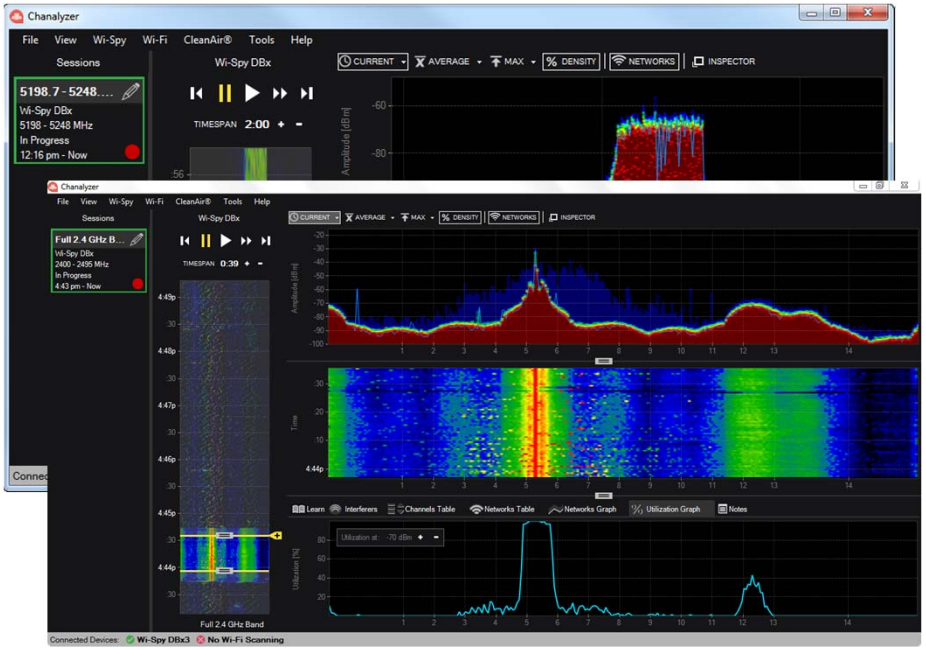
Spectrum Analysis

Troubleshooting Tools – Spectrum Analyzers

Spectrum Analysis Allows You To

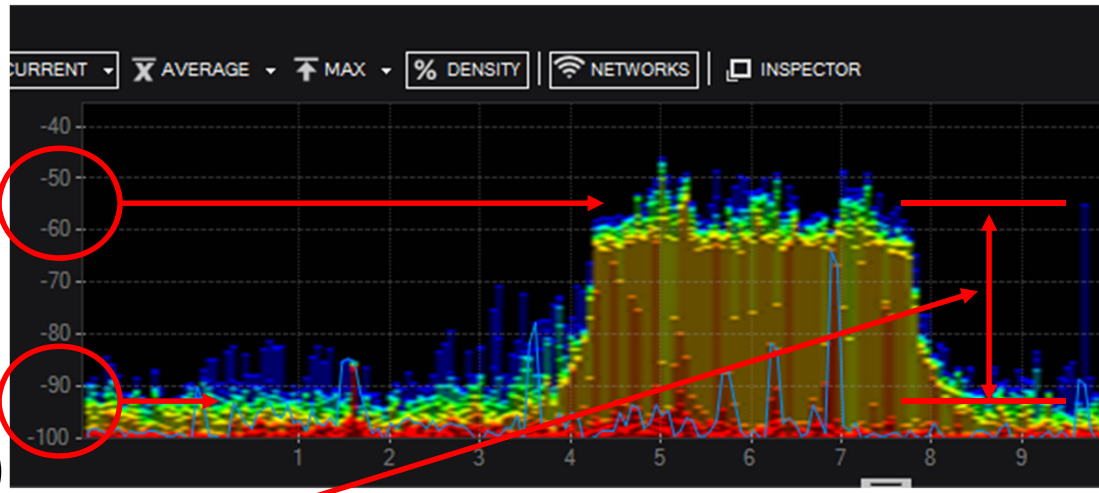
- "See" Your Wi-Fi
  - Visualize Unbounded Medium
- View Interference Types
  - Both Wi-Fi and Non-Wi-Fi



Troubleshooting Tools – Spectrum Analyzers

View Key Information

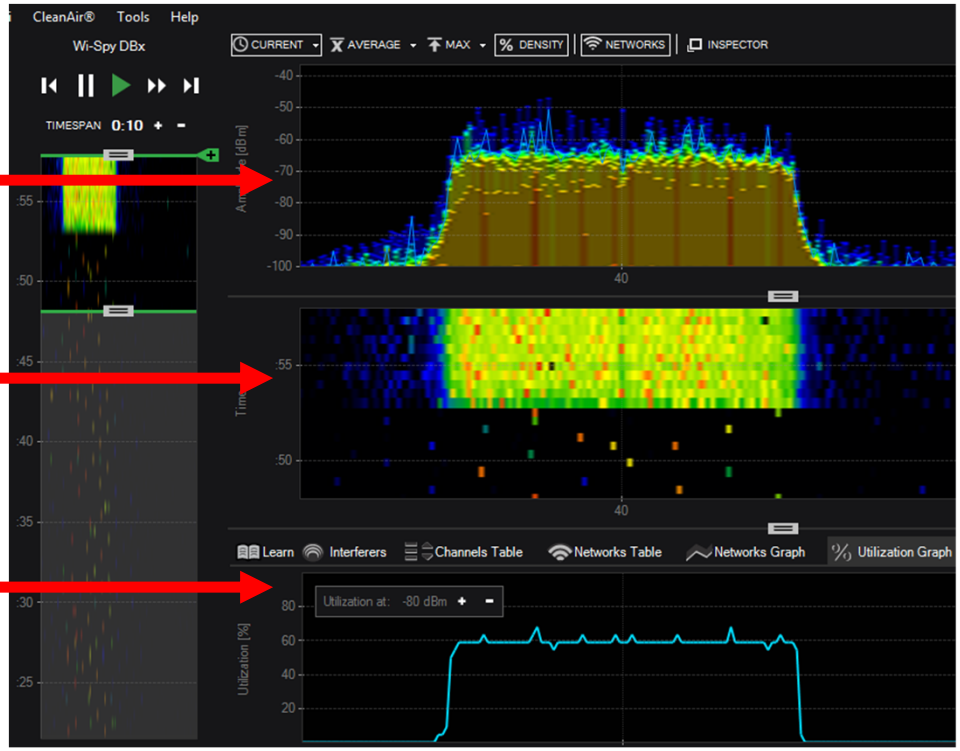
- Signal Strength
  - Received signal (-55 dBm)
- RF Noise Floor
  - Unwanted signal (-95 dBm)
- Signal to Noise Ratio (SNR)
  - Difference between signal and noise
    - » -55 dBm – (-95 dBm) = +40 dBm



Troubleshooting Tools – Spectrum Analyzers

View Key Information

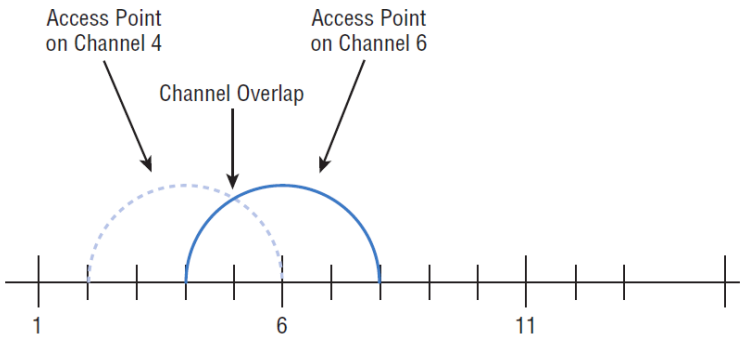
- Real Time FFT
  - Amplitude over frequency
- Waterfall
  - RF signal over a period of time
- Channel Utilization
  - RF activity on the channel



Troubleshooting Tools – Spectrum Analyzers

Spectrum Analysis Allows You To See

- Co-channel Interference (Wi-Fi)
- Overlapping Channel Interference (Wi-Fi)
- Non-Wi-Fi Interference
- Much More



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Spectrum Analyzer Demonstration

Thank You!

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