Society of Cable Telecommunications Engineers
30TH ANNIVERSARY
SCTE CABLE-TEC EXPO '13
OCTOBER 21-24 / ATLANTA, GA

UNDERSTANDING TECHNOLOGY OPTIONS FOR DEPLOYING WIFI

Bill Rink Sr. Director Product Management

Derek Ferro VP Advanced Solutions Engineering

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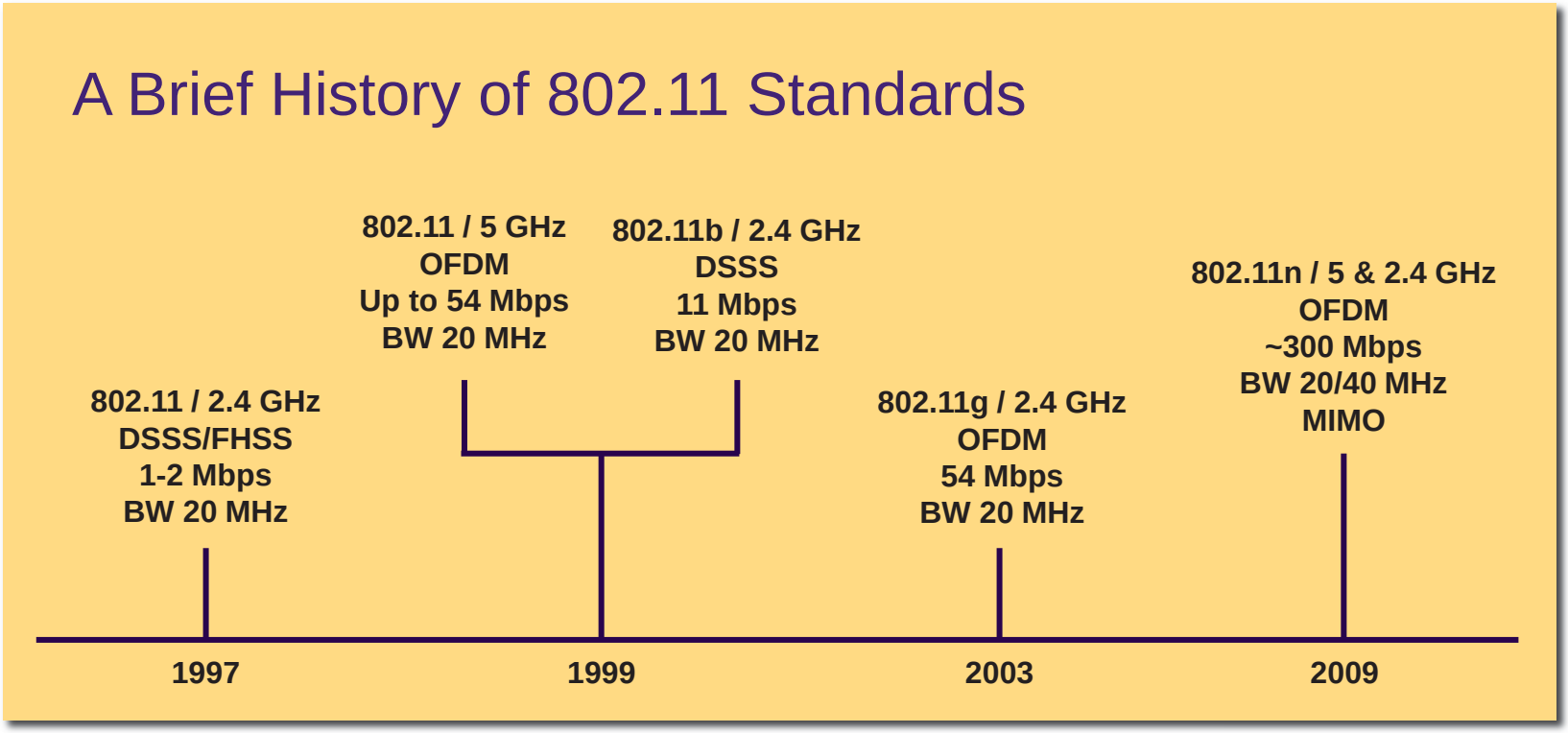
Agenda

- Understanding Wi-Fi Standards
- Wireless Link Overview
- Migrating to 802.11ac
- Wireless Design Enhancements
- Applications Driving Wi-Fi Adoption

Alphabet Soup

Understanding Wi-Fi Standards



Technology Options

What do these mean?

- **Multiple Data Streams: 3x3 Designs**
- **Single Band vs. Dual Band**
- **High Power Designs**
- **Enhanced Receive Sensibility**

Multiple Data Streams

802.11n: Up to 4 spatial streams

MCS Index	Spatial Streams	Modula-tion Type	Coding Rate	Data Rate			
				20 MHz Channel		40 MHz Channel	
				800ns GI	400ns GI	800ns GI	400ns GI
16	3	BPSK	1/2	19.50	21.70	40.50	45.00
17	3	QPSK	1/2	39.00	43.30	81.00	90.00
18	3	QPSK	3/4	58.50	65.00	121.50	135.00
19	3	16-QAM	1/2	78.00	86.70	162.00	180.00
20	3	16-QAM	3/4	117.00	130.00	243.00	270.00
21	3	64-QAM	2/3	156.00	173.30	324.00	360.00
22	3	64-QAM	3/4	175.50	195.00	364.50	405.00
23	3	64-QAM	5/6	195.00	216.70	405.00	450.00
24	4	BPSK	1/2	26.00	28.80	54.00	60.00
25	4	QPSK	1/2	52.00	57.60	108.00	120.00
26	4	QPSK	3/4	78.00	86.80	162.00	180.00
27	4	16-QAM	1/2	104.00	115.60	216.00	240.00
28	4	16-QAM	3/4	156.00	173.20	324.00	360.00
29	4	64-QAM	2/3	208.00	231.20	432.00	480.00
30	4	64-QAM	3/4	234.00	260.00	486.00	540.00
31	4	64-QAM	5/6	260.00	288.80	540.00	600.00

- PHY Data Rates: negotiated between AP and Client
- Guard Interval (GI) protects against signal interference
- Actual Throughput = 40-70% of PHY Rate

Modulation Coding Schemes, Data Rates and RSSI

MCS Index	Spatial Streams	Modulation Type	Coding Rate	Data Rate (Mbps)					
				20 MHz Channel Width			40 MHz Channel Width		
				800ns Guard Interval	400ns Guard Interval	Min. RSSI Sensitivity (dBm)	800ns Guard Interval	400ns Guard Interval	Min RSSI Sensitivity (dBm)
0	1	BPSK	1/2	6.50	7.20	-82	13.50	15.00	-79
1	1	QPSK	1/2	13.00	14.40	-79	27.00	30.00	-76
2	1	QPSK	3/4	19.50	21.70	-77	40.50	45.00	-74
3	1	16-QAM	1/2	26.00	28.90	-74	54.00	60.00	-71
4	1	16-QAM	3/4	39.00	43.30	-70	81.00	90.00	-67
5	1	64-QAM	2/3	52.00	57.80	-66	108.00	120.00	-63
6	1	64-QAM	3/4	58.50	65.00	-65	121.50	135.00	-62
7	1	64-QAM	5/6	65.00	72.20	-64	135.00	150.00	-61
8	2	BPSK	1/2	13.00	14.40	-82	27.00	30.00	-79
9	2	QPSK	1/2	26.00	28.90	-79	54.00	60.00	-76
10	2	QPSK	3/4	39.00	43.30	-77	81.00	90.00	-74
11	2	16-QAM	1/2	52.00	57.80	-74	108.00	120.00	-71
12	2	16-QAM	3/4	78.00	86.70	-70	162.00	180.00	-67
13	2	64-QAM	2/3	104.00	115.60	-66	216.00	240.00	-63
14	2	64-QAM	3/4	117.00	130.00	-65	243.00	270.00	-62
15	2	64-QAM	5/6	130.00	144.40	-64	270.00	300.00	-61

Receiver Sensitivity

- Greater Rx sensitivity allows device to receive weaker signals
- Greater transmission distances supported

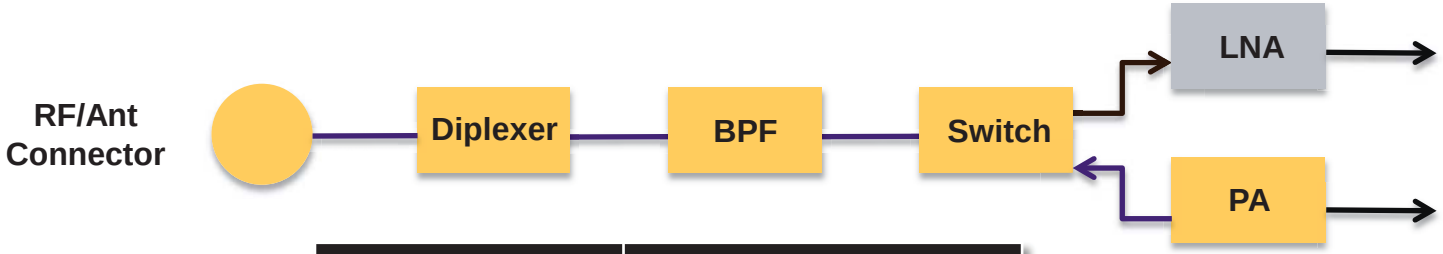
Receiver Sensitivity per Modulation Coding Scheme

Receiver Minimum Input Level Sensitivity					
Modulation	Rate (R)	Adjacent Channel Rejection (dB)	Nonadjacent Channel Rejection (dB)	Minimum Sensitivity (20 MHz channel spacing) (dBm)	Minimum Sensitivity (40 MHz channel spacing) (dBm)
BPSK	1/2	16	32	-82	-79
QPSK	1/2	13	29	-79	-76
QPSK	3/4	11	27	-77	-74
16-QAM	1/2	8	24	-74	-71
16-QAM	3/4	4	20	-70	-67
64-QAM	2/3	0	16	-66	-63
64-QAM	3/4	-1	15	-65	-62
64-QAM	5/6	-2	14	-64	-61

Link Budget

Important Wireless System Design Tool

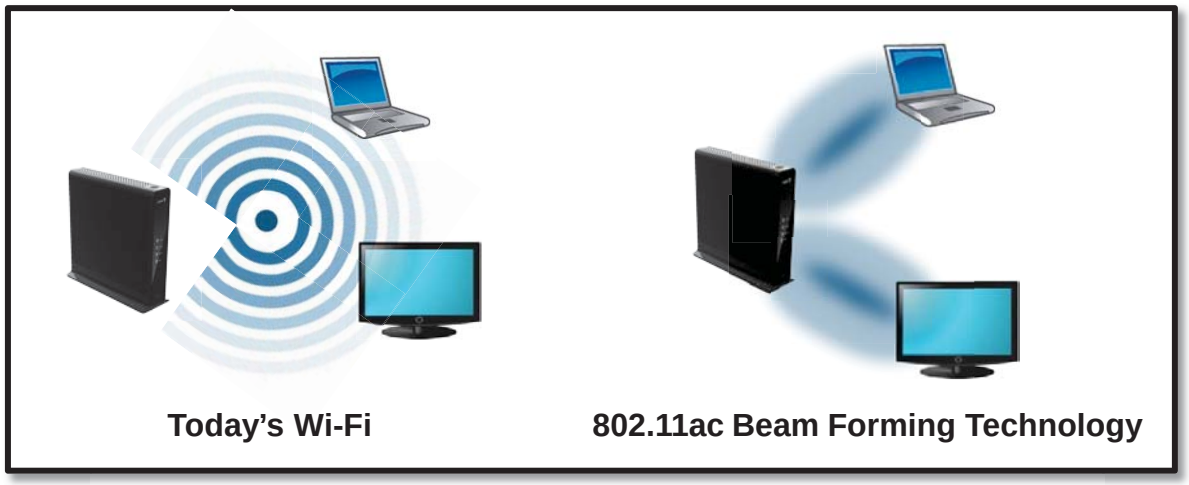
- Sum of Gains & Losses = Satisfactory Performance (typically output is SNR or BER)



Component	Typical Insertion Loss (dB)
RF Connector	0.3
Diplexer	0.65
Switch	0.6
Microstrip Line Loss	0.75
Total	2.3

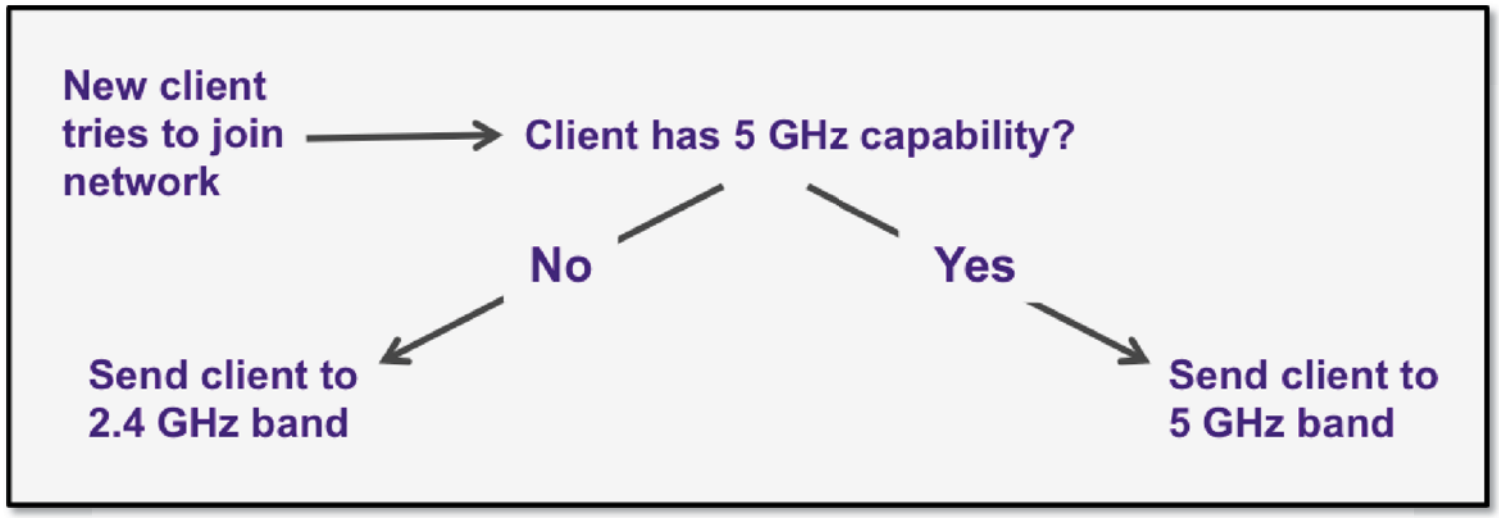
Beam Forming

- Focuses Wireless Signals
- Improves Wireless Performance by 2 – 3x
- Implicit vs. Explicit Beam Forming



Band Steering

- Sends 802.11n clients to the 5 GHz band
- Leaves 802.11b/g clients in the 2.4 GHz band



Spatial Diversity Multiple Access (SDMA)

- 802.11ac specifies 8 spatial streams
- Most significant gains with multi-user MIMO

802.11ac Data Rates: Theoretical throughput for single Spatial Stream (in Mbps)										
MCS Index	Modulation Type	Coding Rate	20 MHz Channels		40 MHz Channels		80 MHz Channels		160 MHz Channels	
			800 ns GI	400 ns GI	800 ns GI	400 ns GI	800 ns GI	400 ns GI	800 ns GI	400 ns GI
0	BPSK	1/2	6.5	7.2	13.5	15	29.3	32.5	58.5	65
1	QPSK	1/2	13	14.4	27	30	58.5	65	117	130
2	QPSK	3/4	19.5	21.7	40.5	45	87.8	97.5	175.5	195
3	16-QAM	1/2	26	28.9	54	60	117	130	234	260
4	16-QAM	3/4	39	43.3	81	90	175.5	195	351	390
5	64-QAM	2/3	52	57.8	108	120	234	260	468	520
6	64-QAM	3/4	58.5	65	121.5	135	263.3	292.5	526.5	585
7	64-QAM	5/6	65	72.2	135	150	292.5	325	585	650
8	256-QAM	3/4	78	86.7	162	180	351	390	702	780
9	256-QAM	5/6	N/A	N/A	180	200	390	433.3	780	866.7
Up to 8 streams, MU-MIMO = 6.77G										

Design Enhancements

What is Allowing Increasing Speeds?

- High Power Transmit
- Receive Sensitivity (High Gain LNA)
- Auto-Channel Selection
- Influence of Antenna Designs
- Dual Band Wi-Fi

Design Enhancements

High Power Amplifiers

- Proliferation of MIMO designs leading to internal vs. external antennas
- FCC Part 15 Subpart C mandates
  - Peak conducted power output of an intentional radiator shall not exceed 1 Watt (30dBm).
  - Max EIRP = 36 dBm (4 watt)
  - EIRP = transmit output power (dBm) + antenna gain (dBi)
- To recover lost gain afforded by dipole antennas, an external Power Amp provides up to an additional 23dBm of amplification to help boost the transmit signal

Design Enhancements

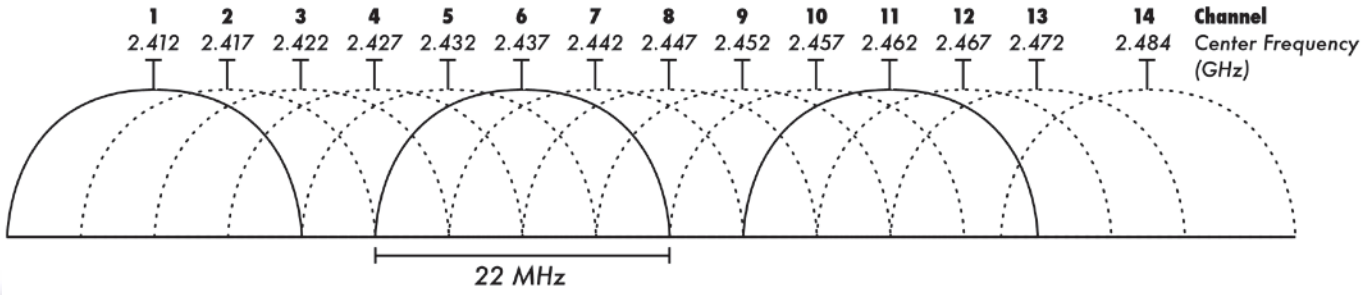
Increasing RSSI of the Wireless Router

- Exchange of packets requires transmission and reception of frames for control and data
- Boosting XMT Power is only half of a solution
  - Link speed is determined by client's RSSI, improved by High Power PA, and packet loss on the connection
- Increase of receive sensitivity by using an external low-noise amplifier (LNA) capable of boosting the receive signal 12dB for the appropriate frequency range

Design Enhancements

Auto Channel Selection

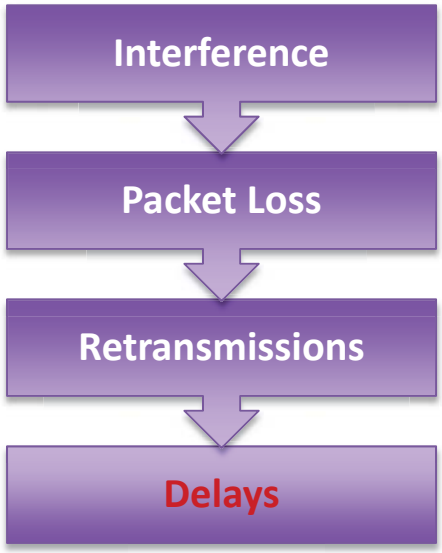
- 802.11 standard defines 14 channels for 2.4GHz
  - FCC allows channels 1 through 11
- Each carrier requires between 16.25 to 22 MHz of channel separation between adjacent channels
  - 3 non-overlapping channels (1, 6, and 11 for the US)

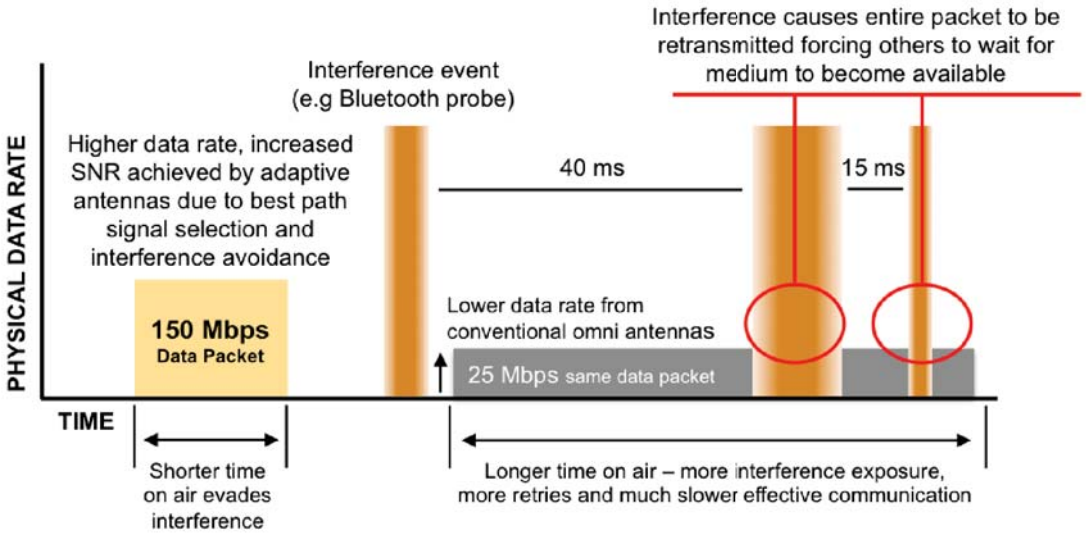


Design Enhancements

Auto Channel Selection

- When two or more transmitters are operated in the same airspace, their signals must be attenuated by -50dB and/or separated by 22 MHz to prevent interference.





Design Enhancements

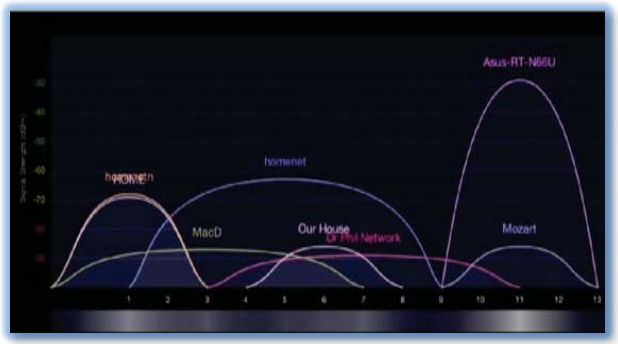
Auto Channel Selection

- ACS allows wireless router to choose its control channel based on spectrum utilization at boot time
  - the dynamic nature of surrounding wireless networks makes it difficult for a one-time decision to be optimal
  - Some devices have the capability of changing channels as the situation varies although this could lead to client disconnection or maybe worsen the channel congestion if the algorithm gets it wrong.
  - on 802.11k supports AP-client coordination that allows messaging to the client that a channel change is about to occur

Design Enhancements

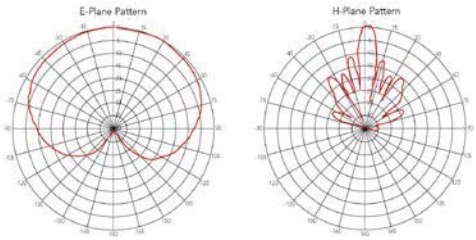
Auto Channel Selection

- Tunnel Vision? The wireless router makes channel selection based on interference seen from it's own vantage point.
  - Is the algorithm used by the ACS reliable and trusted to make the right channel selection?
- Manual selection of channel 1, 6, or 11 recognized as the safest method

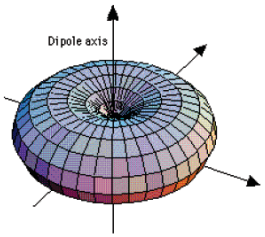


Design Enhancements

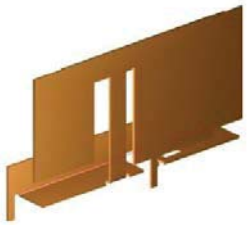
Influence of Antenna Design



- Antennas provide:
  - ✓ Gain
  - ✓ Direction
  - ✓ Polarization



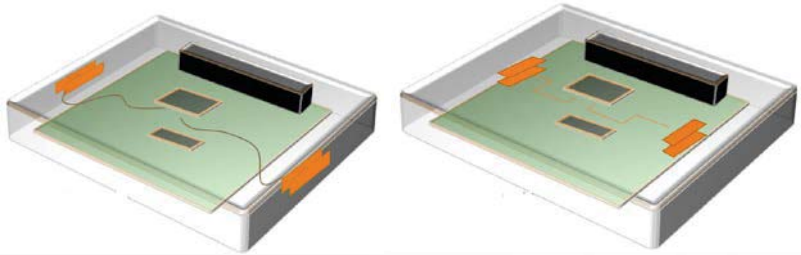
- Antenna selection is typically driven by range and coverage factors
- Internal antenna design evolving
  - Higher levels of efficiency and performance
  - Integrated multi-element and dual polarization designs



Design Enhancements

Influence of Antenna Design

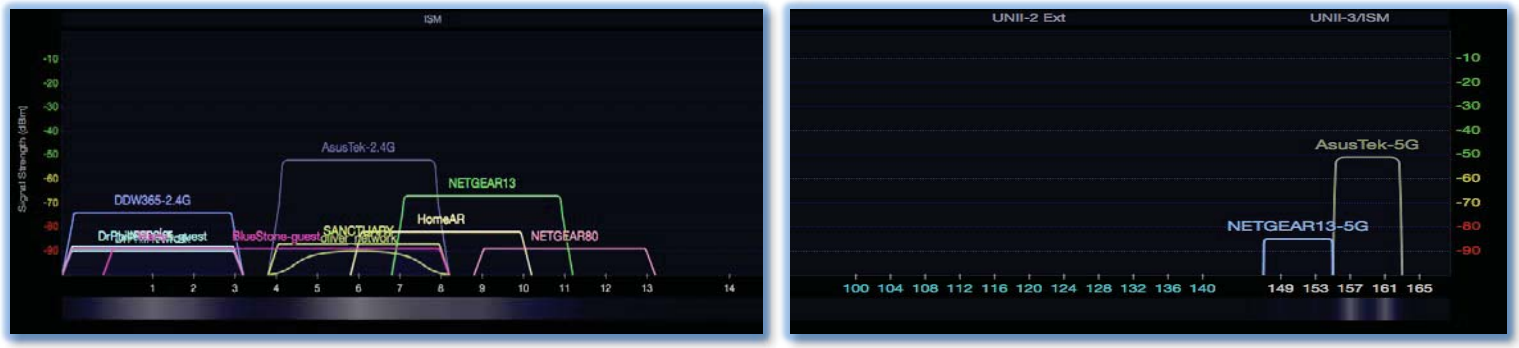
- Antenna type and placement require careful consideration
  - Performance, manufacturability, enclosure design, and cost will influence the final selection
  - Products have improved esthetics while still providing exceptional performance and range



Design Enhancements

Dual Band Wi-Fi

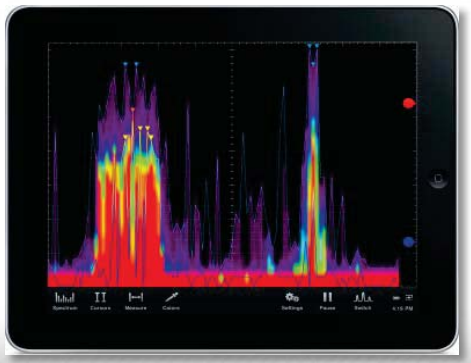
- Dual-band enables the separation of high bandwidth tasks from checking email and browsing the Internet
- Avoid congestion of the 2.4GHz band by utilizing the 5GHz band that has more non-overlapping channels



Design Enhancements

Dual Band Wi-Fi

- Home appliances such as cordless phones, intercoms, baby monitors and microwave ovens also run on the 2.4-GHz band
- Not all devices support dual band. So it may not be possible to fully utilize the 5GHz band
- 5GHz will likely become equally crowded as dual band popularity grows.



Applications Driving Wi-Fi Adoption

What Applications are Subscribers Using?

- **Networking devices**
- **Productivity**
- **Multimedia**
- **Gaming**
- **Off-loading Cellular**

Applications Driving Wi-Fi Adoption

802.11ac Devices Driving Wi-Fi Offloading

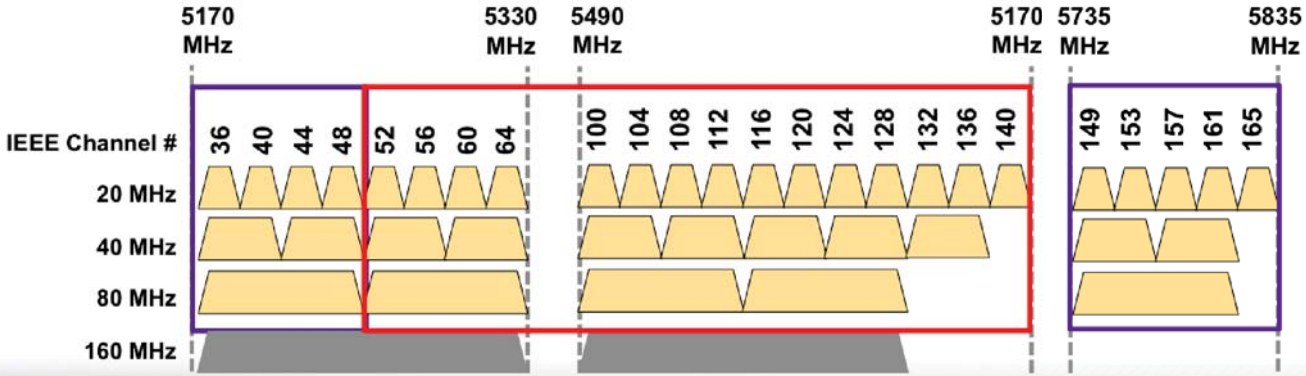
- Incorporates beam-forming, wide bands and multiple antennas to initially deliver data speeds up to 1.3Gbps (ultimately as high as 6.9 Gbps)
- Provides reduced latency and data rates more than double those of a typical 802.11n network
- Expected adoption by handset vendors will drive adoption in Wi-Fi routers used by hotspot providers

Applications Driving Wi-Fi Adoption

802.11ac will ultimately over crowd 5GHz band

- 5 GHz band: 24 non-overlapping 20 MHz wide channels
- Radar system interference means only the bottom 4 and top 5 channels (9 total) are commonly used

- In 80MHz mode, available 5GHz channels of router will reduced from 9 to 2
- Dynamic Frequency Selection (DFS) enables detection of the presence of a radar system



Applications Driving Wi-Fi Adoption

Wireless Homes are the Norm

- Freedom from Ethernet cable hassles
- Free roaming (inside and outside the home) for laptop, tablets, and smartphones
- Video streaming to TV monitors throughout the house without being concerned with coax outlet availability

Applications Driving Wi-Fi Adoption

Wireless Homes are the Norm

- What is driving the proliferation of wireless devices in the home?

The need to access information found on the Internet

The desire to access entertainment content and social media from anywhere in the home

The growing focus on streaming media, which has the highest level of consumption overall

Applications Driving Wi-Fi Adoption

Wireless Homes are the Norm

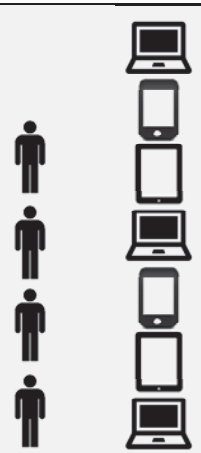
- Based on ITU data:
  - Estimated 2.8 billion Internet users Worldwide March, 2013
- A day of usage in the USA

Usage	Consumption
Information/Web Browsing	78,900 Trillion Bytes
Emails	294 Billion Bytes
Facebook Visits	172 Million
Photos Uploaded	22 Million Hours
Videos Uploaded	864 Thousand Hours
Music Streamed	18.7 Million Hours
Videos Watched on Netflix	22 Million Hours
Apps Downloaded	35 Million

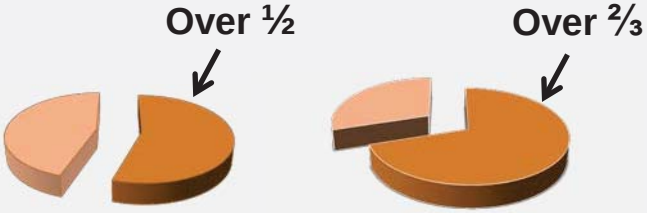
Applications Driving Wi-Fi Adoption

Explosive Growth of Internet Capable Devices

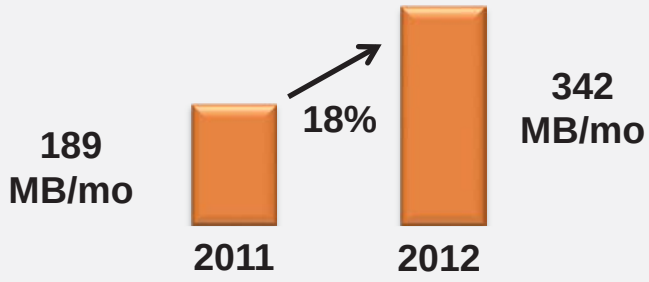
Smartphones, tablets, laptops, Internet-capable phones will outnumber humans in 2013.



Mobile video makes up the lion's share of worldwide data transmissions.



Smartphone data traffic is skyrocketing.



Smartphones

18% of global handsets

Consume 92% of global mobile data traffic

Applications Driving Wi-Fi Adoption

Explosive Growth of Internet Capable Devices

- Media tablet will pull customers into the era of the digitally connected home
- Wireless connectivity has become the predominate means to access the content on the Internet
  - Consumers view speed as the prime metric when considering a broadband service
  - Despite knowing wireless connections can be slower, they increasingly choose Wi-Fi as the preferred method
- Operators benefit from understanding the extent to which the last “air” mile can affect performance

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Bill Rink and Derek Ferro

bill.rink@ubeeinteractive.com

derek.ferro@ubeeinteractive.com

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