Cisco live!

What You Make Possible

TOMORROW starts here.

CISCO

802.11 Standards

BRKEWN-2066

Wi-Fi is Touching Our Lives …

The Wi-Fi Alliance found ...

... 90% would rather go without their daily coffee than their Wi-Fi

Wi-Fi is Touching Our Lives …

The Wi-Fi Alliance found ...

... 70% would rather give up chocolate rather than give up Wi-Fi

What is Today's Agenda?

Today's Presentation is Going to Focus on Various Aspects of Wi-Fi & Standards

1	• **Why is Wi-Fi so successful?**
2	• **Who are key players in Wi-Fi standards?** *IEEE 802.11 WG, Wi-Fi Alliance … with Cisco leadership!*
3	• **What is coming down the standards pipeline?** *802.11ac, Passpoint, and many others!*

Make sure you keep up to date with Wi-Fi, because - more and more - it's driving the network edge and mobility

Brian Hart has Participated in 802.11 Standards and Wi-Fi Development For Many Years

Standards

- IEEE 802.11 (2005-)
  - 802.11n 20/40 vice-chair
  - 802.11ac MU-MIMO co-chair
  - Awards for contributions to 11k, 11n, 11v, 11y, 11aa, 11mb
  - Also active in 11ac, 11ad
- Wi-Fi Alliance (2008-)
  - Active in Wi-Fi Direct, VHT5G
- WiGig Alliance (2010-)
  - Director
- Other special interest groups and organisations

Development

- 11a/b/g/h DSP chipset architect for AP1131 and AP1242 (2000-2004)
- Wi-Fi RRM (2004-2006)
- Wi-Fi location signal processing architect (2006-)
- Other strategic initiatives (2011-)

Your Assistance Requested

- In this presentation we're going to discover that the next generations of Wi-Fi allows gigabit+ speeds
- What use cases will drive wireless throughput demand in your business?
- Why might you pick both 802.11ac and 802.11ad?
- Keep these questions in mind
- If you don't get a chance to answer today, please email brianh@cisco.com

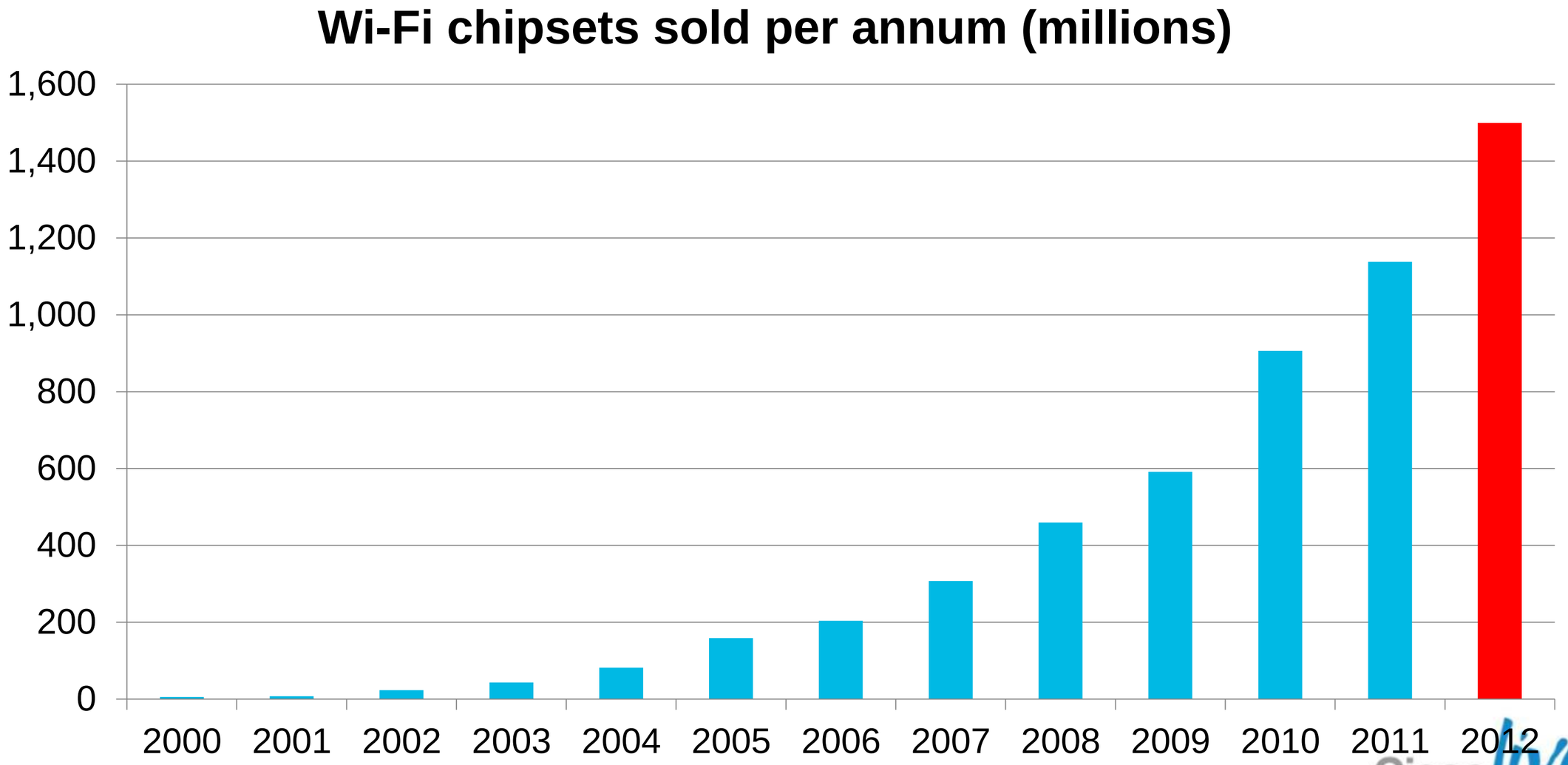
Today's Presentation Comes with Some Important Caveats …

Today's talk WILL NOT ...

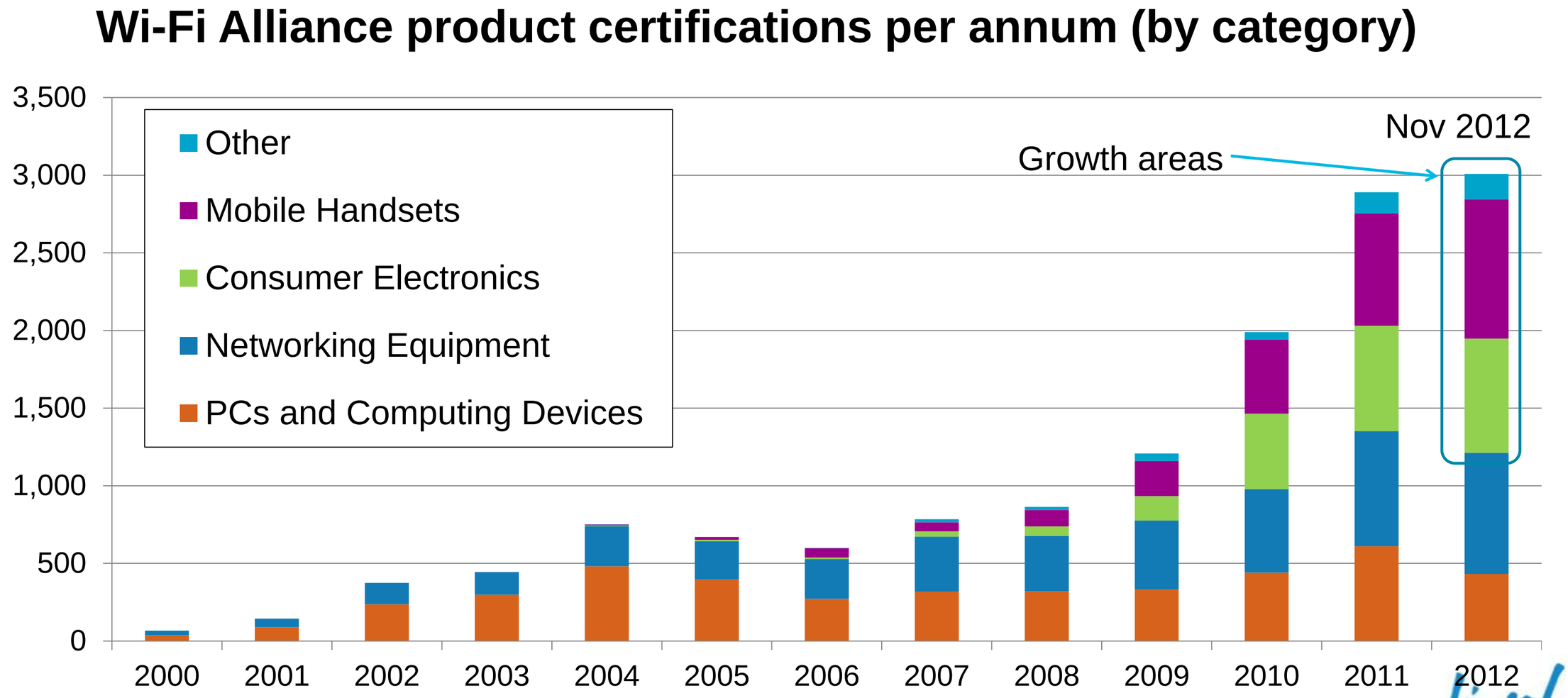
- Provide any information about Cisco's specific wireless product plans …
- Represent the views or plans of any SDO's or ITA's …
  - …because I am representing Cisco today and am not authorised to speak on behalf of any SDO's or ITA's

Why is Wi-Fi so Successful?

Wi-Fi has Grown from Almost Nothing in 2000 to Over 1.5 Billion Devices Per Annum in 2012 …



... in Many Thousands of Wi-Fi Certified Devices (& Increasingly Diverse Devices)



... in a Myriad of Devices – Wi-Fi is in Anything that Might Ever Have a Need to Communicate

Refrigerator

Smart TV

Plant sensor

Air Conditioner

Bathroom scales

Projector

Industrial sensors

Thermostat

Smart-phone

Security Camera

Automobile

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... Generating More Wi-Fi Data Traffic than Wired Data Traffic by about 2015

Monthly data traffic (by category)

Wi-Fi's Success is Based on a Bit of Luck and a Great Brand with Good Interoperability ...

- Designed from the ground up to work well, however installed
- Unlicensed spectrum become available at key times
  - Most cellular SPs are now realising unlicensed Wi-Fi spectrum will get them through the licensed spectrum "crunch"
- Wi-Fi Alliance certification ensures interoperability and is associated with a great brand
  - "Wi-Fi" is so much better than "WECA"! ☺

Wi Fi® CERTIFIED

← This brand actually means something in the market!

Wi-Fi's Success is its Expanding Freedom ...

- Anyone can set up a "rough and ready" Wi-Fi network anywhere and at any time ... cheaply
- IEEE 802.11 standards have expanded incrementally to meet the new needs of QoS, security, speed, reliability, manageability etc
- So serious users (i.e. enterprise) can build managed networks that meet their needs too
  - With visibility, control and reliability – assuming you use Cisco gear ☺
- And Wi-Fi is continually being used as the basis of innovation
  - Wi-Fi Direct, Smartgrid, IoT, …

Who are the Key Players in Wi-Fi Standards?

The Wi-Fi Ecosystem is Mainly Based on Cooperation Between 3 Main Stakeholders

Standards

Certification

Vendors

My favourite vendor ☺

IEEE 802 is Probably the Most Famous Example of a Very Successful IEEE Standards Activity …

Sponsor	*IEEE Computer Society*
Formal goal	*… develops Local Area Network standards and Metropolitan Area Network standards.*
Current activities	• **802.1** - architecture, internetworking, security, network management • **802.3** - Ethernet • **802.11** - Wireless LAN • 802.15 - Wireless PAN • 802.16 - Broadband Wireless • 802.18 - Radio Regulatory • 802.19 – Coexistence • 802.21 - Handover Services • 802.22 - Wireless RAN • 802.24 – Smart Grid

Of Course, the IEEE Process is Not Perfect ...

… too slow

- Many standards take 6+ years to develop
- The process is often rule bound
- The process relies on standardisation by:
  - R&D in parallel with the std writing
  - Regular F2F meetings punctuated by down-time

… too political

- Sometimes not very good at dealing with conflict
- The conflicts are based on combinations of:
  - Technology
  - Business
  - Bragging rights

… too compromising

- Contention is often resolved by letting everybody “win”
- This can lead to very long & complex standards with many options

… but the IEEE Standards Process has just "Worked" Pretty Well for IEEE 802

- The "IEEE way" has led to the creation of some very successful IEEE 802 standards …
  - Consensus driven standards (mostly) defined by people interested in building gear for real customers
- …and has allowed the IEEE 802 standards family to continue developing over a long period
  - IEEE 802 celebrated its 30th anniversary in March 2010
  - IEEE 802.11 celebrated its 20th anniversary in Sept 2010
- … for billions of people to use every day

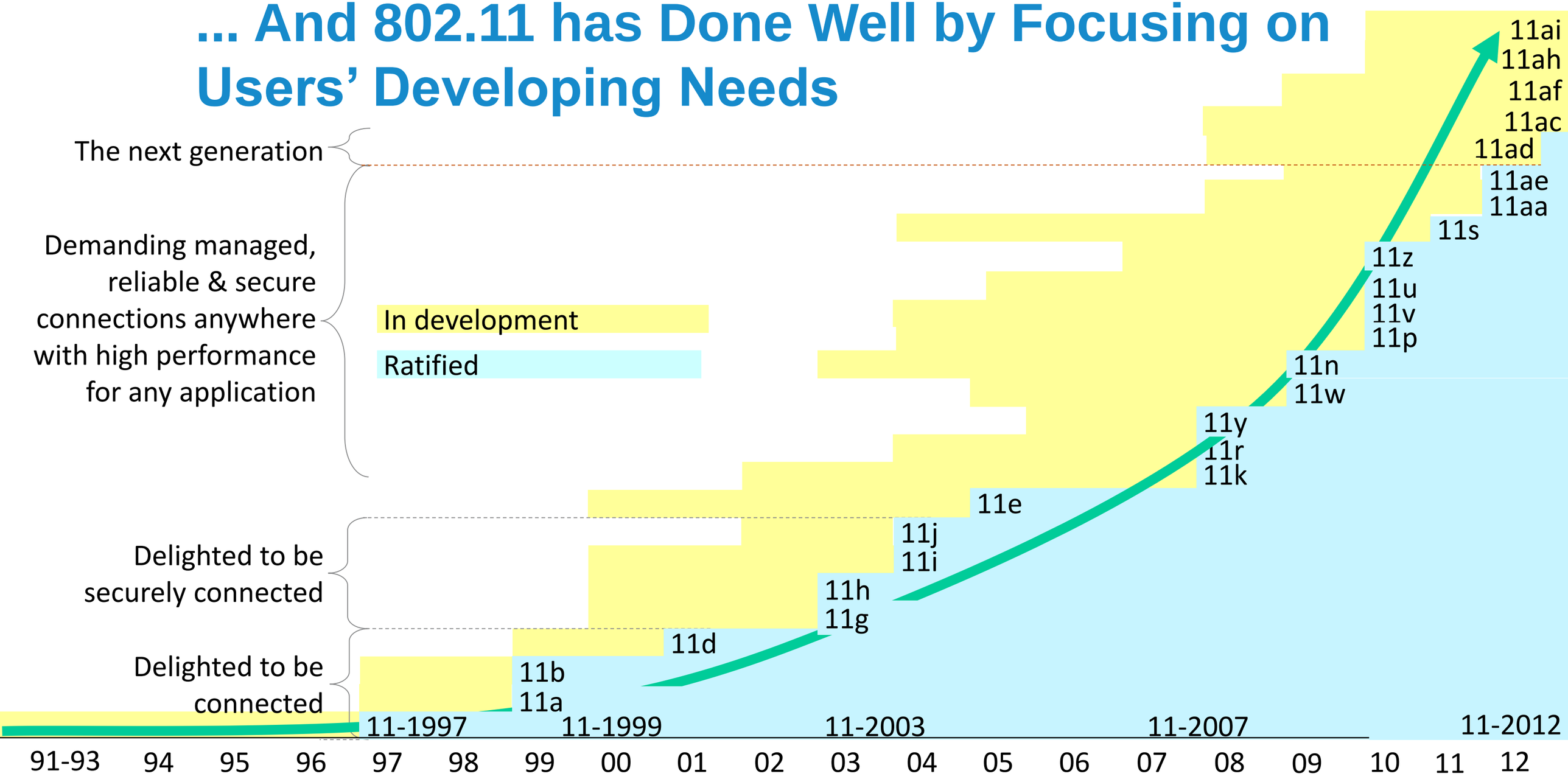
… based on a Modern Paradigm for Standards that Gives the Best Possible Chance of Success

OpenStand's Modern Paradigm

- Cooperation between standards organisations
- Adherence to development principles
  - Due process
  - Broad consensus
  - Transparency
  - Balance
  - Openness
- Collective empowerment of participants
- Availability under reasonable terms
- Voluntary adoption with the market deciding

http://open-stand.org

… And 802.11 has Done Well by Focusing on Users' Developing Needs



The Wi-Fi Alliance is an International Trade Association (ITA) for 802.11-based Products

- Certifies the interoperability of 802.11 based products
  - 12 test labs in 8 countries
  - 16,000+ products certified since March 2000
- Facilitates collaboration within the ecosystem
  - "What is worth certifying"
  - With some spec development
- Acts as a thought leader on all issues related to Wi-Fi products and technology

- The goal is to help ensure multi vendor interoperability
- Most testing utilises a test-bed of "golden products" and "low bar" performance testing
- This is a pragmatic solution well suited to the WLAN industry

The Wi-Fi Alliance has over 500 Members Across the Value Chain in Different Segments

Sponsor members

T-Mobile
cisco
QUALCOMM
intel
Microsoft
LG
NOKIA
Connecting People
Texas Instruments
HUAWEI
DELL
The power to do more
BROADCOM
Comcast
SONY
SAMSUNG
SAMSUNG ELECTRONICS
MOTOROLA SOLUTIONS

Selection of regular members

SK telecom
中国移动通信
CHINA MOBILE
Ruckus
WIRELESS
ARUBA
networks
at&t
Your world. Delivered.
vodafone
RIM
NTT
Deutsche Telekom
ftgroup
TELECOM ITALIA
BelAir
NETWORKS
verizon
csr
NEC
ROGERS

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… Who Have a Shared Vision of Seamless Connectivity

Seamless connectivity…

… using Wi-Fi

Cisco is a Champion of Wireless Standards

By developing certified WLAN products

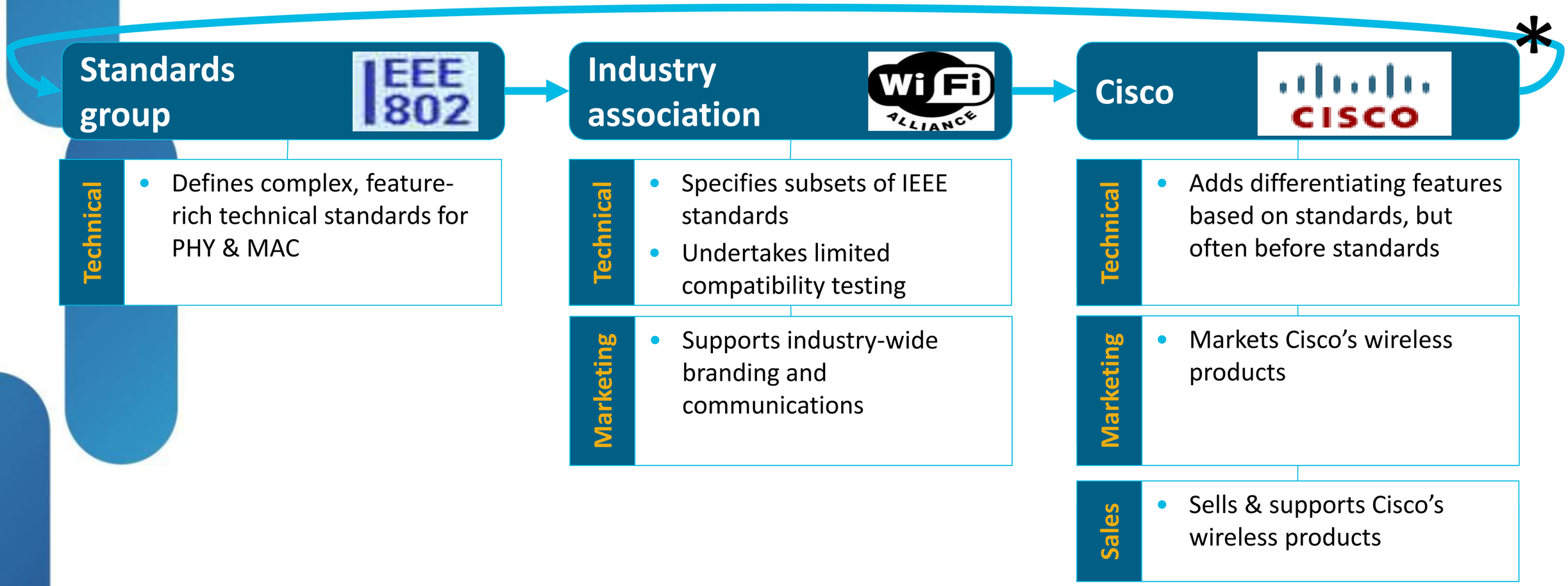
- Cisco policy is to implement useful 802.11 standards as soon as practical
- Cisco policy is to prove interoperability by Wi-Fi certifying equipment

By investing in open WLAN standards

- Cisco provides officers & contributions to IEEE 802.11 WG
- Cisco is Sponsor of Wi-Fi Alliance & provides major contributions

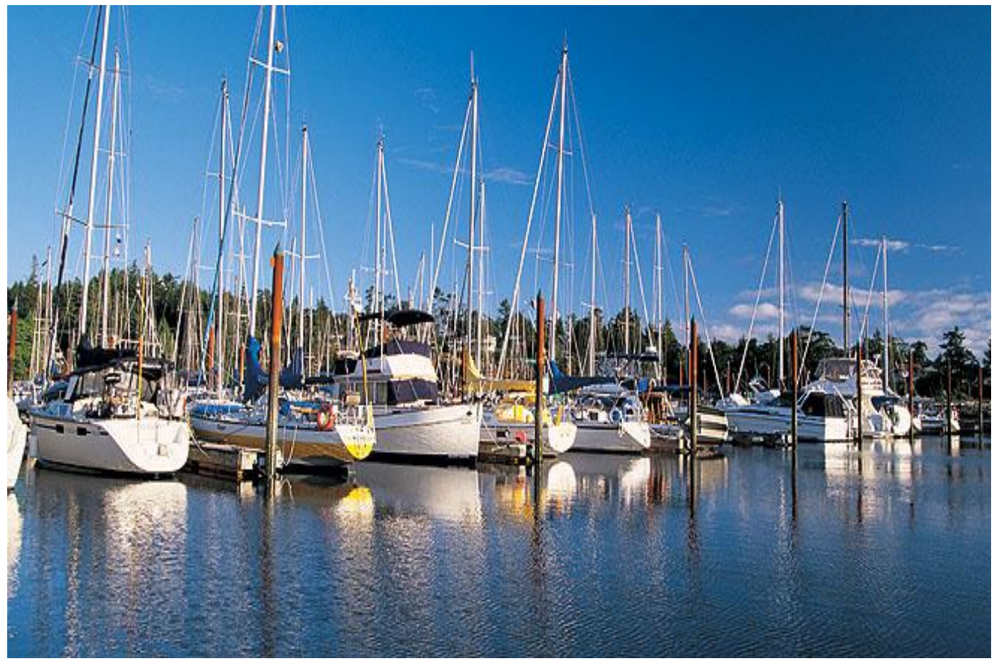
Cisco Innovates, and Then Contributes its Innovations into the Standards Process

Cisco feeds tested features back into standards



Cisco Aims to use Standards to be the "Prettiest Ship" on the "Biggest Ocean"

Proprietary systems are good for a while ….



… but global standards & certifications open up the world

Cisco Supports the Development of the 802.11 Standard with Officers & Participation

TG	Officer	Participate	Done	Comment
802.11e		✓	2005	QoS
802.11g		✓	2003	54Mb/s at 2.4GHz
802.11h	✓	✓	2003	DFS and TPC
802.11i	✓	✓	2004	Security
802.11j	✓	✓	2004	Regulatory domain support
802.11k		✓	2008	Radio Resource Measurement
802.11ma	✓	✓	2007	Maintenance of standard
802.11mb		✓	2012	Maintenance of standard
802.11mc		✓	-	Maintenance of standard
802.11n		✓	2009	>100 Mb/s at 2.4GHz and 5GHz
802.11p		✓	2010	Vehicular
802.11r		✓	2008	Fast roaming
802.11s		✓	2011	Mesh
802.11u	✓	✓	2011	Internetworking with external networks

Cisco Supports the Development of the 802.11 Standard with Officers & Participation

TG	Officer	Participate	Done	Comment
802.11v	✓	✓	2011	Radio Resource Management
802.11w	✓	✓	2009	Management Frame Protection
802.11y	✓	✓	2008	3.6GHz operation
802.11z		✗	2010	Direct link – a consumer issue
802.11aa		✓	2012	Video
802.11ac	✓	✓	-	>1Gb/s @ 5GHz
802.11ad		✓	2012	>1Gb/s @ 60GHz
802.11ae		✓	2012	QoS for management frames
802.11af	✓	✓	-	TV White Space
802.11ah		✓	-	<1GHz PHY
802.11ai		✓	-	Fast Initial Link Setup
802.11aj		✗	-	802.11ad for China
802.11ak		✓	-	802.1 bridging over Wi-Fi
802.11aq		✓	-	Service Discovery
JTC1 SC	✓	✓	-	JTC1 liaison

Cisco is Involved in Many Current WFA Activities as a Sponsor Member and in Task Groups

Near term	Cisco
Hotspot 2.0	✓ *
VHT in 5G	✓
Direct Services	Consumer
Security	✓
Smart Grid	✓
Voice	✓
WMM-AC	✓
Display	Consumer
IBSS	Consumer

Long term	Cisco
60 GHz	✓
NPS	✓
WNM	✓
TV White Spaces	✓
WPS (NFC)	Consumer
NAN	Consumer
Docking	Watching
Service Discovery	✓
Serial Bus	Consumer
NAN	Consumer
SensorNet	Watching

Other activities	Cisco
Board	✓
Spectrum.	✓
Health & Science	✓
Enterprise	✓
Healthcare	✓
Operator	✓

“*” = officer

Note: Cisco provided Board Chair from 2006-2011

There are Many Examples where Cisco has Driven an 802.11 Activity with CCX & Other Material

Standard	Activity	Cisco contribution
802.11h	Spectrum management	Editor and main author, enabling 5GHz operation; participated in WFA certification process
802.11i	Security	Significant contributor, based on 802.1X for LEAP & group key rotation, TKIP; part of WPA/WPA2 certification test bed
802.11j	Multiple regulatory domains	Editor and main author, enabling operation in multiple regulatory domains
802.11k	Wireless Network Measurement	Significant contributor of various features, many based on CCX features; elements now certified by WFA as part of Voice Enterprise with Cisco in test bed
802.11r	Fast roaming	Significant contributor, with CCKM (Cisco) + WARP (Airespace) as basis; now certified by WFA as part of Voice Enterprise with Cisco in test bed

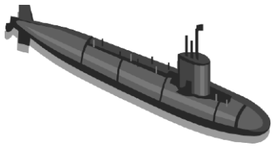
There are Many Examples where Cisco has Driven an 802.11 Activity with CCX & Other Material

Standard	Activity	Cisco contribution
802.11u	WIEN	Reinvigorated group and incorporated into Hotspot 2.0 activity (in SIG, WFA, WBA and GSMA) with Cisco in test bed
802.11v	Wireless Network Management	Author and contributor of a variety of location, diagnostic and other features, some derived from CCX features; participating in the certification processes
802.11w	Management Frame Protection	Editor and significant author, based on CCX feature; participated in certification process in WFA
802.11y	3.6GHz	Editor and main author, documenting new ways of opening up new spectrum
802.11aa	Video	Significant contributor of reliable multicast features, based on CCX feature

There are Many Examples where Cisco has Driven an 802.11 TG with CCX & Other Material

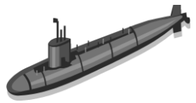
Standard	Activity	Cisco contribution
802.11ae	Management frame priority	Significant contributor of mechanisms to allow prioritisation of management frames
802.11ac	VHT <6GHz	Contributions to ensure utility in dense enterprise environment, especially better multi-channel operation & MU-MIMO – and Suite B
802.11ad	VHT 60GHz	Contributions to ensure useful for sea of desks enterprise environment and not just the consumer space
802.11af	TVWS	Editor and main driver, focused on developing mechanisms that can be used to open up new spectrum
802.11ai	Fast initial link setup	Redirected work to a more useful direction; they originally wanted to replace 802.11 security

Actually the Standards World is Even More Complicated Than Presented ...



Partners

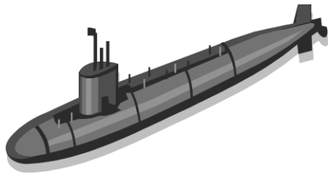
Anti-trust laws



Regulations

Industry

Cisco



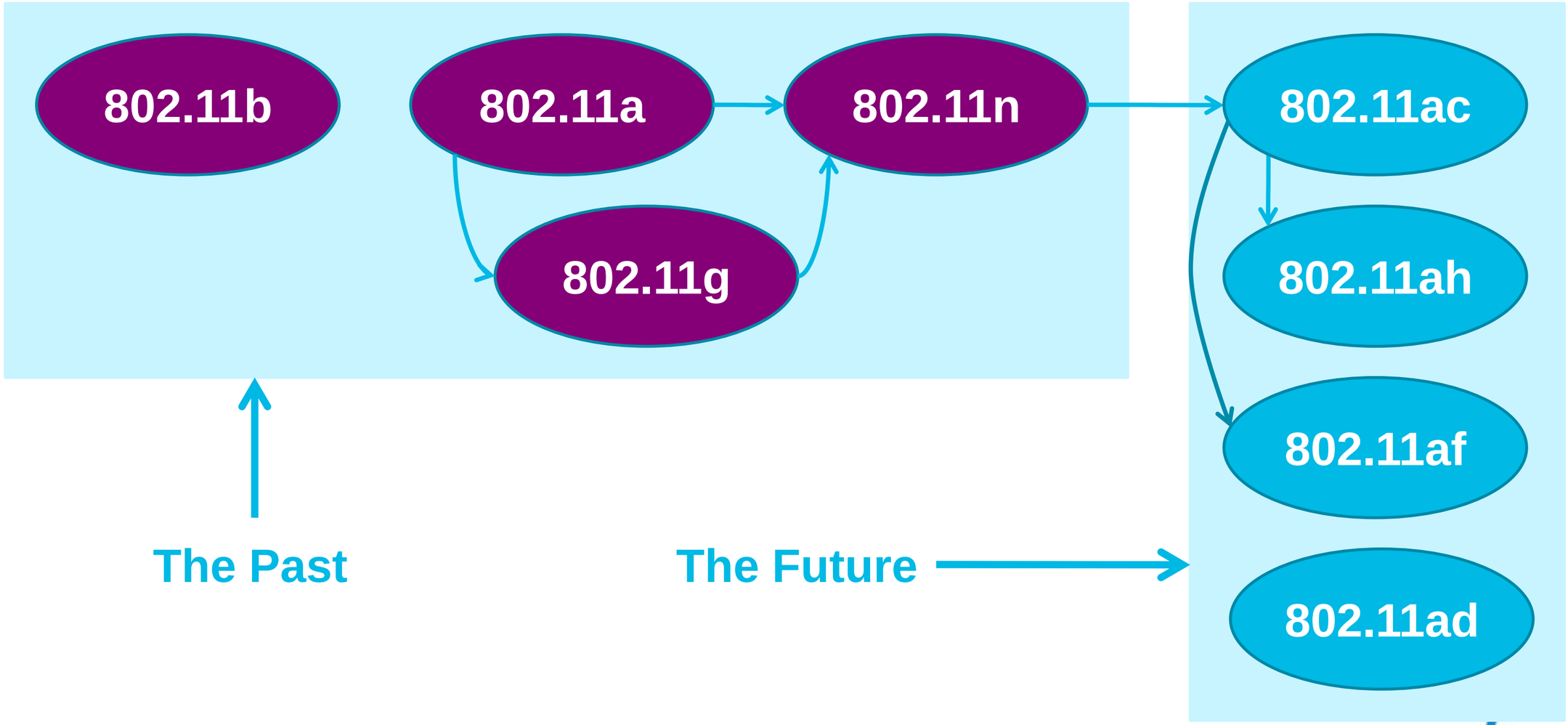
Competitors

What is Coming Down the Standards Pipeline?

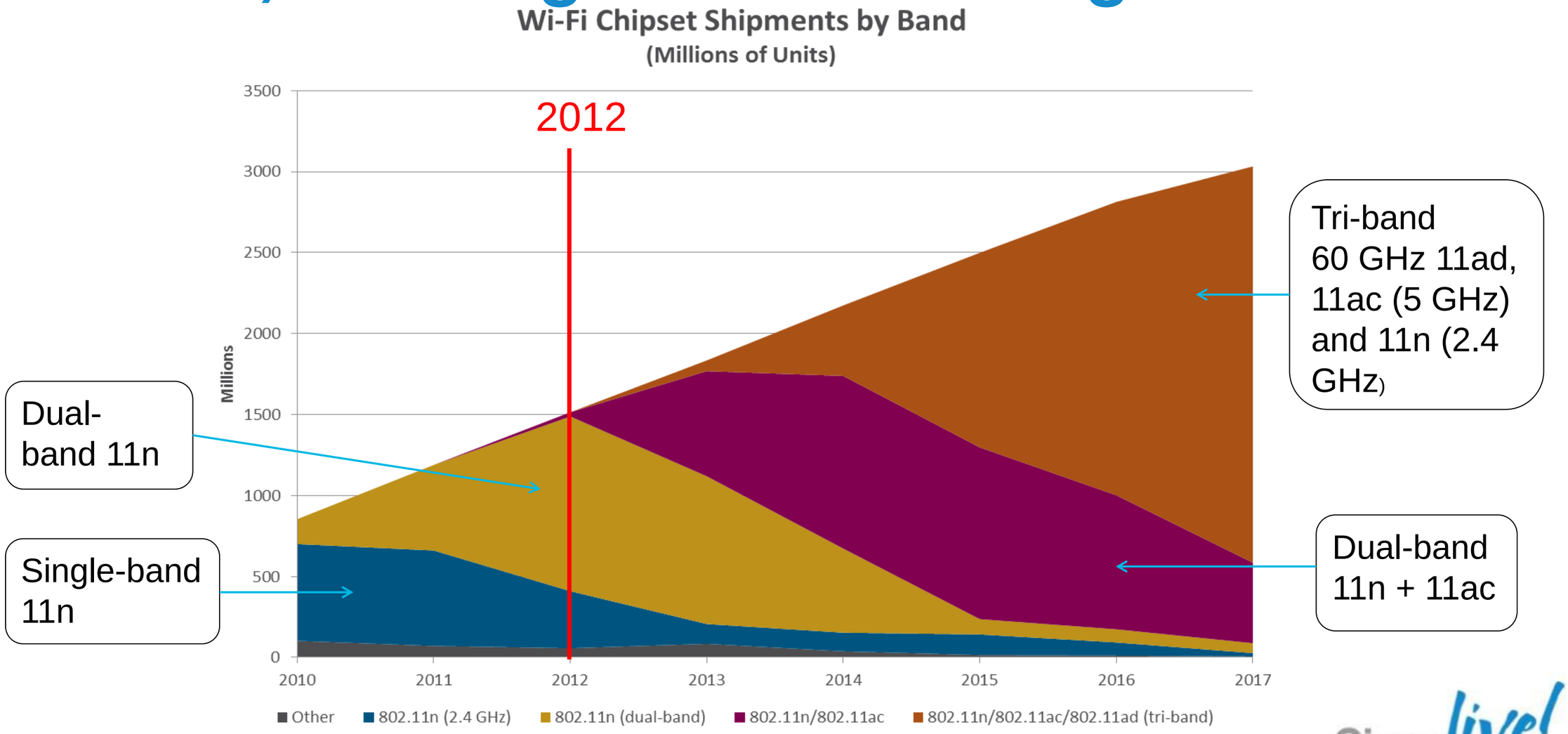
The Remainder of the Presentation will Provide an Update of the 802.11 and Wi-Fi "Alphabet Soup"

Wi-Fi Connectivity

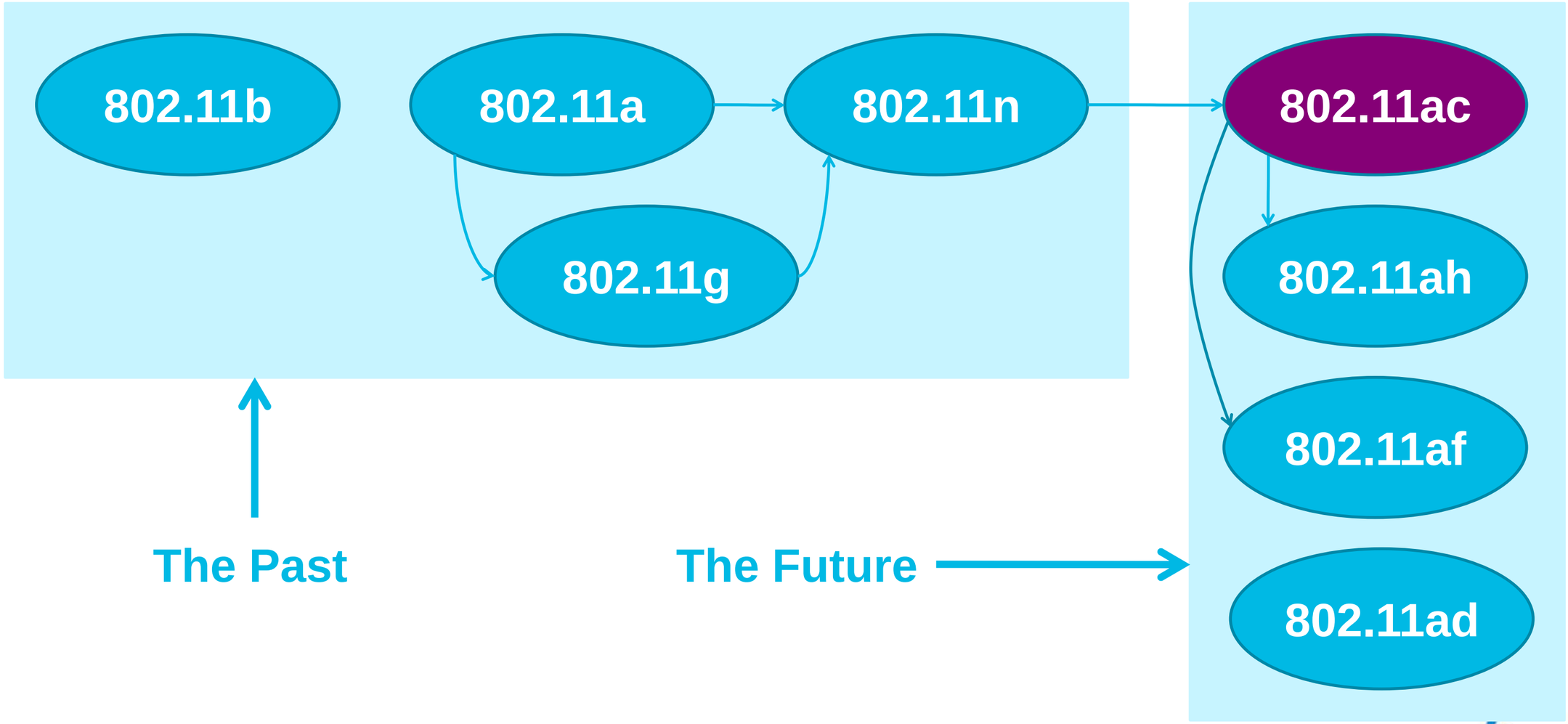
Wi-Fi Connectivity is Based on a Series of 802.11 PHY Standards



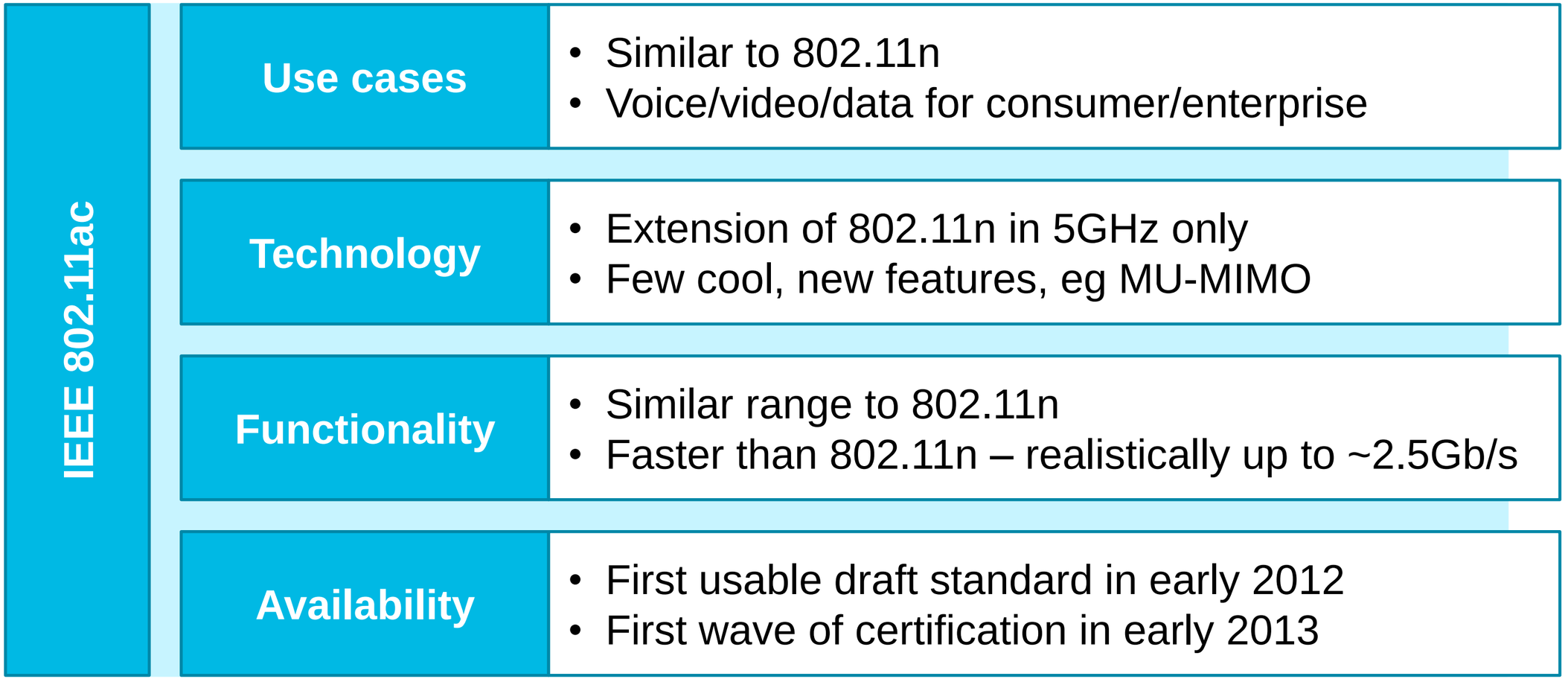
… with 802.11n Predominant in the Market, Although Not For Long



Wi-Fi Connectivity is Based on a Series of 802.11 PHY Standards



802.11ac, the Next Generation Wi-Fi, is "Just Around the Corner"

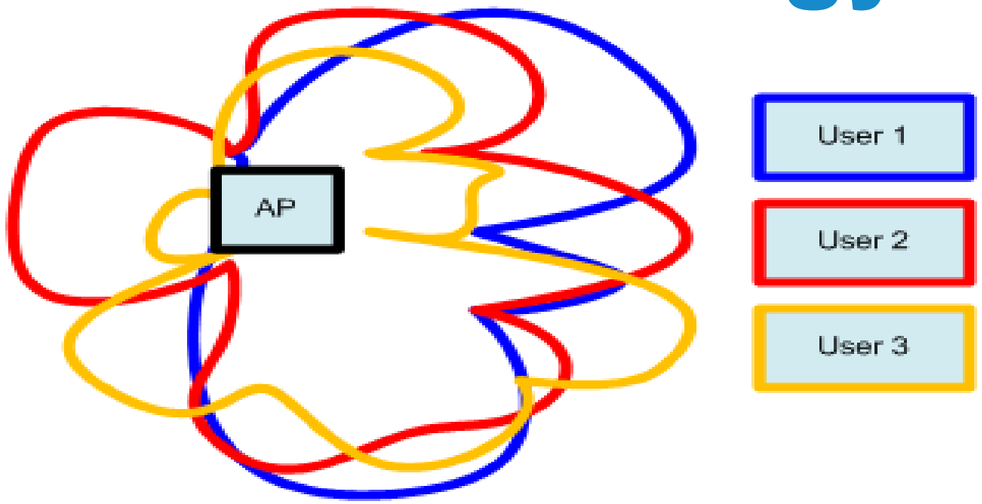


802.11ac Mainly Just Extends 802.11n Technology … and Adds MU-MIMO

Feature	Comments
5GHz only	Avoids interference-plagued 2.4 GHz
80MHz channels	Optional 160MHz and 80+80MHz
256QAM	802.11n has lower modulations
Up to 8 spatial streams	1 SS mandatory, 2 SS for non-battery APs at WFA
Beamforming	Single mechanism this time
MU-MIMO	Cool new technology! MU = Multi-User
RTS/CTS	Improvements for wider bandwidths
Better CCA	Detects energy in secondary channel
Deletes stuff	“Dark corners of 802.11n left to die” ☺

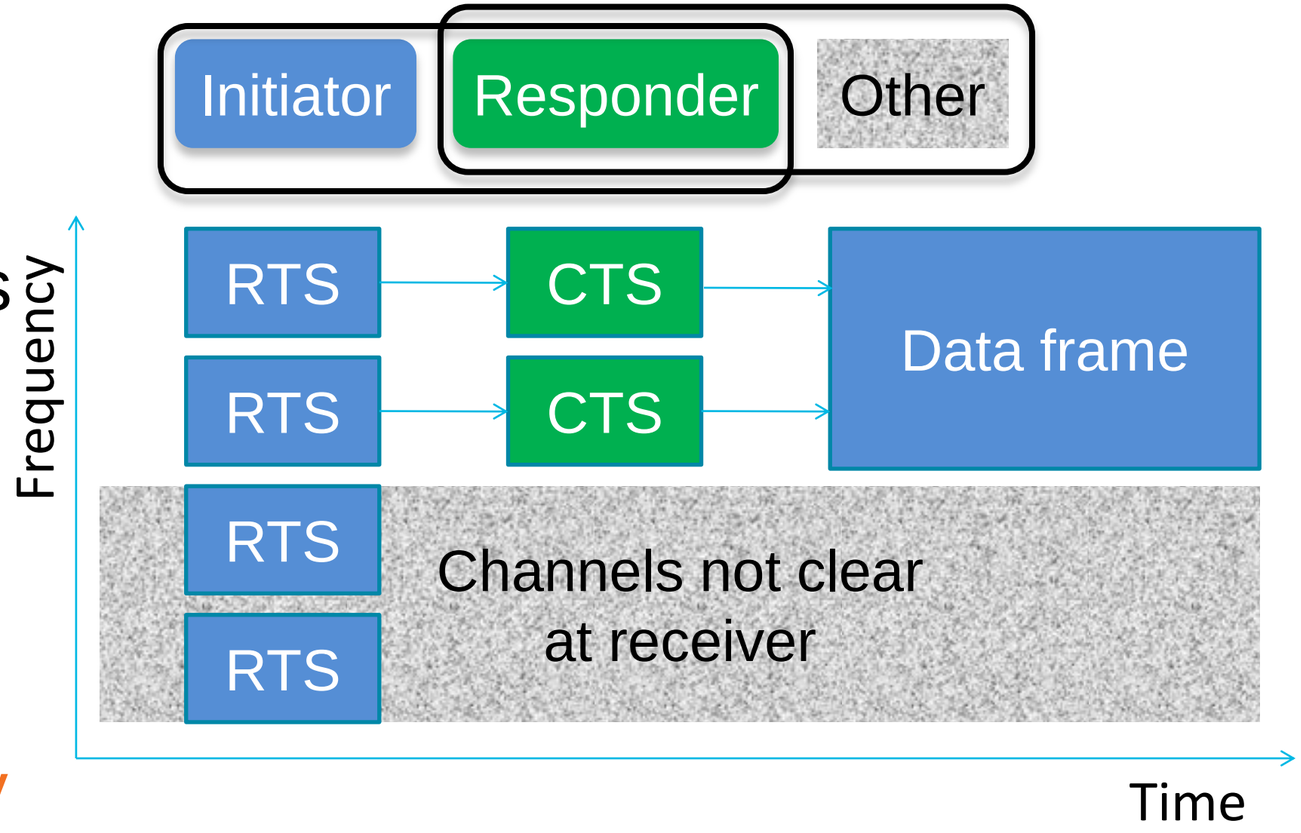
802.11ac Uses MU-MIMO to Provide "Switch" Rather than "Hub" Technology

- Single User MIMO in 802.11n sends one frame to one receiver
- Multi-user MIMO in 802.11ac sends multiple frames to multiple receivers
  - AP with 4 antennas can send 1 stream each to 3 smartphones, all at the same time
  - AP must beam form 1 space-time stream to the each receiver & simultaneously null-steer that space-time streams to the two other receivers



802.11ac Supports Extended RTS/CTS Mode for Dynamic Wider Bandwidth

- Initiator transmits multiple RTSs on free channels
- Responder transmits CTSs on channels it:
  - Received an RTS
  - Senses as free
  - Supports bandwidth-wise
- Initiator transmits data only over free channels



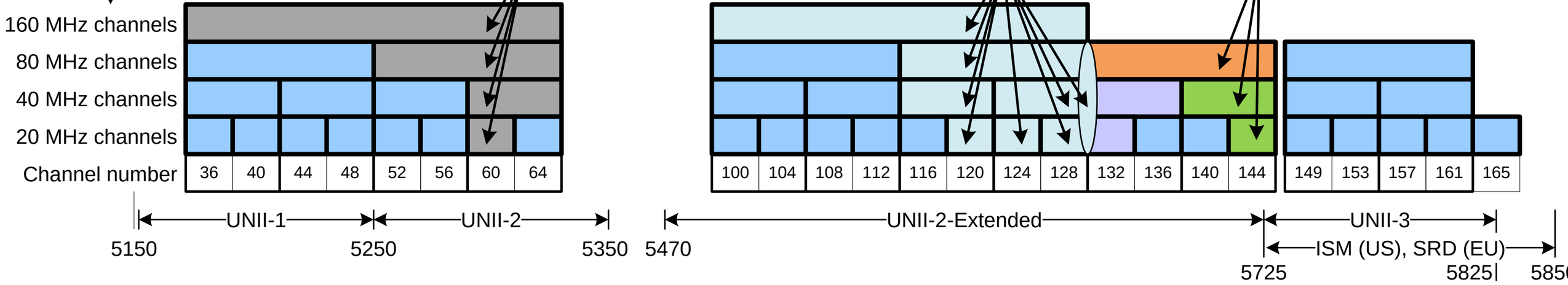
Channelisation for 802.11ac

40 MHz = adjacent 20 MHz channels grouped into pairs;
80 MHz = adjacent 40 MHz channels grouped into pairs;
160 MHz = adjacent 80 MHz channels grouped into pairs

Example of a channel-set for a BSS:
- primary 20 MHz on ch60 (beacons, virtual carrier sense and 802.11a devices)
- primary 40 MHz on ch60+64 (802.11n devices)
- primary80 on ch52-64 and 160 MHz on ch36-64 (802.11ac devices)

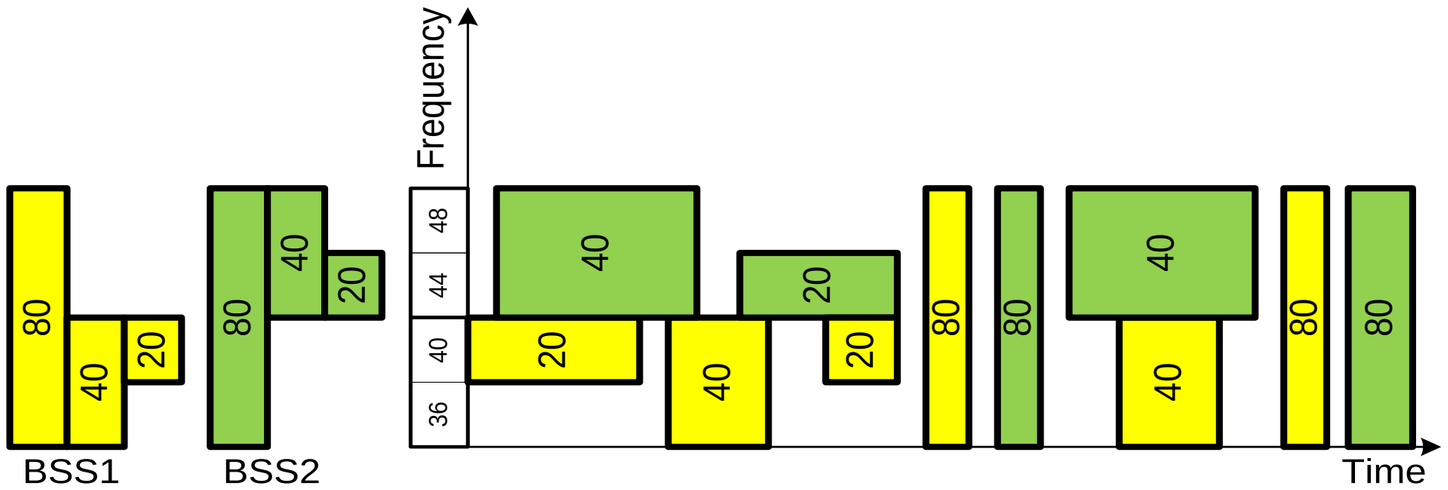
Weather radar issue

Available in US, not available in EU

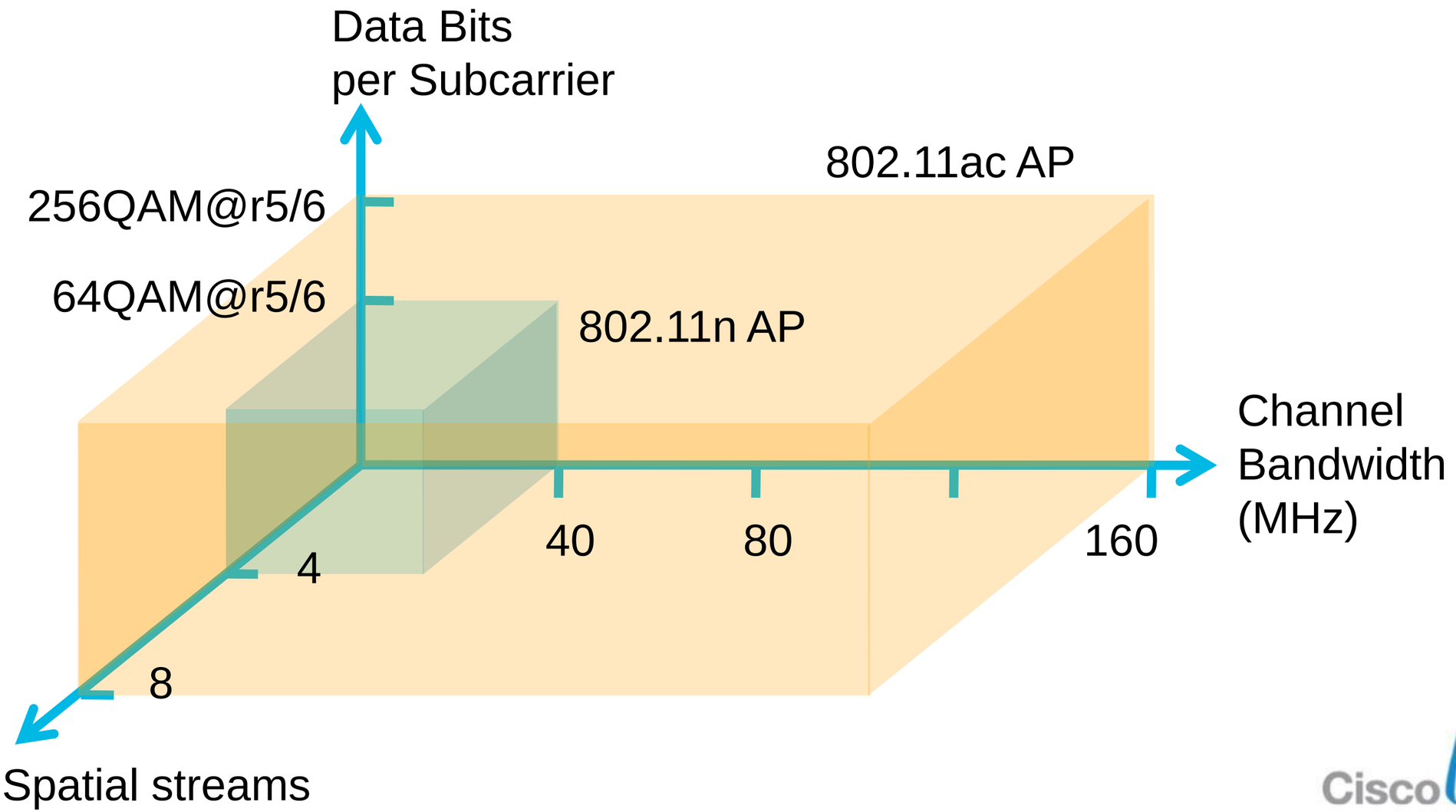


802.11ac Can Be Managed to Effectively Use Wide Bandwidths

- Wider bandwidth options in 11ac are: 80MHz, 160MHz, and 80+80MHz
- Appears to reduce the number of channels available if predominantly 11a/11n clients ... but not so
- Primary channels need not be aligned, so a deployment can work as a collection of 40 MHz channels, plus a 80 MHz ultra-speed mode



802.11ac Goes Faster with More Bits/Subcarrier, Bandwidth & Spatial Streams



802.11ac can plausibly operate at up to ~3.5Gb/s (@PHY) or ~2.5Gb/s (@MAC)

80 MHz PHY rate	MCS (QAMr5/6)	
Spatial streams	64	256
1	290[1]	430
	330	
2	650[2]	870
3	980	1300
4		1700
8		3500

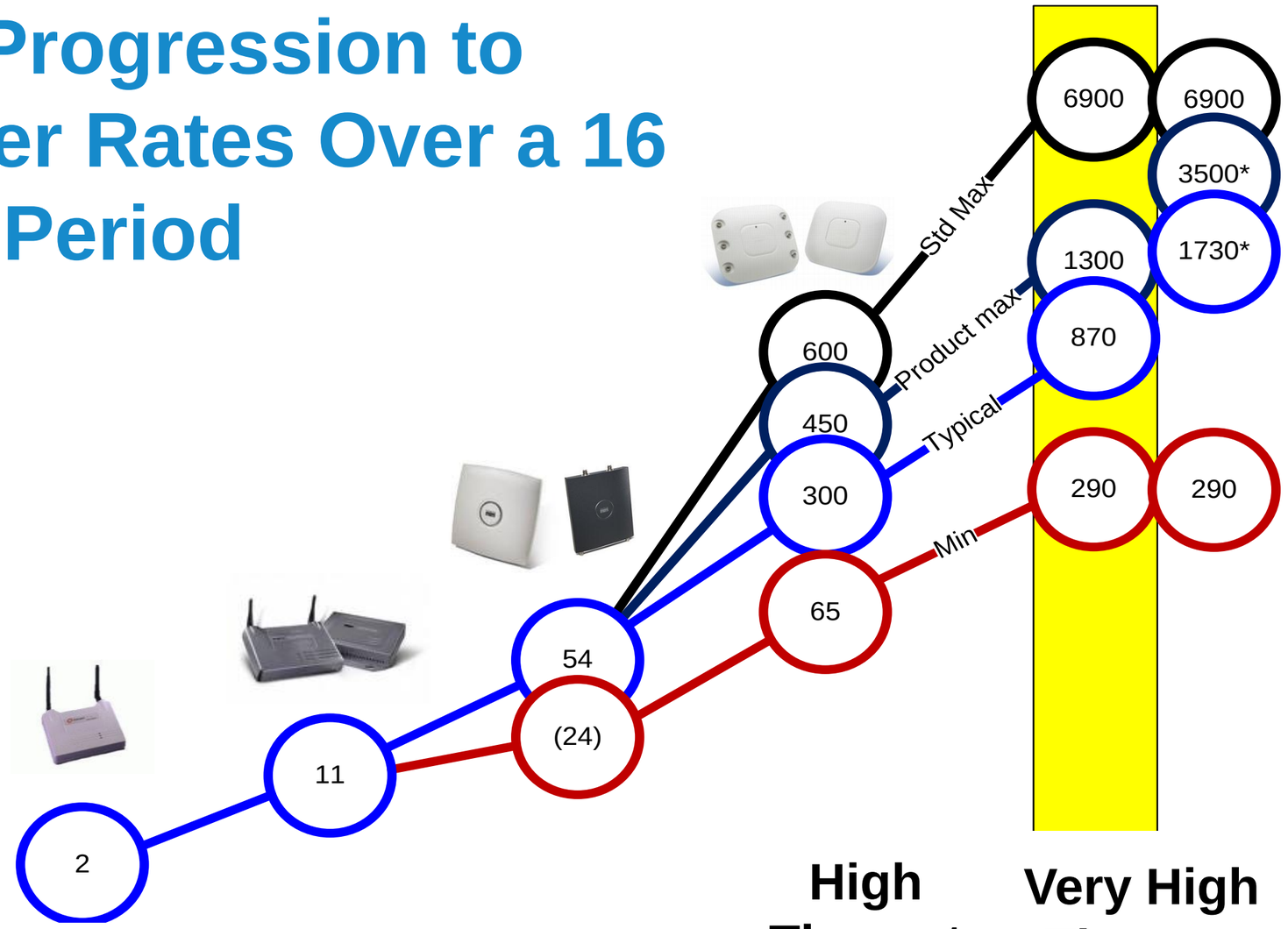
160 MHz PHY rate	MCS (QAMr5/6)	
Spatial streams	64	256
1	650	870
2	1300	1700
3	2000	2600
4		3500
8		6900

Easy | Plausible | Fantasy

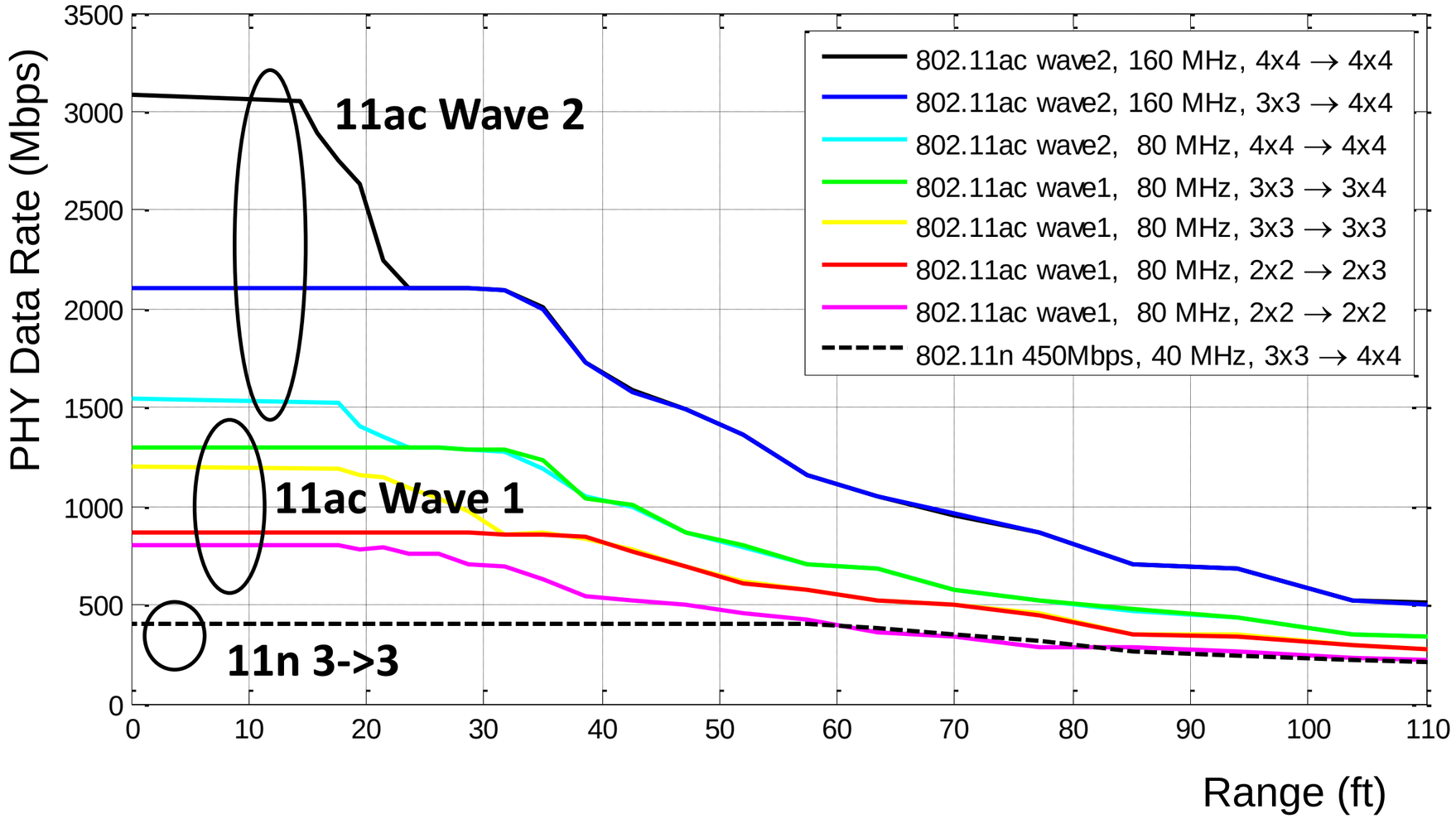
[1] Mandatory for battery devices, long GI

[2] Mandatory for powered APs

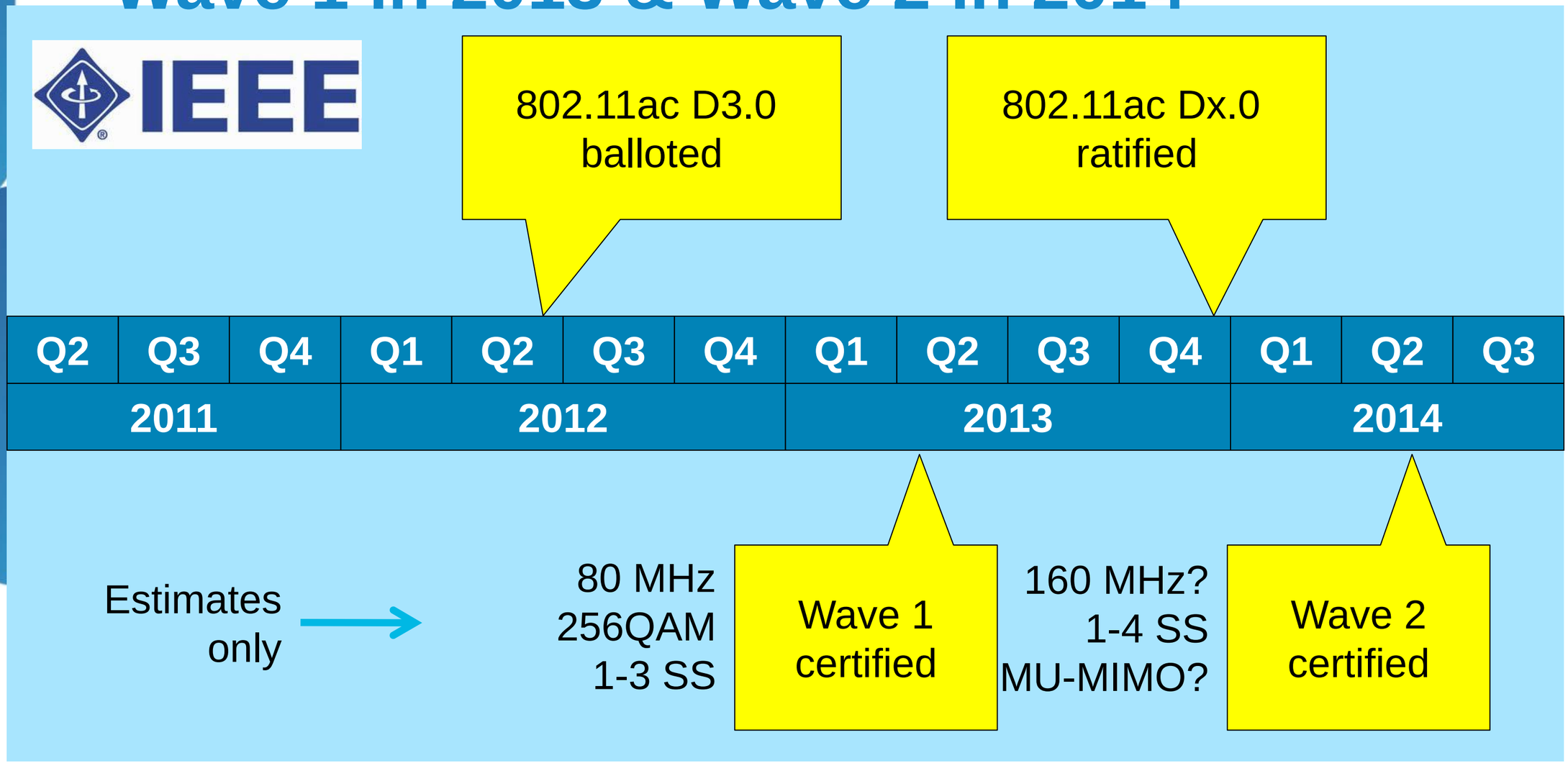
802.11ac is at the End of a Progression to Higher Rates Over a 16 Year Period



802.11ac Delivers Distinctive Rate-at-Range Improvement Compared to 802.11n



Certified 802.11ac is Expected in Two Waves; Wave 1 in 2013 & Wave 2 in 2014

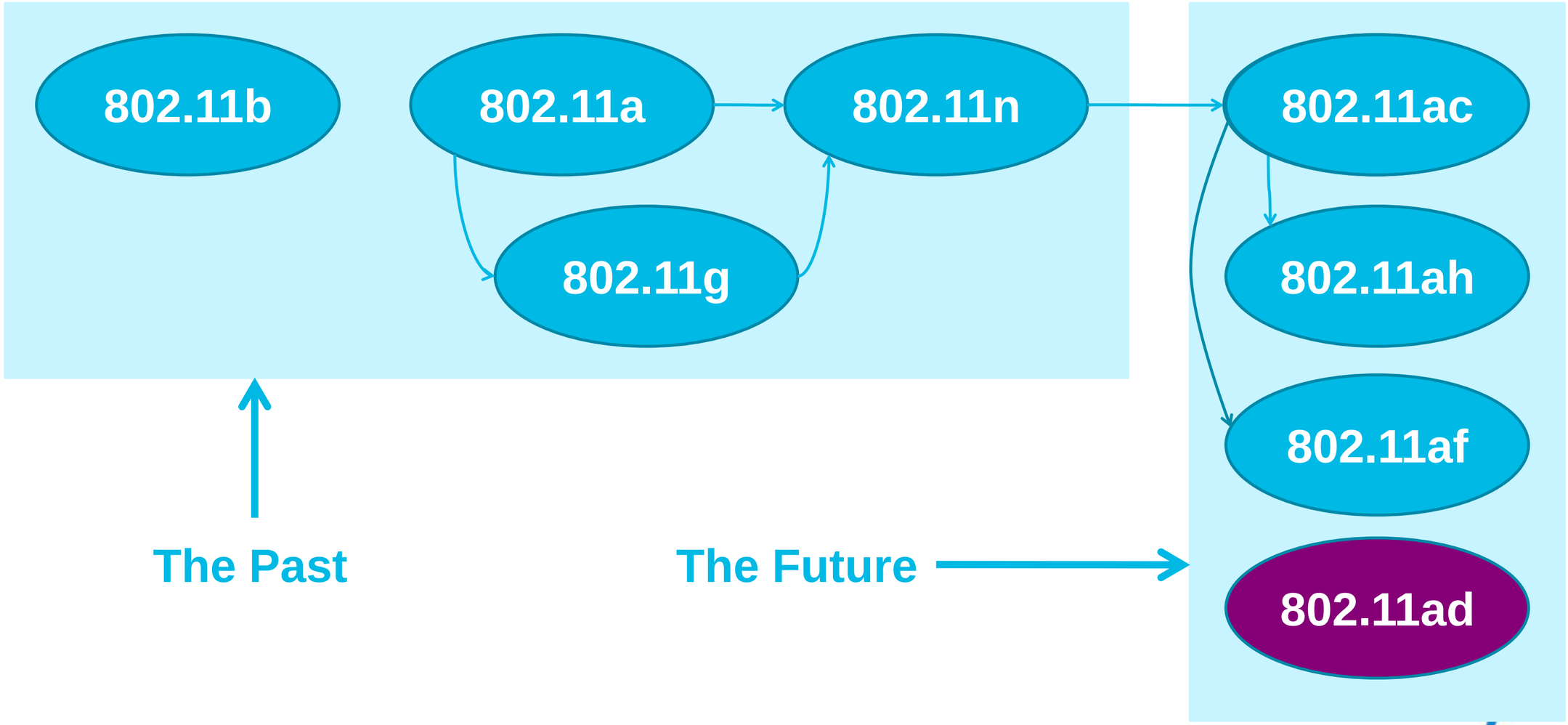


The Enterprise Should Upgrade to 802.11ac During the Next Upgrade Cycle

Recommendation

- 802.11ac definitely represents a valuable refinement of 802.11n functionality
- Certainly do not buy anything pre-certification
- Instead, you should transition to 802.11ac as part of your regular AP and client upgrade cycle
- And we recommend that, if this means investing in an 802.11n AP, then strongly consider selecting one that is readily field-upgradeable to 802.11ac

Wi-Fi Connectivity is Based on a Series of 802.11 PHY Standards



Use of 60GHz by 802.11ad (aka WiGig) Means Very High Rate, Beamformed, “Room Area Networking”

Lots of spectrum	Small wavelength	Propagates like light
• About 7 GHz of spectrum available (varies by country) • Can go very fast even with only one RF chain • Potential for lower cost and lower energy per bit	• 5mm wavelength • Multiple (<64) antennas can beamform for more range & less interference	• Easily blocked by humans, whiteboards, books, wall & concrete • This means poor range in typical environments • But also less interference from neighbours
✓	✓ ✗	✓ ✗
Rates >1Gb/s	**Beam forming**	**Room area networking**

802.11ad Will Realistically be Able to Achieve PHY Rates of 4.6Gb/s

Modulation	MCS	PHY rate (Mbps)	Comment
SC	BPSK-r3/4	1200	Required
OFDM	QPSK-r3/4	2100	Plausible
SC	16QAM-r3/4	4600	Plausible
OFDM	64QAM-r13/16	6800	Mostly Plausible

Properties: bandwidth = 2520MHz, spatial streams = 1

802.11ad has the "Potential" to Create New User Experiences

WiGig Alliance specifications

- A/V PAL
- PCIe PAL
- USB PAL
- etc

IEEE 802.11 WG standard

- 802.11ad

Potential applications

- Wireless docking
- Wireless peripherals
- Sync'n'go
- HDMI replacement
- WLAN applications

Potential issues

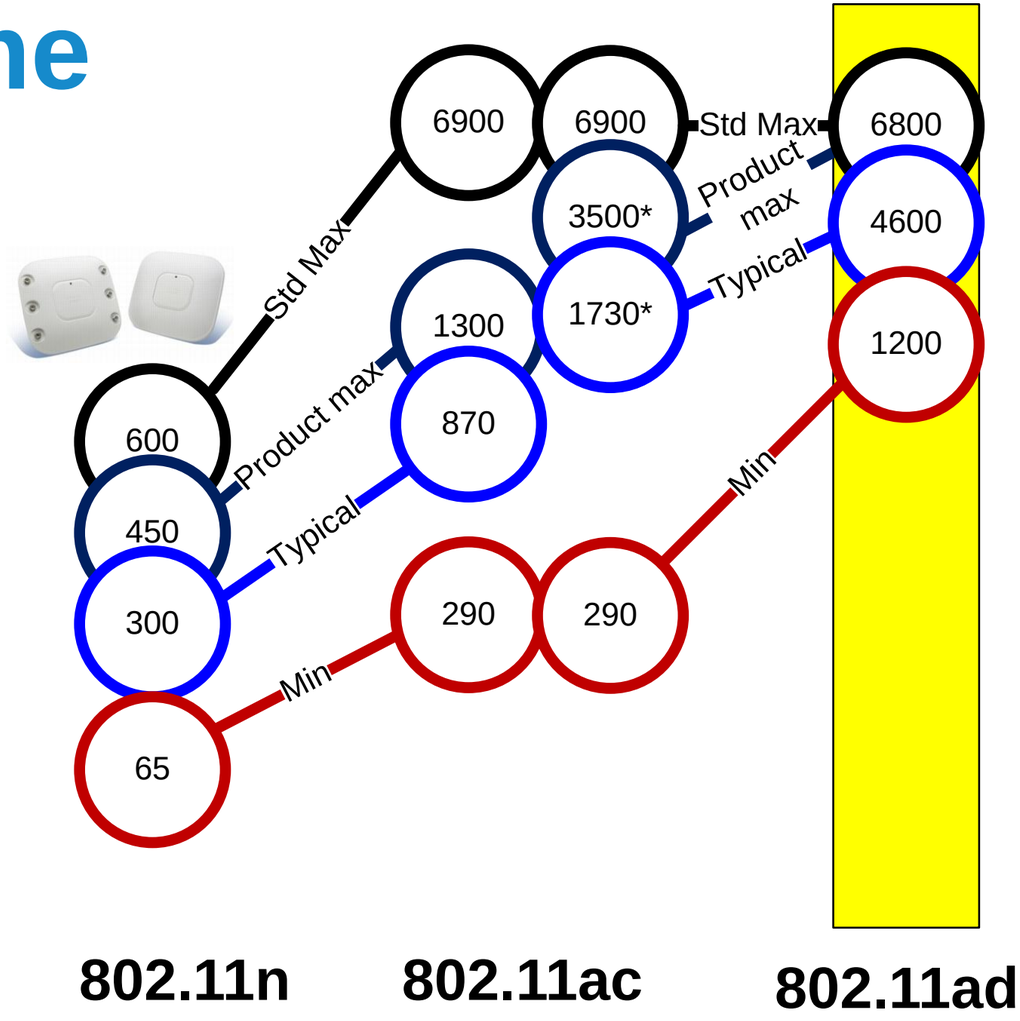
- HDMI using 60GHz failed commercially ($600)
- 802.11ac may be "good enough", particularly if video compression is "acceptable"!

Wireless Docking for Smartphones, Ultrabooks and Tablets

- Is this the work environment of the future?

802.11ad is of Less Interest to the Enterprise for Some Time

- Considerations:
  - There may be some early interest in the enterprise for docking and video applications
  - Need to go beyond non “enterprise class” WPS based security
  - Further out, 11ad may be useful for wireless networking, but a) as a follow-on to 11ac, b) when low cost/power 10 GigE backhaul becomes available OR when QoS is vital and range is not a requirement, and c) if 11ad is adopted by device manufacturers



The certification of 802.11ad has Slipped and the Scope of the Initial Certification Reduced

802.11ad ratified

Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
2011			2012				2013				2014		

Delayed by two years!

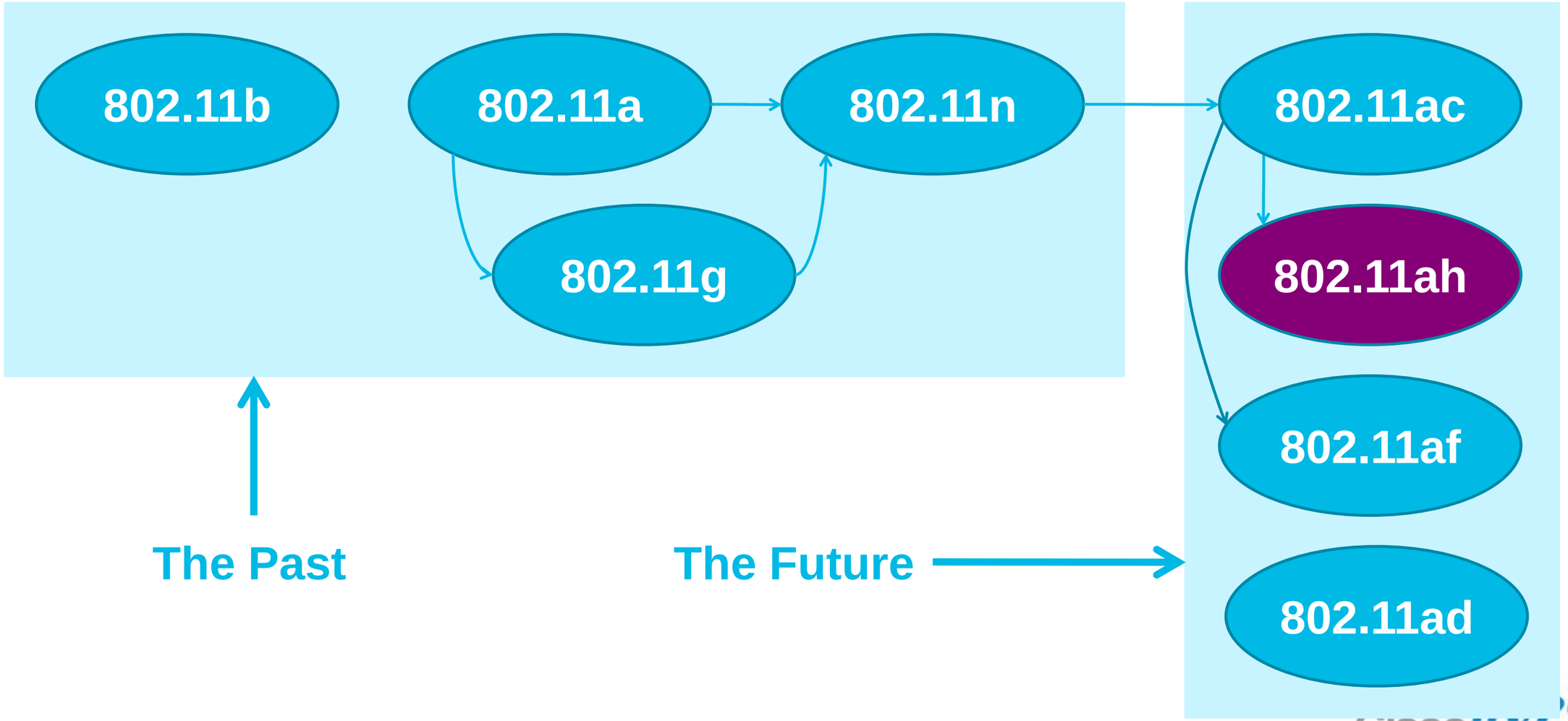
Estimate only → Peer-to-peer functionality only

Wave 1 certified

AP cert

Wave 2 certified

Wi-Fi Connectivity is Based on a Series of 802.11 PHY Standards



802.11ah is Focused on Applications Below 1 GHz for Lower Power/Rates & Longer Range

- Proposed “niche” use cases
- Smartgrid ← Primary application
  - Strong requirement for low power, low rate and long range
  - Including bridging and mesh backhaul solutions
  - 802.15.4g is possible competitor?
- Video surveillance
- Consumer electronics, eg cameras
- Healthcare, eg bio-sensors

802.11ah is Focusing on >100kb/s at <1km with a Traditional Wi-Fi "Feel"

What is 802.11ah specification?	
Spectrum	• Europe: 868-868.6 MHz • Japan: 950-958 MHz • China: 314-316, 390-434, 470-510 & 779-787 MHz • Kor: 917-923.5 MHz • USA: 902-928 MHz
Channel width	• 1,2,4,8,16 MHz (compared to 20/40 MHz in 802.11n)
PHY	• Based on 802.11ac

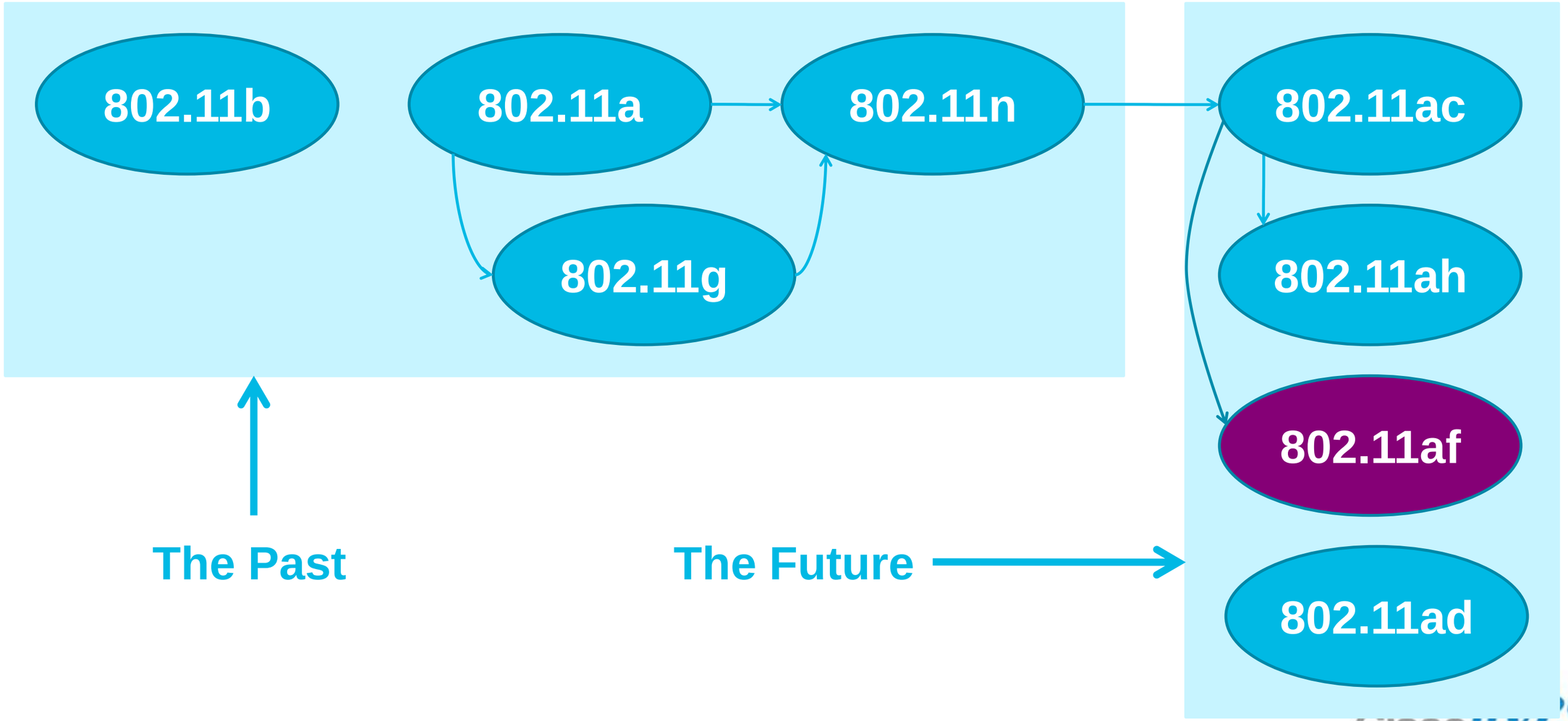
What will 802.11ah achieve?	
Rate	• > 100kb/s (less than traditional 802.11)
Range	• < 1km
Feel?	• "*the IEEE 802.11 WLAN user experience for fixed, outdoor, point to multi point applications*" (source: PAR)

802.11ah Should be Monitored until Standards & Market Situation Become Clearer

Recommendation

- We don’t expect significant market success for 802.11ah in the near future
  - Need a standard – planned for 2014
  - Need a certification – none yet discussed
  - Need an ecosystem – chip vendors interested and a SIG has formed!
  - Need to compete – there is competition from 802.15.4g/WiSun
  - Not a lot of common spectrum worldwide
- Watch this space!

Wi-Fi Connectivity is Based on a Series of 802.11 PHY Standards



802.11af will Define Operations in TV White Space Bands

- The repacking of TV bands in many countries has resulted in opportunity for new unlicensed spectrum
  - This spectrum is often called TV White Space (TVWS)
- New rules are being designed to protect existing users from interference from unlicensed devices
  - Especially protecting digital TV & wireless microphones
- An amendment of 802.11, called 802.11af, is being defined to enable the use of this new spectrum

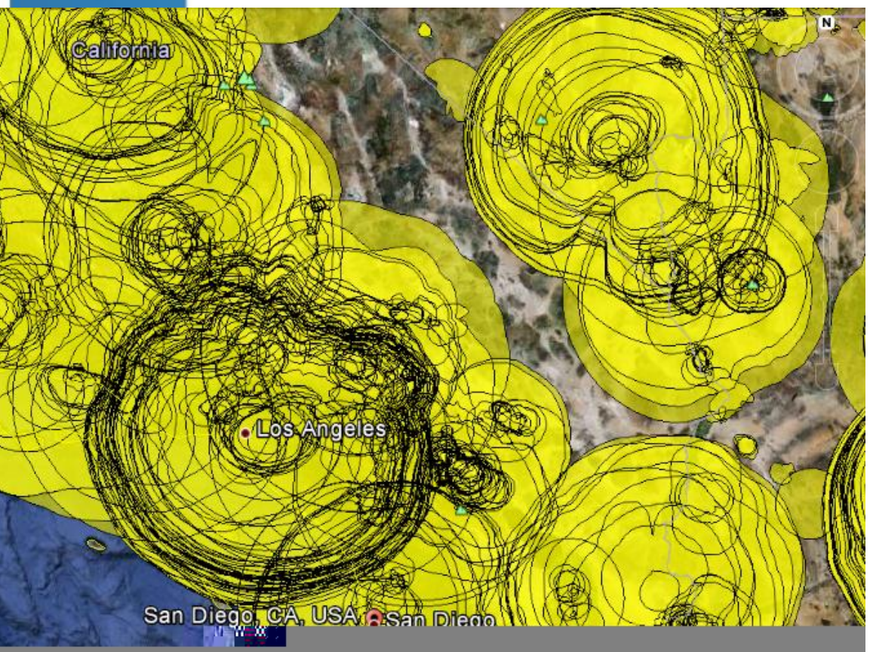
802.11af is Focusing on Using a Database to Avoid Interfering with Primary Users

What is 802.11af specification?	
Spectrum	• 470-698 MHz (UHF) • VHF varies by country
Channel width	• 6, 7, 8 MHz (vs 20/40 MHz in 802.11n)
PHY	• Based on 802.11ac
Coexistence	• Database enabled to avoid interfering with TV & licensed microphones

What will 802.11af achieve?	
Rate	• Less than traditional 802.11 due to narrow channels
Range	• More (3.5x) than traditional 802.11 due to superior propagation of TVWS

Geolocation data base contains info about protected users; it will be able to authorise the use of a channel at a particular time, location & power for unlicensed operation

The Potential of TVWS is Often Oversold



- There was been a lot of publicity related to TVWS
  - The FCC even called it “Super Wi-Fi” in 2010
- However, much of the TVWS publicity is hype
  - Regulations are not yet in place in most/all countries
  - There is often not much available TVWS where people live

    Particularly in US metro areas (10% have 2 channels or fewer)
  - Likely some of today’s TVWS will be allocated to cellular
  - Standards & certification not ready until 2014
  - Not clear the case for yet another new radio is compelling given alternate solutions for most/all use cases

The Real Value of 802.11af is the Database Approach to Protect Existing Users

Recommendation

- We don’t expect significant market success for 802.11af in TVWS in the near future
  - Too much hype, not enough reality until beyond 2014
  - Possible cellular offload & extended coverage interesting
- The real value of TVWS is the database approach
  - Approach could be used to open up other bands by providing a mechanism to protect existing users

    Proposed for use in 3.55-3.65GHz band in the US
  - Trials of database sharing have already occurred in US, UK, Singapore, Japan, ….

Spectrum

Wi-Fi's Success has Resulting in a Growing Need for More Spectrum

- 802.11/Wi-Fi has been a wildly successful technology, and is now going into "everything"!
- Wi-Fi requires more & more spectrum to support its rapidly growing use "everywhere"
  - Recall the forecasts of Wi-Fi use!
- This requirement has led to a series of efforts to:
  - Identify new Wi-Fi spectrum for niche & mainstream use
  - Define rules to allow sharing with existing users

A Variety of New Wi-Fi Spectrum has been Identified Over the Years ...

	Spectrum in 2000	Spectrum since 2000	Planned new spectrum
Mainstream	• 2.4 GHz • 5150-5350 MHz • 5725-5850 MHz – 5GHz not often used	• 5250-5350 MHz – New rules • 5470-5725 MHz – DFS/TPC for sharing	• All of 5GHz! – Required to obtain full benefit from 802.11ac – US & Europe
Niche		• 60 GHz • 5850-5925 MHz – Automotive applications • 3650-3700 MHz (US)	• <1GHz (various) – eg. smartgrid • TVWS (various) – eg. rural broadband • 3550-3650 MHz (US)

Note: spectrum availability varies by country; this table is representative

... the New Wi-Fi Spectrum has been Supported by Various 802.11 Amendments

Year	Amend.	Description	
1999	802.11a	Defined operation in 5GHz bands	Mainstream
2003	802.11h	Enabled sharing with radar at 5GHz	Mainstream
2004	802.11j	Defined regulatory classes	Mainstream
2008	802.11y	Defined enablement concept	Niche
2010	802.11p	5.9GHz for automotive applications	Niche
2012	802.11ad	Defining operation in 60GHz bands	TBD
2014	802.11af	Defining operation in TVWS bands	Niche
2016	802.11ah	Defining operation in bands < 1GHz	Niche

The Key to Most New Wi-Fi spectrum are Various Techniques for Sharing

Dynamic Frequency Selection (DFS)

- Typically used to avoid radar after detection
- Mostly successful technique, but some issues in relation to weather radar that are being resolved ... with more to be done
- Cisco led development of this technique with regulators

Transmit Power Control (TPC)

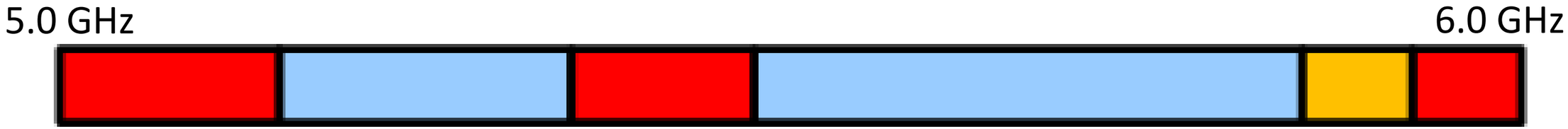
- Typically used to avoid interfering with satellites by reducing power to the level actually needed
  - Also useful to avoid interfering with neighbours

Geolocation Database

- Database records characteristics of primary users
- Users must consult database to determine if & how allowed to operate at a particular location & time
- Cisco led development of this technique with regulators

It is Hoped that Sharing Techniques will Soon Enable Use of All of 5GHz by 802.11ac

- 802.11ac defines use of 20, 40, 80, 80+80 & 160MHz channels
- The use of multiple 160MHz channels requires more contiguous spectrum
- There are regulatory & legislative efforts in US & Europe to allow more sharing of 5GHz spectrum
  - 5350-5470 MHz (sharing with radar)
  - 5855-5925 MHz (sharing with ITS)
- It is likely 5GHz band will open soon in China
  - 5150-5250 MHz
  - 5470-5725 MHz

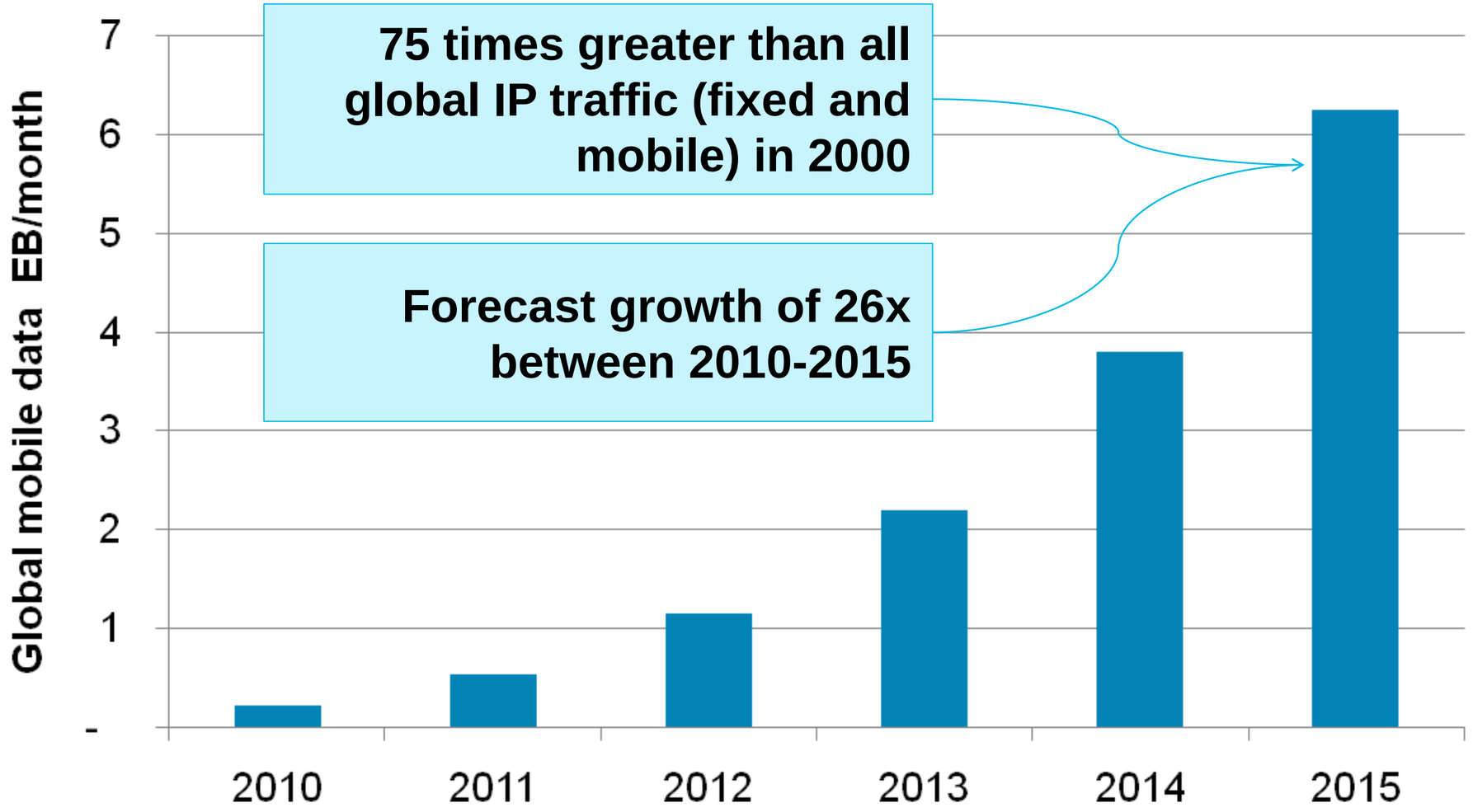


With Increased Use of 5GHz Might Come Tougher Rules!

- Cisco has been a leader in developing radar detection technology & regulations for 5GHz
- Unfortunately, some of our competitors have not been so “disciplined”
  - A number have been fined heavily in the US for breaking radar interference rules
- This, along with better understanding, could result in regulators imposing tougher radar detection rules
- Watch this space … because Cisco is!

Hotspot 2.0 (Passpoint): Making Wi-Fi Easy

There is a Massive Forecast Increase in the Amount of Mobile Data over the Next Few Years

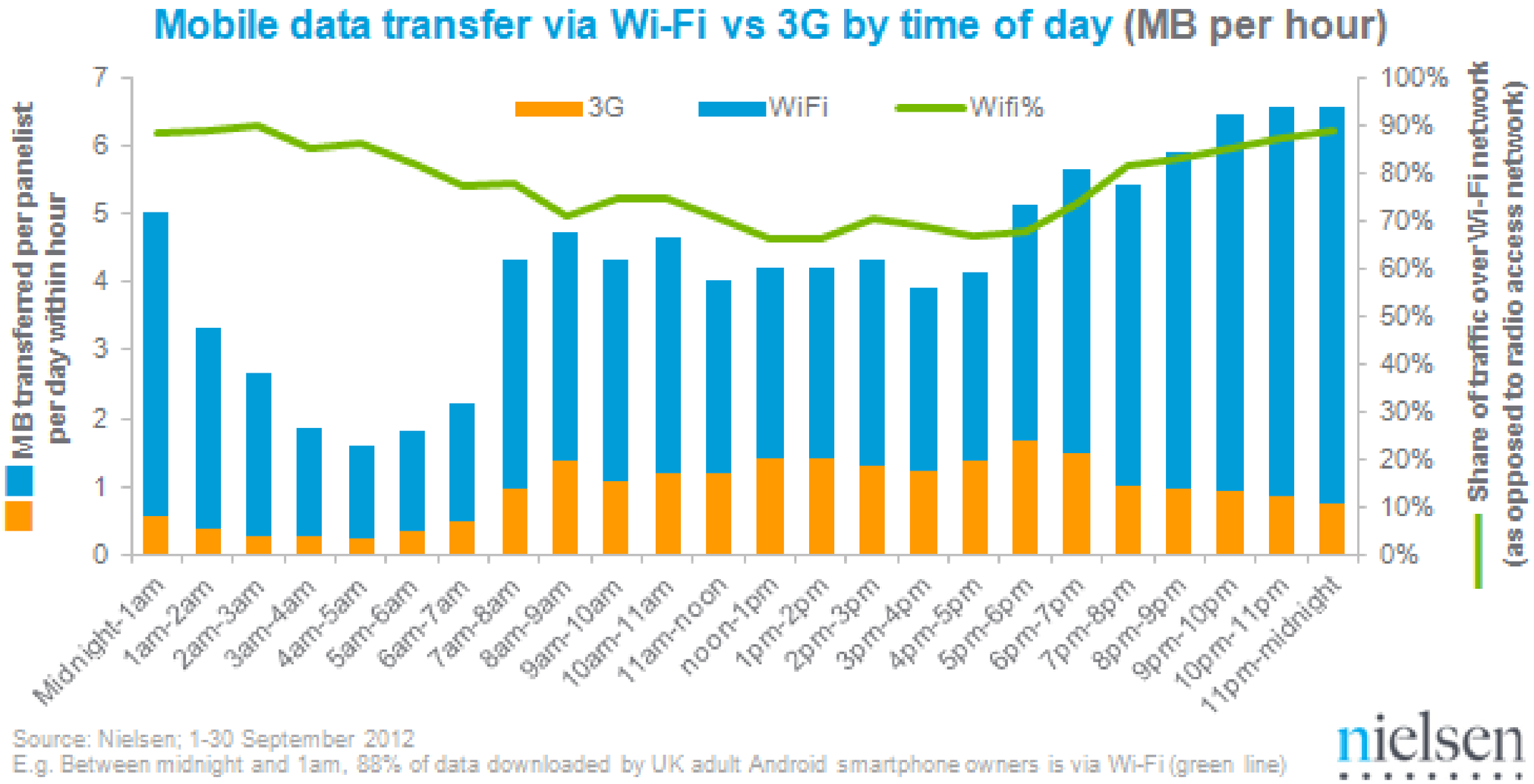


Source: Cisco Visual Networking Index (VNI) Global Mobile Data Traffic Forecast, 2010–2015

… But There is Not Enough Licensed Spectrum to Satisfy Mobile Data Demand

- It is a truism that operators need spectrum to operate their networks
- The question is how much?
- The answer is that they clearly do not have enough for future needs!
  - Operators are keenly lobbying for more licensed spectrum in most countries
  - Operators did not embrace Wi-Fi; now they can't get enough of it as they recognise it can be used for data offload

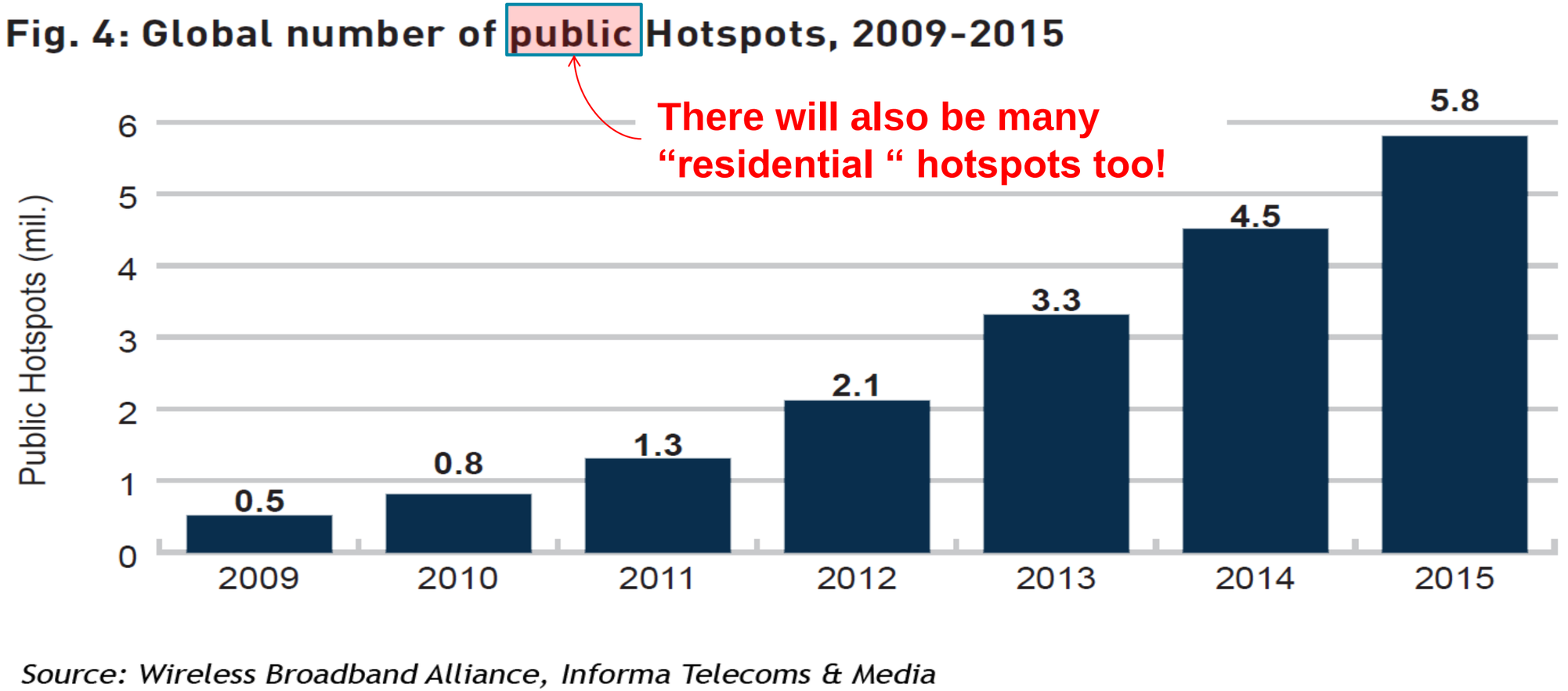
… and Many People Want to Use Wi-Fi Rather Than 3G/4G on Their Smartphones



Source: Nielsen; 1-30 September 2012
E.g. Between midnight and 1am, 88% of data downloaded by UK adult Android smartphone owners is via Wi-Fi (green line)

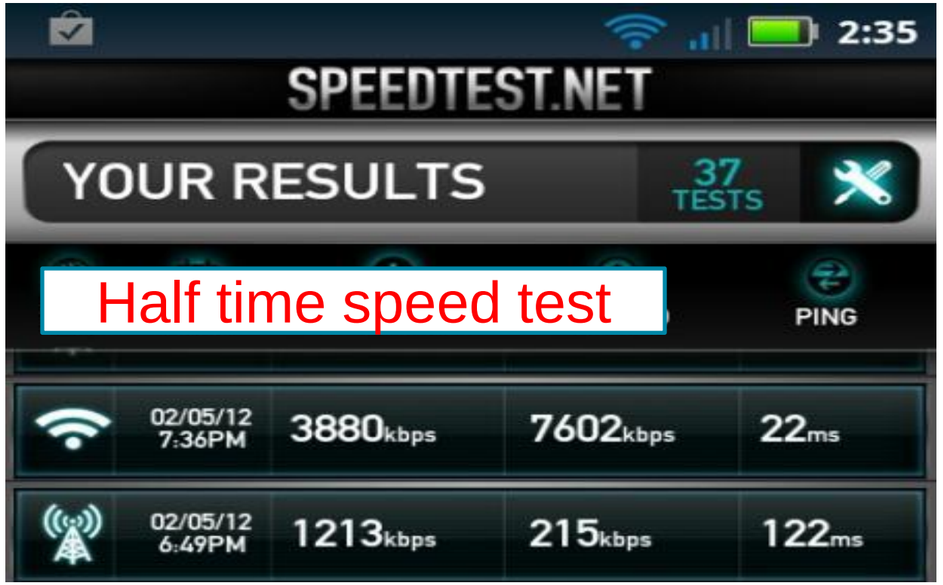
nielsen

… Supported by Many New Public and Residential Wi-Fi Hotspots



Super Bowl XLVI Provides an Example of How Well Offload Can Work …

- Cisco's Wi-Fi solution was used at Super Bowl XLVI
  - Unique: 13k (19%)
  - Simultaneous: 8k (12%)
  - Aggregate traffic: 369.9 GB
  - Max rate: 75/42 Mb/s

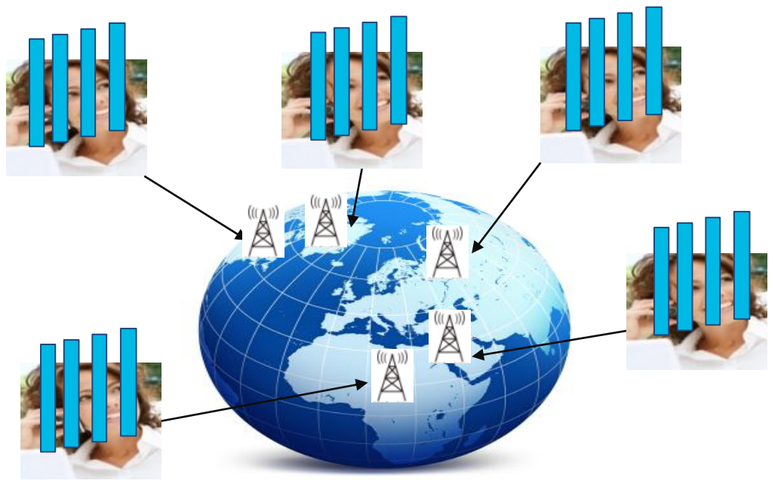


Cellular = 1.2Mb/s

Wi-Fi = 3.9Mb/s

…But the Traditional Wi-Fi Hotspot Experience is Often Frustrating Compared to Cellular

Today's cellular experience

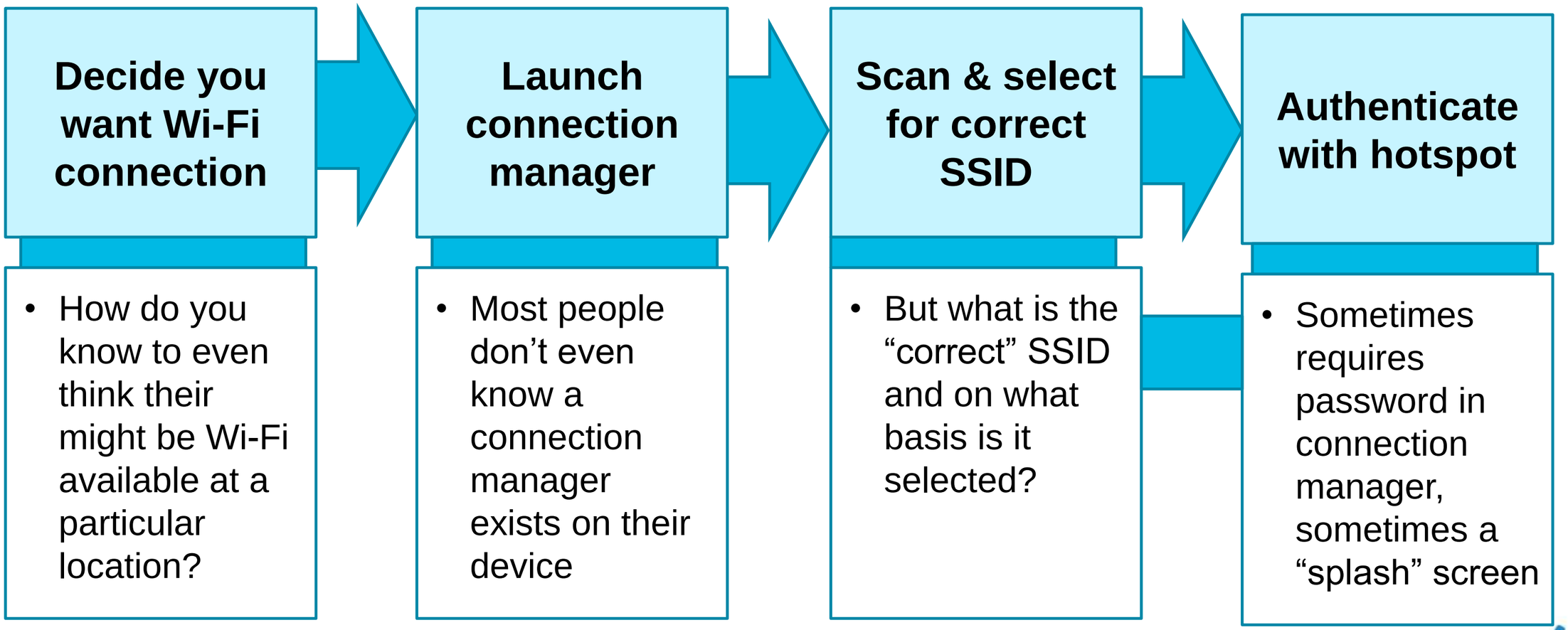


- Operator has a cellular network and cellular roaming agreements worldwide
- Customer turns on phone and gets automatic and secure cellular connectivity anywhere in the world - more "voice" bars in more places

Today's Wi-Fi hotspot experience

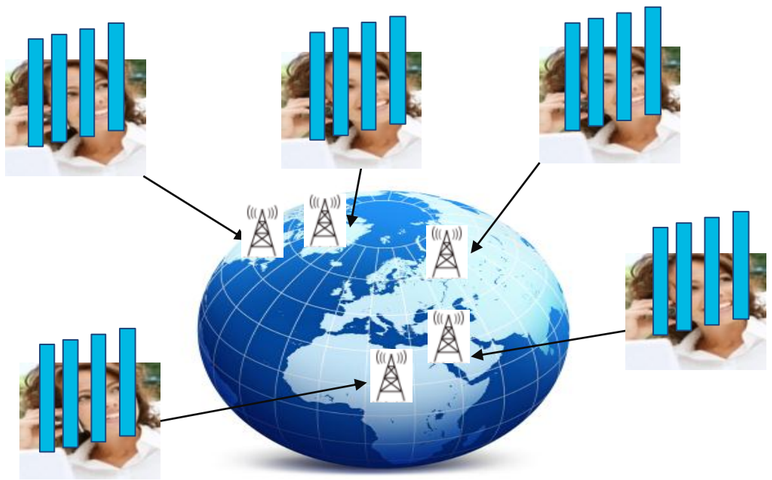
- Operator has home Wi-Fi network & *some* Wi-Fi roaming agreements
- However, customer does not get automatic and secure Wi-Fi connectivity (except maybe at home) and needs to intervene

Connecting to a Hotspot is Way Too Hard Today for the Average Person



The Goal of Hotspot 2.0 is to Make Wi-Fi as Easy to Use and Secure as Cellular

Today's cellular experience



- Operator has a cellular network and cellular roaming agreements worldwide
- Customer turns on phone and gets automatic and secure cellular connectivity anywhere in the world - more "voice" bars in more places

Hotspot 2.0 experience

- Operator has home Wi-Fi network & many Wi-Fi roaming agreements worldwide
- Customer turns on phone & gets automatic secure Wi-Fi connectivity anywhere in the world – more "data" bars in more places

Hotspot 2.0 Consists of Three Basic Technologies

Certified as Wi-Fi CERTIFIED Passpoint

Network Discovery & Selection

- Provides discovery mechanisms (based on 802.11u) to assist automatic selection of most appropriate hotspot
  - Either home or partner SP
  - Based on a range of parameters available before association
- Provides secure connectivity (based on WPA2-Enterprise)
  - Using well known EAP authentication methods & common credentials
  - Credentials include SIM & passwords

Coming soon; probably in 2013

Online Signup

- Allows an SP to securely signup a new customer via the HS2.0 hotspot
  - Expands existing cellular capability
  - Enables enhanced local services

Operator Policy

- Provides mechanism for the home SP to specify connection policies & preferences
  - SP policies may be over ridden by the user

The Work Being Undertaken by the WFA to Develop the Passpoint Certifications is Only Part of the Story

IEEE		Wi Fi™	Wireless Broadband Alliance	GSMA ASSOCIATION
Developed 802.11u	Extended 11u concept to HS2.0	Refined and certified HS2.0 spec as Passpoint	Defines inter operator roaming	Working with WBA
Cisco led this group technically	Cisco led a SIG like activity	Cisco leads this activity in HS2.0 TGs	Cisco was first vendor to join WBA Board	Cisco participates in this activity

… HS2.0/Passpoint is Going to Become the Basis for a Whole New User Experience

- Now suppose we have easy Wi-Fi connectivity ...

  ... and we add Cisco powered indoor location

- We can then define location based services anywhere …

  ... a bit like a location based “app store”

- Now we have a solution that will truly support the explosive growth of Wi-Fi that has been forecast for so long

  … and allow venues to add real value to the customer experience

Technology

- Standard Beacon/Probe – MAC
- HS2.0 (802.11u) – Ext Beacon & Probe Based messaging
- Manual
  - Web Page Portal
  - Loyalty App

- HS2.0 – 802.1x, 802.11i Roaming/Subscription
- Pre-Association Service Advertisement – e.g. MSAP
- Portal Redirect – sign up/in
- Loyalty App – App Store

- OS - Post-Association Service Advertisement - e.g. Bonjour
- Browser – Billboard
- Portal – Redirect (venue owned)
- Loyalty Application
- 3rd Party Application
- Text Message

Wi-Fi QoS

Wi-Fi QoS is Mainly Based on a Wi-Fi Alliance Variant of 802.11e called WMM

Original 802.11 had two forms of access

- DCF: Distributed Coordination Function
  - CSMA/CA access
  - No QoS defined
  - Wi-Fi Certified
- Point Coordination Function (PCF)
  - Scheduled access using a super frame structure
  - QoS defined
  - Never Wi-Fi Certified

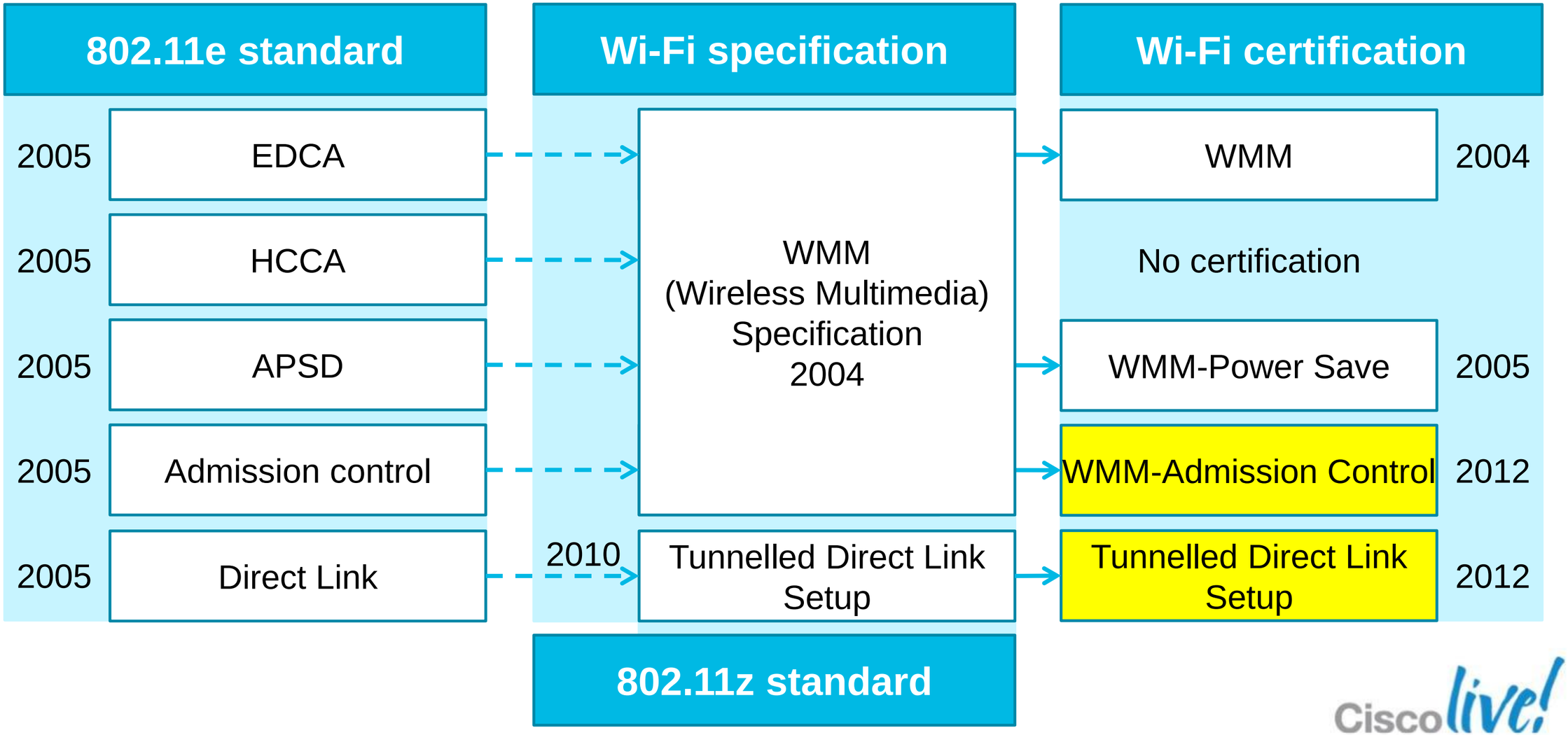
802.11e defined two new forms of access

- EDCA: Enhanced Distributed Channel Access
  - CSMA/CA access
  - QoS on 8 statistical priority levels
- HCF Controlled Channel Access (HCCA)
  - Scheduled access at any time
  - QoS defined

Wi-Fi Alliance certifies Wi-Fi QoS as WMM

- 802.11e took so long to finish that the Wi-Fi Alliance decided to certify a subset of a variant called WMM (Wireless Multimedia)
- This has caused ongoing issues ever since ☹
- There was also a non certified variant of HCCA called WMM-SA

Wi-Fi QoS Features have been Progressively Certified by the Wi-Fi Alliance Since 2004



WMM-AC has Enabled Certified Admission Control for Voice from mid 2012

- WMM defines four priorities but does not limit the use of any priority, and so can increase congestion
- WMM-AC forces devices to request bandwidth before using higher priorities
- AC mechanism likely to be used in enterprise first, especially for voice (but also video)
  - Cisco has a similar mechanism in CCXv4 and CCX Lite
- Wi-Fi certification occurred in mid 2012
  - Cisco AP are in the test bed, but not with an FCS'ed product … yet
  - Certifications have been very slow

Wi-Fi Voice-Enterprise is a Solution, Rather than a Feature Certification

- Most Wi-Fi certifications have been historically been “feature based”
- In contrast, the Wi-Fi Voice-Enterprise certification focuses on certifying a “voice solution”
- The certification was released in mid 2012
  - Cisco AP are in the test bed, but not with an FCS’ed product … yet
  - Certifications have been very slow
- Interestingly, Cisco has provided similar features in CCX for many years
  - Cisco is likely to recommend this certification at some point
  - And we do support 802.11r in released products

Voice Enterprise Brings Together Roaming, Performance, Measurement & Management ...

Measurement

802.11k based measurement

- Clients measure the radio environment on behalf of AP & to troubleshoot performance
- AP summarises data for clients so they can choose BSS

Management

802.11v based management

- APs recommend BSS transitions to clients to move to another AP based on network load & network topology

Wi-Fi CERTIFIED

Voice Enterprise

Roaming

802.11r based transition

- Client is enabled to transition quickly to new AP within the same mobility domain, by re-use of 802.1X security keys
- Transition within 50ms

Performance

802.11e based performance

- Uses WMM-AC (based on 802.11e) to reduce congestion
- Clients required to satisfy limits on latency, jitter, packet loss & consecutive lost packets

Work on QoS for Video Continued with 802.11aa but There are No Certification Plans

Feature	Description	Comment
Groupcast with retries (GCR)	Defines reliable multicast using unsolicited retries or a block ACK scheme	Contributed by Cisco from CCX
Interworking with 802.1AVB	Supports 802.1Qat stream reservation requests for end to end reservations	
Overlapping BSS management	Assists AP to avoid overlap and share in an overlap situation	Heuristic attempting to provide guarantees
Stream classification service	Classifies MSDUs for transmission in a particular stream	
Intra-access category prioritisation	Adds extra EDCA queues for video & voice	Unlikely to work

=> but not enough interest yet to start a Wi-Fi certification programme yet!

Wi-Fi Management

Wi-Fi Certified Management is Expanding to Include 802.11k/v/ae/w/mc

IEEE 802.11 standard		802.11k	802.11v/mc	802.11ae	802.11w
		Measurement	Management	QoS	Security
		2008	2011	2012	2009
Wi-Fi certification	Done	Voice Enterprise			Management Frame Protection
	Soon		Network Power Save		
	Later	WNM (Location, Operations & Troubleshooting)			

IEEE 802.11k, Based on CCX Features, is Focused on "Measurement"

Status

- 802.11k was ratified in 2008
- Was certified in Voice – Enterprise, and maybe in WNM

Goals

- Simplify and/or automate WLAN radio configuration
- Better utilise radio resources
- Achieve better performance in dense deployments
- Alert administrator of problems
- Notify clients of radio status

Features

- Measurement reports
  - Beacon
  - Frame
  - Channel Load
  - Noise Histogram
  - STA Statistics
  - Location
  - Neighbour Report
  - Link Measurement
  - Transmit Stream
- Other features
  - Measurement Pilot

Cisco

- Cisco contributed many CCX features to 802.11k amendment

IEEE 802.11v (aka “the Kitchen Sink”) is Focused on “Management”

Status

- 802.11v was ratified in 2011
- Wi-Fi certifications could eventually include:
  - Voice –Enterprise (done!)
  - Network Power Save
  - WNM

Goals

- An extension of the 802. 11k work into “management” of:
  - STAs by APs
  - WLANs by higher layers

The “kitchen sink” of features

- BSS transition management
- Co-located interfer. reporting
- Diagnostic reporting
- Event reporting
- Flexible Multicast Service
- Multicast diagnostics reporting
- Multiple BSSID & SSID support
- Proxy ARP
- Presence & location
- TIM broadcast
- Traffic filtering service (TFS)

Cisco

- Cisco contributed many CCX features to 802.11v amendment

IEEE 802.11ae is Focused on Appropriate QoS for Management Frames

Status

- IEEE 802.11ae was ratified in 2012
- 802.11ae could be certified as part of WNM

Goals

- Define mechanisms for prioritizing IEEE 802.11 management frames using existing mechanisms for medium access

Features

- Traditionally, management frame were transmitted at the highest priority
- However, this make less sense as management frames are used to transmit less time sensitive (albeit still useful) information
- 802.11ae has been defined to allow management frames to be sent at appropriate priorities

Cisco

- Cisco contributed many of the core ideas used in 802.11ae

Wi-Fi Network Power Save Will Certify Some 802.11v "Power Save" Features

Status

- Wi-Fi Network Power Save certification is in progress
- It is likely to be available some time in 2012-13

Goals

- Wi-Fi Network Power Save certifies features from 802.11v that focus on enhancing battery life of clients

Likely features

- **BSS Max Idle Period** - AP to indicate period in which it won't disassociate STA
- **ARP Proxy** - allows an AP to indicate that it can proxy ARP frames for its associated STAs
- **Wake on WLAN** - allows devices to remain in a very low-power save state until they receive specified frames
- **Directed Multicast Service** - avoids waking all STAs by transmitting group frames as individual frames
- **Flexible Multicast Service** - allows STA to sleep longer using multicast delivery interval for longer than DTIM

Wi-Fi WNM may Certify Various "Enterprise" Focused Features for Location, Operations and Troubleshooting

Status

- Certification plans uncertain; maybe 2014-15, maybe not at all!

Goals

- Using 802.11v, 802.11k, 802.11ae & location
  - Enable management of enterprise networks
  - Improve network & device performance
  - Enable new location-based applications
  - Help reduce IT support costs

Possible features

- Net. connectivity diagnostic (11k/v)
- Net. inventory (11v)
- Net. health" monitoring (11k/v)
- Load balancing (11k/v)
- E-911 location (11k/v)
- Asset recovery using location (11k/v)
- Location enabled troubleshooting (11k/v)
- Efficient channel utilisation (11v)
- Efficient power & channel management (11k/v/y)
- Prioritisation of man. frames (11ae)
- Other (accurate) location features

IEEE 802.11w & Wi-Fi MFP are Focused on Securing Management Frames

Status

- 802.11w was ratified in 2009
- Wi-Fi certification was issued in Jan 2012 but very few cert.s
- Mandatory likely to be delayed

Goals

- Provide data integrity, data origin authenticity, replay protection, & data confidentiality for selected man. frames
- Maintain backward compatibility

Cisco

- Cisco contributed the basis of 802.11w from CCX

The problem & solution

- WPA2/802.11i was defined to provide security for data frames, and not management frames
- At the time this made sense because few management frames were sensitive to attack
- Since then 802.11k & 802.11v, in particular, have defined management frames that could be misused if not secured
- 802.11w has been defined to secure selected Wi-Fi management frames

Wi-Fi Direct

Wi-Fi Direct has had a Slow Start but May Take Off Once Interoperable Services are Defined

- Wi-Fi Direct was certified in 2009 to support peer to peer networking
- Unfortunately, Wi-Fi Direct has been both over & underwhelming so far
  - Over 1000 certifications
  - And almost no use
- This is because no interoperable middleware was certified at the time
  - There is mostly no way to do anything useful with a Wi-Fi Direct connection
- The Wi-Fi Alliance is planning to remedy this problem in late 2013 with a certification of Wi-Fi Direct services
  - Wi-Fi Certified Miracast (aka Display) was certified in 2012 and is an early example of middleware for sending a display cross a peer to peer link
  - Docking, serial bus and other similar certifications are all in the pipeline
- At that point Wi-Fi Direct may take off …

The Use of Wi-Fi Direct in the Enterprise Environment has Some Anticipated Issues

Security issue

- Wi-Fi Direct uses Wi-Fi Protected Setup for security
- Wi-Fi Protected Setup is not “enterprise level security”
- Cisco’s recommendation is that devices using Wi-Fi Direct not be cross connected to the corporate network
- Cisco contributed a feature into the specification to enforce this
- There are efforts starting to make Wi-Fi Protected Setup suitable for use in the enterprise

RF issue

- A Wi-Fi Direct device looks like a rogue AP to the corporate network, with all the usual problems associated with rogues
- Cisco’s recommendation is that devices using Wi-Fi Direct be directed to use a specific channel
- Cisco contributed a feature into the Wi-Fi Direct specification to suggest the use of a channel

There is Growing Evidence that Wi-Fi Direct & Soft APs may Cause Even Bigger Problems in the Future

- At a number of large events in recent times there have been a very large number of soft APs operating
- This has led to much of the bandwidth being used by management traffic normally associated with APs
- Indeed at one recent “prominent” stadium event up to 95% of the airtime was taken up by management traffic from soft APs
- There is a risk that Wi-Fi Direct will overwhelm the 2.4GHz and non radar channels in the 5HGz band
- Cisco is leading an industry effort to understand and hopefully mitigate this issue

Wi-Fi Security

Wi-Fi Security is Well Beyond the "WEP Debacle" of the Past

WEP

- Broken!
- Replaced by WPA & then WPA2
- **Do not use!!!!**

WPA

- Based on TKIP & 802.1X
- Transitional only
- **Avoid use!**

WPA2

- Based on AES & 802.1X
- "Enterprise class"

Wi-Fi Protected Setup

- Designed to encourage consumers to use security
- **Not "enterprise class"** but this may change in the future

- Wi-Fi Alliance is strongly encouraging use of WPA2 (for enterprise & consumer), and Wi-Fi Protected Setup (for consumer)
- 802.11w defines security for management frames and was certified in early 2012 by the Wi-Fi Alliance
- There are ongoing efforts in 802.11ai to optimise the process of setting up WPA2 security
- And Suite-B features coming soon, eg GCMP-256

Where Have We Been Today?

Today's Presentation Focused on Various Aspects of Wi-Fi & Standards

1	• Why is Wi-Fi so successful? *Great technology, great timing, continuous evolution*
2	• Who are key players in Wi-Fi standards? *IEEE 802.11 WG, Wi-Fi Alliance ... with Cisco leadership!*
3	• What is coming down the standards pipeline? *802.11ac, Hotspot 2.0 and many others!*

- Make sure you keep up to date with Wi-Fi, because - more and more - it's driving the network edge and mobility
- (And Wi-Fi won't take your Starbucks or chocolate away)

Your Assistance Requested

- In this presentation we've discovered that the next generations of Wi-Fi allows gigabit+ speeds
- What use cases will drive wireless throughput demand in your business?
- Please email your answers to brianh@cisco.com

Q & A

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