



Hewlett Packard
Enterprise

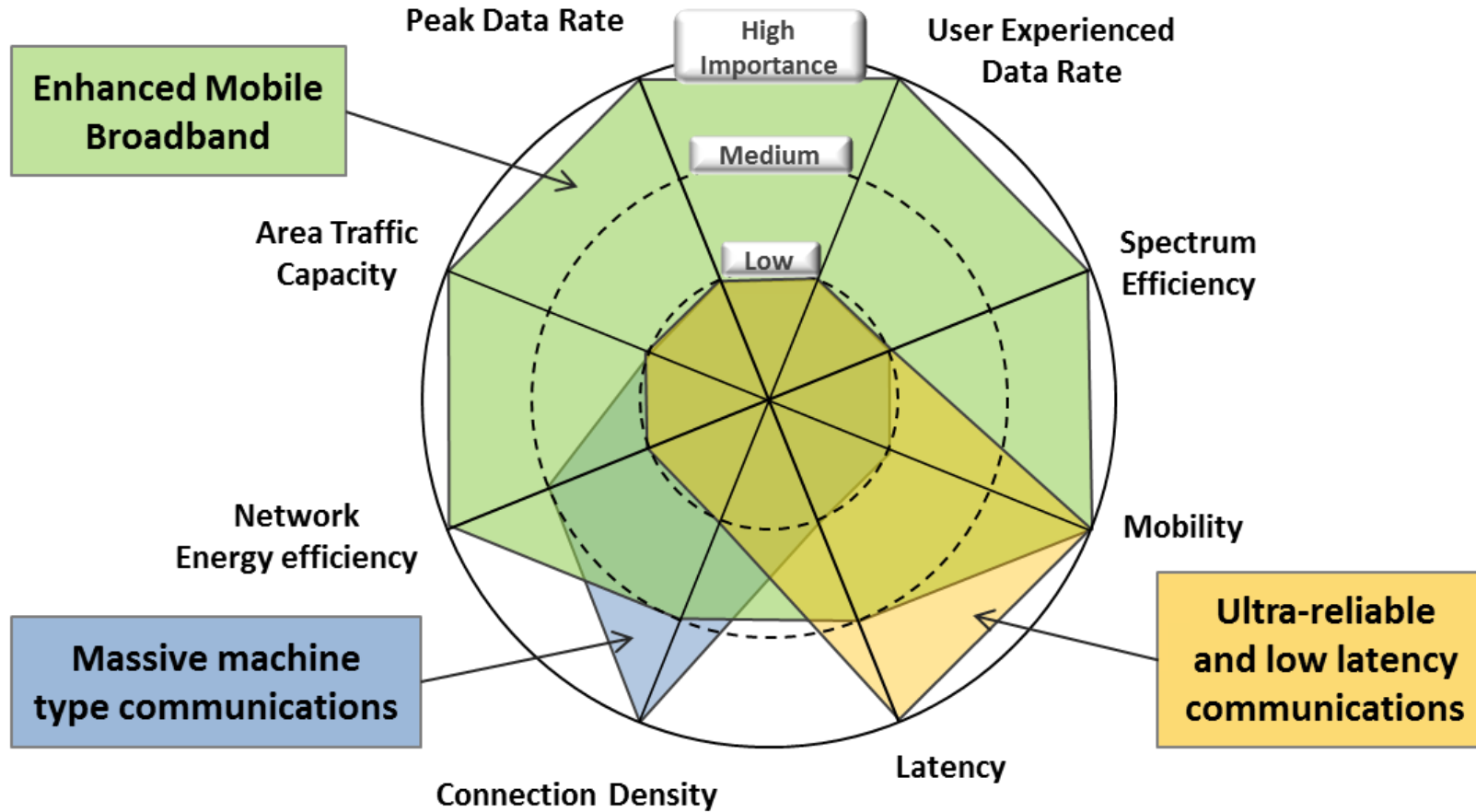
IEEE 802.11 Radio components in 5G Wireless

Dorothy Stanley

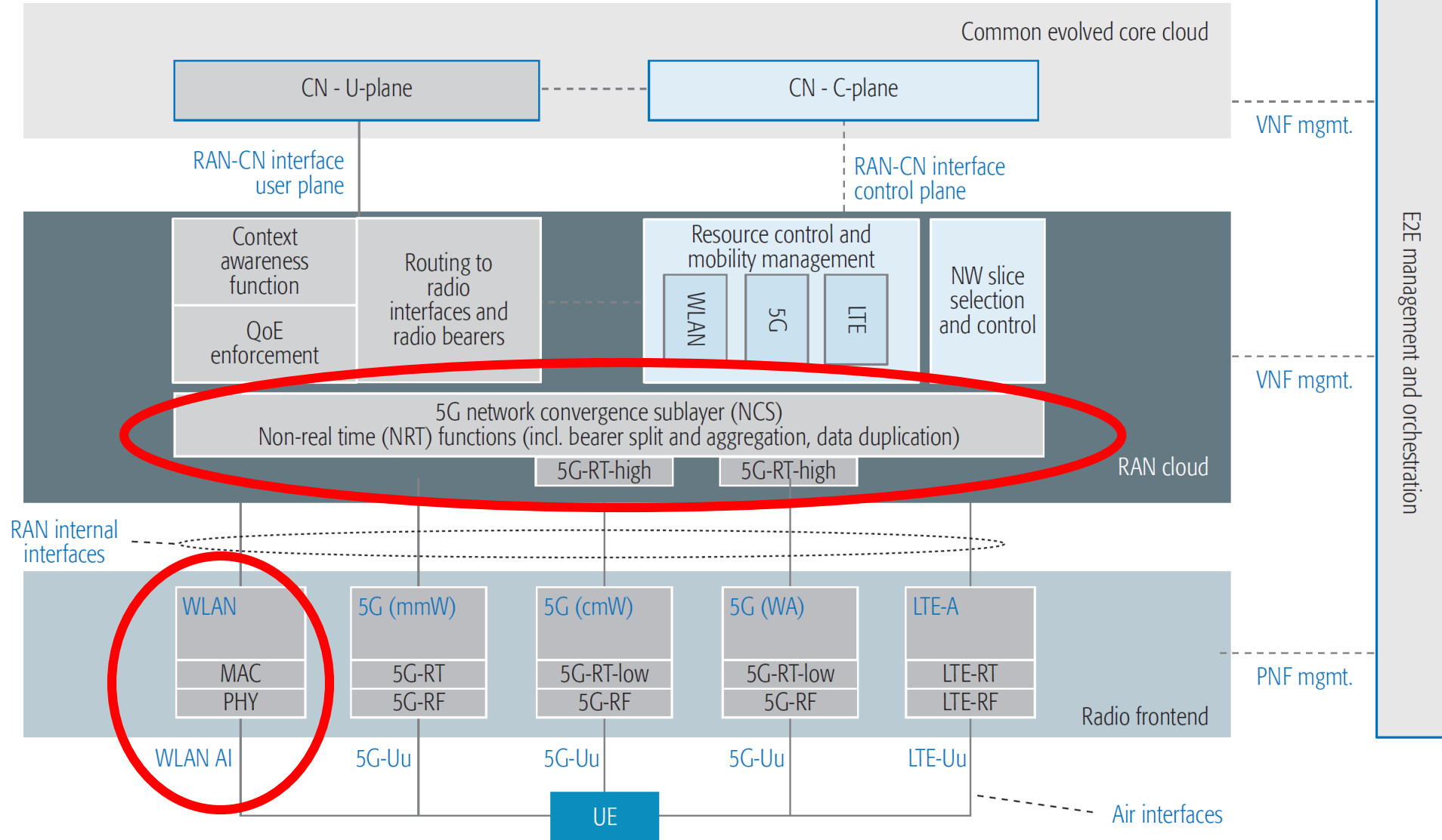
Thank you for the opportunity to present

- IEEE 802.11 as a component in 5G
- IEEE 802.11 Market drivers and technologies under development
- IEEE 5G Initiatives
- Note that this presentation represents my views, not those of the IEEE, IEEE 802 or sub-parts of those organizations

5G Systems have a Wide Range of Requirements

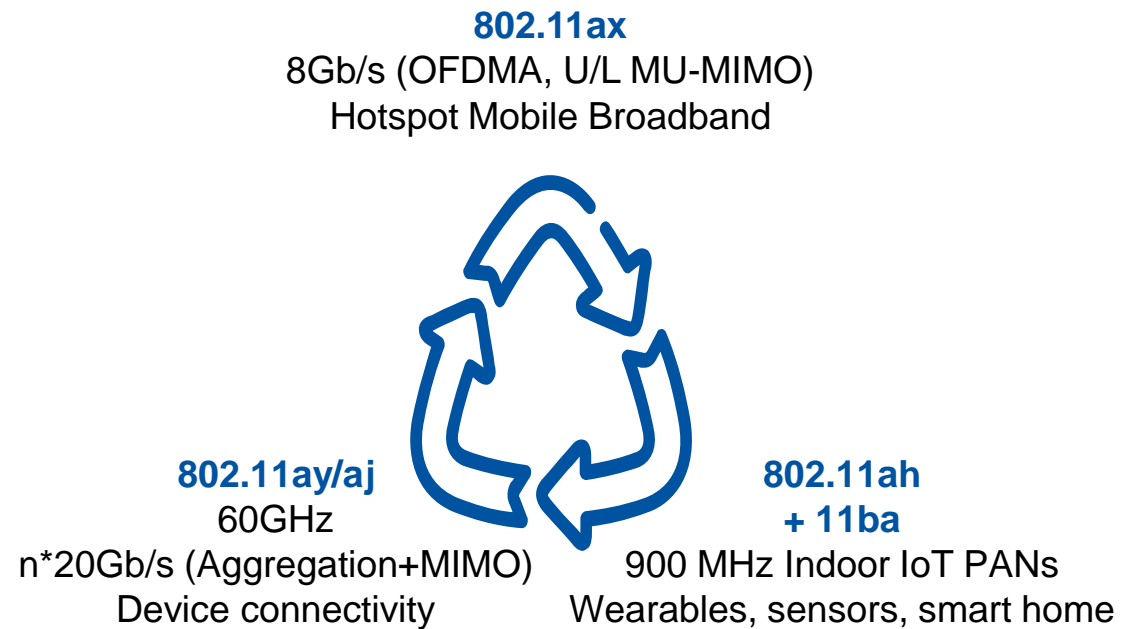


802.11/Wi-Fi is a Peer Radio Access Technology in 5G Architecture



IEEE 802.11 technology will be leveraged to meet 5G requirements

- Wi-Fi carries most public & private Internet traffic worldwide
 - Between 50-80% depending on country.
- 5G radio aggregation technologies will natively incorporate Wi-Fi
 - 802.11 is a peer member of the 5G “RAT Family”
 - IEEE and 3GPP are working together on 5G, coordinating at the highest level
- 5G Success Depends on Wi-Fi & Wi-Gig
- Observe that today’s 3/4G networks include 802.11 technologies
 - For offload: “More traffic was offloaded from cellular networks (on to Wi-Fi) than remained on cellular networks in 2016” (Cisco VNI)
 - For Wi-Fi calling



IEEE 802, 802.11 and 3GPP ongoing communication topics

- eLWA: radio measurements and measurement requirements in the 60 GHz frequency band
 - See <https://mentor.ieee.org/802.11/dcn/16/11-16-0266-02-00ay-a-compendium-of-motions-related-to-the-contents-of-the-specification-framework-document-for-tgay.doc>
 - See <https://mentor.ieee.org/802.11/dcn/16/11-16-0548-00-0000-liaison-from-3gpp-ran2-on-elwa.doc>
- LWA and LWIP
 - See <https://mentor.ieee.org/802.11/dcn/16/11-16-0351-01-0000-liaison-from-3gpp-on-lwa-and-lwip.pptx>
 - See <https://mentor.ieee.org/802.11/dcn/16/11-16-0489-02-0000-liaison-to-3gpp-on-lwa-and-lwip.docx>
- 5G
 - See <https://mentor.ieee.org/802.11/dcn/16/11-16-0449-00-0000-liaison-from-3gpp-on-5g-activities.pptx>
- LAA Coexistence
 - See <https://mentor.ieee.org/802.19/dcn/16/19-16-0077-03-0000-proposed-liaison-on-laa-process.docx>
 - <https://mentor.ieee.org/802.19/dcn/16/19-16-0037-09-0000-laa-comments.pdf>

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Market demands and new technology drive innovation (Current projects)

- Demand for throughput
 - Continuing exponential demand for throughput (**TGax and TGay**)
 - Most (50-80%, depending on the country) of the world's mobile data is carried on 802.11 (WiFi) devices
- New usage models / features
 - Dense deployments (**TGax**), Indoor Location (**TGaz**)
 - Automotive (IEEE Std 802.11p), Internet of Things (**TGah**)
 - Low Power applications (**Tgba**)
- Technical capability
 - MIMO (IEEE Std 802.11n, 802.11ac, **TGay**)
 - 60 GHz radios (**TGay**)
- Changes to regulation
 - TV whitespaces (IEEE Std 802.11af), Radar detection (IEEE Std 802.11h)
 - Coexistence and radio performance rules (e.g., ETSI BRAN, ITU-R)

802.11 technology is serving high density applications today

High Density Wi-Fi Design: How to Deliver 10 TB of Fan Wi-Fi at the Big Game

Total Data Transferred on Wi-Fi
10TB+

Beats Every Past Big Game by 60%+

Unique Wi-Fi Users
28.6K
40% of Attendance

Beats Every Past Big Game

Concurrent Wi-Fi Users
20K+
28% of Attendance

Big Game and Venue Record

Continuous Wi-Fi Bandwidth > 3Gbps
4h 0m

New league record!

Average Data Consumed per Fan
370MB

54% higher than 2014 Big Game

The first Big Game to Deliver
Indoor Navigation

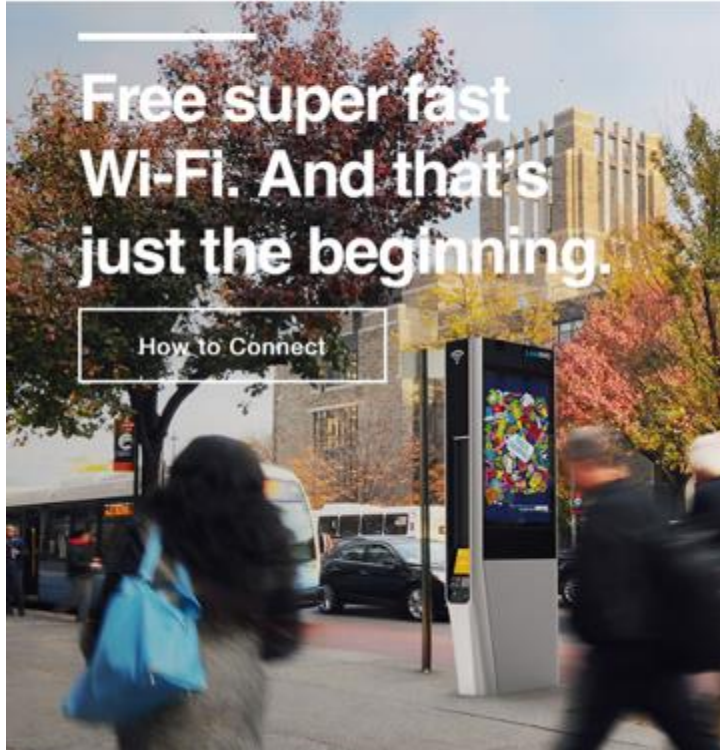
Stadium App

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Enterprise company

LinkNYC

[Find a Link](#) [FAQ](#) [Media Kit](#)



Free super fast
Wi-Fi. And that's
just the beginning.

How to Connect

Good-Bye Pay Phone, Hello Link!

LinkNYC is a first-of-its-kind communications network that will replace over 7,500 pay phones across the five boroughs with new structures called Links. Each Link will provide superfast, free public Wi-Fi, phone calls, device charging and a tablet for Internet browsing, access to city services, maps and directions.

For New Yorkers, By New Yorkers

LinkNYC is now in beta, giving New Yorkers an early opportunity to try out Link's features, provide feedback and help us create the future of our sidewalk experience. Additional apps and services will be rolled out over the next few months. Got feedback? [Contact us.](#)

The LinkNYC Team

LinkNYC is brought to you by the City of New York and CityBridge, a NYC-based consortium of leading experts in technology, media, connectivity and user experience that includes:



Q. What does 'beta phase' mean?

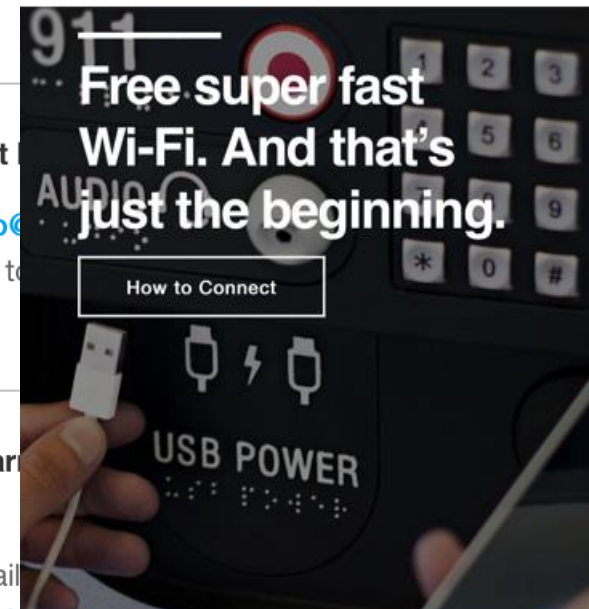
The launch of LinkNYC will begin with a beta phase, giving New Yorkers an early opportunity to try out Link's features, provide feedback and help us create the future of our sidewalk experience. Additional apps and services will be rolled out over the next few months and on an ongoing basis over the next decade. To provide feedback about your LinkNYC experience, please email beta@link.nyc. For updates on LinkNYC, [follow us](#) or sign up for our [newsletter](#).

Q. How can I get...

Email us at hello@link.nyc where you'd like to...

Q. How can I learn more about LinkNYC?

Shoot us an email...

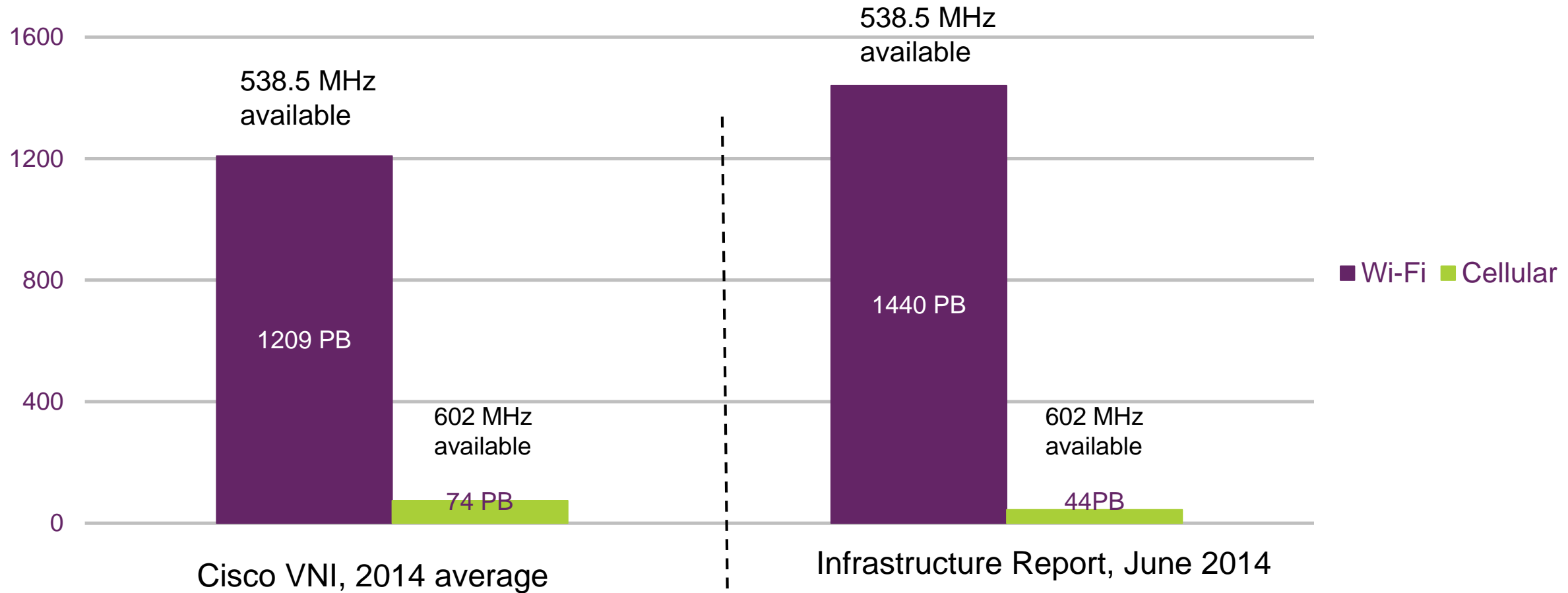


Free super fast
Wi-Fi. And that's
just the beginning.

How to Connect

In 2014 Wi-Fi traffic was 16 times cellular one

UK Data carried in PB (petabytes) per month



Source: Andy Gowans (UK regulator) presentation: <https://mentor.ieee.org/802.18/dcn/16/18-16-0016-01-0000-ofcom-future-spectrum-requirements.pptx>

802.11 Groups

Type	Group	Description	Chair (Affiliation)
WG	WG11	The IEEE 802.11 Working Group (WG)	A. Stephens (Intel)
SC	ARC	Architecture Standing Committee (SC)	M. Hamilton (Ruckus)
SC	PAR	PAR review	J. Rosdahl (Qualcomm)
SC	AANI	Advanced Access Network Interface	J. Levy (Interdigital)
SC	WNG	Wireless Next Generation	J. Lansford (Qualcomm)
802 SC	JTC1	ISO/IEC JTC1/SC6	A. Myles (Cisco)
TG	MC	Revision mc (REVmc) Task Group (TG)	D. Stanley (HPE)
TG	AH	Operation in 900 MHz bands (S1G)	Y. Seok (Newracom)
TG	AI	Fast Initial Link Setup (FILS)	H. Mano (Koden Tech Info)
TG	AJ	China Milli-Meter Wave (CMMW)	J. Chen (HiSilicon/Huawei)
TG	AQ	Pre-association Discovery (PAD)	S. McCann (Blackberry)
TG	AK	General Link (GLK)	D. Eastlake (Huawei)
TG	AX	High Efficiency Wireless LAN (HEW)	O. Aboul-Magd (Huawei)
TG	AY	Next Generation 60 GHz (NG60)	E. Au (Huawei)
TG	AZ	Next Generation Positioning (NGP)	J. Segev (Intel)
TG	BA	Wake Up Radio	M. Park (Intel)
TIG		Light Communications	N. Serafimovski (pureLiFi)

802.11ax Purpose

- Improve performance of WLAN deployments in dense scenarios
 - Targeting at least 4x improvement in the per-STA throughput compared to 802.11n and 802.11ac.
 - Improved efficiency through spatial (MU MIMO) and frequency (OFDMA) multiplexing.
- Dense scenarios are characterized by large number of access points and large number of associated STAs deployed in geographical limited region, e.g. a stadium or an airport.



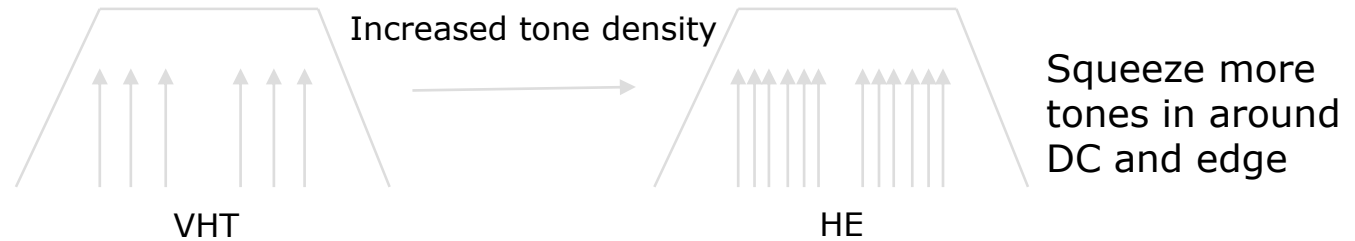
Access to Internet, latest airlines' announcements, and digital media such as movies and sport events

802.11ax Technical Highlights

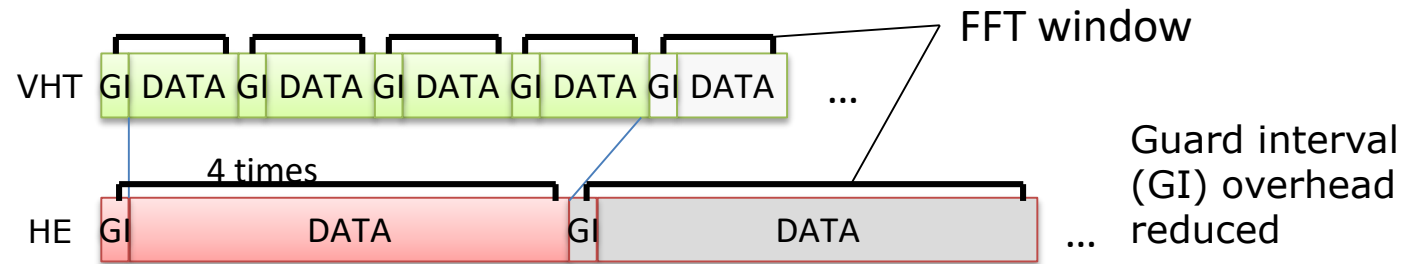
- Increase network efficiency by multiplexing users in both frequency and space
 - UL and DL OFDMA
 - UL and DL MU-MIMO
- Increase spatial reuse through dynamic clear channel assessment (CCA)
- Increase link efficiency with a longer OFDM symbol and high order modulation (1024-QAM)
- Improved support for outdoor operation
- Current schedule: Completion 2019

Increased link efficiency

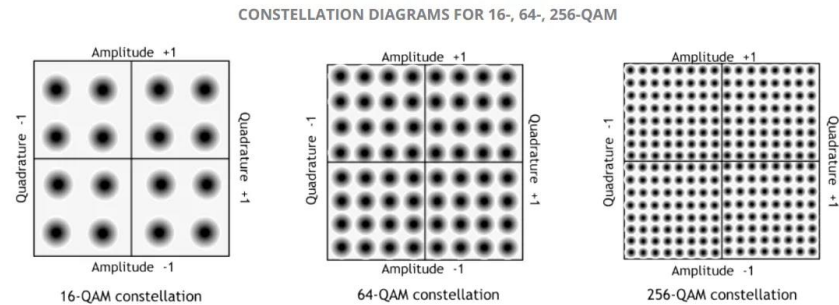
Frequency domain
(~5% gain)



Time domain
(~15% gain)

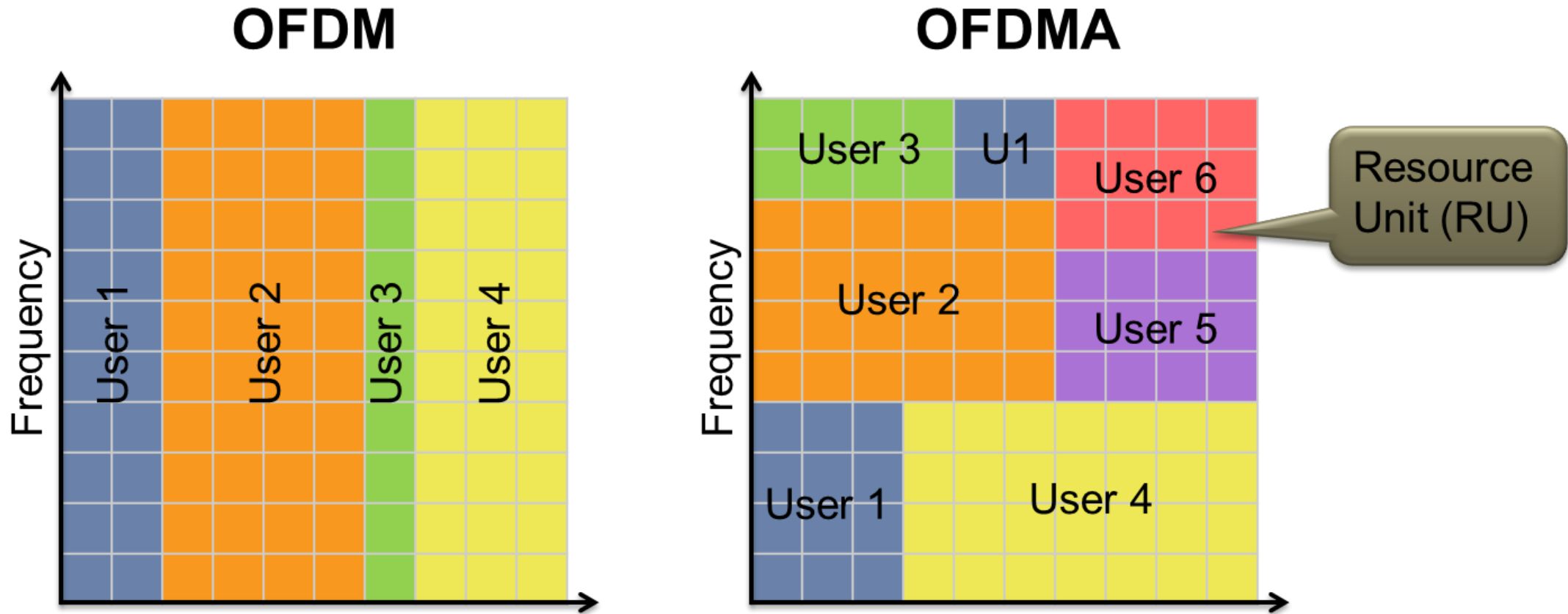


Modulation
(~25% gain)



+ 1024-QAM

OFDMA enables further AP customization of channel use to match client and traffic demands



Increased efficiency for (high percentage of traffic) short data frames

802.11ad 60GHz extensions

- 11ad amendment published in 2012
- Supports short range, very high speed communications
- Provides multi-gigabit performance for in-room connectivity
- WiGig Wireless Docking stations on the market now
- From <http://www.wi-fi.org/discover-wi-fi/wigig-certified> :

Multi-gigabit, low latency connectivity.
Coming in 2016.

Industry momentum and user anticipation of 60 GHz technology is growing. WiGig CERTIFIED™ products operate in the 60 GHz frequency band and deliver multi-gigabit speeds, low latency, and security-protected connectivity between nearby devices. Popular use cases for WiGig® include cable replacement for popular I/O and display extensions, wireless docking between devices like laptops and tablet, instant sync and backup and simultaneous streaming of multiple, ultra-high definition and 4K videos.



Data rates*

MCS	Data Rate (Mb/s)
1	385
2	770
3	962.5
4	1155
5	1251.25
6	1540
7	1925
8	2310
9	2502.5
9.1	2695
10	3080
11	3850
12	4620
12.1	5005
12.2	5390
12.3	5775
12.4	6390
12.5	7507.5
12.6	8085

*SC data rates as proposed to be modified in TGmc, see <https://mentor.ieee.org/802.11/dcn/16/11-16-0670-06-000m-base-mcs-and-length-calculation-for-extended-mcs-set.docx>

802.11ay

Next Generation 60GHz

Status: Pre-D1.0; Functional Reqs

Completion 2019

Key Project Goals

Enhanced Throughput for Operation in License-Exempt Bands Above 45 GHz: Increase aggregated throughput, range and reliability

Expected to develop mode of operation capable of supporting a maximum throughput of at least 20 gigabits per second (measured at the MAC data service access point), while maintaining or improving the power efficiency per station.

Key Parameters

Use cases

- Wireless docking
- Wireless display
- Indoor/Outdoor backhaul
- Ultra short range communications
- 8K UHD streaming
- Data Center Inter-rack connectivity
- Video/Mass Data distribution

Technology

- Channel bonding
- MIMO
- Maintain backwards compatibility with existing deployed 60GHz devices

- Note: 802.11ad products coming on the market now, Wi-Fi Alliance 11ad WiGig Certified launching 2016, see [link](#)



For more information: [channel models](#), [specification framework](#), [use cases document](#) (photos from slide 12)

Key Project Goals

Define operation of license-exempt IEEE 802.11 wireless networks in frequency bands below 1 GHz excluding the TV White Space bands.

868-868.6 MHz (Europe), 950 MHz -958 MHz (Japan), 314-316 MHz, 430-434 MHz, 470-510 MHz, and 779-787 MHz (China), 917 - 923.5 MHz (Korea) and 902-928 MHz (USA), provides mechanisms that enable coexistence with other systems in the bands including IEEE 802.15.4 and IEEE P802.15.4g

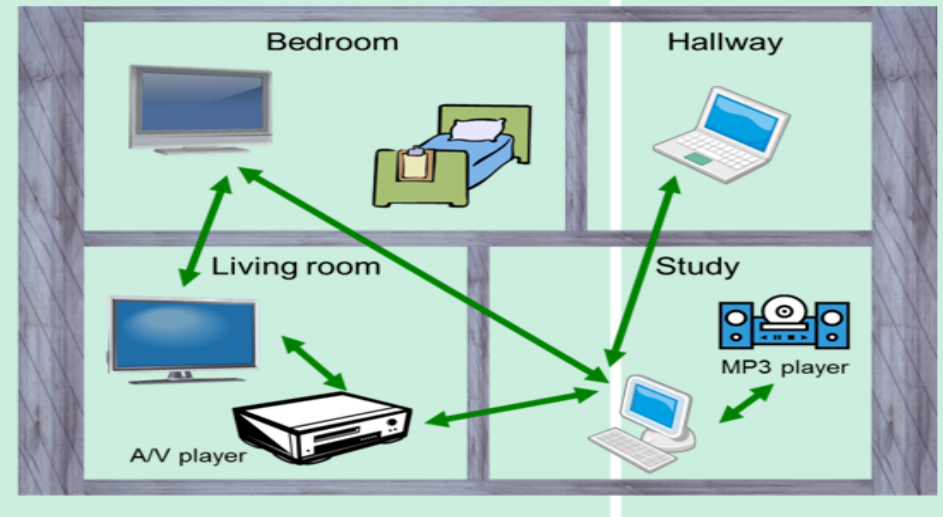
Key Parameters

Use cases

- Extended range WLAN internet access,
- Smart home sensor networking,
- Outdoor access with low data rates – ranch, mountainous areas
- Wearable devices - health, multimedia

Technology

- OFDM PHY
- MAC enhancements
- Transmission range up to 1km
- data rates > 100 kbit/s
- maintain the IEEE 802.11 WLAN user experience for fixed, outdoor, point to multi point applications



For more information: [functional reqs](#); photo from [use cases](#)

IEEE 802.11 components are now and will be an important part of carrier deployments continuing into the future

- A change from say 10 years ago, when carriers would not consider use of unlicensed spectrum
- IEEE 802.11 technology and capabilities are being integrated by 3GPP....
 - LTE WLAN Radio Level Integration with IPsec Tunnel (LWIP)
 - LTE-WLAN Aggregation (LWA, eLWA)
- IEEE 802.11 continues to enhance and develop new capabilities which can be RAN components of 5G
 - P802.11ad/ay/aj: 60GHz band operation, applicable to short range very high bandwidth operation
 - P802.11ah/ba: Sub 1 GHz band, applicable to machine type communication, low power
 - P802.11ax: High efficiency WLANs, applicable to dense deployments

IEEE 5G Initiative Goals/Objectives

- <http://5g.ieee.org/>
- Foster collaboration and connect technical & business communities to IEEE 5G experts and resources
- Establish IEEE as a **Thought Leader** and essential to the 5G community
- To be recognized as the go-to resource for engineering and technology professionals in industry, academia and government working on 5G
- Develop and promote valued programs, products and services for the 5G community
- Present a single IEEE face/voice to the 5G marketplace
- Be a true global 5G initiative capturing the needs of all global regions
- Create a neutral platform/forum where those interested in 5G can engage and collaborate
- Be the catalyst for IEEE cross-society activities on 5G

Thank you!

References

- <http://www.ieee802.org/11/>
- <https://mentor.ieee.org/802.11/documents>
- <https://mentor.ieee.org/802.11/dcn/16/11-16-0351-01-0000-liaison-from-3gpp-on-lwa-and-lwip.pptx>
- <https://mentor.ieee.org/802.11/dcn/16/11-16-0500-00-0000-ietf-95-wireless-tutorial-802-11-overview.pptx>