IEEE Seminar:
Vision of Future Technology in 5G and Wi-Fi:
IEEE 802 5G Activities

Andrew Myles
IEEE-SA Board of Governors
Long term IEEE 802.11 WG participant

30 March 2017
Taipei, Taiwan

IEEE STANDARDS ASSOCIATION

Today's speaker is Dr Andrew Myles …

- Dr. Andrew Myles spent too long at university
  - B.Sc, B.E (Hons) (Syd), PhD (Macquarie)
- Dr. Myles has had a long history in standards work
  - FDDI in ANSI in 1980's
  - Mobile-IP in IETF in 1990's
  - 802.11 in IEEE 802.11 WG since 2001
  - Wi-Fi in Wi-Fi Alliance since 2001
  - Wi-Fi security in ISO/IEC JTC1/SC6 since 2004
  - Wi-Fi/LAA coexistence in 3GPP & ETSI since 2015
- Dr. Myles currently serves as
  - Chair, IEEE 802 JTC1 Standing Committee
  - Chair, IEEE 802.11 PDED ad hoc
  - Governor of IEEE-SA BoG
  - Director and Secretary of Wi-Fi Alliance (former Chair 2007-2011)
- Dr. Myles has been employed by Cisco since 2001

… who needs to start with a disclaimer

At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position, explanation, or interpretation of the IEEE.

IEEE-SA Standards Board Operation Manual (sub-clause 5.9.3)

Today's presentation is going focus on IEEE-SA standardisation, particularly in context of 5G

1	IEEE overview and standards development
2	IEEE 5G initiative
3	IEEE 802 5G activities (and 3GPP coordination)
4	IEEE 802.11 network evolution

Today is a discussion and not a lecture

- I could stand up a her and lecture for hours about topics I care about …
- … but I would prefer a discussion about topics you care about
- So feel free to:
  - Stop me at any time
  - Ask a question
  - Start a discussion

Today's presentation is going focus on IEEE-SA standardisation, particularly in context of 5G

1	**IEEE overview and standards development**
2	IEEE 5G initiative
3	IEEE 802 5G activities (and 3GPP coordination)
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IEEE STANDARDS ASSOCIATION

IEEE is the world's largest professional engineering association …

IEEE

Advancing Technology for Humanity

Global Reach

430,000+ Members	**160+** Countries	**1,300+** Annual Conferences

Technical Breadth

39 Societies **6** Councils	**4,000,000+** Technical Documents	**180+** Top-cited Periodicals

… with activities covering a very broad spectrum

45 societies & technical councils

- Aerospace & Electronic Systems
- Antennas& Propagation
- Biometrics Council
- Broadcast Technology
- Circuits and Systems
- Communications
- Components, Packaging, & Manufacturing Technology
- Computational Intelligence
- Computer
- Consumer Electronics
- Control Systems
- ...

- Council on Electronic Design Automation
- Council on Superconductivity
- Dielectrics and Electrical Insulation
- Education
- Electron Devices
- Electromagnetic Compatibility
- Engineering in Medicine & Biology
- Geoscience and Remote Sensing
- Industrial Electronics
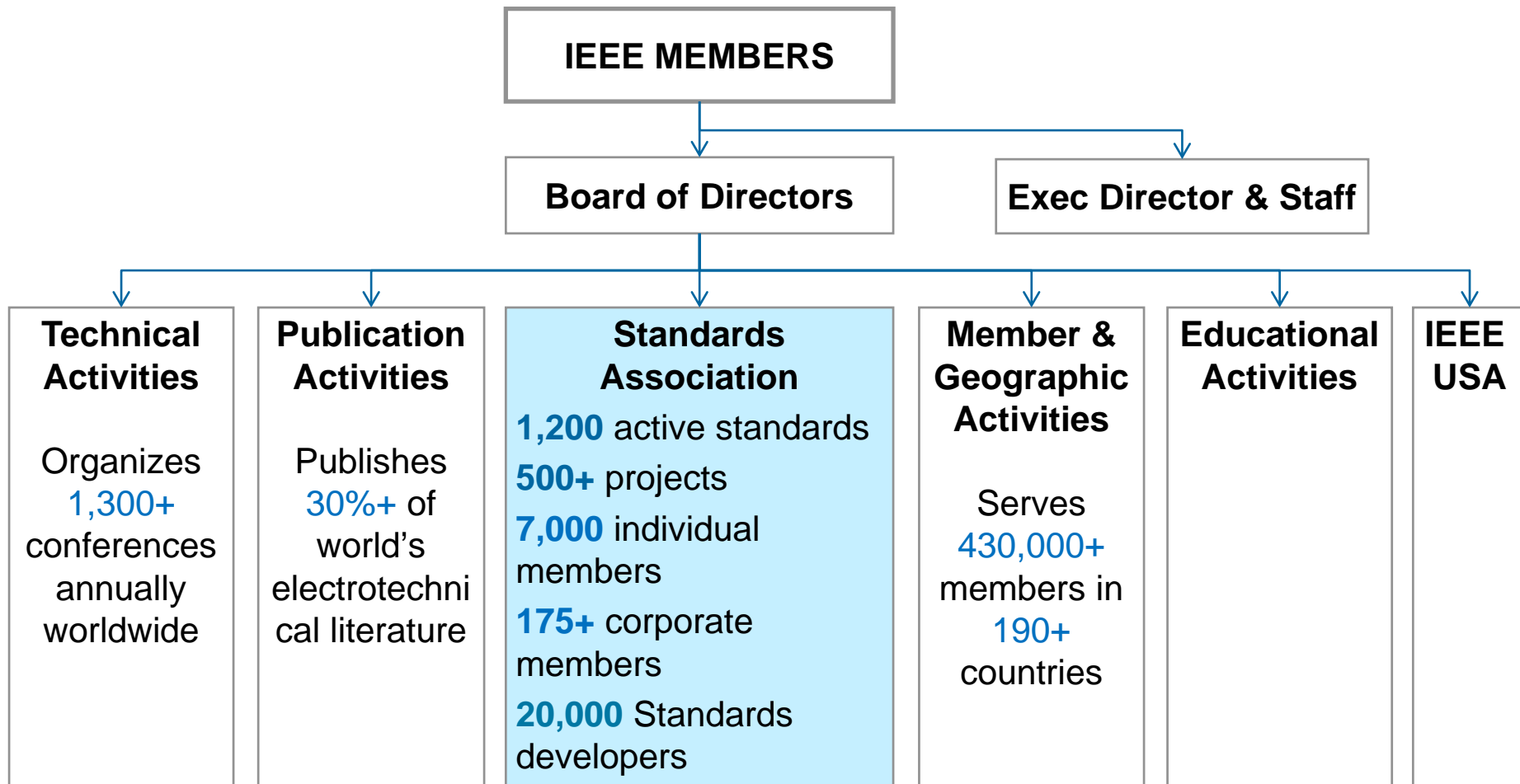- Industry Applications
- Information Theory
- …

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… with activities covering a very broad spectrum

45 societies & technical councils

- Instrumentation & Measurement
- Intelligent Transportation Systems
- Magnetics
- Microwave Theory & Techniques
- Nanotechnology Council
- Nuclear & Plasma Sciences
- Oceanic Engineering
- Photonics
- Power Electronics
- Power & Energy
- Product Safety Engineering
- Professional Communications
- …

- Reliability
- Robotics & Automation
- Sensors Council
- Signal Processing
- Social Implications of Technology
- Solid-State Circuits
- Systems, Man & Cybernetics
- Systems Council
- Technology & Engineering Management
- Ultrasonics, Ferroelectrics & Frequency Control
- Vehicular Technology

IEEE STANDARDS ASSOCIATION

IEEE 802   ◆IEEE

IEEE is organized into six high level units, led by a Board of Director responsible to the membership

IEEE MEMBERS

Board of Directors

Exec Director & Staff

Technical Activities	**Publication Activities**	**Standards Association**	**Member & Geographic Activities**	**Educational Activities**	**IEEE USA**
Organizes 1,300+ conferences annually worldwide	Publishes 30%+ of world's electrotechnical literature	**1,200** active standards **500+** projects **7,000** individual members **175+** corporate members **20,000** Standards developers	Serves 430,000+ members in 190+ countries		

IEEE STANDARDS ASSOCIATION

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The IEEE-Standards Association is focused on creating great standards for the good of all

Vision 愿景

- Be recognized as a preferred global provider of high-quality, market-relevant technology standards and of services that promote their universal adoption
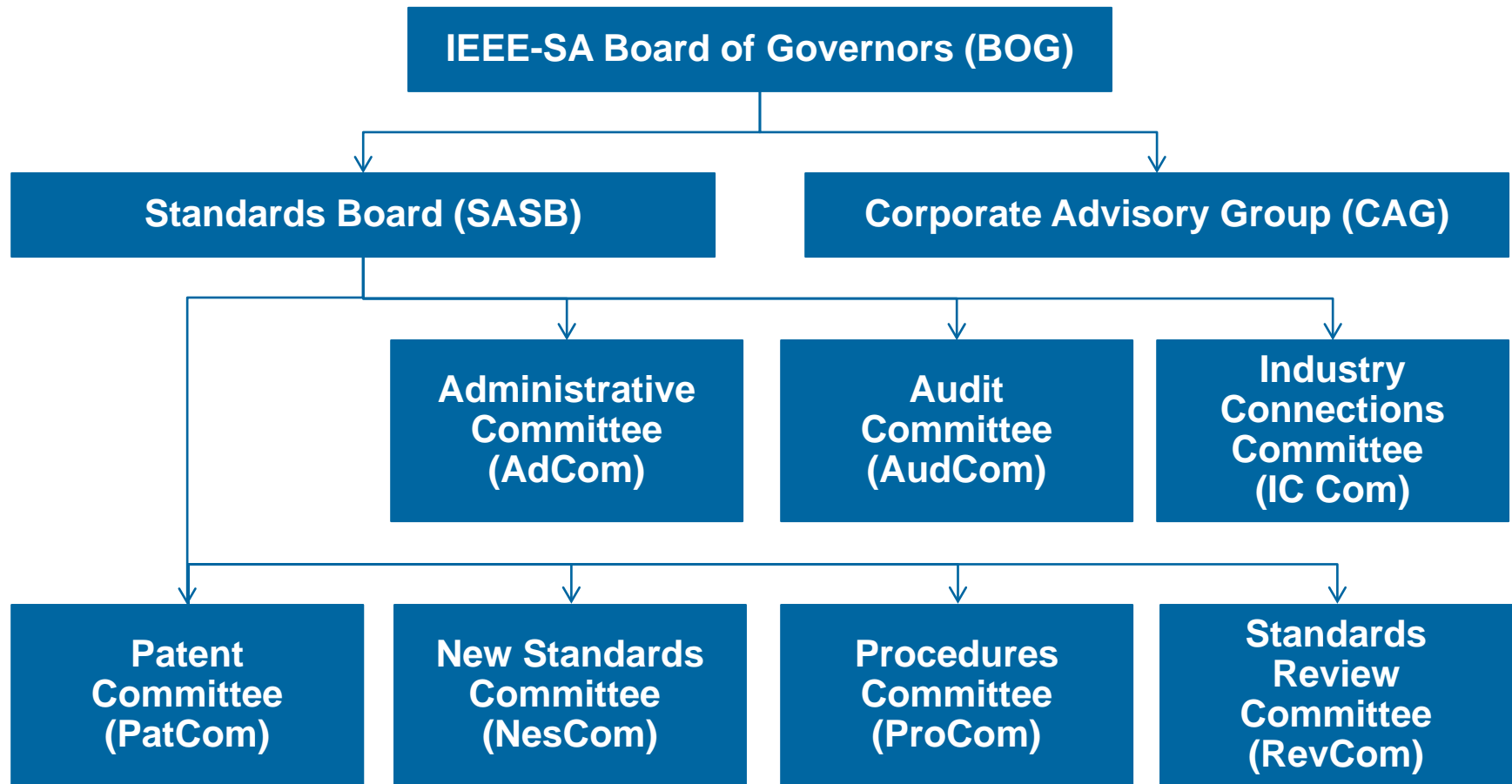
成为全球首选的高质量, 市场驱动标准制订平台

Mission 使命

- Enable and promote the collaborative application of technical knowledge to advance economic and social well-being through the development of technical standards and related activities
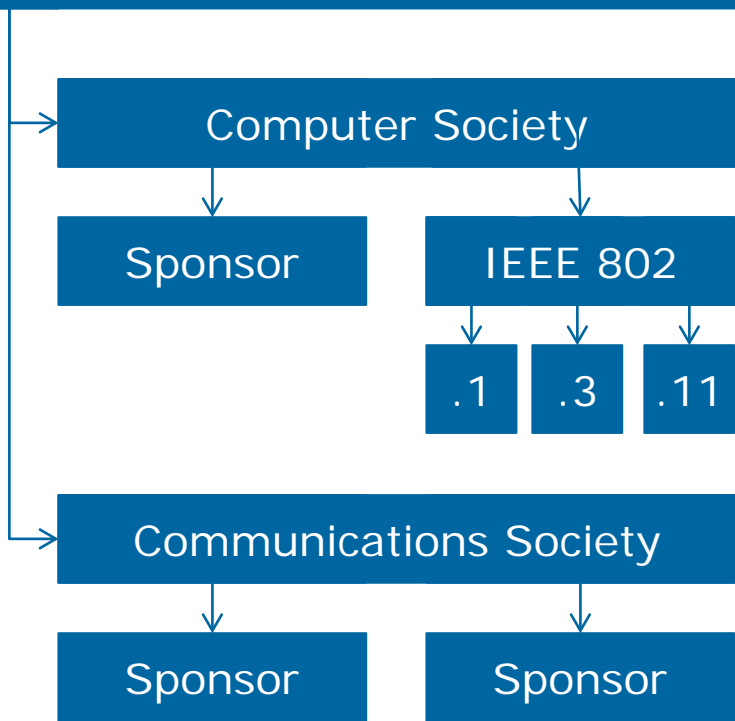
通过标准活动推动技术合作和经济发展

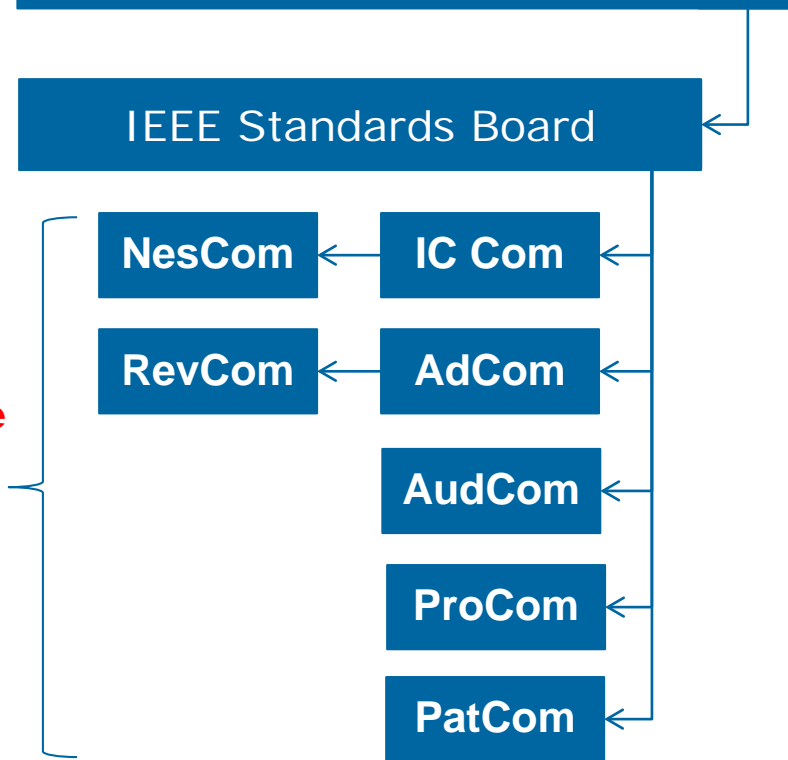# IEEE Standards Association has its own governance structure …

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                    ┌─────────────────────────────────────┐
                    │  IEEE-SA Board of Governors (BOG)   │
                    └─────────────────────────────────────┘
                        │
            ┌───────────┴────────────────────────────┐
            ▼                                         ▼
┌──────────────────────────┐          ┌──────────────────────────────┐
│  Standards Board (SASB)  │          │ Corporate Advisory Group (CAG)│
└──────────────────────────┘          └──────────────────────────────┘
```

| Administrative Committee (AdCom) | Audit Committee (AudCom) | Industry Connections Committee (IC Com) |

| Patent Committee (PatCom) | New Standards Committee (NesCom) | Procedures Committee (ProCom) | Standards Review Committee (RevCom) |

… but IEEE standards work is closely tied into other IEEE activities

IEEE Technical Activities

Computer Society
- Sponsor
- IEEE 802
  - .1
  - .3
  - .11

Communications Society
- Sponsor
- Sponsor

Tying the work & process together

Standards work

IEEE Standards Association

IEEE Standards Board
- NesCom ← IC Com
- RevCom ← AdCom
- AudCom
- ProCom
- PatCom

Standards process

IEEE provides an innovation platform all the way from conceptualization to standardization …

Conceptual	Pre-competitive	Competitive R&D	Development/ Deployment

Workshops

Academic Conferences

Publications

Research/Study Groups

Standards activities

Industry Forums
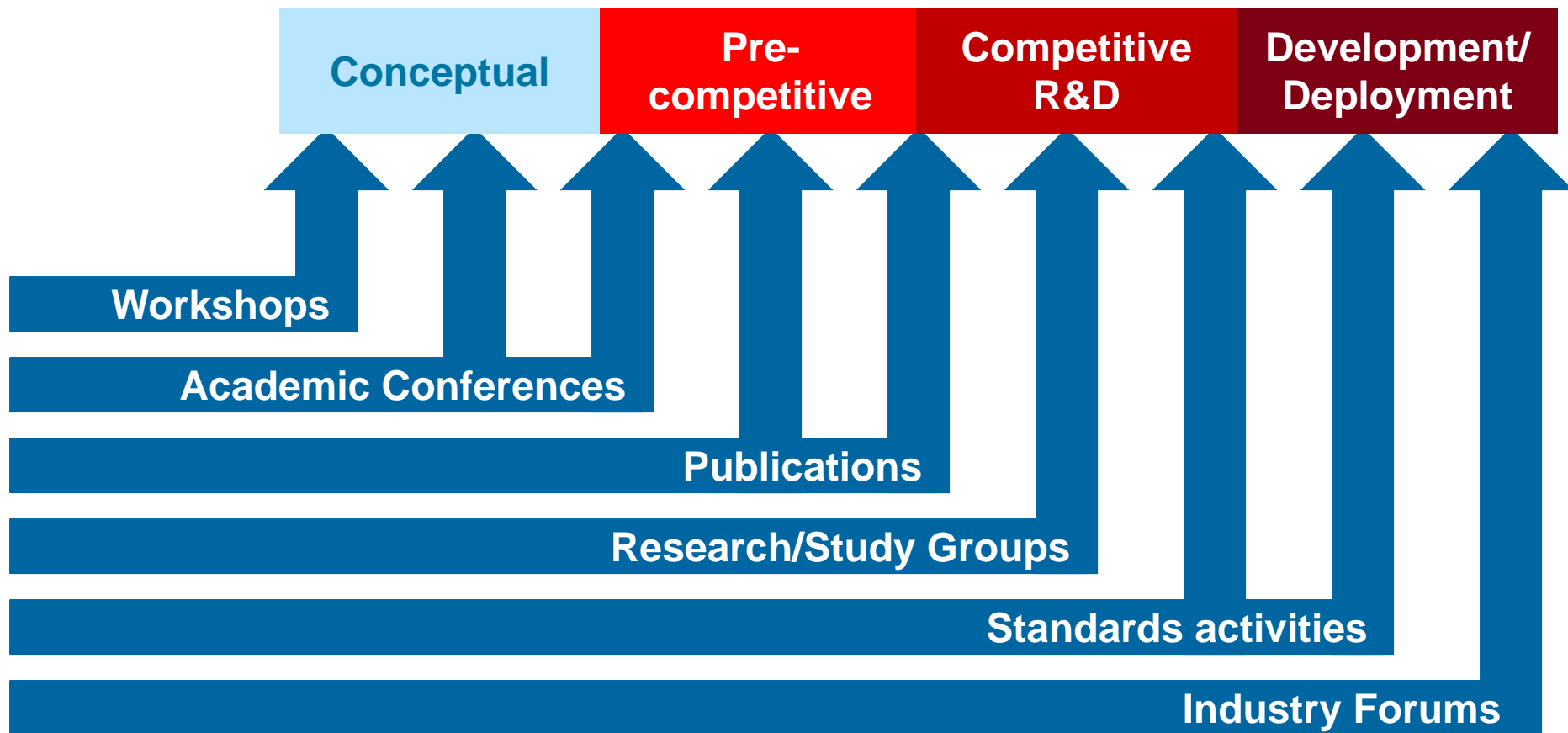
… it is a process that starts with research & invention and finishes with consensus standards

Identify Sponsor(s) & Format
确认发起人&形式

Invent

Research研究

Project approval
项目批准

Develop draft standard
开发标准草案

Sponsor ballot & Public Review
投票&公开评审

Standards Board approval
标准董事会批准

Publish Standard
标准出版

Amend & Revise standard
补遗和修改

Develop Certification Tests
ICAP测试认证项目

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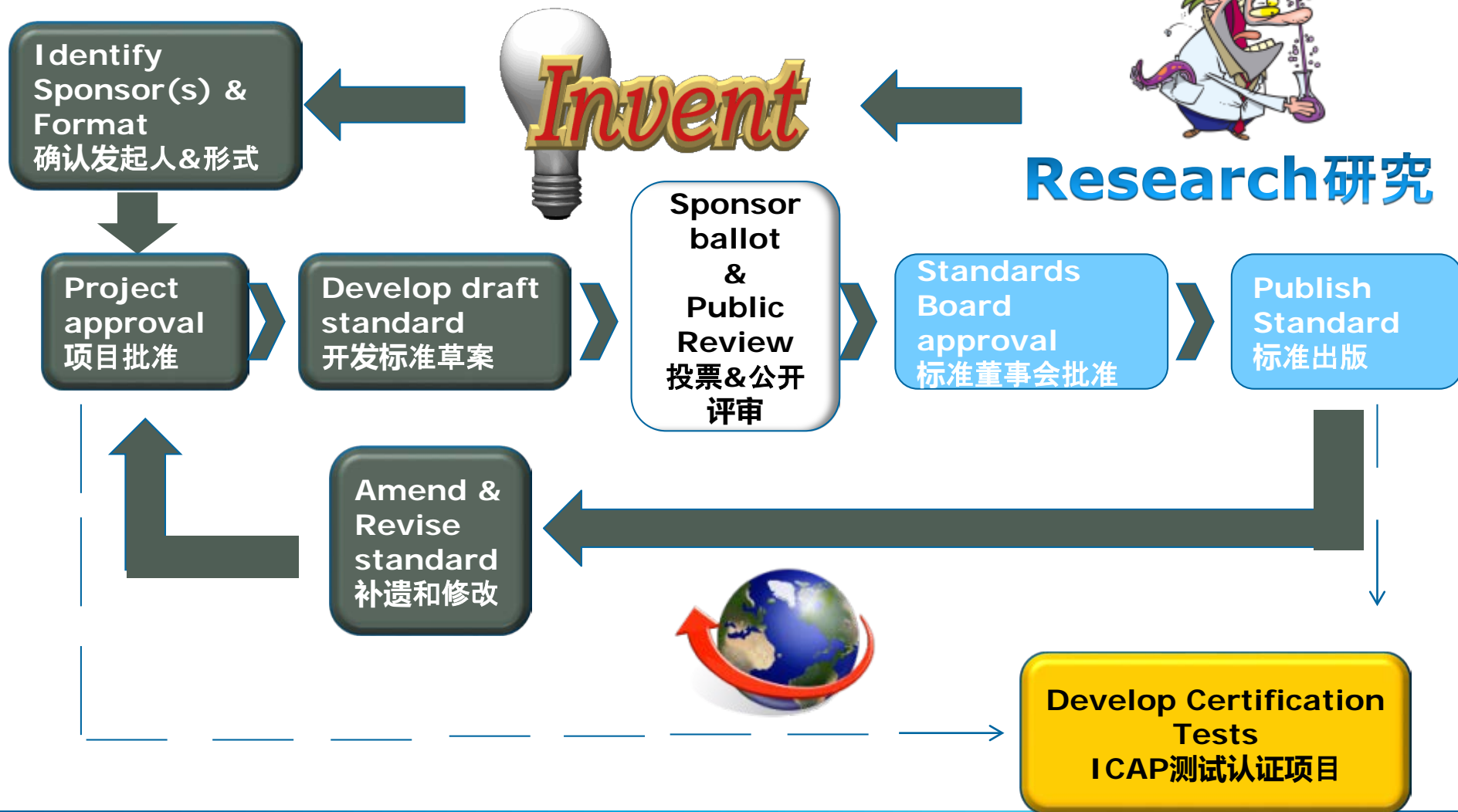
… the IEEE standards process is also flexible enough to operate in other ways too

Companies feed tested features back into standards

Standards group	Industry association	Vendors

Standards group — IEEE 802

Technical
- Defines complex, feature-rich technical standards for PHY/MAC

Bloat-ware

Industry association — Wi-Fi ALLIANCE

Technical
- Specifies subsets of IEEE standards
- Undertakes limited compatibility testing

Marketing
- Supports industry-wide branding and communications

Minimal-ware

Vendors

Technical
- Adds differentiating features based on standards, but often before standards

Marketing
- Markets wireless products

Sales
- Sells & supports wireless products

Differentiated-ware

IEEE-SA defines a Corporate Program for companies to directly influence standards

- Influence technology development
  - Incubate new technologies, standards and related services in a rapidly changing environment
  - Shape the direction of technology and its market place applications
- Drive the development of corporate standards
  - Gain advanced knowledge by engaging in corporate standards projects
- Network with global thought leaders

http://standards.ieee.org/develop/corpchan/

Advanced Members

Basic Members

IEEE-SA works with other international SDOs

ISO	• ISO/IEEE PSDO Agreement address adoptions and joint development work between the ISO and IEEE
	• Currently covers the following areas:
	  • ISO TC 204 — Intelligent transportation
	  • ISO TC 215 — Health Informatics
	  • ISO/IEC JTC 1 — All subcommittees

IEC	• IEC/IEEE Dual Logo Agreement was signed in 2002 to approve IEEE Standards are eligible for adoption by IEC • IEC/IEEE Joint Development Agreement was signed in 2008. It provides an IEEE Working Group and an IEC Maintenance Team the ability to develop one standard with IEC and IEEE logo

ITU	• The IEEE is a Sector Member of
	  • ITU-R (Radiocommunication)
	  • ITU-T (Standardization)
	  • ITU-D (Development)

IEEE 802 has been using the PSDO agreement to ratify the ISO/IEC/IEEE 8802 series of standards

ISO/IEC JTC1/SC6 NBS provide feedback
(for consideration in current or future revisions)

IEEE 802 uses its consensus based process to develop great standards	→	IEEE 802 keeps ISO/IEC JTC1/SC6 NBs informed during process	→	IEEE 802 submits standards for ratification by ISO/IEC JTC1/SC6
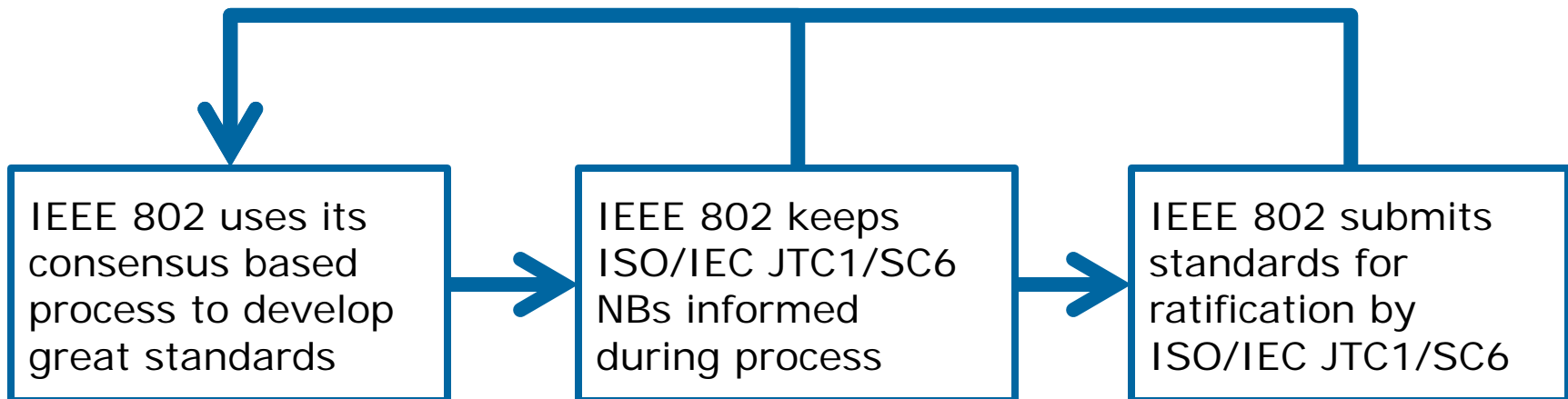
- IEEE 802 uses the PSDO process to:
  - Ensure widest possible review and thus the best possible standards
  - Ensure "international" status (some people only recognise ITU/ISO/IEC)

IEEE 802 has been using the PSDO agreement to ratify the ISO/IEC/IEEE 8802 series of standards

IEEE 802 standard	60-day pre-ballot	5-month FDIS ballot	Comments resolved by IEEE
802	Oct 2014	Nov 2015	Jan 2016
802.1X	2013	Oct 2013	Jan 2014
802.1AE	2013	Oct 2013	Jan 2014
802.1AB	May 2013	Dec 2013	May 2014
802.1AR	May 2013	Dec 2013	May 2014
802.1AS	May 2013	Dec 2013	May 2014
802.1AEbw	Jan 2014	Feb 2015	Apr 2015
802.1AEbn	Jan 2014	Feb 2015	Apr 2015
802.1AX	May 2015	Nov 2015	n/a
802.1Xbx	Mar 2015	Dec 2015	May 2016
802.1Q-Rev	Mar 2015	Jan 2016	May 2016
802.1BA	Sep 2015	Aug 2016	n/a

IEEE STANDARDS ASSOCIATION

IEEE 802 has been using the PSDO agreement to ratify the ISO/IEC/IEEE 8802 series of standards

IEEE 802 standard	60-day pre-ballot	5-month FDIS ballot	Comments resolved by IEEE
802.1BR	Sep 2015	Aug 2016	n/a
802.3	2013	Feb 2014	n/a
802.3.1	Oct 2014	Jun 2015	Apr 2015
802.11	2012	2012	Nov 2013
802.11aa	Feb 2013	Jan 2014	July 2014
802.11ad	Feb 2013	Jan 2014	July 2014
802.11ae	Feb 2013	Jan 2014	July 2014
802.11ac	Sep 2014	Jul 2015	Jul 2015
802.11af	Sep 2014	Jul 2015	Jul 2015
802.22	May 2014	Feb 2015	n/a

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IEEE-SA standardisation is (mostly) driven by an OpenStand culture

The Modern Paradigm for Standards is shaped by adherence to the following five principles:

- Respectful **cooperation** between standards organizations, whereby each respects the autonomy, integrity, processes, and intellectual property rules of the others.

- **Adherence to the five fundamental principles** of standards development:
  - **Due process**: decisions are made with equity and fairness among participants. No one party dominates or guides standards development. Standards processes are transparent and opportunities exist to appeal decisions. Processes for periodic standards review and updating are well defined.

  - **Broad consensus**: processes allow for all views to be considered and addressed, such that agreement can be found across a range of interests.

  - **Transparency**: Standards organizations provide advance public notice of proposed standards development activities, the scope of work to be undertaken, and conditions for participation. Easily accessible records of decisions and the materials used in reaching those decisions are provided. Public comment periods are provided before final standards approval and adoption.

  - …

IEEE STANDARDS ASSOCIATION

IEEE-SA standardisation is (mostly) driven by an OpenStand culture

The Modern Paradigm for Standards is shaped by adherence to the following five principles:

- − …
- − **Balance**: standards activities are not exclusively dominated by any particular person, company or interest group.
- − **Openness**: standards processes are open to all interested and informed parties.

- Commitment by affirming standards organizations and their participants to **collective empowerment** by striving for standards that:
  - − Are chosen and defined based on technical merit, as judged by the contributed expertise of each participant;
  - − Provide global interoperability, scalability, stability, and resiliency;
  - − Enable global competition;
  - − Serve as building blocks for further innovation; and
  - − Contribute to the creation of global communities, benefiting humanity

- …

IEEE-SA standardisation is (mostly) driven by an OpenStand culture

The Modern Paradigm for Standards is shaped by adherence to the following five principles:

- …
- Standards specifications are made **accessible** to all for implementation and deployment.
  - Affirming standards organizations have defined procedures to develop specifications that can be implemented under fair terms. Given market diversity, fair terms may vary from royalty-free to fair, reasonable, and non-discriminatory terms (FRAND).
- Standards are **voluntarily adopted** and success is determined by the market.

It is easy to find out about and participate in the IEEE-SA standardization process

Start
- At the IEEE Standards Association home page: http://standards.ieee.org/
- IEEE Standards Process: http://standards.ieee.org/develop/overview.html

Find
- PROJECTS by topic: http://standards.ieee.org/develop/project/
- WORKING GROUPS by topic: http://standards.ieee.org/develop/wg/
- Search by SPONSOR: http://grouper.ieee.org/groups/detailed_index.html

Contact
- Ask IEEE-SA staff questions: http://standards.ieee.org/contact/form.html
- Reach out to the working group contact to join the working group

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IEEE 802 ◈IEEE

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5G is defined by many to encompass three main groups of features, but it might be more or less
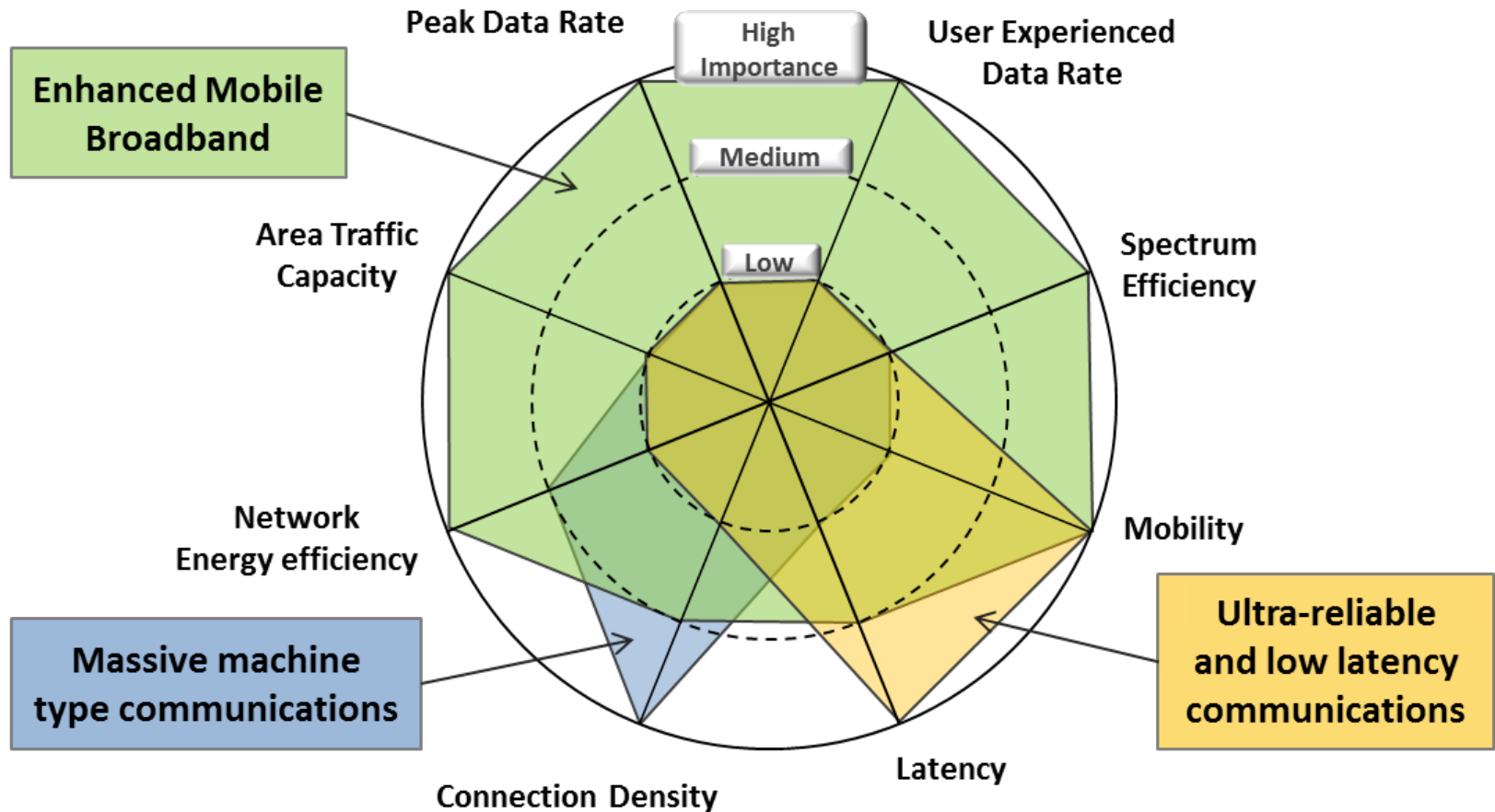
IEEE has defined goals and objectives for its 5G Initiative

Goals & objectives

| **Foster** collaboration & connect technical & business communities to IEEE 5G experts and resources | **Establish** IEEE as a thought leader & essential to the 5G community, academia and government working on 5G | **Develop & promote** valued programs, products and services for the 5G community |

| **Present** a single IEEE face/voice to the 5G marketplace | **Capture** the requirements of all global regions | **Create** a neutral platform/forum where those interested in 5G can engage and collaborate | **Catalyze** IEEE cross-society 5G activities |

IEEE's 5G initiative made a great start in 2016 …

- Initiated launch
  - Convened 2 day kick-off workshop in late August 2016
  - Attended by over 30 volunteers/staff representing 12 societies/councils/OUs
  - Held Steering Committee Meeting in November 2016
- Formed Working Groups
  - Established volunteer led Working Groups to drive activity including: Web Portal, Content Development, Community Development, Standards, Education, Publications, Branding, Roadmap, Events and Industry Engagement
- Conducted 5G Summits
  - Held 8 summits across the world: US, China, Germany, India, and Denmark

- Developed roadmap
  - At Globecom workshop
  - Launched Technical Working Groups including Standardization Building Blocks, Mobile Edge Cloud, Massive MIMO and Millimeter Wave
- Launched IEEE 5G Web Portal
  - In Oct 2016l
- Initiated IEEE 5G Newsletter
  - Named Editor-in-Chief, Managing Editor and Assistant Managing Editor

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IEEE 802   IEEE

… and has plans for a great 2017 too! ☺

- 5G Summits (www.5gsummit.org)
  - Continue to conduct summits on a global basis
- Roadmap
  - Develop an IEEE 5G Whitepaper & roadmap modeled after the ITRS Roadmap
- Publications
  - Launch an IEEE 5G Tech Focus publication with original content focused on a broad audience
- Web Portal/Content Development
  - Refresh the portal on a regular basis with original content including written Q&As, interviews, opinion pieces and podcasts

- Community Development
  - Establish & build a global, engaged IEEE 5G Community through channels including Collabratec, Twitter and LinkedIn
- Education
  - Introduce a series of webinars and tutorials
- Standards
  - Inventory, update and track 5G related standards activity across industries
- Conferences
  - Begin planning for a WF-5G Conference in Jul 2017

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The Roadmap Project is making progress with six Working Groups underway
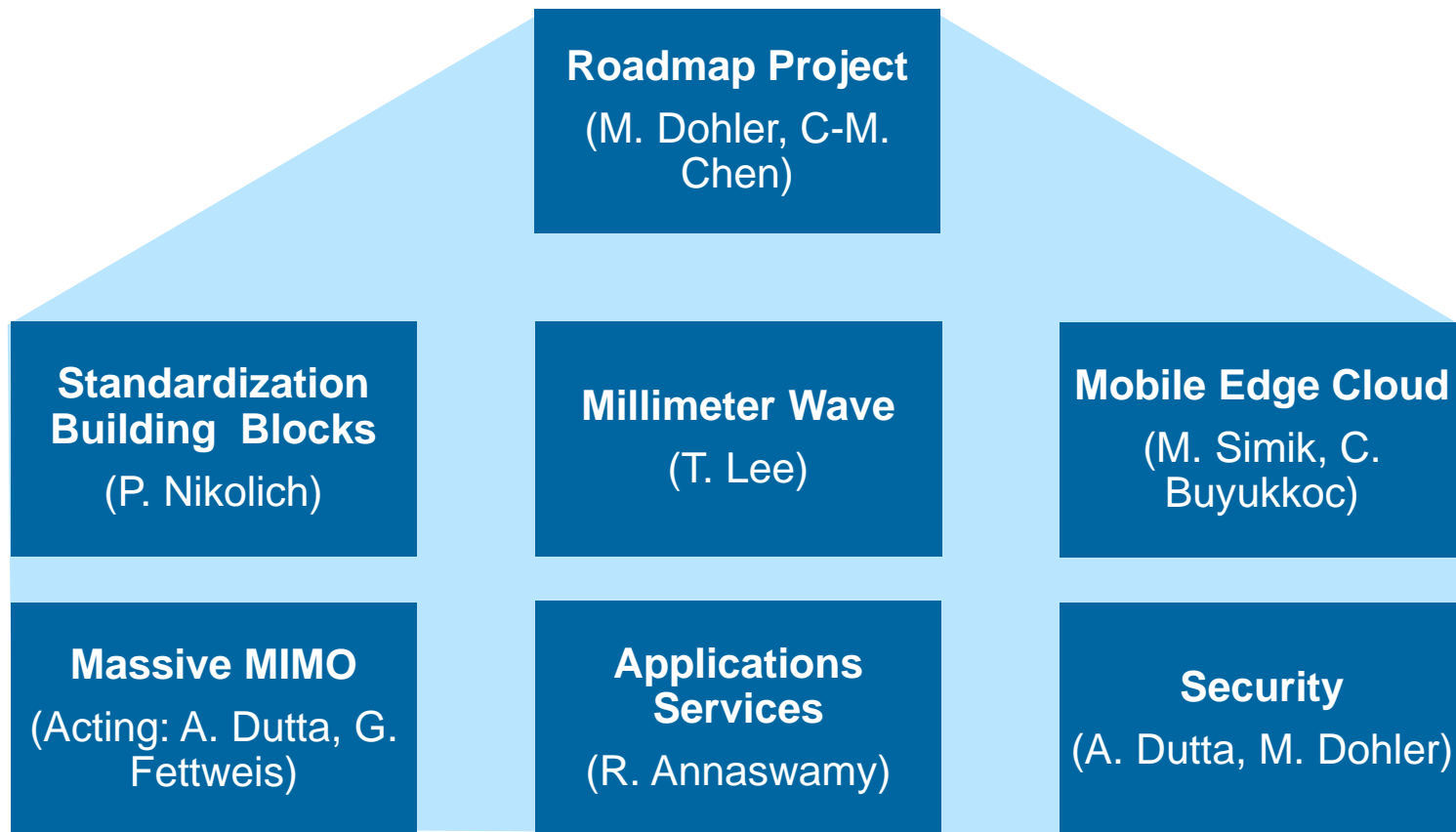
Roadmap Project
(M. Dohler, C-M. Chen)

Standardization Building Blocks
(P. Nikolich)

Millimeter Wave
(T. Lee)

Mobile Edge Cloud
(M. Simik, C. Buyukkoc)

Massive MIMO
(Acting: A. Dutta, G. Fettweis)

Applications Services
(R. Annaswamy)

Security
(A. Dutta, M. Dohler)

The Roadmap Project is focused on developing 5G Roadmap for IEEE … and the broader community

Specific Areas of Focus: Create a 5G Roadmap document

- Identify research, innovation and technology trends in the communications ecosystem
  - Short (~3 years)
  - Mid-term (~5 years)
  - Long-term (~10 years)
- Develop a concrete innovation and engagement roadmap guiding the IEEE community towards maximum impact

Representing the broader community

The Roadmap Project is focused on developing 5G Roadmap for IEEE … and the broader community

Near term work (end of Q1 2017)

- Complete the first draft of the roadmap white paper as a guide for:
  - Positioning
  - Scoping
  - Planning
- … which leads to the completion of the roadmap document
- Finalize the roadmap project sub-teams formation
- Add full scope sub-teams to the current 6 sub-teams
  - Standardization Building Block
  - Millimeter Wave
  - Mobile Edge Cloud
  - Massive MIMO
  - Security and Applications

Longer term work (end of Q2 2017)

- Complete the final draft of the roadmap white paper and go through the approval process for publication
- Start to work on the roadmap document, tentative title:
  - *Global Wireless Roadmap – 5G and Beyond*

An outline of the 5G Roadmap White Paper has been developed

1. **Introduction**
    1.1. Roadmap Process
    1.2 Roadmap Structure
2. **Charter or Mission**
3. **Scope (of roadmap)**
    3.1 Beyond 5G
    3.2 Roadmap timeframe
    3.2 Topics
4. **Stakeholders**
    4.1. Industry Interactions
    4.2. Recognition of Other Efforts
5. **State of Technology (5G Industry Description)**
    5.1. Industry Structure
      5.1.1 Communication Networks
      5.1.2 Distribution
      5.1.3 Other
    5.2. Trends
    5.3. Drivers
    5.4 Applications/Markets (Verticals)

6. **Challenges**
    6.1 The Wireless Roadmap
    6.2 The Massive Connectivity
    6.3 The Tactile Internet
    6.4 Negotiating Service Quality
    6.5 Service Oriented Connection
    6.6. Any-Books
    6.7 Other…
7. **Technology Needs & Potential Solutions**
    7.1 Critical Technology Needs & Solutions
    7.2 Applications Services Needs
    7.3 Security Needs
    7.4 Standardization Building Blocks Needs
    7.5 Other ...
8. **Dependencies and Linkages**
9. **Conclusions**
10. **References**
11. **Acknowledgments**
12. **Appendix**

The 5G Standardization WG is focusing on an inventory of standards

Specific Areas of Focus

- Inventory of all '5G related' standards activity across the industries that are engaged in next generation networking standards development

- … and create a means of dynamically updating and tracking the activities as they evolve

- Scope: all industries engaged in next generation network standards development

Accomplishments to Date

- Agreed on missions statement for Standards Road Map

- Populated <u>Standards web portal</u> with IEEE 802 LMSC content

Problems/Issues and Proposed Solutions

- Lack of dedicated staff resource to drive development of the Road Map

- Solution: hire consultant , funds allocated, pending contract finalization

…

The 5G Standardization WG is focusing on an inventory of standards

…

Near Term Activities/Deliverables (end of Q1 2017)

- Finalize consultant contract, begin organization of Road Map effort
- Begin Standards Road Map project in earnest
- Solicit additional content for the Standards web portal

Longer Term Activities/Deliverables (end of Q2 2017)

- Complete Standards Road Map outline, conduct face-to-face consensus meetings among industry stakeholder
- Create draft text for Road Map sections

IEEE 5G initiative's unique positioning is that it is global, inclusive, broad and open

Global	Engineering individuals from every corner of the globe
Inclusive	Industry, government, academia, individuals, NGOs e.g., NGMN
Broad	All sectors, e.g. education, vehicular, manufacturing, communications, health, computing, agriculture.
Open	Any standards e.g., 3GPP, ITU, IEEE 802 & P19xx.

TIME FOR A BREAK!

Today's presentation is going focus on IEEE-SA standardisation, particularly in context of 5G

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IEEE 802 develops standards for local, metropolitan and other area networks …

From the IEEE 802 website

- *The IEEE 802 LAN/MAN Standards Committee develops and maintains networking standards and recommended practices for:*
  - *Local*
  - *Metropolitan*
  - *and other area networks,*
- *… using an open and accredited process, and advocates them on a global basis.*
- *The most widely used standards are for:*
  - *Ethernet*
  - *Bridging and Virtual Bridged LANs*
  - *Wireless LAN*
  - *Wireless PAN*
  - *…*
- *An individual Working Group provides the focus for each area.*

… particularly focusing on link and physical layers of the network stack since 1980

OSI Reference Model

Application
Presentation
Session
Transport
Network
Data Link
Physical
Medium

IEEE 802 focus
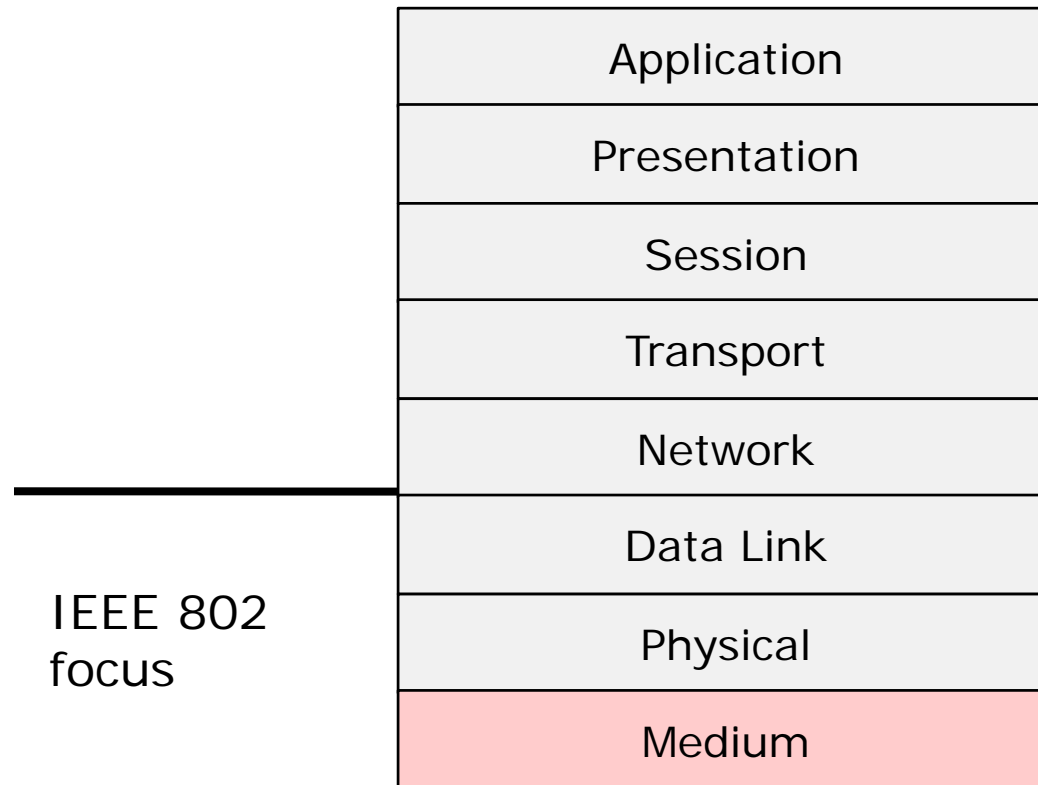
… allowing IEEE 802 to enable (along with higher layer standards) the apps we all rely on every day

- Internet Infrastructure (core, regional, metro, local)

- Data Center Networks
                                                          Traditional

- Enterprise and Home Networks

- Sensor Networks

- Intra and Inter Vehicle Networks
                                                          Emerging

- Manufacturing Networks

- Gaming, Entertainment and Media Networks

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IEEE 802 currently has ten active working groups …

Current IEEE 802.11 WGs

- 802.1 Higher Layer LAN Protocols Working Group

- 802.3 Ethernet Working Group

- 802.11 Wireless LAN Working Group

- 802.15 Wireless Personal Area Network (WPAN) Working Group

- 802.16 Broadband Wireless Access Working Group

- 802.18 Radio Regulatory TAG

- 802.19 Wireless Coexistence Working Group

- 802.21 Media Independent Handover Services Working Group

- 802.22 Wireless Regional Area Networks

- 802.24 Vertical Applications TAG

… but has worked on many other activities over the years

Hibernating groups

- 802.20 - Mobile Broadband Wireless Access (MBWA) WG

Closed groups

- 802.2 - Logical Link Control WG
- 802.4 - Token Bus WG
- 802.5 - Token Ring WG
- 802.6 – Metropolitan Area Network WG
- 802.7 - Broadband TAG
- 802.8 - Fiber Optic TAG

- 802.9 - Integrated Services LAN WG
- 802.10 - Security WG
- 802.12 - Demand Priority WG
- 802.14 - Cable Modem WG
- 802.17 - Resilient Packet Ring WG
- 802.23 Emergency Services WG

IEEE STANDARDS ASSOCIATION

IEEE 802 has proven to be very successful by producing standards desired by billions

Examples of networks driven by IEEE 802 standard

Wi-Fi driven by
IEEE 802.11

Zigbee driven by
IEEE 802.15.4

Ethernet driven by
IEEE 802.3

IEEE 802 success is also driven by a variety of non-technical attributes related to process and culture

Market Relevant

- Industry driven by 1,000s of individual volunteers and hundreds of companies seeking consensus to satisfy demands of their respective markets

High Quality

- Broad and deep technical 'hyper-peer review' by 1,000s of individual world experts

Market Driven

- Performance requirements defined by producers and users

Low cost

- High volumes & multi-vendor result in very low fixed and operational costs: components, systems and services

Dynamic and adaptive

- Rapidly responding to changing markets

Collaborative

- Close relationships with SDOs and Alliances

Highly respected and used world-wide

Humorous aside: success in IEEE 802 actually requires a odd numbered working group

Success

- 802.1
- 802.3
- 802.11
- 802.15

Not sure yet

- 802.21
- 802.22
- 820.24

Others

- 802.18
- 802.19
- 802.24

Not success

- 802.2
- 802.4
- 802.5
- 802.6
- …
- 802.16
- 802.17
- …
- 802.20
- 802.23

IEEE 802 started formally considering 5G related issues in late 2015

- In late 2015 there was increasing activity in other organisations talking about 5G
  - ITU, 3GPP, academia, NGMN, etc

- IEEE 802 became interested as it became clearer that the definition of 5G was very broad, and Wi-Fi/802.11 fitted within its scope
  - In a sense Wi-Fi is already 5G

- The original focus was on the ITU-R activity related to IMT-2020, as a way of getting access to additional spectrum for Wi-Fi

- However, this focus was dropped when it became clear the IMT-2020 work was mostly about spectrum with less interest for Wi-Fi

- Instead, IEEE 802 decided on two actions to ensure IEEE 802 technology was "officially" part of 5G
  - Note: it already "unofficially" 5G, and that is not likely to change

IEEE 802 is now working on three actions formally associated with 5G

Action A

- Develop an Industry Connections project (organized by IEEE 802.1 WG) to evaluate IEEE 802 as part of 5G
- Project approval occurred in March 20 2017: see here

Action B3

- Liaise with 3GPP (organized by IEEE 802.11 WG) to integrate/include 802.11 Radio Access Technology with LTE

Spectrum

- Look for new spectrum for IEEE 802 to support 5G
- Spectrum topics are led by 802.18 Radio Regulations Technical Advisory Group (RR TAG)
- There is a particular focus on new 6 GHz spetrum

Note further details can be found

- See http://ieee802.org/Stand_Com/5G/ and here

Action A: IC project enables wide industry participation to identify new applications & standards

- The goal of this activity is to:
  - assess, outside of the IMT activity, emerging requirements for IEEE 802 wireless and higher-layer communication infrastructures
  - identify commonalities, gaps, and trends not currently addressed by IEEE 802 standards and projects,
  - facilitate building industry consensus towards proposals to initiate new standards development efforts.
- Encouraged topics include:
  - Enhancements of IEEE 802 communication networks and vertical networks
  - Enhanced cooperative functionality among existing IEEE standards in support of network integration.
- Findings related to existing IEEE 802 standards and projects will be forwarded to the responsible working groups for further considerations.

Action B3 – liaise with 3GPP to integrate 802.11 Radio Access Technology into their technologies as 5G

Likely topics

- Extensions to 802.11 to support WLAN integration into 3GPP

- LWA & LWIP
    - 3GPP Release-13 includes LTE-WLAN Aggregation (LWA) and LTE WLAN Radio Level Integration with IPsec Tunnel (LWIP)
    - Completed March 2016.

- eLWA
    - Enhanced LWA (eLWA) included in Release-14
    - Main topics are: uplink support, enhanced mobility, optimizations for high data rate 802.11 technologies (802.11ax, 802.11ad and 802.11ay).

- LAA/eLAA
    - License Assisted Access (LAA) channel access behavior can potentially severely impact 802.11 device performance
    - Extensive liaison activity (from IEEE 802.19 and IEEE 802.11 PDED ad hoc); most recently, see here

Coexistence of different technologies in the same band is a potential issue for 5G

- A key aspect of 5G is its likely technology diversity
  - LTE, Wi-Fi, LORA, Zigbee, … and many others
  - This is good because diversity means use cases are addressed by more specialised technologies
- In an ideal world these technologies would operate independently …
- … but we don't live in an ideal world
- A problem has arisen recently in the context of coexistence in the 5GHz unlicensed band between
  - Wi-Fi/802.11 from IEEE 802
  - LAA & eLAA from 3GPP
  - LTE-U from LTE-U Forum
  - MulteFire from MulteFire Alliance
- The various LWA variants have avoided the issue by using LTE in licensed bands and Wi-Fi in unlicensed bands
  - Maybe this is the best solution?

IEEE 802 and 3GPP have not yet agreed on how 802.11 and LAA should coexist

- The open question is how to the various technologies can coexist given their different architectures and mechanisms?

- There are at least two issues of interest when considering coexistence between 802.11 and LAA/eLAA
  - Mechanisms for detecting each other … so they can avoid collisions
  - Differences between sync architecture of LAA and async architecture of 802.11

- There is ongoing work between IEEE 802 and 3GPP to resolve these issues but there is not yet consensus

Similar coexistence issues exist between Wi-Fi and non 3GPP technologies

LTE-U

- LTE-U has been defined by LTE-U Forum

- Coexistence between Wi-Fi and LTE-U was also contentious but it appears a détente has been reached
  - The Wi-Fi Alliance developed a test plan for coexistence under direction of FCC, although it is not clear it is sufficient to show coexistence
  - LTE-U is mostly only relevant to US (and some Asian countries)
  - Many expect/hope that LTE-U will have no market relevance

MulteFire

- MulteFire is being defined by MulteFire Alliance

- It is essentially LTE operating in unlicensed band without any need for License Assisted Access

- There has not been much discussion about coexistence
  - It is expected issues will be resolved similarly to LAA
  - Some expect MulteFire to fail in market as it is a Wi-Fi clone without ecosystem

The question of fair access for Wi-Fi and LAA is still an open discussion between IEEE 802 & 3GPP

- 802.11 uses two mechanisms to detect other systems
  - Preamble detection (PD) @ -82dBm detects other 802.11 systems
  - Energy detection (ED) @ -62dBm detects other systems more generally
  - RTS/CTS to handle hidden stations
- LAA uses only ED @ -72dBm to detect other systems
- 3GPP asserts the use of ED @ -72dBm results in "fair" sharing with 802.11
  - Although in a contradiction, they also requested that 802.11 adopt ED @ -72dBm
  - The assertion was made based on simulation, which is depends very much on the underlying assumptions
- A review shows there is a high likelihood of unfairness in many cases, eg
  - 802.11 defers to 802.11 at -82 dBm, whereas LAA does not
  - LAA defers to LAA at -72dBm, whereas 802.11 does not
  - LAA does not defer in many hidden stations scenarios
- The two organisations have agreed to disagree at this time, but is hoped 3GPP RAN4 defined testing will provide more insight

The question of synchronisation between Wi-Fi and LAA is still an open discussion

- LAA is mostly based on access for a frame at a synchronous 1ms clock tick (like LTE), whereas 802.11 access is mostly asynchronous

- The problem arises when the two mechanisms are combined
  - LAA often needs to wait between the time in gains access to the medium and the next 1ms clock tick
  - 802.11 may grab the medium in the meantime, locking LAA out
  - One solution is for LAA to transmit blocking energy to stop 802.11 grabbing the medium
  - However, this is contrary to principle (and sometimes law) in unlicensed spectrum that you do not transmit for the purpose of blocking

- This issue has led to multiple liaisons between 3GPP and IEEE 802
  - Strangely, 3GPP were asserting that LAA did not need the blocking energy, and yet were reserving the right to send it

- The issue may be resolved as 3GPP defines shorter clock ticks
  - A similar issue at the end of a fixed frame may also be solved by use of variable length frames

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LTE-WLAN Aggregation LWA: Overview

- Allows aggregating LTE and WLAN at RAN level
- WLAN AP/AC only interacts with the LTE eNB; no interaction with LTE Core Network
- Key drivers: performance, mobility, eliminating need for WLAN-specific Core Network nodes
- LWA is controlled by E-UTRAN Node B(eNB), based on User Equipment (UE) measurement reporting
- Formally completed at RAN#71 in March 2016

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A Plan for IEEE 802 and 3GPP to work together (2016)

The 802 EC has sent an liaison to the 3GPP PCG:
https://mentor.ieee.org/802-ec/dcn/16/ec-16-0158-00-00EC-final-liaison-1-to-pcg-from-802.pdf, or
http://www.3gpp.org/ftp/PCG/PCG_37/docs/PCG37_32.zip

The 802.11 liaison (https://mentor.ieee.org/802.11/dcn/16/11-16-1101-10-0000-draft-ls-from-802-11-to-3gpp-ran-and-sa-on-imt-2020.docx, or
PCG37_20) that 802.11 sent to 3GPP TSG RAN (RAN) and 3GPP TSG SA (SA) in September, was referred to the 3GPP PCG by RAN and SA. Both RAN and SA has asked the PGC to provide their views on how RAN, SA, and 802.11 can interact/work together.

Both of these liaisons were discussed at PCG meeting on 20 October 2016, in London, UK.
(https://portal.etsi.org/webapp/MeetingCalendar/MeetingDetails.asp?m_id=32036). A decision was made at the meeting to encourage and promote interaction between 3GPP and 802.   The next PCG meeting will be 25 April 2017.

Based on a recent 3GPP PCG statement it is hoped that IEEE 802/3GPP collaboration will continue

In October 2016 in 3GPP PCG agreed to continue work with IEEE 802

- *3GPP PCG believes that the existing collaboration between our organizations has proven to be extremely productive and efficient, resulting in increased interconnectivity and many positive outputs for the interworking and aggregation between 3GPP and IEEE 802 technologies*

- *Furthermore, 3GPP PCG believes that the existing collaboration has served the industry well. 3GPP PCG believes the communication and exchange of information between our organizations has proven successful via existing representation at meetings in our respective organizations*

- *We understand this technical cooperation went further with LAA and we encourage further technical collaboration in this manner in the future.*

- *We believe the existing formal and informal processes are sufficient to achieve successful collaboration*

Today's presentation is going focus on IEEE-SA standardisation, particularly in context of 5G

|	
1	IEEE overview and standards development
2	IEEE 5G initiative
3	IEEE 802 5G activities (and 3GPP coordination)
4	**IEEE 802.11 network evolution**

IEEE 802.11 has had a massive global impact based on meeting the needs of billions of users

- IEEE 802.11 was originally conceived for linking wireless cash registers …

- … but today, it underpins a diversity of applications in over 10B devices

- A key factor in its success is not perfection but is its ability to allow "anyone, anytime, anyplace" to connect to the network in a way that is "just good enough" (and often for no direct charge)
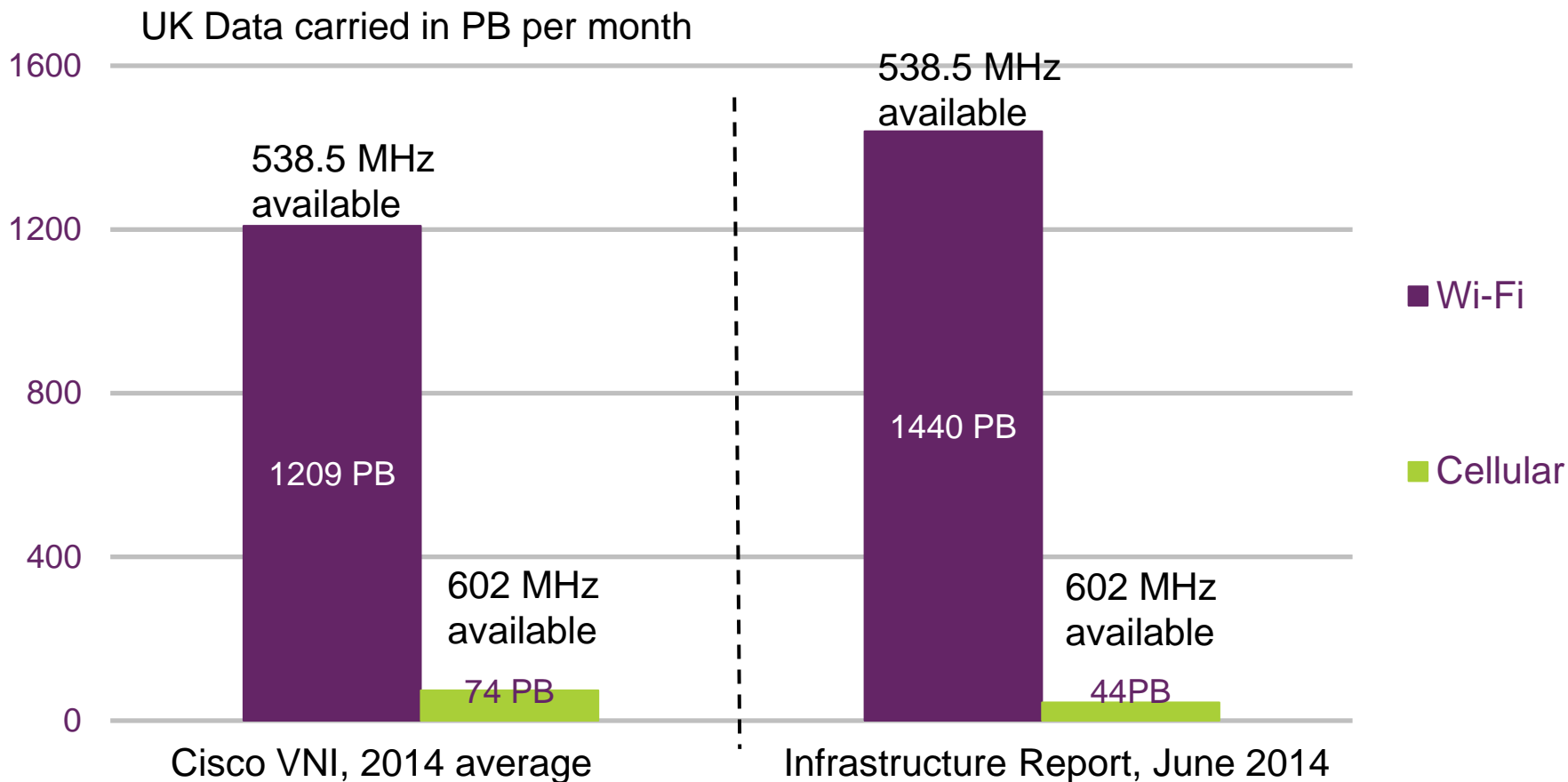
Wi-Fi can meet the needs of a single home user … … or a whole stadium users
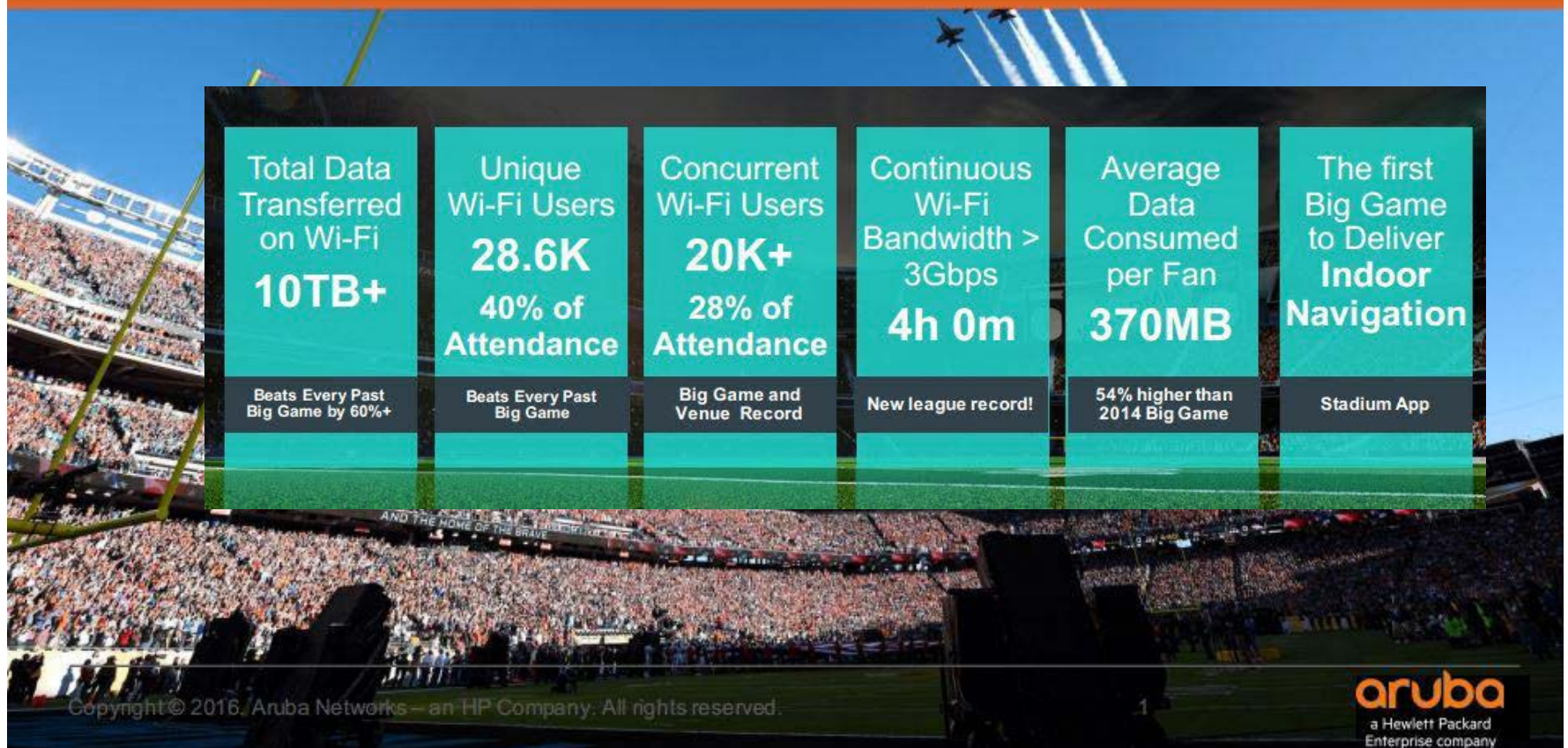
Source: Aruba/HPE, used with their permission

Despite access to less spectrum, Wi-Fi is used much more than cellular (and the gap is forecast to increase)
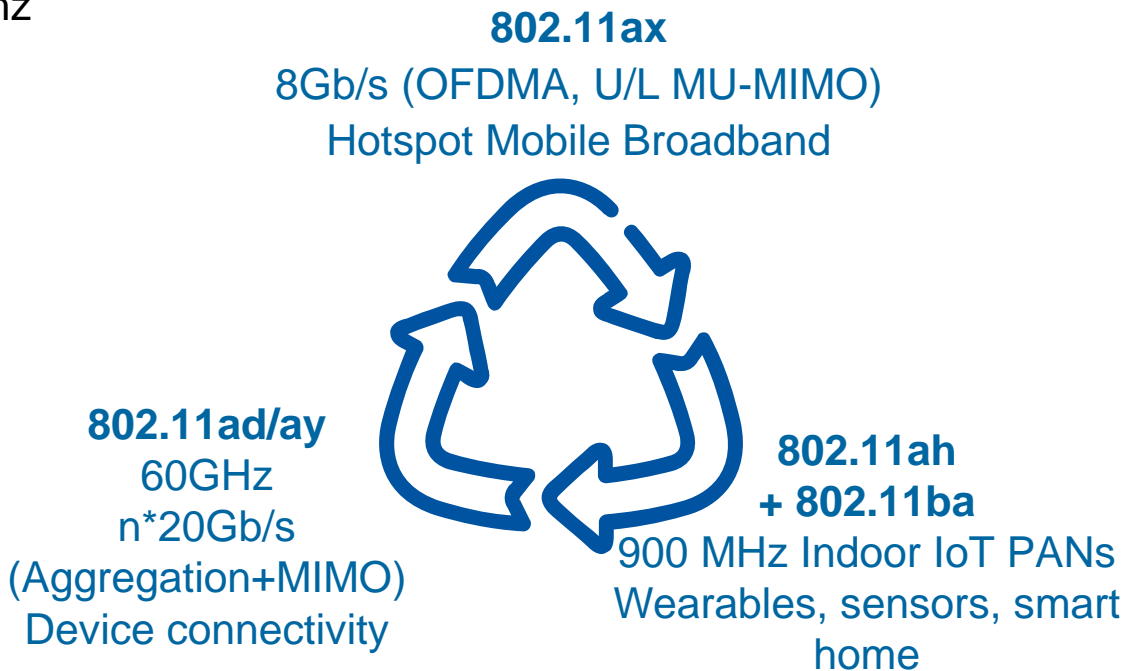

UK Data carried in PB per month

- Wi-Fi
- Cellular

538.5 MHz available — 1209 PB (Cisco VNI, 2014 average)
602 MHz available — 74 PB (Cisco VNI, 2014 average)

538.5 MHz available — 1440 PB (Infrastructure Report, June 2014)
602 MHz available — 44PB (Infrastructure Report, June 2014)

IEEE 802.11 will be part of any 5G solution, and is already 5G in many respects

- Given the diversity of proposed 5G applications, it is certain any 5G solution will need to utilise a diversity of network access types

- There is no doubt that 3GPP will define some of those network access types …

- … but there is also no doubt that IEEE 802.11 will be a key network access type for the foreseeable future:
  - It has a massive existing and growing ecosystem
  - Its typical direct cost is close to zero
  - It "just works" for billions of people today
  - It continues to evolve to meet new needs
  - …

- Indeed it is arguable that IEEE 802.11 is already 5G given the diversity of use cases it already satisfies
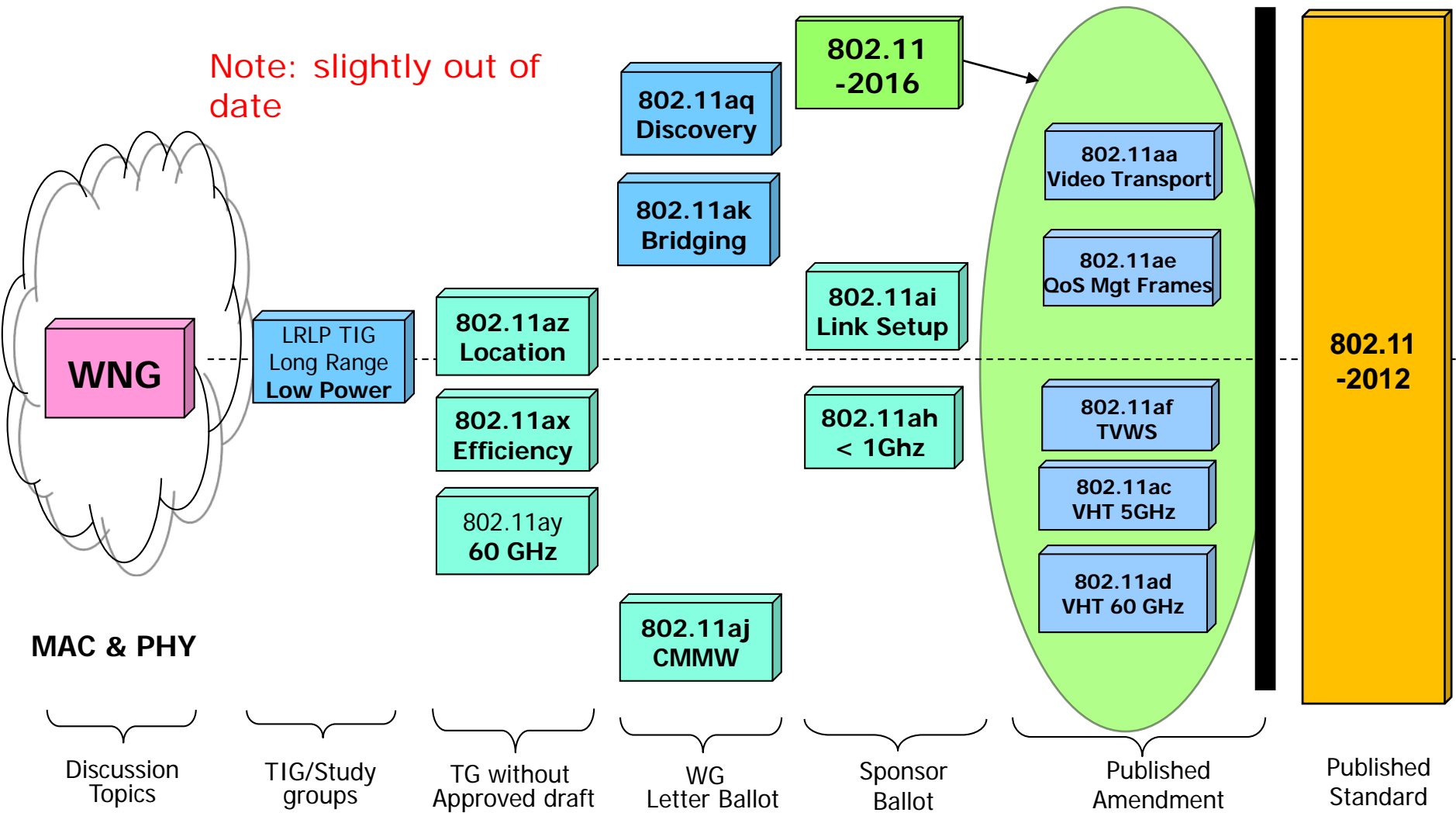
IEEE 802.11 as 5G needs to consider 802.11ax/ah/ad/ay as well as LWA/eLWA/LWIP

- The obvious conclusion for anyone interested in 5G is that they must include IEEE 802.11 and ways of interfacing with IEEE 802.11 in their plans
    - IEEE 802.11ax at 2.4GHz and 5GHz (and other amendments)
    - IEEE 802.11ah at 900MHz
    - IEEE 802.11ad/ay at 60Ghz
    - 3GPP LWA/eLWA/LWIP

802.11ax
8Gb/s (OFDMA, U/L MU-MIMO)
Hotspot Mobile Broadband

802.11ad/ay
60GHz
n*20Gb/s
(Aggregation+MIMO)
Device connectivity

802.11ah
+ 802.11ba
900 MHz Indoor IoT PANs
Wearables, sensors, smart home

IEEE 802.11 consists of an alphabet soup of amendments since 1990 but continues to expand

Note: slightly out of date

WNG

LRLP TIG
Long Range
Low Power

**802.11aq
Discovery**

**802.11ak
Bridging**

**802.11
-2016**

802.11az
Location

802.11ax
Efficiency

802.11ay
60 GHz

802.11aj
CMMW

802.11ai
Link Setup

802.11ah
< 1Ghz

**802.11aa
Video Transport**

**802.11ae
QoS Mgt Frames**

**802.11af
TVWS**

**802.11ac
VHT 5GHz**

**802.11ad
VHT 60 GHz**

**802.11
-2012**

MAC & PHY

Discussion
Topics

TIG/Study
groups

TG without
Approved draft

WG
Letter Ballot

Sponsor
Ballot

Published
Amendment

Published
Standard

IEEE 802.11ax is focused on improving performance in dense environments

- Improve performance of Wi-Fi 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

IEEE 802.11ax will include by a variety of features supporting density and efficiency

Features

- Increase network efficiency by multiplexing users in frequency & space
  - UL and DL OFDMA
  - UL MU-MIMO (adding to DL MU-MIMO in 802.11ac)
- Increase spatial reuse through dynamic clear channel assessment (CCA)
- Increase link efficiency time domain, frequency domain and modulation improvements
- Improved support for outdoor operation

Schedule

- Completion 2019

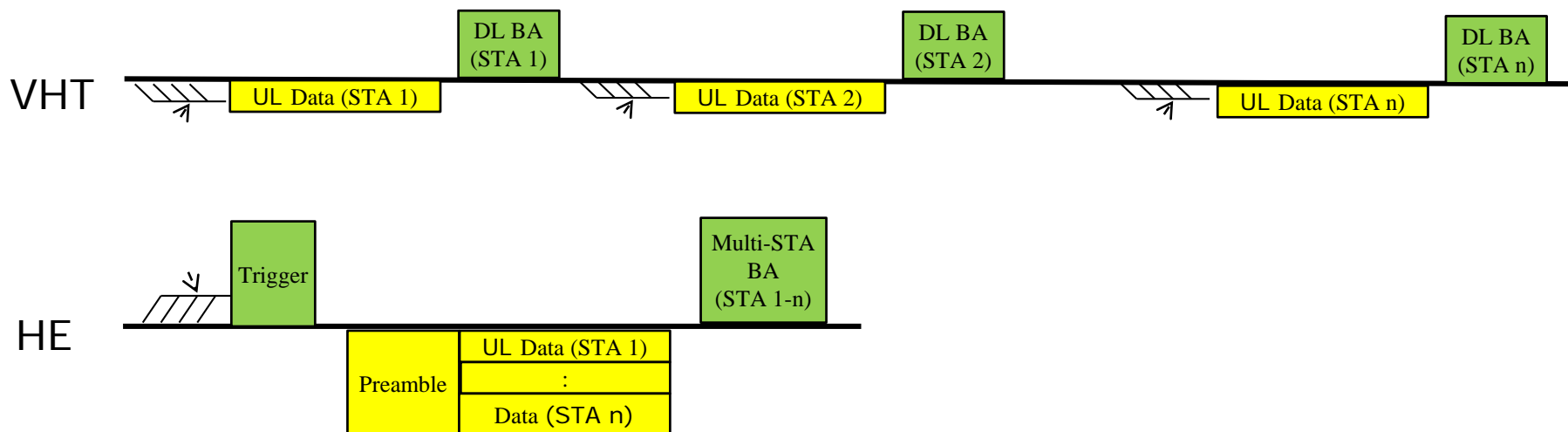# OFDMA and MU-MIMO additions to 802.11ax will increase network efficiency
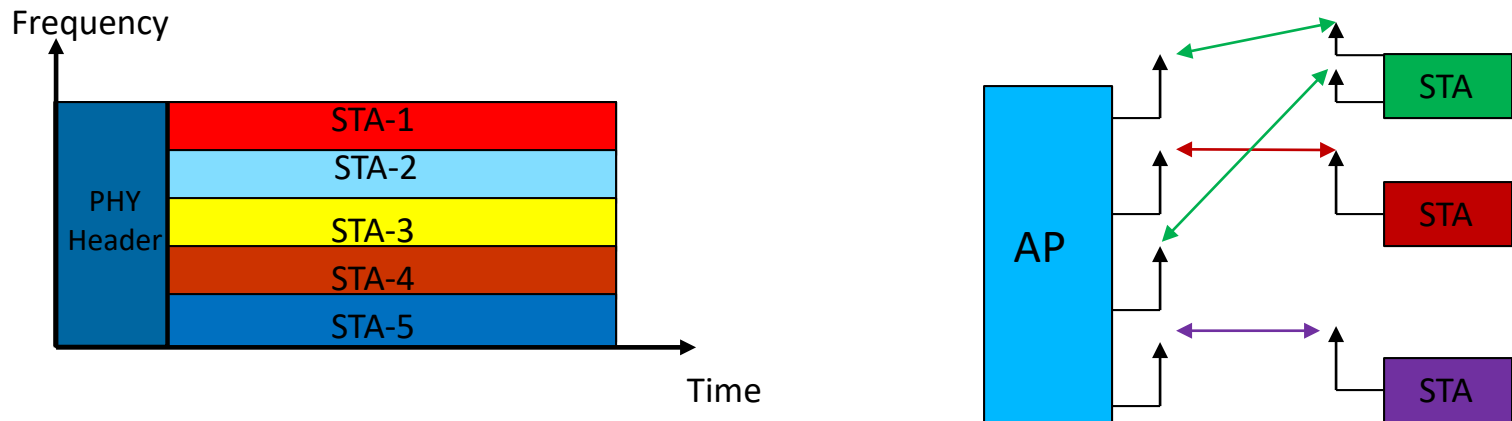
- OFDMA resource allocation is based on buffer status at the STA for better user experience.

- MU MIMO allows a high capability device to simultaneously transmit or receive from a multiple of low capability devices.

UL/DL multi-user links in 802.11ax will support more efficient UL acknowledgments
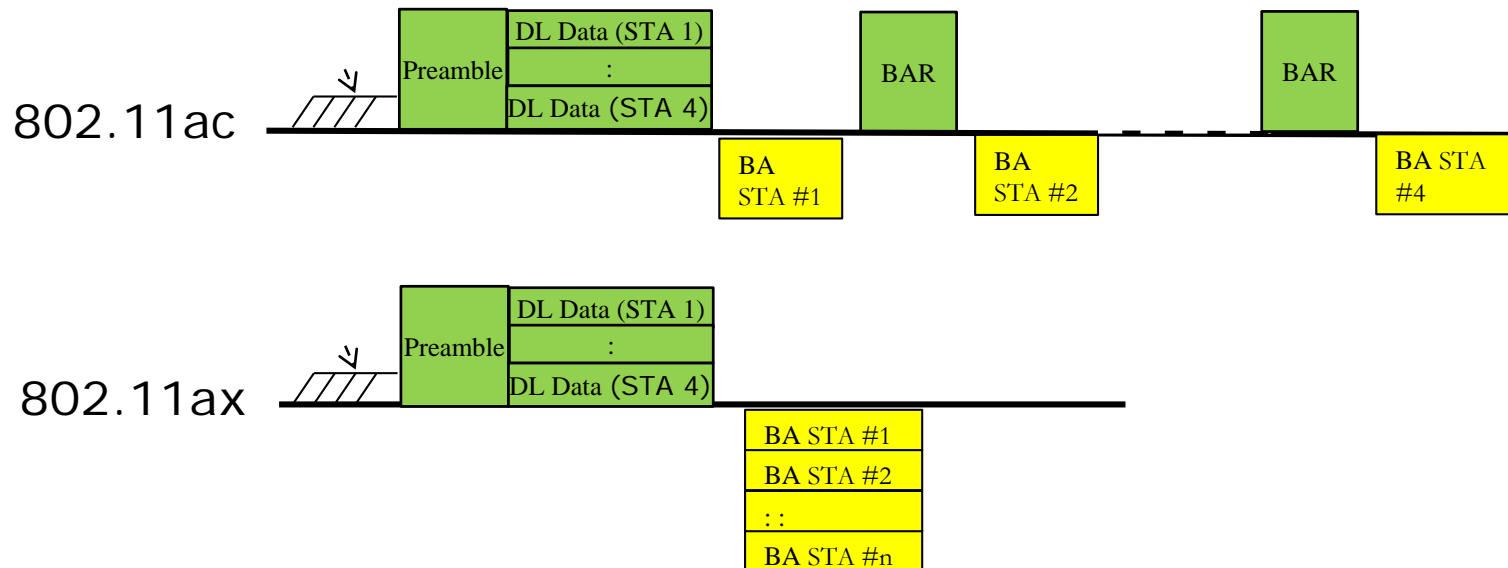
- In a VHT DL MU sequence acknowledgements are serialized
- In an HE DL MU sequence acknowledgements are allocated UL resources and transmitted simultaneously
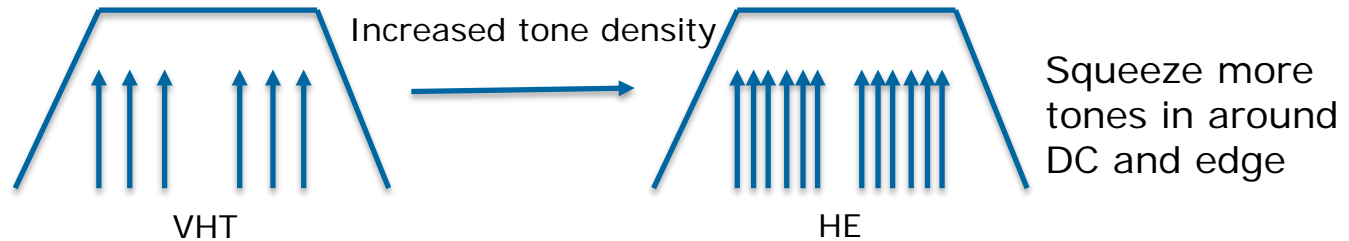
UL/DL multi-user links in 802.11ax will support more efficient UL data

VHT

| | UL Data (STA 1) | DL BA (STA 1) | | UL Data (STA 2) | DL BA (STA 2) | | UL Data (STA n) | DL BA (STA n) |

HE

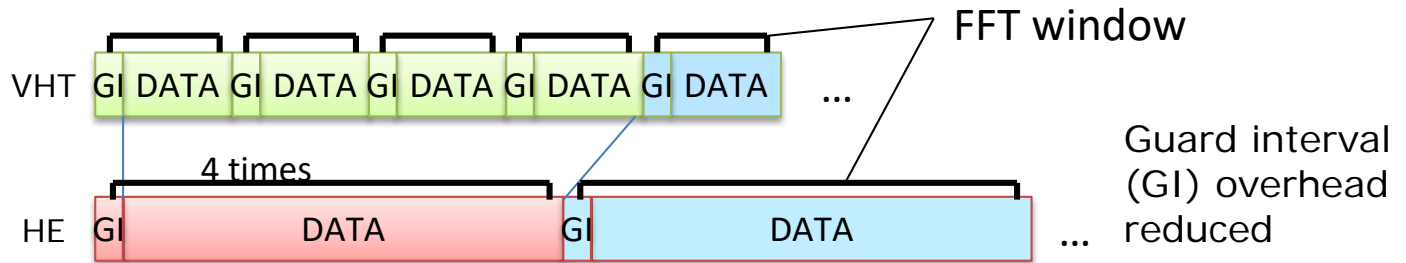Trigger — Preamble — UL Data (STA 1) : Data (STA n) — Multi-STA BA (STA 1-n)

- In a VHT UL sequence, STAs compete for medium access and send sequentially
- In an HE UL sequence, the AP triggers simultaneous transmissions in multiple STAs

Time domain, frequency domain and modulation improvements in 802.11ax will increase link efficiency
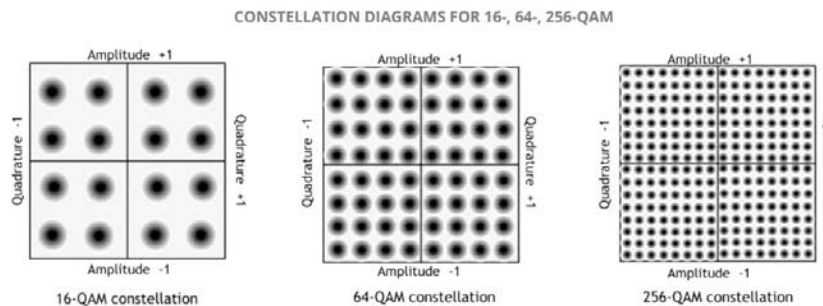

Frequency domain (~5% gain)

Increased tone density

VHT

HE

Squeeze more tones in around DC and edge

Time domain (~15% gain)

FFT window

VHT: GI DATA GI DATA GI DATA GI DATA GI DATA ...

4 times

HE: GI DATA GI DATA ...

Guard interval (GI) overhead reduced

Modulation (~25% gain)

CONSTELLATION DIAGRAMS FOR 16-, 64-, 256-QAM

16-QAM constellation

64-QAM constellation

256-QAM constellation

+ 1024-QAM

Various features in 802.11ax will support improved outdoor operation

- Operates in higher delay spread channels than 11ac:
  - 11ac GI options: 0.4 µs and 0.8 µs
  - 11ax GI options: 0.8 µs, 1.6 µs and 3.2 µs
  - GI overhead mitigated with longer OFDM symbol
- Preamble includes repeated L-SIG
- Extended range preamble includes repeated HE-SIG-A
- Dual carrier modulation improves robustness in Data field

Dynamically adjusted CCA thresholds in 802.11ax will improve frequency reuse
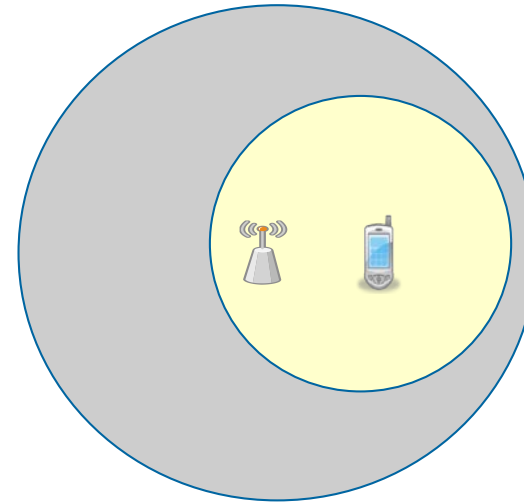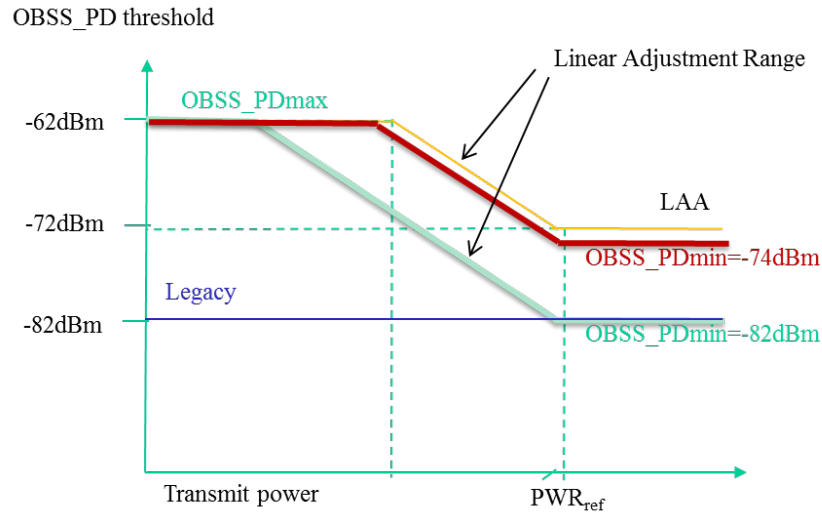
Adjust CCA threshold based on transmit power of device

- A device with low transmit power causes less interference than a device with high transmit power

- CCA threshold is for OBSS traffic

- BSS Color in the PHY header allows the identification of intra-BSS and Inter-BSS PPDUs

802.11ad provides high speed extensions using the 60Ghz band

- 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.

MCS	Data Rate (Mb/s)
1	385
2	770
3	963
4	1155
5	1251
6	1540
7	1925
8	2310
9	2503
9.1	2695
10	3080
11	3850
12	4620
12.1	5005
12.2	5390
12.3	5775
12.4	6390
12.5	7507
12.6	8085

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IEEE 802 ◆IEEE

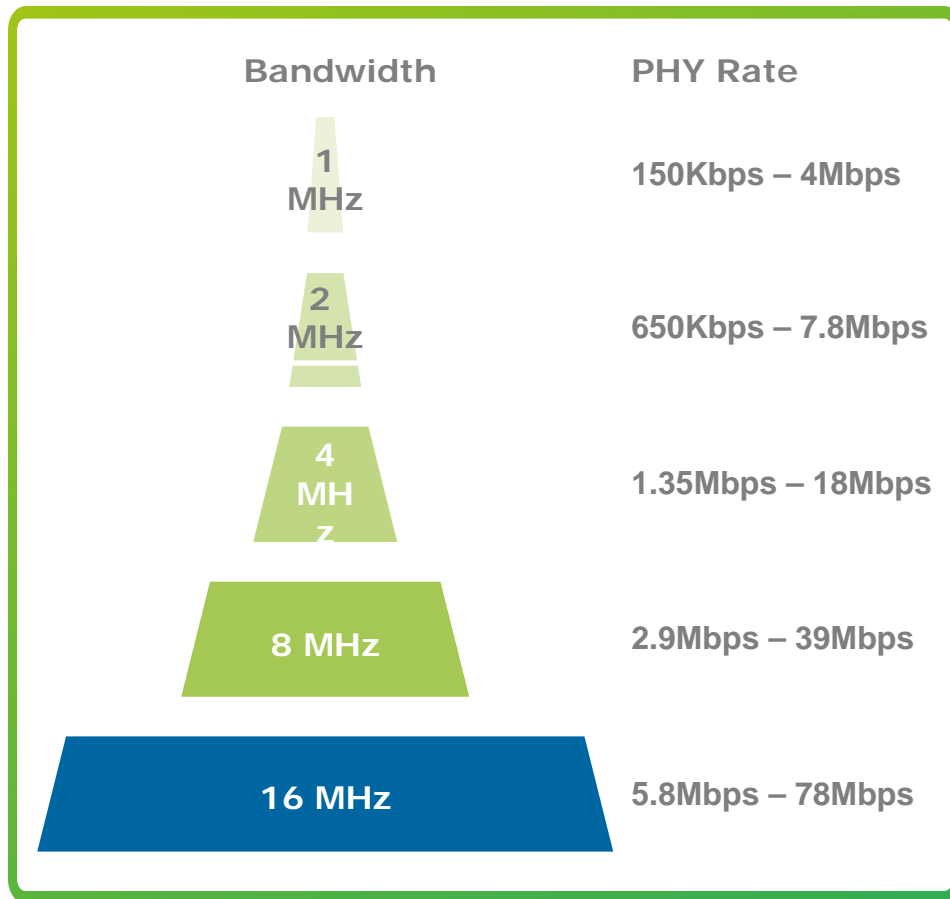# 802.11ay builds on 802.11ad with MIMO and channel bonding features

Use Cases:
- Ultra-Short Range
- 8K UHD - Smart Home
- AR/VR and wearables
- Data Center Inter Rack connectivity
- Video / Mass-Data distribution
- Mobile Offloading and MBO
- Mobile Fronthauling
- Wireless Backhauling
  (w. multi-hop)
- Office Docking

Key additions :
- SU/ MU MIMO
- Channel bonding

IEEE 802.11ah defines a solution for M2M and IoT at 900MHz

Bandwidth	PHY Rate
1 MHz	150Kbps – 4Mbps
2 MHz	650Kbps – 7.8Mbps
4 MHz	1.35Mbps – 18Mbps
8 MHz	2.9Mbps – 39Mbps
16 MHz	5.8Mbps – 78Mbps

- For license exempt bands below 1 GHz
- Enhancements for short packets, reduced power, huge # of devices
  - e.g. machine type communications, home automation, wearable devices
- Extended range connectivity up to 1 km
- IEEE standard approved Dec 2016, publication shortly
- WFA recently started to define HaLow certification program

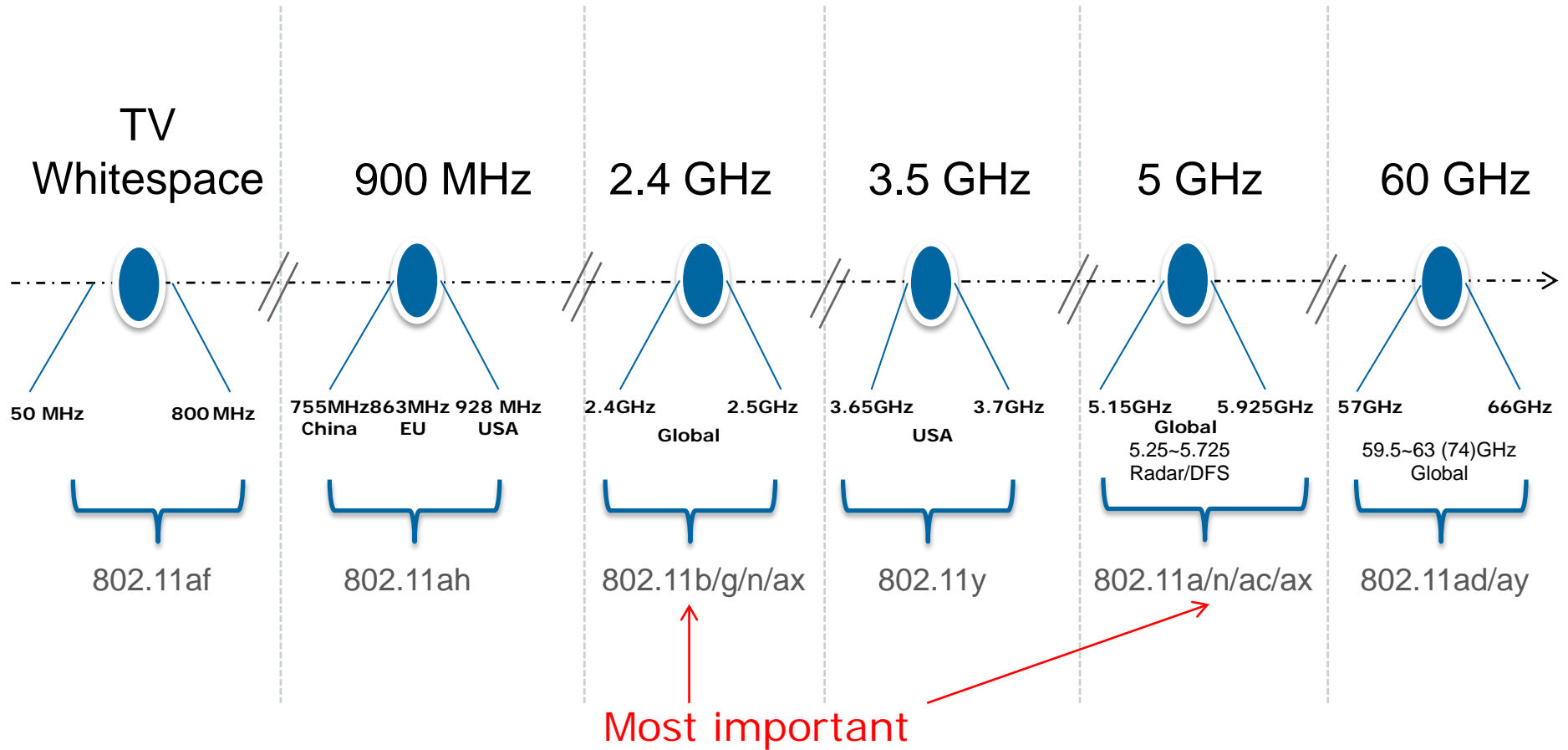# Spectrum availability is going to be a key for the success of 5G

Licensed Dedicated

- Mainstream approach for mobile broadband
- Owned by mobile operators
- 400MHz now, need 1500~2000MHz by 2020

- Effective for large area and population coverage
- Predictable quality of service
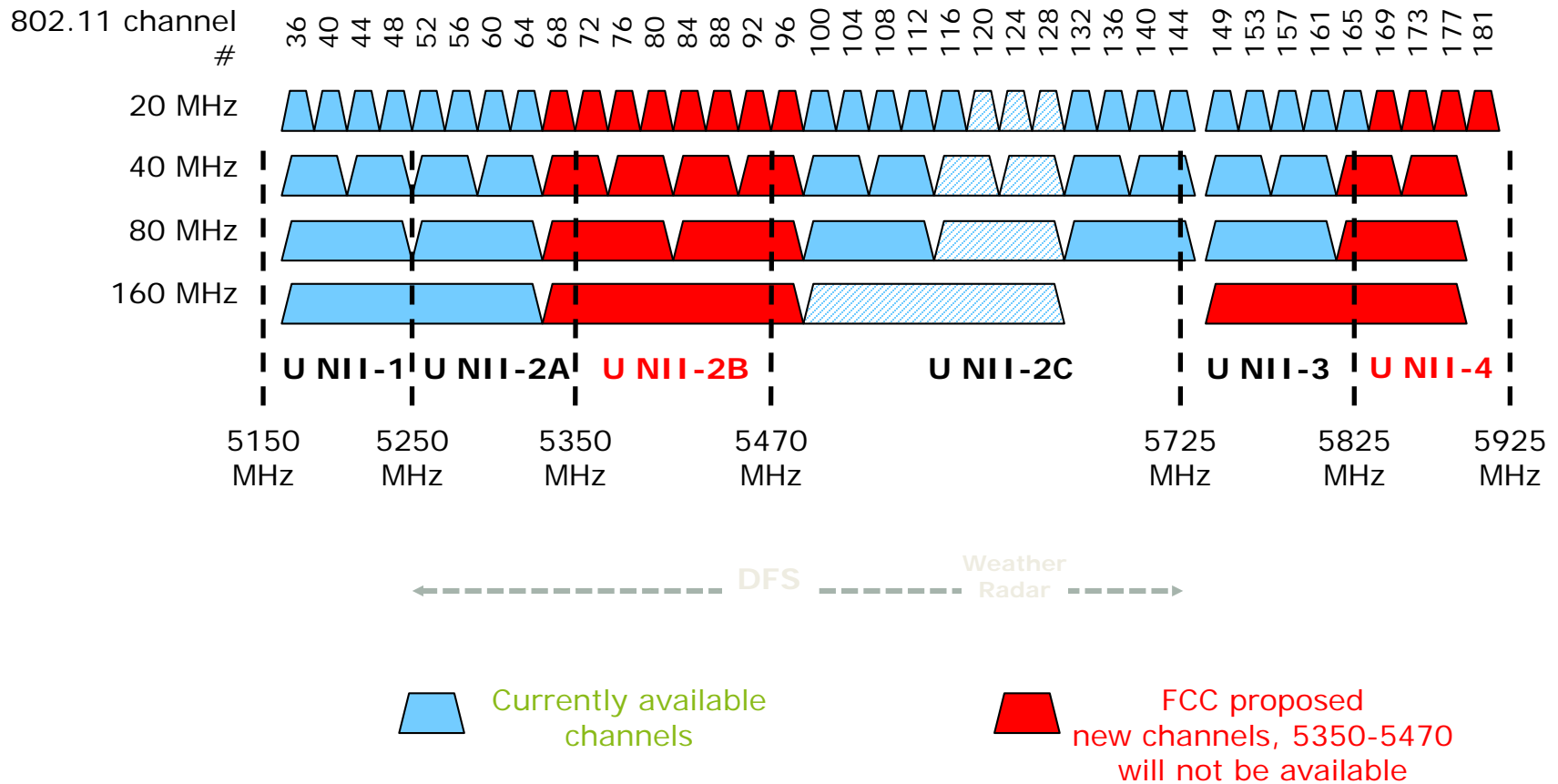- Affordable, economies of scale

Unlicensed Shared

- Over 400MHz available now below 6GHz
- Widely used by Wi-Fi
- Enterprise, residential and fixed operator
- Will be part of 5G networks

- Best for short range e.g. indoor and hotspot
- Variable quality of service
- Affordable, economies of scale

Spectrum availability is similarly a key for the success of 802.11

TV Whitespace	900 MHz	2.4 GHz	3.5 GHz	5 GHz	60 GHz
50 MHz — 800 MHz	755MHz 863MHz 928 MHz — China EU USA	2.4GHz — 2.5GHz Global	3.65GHz — 3.7GHz USA	5.15GHz — 5.925GHz Global 5.25~5.725 Radar/DFS	57GHz — 66GHz 59.5~63 (74)GHz Global
802.11af	802.11ah	802.11b/g/n/ax	802.11y	802.11a/n/ac/ax	802.11ad/ay

Most important

The struggle to obtain 5GHz spectrum has inspired a new effort to look at 6GHz

Currently available channels

FCC proposed new channels, 5350-5470 will not be available

What is the bottom line today? Work on 5G in IEEE

A quick summary of today's presentation in four parts is

- IEEE is a great place for end to end technology development
- IEEE is focusing on an end to end 5G vision, including standards
- IEEE 802 is working on standards related aspects of 5G
- IEEE 802.11 is 5G today and is being refined to continue being 5G

The bottom line

- Anyone interested in 5G needs to watch and participate in IEEE 5G activities, including IEEE 802 standards

THANK YOU

QUESTIONS