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IEEE 802
Local and Metropolitan Area Network Standards Committee

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TO: Marlene H. Dortch, Secretary
Federal Communications Commission
445 12th Street, NW
Washington, DC 20554

CC Julius Knapp via email

SUBJECT: In response to FCC Public Notice DA 15-516

DATE: 19 October 2015

Dear Ms. Dortch:

As chair of the IEEE 802 LAN/MAN Standards Committee (LMSC) Sponsor, I write to express the view of the IEEE 802 LMSC Sponsor's continued desire for collaboration among organizations to ensure fair and reliable coexistence with other unlicensed technologies such as variations of LTE in unlicensed spectrum (e.g., LTE-U, LAA) .

At an August 29th Coexistence Workshop hosted by 3GPP, (the organization designing License Assisted Access) IEEE 802 was invited to present its views alongside 3GPP RAN and others. The material presented by IEEE 802 at this meeting is attached for your information.

IEEE 802 recommended that 3GPP adopt a number of specific 802.11-like coexistence features, and that those features be a mandatory part of the LAA standard, given how successful these features have been in promoting the growth of wireless broadband over unlicensed spectrum.

IEEE 802 requested that 3GPP provide the IEEE the opportunity to review, comment and influence the 3GPP LAA specifications before the March 2016 freeze date. It is IEEE 802's understanding that 3GPP will announce its draft LAA specification available for external review in Q4 2015. At that point, IEEE 802 expects to review 3GPP's draft LAA specification and provide any appropriate feedback, and we hope that input will be incorporated into the LAA specification, due with 3GPP's Release 13 in March 2016.

Thank you for consideration of this information. If there are any questions, please contact me.

/s/ Paul Nikolich

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IEEE 802 submission to 3GPP LAA Workshop on 29 August 2015 in Beijing, China

17 August 2015

- This slide deck has been developed as IEEE 802's submission to the 3GPP Workshop on LAA to be held in Beijing, China on 29 August 2015
- Revision 6 was approved by the IEEE Executive Committee on 17 August 2015
- Revision 7 includes a variety of minor editorial corrections

The key to sharing unlicensed spectrum between LAA & 802.11 is collaboration between 3GPP & IEEE 802

- The prospect of both **LAA** & **802.11** operating in the 5 GHz unlicensed band raises important issues related to **fair sharing** by very **different technologies**

- IEEE 802 welcomes the opportunity at today's workshop to start a process of **true collaboration** with 3GPP to ensure fair sharing

What is collaboration?

- *The action of working with someone to produce something*
- Source: *Oxford English Dictionary*

- This deck consists of **three** topics for discussion today & **in future sessions**:
  - *3GPP should consider "802.11-like" access for LAA, using a collaborative development process* → Today's focus of discussion!
  - *Has the feasibility of the macro cell scenarios in 3GPP TR 36.889 been established?* → Questions & topics for future discussion
  - *A neutral test platform could provide a basis for collaboration between LAA & 802.11 stakeholders* → Questions & topics for future discussion

3GPP should consider
“802.11-like” access for LAA,
using a collaborative development process

3GPP should consider "802.11-like" access for LAA, using a collaborative development process

- Wi-Fi (based on the IEEE 802.11 standard) has been a massive economic success globally
- The significant benefit today from Wi-Fi of "*anyone, anytime, any place*" must not be put at risk

- An evidence based approach suggests the use of an "802.11-like" access mechanism will promote fair sharing between LAA & Wi-Fi

- IEEE 802 recommends that 3GPP adopt an "802.11-like" access mechanism for LAA

- **Collaboration**: IEEE 802 requests 3GPP develop collaborative processes for all stakeholders to have a voice in LAA coexistence mechanisms

Wi-Fi has been a massive socio-economic success in the US, in Europe and globally …

FCC Commissioner **Jessica Rosenworcel** stated at the *2015 State of the Net Conference*:

> *Wi-Fi is a boon to the economy. The economic impact of unlicensed spectrum* (in the US) *has been estimated at more than $140 billion annually and it's only going to grow.*

More than 10 billion Wi-Fi devices sold worldwide!

More than 5 billion devices in use today, and growing!

***EC Study** in 2013 found:*

EUROPE ♥ Wi-Fi

European Commission Vice President **Neelie Kroes** stated in August 2013:

> *"Wi-Fi is a huge success. It's a win for everybody involved. I will make sure the European Commission helps to spread use of Wi-Fi through extra spectrum and lighter regulation."*

… and the significant benefit today from Wi-Fi of "*anyone, anytime, any place*" must not be put at risk

Anyone

Anytime

Anyplace

… Wi-Fi meets users' needs for data, voice, video and much more

Wi-Fi trades some efficiency in favour of "good enough" performance (that still meets users' needs) and fair sharing with other Wi-Fi networks and other technology networks

Wi-Fi is also low cost, generally not requiring a subscription with a licensed operator!

An evidence based approach suggests "802.11-like" access will promote fair sharing

Evidence is vital to confirm unlicensed spectrum is shared fairly by LAA & Wi-Fi

The importance of evidence based decision making in relation to LAA was emphasized both by regulators and other stakeholders at the recent ETSI BRAN meeting

There is evidence for "802.11-like" access

- Evidence from 3GPP suggests an "802.11-like" access mechanism is suitable for sharing 5 GHz channels …
- … confirming 15 years of Wi-Fi experience that LBT (Listen Before Talk) with truncated exponential back off is a good solution

Evidence is available for the efficacy of "802.11-like" access today!

Evidence for other access types is limited

- Innovative new approaches to share the use of unlicensed spectrum must always be considered …
- … but should only be adopted after detailed review and consensus by all stakeholders

There is unlikely to be consensus on any evidence for a new access mechanism in the planned LAA & ETSI BRAN timescales

Evidence from 3GPP suggests "802.11-like" access is suitable for sharing 5 GHz channels …

- 3GPP TR 36.889 recommends a Category 4 LBT mechanism, with many similarities to 802.11, for downlink (DL) data, based on work undertaken by 3GPP during the first half of 2015

- The TR leaves some parameters open for further study but the evidence currently suggests "802.11-like" parameters work well; the TR specifies:
  - The back off as "dynamic variable" or "semi-static", but notes the most of the Category 4 evaluations in the TR are based on exponential back off
  - CW_{min} and CW_{max} as configurable parameters, but almost all the Category 4 evaluations used CW_{min} = 16 and CW_{max} = 1024
  - Either ACK/NACK or sensing based feedback, but all the variations of feedback described for Category 4 use (delayed) ACK/NACK
  - A variable defer period, but the vast majority of Category 4 simulations were based on defer periods of 34-43 µs
  - A slot length less than 20 µs, but with almost all such simulations using a slot length of 9 µs

… confirming 15 years of Wi-Fi experience that LBT with truncated exponential back off is a good solution

- Wi-Fi provides 15 years of evidence that …
  - … the 802.11 access mechanism using LBT with exponential back off provides fair coexistence between independent systems
  - … while also providing good performance that meets users' needs
- The 802.11 access mechanism successfully balances …
  - … the optimal use of the channel
  - … fair sharing of a community resource
- This has been shown to be true over many years for many combinations of:
  - Traffic loads
  - Device densities
  - Hidden stations
  - Traffic types
  - Up and down link traffic

There is evidence that scheduled access does not work well in unlicensed spectrum based on market failures of (including approximate year of "death"):

- ETSI HiperLAN 2 (~2000)
- IEEE 802.11 PCF (~1999)
- IEEE 802.11 HCCA (~2007)

Collaboration

3GPP should develop processes for all stakeholders to have a voice in LAA coexistence

Who should decide what is "fair" access to the unlicensed 5 GHz band?

Regulators? → **Not ideal**

Industry consensus? → **Best option**

How do we ensure the best option is feasible?

- IEEE 802 is concerned that 3GPP does not have processes that promote effective collaboration and thus industry consensus
- IEEE 802 requests 3GPP allow formal external review for LAA, possibly based on the processes used by IEEE-SA

Collaboration

Fair access to 5 GHz band could be decided by regulators alone or by industry consensus

- The 5 GHz band is a community resource that must be available for “fair” sharing by all stakeholders
- However, defining what is “fair” is a difficult problem with many dimensions and conflicting interests
  - e.g., “fair” means absolute priority for radars in 5 GHz band
  - e.g., “fair” means similar throughput & delay for many stakeholders
  - e.g., “fair” means no unlicensed user has special rights for many stakeholders
- It is generally agreed that it is unacceptable for one part of industry to decide how “fair” sharing should occur on behalf of the rest
- That leaves two main methods to decide how to share the unlicensed 5 GHz band:
  - The regulator decides the rules on behalf of all stakeholders
  - The industry & the regulator comes to a consensus on the rules after a process of collaboration

Collaboration

Intervention by regulators is not ideal, but is a real possibility without effective collaboration

- Regulators have a general responsibility to set regulations to ensure the interests of all stakeholders are protected
- Regulators usually prefer that the stakeholders collaborate, leading to a consensus that the regulator can simply implement
  - They also usually prefer a consensus that results in less need for detailed regulations because they are hard to enforce and may stifle innovation
- The lack of industry collaboration or consensus on “fair” sharing of the 5 GHz band means that regulators could start imposing rules
  - It appears that the FCC is exploring this possibility in the US based on the recent Public Notice; many submissions note the lack of collaboration
  - The European regulators already impose some rules, although they are developed using a process in which industry can participate (ETSI BRAN)
- Regulators imposing rules not ideal because it takes decisions about LAA & 802.11 away from the experts in 3GPP and IEEE 802

Collaboration

IEEE 802 is concerned that 3GPP do not have processes that promote effective collaboration

- Effective collaboration on sharing the 5 GHz band is the best way to satisfy stakeholders with the outcome
  - "Collaboration" implies joint work and consensus outputs; "communication" is not the same as collaboration!
- IEEE 802 would like to collaborate effectively with 3GPP on mechanisms for LAA and 802.11 to "fairly" share the 5 GHz band
- However, IEEE 802 is concerned that 3GPP does not have processes that encourage external collaboration on issues related to LAA sharing
  - It appears 3GPP has no formal LAA review processes accessible to external stakeholders, particularly other users of 5 GHz unlicensed spectrum
  - IEEE 802 were told by 3GPP RAN in January 2015 that the best way to influence 3GPP, particularly operator members, is to participate directly in 3GPP
  - Many IEEE 802 participants believe that 3GPP has dismissed many of the comments received via Liaison Statements from IEEE 802
  - The current 3GPP timelines for LAA appear to have insufficient time for proper review by IEEE 802 or other external stakeholders

Collaboration

IEEE 802 requests 3GPP allow formal external review for LAA, possibly based on IEEE- SA processes

- IEEE 802 requests 3GPP develop processes allowing all stakeholders to have an opportunity to review and influence LAA
- The focus should be on collaboration related to fairly sharing the 5 GHz band
- IEEE 802 suggests 3GPP consider using external review processes similar to those used by IEEE-SA

IEEE has external review processes

- IEEE-SA has defined processes that allow a diversity of stakeholders to have a voice:
  - The *Sponsor Ballot* allows all stakeholders to comment on and have a vote on draft standards
  - Historically, any stakeholder could enter a "*rogue comment*", which must be resolved in the same way comments by voters are resolved
  - The rogue comment process has recently been formalized by IEEE-SA as part of the *Public Review Process*
- These processes have particular value in resolving coexistence issues between systems based on IEEE standards and other systems

IEEE 802 recommends that 3GPP adopt an "802.11-like" access mechanism for LAA

- The following slides contain a set of principles that IEEE 802 recommends be considered for adoption by 3GPP for LAA
- **The principles are not intended to represent detailed specifications because that is the responsibility of 3GPP, and not IEEE 802**
- The goal of these recommendations are to enable LAA & Wi-Fi to share the unlicensed 5 GHz band fairly …
- … and ultimately to allow the unlicensed 5 GHz band to continue to be a community resource available for all!
- In summary, various principles are proposed that LAA adopt:
  - "802.11-like" parameters to maximize the probability of coexistence
  - "802.11-like" access rules because they are effective in unlicensed spectrum
  - A variety of other mechanisms to promote fair sharing

It is proposed that LAA adopt “802.11-like” parameters to maximise probability of coexistence

Summary	**Principle**	Adopt “802.11-like” timing parameters to maximize the probability of coexistence
Definitions based on 802.11	**Proposal**	Define “busy” & “free” states based on received energy & channel reservations
	Proposal	Divide the “free” period into slots
	Proposal	Define a “defer” period
	Proposal	Define Energy Detect (ED) & Preamble Detect (PD) thresholds

Principle: adopt "802.11-like" timing parameters to maximize the probability of coexistence

- The reality is that 802.11 standard has defined various timing parameters that are deployed in billions of Wi-Fi devices
  - e.g., slot times, CCA mechanism, AIFS mechanism
- Defining LAA to use completely different timing parameters to those used in 802.11 is likely to make fair sharing much harder ...
- … and specifying LAA to use similar timing parameters to 802.11 is unlikely to make LAA any less functional
- **Principle**: IEEE 802 recommends 3GPP adopt a limited number of timing parameters taken directly from the 802.11 access mechanism
  - This approach is aligned with the Ericsson proposal in 3GPP and ETSI BRAN in relation to "defer" and "slot" times …
  - … and much of the simulation work undertaken during the 3GPP Study Item

Proposal: define "busy" & "free" periods based on received energy & channel reservations

- It is proposed by IEEE 802 that LAA use concepts of a "busy" and "free" medium similar to those used in 802.11
  - Note: 3GPP does not need to adopt exactly the same terms as 802.11
- **Define:** a wireless medium is deemed to be "busy" by a device for the period the device:
  - Receives energy above an energy threshold
  - Transmits energy on the medium
  - The device is aware another device has "reserved" the channel
    - Reservation occurs by the use of NAV in 802.11
  - The device is aware another device is probably transmitting on a channel
    - This idea encapsulates the EIFS concept in 802.11

  … and an additional "defer" period
    - Defined on a following slide
- **Define:** In all other circumstances the medium is deemed to be "free"

Proposal: divide the “free” period into slots

- It is recommended by IEEE 802 that LAA adopt concepts of a “slot” similar to that used in 802.11
- **Define:** The period the medium is “free” is divided into slots
- **Define:** Energy Detection (ED) shall occur during each slot
  - An 802.11 system must be capable of detecting energy (with 90% probability) and executing any other necessary actions, such as processing and turnaround, within each slot period
- **Define:** Each slot has a period of 9 µs
  - Note: this is the same as 802.11
  - Note: 802.11 systems must detect energy in each slot within 4 µs, leaving 5 µs for propagation delay, processing time & turnaround time; other technologies may use different timing

Proposal: define a “defer period”

- It is proposed by IEEE 802 that LAA adopt concepts of a “defer period” similar to that used in 802.11
  - PIFS, DIFS in the DCF (Distributed Coordination Function) version of 802.11
  - AIFS in the EDCA (Enhanced Distributed Channel Access) version of 802.11
  - Note: PIFS, DIFS, SIFS, AIFS are different Inter-frame Spaces in 802.11
- **Define:** The “defer period” is defined to be of length (16 µs + n * slot times), n >= 1, and consists of
  - 16 µs that is analogous to SIFS in 802.11 followed by …
  - … one or more slots
- The value of “n” depends on the priority level
  - See later in this deck for discussion related to priority
- Energy detection is assumed to occur during each of the slots in the “defer period”

Proposal: define Energy Detect (ED) & Preamble Detect (PD) thresholds

- Simulations with 20 MHz channels in 3GPP during the Study Item suggest fairness will be enhanced by LAA adopting:
  - Energy detection (ED) less than -77 dBm OR
    - Based on work during 3GPP SI; see R1-152936, R1-152937 & R1-152938
  - Preamble detection (PD) at -82 dBm & ED at -62 dBm (same as 802.11)
- **Proposal:** It is proposed that 3GPP adopt one of the above mechanisms and the associated thresholds:
  - An ED less than -62 dBm has the beneficial side effect of assisting LAA systems mitigate hidden station issues with Wi-Fi systems
  - PD is not strictly technology neutral but its use pragmatically recognizes legacy equipment can't be changed; it also assists hidden station mitigation, at least with other Wi-Fi devices

It is proposed that LAA use “802.11-like” access rules because they are effective in unlicensed spectrum

Medium access based on 802.11	**Principle**	Define LBT rules in terms that allow flexibility and innovation, within limits
	Proposal	Execute LBT and exponential back-off mechanisms before any transmission
	Proposal	Allow some control frames to be transmitted without any LBT
	Proposal	Count a random number of slots within a contention window as a back-off procedure
	Proposal	Adjust contention window based on successful & unsuccessful transmission of frames
	Principle	Enable QoS using multiple access engines in a device
	Principle	Set minimum parameters for QoS
	Principle	Devices must undertake LBT before accessing secondary channels

Principle: define LBT rules in terms that allow flexibility and innovation, within limits

- **Principle**: IEEE 802 proposes that an LAA device use an LBT plus "truncated, exponential back-off" mechanism for medium access
  - This proposal is roughly aligned with DCF and EDCA in 802.11, and WMM from the Wi-Fi Alliance
  - It is also roughly aligned with the Category 4 LAA concept in 3GPP Study Item
- The rest of this submission defines the mechanism in terms that allows LAA a significant degree of flexibility in implementation details
  - This approach enables innovative solutions, while also achieving the goal of fair sharing of unlicensed spectrum
  - Fair sharing is a goal article that is agreed in many regulatory domains, including under 3.2 of the RE-Directive in Europe

Proposal: execute LBT and exponential back-off mechanisms before and after any transmission

- **Define:** An “access engine” within a device may transmit consecutive multiple frames (within a TxOP) starting on a slot boundary if:
  - The medium is “free” AND
  - Any back-off procedure has completed AND
  - No higher priority “access engine” in the same device is eligible to transmit
- **Define:** An “access engine” within a device must execute a back-off procedure:
  - When the medium is “busy” at the time it queues the first frame in the TxOP for transmission OR
  - After transmission of a complete TxOP OR
  - When an “access engine” in the same device at a higher priority level causes a transmission deferral (see later discussion wrt QoS)

Proposal: allow some control frames to be transmitted without any LBT

- Normally the access mechanism must operate before any transmission but there are exceptions in 802.11
  - This is to provide for ACKs, CTSs, etc. in 802.11
  - Similar exceptions are in ETSI BRAN rules
- **Proposal:** a short control frame may be transmitted immediately after a reception of a frame from another access engine without checking for a “free” medium
  - In 802.11, the control frames are sent at SIFS, ensuring other systems cannot grab the medium during the turnaround
- Note: an alternative approach might be to allow a limited duty cycle for control frames

Proposal: count a random number of slots within a contention window as a back-off procedure

- **Define:** The back-off procedure in each “access engine” in a device is driven by a parameter called CW (Contention Window), which may take values between:
  - CW_{min}: minimum value of CW
  - CW_{max}: maximum value of CW
- **Define:** A back-off procedure in each “access engine” operates as follows:
  - Choose a random number “q” between 0 and CW
  - Count “q” slots
- Note: a back-off procedure will implicitly countdown only while the medium is “free” because slots are defined to be “free”

Proposal: adjust contention window based on successful & unsuccessful transmission of frames

- Each “access engine” in a device adjusts its CW independently
- **Define:** CW is initially reset to CW_{min}, and has a maximum of CW_{max}
- **Define:** CW is reset to CW_{min} when evidence is received that the first frame in a past TxOP has been successfully received
  - e.g., an immediate ACK in 802.11, a delayed ACK in LAA
- **Define:** CW may also be reset after a system defined number of consecutive transmission failures
  - Note: this is analogous to the retry counts in 802.11
- **Define:** CW is doubled (plus one) each time:
  - Evidence is received that the first frame in a past TxOP has not been successfully received
    - e.g., evidence could be from missing ACK in 802.11, a delayed NACK in LAA
  - An “access engine” has an internal collision with higher priority “access engine”

Principle: enable QoS using multiple "access engines" in a device

- 3GPP does not appear to have considered QoS for LAA in their simulations to date
- QoS is enabled in 802.11 using EDCA (Enhanced Distributed Channel Access) via four "access engines" operating in parallel within a device
  - The priority levels are *voice*, *video*, *best effort* (typical) and *background*
  - Each priority level is defined by tuple of: (CW_{min}, CW_{max} , defer period, $TxOP_{max}$)
- **Principle**: 3GPP should adopt a similar QoS concept , if QoS is required in LAA, because it is a proven and mature mechanism
  - Question: Does 3GPP want DL QoS, or is "best effort" enough?
- While this proposal does not limit when higher priority access may be used, it is expected that devices would use higher priorities responsibly

Principle: set minimum parameters for QoS

Level	Priority	n	CW_{min}	CW_{max}	$TxOP_{max}$
Highest	Voice	2	3	7	1.5 ms
Next highest	Video	2	7	15	3.0 ms
Typical	Best effort	3	15	1023	4.0 ms
Lowest	Background	7	15	1023	4.0 ms

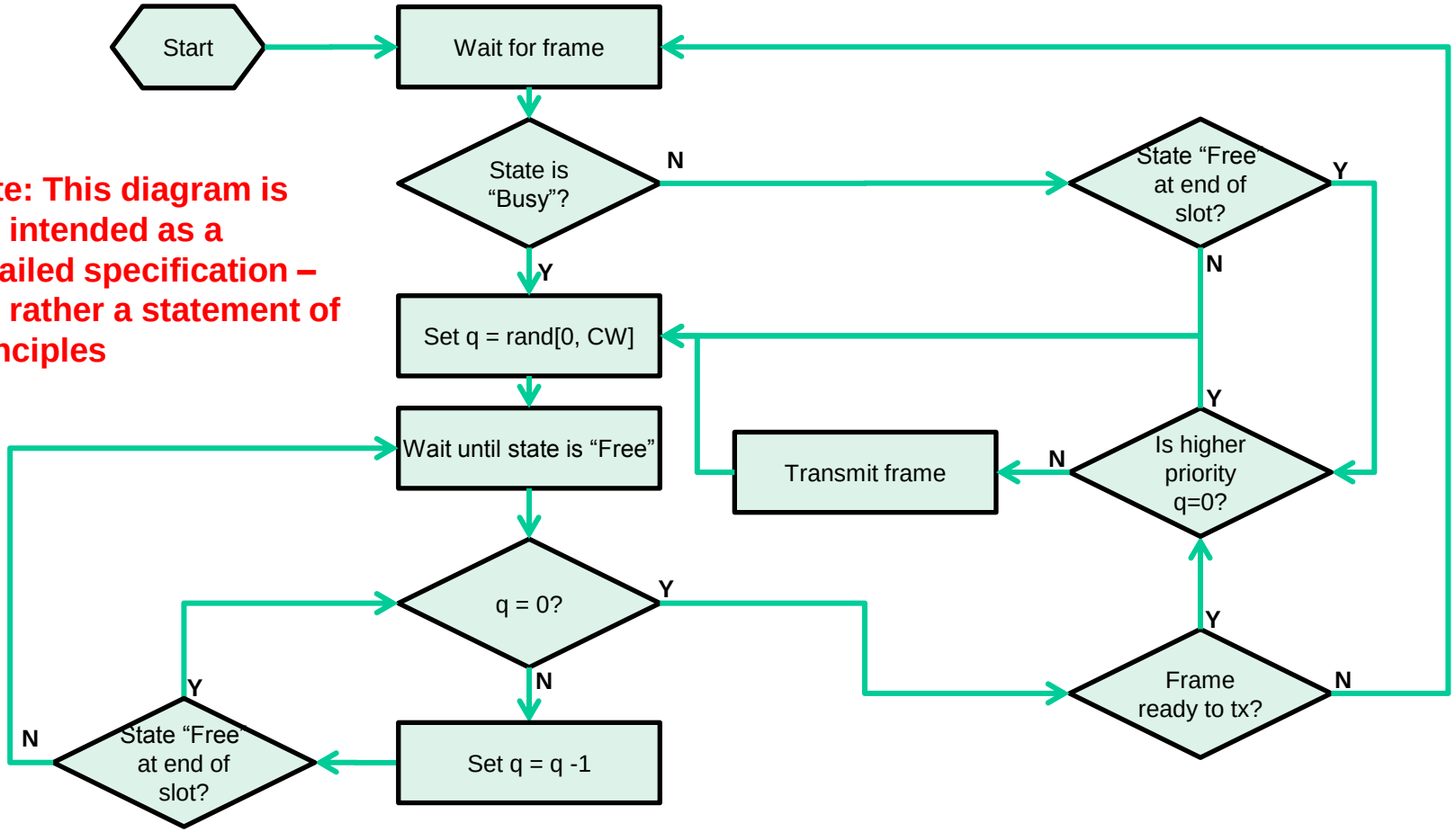
- Note: these parameters are defined to be the similar to those in 802.11 EDCA and Wi-Fi Alliance WMM
- Note: Wi-Fi Alliance WMM defines slightly relaxed parameters for APs

Principle: devices must undertake LBT before accessing secondary channels

- The access mechanisms described in this document are based on access to a 20 MHz channel
- However, 802.11 accesses 40 MHz, 80 MHz, 160 MHz too, and presumably LAA will want the same flexibility
- It is proposed that LAA use a similar mechanism to 802.11 to access secondary channels
  - i.e. channels in which the basic access mechanism is not used
- **Principle**: This means that at least a short LBT is undertaken in secondary channels after execution of a full access procedure in the primary channel

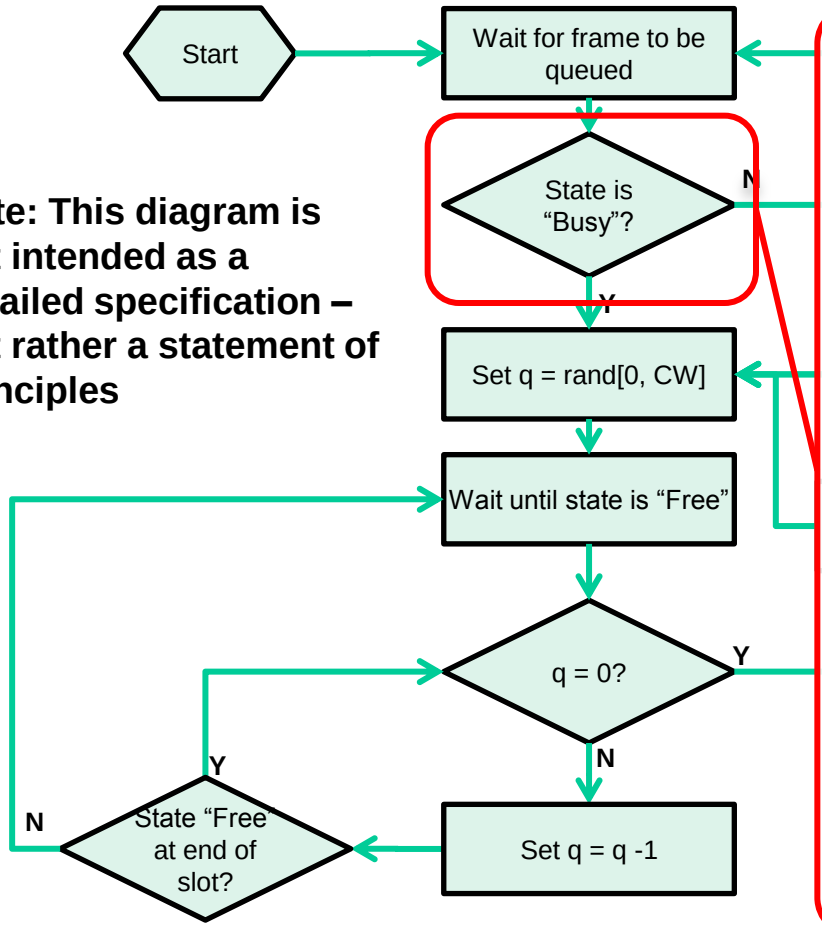
Summary: "Access engine" operation can be illustrated by a conceptual flow diagram

Note: This diagram is not intended as a detailed specification – but rather a statement of principles



Note: CW, "Free" and "Busy" are defined on earlier slides

Summary: The revised flow chart removes iCCA because it is ambiguous and overly conservative

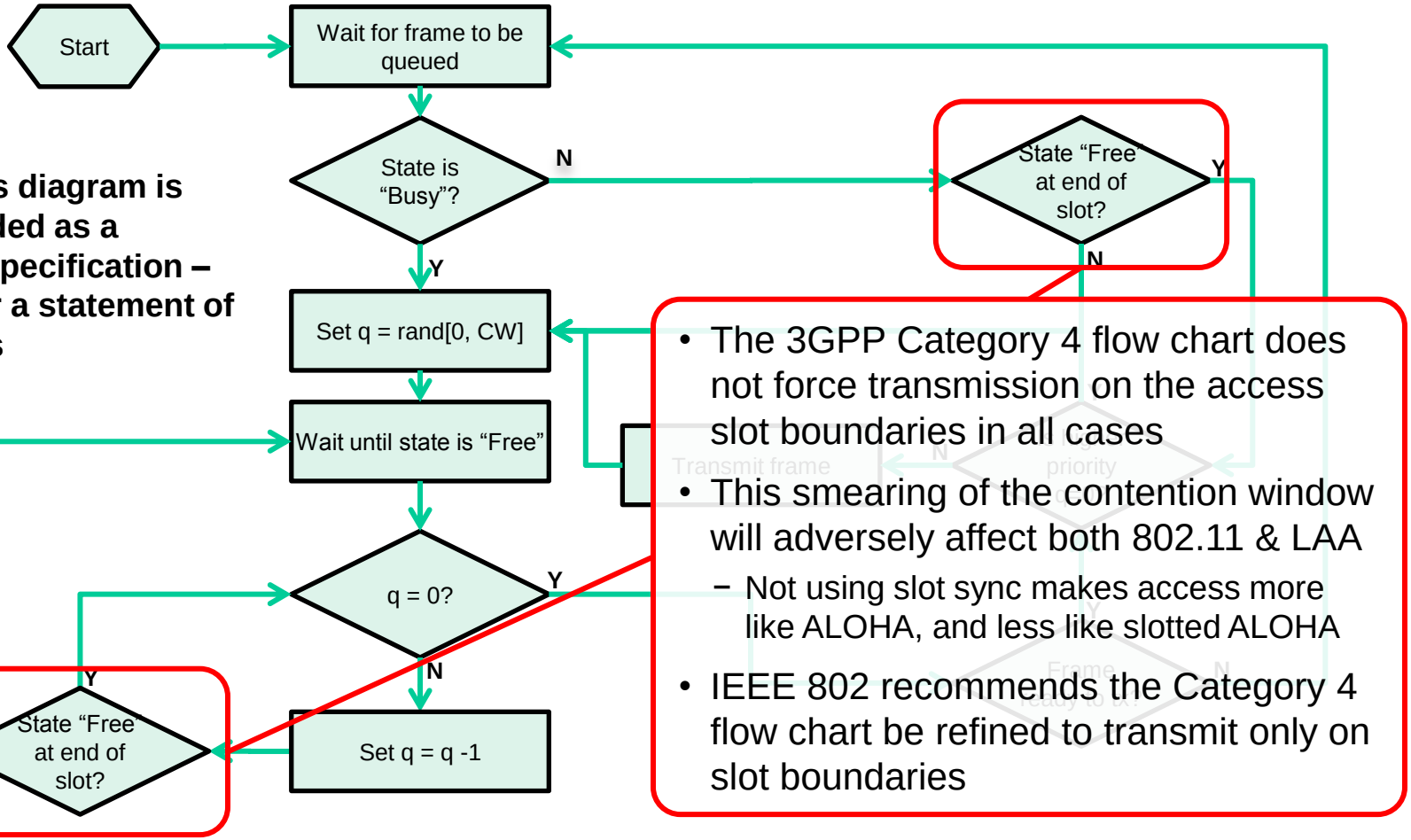


Note: This diagram is not intended as a detailed specification – but rather a statement of principles

- The 3GPP Category 4 flowchart includes a concept called iCCA
- It appears from discussions at ETSI BRAN that some 3GPP participants believed an iCCA was required in Wi-Fi *after* a frame became ready for transmission
- This is not the case; rather an instantaneous evaluation of the medium state is required
- If the flow chart means that an iCCA is always required after the frame becomes available for transmission, then this is overly conservative
- IEEE 802 recommends that the iCCA concept be refined to align better with the 802.11 access mechanism

Note: CW, "Free" and "Busy" are defined on earlier slides

Summary: The revised flow chart ensures transmissions occur on slot boundaries

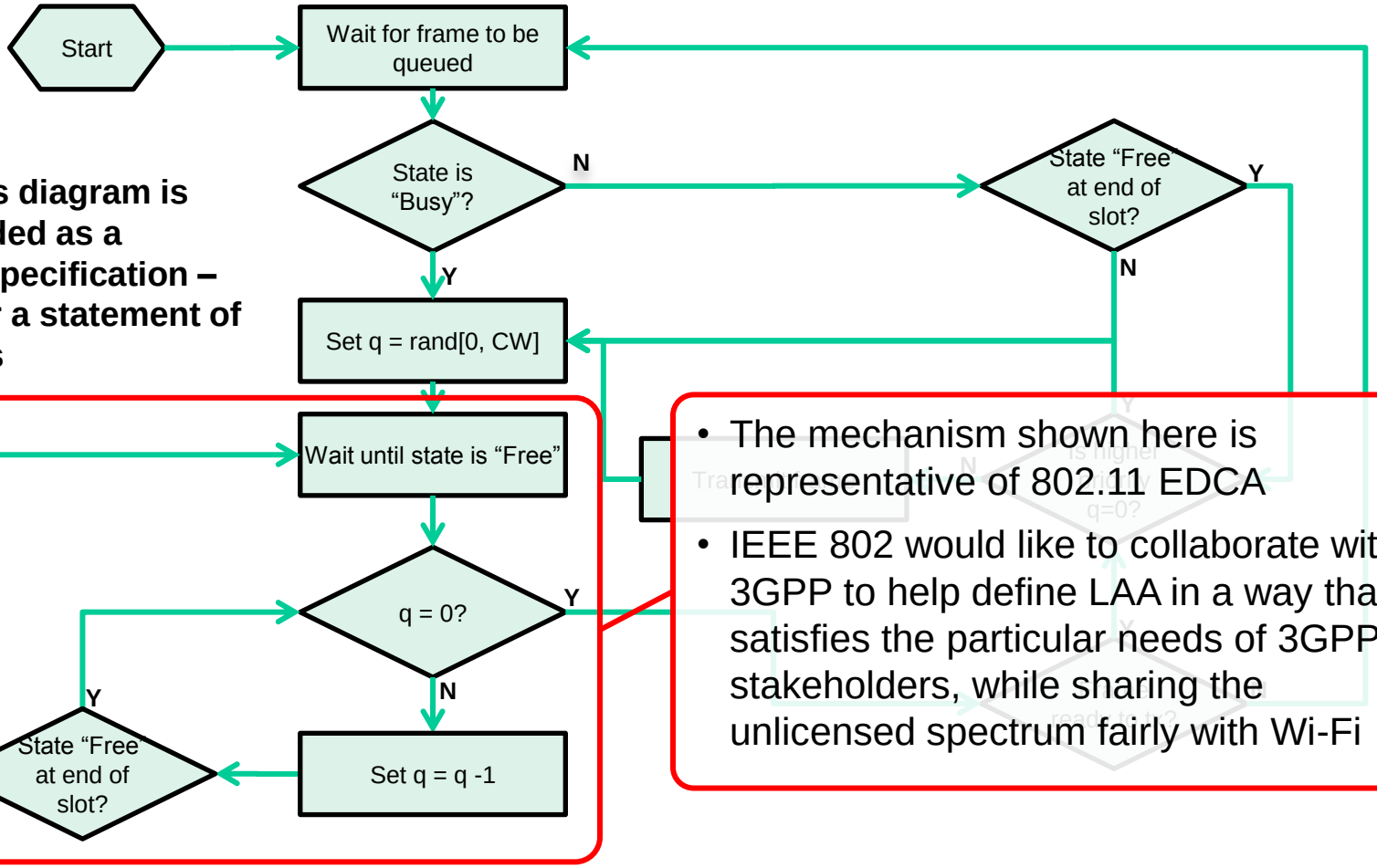


Note: This diagram is not intended as a detailed specification – but rather a statement of principles

- The 3GPP Category 4 flow chart does not force transmission on the access slot boundaries in all cases
- This smearing of the contention window will adversely affect both 802.11 & LAA
  - Not using slot sync makes access more like ALOHA, and less like slotted ALOHA
- IEEE 802 recommends the Category 4 flow chart be refined to transmit only on slot boundaries

Note: CW, "Free" and "Busy" are defined on earlier slides

Summary: The revised flow chart incorporates EDCA as the basis for access



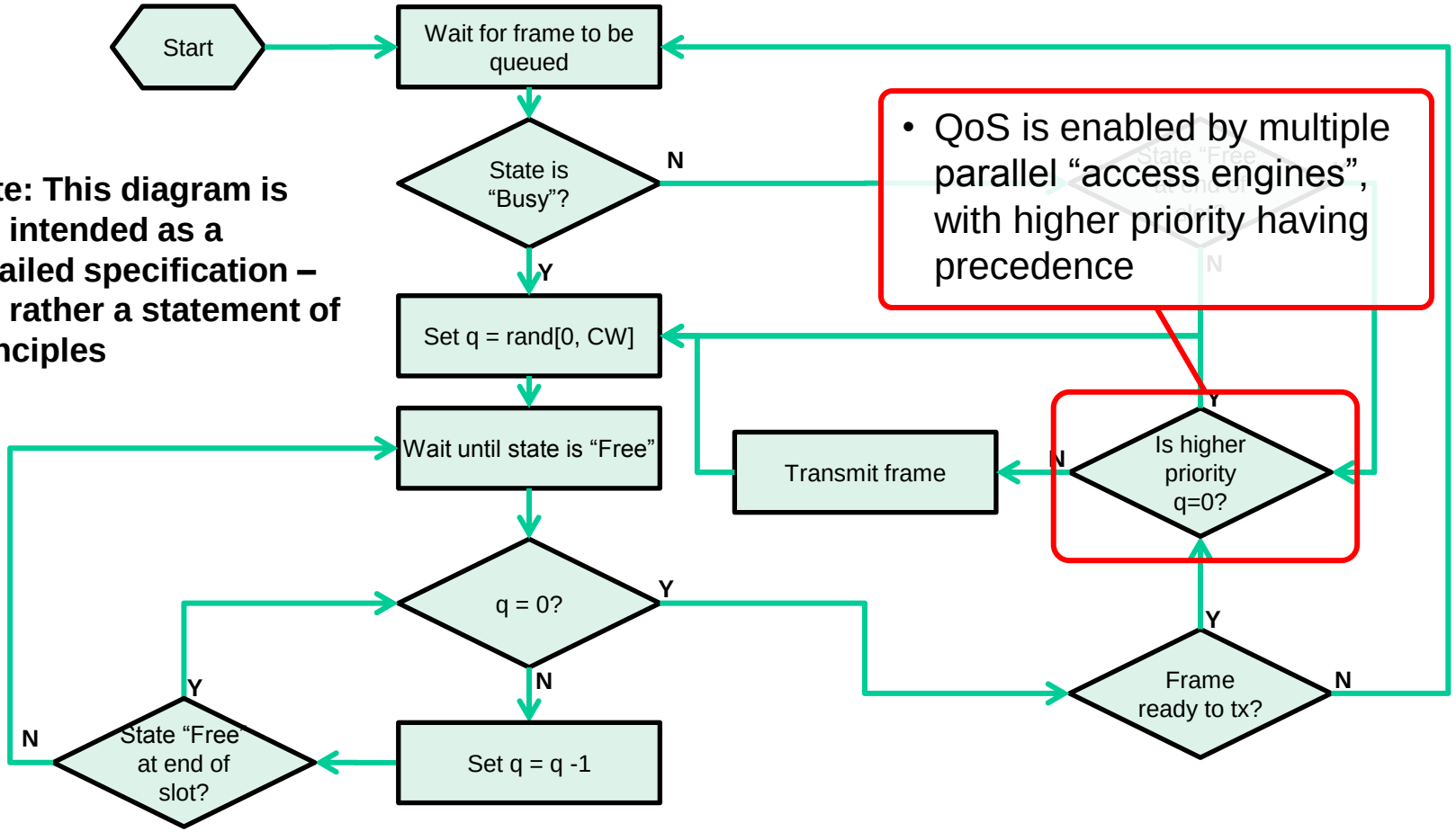
Note: This diagram is not intended as a detailed specification – but rather a statement of principles

- The mechanism shown here is representative of 802.11 EDCA
- IEEE 802 would like to collaborate with 3GPP to help define LAA in a way that satisfies the particular needs of 3GPP stakeholders, while sharing the unlicensed spectrum fairly with Wi-Fi

Note: CW, "Free" and "Busy" are defined on earlier slides

Summary: The revised flow chart incorporates QoS by enabling multiple parallel "access engines"

Note: This diagram is not intended as a detailed specification – but rather a statement of principles



Note: CW, "Free" and "Busy" are defined on earlier slides

It is proposed that LAA adopt a variety of other principles to promote fair sharing

Other principles	**Proposal**	Define the maximum transmission time of 4 ms for each access
	Principle	Do not require LAA to respect NAV received from 802.11
	Principle	Devices shall have mutual respect for reservations made by others using same mechanisms
	Proposal	Collaboration is needed to discuss LBT on TxOPs continued on UL
	Proposal	Devices using or reserving a channel shall use it only for necessary transmission purposes

Proposal: define the maximum transmission time of about 4 ms for each TxOP

- **Define:** a TxOP is the contiguous frame transmissions that result from an "access engine" gaining access to the medium
  - Note: it is assumed a TxOP can be split between DL and UL
- The evidence suggests a $TxOP_{max}$ of ~4 ms as a reasonable compromise between fairness and efficiency
  - Most Category 4 simulations used a $TxOP_{max}$ of about 4 ms, and showed reasonable fairness and performance with exponential back-off; some simulations showed that a $TxOP_{max}$ of 10 ms was too long
  - Measurements in the field (e.g., in a stadium) show that the vast majority of Wi-Fi TxOPs are less than 3 ms; the maximum Wi-Fi TxOP is 5.5 ms
  - Qualcomm noted in their submission to FCC that "*… Wi-Fi data packet transmissions are usually a few milliseconds in duration. LAA transmission duration is expected to be on the same order as the duration of Wi-Fi data packet transmission*"
  - Japan has a regulation specifying a $TxOP_{max}$ of 4 ms

Principle: do not require LAA to respect NAV received from 802.11

- 802.11 partially resolves hidden station problems by its use of the NAV in frames, and particularly its use of RTS/CTS control frames
  - e.g., NAV in data frames protects ACK in Wi-Fi
- These hidden station mitigation techniques may be less effective if LAA does not respect the NAV in frames transmitted by 802.11 devices
- It has been argued by some stakeholders that LAA devices should be required to respect the NAV transmitted by all 802.11 devices
- However, such an approach is not technology neutral and unreasonably forces every LAA device to implement an 802.11 receive function
- Respecting the NAV might also be unnecessary if the LAA devices use a lower ED of -77 dBm as an alternative form of hidden station mitigation
- It may be possible for IEEE 802 and 3GPP to work together to define a reciprocal collision avoidance mechanism

Principle: devices shall have respect for reservations made by others using common mechanisms

- It is generally agreed that it is unacceptable to require LAA to respect an 802.11 NAV because such an approach is not technology neutral
- However, there have been some indications that LAA systems may transmit 802.11 CTS-to-Self control frames to reserve the medium
- It is only fair that if a LAA system expects 802.11 systems to respect a NAV it transmits then the same LAA system should respect any NAV received from 8021.11 systems
- **Principle:** This principle can be generalised by requiring any system using a particular mechanism to reserve the medium shall respect reservations made by other systems using the same mechanism

Proposal: collaboration is needed to discuss LBT on TxOPs continued on UL

- Most of the 3GPP simulations focused in LAA DL only scenarios, but there are plans for LAA to support UL traffic too in the future
- A potential problem is that the UE is scheduled by the eNB, suggesting the UE may not undertake any form of LBT before transmission
- Any possibility of hidden stations suggests that UEs also need to execute at least some sort of LBT to ensure fair sharing of the channel
- **Proposal**: Discussion of this topic by IEEE 802.11 WG participants suggests any form of LBT not based on Category 4 needs detailed investigation using simulations and analysis, by 3GPP, IEEE 802 and any other interested stakeholders

Proposal: devices using or reserving a channel shall use it only for necessary transmission purposes

- Some of the proposals for LAA appear to allow the channel to be reserved before it is needed so that it is available when it is needed
- This could result in the LAA system reserving but not using the channel, effectively representing interference to Wi-Fi
- This is contrary to the widely accepted principle in unlicensed spectrum to accept interference from others but to avoid causing interference to others
- **Proposal**: It is proposed that any system reserving or using a channel must only make use of it for necessary and legitimate data and management transmission purposes

IEEE 802 welcomes the opportunity to collaborate with 3GPP to ensure LAA & Wi-Fi share fairly

Wi-Fi's operation must not be threatened in 5 GHz unlicensed spectrum

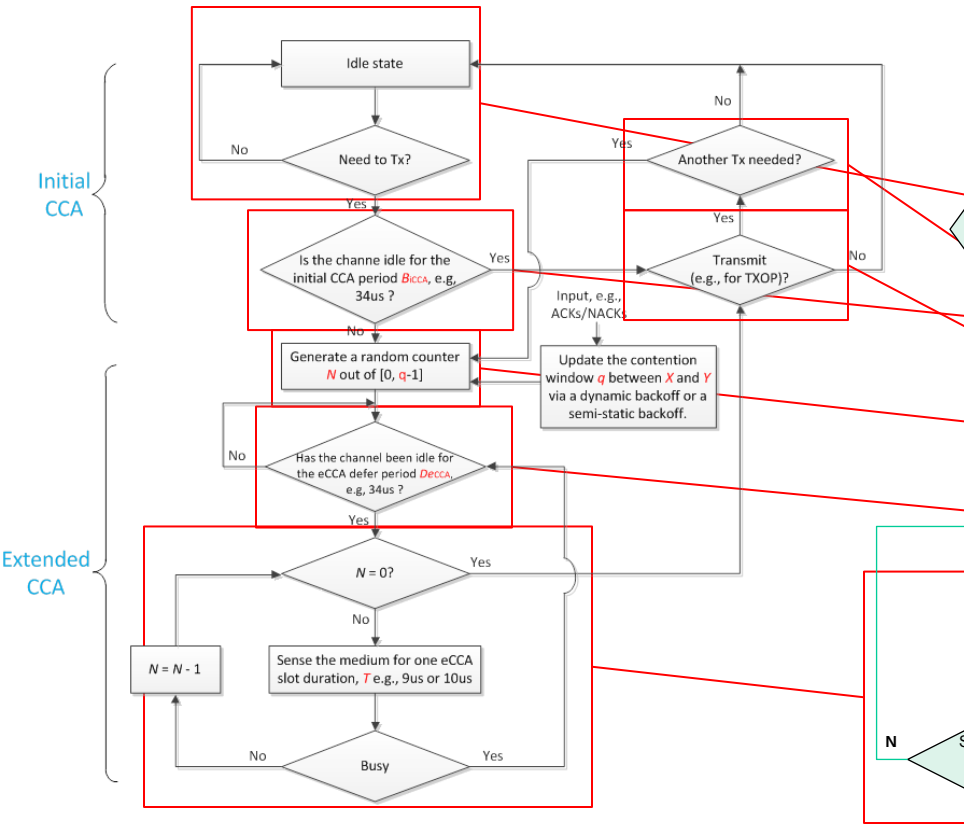
LAA has every right to use the same 5 GHz unlicensed spectrum as Wi-Fi

The currently available evidence shows the best way for LAA and Wi-Fi to **share the 5 GHz unlicensed spectrum** is for LAA to adopt "802.11-like" access

IEEE 802 is ready and willing to work with 3GPP in a **truly collaborative manner** to achieve our common goal of LAA & Wi-Fi sharing the 5 GHz unlicensed spectrum fairly

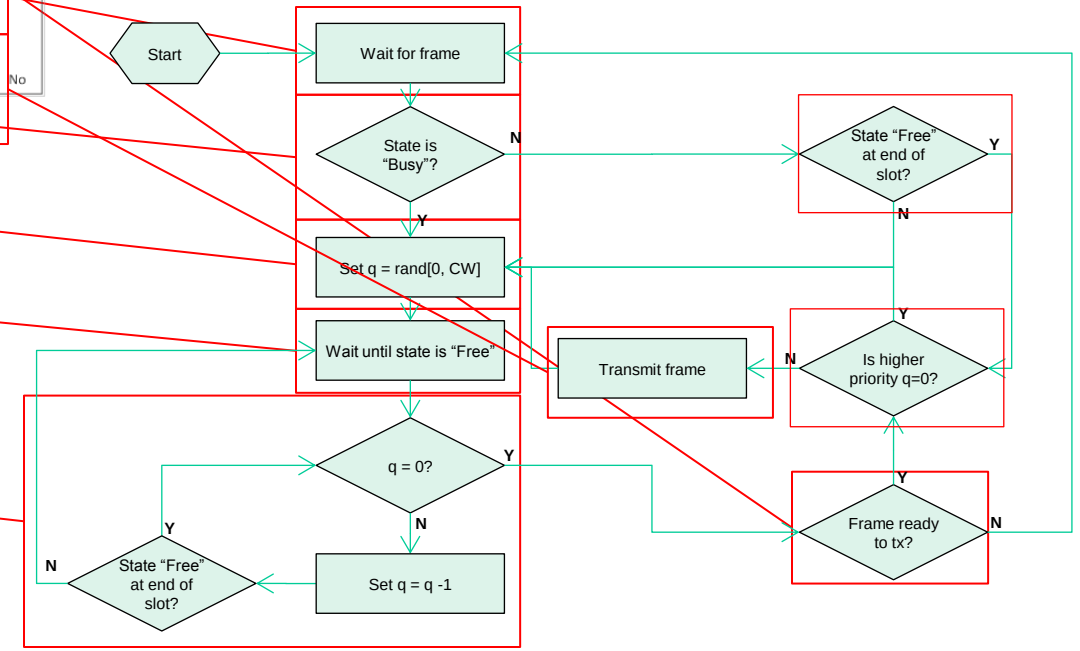
Backup: 3GPP and IEEE 802 flow charts are similar, but sufficiently different to require collaboration

3GPP Category 4 Flow Chart



IEEE 802 conceptual flow chart

Essentially the same



Note: slide contains animations

Has the feasibility of the macro cell scenarios in 3GPP TR 36.889 been established?

Has the feasibility of the macro cell scenarios in 3GPP TR 36.889 been established?

- 3GPP TR 36.889 V1.0.1 (2015-06) provides a carrier aggregation feasibility study
- Macrocell scenarios are included
- The one macrocell scenario evaluated in TR 36.889 requires different licensed bands for macrocell and small cell
- The other macrocell scenarios may result in unique challenges for LBT
- Has the feasibility of the macro cell scenarios been established?

3GPP TR 36.889 defines four LAA deployment scenarios

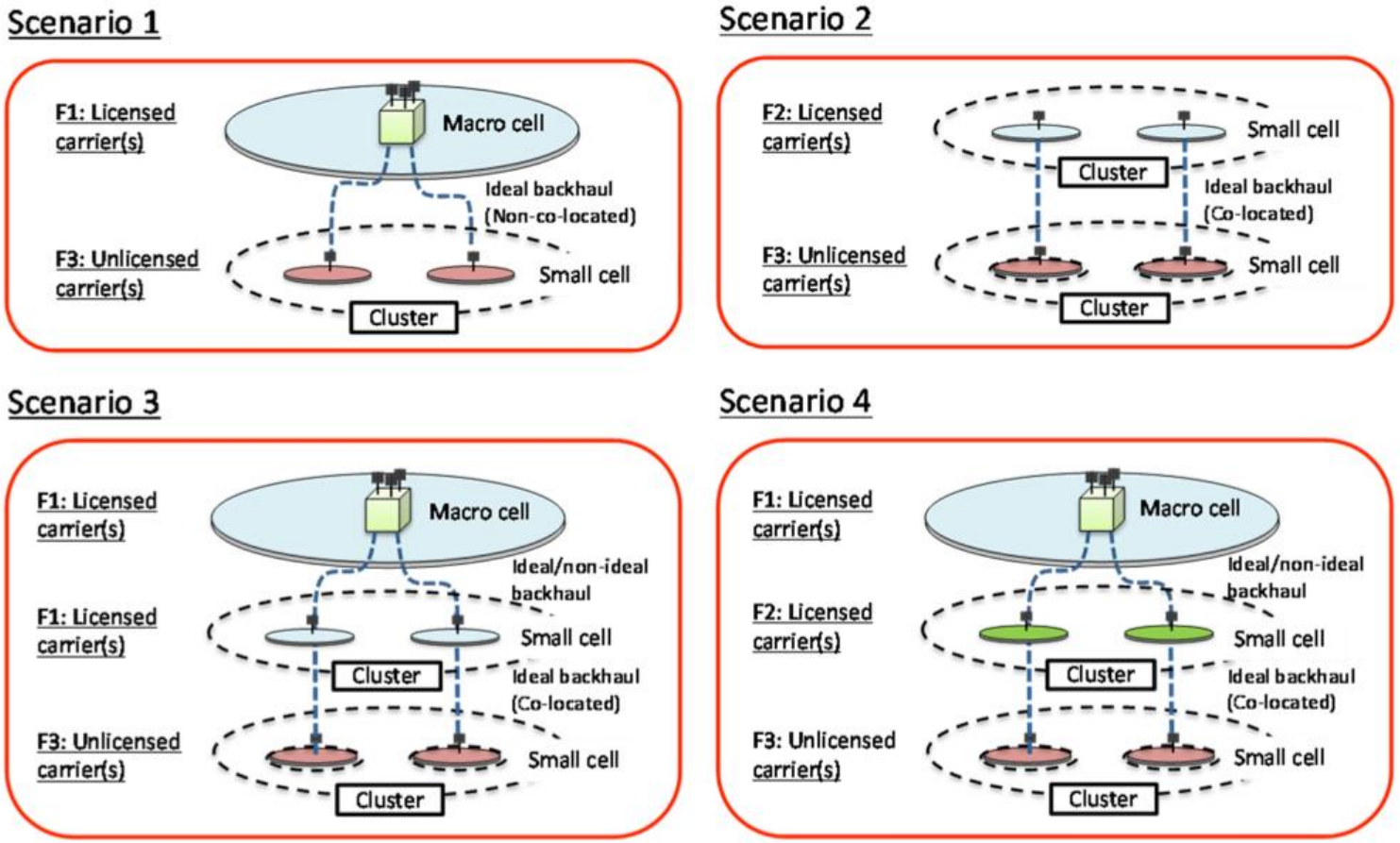


Figure 6-1: LAA deployment scenarios

source: 3GPP TR 36.889

3GPP TR 36.889 conclusions are based on two LAA evaluation scenarios

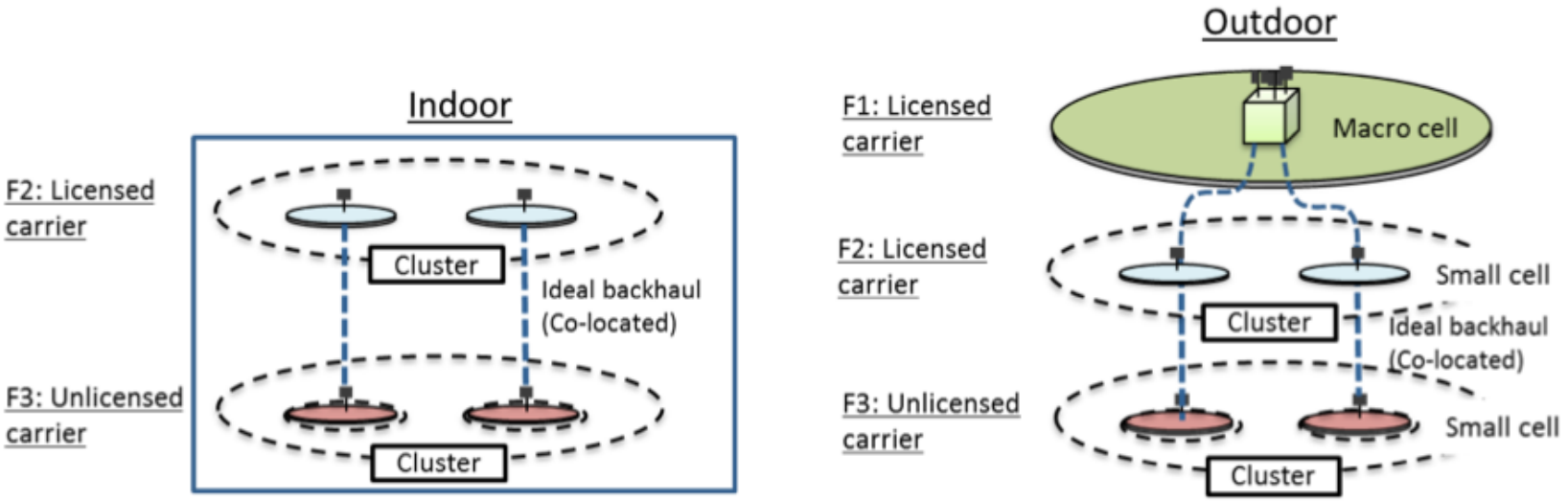


Figure 8.1-1: LAA evaluation scenarios

- per TR 36.889, indoor scenario based on Scenario 3 of TR 36.872
  - but comparable to Scenario 2 of TR 36.889
- per TR 36.889, outdoor scenario based on Scenario 2a of TR 36.872
  - but comparable to Scenario 4 of TR 36.889

The three macro-cell scenarios are not evaluated or have limited applicability

- Scenario 4 is evaluated in TR 36.889
  - requires different licensed channels for macro and small cell
    - limited applicability: not all operators have multiple licensed channels available
- Scenario 1 is not evaluated in TR 36.889
  - Requires “ideal backhaul” between the macro site and the unlicensed small cell.
  - DL and UL scheduling take place at the macro site, not at remote radio head.
  - CCA takes place at the small cell, and at remote UE for uplink.
- Scenario 3 is not evaluated in TR 36.889
  - Macrocell and small cell share the same licensed channel.
    - may require coordination of scheduling between macrocell and small-cell licensed

There are open questions relating to macro-cell scenarios 1 & 3 that could be subject to collaboration

Scenario 1

- Is the scheduler, at the macrocell, aware of remote CCA status?
- Have simulations studied LBT in Scenario 1? Do these consider:
  - "ideal" but realistic backhaul latency
  - when unlicensed uplink is supported, latency in passing CCA status from UE over the air (using licensed or unlicensed uplink)

Scenario 3

- In case of "ideal" backhaul, see questions from Scenario 1.
- In case of "non-ideal" backhaul, have simulations studied LBT?
  - Can the presence of the macro-cell affect the latency of the DL and UL LBT operation, considering that small-cell licensed and unlicensed carriers are carrier-aggregated while licensed small-cell operation is not independent but must be coordinated with co-channel macro-cell?

A neutral test platform could provide a basis for collaboration between LAA & 802.11 stakeholders

A neutral test platform could provide a basis for collaboration between LAA & 802.11 stakeholders

- The coexistence discussion is not going to end once LAA is defined …
  - Let's look forward and find ways to communicate issues between groups
  - Common testbed promotes goodwill and collaboration
- … and everyone benefits from testing real devices and applications
  - Simulations are useful …
  - … but don't capture real device behavior
- **A neutral test platform can provide fair sharing data for both the 802.11 and 3GPP communities to help inform future decisions**
  - The 802.11 community will benefit from "hands on" experience with Unlicensed LTE to evaluate their own applications and devices
  - The 3GPP community will benefit by alleviating concerns about coexistence mechanisms and using the data to inform decisions about LAA

IEEE 802 recommends 3GPP work with IEEE 802 to define a neutral coexistence testbed

- An agreed neutral coexistence testbed will allow for any early LAA development units to be tested
- It can also be used with existing 802.11/LTE-U devices to help drive LAA decisions based on real interactions
  - Best coexistence mechanisms
  - Best energy detection thresholds
  - Real device traffic patterns and application behaviour
  - Channel selection algorithms
- Some LTE-U coexistence testing already has been started …
  - See LTE-U Technology and Coexistence, LTE-U Forum, 28 May 2015
- … but we need to continue and expand these tests to understand full impact of all LAA design decisions on Wi-Fi

What would a neutral coexistence testbed look like?

- A neutral coexistence testbed would use a controlled RF environment to study Unlicensed-LTE/Wi-Fi and Wi-Fi/Wi-Fi interactions, possibly located in a neutral test or certification lab
- It must have at least the following characteristics
  - High isolation from external devices
  - Good control over power levels across devices
  - Multipath environment to test MIMO STA's
  - Ability to test real applications (VoIP, Video streaming, file transfer, etc.)
  - Flexibility to test high channel load environments
  - Repeatable configuration that can be reproduced across labs
- There are many possible test scenarios already in discussion
  - Fairness testing of Wi-Fi vs Wi-Fi/LTE-U (TPT, jitter, latency, air-time, etc.)
  - Above/below ED device performance across vendors/devices
  - Hidden node testing