



Understanding MulteFire's Radio Link

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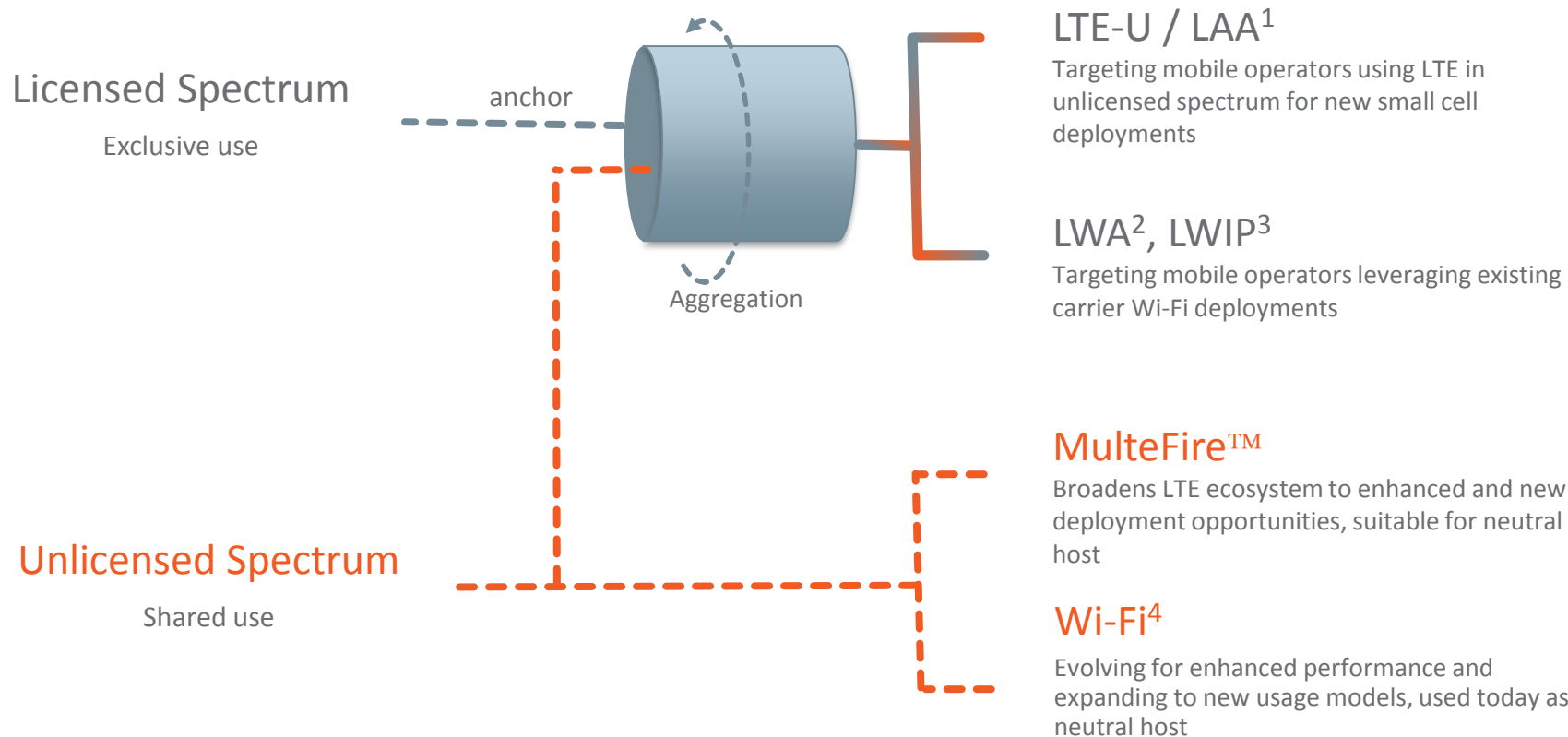


Agenda

- Coexisting in unlicensed spectrum
- MulteFire Technology—extensions added to 3GPP LAA and eLAA
- MulteFire performance advantages and results
- Summary

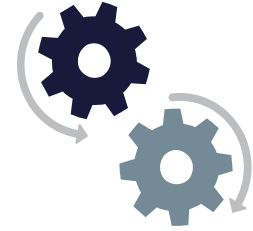
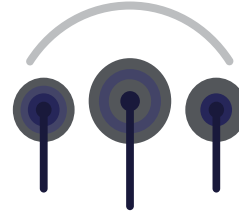
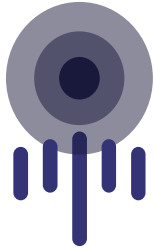


Multiple technologies will coexist in unlicensed spectrum



1) Licensed-Assisted Access (LAA), also includes enhanced LAA (eLAA); 2) LTE Wi-Fi Link Aggregation (LWA); 3) LTE Wi-Fi radio level integration with IPsec tunnel (LWIP); 4) 802.11ac / .11ad / .11ax / .11ay

MulteFire performance advantages



Coverage

- Retains LTE's deep coverage characteristics
- Targets control channels to cell edge SINR¹ of -6dB
- 5-6dB link budget advantage over Wi-Fi

Capacity

- Leverage LTE link efficiency and MAC²
- Significant gains (~2X) over 802.11ac baseline
- Comparison with .11ax under investigation

Mobility

- Brings carrier-grade LTE mobility to unlicensed
- Seamless & robust mobility
- Service continuity to WAN
- Significantly better than Wi-Fi, esp. outdoor, 50 km/h

Robustness

- More predictable & robust performance than Wi-Fi
- Forward HO³ enables recovery when RLF⁴
- Enhanced RLF⁴ triggers
- Mature SON techniques

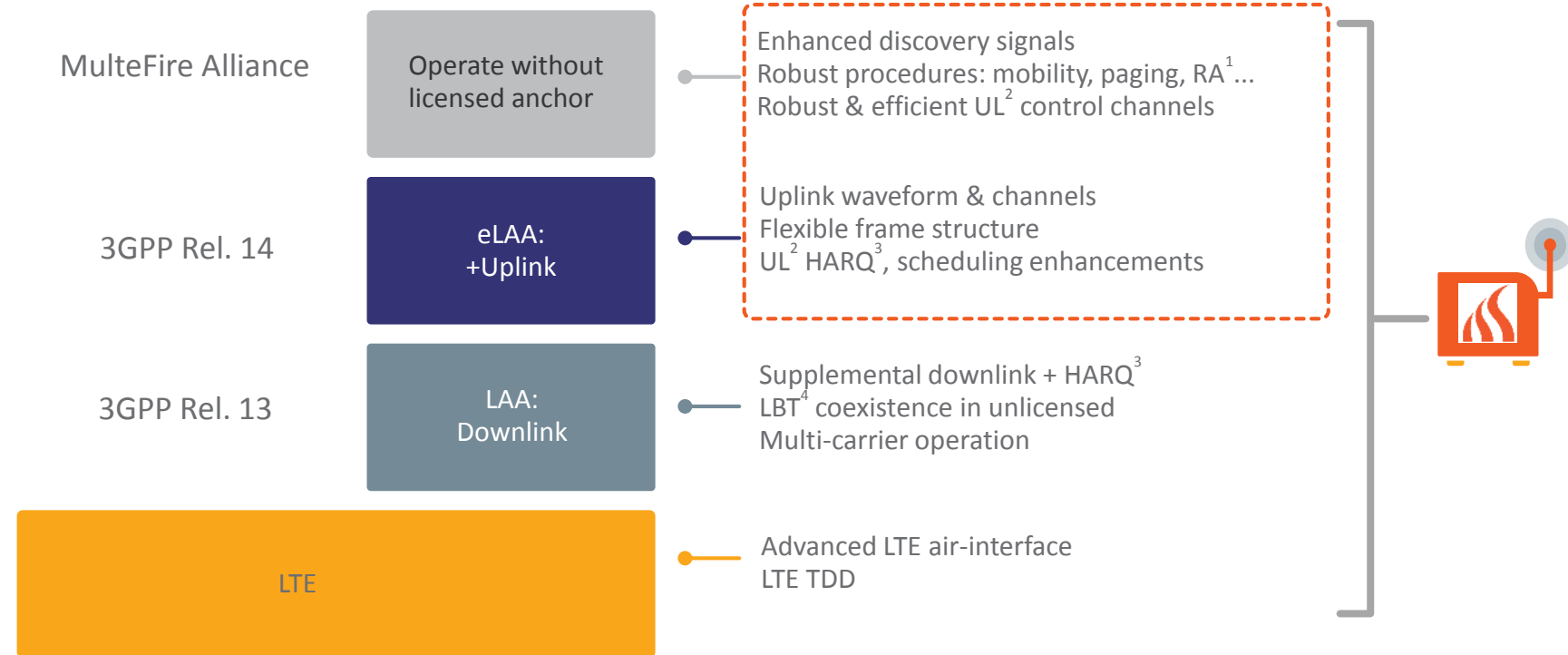


1) Signal-to-interference-plus-noise ratio (SINR); 2) Media Access Control (MAC) Layer; 3) Handover (HO); 4) Radio link failure (RLF)

MulteFire technology is based on 3GPP LAA and eLAA

Extends eLAA—uplink & downlink—to operate without anchor in licensed spectrum

New features

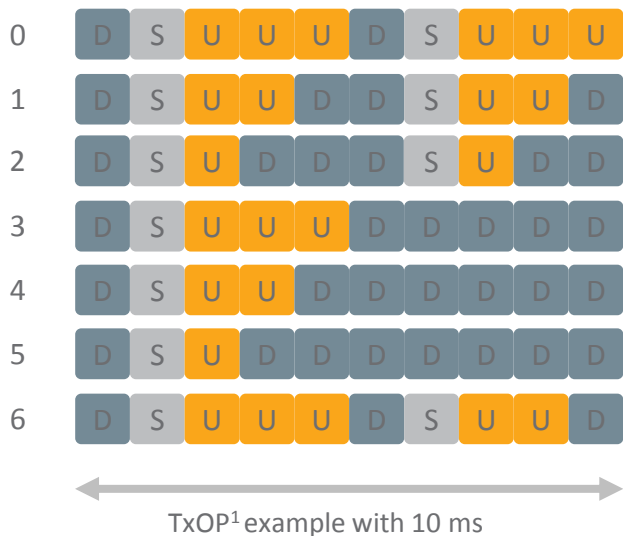


1) Random Access; 2) Uplink; 3) Hybrid automatic retransmission request; 4) Listen before talk

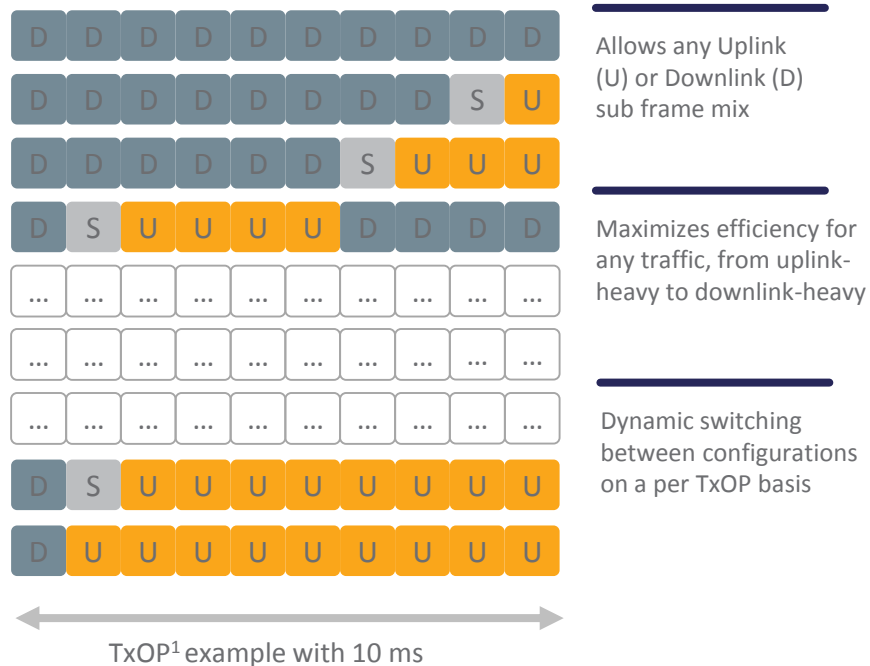


Flexible frame structures supporting any UL/DL traffic mix

Rel.8: limited TDD configurations,
Semi-static switching



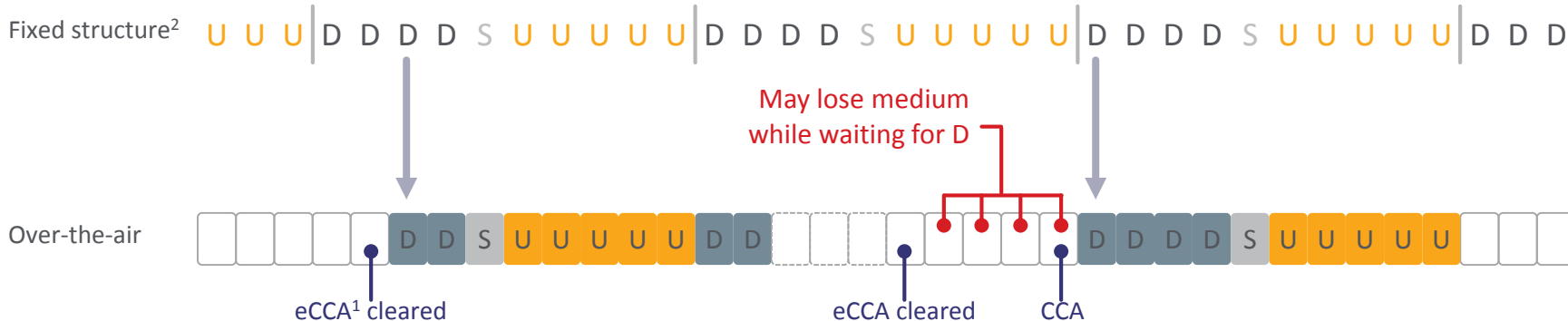
Rel.14: numerous TDD configurations,
Dynamical switching



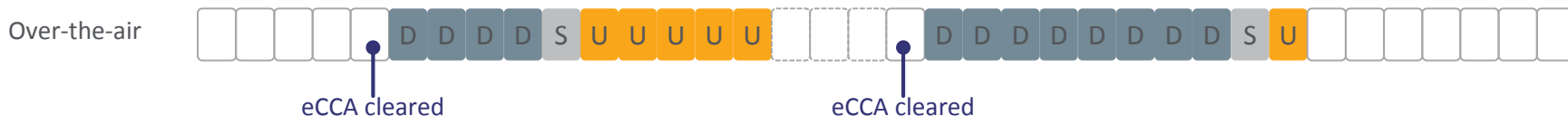
1) Transmit opportunity (TxOP)

Flexible frame structure for more efficient LBT¹

Fixed frame structure — wait for next downlink sub-frame (D), fixed to system time



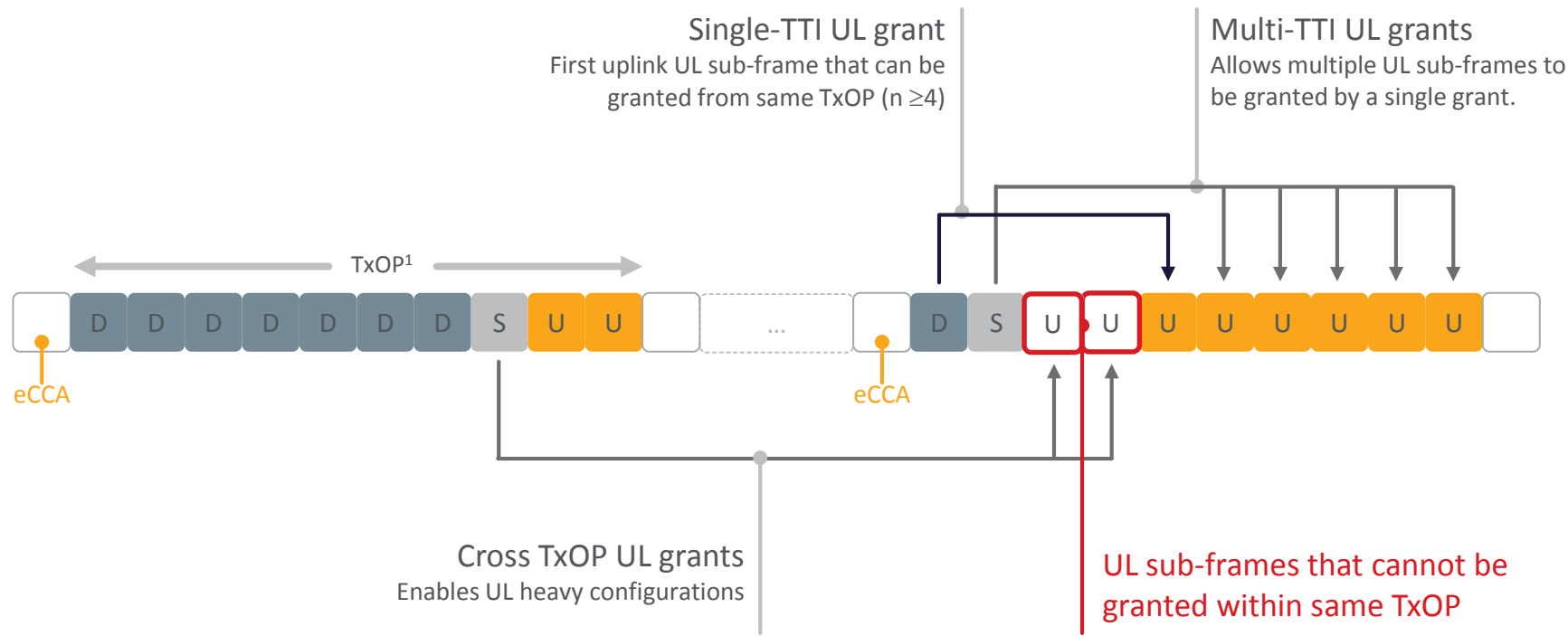
Flexible frame structure — any sub-frame can be downlink (D), no need to wait



1) Listen before talk (LBT) using enhanced Clear Channel Assessment (eCCA); 2) D = Downlink (DL), U = Uplink (UL), and S = Special sub-frame (mix of UL, DL and guard period)

Uplink scheduling enhancements improves performance

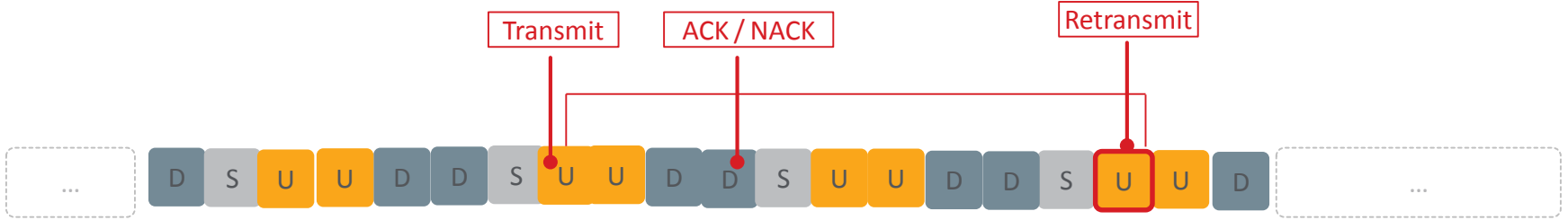
Efficiently support flexible frame structure



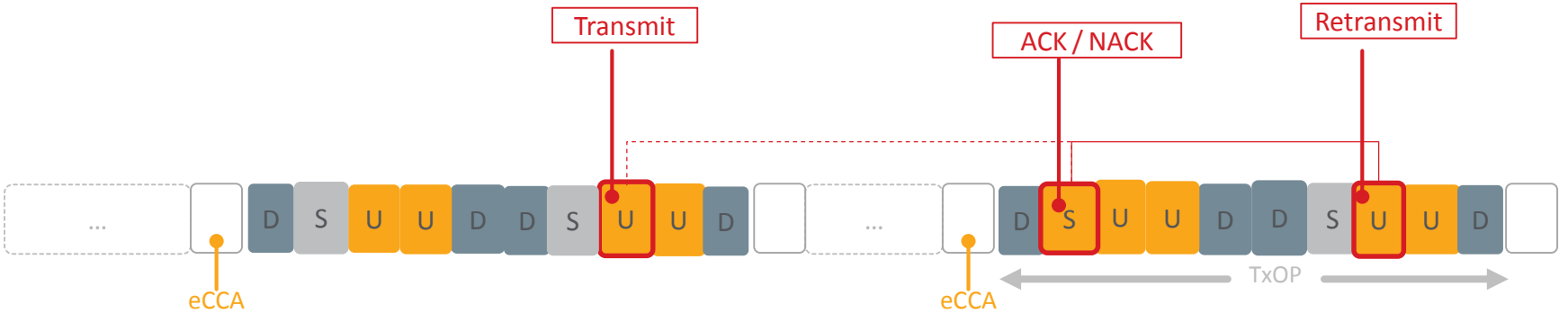
1) Transmit opportunity (TxOP)

Asynchronous UL HARQ handles unknown timing of LBT

Synchronous UL HARQ—fixed timing for ACK/NACK and retransmissions



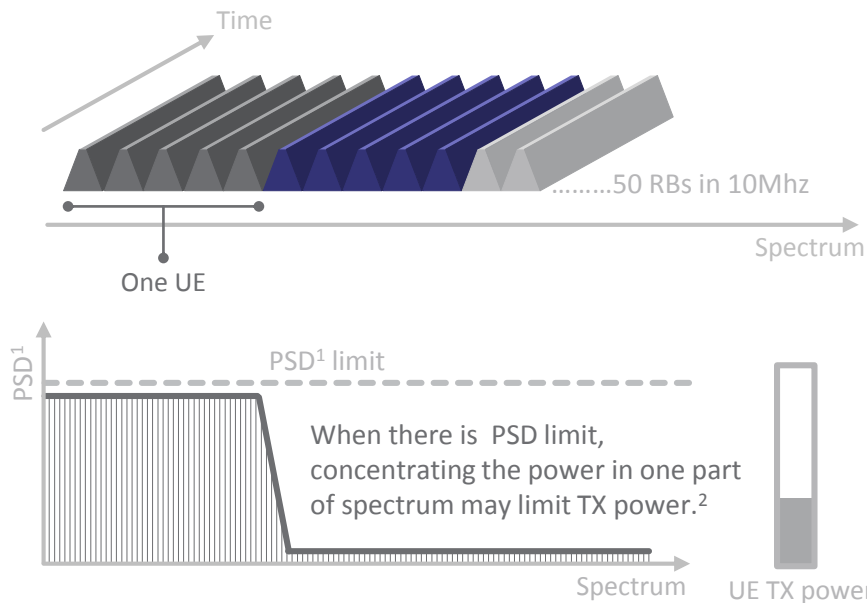
Asynchronous UL HARQ—ACK/NACK and retransmissions adapt to actual TxOP from LBT



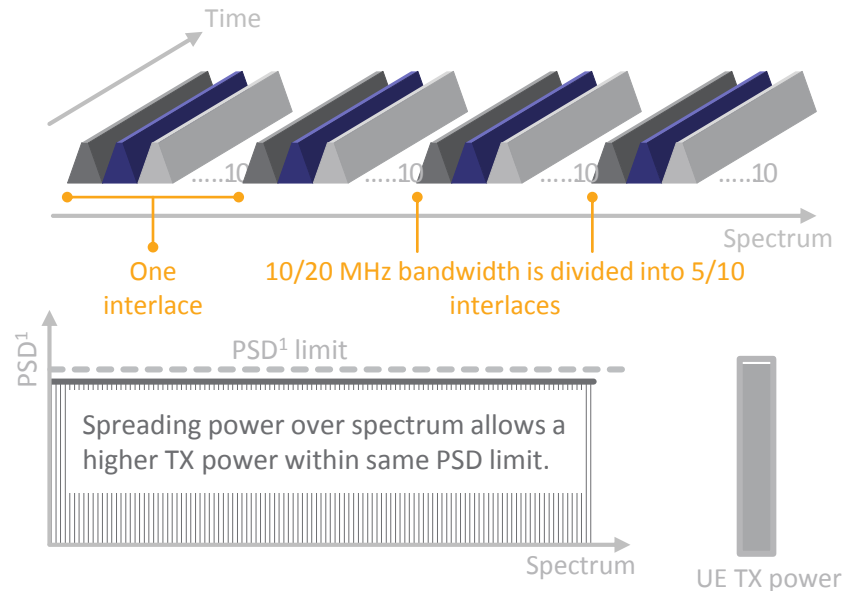
Flexible uplink waveform to meet spectrum requirements

Meets PSD¹ limits for 5GHz unlicensed with better link budget (coverage)

LTE SC-FDM uplink—localized power



RB interlaced—distributed power

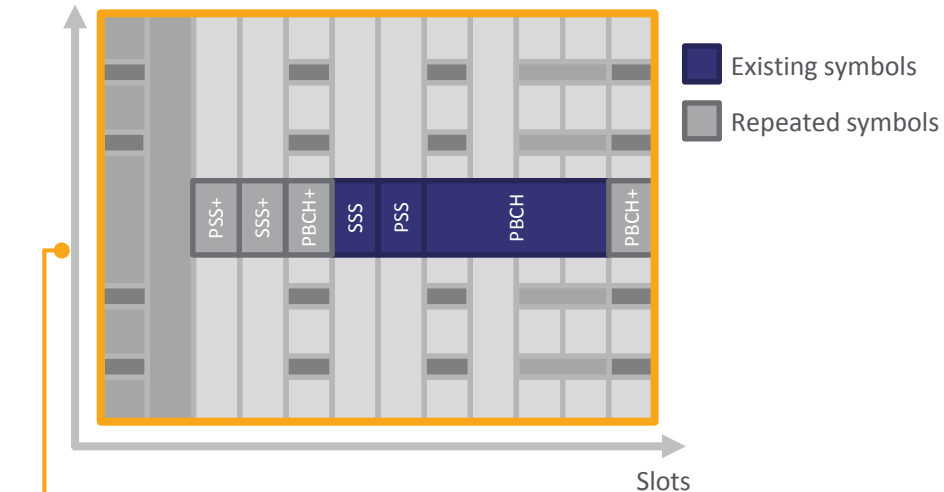


1) Power Spectrum Density (PSD) measured in power per spectrum, e.g., dBm/MHz; 2) Power concentrated in one part of the spectrum generally good for uplink coverage—but not if there is PSD limit.

Enhanced discovery signals handles unlicensed operation

Increased robustness needed without a licensed anchor used by LAA/eLAA

Sub-carriers



Repeats critical symbols¹ for faster and more robust acquisition

Enables decoding with a single instance for cell edge users

Backwards compatible — LAA/eLAA understands MulteFire signals

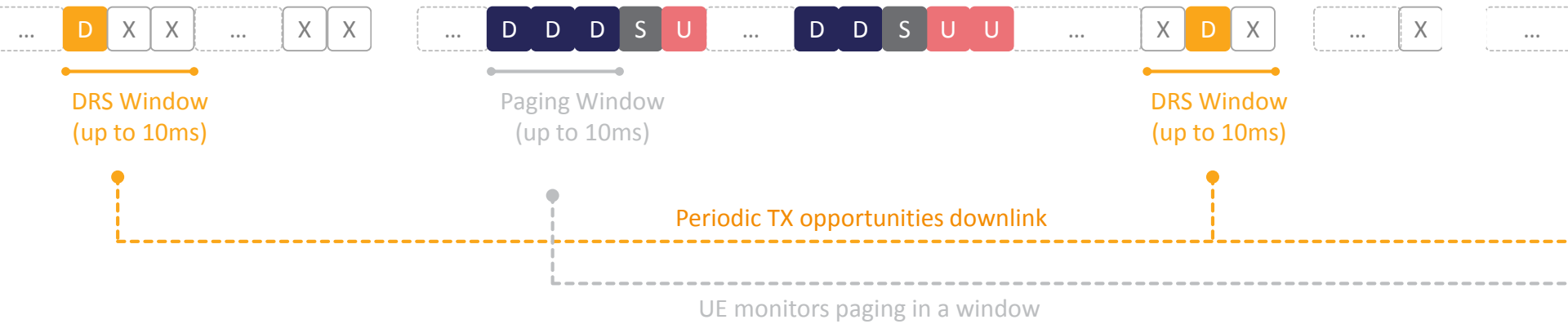


1) Primary Synchronization Signals (PSS), Secondary Synchronization Signals (SSS), and Physical Broadcast Channel (PBCH).

Periodic TX opportunities defined to handle LBT

Defined TX windows for critical operations, e.g., DRS, RACH, RRM¹

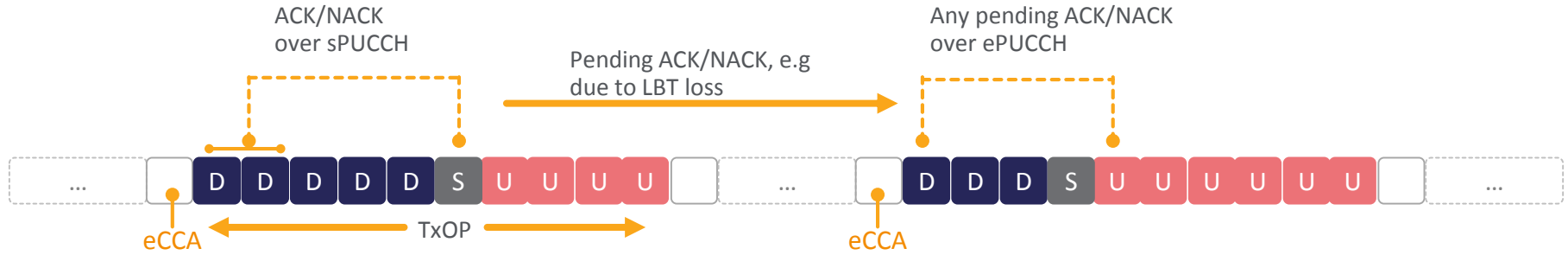
Periodic TX opportunities for pre-configured uplink



1) Discovery Reference Signal (DRS), Random Access Channel (RACH), Radio Resource Management (RRM)

Introducing PUCCH¹ for standalone operation in unlicensed spectrum

Short PUCCH (sPUCCH) combined with extended PUCCH (ePUCCH)



ACK/NACK, CSI & SR
feedback for DL TX on
sPUCCH & ePUCCH

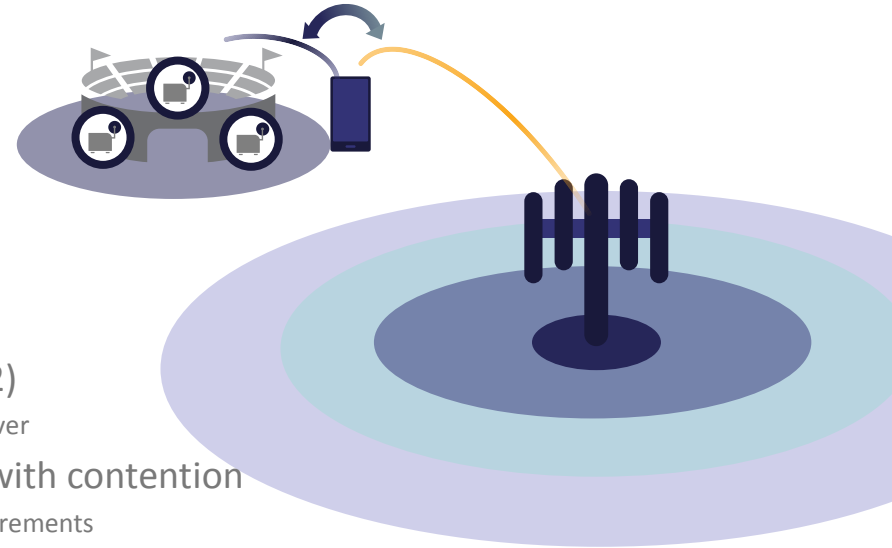
sPUCCH for small
payloads in part of a
special sub-frames (S)

ePUCCH for larger
payload and high user
mux capability

Robust mobility

- Seamless experience for various mobility modes

Mobility	Idle	Connected
Between MulteFire nodes	✓	✓
Moving from MulteFire to Macro network	✓	✓
Moving from Macro to MulteFire	✓	✓

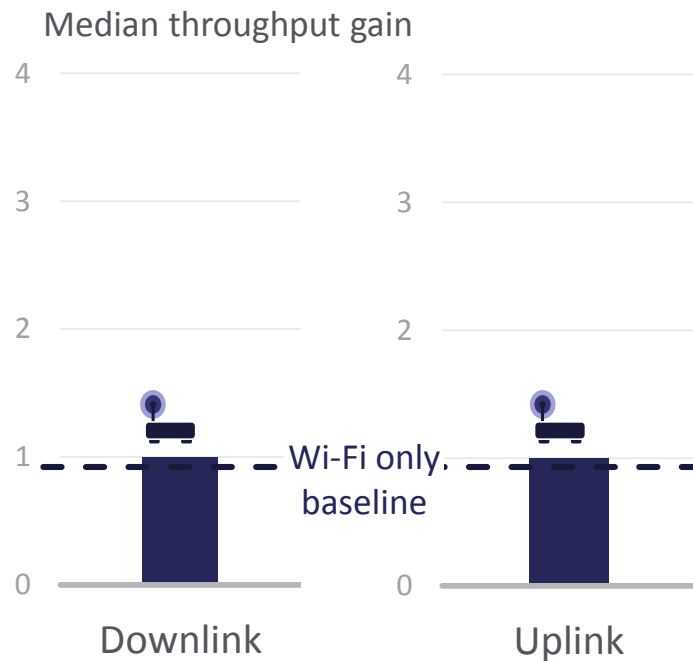
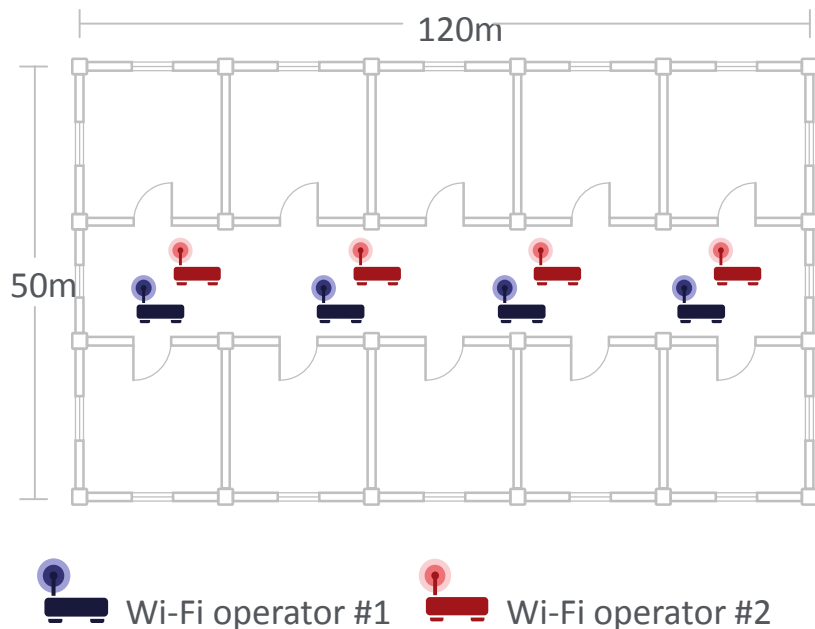


- Backward and forward handover supported (as Rel. 12)
 - Shorter interruption in case of radio link failure from forward handover
- Enhancement to radio link failure triggers to operate with contention
 - Detect missing DRS sub-frames as part of in-sync/out-of-sync measurements
- Enhancements for RRM measurements in async. deployments
 - New measurement gap configurations defined to enable measuring infrequently occurring DRS



Indoor simulations results

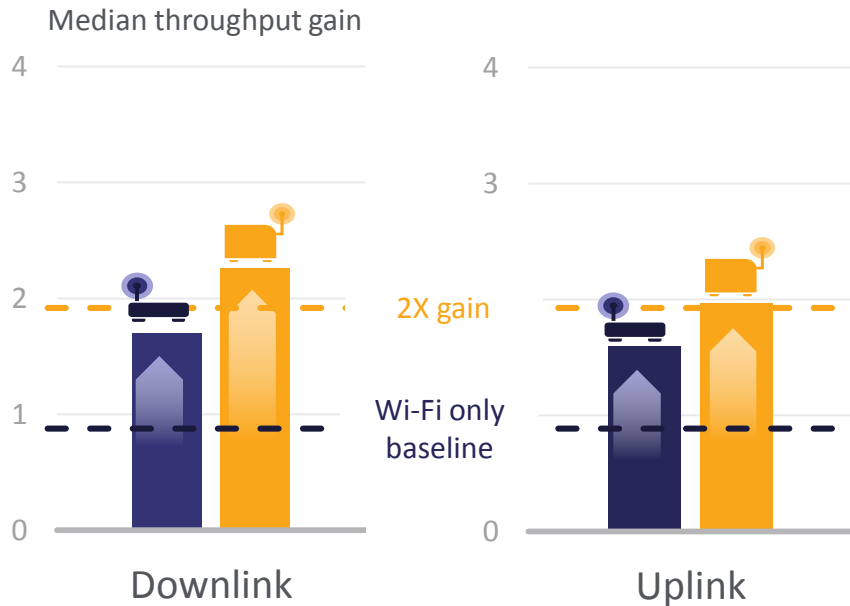
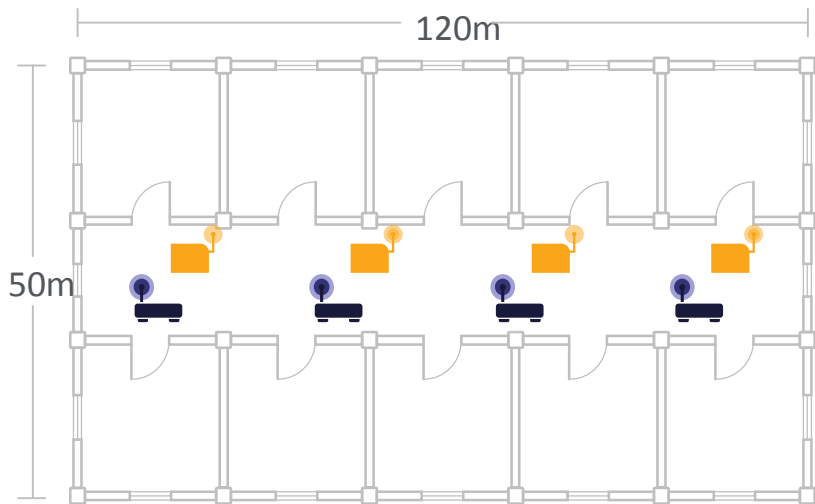
Baseline with 2 Wi-Fi operators in an office building, each with 4 access points¹



1) Indoor, single 20 MHz channel in 5 GHz, 80%-20% traffic split between down- and uplink, bursty traffic generated with 4 Mb files arriving with exponential inter arrival times, high traffic load with buffer occupancy at 50% in downlink and 20% in uplink for Wi-Fi only baseline, 4 APs per operator, 2 operators, office building size 120m x 50m, propagation model 3GPP indoor hotspot (InH), Wi-Fi is 802.11ac, MIMO 2x2, no MU-MIMO

MulteFire offers ~2X capacity gain over Wi-Fi baseline¹

Wi-Fi performance preserved, sometimes better, when neighbor switch to MulteFire



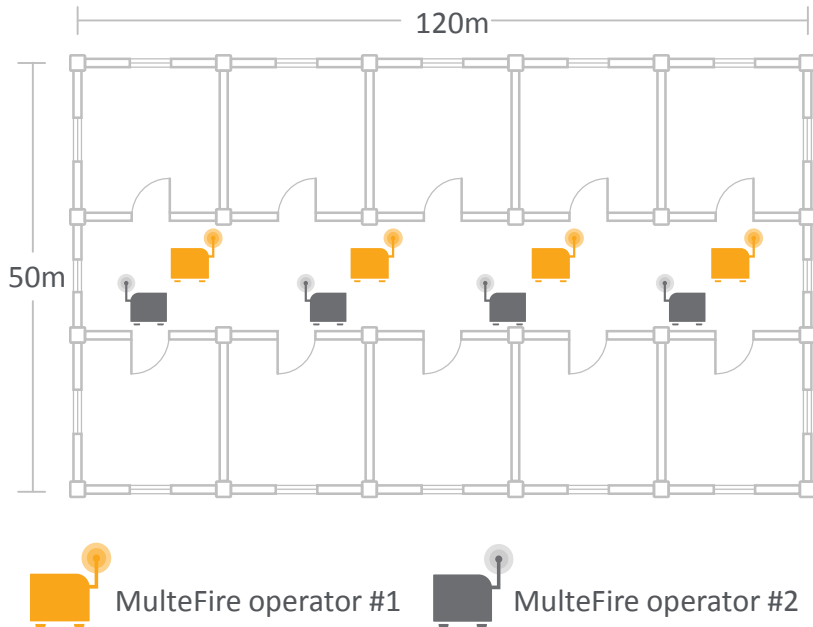
Wi-Fi operator #1 MulteFire operator



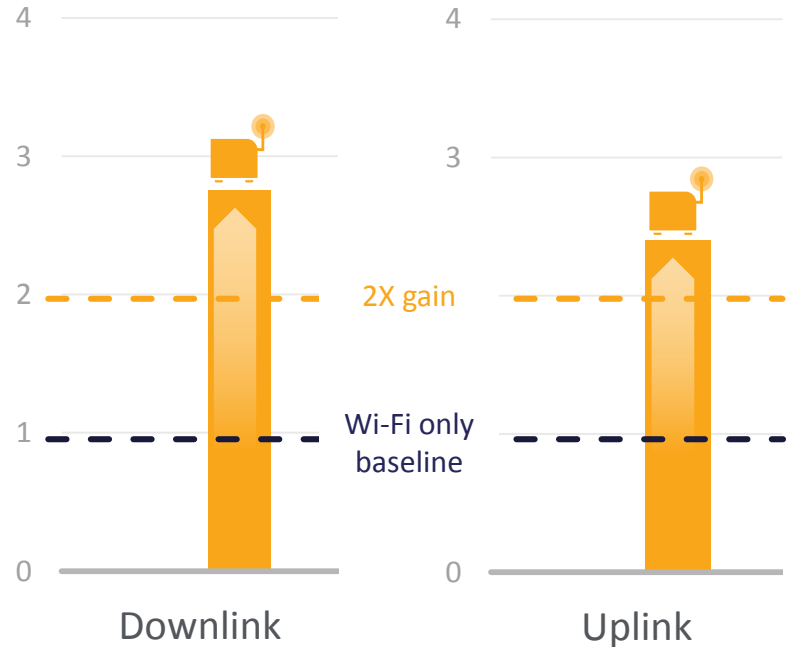
¹ Indoor, single 20 MHz channel in 5 GHz, 80%-20% traffic split between down- and uplink, bursty traffic generated with 4 Mb files arriving with exponential inter arrival times, high traffic load with buffer occupancy at 50% in downlink and 20% in uplink for Wi-Fi only baseline, 4 APs per operator, 2 operators, office building size 120m x 50m, propagation model 3GPP indoor hotspot (InH), Wi-Fi is 802.11ac, MIMO 2x2, no MU-MIMO

MulteFire by itself offers >2X capacity gain over Wi-Fi¹

Higher gains in MulteFire only deployments, especially in dense scenarios



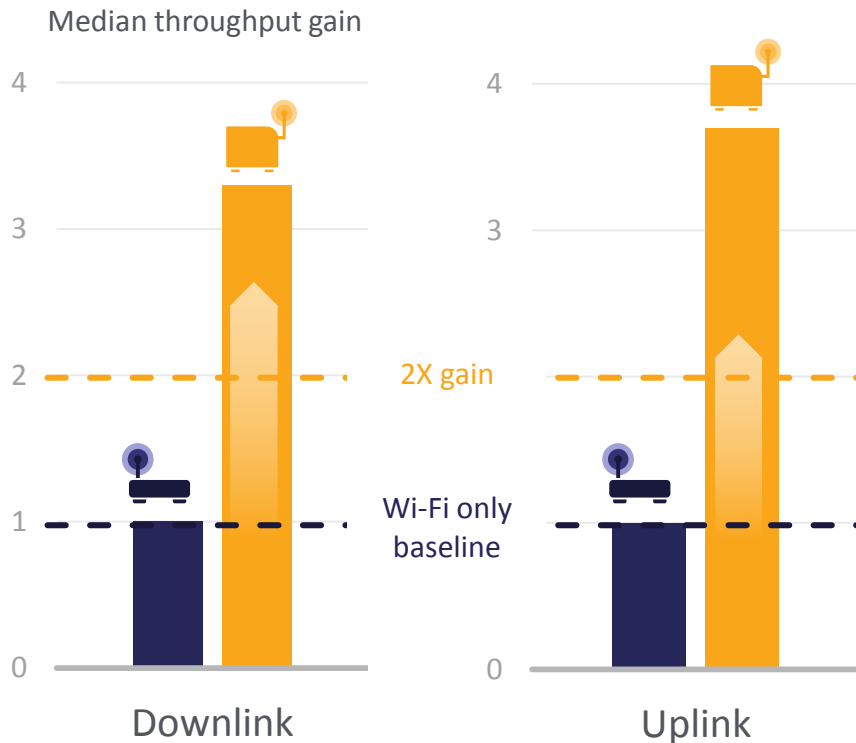
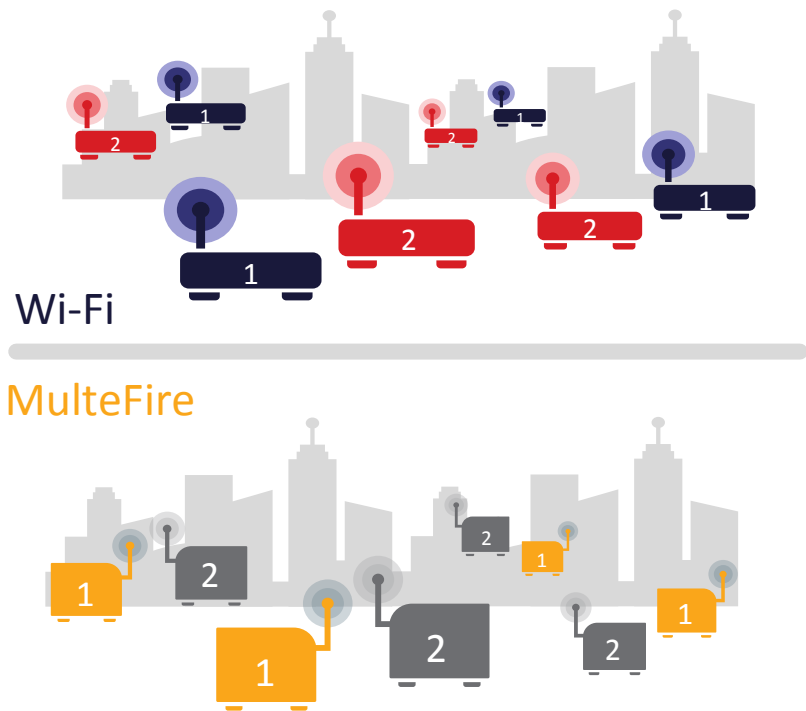
Median throughput gain



¹ Indoor, single 20 MHz channel in 5 GHz, 80%-20% traffic split between down- and uplink, bursty traffic generated with 4 Mb files arriving with exponential inter arrival times, high traffic load with buffer occupancy at 50% in downlink and 20% in uplink for Wi-Fi only baseline, 4 APs per operator, 2 operators, office building size 120m x 50m, propagation model 3GPP indoor hotspot (InH), Wi-Fi is 802.11ac, MIMO 2x2, no MU-MIMO

MulteFire offers significant capacity advantage outdoors¹

Gain over Wi-Fi depends on load and traffic mix, 2X-6X in simulation scenarios



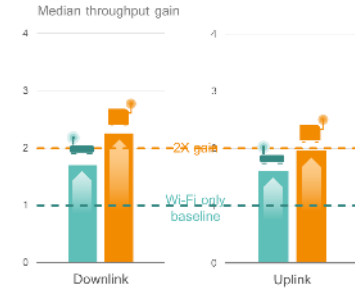
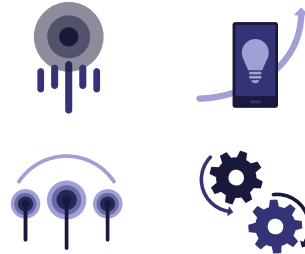
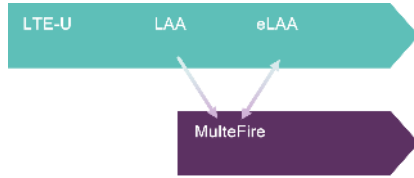
1) Outdoor, single 20 MHz channel in 5 GHz, 50%-50% traffic split between down- and uplink, bursty traffic generated with 4 Mb files arriving with exponential inter arrival times, medium traffic load with buffer occupancy at 38% in downlink and 51% in uplink for Wi-Fi only baseline, dense cluster deployment, 2 operators, 4 APs each, propagation model 3GPP outdoor scenario with all APs in 50m radius, Wi-Fi is 802.11ac, MIMO 2x2, no MU-MIMO

A stylized graphic of three flame-like shapes in shades of gray, rising from the bottom left towards the top right. The largest flame is in the foreground, with two smaller ones behind it.

MULTEFIRE™

MulteFire Summary

MulteFire summary



Based on 3GPP standards

MulteFire Technology is based on 3GPP LAA and eLAA

Similar performance & coexistence as LAA/eLAA in unlicensed

Extends eLAA—uplink & downlink—to operate without anchor in licensed spectrum

Performance advantages

Coverage: LTE like, +5-6dB link budget

Capacity: LTE link efficiency & MAC

Mobility: carrier grade, seamless

Robustness: predictable, RLF, SON

Capacity gains over Wi-Fi

~2X capacity gain over Wi-Fi baseline

Higher gains when MulteFire only, especially in dense scenarios

Significant capacity advantage outdoors





Thank You

For more information,
visit us at www.multefire.org