MulteFire™ Technology Progress and Benefits, and How It Enables A New Breed of Neutral Hosts

Qualcomm Technologies, Inc.

May 24, 2016

More data to more devices in more places

~75%

Mobile traffic that will be rich content & video by 2020[1]

25-50B

Connected devices and IoT by 2020[2]

26 TB

Amount of data used at a single venue[3]

~80%

Fraction of wireless data that is consumed indoors[4]

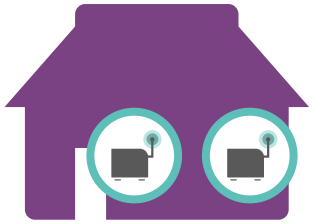
Source: 1) Cisco, Feb. '16; 2) Machina, Feb. '14, Cisco, Jul. '13; 3) Mobile Sports Report Feb.' 16 (16 TB DAS), Levi Stadium Feb.' 16 (10 TB Wi-Fi); 4) Gartner '14

Unlicensed spectrum enables small cells in more places

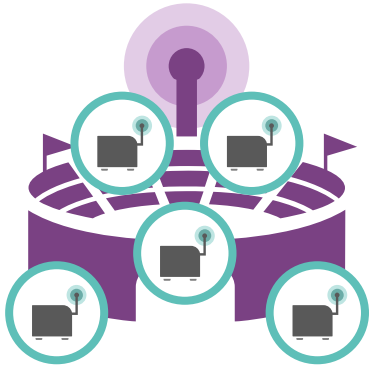
Need to leverage all spectrum types to meet data demands and IoT challenges

In-building/ Enterprises

Small Businesses



Venues



Residential/ Neighborhood

Large amounts of unlicensed spectrum available globally[1]

Ideal for small cells thanks to typically lower transmit powers

Non-exclusive spectrum can serve users from any operator, ideal for Neutral Host

1) Regionally dependent, e.g. ~500 MHz available in 5 GHz unlicensed spectrum in USA

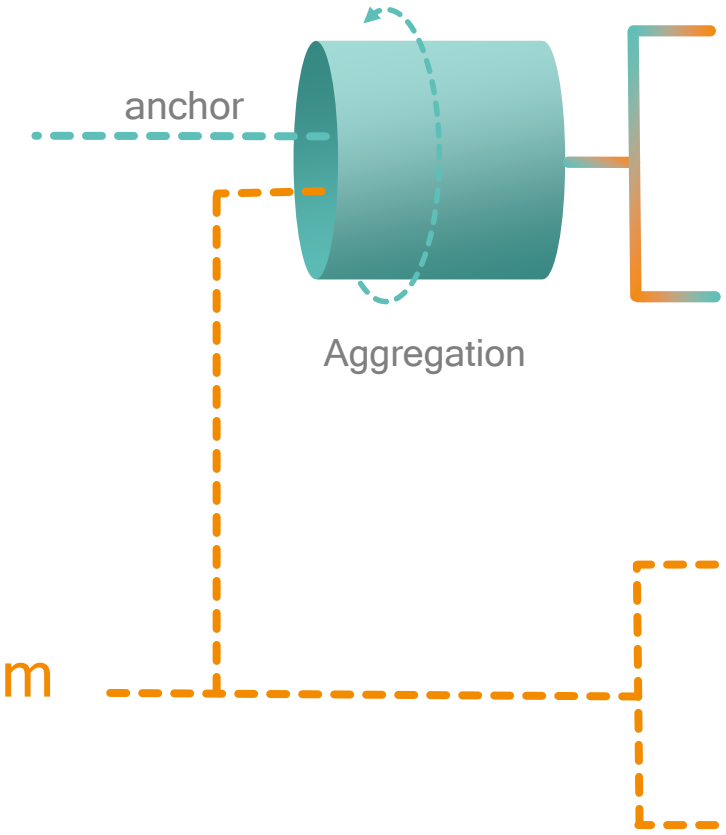
Multiple technologies will coexist in unlicensed spectrum

Licensed Spectrum

Exclusive use

Unlicensed Spectrum

Shared use



LTE-U / LAA[1]

Targeting mobile operators using LTE in unlicensed spectrum for new small cell deployments

LWA[2] / LWIP[3]

Targeting mobile operators leveraging existing carrier Wi-Fi deployments

MulteFire

Broadens LTE ecosystem to enhanced and new deployment opportunities, suitable for neutral host

Wi-Fi[4]

Evolving for enhanced performance and expanding to new usage models, used today as neutral host

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 provides the best of both worlds

LTE technology operating solely in unlicensed or shared spectrum

LTE-like performance

Enhanced capacity and range
Seamless mobility
Robust user experience
Hyper-dense, self-organizing
LTE security
VoLTE, LTE IoT, LTE broadcast...

Harmoniously coexist with
Wi-Fi and LTE-U/LAA[1]

Wi-Fi-like deployment simplicity

Unlicensed spectrum, e.g., 5 GHz
Suitable for neutral hosts
Leaner, self-contained architecture
Over-the-air contention

1) Licensed-Assisted Access, also includes enhanced LAA (eLAA);

MulteFire brings LTE benefits to a larger eco-system

Enabling new deployments indoors, in venues, enterprises, managed services,…

Plug-and play deployments

Self-contained, self-organizing suitable for high-capacity dense deployments

Excels both indoor & outdoors

To serve any users, employees, customers, visitors with LTE-like security[1]

Offloads mobile operators

Extends indoor coverage with service continuity to mobile networks–neutral host

Better end-user experience

Consistent data rates that reaches further, seamless mobility within deployments

Expands IoT opportunities

LTE IoT optimizations further extends range and battery life

Fair sharing with everyone

Fair sharing of spectrum among multiple deployments and other technologies

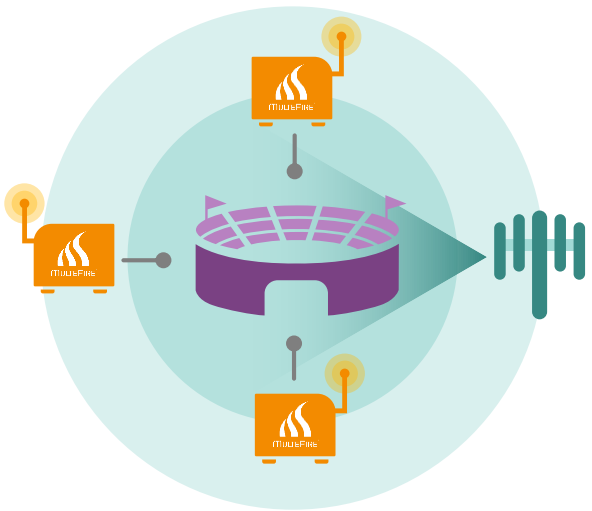
1) Both with and without SIM

MulteFire serves mobile subscribers, patrons and IoT

Same deployment can serve multiple use cases at the same time

Neutral host to augment mobile networks

SIM based authentication to offload capacity in crowded places and/or extend coverage indoors

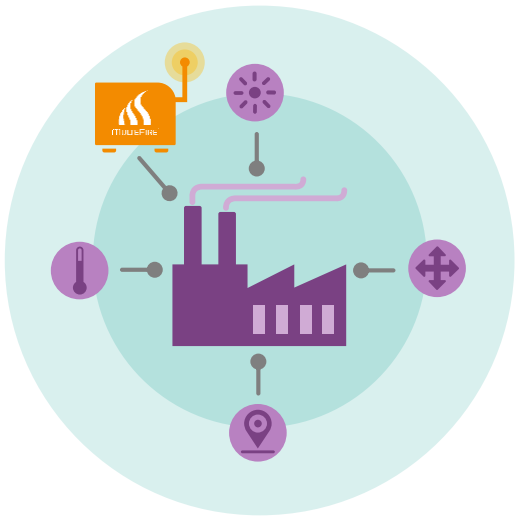


Enhanced local broadband access

Enhanced broadband access to employees, customers or visitors, typically without a SIM card

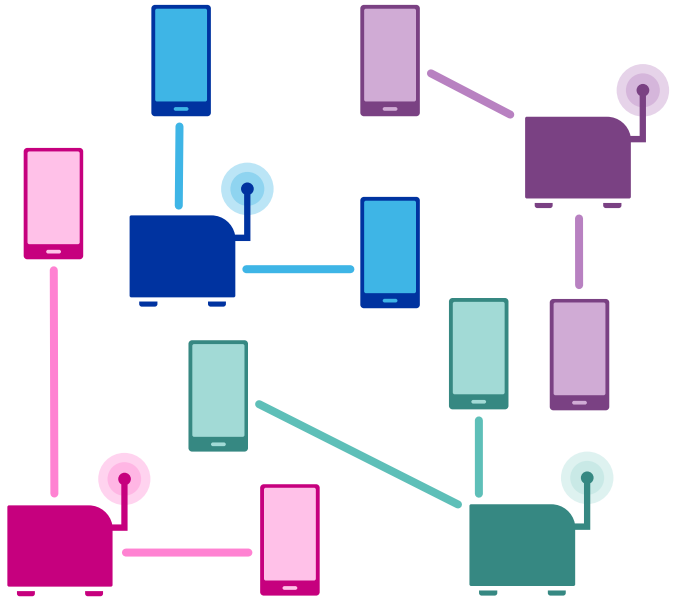
Internet of Things verticals

Expand LTE value-added services to more places, such as dedicated industrial IoT deployments



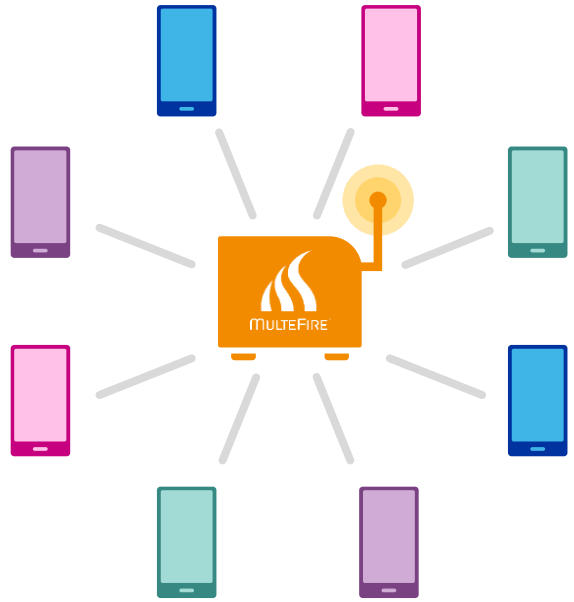
MulteFire enables neutral hosts in more places

Augments mobile networks with offload capacity and extended coverage indoors



Traditional mobile deployments

One deployment per operator is not always feasible or cost efficient, e.g., venues or in-building

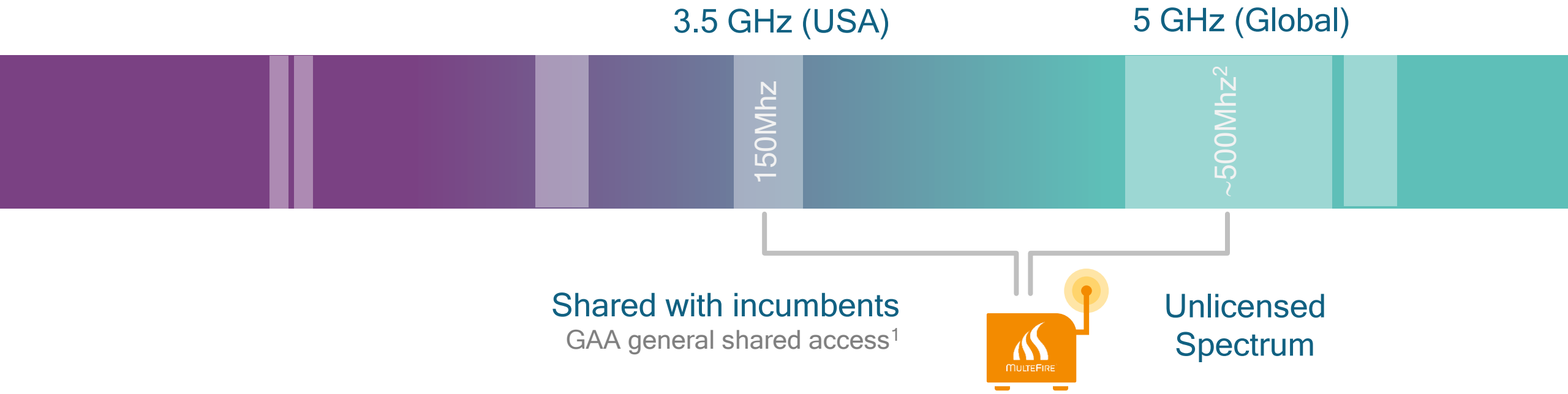


Neutral host deployments

Shared equipment on non-exclusive spectrum can serve any device on behalf of multiple mobile operators

For any spectrum that needs over-the-air contention

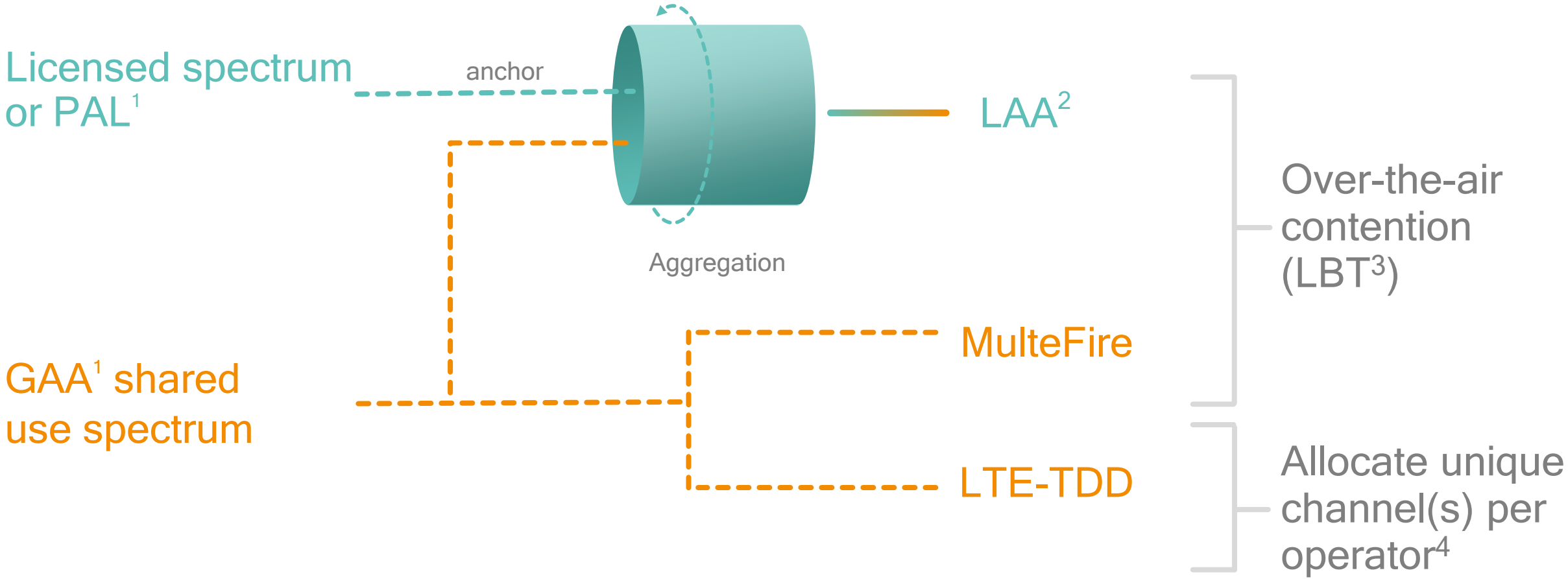
MulteFire supports Listen Before Talk (LBT) for fair sharing of spectrum



1) General Authorized Access (GAA) is tier 3 in the US 3.5 GHz 3-tier licensing model; 2) Regionally dependent, e.g. ~500 MHz available in 5 GHz unlicensed spectrum in the USA.

High performance options for GAA[1] in 3.5 GHz USA

Multiple LTE options will coexist in 3.5 GHz GAA

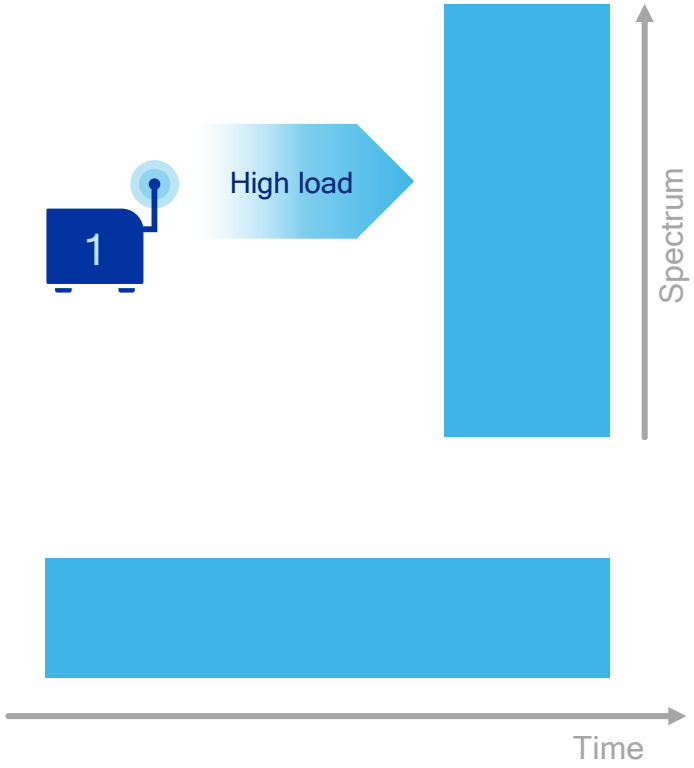


1) Priority Access Licenses (PAL) is tier 2 and General Authorized Access (GAA) is tier 3 in the 3-tier licensing model for shared 3.5 GHz in USA; 2) Licensed-Assisted Access, also includes enhanced LAA (eLAA);
3) Listen before talk; 4) Channels can be reused with sufficient RF isolation

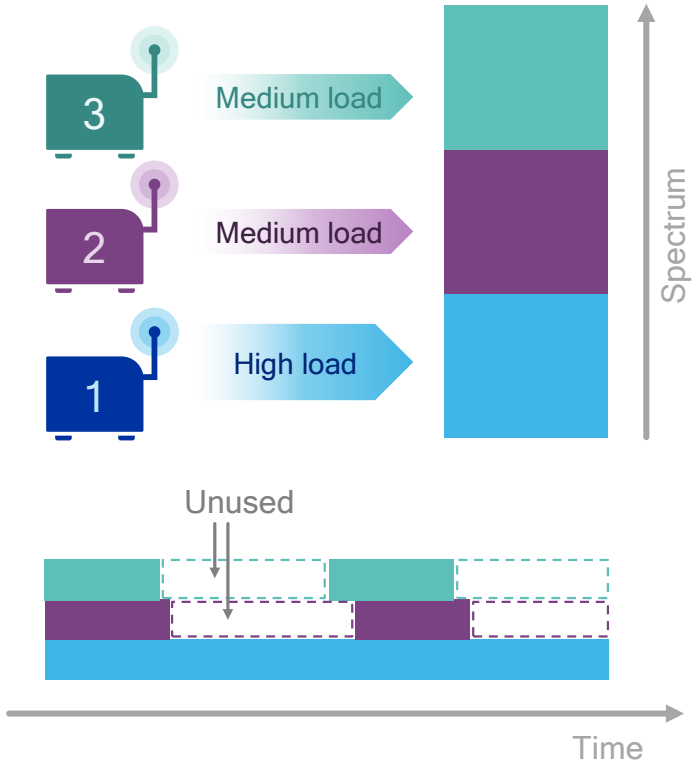
MulteFire helps 3.5GHz GAA scale to multiple deployments

Multiple deployments share a wide channel–better spectrum utilization & peak-rate

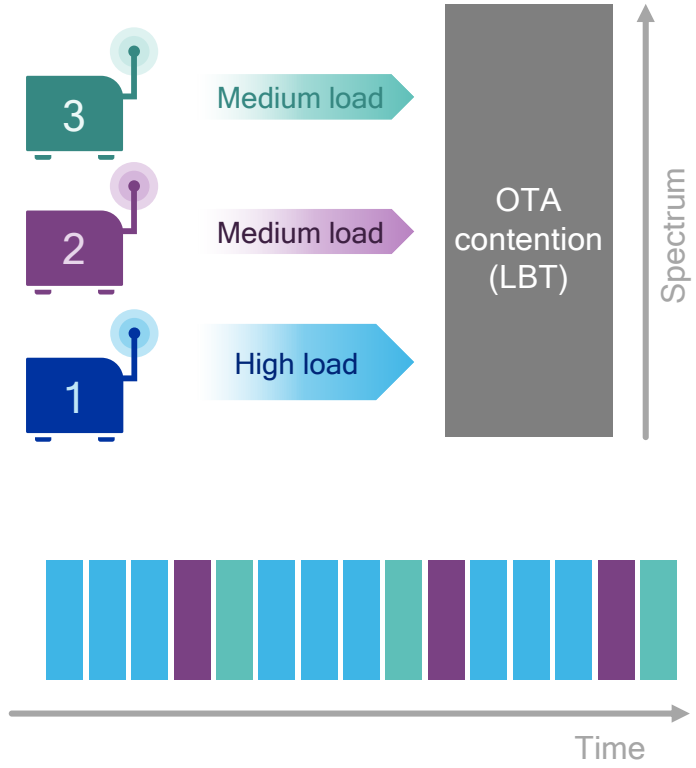
Highest spectrum efficiency with one LTE-TDD deployment



Multiple LTE-TDD deployments with reduced channel size, spectrum may become underutilized[1, 2]



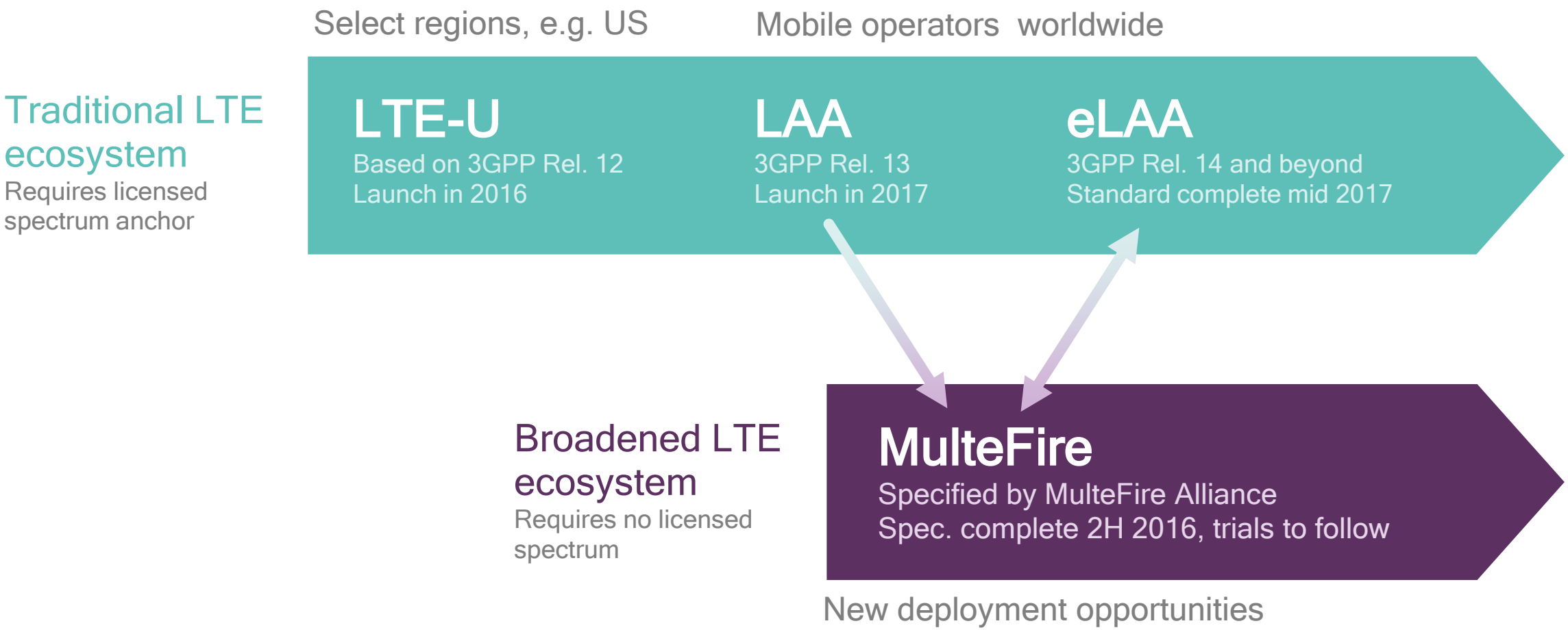
MulteFire brings trunking efficiency from sharing a wide channel to improve spectrum utilization[1,3]



1) Example with one deployment (#1) with a high traffic load and two deployments (#2 and #3) with medium traffic loads; 2) Spectrum cannot always be evenly split; 3) Trunking benefits depend on relative traffic loads.

MulteFire is based on 3GPP standards

Similar performance and same coexistence as LAA[1]/eLAA[2] in unlicensed



1) Licensed-Assisted Access (LAA); 2) enhanced LAA (eLAA)

MulteFire Technology is based on 3GPP LAA and eLAA

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

MulteFire Alliance

Operate without licensed anchor

- Enhanced discovery signals
- Robust procedures: mobility, paging, RA[1]...
- Robust & efficient UL[2] control channels

3GPP Rel 14

eLAA: +Uplink

- Uplink waveform & channels
- Flexible frame structure
- UL[2] HARQ[3], scheduling enhancements

3GPP Rel 13

LAA: Downlink

- Supplemental downlink + HARQ[3]
- LBT[4] coexistence in unlicensed
- Multi-carrier operation

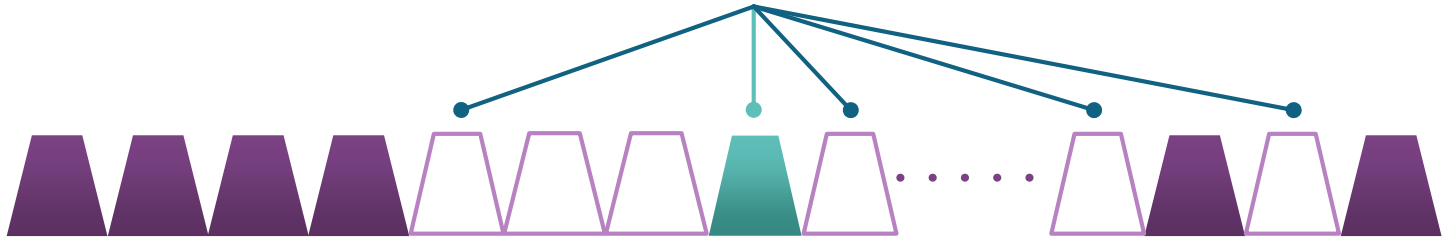
LTE

- Advanced LTE air-interface
- LTE TDD

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

MulteFire is designed share spectrum fairly

Select clear channel(s): Dynamically avoid other users such as Wi-Fi



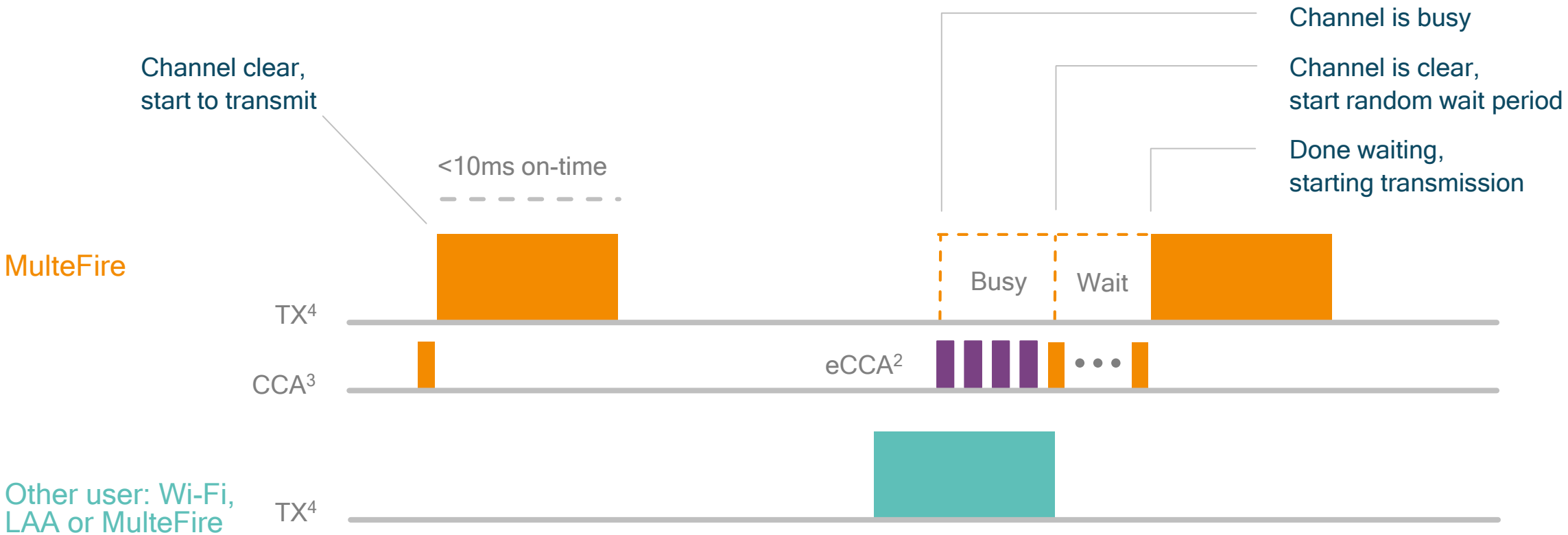
E.g. 20MHz channels in 5Ghz unlicensed

If no clear channel then share fairly: “Listen before talk” (LBT)

When available, aggregate multiple channels

LBT ensures fair sharing in unlicensed spectrum

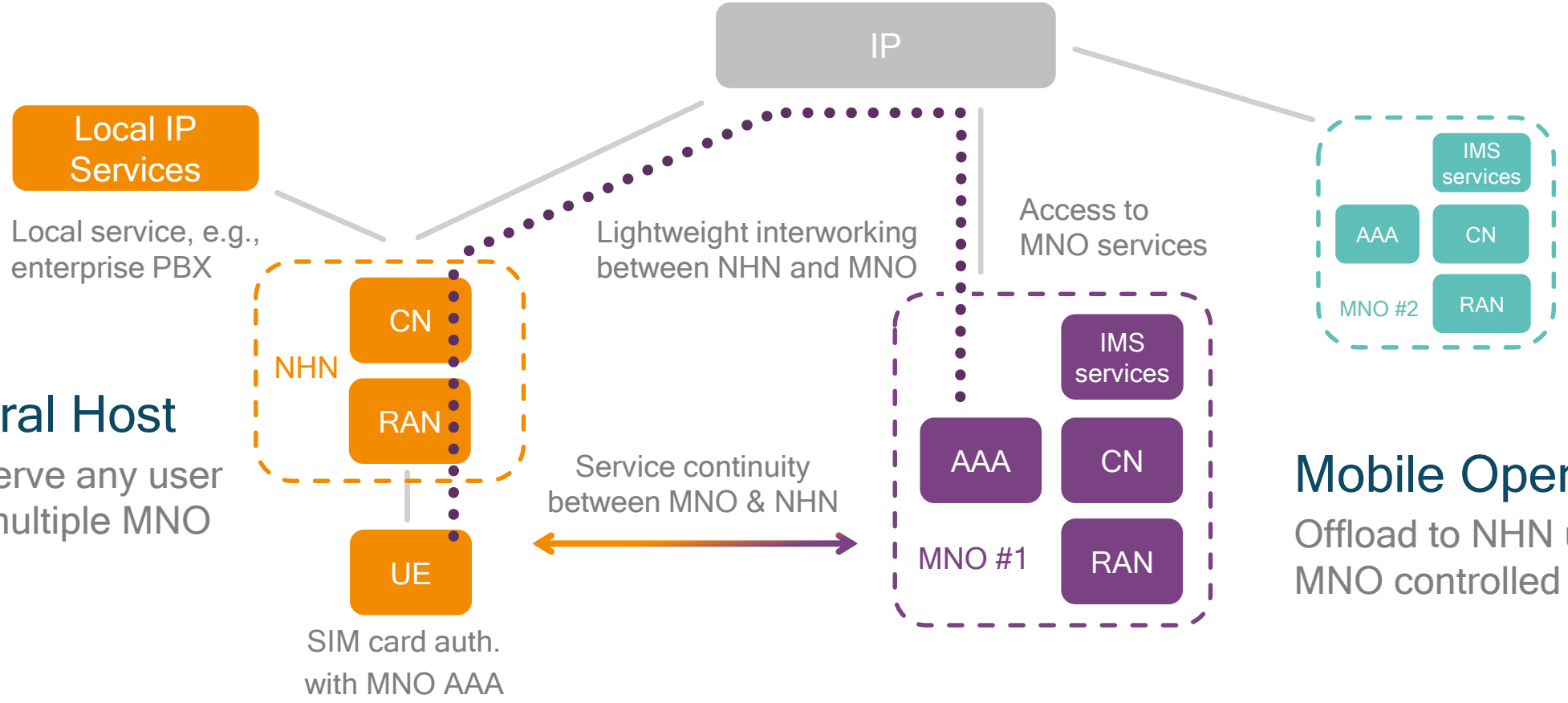
Same global over-the-air contention mechanism for MulteFire, (e)LAA and Wi-Fi[1]



1) LBT applies on LAA, eLAA, MulteFire, and Wi-Fi in the proposed next release of ETSI EN 301 893; 2) Extended CCA (eCCA): If channel is busy (CCA[3]) wait until cleared and then perform a random number of additional successful CCAs[3] before starting transmission; 3) Clear Channel Assessment (CCA): Sense if channel activity is below a certain energy detect (ED) threshold and if so start transmission; 4)Transmit (TX)

Self-contained NHN[1] architecture supports multiple MNOs[2]

Proposed by MulteFire Alliance–applies both on MulteFire and regular LTE



Neutral Host

Can serve any user from multiple MNO

Mobile Operators

Offload to NHN under MNO controlled policies

1) Neutral Host Network; 2) Mobile Network Operator

MulteFire Alliance is an open international organization

Promote MulteFire technology

Drive global technical specifications

Enable product certification

Drive future evolution

Promote effective regulatory policy

3GPP/ETSI style organization

www.multefire.org

Pioneering 5G technologies today with LTE in unlicensed

Leading the world to 5G

Licensed Spectrum
EXCLUSIVE USE

Shared Spectrum with Incumbents
SHARED EXCL. USE or SHARED USE

Unlicensed Spectrum
SHARED USE

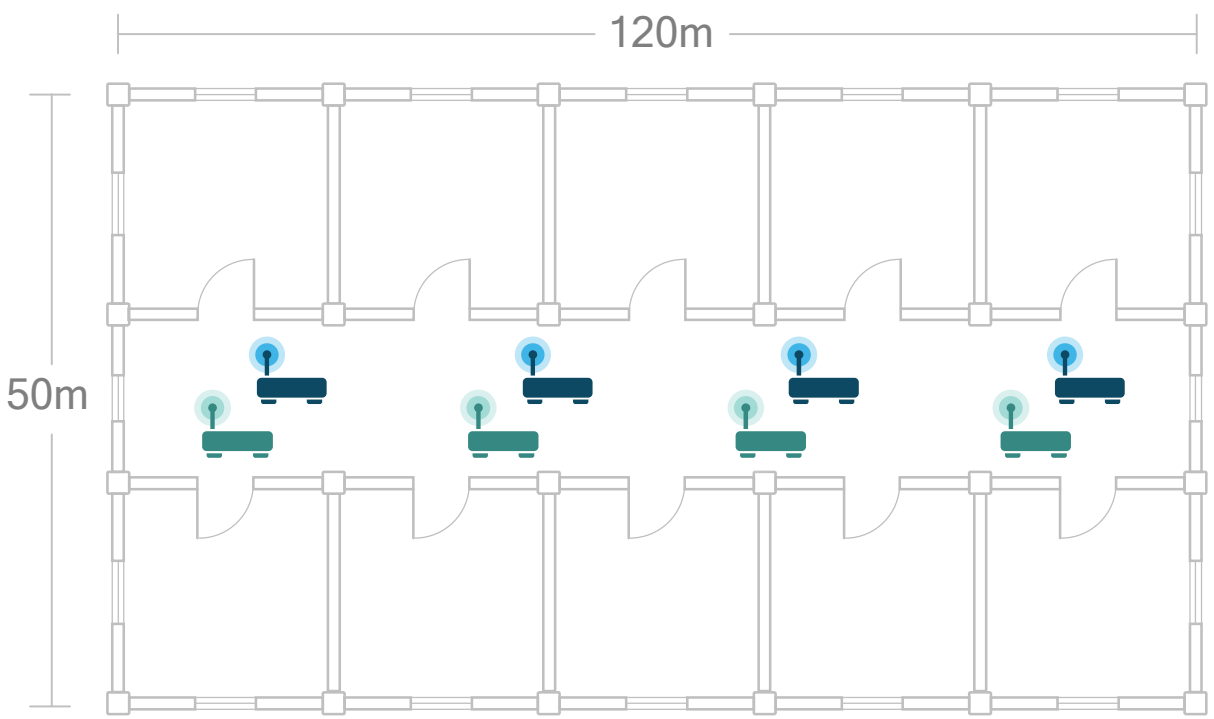
Below 1 GHz: longer range for massive Internet of Things

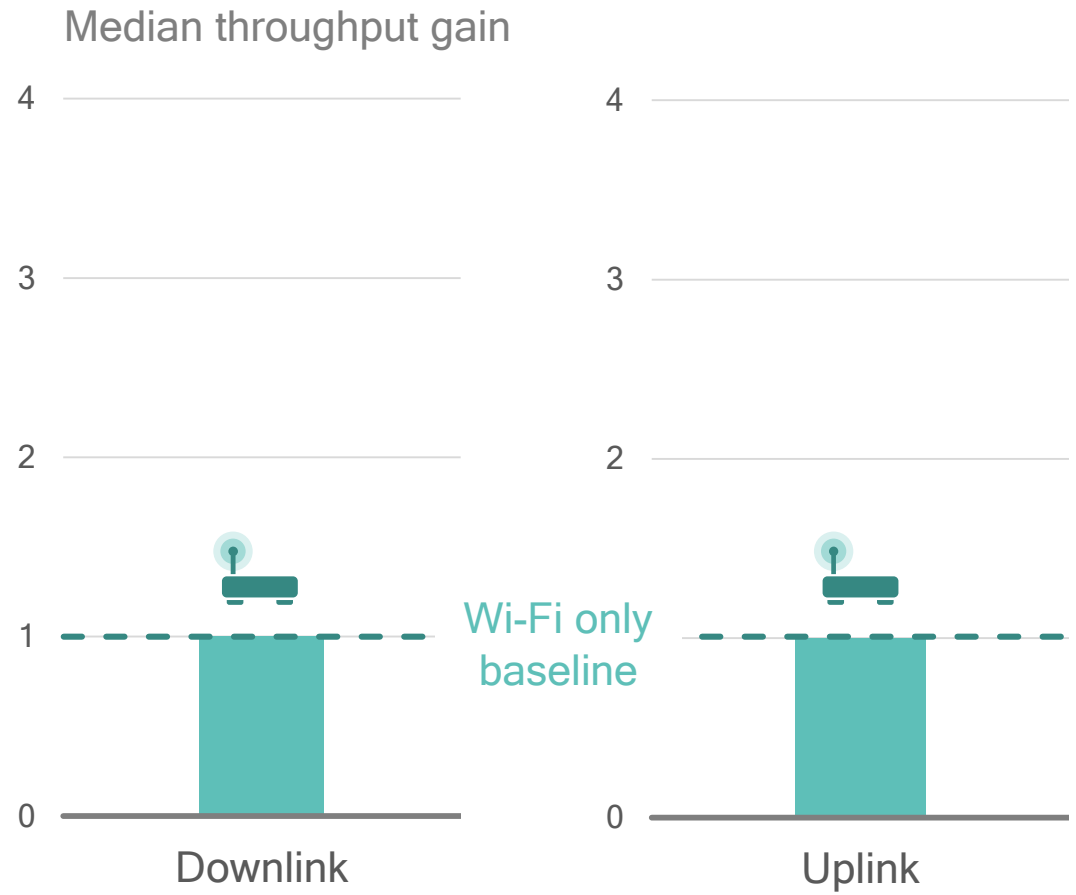
1 GHz to 6 GHz: wider bandwidths for enhanced mobile broadband and mission critical

Above 6 GHz, e.g. mmWave: extreme bandwidths, shorter range for extreme mobile broadband

Indoor simulations results

Baseline with 2 Wi-Fi operators in an office building, each with 4 access points[1]

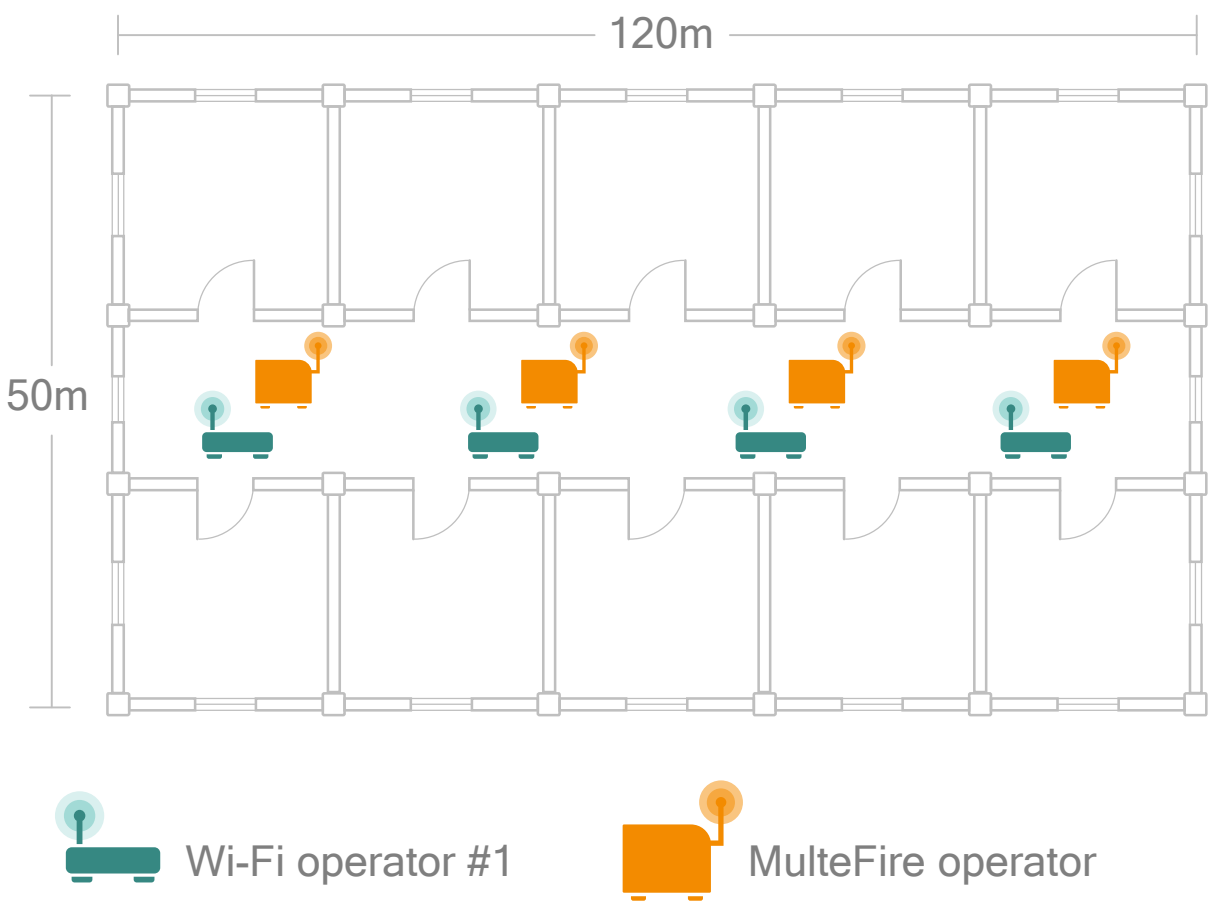


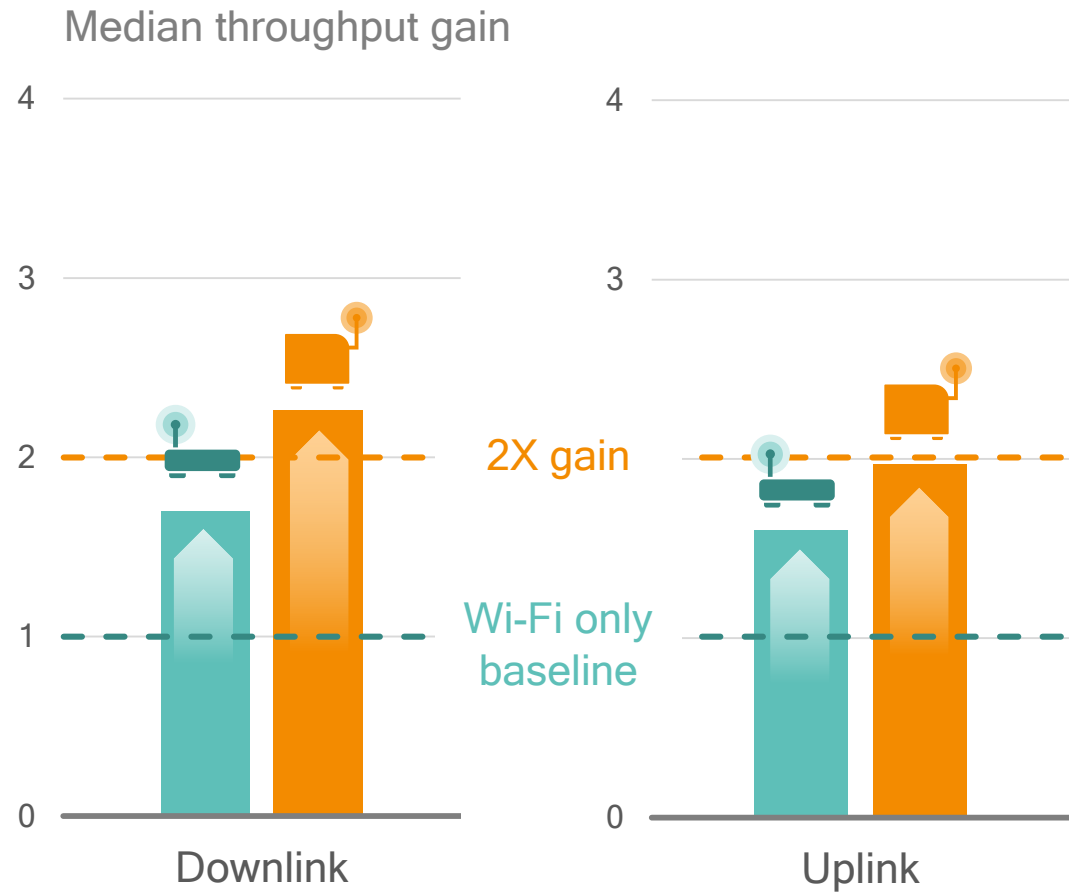


1) Indoor, single 20 MHz channel in 5 GHz, 80%-20% traffic split between down- and uplink, bursty traffic generated with 4 Mb files arriving with exponential inter arrival times, high traffic load with buffer occupancy at 50% in downlink and 20% in uplink for Wi-Fi only baseline, 4 APs per operator, 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 baseline[1]

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





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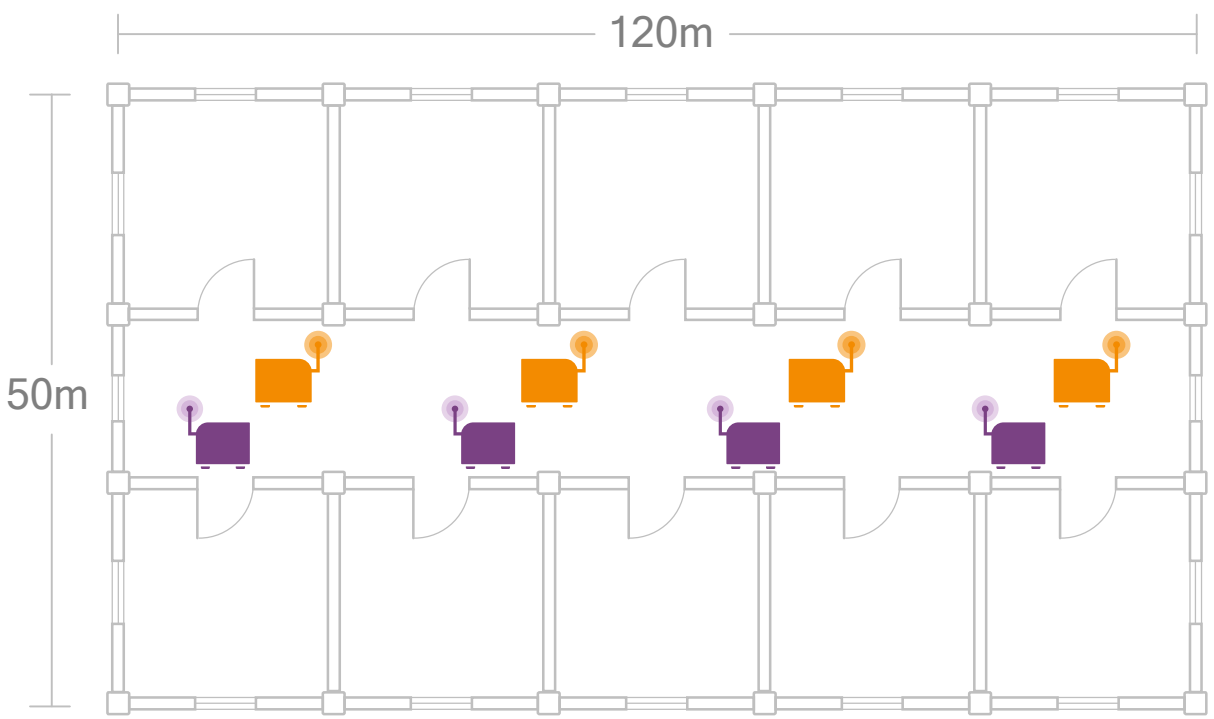
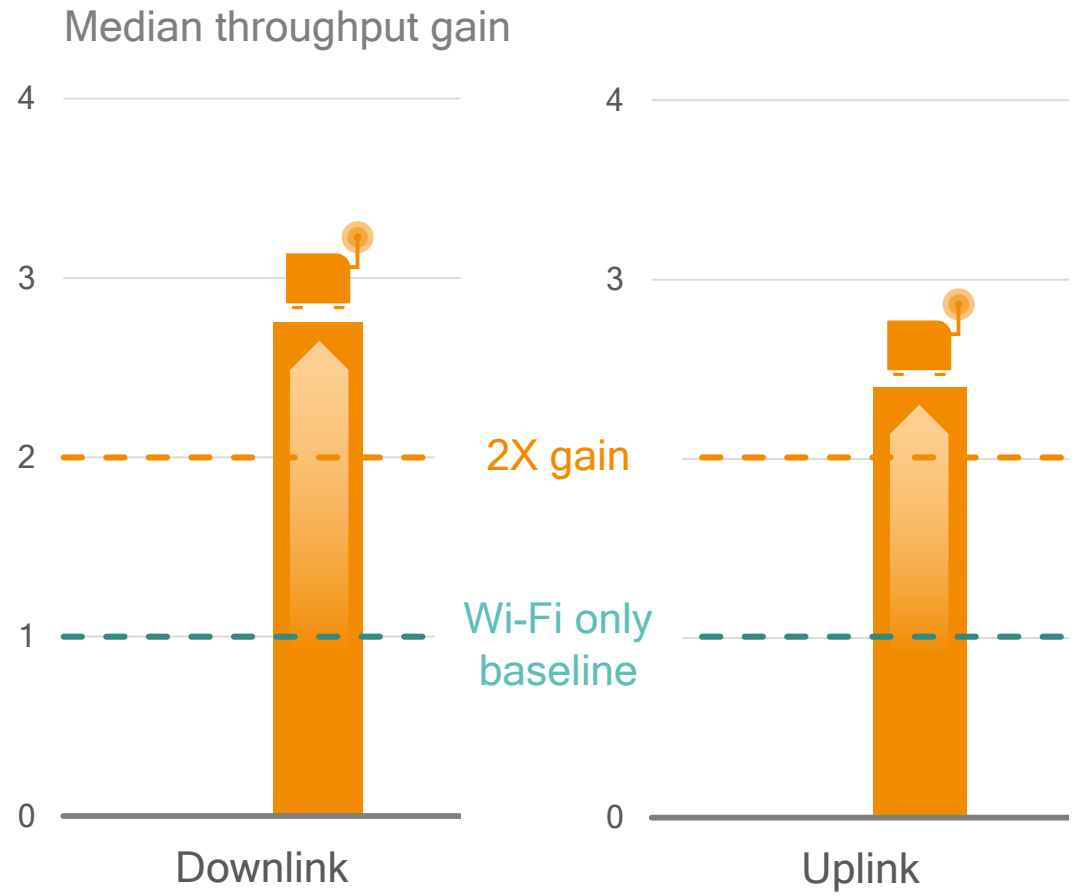
MulteFire by itself offers >2X capacity gain over Wi-Fi[1]

Higher gains in MulteFire only deployments, especially in dense scenarios



MulteFire operator #1

MulteFire operator #2



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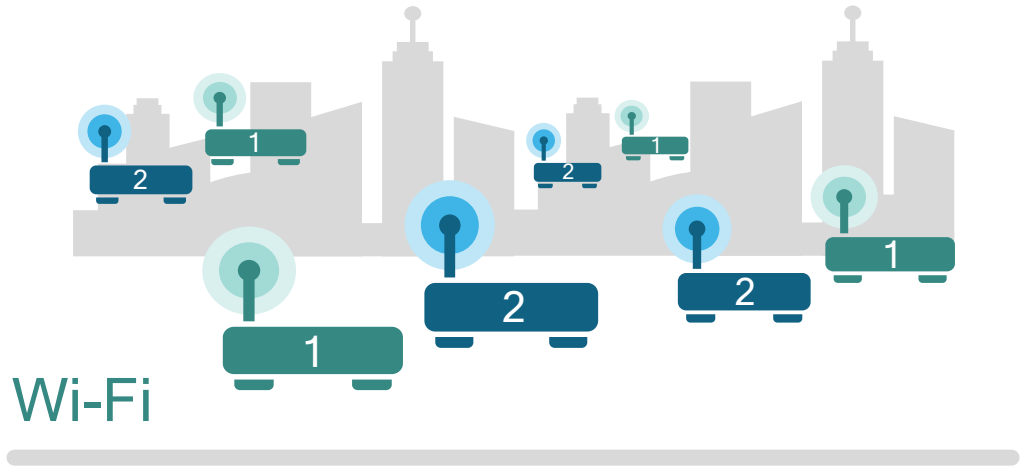
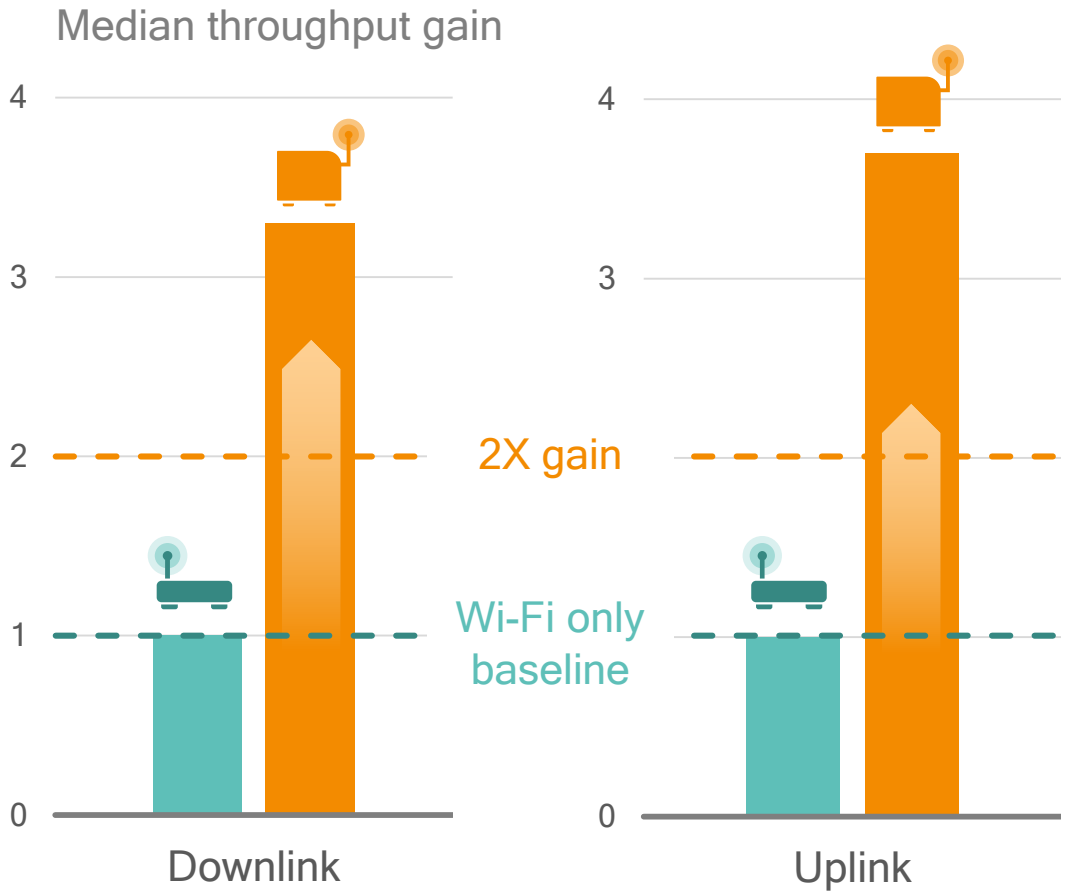
MulteFire offers significant capacity advantage outdoors[1]

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



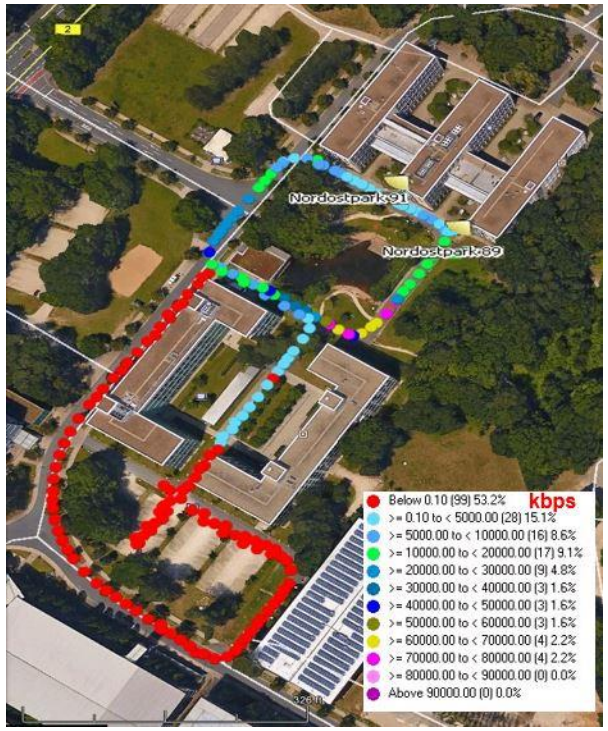


1) Outdoor, single 20 MHz channel in 5 GHz, 50%-50% traffic split between down- and uplink, bursty traffic generated with 4 Mb files arriving with exponential inter arrival times, medium traffic load with buffer occupancy at 38% in downlink and 51% in uplink for Wi-Fi only baseline, dense cluster deployment, 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

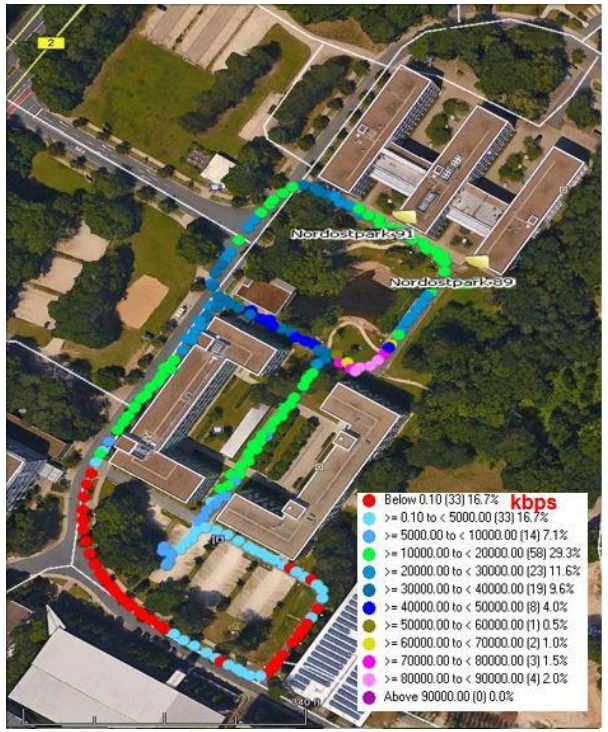
MulteFire ~2X coverage outdoors compared to Wi-Fi

World's first OTA LAA trial in Nov. 2015–MulteFire downlink performance similar

LWA (Wi-Fi)



LAA



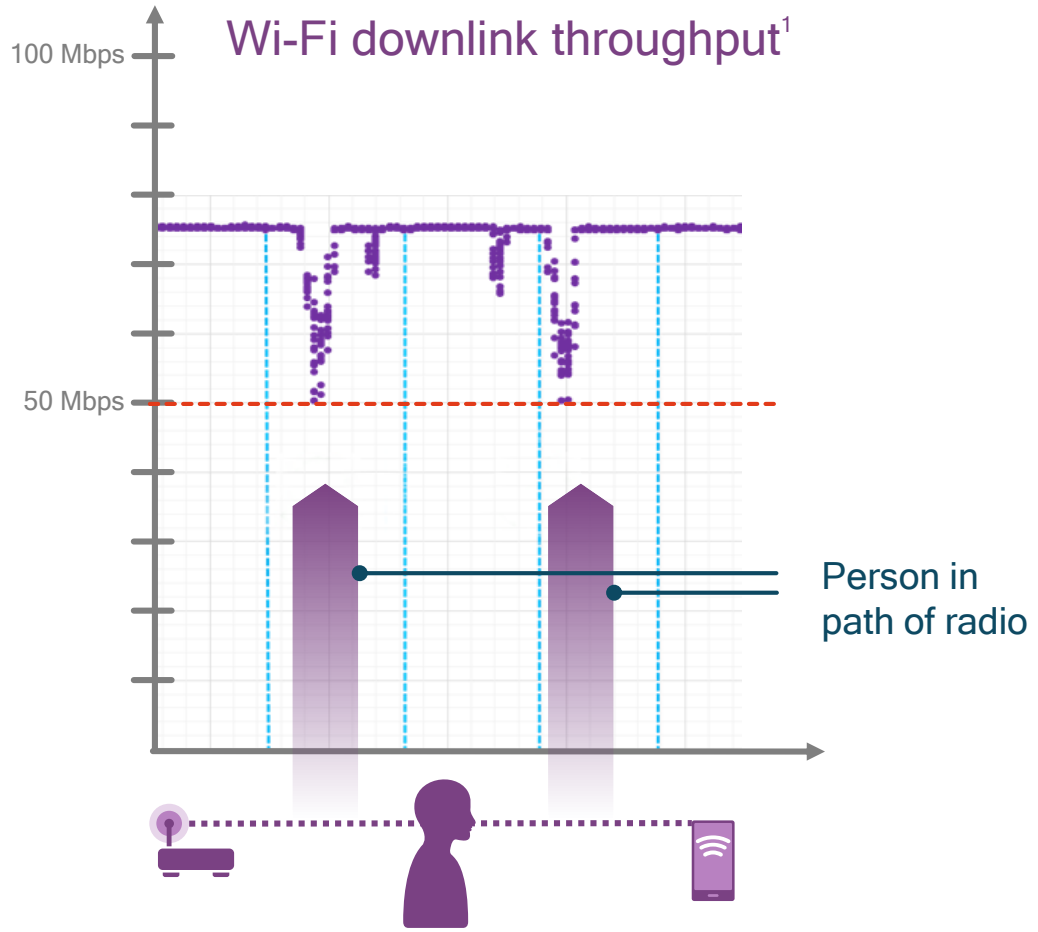
Downlink coverage[2] in unlicensed

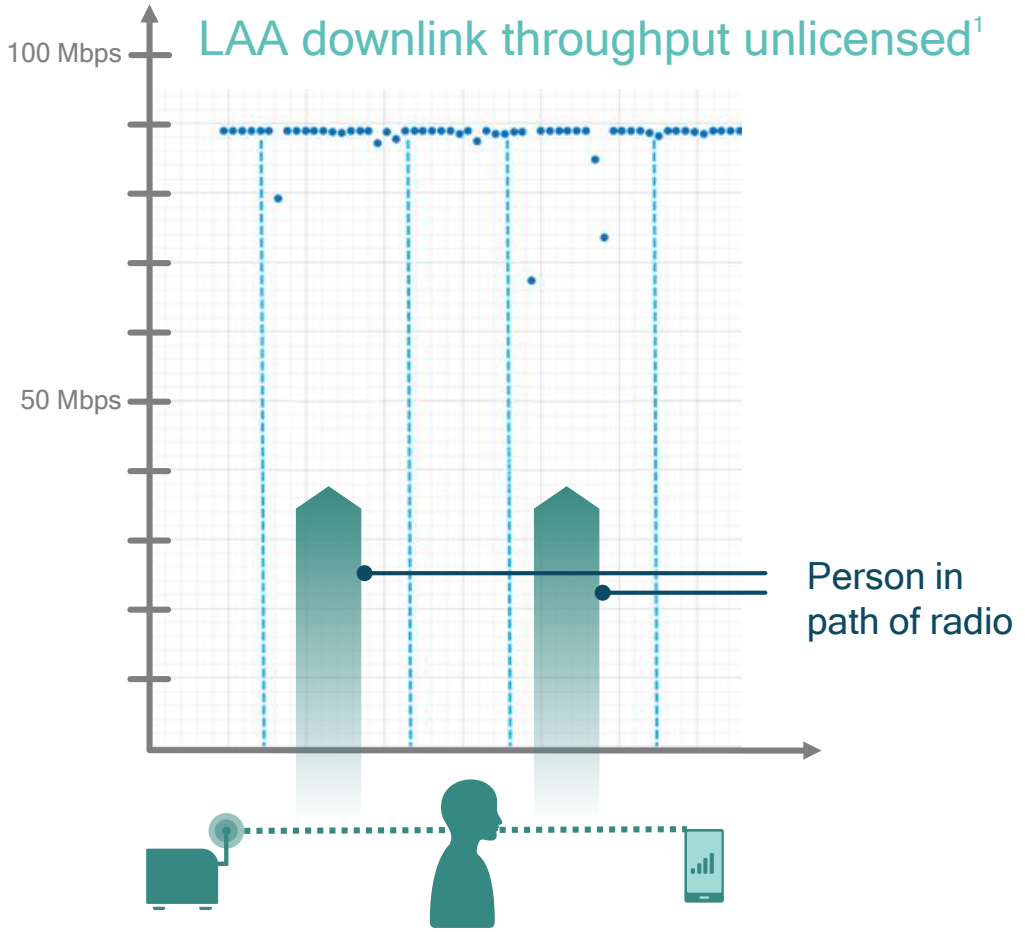
Mbps	Wi-Fi	LAA
		x2.5
>10	24% of route	60% of route
		x1.8
>1	39% of route	71% of route
		X1.7
>0	47% of route	82% of route

1 Single small cell, LAA based on 3GPP release 13; LWA using 802.11ac; LTE on 10 MHz channel in 2600 MHz licensed spectrum with 4W transmit power; the following conditions are identical for LAA and Wi-Fi: 2x2 downlink MIMO, same 20 MHz channel in 5 GHz unlicensed spectrum with 1W transmit power. terminal transmit power 0.2W, mobility speed 6-8 mph; 2 Based on geo-binned measurements over test route

MulteFire provides more consistent throughput than Wi-Fi

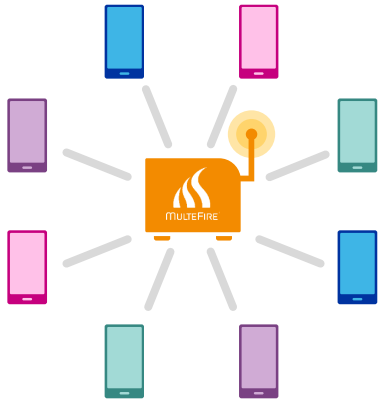
World's first OTA LAA trial in Nov. 2015–MulteFire downlink performance similar





[1] Single small cell indoor; a person walking in path of radio signal in between transmitter and receiver; LAA based on 3GPP release 13, Wi-Fi using 802.11ac, LTE on 10 MHz channel in 2600 MHz licensed spectrum with 0.2W transmit power, the following conditions were identical for LAA and Wi-Fi: 2x2 downlink MIMO, same 20 MHz channel in 5 GHz unlicensed spectrum with 0.2W transmit power; terminal transmit power 0.2W;

MulteFire Summary



Best of both worlds

LTE-like: ~2X capacity over Wi-Fi in dense deployments, ~2X range, improved mobility, SON

Wi-Fi-like: self-contained, unlicensed spectrum, neutral host

LBT used by LAA, MulteFire and Wi-Fi for fair coexistence.

Natural path to Neutral Hosts

Neutral hosts expand LTE to more places. Augments mobile networks with capacity and coverage.

3.5 GHz USA is a great fit for LTE-based neutral host small cells. MulteFire helps GAA to scale towards multiple deployments.

LTE benefits to larger eco-system

Applicable to any spectrum for fair sharing using OTA contention, e.g., 5 GHz global and 3.5 GHz USA.

Leverage assets across eco-systems to enable new business models.

New opportunities with LTE IoT.

Thank you

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