April 2014

Extending the benefits of LTE Advanced to unlicensed spectrum

QUALCOMM®

Mobile data traffic growth—industry preparing for 1000x

Industry preparing for

1000x

data traffic growth*

Richer content

more video

Bestseller example:

- **5.93 GB** Movie (High Definition)
- **2.49 GB** Movie (Standard Definition)
- **1.8 GB** Game for Android
- **0.14 GB** Soundtrack
- **0.0014 GB** Homepage
- **0.00091 GB** Book

More devices

everything connected

~25 Billion Interconnected device forecast in 2020[2]

~7 Billion Cumulative smartphone forecast between 2013-2017[1]

*1000x would be e.g. reached if mobile data traffic doubled ten times, but Qualcomm does not make predictions when 1000x will happen, Qualcomm and its subsidiaries work on the solutions to enable 1000x

Small cells in licensed spectrum—the foundation of 1000x

Continue to evolve LTE Advanced and extend its benefits to unlicensed

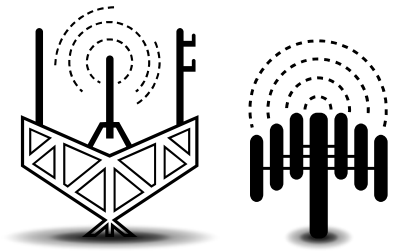
More licensed spectrum is industry's top priority
Also leveraging unlicensed spectrum opportunistically in small cells

More Small Cells is Key to 1000x

We need to make best use of all spectrum types for 1000x

Licensed Spectrum

Auctions of cleared spectrum for 3G/4G

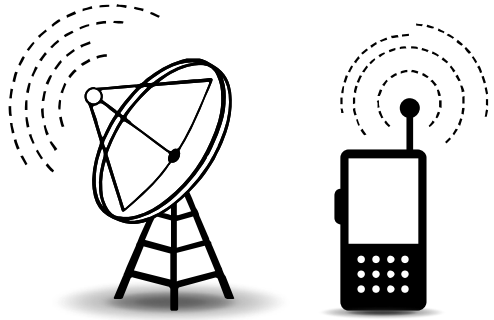


Exclusive use

Industry's top priority, ensures quality of service (QoS), mobility and control

Shared Licensed Spectrum

Complementary licensing for 3G/4G: Authorized Shared Access (ASA)

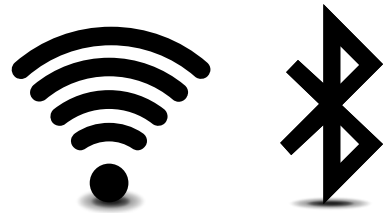


Shared exclusive use

ASA required when government spectrum cannot be cleared within a reasonable timeframe, or at all locations

Unlicensed Spectrum

Multiple technologies (Wi-Fi, LTE in unlicensed, BT & others)



Shared use

Unpredictable QoS, ideal for local area access, and opportunistic use for mobile broadband

LTE provides a solid foundation for the evolution of mobile

A vibrant, global ecosystem developed LTE and made it a success

Common global standard

Support for paired (FDD) and unpaired (TDD) spectrum

Seamless interworking with 3G

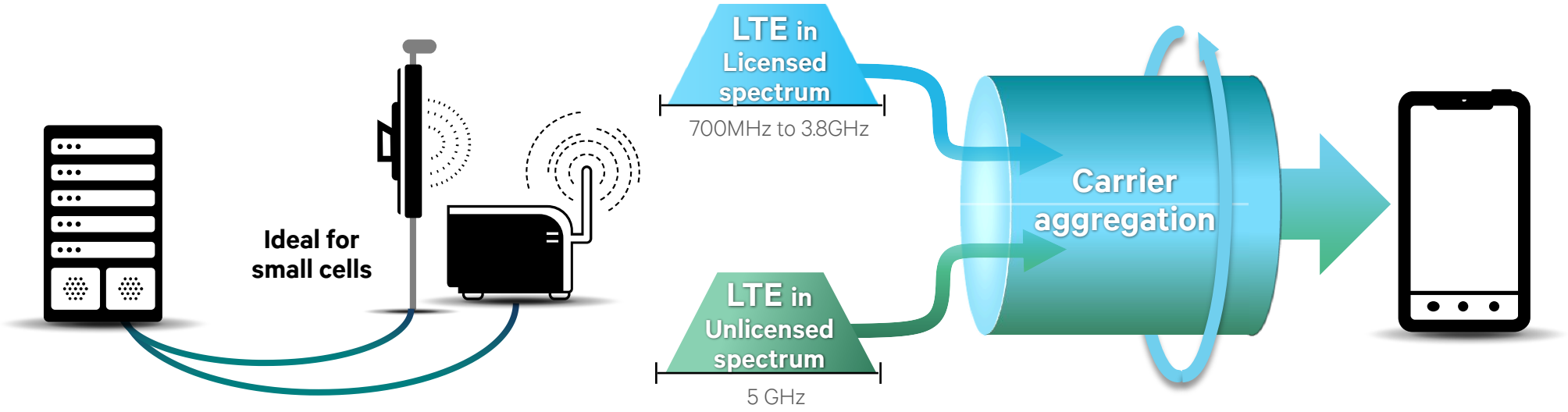
Extending the benefits of LTE Advanced to unlicensed spectrum

Better network performance

Longer range and increased capacity[1]

Enhanced user experience

Thanks to LTE Advanced anchor in licensed spectrum with robust mobility



Unified LTE Network

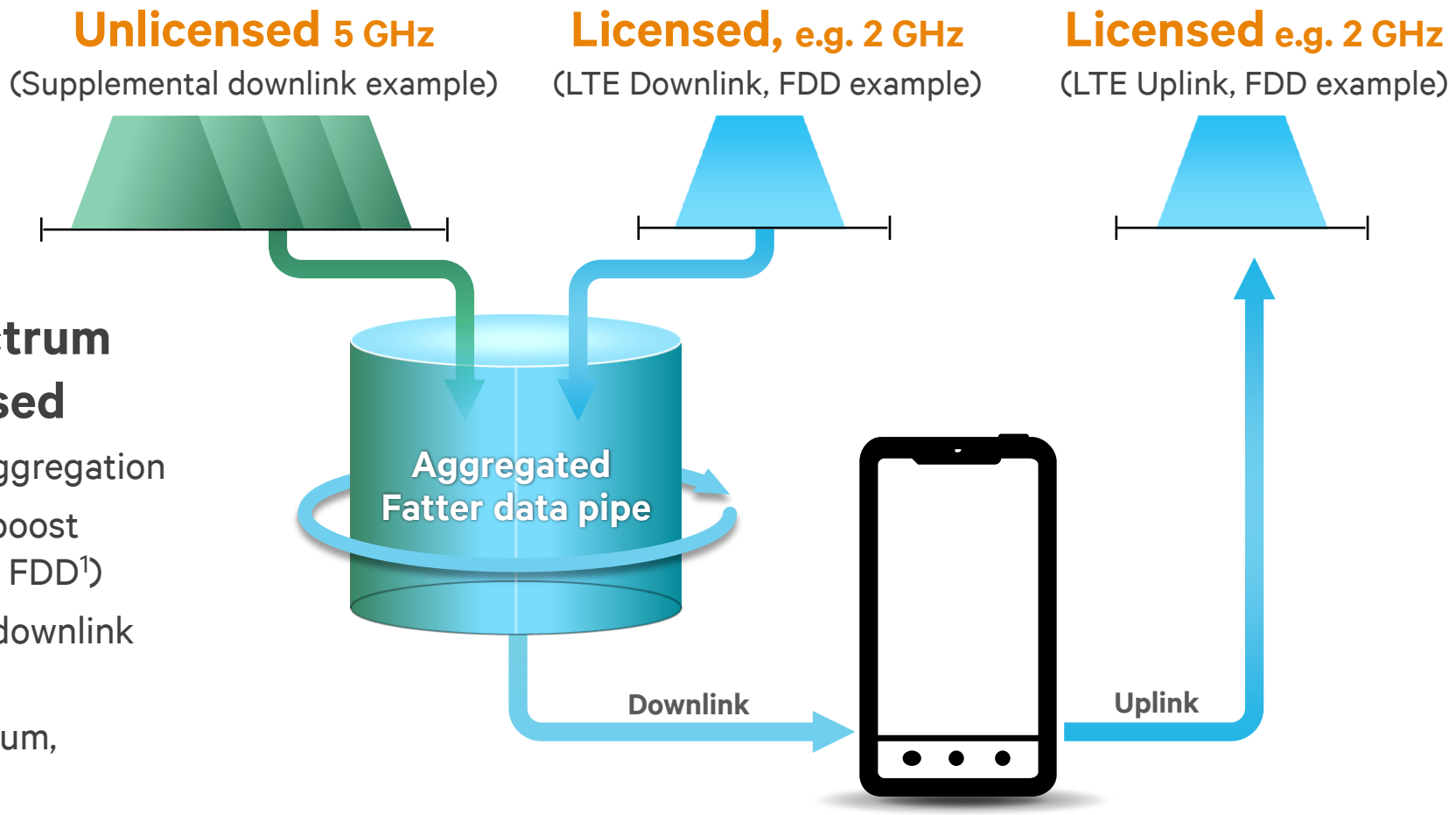
Common LTE network with common authentication, security and management.

Coexists with Wi-Fi

Features to protect Wi-Fi neighbors

[1] Compared to carrier Wi-Fi

Better user experience with a solid anchor in licensed spectrum



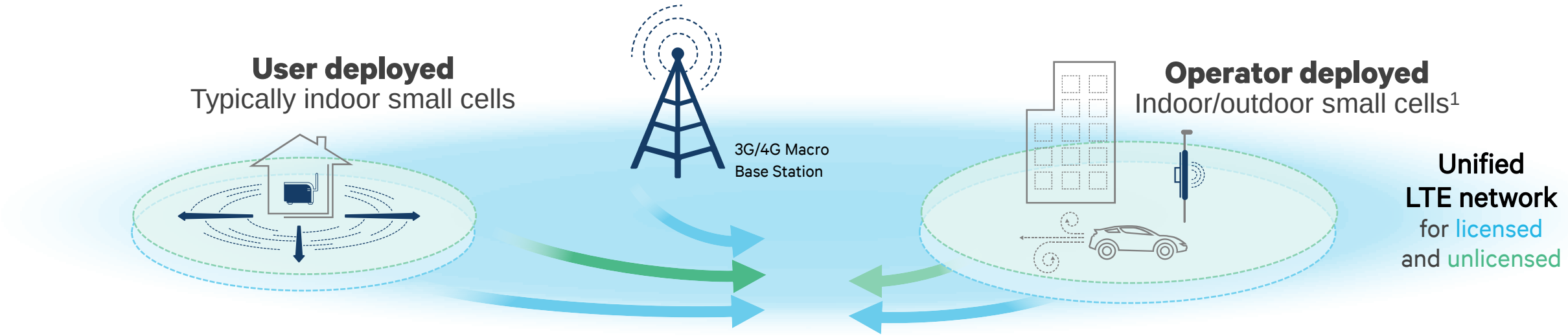
Aggregate unlicensed spectrum with a solid anchor in licensed

- Leverages LTE Advanced carrier aggregation
- 'Supplemental Downlink' (SDL) to boost downlink only (main option for LTE FDD[1])
- Carrier aggregation to boost both downlink and uplink (using LTE TDD[2])
- Control and data in licensed spectrum, unlicensed used for data only

[1]Leverages LTE Advanced carrier aggregation, but the specific band for SDL need to be standardized. Either TDD or FDD aggregation is possible with SDL (FDD aggregation is commercial June 2013),. [2]Using TDD + TDD aggregation, FDD + TDD aggregation is a 3GPP R12 candidate,

Unlicensed 5 GHz spectrum is ideal for small cells with LTE

Complementing licensed spectrum—the foundation of mobile data and 1000x



Opportunistic use

While shared, unlicensed spectrum is “free”, it has unpredictable performance

~500 MHz spectrum available

for opportunistic use around 5 GHz, even more in pipeline, to complement licensed

Shorter range

Higher 5 Ghz spectrum, lower transmit power regulations – ideal for small cells

Wider bands suitable for sharing

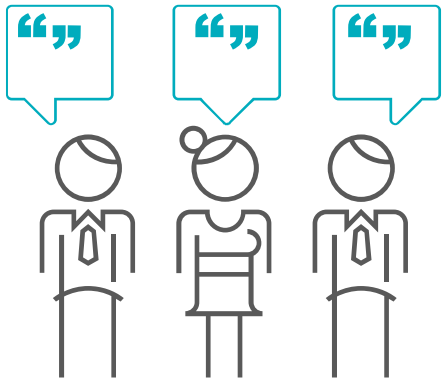
Efficiently shared amongst multiple users thanks to wide 5 GHz spectrum bands

[1] Such as relay and Pico/Metro/RRH small cells for hotspots. RRH= Remote Radio Heads, in addition Distributed Antenna Systems are used in HetNets

Unified LTE network for all spectrum types

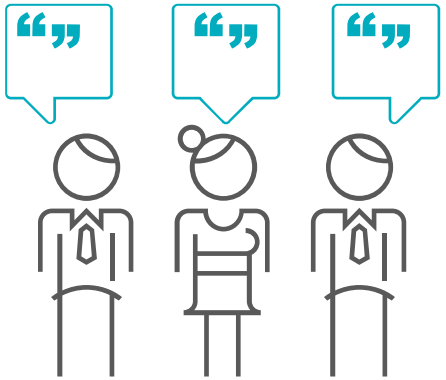
Extending LTE Advanced to unlicensed spectrum enhances user experience

Anyone can talk
(with listen before talk features[1])



Wi-Fi
(unlicensed)

Coordinate before/while talking
(Synchronous operation)



Bringing LTE benefits

Also to unlicensed spectrum

Common LTE core network

1. Seamless mobility and robust control signaling
2. Integrated authentication, security and management

[1]Depending on region, more stringent listen before talk features generally required, except e.g. US, Korea and China

Leverages existing LTE standards, ecosystem and scale

LTE transmitted according to unlicensed spectrum regulations, such as power levels

1 Large scale, global LTE deployments

- 270+ network launches in 100+ countries[1]
- LTE Advanced 3GPP R10 launched June 2013

2 LTE in unlicensed spectrum for USA, Korea and China

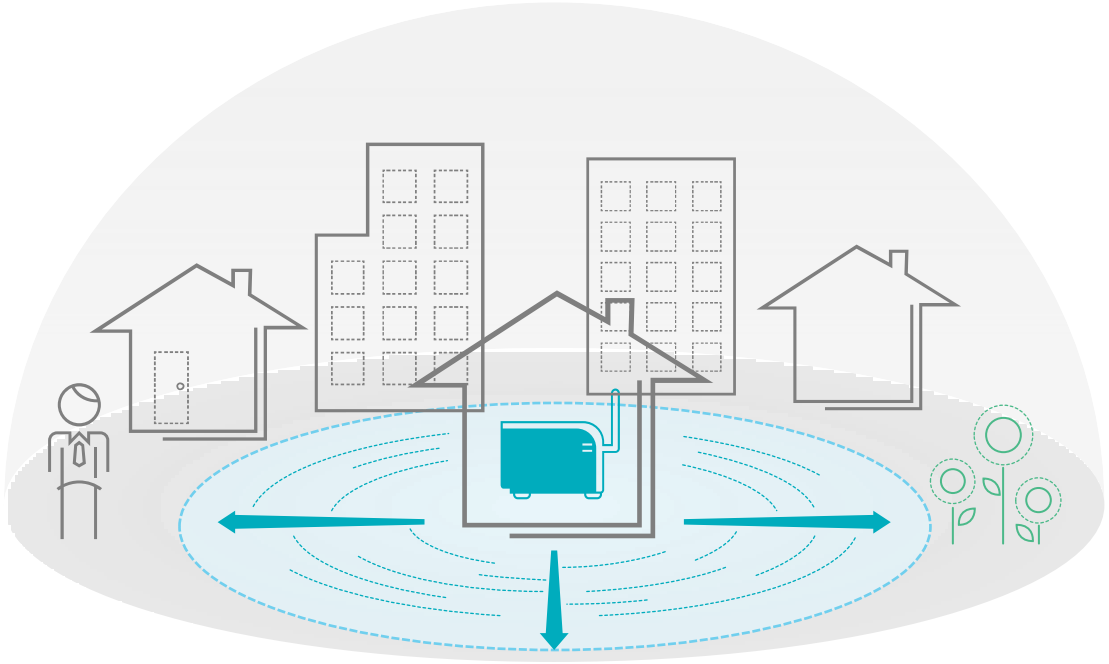
- LTE Advanced 3GPP R10/R11/R12
- Targets 5 GHz unlicensed bands
- Wi-Fi and LTE co-existence features[2]

3 LTE in unlicensed spectrum everywhere

- Extend deployment to regions with 'Listen Before Talk' (LBT) regulations
- Optimized waveform enabling LBT, carrier discovery and expanded uplink coverage
- Candidate for 3GPP R13 standard

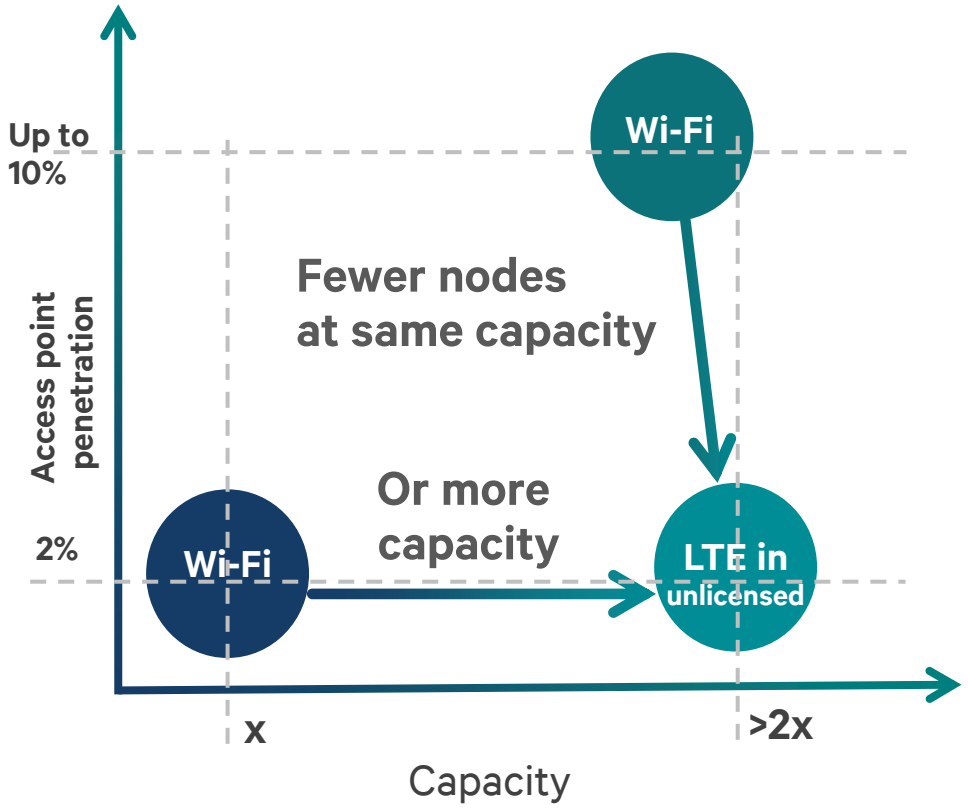
[1]Per GSA as of as of Feb 5th 2014. [2] With Carrier Sensing and Adaptive Transmission (CSAT) in the time domain, in addition to channel selection and opportunistic use of unlicensed spectrum .

Longer range and more capacity compared to carrier Wi-Fi



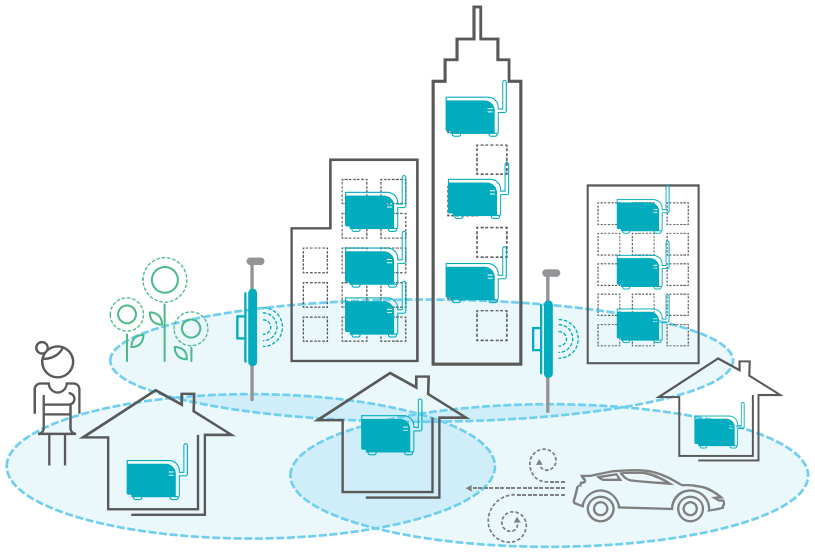
Inside-out, neighborhood small cell example

Two operators; one using Wi-Fi, one switching from Wi-Fi to LTE in unlicensed.
Hetnet in licensed spectrum augmented with unlicensed spectrum.
100% overall Wi-Fi penetration due to private Wi-Fi.

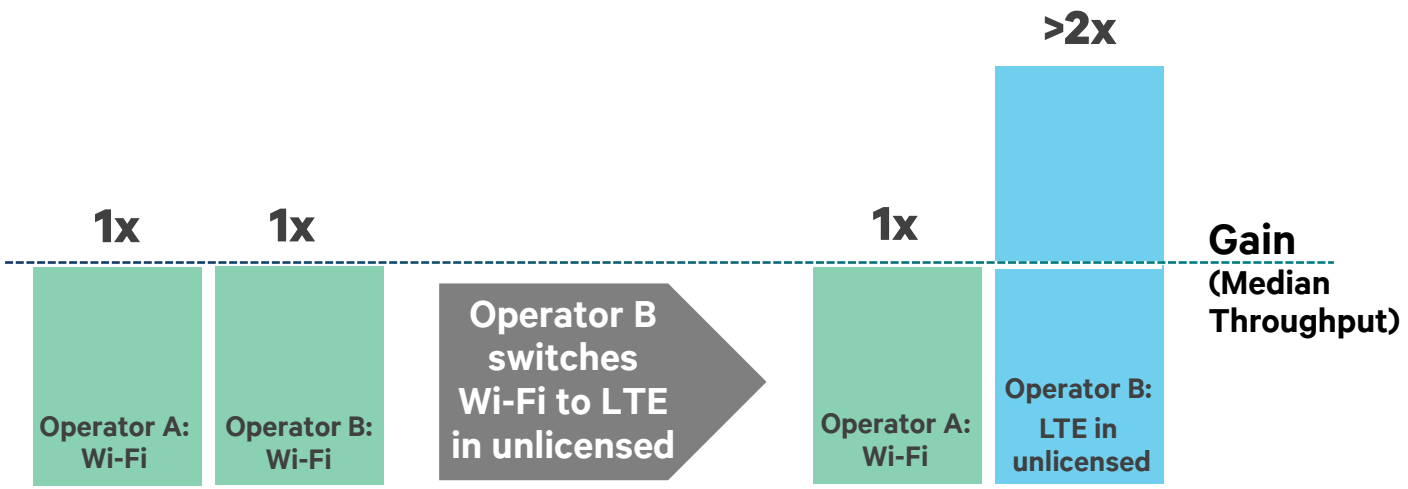


Assumptions:, Dense urban simulation model with residential apartments and first floor commercial units. Penetration corresponds to the fraction of residences and commercial units with a small cell or AP from a given operator, but overall Wi-Fi penetration is 100% (e.g. due to private users). 2 operator networks simulated. One network (interfering) is always Wi-Fi . The other (target) is either Wi-Fi or LTE in unlicensed. There are 1200 visiting users per sqkm per operator which are used to model capacity gains. 50% indoor/50% outdoor. Total traffic capacity is the amount of total bursty traffic captured by the macro + indoor small cells or APs satisfying a QoS criteria.

Coexists with Wi-Fi—features to protect Wi-Fi neighbors



Indoor and outdoor small cells



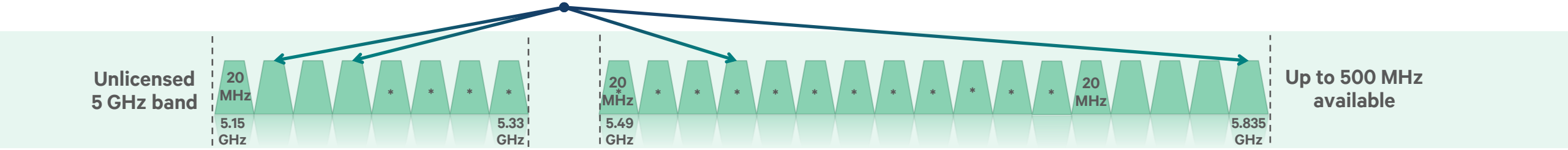
Wi-Fi in unlicensed

LTE gain without impacting Wi-Fi

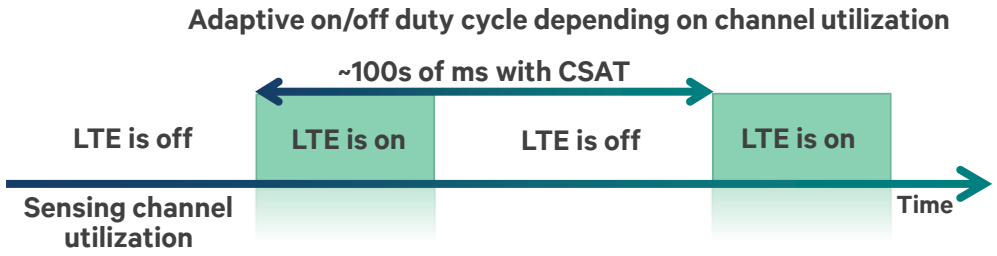
Assumptions: Two operators. 48 Pico+108 Femto cells per operator. 300 users per operator with 70% indoor. 3GPP Bursty model. 12x40MHz @ 5GHz for unlicensed spectrum.
LTE 10 MHz channel at 2 GHz. 2x2 MIMO for Wi-Fi , LTE and LTE in unlicensed phase II with Rank 1 transmission. eICIC enabled.

Coexists with Wi-Fi—features to protect Wi-Fi neighbors

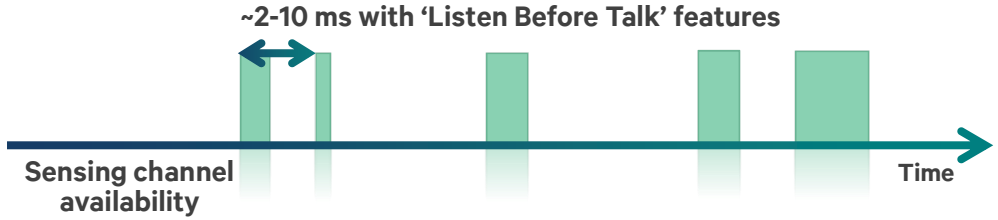
1 **Dynamically select clear channel:** channel selection based on interference



2 **Mitigate if no clear channel is available:** co-channel co-existence features



Carrier Sensing Adaptive Transmission (CSAT) for fair co-existence with Wi-Fi with 3GPP R10/11 for e.g. US, Korea and China.

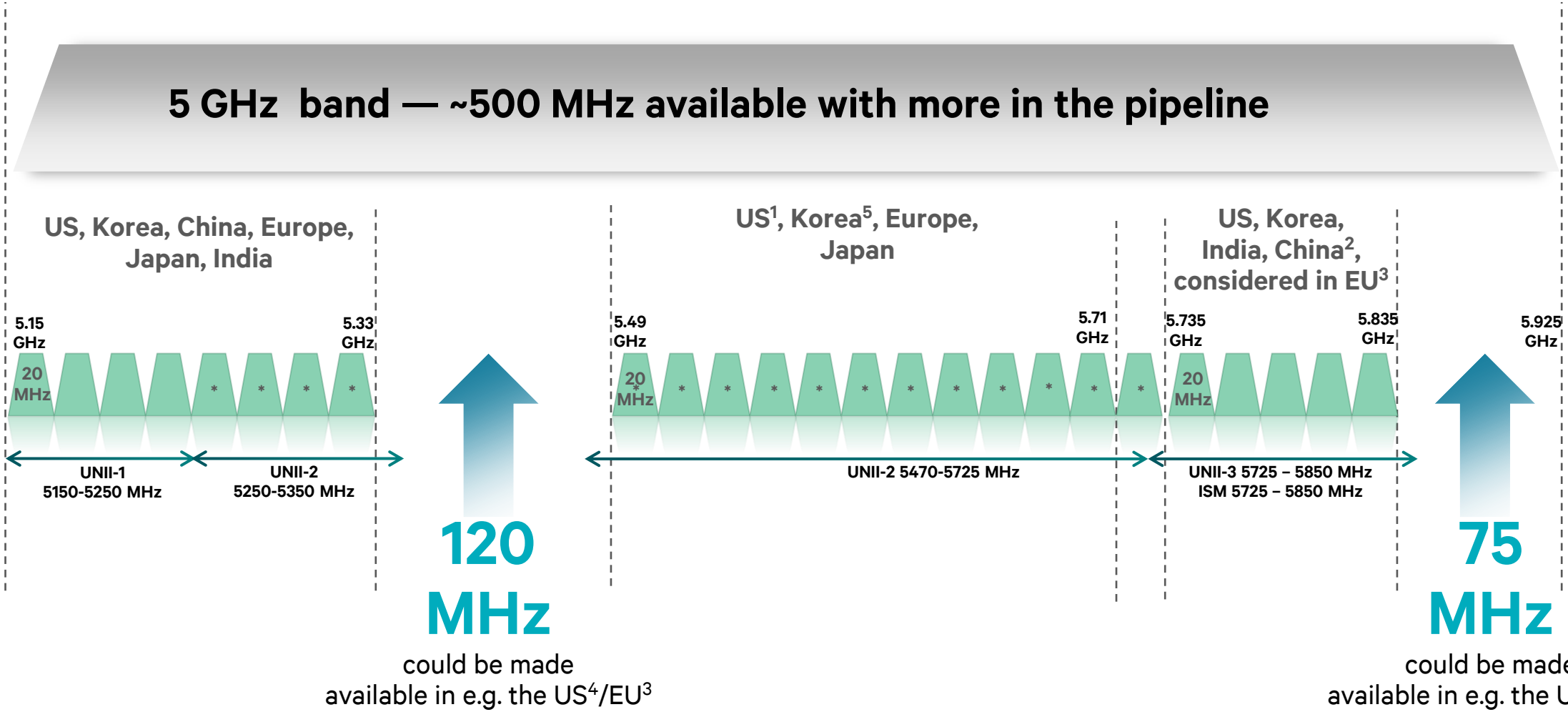


Optimized LTE waveform for Listen-Before-Talk targeting 3GPP R13 to meet regulatory requirements for rest of world

3 **Opportunistic use – release unlicensed channel at low traffic load:** fall back to licensed spectrum operation only

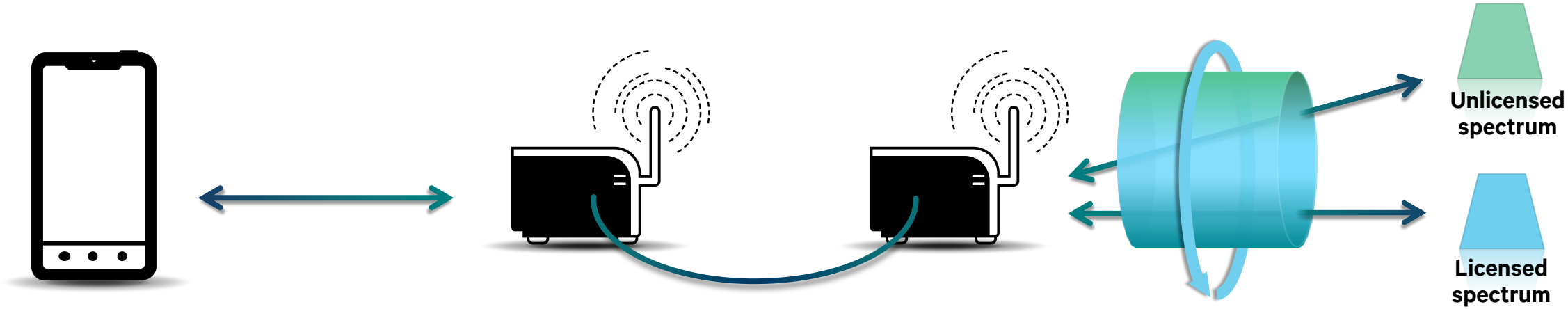
* These 5GHz channels typically require DFS, Dynamic Frequency Selection

More and wider unlicensed spectrum around 5 GHz



[1] Channel 120, 124 and 128 (5.6-5.65 GHz) currently not permitted in the US. [2] 5725MHz-5850MHz has been assigned to ISM services in China [3] Study of 5350MHz-5470MHz and 5725MHz-5925MHz use for license exempt is being planned in EU'. [4] Feasibility studies directed by the Middle Class Relief & Job Creation Act of 2012., in 5350-5470 MHz and 5850-5925 MHz . [4] 5470-5650 MHz in Korea* These 5GHz channels typically require DFS, Dynamic Frequency Selection

How robust LTE enhances user experience and performance



Efficient LTE radio link

- Robust link designed for mobility with less overhead
- Coverage gain also due to ability to handle larger delay spreads

Synchronous operation

- Handles interference bursts better
- Better coordination and scheduling

Anchor in licensed spectrum

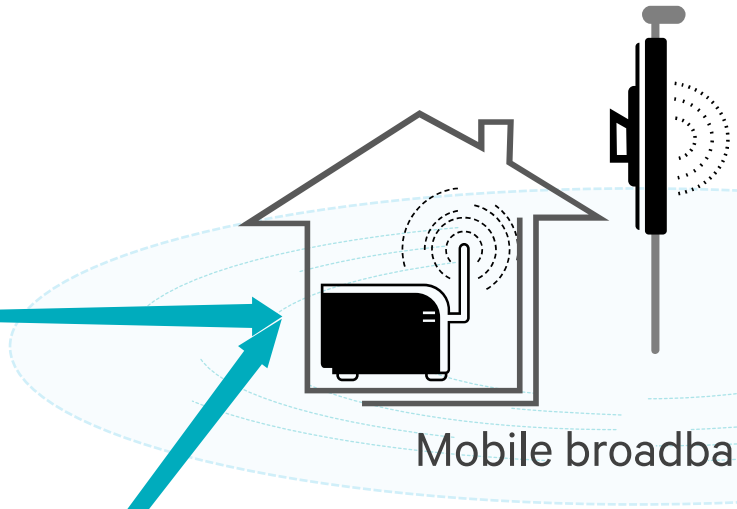
- Signaling in licensed spectrum means robust control
- Less overhead in unlicensed (no control plane signaling)
- No uplink in unlicensed spectrum with SDL operation

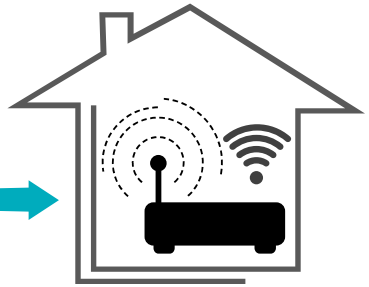
A leader in all solutions to best leverage unlicensed spectrum

Committed to continued leadership in both Mobile 3G/4G and Wi-Fi

Licensed Spectrum
Cleared spectrum for 3G/4G, ASA for 3G/4G
Exclusive use

Unlicensed Spectrum
Multiple technologies (Wi-Fi, LTE in unlicensed)
Shared use





LTE Advanced for licensed and unlicensed spectrum

Mobile operator managed service with unified LTE network aggregating licensed and unlicensed spectrum[1]

3G/4G for licensed and carrier Wi-Fi for unlicensed spectrum

Mobile operator managed service with tighter Wi-Fi integration for better offload and enhanced services

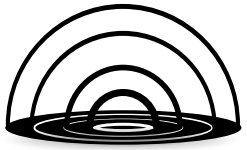
Wi-Fi in unlicensed spectrum

Local area access for private/residential, enterprise users

[1]With Wi-Fi for backward compatibility

Summary: Qualcomm committed to extending the benefits of LTE Advanced to unlicensed spectrum

1



Enhanced user experience

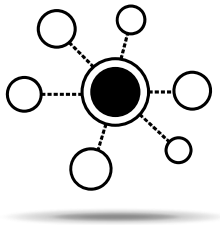
Robust LTE enables a better user experience with seamless mobility

2

Coexists with Wi-Fi

Features to protect Wi-Fi neighbors

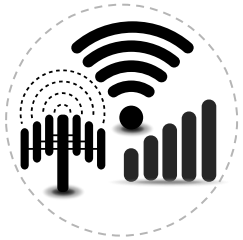
3



Unified LTE network

Common core network, common authentication, security, management

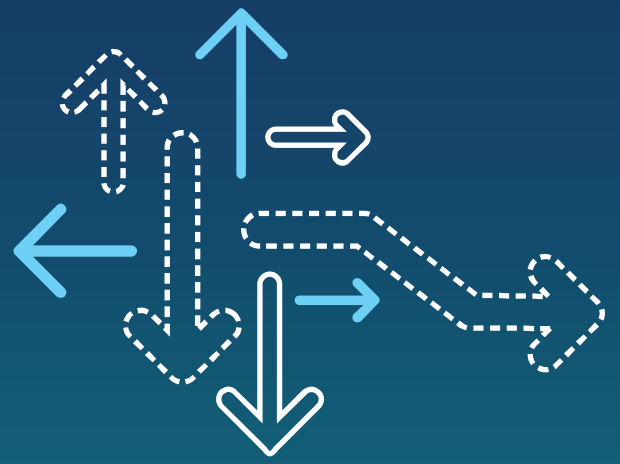
4



A leader in all solutions to best leverage unlicensed spectrum

Wi-Fi, carrier Wi-Fi, interworking and LTE in unlicensed spectrum

Questions? - Connect with Us



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