November 2013

1000x: More spectrum—especially for small cells

Including ASA—a new license model to access underutilized, high quality spectrum

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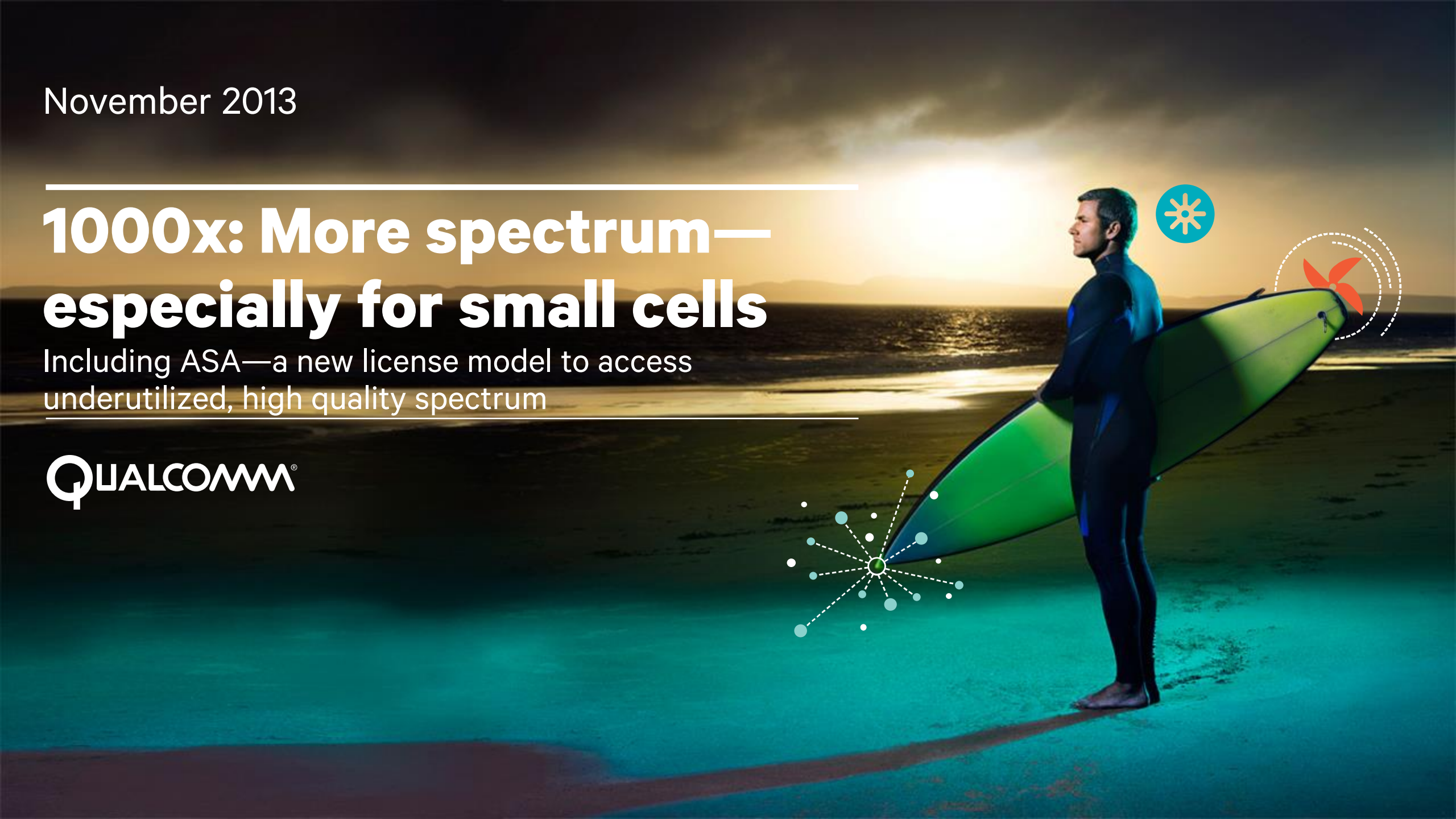


Mobile data traffic growth—industry preparing for 1000x

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)
- **0.0014 GB** Homepage
- **1.8 GB** Game for Android
- **0.14 GB** Soundtrack
- **0.00091 GB** Book

More devices

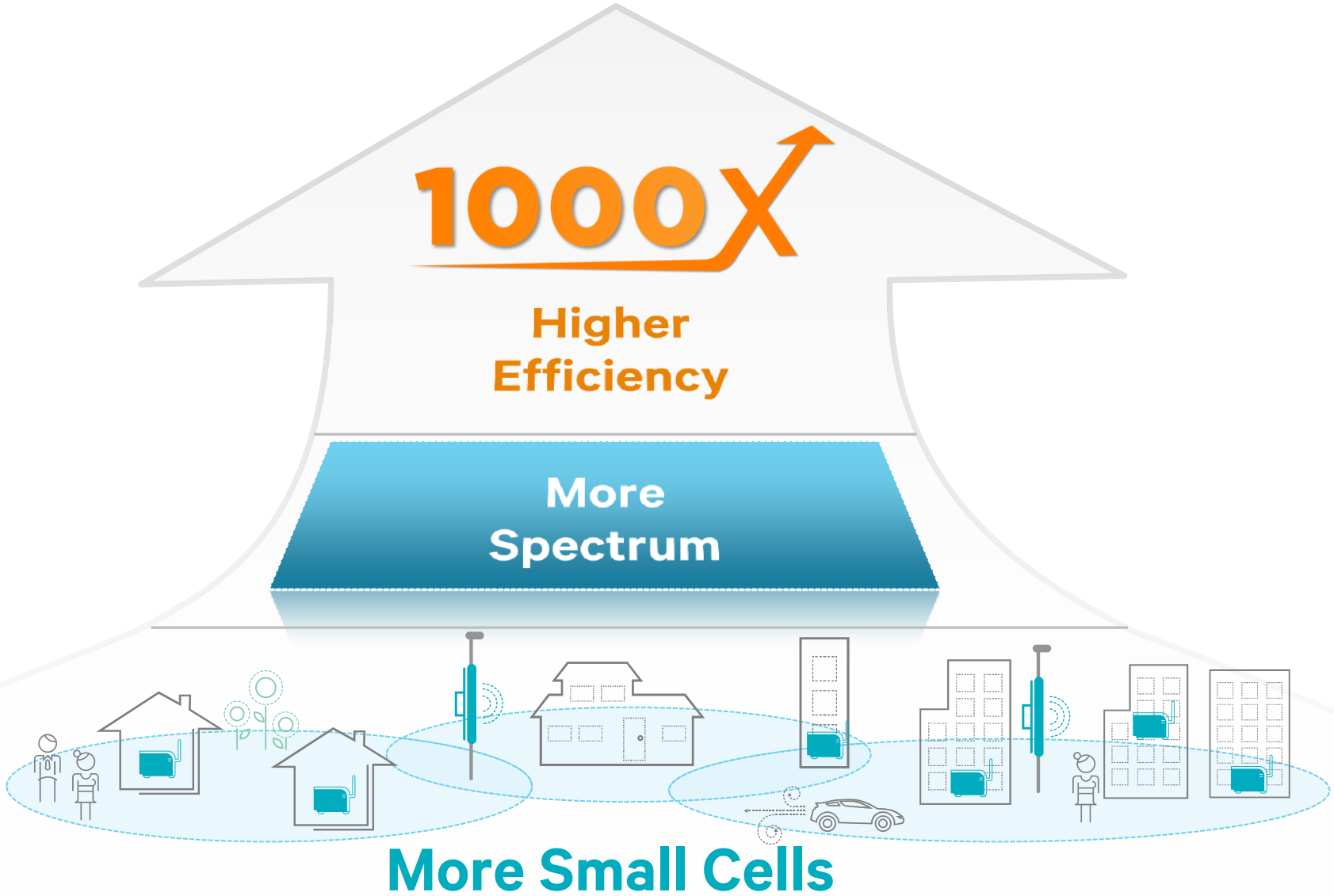
everything connected

~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

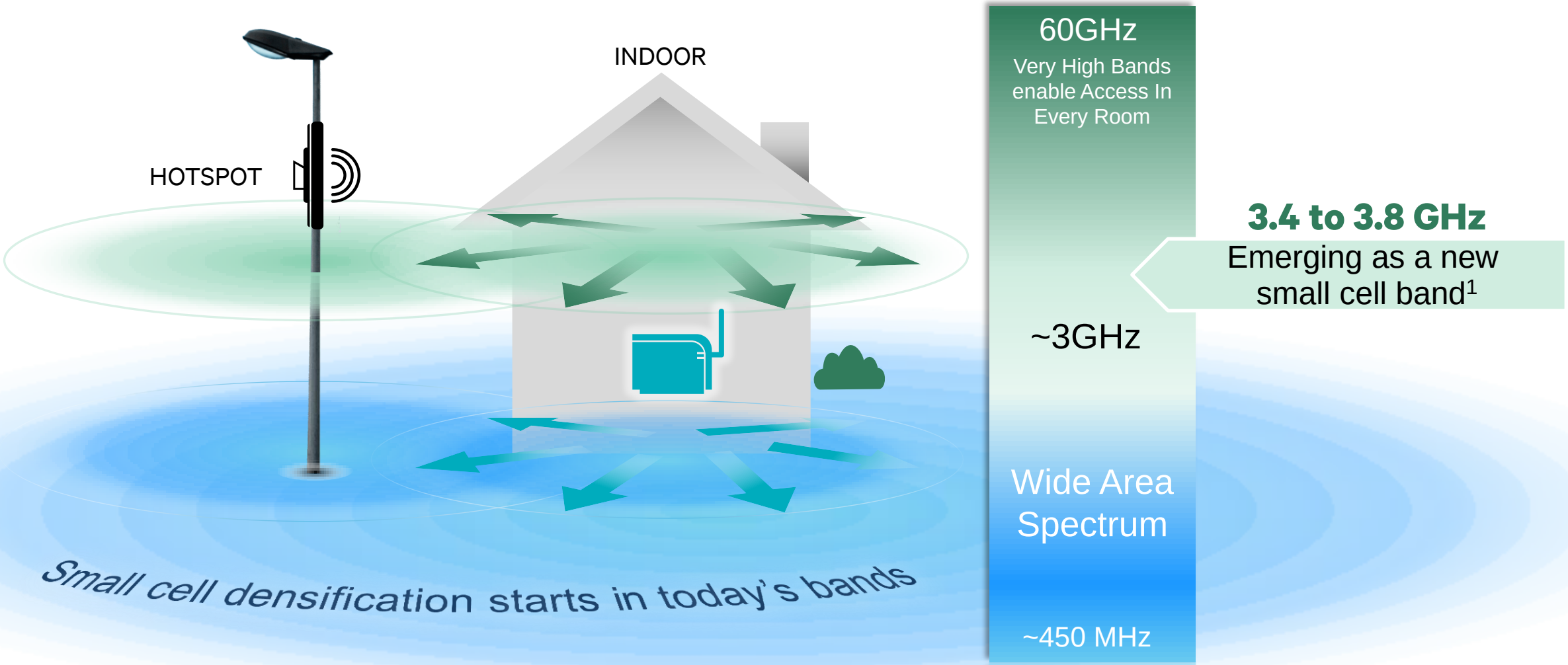
Rising to meet the 1000x mobile data challenge



Current spectrum provides the foundation of 1000x – with more small cells and higher efficiency

Harmonization and global standards drive economies of scale

Introduce higher spectrum bands suitable for small cells

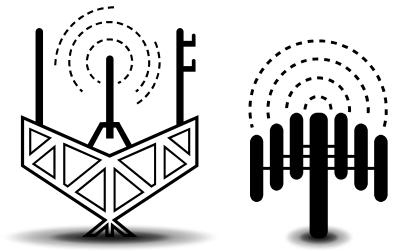


[1] Some parts can be traditionally licensed, some parts need to be **ASA licensed**, such as ~3.5GHz in the US/EU[1]. 3GPP has already defined 3G/4G bands 42/43 for 3.4 GHz to 3.8 GHz, 3.5GHz in the US defined as 3550 – 3650 MHz. In addition, Wi-Fi in unlicensed such as 2.4GHz, LTE Advanced and 802.11 ac in 5GHz and 60GHz (802.11 ad).

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

Licensed Spectrum

Auctions of cleared spectrum for 3G/4G

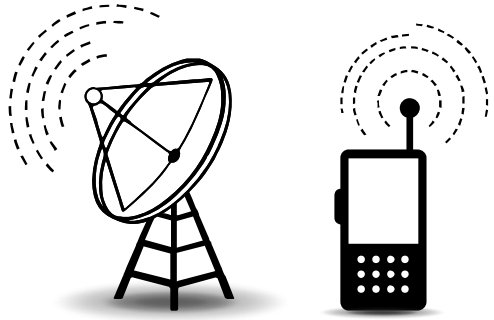


Exclusive use

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

Shared Licensed Spectrum

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

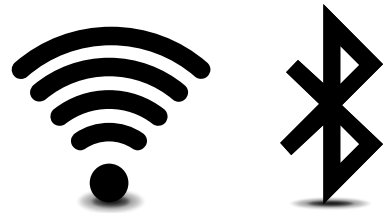


Shared exclusive use

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

More licensed spectrum is the industry's top priority

Auction before clearing

Such as original US 700 MHz, AWS-1, and PCS, and Digital Dividend in the EU

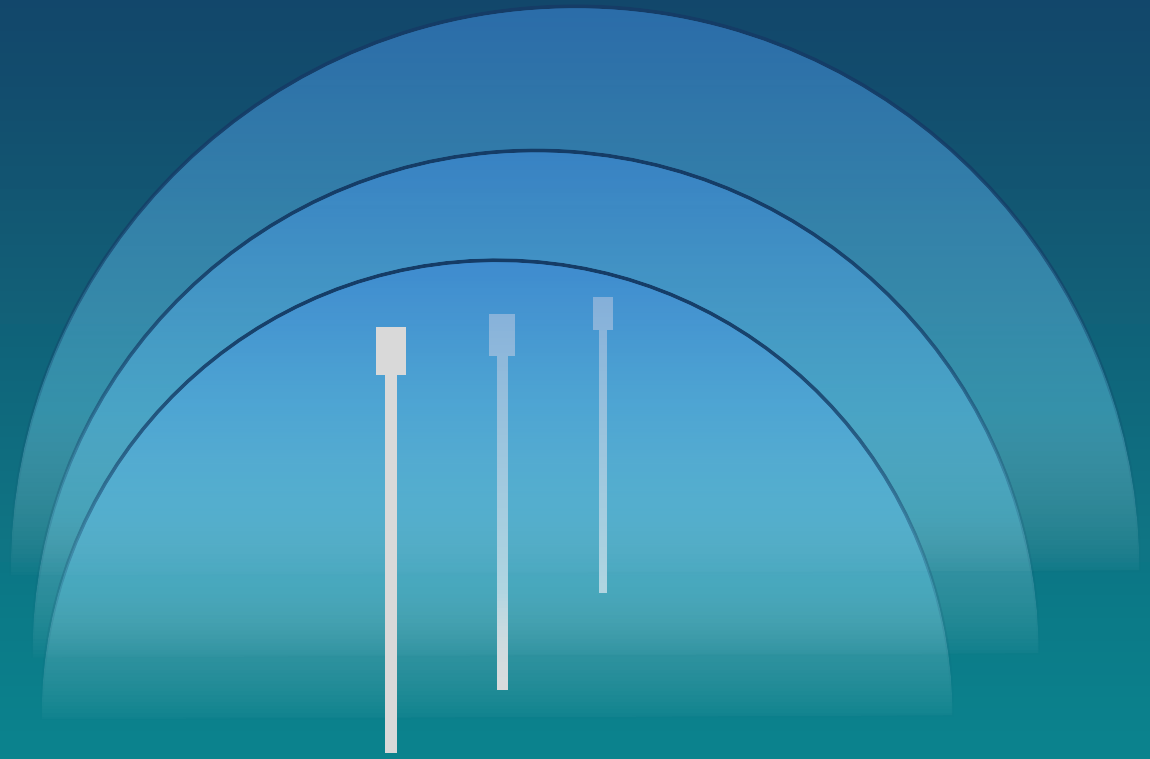
Clearing through auction

Such as upcoming US voluntary incentive auction in TV band 600 MHz

Auction after clearing

Such as Canadian 700 MHz auction and Digital Dividend 800 MHz in the EU

But if spectrum cannot be cleared within a reasonable time frame, at all times, nationwide, or by a certain date? Then we need a new licensing model. . .



Authorized shared access

A new way to access underutilized spectrum in higher bands

Allocated spectrum may be underutilized

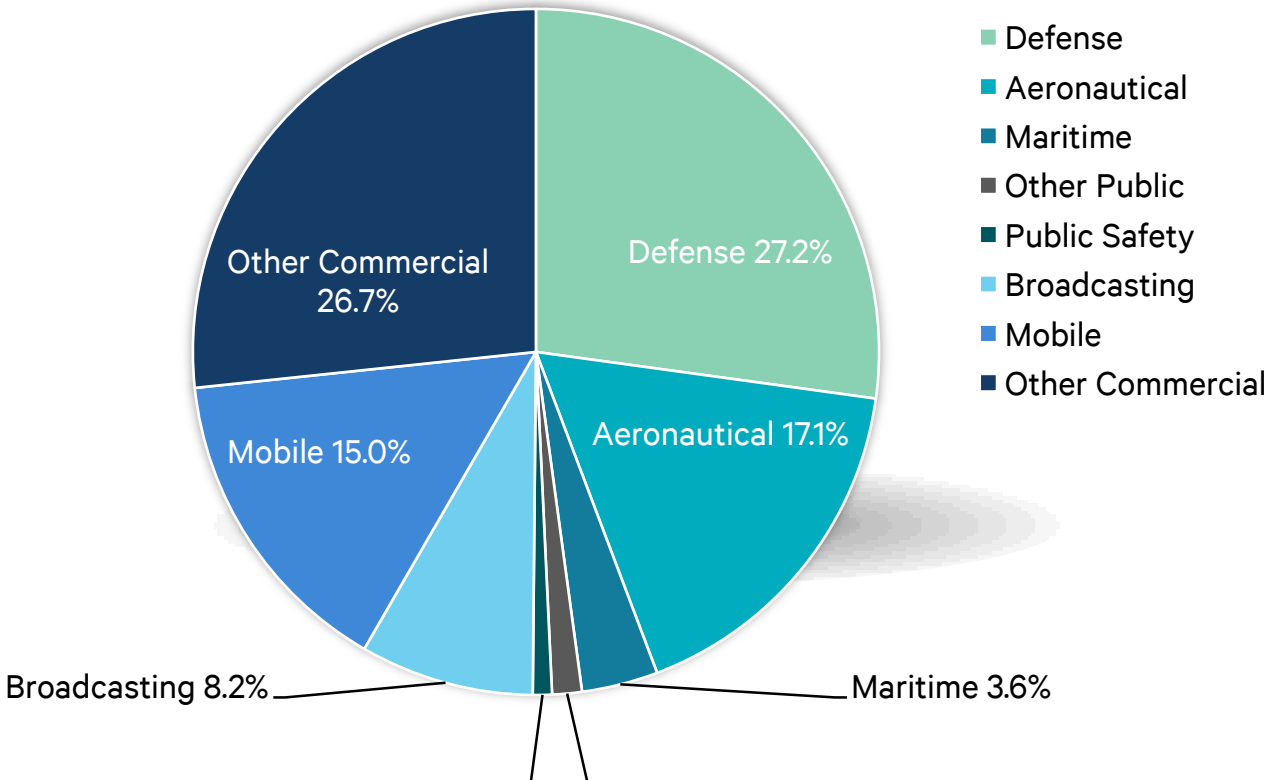
Incumbents (e.g. government) may not use spectrum at all times and locations

Challenge today

Repurposing and vacating spectrum takes longer and longer time.

ASA opportunity

- Accelerate harmonization and potential re-farming.
- Access underutilized spectrum, which may always have incumbent spectrum holders.

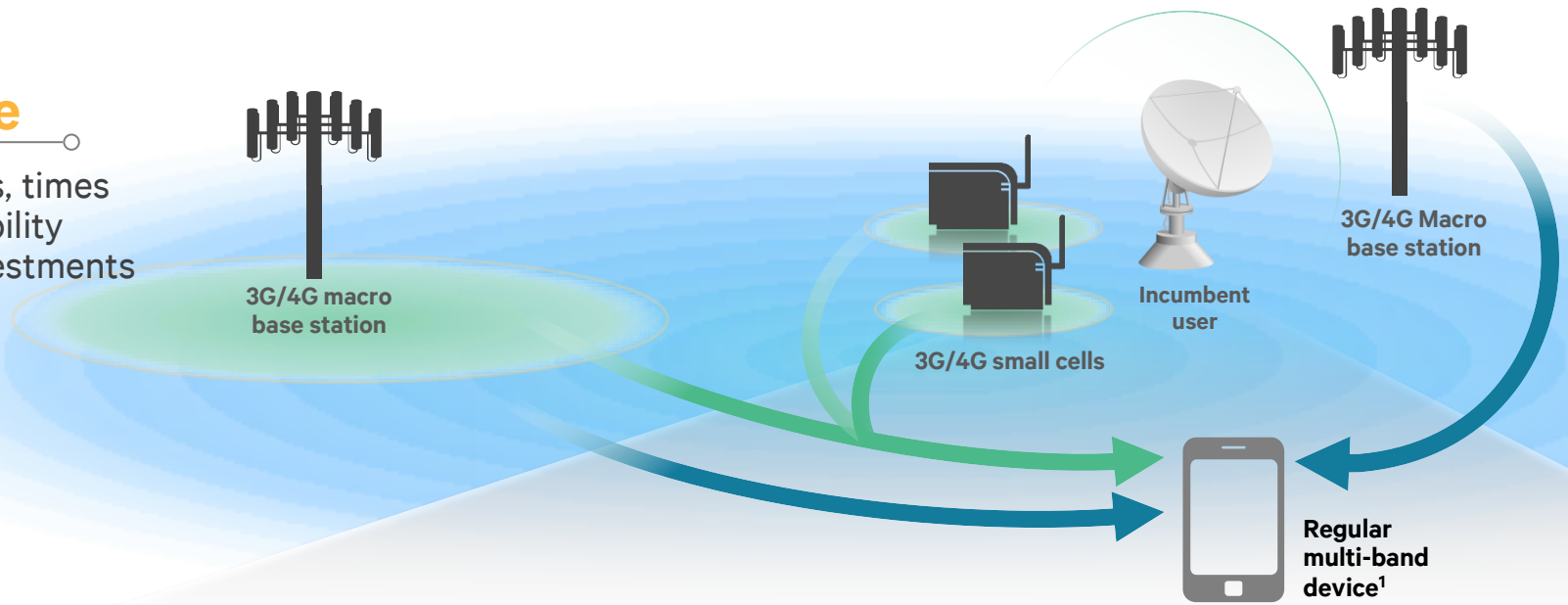


Shows Spectrum Allocation by Sector within in a typical EU country 108 MHz – 6 GHz

Authorized shared access (ASA) is optimal for small cells

Exclusive use

- At given locations, times ensures predictability for long-term investments



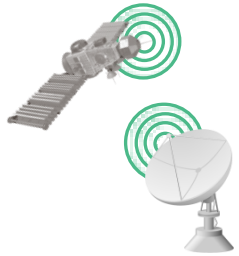
Optimal for small cells

- Small cells can be closer to incumbent than macros

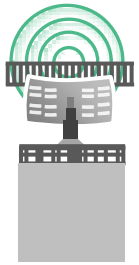
Incentive-based cooperation model

Protects incumbents

- Binary use—either incumbent or rights holder
- Protection zones



Satellite



Military radar

Public safety ....

[1] No device impact due to ASA, just a regular 3G/4G device supporting global harmonized bands targeted for ASA. Carrier aggregation would be beneficial to aggregate new ASA spectrum with existing spectrum, but is not required.

ASA enables new business models and fosters competition

ASA targets harmonized spectrum—suitable for small cells

Leveraging global, available 4G technologies to ensure economies of scale

ASA CANDIDATE EXAMPLES	2.3 GHz (100 MHz)	2.6 GHz (100+ MHz)	~3.5 GHz (100-200 MHz)
Applicable Regions	EUROPE (Traditionally licensed in e.g. India)	MENA (Traditionally licensed in e.g. Europe)	USA, EU, LATAM, SEAP
Incumbent Users	Telemetry, public safety, cameras	Various	Naval Radar (US) Satellite (EU, LATAM. SEAP)
Suitable Technology	LTE TDD	LTE FDD/TDD	LTE TDD
Possible Launch	~2015		

3.4 to 3.8 GHz

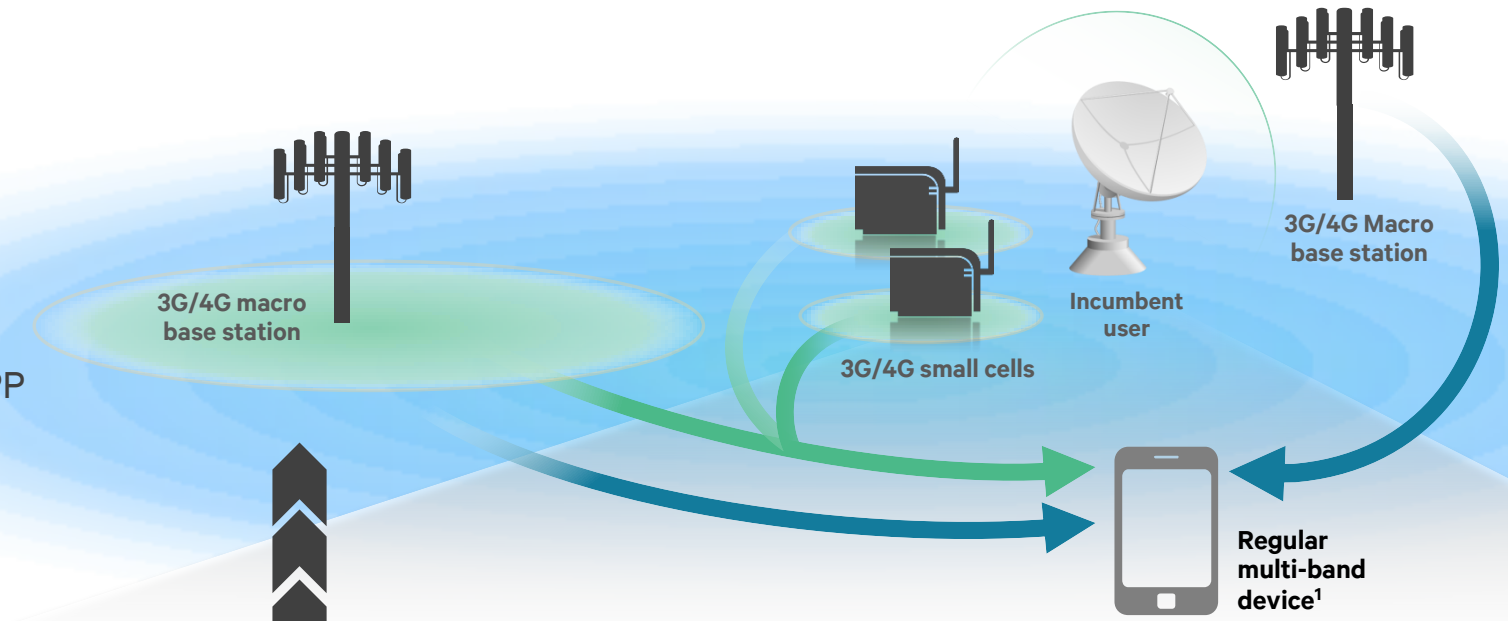
Emerging as a key band for 3G/4G small cells, some parts can be traditionally licensed, but some parts need to be **ASA licensed,** such as ~3.5GHz in the US/EU[1]

[1] 3GPP has already defined bands 42/43 for 3.4 GHz to 3.8 GHz, 3.5GHz in the US defined as 3550 – 3650 MHz, but up to 200MHz could be targeted for ASA in e.g. SEAP/LATAM. Note that ASA targets IMT spectrum bands, but the concept can be applied generally to all spectrum bands and other technologies

ASA takes advantage of existing products and standards

Cost-effective

- Use available 3G/4G infrastructure
- Complements installed 3G/4G
- Leverages existing 3GPP standards



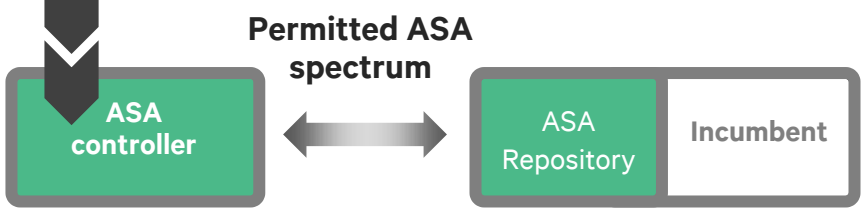
Regular multi-band device[1]

Opportunity to aggregate wider spectrum

Network controls device spectrum access[2]

Simple

- Simple technology with defined interfaces
- Regulatory framework



Controlled

- Enables predictable quality of service
- Protects incumbent from interference

[1] No device impact due to ASA, just a regular 3G/4G device supporting global harmonized bands targeted for ASA. Carrier aggregation would be beneficial to aggregate new ASA spectrum with existing spectrum, but is not required.
[2] The O&M system of the ASA rights holder enforces the permitted bands

EU and US are considering ASA to unlock spectrum for MBB

Endorsed by EU 27 Member States, naming it LSA (Licensed Shared Access)[1]

Endorsed by CEPT, releasing a report on ASA's benefits and working on LSA authorizations guidelines

Implemented by CEPT, for the harmonization and release of the 2.3GHz[2] on a shared basis with various incumbents – telemetry, defense etc.

Studied by ETSI, defining LSA requirements and network architecture

Spectrum Sharing proposed by FCC for the release of 3.5 GHz[3] for small cells on a shared basis with radars

[1] ASA has been named LSA (Licensed Shared Access) in the EU by the Radio Spectrum Policy Group
[2] 3GPP Band 40, 2.3-2.4 GHz 3Target 3.5 GHz in the US is 3550-3650 MHz

ASA supports continued mobile broadband growth

Unlocks new underutilized spectrum

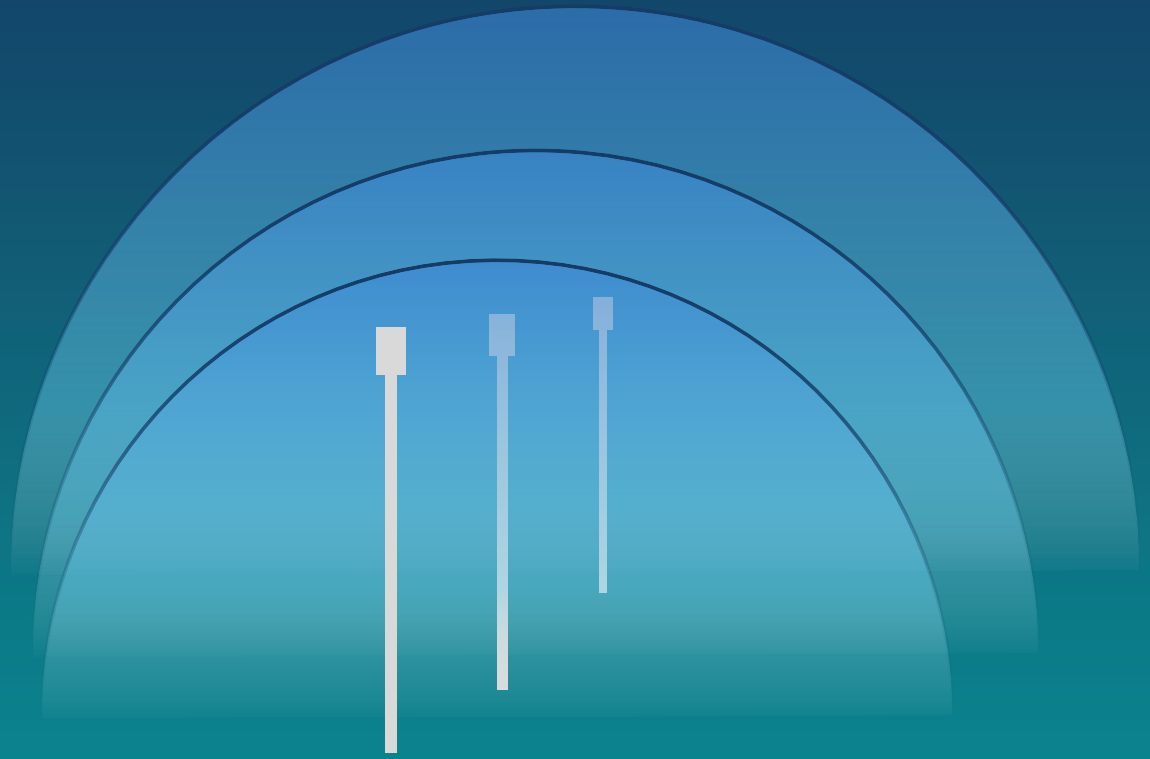
Not possible, or only partially, with traditional licensing

Faster access to spectrum means faster economic benefits

€65 billion economic benefits per year in the EU alone[1]

Enabling access to spectrum in higher bands for more small cells

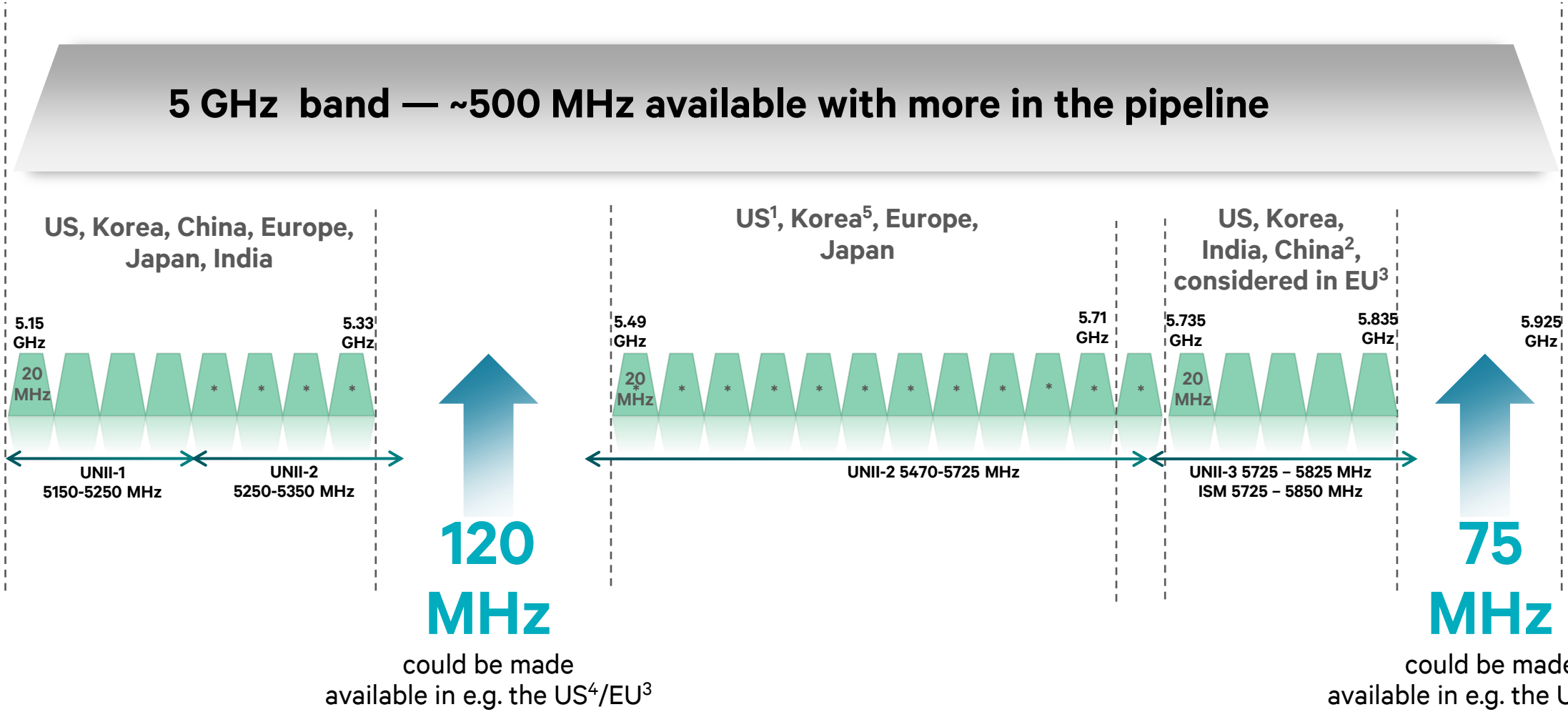
[1] Per year 2020 to 2025. Source: Authorized Shared Access (ASA): An Evolutionary Spectrum Authorization Scheme for Sustainable Economic Growth and Consumer Benefit, Ingenious Consulting Network, Jan. 2011



Leverage unlicensed spectrum

Wi-Fi and LTE Advanced in unlicensed spectrum

More and wider unlicensed spectrum around 5 GHz

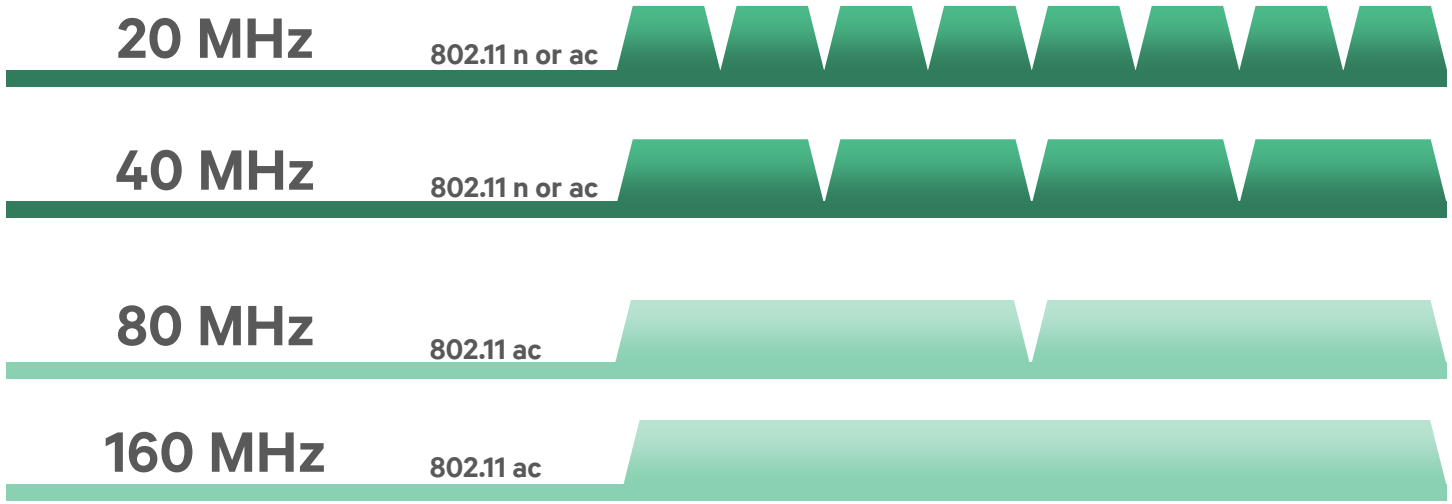


[1] Channel 120, 124 and 128 (5.6-5.65 GHz) currently not permitted in the US. [2] 5725MHz-5850MHz has been assigned to ISM services in China [3] Study of 5350MHz-5470MHz and 5725MHz-5925MHz use for license exempt is being planned in EU'. [4] Feasibility studies directed by the Middle Class Relief &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

Next generation Wi-Fi needs wide contiguous spectrum

802.11 ac targets unlicensed 5 GHz and uses up to 160 MHz for enhanced performance.

5 GHz
802.11 ac



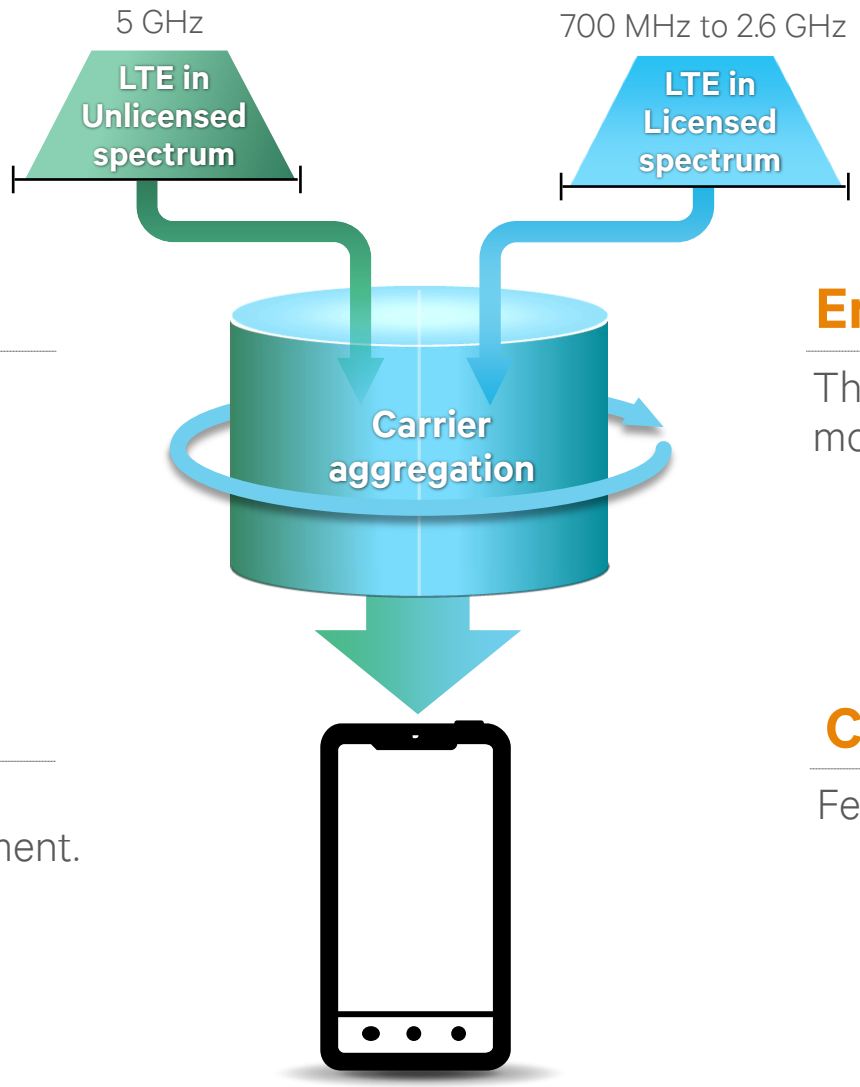
Primary
To access and for backward compatibility

Secondary
To boost performance

60 GHz
802.11 ad

802.11ad offers bandwidth of 2 GHz or more to enable high performance in-room media distribution, available at 60 GHz.

Extending benefits of LTE Advanced to 5Ghz unlicensed spectrum



Better performance

Longer range and increased capacity

Enhanced user experience

Thanks to common LTE with robust mobility and anchor in licensed

Unified LTE Network

Common LTE network with common authentication, security and management.

Coexists with Wi-Fi

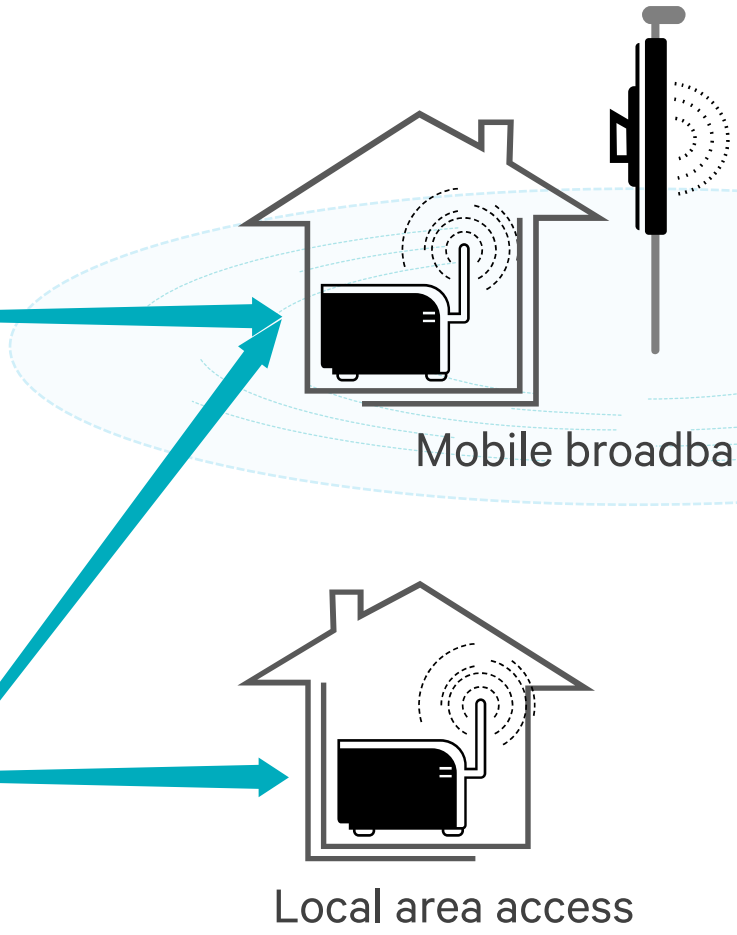
Features to protect Wi-Fi neighbors

A leader in all solutions to best leverage unlicensed spectrum

Committed to end-to-end Wi-Fi, carrier Wi-Fi, bringing LTE Advanced to unlicensed spectrum

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

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



Common LTE Advanced for licensed and unlicensed spectrum

Mobile operator managed service that aggregates licensed and unlicensed spectrum[1]

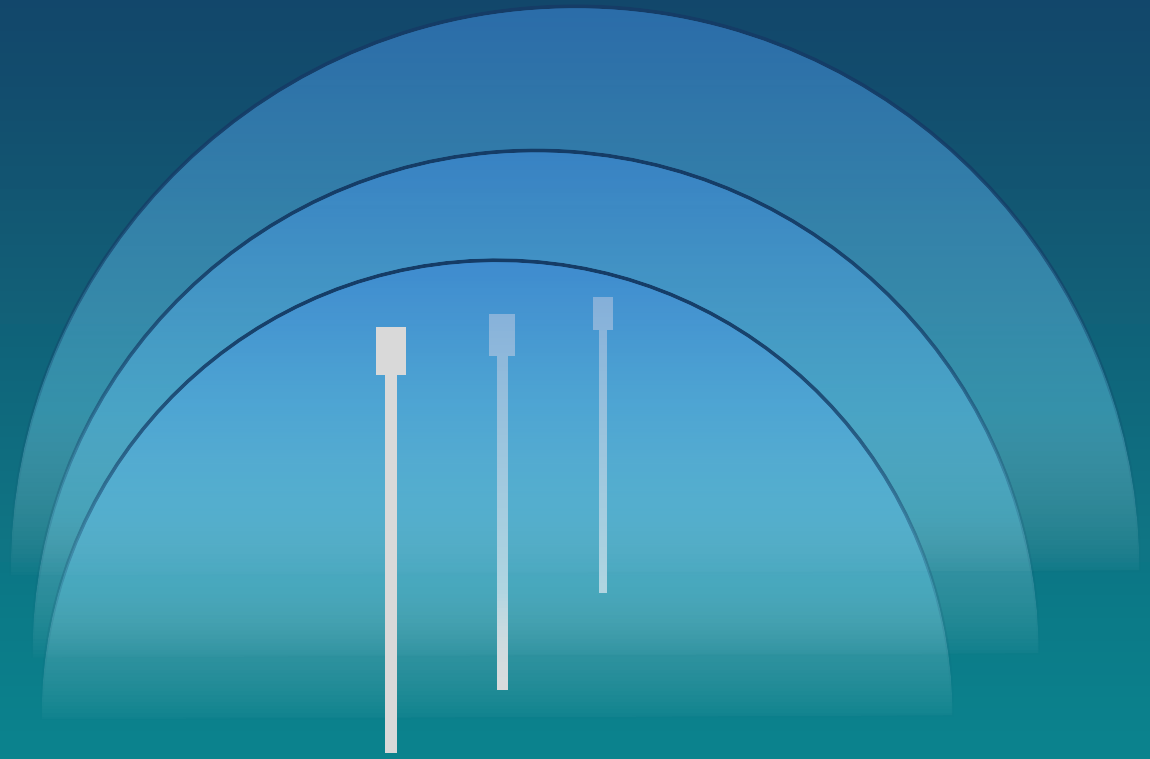
3G/4G for licensed and carrier Wi-Fi for unlicensed spectrum

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

Wi-Fi hotspots in unlicensed spectrum

Local area access for private/residential, enterprise users.

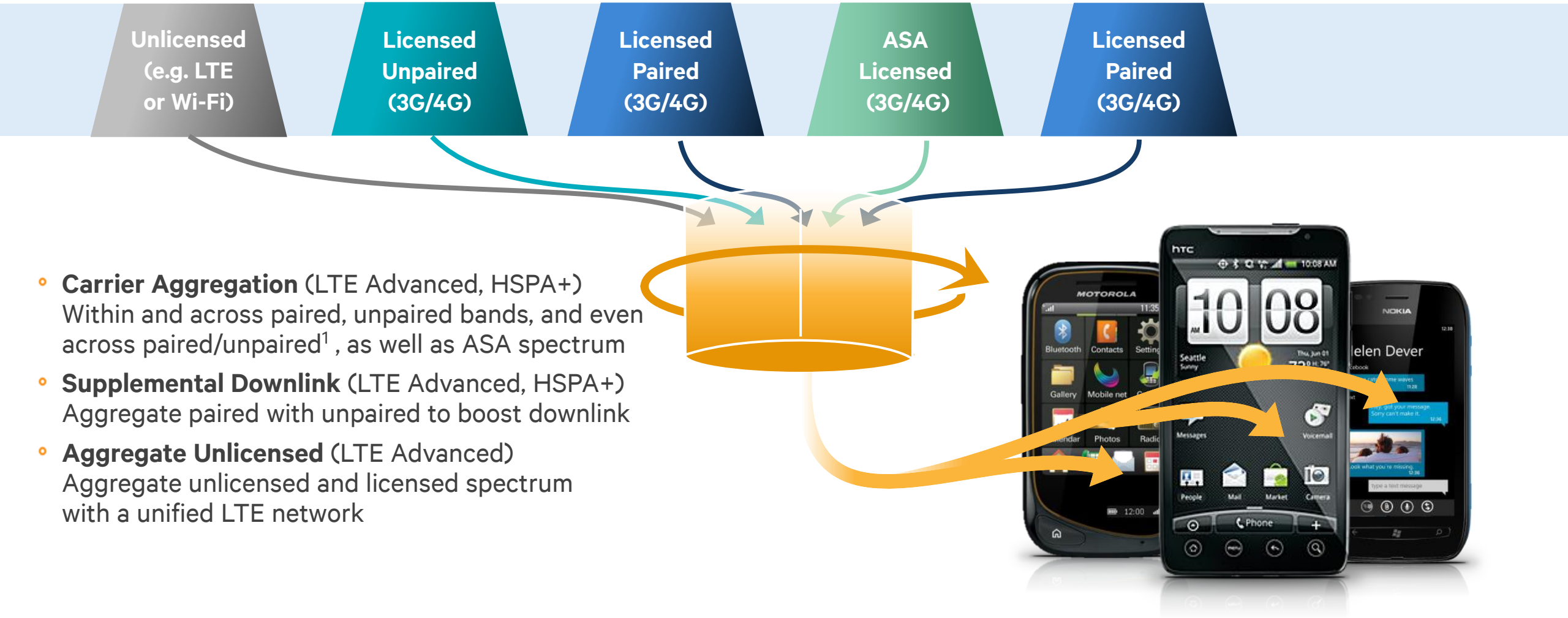
[1]With Wi-Fi for backward compatibility



Spectrum aggregation

And supplemental downlink

Spectrum aggregation makes best use of all spectrum assets

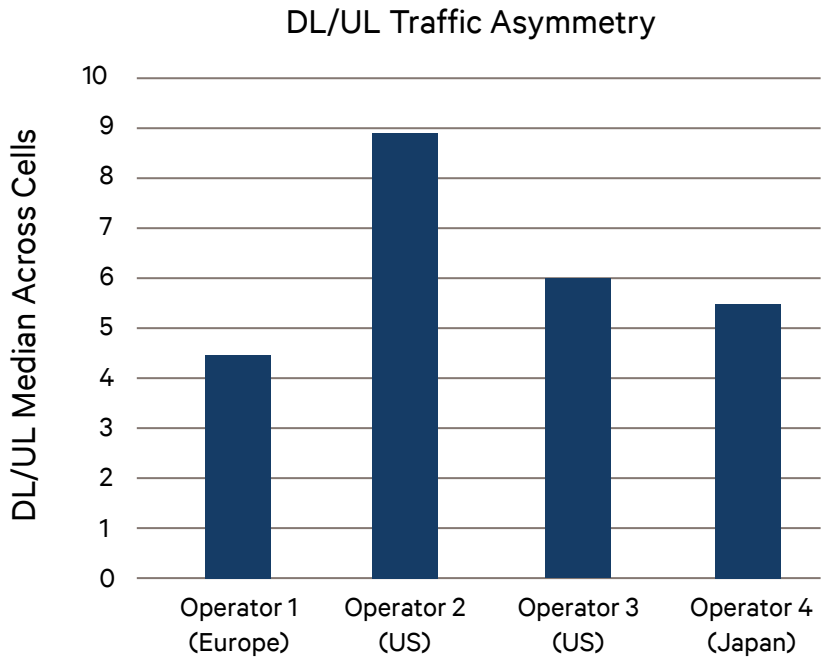


- **Carrier Aggregation** (LTE Advanced, HSPA+)
  Within and across paired, unpaired bands, and even across paired/unpaired[1] , as well as ASA spectrum
- **Supplemental Downlink** (LTE Advanced, HSPA+)
  Aggregate paired with unpaired to boost downlink
- **Aggregate Unlicensed** (LTE Advanced)
  Aggregate unlicensed and licensed spectrum with a unified LTE network

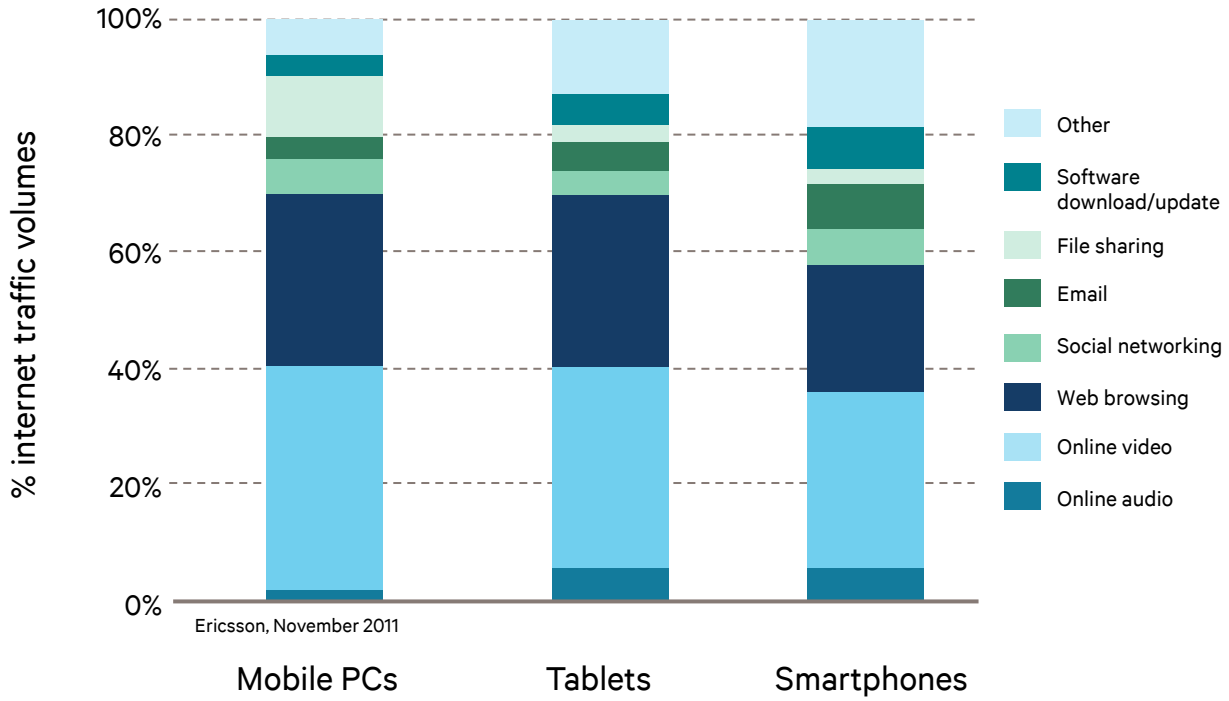
[1]LTE Advanced supports FDD or TDD aggregation, but FDD and TDD aggregation is a candidate for future revisions of the standard

Mobile traffic typically downlink centric

MAJORITY OF TRAFFIC ON DOWNLINK (DL) [1]



VIDEO BIGGEST CONTRIBUTOR TO TRAFFIC VOLUMES[2]



Traffic asymmetry could rise to a **10:1** ratio or more[3]

[1] Based on measurements (median) in live networks in 2009. [2] Ericsson, November 2011. [3] Plum consulting, 2011, some networks may already exceed 10:1 asymmetry

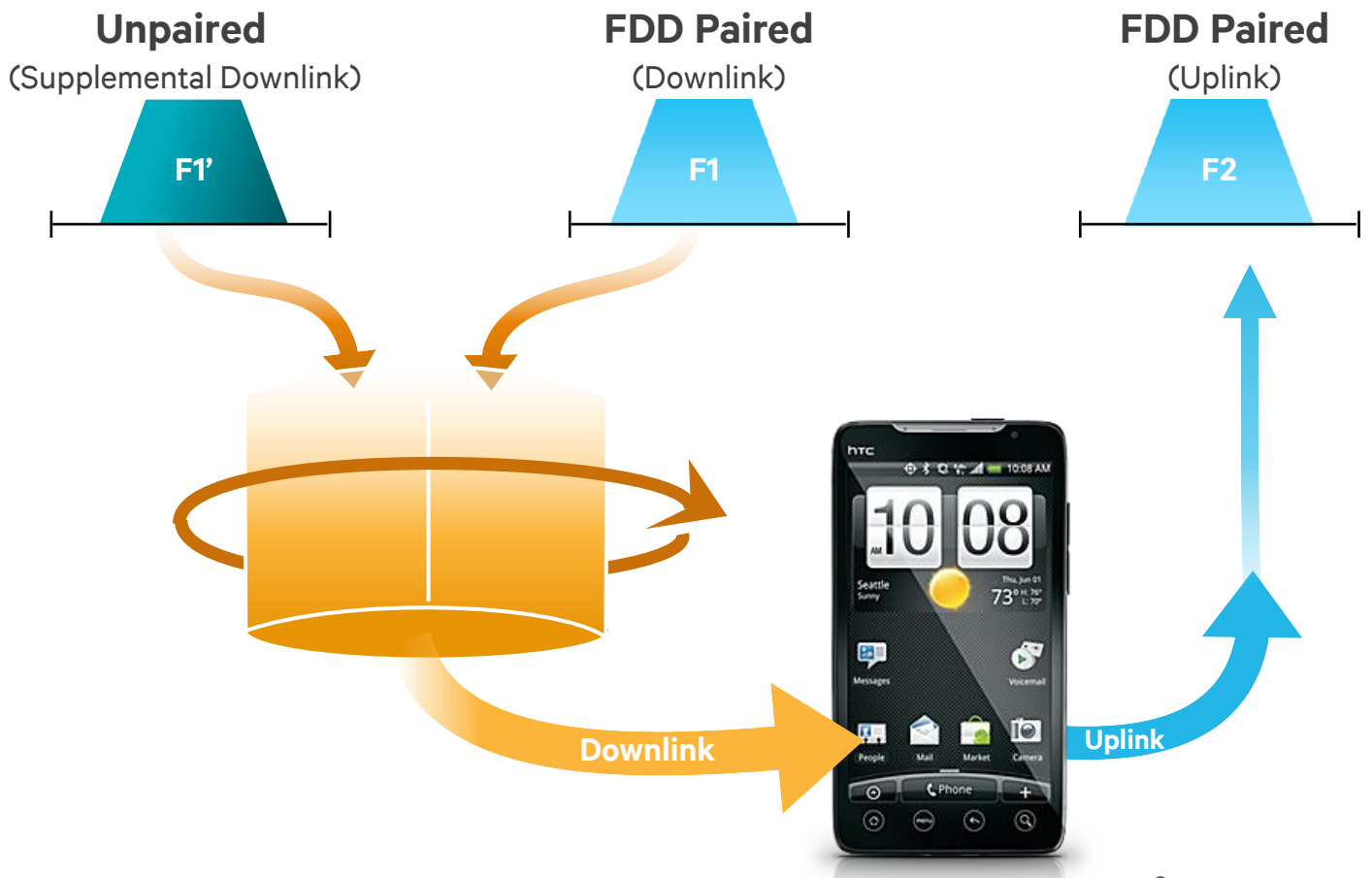
Aggregate unpaired spectrum for more downlink capacity—supplemental downlink

L-Band 1.4GHz Harmonized in Europe[1]

- L-Band 1452 MHz to 1492 MHz, with 40 MHz of idle unpaired spectrum available[2].
- Other opportunities are country specific.

700 MHz to Launch in the US

- 700 MHz in the US with AT&T[3], planned launch as early as 2014.

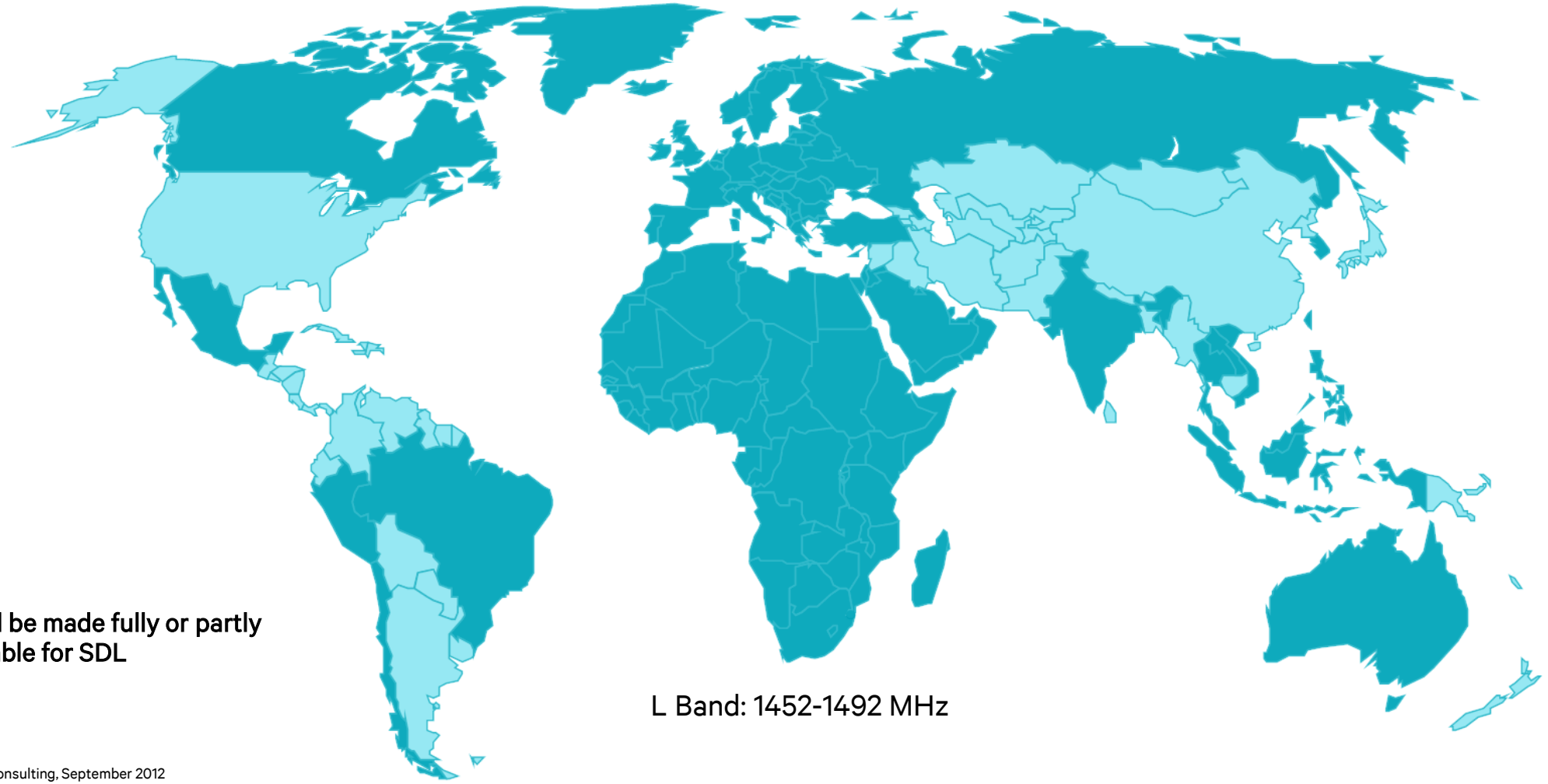


USES HSPA+ MULTICARRIER ACROSS BANDS[2], OR LTE ADVANCED CARRIER AGGREGATION[2]

[1] L-Band in Europe: 1452 MHz to 1492 MHz, sometimes referred to as 1.4GHz or 1.5GHz spectrum. [2] Aggregation across bands is supported in HSPA+ R9 (and beyond) and LTE R10 (and beyond), but each specific band combination, e.g. combination of band 1 and L-band, has to be defined in 3GPP. [3] AT&T is planning to deploy supplemental downlink in lower 700 MHz (12 MHz of unpaired spectrum)

Globally available L-Band ideal for supplemental downlink

L-Band now harmonized in Europe—commercialization next[1]

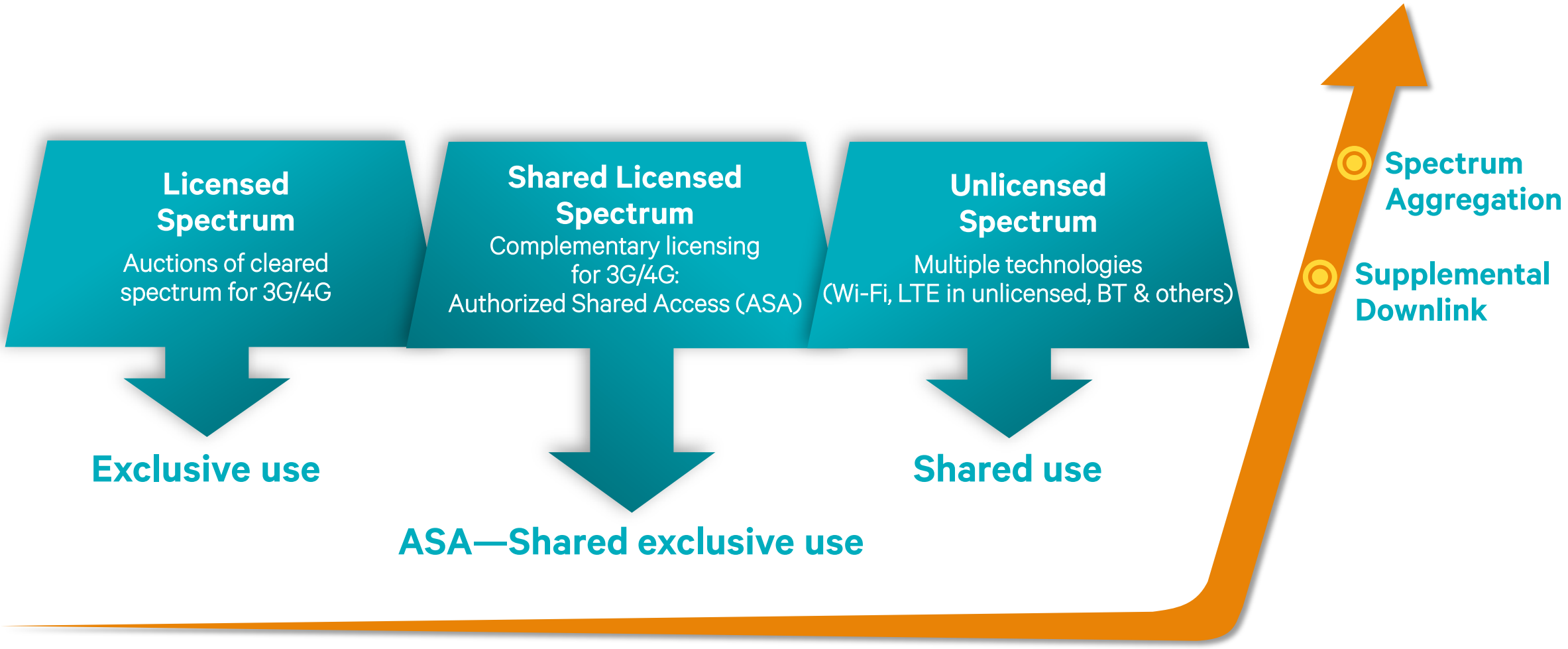


Map source: Plum Consulting, September 2012

[1]ECC Decision (13)03 on the on the harmonized use of the frequency band 1452-1492 MHz for Mobile/Fixed Communications Networks Supplemental Downlink (MFCN SDL)

Summary: multiple efforts required to access more spectrum

More licensed spectrum is the industry's top priority—need to leverage all spectrum for 1000x



Will there be 1000x demand?
It's just a matter of time...

Driving Network Evolution

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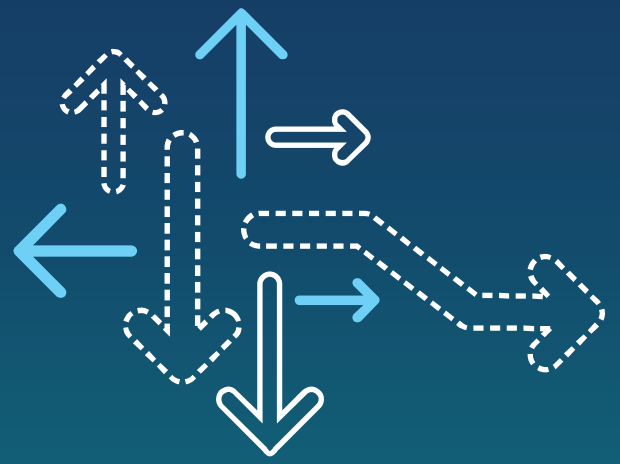

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