

Practical aspects of Carrier Aggregation in LTE-A

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Outline

- **Basics of Carrier Aggregation**
- **CA implementation challenges**
- **Other usages of CA: LTE-U, LAA**
- **Conclusion**



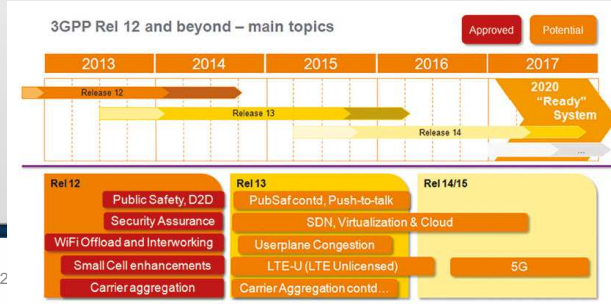
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Carrier Aggregation: the main feature of LTE-Advanced

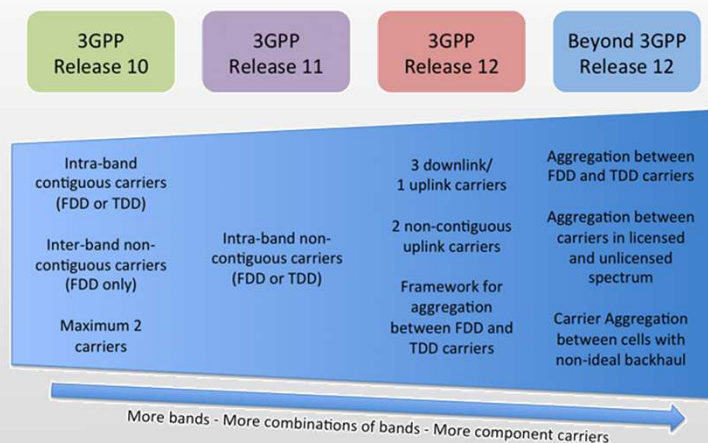


- **LTE-A was started in Dec. 2004 to fulfil the IMT-Advanced requirement set by ITU**
 - And get the label of "4G"
 - In practice, 4G is awarded to LTE (and WiMAX)
- **Foundation completed in Dec. 2010**
 - CA is still being improved
 - Now: Rel. 12 almost completed, work ramping up for Rel.13
 - 5G possibly falling into Rel. 14/ Rel.15



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Evolution of CA in 3GPP



Source: <http://www.umnroading.com/2014/06/carrier-aggregation-evolution>



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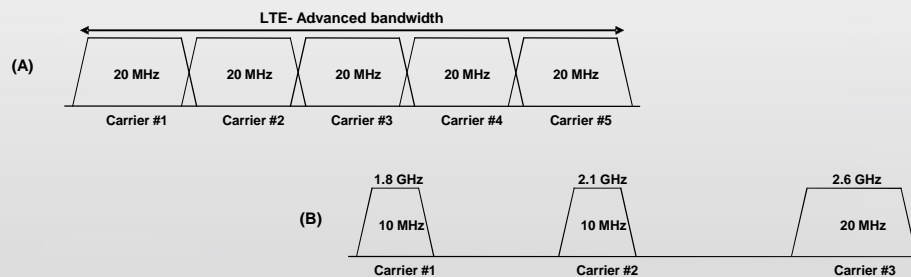


LTE-A: Carrier aggregation

- **Examples**

(A) Equal bandwidth, intra-band, contiguous

(B) Inter-band, different bandwidths



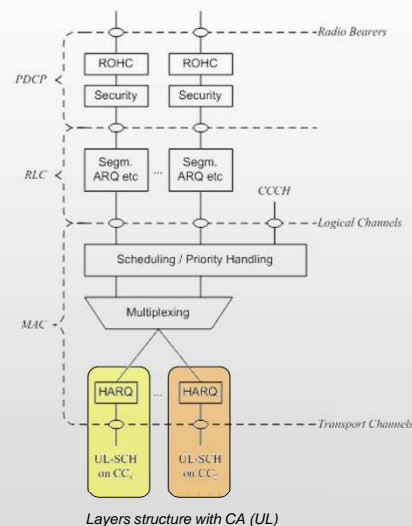
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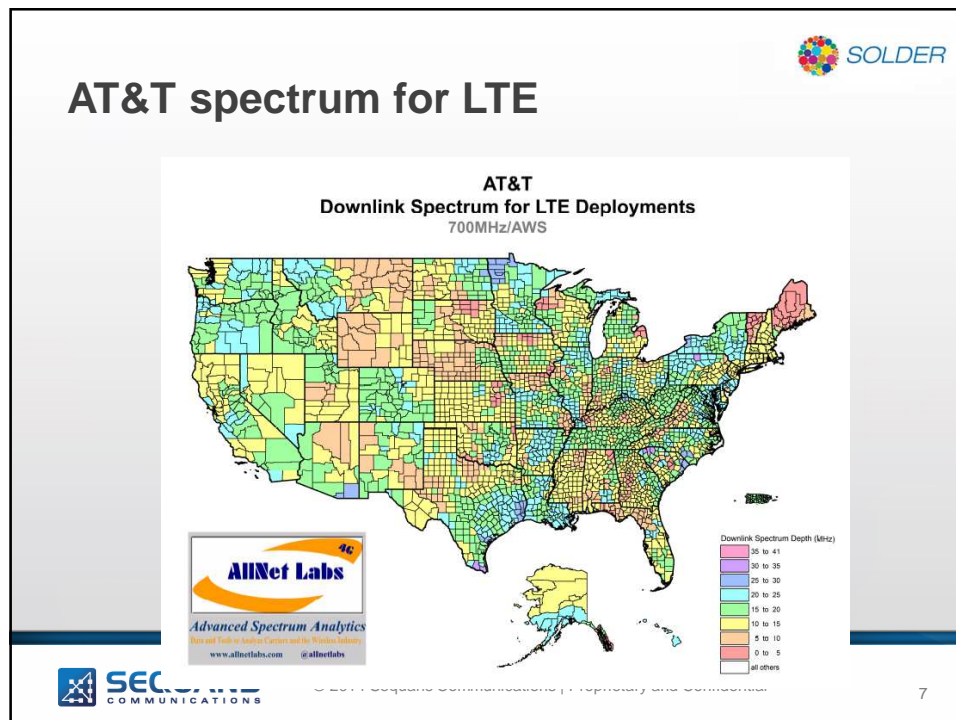
CA: How it works


- **One PHY per CC**
- **MAC is the multiplexing layer for CA**
 - HARQ is per CC
 - Scheduling is global
 - and implementation dependent
- **Transparent for RLC, PDCP**
- **Some changes in RRC layer**
 - For configuration, measurements



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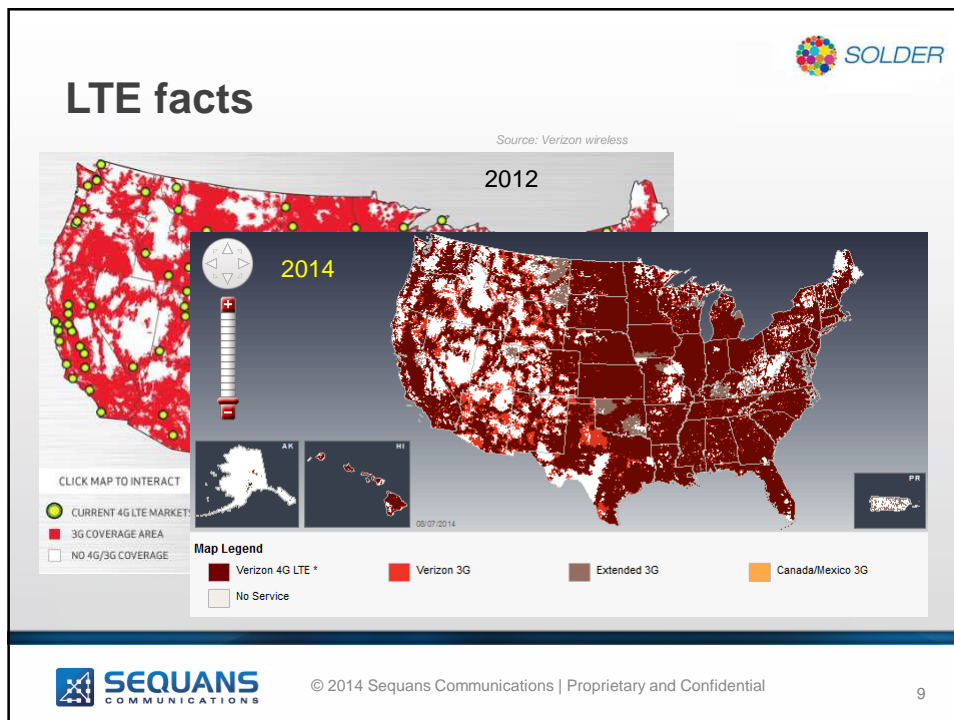
CA: a shift in interest...


- **Originally designed to reach IMT-A requirements**
 - Aggregating 5 CC, up to 100MHz
 - For very high data rates
- **Progressively as an answer to operators' "real" concerns**
 - Better use of (expensive) spectrum
 - Interference management, load balancing
 - Backward compatibility
- **It translates into the standard as:**
 - More and more inter-band cases
 - **Almost one per operator/region**
 - Limitation to (reasonable) number of aggregated carriers
 - **5 in theory, 2 in practice to start with, now 3DL cases are being standardized**
 - **Only 1 CC in UL**
 - UL will likely become a real limitation



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LTE-A facts

- **Devices**
 - Samsung Galaxy S4 and S5 (models for Korea)
 - <http://www.cnet.com/news/samsung-announces-new-galaxy-s5-with-lte-a-capabilities-for-korea/>
 - Huawei E5186, E5786
 - <http://consumer.huawei.com/en/press/news/hw-327681.htm>
 - ZTE Flare
 - http://www.zte.com.cn/en/press_center/news/201402/t20140225_418447.html
- **Demonstrations, deployment announcements**
 - http://en.wikipedia.org/wiki/LTE_Advanced#Technology_demonstrations

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LTE-A facts

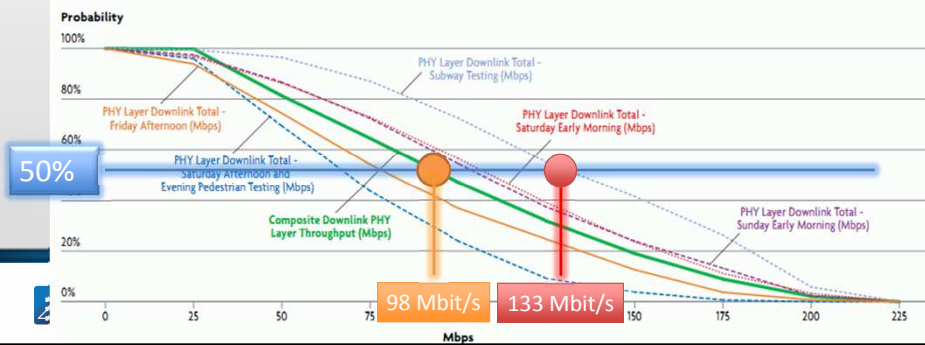
- **Example SKT deployment**

- Band 3: 20MHz @ 1800MHz + Band 5: 10MHz @ 850MHz
- 30 MHz in total, theoretical DL peak rate of 150+75 = 225Mbit/s

TOTAL DATA TRANSFERRED = 393.1 GB
Maximum Physical Layer Throughput (1 second interval) = 221.11 Mbps
Median Physical Layer Throughput = 98.9 Mbps

Composite Throughput (Median) = 98.9 Mbps	Saturday Pedestrian (Median) = 67.9 Mbps
Friday Afternoon (Median) = 87.9 Mbps	Subway (Median) = 133.6 Mbps
Saturday Early Morning (Median) = 110.0 Mbps	Sunday Early Morning (Median) = 106.0 Mbps

Source: signal research group, Aug 2014



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- **Challenges for the UE on practical implementation**
- Other usages of CA: LTE-U, LAA
- Conclusion



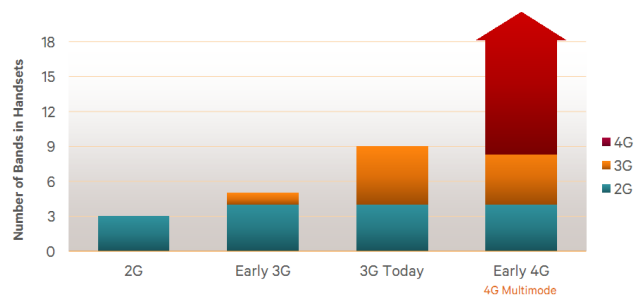
CA challenges (from UE perspective)

- **Main challenge**
 - Multiple bands, bandwidths, duplex modes and band combination support
 - Higher data rate
- **Challenges worth being mentioned but not developed today**
 - Multi-modes support and in-device coexistence
 - Simultaneous radio operation
 - e.g. Voice + Data
 - e.g. UL carrier aggregation
 - Power consumption
 - Challenge for test and conformance (exponential number of cases)



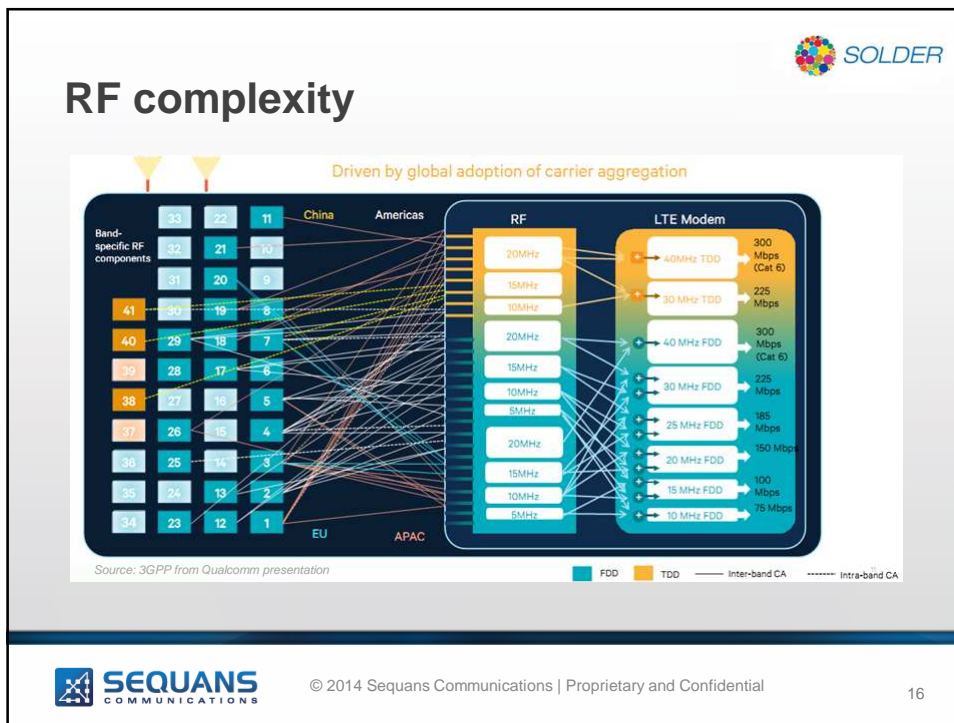
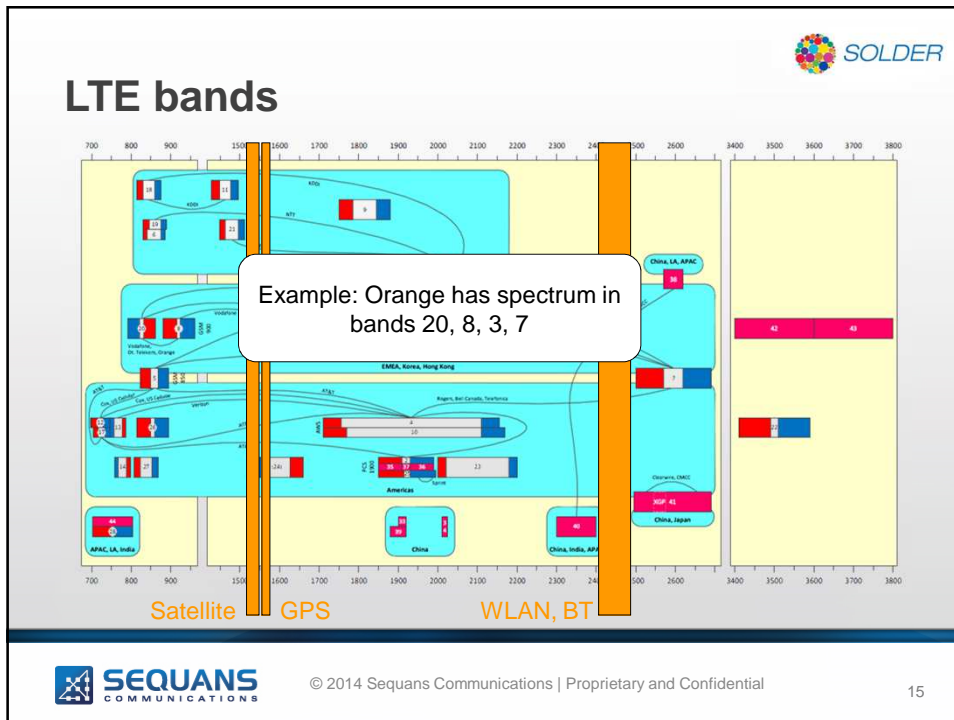
Multiple bands support

Driving up the number of bands in a mobile device



Major impact on smartphone design is on the radio frequency “front end”

Source: Qualcomm





What is RF Front end ?

- **Example**

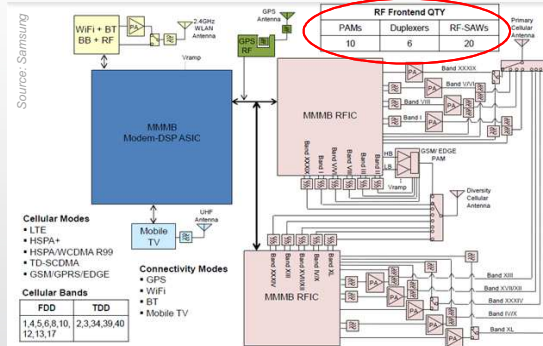
- 14 bands, 7 modes platform

- **Cost**

- Each new band needs at least a set of filters/duplexers and in many cases a new power amplifier or even new antenna pair. The incremental cost per band is \$0.30...\$2.00.

- **Power consumption**

- Higher consumption due to higher data rates despite more efficient circuits and protocols
- More uploads (e.g. photo/video storing on cloud) dramatically increases power drain
- Battery technology not keeping up with increasing consumption



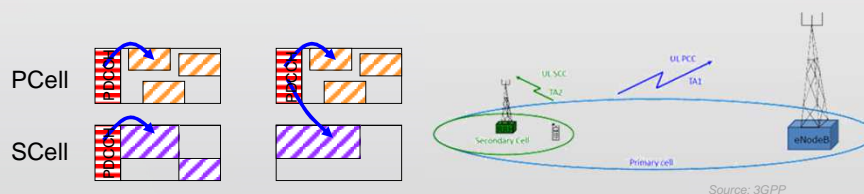
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CA challenges on the digital side

- **Measurement and synchronisation**
- **Close-loop schemes**
- **Cross carrier scheduling**
- **Multiple timing advance support**
 - UL, in case of heterogeneous deployment
- **Possibly higher data rates**



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About data rate and UE category

- **CA does not necessarily mean increase in data rate**
 - E.g. 10MHz + 10MHz = 20MHz, still Category 4 UE
- **But it open the door to higher rates...**
 - Commercialization of category 6 devices

		Component carriers				
		1	2	3	4	5
MHz		20	40	60	80	100
layers	2	150	300	450	600	750
	4	300	600	900	1200	1500
	8	600	1200	1800	2400	3000

Max DL data rate (Mbit/s) as a function of MIMO and CA capability (20MHz per cc)



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CAT 4



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CAT 6, 7



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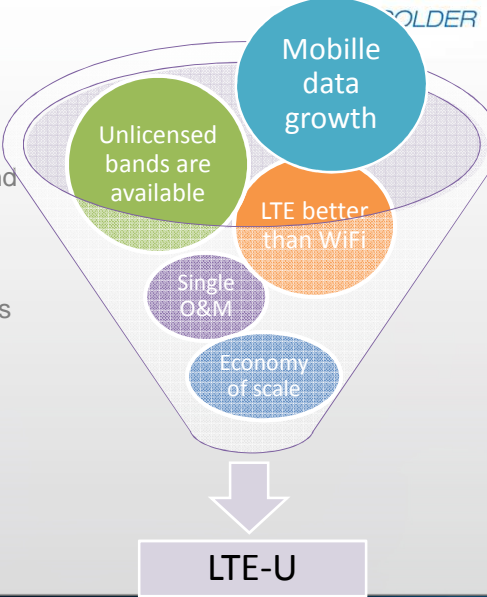
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Rationale for LTE-U



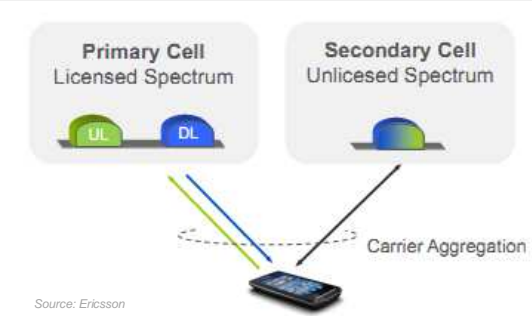
- **Definitions**
 - LTE-U = LTE in Unlicensed band
 - LAA = Licensed Assisted Access
- **Licensed spectrum**
 - Top priority for cellular operators
 - Exclusive use
- **Unlicensed spectrum**
 - Unpredictable QoS
 - To be (fairly!) shared with other technologies
 - Seen as complementary

→ **Notion of LAA leveraging CA**

LTE-U

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CA role in LAA



- **Primary Carrier always in licensed spectrum**
 - Mobility, control, QoS critical traffic
- **Secondary carrier in unlicensed spectrum**
 - Best effort
 - DL only or DL+UL
- **See also SDL**
 - Supplementary DL
- **Alternative**
 - Dual connectivity
 - Stand-alone operation

Source: Ericsson

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Some LTE-U challenges

- **Fair and friendly coexistence**
 - With other technology
 - With other LTE-U operators
- **Yet new bands (and band combinations) to support**
 - 5GHz is foreseen as the primary target for LTE-U
- **Toolbox almost defined or being defined in 3GPP**
 - Carrier aggregation
 - Supplementary DL
 - TDD+FDD CA
 - Cross carrier scheduling



Conclusion

- **LTE-A is becoming real**
- **Carrier aggregation is one of the key features of LTE-A**
- **CA mitigates operator's spectrum fragmentation**
- **CA brings challenges for UE design that could be overcome**
 - Especially at RF front-end side
 - Also in the base band
- **Still many areas for research**
 - On generalization of CA
 - E.g. LAA in context of LTE-U
 - 0-duplex FDD
 - On aggregation of LTE with non-LTE systems
 - Aggregation of different waveforms, at different layers

