

**3GPP TSG RAN Meeting #70**  
**Sitges, Spain, December 7 - 10, 2015**

**RP-151892**

Document for: Information  
Agenda Item: 14.1.1

# Motivation for new WI Proposal: Advanced Carrier Aggregation Techniques for LTE

Huawei, HiSilicon

# Advanced CA Technologies

- **Complexity reduction for massive CA**

- Reduce baseband complexity of UE implementation to support massive CA
- Shorten time to market

- **Secondary cell/carrier dynamic on/off**

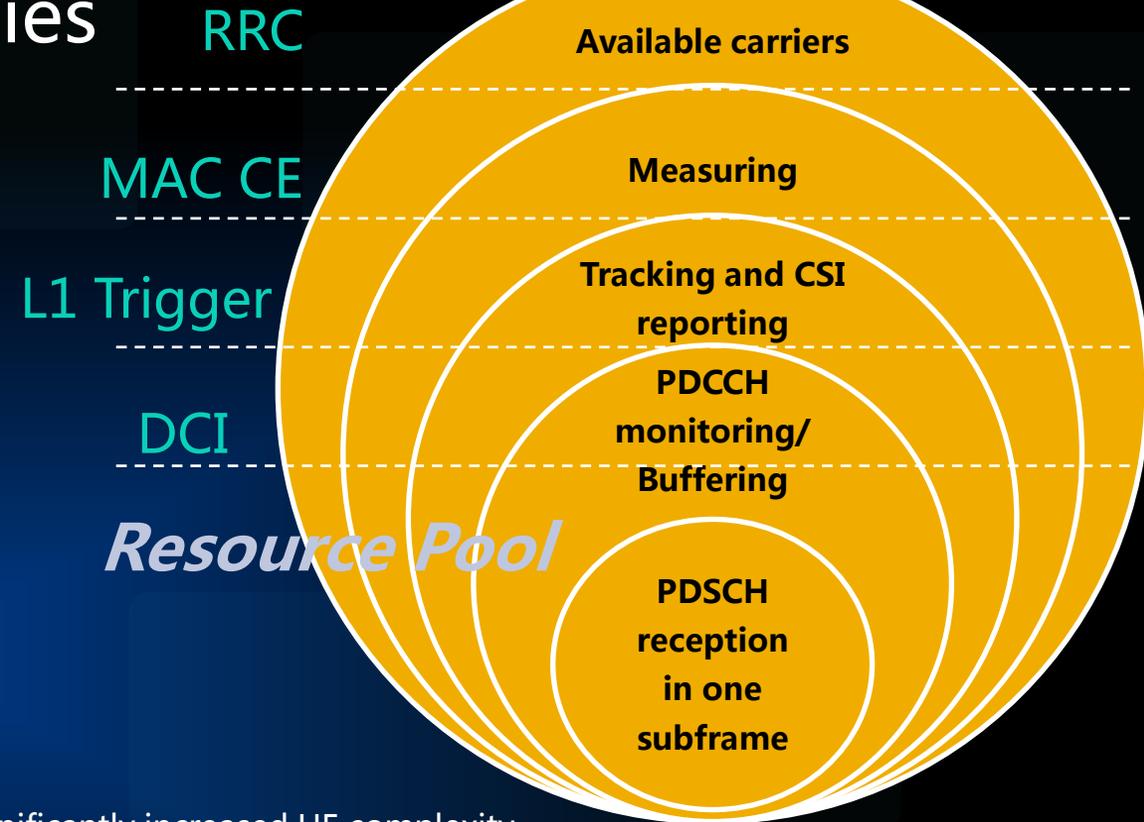
- Light-weighted carriers with minimum interference from common channels
- Significant gain showed in Small Cell Enhancement SI (see TR36.872)
- Enable forward compatibility
- It has already been done for LAA carrier with LBT

- **Fast Carrier switching**

- Enable utilization of the entire available eNB spectrum over time without significantly increased UE complexity
- Improve network interference coordination and load balancing, and take full advantage of multi-carrier LBT for LAA

- **UL SRS transmission switching over TDD carriers**

- Allow UE to transmit SRS on all the TDD carriers over time
- Improve DL beamforming performance
- Allow the number of configured carriers for SRS transmission to exceed the number of carriers of the UE UL CA capability



# Performance Benefits

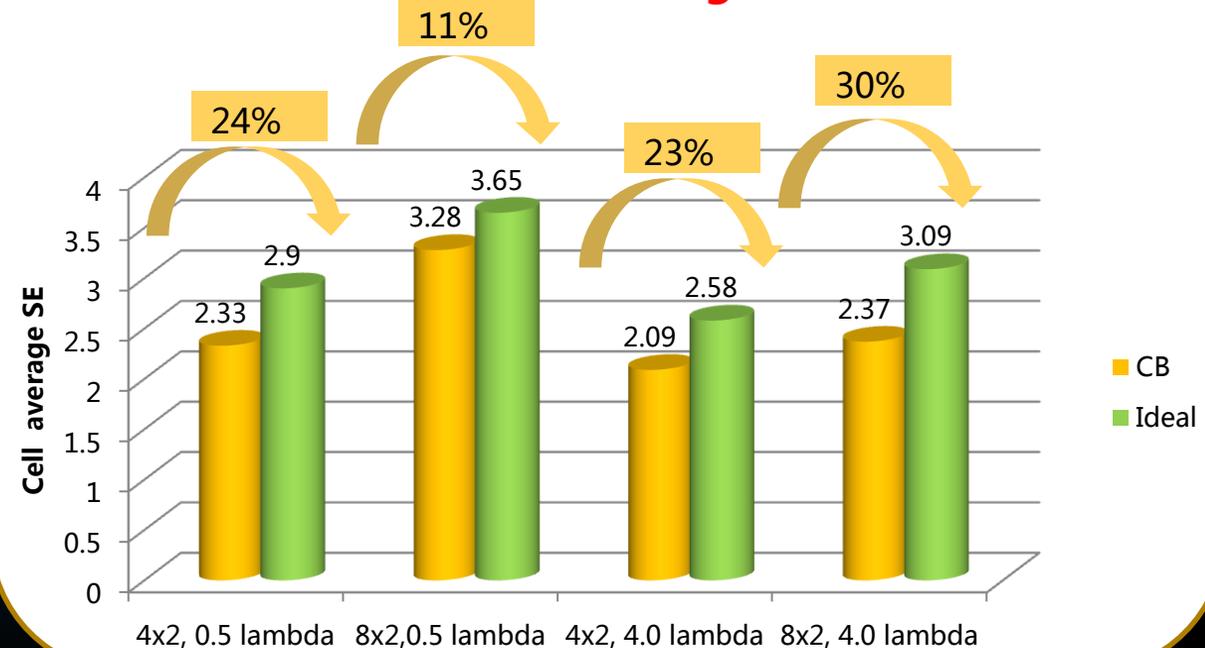
Throughput performance gains with **fast carrier switching** in LAA

Traffic load	LAA coexists with LAA	
	Gain for average UPT	Gain for 10% UPT
Low load (Packet arrival rate: 0.2)	10.75	29.89
Medium load (Packet arrival rate: 0.4)	31.31	87.22
High load (Packet arrival rate: 0.6)	49.91	215.53

R1-151297, "Evaluation results for LAA with fast carrier selection", Huawei, Hi

**Dynamic on/off** based on packet arrival/completion can offer large gains according to SCE SI in TR36.872.

Throughput performance gains with **SRS switching** in TDD



# Standards Impacts

- Requires much less standards (esp. RF related) and implementation effort than legacy CA-based approach
- SCell configuration related: #CCs configured to a UE  $\geq$  #CCs for simultaneous data reception/transmission
- RRM measurements and synchronization related: Rely on alternative measurements (e.g., RSSI-like in LAA); Extension of quasi co-location concept to across co-located intra-band carriers
- Preamble (plus DRS) designed to achieve fine synchronization
- Dynamic indication: unified design for dynamic on/off and fast switching

# Feasibility Analysis

- **UE switching operations (for DL and/or UL) may include:**
  - RF retuning
  - AGC setting
  - Tracking
- **Related RAN4 studies/conclusions:**
  - RF retuning for eMTC: 200~300 ms
    - R4-152889, “RF design considerations for eMTC”, Qualcomm.
  - AGC setting for D2D: < 1 OFDM symbol duration
    - R4-140973, “AGC and Frequency Error for D2D”, Qualcomm.
  - RF/AGC for eMTC: 200~300 ms
    - R4-141235 (R1-141109), “Reply LS on half duplex FDD operation for Low complexity MTC UE”, RAN4, Huawei.
  - Switching for measurement gap: < 0.5 ms
    - Total: 6 ms; measurements: 5 ms; one way switching: < 0.5 ms
- **Tracking:**
  - Not needed for intra-band co-located

# Conclusions

- **Further enhancement of CA is crucial for future networks**
- **Multiple related advanced technologies for further CA enhancements:**
  - Complexity reduction for massive CA
  - Secondary cell/carrier dynamic on/off
  - Carrier switching in DL/UL is beneficial
  - Carrier switching can be enhanced with reduced transition times
- **Consider to propose a WI for Rel-14**

# Outline of detailed discussions

- **Background**
- **Enhancements**
  - **Complexity reduction for massive CA**
  - **Secondary cell/carrier dynamic on/off**
  - **Fast carrier switching (FCS)**
  - **SRS transmission switching over TDD carriers**
  - **Feasibility considerations**
- **Conclusions**

# Background

- **Status in Rel-12**
  - B5C: Up to 32 carriers w/ 20 MHz BW each for a UE
  - LAA: 14 unlicensed carriers available @ 5.8GHz
- **Limitations and problems**
  - UE capability limitation (in DL and UL) should be considered
    - Baseband capability
    - RF capability
  - Slow standards should be considered
    - Especially RAN4 RF requirements
    - Currently still working on CA w/ 3 or 4 CCs; 32 CCs may take another few years
- **Further performance enhancements for massive CA are desirable**

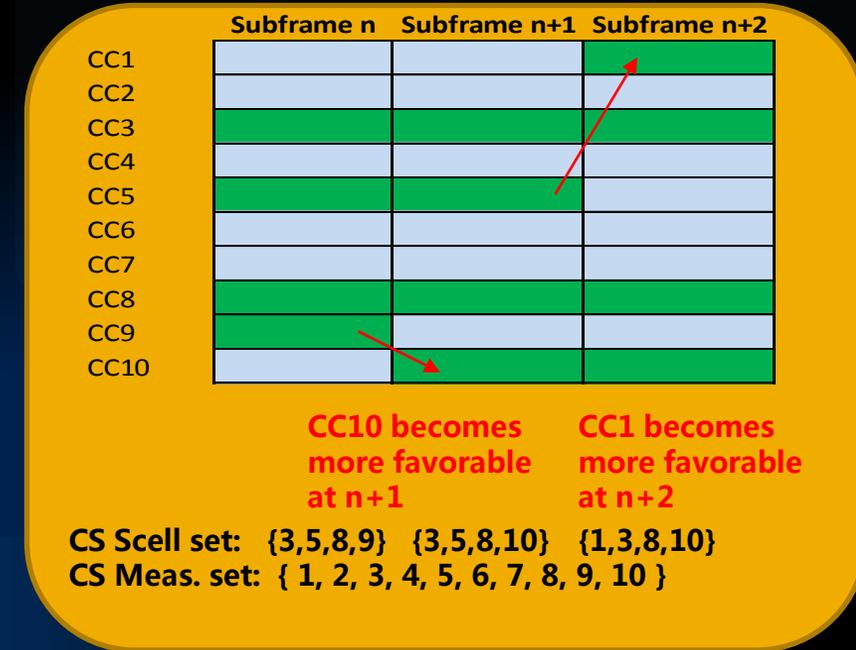
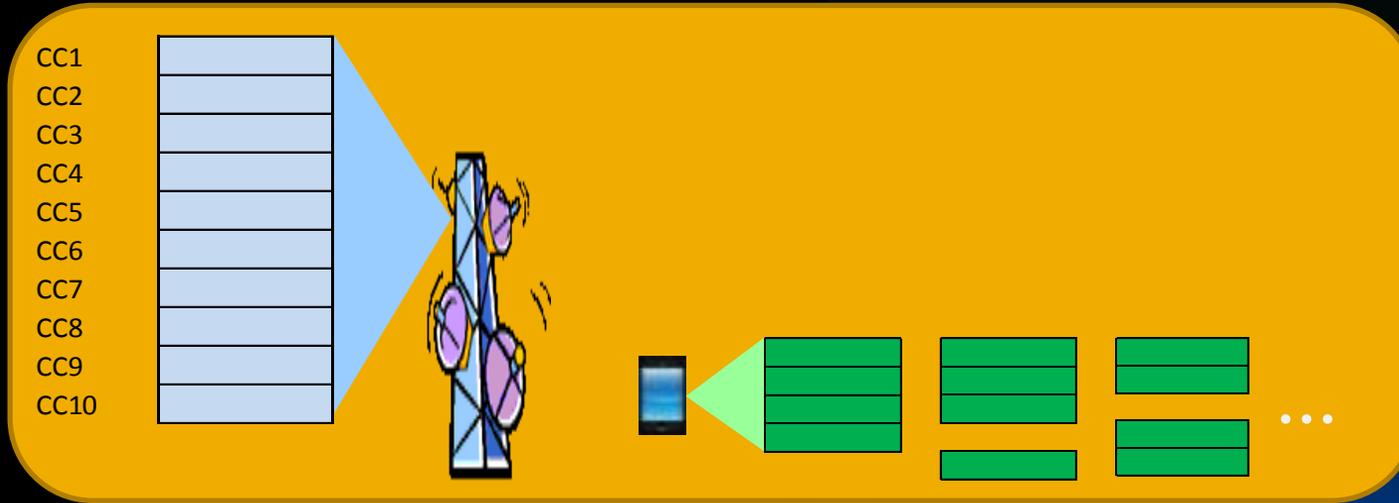
# Complexity reduction for massive CA

- **Reduces baseband complexity of UE implementation**
  - Low-category CA
  - Soft buffer management
  - HARQ
- **Shortens time-to-market (TTM)**

# Background for carrier switching

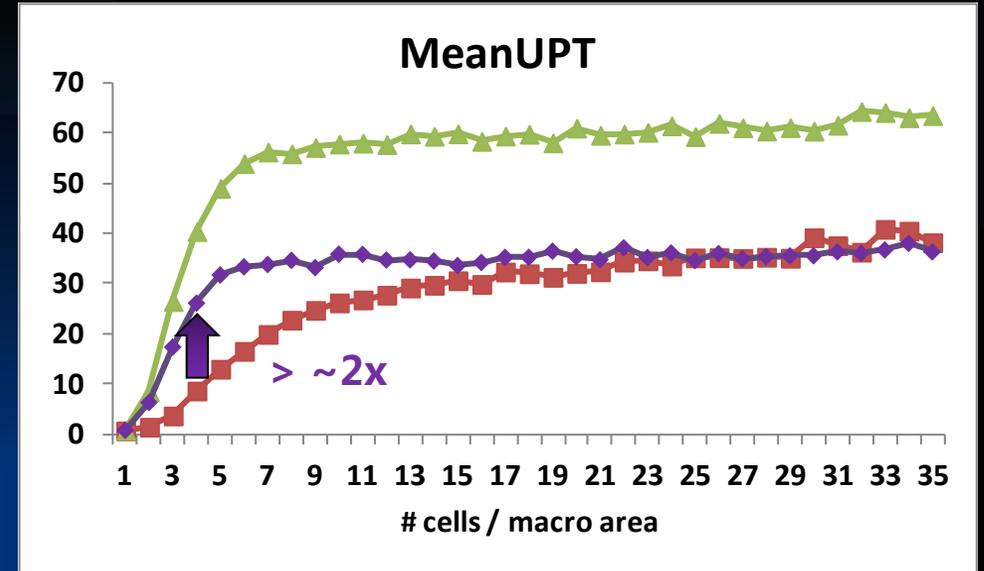
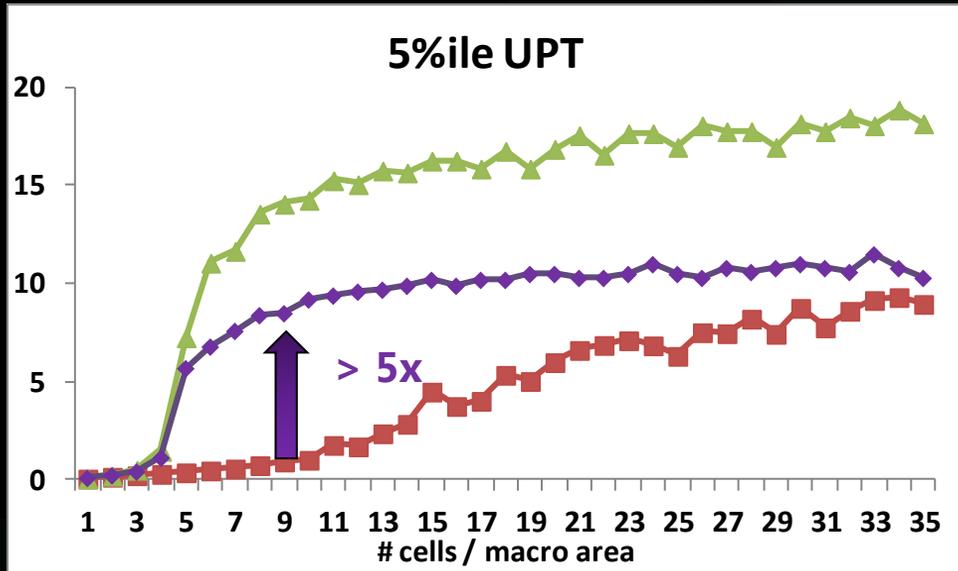
- **Carrier selection vs carrier switching**
  - Carrier selection
    - eNB-level selection out of a number of carriers
    - Widely accepted as beneficial (see later slides for evaluations) and essential to efficient LAA operations (e.g., LBT operations)
    - Mainly implementation issues, but require UEs to follow to be more useful
  - Carrier switching
    - UE-level switching from one CC to another, per eNB instruction
    - May be done for DL and UL
    - Semi-static carrier switching: 10s ms or longer
    - Fast carrier switching (FCS) or dynamic carrier switching: subframe-level

# Motivation for carrier switching from Rel-12 CA B5C



- UE capability limitation (in DL and UL) should be considered
- Can the network/UE better utilize the large number of carriers available at a cell?
  - Carrier switching enables utilization of the entire available eNB spectrum over time without significantly increased UE complexity

# FCS performance with UE CA capability limitation



## Fast carrier switching

- Beneficial to UEs without largely increasing their capability requirements
- Shorter transition time is more beneficial to performance (similar to Rel-12 SCE cell on/off conclusion)

— 40 MHz @ eNB/UE  
— 20 MHz @ UE, 40 MHz @ eNB, *FCS*  
— 20 MHz @ UE, 40 MHz @ eNB, *slow CS*

1. FCS is based on min packet completion time
2. Further optimization may be possible

BW: 20/40 MHz  
 #UE: 30 / macro area  
 Filesize: 0.5 MB  
 Ovhd: 9%  
 RSRP

# Motivation for carrier switching from Rel-12 LAA

- **Carrier availability not known well ahead of time**
  - Subject to LBT-based opportunistic channel access, for a single carrier or multiple carriers
- **14 orthogonal channels w/ 20 MHz BW each**
  - May be beyond typical UE capability

## TR36.889 v13.0, 7/3/2015

### 7.1 Design targets and functionalities

- Carrier selection

As there is a large available bandwidth of unlicensed spectrum, carrier selection is required for LAA nodes to **select the carriers** with low interference and with that achieve good co-existence with other unlicensed spectrum deployments.

### LAA WID RP-151045

The detailed objectives of the work item are to specify support for the following functionalities:

- Discontinuous transmission with limited maximum transmission duration (RAN1, RAN4)
- UE support for carrier selection** (RAN1, RAN2)

# FCS performance in LAA

## Throughput performance gains with **fast carrier switching** in LAA

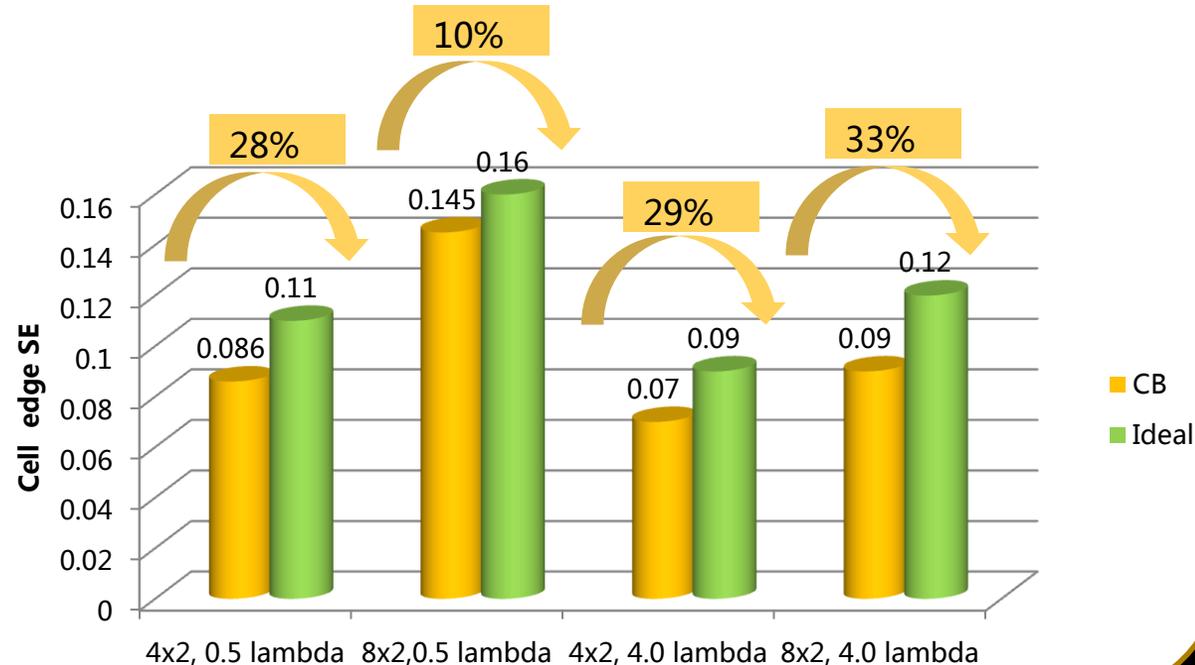
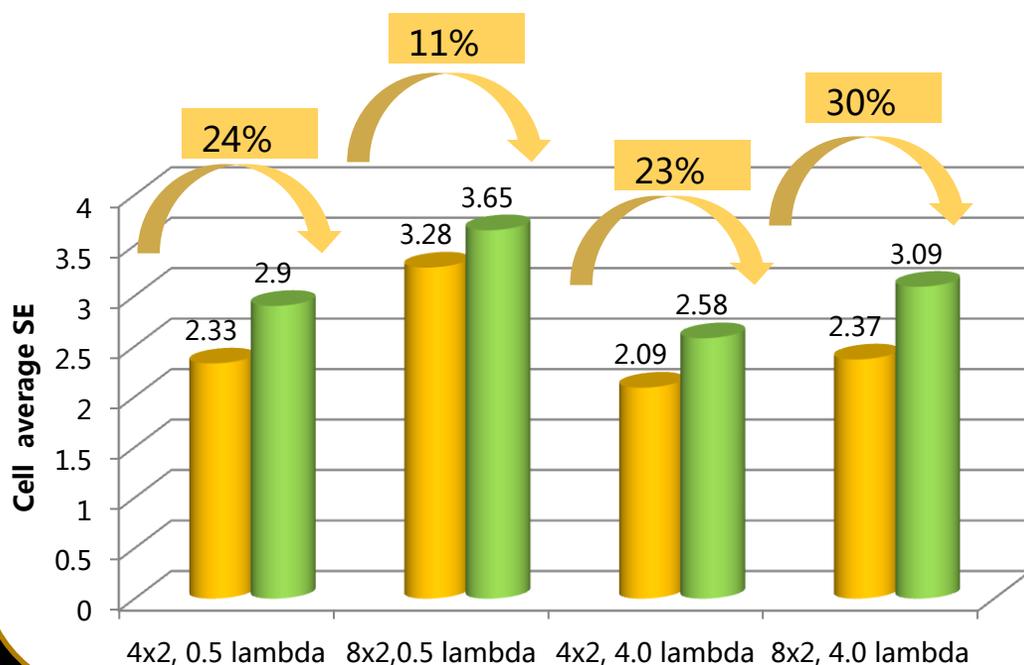
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R1-151297, "Evaluation results for LAA with fast carrier selection", Huawei, HiSilicon.

# Motivation for carrier switching from TDD

- There is a significant performance gain w/ SRS than codebook based PMI feedback for TDD carrier
- However, SRS cannot be transmitted on TDD SCells with DL transmission only and no UL transmission, when the UE has more DL carriers than UL carriers

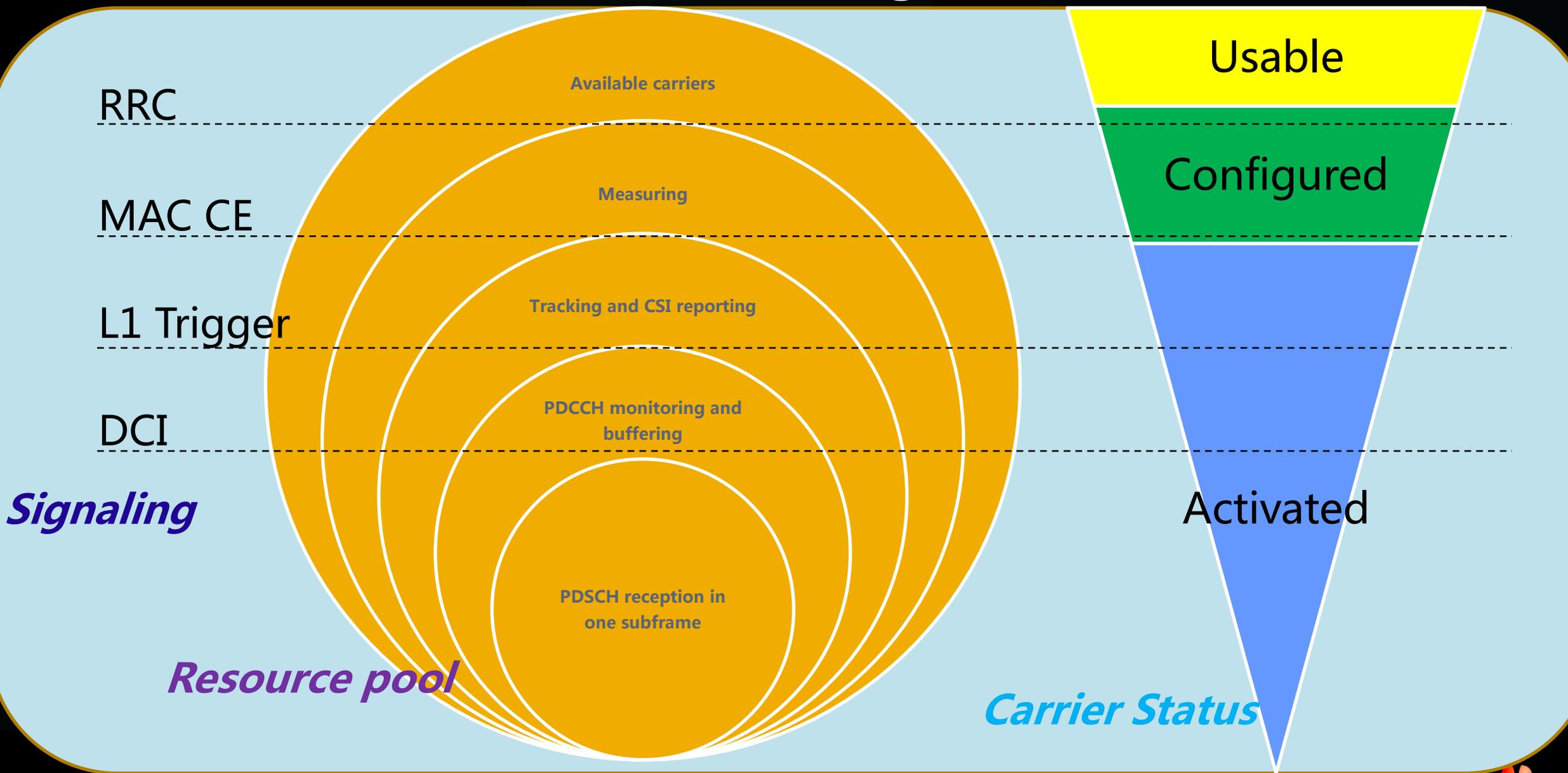
Throughput performance gains with **SRS switching** in TDD



# FCS: Overview and enhancements

- **Enable utilization of the entire available eNB spectrum over time without significantly increased UE complexity**
- **Improve network interference coordination and load balancing, and take full advantage of multi-carrier LBT for LAA**
- **Enhancements**
  - Requires much less standards (esp. RF related) and implementation effort than the CA-based approach
  - SCell configuration related: #CCs configured to a UE  $\geq$  #CCs for simultaneous data reception/transmission
  - RRM measurements and synchronization related: Rely on alternative measurements (e.g., RSSI-like in LAA); Extension of quasi co-location concept to across co-located intra-band carriers
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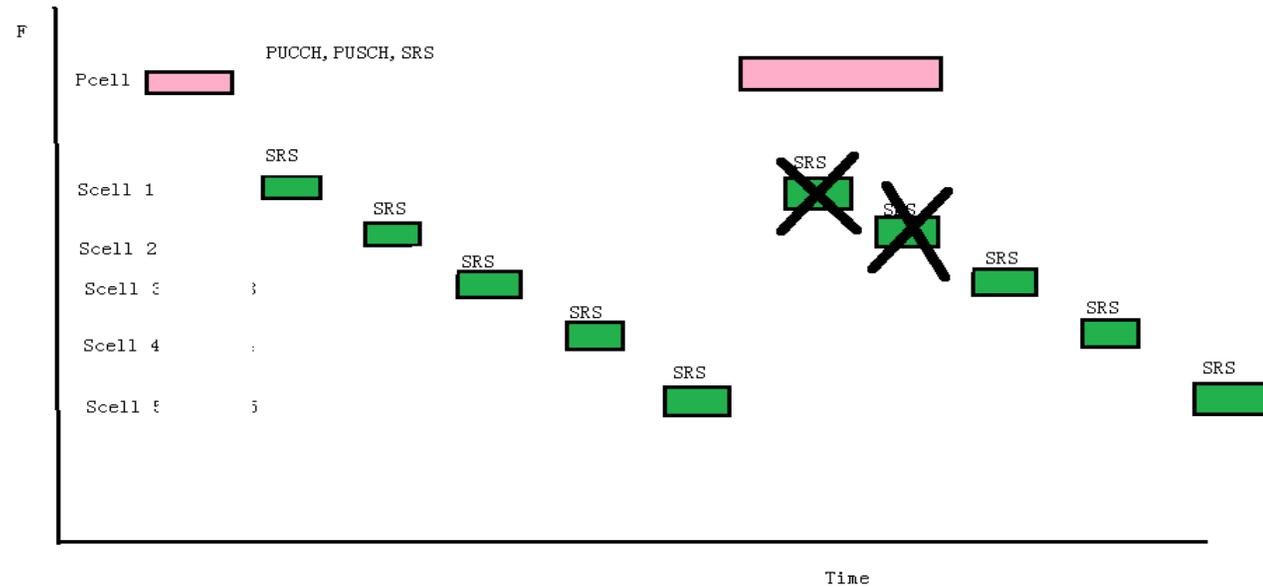
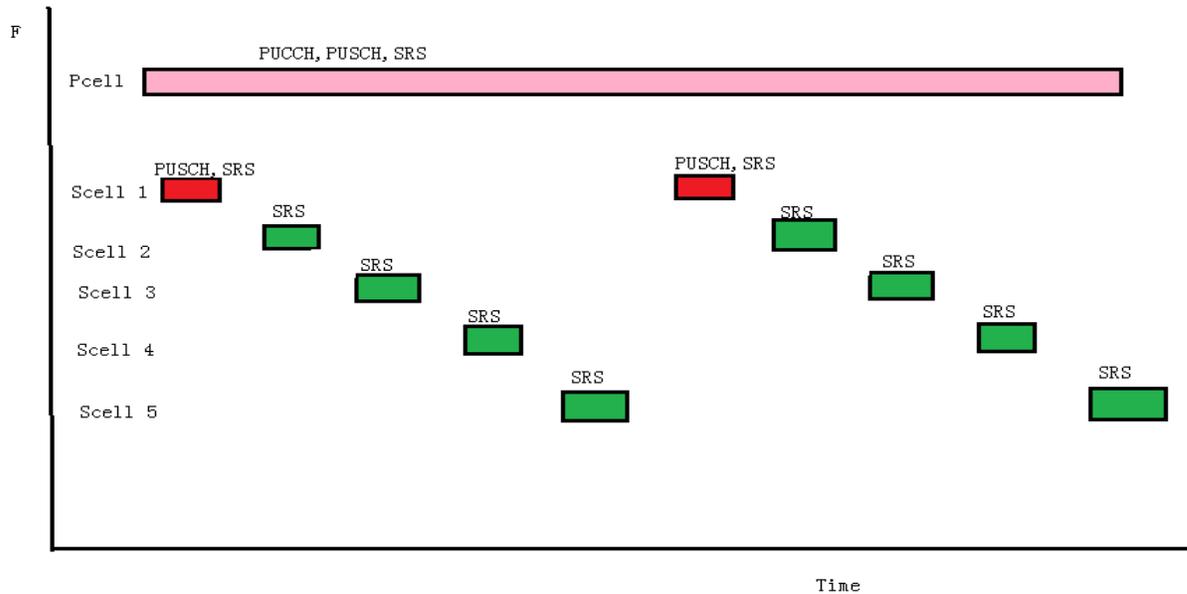
# FCS: Design



# SRS switching among TDD SCells

## • Solution

- Allow the # of configured carriers for SRS transmission to exceed the # of carriers dictated by the UE UL CA capability
- Allow UE to transmit SRS on the TDD carriers over time



### If UE supports 2 UL CCs:

- PUCCH on PCell only
- PUSCH can be transmitted on PCell & SCell 1 at the same time
- SCell 2~5: no PUSCH or PUCCH; SRS only
- UE transmits UL signal only on one SCell in one time

### If UE supports only 1 UL CC:

- PUCCH on PCell only
- SRS on SCells
- SRS dropped when UL transmission on PCell collides with SRS on SCell

# SRS switching among TDD SCells

- **Allow UE to transmit SRS on all the TDD carriers over time**
- **Improve DL beamforming performance**
- **Allow the number of configured carriers for SRS transmission to exceed the number of carriers of the UE UL CA capability**
- **Enhancements**
  - Small standard effort is needed in RAN1 to support SRS switching among TDD SCells with DL transmission
  - HW will give analysis and conclude that small standard impact in RAN2 is expected if single TA is assumed
  - It is feasible to implement SRS switching for some CA configurations from RAN4 standard perspective

# Light-weighted SCell dynamic on/off

- Light-weighted SCell
  - Mainly for opportunistic transmission/reception
  - With significantly reduced common/broadcast channel overhead (esp. CRS), and transmitted only during data or DRS bursts
  - Significant gains showed in Small Cell Enhancements SI (see TR36.872)
  - Encompassing LAA SCell and licensed SCell
  - A unified design for dynamic on/off and fast carrier switching is desirable
  - Enable forward compatibility
  - It has already been supported for LAA LBT

# Light-weighted SCell dynamic on/off performance

Table 6.1.1.1.2-1 Performance gains for ideal, dynamic on/off based on packet arrival/completion, with 0 MBSFN per radio frame and no cell ID planning

Scenario	Source	UPT gains				Traffic load	RU
		Mean	5%ile	50%ile	95%ile		
1, 4pico	1 (R1-133431)	30%	18%			100Mbps/km2, ~7Mbps/macro, ~0.23Mbps/UE, lambda=0.06	baseline M-RU 20%
		30%	32%			190Mbps/km2, ~14Mbps/macro, ~0.5Mbps/UE, lambda=0.12	baseline M-RU 40%
2a, 4pico	1 (R1-133431)	41%	5%			100Mbps/km2, ~7Mbps/macro, ~0.23Mbps/UE, lambda=0.06	baseline M-RU 20%
		45%	16%			190Mbps/km2, ~14Mbps/macro, ~0.5Mbps/UE, lambda=0.12	baseline M-RU 40%
		52%	44%			310Mbps/km2, ~22Mbps/macro, ~0.75Mbps/UE, lambda=0.2	baseline M-RU 60%
	3 (R1-133023)	23%	13%	35%	2%	5/s/macro	
		22%	10%	26%	0%	7.5/s/macro	
17%		6%	19%	3%	10/s/macro		
2a, 10pico	1 (R1-133431)	97%	23%			100Mbps/km2, ~7Mbps/macro, ~0.23Mbps/UE, lambda=0.06	baseline M-RU 20%
		100%	27%			190Mbps/km2, ~14Mbps/macro, ~0.5Mbps/UE, lambda=0.12	baseline M-RU 40%
		108%	44%			310Mbps/km2, ~22Mbps/macro, ~0.75Mbps/UE, lambda=0.2	baseline M-RU 60%
	2 (R1-133591)	53%	71%			low	
		44%	75%			medium	
		20%	52%			high	
	6 (R1-132933)	53%	71%			4 file/s/macro, 0.13 file/s/UE	
2a, 10pico	4 (R1-133871)	53%	120%			lambda=2	
2a, 10pico	9 (R1-134105)	61%	39%	95%	17%	lambda= 3 per macro cell (packet size=0.5M bytes)	baseline M-RU 18%
		59%	25%	72%	24%	lambda= 7.5 per macro cell (packet size=0.5M bytes)	baseline M-RU 41%
		59%	28%	68%	31%	lambda= 10 per macro cell (packet size=0.5M bytes)	baseline M-RU 53%
2a, 4pico	12 (R1-134375)	4%	19%			lambda= 3.1	baseline M-RU 17.78%
		5%	12%			lambda= 9.1	baseline M-RU 60.13%
2a, 10pico	13 (R1-134446)	165%	134%			FTP Model 1, lambda = 6	7.7%
2a, 10pico	15 (R1-134562)	24%	0%			lambda= 1/3	
2a, 10pico	22 (R1-135673)	81%	99%	128%	1%	FTP Model 1, lambda = 1	
		46%	56%	61%	1%	FTP Model 1, lambda = 1.5	
		32%	34%	44%	3%	FTP Model 1, lambda = 2	

- TR36.872 example 1:
- It is observed from the evaluation results that
  - Ideal, dynamic on/off based on packet arrival/completion, with 0 MBSFN per radio frame and no cell ID planning, can offer **large (>20%) gains** with low/medium traffic loads. **Very large gains (>50%)** are observed in some sources.
  - The gains are lower with high traffic load.

# Light-weighted SCell dynamic on/off performance

Table 6.1.1.1.2-4 Performance gains for ideal, dynamic on/off based on packet arrival/completion, with 6 MBSFN per radio frame and cell ID planning ensuring aligned small cell CRS within cluster

Scenario	Source	UPT gains				Assumptions	
		Mean	5%ile	50%ile	95%ile	Traffic load	RU
1, 4pico	1 (R1-133431)	3%	4%			100Mbps/km2, ~7Mbps/macro, ~0.23Mbps/UE, lambda=0.06	M-RU 20%
		3%	2%			190Mbps/km2, ~14Mbps/macro, ~0.5Mbps/UE, lambda=0.12	M-RU 40%
2a, 4pico	1 (R1-133431)	8%	-4%			100Mbps/km2, ~7Mbps/macro, ~0.23Mbps/UE, lambda=0.06	M-RU 20%
		7%	-11%			190Mbps/km2, ~14Mbps/macro, ~0.5Mbps/UE, lambda=0.12	M-RU 40%
		6%	-4%			310Mbps/km2, ~22Mbps/macro, ~0.75Mbps/UE, lambda=0.2	baseline M-RU 60%
2a, 10pico	1 (R1-133431)	14%	4%			100Mbps/km2, ~7Mbps/macro, ~0.23Mbps/UE, lambda=0.06	M-RU 20%
		12%	6%			190Mbps/km2, ~14Mbps/macro, ~0.5Mbps/UE, lambda=0.12	M-RU 40%
		13%	10%			310Mbps/km2, ~22Mbps/macro, ~0.75Mbps/UE, lambda=0.2	baseline M-RU 60%
2a, 4pico	16 (R1-134816)	8%	20%				20%
		6%	16%				40%
		7%	13%				60%
2a, 10pico	16 (R1-134816)	12%	26%				20%
		12%	16%				40%
		15%	16%				60%

- TR36.872 example 2:
- It is observed from the evaluation results that, for ideal, dynamic on/off based on packet arrival/completion, with 6 MBSFN per radio frame and cell ID planning ensuring aligned small cell CRS within cluster,
  - Low (<10%) gains are observed in Scenario 1 with low/medium traffic loads.
  - Low to moderate (<10%) or no gains are observed in Scenario 2a with 4 small cells per macro and with low/medium/high traffic loads.
  - Moderate to large (10%~30%) gains are observed in Scenario 2a with 10 small cells per macro and with low/medium/high traffic loads.
  - The gains are lower than those with 0 MBSFN and no cell ID planning indicated in Table 6.1.1.1.2-1, lower than those with 0 MBSFN and cell ID planning ensuring aligned small cell CRS within cluster indicated in Table 6.1.1.1.2-2, and lower than those with 6 MBSFN and no cell ID planning indicated in Table 6.1.1.1.2-3.

# Feasibility of fast switching

- **UE switching operations (for DL and/or UL) may include:**
  - RF retuning
  - AGC setting
  - Tracking
- **Related RAN4 studies/conclusions:**
  - RF retuning for eMTC: 200~300  $\mu$ s
    - R4-152889, “RF design considerations for eMTC”, Qualcomm.
  - AGC setting for D2D: < 1 OFDM symbol duration
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  - RF/AGC for eMTC: 200~300  $\mu$ s
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  - Switching for measurement gap: < 0.5 ms
    - Total: 6 ms; measurements: 5 ms; one way switching: < 0.5 ms
  - Tracking:
    - Not needed for intra-band co-located

# Conclusions

- **Further enhancement of CA is crucial for future networks**
- **Multiple related advanced technologies for further CA enhancements:**
  - Complexity reduction for massive CA
  - Carrier switching in DL/UL is beneficial
  - Carrier switching can be enhanced with reduced transition times
  - Light-weighted SCell dynamic on/off can be integrated into this framework
- **Consider to propose a WI for Rel-14**