TIMING; The Key To Unlocking The Benefits Of LTE-A

Timing & Security Considerations for Evolved IP Backhaul

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Market Trends & The Network Environment

Mobile Market Trends: The Customer Experience

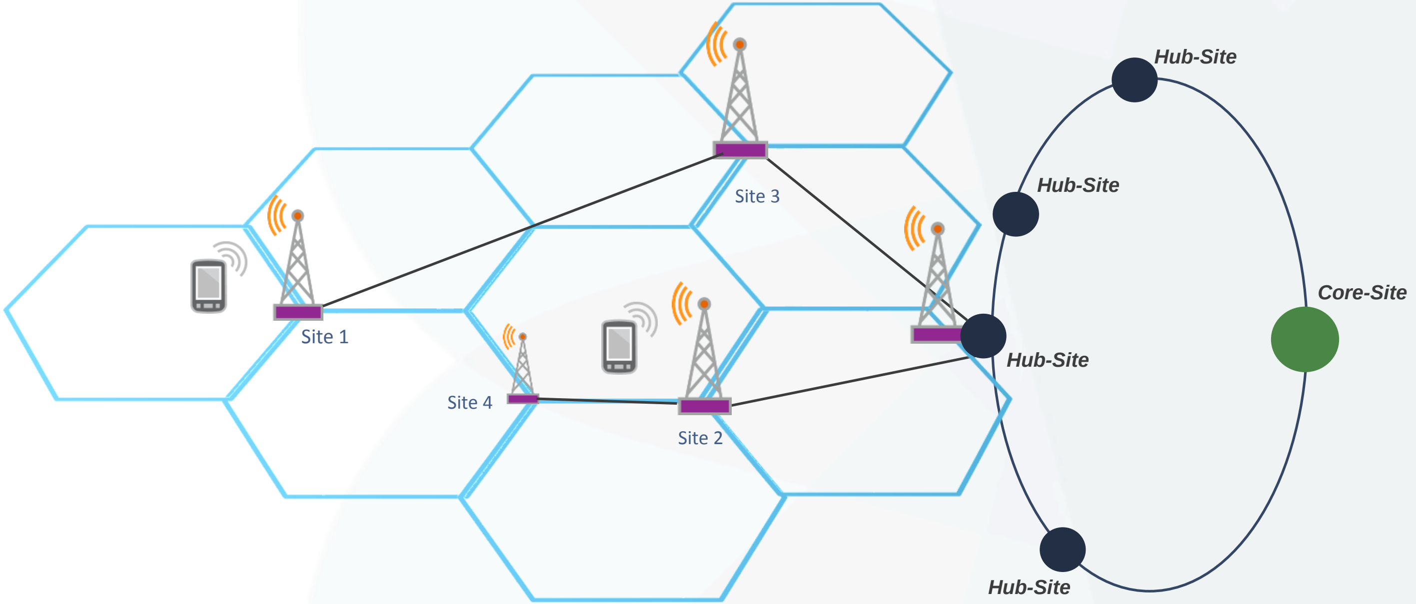
Google | amazon.com | ebay | NETFLIX




Trusted Reliability | **Pervasive Coverage** | **Seamlessly Converged** | **Application Optimized**

- The Smartphone and Tablet, combined with 3G HSPA and 4G have driven the proliferation of applications for business, lifestyle and pleasure
- Availability of those applications and the network latency impacting them is key to the end user experience which in turn impacts Churn and Market Share for mobile operators
- OTT Content drives the need for mobile broadcast and higher speed access

Mobile Backhaul Environment: Moving To Extensive 4G & Multi-Service Access



- Mixed 2G, 3G HSPA, LTE, LTE-A Coverage
- Macro Sites Used as Hub-Sites for surrounding Small-Cells
- Hub-Sites Aggregate 10-20 Macro and associated Small Cells
- All IP, MPLS Access Network
- For 4G, IPsec Tunnels from Base Station (eNode B) to Core Site, terminated on SecGW
- All data traffic is currently backhauled to the core – cost and latency impact

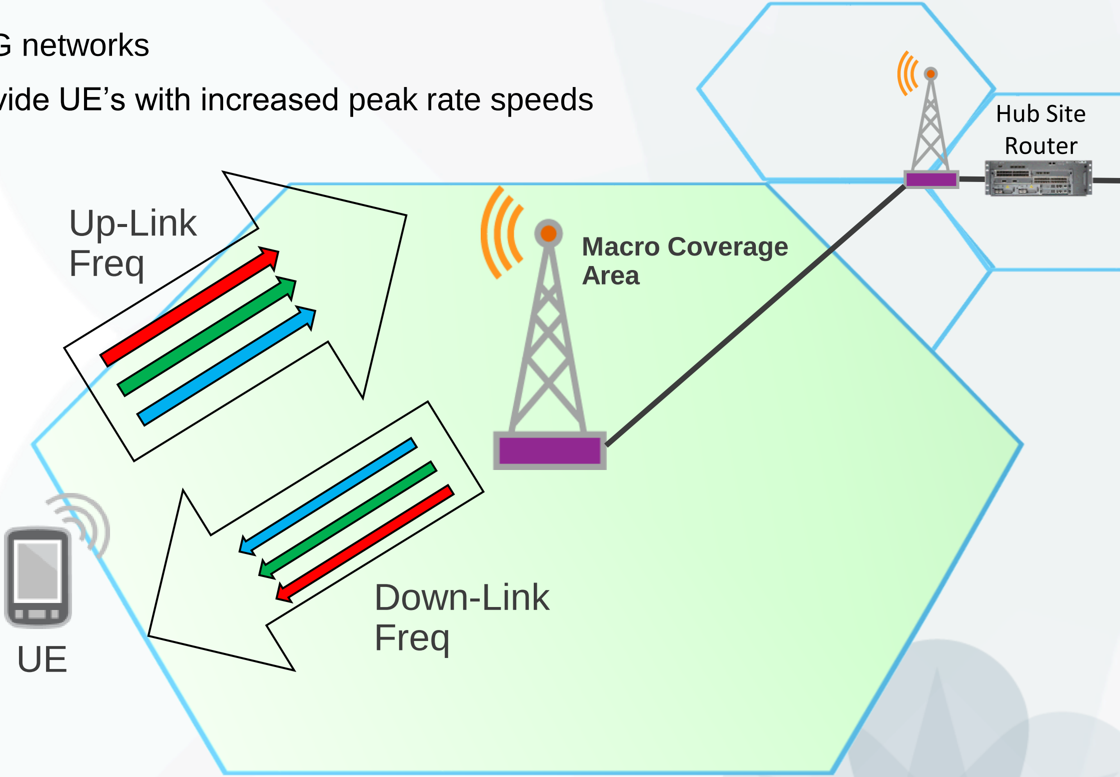
Mobile 2020: “All IP Open Cloud”

- Ubiquitous 4G LTE & LTE-A Drive Growth in Backhaul, Core and Peering Bandwidth and require Security
  - Seamless MPLS Access, Core and International
- NFV Telco Cloud (e.g. EPC, IMS, SBC, Cloud CPE)
- 5G brings latency sensitive apps to the mobile RAN with MEC for improved customer experience.
- Extensive small cell capacity layer, indoor and outdoor
- GPS can’t time all the cells but timing (Phase & Freq) is needed to achieve throughput requirements

RAN Evolution & Content Driving Timing Requirements

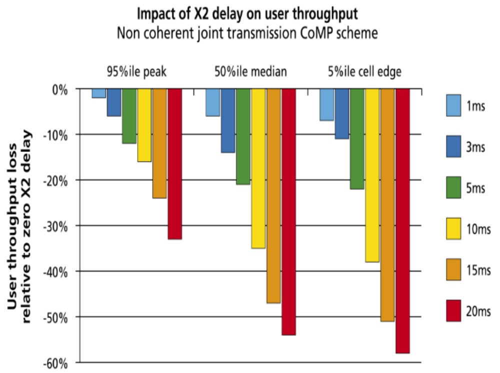
“I Have LTE-A & No Timing Problem”: LTE-Advanced: Carrier Aggregation

- LTE-A is already with us and deployed in many 4G networks
- Carrier Aggregation is the simplest method to provide UE’s with increased peak rate speeds
- Using 3GPP R8 & 9 compatible carriers
  - Component Carriers are aggregated
  - Can be 1.4, 3, 5, 10 or 20MHz (Max)
  - Maximum 5 Component carriers = 100MHz
  - Can be different in UL & DL
- The eNode B requires only LTE Frequency timing

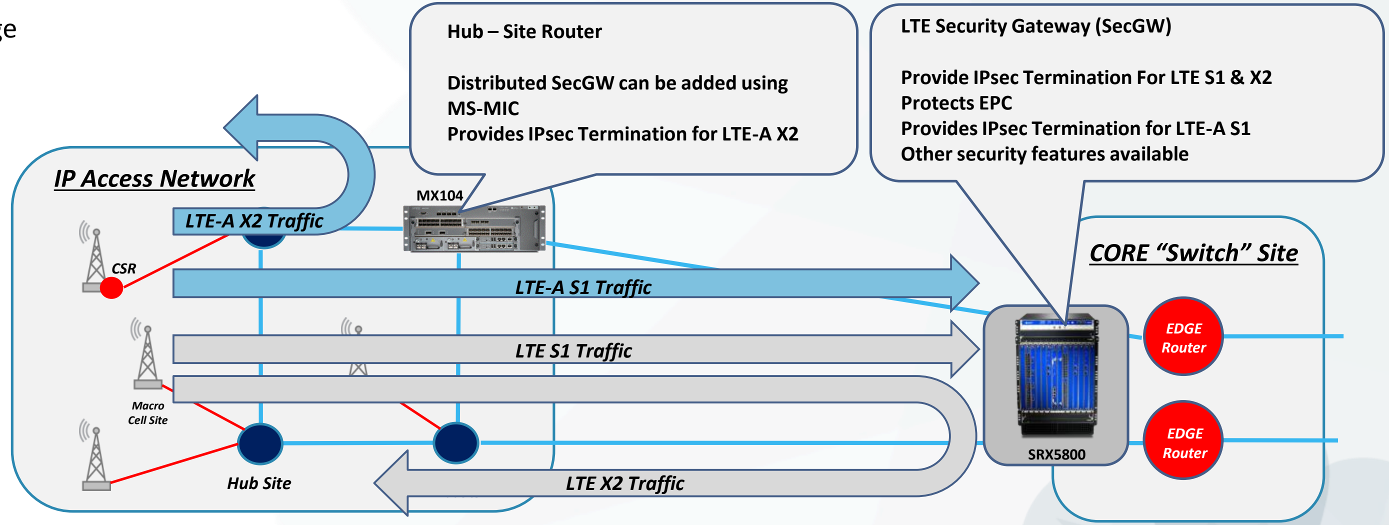


Mobile Backhaul Environment: The Move To LTE-A And On To 5G

- LTE-A Features such as Coordinated Multi-Point (CoMP) and Enhanced Inter-cell Interference Coordination, (eICIC) become available as s/w upgrades to 4G base stations from 2016
- These features drive close coordination between cell sites and place requirements on the backhaul network:
  - **Timing**: Frequency & Phase: Frequency16ppB, Phase +/- 0.5µSecs
  - **Distributed Security**: X2 Handover Interface requires a latency of <u><</u>3-5ms
- Accurate timing with many vendors current and installed backhaul solutions is a major change as accuracy relies on hardware
- The Core LTE Security Gateway remains at the Core site to terminate the S1 IPsec tunnels and to protect the EPC, Distributed LTE-A SecGW For X2, on the Hub-Site, deployed at Fibre Edge



Source: Qualcomm

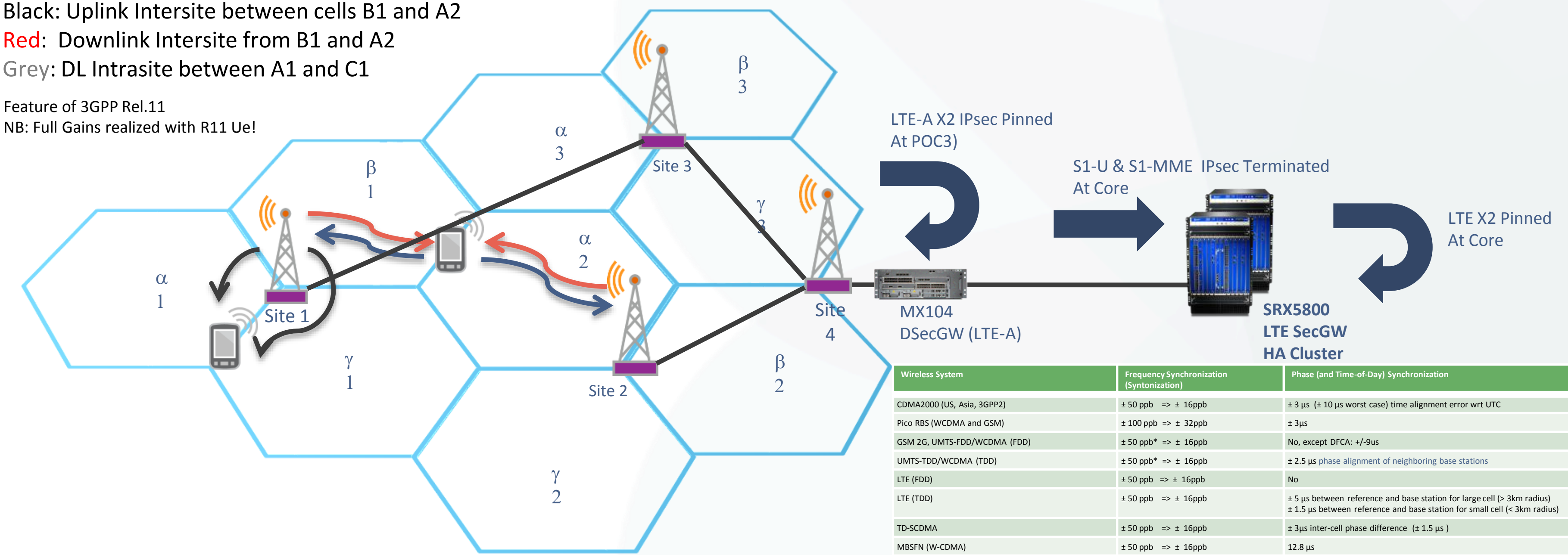


LTE-Advanced: Coordinated Multipoint

Accurate Timing (Phase & Frequency) & Low Latency Are Key

- Black: Uplink Intersite between cells B1 and A2
- Red: Downlink Intersite from B1 and A2
- Grey: DL Intrasite between A1 and C1

Feature of 3GPP Rel.11
NB: Full Gains realized with R11 Ue!



Wireless System	Frequency Synchronization (Syntonization)	Phase (and Time-of-Day) Synchronization
CDMA2000 (US, Asia, 3GPP2)	± 50 ppb => ± 16ppb	± 3 µs (± 10 µs worst case) time alignment error wrt UTC
Pico RBS (WCDMA and GSM)	± 100 ppb => ± 32ppb	± 3µs
GSM 2G, UMTS-FDD/WCDMA (FDD)	± 50 ppb* => ± 16ppb	No, except DFCA: +/-9us
UMTS-TDD/WCDMA (TDD)	± 50 ppb* => ± 16ppb	± 2.5 µs phase alignment of neighboring base stations
LTE (FDD)	± 50 ppb => ± 16ppb	No
LTE (TDD)	± 50 ppb => ± 16ppb	± 5 µs between reference and base station for large cell (> 3km radius) ± 1.5 µs between reference and base station for small cell (< 3km radius)
TD-SCDMA	± 50 ppb => ± 16ppb	± 3µs inter-cell phase difference (± 1.5 µs)
MBSFN (W-CDMA)	± 50 ppb => ± 16ppb	12.8 µs
MBSFN (LTE eMBMS Rel. 9)	± 50 ppb => ± 16ppb	< ± 1.5 µs inter-cell phase difference, with respect to a common time reference, e.g.. UTC
LTE-A CoMP DL – intra-eNodeB	± 50 ppb => ± 16ppb	No phase synchronization known for transport backhaul network. Phase synchronization only for “fronthaul” (i.e. remote RRH)
LTE-A CoMP DL – inter-eNodeB CS/CB & DCS	± 50 ppb => ± 16ppb	± 3µs phase accuracy for Coordinated Scheduling/ Beamforming (CS/CB) and Dynamic Cell/ TX Point Selection (DCS)
LTE-A CoMP DL – inter-eNodeB JT	± 5 ppb	± 0.3µs to ± 0.5µs phase accuracy for Joint Transmission
LTE-A eICIC (Inter-Cell Interference Coordination)	± 50 ppb => ± 16ppb	± 3µs to ± 10µs depending on small cell/macro and propagation distance and cell radius
LTE-A Rel. 9 OTDOA Observed Time Difference Of Arrival (E911, geo-location)	± 50 ppb => ± 16ppb	±0.1 µs phase accuracy, depending on location accuracy requirement

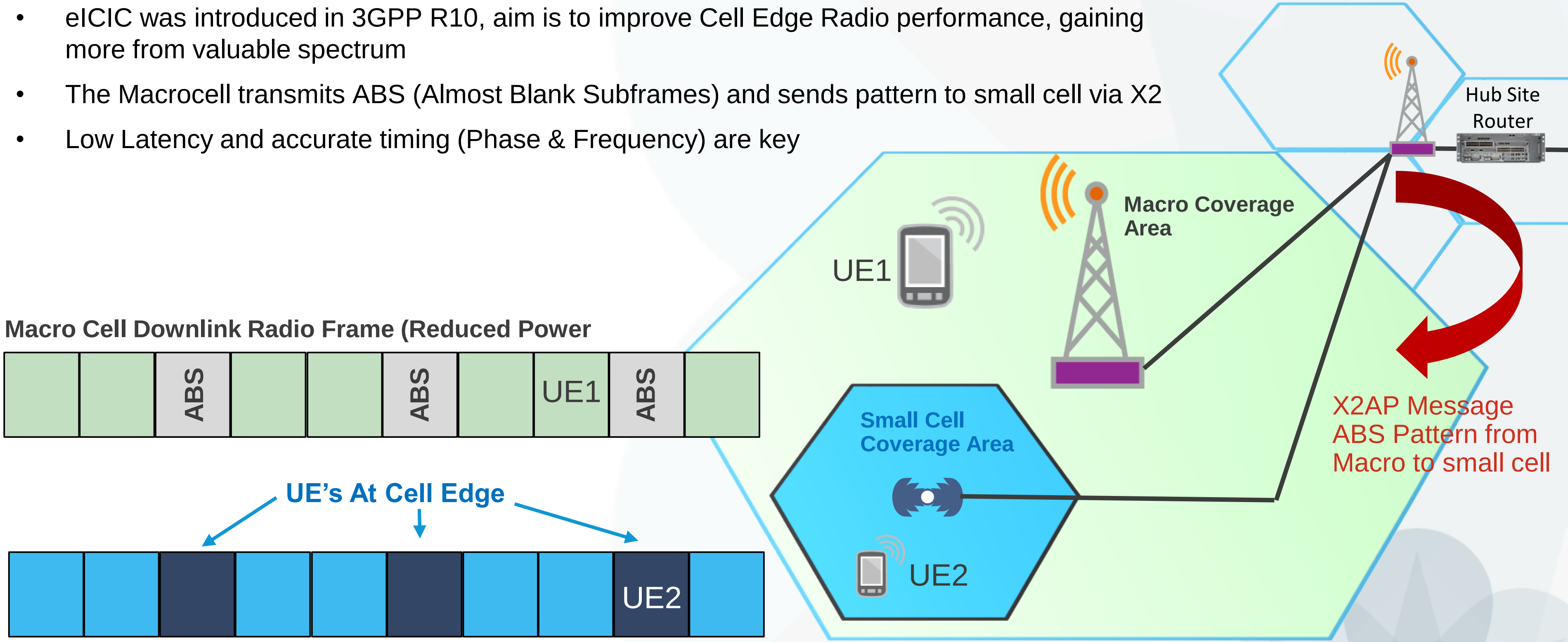
- LTE Requires Frequency Timing: 50ppB
- LTE-A (CoMP & eICIC) Require Frequency & Phase:
  - Frequency16ppB, Phase +/- 0.5µSecs

eICIC: enhanced Inter-Cell Interference Coordination

Accurate Timing (Phase & Frequency) Are Key

eIC IC Feature of 3GPP Rel.10

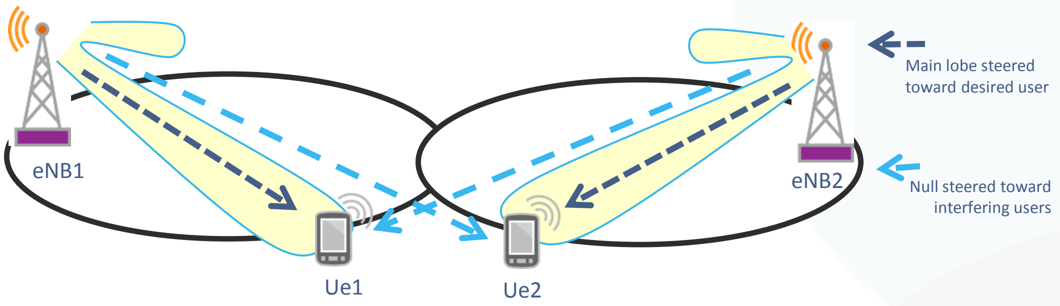
- eICIC was introduced in 3GPP R10, aim is to improve Cell Edge Radio performance, gaining more from valuable spectrum
- The Macrocell transmits ABS (Almost Blank Subframes) and sends pattern to small cell via X2
- Low Latency and accurate timing (Phase & Frequency) are key



Small Cell Downlink Radio Frame, Cell Edge UEs told to transmit in ABS subframes

Down-Link CoMP

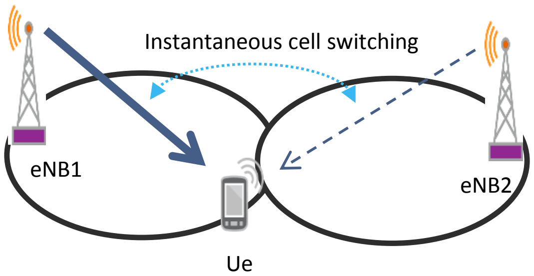
1. Coordinated Scheduling/Coordinated Beamforming (CS-CB)



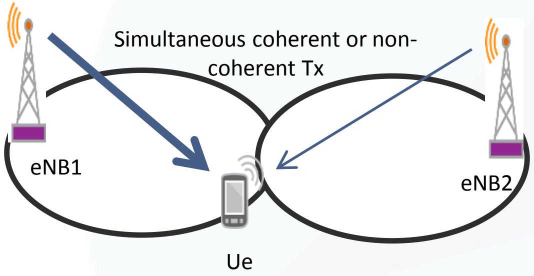
DL CoMP Requirements	Coordinated Scheduling/ Beamforming (CS/CB)	Joint Processing (JP)	
		Dynamic Cell/ TX Point Selection (DCS)	Joint Transmission (JT)
Data availability	At one TX point only	At cells/ TX points in CoMP set	At cells/ TX points in CoMP set
Data transmission	Always from serving cell	Coordinated transmission from single TX point at a time	Coherent transmission from multiple TX points at a time
Transport data	Control messages	HARQ block/ IQ data + Control messages	HARQ block/ IQ data + Control messages
Transport latency*	~< 5 ms	< 1ms*	< 1 ms*
Transport capacity	Only control requirements	HARQ block/ IQ data: 0.1 Gbps/ 1 Gbps per 20 MHz per antenna	HARQ block/ IQ data: 0.1 Gbps/ 1 Gbps per 20 MHz per antenna
Inter TX point synchronization	RAN4 inter-BS: 0.05 ppm frequency TDD: <3 µs timing accuracy	RAN4 inter-BS: 0.05 ppm frequency TDD: <3 µs timing accuracy	0.005 ppm frequency 0.3 – 0.5 µs timing accuracy
Channel State Info (CSI)	Multiple CSI process using different IMR	Multiple CSI process each corresponding to one Cell/TP	Multiple CSI process each corresponding to one cell/TP with common IMR

Down-Link LTE-A CoMP Requirements

2a. Dynamic Cell Selection

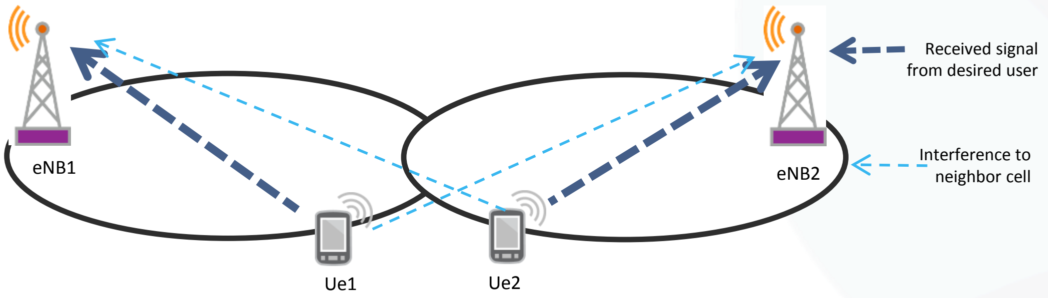


2b.Joint Transmission



Up-Link CoMP

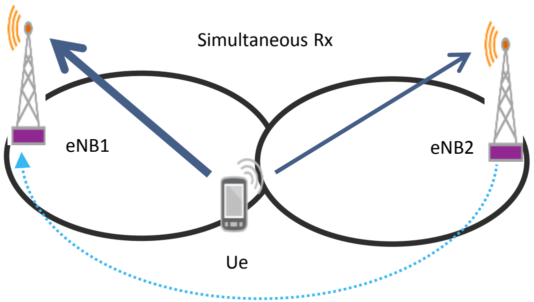
1. Coordinated Scheduling



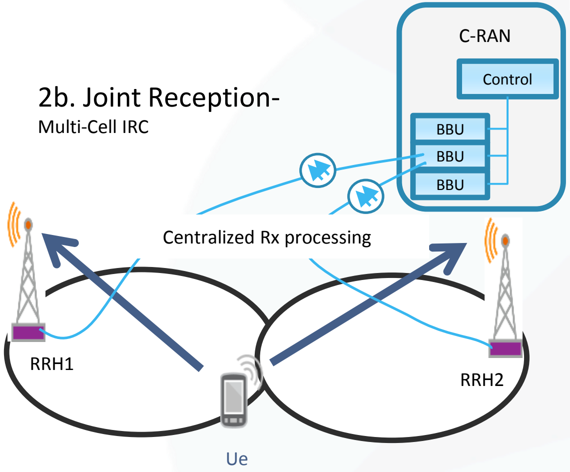
UL CoMP Requirements	Coordinated Scheduling (CS)	Joint Reception (JR)	
		Distributed Interference Cancelation (DIC)	Multi-cell IRC
Data collection	One RX point at a time	Multiple cells/ RX points at a time	Multiple cells/ RX points at a time
Data reception	Always in serving cell	Distributed reception	Centralized reception
Transport data	Control messages	Hard-bit Transport Block + Control messages	I/Q data + Control messages
Signaling transport latency	=< 4 ms	=< 4 ms	=< 4 ms
Received data transport latency	n/a	=< 1 ms preferred 10-20 ms being investigated	=< 1 ms preferred 10-20 ms being investigated
Transport capacity	Only control requirements	0.1 Gbps/ 20 MHz	1 Gbps/ 20 MHz/ antenna
Inter RX point synchronization	RAN4 inter-BS: 0.05 ppm frequency	RAN4 inter-BS: 0.05 ppm frequency	RAN4 inter-BS: 0.05 ppm frequency UE TA at all RX points within fraction of Cyclic Prefix: < 2 µs

Up-Link LTE-A CoMP Requirements

2a. Joint Reception-
Distributed Interference Cancellation (DIC)



2b. Joint Reception-
Multi-Cell IRC



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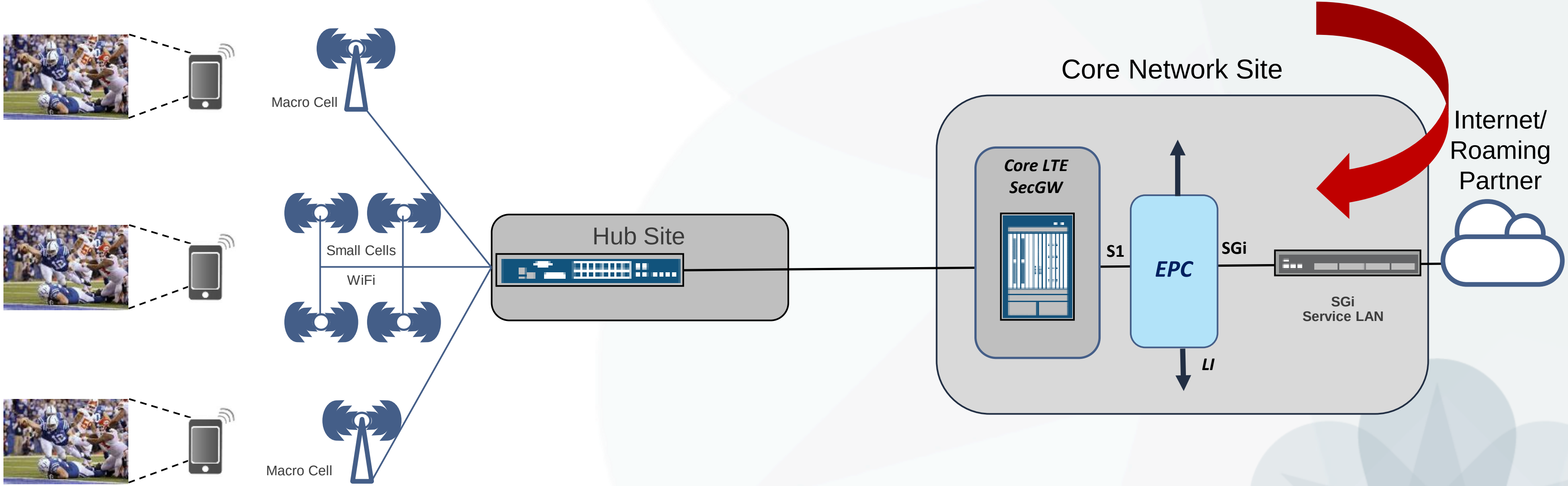
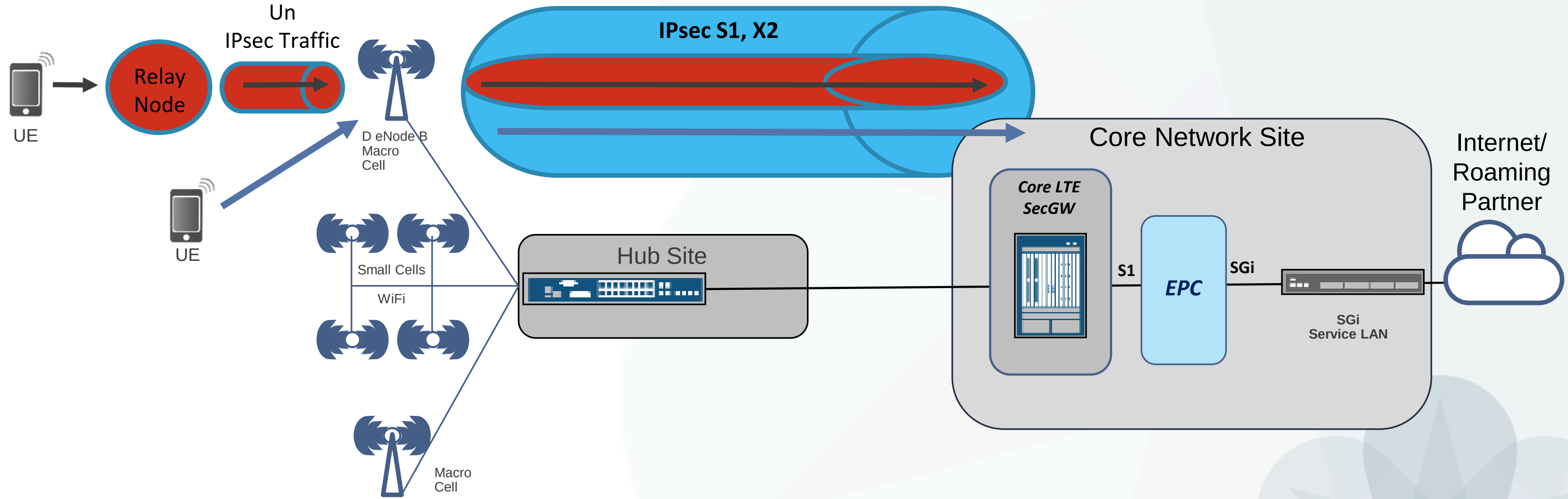
eMBMS: Broadcast Requires Tight Timing

- Some content is consumed by many at the same time
- Mobile broadcast is the efficient method: eMBMS
- eMBMS Requires Accurate Timing: Frequency16ppB, Phase +/- 1.5µSecs
- Current, purely frequency timing based networks cannot support this service without addressing timing distribution



LTE Relay Node: Further Complicates RAN Timing, Security & Latency

- LTE-A Relay Nodes are LTE-A Radio Repeaters
- The UE sees them as a base station (eNode B) but the eNode B sees them as a device (UE)
- Relay Node transmits to "Donor" or D eNode B via to Un interface (radio)
- Hence, an IPsec "tunnel in tunnel" is created to allow the traffic to pass to the core network SecGW
- Whilst they are designed for rural coverage improvement, as LTE-A eICIC and in particular CoMP is rolled out, timing and X2 handover optimisation will be an issue.



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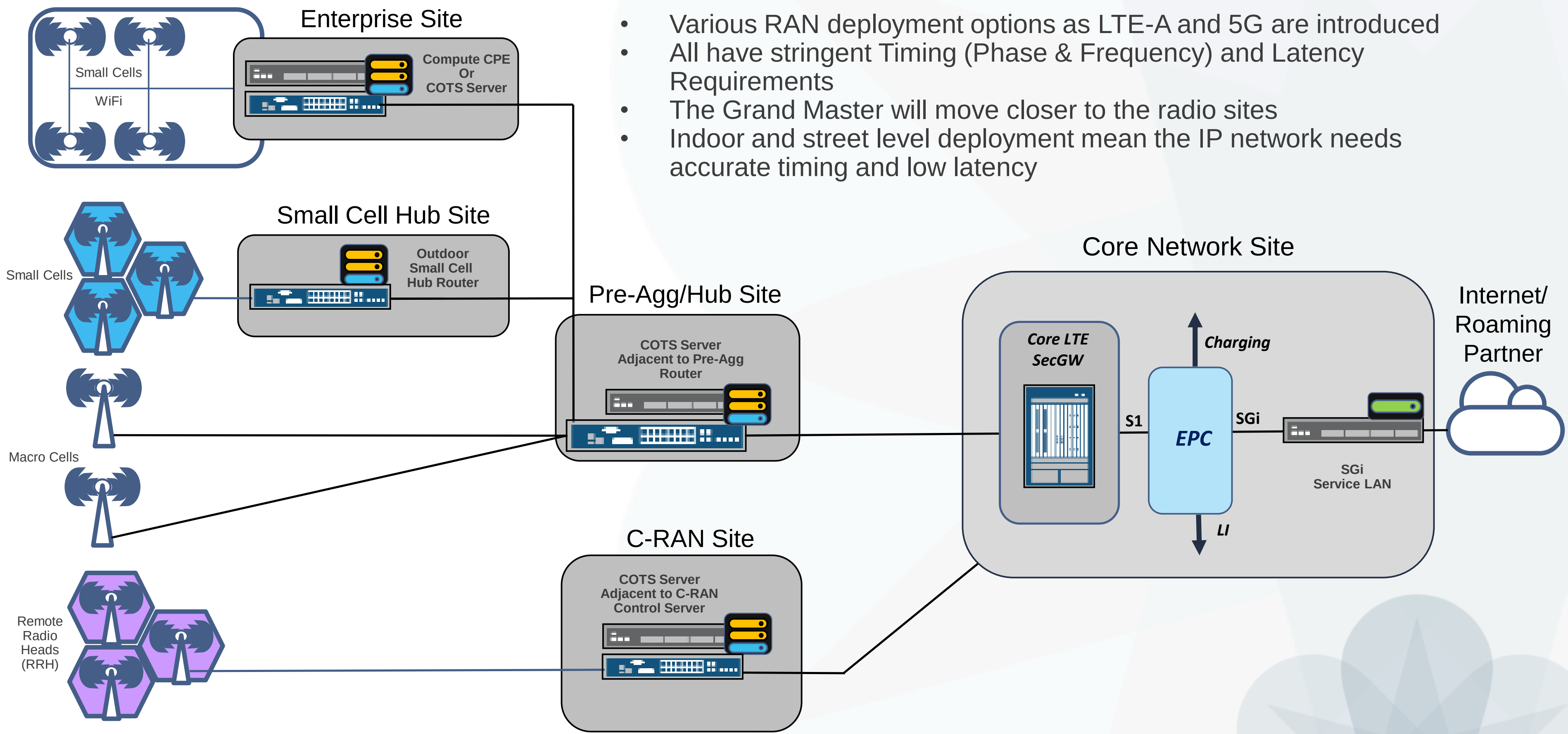
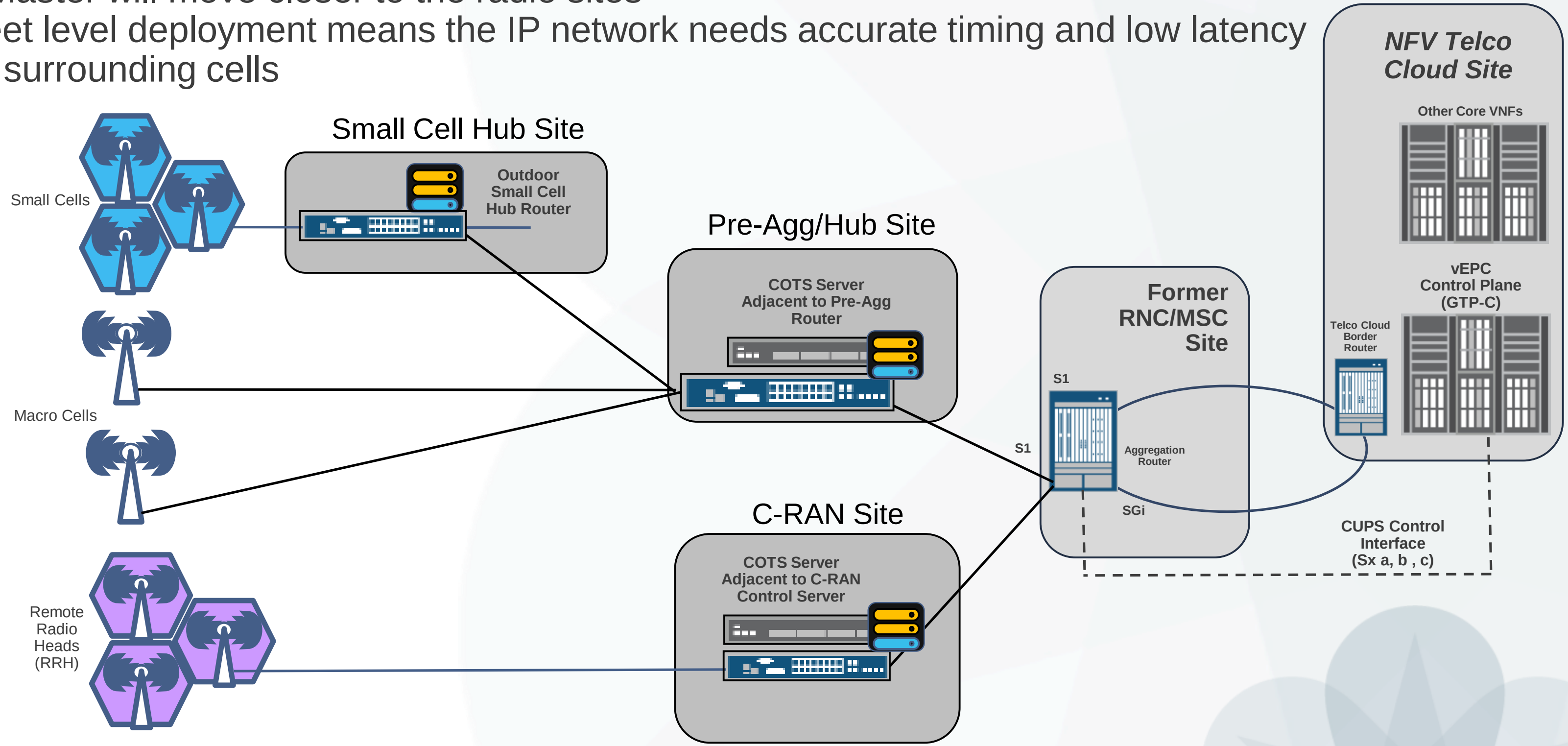
Evolving RAN Network: Timing & Latency Sensitive

- Various RAN deployment options as LTE-A and 5G are introduced
- All have stringent Timing (Phase & Frequency) and Latency Requirements
- The Grand Master will move closer to the radio sites
- Indoor and street level deployment mean the IP network needs accurate timing and low latency



Evolving The RAN To 5G: Timing & Latency Sensitive

- Various RAN deployment options as LTE-A and 5G are introduced, including C/V-RAN
- All have stringent Timing (Phase & Frequency) and Latency Requirements
- The Grand Master will move closer to the radio sites
- Indoor / Street level deployment means the IP network needs accurate timing and low latency to serve the surrounding cells



Mobile Backhaul Solutions : Juniper’s Core, Hub & Cell-Site Solutions Support LTE-A Timing Requirements

ACX500 Cell Site & Small-Cell Hub Router

- PoE For Powering Microwave Connectivity
- Security Features: 802.1x and 802.1ae MacSec
- Outdoor and Indoor Versions:
  - Outdoor IP65 Compliant Housing
- Zero Touch Provisioning Through Space Connectivity Services Director

ACX500 Macro-Cell Rack (Indoor)

ACX500 Outdoor IP65 Compliant

MX104: Hub Site AGGREGATION

3.5 RU

ETSI-300 Deep

- **Compact, Redundant & Future proof:**
  - Based on successful Juniper Trio PFE
  - 80G full-duplex
  - Hardware redundancy (control plane)
  - 600 Watt PSUs; AC and DC inputs
  - Wide operating temp range -40C to +65C
  - Forced cooling with side-to-side airflow; FRU’able fan tray
  - MIC Services Cards
    - Distributed LTE-A SecGW for Hub site X2 LTE-A Handover
- **Modular Design:**
  - 4x10GE SFP+ LAN/WAN uplink ports (built-in)
  - 4 MIC Slots -~20G BW per slot

Thank you