SCT-120
SpiderCloud E-RAN System Description

CLARO AR (AMX)
Cordoba, Argentina
April, 2017

SpiderCloud Wireless

Company Overview

Beyond Basic Coverage & Capacity: A Scalable Small Cell System & Services Enabler

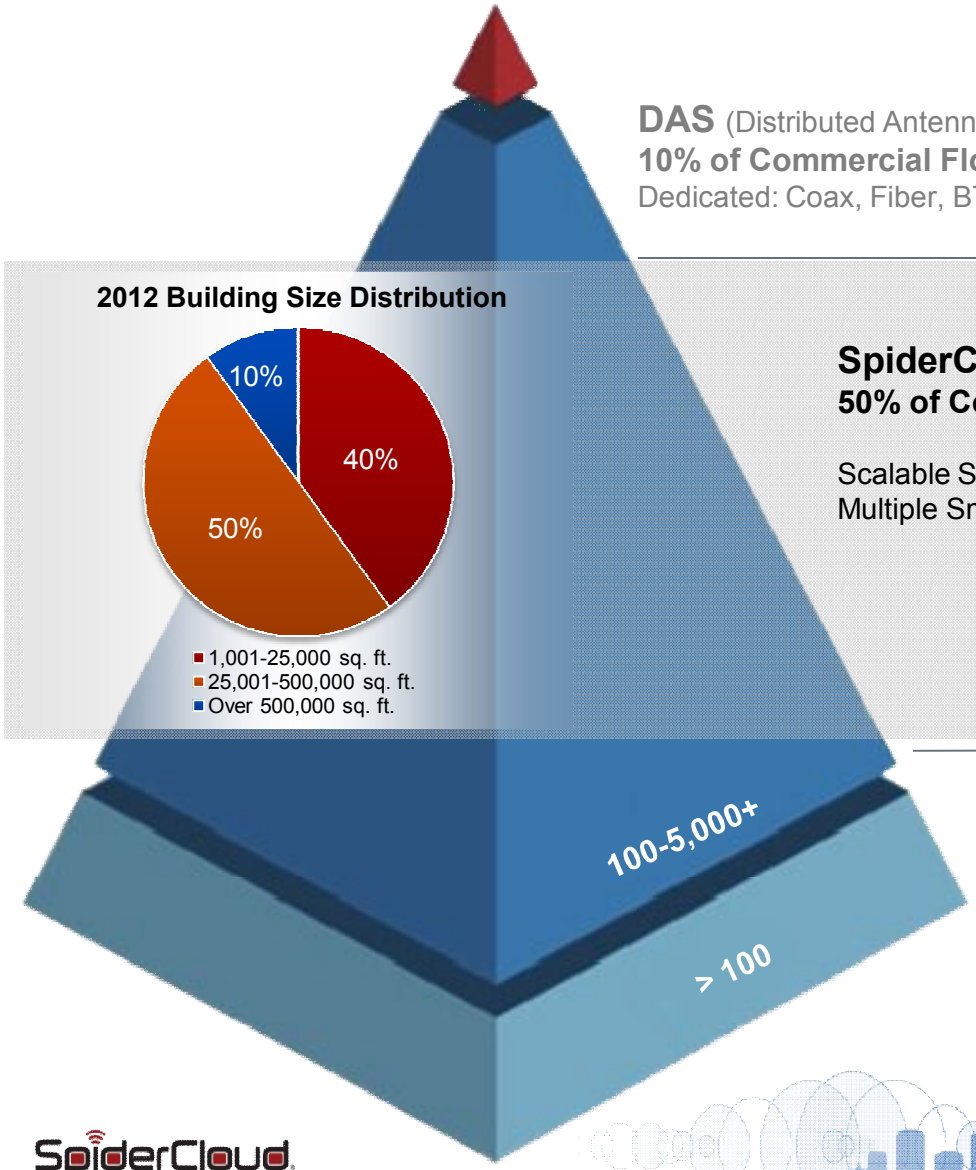
SpiderCloud Wireless

SpiderCloud Wireless

Scalable Small Cell Systems for Mobile Operators to Address Enterprises & Venues with Coverage, Capacity & Managed Mobility Services

- **Based in Silicon Valley (USA)**
- **Management team with proven RAN & enterprise success**
- **Customers: Mobile Operators such as: Vodafone, America Movil, Verizon Wireless, AT&T and more...**
- **3 Years Competitive Head Start w/Scalable 4G & 3G Deployments**
- **Started shipping dual-band 3G/4G and 4G/4G Radio Nodes June '14**
- **Why SpiderCloud? Scale, Speed, Cost and Simplicity**
  - Enable a mobile enterprise inside
  - Time to revenue
  - New Services

E-RAN Delivers Coverage, Capacity & Services to Medium-to-Large Enterprises & Venues



DAS (Distributed Antenna Systems)
10% of Commercial Floor Space
Dedicated: Coax, Fiber, BTS, Amplifiers, Repeaters, Backhaul

SpiderCloud E-RAN
50% of Commercial Floor Space

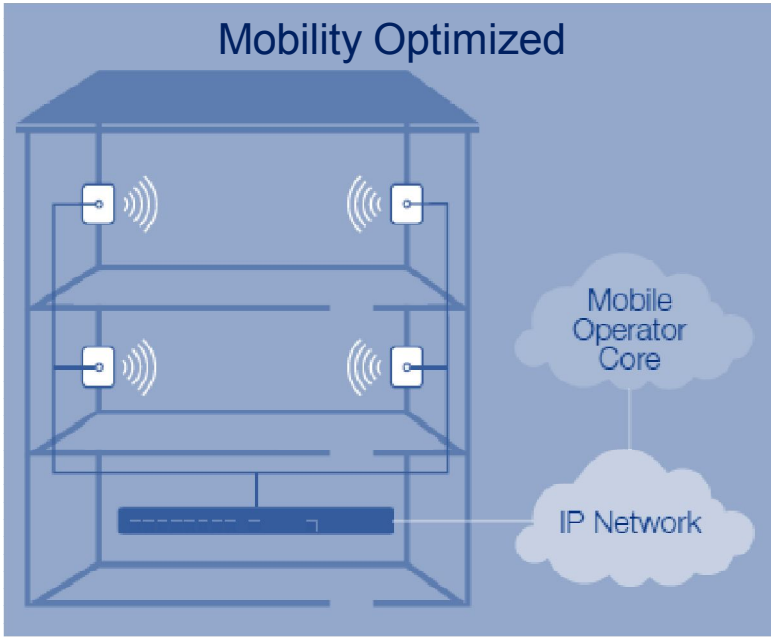
Scalable System for Medium to Large Businesses
Multiple Small Cells in Building, Performance Matters, PoE LAN

Femto Cells
40% of Commercial Floor Space
Consumers & Small Business

SpiderCloud Wireless

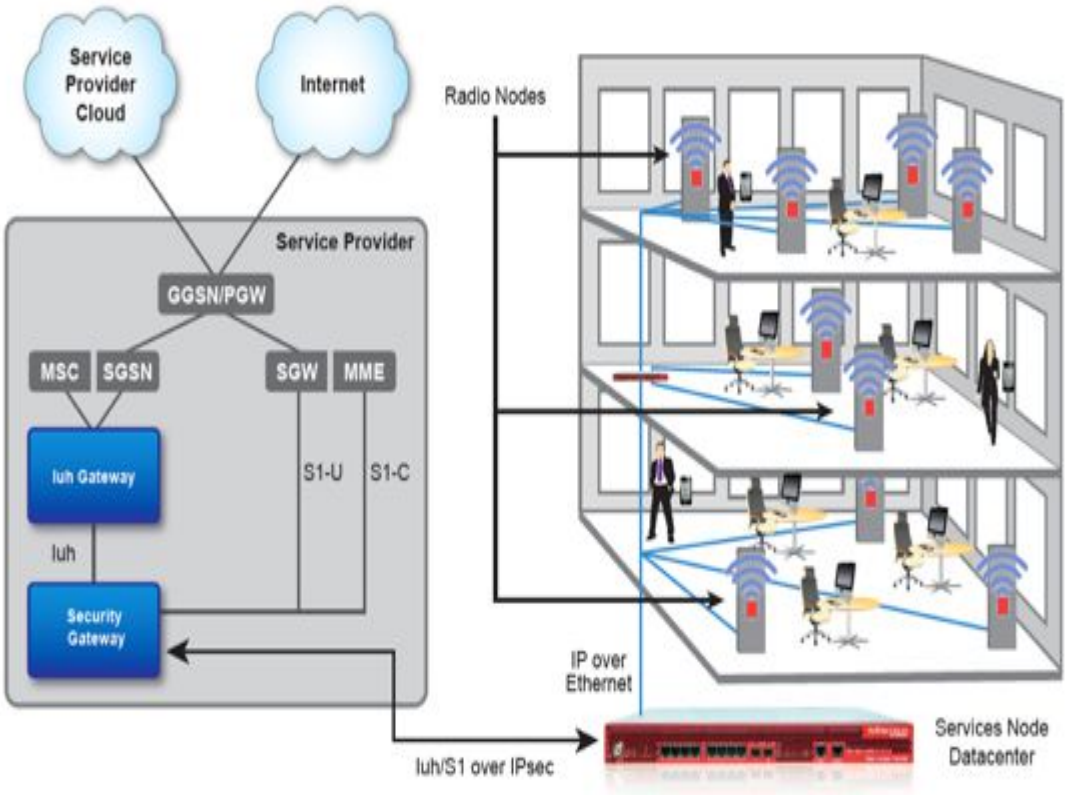
Technology Value Proposition

- Multi-Access Small Cells as easy to install as Wi-Fi - SpiderCloud Radio Nodes
- Unique Self Organizing Network (SON) capabilities enables rapid deployment of dense small cell networks
- World's first 3G "local" Small Cell controller – SpiderCloud Services Node
- Seamless enterprise mobility and true HSPA speeds with Soft Handover
- Wireless Traffic Management optimized for operators and enterprise
- We enable Cloud & API Services



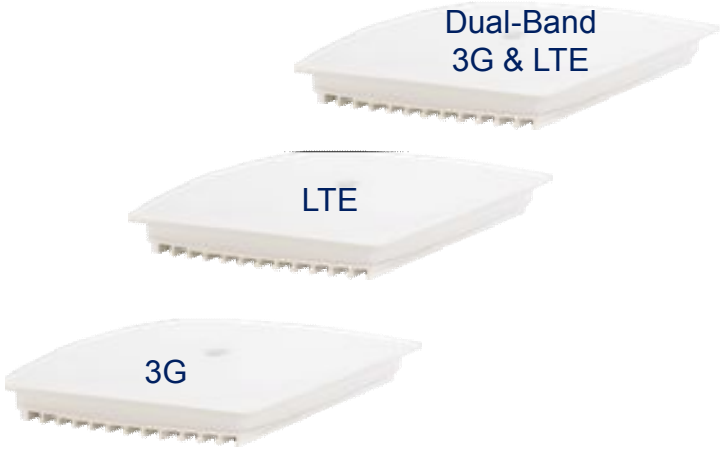
We Make Scalable Small Cell Systems

One System of 1 Services Node and 100 PoE-powered Radio Nodes
Can Scale to Cover 139K Square Meters



Services Node

(1U in the enterprise data center)



Portfolio of Radio Nodes

A “Local” Services Node Plays a Critical Role

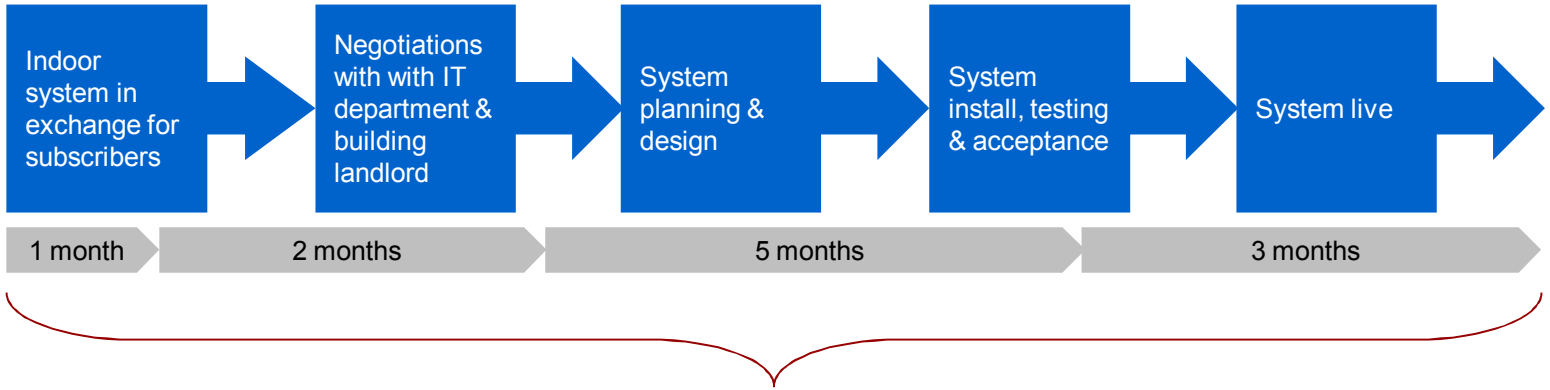
Enables Scale and Manages Small Cell-to-Small Cell Mobility & Handoff and Macro Cellular Interference

- The SN = Increased reliability, security, and manageability
  - Enforce small cell-to-small cell mobility and manages interference between the system and the macro cellular network.
  - Handovers between RN’s handled at the SN.
  - Manage up to **100 Multi-Access 3G/LTE Radios**
  - Reliable voice and data coverage for thousands of calls

- The SN enables a highly scalable deployment model
  - Distributed configuration and processing, centrally managed
  - Dramatic improvement in RF performance and interference management
  - Provides a single firewall and IPsec connection into core
  - Easy administration of new local service delivery and traffic management
  - Allows tight control of access to enterprise data with multifactor authentication

Today's Situation

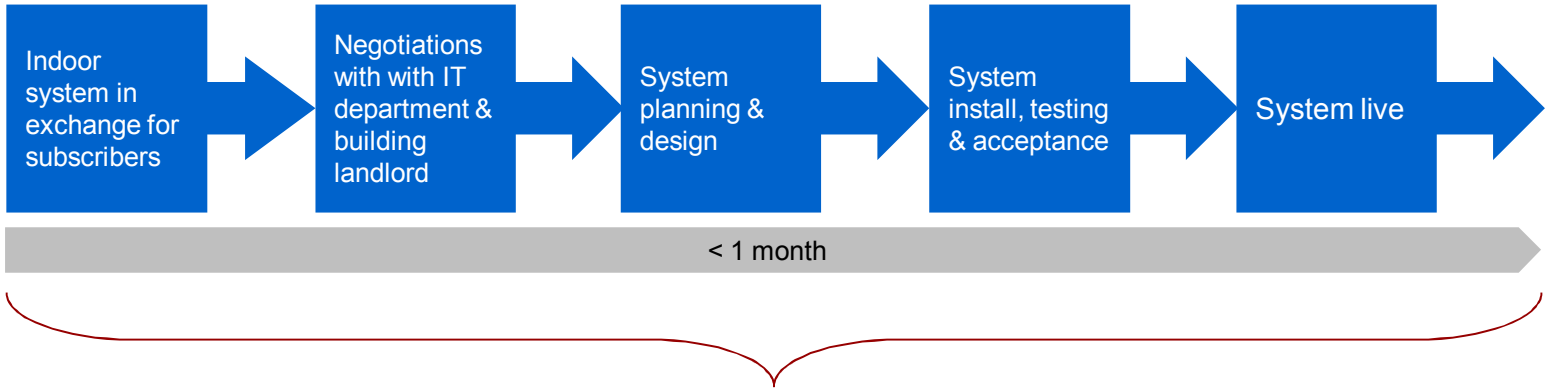
- A typical offer from network operators to IT managers seeking for better indoor coverage



  - Disrupted office space and business upheaval
  - Multi-party contract & planning process
  - Months before one phone works any better

Mobile Operator's Advantage With SpiderCloud

- E-RAN enables the mobile operator to bypass technology & engineering bottlenecks

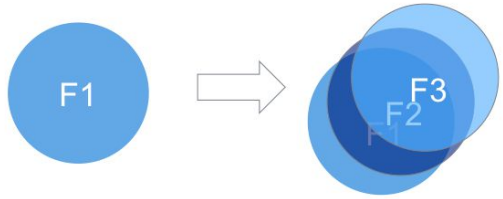


- Optimal user experience in a fraction of the time
  - Platform for follow-on enterprise services
    - Minimal time to revenue

>10X Capacity Compared to DAS

Spectrum Re-use and Capacity
HSPA with Macro/DAS at 4.5Mbps/sector

Single sector-carrier **Multi sector-carrier**



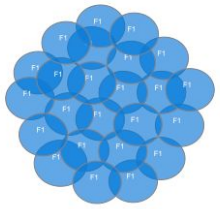
Additional Spectrum ?

200 Users
1 sector
1 channels
HSPA DL Available* = 4.5 Mbps
Avg. 345 kbps/user

200 Users
1 sector
3 channels
HSPA DL Available* = 13.5 Mbps
Avg. 1,038 kbps/user

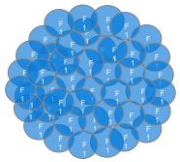
Spectrum Re-use and Capacity
HSPA with SpiderCloud at 3Mbps/sector

Singe sector-carrier
20 Radio Nodes



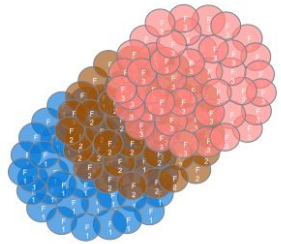
600 Users
20 RadioNodes/channel
1 channel
HSPA DL Available* = 60 Mbps
Avg. 1,538 kbps/user
5x throughput of DAS
3x # of users supported

Single sector-carrier
30 Radio Nodes



600 Users
30 RadioNodes/channel
1 channel
HSPA DL Available* = 90 Mbps
Avg. 2,307 kbps/user
7x throughput of DAS
3x # of users supported

Multi sector-carrier
90 Radio Nodes



1800 Users
30 RadioNodes/channel (90 total)
3 channels
HSPA DL Available* = 270 Mbps
Avg. 2,307 kbps/user
7x throughput of DAS
9x # of users supported

Government building (Mexico)

Solution

- E-RAN over new infrastructure
  - One E-RAN systems with 72 Radio Nodes installed within two months (15 floors)
  - One E-RAN systems with 65 Radio Nodes installed within two months (10 floors)
- SCW´s partner performed installation

Results

- A Happy E-RAN enabled Customer
  - Excellent coverage throughout. From “Drop calls” to “uninterrupted calls” service
- Torre Chiapas 1: 4,900 + Voice calls and 149K+ data sessions per day (1200+ users)
- Torre Chiapas 2: 3,050 + Voice calls and 90K+ data sessions per day (800+ users)

Enterprise building (Mexico)

Solution

- E-RAN over new infrastructure
  - One E-RAN systems with 43 Radio Nodes installed within three months
- SCW´s partner performed installation

Results

- Semarnat : 3,000 + Voice calls and 77K+ data sessions per day (Population remains growing since it is a new government building)

Unmatched Performance in Dense Deployments

	KPIs – Deployed 65-cell SpiderCloud System*	Projected KPIs – Femtocell clusters with Hard Handover*
CS call drop rate (CDR)	<0.8%, no manual tuning	> 10%, depends on extensive manual tuning
CS voice quality (PESQ)	Average PESQ: 3.7	Average PESQ <2.6; Perceptible voice outages during HHO events
CS CSSR	> 98.7%	??
HSPA throughput	During Soft Handover: No impact on UL throughput Loss-less transition across HOs	During Hard Handover: DL TCP throughput < 50% of peak UL TCP throughout < 10% of peak Handovers are not loss-less
HO failure rate	<0.5%	>5%
SON	<1 hour, automatic	Days or weeks to manually assign 65 PSCs, 65 transmit powers, and over 2,000 neighbors

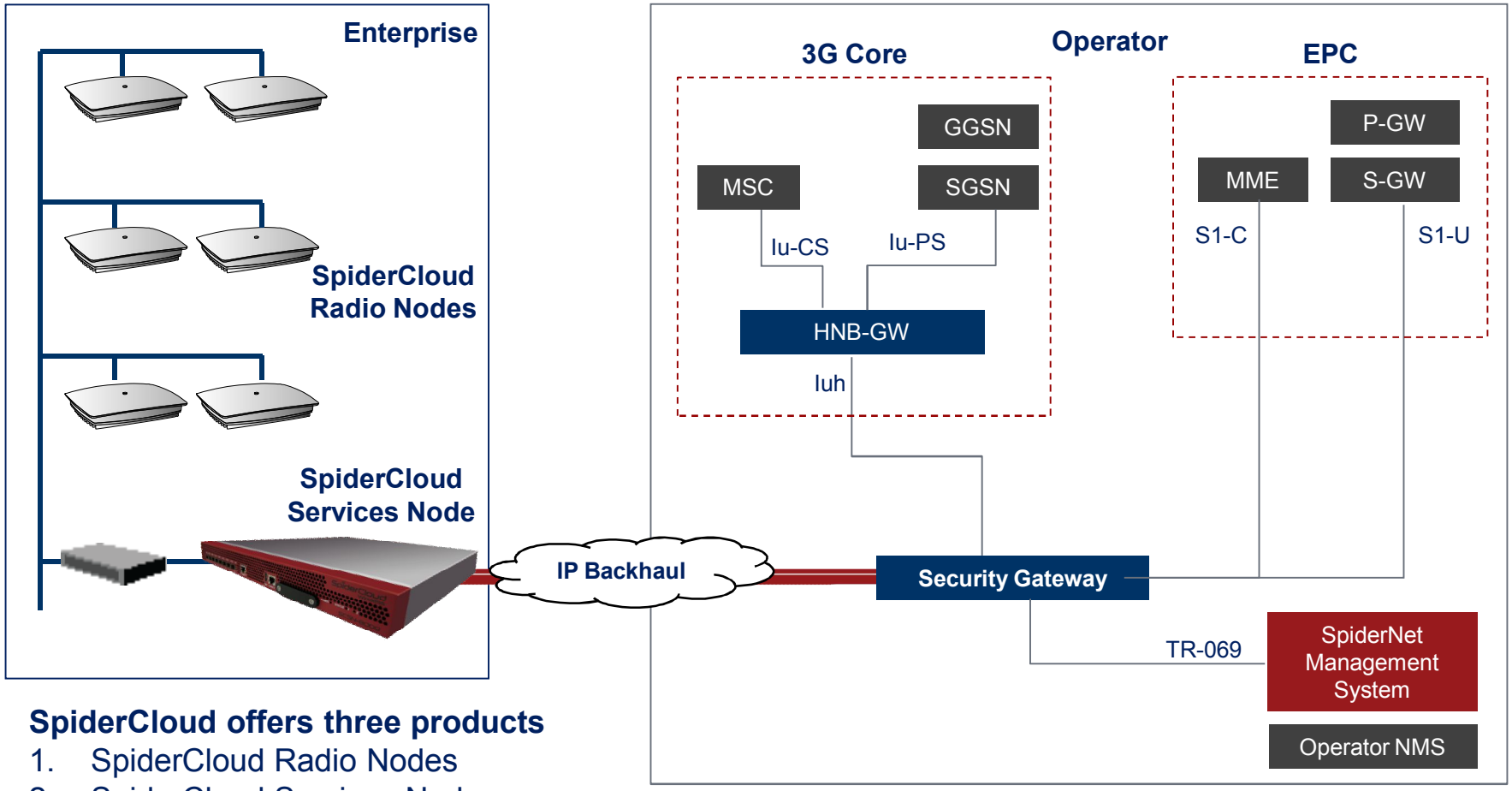
* 65-radio nodes, 16 floors, 500K square feet, >2000 users. KPIs for HHO case are “projected” because no comparable network exists

E-RAN Architecture

SpiderCloud Design Goals

- Significant increase in 3G/LTE coverage and capacity
- Offload signaling and backhaul from the RAN Core
- Mixed user class environments (voice, data or MRAB, with hybrid access for private (enterprise) users and public (guest) users
- Full macro mobility (LTE, 3G and 2G macro networks)
- Clean integration with operator and enterprise infrastructure

SpiderCloud Enterprise Radio Access Network (E-RAN)

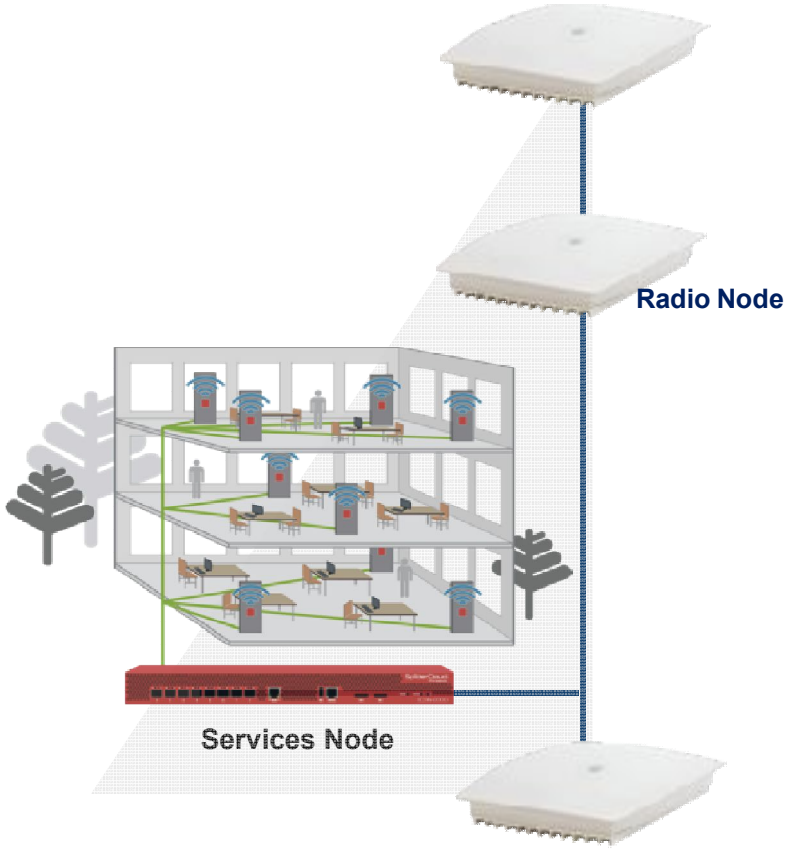


SpiderCloud offers three products

1. SpiderCloud Radio Nodes
2. SpiderCloud Services Node
3. SpiderNet Management System

Optimized for Dense Indoor Deployments

- **Unique Architecture** - Services Node manages mobility, interference & SON; provides single point of integration with core network
- **Soft Handover** between small cells enables <1% voice CDR and consistently high HSPA throughput
- **Centralized SON** technology enables rapid deployment of dense small cell networks
- **Optimized for Enterprise Deployment,** with single, QoS-enabled, secure, backhaul link to operator
- **10x Capacity of Comparable DAS** systems at less than half the price

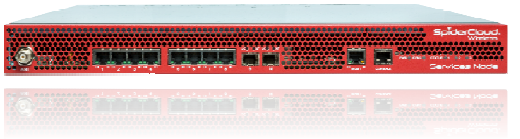


Hardware and Topology

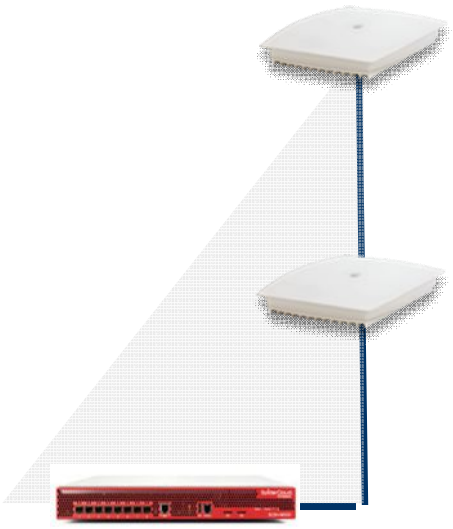
E-RAN System Components

- **Radio Node**
  - Enterprise Small Cell
  - Installed on ceiling, wall, or above ceiling
  - Available as single-access (3G) or multi-access (3G/LTE)
  - Internal antennas (or option for external antenna connectors)
  - Power-over-Ethernet
  - Secure / hardened platform with TPM capabilities

- **Services Node**
  - Installed on enterprise premises
  - Aggregates up to 100 Radio Nodes into a single H(e)NB
  - Single point of management for enterprise small-cell network
  - Single Iuh and S1 (over IPSec) connection to EPC
  - Responsible for self-organizing, and RF management
  - Synchronization for network of Radio Nodes
  - Secure boot, signed images, encrypted HD



SpiderCloud Radio Nodes



- **SCRN-200: 3G-only Radio Node**
  - 32 3G channels
  - HSPA+ (21 Mbps DL)
  - 250 mw peak transmit, receive diversity
  - Single Ethernet Cable, PoE
- **SCRN-310: 3G and LTE Radio Node**
  - 32 3G channels
  - 250 mw peak transmit, receive diversity
  - 32 active LTE users
  - 2x2 MIMO, 21 dBm per transmitter
  - Single Ethernet cable, PoE+

- Each Radio Node is a full 3G (or 3G and LTE) cell, not just a radio head
- Deployed over Enterprise Ethernet LAN
- SCRN-310 is available in several band combinations; can be upgraded to two carriers of LTE
- RN operating at 250 mw covers ~ 1,400 m^2
- Single Services Node supports up to 100 RNs; systems can serve building as large as 140K m^2

SpiderCloud Radio Node SCRN-310

- Hardware
  - Ports: One Power-over-Ethernet+ (802.3at) port
  - Size: 5.3 X 20.6 X 23.9 cm
  - Weight: 1.63 kg with mounting bracket
  - 1 x 100/1000 Mbps Ethernet (RJ45)
  - Single top-panel LED for status & troubleshooting
- Antennas
  - 2 x UMTS: radio operates in 1x2 mode with receive diversity
  - 2 x LTE: radio operates in 2x2 MIMO mode
- Radio Specifications
  - Band 7 (LTE) and Band 1 (3G)
  - Band 4 (LTE) and Band 2 (3G)
  - Band 3 (LTE) and Band 1 (3G)
  - Band 4 (LTE) and Band 13 (LTE)
- Frequency synchronization to SN via PTP

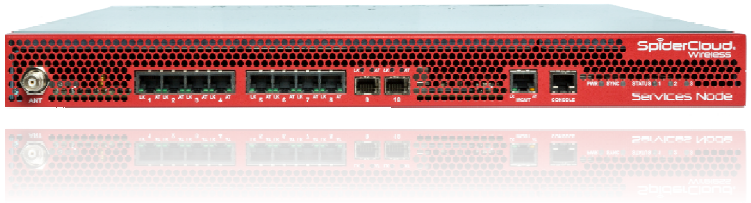
3G NodeB / LTE eNodeB that exchanges user calls/data to/from the services node

Power Over Ethernet

- Two IEEE standards for adding power to Ethernet
  - Requires Cat 5e (or better) cable
  - Maximum Run: 100 meters
    - 802.3af PoE: 15.4 Watts DC per port
    - 802.3at PoE+: 25 Watts DC per port
    - Backwards compatible with 802.3af
- Future Proof: Most operators will opt for POE+ for dual-mode LTE/3G radios
- SpiderCloud RN200: Can be powered by POE or POE+

  - PoE +Switches: Commonly used to power IP phones, Wireless Access Points, security cameras.
  - POE+ Injectors: Used for longer distance Ethernet runs, or when PoE+ switches aren't available.

Services Node



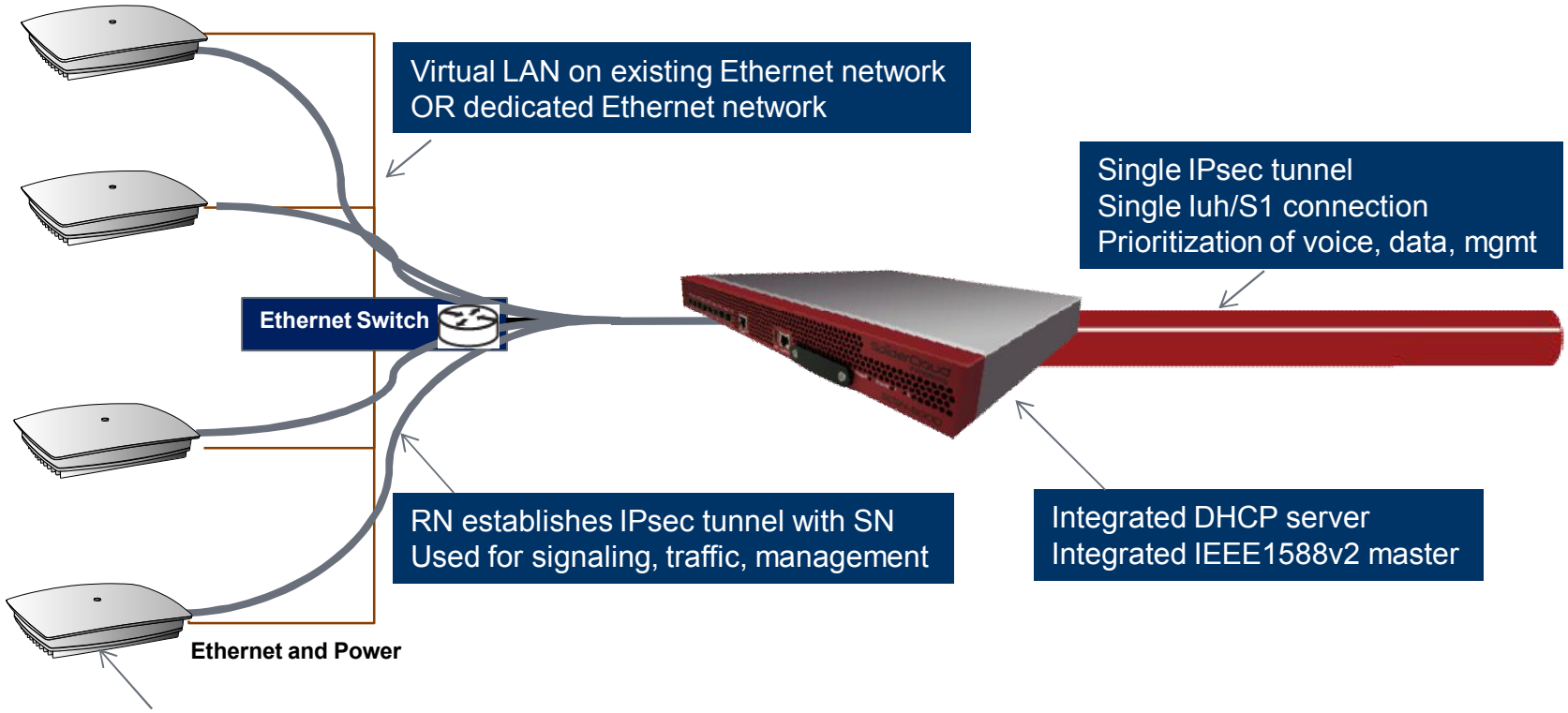
High-Level Specifications

- 8 x Gbps Ethernet ports
- Size: 603 x 448 x 44 mm, 1 RU (19 in rack) Weight: 10.7 kg
- Input power: 100-240VAC, 4.5A, 50-60Hz (100-150W power consumption)
- 2 x redundant AC power supplies and 5 x hot-swappable fans
- High reliability / MTBF

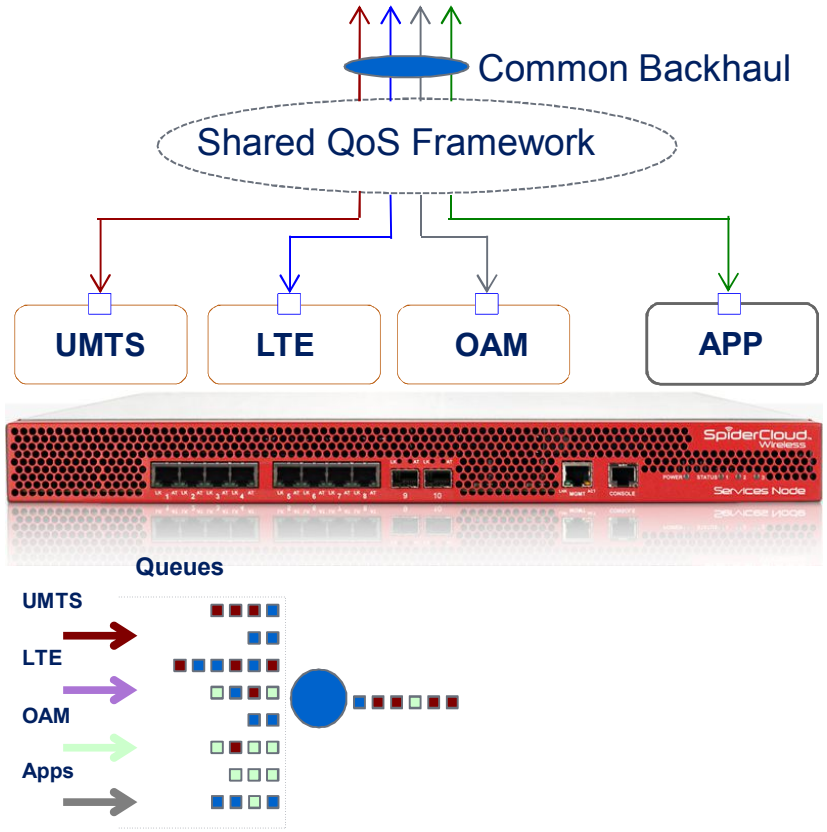
High-Level Functionality

- Aggregates data and coordinates Radio Nodes
- Fast inter small cell mobility
- Interference management between small cells and with macro cells
- Self-Organizing Network (SON) capability for in-building network
- High-precision OCXO
- Integrated PTP master clock

Optimized for Enterprise Deployment

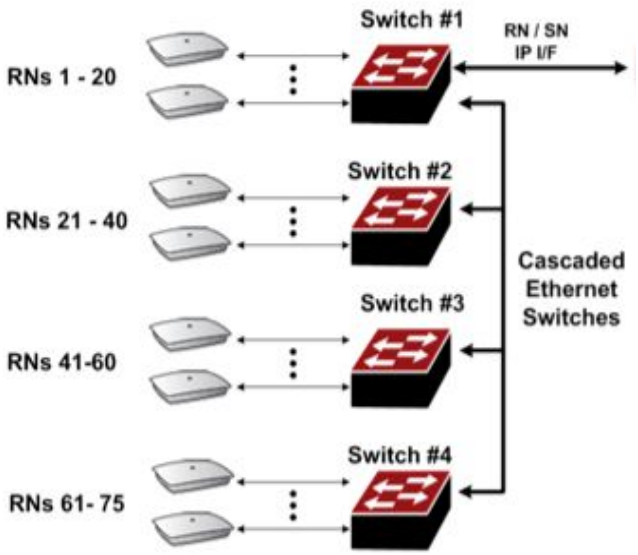


Integrated Backhaul Router



- Aggregates backhaul for all the small cells in the building
- Edge routing functionality (e.g. BGP)
- Policing and rate limiting on ingress
- Traffic shaping on egress
- 802.1p tagging based on DSCP

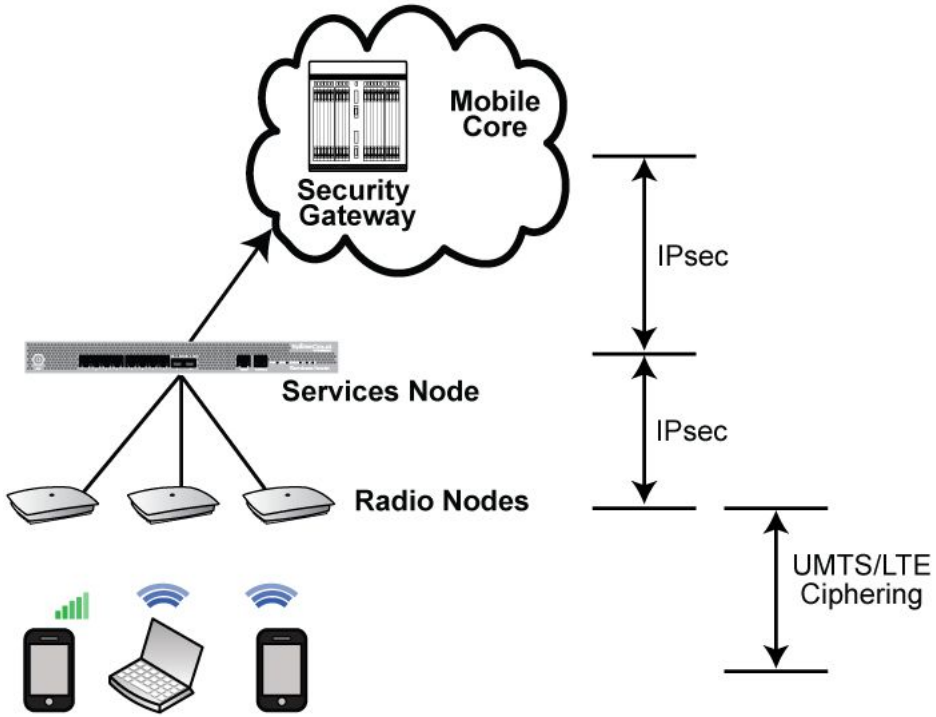
Synchronization



- HW-based time-stamping on SN provides accurate clocking data to the PTP algorithm on the RN
- Oven-Controlled Crystal Oscillator (OCXO) timing reference on SN exceeds 3GPP standards for stability
- Option to discipline SN with external PTP master clock or GPS signal for synchronization with macro
- Underlying mechanism based on IEEE 1588v2
  - RN receives PTP packets and filters out PDV due to intermediate switch hops
  - RN disciplines local Temperature-Controlled Crystal Oscillator (TCXO) to ensure inter-RN frequency tolerance is achieved

Security

Security Architecture Summary

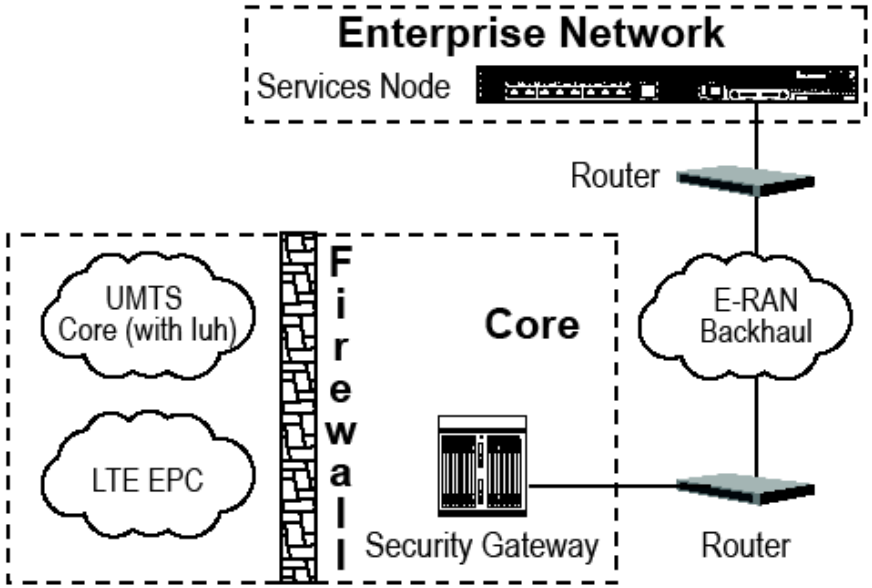


- Certificate-based authentication between SN/RN and SN/SeGW
- IPSec encryption
- Radio interface ciphering (3G/LTE)
- Radios not allowed to radiate without active core connection
- Factory provisioned X.509 certs through secure CA channel
- Secure boot process and encrypted file system
- Vulnerability system testing by independent lab

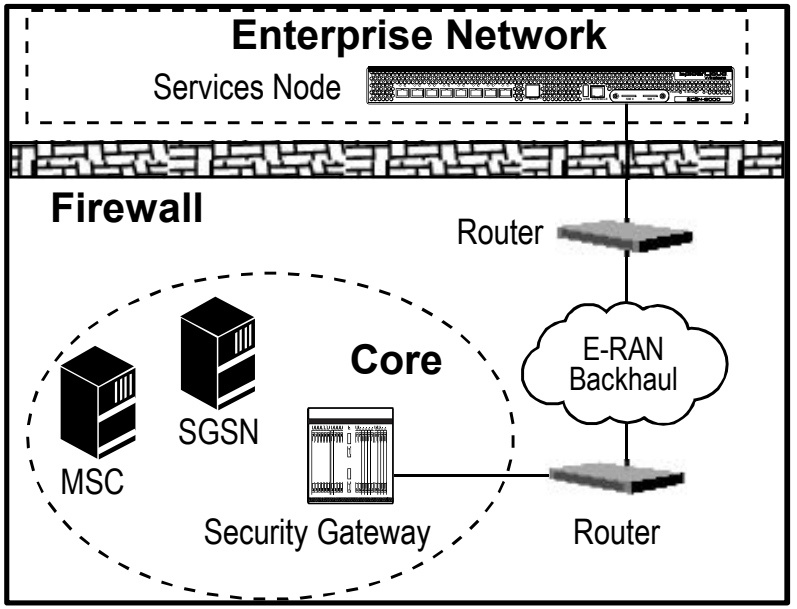
Firewall Traversal

- **Services Node Location**: The SN is usually deployed within the enterprise's DMZ
- **This Reduces Complexity**: Lets the SN connect directly with the mobile core with no enterprise firewall restrictions
- **Firewall Deployment Options (Multiple May Apply)**
  - **Option 1:** Firewall between RN and SN
  - **Option 2:** Firewall between SN and luh GW
  - **Option 3:** Firewall between security gateway and operator core
- **Firewall Configuration**: Each option requires a unique firewall configuration

Firewall NAT Traversal in the Core Network



Firewall NAT Traversal between the Services Node and Iuh Gateway



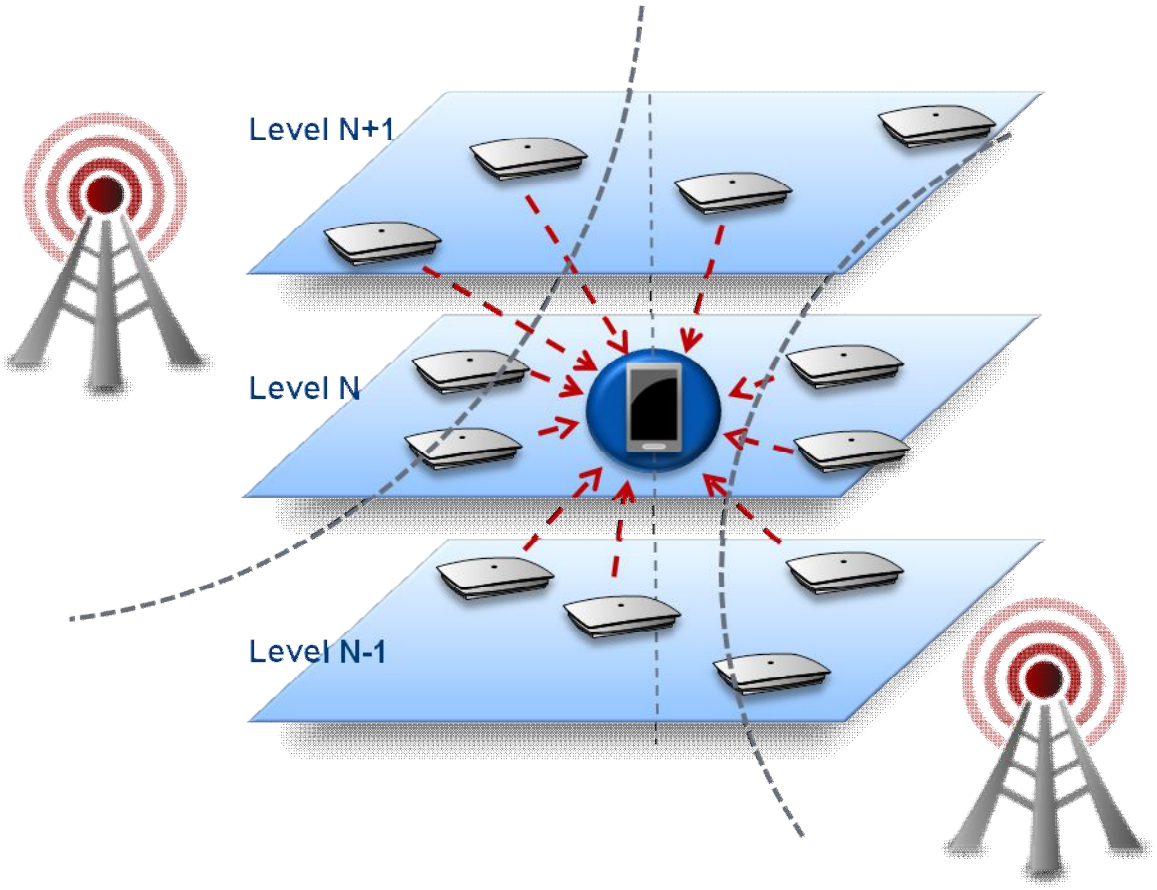
- In UMTS only configurations

E-RAN System Features Part I

Self Organizing Networks
3G Soft Handover, Mobility,
Interference Management

SpiderCloud Wireless

3D RF Environments



- 3-dimensional RF interference
- Flat fading
- Rapidly changing channel
- Reliable voice handovers difficult

Challenging Indoor RF Environments!!!

Self-Organizing Network RF Management

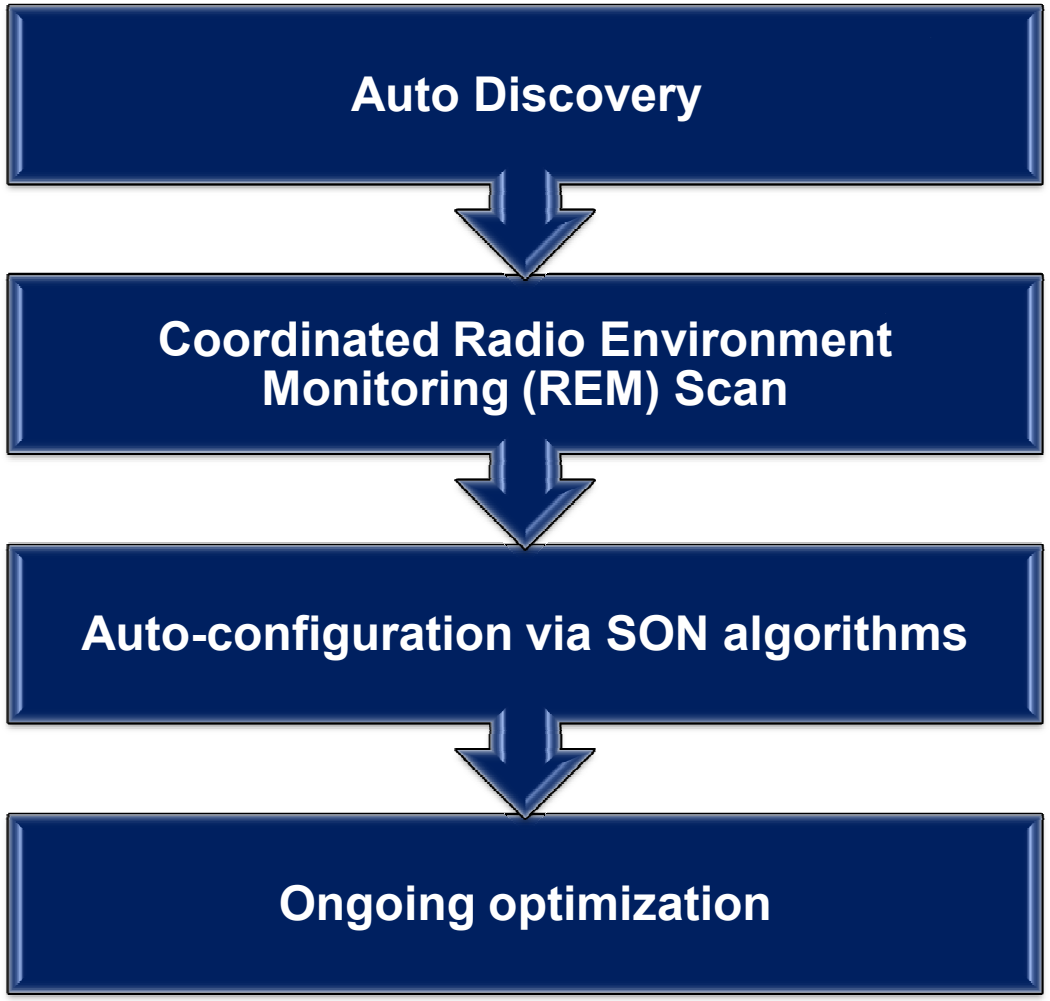
Design Considerations

- Relatively less control over the exact placement of cells
  - Placement may depend on existing wiring, other aesthetic considerations
- Need to automatically assign PSCs/PCIs, neighbor tables and transmit powers on a per-cell basis
- Manual optimization is not an option
- Cannot blindly set transmit powers to maximum
  - Results in severe bleed-out and interference to UEs outside the deployment area
- Need to react to changes in the macro network
  - Else, will result in poor handout performance
- Minimize the total installation time

SON Capabilities

- Coordinated Radio Environment Monitoring
- Automatic PSC and PCI Assignment
- Automatic TX Power Assignment
- Automatic Neighbor-list Creation
- Ability to perform partial or complete manual overrides

SON Steps

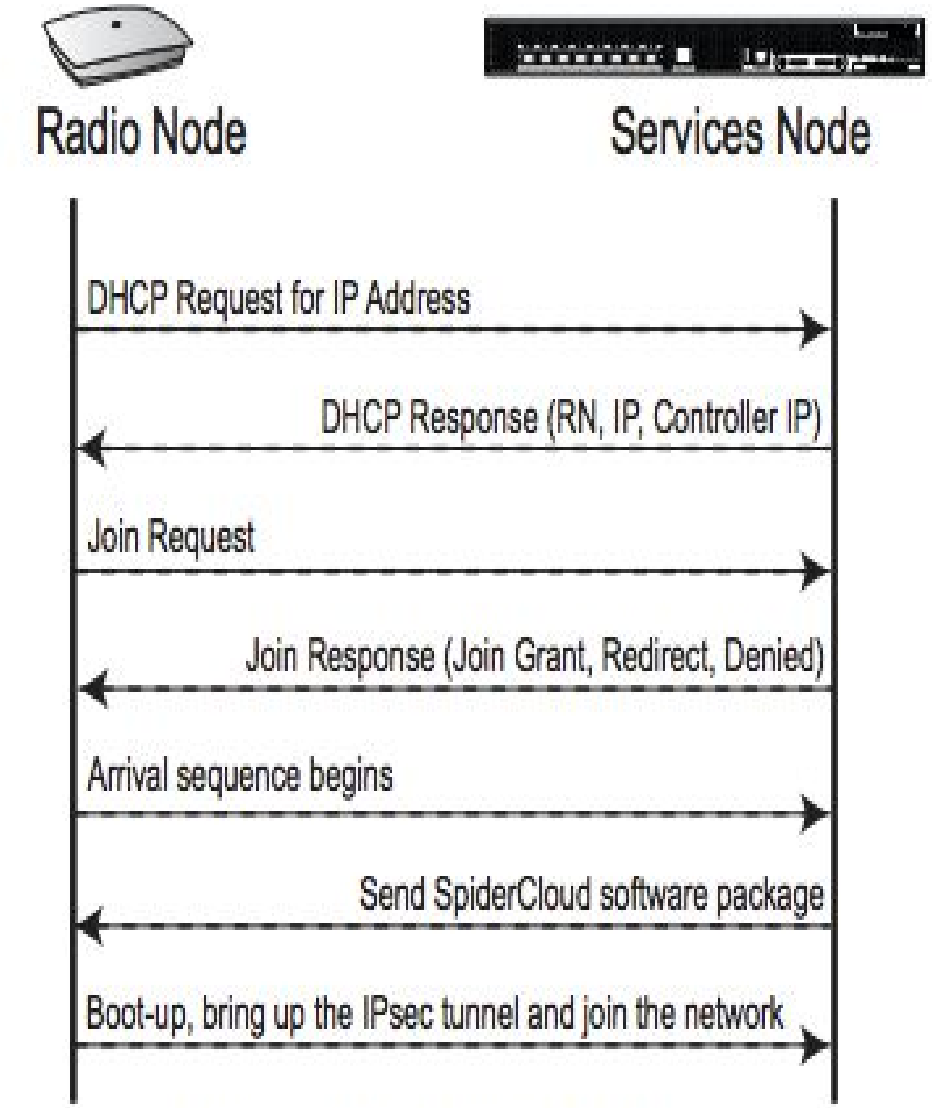


Auto Discovery

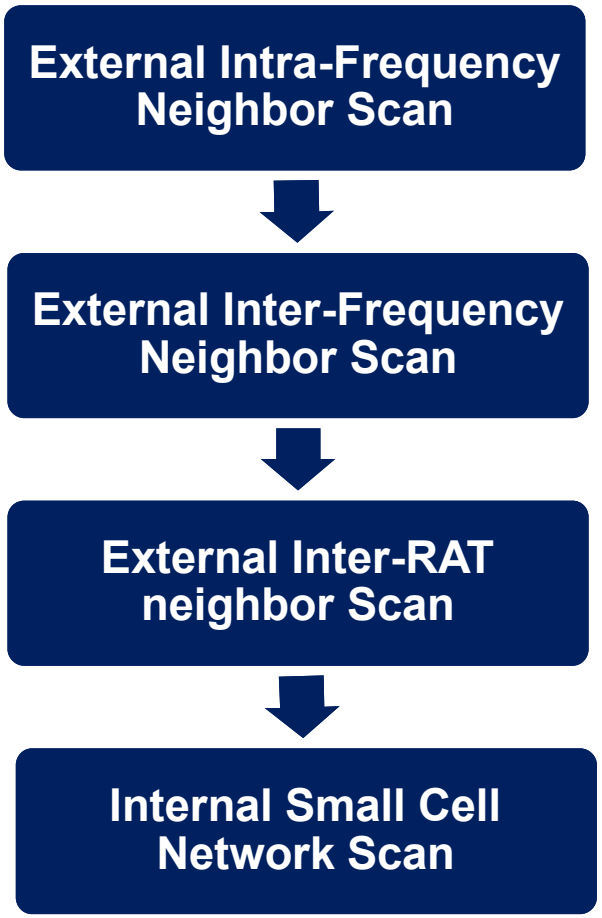
- **Upon power up, SCRN auto configures itself**
  - Obtains IP address via Enterprise DHCP or DHCP server on SCSN
  - Authenticates itself with SCSN (SCRN disabled if authentication fails)
  - Downloads the software image from SCSN
  - Establishes IPSec Tunnels
  - Visual indications provided to installer throughout the process

- **Waits for SON methods to be invoked**

RN Boot Sequence

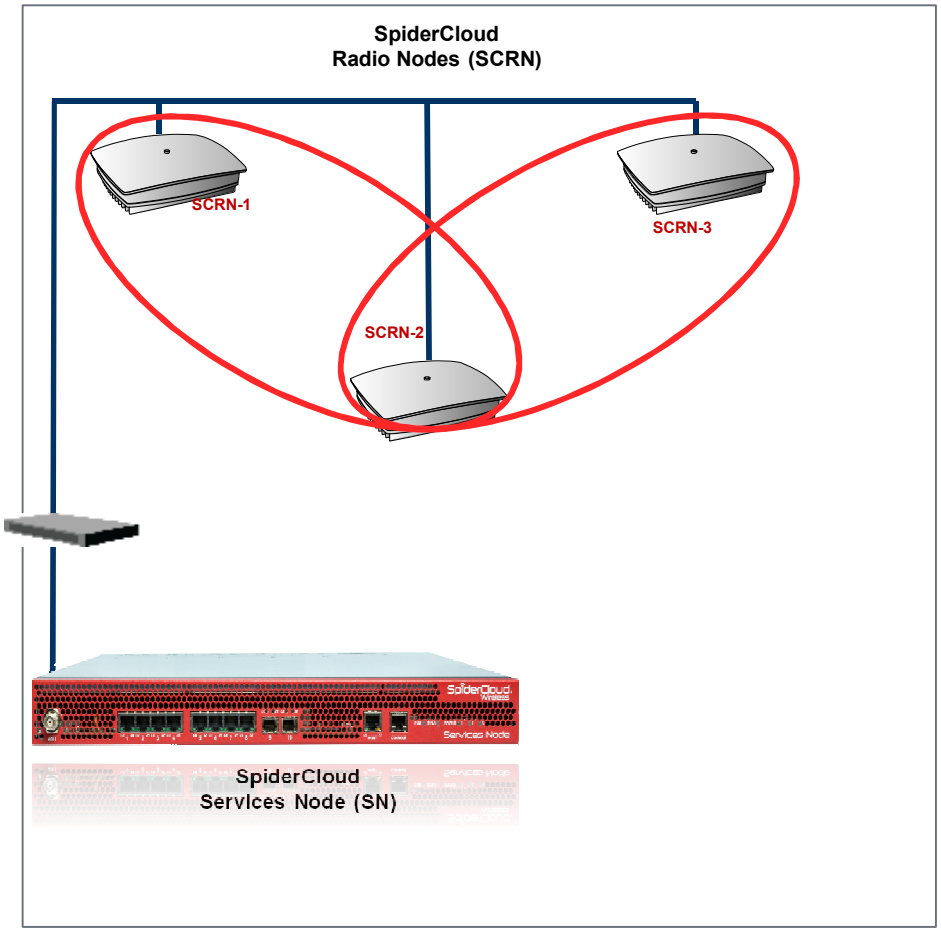


Radio Environment Monitoring



- Macro Network Topology Discovery
  - Detects intra frequency, inter frequency and inter-RAT neighbors
  - All radio nodes sniffs for macro simultaneously
  - Having a quiet small cell network during this phase ensures improved co-channel detection accuracy
- Internal Small Cell Network Topology Discovery
  - SCSN has global visibility over entire network
  - One cell radiates, while all cells are in monitoring mode
  - Having only one small cell radiating at any time improves detection sensitivity by at least 10dB
  - Offers efficient coverage hole detection
- Option to bypass any step

SON: Multi-tier neighbor list



- SCRN 1 detects SCRN 2 but could not detect SCRN 3.
- SCRN 2 detects both SCRN 1 as well as SCRN 3.
- SCRN 3 is added as second tier neighbor to SCRN 1.
- Potentially UE can handover from SCRN 1 to SCRN 3 hence it is important to avoid PCI re-use between second tier neighbors.

SON: PSC/PCI Allocation and Neighbor List Generation

- Primary Scrambling Code(PSC's) and Physical Cell Id's(PCI's) are assigned to each SCRN by Spidercloud SON algorithm during initially bring up of the system.
- All neighbors (macro networks, small cells) considered
  - Multi-tiered approach: Neighbors of neighboring cells considered as well
- Optimize PSC/PCI reuse
  - Discovered neighborhood along with path-loss information used
- "Macro Advertised" PSCs(Active PSCs) allocated to boundary cells for UMTS
  - Enables idle mode reselection and hand-in
  - Can be integrated with centralized SON(C-SON)
- 3G Neighbors advertised on SIBs of each small cell

SON: Transmit Power Allocation

- Multiple methods available for TX power allocation
  - Based on discovered topology and macro interference levels
- Automatically deals with strong/weak macro network
  - Coverage base is affected only by co-channel external cells
  - Used for setting transmit powers, compressed mode thresholds
- Balance DL and UL Cell Boundaries
  - Avoids UL/DL imbalance due to small cell power differentials

E-RAN Extension: Adding New RN

- **Easy to add new RN to system**
  - New RN auto configured on the system
- **Cell goes through SON add cycle**
  - PSC/PCI assigned to new cell based on RF topology
  - Cell assigned TX power based on discovered topology
  - Neighbor table updated for existing cells

On-going Optimization

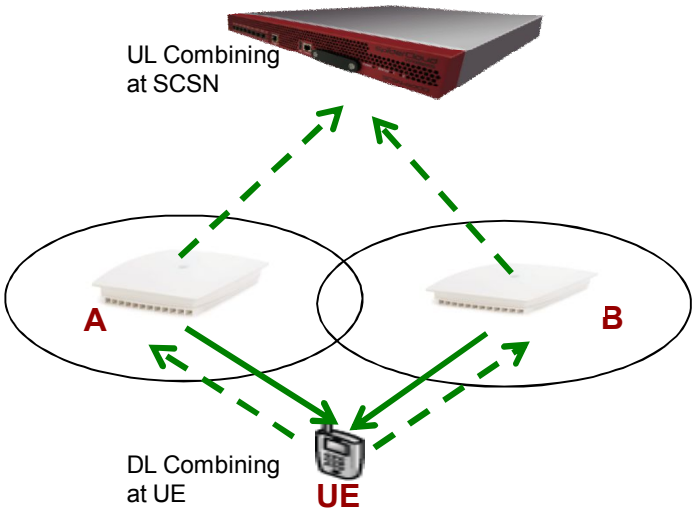
- **Periodic REM Operations**
  - Periodic REM Scans to detect Macro Network Changes
  - Periodically re-optimize transmit powers
  - Power assignments based on actual UE measurements, thus continually verifying and adjusting coverage
  - Uplink levels are correspondingly adjusted to ensure balanced cell boundaries
- **Passive REM Scans**
  - Monitor the state of the environment without changing the neighbor-lists

Summary

- Fully automatic topology discovery
- Optimal allocation of PSCs, PCIs and Transmit Powers
- Automatic Neighbor-list maintenance for seamless mobility
- Ongoing adaptation to macro-network signal levels and network topology changes
- System operational with previous state upon reboot

3G Soft Handover

Soft Handover – Essential for Dense 3G Networks



DL soft-combined => **SINR improves**

UL decoded at both cells => **BLER improves**

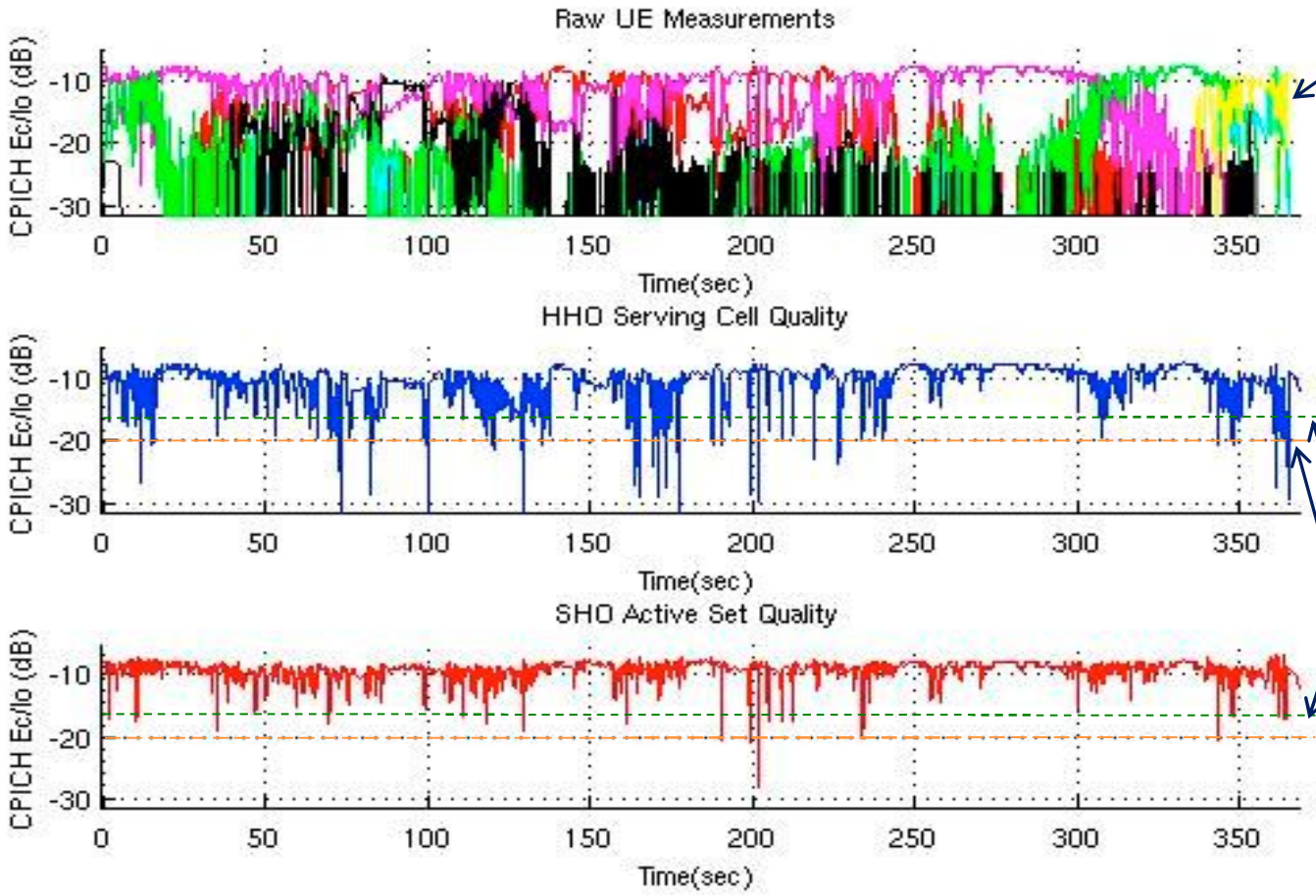
Improved capacity & system performance with Soft Handover

- Uplink and downlink transmit power reduction
- Reduced interference on co-channel macro networks
- UL / DL data capacity Increase
- Macro diversity gains and reduced system fade margins
- Minimal cell overlap with flexible cell placements

Comparing SHO vs. HHO Systems - Methodology

- Start with real-world indoor small cell UE measurements
- Simulate SHO decision process
  - Factor in hysteresis, time-to-trigger and signaling delays
  - Determine which cells would be in active set at any given time
- Repeat for HHO
- Compare resulting signal quality

Soft Handover vs Hard Handover Comparison:
Soft Handover Increases Active Set CPICH



UE sees large # of pilots (each shown with different color)

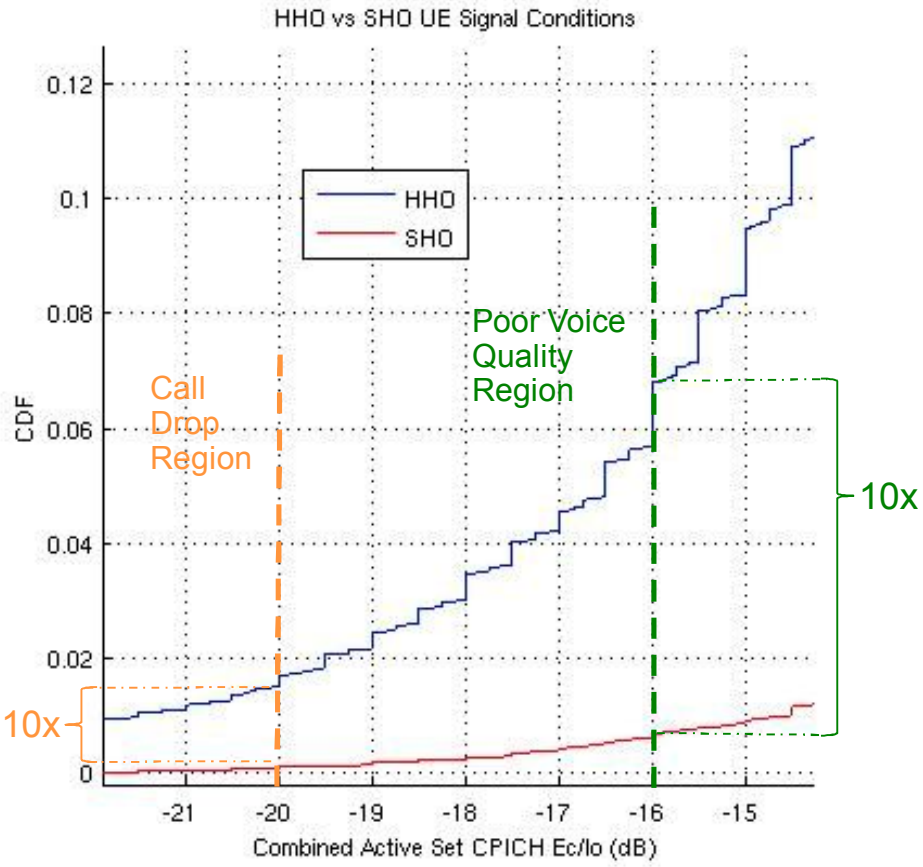
CPICH < -16dB
Poor voice quality*

CPICH < -20 dB
Risk of call drop*

*Source: Small Cell Forum

Soft Handover vs Hard Handover Comparison:
10x Reduction in Voice CDR Compared to HHO

CDF Active Set CPIC Ec/Io



- Combining CPICH from multiple small cells increases CPICH Ec/Io
- SHO provides 10x reduction in probability of poor voice quality (compared to HHO)
- SHO provides 10x reduction in call drop probability (compared to HHO)

Role of RNC in Soft Handover

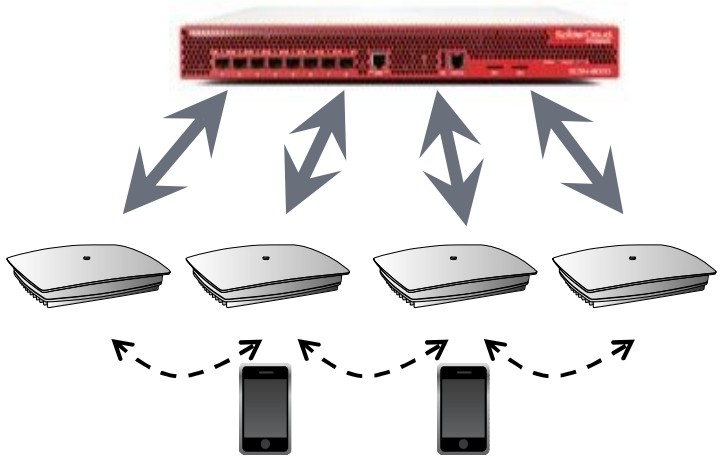
- Key element in the handover processes
  - Anchors calls in the macro networks
  - Responsible for Handover decisions
- Responsible for macro diversity gains
  - Responsible for sending downlink data/voice over multiple cells
  - Responsible for combining uplink data received from multiple cells
  - Performs the outer loop power control

- **SN performs the role of RNC in the E-RAN**

Making SHO Work Indoors

- Highly interconnected cells in a 3D deployment
  - More than 10 first tier neighbors per cell
- Rich multipath environment with flat fading
  - Rapid fluctuations in strongest cell powers leading to DL-UL imbalance
- Frequent serving cell changes due to small cell radius
  - About 18+ active set update commands per minute per cell
  - 2-3 Serving Cell Changes (SCC) per minute per cell
  - Need to redirect user plane data during SCC for lossless operation
- Need frequency synchronization between small cells
  - Accuracy within 100ppb with PTP synchronization with the controller

SpiderCloud Soft Handover Implementation



- All sessions are anchored at SN
  - SN acts as 3G RNC
- RNs configured with neighbor lists
  - Automatic detection of UMTS/GSM neighbors
  - Neighbor lists contain both internal and macro neighbors
- Configurable handover thresholds
  - E1A, E1B, E1C, E1D
  - Values optimized in real-world deployments
- Smart inner loop and outer loop power control to maximize diversity gains
- Uplink interference management
  - RNs active set can ask UE to reduce its uplink power using NS-RGCH
- SHO-optimized PHY implementation

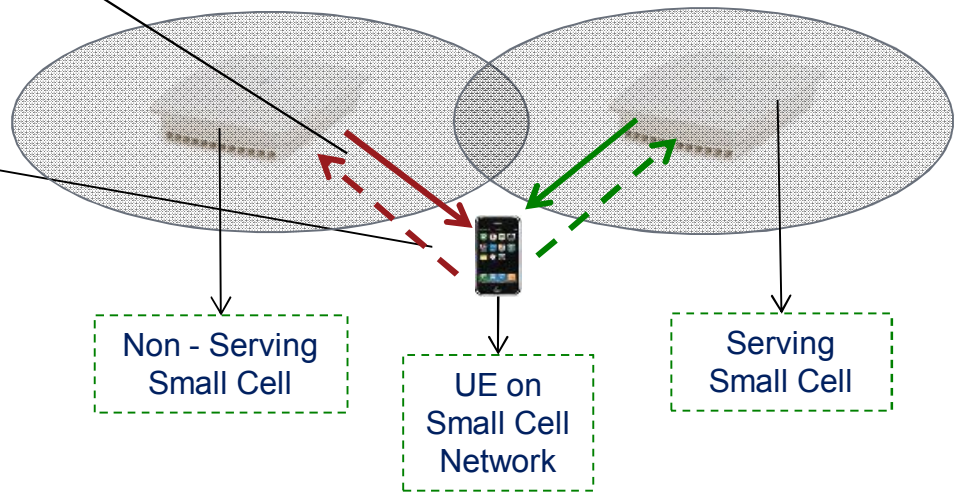
Interference Management

Interference Management within Small Cell Networks

Scenario

Small cell downlink (DL) interferes with DL from serving cell

UE causes uplink (UL) interference to other small cells



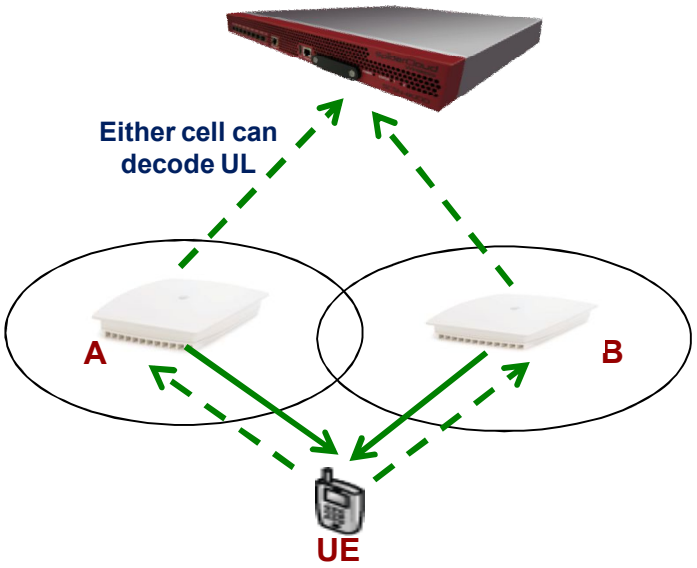
Solutions

1. Soft Handover for UMTS ensures minimal DL and UL powers throughout the E-RAN, keeps interference levels low
2. Mechanisms to handle UL interference problems employed within E-RAN

UMTS: Soft-Handover (SHO) minimizes interference within E-RAN

- Soft Handover (SHO)

Uplink combining at SCSN
Realize macro diversity gains



Downlink combining gains at UE
Improved SIR

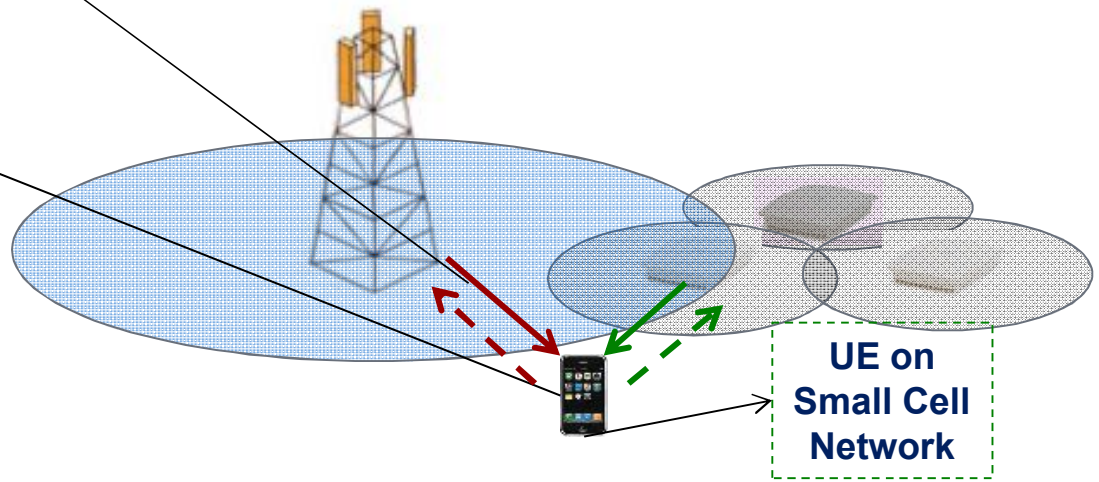
- Improved system performance with SHO
  - Macro diversity gains and reduced system fade margins
  - Improved Signal to Interference Ratio (SIR)reduces UL and DL transmit powers
- Quick handover decisions at the local controller
  - Low signaling latency reduces interference spikes
  - Improved performance during mobility events
- SHO provides control over UL interferers
  - Cells can communicate with UEs in SHO on neighboring cells
  - Non-serving UEs asked to reduce UL power using Non Serving – Relative Grant Channel (NS-RGCH)
- Efficient Power Control
  - Best link controls the inner loop power control (ILPC) ensuring low UL and DL Transmit Powers

Interaction of Small Cell UE with Macro Network

Scenario

Macro Cell DL interferes with DL of Small Cell

UEs on small cell network pose UL interference to Macro Cells



Solutions

1. SON algorithms automatically detect and adjust coverage areas based on macro network signal coverage
2. Low uplink powers due to SHO for UEs within the small cell network mean minimal impact to UEs on macro networks

E-RAN works as underlay within the Macro Network

- SON algorithms help reduce interference to macro network
  - Provides accurate information on the macro signal strength
  - Adjusts E-RAN coverage relative to macro networks

- Seamless mobility between E-RAN and Macro Network
  - Neighbor lists with combined macro and E-RAN neighbors enable seamless mobility
  - E-RAN UE handed over to macro network when macro network is the dominant link

- Minimal UL interference to macro network
  - Low UL transmit powers ensured due to SHO within E-RAN
  - UEs will be handed over to macro network when interference level exceed set thresholds

Mobility

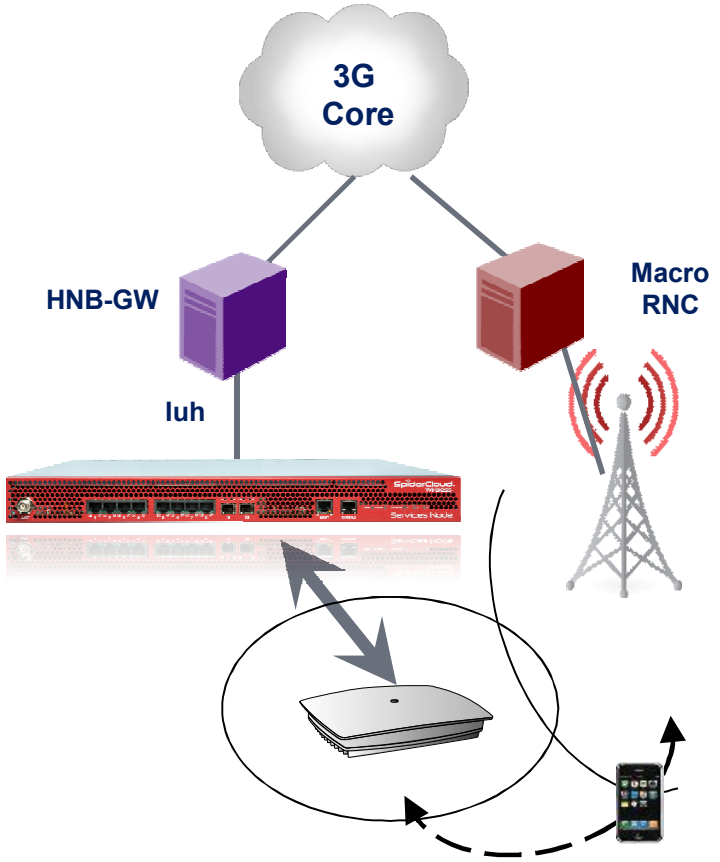
UMTS: Idle Mode Mobility between E-RAN and Macro

Idle Mode Reselection

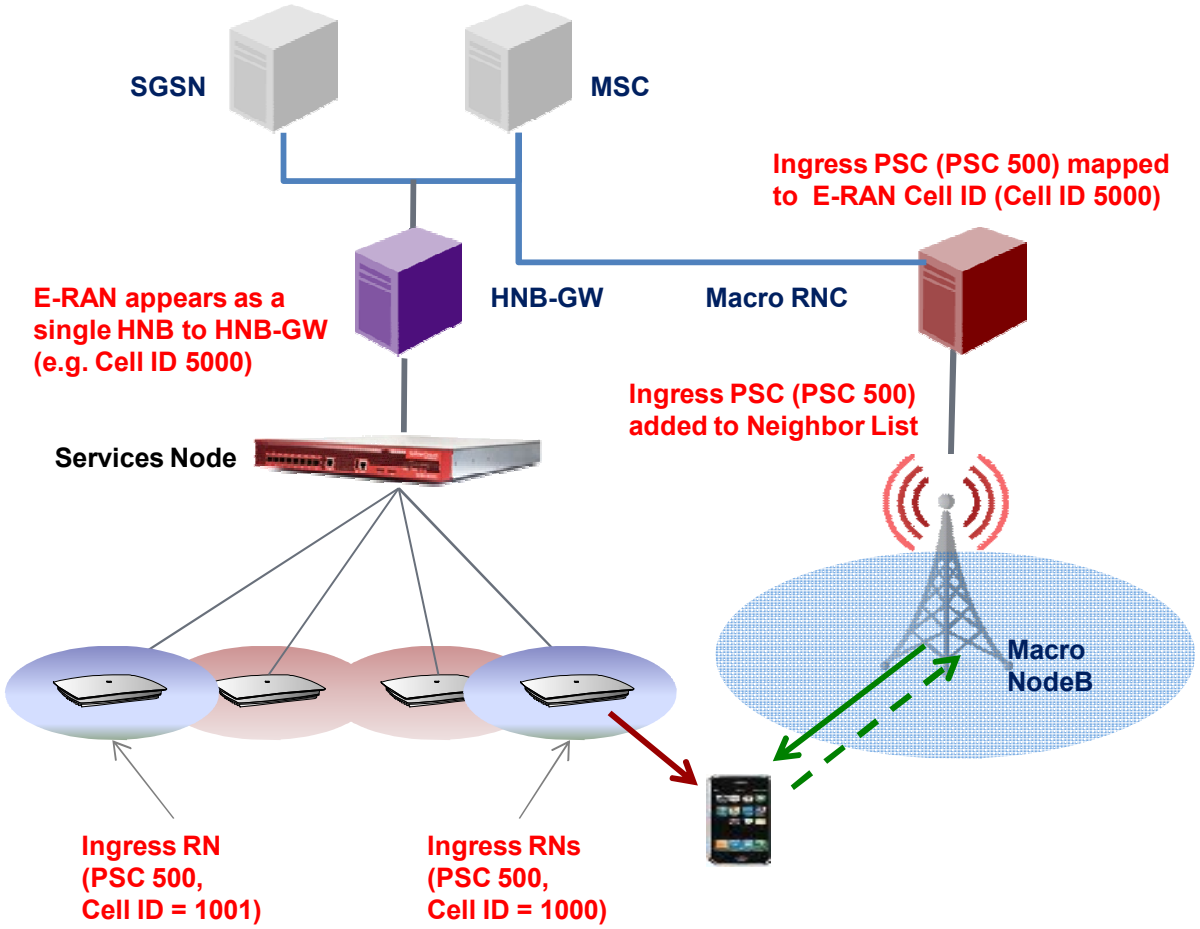
- ***From macro to E-RAN***
  - Idle mode reselection is based on PSCs advertised in macro SIB-11
  - E-RAN uses macro advertised “active PSCs” for boundary cells
  - UE walking into E-RAN reselects to E-RAN based on cell reselection criteria to the boundary cell
  - Location/Routing area update upon reselection (E-RAN assigned unique LAC/RAC)
- ***From E-RAN to macro***
  - E-RAN advertises SON discovered macrocells in boundary cells’ neighbor lists

UMTS: Handovers to 3G/2G Macro

- **Hand-out**
  - Enabled through SON neighbor list discovery
  - Intra-frequency or inter-frequency hard handover from E-RAN to 3G macro cell
  - Inter-RAT hard handover from E-RAN to GSM
- **Hand-in**
  - Intra-frequency or inter-frequency hard handover from 3G macro cell to E-RAN
  - Ingress PSC allocated per E-RAN deployment on neighboring macro cells
  - HNB-GW forwards Hand-In requests to target E-RAN



UMTS Hand-in: With no Change on HNB-GW and UMTS Macro Network



Illustration

- UE sends a message with PSC=500 (hand-in PSC)
- Macro RNC refers to neighbor list; figures out target cell and includes target cell ID (5000) in the hand-in relocation request
- HNB-GW receives all hand-in messages
- E-RAN would have registered with HNB-GW as a single HNB
- HNB-GW will forward the hand-in message to the proper E-RAN
- E-RAN identifies which small cell the UE is handing into

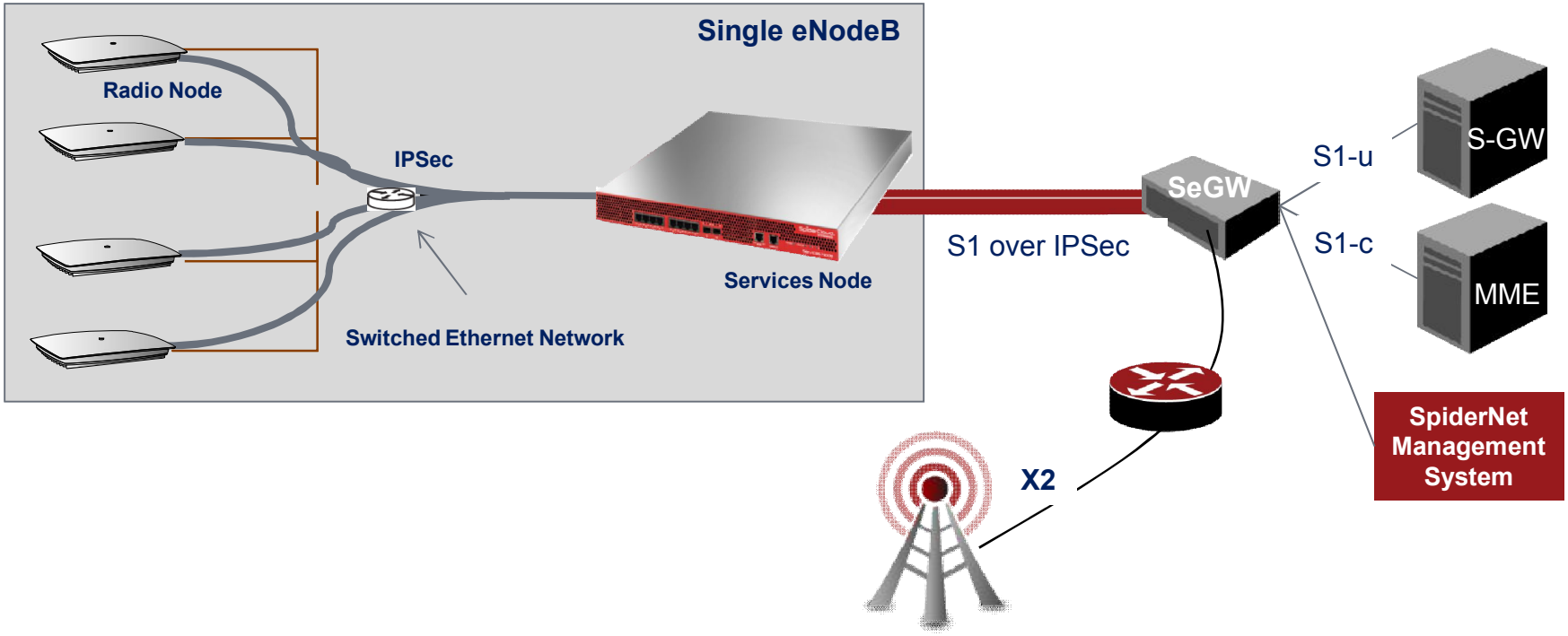
E-RAN System Features Part II

LTE Architecture, Mobility, Interference Management, and Voice Services

Admission and Access Control

SpiderCloud Wireless

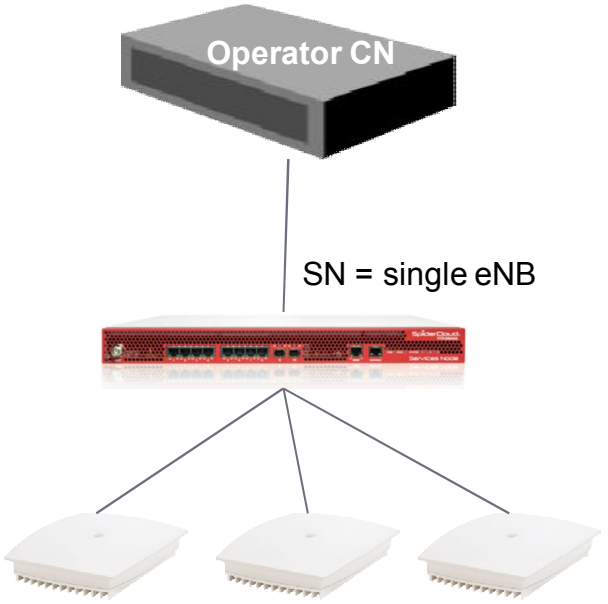
SpiderCloud LTE Enterprise RAN (E-RAN)



Enables operators to deploy dense small cell networks and grow them as demand for mobile data increases – with no impact on macro or packet core

Dual-Carrier LTE Service

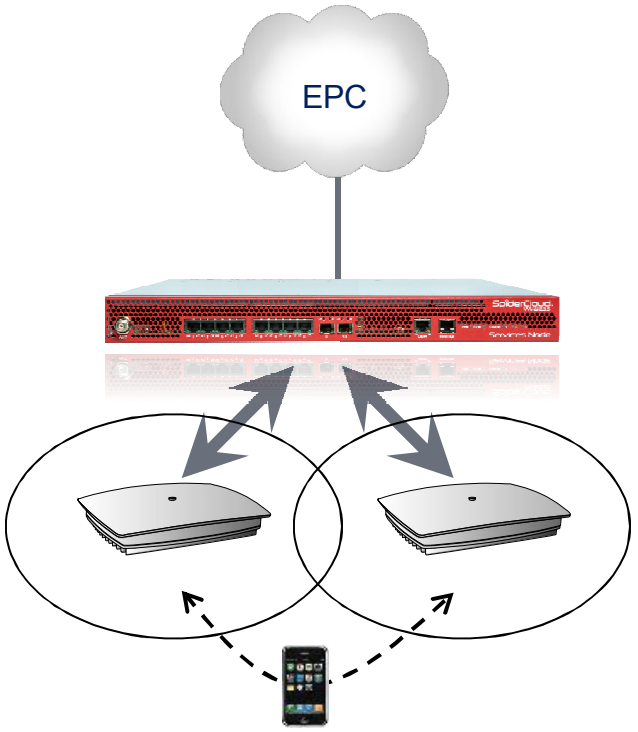
- **Feature Description**
  - Radio Nodes operates with two simultaneous LTE carriers / two LTE cells
  - Services Node appears as single eNB to EPC
  - UE load balancing across carriers
  - Available on Band 4/Band 13 model
  - Additional LTE band combinations planned
- **Benefits**
  - Additional capacity in markets where operator has multiple LTE carriers
  - Balancing UEs across two carriers reduces the probability of overload congestion



Each RN = 2 LTE Cells

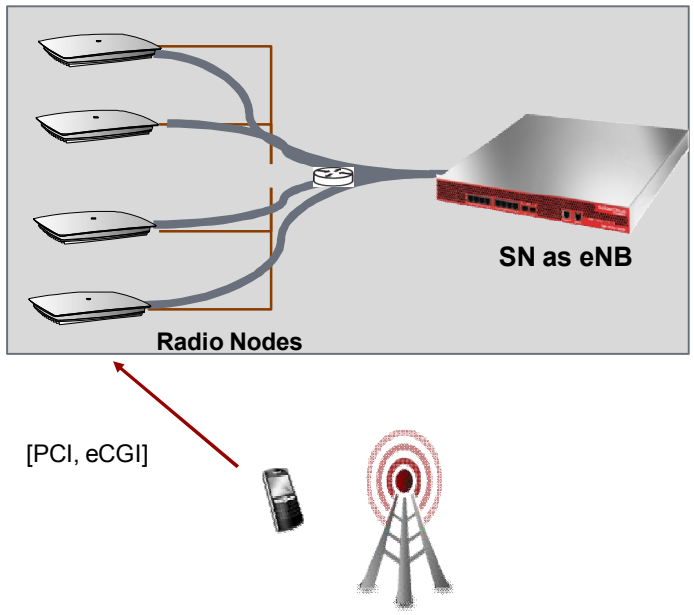
Fast Handover between RNs

- Inter-RN mobility managed by SN
  - EPC unaware of inter-RN handovers
- Services Node functions
  - Single point of anchoring for S1 sessions
  - Maintain L3 (RRC) state
  - Process measurement reports
- Architecture benefits
  - Handovers do not generate path switch requests to MME/S-GW
  - Increase in “local” mobility events does not increase load on EPC
  - Eliminates the need for “X2 mesh” provisioning
  - Lowers handover latency



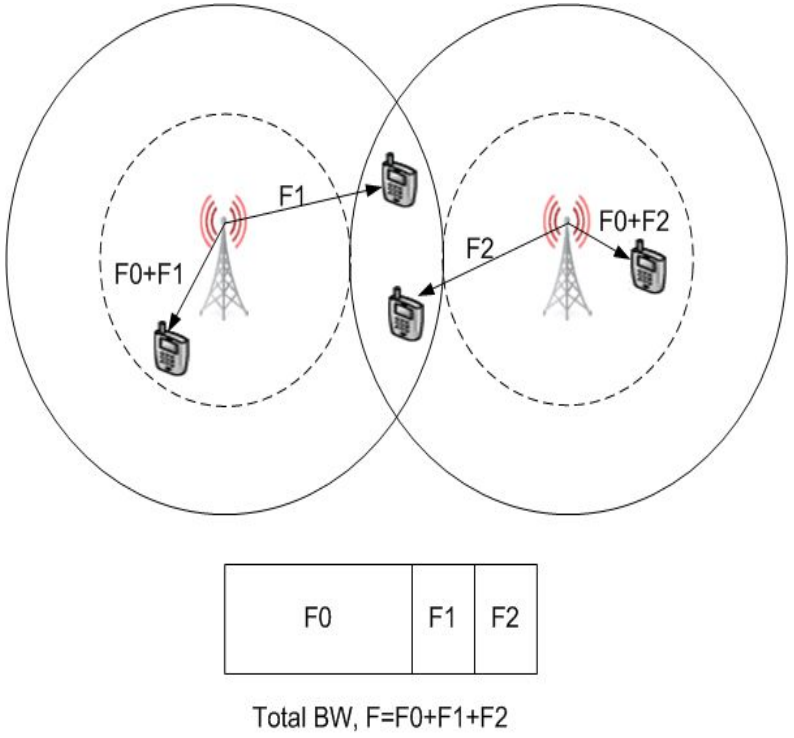
SON: Neighbor Relation Table

- SON builds neighbor relation table
  - Individual neighbor table for each cell
  - Includes both intra SN and macro neighbor
- Detection of new neighbors through UE measurements (ANR)
  - Updates neighbor table based on UE reported eCGI
  - Reduce the need for frequent periodic REM scans to detect changes in macro network
- Optimized PCI reuse(in future)
  - In case of PCI reuse network relies on ANR feature(eCGI report)



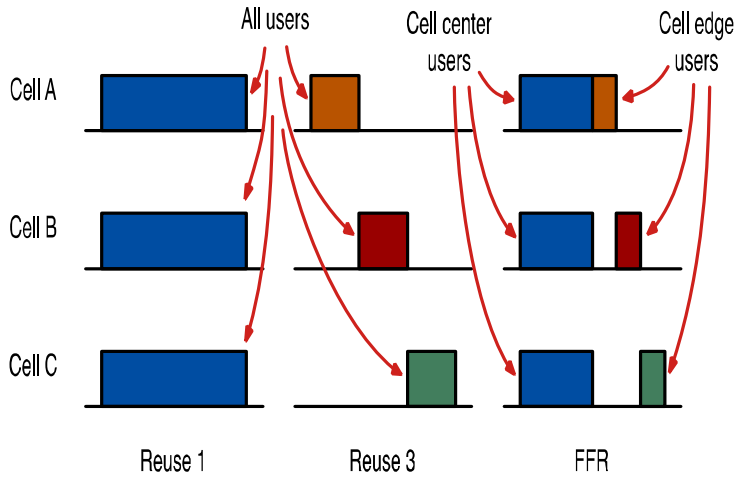
LTE: Centrally-Coordinated Dynamic FFR

- Fractional frequency reuse (FFR) essential for interference coordination.
- SON functionality helps to maintain Radio Frequency (RF) topology information for the small cell RAN.
- SN continuously monitors network-wide interference and varying traffic loads and centrally coordinates FFR across different RN's.
- Coordinated scheduling improves spectral reuse and optimizes throughput.



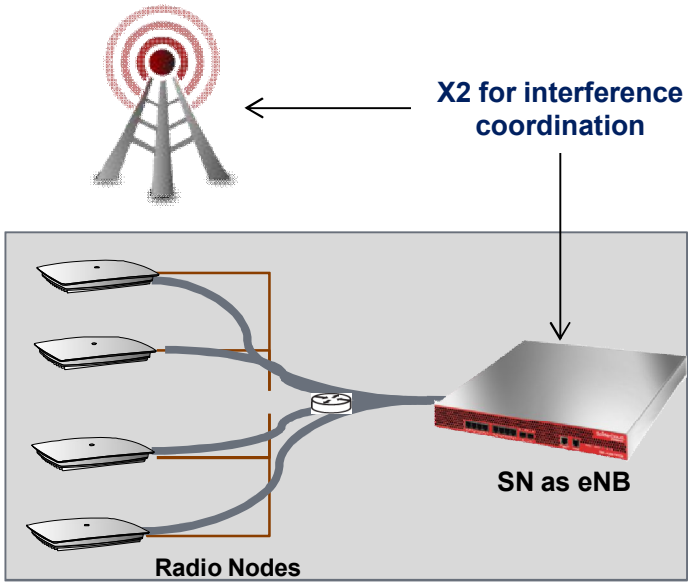
LTE: Centrally-Coordinated Dynamic FFR

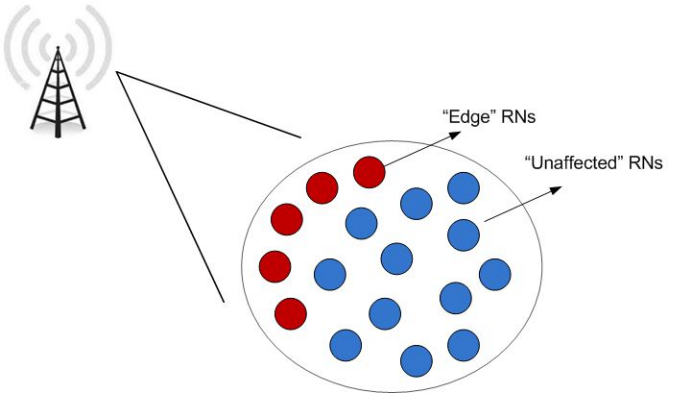
- E-RAN Inter-Cell Interference Coordination (ICIC) ensures reliable intra-system mobility and improve cell edge users' performance.
- Dedicated frequency bands (edge bands) for each cell to create interference free or less-interfered frequency bands for cell edge users
- Performance is maintained for cell center users by scheduling them on center band frequency resources that are common to all cells.
- Free up cell edge resources in idle cells and re-allocate to loaded cells



Interference Coordination with Macro eNBs

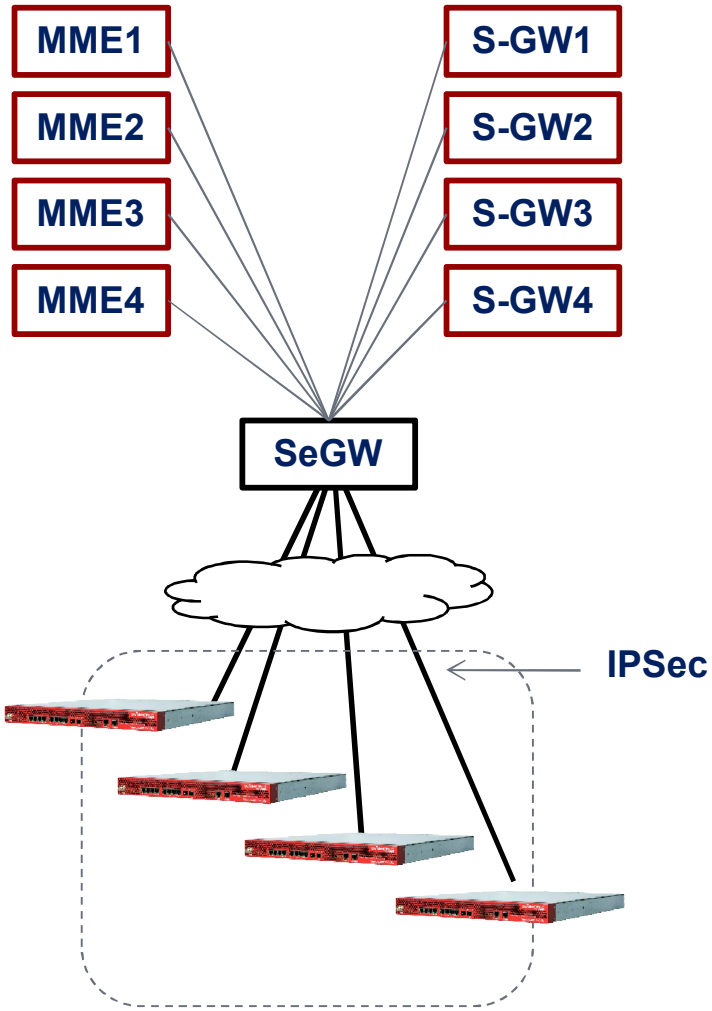
- **SN interfaces with macro network as eNB**
  - Relies on X2 messages for ICIC and eICIC
  - SN's SON algorithm identifies "edge cells"
  - SN dynamically coordinates ICIC restrictions on "edge-cells" in the macro-interference region
  - Supports ABS configurations and corresponding scheduler modifications
  - SN (and RNs) time synchronized with macro
- **Architecture Benefits**
  - Scalable. SN offers single point of interference coordination with macro-cell.





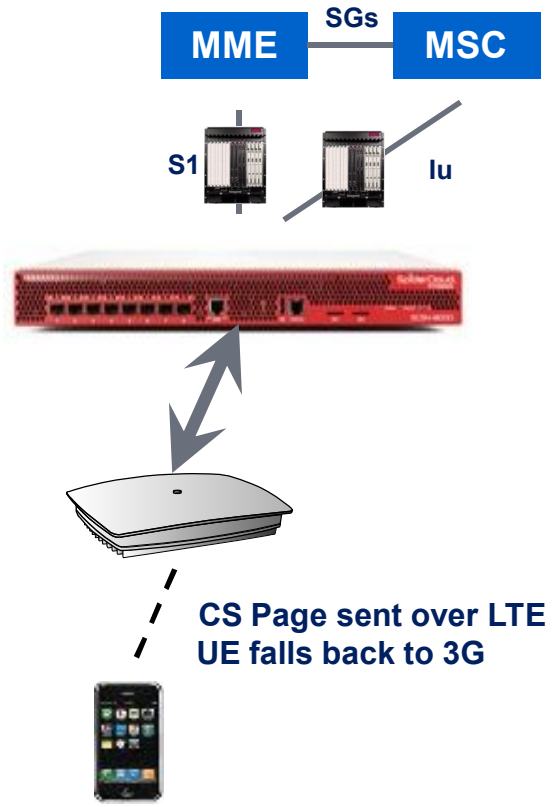
S1 Flex

- **Feature Description:**
  - Enable one SN to connect with a pool of MMEs for redundancy.
  - SN selects and manages connections with multiple MMEs
  - Up to 8 simultaneous S1 connections to MMEs
- **Feature Benefits**
  - Load balancing among the core network elements in a pool
  - Signalling load reduction
  - High availability of the core network



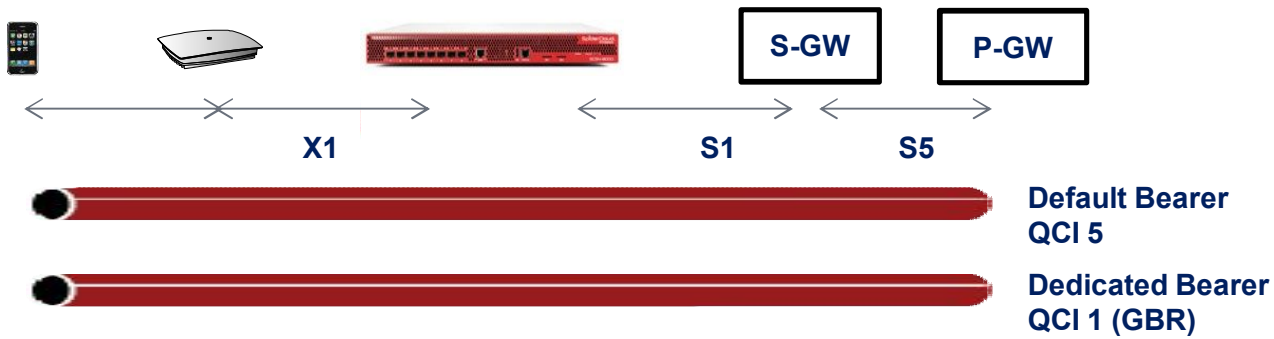
Circuit Switched Fallback (CSFB)

- **Feature description:**
  - CSFB based on UE redirect
  - If UE in E-RAN receives CS call, MME sends page to SN. SN pages UE on LTE through radio nodes.
  - The UE initiates CSFB with a service request to switch to 3G, which is forwarded through SN to the core network(MME).
  - MME forwards a request to SN to switch the UE to 3G and SN initiates cell change procedures
  - SIB19 support for fast return to LTE
- **Feature benefits**
  - Support voice services using existing 2G/3G CS domain functions
  - E-RAN is multi-access (3G/LTE), ensuring that UE has 3G service



Voice over LTE

- **Support for multiple Radio Bearer (RB) combinations**
  - IMS signaling on Default Bearer (QCI=5)
  - Voice traffic (user plane) on Dedicated Bearer (QCI=1)
- **QoS-aware MAC scheduler**
  - Guarantees QoS metrics (QCI, GBR, priority) on the air interface
  - Optimized for delay-sensitive, high-priority traffic
  - Optimized for guaranteeing QoS in a dense multi-cell interference environment

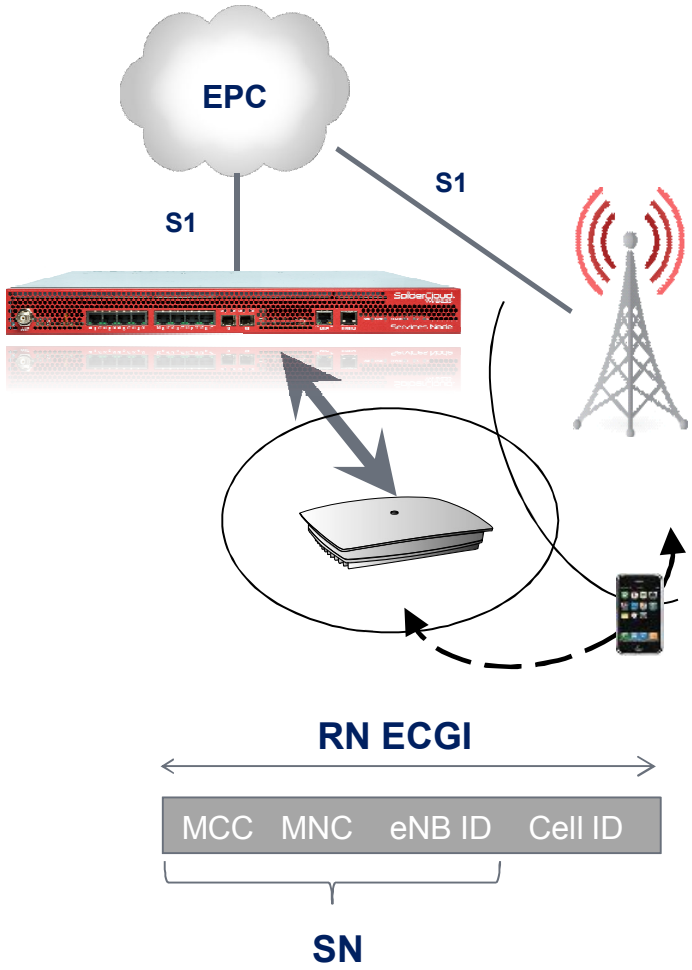


LTE: Idle Mode Mobility between E-RAN and Macro

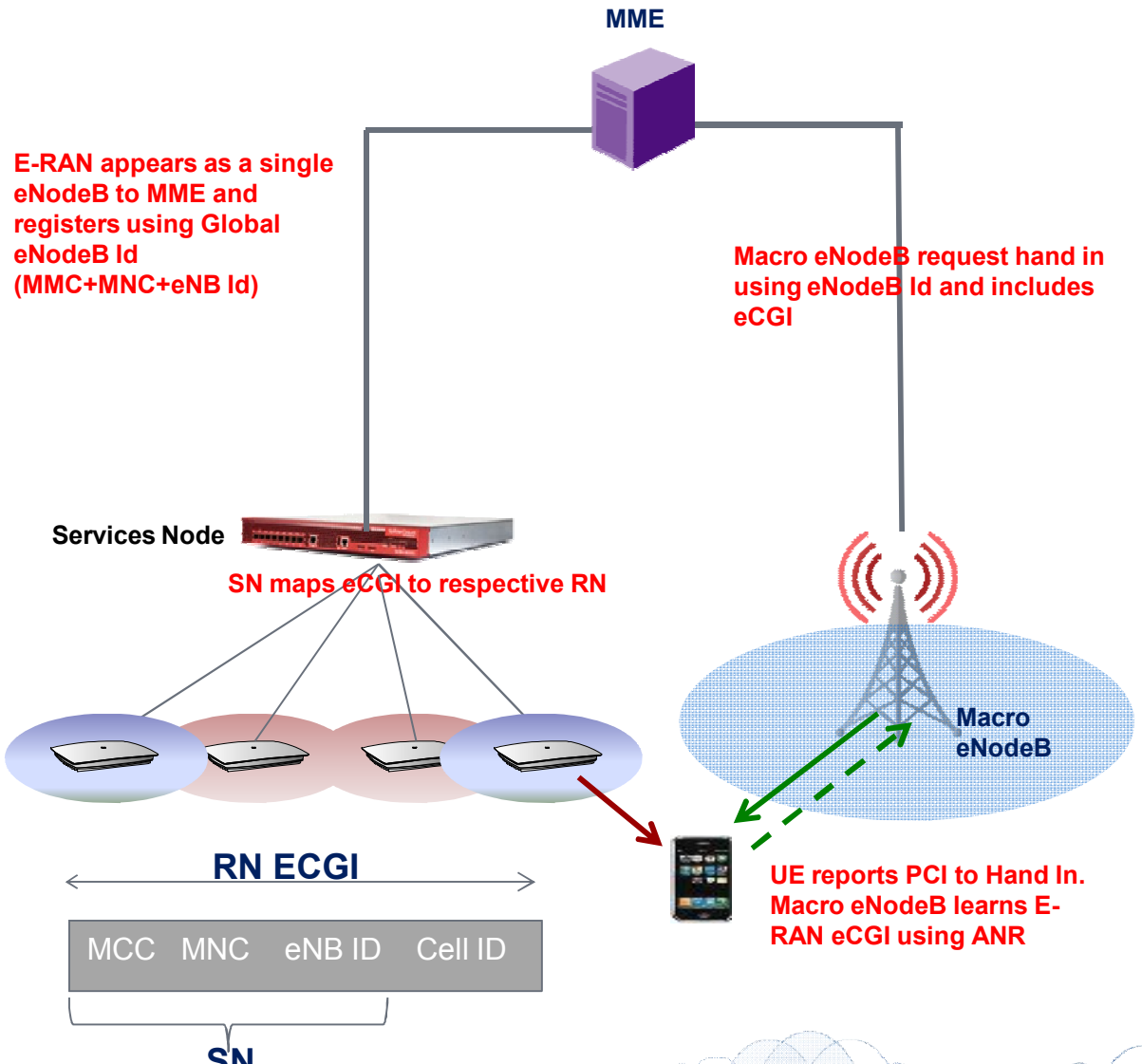
- **From macro to E-RAN**
  - Idle mode reselection is based on eARFCN advertised in macro SIBs(SIB-3/SIB-5).
  - No special PCI assignment required for boundary cells.
  - Macro can assign priorities to E-RAN eARFCN if E-RAN is operating on a different frequency than macro.
  - UE walking into E-RAN reselects to E-RAN based on Cell Reselection criteria - $S_{searchP}$ and $S_{searchQ}$.
- **From E-RAN to macro**
  - E-RAN advertises SON discovered LTE eARFCN in boundary cells' neighbor lists

LTE Handovers to Macro eNBs

- **Hand-in**
  - S1-based handover from macro eNB to SN
  - SN maps handover request to RN
- **Hand-out**
  - S1-based handover from SN to macro eNB
  - SN maintains PCI-to-ECGI mapping based on SON
- **Architecture benefits**
  - Add small cells inside buildings without provisioning new eNBs at MME
  - Easy to support X2-based handovers in partnership with macro eNB vendors



LTE Hand-in using ANR



Illustration

- SN registers to MME using Global eNB id and appears as a single eNode B
- UE sends a measurement report with small cell PCI
- Macro eNodeB will request for ANR and learns eCGI
- Macro eNodeB request S1 Handover using Global eNB Id and includes eCGI.
- MME will forward the hand-in message to the proper SN using Global eNB id.
- E-RAN identifies which small cell the UE is handing into

Admission Control and Access Schemes

Centralized Admission Control and Congestion Handling at SN

SN has system Level View for Intelligent Decisions

- Centralized RRM functionality at the SN
- Prioritize existing calls over new calls
- Prioritize CS calls over PS calls
- Prioritization of emergency calls
  - Will disconnect existing call to make room for emergency call, if required
  - UMTS implementation based on RRC establishment cause
  - LTE implementation based on ARP value in Initial Context setup
- Optionally prioritize white-list users over guest users.
- Under overload conditions, redirect CS calls to the macrocell

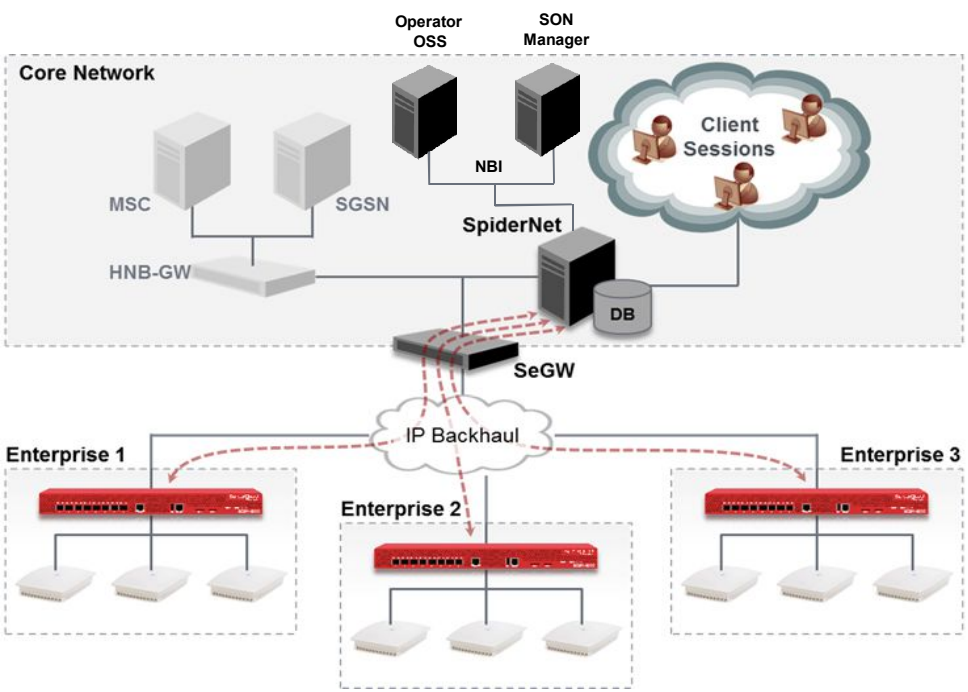
OSS/EMS

SpiderCloud Wireless

SpiderNet Overview

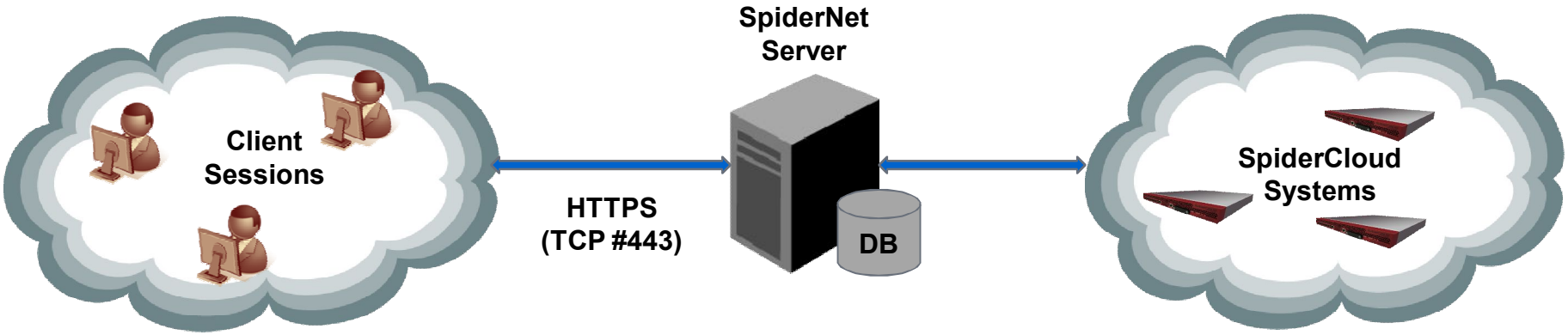
- **SpiderNet:** Management software used to remotely manage, configure, monitor, and troubleshoot the E-RAN.
- **Management Hierarchy**: SpiderNet manages the Services Node, which manages all Radio Nodes. Connects to core via TR-069. Also uses SNMP, Syslog, SCP, FTP.
- **Security**: Users are segregated via role-based access control. Audit logs.
- **Location**: SpiderNet server in operator core, behind security gateway.

SpiderNet: E-RAN Management System



- GUI based centralized E-RAN management system
- Rapid provisioning and remote administration of E-RAN deployments
- Northbound interface to operator's network management and SON systems
- Features
  - Configuration management
  - Bulk provisioning (templates)
  - Scheduled operations (upgrades, backups)
  - Access control and audit trails
  - Fault management and correlation
  - NBI for alarm forwarding to OSS
  - Performance counters and KPIs
  - Threshold crossing alerts
  - Reports, emails

Hardware Requirements



Client
Java Desktop Application or
Java Applet (in web browser)

Windows and/or Linux

Minimum Server Requirements
Intel Xeon 6-core 64-bit
CPU 2.4 GHz or equivalent
16GB RAM
1 TB free disk space
O/S:
RedHat Enterprise Linux Server (RHEL 6.4)
or Linux CentOS 5.8 (or later)
Database:
MySQL Classic Edition

Benefits to Operators

- Centralized Configuration Management
  - Apply changes to multiple deployments at once
  - Template-based configuration simplifies provisioning process
- Scheduled Software Upgrades
  - Conveniently schedule software upgrades during maintenance slots for multiple small-cell clusters
- Fully Integrated with SCW's TR-069 Client, TR-196 Data Model, and All Extensions
  - Support for hundreds of configurable and thousands of status (read-only) attributes at the services node and radio nodes
- Single Point of Management for Scheduling Maintenance Tasks
  - Database backups
  - Periodic uploads of log files and performance reports
- Fault Management and Performance Management
  - Supports both local and NBI function

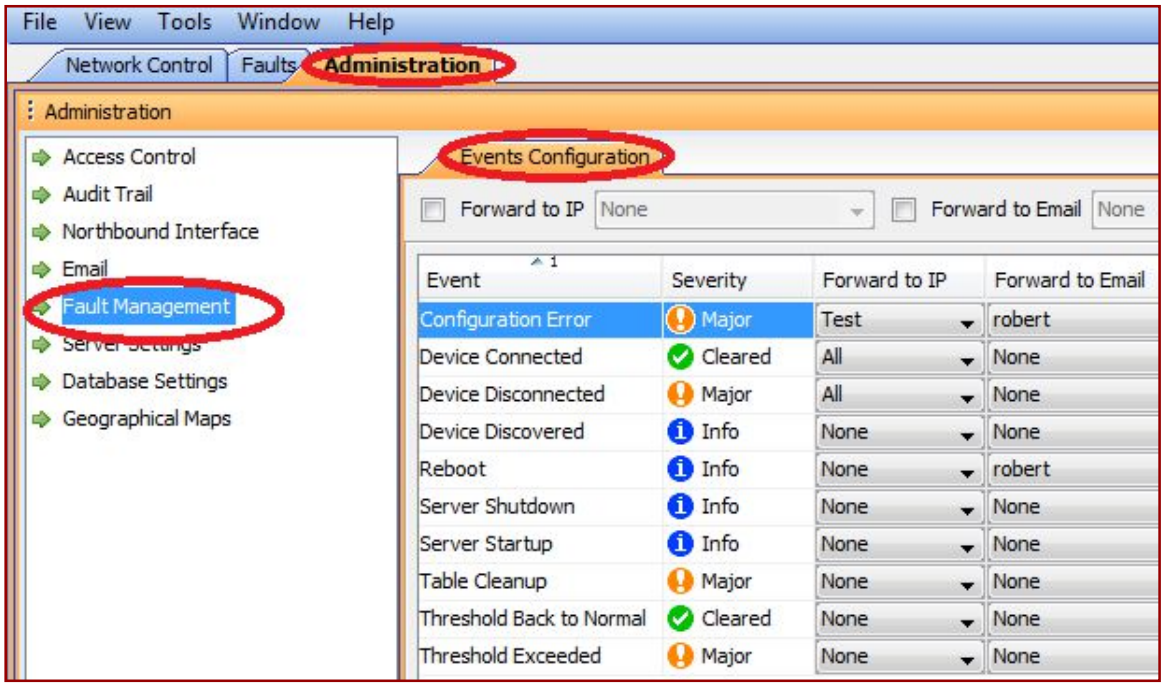
Services Node Configuration and Provisioning

- **TR-069 Standards-Based**
  - **TR-069:** Services node configuration through the TR-069 interface
  - **Purposes:** Synchronizes services node and SpiderNet configurations
- **Tasks**
  - **Scheduled Maintenance:** OS upgrades, network changes
  - **Regular Tasks:** KPI reports, configuration backups, log bundles
  - **Advanced:** Access to all parameters in the SpiderCloud data model
- **Configuration Templates**
  - Create/modify/delete templates for commonly applied parameters
  - Templates tied to specific software version(s)
  - Can be applied to multiple services nodes at once for consistent provisioning

Fault Management

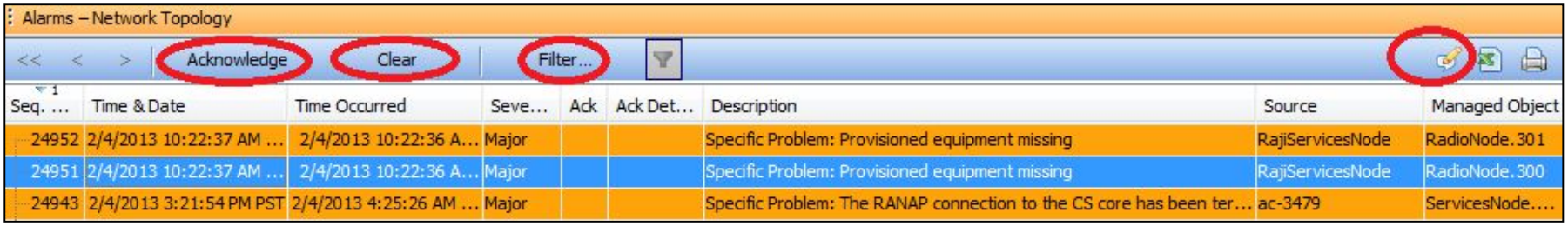
SpiderCloud Wireless

Fault Management Overview



- **Purpose:** Sends alerts and notifications.
- **Setup:** Can be sent to administrators by email or forwarded to NBI using SNMP traps.

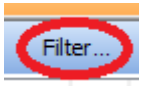
Alarm Options



- **Helpdesk Operations**
  - **Annotate:** Add ticket number, assignee, and comments.

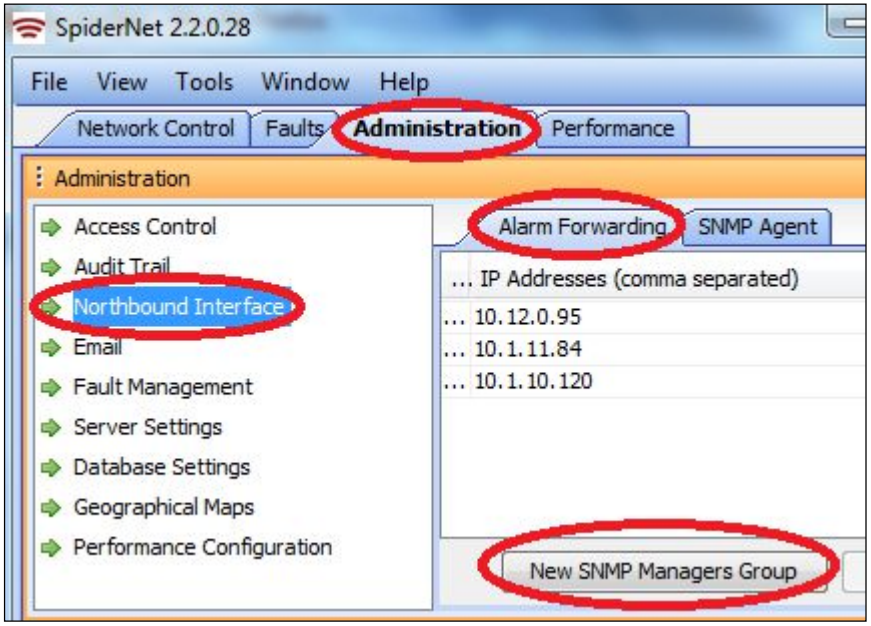
  - **Manage:** Clear to remove alarm. Acknowledge to confirm that an alarm has been viewed/processed by a given user.

  - **Filter:** Display only alarms based on alarm time, type, severity, alarm type.

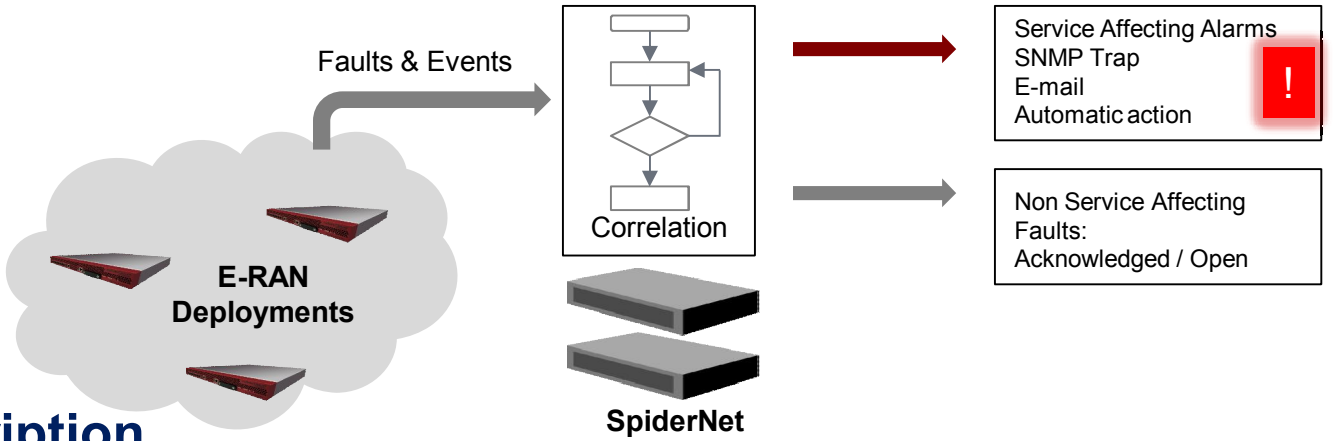


Network Management System Integration

- **Overall**
  - **Purpose:** To permit SNMP traps to be forwarded to another NMS
  - **Routing:** Traps are first sent to SpiderNet, then forwarded
- **Options**
  - **Specify Multiple Servers**
  - **Support for SNMP v2C and v3**
  - **Alarm Sync**
  - **Heartbeat**



Fault Correlation Framework



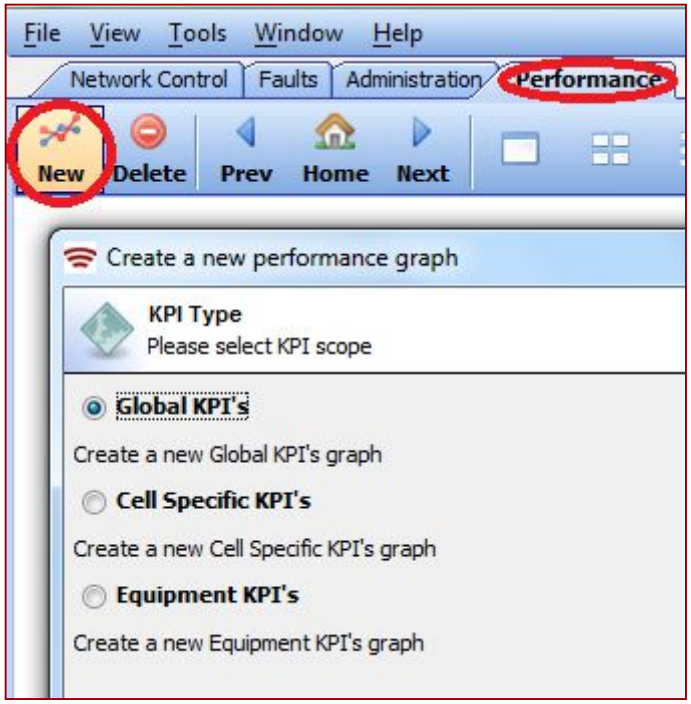
- **Description**
  - Interface for developing intelligent fault and event correlation rules
  - Reduce alarm redundancy by grouping events referring to the same symptom and highlighting probable system fault
  - Automatic action depending on correlation rule logic
- **Benefits**
  - Provide higher visibility into service affecting alarms
  - Reduce number of alarms seen by higher level OSS

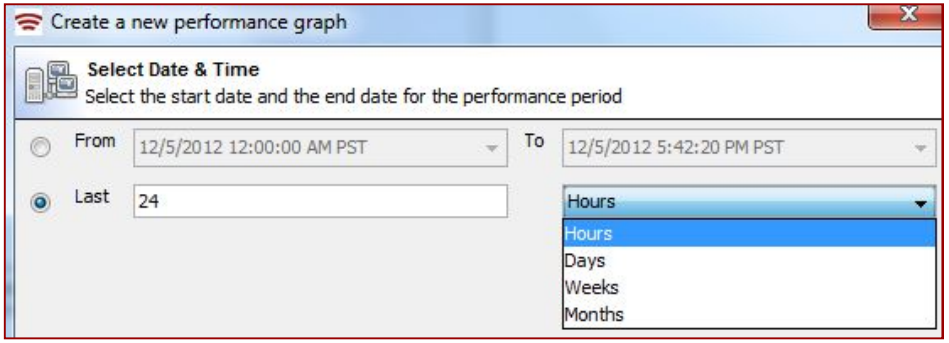
Performance Monitoring

SpiderCloud Wireless

Key Performance Indicators (KPIs)

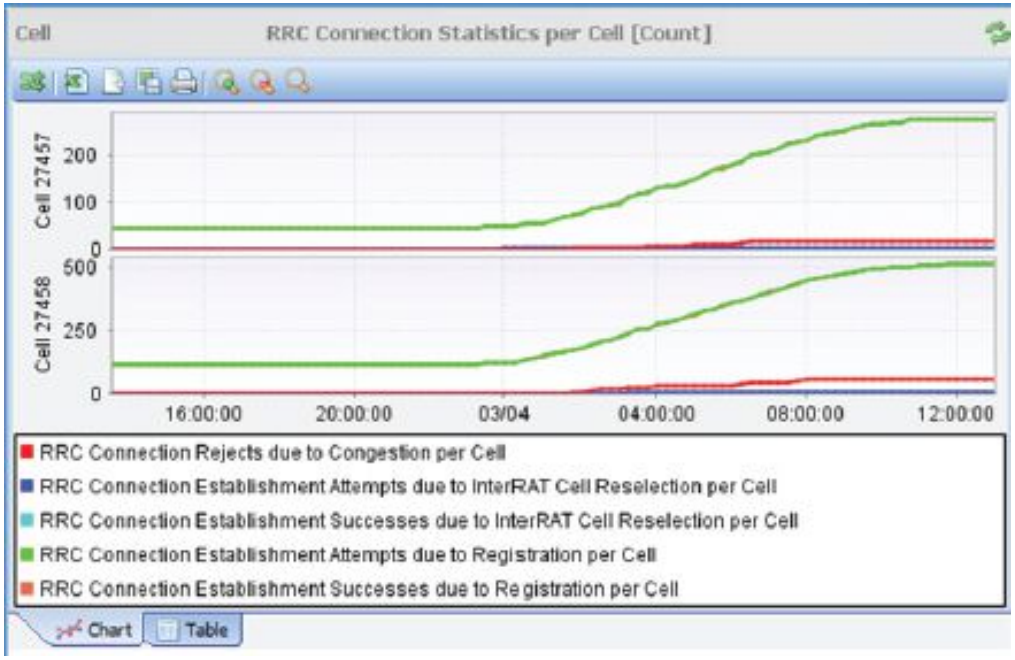
- **KPIs:** System-wide, cell, or equipment
- **Report Period:** Between two dates or over the last X hours or days
- **Polling:** Data collected at configurable intervals
- **Aging:** Reports for older data (>1 day) are based on less frequent sampling
- **Views:** Multiple KPIs can be displayed on the SpiderNet GUI.
- **Data Export:** CSV or raw text





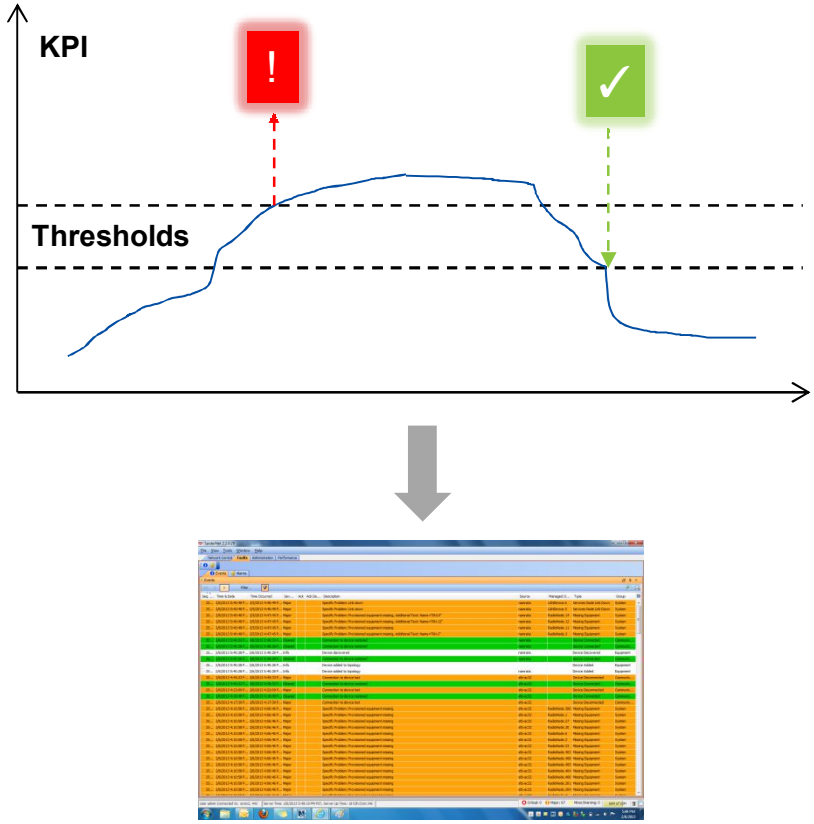
The Performance Tab

- Displays snapshots of collected performance monitoring data for a selected services node.
- For example, the statistic RRC Connection Statistics per Cell contains the KPIs listed at the bottom of the chart.



Threshold Crossing Alerts (TCA)

- **Description**
  - Alert NOC on deviations from normal operation or performance
  - User-defined KPI thresholds
    - Examples: CDR > 1%, CPU>50%.
  - Severity based alarms triggered on KPI threshold crossing
  - Alarms can be forwarded as SNMP traps on the NBI
- **Benefits**
  - NOC can be alerted and take action immediately on system performance degradation



Email: Daily KPI Reports

- Configure daily KPI reports from the **Scheduled Task** tab
- Report formats are based on templates
- Reports are sent to email groups configured in the **Administration** tab
- Select or configure the:
  - report template
  - list of services nodes
  - report name and description
  - dependency task
  - start time
  - frequency (default does not repeat)
  - name of email group
  - report format (default ASCII)

Northbound Interfaces

SpiderCloud Wireless

Northbound Interfaces

- Fault Management (FM)
  - Alarm forwarding to northbound OSS via SNMP traps
  - Periodic alarm synchronization
  - Periodic heartbeat (keep alive)
- Performance Management (PM)
  - Performance data stored in XML files on SpiderNet
  - XML files can be periodically FTPed to northbound OSS
- Configuration Management (CM)
  - Support for periodic SN configuration backup (XML format) to a northbound OSS