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Planning Small Cells – Het-Net

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GOALS OF THE WORKSHOP

Participants to the workshop will get an understanding of the benefits and challenges offered by small cell technologies so that they will be in the position to:

- Determine the specific options they have in terms of applications and benefits;
- Initiate key strategic activities that will lead to defining their optimal small cell strategy, on both the technology and the marketing fronts;
- Understand all areas of their business that will be affected by small cells;
- Start fleshing-out their specific requirements, for both the macro and the small cell network , necessary for their small cell deployment; and
- Initiate an educated dialog with equipment vendors on procurement initiatives.

Agenda

- Categories of Small Cells
- Heterogeneous Network
- Benefits of Small Cells
- Market Update
- Challenges
- Solutions
- Strategy Roadmap

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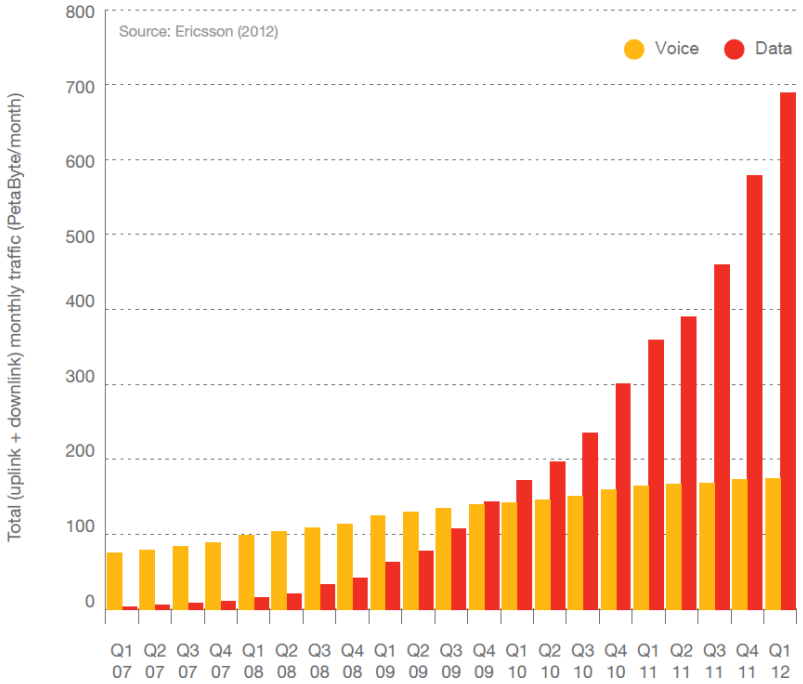
Introduction

Increasing Capacity & Performance

- Acquire New Spectrum
- Increasing Spectral Efficiency
  - MIMO
  - LTE
  - …
- Increase Spectrum Re-use
  - Split Existing Cells
  - Build New Cell Sites
  - Deploy Small Cells

Increasing Coverage

- Build New Cell Sites
- Deploy Small Cells



Global Total Traffic

$$C_{supply} = B_{MHz} \times E_{Mbps/MHz} \times N_{cells}$$

Small cells are cost-effective solutions to provide capacity, coverage, higher spectral efficiency and performance in areas whose scales are much smaller than a macro cell.

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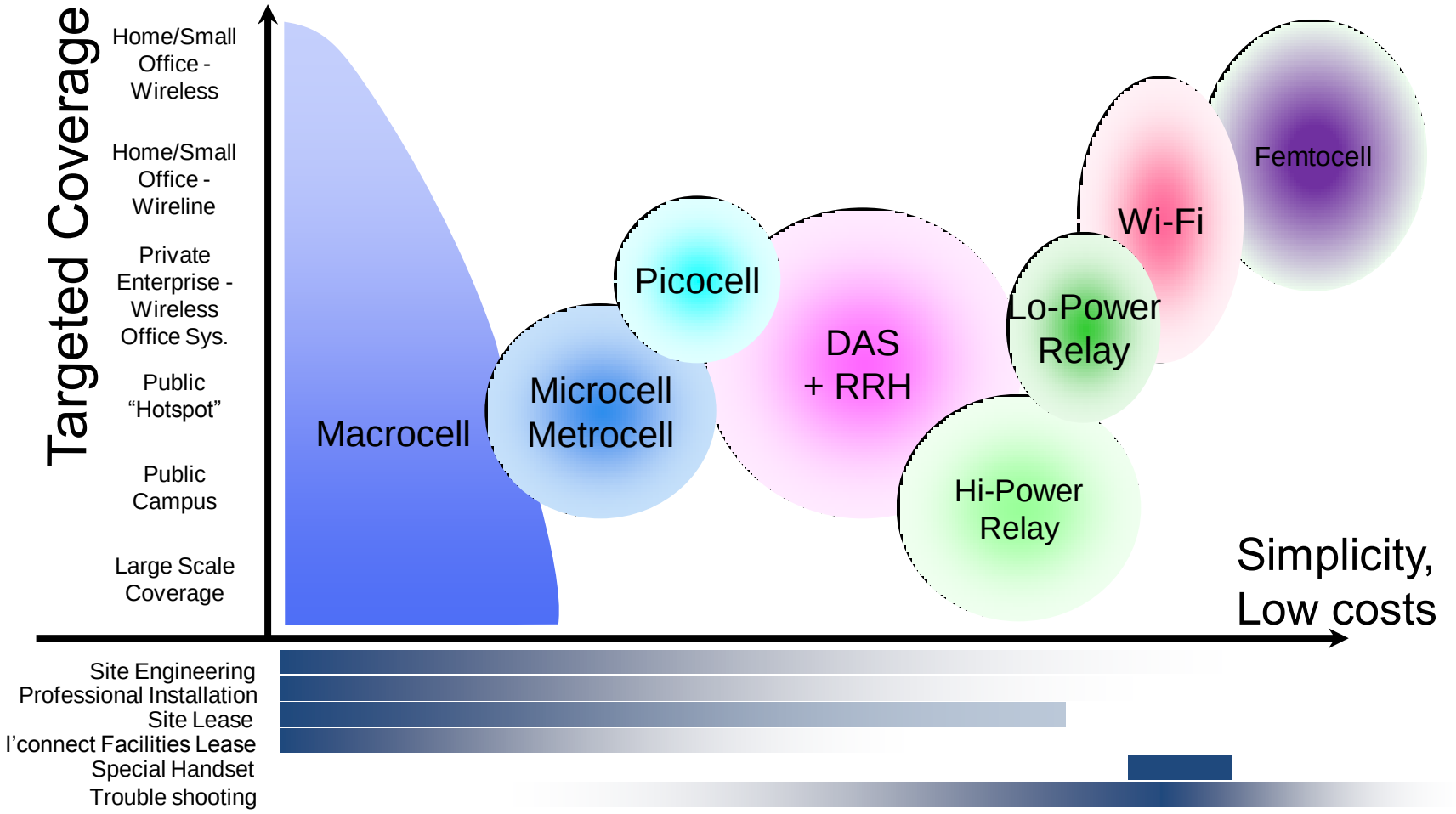
Categories of Small Cells

Scope of Small Cell Forum

- Femtocells: Primarily deployed in consumer and enterprise environments
- Picocells: Deployed in indoor public areas (airports, train stations, shopping areas)
- Microcells: Usually deployed in urban areas or in cases where the footprint of a macrocell is not necessary
- Metrocells: Deployed in urban areas to alleviate capacity bottlenecks
- Relay Nodes: repeaters or small base stations linked to a donor base station
- Distributed Antenna Systems (DAS): distribution network using coaxial cables, couplers and power splitters to distribute the RF signals to several antennas (passive or active)
- Remote Radio Head (RRH): RF transceiver, amplifier and filter remotely located from the baseband system
- Carrier Wi-Fi Access Point (AP)

Categories of Small cells



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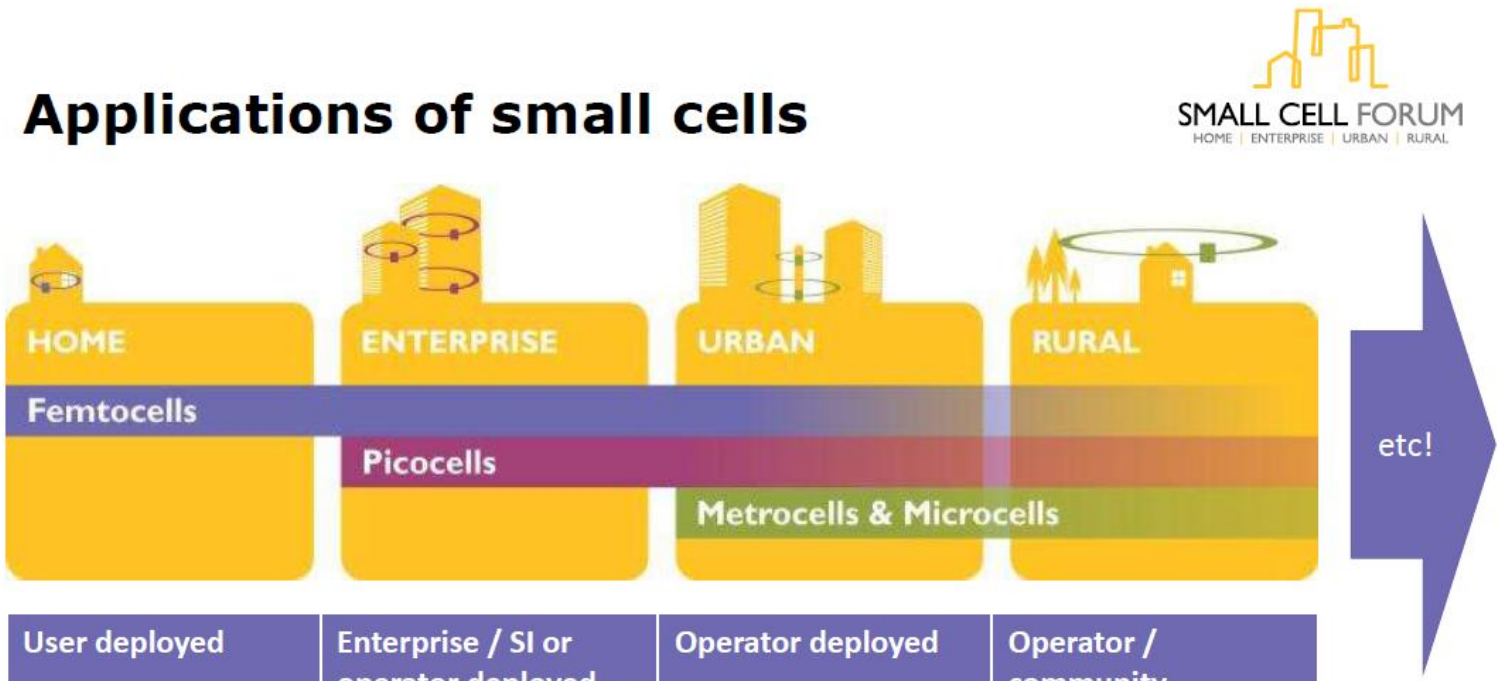
Source: Crown Castle International

Applications of Small Cells



User deployed	Enterprise / SI or operator deployed	Operator deployed	Operator / community deployed
Shared backhaul	Shared or dedicated backhaul	Dedicated wired or wireless backhaul	Dedicated wired or wireless backhaul

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Types of small Cells

Specifications	Microcells	Picocells	PS Femtocells
Cell radius	2 km maximum	200 meters max	10-100 meters
Output Power	33—36 dBm/2—5 W	250 mW—1 W	1 mW—250 mW
Number of users	More than 100	30 to 100	Less than 20
Controller signaling protocol	Iub	Iub	Iub
RRH/RRU option	Yes	Yes	No
DAS usage	Yes	Yes	No

Applications	Microcells	Picocells	PS Femtocells
Low power outdoor sites	Yes	Yes	No
Villages and road sites	Yes	Yes	No
City centers	Yes	Yes	No
Rooftop sites	Yes	Yes	No
Stadiums	Yes	Yes	No
Tunnel sites (e.g., subway)	Yes	Yes	No
In-building sites (e.g., buildings}	Yes	Yes	Yes
Shopping centers, malls	Yes	Yes	Yes

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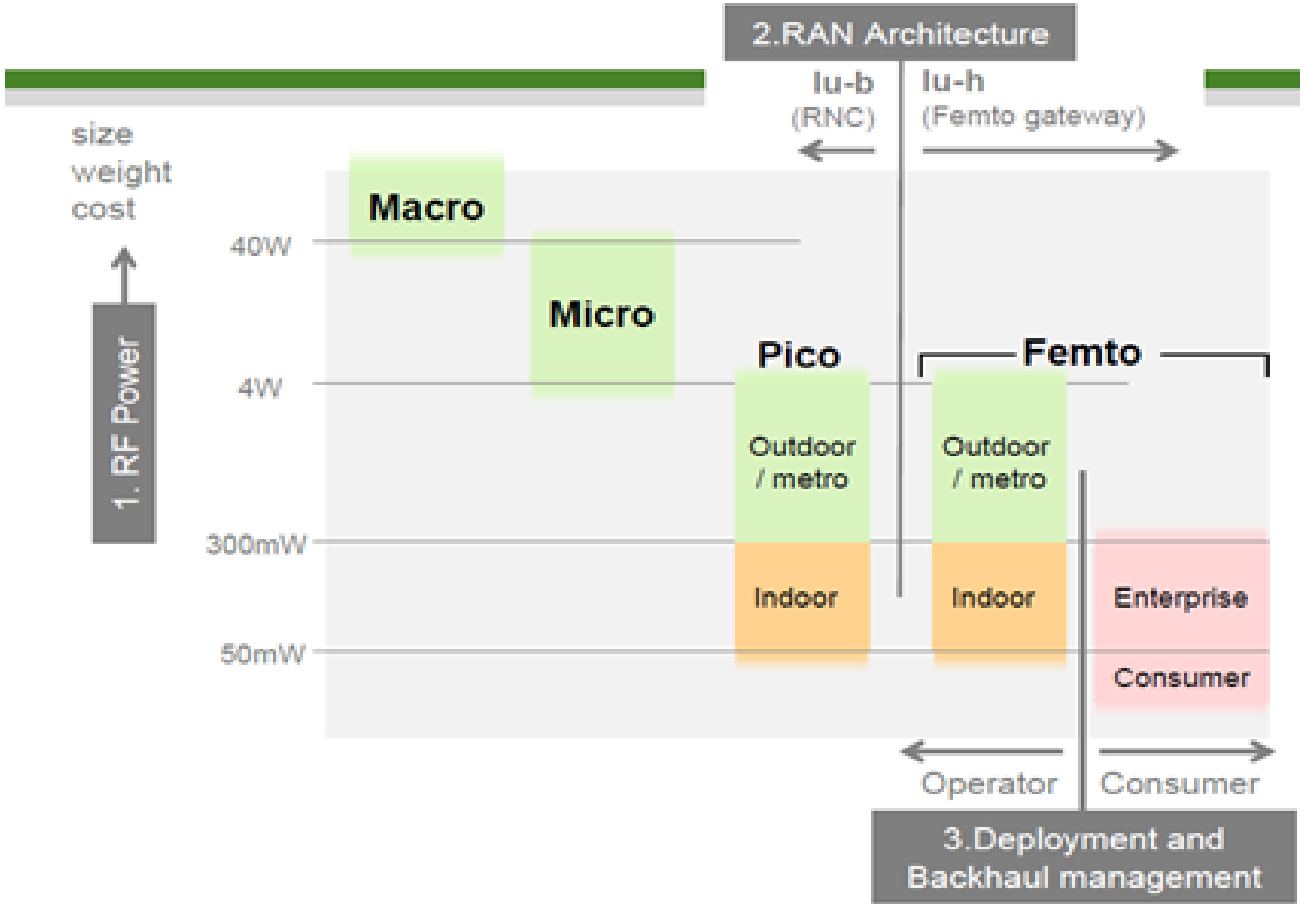
Source: ALU

Categories of Small cells



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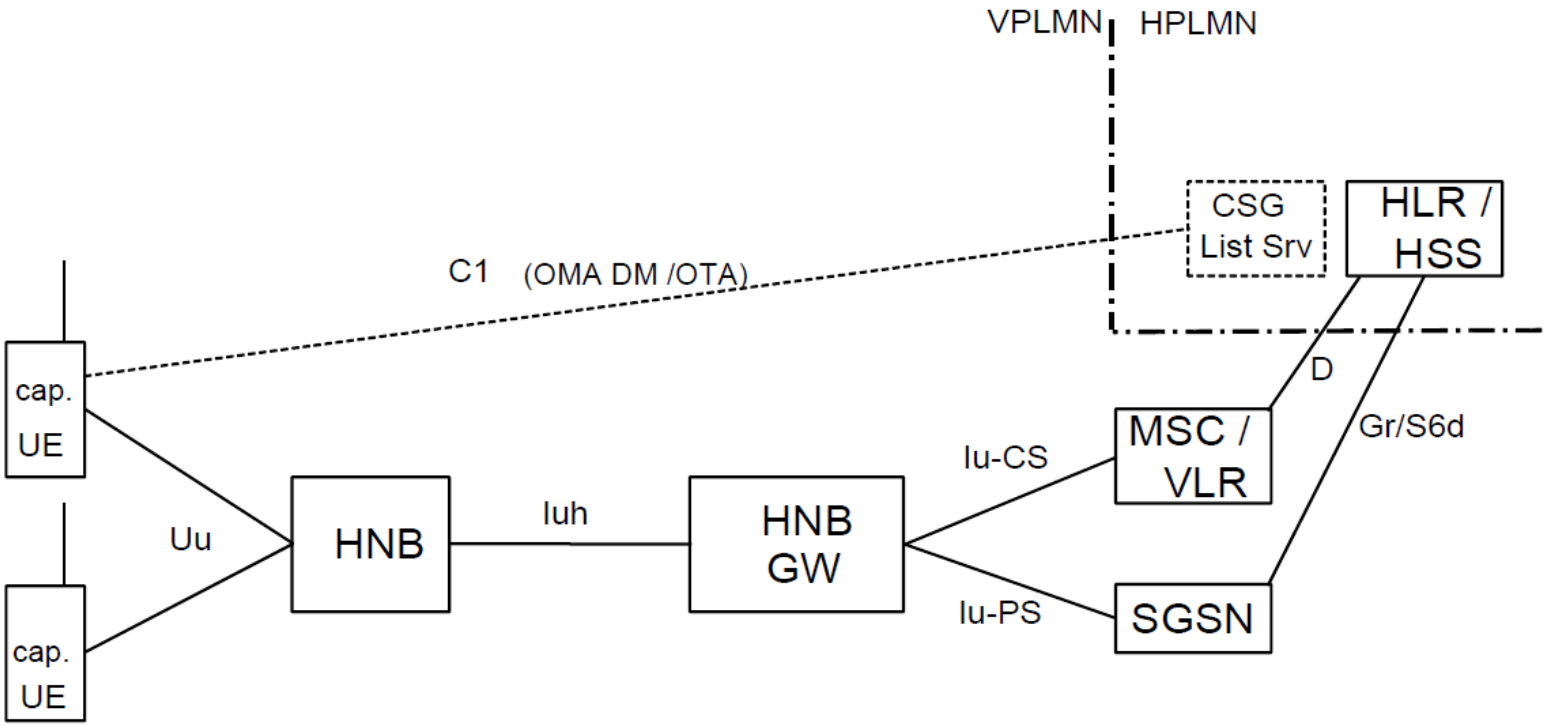
Source: Ceragon Networks, Wireless Backhaul Solutions for Small Cells

3G Femtocell – Home Node-B Rel8



Source: 3GPP TS 23.830

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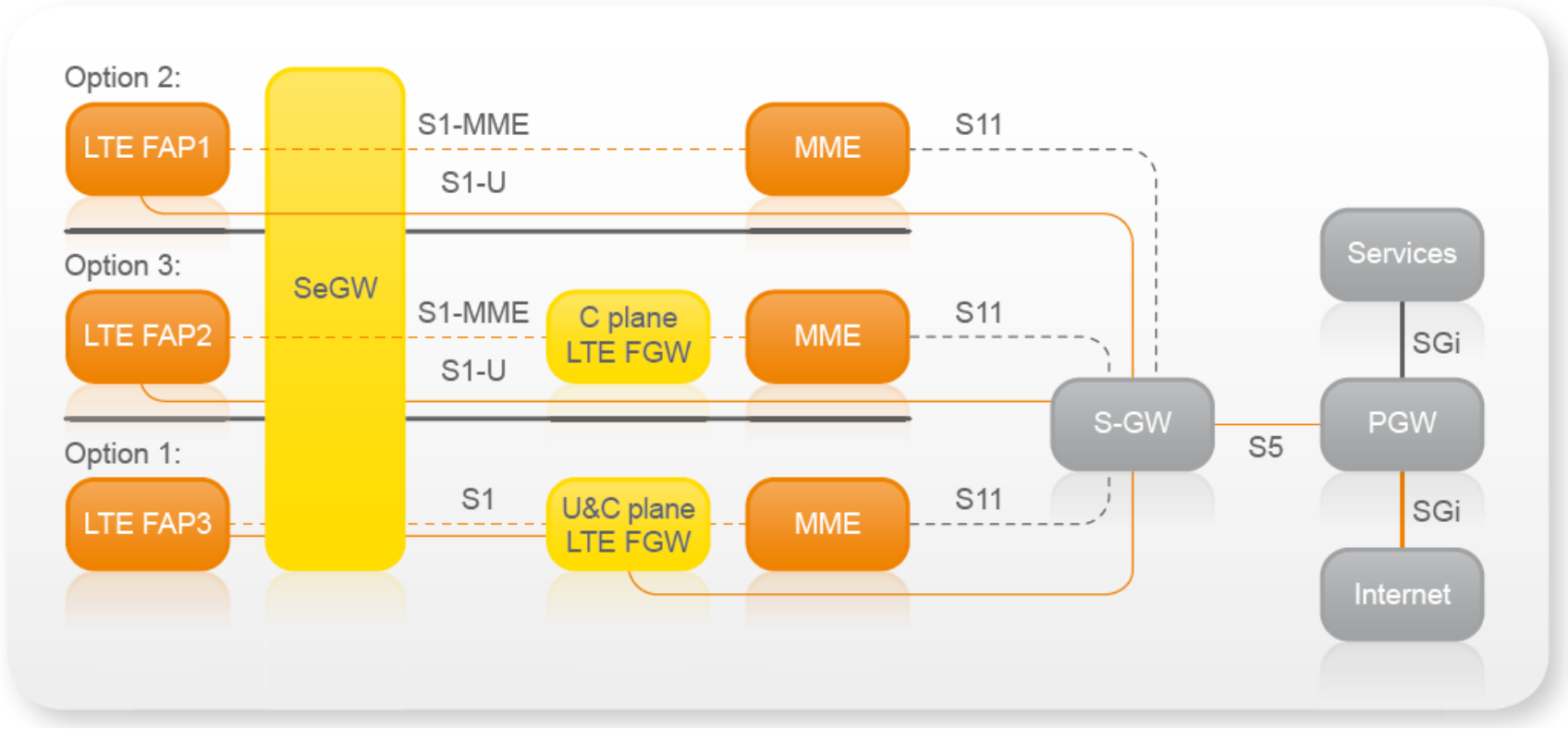
LTE Femtocell – Home eNB Rel9&10



Source: NSN/3GPP TS 23.830

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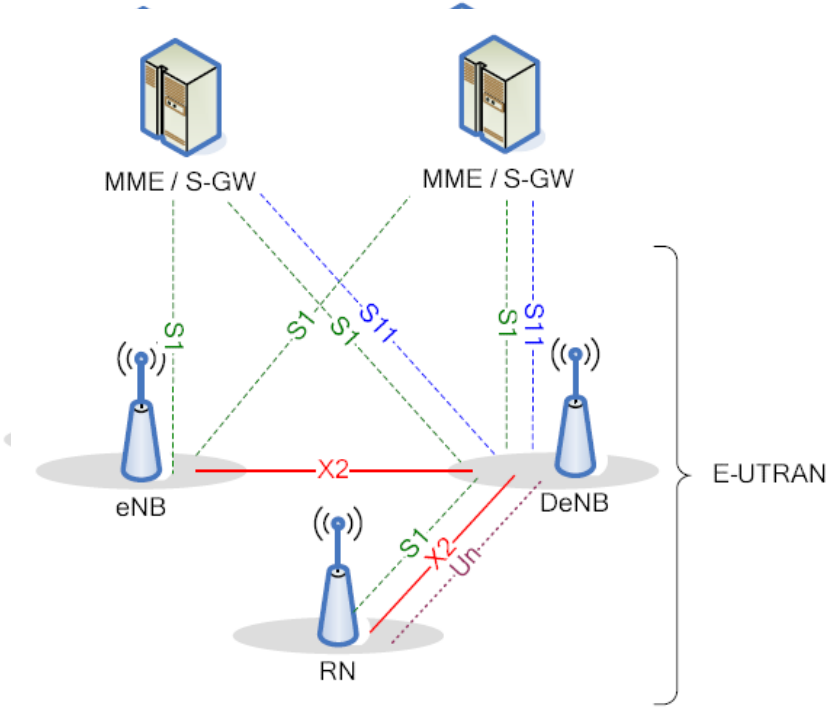
Advanced Relays – Rel 10

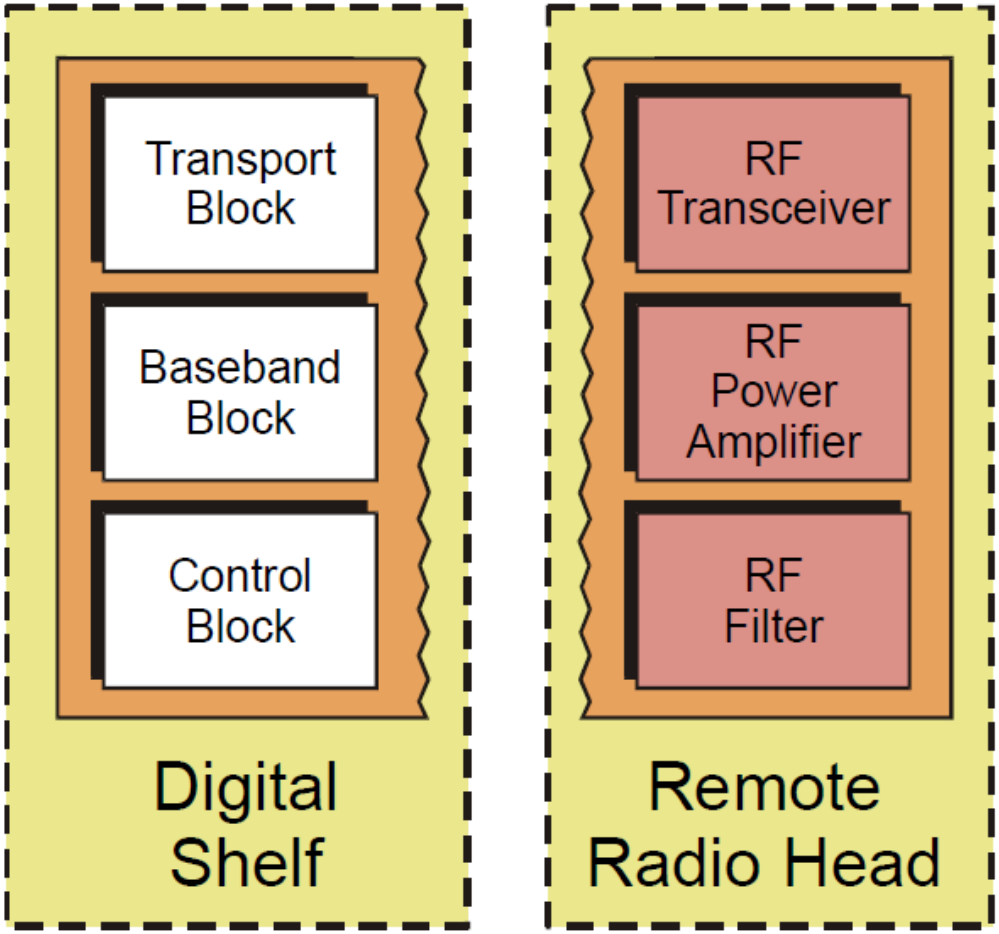


Source: 3GPP TS 36.300

Type 1 Relay Node

- The eNB-to-relay link is operating in the same carrier frequency as eNB-to-UE link.
- The Relay Node (RN) has the following characteristics:
  - It control cells, each of which appears to a UE as a separate cell distinct from the donor cell
  - The cells shall have their own Physical Cell ID (defined in LTE Rel-8) and the relay node shall transmit its own synchronization channels, reference symbols, …
  - The UE shall receive scheduling information and HARQ feedback directly from the relay node and send its control channels (SR/CQI/ACK) to the relay node
- No UE impact, and all legacy LTE UEs shall be served by the relay cell.
- Two use-cases: Coverage-area extension and Capacity/data-rate area extension

Remote Radio Head



Wi-Fi APs

- Can be cost-effective for data
- Standalone Wi-Fi AP or integrated with HSPA/LTE (*)
- Optimal for high-traffic low-mobility scenarios : conference rooms, stadiums
- Carrier-grade Wi-Fi AP support 2.4 and 5 GHz, and 2X2 MIMO (i.e. aggregate throughput of 200Mbps)
- According to the Wi-Fi Alliance, about 200 million households use Wi-Fi networks, about 750,000 Wi-Fi hotspots worldwide, by over 700 million users and there are about 800 million new Wi-Fi devices every year.
- Cisco has shipped over 11 million access points to customers worldwide.

(*) alcatel-lucent's lightRadio now integrates WiFi; Nokia Siemens Networks' Flexi Zone and ericsson's mRBS and pRBS small cell series integrate Belair's WiFi features

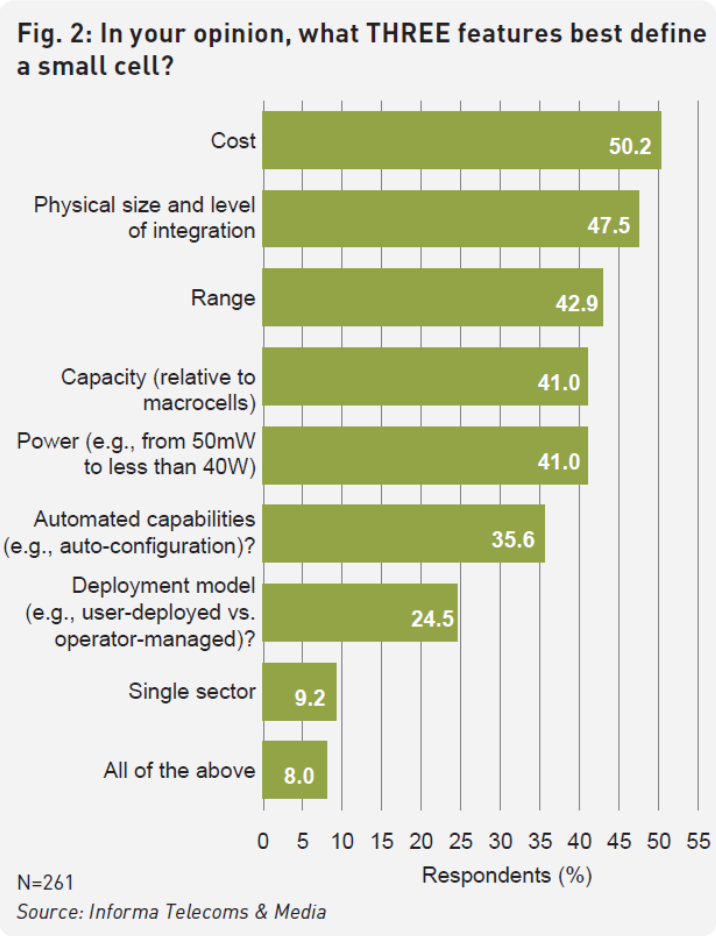
Wi-Fi Cellular Integration

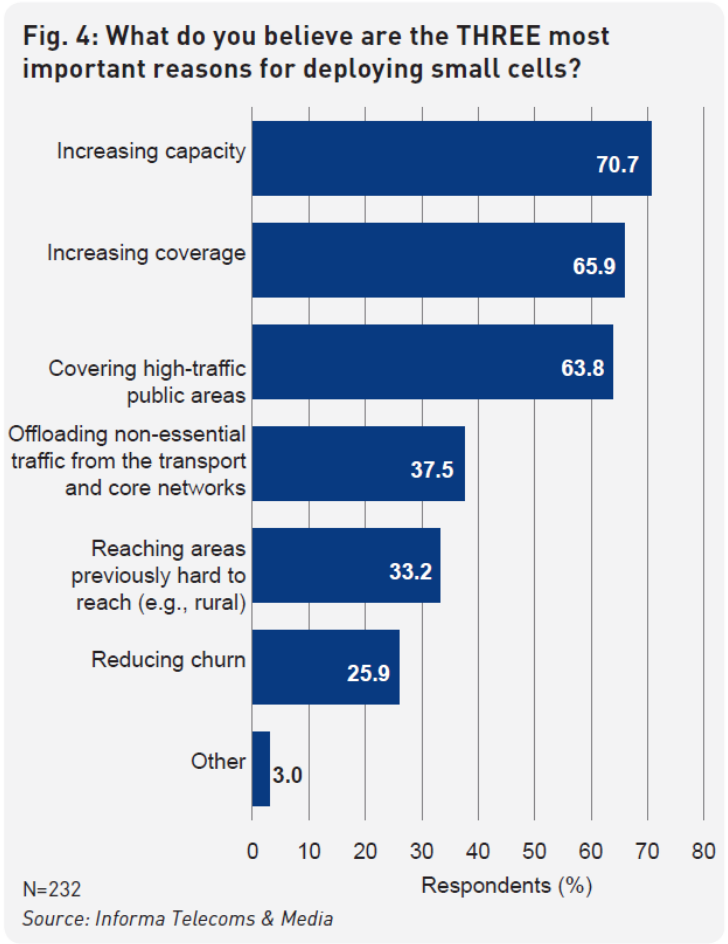
- I-WLAN
  - 3GPP-based
  - Integrates wifi as another radio access connected to the mobile core
  - Provides operator's policies
  - Late relative to Hot Spot 2.0
- Hot Spot 2.0
  - Wi-Fi Alliance
  - Certification program in 2012
  - Covers network discovery, authentication, roaming
  - Interworking with 3GPP not optimal

I-WLAN vs Hot Spot 2.0

- I-WLAN
  - IPSec tunnel from the mobile to the P-GW (i.e. untrusted network): scalability issues
- Hot Spot 2.0
  - IPSec tunnel from the AP to the P-GW (i.e. trusted network)
  - AP-based authentication via STa IF to the EPC AAA server
  - Rel-10 S2a-based mobility over GTP (SaMOG)
  - Air IF secured through 802.1x EAP-SIM/AKA authentication and AES128 encryption

Small Cells : Definition & Rationale





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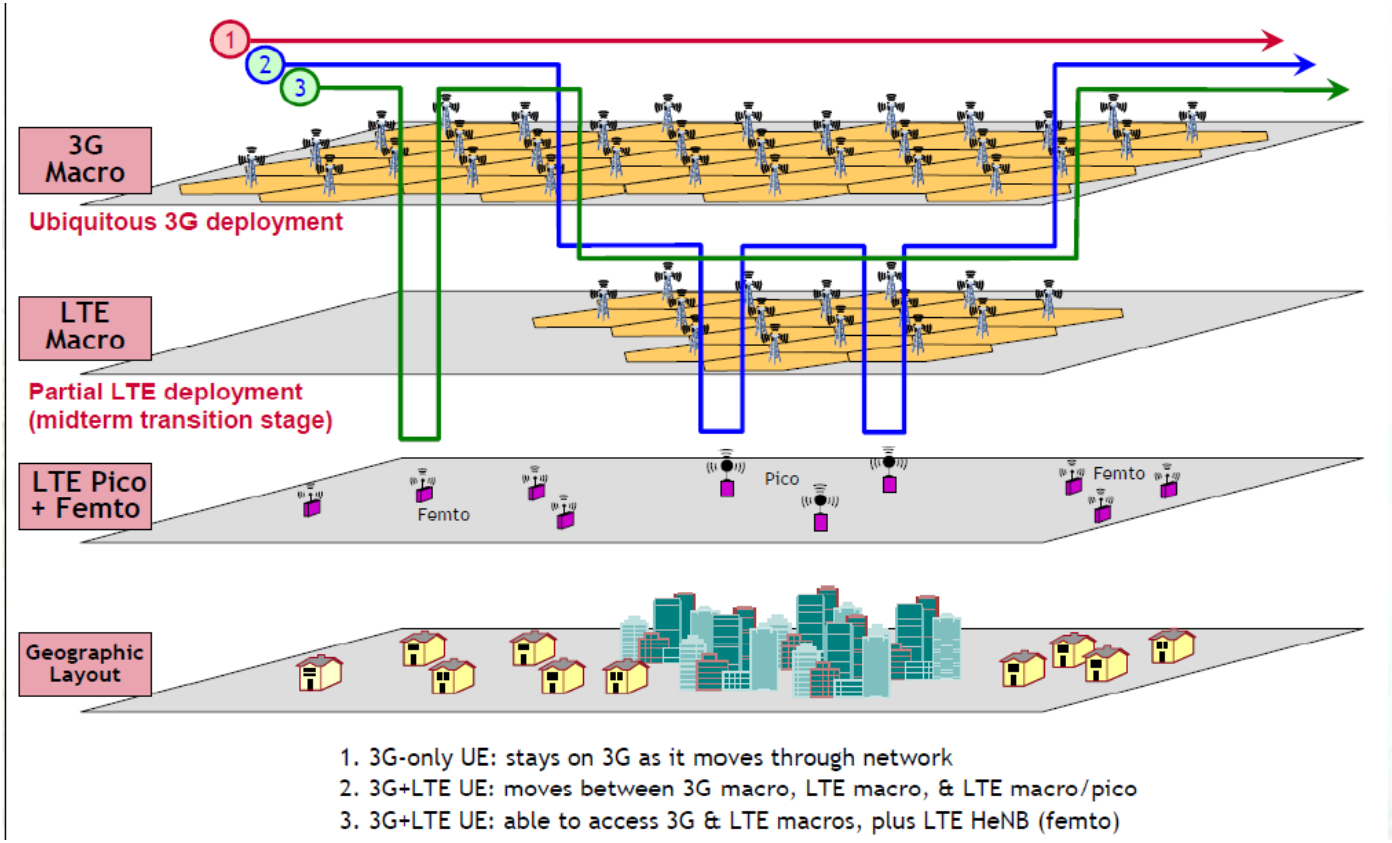
Heterogeneous Networks



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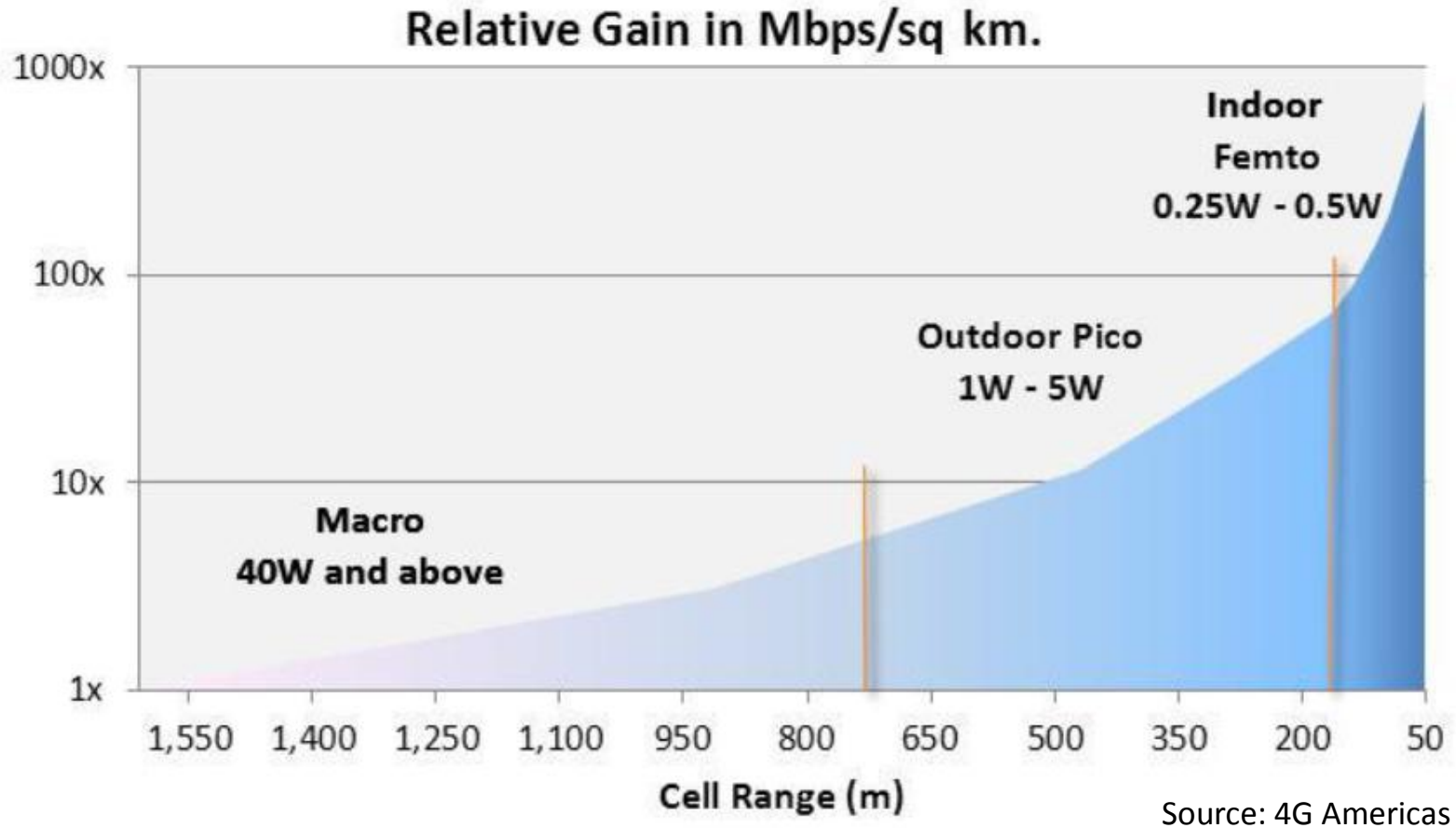
Small Cell Benefits



Source: 4G Americas

- 4 picocells in each macro sector show capacity gains over 10x (per 3GPP 36.814)
- HET-NET's enabled UEs reduce transmit power and improve battery life

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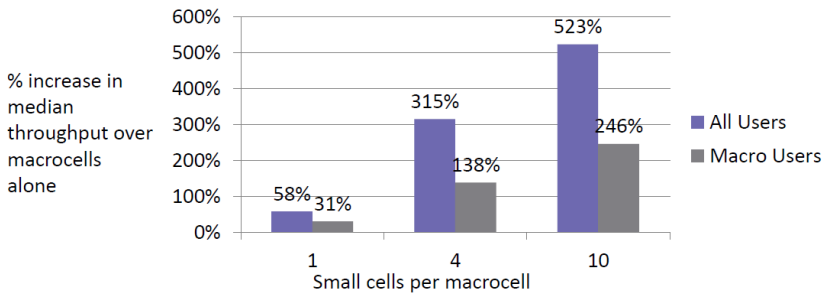
Small Cell Forum Analysis

- Offloading the macro cell
  - **One** small cell per macro: **21%** of users offloaded
  - **Four** small cells per macro: **56%** offloaded
  - **Ten** small cells per macro: **75%** offloaded
- Increasing typical throughput for both macro & small cell users



	Capacity/Mbps	
	Femto + macro	Macro-only
Expected available throughput per UE	7.87	0.08
Number of UEs per cell (34 UEs across three macro cells)	11.3	11.3
Expected available throughput per macro cell (= network capacity)	88.9	0.9

Increasing the available throuput with the use of femto plus macro cells (Small Cell Forum).

Source: Small Cell Forum & ALU

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DAS Benefits

- **Coverage**: DAS architecture provides coverage in areas that cannot be effectively addressed with traditional sites.
- **Capacity**: DAS can closely align capacity to actual market requirements, managing available radio resources.
- **Spectrum**: DAS uses available frequency spectrum efficiently through multiple low-power transmission points.
- **Interference**: DAS reduces interference through low radiation centers and lower output power.
- **Data**: DAS provides better data throughput given signal strength and proximity of transmission points to user equipment.
- **Scalability**: DAS is a scalable network that can meet future capacity requirements, or additional carriers, by adding additional nodes.
- **Adaptability**: DAS can respond to market dynamics, equipment architecture changes and new technologies.

Source: Crown Castle International

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- Pros & Cons
- Challenges
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Microcells

Pros:

- Easier to find sites
- Fast deployment
- Gives good indoor coverage and capacity without being deployed inside the building (as
- an indoor solution)
- Cost efficient deployment due to low site costs
- Capability of increasing system capacity with a limited interference contribution
- Can be deployed on the same frequency as a Macro layer as long as the isolation is sufficient.

Cons:

- Lower capacity and output power than a Macro
- Less flexibility and harder to expand than a Macro
- Expensive solution for wide area coverage

Picocells

Pros:

- Small and easy-to-find sites
- Support for high traffic density in small hotspot indoor areas
- Due to its size, it can often be placed close to the traffic it is aimed to cover.

Cons:

- Indoor installations require transmission and power supported by the “building owner”
- Many nodes are needed for continuous coverage
- Less flexible. If traffic changes, the Pico must be moved (office space moves, Pico needs to be moved)

Femtocells

Pros

- An ability to provide a DSL-like service to the home, thereby greatly increasing the potential market for the operator
- An ability to offer additional coverage and/or capacity within their existing network without incurring infrastructure or site rental costs.

Cons

- Unplanned interference with macro
- Closed-User Group management
- Location determination (E911, location-based frequency plan…)
- Backhaul QoS control
- More complex integration into the macro network (location areas, Primary Scrambling Codes, femtocell network name display, special billing…)
- Integration with a home IP network

Passive DAS Systems

Pros

- Lower initial costs (compared to active DAS)
- Higher reliability (compared to active DAS)
- Support multi-operators and RF technologies
- Spectrum efficiency (all radio channels are available in all parts of covered area)
- Adaptive to different coverage area shapes
- Easy to confine coverage and reduce interference from and to the macro network
- Requires one single transmission line for multiple “cells”

Cons

- RF loss can limit distance/coverage
- Need to layout cables
- Require inbuilding RF planning

Remote Radio Head

Pros

- Lower power PA requirement, due to the elimination of coax cable losses
- Lower OPEX (electricity) costs, for the same reason
- Lighter weight on the mast, due to the replacement of copper with optical fiber
- Less footprint at the site reducing the site rent and the need for site cooling (OPEX)
- Allows bigger distances between the Node B cabinet and the RRH, and also makes it possible to use dark fiber from a fiber provider.

Cons

- Weight moved to the top of the mast/tower creating instability
- Opex costs: rigger, daylight and weather conditions

Wi-Fi Access Points

Pros

- Ubiquity of APs
- Low-costs
- Offloads the licensed spectrum

Cons

- Not supported on all UEs
- Limited QoS management (RF and backhaul)
- Voice support
- Security
- Low Integration into macro network & services (authentication, handover, special billing, home zone, SMS…)
- UE battery drain

Comparative Analysis

Solutio	Strengths	Primary Applications	Application considerations
Macro Cell	Large coverage areas, primary source of capacity and coverage	Large scale deployments, primary source of coverage in networks Today. Driver for DAS, and remote radio heads	Physical Size/footprint, most extensive and advanced feature sets are available as compared to Micro or Pico, higher capacity than other Node B options
Microcell	Ease of deployment, smaller size. Can be wall-mounted	Focused outdoor coverage, and directed indoor coverage Could be used to improve indoor coverage from outside Often used as a hotspot solution Driver for DAS, and remote radio heads	Future capacity needs. Less flexibility than Macro Node B in terms of feature set.
Picocell	Very small size Easier to place in required locations	Indoor hotspots. Indoor installations, such as shopping malls.	Lower capacity than Micro, but smaller in size
Femtocell	Smallest size	Residential or very small enterprise	Limited capacity, 2-4 voice users
Passive DAS	High reliability, multiple technologies and multiple bands	In-building, tunnels, smaller campus, convention centers, and areas difficult to gain approval of planning boards.	Not suitable for very long distances outdoors. Preferred solution for many indoor applications
Relay Nodes	Targeted outdoor and Indoor coverage	Greenfield and coverage extension, fill-in, inbuilding	Consider capacity impacts on donor site, poor deployment may de-sensitize Node B RX
Remote Radio Heads	Ease of deployment, lower power requirements, long distances from Node B are possible (20 kM)	All Macro and Micro Node B applications, areas difficult to gain planning approval.	Expected deployments on rooftops, however if deployed on tower tops may expect maintenance and repair challenges. Link to radio heads requires fiber (>1.5 gbps BW)

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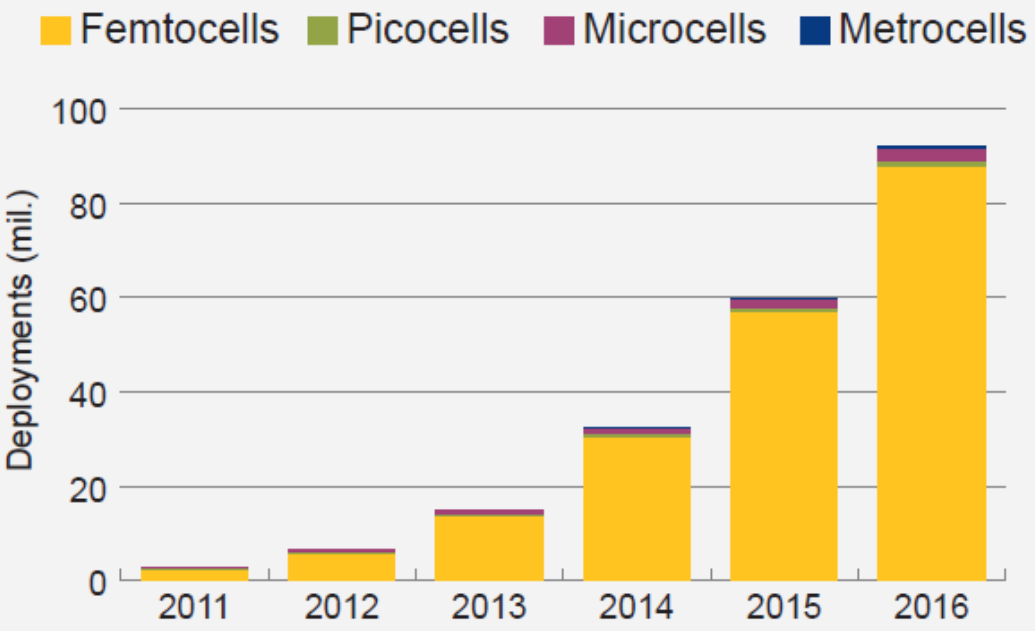
Small Cell Market Forecasts

Fig. 3: Global, small-cell deployment forecasts, by category, 2011-2016



Note: Figures refer to year-end

Source: Informa Telecoms & Media

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Femtocell Market Update

Fig. 1: Femtocell deployment segmentation according to target group		
Target group	Number of deployments	Examples
Consumer	24	Vodafone UK, AT&T, Cosmote
Enterprise	6	T-Mobile UK, Network Norway, Orange France
Consumer and Enterprise	7	Vodafone NZ, Verizon Wireless, Sprint
Public	3	Vodafone Qatar, SK Telecom, TOT Thailand
Rural	1	Softbank (using satellite backhaul)
Source: Informa Telecoms & Media		

Fig. 2: Small-cell industry firsts		
First launch	Sprint Wireless (US)	September 2007
First enterprise launch	Verizon Wireless (US)	January 2009
First public safety launch	TOT (Thailand)	March 2011
First standardized launch	Mosaic (US)	February 2012
First LTE femtocell	SK Telecom (South Korea)	June 2012
Source: Informa Telecoms & Media		

Fig. 4: Commercial femtocell service launches by geography and technology, 2Q12		
Regional view	UMTS femtocell launches	CDMA femtocell launches
Asia Pacific	9 (8 FDD and 1 TDD)	1
EMEA	27	-
Americas	2	2
Source: Informa Telecoms & Media		

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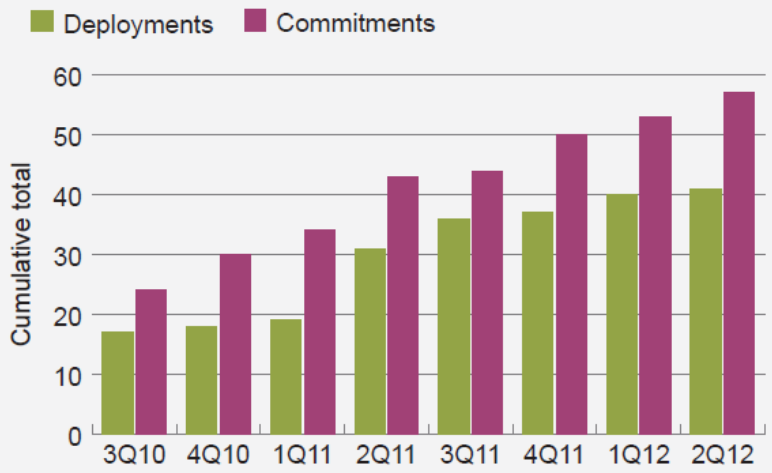
Femtocell Market Update

Fig. 3: Femtocell service deployments and commitments, cumulative totals, 3Q10-2Q12



Note: Figures refer to quarter-end

Source: Informa Telecoms & Media

Operator	Country	Launch Date
AT&T	US	April 2010
Sprint	US	December 2007
Verizon	US	January 2009
Asia Pacific		
China Unicom	China	December 2009
KDDI	Japan	July 2010
NTT DoCoMo	Japan	November 2009
Optus	Australia	April 2011
SingTel	Singapore	January 2010
SK Telecom	South Korea	December 2010
SoftBank	Japan	June 2010
StarHub	Singapore	November 2008
Vodafone	Australia	May 2011
Vodafone	New Zealand	February 2011
EMEA		
Everything Everywhere	UK	October 2010
Moldtelecom	Moldova	November 2010
Movistar	Spain	August 2010
MTS	Russia	May 2011
Network Norway	Norway	February 2011
Optimus	Portugal	December 2009
Orange	France	May 2011
Orange	Romania	May 2011
SFR	France	December 2009
Vodafone	Greece	July 2010
Vodafone	Hungary	May 2011
Vodafone	Ireland	February 2011
Vodafone	Italy	May 2011
Vodafone	Qatar	June 2010
Vodafone	Spain	June 2010
Vodafone	UK	July 2009

Source: IDATE, various

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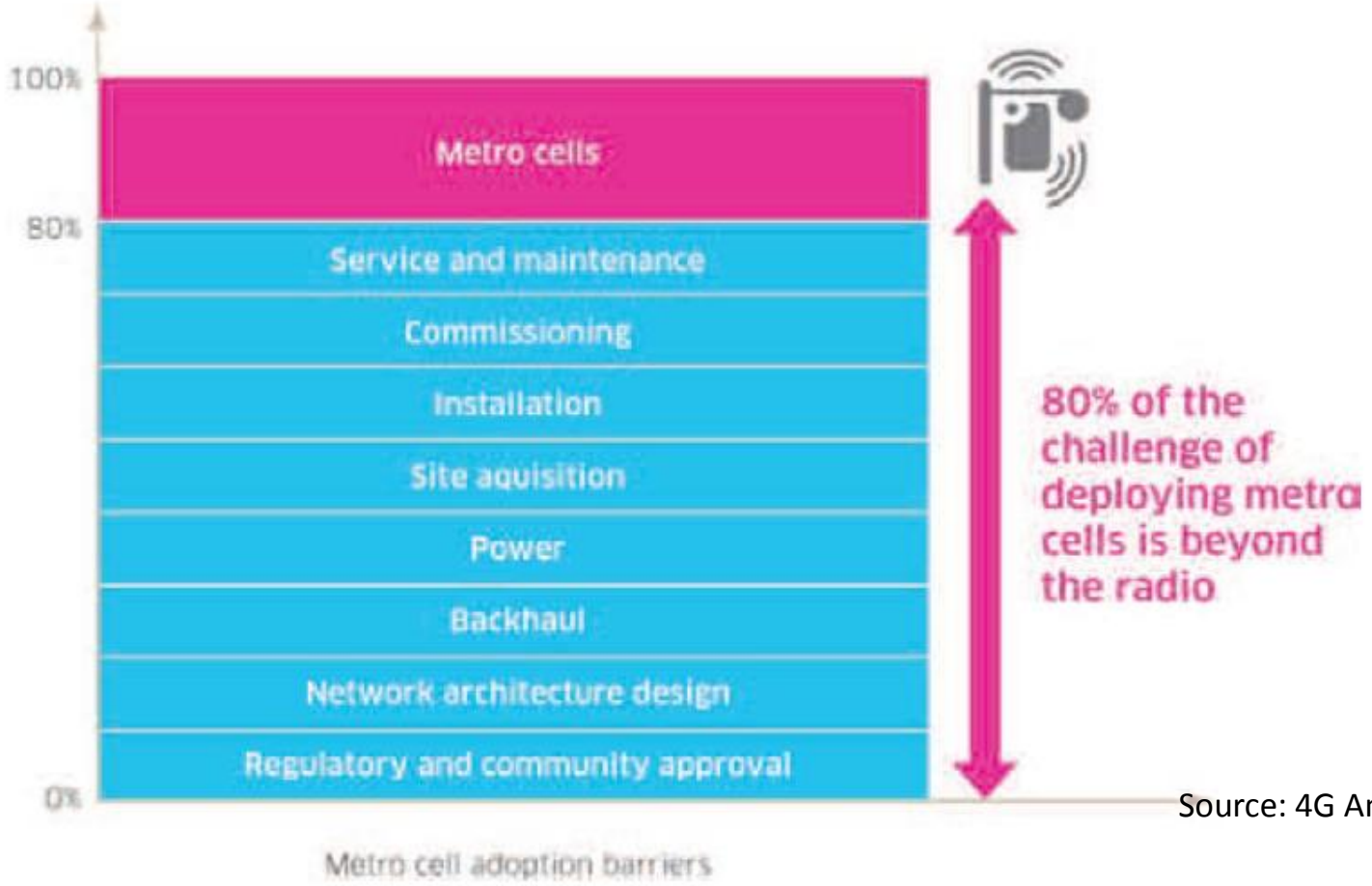
SMALL CELL CONSIDERATIONS

- Interference Management
- Mobility Management
- Site Selection & Acquisition
- Backhauling
- Traffic Management
- Security
- Deployment Challenges
- Operational Challenges
- Vendor Interoperability?

Barriers to Adoption



Source: 4G Americas

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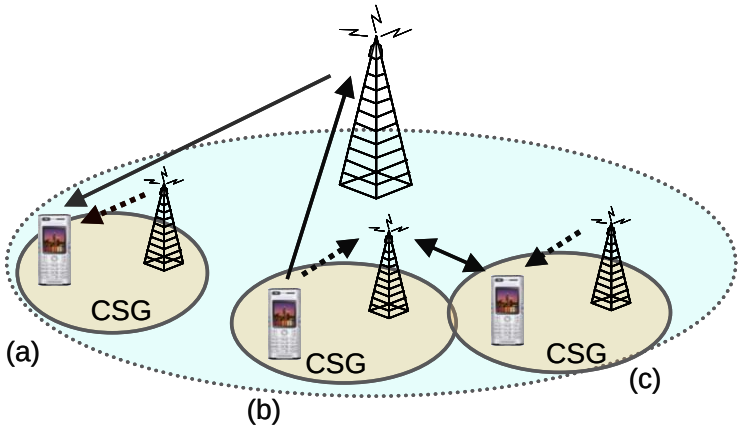
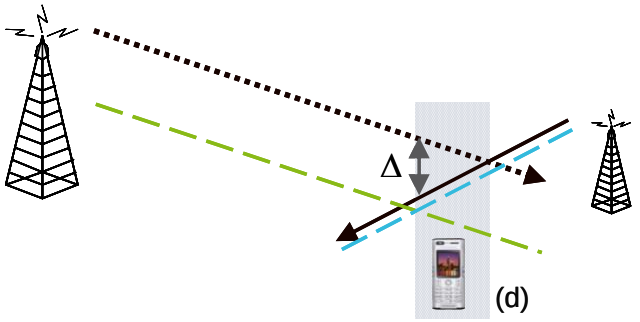
Interference - Macro-Femto Scenarios



Inter-cell interference (dotted)



Rx power (solid, dotted->macro), 1/pathloss (dashed)

(a) a macro user with no access to the CSG cell will be interfered by the HeNB
(b) a macro user causes severe interference towards the HeNB
(c) a CSG user is interfered by another CSG HeNB.
(d) path-loss based cell association (e.g. by using biased RSRP reports) may improve the uplink but at the cost of increasing the downlink interference of non-macro users at the cell edge.

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Source: 3GPP 36.814

Femto Forum Analysis

The following scenarios may benefit from interference mitigation techniques, i.e. could have the most significant impacts on performance:

- Femto DL to macro UE on the same carrier
- Femto UL to macro BS on the same carrier
- Femto DL to other nearby Femtos UE on the same carrier
- Femto UL to other nearby Femto AP on the same carrier

Interference mitigation techniques already applied in WCDMA femtos may be applied in addition to techniques made possible by new tools provided by the LTE standards and architecture (e.g., the flexibility of frequency-domain resource management, the X2 interface). These form the bases for new interference management techniques that may be used to build operational OFDMA femtocell systems.

Interference Scenarios

- More challenging in co-channel deployment and in CSG mode
- Downlink
  - Unauthorised UE close to a CSG femtocell (suffering interference)
  - Authorised UE at the edge of the femto coverage (suffering interference)
- Uplink
  - Macro UE close to the femto (creating interference)
  - Many femtos towards the macro network (creating interference)

Mobility Management

- **Idle-mode mobility**: camping strategy and implemetation is key to load sharing between macro cells and small cells
- **Connected-mode mobility**: macro-to-small HOs, small-to-macro HOs, small-to-small HOs
- **High-speed UEs**: requires speed-based mechanisms to improve mobility robustness

LTE-Based HET-NET Challenges

Mobility & Interference

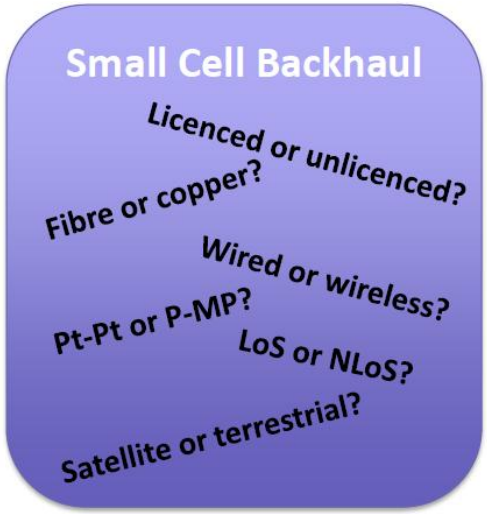
- Inter-cell radio resource Management between layers based on X2 interface: multi-vendor scenarios
- Handovers: eNB-based (LTE) vs UE-based (better view into multiple layers)
- Handover S1-based (multi-vendor) vs X2-based (single-vendor)

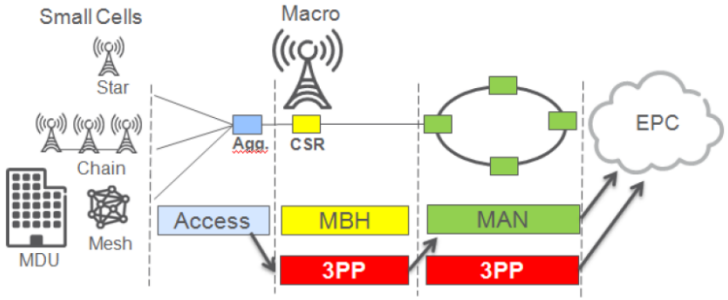
Optimal Small Cell Site Selection

- Optimal hotspot locations may be within 10s meters
- Hotspots vs Coverage Gaps
- Getting the backhaul resources
- Locating Traffic Hotspot
  - Network-assisted Tools
  - UE-based Tools
- Femtocells: location determination issue, particularly in user-controlled installation

Backhauling

- Technologies
  - Cable
  - DSL
  - Microwave (LOS and NLOS)
  - Fiber
  - Ethernet
- Relaxed performance, reliability vs macro
- User-plane, control-plane, management-plane, synchronization
- 50-100 Mbps
- Macro-subtended vs 3rd-party: sharing macro backhaul requires proper capacity dimensiong





Source: 4G Americas

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Traffic Management Challenges

- Optimal load sharing between macro- and small-cell layers (single-RAT or multi-RAT)
  - "Camping" load
  - Traffic load i.e. traffic steering
- Traffic Offloading Thresholds Definition
  - Ping-pong effects
  - Application-driven e.g. only on wifi

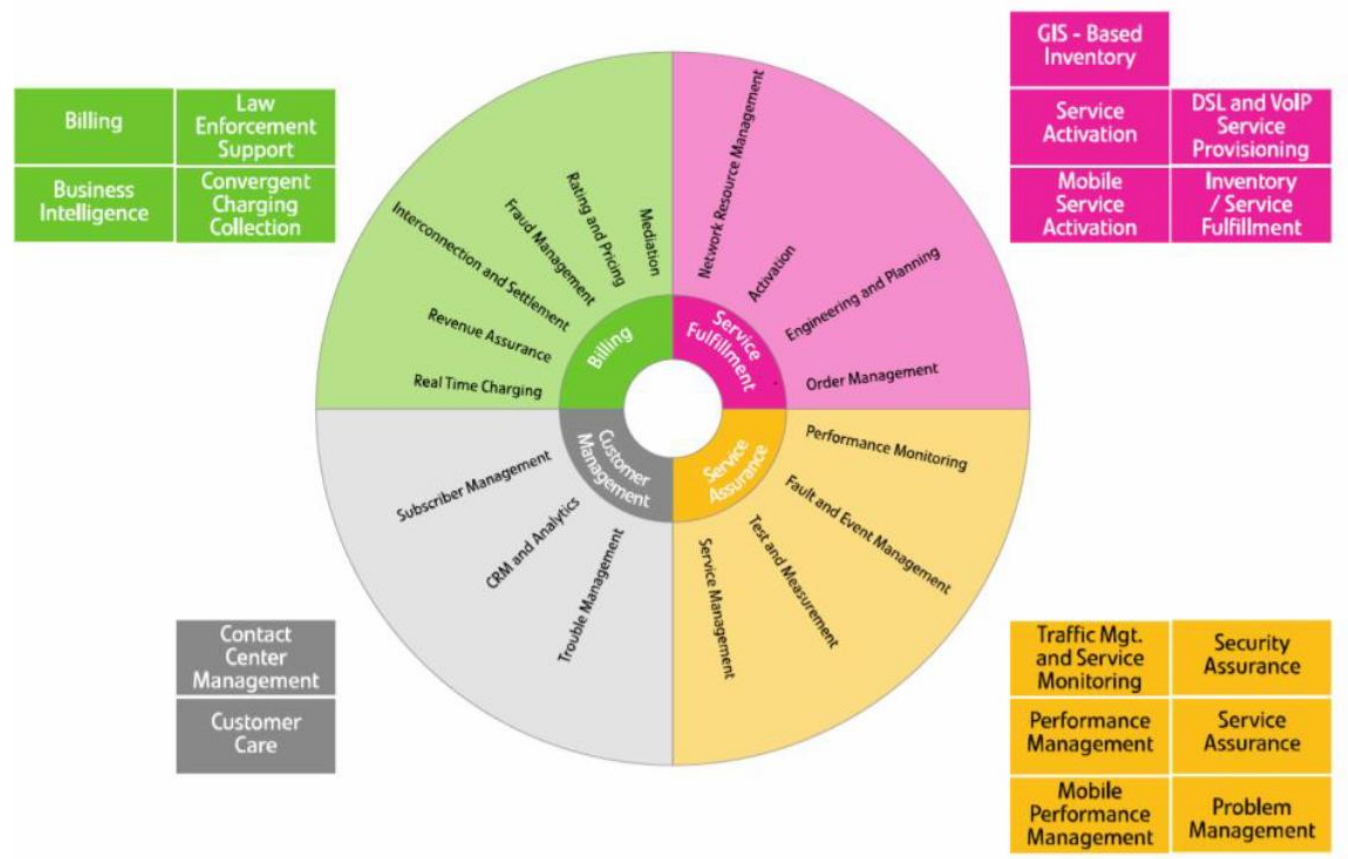
Security Challenges

- Physical Security
- Data & Network Security
  - Untrusted backhaul
  - IP-based solutions (vs TDM)
  - Encryption can terminate in eNB with LTE (vs in RNC with HSPA)
  - Air interface may not be secured on untrusted Wi-Fi APs

Deployment Challenges

- Deployment process need to be streamlined from macro to small cells (i.e. due to increased scale of small cells)
  - Site Selection
  - Lease Agreements
  - Installation
  - Configuration
  - Backhaul Provisioning
- SON-based Deployments : centralized vs distributed

Operational Challenges



Source: 4G Americas

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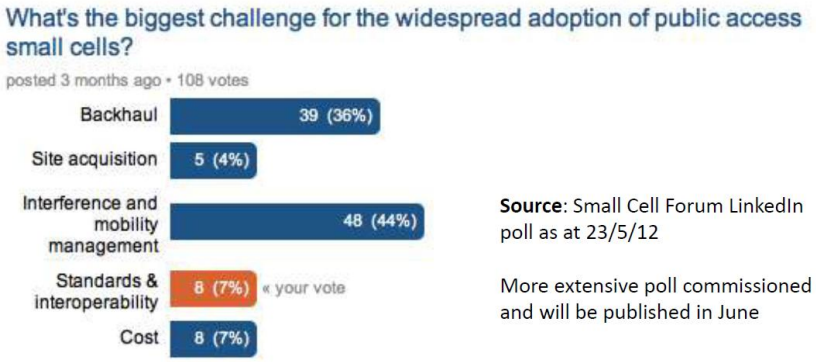
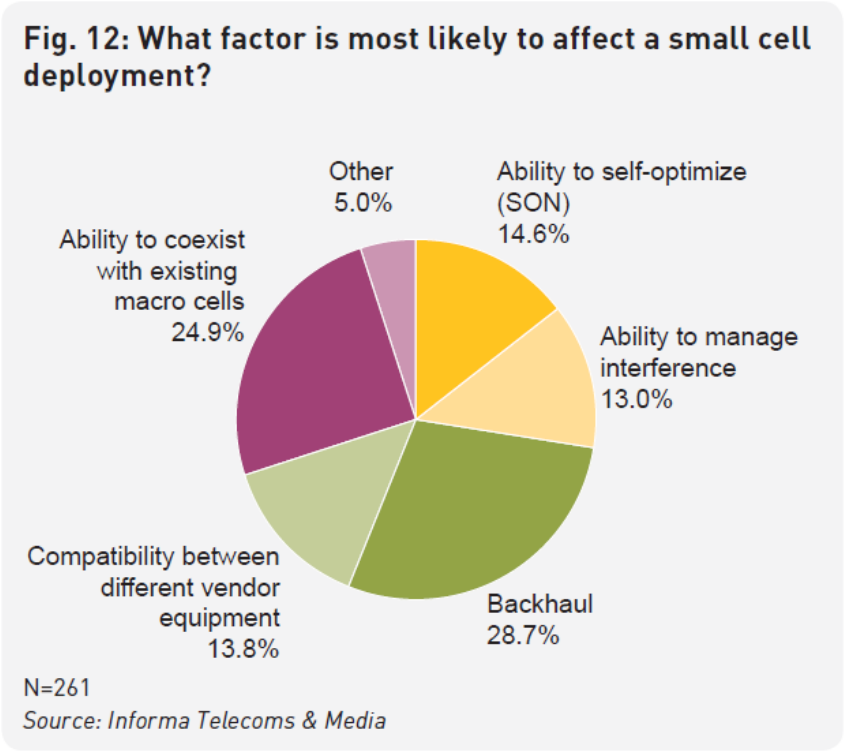
Small Cells Challenges : Survey



Source: Small Cell Forum LinkedIn poll as at 23/5/12

More extensive poll commissioned and will be published in June



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Agenda

- Categories of Small Cells
- Heterogeneous Network
- Benefits of Small Cells
- Market Update
- Challenges
- Solutions
- Strategy Roadmap

SMALL CELL SOLUTIONS

- Interference Management
- Mobility Management
- Site Selection & Acquisition
- Backhauling
- Traffic Management
- Security
- Deployment Challenges
- Operational Challenges
- Vendor Interoperability?

Interference Management

2G&3G

- Several variants of time and frequency domain co-ordination
- Interference cancellation techniques.
- Interference rejection combining and MMSE-SIC based receivers

3G&LTE

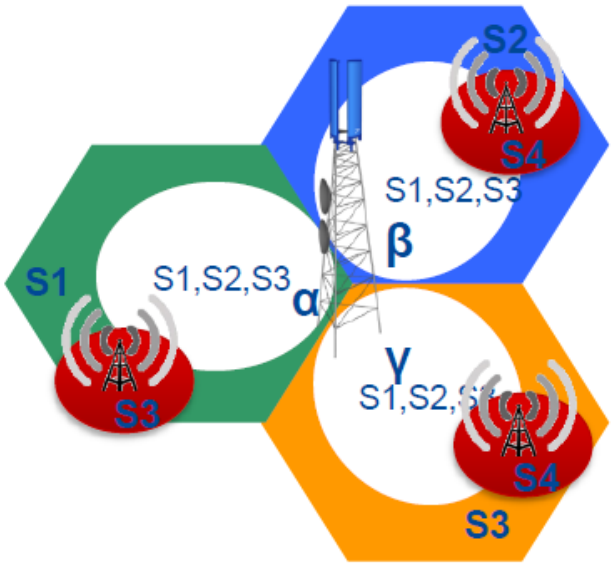
- Adaptive femto power control based on distance or macro signal measurements at the femtocell on the downlink

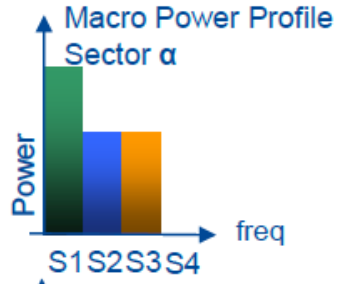
LTE-Specific

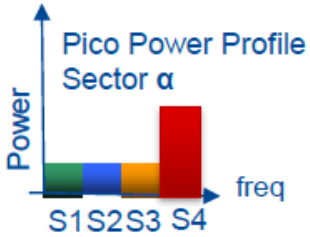
- Enhanced frequency selective scheduling
- Semi-static Fractional Frequency Reuse
- Dynamic Resource Coordination
- 3GPP study reports 36.921 and 36.922 evaluate the ICIC mechanisms which could be implemented for support of Rel9 LTE femtocells.

Femto Forum study found that LTE femtocells can coexist with macrocells in the same channels, given the use of appropriate interference mitigation techniques, even in the most challenging situations for interference.

Interference Management – LTE Rel8







- Interference mitigation in 3GPP Release 8 is achieved by using static or dynamic (via X2 or centralized SON) frequency domain co-ordination between cells.
- Each cell can use a subset of resource blocks at higher transmit power whilst reducing power (or completely muting) other resource blocks to mitigate inter-cell interference to neighbors.
- Achieved **on DL+UL Shared Channels** and **UL Control Channel**

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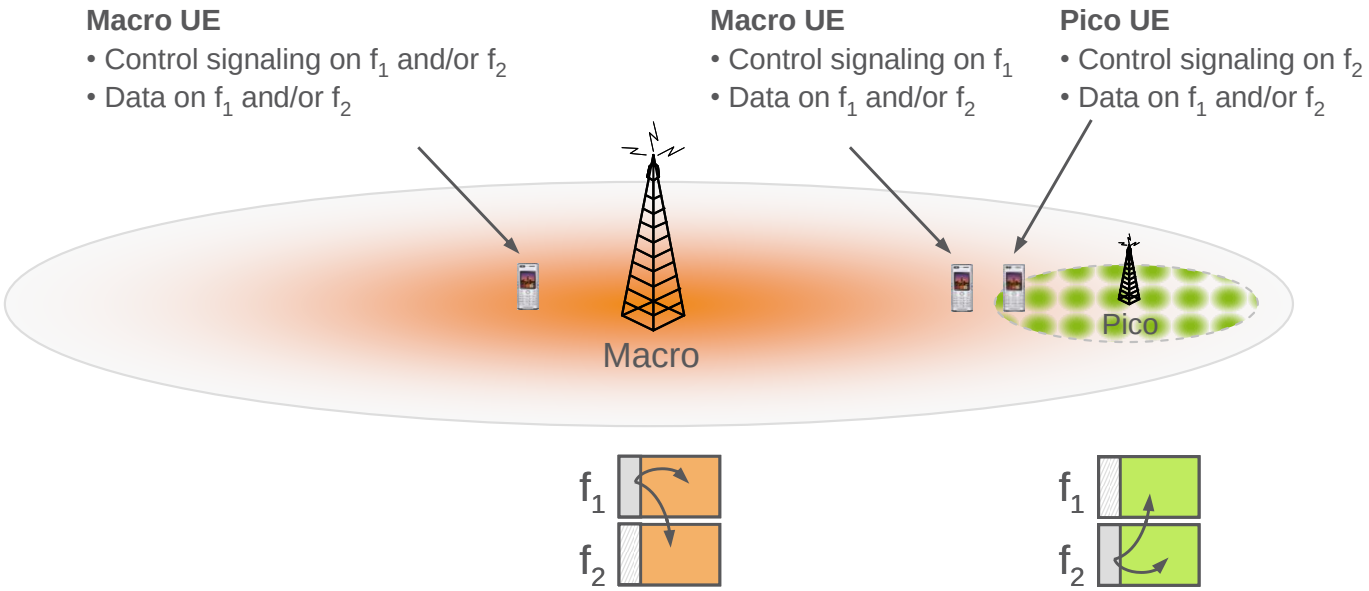
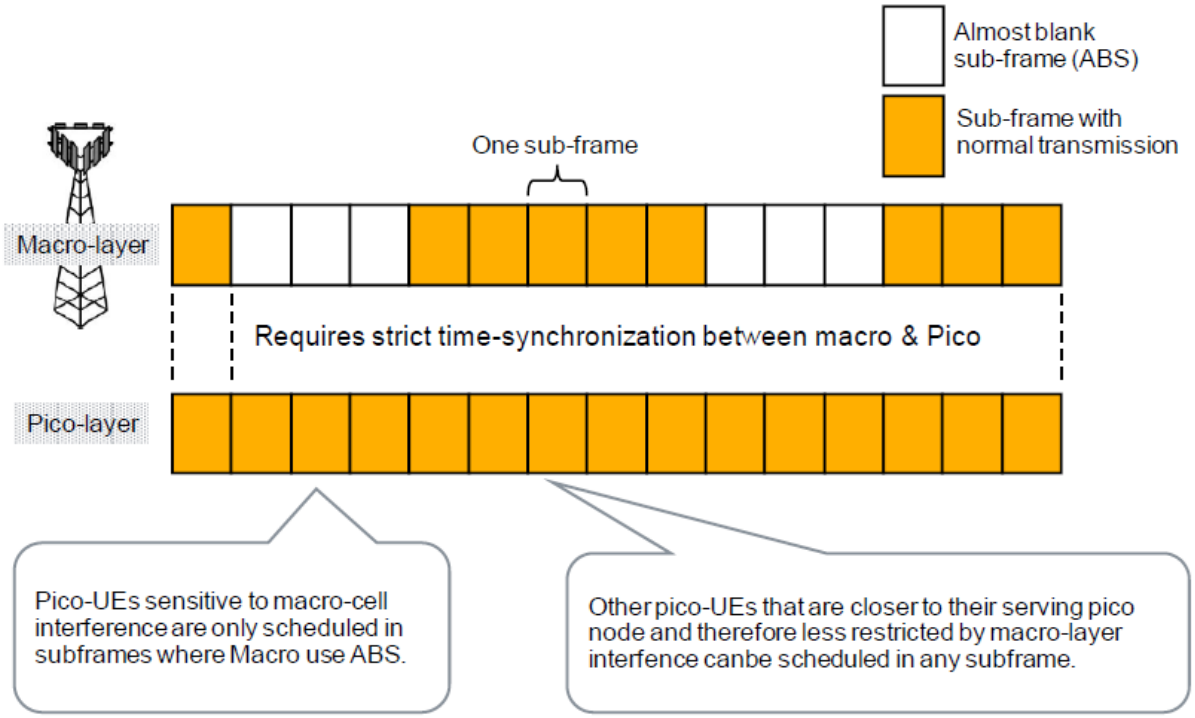
HetNet Support – LTE Rel10



Source: 3GPP 36.814

For carrier aggregation based support (i.e. dedicated carrier), cross-carrier scheduling is used to avoid the interference of PDCCH between macro cell and small cell

HetNet Support – LTE Rel10



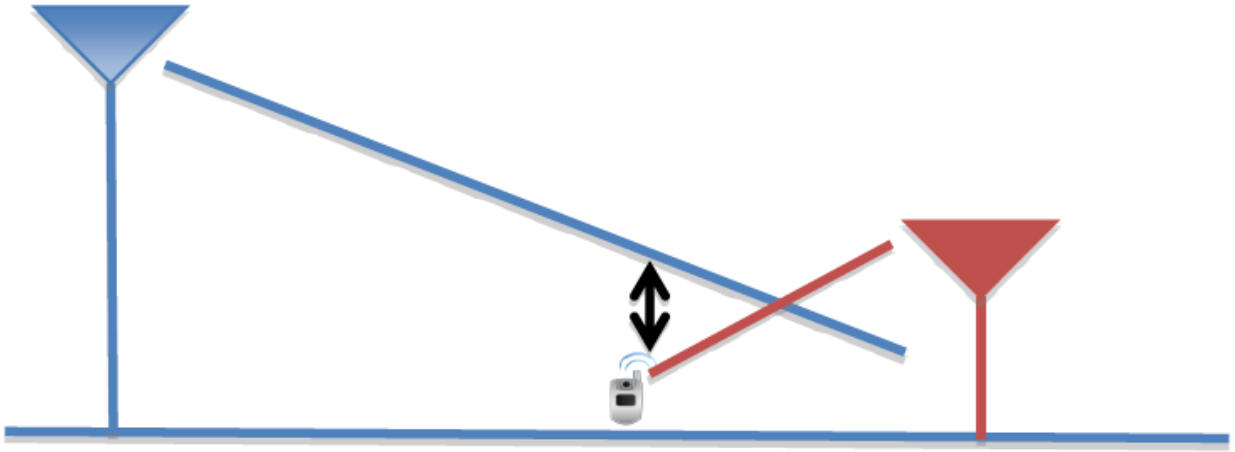
Enhanced Inter-Cell Interference Control (ICIC) for **non-Carrier Aggregation** (CA) (i.e. shared carrier) based deployments of heterogeneous networks for LTE.

DL Control Channel: interference managed via TDM eICIC (coordination in time domain)

Mobility

Frequency Plan	Definition	UE Measurements
Same Carrier	Macro-carrier used by small cells Interference Mgt Needed (except if coverage gap only)	No new inter-frequency measurements/reporting are needed, but need to implement same-layer preference for Handover targets
Dedicated Carrier	Dedicated Carrier for small-cells Neighbor relationship via SIB5 (allowing UE to search small cells)	Inter-frequency measurements and reporting needs to be configured for target frequencies. Same-layer preference logic is much simplified.

Mobility – Idle Mode



$$CellID_{serving} = \arg\max_{\{i\}} \{RSRP_i + bias_i\}$$

Cell reselection bias on RSRP (0-20 dB) can be used to extend small cell coverage

Mobility – Connected Mode

- General: keep the HO in the same layer (small or macro) if possible
- Coverage-based
  - Small-to-macro : most important
  - Macro-to-small : may not be needed, except:
    - Macro layer has a coverage gap
    - Week macro signal/cell-edge
- Load-based (e.g. SON feature load balancing)
  - Small cells shall be configured to perform load-based HO to macros (but not for coverage gaps)
- High-Speed UEs (mostly outdoors)
  - Need to be identified (based on historical frequency of handover)
  - Higher TTT values or prevented from small cells

HO hysteresis parameters (i.e. Time to Trigger (TTT) and the parameter cell Individual Offset (Oc)) can be optimized for small cells.

Mobility : WIFI

Standards related to Hotspot 2.0 address roaming between Cellular and Wi-Fi technologies. This is mainly built around device and network changes in the following areas:

- Network discovery and selection: Mobile devices will discover and automatically select and connect to Wi-Fi networks based upon user preferences and network optimization.
- Streamlined network access: Mobile devices will automatically be granted access to the network based upon credentials such as SIM cards, which are widely used in cellular devices today. No user intervention will be required.
- Security: Over-the-air transmissions will be encrypted using the latest-generation security technology (Wi-Fi Certified WPA2-Enterprise).

The key elements of the Wi-Fi Certified Phase 2 Pass point certification program are as follows:

- Immediate account provisioning: The process of establishing a new user account at the point of access will be simplified, eliminating many user steps and driving a common provisioning methodology across vendors.
- Provisioning of operator policy for network selection is an important issue: A mobile device's connection manager uses this policy to select the best Wi-Fi network to join when multiple networks are available.

Optimal Small Cell Location Planning

- Need traffic density maps (alias “hot maps”)
- Network-based Solutions
  - RF Fingerprinting (based on drive-test RF measurements)
  - RTT Fingerprinting; Time-Of-Arrival(TOA, TDOA, AOA); subject to NLOS corruption, requires building a NLOS error correction map
- Handset-based Solutions
  - Device assisted MDT based location data
  - GPS-based
    - Not all handsets have GPS or AGPS capability.
    - GPS –based solutions do not work well in buildings.
    - GPS reports from all devices in the field are not part of current signaling. Accordingly, transmission of GPS information would place a significant additional signaling load on the network.

Cell Location - Process

- Create a “heat map” i.e. geo-coded traffic volume
- Identify best Macro Cell candidates for off-loading
- Number and locations of small cells within the macro cell considering
  - Offloading opportunity
  - Friendly Landlord
  - Power availability

SITE SOLUTION

- Compact and Flexible Form Factor
- Zero-footprint configuration
- Passive Cooling
- Can be mounted on lamp posts, utility poles, interior/exterior walls, cell towers for all applications
- Relationships with utilities, municipalities vs landlords

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Backhauling

- Backhauling to nearest macro site:
  - Environment: urban
  - Distance: 300-500 m
- Fiber: Costly
- Ethernet: GigE (shared backhaul)
- NLOS Microwave: sub-6 GHz in point-to-multipoint
- Relaxing performance requirements: voice vs data traffic

Backhaul options

	Throughput	Pros	Cons	Suitable for open access femto
DSL	VDSL: 50 Mb/s; up to 100 Mb/s	High capacity	Need multiple pairs	✓
Fiber / GPON	≥ 100 Mb/s	Very high capacity	Upfront Infra structure required	✓
HFC/Docsis	30 Mb/s; 100 Mb/s – 1Gb/s	Large availability in Americas	Low penetration in Europe	✓
PLC	100Mb/s over 300 meters	Existing technology/ Easily available	Distance / Bandwidth	☑
Wi-Fi	100 Mb/s	Rapidly deployable, quasi-LOS, Cost	Quality Cell range in Non LOS	✓
Micro-waves **60 / 80 GHz**	100Mb/s – up to 1Gb/s	High bandwidth, Good QoS	Expensive, LoS required	✓
NLOS LTE / WiMAX TDD technologies	100 Mb/s	QoS, Coverage No need of LoS	Expensive Spectrum availability	✓
Satellite	variable	Rapidly deployable - everywhere	Cost,delay, location, QoS	☑

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Source: Small Cell Forum

TRAFFIC MANAGEMENT - SOLUTIONS

- Idle-mode load steering via camping strategies
  - Free camping based on best serving cells listed in SIB5 (macro usually favored)
  - Preferred camping: Qoffset (db) parameter to biais reselection towards small cells dynamically (same carrier and dedicated carrier)
  - Priority camping: dedicated carrier
  - Idle-mode Load-balancing via Range Extension
- Connected-mode steering: load-based HO

TRAFFIC MANAGEMENT - SOLUTIONS

- Wi-Fi Alliance Hotspot 2.0
  - IEEE 802.11u (new standard approved in 2011): network discovery and selection
  - IEEE 802.11i: encryption (using WPA2-enterprise)
  - IEEE 802.1x: authentication (using SIM/USIM device credentials with new EAP additions)
- Common core (cellular & wifi) steering the load

SECURITY - SOLUTIONS

- Air Interface secured through standards authentication & encryption mechanisms
- Untrusted transport networks secured through the used of secure IP tunnels (GRE, IPSec)
- Small cells should be tamper-proof, i.e. unauthorized access to the unit should generate alarms. In addition, moving or displacing the device should also generate an alarm or notification.

OPERATIONS - SOLUTIONS

- Billing: cell-id-based for closed-user-group e.g. femto
- CM, FM, PM
  - Scalable platforms required for the increased number of cells
  - PM not standardized among vendors; multi-vendor integration in same geographical market required
- SON
  - Can a centralized implementation of SON integrate both macro and small cell layers? From multiple vendors?

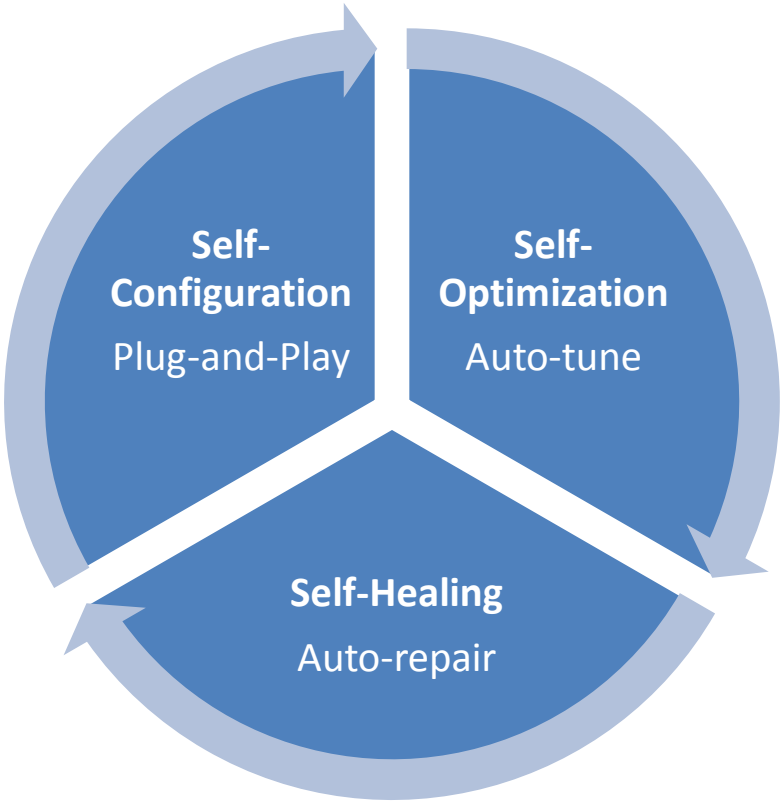
CATEGORIES OF SON FEATURES

- **Self-Configuration**

  Autonomous configuration of parameters during commissioning
- **Self-Optimisation**

  Continuous improvement of service quality, network performance, and network capacity
- **Self-Healing**

  Detection, analysis, and mitigation of network outages



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SON IMPLEMENTATIONS

Speed Required

Number of Sectors

Network Management Systems	 NMS manages the policies
Element Manager Systems	 Some SON functions are implemented in the EMS
Network Elements	 The eNB implements some SON functions and analyzes UE measurements
User Equipment	 The UE performs over-the-air measurements

SON implementations are typically multi-layered in a distributed, centralized, or hybrid architecture.

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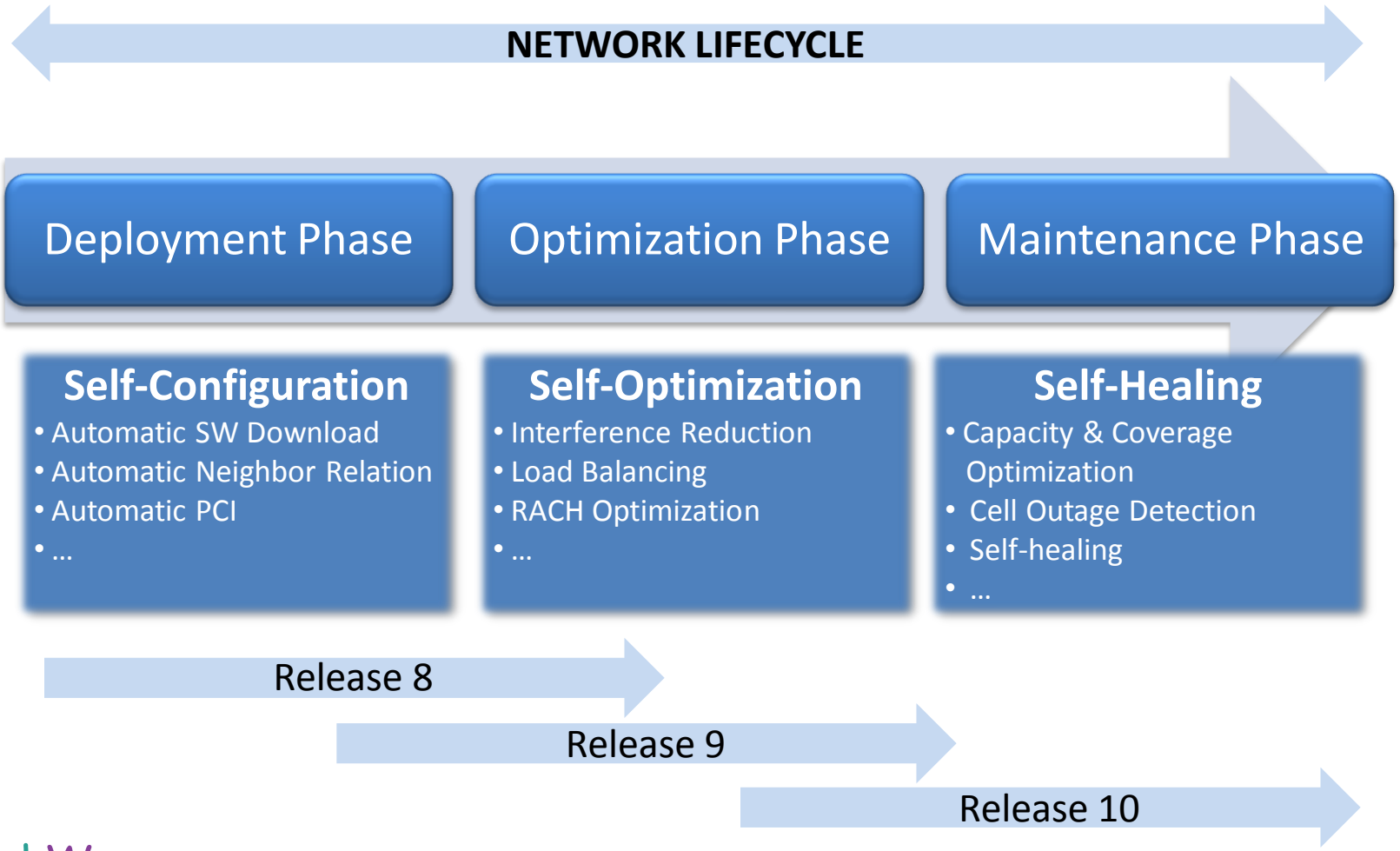
SON LIFECYCLE



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3GPP TS36.902

1. Coverage and Capacity Optimization (Rel 9,10);
2. Energy Savings (Rel 9);
3. Interference Reduction (Rel 10);
4. Automated Configuration of Physical Cell Identity (Rel 8);
5. Mobility Robustness Optimization (Rel 9,10);
6. Mobility Load Balancing Optimization (Rel 8,9,10);
7. RACH Optimization (Rel 9);
8. Automatic Neighbor Relation Function (Rel 8,9);
9. Inter-cell Interference Coordination (Rel 8,9)

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Slecting the best Option : Design Requirements

- Access mode: open, closed, or hybrid
- Private or public
- Coverage & capacity requirements
- Backhaul Options Available
- Frequency Plan : shared or dedicated
- Rationale: coverage, capacity, or both
- Site availability
- Mobility requirements
- Voice vs Data Services
- QoS requirements

AT&T – A multi-solution approach

- Multi-beam DAS systems
- RRH
- Metrocells Hotspots (32-64 users): capacity & coverage increase in urban areas
- Wi-Fi Hotspot network (30,000 APs in the US)
- Femtocells

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