Contents
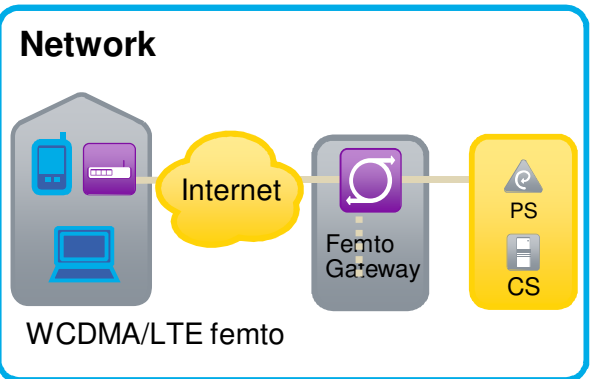
Overview & market drivers

Small cell and HetNet architecture

Deployment considerations

Microcells

Picocells and pico clusters

Distributed antenna systems

Femtocells

Operator Wi-Fi

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What are femtocells?

Base station

- Low cost very small HSPA/LTE base station for home or office
- Transmit power 10-100 mW *)
- Zero-touch installation, auto-configuration
- Open or closed access

*) can be higher, ~ 250 mW if operator-installed

Site

- Indoor use: Home, SoHo, enterprise, office
- Single cell and multi-cell deployments

Network

WCDMA/LTE femto

- Unplanned deployment
- Existing fixed broadband access used for backhaul
- Attaches to voice & packet core via femto gateway, optional local Internet offload (LIPA)
- 3GPP standardized interfaces (Iuh, S1, TR-69/196)

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Femtocell architecture
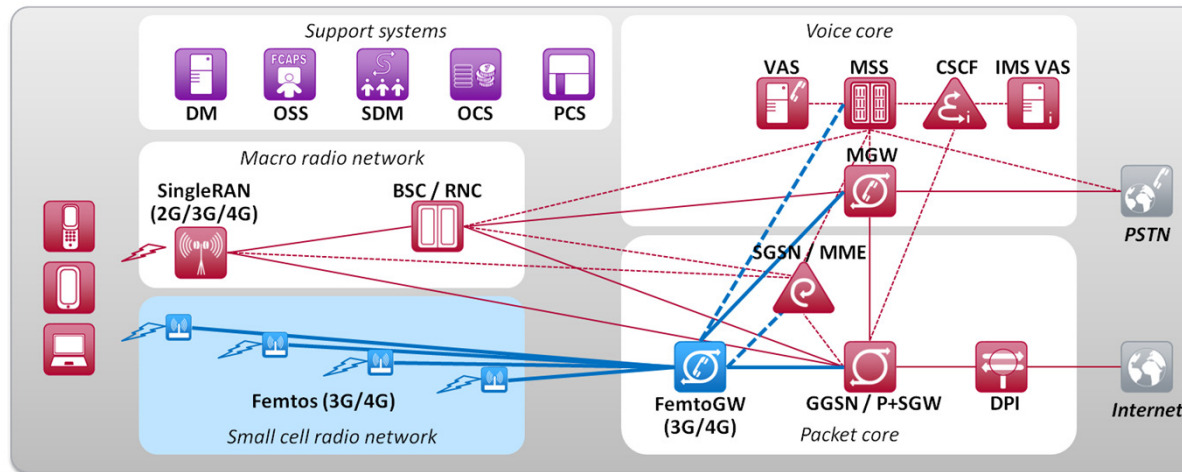
WCDMA/HSPA: connected to core network with standard Iu-CS and Iu-PS interfaces via the femto GW. Femto access security and O&M also handled via the femto GW.

LTE: architecture still partly under discussion. Femto GW expected to be needed at least for security purposes.

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Femtocell business drivers

Coverage enhancement
- Customer retention

Capacity boost
- Macro network offload

Femtocell–enabled value added services
- For example presence based applications

Today the most evident benefit of femtocells is to improve indoor coverage for voice and smartphones, especially where the operator does not have spectrum in low bands

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Key femto deployment issues

Security
- Prevent tampering of FAP, transport security
- Solved by FAP hardening, IPSec transport, certificate based authentication

Interference mitigation and location locking
- Algorithms are in place, more advanced ones being developed

Mobility management
- UE capture by FAP, avoiding ping-pong with macro network

Cost of service provisioning and customer care
- Automated low-cost provisioning needed in mass deployments

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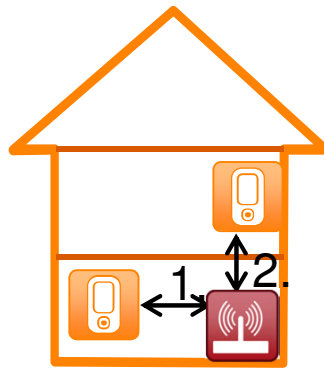group

Main femto deployment scenarios

Closed Residential SoHo	Semi-open residential	Enterprise	Metro
Only family members have access	All customers have access, family members prioritized	Also multi-cell Mobility between femtocells	All customers have access

Single cell

Single cell
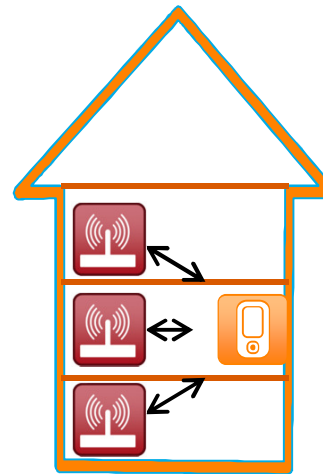
Single and multi-cell
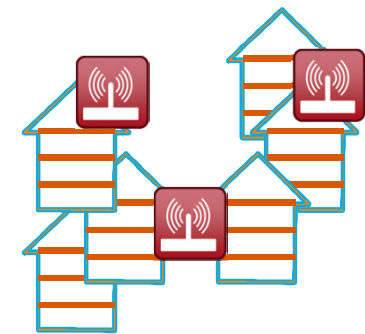
No significant deployments yet

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3G femto mobility

2G/3G macrocell

Hand-out

Bi-directional
cell reselection

3G
femtocell

3G
femtocell

Only coordinated
(planned) hand-in

Femto-femto mobility

For LTE femtocells full mobility is supported from day
one, with enhancements planned in Rel10

- - - - Idle mode

———— Connected mode

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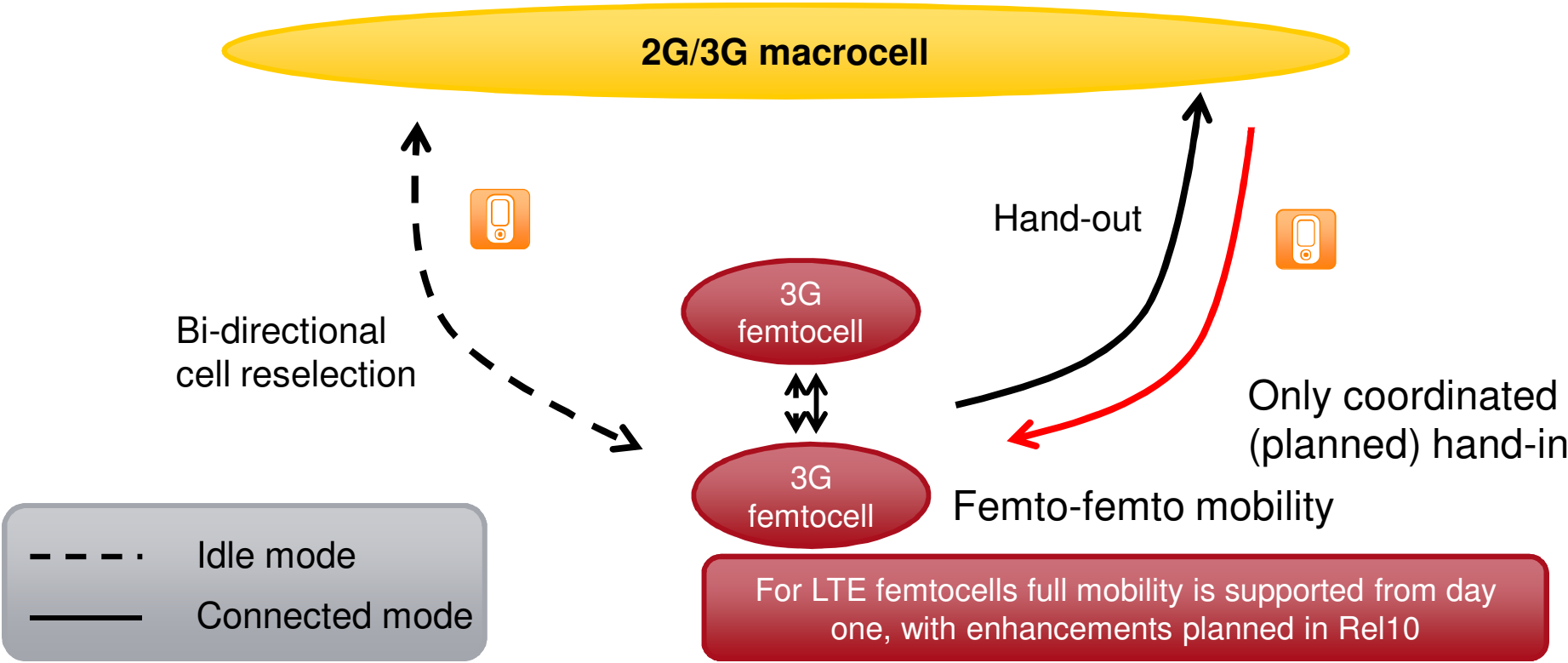
Softbank, Japan offers free femtos

- Customer gets FREE femtocell and even ADSL
- Open access, any Softbank subscriber can connect
- Offered to both private and small business customers
- For the owners only $5 dollars per year electricity cost expected from taking the FAP from Softbank
- Requires 2-year contract

Enhance the Network Available in Households
Provide home femto (small base stations) to households for free
Communication speed (theoretical value) Downlink maximum14.4Mbps Uplink maximum 5.7Mbps
ADSL service exclusively for home femto will be provided for free as well
64

Enhance the Network Available in Shops and Offices
(Shops/offices) Provide small base stations for free to shops and offices
ADSL service exclusively for femtocell will be provided for free as well
65
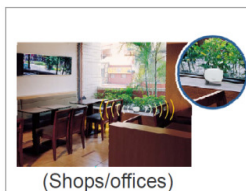
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**Enterprise femto deployment
Network Norway "Full Dekning"**

- 99 NOK (13 €) / month, no upfront fee
- Operator installs the FAP
- Also multi-cell with SON features
- Interference control
- Automatic neighbor discovery
- Load balancing

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Operator Wi-Fi

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What is operator Wi-Fi?

Access points
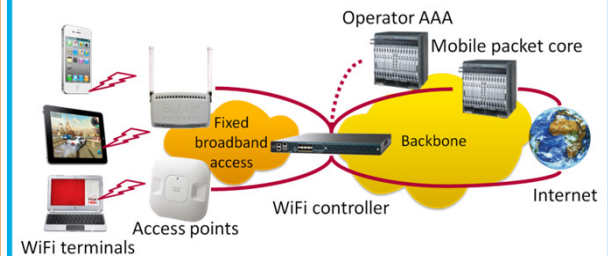
Indoor
- Output power 20 mW-100 mW
- Size <1 L, <1 kg

Outdoor
- Output power 0.2 – 1 W
- Coverage radius 10s of meters
- Size 3-8 L, 2-5 kg
- Integrated antenna
- Simultaneous users 20-150

Site

- Increasingly used in public hotspots like restaurants, cafes, transportation hubs and hotels
- Lamp posts, utility poles and building wall outdoor locations
- Municipal, campuses and street-walks popular outdoor locations

Network

- Unlicensed spectrum
- Requires Wi-Fi capable terminals
- Planned or unplanned
- Utilizes controller architecture
- Authentication from operator AAA
- Userplane offloaded or through packet core
- Utilizes fixed broadband backhaul
- Mobility and voice services require additional solutions

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Traffic offload from mobile networks to carrier Wi-Fi networks

Global mobile data traffic
Exabytes per month

20

10

0

2011

2016

■ Carrier Wi-Fi Offload
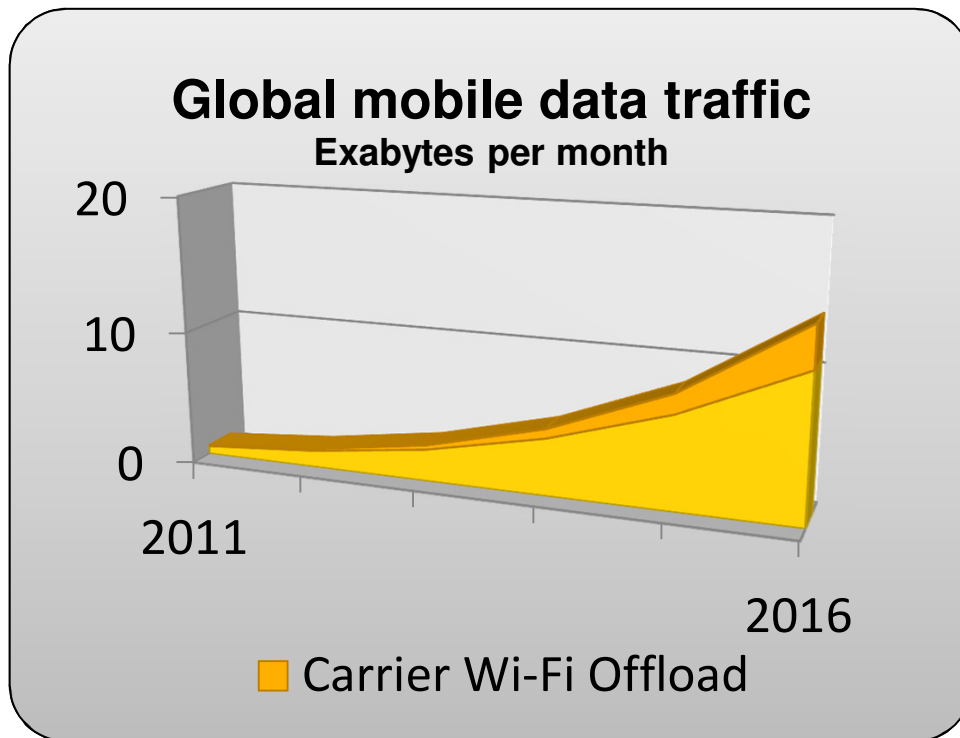
Source: Cisco, Gartner, Informa

Carrier Wi-Fi offloading from mobile devices grows from 11% in 2011 to 22% in 2016

Share of Wi-Fi capable handsets will grow from under 10% in 2011 to over 50% in 2016

Additionally by 2016 more than 500 million other Wi-Fi capable mobile broadband devices are in use

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Strong growth in Wi-Fi hotspots

Private Wi-Fi hotspots
(millions)
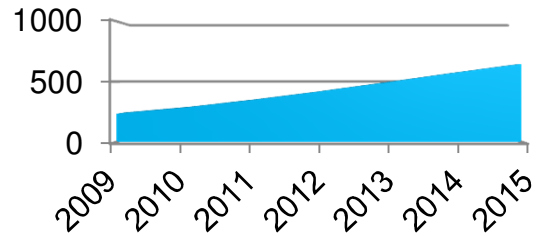
Public Wi-Fi hotspots
(millions)
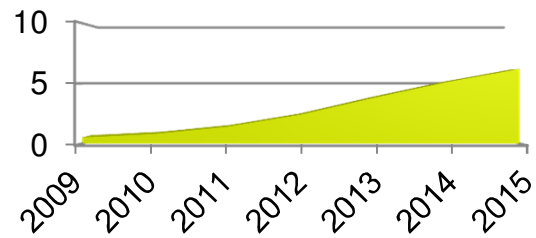
Source: Informa telecoms & media

Home | Residential | Office | Campus

Café & restaurants | Shopping center | Airport | Hotels

City center | Stadium | City walk | Village

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Topics to consider in the Wi-Fi offloading

Business model

Voice and value added services

Wi-Fi device penetration and availability

Ease of use

Quality of experience (mobility, security, interference)

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Three main operator public Wi-Fi offloading target use cases

Customers with cellular devices

- Operator mobile customers
- Consumers and enterprises
- Using smart phones and tablets with SIM and suitable plan
- Target seamless experience
- Service consistency with cellular access desired

Customers with portable devices

- Operator broadband or mobile customers with Wi-Fi plan
- Consumers and enterprises
- Using mobile Wi-Fi devices like laptops, media players and tablets
- Target seamless experience

Visitors

- Not customers of operator providing Wi-Fi services
- Consumer and enterprise users
- Smart phones and Wi-Fi devices like media players, laptops and tablets
- Secure on-line charging and authentication

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HetNet load balancing features
Managing load and experience in multi-layer, multi-band networks

Example

Slow mobility

Slow mobility

2100 MHz micro

2100 MHz macro

2100 MHz macro

900 MHz macro

Portable DC-HSPA

Fast device

Traffic steering to balance load and improve user experience between frequency, hierarchy, and radio technology layers
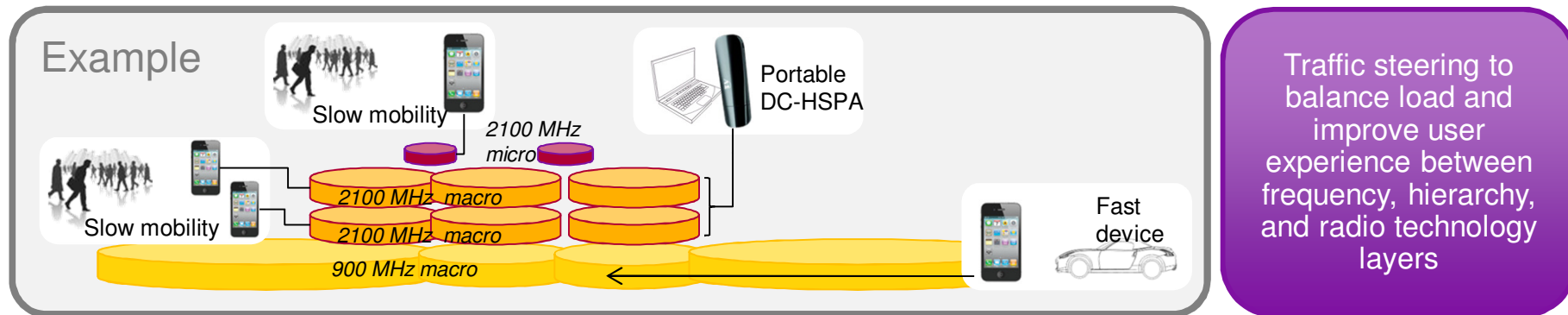
Traffic steering in idle mode
- Direct devices to the preferred active state use layer to avoid unnecessary handovers and ping-pong for improved network service quality
- Layer selection is steered by adjusting measurement rules, cell reselection priorities, thresholds and offsets and using Smart Connectivity for WiFi (ANDSF)
- Connected state layer change can be based on handover
- Criteria for layer selection: used services, UE velocity, UE and network capabilities matching, load in source and target cells, signal strength

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HetNet features
HSPA and LTE small cell range extension

→ **Range Extension can help to move traffic load to small capacity expansion cells**

→ **Moderate range extension (~3dB) with shared frequency in cell edge areas typically provides good performance gain (3G and LTE)**

→ **LTE Rel10 eICIC allows significantly larger range extension values (10-15 dB) for better small cell utilization**

As part of the network planning, macro BTS handover parameters are set so that positive offset is applied to small cell measurements by mobiles

Due this offset – known as Range Extension – mobile will select small cell in worse radio conditions than without Range Extension in place

Macro

Micro

Extended range

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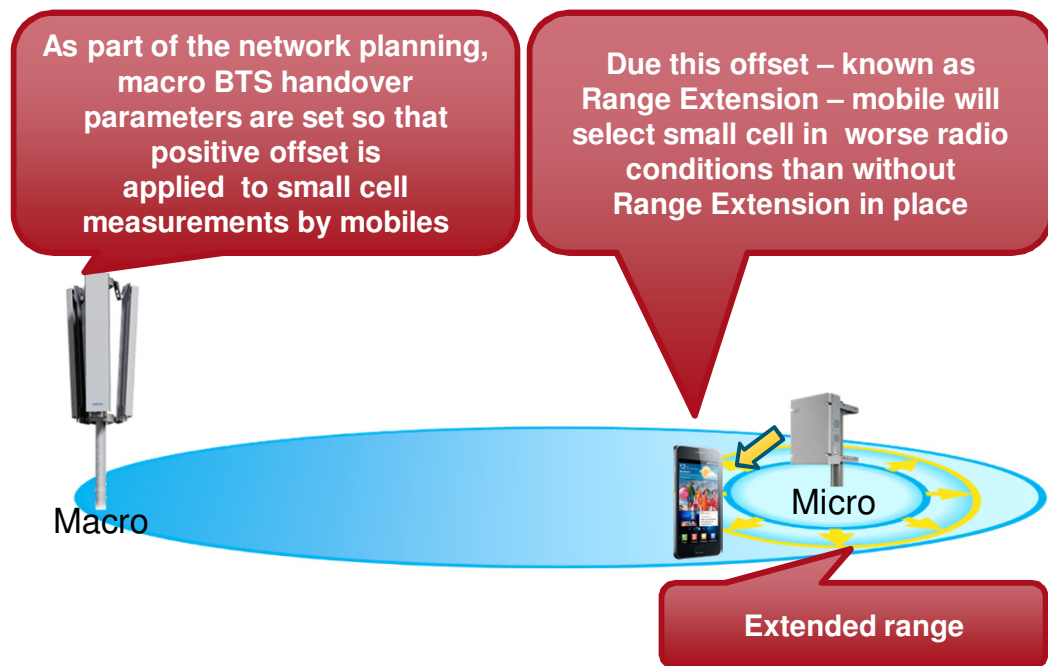
HetNet features

HSPA multi-carrier MultiFlow downlink range extension (3GPP rel. 11 onwards)

→ **When multiple carriers are available macro power and range extension can be separately configured for each carrier**

→ **Dual-frequency MultiFlow capable terminals can receive downlink signal from macro and small cell**

→ **HSUPA soft-handover provides similar functionality in uplink**

→ **MultiFlow can be implemented via network software upgrade**

Reduced power on second carrier

Range extension on second carrier

Macro

Micro

Dual-carrier device

Dual-frequency MultiFlow device

Dual-carrier device

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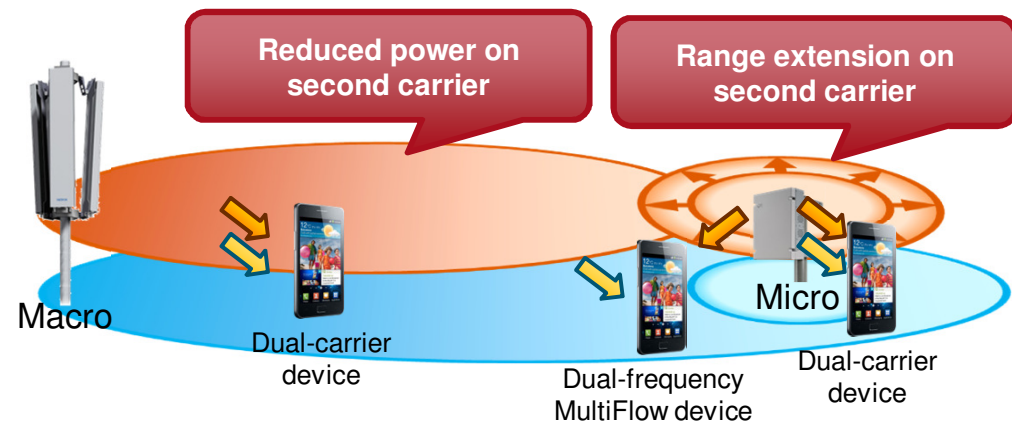
LTE-Advanced contains significant small cell features

Smooth migration to LTE-A and backward compatibility with LTE

Heterogeneous Networks

Enables focused capacity enhancement with small cells by interference coordination

Coordinated Multipoint

Capacity and cell edge performance enhancements by active interference cancelation

Relaying

Enables focused coverage extensions with small cells by self-backhaul

8x MIMO 4x

Carrier Aggregation
up to 100 MHz

Carrier1 Carrier2 Carrier3 ... Carrier5

IMT-A
LTE-A

LTE

HSPA
UMTS

VEHECILE | WALKED | FIXED

1 Mbps | 10 Mbps | 100 Mbps | 1 Gbps

Efficient use of small cells

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HetNet features
LTE enhanced Inter-Cell Interference Co-ordination (eICIC) (3GPP rel. 10)

Muted subframes known as ABS (Almost Blank)

MACRO cell transmission subframes

During ABS-frames small cells can server cell edge mobiles

SMALL cell transmission subframes

During all subframes good radio condition mobiles served

Macro

Micro

X2-link with eICIC co-ordination and GPS or IEEE 1588 phase synchronization
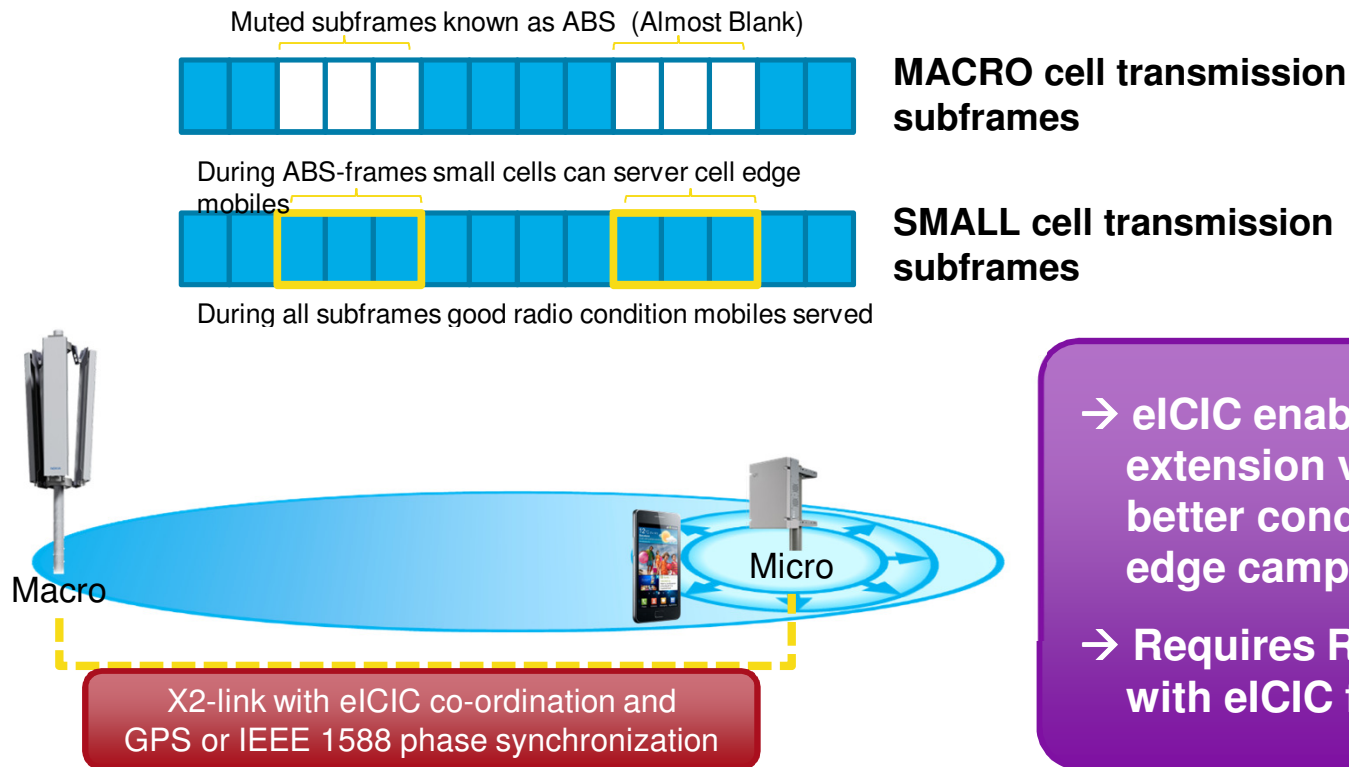
→ **eICIC enables larger range extension values + provides better conditions for small cell edge camped mobiles**

→ **Requires Rel10 LTE terminals with eICIC for full benefits**

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HetNet features
LTE Coordinated Multipoint (CoMP) (3GPP rel. 11 onwards)

Macro

Micro

Common baseband
with CoMP
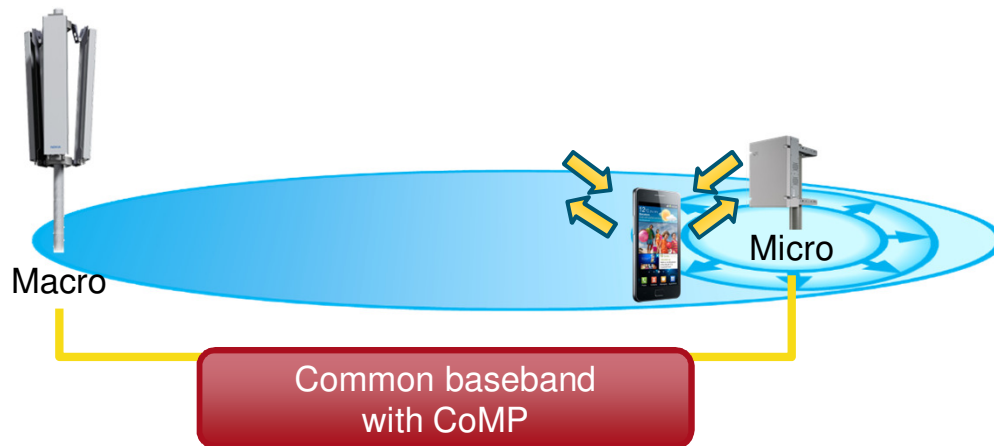
→ **Improved uplink cell edge performance as the same mobile's signal is received by both the macro and small cell**

→ **Improved downlink cell edge performance as data received from small and macro cell**

→ **In practice requires that both macro and small cell have common base band + good fiber transmission**
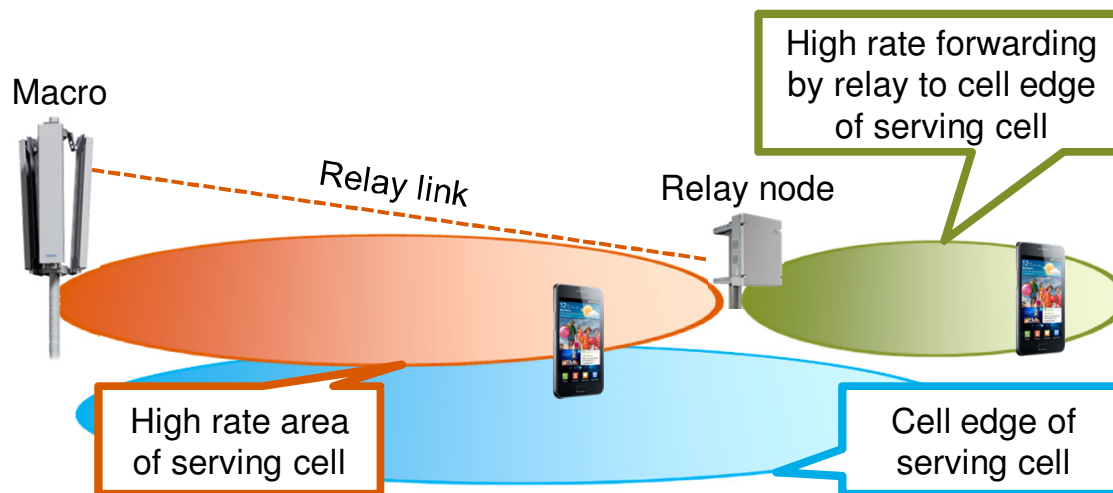
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Relaying for improved reach in LTE-Advanced

Concept of self-backhauled base stations

Backhaul provided by an in-band connection

Each relay looks like an independent cell

Main focus on single-hop relays

Macro

Relay link

Relay node

High rate forwarding by relay to cell edge of serving cell

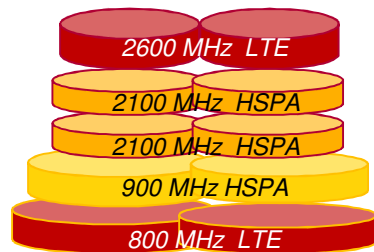High rate area of serving cell

Cell edge of serving cell

→ **Improved downlink cell edge performance due to relay signal boost**

→ **Improved uplink cell edge performance from better signal reception by relay node**

→ **Downside is that relay link consumes macro capacity**

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Cellular mobility management and traffic steering

Homogeneous macro layers

| 2600 MHz LTE |
| 2100 MHz HSPA |
| 2100 MHz HSPA |
| 900 MHz HSPA |
| 800 MHz LTE |

Balance load between macro layers
- Multiple carriers
- Multiple bands
- Multiple technologies

Idle mode steering
- Direct devices to preferred macro layer
- Priorities and power offsets for cell re-selections

Active mode steering
- Service and load based handovers and blind redirections
- Match UE capabilities with network layer capabilities (e.g. MIMO)

Heterogeneous network

| 2600 MHz LTE |
| 2100 MHz HSPA |
| 2100 MHz HS |
| 900 MHz HSPA |
| 800 MHz LTE |
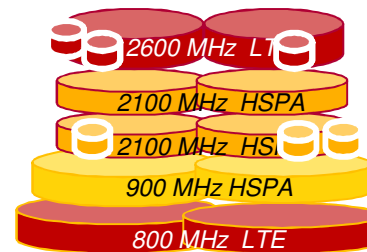
Small cell layers creating additional complexity for traffic steering

Further small cell topics for steering
- Avoid fast moving UEs to select small cells
- Balance load ensuring that also small cell layers get traffic
- Cell specific offsets for small cell range extension
- Femto closed subscriber group (CSG) option
- Advanced ANR due to large number of potential (3G) neighbor cells in large scale small cell deployment

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Overview of selected 3GPP HetNet features
Emphasis on H(e)NB features, mobility, and interference management

Rel-9

H(e)NB related features such as:
More mobility options (e.g. hybrid and open access mode, HO between HeNBs), operator CSG lists, uplink user plane mux on Iuh for 3G HNB, LTE HeNB RF requirements, H(e)NB security aspects, H(e)NB OAM support, etc.

H(e)NB interference management in terms of power control discussed intensively for Rel-9/10 – but without any text going into specs (except for controlling adjacent interference level over macro level)
Thus, today we see many different implementation specific H(e)NB power setting schemes.

Rel-10

Additional H(e)NB architecture improvements such as:
intra 3G HNB-GW mobility, X2 for LTE HeNBs, LIPA/SIPTO in H(e)NB based networks, subsystem performance measurements, etc.

LTE Time-domain enhanced inter-cell interference coordination (TDM eICIC)
Addresses downlink interference management for co-channel scenarios with macro, pico, and HeNB deployment

Rel-11

Further H(e)NB architecture improvements:
Examples include HeNB network sharing, LIPA/SIPTO, more X2 options for HeNBs, etc. ...

Further improvement of LTE TDM eICIC – main focus is on UE interference supression enhancements

Nokia Siemens Networks/Nokia rapporteur for "Carrier based HetNet ICIC for LTE"

Study item "HetNet mobility improvements for LTE"

Notice: Currently no 3G HetNet interference management features standardized (except for HNB adjacent channel requirements),
and no such proposals for Rel-11. 3GPP HetNet focus seems to be on LTE.

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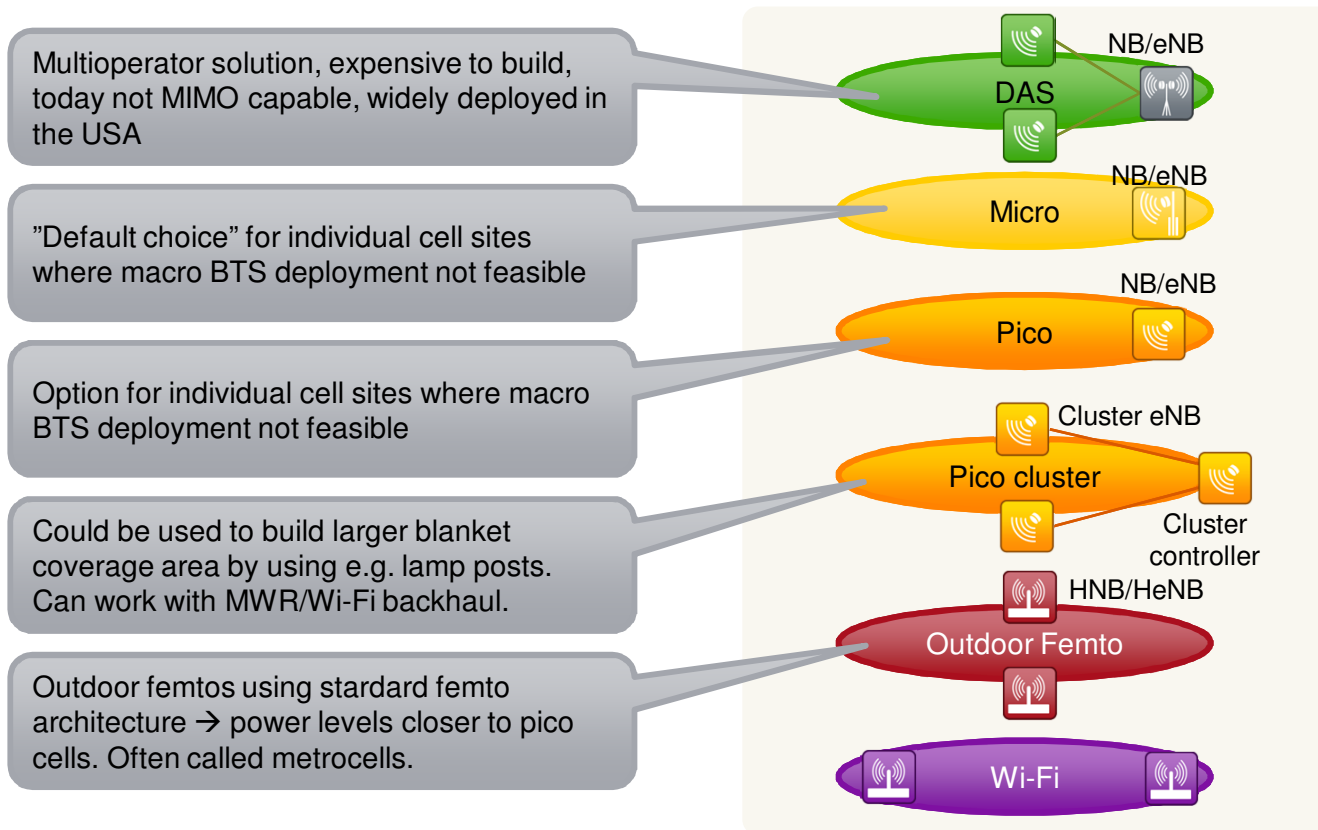
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Small cell network architecture

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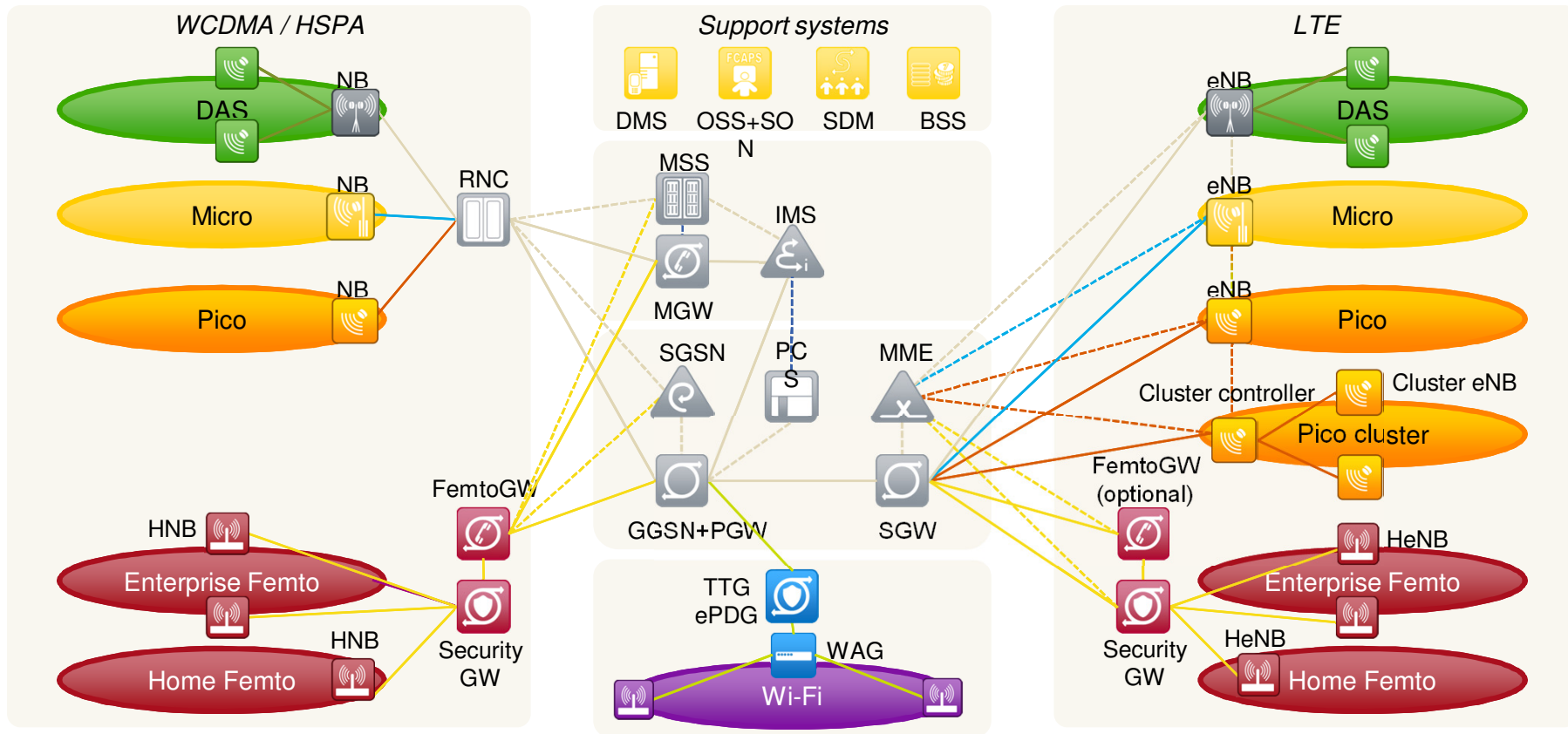
Future small cell solutions for OUTDOOR coverage/capacity

Multioperator solution, expensive to build, today not MIMO capable, widely deployed in the USA

"Default choice" for individual cell sites where macro BTS deployment not feasible

Option for individual cell sites where macro BTS deployment not feasible

Could be used to build larger blanket coverage area by using e.g. lamp posts. Can work with MWR/Wi-Fi backhaul.

Outdoor femtos using stardard femto architecture → power levels closer to pico cells. Often called metrocells.

DAS — NB/eNB

Micro — NB/eNB

Pico — NB/eNB

Pico cluster — Cluster eNB / Cluster controller

Outdoor Femto — HNB/HeNB

Wi-Fi

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Future small cell solutions for INDOOR coverage/capacity

Multioperator solution,
expensive to build, today not MIMO capable

Indoor BTS with use of
macro network architecture

Pico cluster covering building with localized
moblity + optional local breakout

Standardized femto architecture,
coordinated deployment, local breakout

Plug & play uncoordinated deployment

NB/eNB

DAS

NB/eNB

Pico

Cluster eNB

Pico cluster

Cluster
controller

HNB/HeNB

Enterprise Femto

Home Femto

HNB
/HeNB

Wi-Fi

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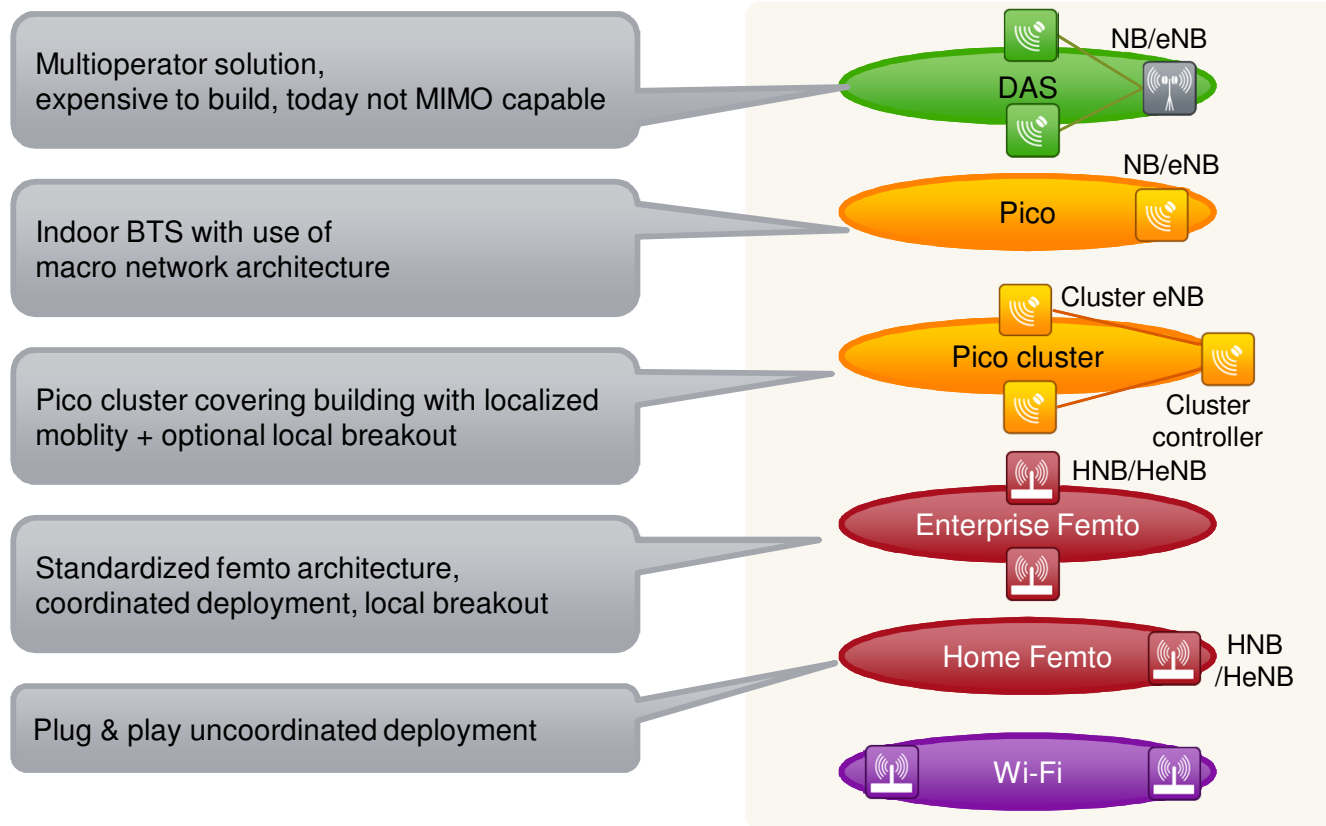
Network architecture

Transport

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Small cell backhaul options

Wireless backhaul is the only practical option when existing fixed infrastructure is not available.

Traditional LOS microwave solutions are often too costly for small cells.

Utilize existing macro sites for backhaul aggregation.

Leverage existing fixed broadband and Ethernet access where available.

Prefer packet only access with timing.

Femto and Wi-Fi can use Internet as backhaul.

Start with 20 Mbps for HSPA and evolve to 100Mbps backhaul capacity to match peak rate of HSPA+, LTE and Wi-Fi.

Interesting backhaul technology choices

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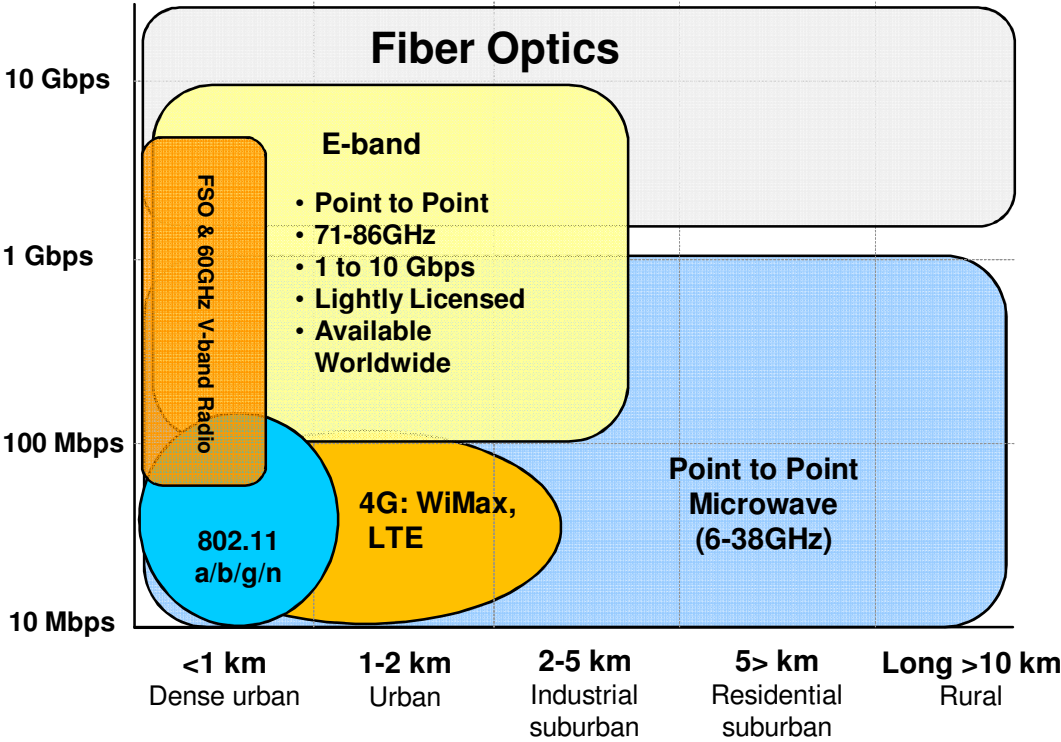
Wireless small cell backhaul options

Technology	Line of sight	Typical bands (country specific)	Band availability	Outdoor max reach	Capacity	Antenna size	Form factor
Microwave	NLOS	2.3, 2.5, 2.6, 3.X, 5.8 GHz	Available but not restricted to microwave backhaul	1 km	40-100 Mbps (10 MHz channel)	<1 foot	All outdoor & very small
Microwave	LOS	6, 11, 18, 23, 38 GHz	Licensed and can be crowded	30 km	10-500 Mbps	1-3 feet	All outdoor or split-mount
Millimeter wave	LOS	60, 76, 86 GHz	Available with light license in most countries	3 km	1,000+ Mbps	1 foot	All outdoor or split-mount
Wimax	NLOS	2.3, 2.5 & 3.5 Ghz	Licensed and expensive	20 km	20-100 Mbps (20 Mhz channel)	<1 foot	All outdoor & very small
FD/TD-LTE, LTE-A	NLOS	FDD/TDD-LTE bands	Licensed and expensive, in-band consumes access capacity	20 km	50-100 Mbps (20 Mhz channel)	<1 foot	All outdoor & very small
Wi-Fi	NLOS	2.4 GHz, 5 Ghz	Unlicensed but crowded	100 meters	20-54Mbps (40Mhz channel)	<1 foot	All outdoor & very small
Satellite	LOS	Ku & Ka	Licensed	Unlimited	1-10 Mbps	1-4 feet	All outdoor

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Small cells require new security measures

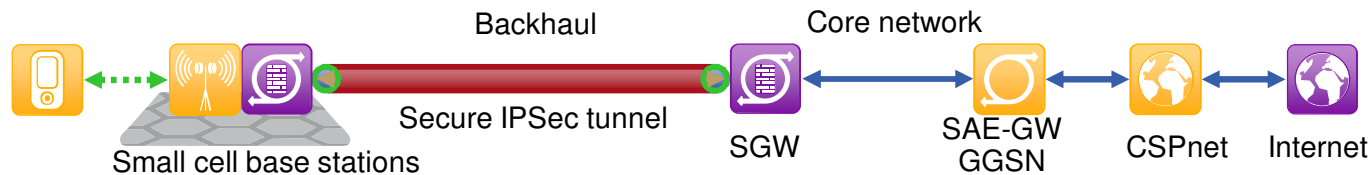## Small cell security considerations

- Small cell sites and equipment easier to access physically than traditional macro – Indoor Femto and Wi-Fi access points especially easy to access physically
- Outdoor equipment must be protected from weather, vandalism and theft
- Installing rogue base stations or backhaul snooping devices is significantly easier
- Internet often used for backhaul increasing security risks
- Wi-Fi authentication and network identification significantly weaker than cellular networks
- With local breakout attacks from Internet easier to perform

Security threats

Attacks on air interface
- Man in the middle and spoofing
- Identity stealing
- Eavesdropping
- Fraud

Attack on sites
- Theft or vandalism
- Hardware changes or rogue elements
- Software updates or modifications
- Stealing of security keys

Attack on backhaul
- Eavesdropping
- Denial-of-service

Attacks on controller
- Over backhaul or from Internet

Security solutions

- Tough and weatherproof outdoor enclosures
- Tamper free outdoor mounting
- Separate logical network interfaces for management, signaling and user plane
- Secure remote management solution
- Special attention on security of local diagnostics and management ports
- IPSEC backhaul mutual authentication and encryption – quality of implementation and key management very important
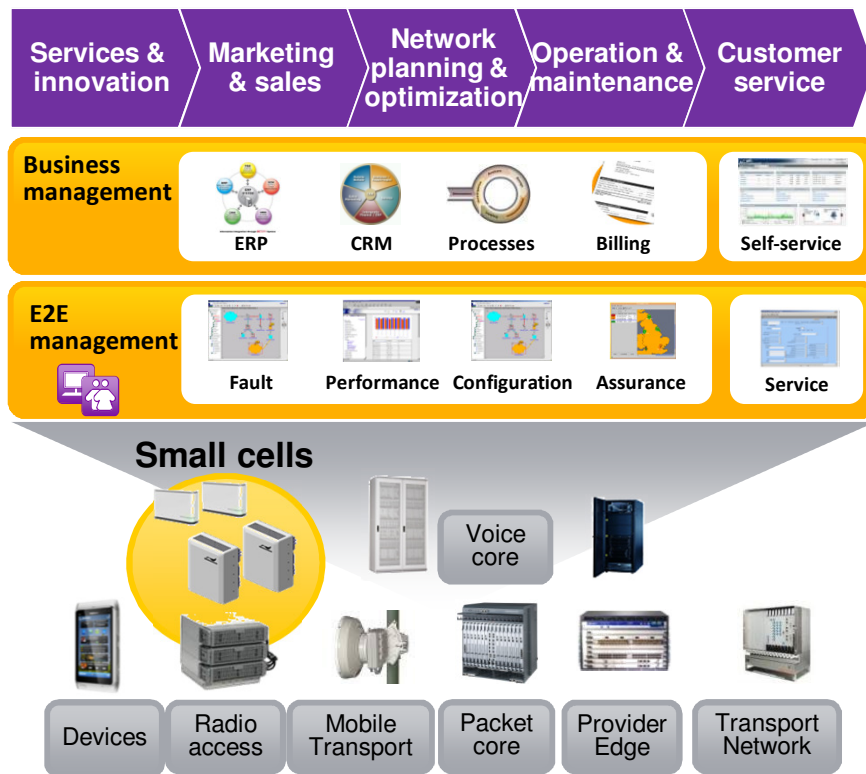- Independent security audits

Backhaul

Core network

Secure IPSec tunnel

Small cell base stations

SGW

SAE-GW GGSN

CSPnet

Internet

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Small cells part of e2e mobile broadband services management

Services & innovation	Marketing & sales	Network planning & optimization	Operation & maintenance	Customer service

Business management

ERP CRM Processes Billing Self-service

E2E management

Fault Performance Configuration Assurance Service

Small cells

Voice core

Devices | Radio access | Mobile Transport | Packet core | Provider Edge | Transport Network

- Small cells seamless part of operator e2e management systems
- Management scalability to large number of BTSs
- Easy plug and play installations
- Automated network management with SON
- Management requirements for small cell transport
- Mobility handovers and interference management between small cells and macro
- Layer optimization management and traffic steering within whole radio access network
- Customer experience management, use and usage reporting

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SON automation for Heterogenous Networks

- Automated Neighbour Relationship inter-RAT for LTE, 3G and GSM

- SON Plug and Play network installations

- Load Balancing GSM/3G/LTE

- Mobility management and handover optimization

- InterRAT neighbor relation optimization and synchronization

- Smart energy management

- Self-Healing – automated fault detection, analysis and corrective actions

- SON automation functions for all small cell and macro cell types and network layers

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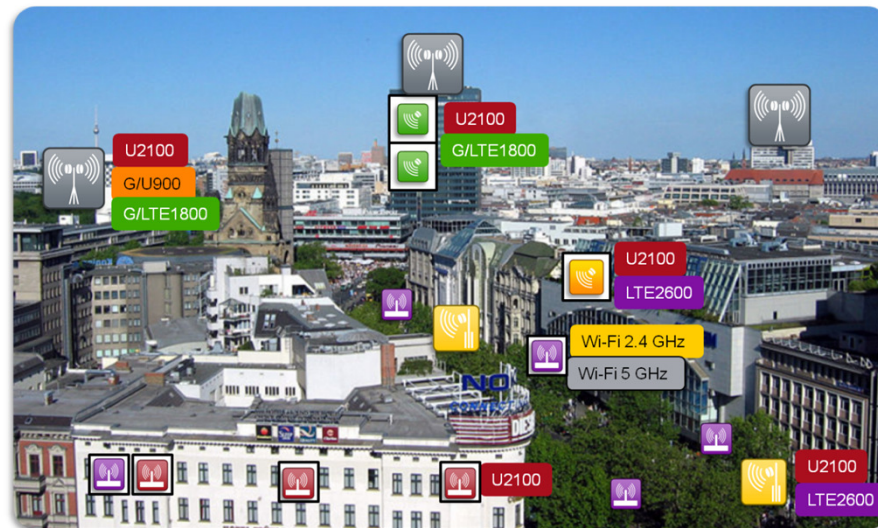
Small Cells and HetNets - Summary

- Small cells are cellular base stations concepts with significantly lower power and range than traditional macro cells
  - Many different type: micro- pico-, and femtocells and Wi-Fi
  - Main drivers are coverage, capacity and new opportunities where macro-cells are not feasible

- HetNets means that large (macro-) and small cells are combined to provide improved service quality for the users
  - Traffic steering and load balancing mechanisms are required

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