



UNIK4230: Mobile Communications

Spring 2015

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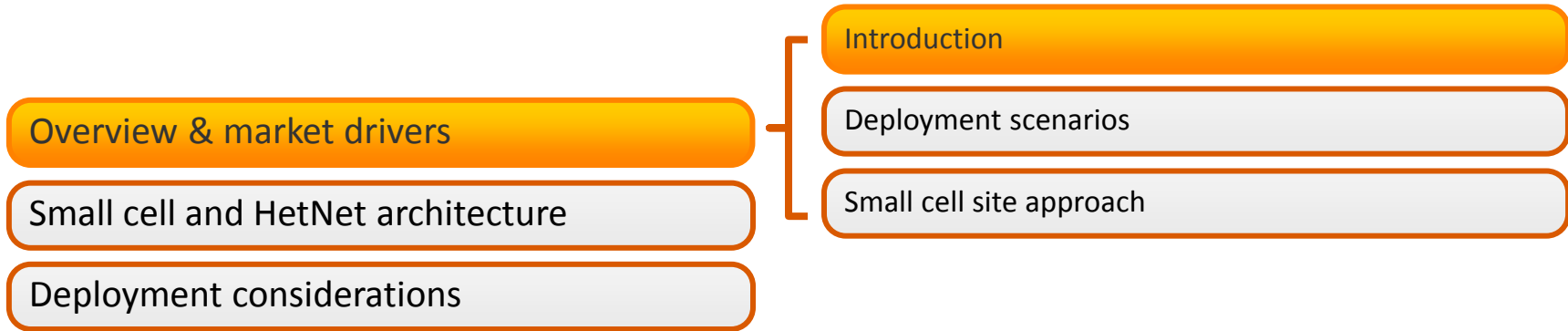
Tel: 916 94 909

Small cells and HetNet

21.05.2014

Materials contribution: Nokia Siemens
Networks

Contents



Drivers for small cells

Coverage

Improve indoor coverage



Fill coverage gaps & holes



Fill new coverage areas



Enterprise solutions



New services



Fixed mobile convergence



New opportunities

Capacity

Macro not feasible



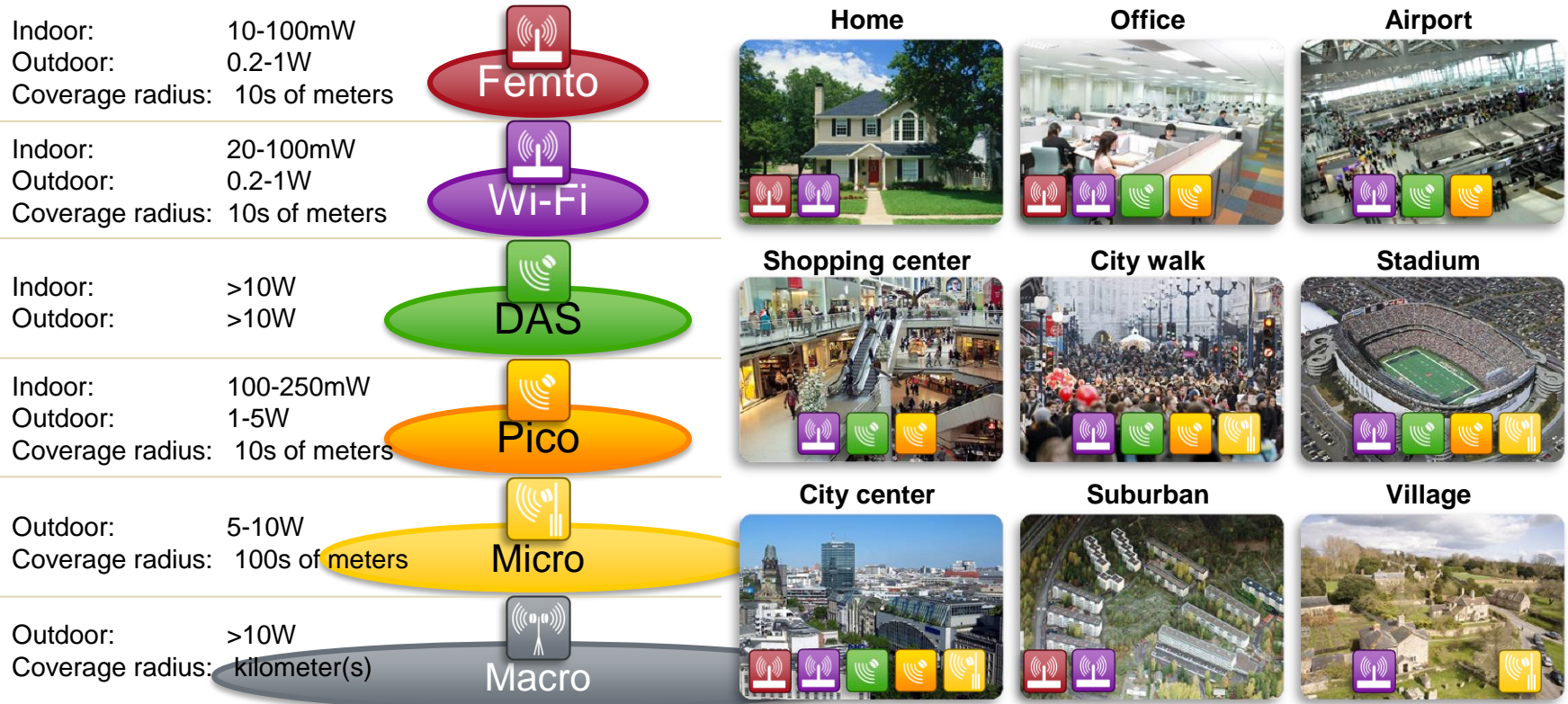
Dense hotzone capacity



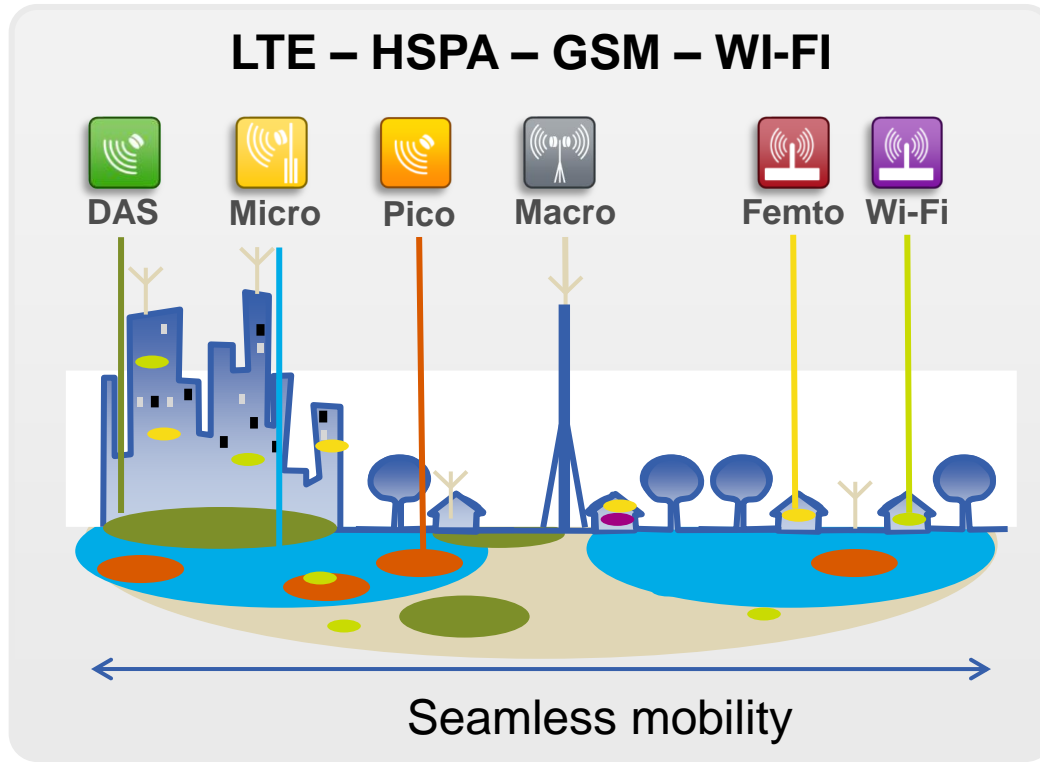
Offload from macro



Different small cell deployment scenarios



Small cells and heterogeneous network



Always best connected user experience

Seamless interworking between different cell sizes, frequency layers and radio technologies

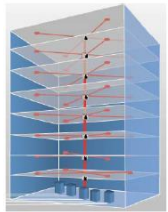
Interference management

Layer optimization and traffic steering

Scalable smart network management and SON automation

Maturity level of different small cell technologies

Mature mainstream -
Widely used globally



Indoor DAS



Outdoor DAS

Wi-Fi



Enterprise



Home

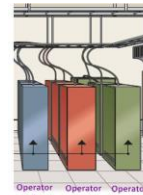


Public

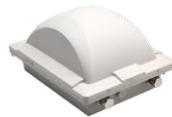
Emerging solutions



HSPA Femto



LTE DAS



Wi-Fi cellular
interworking

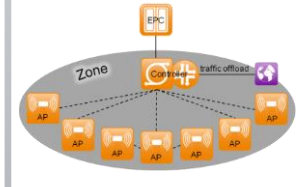


HSPA Micro

Future technologies



LTE Micro/Pico



LTE Pico cluster

Heterogeneous Networks



LTHE

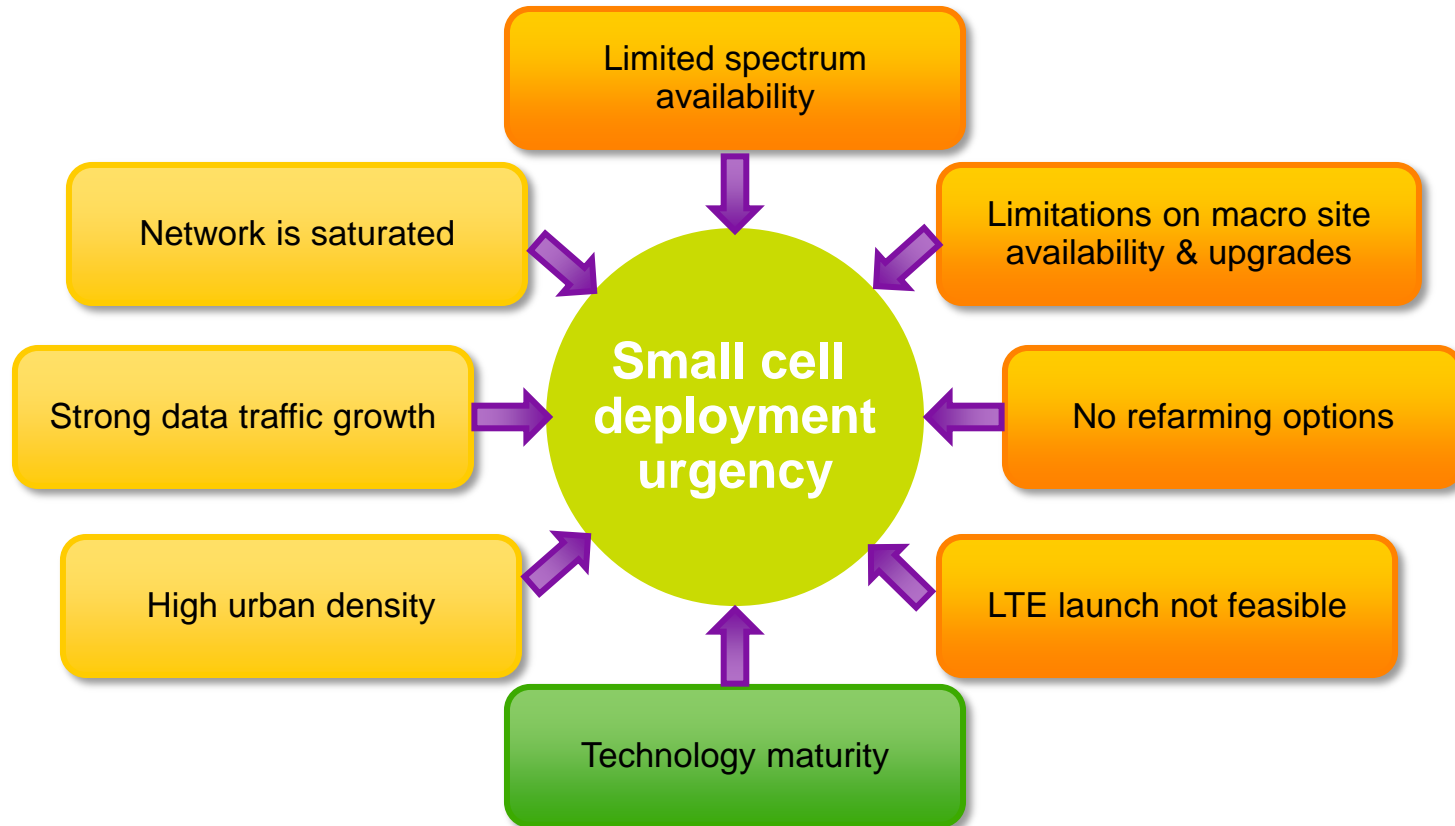


LTE-A











802.11ac

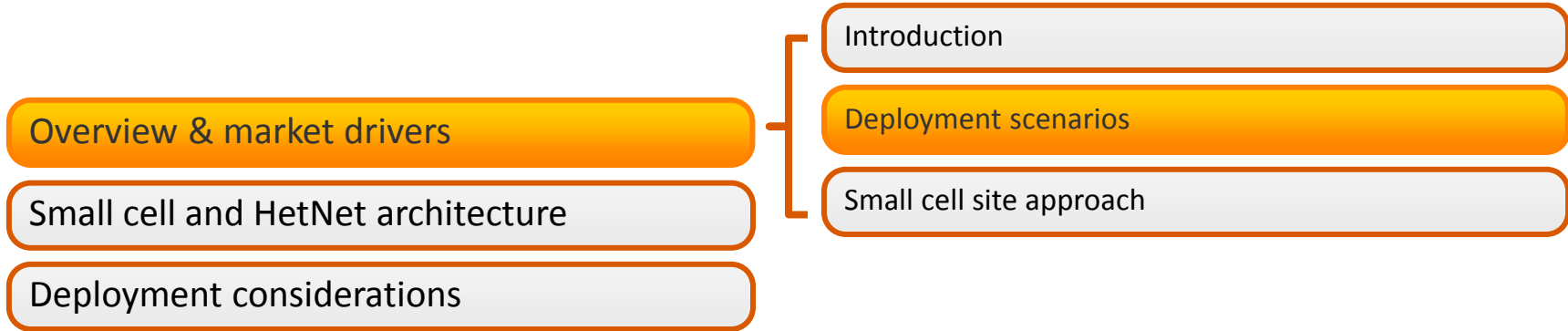
Factors impacting operator small cell deployment timing



Definitions of different small cell types

	Indoor			Outdoor				
								
	Wi-Fi	Femto	Pico	Wi-Fi	Femto	Pico	Micro	Macro
Output transmit power	20mW - 100mW	Residential 10 -100mW Enterprise 100-250mW	100mW - 250mW	200mW - 1W	200mW – 1W	1 - 5W	5 - 10W	>10W
Architecture	LAN	Gateway	Macro / Gateway	Gateway	Gateway	Macro / Gateway	Macro	Macro
Coverage radius	<50 meters	<50 meters	<100 meters	10s of meters	10s of meters	~100 meters	100s of meters	Kilometer(s)
Size and weight	<1L <1kg	<1L <1kg	2-4L 1-3kg	3-8L 2-5kg	3-8L 2-5kg	5-10L 5-10kg	10-50L 8-20kg	30-500L 30-200kg
Max users	20-30	8-16	16-64	30-150	8-32	16-64	64-256	>256
Typical deployments	Consumer Enterprise Cafe	Consumer	Enterprise	Lamp posts Building walls Utility poles	Lamp posts Building walls Utility poles	Lamp posts Building walls Utility poles	Lamp posts Building walls Utility poles	Tower masts Rooftops

Contents



Small cell deployment example: City center

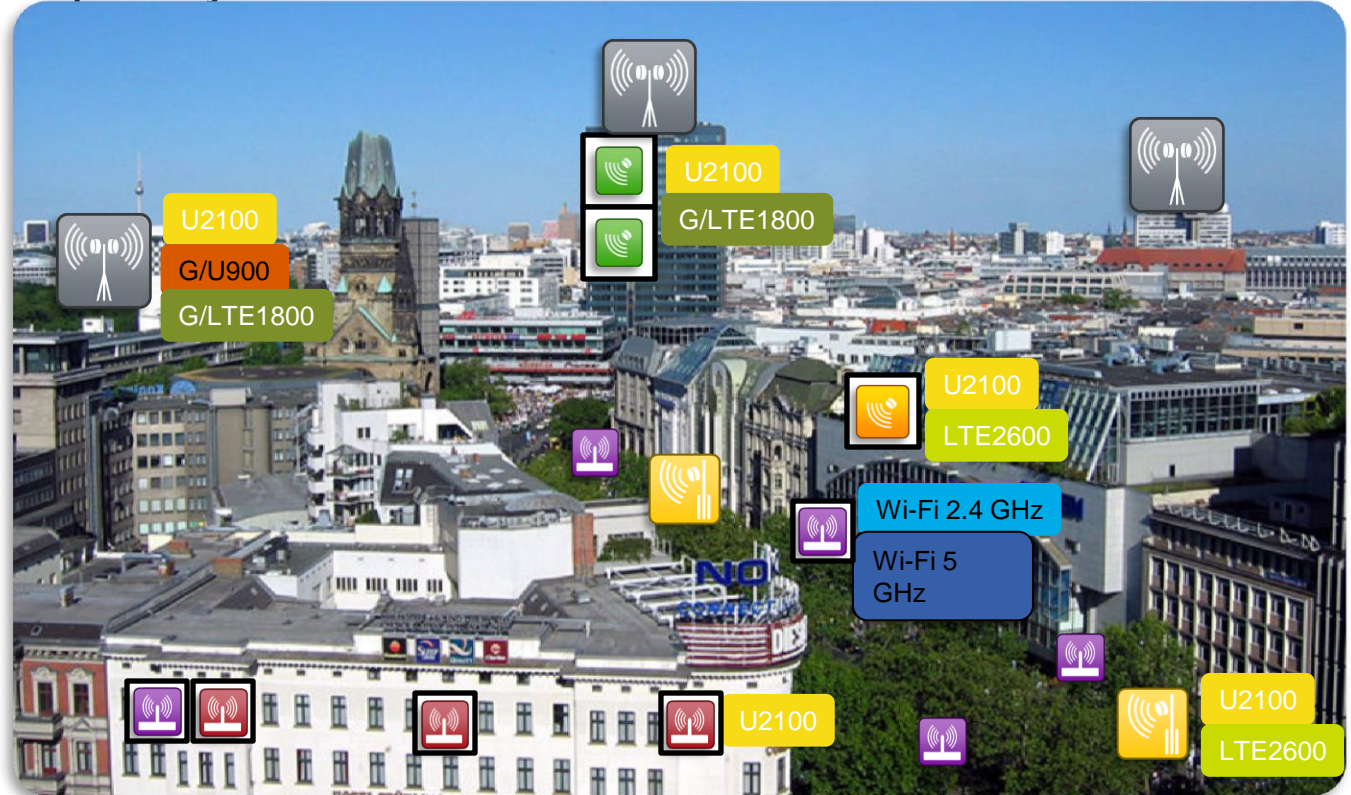
Example EMEA frequency use scenario

indoor

-  Public Wi-Fi
-  Femto
(10-100 mW)
-  Pico
(0,1 – 1 W)
-  DAS
(macro)

outdoor

-  Public Wi-Fi
-  Pico/Micro
(1 – 10 W)
-  Macro
(> 10 W)



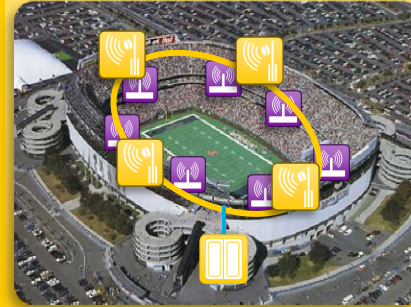
Small cell deployment alternatives: Stadium

Need for dense capacity



Outdoor DAS

- Can be shared with other operators
- Part of macro network
- Additional capacity using carrier Wi-Fi



Remote radio heads

- Typically operator specific
 - Fiber fronthaul to centralized baseband
 - Part of macro network topology
- Additional capacity using carrier Wi-Fi



Micro/pico cells

- Typically operator specific
 - Part of macro network topology
- Additional capacity using carrier Wi-Fi



Pico cluster

- Typically operator specific
 - Local cluster network topology
- Carrier Wi-Fi can be co-located with pico BTSs

Small cell deployment example: Suburban

Femto coverage & offloading, private Wi-Fi for fixed BB extension

indoor



Private Wi-Fi



Femto

(10-100 mW)

outdoor



Macro

(> 10 W)



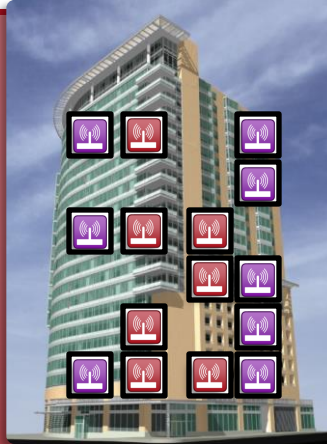
Small cell deployment alternatives: High rise building

Small cells for indoor coverage and capacity



In building DAS

- Initiated by real estate
- Typically multi-operator
- Open to all subscribers
- Utilizes macro base stations
- Planned interworking with macro
- Backhaul from building telco-room



Femto

- Planned and deployed by customer
- Dedicated to customer or open to all
- Utilizes femto gateway architecture
- Utilizes building LAN for backhaul



Pico

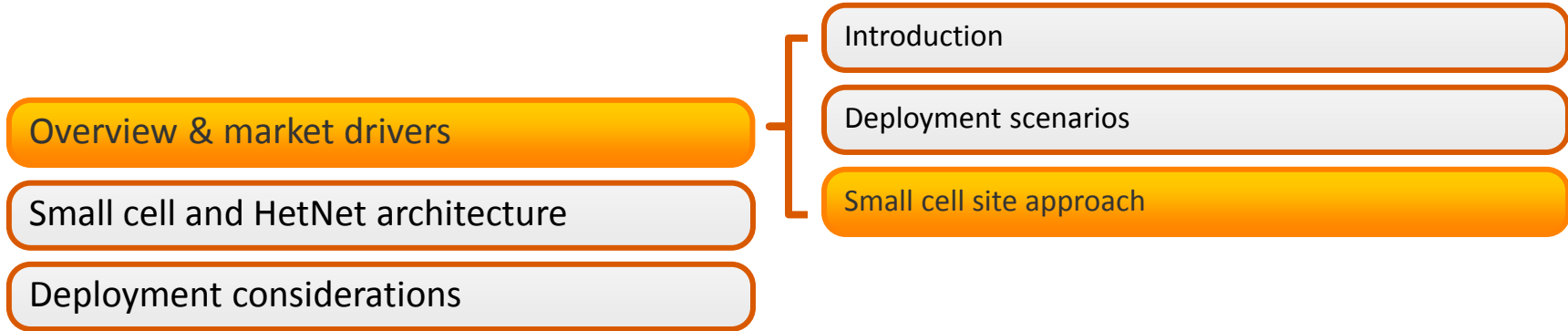
- Initiated by operator
- Open to all subscribers
- Part of macro architecture
- Planned interworking with macro
- Utilizes building cabling for backhaul



Customer deployed private Wi-Fi and optional guest Wi-Fi

Small cells

Contents



When might a new macro site not be feasible?



- No space for new macro site BTS or antennas.
- New macro site permits not granted or site lease is very expensive
- Site is too far from optimal location



- Cellular tower or pole is not accepted by authority community
- New macro site is overkill



- Macro sites cells capacity is not enough
- More and smaller capacity cells need to be added



- Safety regulations limit the transmitted power at street level



- Smaller cell and low transmit power is optimized for e.g. indoor usage, tunnels and parking lots



- New macro site is overkill (cost, capacity, size) for coverage fix or extension

Small cell site examples

Small cell site examples



Indoor enterprises



Indoor public spaces



Utility poles



Lamp posts



Residential homes



Outdoor building walls & rooftops



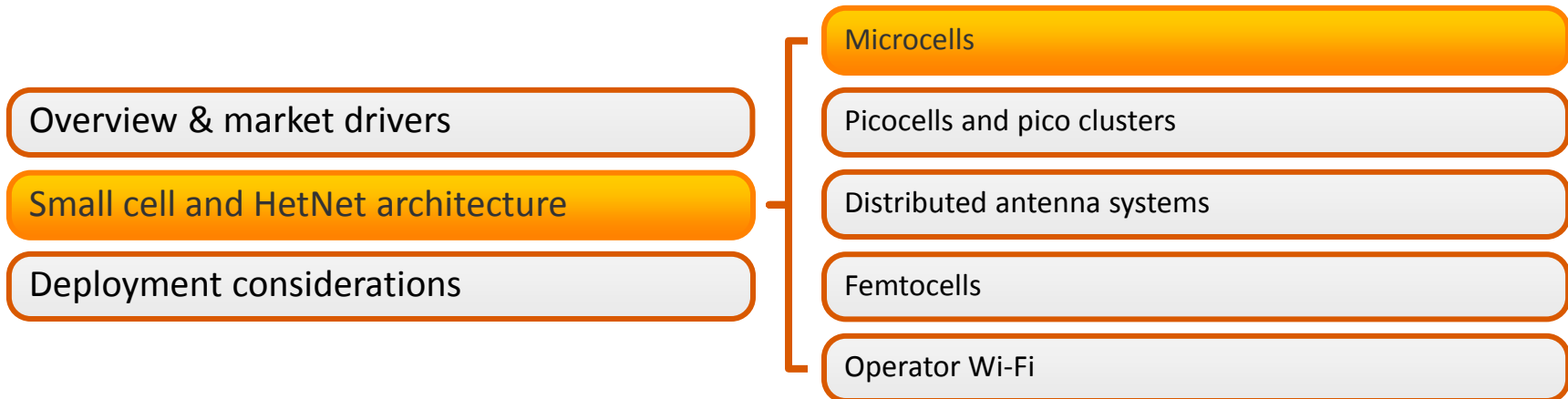
Strands



Bus stops

Key small cell cost items are site and backhaul

Contents



What are micro base stations?

Base station

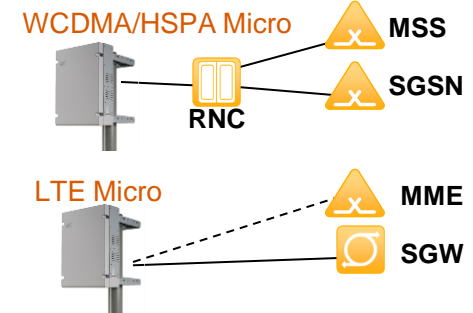


Site

Proposed 3g Bellbox Antennae Positions



Network



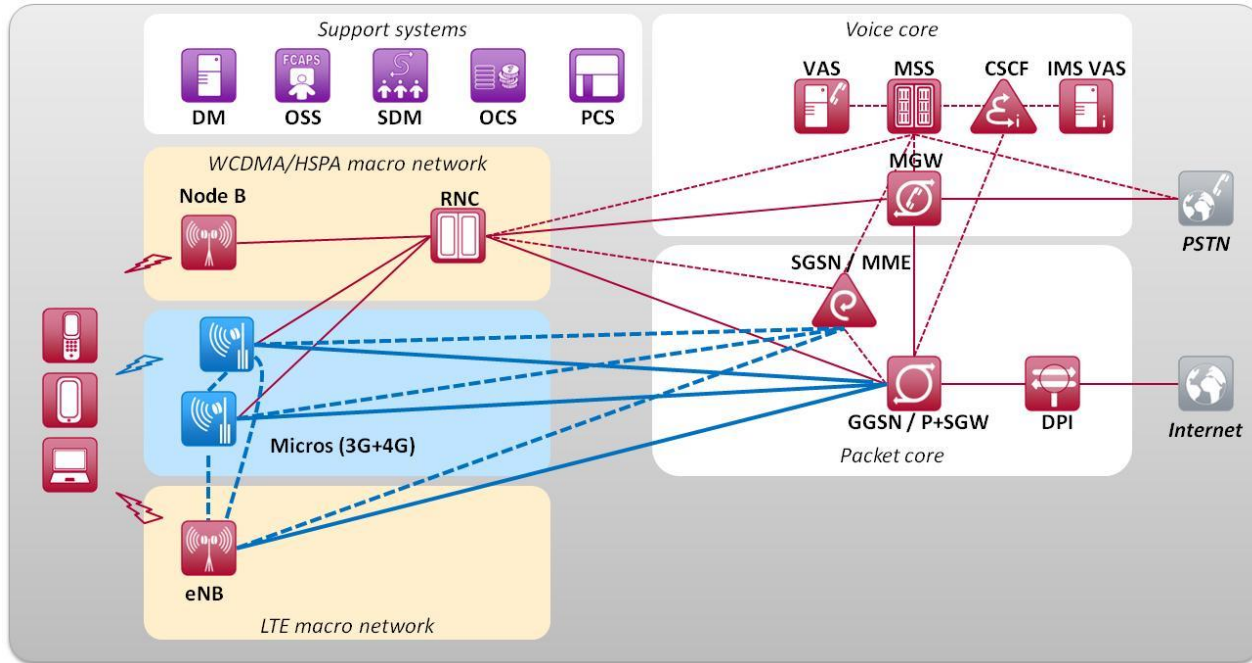
Outdoor

- Output power 1-10W, typically 5W
- Cell size typically 100s of meters
- BTS size 10 – 50L, expectations about 10L
- Small configurations, typically 1-2 cells/1 cell MIMO
- Typically 50-200 3G/4G users per BTS

- Deployment on wall, roof top and utility pole
- Small antennas typically quite close to users e.g. street level (short safety distance)
- Mainly outdoors, but possible also indoors e.g. airports, shopping malls and railway stations
- Medium BTS and site cost

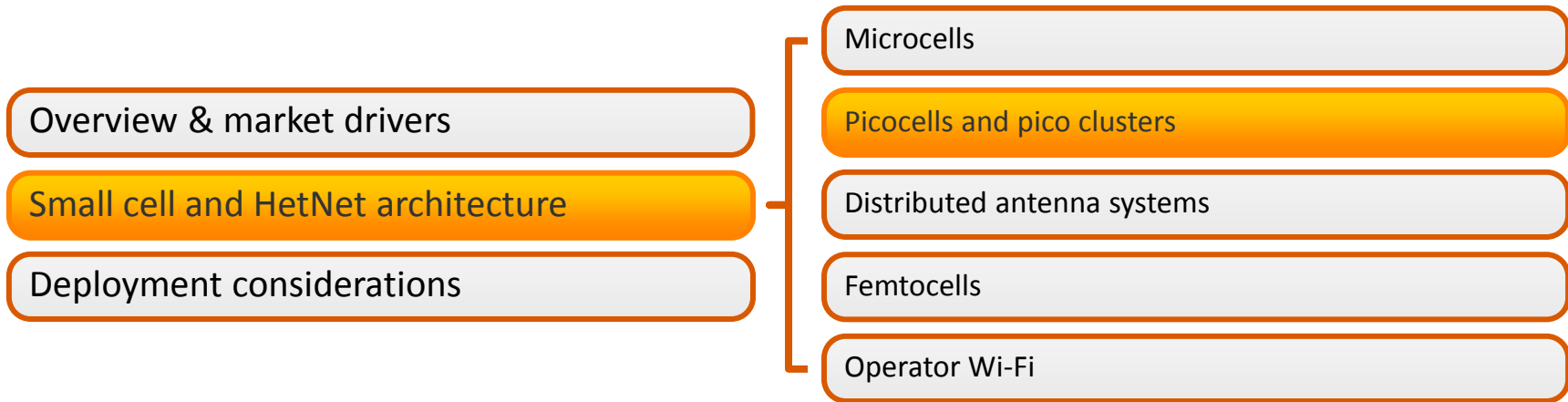
- Utilize macro network topology
- Same features as macro cells
- Planned deployment & full mobility
- Dedicated or macro shared carrier
- For traffic hot spots or coverage fix
- Capacity & coverage when macro cell deployment is not feasible
- Fixed broadband and microwave backhaul

Micro uses common architecture with macro



- WCDMA/HSPA:** connected to RNC with same Iub-interface as macro Node B
- LTE:** connected to MME+SGW with same S1-interface as macro eNB.
X2 links needed between micro + surrounding macros/micros

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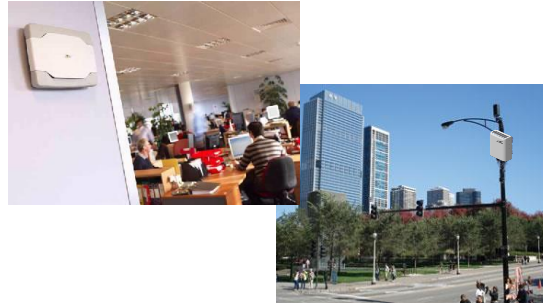


What are pico base stations?

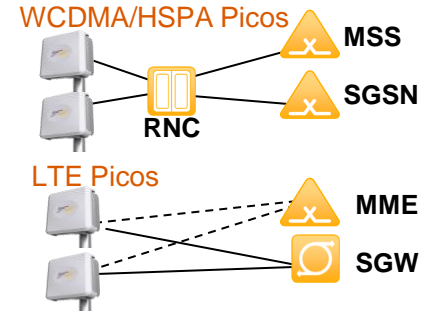
Base station



Site



Network



Indoor

- Output power 100-250 mW
- Size 2-4 L, 1-3 kg

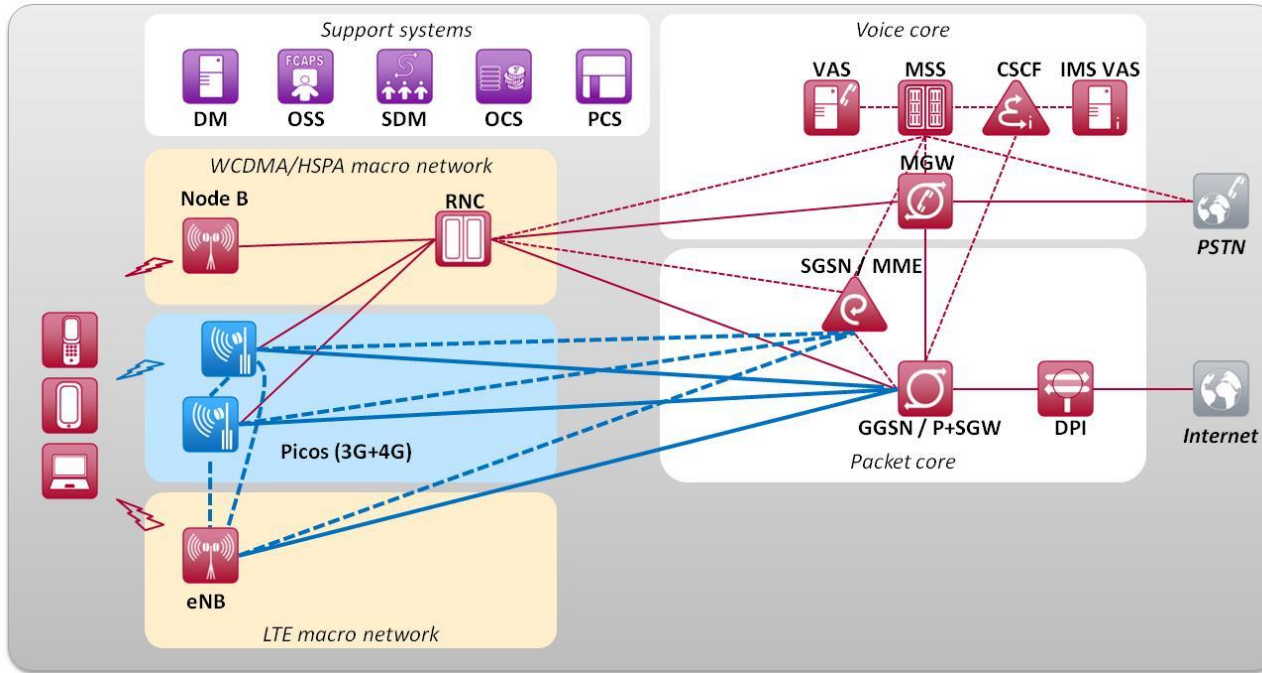
Outdoor

- Output power 1-5 W
- Coverage radius 10s of meters
- Size 5-10 L, 5-10 kg
- Integrated antenna
- Simultaneous users 16-64

- Indoor building visible location
- Outdoor lamp posts, building walls and utility poles
- Easy site acquisition and rental costs
- Requires low cost high speed backhaul transport solution
- Requires network planning, operator installation

- From network architecture perspective looks like macro cells
- Could be a subset of features and functionalities of macro cells
- Dedicated carrier (frequency) or same as for macro
- Indoor coverage/capacity or outdoor street level capacity solution

Traditional Pico architecture



WCDMA/HSPA:

connected to RNC with same lub-interface as macro Node B

LTE:

connected to MME+SGW with same S1-interface as macro eNB.
X2 links needed between picos + surrounding macros/micros/picos

What are pico clusters?

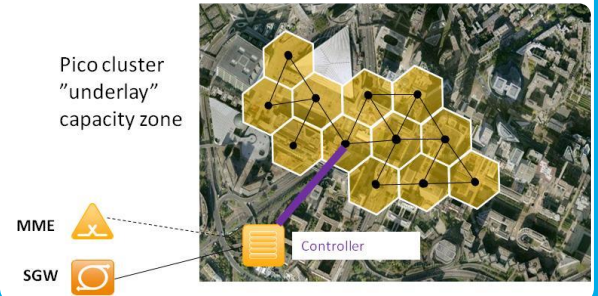
Base station



Site



Network



Indoor

- Output power 100-250mW
- Size 2-4 L, 1-3 kg

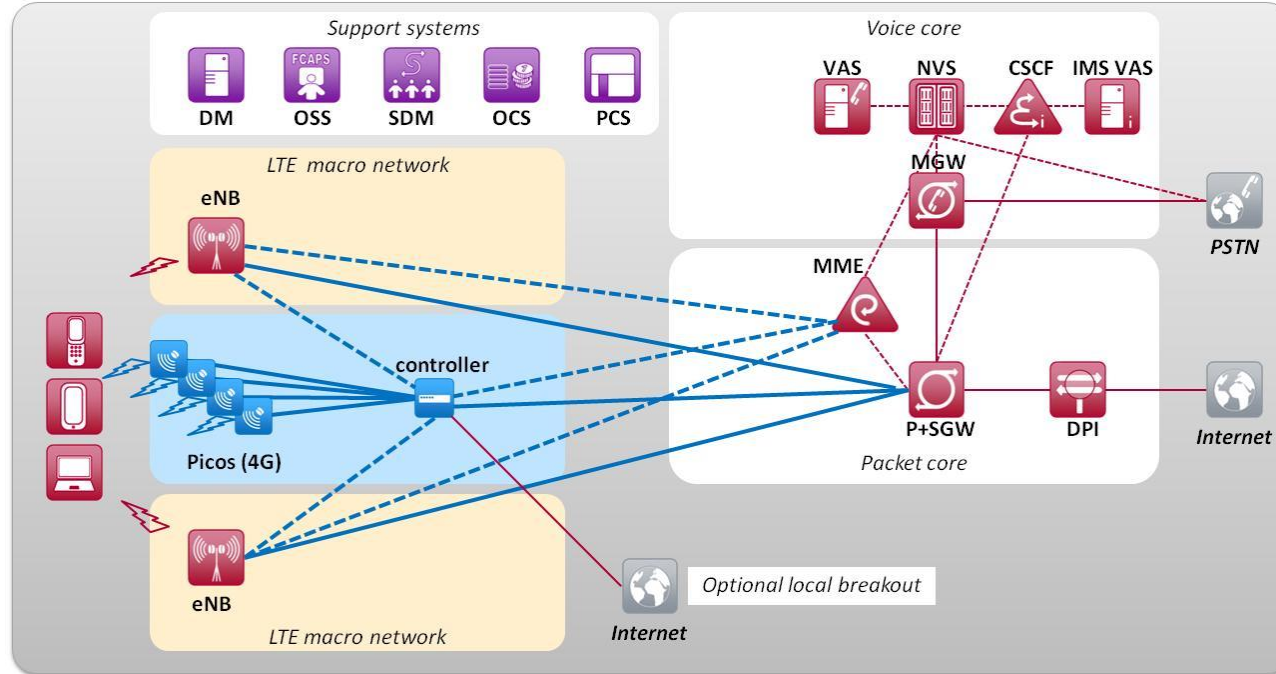
Outdoor

- Output power 1-5 W
- Coverage radius 10s of meters
- Size 5-10 L, 5-10 kg
- Integrated antenna
- Simultaneous users 16-64

- For areas where larger number of neighboring pico cells used to build outdoor "underlay" capacity zone or indoor small cell coverage/ capacity cluster
- Otherwise similar characteristics as with traditional pico sites

- Controller taking care of cluster internal signaling & mobility
- Dedicated carrier (frequency) or same as for macro
- Indoor coverage/capacity or outdoor street level capacity solution

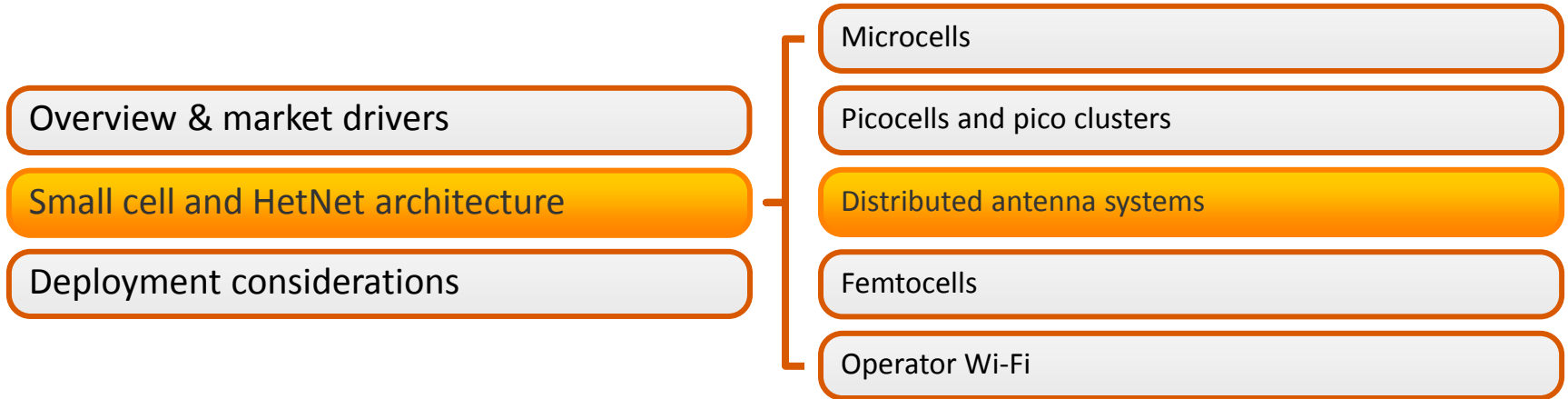
Pico cluster architecture



LTE:

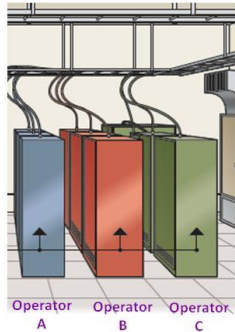
The entire cluster looks like one S1 connection to MME+SGW. No X2 links needed between the nodes inside the cluster, towards surrounding macros X2 links from the controller.

Contents



What are distributed antenna systems (DAS) ?

Base station



Site

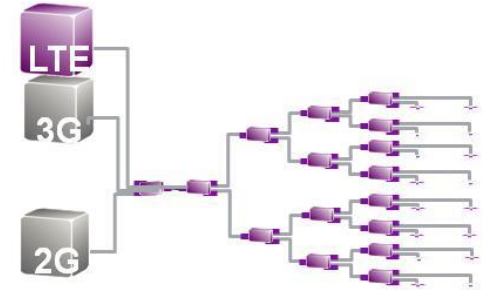


Indoor antenna



Outdoor antenna

Network



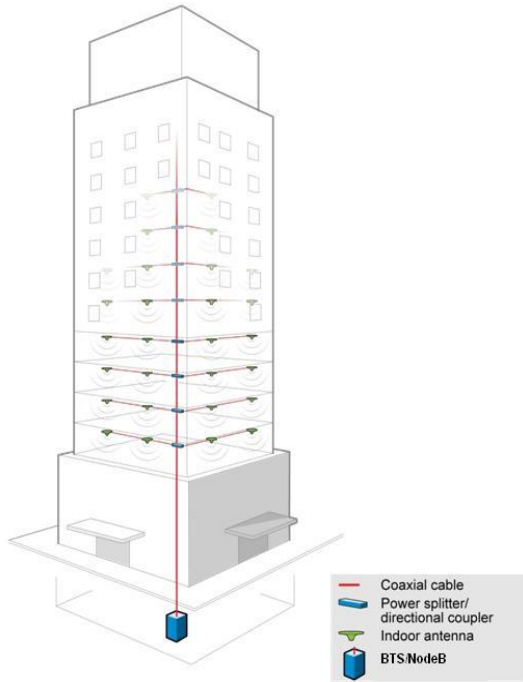
Macro BTS

- Typically normal macro BTS connected to the DAS
- DAS can support sharing the antennas between multiple operators base stations

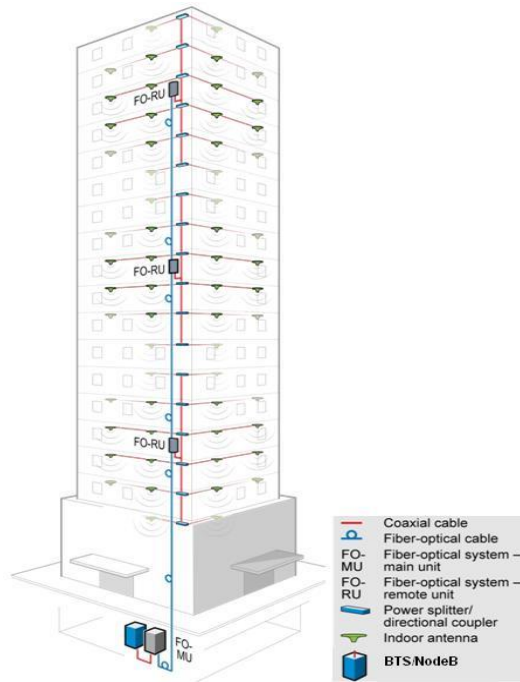
- Small indoor antennas in various building locations
- Outdoor lamp posts, building walls and utility poles
- Requires special DAS cabling in the buildings or outdoor area
- Requires network planning, operator installation

- From network architecture perspective looks like macro cells
- Macro features and functionalities
- Passive, active and hybrid options
- Shares carrier with macro
- Can be operated by 3rd party operator-independent companies
- Especially used as multi-operator indoor coverage solution

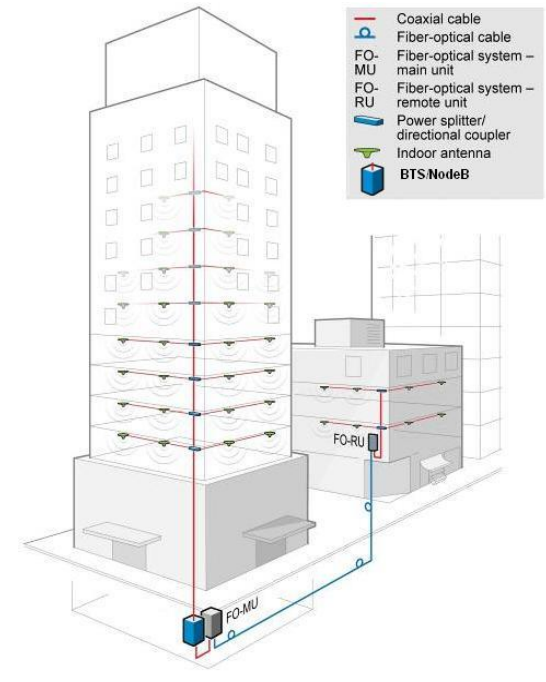
DAS Solution Examples



PASSIVE DAS

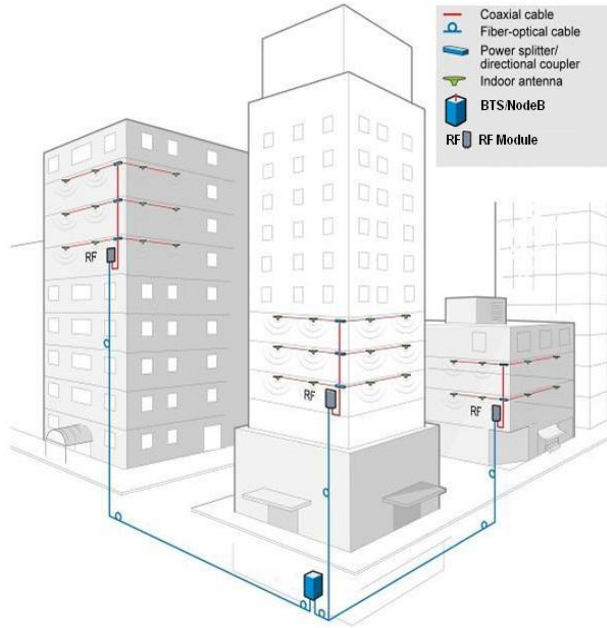


ACTIVE DAS

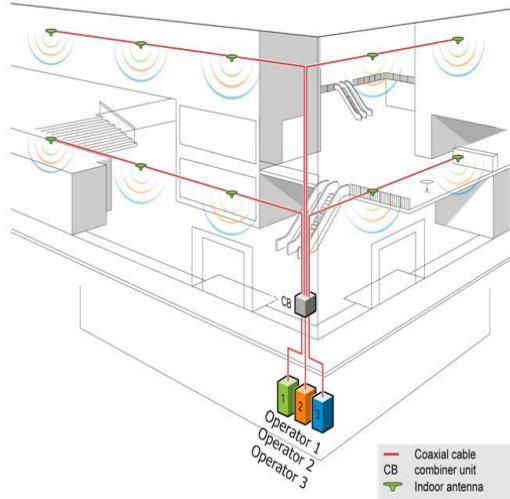


HYBRID DAS

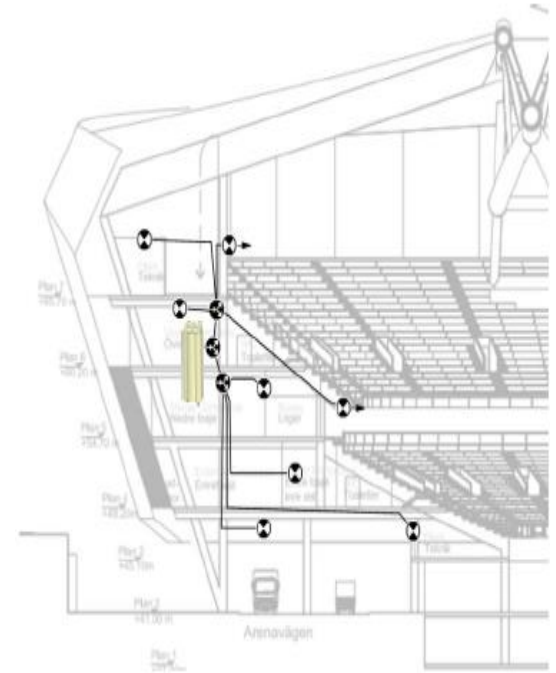
DAS Solution Examples



Distributed BTS



**Multi Operator –
Multi Technology DAS**



Outdoor DAS for Stadium

What are outdoor DAS systems ?

Outdoor DAS

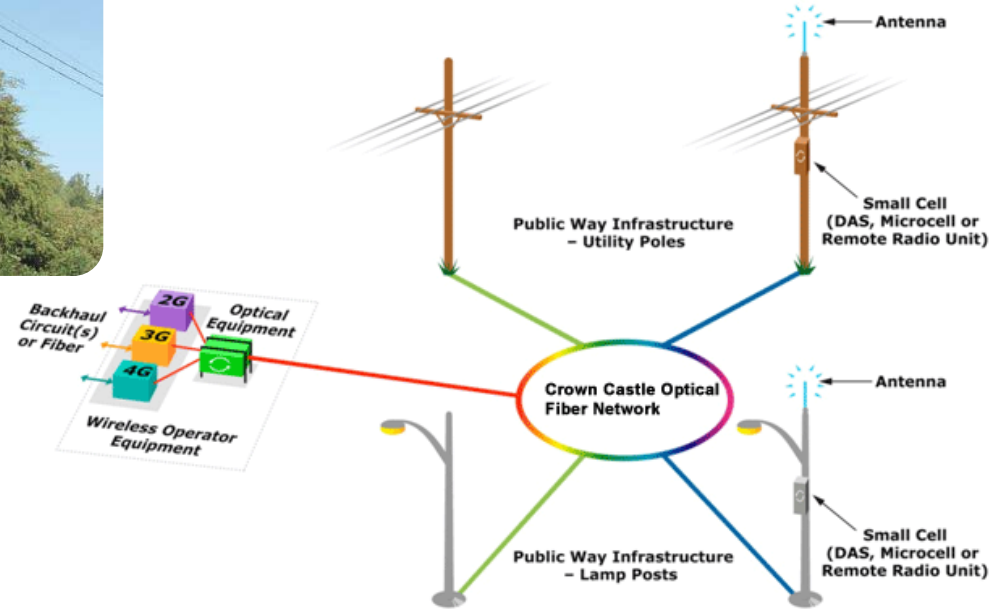
Capacity or coverage needs

Tough permitting environments

Densely populated areas

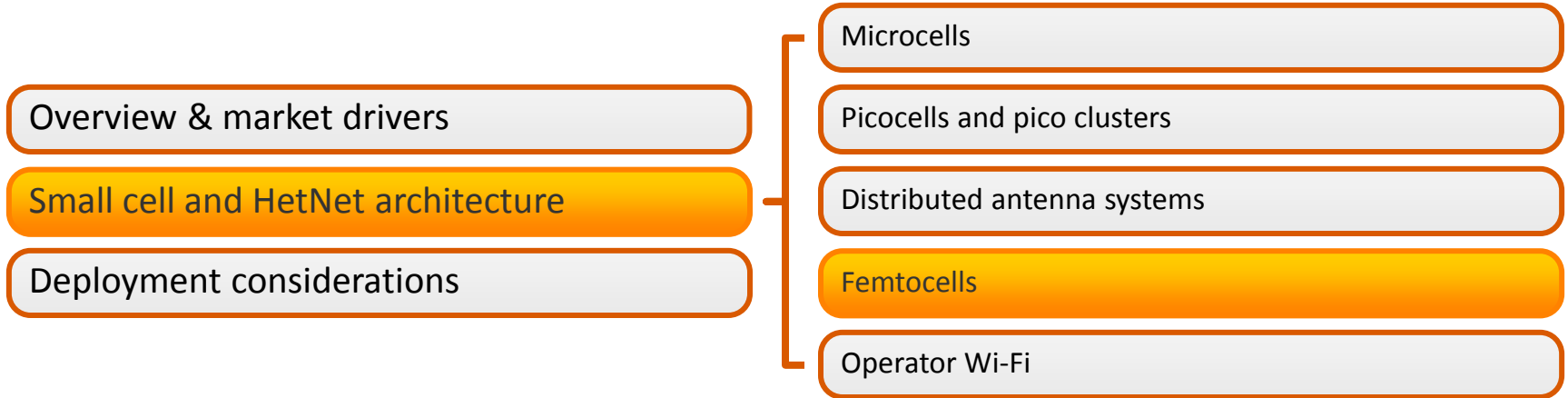


- Using lamp posts and similar infrastructure
 - Typically run by dedicated companies that lease capacity to mobile operators
- Today used especially in big US cities



Source: Crown Castle: <http://www.crowncastle.com>

Contents



What are femtocells?

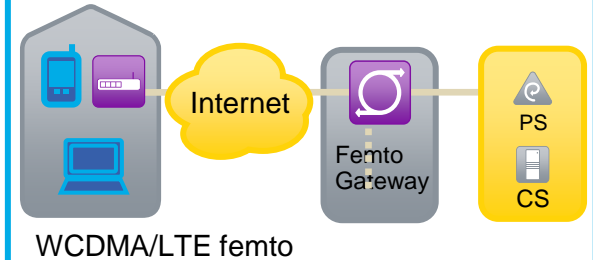
Base station



Site



Network



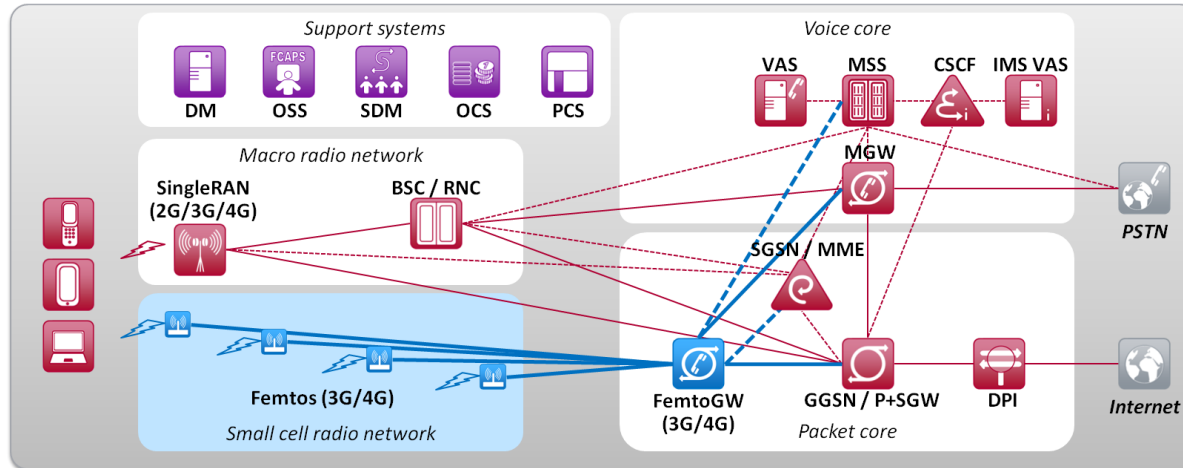
- Low cost very small HSPA/LTE base station for home or office
- Transmit power 10-100 mW *)
- Zero-touch installation, auto-configuration
- Open or closed access

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

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

- 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)

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:

connected to the core network via a HeNB GW using the S1 interface. Can also be connected directly to the macro network. (HeNB = LTE femto)

Femtocell business drivers

Coverage enhancement

- Customer retention

Capacity boost

- Macro network offload

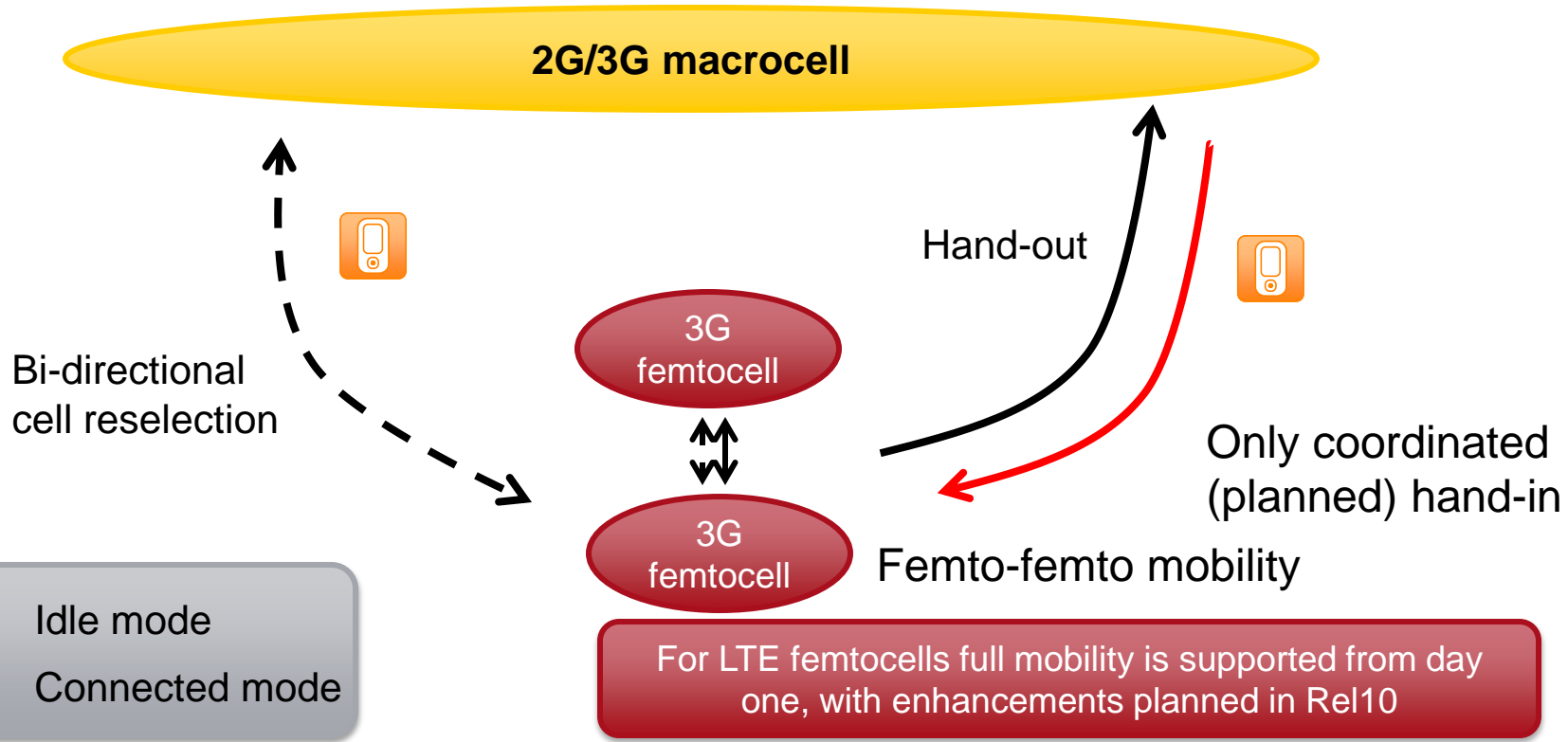
Femtocell-enabled value added services

- For example presence based applications

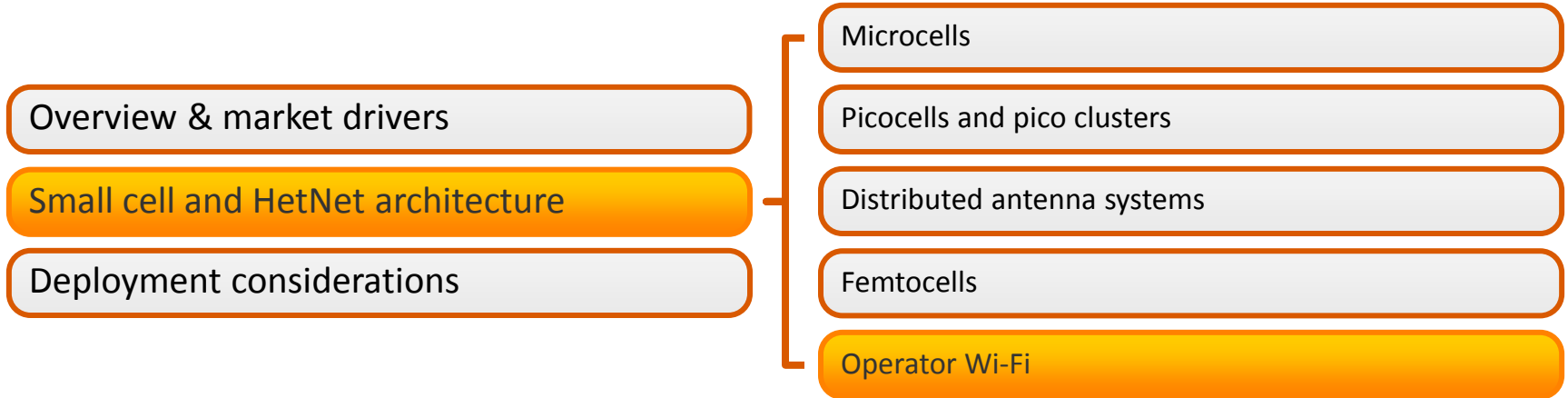


Today the most evident benefit of femtocells is to improve indoor coverage for voice and smartphones, especially where the operator does not have spectrum in low bands

3G femto mobility



Contents



What is operator Wi-Fi?

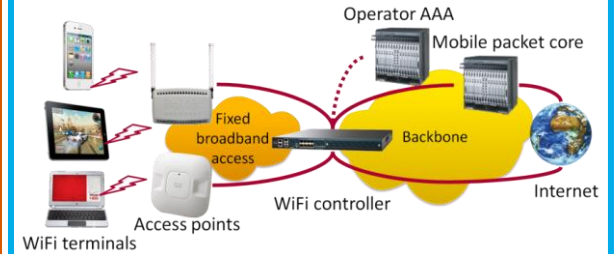
Access points



Site



Network



Indoor

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

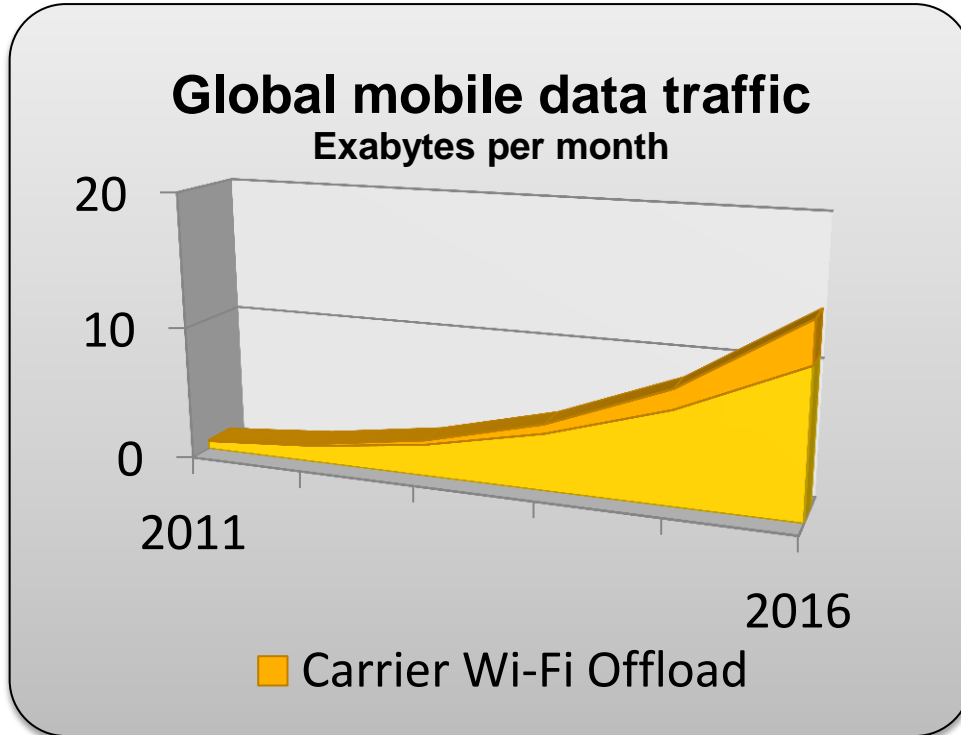
Outdoor

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

- 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

- 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

Traffic offload from mobile networks to carrier Wi-Fi networks



Source: Cisco, Gartner, Informa

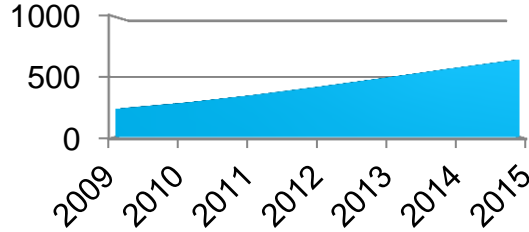
Carrier Wi-Fi offloading from mobile devices grows from 11% in 2011 to 22% in 2016

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

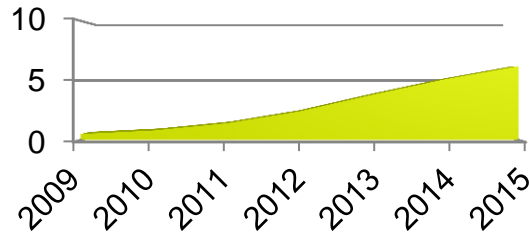
Additionally by 2016 more than 500 million other Wi-Fi capable mobile broadband devices are in use

Strong growth in Wi-Fi hotspots

Private Wi-Fi hotspots (millions)



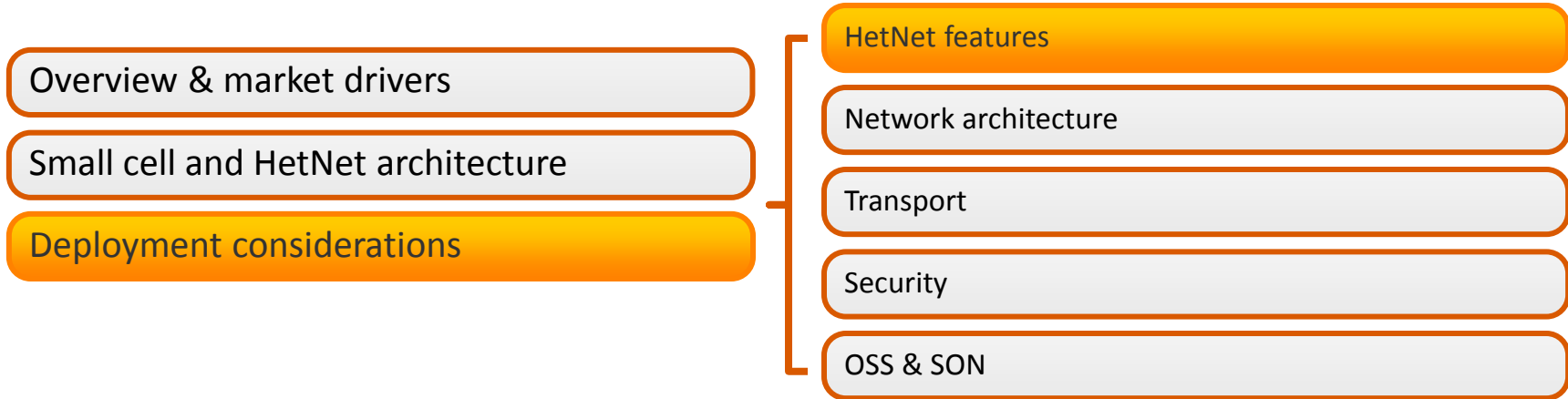
Public Wi-Fi hotspots (millions)



Source: Informa telecoms & media

Private Wi-Fi Hotspots			
<p>Home</p>	<p>Residential</p>	<p>Office</p>	<p>Campus</p>
<p>Café & restaurants</p>	<p>Shopping center</p>	<p>Airport</p>	<p>Hotels</p>
<p>City center</p>	<p>Stadium</p>	<p>City walk</p>	<p>Village</p>

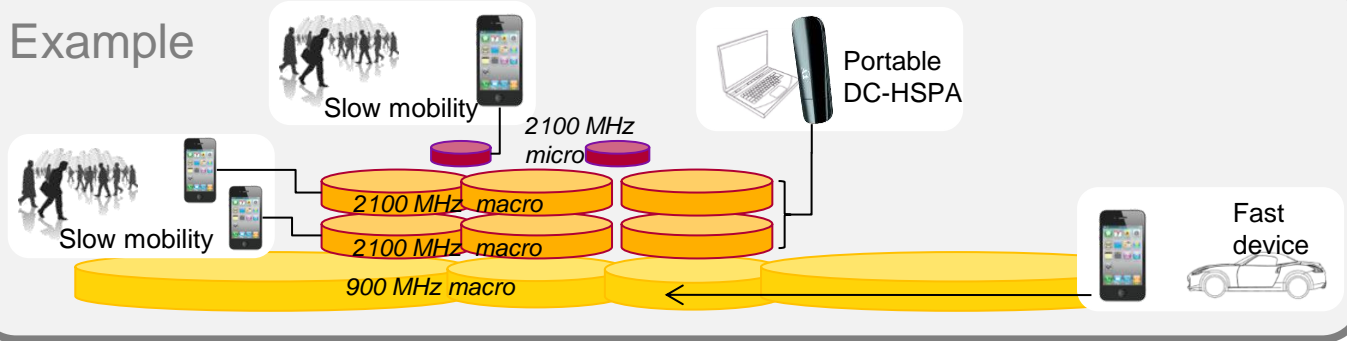
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HetNet load balancing features

Managing load and experience in multi-layer, multi-band networks

Example



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

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

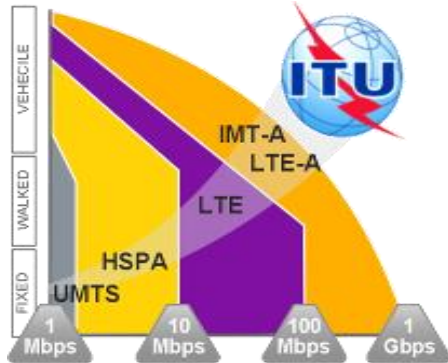
Due this offset – known as Range Extension – mobile will select small cell in worse radio conditions than without Range Extension in place



LTE-Advanced contains significant small cell features



Smooth migration to LTE-A and backward compatibility with LTE



Enables focused capacity enhancement with small cells by interference coordination



Capacity and cell edge performance enhancements by active interference cancelation



Enables focused coverage extensions with small cells by self-backhaul



Efficient use of small cells

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 serve cell edge mobiles



SMALL cell transmission subframes

During all subframes good radio condition mobiles served



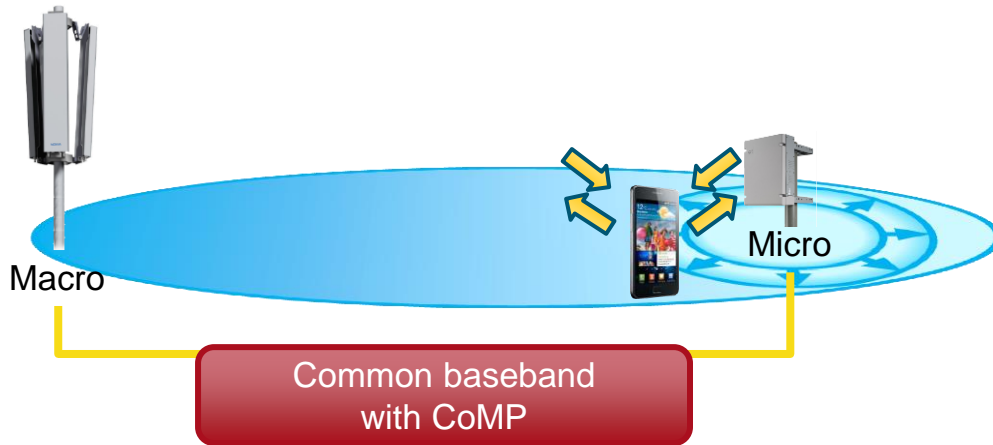
X2-link with eICIC co-ordination and GPS or IEEE 1588 phase synchronization

→ eICIC enables larger range extension values + provides better conditions for small cell edge camped mobiles

→ Requires Rel10 LTE terminals with eICIC for full benefits

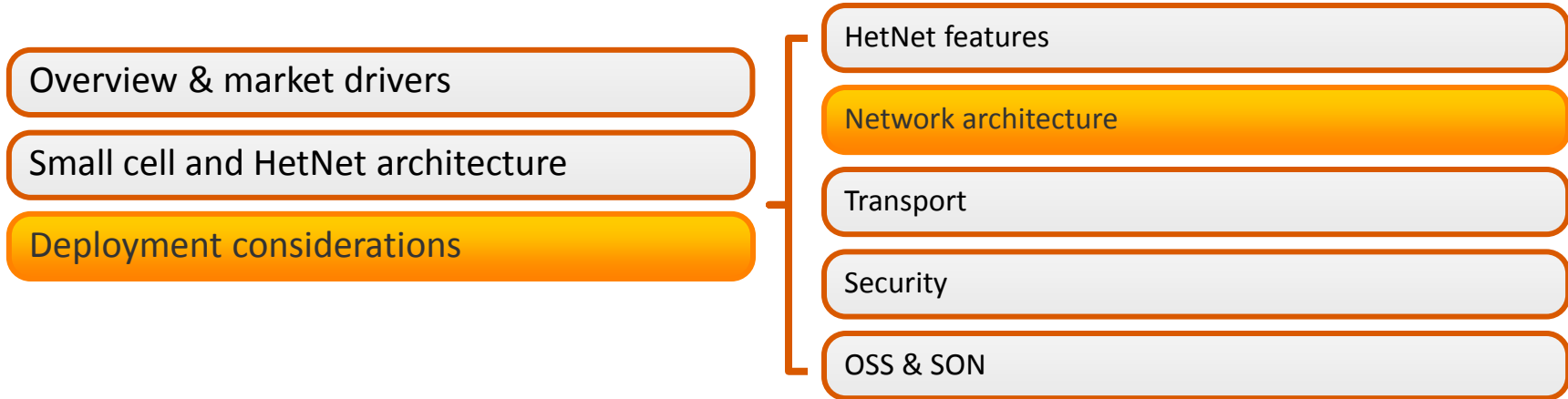
HetNet features

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

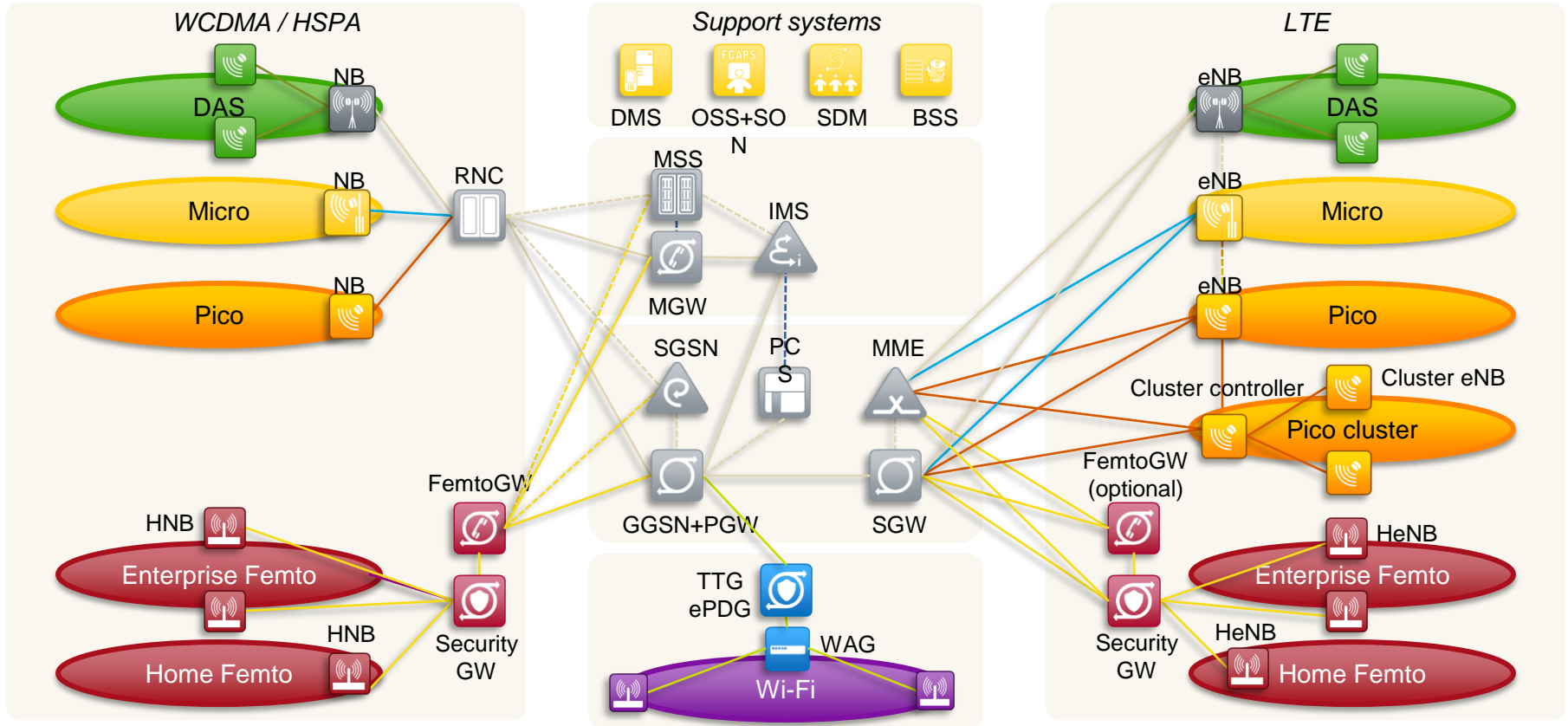


- Improved uplink cell edge performance as the same mobile's signal is received by both the macro and small cell
- Improved downlink cell edge performance as data received from small and macro cell
- In practice requires that both macro and small cell have common base band + good fiber transmission

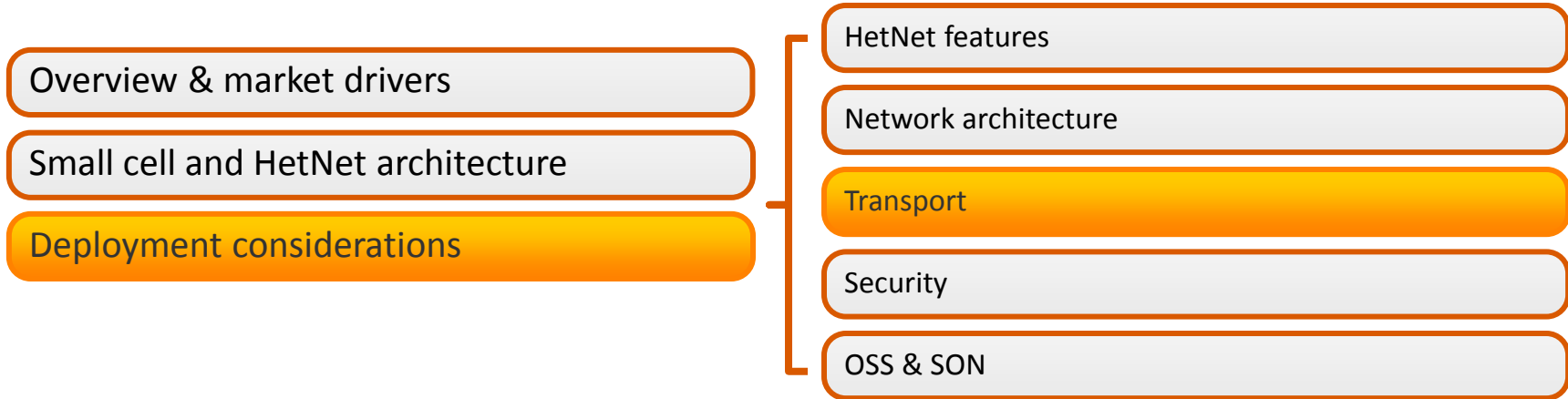
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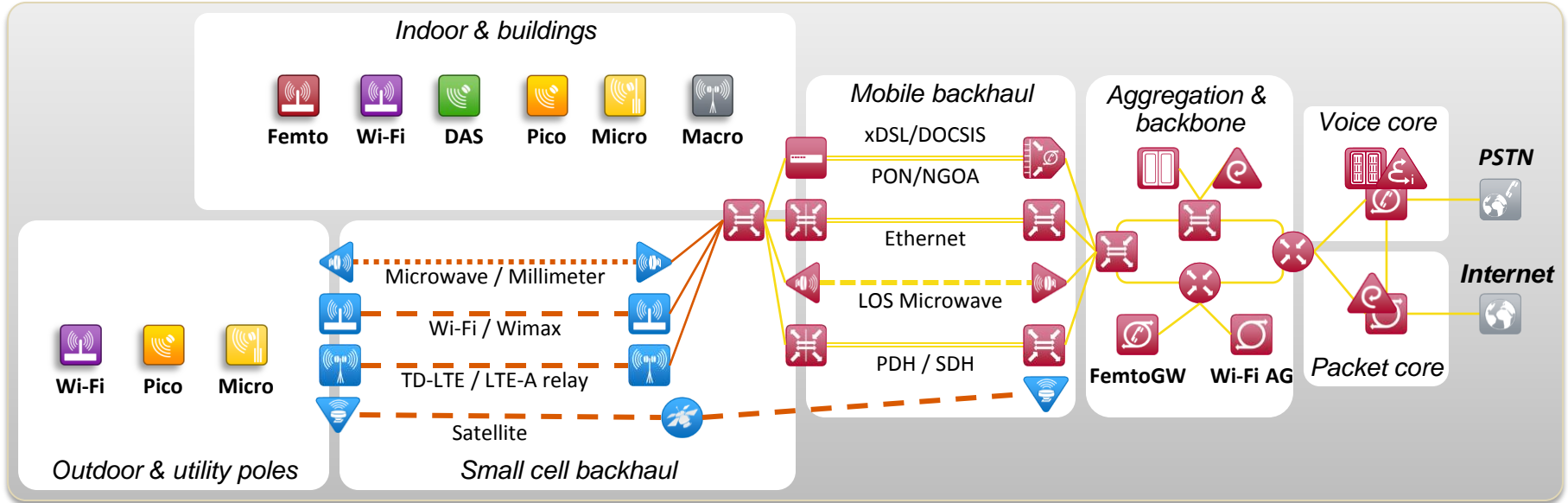
Small cell network architecture



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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.

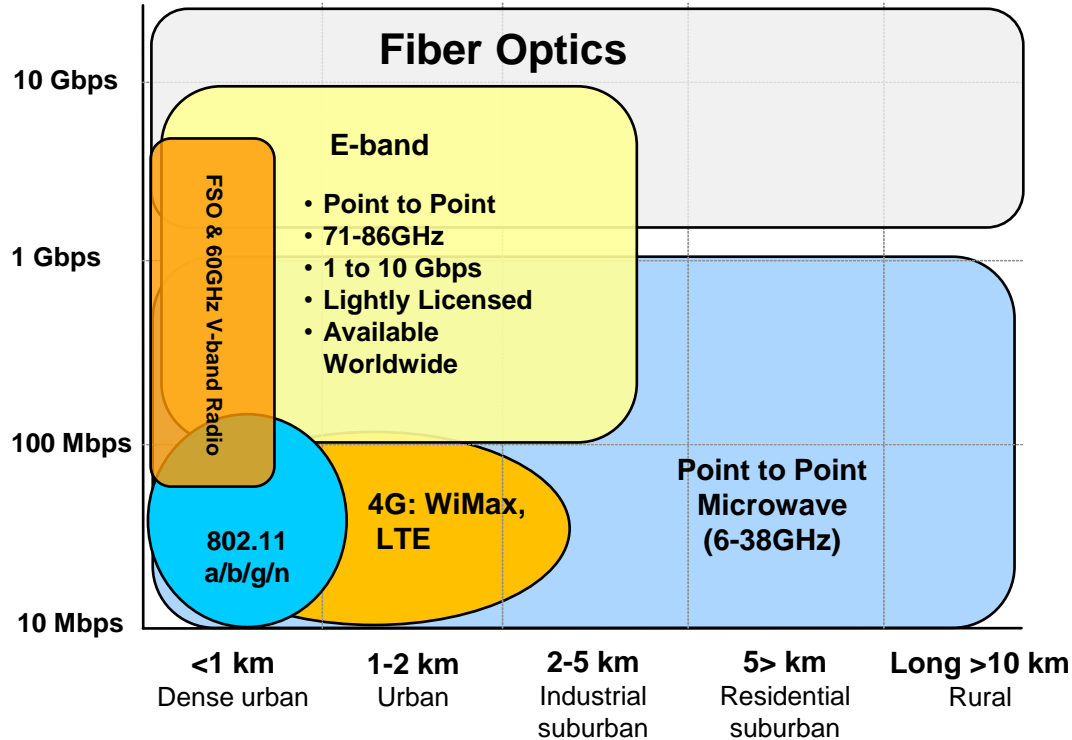
Leverage existing fixed broadband and Ethernet access where available.

Prefer packet only access with timing.

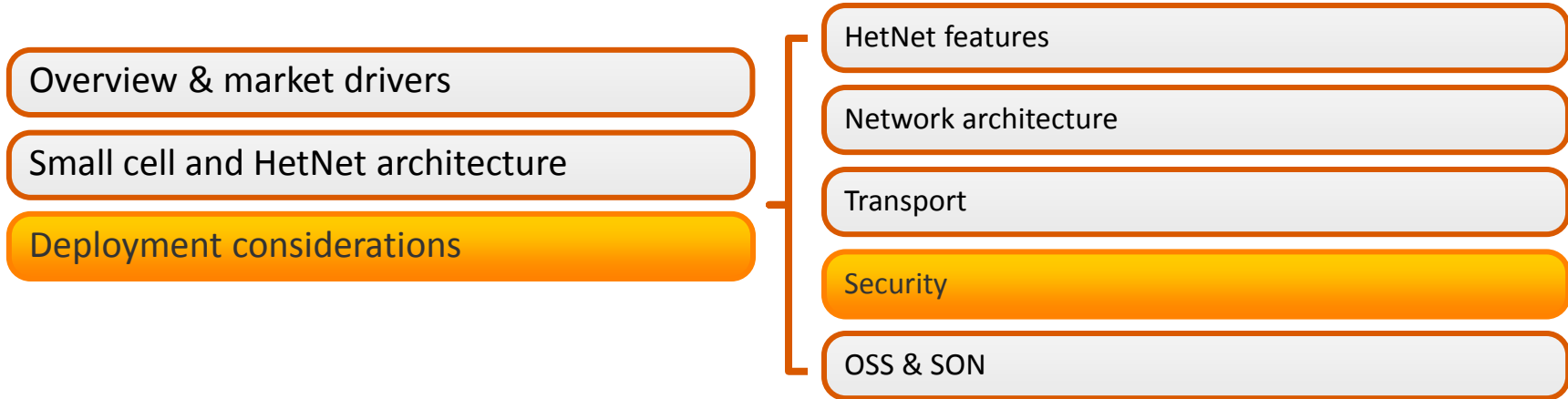
Femto and Wi-Fi can use Internet as backhaul.

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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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

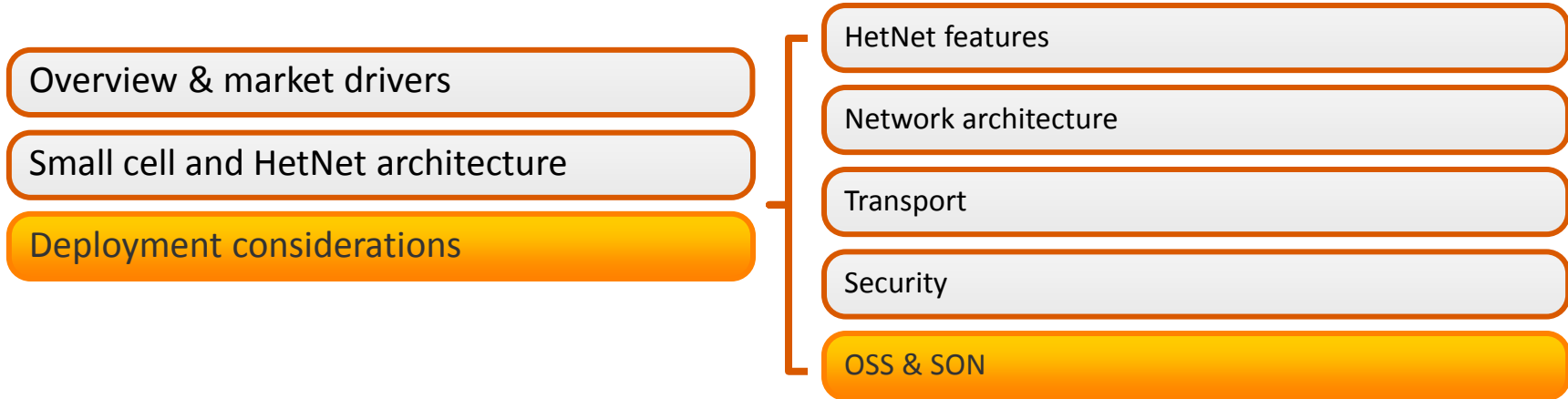
- Attacks on air interface
 - Man in the middle and spoofing
 - Identity stealing
 - Eavesdropping
 - Fraud
- Attack on sites
 - Theft or vandalism
 - Hardware changes or rogue elements
 - Software updates or modifications
 - Stealing of security keys
- Attack on backhaul
 - Eavesdropping
 - Denial-of-service
- Attacks on controller
 - Over backhaul or from Internet

Security solutions

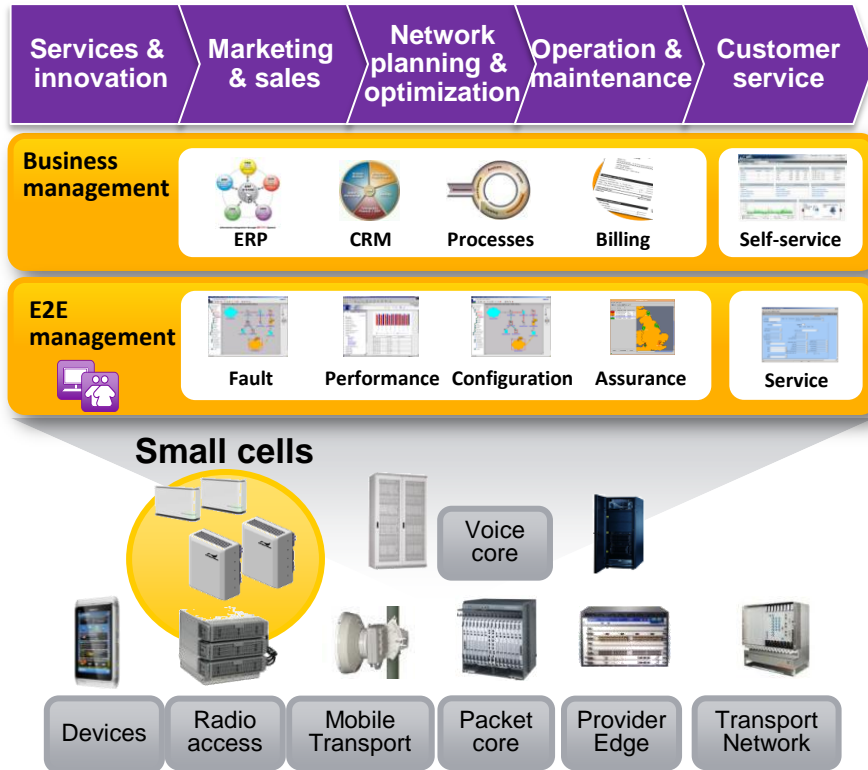
- Tough and weatherproof outdoor enclosures
- Tamper free outdoor mounting
- Separate logical network interfaces for management, signaling and user plane
- Secure remote management solution
- Special attention on security of local diagnostics and management ports
- IPSEC backhaul mutual authentication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



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Small cells part of e2e mobile broadband services management

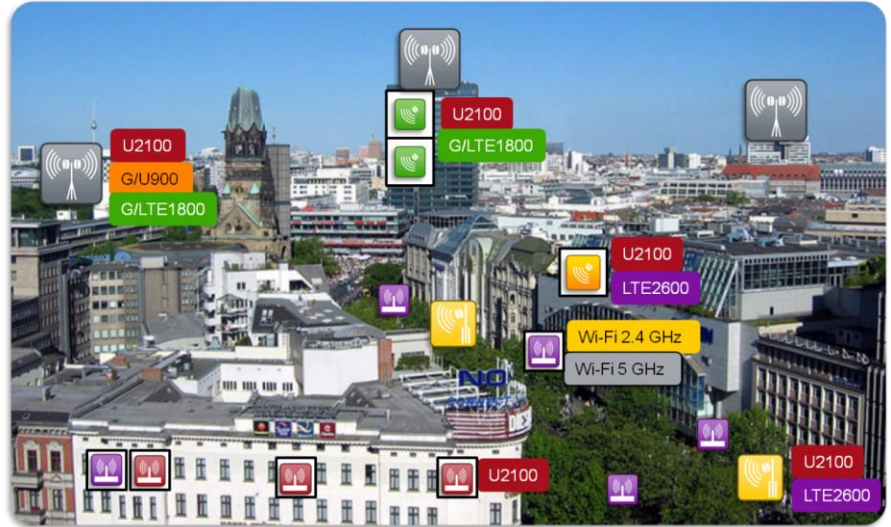


- Small cells seamless part of operator e2e management systems
- Management scalability to large number of BTSs
- Easy plug and play installations
- Automated network management with SON
- Management requirements for small cell transport
- Mobility handovers and interference management between small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

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



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
 - Different radio access technologies are coordinated (3G, LTE)
 - Traffic steering and load balancing mechanisms are required