P-SMALLCELLS: RECOMMENDATIONS FOR SMALL CELL DEVELOPMENT AND DEPLOYMENT BY NGMN ALLIANCE

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CONTENTS

1 OVERVIEW

This document is deliverable D5, which is the final deliverable of the Small Cell project. It summarizes all the activities that have run in parallel in the 3 work streams of the project and it contains recommendations for cost effective Small Cell deployment and development.
In particular, this deliverable contains a summary of the most promising use cases and scenarios for Small Cell deployment that have been identified among the operators members of NGMN. Some technical solutions able to proper address the identified scenario, are also analysed. Moreover, a list of the most critical barriers for Small Cell deployment have been identified and some of those barriers have been addressed (i.e. traffic geolocalization in order to proper place Small Cells, macro-Small Cell mobility and load coordination, …).
This deliverable also contains the requirements for multi-vendor deployment of HetNet networks that are broadly addressed in dedicated deliverables [3, 4].
At last, also backhaul requirements for HetNet networks beyond release 8 are included, summarizing and complementing further requirements contained in other NGMN deliverables.

2 DEFINITION OF SMALL CELL

A Small Cell is defined by the Small Cell Forum as "*an umbrella term for operator controlled, low-powered radio access nodes, including those that operate in licensed spectrum and unlicensed carrier-grade Wi-Fi. Small Cells typically have a range from 10 metres to several hundred metres. …. Types of small cells include femtocells, picocells, metrocells and microcells*" [1]

The following characteristics are also part of the Small Cell definition:

- Can use 3GPP and non-3GPP technologies (current non-3GPP focus is on carrier grade Wi-Fi)
- Operator controlled
- Can be deployed indoor or outdoor
- Can be in sparse or dense deployments

A Small Cell contrasts with a typical wide area macro cell that might have a range up to several tens of kilometres. Heterogeneous Networks or *HetNets* are a combination of macro cells and Small Cells in complement to one another. Macro cells can help provide seamless coverage for Small Cells, while Small Cells can provide coverage infill and high capacity offload for macro cells.

3 USE CASES AND SCENARIOS

3.1 Introduction

The NGMN Alliance has a wide membership of operators from around the globe, each with their own rationale for deployment of Small Cells, in line with their company strategy and the market conditions in the countries in which they operate. Whilst the high level aims of enhancing capacity or coverage apply to all Small Cell deployments, the specific use cases and scenarios for each operator can vary considerably. NGMN Project P-SmallCells undertook a survey of member companies to determine the deployment scenarios to be covered by the project work, and the results of the survey are presented here. Individual operators have not been identified, but rather the approach has been to pinpoint commonalities between the different operator use cases in order to minimize the number of unique scenarios for the project to consider. Thus, the scenarios presented represent a synthesis of requirements from more than one operator.

As a result of examining the data from the operator survey, the project has considered eight unique use cases. These fall into three distinct scenarios, which are addressed in turn in the following sub sections before a concluding review. The use case groupings are summarized in the table below. All aspects of the project work can be referenced to one or more of the three scenarios. There is no priority implied by the order of precedence of the use cases or of their parent scenarios.

Table 1: Use case grouping.

Scenario:	**Indoor Small Cells, including Wi-Fi**	**Outdoor Small Cells, including Wi-Fi**	**Radio over Fibre Small Cells (indoor and outdoor)**
Related Use Cases:	Indoor Small Cells, e.g. in airports, malls	Add-on cells (e.g. outdoor hotspots)	Indoor Small Cells using Radio over Fibre (RoF)
	LTE Small Cells for public use, e.g. in airports, malls		
	"Nanocell": Small Cell and Wi-Fi integration	3G+4G+Wi-Fi hotspots	
	Private LTE Small Cell for home use		
	Private LTE Small Cell for enterprise use		

3.2 Indoor Small Cells use cases, including Wi-Fi

The indoor scenario is represented by five different use cases from different sources.

3.2.1 Use case A: Indoor Small Cells (e.g. in airport, shopping malls)

This use case has the following features, based on the operator survey responses:

- Motivation: improve quality of experience, capacity
- Technology support: LTE and HSPA
- Frequency/carrier, compared to macro:
  - LTE: separate frequency
  - HSPA: same frequency
- Bandwidth: LTE: 10, 15, 20 MHz, HSPA: 10 MHz (Dual Carrier)
- Expected output power 100-250+ mW
- Some radiated points may have the same PCI (same cell), both for LTE and HSPA
- Support of carrier grade Wi-Fi (integrated in the same product)
- To be installed on indoor walls
- Backhaul: fibre/copper if available, other solutions could be analysed
- Power supply is available
- Small Cell could be also from a different vendor (respect to macro)

3.2.2 Use case B: LTE Small Cells for public use (e.g. airports, malls)

This use case has the following features, based on the operator survey responses:

- Motivation: improve quality of experience, capacity
- Technology support: LTE
- Frequency/carrier, compared to macro: separate frequency
- Bandwidth: 5, 10, 15 or 20 MHz
- Expected output power 100-250+ mW

- Support of carrier grade Wi-Fi (integrated in the same product)
- Backhaul: fibre
- AC power supply, or PoE
- Small Cell could be from a different vendor (respect to macro)

An extreme example of the public use case would be a Small Cell cluster for a stadium (possibly working with a distributed antenna system (DAS)).

3.2.3 Use case C: "Nanocell": Small Cell and Wi-Fi integration

This use case has the following features. The survey response has been provided in a different format to most other use cases, but it is still possible to undertake comparison of the content.

Table 2: Main features for "Nanocell" use case.

Use case feature	Use case support
Integrated carrier grade Wi-Fi	Yes
Cellular TX power [dBm]	Indoor home-class >100mW: enterprise-class >250mW
Cellular technologies [2G, 3G, LTE]	LTE is high priority. 3G and 2G
Cellular frequency bands	10MHz/20MHz mandatory; 5MHz/15MHz optional
Wi-Fi frequency bands	Support 2.4G/5.8G (5725~5850MHz) simultaneously, and can support 5150~5350MHz and 5470~5725MHz bands by software update
Wi-Fi channel bandwidth	20MHz/40MHz
Wi-Fi max. output power	Indoor 100mW/band, outdoor 500mW/band
Backhaul type	XPON is must, Wireless if optional
Coexistence interference control	WLAN receiver sensitivity loss ≤3dB when LTE DL transmit at full output power, LTE receiver sensitivity loss ≤3dB when WLAN DL transmit at full output power
LTE RF path number	2 TX, 2 RX
WLAN RF path number	2 TX/band, 2 RX/band
Dimension and Size	Indoor home-class 1kg/1L enterprise-class 3kg/3L, outdoor TBD
Security	Support IKEv2, EAP-AKA, certificate-based authentication
Interface	CAPWAP for Wi-Fi and IPSec for Cellular
Type of power supply	AC power supply (internal / external AC-DC adapter, mandatory); -48V DC (optional); POE / POE + (best to support)
Synchronization	Air-interface sniffing, IEEE1588v2, GPS/A-GPS (support GPS synchronization signal connector that can connect to external GPS receiver and antenna)
SON and O&M aspects	Self-start, PCI self-configuration and self-optimization, Automatic Neighbour Relation (ANR)

3.2.4 Use case D: Private LTE Small Cell for home use

This use case has the following features, based on the operator survey responses:

- Motivation: improve quality of experience, capacity
- Technology support: LTE
- Frequency/carrier, compared to macro: same or separate
- Bandwidth: 5, 10, 15 or 20 MHz
- Expected output power 100-250 mW

- Support of carrier grade Wi-Fi (integrated in the same product)
- Backhaul: fibre/xDSL/Ethernet/wireless
- AC power supply
- Small Cell could be from a different vendor (respect to macro)

3.2.5 Use case E: Private LTE Small Cell for enterprise use

This use case has the following features, based on the operator survey responses:

- Motivation: improve quality of experience, capacity
- Technology support: LTE
- Frequency/carrier, compared to macro: separate frequency
- Bandwidth: 5, 10, 15 or 20 MHz
- Expected output power 250 mW or more
- Support of carrier grade Wi-Fi (integrated in the same product)
- Backhaul: fibre/xDSL/Ethernet/wireless
- AC power supply, or PoE
- Greater number of concurrent users than for home product
- Small Cell could be from a different vendor (respect to macro)

3.3 Outdoor Small Cells use cases, including Wi-Fi

The outdoor scenario is represented by two different use cases from different sources.

3.3.1 Use case F: Add-on cells (e.g. outdoor hotspots)

This use case has the following features, based on the operator survey responses:

- Motivation: improve capacity, quality of experience, and reduce handover (signalling to core network)
- Technology support: LTE (and its roadmap)
- Frequency / carrier compared to macro: (same or) potentially separate frequencies
- Bandwidth: 10, 15, 20 MHz (may also depend on carrier aggregation band combination)
- Expected output power: lower than Macro cells
- Support of carrier grade Wi-Fi: possible but typically not the use case
- Available backhaul: fibre
- Available fronthaul: fibre (ORI)
- Installation: installed on e.g. outside building walls, roofs of low-rise buildings

The following diagram expands on the benefits of add-on cells in a C-RAN architecture, and in conjunction with carrier aggregation:

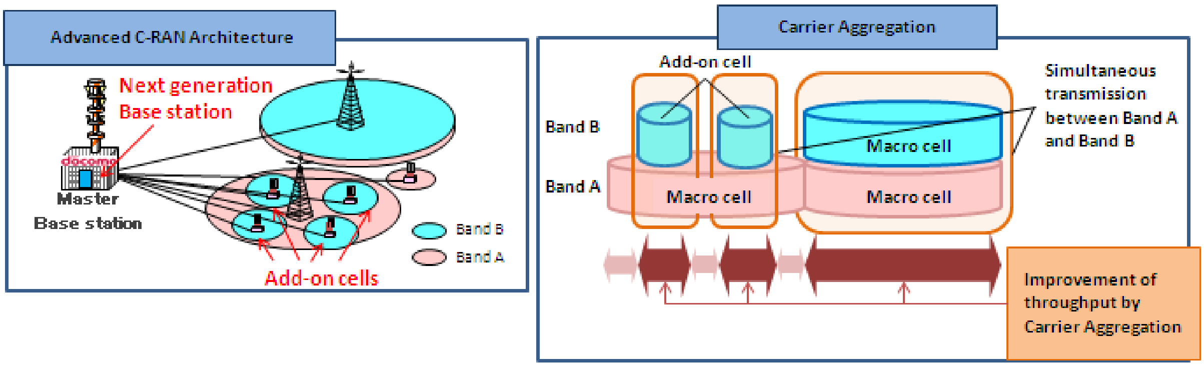

Figure1: Add-on cells in C-RAN architecture, in conjunction with carrier aggregation.

3.3.2 Use case G: 3G+4G+WiFi outdoor hotspots

This use case has the following features, based on the operator survey responses. The responses were received in both bullet point and tabular format as shown below:

- Motivation: macro network off-load
- Technology support: HSPA & LTE
- Support of carrier grade Wi-Fi (integrated in the same product)
- Support of wireless backhaul options in LOS and NLOS

Table 3: Main features for "3G+4G+WiFi outdoor hotspots" use case.

Use case feature	Use case support
Integrated carrier grade Wi-Fi	Yes
Cellular TX power [dBm]	EIRP > 5W
Cellular technologies [2G, 3G, LTE]	3G + LTE
Cellular frequency bands	For 3G: 2,1 GHz / For LTE: 2,6 GHz
Wi-Fi frequency bands	Support 2.4G/5.8G (5725~5850MHz) simultaneously, and can support 5150~5350MHz and 5470~5725MHz bands by software update
Wi-Fi channel bandwidth	20MHz/40MHz
Wi-Fi max. output power	100mW/band in 2.4 GHz, 1W in 5 GHz
Backhaul type	xDSL / FTTx / Wireless LOS (60/80 GHz) and NLOS

3.4 Radio over Fibre Small Cells use cases (indoor and outdoor)

This scenario is represented by a single use case for indoor coverage. The indoor Small Cells are provided through a RoF (Radio over Fibre) system (e.g. inside buildings, underground arcades, subway). It is clear that RoF Small Cells could also be provided in an outdoor situation, although no operator provided an example outdoor use case.

3.4.1 Use case H: Indoor Small Cells (RoF)

The use case has the following features, based on the operator survey responses:

- Motivation: improve indoor coverage and capacity
- Technology support: HSPA and LTE (and LTE-Advanced in future)

- Frequency / carrier compared to macro: same or separate frequency
- Bandwidth: up to 20 MHz (up to 100 MHz for LTE-Advanced in future)
- Expected output power: less than 100 mW
- Support of carrier grade Wi-Fi: basically no
- Available backhaul: fibre
- Available fronthaul: fibre (radio over fibre)
- DC or AC/DC power supply for base units
- AC or AC/DC power supply for remote units
- Installation: typically installed on ceilings (antennas)
- Small Cell could be from a different vendor (respect to macro)
- 128 remote units or more

The following diagram compares deployment situations against traffic density for this operator:

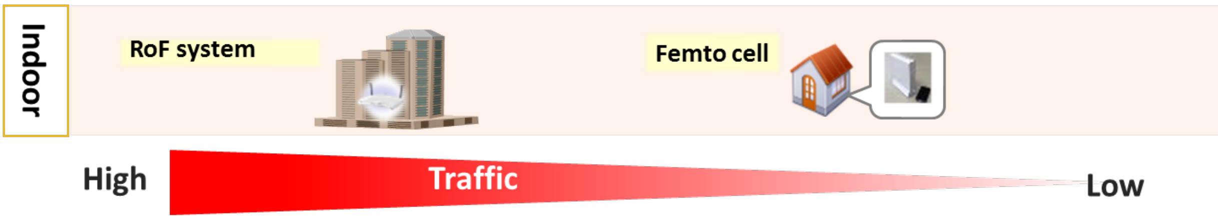

Fig. 2: Deployment solutions against traffic density .

3.5 Review and summary of scenarios

Having grouped the eight use cases into three scenarios, it has been possible to summarise the common features of the use cases within each group, enabling the project to focus on addressing a simple set of operator scenarios. The summary is shown in the tables below. Where features are not mentioned, then either there was no clear agreement on the feature support, or no data was presented by operators in the survey phase.

Scenario: Indoor Small Cells, including Wi-Fi:

Feature	Support
Motivation	Quality of experience, capacity, coverage
Technology support	LTE, HSPA
Frequency/carrier, compared to macro	Separate and/or same frequency
Bandwidth	LTE 5, 10, 15, 20 MHz; HSPA 10 MHz (Dual Carrier)
TX power	Typically 100 mW for home; 250 mW+ for enterprise/public
Support of carrier grade Wi-Fi (integrated in the same product)	Yes
RAN architecture	Traditional (backhaul) and cloud RAN (fronthaul)
Backhaul/Fronthaul	Fibre (optionally wireless), xDSL
Power supply	AC (optionally DC)
Dimensions/size	Preferably 1kg/1L for home and 3kg/3L for enterprise
Installation constraints	Installation on indoor wall
Small Cell could be also from a different vendor (respect to macro)	Yes
Recommended number of simultaneous users	16 (home), 64 (enterprise), 128 (public)

SON and O&M aspects	As determined by the project work, but to include self-configuration and self-optimization features

Scenario: Outdoor Small Cells, including Wi-Fi:

Feature	Support
Motivation	Capacity, quality of experience, reduce handover (signalling to core network), macro network off-load
Technology support	HSPA, LTE and LTE-Advanced (in future)
Frequency/carrier, compared to macro	Separate and/or same frequency
Bandwidth	LTE 10, 15, 20 MHz plus CA; HSPA 10 MHz (Dual Carrier)
TX power	Up to 5W EIRP
Support of carrier grade Wi-Fi (integrated in the same product)	Preferably yes
RAN architecture	Traditional (backhaul) and cloud RAN (fronthaul)
Backhaul/Fronthaul	xDSL / FTTx / Wireless LOS (60/80 GHz) and NLOS (backhaul); fibre/ORI (fronthaul)
Power supply	AC, DC
Installation constraints	Installed on e.g. outside building walls, roofs of low-rise buildings
Small Cell could be also from a different vendor (respect to macro)	Yes
Recommended number of simultaneous users	128
SON and O&M aspects	As determined by the project work

Scenario: Radio over Fibre Small Cells (indoor and outdoor):

Feature	Support
Motivation	Coverage and capacity
Technology support	HSPA, LTE and LTE-Advanced (in future)
Frequency/carrier, compared to macro	same or separate frequency
Bandwidth	up to 20 MHz (up to 100 MHz for LTE-Advanced in future)
TX power	Indoor less than 100 mW
Support of carrier grade Wi-Fi (integrated in the same product)	basically no
Backhaul/Fronthaul	fibre
Power supply	DC or AC/DC for base units AC or AC/DC for remote units
Installation constraints	typically installed on ceilings (antennas)
Small Cell could be also from a different vendor (respect to macro)	Yes
Recommended number of remote units	128 or more

4 MAIN BARRIERS FOR DEVELOPMENT/DEPLOYMENT OF SMALL CELLS

The NGMN Alliance has a wide membership of operators from around the globe, each with their own rationale for deployment of Small Cells, in line with their company strategy and the market conditions in the countries in which they operate. Nevertheless, NGMN members acknowledge that there are barriers for the development and the deployment of Small Cells. NGMN Project P-SmallCells undertook a survey of member companies to determine those barriers. Individual operators have not been identified, but rather the approach has been to pinpoint commonalities between the different barriers identified by the operators. Thus, the topics presented represent a synthesis of the barriers identified from more than one operator. .

NGMN operators acknowledge that the 3GPP standard that enables the deployment of Small Cells is ready, starting from Rel. 8. Further evolution of the standard (i.e. beyond Rel. 8) will include features to help Small Cell development and deployment. Moreover a lot of industry fora and initiatives are working on Small Cells and there are a lot of available products for the different deployment types. Nevertheless the deployments of Small Cells around the world are not so massive. NGMN would like to contribute to this area by identifying the main barriers for development/deployment of Small Cells.

The survey among member companies identified that one of the most critical barriers is the **coordination between macro and Small Cell layer,** in particular, when the deployment of Small Cells is on the same frequency as the macro deployment. Macro-Small Cell mobility and load coordination is addressed in Chapter 7.

Also the possibility to have a **multivendor deployment** is perceived by NGMN operators and vendors as a critical barrier for deployment, in particular, the possibility to have Small Cell layer from Vendor A and macro layer from Vendor B. Multi-vendor deployment is considered in Chapter 9.

Small Cell deployment requires the acquisition of a large number of sites, with different characteristics compared to macro sites. Thus **site acquisition** is another main barrier. More generally, **overall technology enabling maturity** (e.g. SON-based plug & play, multi-frequency, eICIC ...) is perceived as a big barrier. Another important barrier is a non-purely technical matter, which is the **business case to prove benefits** of Small Cell deployment.

When an operator decides to deploy Small Cells, it is necessary to define exactly where to put the Small Cells. One interesting means to identify such locations is **traffic geo-location** (see Chapter 6). Moreover, it is crucial to have the access to the proper backhaul techniques. In fact, **backhaul issues** are among the most important to consider, in particular the **access to fixed solutions** (e.g. fibre, copper), and backhaul is addresses in Chapter 10.

Also relevant is the issue of **availability of products** for the desired deployment. In order to help economies of scale, particular attention needs to be paid to **fragmentation of frequency/bandwidth**.

5 SMALL CELL WITH INTEGRATED WI-FI

Small Cell have several similarities with Wi-Fi access points in the sense of coverage, power supply and backhaul. There are mainly two types of wireless LAN (WLAN) Wi-Fi Access Point (AP) mode. One is the Fat WLAN AP, and another type is the Fit WLAN AP type.

For the residential scenario, the Wi-Fi is generally used in fat mode, and Wi-Fi is only used by the family. The Wi-Fi part can be easily integrated with residential Small Cell (Femto) which also generally provides services limited to the family or the friends of the family, i.e., in Closed Subscriber Group (CSG) mode. Generally the operator does not manage the Wi-Fi part. In this case, there is no architecture requirement for the Wi-Fi part.

For the hotspot scenario, the Wi-Fi and Small Cell are deployed in places such as airport, university, mall, hospital, etc.. The Small Cell works in open mode and can provide service to all the users. The Wi-Fi AP provides carrier-grade WLAN access. The Wi-Fi AP uses the fit mode and the operator manages both Wi-Fi and Small Cell.

We use "Nanocell" in this section to represent such a Small Cell and carrier-grade Wi-Fi integrated solution. The architecture of Small Cell and Carrier-grade Wi-Fi integration is illustrated in Figure 3.

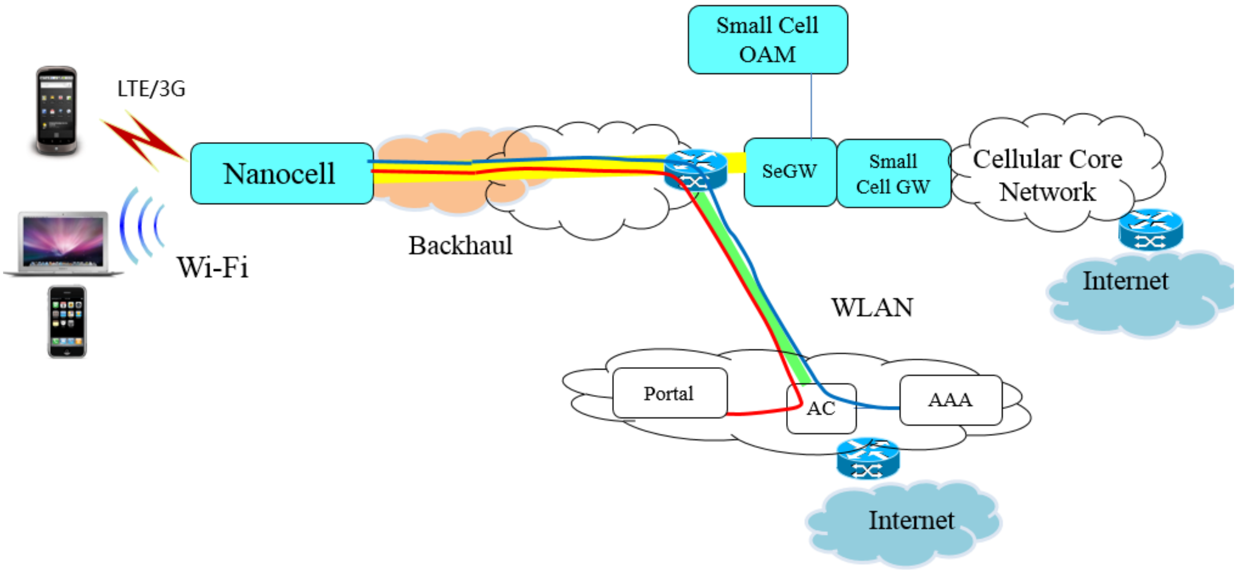

Fig. 3: Small Cell and Carrier-grade Wi-Fi integration architecture.

To enable Wi-Fi and cellular traffic routing to the WLAN network and the cellular core network accordingly, the Small Cell and Wi-Fi integration AP shall have the capability of different VLAN marking for those two types of traffic.

The backhaul may become the bottleneck for both cellular and Wi-Fi traffic. The Wi-Fi and Small Cell integration AP shall be able to configure the policy such that the cellular traffic could take higher priority than Wi-Fi traffic.

To relax the requirement of backhaul bandwidth and provide a local IP service access capability, the Small Cell and Wi-Fi integration AP is recommended to have LIPA (Local IP Access) or SIPTO (Selected IP Traffic Offload) capability. Only the signalling part of cellular traffic is routed to the core network while the user traffic is all routed locally.

Hotspot 2.0 compliance is recommended for the Wi-Fi part so that the Wi-Fi can provide information such as Wi-Fi load, network type, roaming relation information etc. This helps terminals to select the right Wi-Fi network and steering of traffic among WLAN and cellular in an optimal way. The terminal may have the Access Network Discovery and Selection Function (ANDSF) client application so that the operator can provide some network usage guidance to terminals.

Fig. 5.1 illustrated the Small Cell and Wi-Fi integration in the AP part. To enable a converged architecture so that traffic can be managed in a unified way, both Wi-Fi and Cellular are managed through "Policy Control and Charging" (PCC) architecture. Both types of traffic leverage the same charging architecture and the mobility is supported between Wi-Fi and cellular. The Wi-Fi traffic can be routed to the core network. To reduce terminal impact, the S2a based solution defined in 3GPP is recommended to be used for integrating traffic into the cellular core network.

POE (Power over Ethernet) or POE+ is recommend to ease the power supply mechanism.

6 REQUIREMENTS FOR SMALL CELLS GEOPOSITION (TRAFFIC GEOLOCALIZATION)

In order for the Mobile Network Operator (MNO) to take full advantage of network densification by means of Small Cell deployment, the ability to identify locations where Small Cells are most needed is crucial. This section deals with the task of geo-locating traffic with high accuracy prior to Small Cell installation in the field. To be more specific, the problem to be solved is identifying those locations where **a need for** over the air data transmission arises (e.g., when data is actually *generated* or *requested* by an application or service running on the mobile device). In the present document these locations are termed “Traffic Hot Spots”. They don’t necessarily have to be the same spots where traffic is actually transmitted over the air interface.

6.1 Out of Coverage Scenario

In this scenario the user moves through a PLMN with patchy coverage. Start of his journey is location L1. The Destination of his journey is location L4. Between locations L1 and L3 the user experiences the typical service behaviour of an out of coverage scenario.

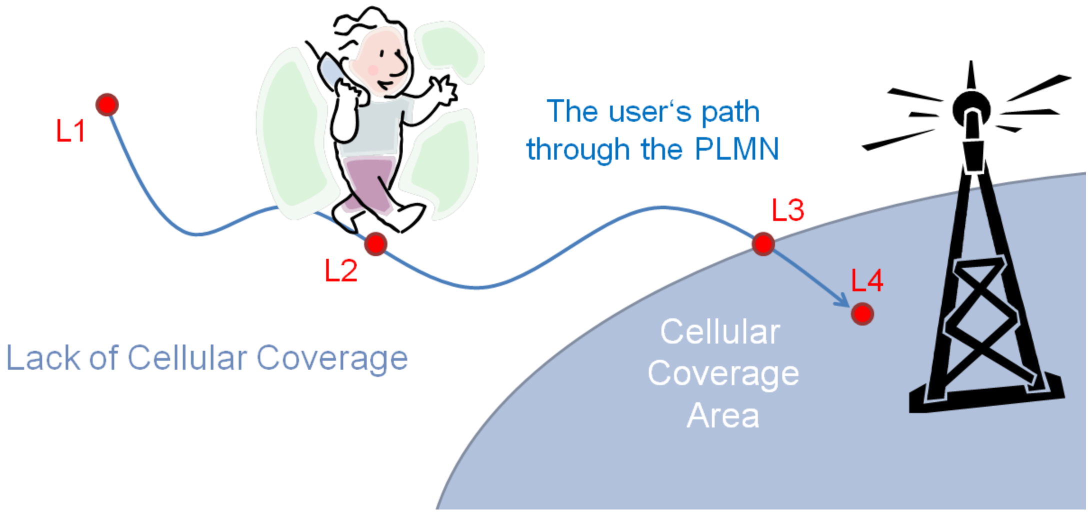

Figure 4: User moving through coverage hole of PLMN.

6.1.1 Application Initiated Download Operation Fails

At some point in time (e.g., at location L2) an application running on the user’s device tries to initiate the connection establishment procedure in order to download data. For instance, the application could be an e-mail client that is configured to regularly poll for new e-mails from an e-mail server.

6.1.2 User Initiated Voice Call Fails

At some point in time (e.g., at location L2) the user wants to place a voice call. He therefore dials a number and the mobile device tries to initiate the connection establishment procedure.

6.1.3 Experienced Service Behaviour

Due to lack of network coverage at location L2 the connection set-up attempt is unsuccessful. Probably further connection set-up attempts follow in short sequence, until the user's mobile device can connect successfully to the network. In some cases (application triggered connection set-up attempts) the user may remain unaware of the mobile device's automatic behaviour.

6.2 Within Coverage Scenario

In this scenario the user moves through a PLMN with good overall coverage. As in the previous example the start of his journey is location L1. The destination of his journey is location L4. At locations L2 and L3 the user experiences the typical service behaviour of a lack of capacity scenario.

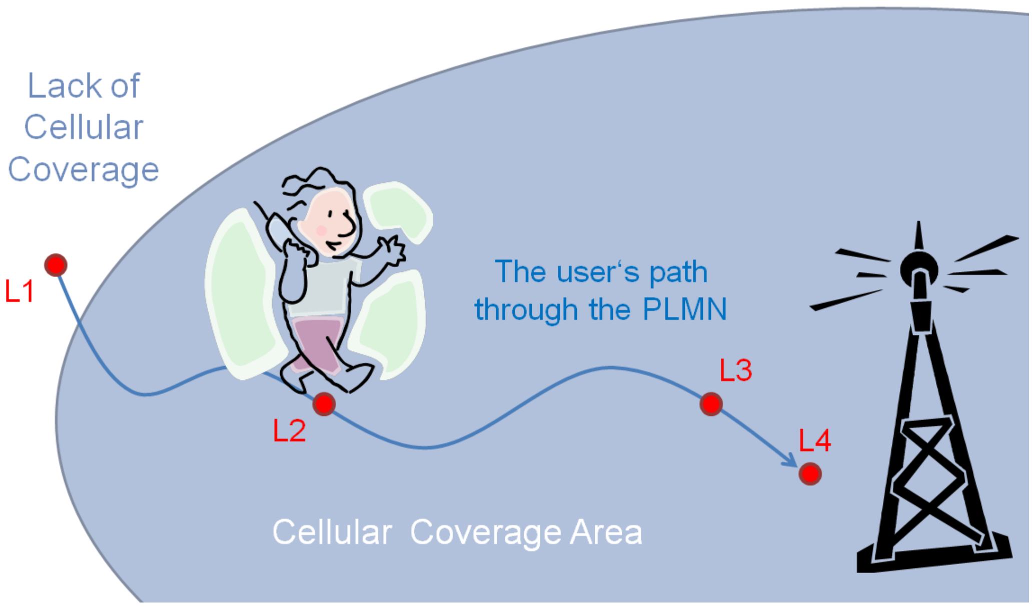

Figure 5: User experiencing capacity constraints while residing within coverage of a PLMN.

6.2.1 Application Initiated Download Fails

At some point in time (e.g., at location L2) an application running on the user's device tries to initiate the connection establishment procedure in order to download data. For instance, the application could be an e-mail client that is configured to regularly poll for new e-mails from an e-mail server.

6.2.2 User Initiated Voice Call Fails

At some point in time (e.g., at location L3) the user wants to place a voice call. He therefore dials a number and the mobile device tries to initiate the connection establishment procedure.

6.2.3 Experienced Service Behaviour

Although coverage is generally provided at locations L2 and L3 the connection set-up attempts (in case of LTE, the attempts to switch from IDLE to CONNECTED mode of operation) are delayed or rejected for one of the following reasons:

- overload situation on the air interface
    - lack of control plane resources
    - lack of user plane resources
- overload situation on some backhaul link.

6.3 Type and Granularity of Information to be Collected

Discussions in NGMN showed that in addition to a location stamp, which appears to be the most important piece of information for the Mobile Network Operator (MNO) to be collected in the context of Small Cell Geopositioning, it may make sense to collect further pieces of information, for instance related to:

- Location
- Time Stamp
- Details about the Type of Traffic
    - QoS Class Identifier
- Details about the Type of Application
    - Class of Application
    - Software Version Number
- Distance (between a detected Traffic Hot Spot and the next place offering a transmission/reception opportunity)
- Latency (How long did the UE have to wait for a transmission/reception opportunity?)
- End point of traffic
    - IP address, Host names etc.
- Volume of traffic per QCI
    - In UL & DL
- Quality of connection per QCI
    - TCP performance
    - UDP / RTP performance
    - Differentiated by UL & DL

6.4 Methods that can potentially be used for geo-locating traffic for the purpose of Small Cell Deployment

NGMN envision that several methods will be available to Mobile Networks Operators (MNOs) to collect data that may be used for proper Small Cells Geopositioning, including proprietary solutions and standardized solutions. Two solutions are discussed below: MDT (Minimization of Drive Tests); and proprietary tools .

Both methods can provide similar information content to the operator. A summary of their strengths and weaknesses can be found in the following table.

Table 4: Strengths and weaknesses of methods for Small Cells Geopositioning.

	Strengths	Weaknesses	Weakness Mitigation strategies
MDT	Can monitor call attempts in a coverage hole Can provide GNSS information	Limited device support currently Difficult to judge statistical significance Some proprietary tools may be needed to analyse data feeds Minor standards changes required UE battery impact	Device upgrades Comparison with PM data to judge statistical significance
Proprietary tools	Can collect information from all UEs via existing call-trace-like mechanisms Minimal/Zero UE battery impact (some impact if GNSS is requested)	Cannot monitor call attempts in coverage holes – but can detect hole boundaries	Can monitor call drop locations to locate coverage holes

6.4.1 MDT

One promising candidate method to meet all Small Cells geopositioning requirements is MDT which can easily be enhanced to satisfactorily accommodate all of the “Small Cell Geopositioning” use cases described above. The term MDT is the acronym for “Minimization of Drive Tests”, a functionality defined by 3GPP for UMTS and LTE starting from 3GPP Rel-10 onwards. Currently, two modes of MDT operation exist:

- Immediate MDT: MDT functionality involving measurements performed by the UE in CONNECTED mode and reporting of the measurements to eNB/RNC available at the time of reporting condition as well as measurements by the network for MDT purposes.
- Logged MDT: MDT functionality involving measurement logging by UE in IDLE mode (in case of LTE), CELL_PCH and URA_PCH states (in case of UMTS) for reporting to eNB/RNC at a later point in time.

3GPP document TS 37.320 [2] describes functions and procedures to support the collection of UE-specific measurements for MDT using the cellular system’s respective control plane architecture, for both UTRAN and E-UTRAN.

Current MDT functions allow:

- DL signal strength measurements (for generation of coverage maps);
- Data Volume and Throughput measurements of traffic that is transmitted over the air in uplink and downlink direction (for QoS verification);
- Enhanced RLF reporting (for UEs in RRC_CONNECTED);
- Accessibility Measurements (RACH procedure).

with location stamping, but these locations are not necessarily the same locations where the need for data transmission over the air interface arises (as defined in the beginning of this section).

Details of Location Stamping in MDT

In principle, MDT supports two different sets of positioning information for location stamping of measurements.

- RF Fingerprints
  - offer rough granularity for positioning
  - readily available
  - based on measured DL signal strength
  - collected as part of normal RRM measurements on neighbouring cells
- Detailed Location Information (DLI), based on GNSS
  - offers finer granularity for positioning
  - For example, location fixes may be performed by means of a GPS module. In this case the data consists of
    - Longitude + Latitude (mandatory)
    - can be supplemented with altitude, uncertainty and confidence (optionally)
    - can be supplemented with altitude, velocity and direction (conditionally)
  - DLI should be used to tag MDT when this data is available anyway in the UE.
  - The network may request the GNSS module to be activated in the UE for MDT purposes. However, there are cases in which availability of DLI in the mobile device can still not be guaranteed (e.g., indoors).

6.4.2 Other means/tool (including proprietary)

This section gives some details on proprietary solutions that may be used for proper Small Cells Geopositioning.

MDT requires UEs to collect and upload RF measurement information. The alternative is to collect relevant data in the network itself, with no special requirement on the UE. A solution in this space would have the advantages of minimally impacting UE battery life, and being able to capture information pertaining to a larger number of devices performing calls and using data. Samples obtained via this method should provide more statistically significant metrics of traffic density in the network.

Similar information would be required as is made available by MDT. This might be achieved simply by activating subscriber tracing in the site(s) in question to capture measurements and other signalling to/from UEs in its coverage. This approach could target tracing of a subset of subscribers for a short period of time, or a wholesale trace of all subscribers all of the time (subject to availability of computing resources). It would also be a logical extension for the network to be able to use different RRC measurement reporting thresholds and parameters during such a period of tracing to further increase the usefulness of the collected data.

From a geolocation perspective, such tracing will at least give RF fingerprinting information for the cell performing the tracing, which may be post-processed to derive coverage and traffic density maps for each site. Subject to vendor and subscriber device support, additional features within the specifications can refine the information produced – for example requesting UE positioning RRC measurements.

6.5 Conclusion

Short term non-standardized solutions might be the only option available for MNO's to achieve proper Small Cells Geopositioning in near future. Once terminals with capabilities for MDT with the relevant output are available and widely deployed, MDT can be used for proper Small Cells Geopositioning.

Currently, NGMN believe MDT can be enhanced with marginal effort to support "Traffic Hot Spot Detection to provide a standardized long term solution for proper Small Cell Geopositioning.

6.6 Recommendation

- NGMN recommends relevant parties to actively engage in MDT WID creation in 3GPP.
    - Responsible working group would be RAN2
    - Target release could be Rel-13 (or later)
- For immediate and medium term needs of proper Small Cell Geopositioning MNO can work and evaluate solutions other than MDT

7 REQUIREMENTS FOR MACRO-SMALL CELL MOBILITY AND LOAD COORDINATION

To maximise the rewards of Small Cells deployed within a HetNet, there should be mechanisms in place that allow for a variety of mobility scenarios. Mobility may be between different layers (e.g. from macro layer to Small Cell layer) and it maybe between equipment of multiple vendors (e.g. vendor 1 Small Cell to vendor 2 Small Cell). The reasons for invoking mobility include coverage issues and maximizing system capacity (e.g. load balancing). Various SON features may be used to improve system performance within a HetNet, such as MLB, MRO and CCO, and any interoperability issues should be addressed in advance. In [3] many potential multi-vendor interoperability issues for SON have been addressed and recommended practices provided. This section extends on that work by considering further scenarios where interoperability issues could occur within HetNets.

7.1 Basic HetNet mobility

For mobility within a HetNet environment the following basic mobility scenarios are foreseen:

- Small Cell hand-in – This describes mobility from a macro cell to a Small Cell.
- Small Cell hand-out – This describes mobility from Small Cell to a macro cell
- Small Cell to Small Cell mobility – This describes mobility between Small Cells
- Macro cell to macro cell mobility – This describes mobility between macro cells. As this work is focused on Small Cell issues, this form of mobility is not directly addressed in this work, although many issues may be common with the other forms of mobility that are addressed.

From a spectrum point of view a HetNet may use the same frequency for a Small Cell layer as for its macro layer (co-channel). Alternatively a Small Cell layer is on a separate frequency.

The basic options for mobility are summarized here. Different options are available for UEs dependent on whether they are in connected mode or idle mode.

7.1.1 Connect Mode Mobility Options

Measurement configuration (to initiate handover or redirection) - When a UE is in connected mode it is the serving cell that is responsible for deciding on mobility actions. The serving cell will typically make mobility decisions based on measurement reports sent from UEs (The serving cell may also take other information into account, .e.g. Load information of neighbours in MLB). The serving cell configures the measurement reporting of each UE. The measurement configuration can specify the frequency/frequencies to search and can also include a whitelist or blacklist of cells to measure on each frequency. Measurements can be periodic or event triggered. Event triggered measurements allow the serving cell to be informed when conditions occur which may be suitable for initiating a mobility procedure for a UE. There are a range of parameters that can be tuned to get the desired mobility within a

HetNet, using various event triggers. In particular, different frequencies can have different thresholds, and/or offsets can be applied on a per frequency or per cell basis. The tuning of these offsets can be done as part of MRO. ***Range Expansion (RE)*** is one particular technique that can optimize mobility (in order to maximise system capacity) within a HetNet. Here offsets are applied to bias UEs to Small Cells, instead of the macro cell. Range expansion is applicable to both inbound and outbound mobility. In general, measurement configuration can apply to all connected mode scenarios. The description is focused on LTE terminology, but the concept is similar for 3G/2G. In 2G however, measurements are always periodic and not event triggered. A common issue with making mobility decisions based on the latest measurement reports could be that a serving cell may try to limit the amount of measurements that a UE carries out in order to maintain battery life. This would be at the expense of optimal mobility (due to delays in becoming aware of some suitable target cells, or never becoming aware of some suitable target cells at all).

Handover – Handover procedures are defined for both X2 and S1 based handover, which can allow seamless mobility for the user. If available, X2 is likely to be used. One potential issue with handover in HetNets is that the number of neighbours could exceed the maximum number of entries that can be stored in neighbour lists. This could be a problem for a macrocell, when there are a large number of Small Cells within its coverage. It could also be an issue for Small Cells that are in dense deployments.

Redirection – A serving cell can also send an RRC connection release message to a connected UE and encourage it to reselect to another cell. There are several options available here, which are covered in the idle mode mobility options. If the macro layer is not co-channel with the Small Cell layer, an RRC connection release message with ***redirected carrier info***, can be a simple and effective way to implement inbound or outbound mobility. The main issue with the use of redirection of connected UEs is that it involves the UE going into idle mode, thus seamless mobility is not possible. More discussion on redirection with redirected carrier info is provided in the idle mode mobility options below.

7.1.2 Idle Mode Mobility Options

Broadcast system information – A serving cell can broadcast a range of parameters to help guide the mobility of attached idle mode UEs. For reselection there are a wide range of parameters that can be used to optimize mobility within a HetNet. In particular Offsets and absolute priorities can be used. ***Offsets*** allow for a bias to be applied in cell rankings. These offsets can be applied to individual cells within a layer. Each layer that is not on the serving cell frequency can also have a frequency specific offset. ***Absolute priorities*** allow for the serving cell to assign different priorities to different layers (different RATs cannot be assigned the same priority). Based on a few other broadcast parameters which control reselection, absolute priorities mean that a UE will try to reselect to the highest ranked cell on the highest priority layer that can be selected. Reselection to equal priority layers only occurs when there is a higher ranked cell and no higher priority layers can be selected, and reselection to a lower layer will only occur to the highest ranked cell on the layer where no higher priority layers can be selected. The serving cell can therefore use absolute priorities to control HetNet mobility when there are multiple layers (Either multiple RATs and/or multiple frequencies per RAT). By using a combination of offsets and absolute priorities, mobility for HetNets can be well managed.

Range Expansion – This concept applies to both connected mode and idle mode UEs, but the implementation options are different. In idle mode the use of cell specific and frequency specific offsets in a serving cell's broadcast system information can allow for Small Cells to be given a bias over macro cells.

Redirected carrier info – UE specific absolute priorities can also be set by a serving cell in an RRC connection release message. When a UE receives these specific absolute priorities, the absolute priorities given in broadcast system information are ignored. If a T320 timer (minimum 5 minutes, maximum 180 minutes) is also specified, then the specific absolute priorities are deleted upon expiry of the timer and broadcast system information will then be used. This can be a suitable way to encourage a particular UE towards cell on a particular frequency. This is therefore suitable for both inbound and outbound mobility in a HetNet where the macro layer and Small Cell layer are not co-channel.

One potential consideration for an operator, when designing its mobility solutions, is how often UEs are in idle mode and therefore how much influence idle mode procedures will have on overall system mobility. There is a potential issue, particularly with modern smart phones, that the UE may remain in connected mode and never return to idle mode. When there is an ongoing service this is expected, but connected mode can be maintained for a number of reasons. These reasons include minimizing the amount of signalling for a device that switches between connected and idle mode often. An operator can adjust its idle mode timeout parameter, but the idle mode behaviour is still likely to vary from UE to UE.

7.2 Inter-RAT mobility

While the focus of this work is on mobility between LTE cells, inter-RAT mobility is also considered important. This is particularly important in areas where LTE does not have coverage as good as 2G or 3G. The following mobility options are foreseen:

- LTE to LTE
- LTE to 2/3G
- 2/3G to LTE

LTE to 2/3G may be useful for a number of reasons. In particular, early LTE coverage may not be as good as 2/3G. Support for voice services can be a major consideration. Circuit switched fallback (CSFB) may be required if the LTE deployment doesn't support voice. CSFB is performed by the LTE serving cell using redirection with redirected carrier info, which guides the UE to 3G frequencies. Single Radio Voice Call Continuity (SRVCC) may be required to maintain a call between LTE and 3G areas. When CSFB or SRVCC are used, fast return mechanisms might be required to return the UE to the LTE layer(s) after a call has ended.

7.3 Inter-PLMN mobility

Mobility is also important within a roaming environment, especially when a visited network has overlapping or neighbouring coverage to the home network, as mobility between the two networks may often be desirable. An example of this situation can be where national roaming agreements occur between two networks that nominally cover the same geographic area, but with different coverage footprints. Another example is the border area between two networks which provide coverage to two separate and adjacent geographic areas. This adds the following mobility scenario to be considered:

- inter-PLMN mobility.

Higher Priority PLMN search – When a UE is in idle mode in a visited PLMN it will periodically search for its home PLMN, or a higher priority PLMN. The period of scanning can be in the range of 6 minutes up to 8 hours. A default of 60 minutes is defined. This period, T, is set on the SIM card.
Equivalent PLMN - When on a visited PLMN, the UE can be provided with an equivalent PLMN list that includes the home PLMN.
For an idle mode UE this means that cell reselection techniques can be used to discover the home network (e.g. absolute priorities) rather than via PLMN selection.
In connected mode, the lack of an equivalent PLMN may not prevent a UE from being configured to perform measurements and send measurement reports for the frequencies of the home PLMN, however the serving cell may not initiate a handover to a cell that is not considered as an equivalent to its own PLMN. When this is the case, an alternative can be to perform redirection with carrier info.

7.4 X2 availability for Small Cells

Within LTE, the S1 interface is always available for eNBs. X2 availability should also be available. One reason that X2 might not be supported is scalability issues. To reduce the high amount of control signalling exposed to the EPC, RAN connectivity sites can be deployed within the network (see chapter 10). This can help alleviate X2 scalability issues.

If X2 is not available for Small Cells then certain features are not possible. Clearly X2 handover cannot be used, but S1 based handover will be used instead. However, many SON techniques rely on or can be enhanced by the availability of X2. MLB relies on X2 for load reporting. CCO may also rely on this load reporting for its decision making. MRO relies on X2 to transmit radio link failure (RLF) messages to the source cell, if a RLF message is sent to another cell. The lack of X2 does not necessarily mean that SON cannot be implemented, but that options are reduced. For example centralized solutions may be preferred as they don't rely on X2.

If the Small Cell is a HeNB rather than an eNB, then the interfaces available at the Small Cell within a HetNet can also depend on the 3GPP release that it supports.

Mobility issues that an operator may wish to consider include:

- HeNB to HeNB mobility
- HeNB to eNB mobility (focus where eNB is a Small Cell)
- eNB to HeNB mobility (focus where eNB is a Small Cell)
- eNB to eNB mobility (focus where eNB is a Small Cell)
-

In Release 8/9 X2 will only be supported for Small Cells that are not classed as HeNBs (i.e. X2 is only between eNBs). In release 10 HeNBs support X2 between other HeNBs. From release 11 X2 is also supported between HeNBs and eNBs. Within the HetNet architecture HeNBs may also connect to the EPC via a HeNB GW, which can help reduce signaling exposed to the EPC. HeNB GWs can be deployed as part of RAN connectivity sites.

7.5 Closed Subscriber Groups

Small cells may operate in open mode, but may also have the option to work in closed subscriber group (CSG) or hybrid modes. The use of CSG can affect mobility options. First of all, a UE may have a reduced number of cells that it can attach to (depending on which CSG cells are in its whitelist). A CSG cell that is not available for inbound mobility will still act as an interferer and so can still affect mobility decisions and mobility parameter optimization in the surrounding network. Inbound mobility to a CSG cell also allows for some additional mechanisms which allow a UE to attach to a CSG cell in either idle or connected mode. This adds the following mobility scenario:

- Inbound CSG mobility – This is mobility from the serving cell into a CSG cell that is in the UE's whitelist.

In addition to standard idle mode reselection, if an idle mode UE discovers a CSG cell that is in its CSG whitelist, it will reselect onto that cell so long as it is the highest ranked cell on that layer, regardless or the priority of the layer. This means that CSG can be used as a prioritization method to encourage mobility towards member cells. However, discovery of the CSG cell is reliant on standard idle mode procedures or an autonomous search function (from Release 9) within the UE. As the autonomous search function is not defined, the effectiveness of this mobility method may vary from UE to UE.

In addition to standard measurement reporting, a connected mode UE can also use an autonomous function (from release 9) to send a proximity indication message to its serving cell to inform it about any suitable member cells that are discovered. The serving cell can then initiate handover to the member cell. As with the idle mode CSG option, this connected mode CSG option can be used to encourage mobility towards member cells. Again, the reliance on the unspecified autonomous search function in the UE means that the effectiveness of this mobility option may vary from UE to UE.

7.6 Wi-Fi Integration

Handover to or from non-3GPP devices is also relevant to the HetNet discussion. In particular integration with carrier-grade Wi-Fi Small Cells is considered. The discussion on this form of mobility can be found in section 5, which includes considerations such as Hotspot 2.0 and ANDSF. One concern may be the reliance on the UE to make decisions for mobility between 3GPP and Wi-Fi (in either direction).

8 ANALYSIS OF TECHNICAL SOLUTIONS FOR SMALL CELLS

The can be several technical solutions able to cover the use cases identified in Chapter 3 for the deployment of Small Cells. In particular, the following technical solutions have been identified within the project:

1. ***Traditional Small Cells:*** in this technical solution both the base band and the RF part are located in the same Small Cell equipment.

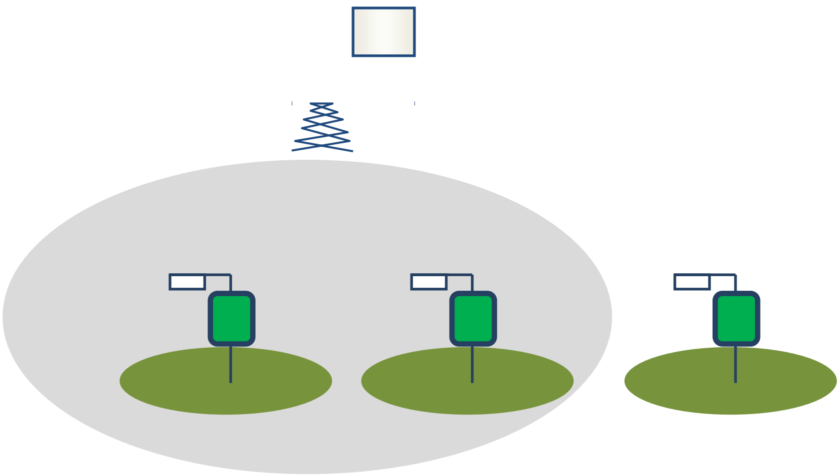

Figure 6: traditional Small Cells.

2. ***Cloud RAN Based Small Cells with fibre fronthaul:*** in this technical solution the radiating point contains only the RF part. The base band processing is centralized in a different location (i.e. in a central office). The BB and the RF part are connected using fibre fronthaul (the interface could be CPRI, ORI, …).

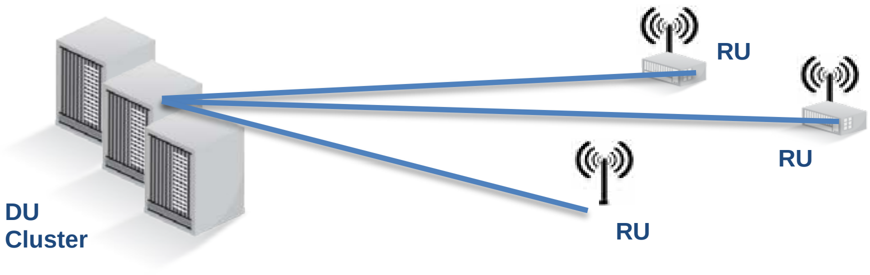

Figure 7: Cloud RAN Based Small Cells with fibre fronthaul.

3. ***Cloud RAN based Small Cells with radio fronthaul:*** in this technical solution the radiating point contains only the RF part. The base band processing is centralized in a different location (i.e. in a central office). The BB and the RF part are connected using radio fronthaul (the interface could be CPRI, ORI, …, or optimized compressed version of the above interfaces).

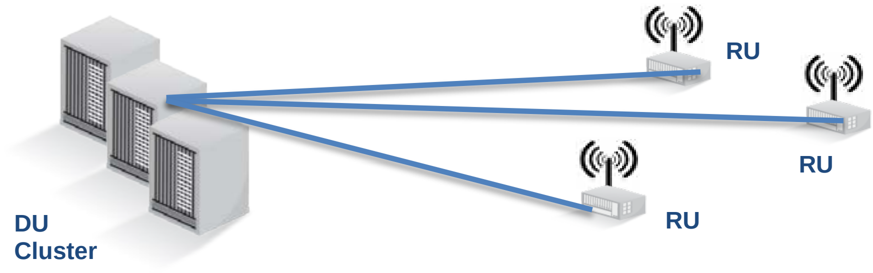

Figure 8: Cloud RAN Based Small Cells with radio fronthaul

4. ***Distributed Antenna System:*** in this technical solution the low power antennas distribute the signal of an eNodeB. The distributed antennas are connected to the eNodeB with fibres. RF-to-optical conversion is needed at eNodeB interface; optical-to-RF conversion is needed close to antennas.

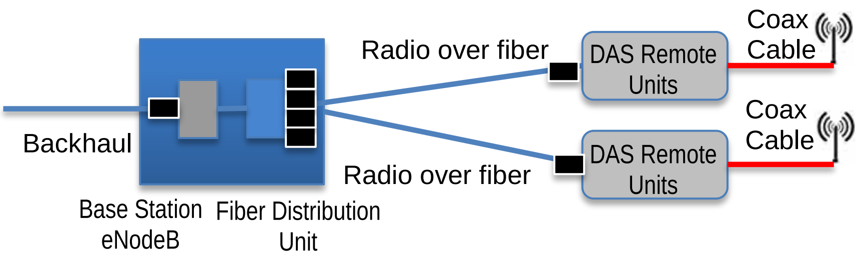

Figure 9: Distributed Antenna System.

5. ***Passive distributed architecture:*** In this technical solution the low power antennas distribute the signal of an eNodeB. The distributed antennas are connected to the eNodeB using only passive cable, splitters and combiners.

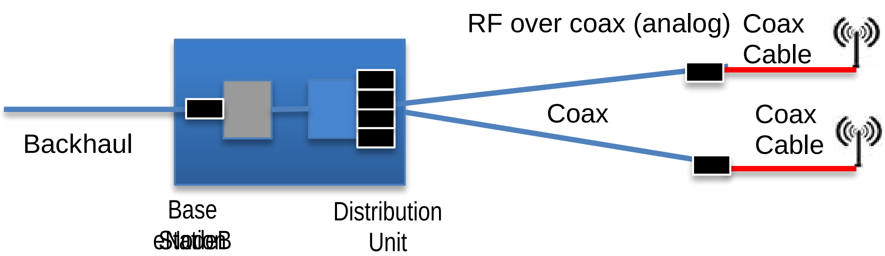

Figure 10: Passive distributed architecture.

6. ***Small Cell with AAS:*** In this technical solution, Small Cells are equipped with Active Antenna System, with the goal to extend the coverage and/or to better shape the coverage of Small Cells.

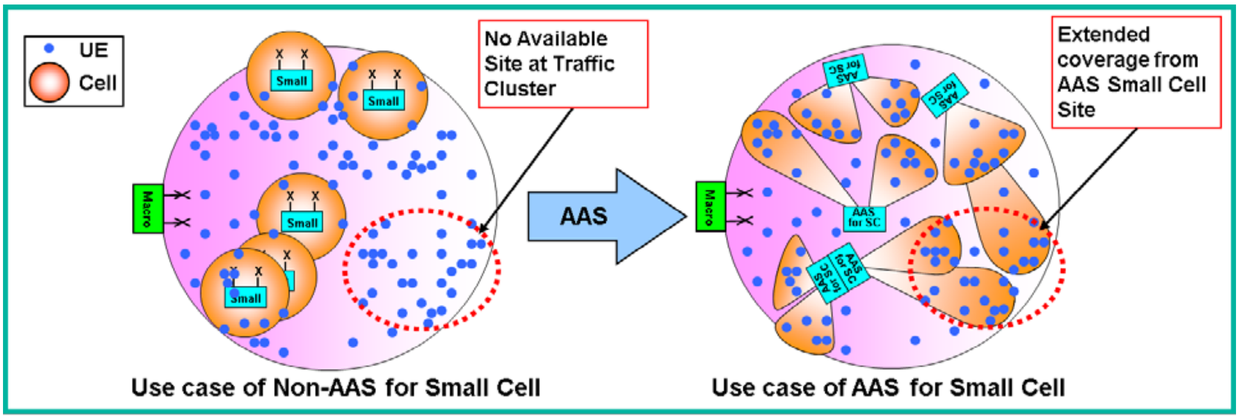

Figure 11: Small Cell with AAS.

The following table compares in a qualitative way the identified technical solutions in terms of: enabled 3GPP features (i.e. eICIC, CoMP …), Network performance, complexity, flexibility, and multi-operator approach.

Table 5: Qualitative comparison of different technical solutions.

Technical solution	***Enabled 3GPP features***	***Network performance***	***Complexity***	***Flexibility***	***Multi-operator approach***
Traditional Small Cells *(BB and RF in the same equipment)*	*eICIC*	*Medium*	*Low*	*Low*	*Low*
Cloud RAN Based Small Cells with fibre fronthaul *(BB and RF in different equipment)*	*eICIC, CoMP*	*High*	*High*	*High*	*Low*
Cloud RAN based Small Cells with radio fronthaul	*eICIC, CoMP*	*High*	*Medium*	*High*	*Low*
Distributed Antenna System *(distributed antennas, connected with fibres, in a RF-to-optical-to-RF configuration)*	*eICIC*	*Medium*	*High*	*High*	*High*

Passive distributed architecture *(distributed antennas, using only passive cable, splitters and combiners)*	*eICIC*	*Low*	*Medium*	*Medium*	*High*
Small Cell with AAS	*eICIC*	*High*	*Medium*	*Low*	*Low*

9 REQUIREMENTS FOR MULTI-VENDOR DEPLOYMENT OF HETNET NETWORKS

9.1 Introduction

The main objectives of Work Stream 2 of NGMN-P-SmallCells are to promote multi-vendor deployments in HetNets by providing the ecosystem with recommendations and guideline on SON multi-vendors implementations [3]. The guideline is developed by analysing implementations options for interoperability issues and makes recommendations remedying/mitigating the identified IOT issues. Work stream 2 also developed test specification for Multi-Vendor X2 SON Deployment [4] which can be used to test multi-vendor interoperability for SON, and verify the recommended remedies identified in the recommended practice document [3].

9.2 Recommended Practices for Multi-vendor SON Deployment

The project defined the reference architecture identifying the interfaces involved in multi-vendor mode. The SON features were also analysed by defining SON operation, diagnosing possible issues in multi-vendor operation and proposing remedies for issues that are found to be significant. These remedies were presented in deliverable D2 as "Recommended Practices for Multi-vendor SON Deployment" and published by the NGMN as outcome from this project.

The recommended practice document covers the following:

- General multi-vendor interoperability assumptions and targets
- Perimeter of the study
- Performance metrics definition and performance targets in multi-vendor configurations
- Reference SON architectures and interfaces and some implementation options
- SON features description and analysis of multi-vendor deployments
- Descriptions of potential interoperability issues for each SON feature and the recommended proposals for solving or reducing these issues.

The scope of the work in this deliverable is limited to LTE technology in 3GPP Releases 8 & 9 and excluded HeNB.

SON features analysed includes:

- PCI Optimization,
- Automatic Neighbour Relation (ANR),
- Mobility Load Balancing (MLB),
- Mobility Robustness Optimisation (MRO),
- Coverage and Capacity (CCO)

SON features not included in the analysis:

- eNB and MME Self Configuration,
- RACH Optimisation (future work),
- Energy Saving (future work),

A variety of vendors' implementations is considered in this analysis.

9.3 Reference Architecture

The reference architecture used for this study on Multi-Vendors is based on the 3GPP Management architecture and interfaces for both centralised and distributed SON as shown in the figure below.

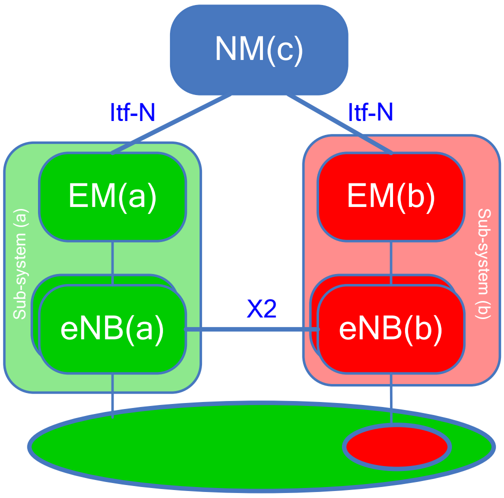

Figure 12: Reference architecture for multi-vendor SON.

The present interoperability analyses solely rely on X2 and Itf-N interfaces.

9.4 Performance metrics and targets

Four categories of metrics have been selected. They constitute the most relevant criteria to measure performance in multi-vendor mode.

Table 6: Performance metrics in multi-vendor environment.

Top Metrics → SON features ↓	Quality of Experience	Throughput	Operational Efficiency
ANR			Reduces human intervention
MLB	Setup Success Rate QoS, call drops reduction	Avg. & cell edge gain	Reduces human intervention (HO triggers)
MRO	Reduces drops, Avoid unnecessary HO (ping pong)		Reduces human intervention
PCI opt	Reduces drops		Reduces human intervention
CCO	Coverage Quality Setup success rate	Tput distribution	

In view of simplifying the process, the methodology consists of measuring performance improvements of each SON feature by comparing cases with SON feature activated versus SON feature deactivated. Absolute minimum performance improvements are used as acceptability criteria.

9.5 Implementation Options

The studies identified 4 different implementations options related to the location of the SON function. As a Macro cell and Small Cell in this case are controlled by different eNB-EM sub-systems the following combinations of inter-working should be possible.

Table 7: Implementation options for the location of SON functions.

No	Location of a SON Function		
	Vendor A	Vendor B	Vendor C*
1	eNB-EMS Sub-system	eNB-EMS Sub-system	
2		eNB-EMS Sub-system	NM for Vendor A
3	eNB-EMS Sub-system		NM for Vendor B
4			NM for both A and B

Possible locations of the SON functions are illustrated for the various implementations in the diagram below. (Note implementation option 3 is not shown as it has not been addressed by the study)

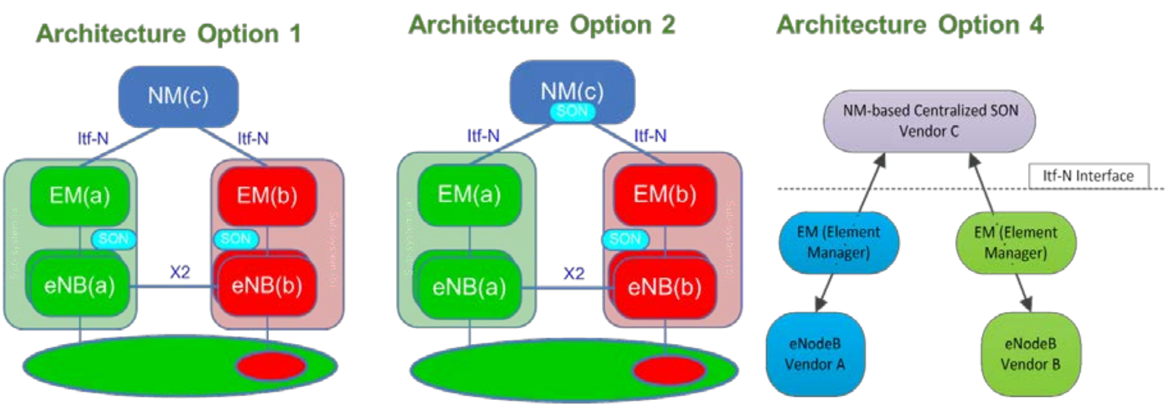

Figure 13: Architecture options for SON implementation.

9.6 Conclusion and Future work on Multi-Vendor SON deployment

High-level analysis is presented for multi-vendor interoperability deployment of SON features as PCI Optimisation, ANR, MRO, MLB and CCO in Small Cell populated LTE HetNet environment.
Examples for both distributed and centralised SON architectures were discussed and potential problems highlighted with recommended practices for solving these problems were identified.
It is believed that both SON architectures have potential to provide effective and efficient operations in terms of network performance and stability when recommended practices are understood and followed.
NGMN developed IOT test cases to verify SON interoperability between vendors and confirm the relevance of the proposed recommendations in a Joint Plugfest organised by the SCF and ETSI in June 2014 [4].
It is believed that as SON functionality and products mature there is a scope for future work on other SON features, such as:

- RACH Optimization
- Cell Outage Compensation (COC)

- Energy Savings
- Etc.

9.7 Cooperation with the Small Cell Forum and possible Plugfest activities

NGMN and SCF have engaged in collaboration agreement on activities on the development of test cases on SON with the aims for NGMN vendors to participate in SCF Plugfest activities. In this draft agreement:

- SCF provides access to the basic X2 tests (that are prerequisite for advanced SON test cases developed by NGMN)
- Draft test cases document [4] was shared with SCF (as per the agreement between SCF and NGMN) and was adopted for Plugfest and included in the Plugfest test cases database. In parallel, we would go for the standard approval process (i.e. with position statement etc.) within NGMN for these test cases

The first plugfest took place in Paris in June 2014 and is hosted by Orange Lab. This is the first Plugfest in which NGMN is engaged and marks the start of long-term collaboration with SCF for subsequent joint Plugfests.

10 BACKHAUL REQUIREMENTS FOR HETNET NETWORKS BEYOND RELEASE 8

10.1 Introduction

The term heterogeneous network refers to one comprising mixture of different radio access technologies. Here, we are particularly focused on HetNets where a high power macro cell network is later augmented with lower power Small Cells. We assume a starting point of a macrocell network, to which Small Cells are added, requiring their own last mile backhaul integrated into the existing transport network.

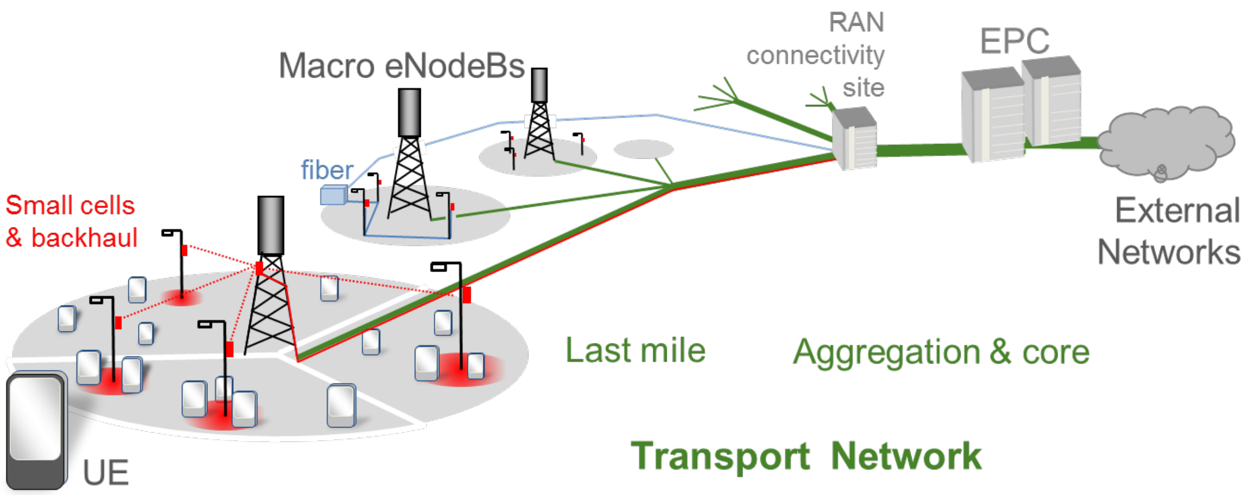

Figure 14: Transport connectivity in the heterogeneous network.

Figure 14 illustrates typical transport connectivity in the HetNet. The existing macro transport (in green) has last mile ‘access tails’ to the macro sites, which aggregate towards the Enhanced Packet Core (EPC). The RAN connectivity site may contain intermediate switches, routers and security gateways.

Small Cells may be added to this network and backhauled in a variety of ways. A ‘macro launched’ topology shown in red uses the macro site as the first point of aggregation for Small Cell backhaul, and then the existing macro backhaul from then on. A ‘street launched’ topology shown in blue uses street cabinets with wireline connectivity back to the RAN connectivity site.

The RAN connectivity site provides switching and or routing functions and may terminate security. It can serve as the turnaround point for peer-peer interfaces such as the X2. In the evolution to a HetNet, Small Cell network functionality may be added here, such concentration to reduce volume of signalling traffic toward the core. This site may also be a suitable location for centralized co-ordination and SON functions.

The NGMN has published a number of documents providing operator requirements and recommendations across a range of aspects for Release 8 LTE backhaul:

- “NGMN Optimized Backhaul Requirements”, NGMN, August 2008, http://www.ngmn.org/uploads/media/NGMN_Optimised_Backhaul_Requirements.pdf,
- "Guidelines for LTE Backhaul Traffic Estimation", NGMN, July 2011, http://www.ngmn.org/uploads/media/NGMN_Whitepaper_Guideline_for_LTE_Backhaul_Traffic_Estimation.pdf
- "Integrated QoS Management", NGMN , December 2012, http://www.ngmn.org/uploads/media/NGMN_Backhaul_Evolution_-_Integrated_QoS_Management_Part_One_v1.3.pdf
- "LTE Backhauling Deployment Scenarios", NGMN , July 2011, http://www.ngmn.org/uploads/media/NGMN_Whitepaper_LTE_Backhauling_Deployment_Scenarios_01.pdf
- "Security in LTE backhauling", NGMN, February 2012, http://www.ngmn.org/uploads/media/NGMN_Whitepaper_Backhaul_Security.pdf

We have furthermore developed requirements for Small Cell backhaul, which considers both HPSA and LTE Release 8 Small Cells deployed in dedicated carriers – or otherwise outside of macro cell coverage.

- “Small Cell Backhaul Requirements”, NGMN , Jun 2012, http://www.ngmn.org/uploads/media/NGMN_Whitepaper_Small_Cell_Backhaul_Requirements.pdf

LTE-Advanced provides a range of features which tighten the integration of macro and Small Cell layers with the ultimate aims of seamless and high quality mobile connectivity experiences for users and maximized network capacity for operators. Features such as eICIC, CoMP or Carrier aggregation all include the facility to co-ordinate small and macro RANs within the het net, which in turn have implications for backhaul connectivity and the performance required.

Here we consider requirements of transport networks to support the coordinated macro-small HetNets of LTE-Advanced.

10.2 Architectures and Transport Topologies for LTE-A Het Nets

The architecture and topology of a backhaul network that supports HetNets and LTE-A functions may depend on several factors related to the use cases presented earlier in this paper:

- Level of coordination between macro and Small Cells and degree of SON and LTE-A functions enabled for spectrum, interference and capacity coordination;
- Area of deployment of a Small Cell, whether it is indoor vs outdoor, urban, suburban or rural
- Presence / availability of a backhaul network demarcation device at the cell site
- Split of RAN functions (if adopted)
- Transmission technology available at the site
- Security requirements
- Performance and QOS related requirements
- Etc.

Depending on the mix of solutions to address the above requirements different network architectures are envisaged. From a physical connectivity standpoint it is assumed that a Small Cell site is connected to either a macro cell site or network site via:

- **Point-to-point connectivity**. This is applicable both to fronthaul and backhaul cases. In fronthaul architectures a Small Cell site is connected to a BBU controller site available in a Cloud RAN. In backhaul architectures a Small Cell site is connected to either a macro cell site or a network site. Point-to-point connectivity also includes cases such as daisy-chain, where a Small Cell site may be relayed through another Small Cell site
- **Point-to-multipoint connectivity**. This is applicable mainly to backhaul architectures. A cluster of Small Cells are connected to either a macro cell site or a network site.
- **Other physical topologies** (e.g. ring and/or mesh) are also possible but less likely and are not considered at this stage.

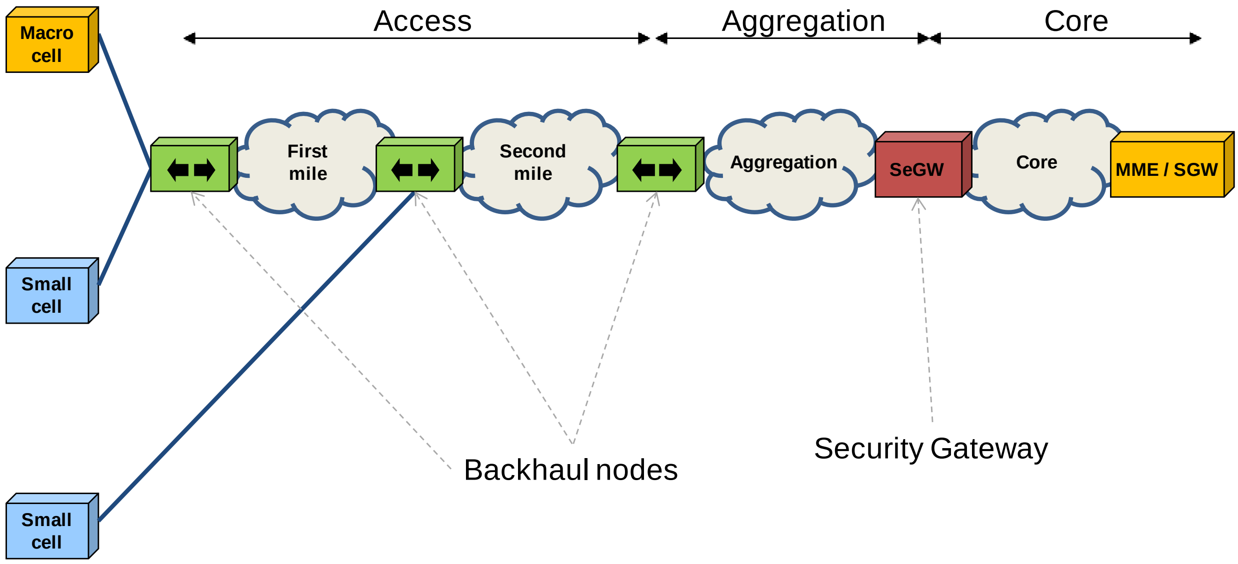

Figure 15 RAN architectures show different options for macro-Small Cell het-nets.

The logical architecture is analysed here only in the context of backhaul, as it is assumed that in fronthaul scenarios the transport of services enabled by a packet network is limited at the backhaul node available at the BBU site. In backhaul cases the transport of services may be based either on a layer 2 architecture (e.g. Carrier Ethernet), layer 3 (e.g. IP/MPLS) or a mix of the two (e.g. access network based on layer 2 and aggregation network based on layer 3). The choice of the logical architecture is influenced by the service layer. The main assumptions considered here follows:

- A Small Cell likely communicates through the S1 interface with a Gateway (either MME/SGW, HeNB GW, SeGW, etc.)
- The S1 interface is assumed to be encrypted through IPsec, so from a backhaul perspective its transport crosses a SeGW somewhere in a backhaul network
- The usage of the X2 interface for both Small Cell to Small Cell and Small Cell to macro cell communications is expected to increase with respect to the base utilization for LTE hand-over
    - o SON information exchange, in particular for functions such as Physical Cell Identity (PCI) exchange, Automatic Neighbour Relation (ANR), Mobility Robustness Optimization (MRO), Mobility Load Balancing (MLB) Coverage and Capacity Optimization (CCO)

- o Interference control functions between small and macro cells, as enhanced Inter Cell Interference Coordination (eICIC), Carrier Aggregation (CA), Coordinated Multi Point (CoMP) processing
- o More in general, multi-vendor, multi-RAN scenarios, where the need to exchange control information among cells of different manufacturers and generations may arise

- It is assumed that X2 traffic may or may not be encrypted, to facilitate local switching / routing.

10.2.1 Midhaul

MEF 22.1 amendment 1 (MEF 22.1.1[1]) gives different names to the transport links based on the level of coordination between cells and the resulting impact on the performance needed. In particular, MEF 22.1.1 identifies 4 cases: "no coordination", "moderate coordination", "tight coordination" and "very tight coordination". The first two do not impose specific requirements on the backhaul network (so correspond to no / limited coordination of this paper). The last one is reserved for fronthaul. The case "tight coordination" poses specific requirements that lead to the introduction of a network domain called "midhaul", characterized by low latency and direct point-to-point connectivity between a Small Cell and its relevant reference macro cell. Even if the term "midhaul" is also used outside the context of MEF 22.1.1 in this paper the term non-ideal backhaul is utilized instead, specifying where necessary the characteristics or requirements that have to be supported".

10.3 Transport Requirements

10.3.1 Capacity Provisioning

In general, it is desirable that the transport network should not limit the traffic generated by the RAN. However, with peak rate capabilities potentially exceeding 1 Gbps for certain LTE-Advanced configurations, it would not be viable to provisioning a network where this may occur in all cells simultaneously. In reality, cells only generate these very high peaks during quiet times when other cell interferences is low and only a single user with and ideal channel is connected to the cell. In a loaded network, we see lower rates per cell, as high path loss and interference seen by cell edge users bring down the average cell efficiency. We provide a detailed description of these characteristics, supported by a detailed set of simulation results in our backhaul provisioning guidelines document[2]. Overall, we see last mile backhaul is typically provisioned to support the peak rates of individual cells or cell sites, whereas aggregation and core segments of the transport is provisioned to the lower busy time loaded cell throughput of many sites combined.

10.3.2 Transport Latency

Delay performance may be driven by a number of different factors:

- **Delivery of phase synchronization over packet backhaul**. This is needed to align timing of resource block transmissions from multiple sites for TD-LTE, MBMS SFN, coordinated scheduling and eICIC. Packet synchronization techniques require symmetrical transport delay and low floor delay variation. The absolute delay itself is less of a problem. A detailed description of synchronization requirements and technologies can be found in [3].
- **User plane delay.** Different services have different requirements for the end-end user plane delay which they can tolerate, with gaming and voice more sensitive than web browsing or video streaming. Since the

[1] MEF, "Implementation Agreement MEF 22.1.1 Mobile Backhaul Phase 2 Amendment 1", April 7, 2014
[2] "Guidelines for LTE Backhaul Traffic Estimation", NGMN, July 2011, http://www.ngmn.org/uploads/media/NGMN_Whitepaper_Guideline_for_LTE_Backhaul_Traffic_Estimation.pdf
[3] "Synchronisation for LTE Small Cells", Small Cell Forum, Dec 2013, www.scf.io/document/075

delay budget is end-end, it is difficult to place hard requirements on any one segment. However, we can apply some general guidelines recommended by the Small Cell Forum in their backhaul solutions document[4]. This works on the basis that the most significant component of delay is added by the Uu air interface, which is a minimum of 10ms round trip.

  - Last mile backhaul round trip delay performance
    - <1ms: Negligible compared to air interface
    - 1-10ms: good
    - 10-60ms: commensurate with 3GPP upper bound for their gaming QCI
    - >60ms: Potentially usable depending on specific service requirements
  - We note that during an X2 handover with packet forwarding, the X2 latency is added to the S1 latency. The user plane delay budget may consider this as a worst case scenario.

- **Co-ordination.** Co-ordinated scheduling and eICIC have been designed to work over non ideal backhaul, and are therefore delay tolerant. Signalling required to support co-ordination may update a transmission pattern (ABS pattern in the case of eICIC) every few seconds at most. However, it is then the more demanding phase synchronization which ensures that patterns are transmitted with the correct time alignment.
- **Fronthaul:** Fronthaul is a special case of transport as distinct from 'non ideal' backhaul. Here, very low delay performance of [tens of microseconds] [17] is needed to ensure correct functionality of L1/L2 functions such as Hybrid ARQ. A detailed set of transport requirements for fronthaul are provided in [19], [17].

10.3.3 Availability

Different levels of availability may be envisaged, depending on application and network requirements. From a physical viewpoint, connection availability may range from three 9s up to six 9s

10.3.4 Security

Small Cells are often considered as more exposed to attacks or tampering, due to more diversified deployment cases than macro cells. So, a few aspects may be analysed to determine the requested degree of security the underlying backhaul network has to provide.

A first aspect is whether the backhaul network can be considered as trusted [5] (typically this is the case when a service provider / operators entirely owns and controls the transport network). If this is the case security requirements may be less a concern, as an operator is not forced to enable mechanisms such as those included into the IPsec framework, comprising data integrity, authentication and confidentiality.

On the other hand, if the network is considered as un-trusted then IPsec sessions should be established end-to-end between a Small Cell and a Security Gateway (SeGW) located in the network. Specifically, a mutual authentication should be enabled by any Small Cells and the core elements, based on the IPsec framework. IPsec should also be enabled to support data confidentiality and integrity.

A second aspect that may have impact over security is related to the level of integration [6] between the Small Cell and the backhaul / transport equipment / function deployed at the cell site (if any).

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[4] "Small Cell Backhaul Solutions", Small Cell Forum, Feb 2013, www.scf.io/document/049
[5] 3GPP TS 33.320, "Security of Home Node B (HNB) / Home evolved Node B (HeNB)", September 2011
[6] Small Cell Backhaul Requirements, June 2012, https://www.ngmn.org/uploads/media/NGMN_Whitepaper_Small_Cell_Backhaul_Requirements.pdf

As an example, to enforce hardening both the Small Cell and the backhaul equipment might be integrated or packaged into a single enclosure. Since most of deployments may be based on physical decoupling between the Small Cell and the backhaul unit, to improve installation flexibility, some security mechanisms should be found in field: e.g. minimal power and data cable accessibility to non-authorized people, security mechanism to filter traffic and verify source and destination, port activation control.

Site engineering could also pose constraints on security. An easily accessible site, e.g. a cell installed on a bus shelter, might be more exposed to hacking or hijacking. In that case it is envisaged that all the non-utilized components of backhaul (e.g. unused Ethernet port) are administratively disabled.

10.3.5 QoS support

Previous work within NGMN [18] has looked at Quality of Service functions in order to deliver a coherent end user Quality of Experience (QoE) across a backhaul transport network comprising of Ethernet, MPLS and IP layers.

The document "Integrated QoS Management", NGMN, December 2012, http://www.ngmn.org/uploads/media/NGMN_Backhaul_Evolution_-_Integrated_QoS_Management_Part_One_v1.3.pdf discusses two fundamental QoS management functions such as:

1. Service flow classification, or the mapping of service data and signalling flows into classes of service (CoS)
2. Inter-layer CoS alignment or the alignment of the different classes of service of the various RAT (service -) and the Ethernet, MPLS and IP network (transport -) layers.

The service flow classification in itself is an operator decision, based on operational and commercial policies, but alignment between operators and between operators and third-party content providers is especially important for a consistent end user experience.

In all cases, the inter-layer CoS alignment is important in order to guarantee that the QoS requirements of a service flow are not compromised when traversing different backhaul network segments or third-party networks. Especially with inter-layer CoS alignment strategies, some basic recommendations would be; to either use the same number of CoS, or alternatively, to aggregate certain service classes into one CoS consistently throughout the path of a service flow. In essence, the priority hierarchy is important; not the absolute marking values per se.

Coordinated HetNets introduce additional considerations. In order to assure a coherent end user QoE when migrating between macro and Small Cell layers and potentially between different RAT at the same time, a coherent QoS management strategy of all the associated physical and/or logical backhaul sections should be taken into account.

When Small Cell backhaul is added to the existing macrocell backhaul network the Small Cell and macro cell service flows can be combined into “one big pipe” with for example four classes of service where identical service flows are classified into the same CoS, or they can be logically separated. In the latter case Small Cell service flows can have the same classification scheme as the macro cell layer but, for example, the allocated backhaul capacity and resiliency is provisioned differently depending on operator policy and use case.

The various backhaul sections that would require CoS alignment could be one or a combination of;

1. Macro cell site to backhaul aggregation node using wireless or optical fibre transport or both
2. Small Cell site to backhaul aggregation node using wireless or optical fibre transport or both
3. Small Cell to associated macro cell site using wireless, copper-based or optical fibre transport

4. Wi-Fi physical or logical backhaul network for Small Cells supporting Wi-Fi in addition to 3GPP RAT.

Especially for the case where an operator wishes to apply QoS policies on a per end user/application basis regardless of RAT, the service behaviour of the different backhaul segments need to be aligned. This might be done more easily for inter cell layer handovers (e.g., small to macro cell) or inter 3GPP RAT (e.g., HSPA to LTE-A) than between Wi-Fi and 3GPP RAT in case different backhaul networks are used for Wi-Fi offload.

New requirements for coordinated HetNets using LTE-Advanced that need special attention versus LTE (Release 8) are the signalling flows supporting the Interference management features as mentioned in chapter 10.3.2 "Transport Latency". As per the proposed NGMN service flow classification in [7], these signalling flows should be classified into "C1", meaning the highest class of service due to their low delay and delay variation requirements.

Requirements for centralized, distributed CoMP architectures for non-ideal backhaul can be found in document [[20] table 1 and table 11].

See below the proposed service flow classification tables for various CoS schemes.

10.3.5.1 Two-CoS Classification Scheme

In this case, the only separation is for the most sensitive flows. All other flows, which would consume significantly more resources, are considered as "Best Effort" (C8). This scheme is adapted to scenarios where the basic service level expectation is analogous to internet service. OAM messages may need to use the same CoS used from service flows they are associated to.

Table 8: NGMN – Two Classes of Service Classification Scheme for LTE/LTE-A.

C1	Voice, Real-Time Gaming, Synchronization and Control Plane/OAM (including interference management signalling flows for LTE-A)
C8	Everything Else (Wi-Fi offload is typically best effort for all service flows)

10.3.5.2 Three-CoS Classification Scheme

This scheme improves upon the previous one by splitting a new class of service (C2) out of the Best Effort category (C8). OAM messages may need to use the same CoS used from service flows they are associated to.

Table 9: NGMN – Three Classes of Service Classification Scheme for LTE/LTE-A.

C1	Voice, Real-Time Gaming, Synchronization and Control Plane/OAM (including interference management signalling flows for LTE-A)
C2	Real-Time Video
C8	Everything Else (WiFi offload is typically best effort for all service flows)

10.3.5.3 Four-CoS Classification Scheme

In this scheme, C3 is truly a “better-than-Best-Effort” CoS. We’ve chosen to include in C3 the three LTE QCIs that really involve a notion of quality of service expectation, while keeping the other three existing classes of service in place. This reflects the fact that LTE brings greater granularity to QoS management than 3G or 2G, as illustrated by the larger number of different bearer types that is available in this standard.

Table 10: NGMN – Four Classes of Service Classification Scheme for LTE/LTE-A.

C1	Voice, Real-Time Gaming, Synchronization and Control Plane/OAM (including interference management signalling flows for LTE-A)
C2	Real-Time Video
C3	Premium Data (buffered Video, non-GBR Real-Time)
C8	Everything Else (WiFi offload is typically best effort for all service flows)

10.3.6 SDN in the HetNet

Software Defined Network (SDN) is based on a new network architecture in which the control and data planes are decoupled from each other's. In the SDN architecture, the network controller is centralised in a logical entity while the underlying network elements (NE) are abstracted and presented in an information model form. This allows the network to become programmable with a high degree of flexibility, controllability and automation. SDN therefore allows operators to deploy a highly scalable network that is able to adapt to their changing business needs.

The Open Networking Foundation (ONF) is currently developing an architectural framework for wireless transport adopting the SDN architecture based on ONF OpenFlow™ technologies applicable to radio links and nodes of the backhaul network.

An overview of an SDN architecture is shown in the figure below. This introduces the concept of an SDN controller in which the transport nodes are then considered as NE, which are part of the overall SDN transport network.

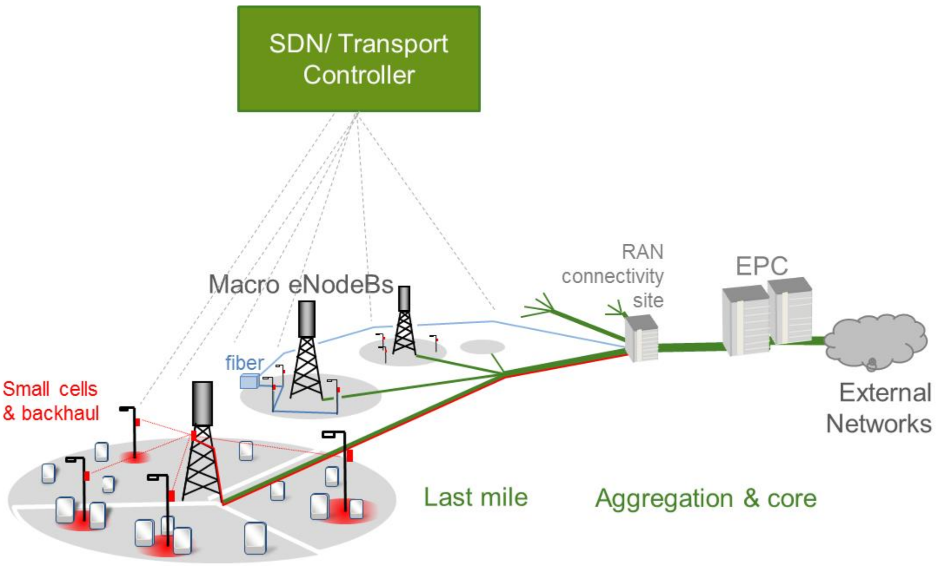

Figure 16 An overview of an SDN based backhaul network.

Whilst the application of SDN to the transport network has not been considered in this document, the NGMN will continue monitoring the development of SDN and its application to backhaul. Once this technology and standards are matured, the NGMN will further explore its practicality and impact on small-cells and backhaul networks.

11 RECOMMENDATION FOR COST EFFECTIVE SMALL CELL DEVELOPMENT AND DEPLOYMENT

The present deliverable provides recommendations for cost effective development and deployment of Small Cells. Even though more detailed recommendations maybe found in the text, please find in the following a summary table of recommendations to enhance cost efficiency of the main cost elements:

- Greater availability of products and overall technology maturity is recommended in order to efficiently allow the deployment of the above mentioned use cases (see Chapter 3)
- Wi-Fi and Small Cell integration (see chapter 5):
  - POE(Power over Ethernet) (or POE+ in Wi-Fi and Small Cell integration case) is recommend to ease the power supplier mechanism.
  - SoC (System on Chip) solution is recommended so that the Small Cell and Wi-Fi Small Cell integration product can be built on an integrated chipset.
  - Flexible backhaul interface shall be supported. PTN and xPON (EPON/GPON) shall be supported. Wireless backhaul is recommended in case there is no fixed access backhaul.
  - When a Small Cell gateway is deployed, the gateway virtualization is recommended to meet with multiple logic core networks. Multiple mode of gateway, i.e., support 3G & LTE simultaneously are recommended. The Small Cell system software should be able to be updated remotely.
- Traffic geolocalization mechanisms to find the proper locations for Small Cell (see Chapter 6):
  - It is recommended to implement standard mechanism, i.e. MDT
  - NGMN recommends relevant parties to actively engage in MDT WID creation in 3GPP.
  - For immediate and medium term needs of proper Small Cell Geopositioning, MNO can work and evaluate solutions other than MDT
- Mobility, coordination between macro and Small Cell layer (see chapter 7)
- Multivendor deployment of HetNet networks (see chapter 9):
  - There is a wide range of mobility options available, which offer varying levels of user experience. It is recommended that an operator carefully considers the desired user experience when selecting from these options
  - It is recommended that SON features are used to help Small Cells achieve the desired mobility performance
- It is recommended to provide X2 whenever possible, to allow for the benefits of several mobility and SON solutions to be realised Backhaul (see Chapter 10):
  - Integration of backhaul in Small Cell equipment could make easy the deployment.

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