Neutral Host Solutions for Multi-Operator Wireless Coverage in Managed Spaces

September 2016

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This document was developed for the ATIS Technical and Operations (TOPS) Council Neutral Host Landscape Team, which had the following leadership:

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Abstract

The concept of a neutral host is considered a potentially interesting approach to improving wireless coverage in environments such as shared offices, sports venues, and shopping malls. In the neutral host concept, a shared wireless infrastructure is created which is used to provide services to end-users with subscriptions to several different hosted operators. This landscape assessment defines the neutral host concept and provides an overview of the existing technical solutions to support neutral host.

Table of Contents

Table of Figures

Neutral Host Solutions for Multi-Operator Wireless Coverage in Managed Spaces

1 Scope, Purpose, & Application

1.1 Scope

Today, when deploying small cells within a managed space such as an enterprise office, a shopping mall, or a stadium, the landlord controls access to infrastructure. Visitors to the space will subscribe to many different wireless network providers. Thus, to get uniform cellular coverage for all employees, customers, and guests, small cells from all major providers must be deployed in addition to Wi-Fi and unlicensed access. This is a high-cost and complex arrangement involving deployment of multiple infrastructures. A potentially more attractive arrangement is to have one common infrastructure system deployed that could be used by all service providers. Thus the landlord, or delegate, becomes a neutral (not aligned with any specific provider) host for small cell coverage.

This paper examines and analyzes neutral host solutions assessing the technical and logistical implications.

2 Normative References

The following references contain provisions which, through reference in this text, constitute provisions of this document. At the time of publication, the editions indicated were valid.

[017 Market Drivers for Small Cells] Small Cell Forum SCF017.06.01, *Multi-operator market drivers*[1]

[22.951] 3GPP TS 22.951, *Service aspects and requirements for network sharing*[2]

[23.251] 3GPP TS 23.251, *Network sharing; Architecture and functional description*[3]

[23.402] 3GPP TS 23.402, *Architecture enhancements for non-3GPP accesses*[4]

[MulteFire] MulteFire Alliance[5]

3 Definitions, Acronyms, & Abbreviations

For a list of common communications terms and definitions, please visit the *ATIS Telecom Glossary*, which is located at < http://www.atis.org/glossary >.

[1] Available from the Small Cell Forum at: < http://scf.io/en/documents/017_-_R6_-_Multi-Operator_Market_Drivers.php >.

[2] Available from 3GPP at: < http://www.3gpp.org/DynaReport/22951.htm >.

[3] Available from 3GPP at: < http://www.3gpp.org/DynaReport/23251.htm >.

[4] Available from 3GPP at: < http://www.3gpp.org/DynaReport/23402.htm >.

[5] See: < http://www.multefire.org/ >.

3.1 Acronyms & Abbreviations

AC	Alternating Current
3GPP	Third Generation Partnership Project
AP	Access Point
API	Application Programing Interface
ATIS	Alliance for Telecommunications Industry Solutions
CBRS	Citizens Broadcast Radio Service
CMSP	Commercial Mobile Service Provider
DAS	Distributed Antenna System
DC	Direct Current
eNB	eNode B
EPC	Enhanced Packet Core
ePDG	Evolved Packet Data Gateway
FAPI	Functional API
FCC	Federal Communications Commission
GAA	General Authorized Access
GERAN	GSM EDGE Radio Access Network
IMS	IP Multimedia Subsystem
ISM	Industrial, Scientific, and Medical
ISP	Internet Service Provider
KPI	Key Performance Indicators
LTE	Long Term Evolution
MAC	Media Access Control
MNO	Mobile Network Operator
MOCN	Multi Operator Core Network
M-SSID	Multi Service Set Identifier
MVNO	Mobile Virtual Network Operator
nFAPI	Network Functional Application Programing Interface
NFV	Network Function Virtualization
PAL	Priority Access License
PBX	Private Branch Exchange
PHY	Physical (protocol layer)

QoS	Quality of Service
RAN	Radio Access Network
RF	Radio Frequency
SAS	Spectrum Access System
SLA	Service Level Agreement
SON	Self-Optimized Network
SSID	Service Set Identifier
UE	User Equipment
UICC	Universal Integrated Circuit Card
UMTS	Universal Mobile Telecommunications System
VLAN	Virtual Local Area Network
VNF	Virtual Network Function
VoWi-Fi	Voice over Wi-Fi
WLAN	Wireless Local Area Network
WWAN	Wireless Wide Area Network

4 Introduction to Neutral Host

4.1 General Description of a Neutral Host

The term "neutral host" combines two concepts – the aspect of "hosting" and the aspect of "neutrality". The hosting aspect refers to an entity that provides a certain set of resources that are made available to clients such as mobile network operators in order to allow the hosted clients to provide continuous services. The resources that may be offered by a neutral host are addressed in the next section. The "neutrality" aspect refers to the host acting as a shared platform to multiple hosted clients. Neutrality in this context does not imply strict equality between hosted clients, as the resources offered to each hosted client are subject to commercial agreement between the neutral host and the hosted client, and policy-based management may be applied.

From a user's point of view, the system behavior and services using the resources of a neutral host should be available without user intervention and, ideally, these should be seamless and identical to those provided by their hosted clients' dedicated resources. Because neutral hosting provides service equivalence to the user, it can be a viable alternative to conventional dedicated infrastructure.

4.2 Definition of a Neutral Host

In the language of this report, neutral host is defined as the provider of a shared platform to hosted clients that requires the following resources:

- Permanent Physical Equipment infrastructure: this refers to permanent (or quasi-permanent in the case of special events) structures and utility infrastructure needed to support the installation and operation of equipment. This could include:
    - Antenna towers, distribution systems, and/or other antenna mounting points.
    - AC/DC power and uninterruptable power equipment as needed.
    - Equipment racks or other locations to mount electronic equipment.

    - Signal cabling or optical fiber connectivity within the local environment (e.g., antenna feeders between antennas and equipment racks).
- Spectrum: refers to mobile coverage as licensed (e.g., owned or leased/borrowed from hosted clients) or unlicensed.
- Antennas: this refers to physical antennas and associated equipment such as mast-head amplifiers as needed.
- Radio Access Network (RAN) edge node: this refers to the typical "base station" node such as an LTE eNB (eNodeB) or a Wi-Fi access point.

The neutral host:

- Obtains use of the necessary resources in a specific geographic region (which could be within a building or a public space like a sports stadium or a distributed geographic area like a municipality's street light poles);
- Manages these resources, subject to agreements with resource owners and clients; and
- Provides facilities and/or interconnection allowing hosted clients to make use of the platform(s) to provide continuous services to their end user customers.

The spectrum used by the neutral host may be licensed or unlicensed. In the case of licensed spectrum, it may be owned by the neutral host directly or may be obtained by the neutral host via an agreement with a licensed spectrum owner. The neutral host is active in managing the planning and utilization of the spectrum within its geographic area subject to agreement with the license holder, if any. Several hosted clients may share common spectrum, or individual hosted clients may use individual spectrum blocks.

Bearer and signaling interconnect is subject to agreement between the neutral host and the hosted clients.

The concept of a neutral host as defined in this document is different from other resource sharing models such as tower sharing, Distributed Antenna Systems (DAS), and Mobile Virtual Network Operators (MVNOs).

4.3 Hosted Client

The hosted client is identified as the entity using all or a portion of the resources provided by the neutral host, possibly alongside other hosted clients to bring services to their end users. The relationship between the neutral host and the hosted client will be governed by a commercial agreement including a technical Service Level Agreement (SLA).

4.4 Requirements on Neutral Host from an End User Perspective

From an end user perspective, the provision of services by a neutral host should, ideally, appear identical to the provision of resources by the hosted client's dedicated resources. This implies that:

- The UEs shall perform network selection and attachment according to the hosted client network's selection policy, and the policy of other stakeholders and user preferences. When the end user is in the area of the neutral host, according to the selection algorithm, the neutral host's coverage shall be selected seamlessly and without user intervention.
- Subject to business agreement and SLA, the services, including regulatory services, provided by the neutral host, should operate in a similar fashion to when in the hosted client's dedicated coverage.
- Mobility between dedicated and neutral host coverage should operate in a similar fashion to corresponding mobility events in dedicated networks.

Technical restrictions in neutral host solutions may prevent this ideal behavior from being realized. Limitations of particular solutions will be addressed in later sections.

On occasion, demand overload on the neutral host may mean it is not able to fulfill this ideal, and services have to be managed to maintain system operation. In this case, the neutral host shall apply a policy-based approach to manage the overload governed by the commercial agreement between the neutral host and the MNO.

4.5 Resource Management Within a Neutral Host

A neutral host offers resources that are shared by multiple end users which may belong to several hosted clients. As such, resources must be managed between users of one neutral host client, as well as between users belonging to different neutral host clients. This may be influenced by:

- The policy of one hosted client for its own end users
- The SLAs agreed between the neutral host and the hosted clients, and how the neutral host implements that SLA in its policies.

The neutral host shall have the ability to:

- Obtain policy information from a hosted client in order to manage that client's end users.
- Define its own policies for management of resources, and particularly for how resources are partitioned between hosted clients.

4.6 Neutral Host Relationship to Hosted Clients

A number of points are important to consider in the context of the relationship between the neutral host and hosted client. These include:

- Confidentiality of sensitive information: the neutral host should provide role-based access controls to ensure different hosted clients are only able to access and control the resources assigned to them.
- Security: the solution should ensure that the hosted client's network security is comparable to that offered by individual hosted clients dedicated resources.
- Charging: the neutral host shall provide wholesale charging to the hosted client for usage of neutral host resources by that client's subscribers.
- Service level: the neutral host must form an SLA with hosted clients to set agreed performance standards.
- SLA verification: processes are required to ensure that the terms of SLAs are being met.
- Network management: processes are required to ensure that hosted clients can continue to provide the expected levels of customer support and network management, including fault resolution, when users are within the coverage of a neutral host.

4.6.1 Radio Network Planning Considerations

Because the goal of a neutral host is to act as a shared platform for several hosted clients, it is unlikely that the siting and specification of equipment will be individually optimized for each hosted client. Therefore, the neutral host should, guided by technical and business considerations, establish an approach that offers an attractive platform to a variety of hosted clients.

5 Neutral Host Example Scenarios

5.1 Company with a Real Estate Portfolio Acts as a Neutral Host

5.1.1 Description

This scenario is based on the Small Cell Forum publication [017 Market drivers for multi-operator small cells] section 5 "New approaches to kick-start the multi operator model".

An emerging model is for companies, who are not network operators, to build a portfolio of property, or property rights, that gives them access to sites that are suitable for deployment of cells. Examples of ways in which this type of company may operate include:

- An organization has a large existing property portfolio (e.g., from broadcast infrastructure, transport infrastructure, or utility infrastructure). This organization sells rights to deploy cells on its property to a specialist company which establishes a neutral host, and then forms agreements with mobile operators or other hosted clients.
- A company purchases or leases from city government the right to use city facilities (e.g., lamp posts) as cell sites. The company then establishes a neutral host and forms agreements with mobile operators or other hosted clients.
- A company recognizes that property owners may prefer to outsource the activity of selling the rights to place small cells in their buildings, campus, or physical structures (e.g., lamp posts). The company makes agreements with several property owners and then establishes a neutral host and makes agreements with mobile operators or other hosted clients.
- The company owning the real estate rights typically does not have spectrum, or a license, to provide cellular coverage. However, it may have microwave spectrum to support back-haul from the cell sites and may either make use of unlicensed spectrum or hold non-cellular licenses.

5.1.2 Advantage of Neutral Host to Real Estate Owners

Historically, companies with sites suitable for deployment of small cells sold rights to individual network operators. This simple relationship allows sites to be utilized but means that the individual operator has to bear all costs (capital and operating) associated with the use of the site. Users only gain benefit if they are subscribed to that operator.

Where space and other constraints permit, multiple operators may host small cells on the same site. Depending on the constraints, this may require one operator to act as the primary facilitator for the site with other operators' equipment being added with their consent. This kind of primary/secondary relationship can be difficult to establish and manage in practice.

By establishing a neutral host infrastructure, the company with the site portfolio gains several advantages:

- The ability to simultaneously sell to multiple operators increasing revenue opportunity.
- Increased participation in the value chain as a gate opener to operators and a service value add to real estate owners.

Mobile network operators and other hosted clients purchasing from such a neutral host also gain advantages:

- Effective sharing of infrastructure costs between multiple entities, thus reducing costs to individual hosted clients.
- Outsourcing of management of small cell infrastructure.
- Possibly increased flexibility of contract terms and reduction in length of commitments including short-term needs (e.g., for special events).
- Offers the possibility of social benefits and real estate added value due to coverage being provided from a wider variety of network operators.

5.2 Spectrum Scenarios

5.2.1 Neutral Host in Licensed Spectrum

A neutral host may operate in licensed spectrum with agreement of the license holder. Scenarios involving use of licensed spectrum are addressed in sections 6.1 and 6.2.

5.2.2 Neutral Host in Shared Spectrum (e.g., US 3.5 GHz CBRS)

5.2.2.1 Description

A neutral host small cell network in shared spectrum allows for cost-effective network sharing with Commercial Mobile Service Providers (CMSPs). An example of shared spectrum is the Citizens Broadband Radio Service (CBRS) established by Federal Communications Commission (FCC) for shared wireless broadband use in 3550-3700 MHz band (3.5 GHz Band) in the U.S. When potential customers see Joe's advertisement, they can get the relevant information efficiently.

For the 3.5GHz bands there will be 3 tiers of users:

- Incumbent users: Highest priority, other users must vacate channel for incumbent users:
    - Federal users (e.g., Navy), Fixed Satellite Service, grandfathered terrestrial wireless ops for short time.
- Priority Access Licensees (PAL) users:
    - Each licensee can get up to 4 channels (40 MHz) in one licensing area which is a census tract.
    - License term is for 3 years, and can be renewed for 3 more years with no guaranteed renewal.
    - In one licensing area, up to 70 MHz can be licensed.
- General Authorized Access (GAA) users:
    - Can use any channel not used by incumbent or PAL users.
    - Potentially up to 80 MHz available for GAA users even if all 7 (70 MHz) PAL channels are awarded and deployed.

The Spectrum Access System (SAS) coordinates channel access, and needs channel usage information from incumbent, PAL, and GAA users.

5.2.2.2 Advantage of Neutral Host in Shared Spectrum

Traditional small cells solutions need separate deployments for each wireless provider. The neutral host small cell solution offers a simple, low cost, venue/enterprise owners-led deployment option providing service to subscribers of multiple wireless service providers. Because these neutral host small cell networks operate in neutral spectrum, there is no need to coordinate Radio Frequency (RF) network planning with a mobile network operator's macro network. This solution also provides WWAN grade of coverage, and service quality that is not provided by unlicensed technologies such as Wi-Fi. This also has the advantage of evolution paths comprising of LTE variants (e.g., MulteFire (see [MulteFire])).

5.2.2.3 Limitations of Neutral Host in Shared Spectrum

The wide scale adoption of a neutral host shared spectrum solution is dependent on availability of neutral spectrum (i.e., spectrum that is not used by one of the participating mobile network operators). However, recently there is a move in the industry towards tiered spectrum opportunities such as 3.5GHz in the U.S. The 3.5GHz (3550-3700 MHz) spectrum is well suited for deployments by third parties because of the lightly licensed regulatory approach adopted by the FCC.

5.2.3 Neutral Host in Unlicensed Spectrum

5.2.3.1 Description

Enterprise and even residential deployments of unlicensed technologies such as Wi-Fi are widespread, in-building, and increasingly outdoors. This use case leverages the ubiquity of this already extant technology to provide transparent or nearly transparent connectivity to customers of neutral host client operators, with minimal changes to existing radio resources. The neutral host may contract directly with client neutral host service providers to establish this capability via open SSIDs, or may leverage more general registry and authentication mechanisms (such as Hotspot 2.0).

Another technology option in the 5GHz unlicensed spectrum is MulteFire, which brings LTE-like performance with Wi-Fi-like simplicity. The MulteFire specifications are being developed by the MulteFire Alliance based on 3GPP standards. Wi-Fi and MulteFire will coexist in the 5GHz unlicensed band that offers global neutral spectrum.

5.2.3.2 Advantage of Neutral Host in Unlicensed Spectrum

The primary advantage of an unlicensed neutral host solution is that networks in unlicensed spectrum are already nearly ubiquitously deployed in-building, and there are minimal changes to existing networks and user devices required to provide service to customers of neutral host client service providers. Because these networks operate in unlicensed spectrum, there is no need to coordinate RF network planning with a client operator's macro network, and interference with an existing licensed macro network is non-existent.

MulteFire brings LTE-like performance (e.g., enhanced capacity and range, enhanced mobility, and QoS) to 5GHz unlicensed spectrum deployments.

5.2.3.3 Limitations of Neutral Host in Unlicensed Spectrum

The primary limitation of an unlicensed solution is that use of unlicensed spectrum is not controlled as tightly as licensed spectrum, resulting in the possibility of uncontrollable and/or unexpected interference. In many in-building venues, this has not proven to be a problem, since the unlicensed network operator has control of the physical premises in which the network is deployed, and is able to control interference acceptably well. (If that were not the case, unlicensed networks would not enjoy the ubiquity they do today.) A second caveat, not really a limitation, is that – as is the case for the other neutral host use cases – a separate pairwise agreement may be required for each neutral host client and neutral host operator. However, mechanisms such as Open SSID (established by the Cable Consortium), and Hotspot 2.0 (marketed as Passpoint by the Wi-Fi Alliance) overcome this limitation by establishing a network of participating Wi-Fi hotspots that can be accessed transparently by end-user devices, providing authentication and identity management.

6 Current Industry Landscape & Solutions

6.1 Roaming

6.1.1 Description & References

From a technical point of view, the simplest means to provide a neutral host solution is via inter-carrier roaming agreements. This can be implemented in several ways. One is that a spectrum license holder executes agreements with one or more prospective neutral hosts, providing the use of its spectrum and Enhanced Packet Core (EPC) network for use in those venues. Either the spectrum license holder or the neutral host then executes roaming agreements with other wireless service providers, allowing their customers' User Equipment (UEs) to roam onto the license holder's network while in the neutral host venue. Either the neutral host or the spectrum license holder builds the necessary RAN infrastructure to provide service in the neutral host's venue. UEs entering the neutral host venue roam onto the spectrum license holder's network following the same rules applied for other roaming scenarios (i.e., the spectrum license holder's network is treated as a visited network).

Another way that roaming can be employed to realize a neutral host solution is for a prospective neutral host to execute an agreement with a spectrum license holder that does not operate its own EPC network. In this case, the neutral host may operate the RAN and the EPC, and would act as the “visited network”.

Because roaming is very well understood, further details of this solution are not provided. Roaming is attractive because it is technically straightforward, but it gives the hosted client less control over the user experience than in the other solutions described below.

6.2 Multi Operator Core Network (MOCN)

6.2.1 Description & References

The Multi Operator Core Network (MOCN) solution is standardized by 3GPP. The requirements are documented in [22.951] and the solution is defined in [23.251]. The MOCN standard is a general approach to allow several operators with different core networks to share common RAN nodes. Though MOCN does not specifically target neutral host scenarios, MOCN could be used as a basis for a neutral host platform.

The figure below shows an overview of the MOCN solution as applied to neutral host. Though MOCN can support GERAN, UMTS, and LTE services, this discussion will focus on the case of MOCN applied to LTE. As shown in the diagram, the neutral host provides a shared LTE eNodeB and associated radio equipment. The MOCN standard allows this eNodeB to be connected to more than one core network belonging to different hosted clients. The eNodeB broadcasts the identity of all core networks it is serving. Using standard procedures defined by 3GPP the UE will automatically select the MOCN eNodeB if it serves its home network. Using MOCN procedures, the eNodeB will route communications from the UE to the correct core network.

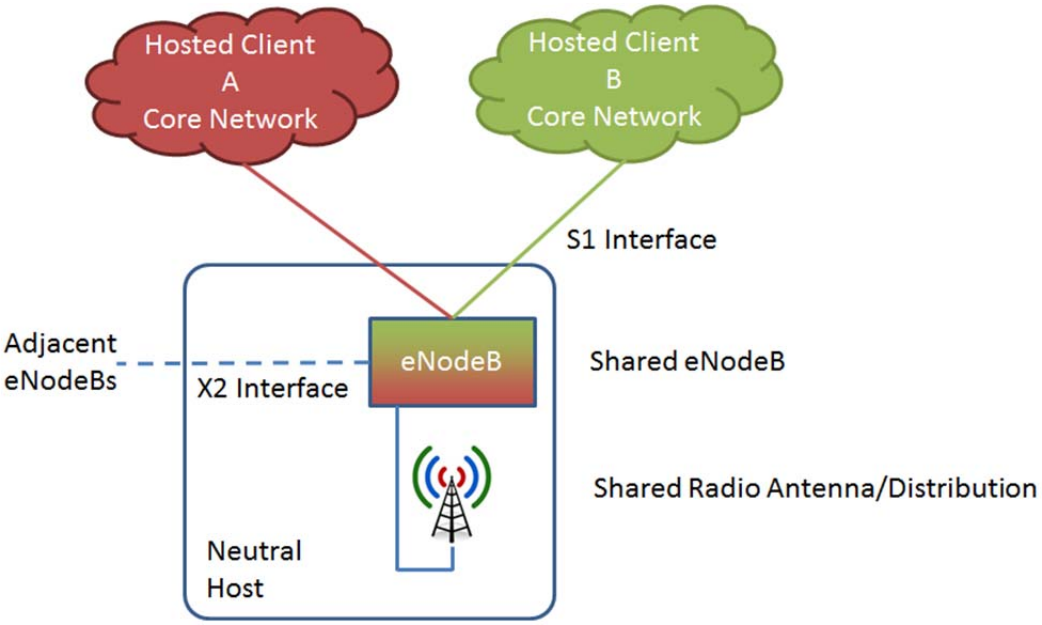

Figure 6.1 – Overview of MOCN for an LTE Neutral Host

6.2.2 Deployment Issues

MOCN is only standardized for 3GPP networks and radio technologies. Hosted clients must support a 3GPP core network and must have issued users with Universal Integrated Circuit Cards (UICCs) containing 3GPP subscription information and security credentials.

The use of MOCN requires a suitable SLA to be formed between the neutral host and the hosted clients. As well as addressing policy aspects, this SLA must make technical provisions for connection of the neutral host's

eNodeB to the client core network via the S1 interface. Deployment of this S1 interface will require both parties to work to ensure technical integration and interoperation.

In operation, the MOCN neutral host requires access to certain hosted client-specific information. For example, the neutral host must be able to communicate the appropriate list of adjacent cells for each hosted client.

6.2.3 Spectrum, Radio Coverage, & Radio Capacity Issues

The radio interface for a MOCN solution will typically operate in spectrum owned by one or more of the hosted client networks. The neutral host must form an agreement with its hosted clients to gain access to such spectrum. The MOCN standard does not specify how spectrum is divided between hosted clients. Therefore, it is up to the neutral host to agree upon a policy with their clients for the spectrum to be used. Possibilities include each client network operating in its own spectrum or all client networks sharing the same spectrum. Another possibility is to use neutral spectrum (e.g., 3.5GHz spectrum) in the U.S. which may be well suited for MOCN deployments.

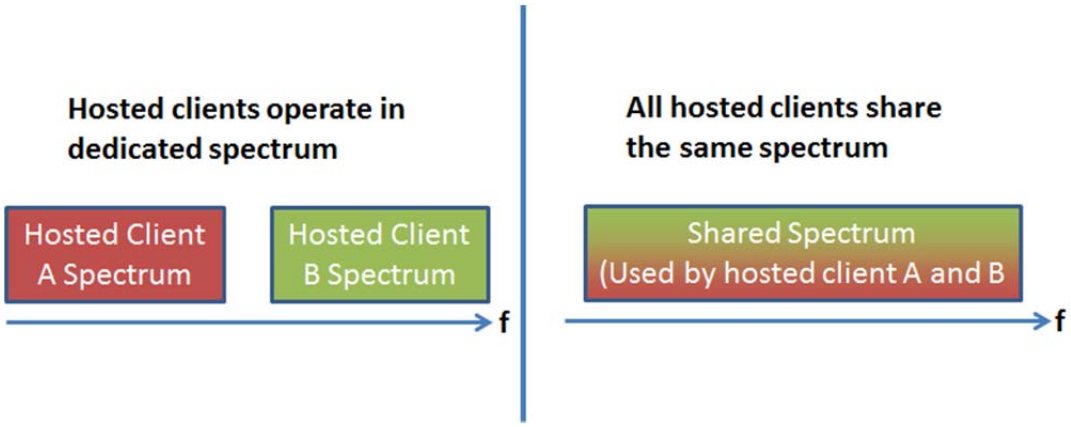

Figure 6.2 – Example Approaches to Spectrum Management in MOCN

Prioritization and management of traffic on the radio interface and for other limited resources is also not standardized in MOCN. The eNodeB is responsible for enforcement of policy which must be agreed between the neutral host and each hosted client. Possibilities include fixed resource reservations for each client, completely shared resources for all clients, or combined approaches that support a mixture of reserved and shared resources.

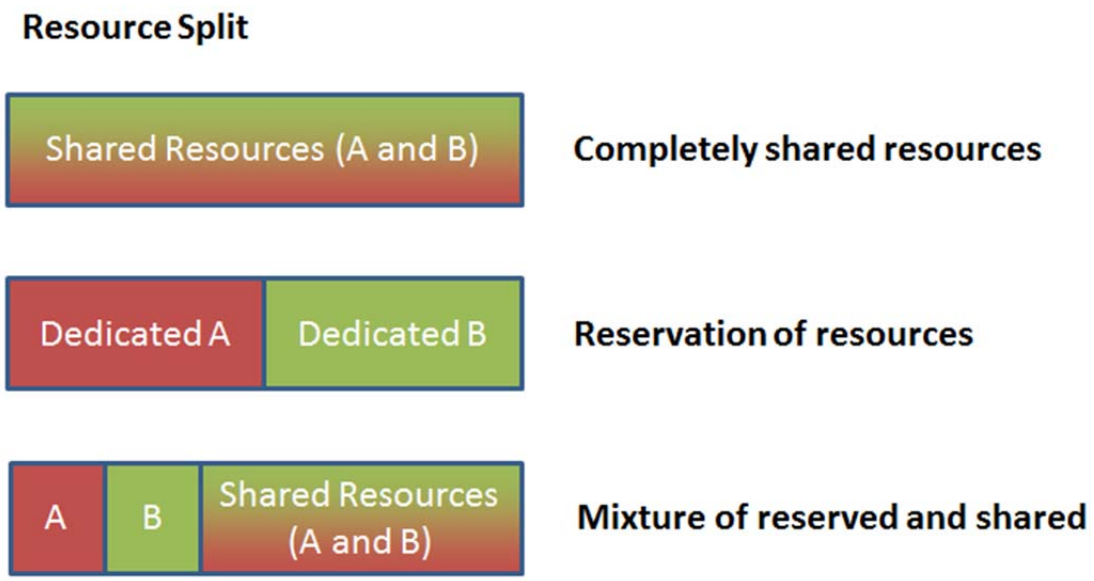

Figure 6.3 – Example Strategies for Resource Management in MOCN

Arrangements will need to be made with each hosted client to support mobility in and out of the neutral host's coverage area. This will require specification of appropriate radio parameters and possibly connectivity between eNodeBs via the "X2" interface.

6.2.4 Network Issues

S1 connectivity is required between the Neutral Host and each client Core Network. This may require support of multiple IP Virtual Local Area Networks (VLANs) by the neutral host with flexibility to support different configurations and routing behavior for each client network. Security of the IP networks between the neutral host and the different hosted clients should be considered.

If the X2 interface is supported, then similar network flexibility is also required to support connection to adjacent dedicated eNodeBs belonging to different hosted clients.

6.2.5 Broadcast Services

For services that use information broadcast by the eNodeB, 3GPP specifications do not support separate broadcasts for each MOCN hosted core network. Therefore, special non-standard arrangements and coordination of broadcast information between hosted core networks may be required. This may include broadcasts used for emergency alerting services.

6.2.6 Other Operational Issues

The neutral host must capture all information needed for charging of hosted clients and for SLA verification. MOCN standards have not defined the contents of this data or how it should be exchanged between the neutral host and the hosted clients.

6.2.7 Evaluation

The MOCN solution is very compatible with hosted clients and devices that support 3GPP specified technology in licensed spectrum.

The basic functions needed to support neutral host are specified by 3GPP which should help with the design and integration of such systems. Standardization should also ensure a good user experience as normal 3GPP procedures are extensively reused. In concept, particularly for LTE, the MOCN neutral hosts are technically straightforward. However, the 3GPP standards do not specify how important operational requirements are to be realized; for example, how policies and SLAs can be defined and validated and how spectrum should be managed in MOCN neutral hosts. Therefore, neutral hosts will need to develop their own solutions for these aspects.

6.3 Cloud RAN Neutral Host

6.3.1 Description & References

Neutral host solutions can be created using cloud RAN technology. One example of a Cloud RAN Neutral Host leverages the new Small Cell Forum Network Functional Application Programing Interface (NFAPI) interface[6] as in the architecture shown below. The key elements in the architecture include:

- Broadband / multi-band intelligent radio heads are deployed in the venue of interest. These radio heads support multiple bands across the entire defined bandwidth of each band with an Ethernet friendly interface to a centralized baseband and control unit, and can then be configured to segment the baseband content onto separate Ethernet streams for each specific band or sub-band of interest back to the central unit. The baseband unit deployment and operational management would be via the Neutral Host. Management would include such activities as radio head fault management, configuration management, accounting/charging management, security management, and necessary resource management of shared resources.
- The broadband / multi-band radio heads communicate with a more centralized baseband processing and control unit via the newly defined Small Cell Forum nFAPI interface. nFAPI extends the Functional API (FAPI) multi-vendor platform interface to support a virtualized small cell architecture. nFAPI supports a virtualized MAC/PHY split enabling the use of standard Ethernet LAN technologies to connect baseband and control processing to a new “intelligent” radio head avoiding the need for direct fiber interfaces.
- A demarcation point separates the neutral host managed aspects from the hosted client aspects of the solution.
- The neutral host managed aspects include the radio heads along with the Ethernet LAN connection to a physical point of demarcation. Additionally, the neutral host provider may provide a centralized virtualized server infrastructure that terminates the Ethernet streams from the radio heads and provides basic routing and security functions as required.
    - This virtualization infrastructure could be centralized in an enterprise or in a network location that serves multiple venues and enterprises for a neutral host provider.
    - This virtualization infrastructure supports Network Function Virtualization (NFV) and as such, allows the neutral host to instantiate virtual baseband units to support all operators/vendors participating in the neutral host solution. Ideally, the neutral host provider supports inter-administrative domain NFV as being studied and defined in the ATIS NFV Forum to allow operators to dynamically order and have instantiated baseband and control Virtual Network Functions (VNFs) in a venue as needed.
- Hosted Client aspects can include the hosted client’s own baseband and control processing function, either as a physical function, a VNF in the hosted client’s data center or a VNF specified and managed by the Hosted Client but instantiated in the neutral host’s virtualization infrastructure.

The solution also supports native enterprise Wi-Fi for the enterprise use.

[6] Small Cell Forum Press Release: < http://www.smallcellforum.org/press-releases/small-cell-forums-nfapi-will-make-virtualized-hetnet-reality/ >.

Effectively, this arrangement allows any hosted service provider that supports the deployment of a virtual baseband VNF to then instantiate that VNF in the target neutral host system, and access its own spectrum deep within the enterprise facilities that may otherwise not be available.

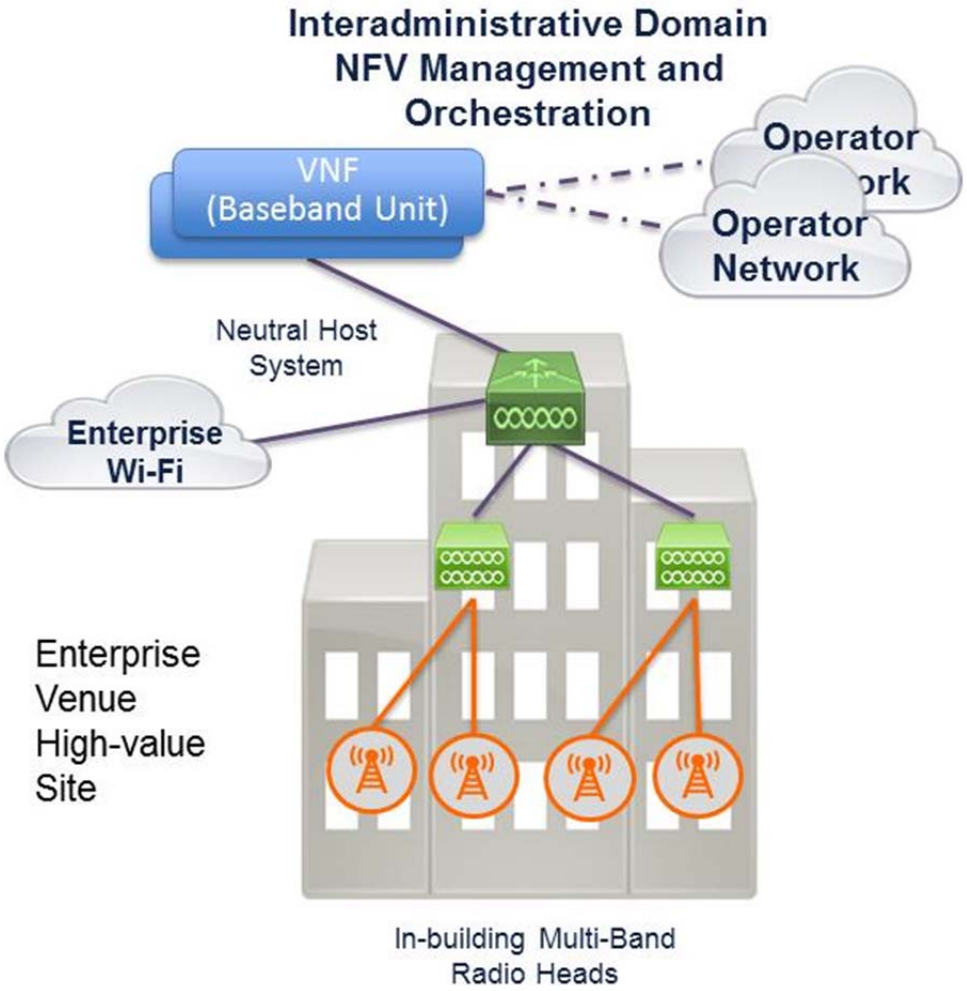

Figure 6.4 – Cloud RAN Based Neutral Host Solution

6.3.2 Spectrum, Radio Coverage & Radio Capacity Issues

In this case, the hosted operator is using its own (separate) licensed spectrum to provide service in the venue. As such, no new spectrum, radio coverage, or radio capacity issues exist other than the common issues associated with any licensed small cell radio system. It is of course highly desirable for the VNF baseband unit to support sufficient Self-Optimized Network (SON) logic and algorithms to manage normal interference and hand-off issues that occur based on the physical deployment of the radio heads. Generally, the hosted operator has little control as to where the radio heads are deployed. Certainly interference and handover performance will also depend on the specific band used. As such, this class of solutions may be challenged relative to interference and handover management in some situations. This may require close coordination between the hosted operators and the neutral host provider.

6.3.3 Network & Deployment Issues

The Cloud RAN neutral host solution assumes:

- The existence of a standardized “MAC/PHY” split to efficiently support “Ethernet connected” radio heads at reasonable bandwidth and latency attributes to support the model. It is noted that the Small Cell Forum[7] is addressing Cloud RAN issues in support for neutral host.
- Virtualized baseband and control units.
- An inter-administrative domain NFV environment to allow multiple vendor/operator VNFs to run within the same neutral host centralized unit.

6.3.4 Other Operational Issues

In the stated solution, the hosted operator controls dedicated aspects of the radio heads but does not completely control the management or placement of the radio heads themselves. As such, operationally, the neutral host provider and the associated environment must somehow provide sufficient operational capabilities to enable the operator to properly manage its subscribers in the venue.

6.3.5 Regulatory Issues

No new regulatory issues have been identified.

6.4 Neutral Host in Unlicensed Spectrum using Wi-Fi

6.4.1 Description & References

There are a number of neutral host solutions that can be deployed in unlicensed spectrum using Wi-Fi as the radio access technology. Some are already in widespread use; others are in various stages of development/deployment. The figure below illustrates an embodiment of Wi-Fi neutral host.

[7] Small Cell Forum press release: < http://www.smallcellforum.org/press-releases/small-cell-forum-identifies-virtualization-opportunity-small-cells/ >.

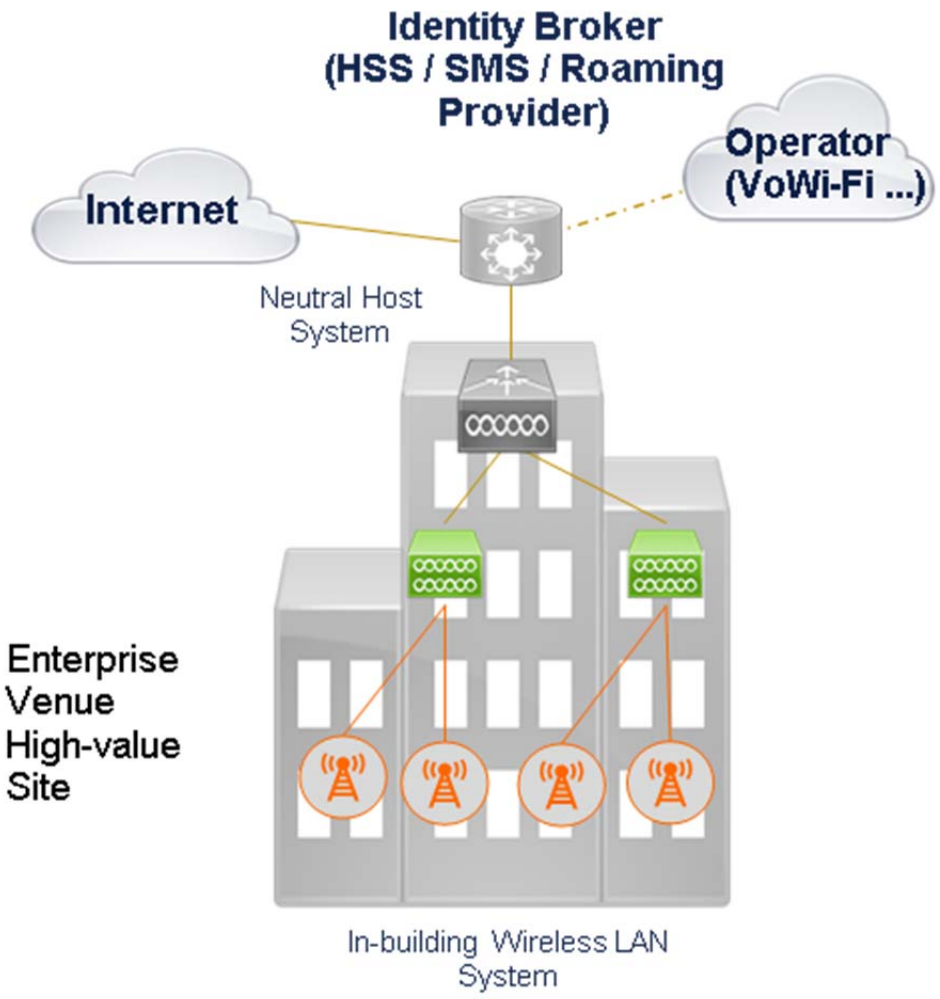

Figure 6.5 – Neutral Host Using Wi-Fi

A general description of the characteristics of a Wi-Fi neutral host solution is:

- The Wi-Fi neutral host system advertises the appropriate SSIDs for hosted clients. These may or may not be unique SSIDs for each hosted client.
- The neutral host system must broker and manage authentication with appropriate hosted operator's HSS. This may be accomplished using the mechanisms described in 3GPP 23.402 [23.402], section 4.2.2ff.
- Data services can be provided by the neutral host in two ways:
    - Via Wi-Fi and the neutral host's ISP in a data offload model, and may not necessarily incorporate the hosted client's policies, etc.); or
    - May be tunneled through an Evolved Packet Data Gateway (ePDG) to route all data back to the hosted client's core network for the application of operator policies and charging rules.
- Voice services are provided via VoWi-Fi, tunneled to the hosted client's network.

Several embodiments are described below:

- *Multi Service Set Identifier (M-SSID):* In this embodiment, the Wi-Fi access point transmits multiple SSIDs, each potentially corresponding to a different neutral host client service provider network. The device attaches to the SSID corresponding to its home provider, and authenticates transparently. This implementation requires the Wi-Fi Access Point (AP) to support multiple SSIDs.

- *Cable Consortium Open Service Set Identifier (SSID)*: This case is similar to the previous one, except that an AP supporting multiple SSIDs is not required. Instead, a registry of participating neutral host clients is maintained, spanning many enterprise networks and APs. Identity management and authentication is provided by a central server. While this is conceptually simple, there are security concerns since traffic may be observed over the air. It will ultimately be replaced by the next example, HotSpot2.0.
- *HotSpot2.0 (HS2)*: This mechanism, marketed as Wi-Fi Certified Passpoint by the Wi-Fi Alliance, addresses many of the security issues of the Open SSID mechanism, but further security will be provided via WPA2 encryption of over-the-air traffic. An HS2-enabled device, upon entering an HS2 network, automatically joins the network without any user intervention. Support for billing based on tonnage, network loading, and user needs is supported.

6.4.2 Spectrum, Radio Coverage & Radio Capacity Issues

Neutral host WLAN solutions in unlicensed spectrum operate primarily in the 2.4 GHz ISM band (802.11b, g/n, n), and in the 5 GHz band (802.11a/.h/j/n/ac). The ISM band is prone to interference, not only from nearby Wi-Fi networks, but also from other devices (e.g., microwave ovens, cordless phones) and can become very cluttered. While the 5GHz band is less cluttered with interferers, it does not propagate as well through obstructions. In practice, a well-designed Wi-Fi network for WLAN applications will also serve well as a neutral host network.

6.4.3 Network & Deployment Issues

From a deployment point of view, a neutral host solution can leverage an existing WLAN deployment, provided the WLAN was engineered to provide sufficient capacity for the traffic that client subscribers will bring. For the M-SSID solution, APs must be capable of transmitting multiple SSIDs.

6.4.4 Other Operational Issues

There are several challenges to an unlicensed neutral host solution:

- Emergency Location information: E-9-1-1 services via WLAN is being addressed by another ATIS effort.
- SMS Support: Non-IP based SS7 SMS is not supported, but SMS is supported via IMS SIP or other IP-based messaging services.
- Neutral host must support IPsec tunneling through Wi-Fi access network in order to support VoWi-Fi.
- Wi-Fi resource allocation.

In addition to these, the same issues described for shared spectrum and Cloud RAN solutions apply (i.e., the client service provider does not control the management or placement of the APs). As such, operationally, the neutral host and the associated environment must somehow provide sufficient operational capabilities to enable the operator to properly manage its subscribers in the venue, or must otherwise satisfy the operator that the user experience provided is sufficient.

6.4.1 Regulatory Issues

No new regulatory issues identified. E9-1-1 services via WLAN is being addressed by another ATIS effort.

6.5 MulteFire Self-contained Neutral Host network

6.5.1 Description & References

A self-contained neutral host network architecture supporting multiple hosted client operators has been proposed by MulteFire Alliance [MulteFire]. At publication of this report, the details of the MulteFire solution were still being developed, and therefore this discussion is limited to a high-level description of the intended solution and its attributes.

The figure below shows the high-level self-contained neutral host network architecture. The neutral host can serve users from multiple hosted client operators. There is lightweight interworking between neutral host and the hosted client operators providing access to hosted client operator services (e.g., IMS voice) in neutral host coverage. The interworking framework leverages the WLAN interworking framework defined in 3GPP, and neutral host network connects to the hosted client operator's network using WLAN interworking interfaces. The UE can use ePDG (via SWu) to gain access to the hosted client operator's IP services.

There is also service continuity between the hosted client operator and neutral host for hosted client operator's services. Local IP services (e.g., enterprise PBX) are provided by local breakout at neutral host. Neutral host networks complement the hosted client's networks, extend indoor coverage, and offload data. Offload of hosted client operator's UEs to the neutral host is controlled by hosted client operator's policies.

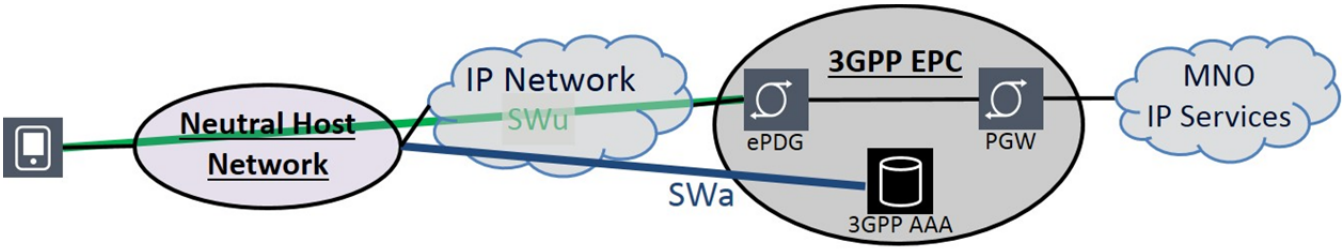

Figure 6.6 – Self-contained Neutral Host Architecture

6.5.2 Deployment Issues

Neutral hosts must support subscribers of multiple hosted client operators. These hosted client operators have SLAs with the neutral host for hosted client operator offload services using hosted client operator issued SIM cards. There is also a need to develop solutions for KPI management and charging using existing industry standard interfaces.

6.5.3 Spectrum, Radio Coverage, & Radio Capacity Issues

For wide scale adoption of this neutral host solution, it is beneficial to have a neutral spectrum (i.e., spectrum that is not used by one of the Commercial Mobile Service Providers [CMSPs]).

The U.S. 3.5GHz spectrum is well suited for deployments by neutral host providers because of the lightly licensed regulatory approach adopted by the FCC, and is generally less congested than the unlicensed spectrum.

7 Summary & Recommendations

Several different technical approaches to supporting neutral hosts are possible. Each approach has different characteristics and range of applicability, and the approach used should be selected according to the specific objectives and requirements of the particular situation being considered. In addition to the technical implications, the practical deployment of neutral hosts introduces a range of commercial considerations that must be addressed by the neutral host and their hosted clients. Commercial use of neutral hosts should be supported by strong SLAs between the neutral host and the hosted clients, and provide sufficient operational capabilities to enable the operator to properly manage its subscribers.