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| Source(s) | Paul Trubridge, Paul Senior and  David Castelow Airspan Communications Ltd Capital Point, 33 Bath Road  Slough, SL3 1UF, UK | Voice: +44 1895 467261 E-mail: ptrubrid at airspan dot com  \*<<http://standards.ieee.org/faqs/affiliationFAQ.html>> |
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| Abstract | The objective of this document is to provide text for the Architecture and Requirements document of the Small Cell Backhaul Amendment. | |
| Purpose | For incorporation into the 16r Architecture and Requirements Document. | |
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**[Draft Working Document]**

***IEEE 802.16r Architecture and Requirements***

***for Small Cell Backhaul***

**IEEE 802.16 Working Group**

**Project P802.16r**

Table of Contents

Contents

[*1* Scope 3](#_Toc372143216)

[*2* References 3](#_Toc372143217)

[*3* Introduction (Informative) 4](#_Toc372143218)

[4 Abbreviations, Definitions, and Conventions *(Informative)* 5](#_Toc372143219)

[4.1 Conventions *(Informative)* 5](#_Toc372143220)

[4.2 Abbreviations and Acronyms (Informative) 5](#_Toc372143221)

[4.3 Definitions (*Informative)* 5](#_Toc372143222)

[4.3.1 POP 5](#_Toc372143223)

[5 References 5](#_Toc372143224)

[6 Deployment Scenarios (Informative) 5](#_Toc372143225)

[6.1 Deployment Scenario 1 - Mobile Carrier, Backhaul for Outdoor LTE Pico-cell Deployment, POP at existing macro-sites. 5](#_Toc372143226)

[6.1.1 Short Description 5](#_Toc372143227)

[6.1.2 Actors 6](#_Toc372143228)

[6.1.3 Pre-conditions 6](#_Toc372143229)

[6.1.4 Post-conditions 6](#_Toc372143230)

[6.1.5 Normal Flow 6](#_Toc372143231)

[6.2 Use Case 2 – Mobile Carrier, Backhaul for Indoor LTE Enterprise Pico or Femto Cell Deployment. 7](#_Toc372143233)

[6.2.1 Short Description 7](#_Toc372143234)

[6.2.2 Actors 8](#_Toc372143235)

[6.2.3 Pre-conditions 8](#_Toc372143236)

[6.2.4 Post-conditions 8](#_Toc372143237)

[6.2.5 Normal Flow 8](#_Toc372143238)

[6.2.6 Alternative Flow 8](#_Toc372143239)

[TBD. 8](#_Toc372143240)

[7 Use Cases (Informative) 8](#_Toc372143241)

[7.1 Use Case 1 - Shared Wireless Backhaul 8](#_Toc372143242)

[7.1.1 Short Description 8](#_Toc372143243)

[7.1.2 Actors 9](#_Toc372143244)

[7.1.3 Pre-conditions 9](#_Toc372143245)

[7.1.4 Post-conditions 9](#_Toc372143246)

[7.1.5 Normal Flow 9](#_Toc372143247)

[7.1.6 Alternative Flow 9](#_Toc372143248)

[8 Architecture 9](#_Toc372143249)

[8.1 Convergence Sublayer 10](#_Toc372143250)

[8.2 Bridged Ethernet Support 11](#_Toc372143251)

[9 Requirements (Conditional Normative) 11](#_Toc372143252)

[9.1 Mandatory Requirements 11](#_Toc372143253)

[9.2 Optional Requirements 11](#_Toc372143254)

[9.3 Network Requirements 11](#_Toc372143255)

[9.4 Air Interface Requirements 11](#_Toc372143256)

[9.4.1 Overview 11](#_Toc372143257)

[9.4.2 Spectrum and Licensing 12](#_Toc372143258)

[9.5 Security Requirements 12](#_Toc372143259)

[9.6 Management Requirements 12](#_Toc372143260)

[9.7 Performance Requirements 12](#_Toc372143261)

[9.7.1 Capacity 12](#_Toc372143262)

[9.7.2 Latency 13](#_Toc372143263)

[9.7.3 Coverage 13](#_Toc372143264)

[10 Guidance and Recommendation to other Standards Organizations 14](#_Toc372143265)

[Annex A Document History (*Informative)* 15](#_Toc372143266)

**[Draft] IEEE 802.16r Architecture and Requirements**

**for Small Cell Backhaul**

1. Scope

The IEEE P802.16r draft standard shall be developed in accordance with the P802.16r project authorization request (PAR) and Five Criteria Statement (IEEE 802.16-12-0587-05-Gdoc), as approved on 5 December 2012 [1]. According to the PAR, the scope of the resulting standard shall be:

*This project will develop an amendment specifying enhancements to the WirelessMAN-OFDMA*

*air interface for effective use in wireless fixed and nomadic Ethernet transport, including small cell backhaul applications, providing core network services to radio access networks. It will focus on backhaul operating in licensed bands below 6 GHz, in which the backhaul radio operates far enough outside the band of the small cells that interference is negligible. It will add 256QAM, 512QAM, and 1024QAM options in both uplink and downlink, with optional 4x4 MIMO in both directions, along with further enhancements that address small cell backhaul efficiency. Significant latency improvements will be attained. Enhancements to the Convergence Sublayer specifications will be incorporated as necessary for support of Carrier Ethernet 2.0 backhaul requirements. The functionalities required for small cell backhaul support, including new functionalities but not necessarily all those included the baseline standard, will be specified explicitly.*

The standard will address the following purpose:

*This standard enables rapid worldwide deployment of innovative, cost-effective, and interoperable multi-vendor broadband wireless access products, facilitates competition in broadband access by providing alternatives to wireline broadband access, encourages consistent worldwide spectrum allocation, and accelerates the commercialization of broadband wireless access systems.*

and the following need:

*As the spectral efficiency of wireless links approaches its theoretical limits, and with the data*

*traffic requirements continuing to grow rapidly, cell density and cooperation among base stations must increase in order to further improve network capacity and efficiently manage radio resources. Multi-tier access network architecture consisting of macrocells and a variety of overlaid smaller cells provides an approach towards solving the problem, allowing low cost per bit and efficiently utilizing all spectral resources in the system. Some such systems will be deployed using radio access technology outside the realm of IEEE 802.16. In such cases, IEEE Std 802.16, as enhanced, can provide out-of-band wireless backhaul to the small cells, allowing those cells to be positioned for optimal performance without regard to the local availability of*

*high-capacity wired backhaul. The resulting system design will offer improvements in spectral efficiency needed to support the rapidly expanding demand for mobile broadband access.*

This document specifies, in addition, the requirements to be satisfied by the IEEE P802.16r draft standard. In order to explain and specify those requirements, it also indicates suitable use cases and architecture.

1. References

[1] IEEE 802.16-12-0587-05, “Approved PAR P802.16r, with Five Criteria: Amendment for Small Cell Backhaul (SCB)” ([link](http://doc.wirelessman.org/16-12-0489-01))

1. Introduction (Informative)

As the spectral efficiency of wireless links approaches its theoretical limits, and with the data traffic requirements continuing to grow rapidly, cell density and cooperation among base stations must increase in order to further improve network capacity and efficiently manage radio resources. Multi-tier access network architecture consisting of macrocells and a variety of overlaid smaller cells provides an approach towards solving the problem, allowing low cost per bit and efficiently utilizing all spectral resources in the system. Some such systems will be deployed using radio access technology outside the realm of IEEE 802.16. In such cases, IEEE Std 802.16, as enhanced, can provide an out-of-band connection, allowing those cells them to be positioned for optimal performance without regard to the local availability of high-capacity wired backhaul. The resulting system design will offer improvements in spectral efficiency needed to support the rapidly expanding demand for mobile broadband access.

This project will specify a high capacity network for carrying the traffic between end points and a central location at which wired/fibre network services are available. It is envisaged that these “end points” are connected to wireless access points for other radio protocols.

The following sections contain examples of how it is envisaged that the network be deployed, providing examples of the types of traffic that the network is expected to carry.

The requirements of these traffic flows will determine elements of the standard.

Section 6 describes deployment scenarios: typical arrangements of network equipment, while section 7 describes more abstract “use cases” of the proposed system. These deployment scenarios and use cases are not mutually exclusive.Editor’s Note:

As part of a subgroup review, a number of paragraphs have been highlighted in yellow to indicate concerns about the text that will be addressed in future revisions.

Abbreviations, Definitions, and Conventions *(Informative)*

* 1. Conventions (Informative)
  2. Abbreviations and Acronyms (Informative)

3G 3rd Generation Mobile Network

4G 4th Generation Mobile Network

AP Access Point

eNB Enhanced Node B

LTE Long Term Evolution (of 3GPP)

NB Node B

POP Point of Presence

QoE Quality of Experience

QoS Quality of Service

RAN Radio Access Network

* 1. Definitions (*Informative)*
     1. Small Cell

In this document, the phrase small cell is used to describe any of the following:

Small eNodeB

Small NodeB

Wi-Fi Access Point

or any other equivalent RAN access point.

* + 1. POP

POP is used in this document to refer to a “Point of Presence.” This refers to a node at which wired/cabled network infrastructure is available.

References

1. Deployment Scenarios (Informative)
   1. Deployment Scenario 1 - Mobile Carrier, Backhaul for Outdoor Small Cell Deployment.
      1. Short Description

As part of a heterogeneous network supporting LTE and other RANs. Providing backhaul for a layer of cells deployed outdoors on street poles such as lamp posts or utility poles, advertising billboard, or on building in non-traditional cell-site locations. The small cell layer is deployed to increase overall capacity of the network by providing data offload from the macro-cell in areas of high usage.

The wireless backhaul basestation is located on a high site and connected to a co-located POP.. Small cell locations are generally non-LOS from the backhaul basestation site.

(Could be replaced by description of possible operational scenarios including independent backhaul provider and shared backhaul as well as mobile carrier owned/operated backhaul).



TypicalSmall Cell Backhaul Scenario, with Basestation located at macro cell site.

[Needs an additional logical network diagram naming entities, e.g. POP, (feeder), MS/UE, etc].

* + 1. Actors

Outdoor pico eNB, 3G Pico NodeB or Carrier Grade Wi-Fi Access Point

Small cell location – eg. Lamp post or utility pole, advertising billboard, or non-traditional building locations.

Backhaul channel bandwidth typically between 5 MHz and 20 MHz TDD. Some operators may use multiple channels to ensure the backhaul has high enough capacity.

Existing mobile carrier macro-cell site, or street-side access from fibered street assets.

* + 1. Pre-conditions

POP site able to accommodate 802.16 backhaul basestation.

Sub-6GHz (NLOS) Licensed spectrum available for backhaul.

Traffic from Macro network is overloaded and requires off-load or capacity augmentation from Small Cell Pico network.

The 802.16 Small Cell backhaul transport network provides adequate backhaul capacity so that a typical user’s “Quality of Service” QoS and “Quality of Experience” QoE of the cellular services are equal to or better than a typical Macro based RAN. [while increasing system capacity of the RAN].

The 802.16 small cell backhaul transport network provides high capacity links, with low latency. Depending on the type of small cells these links range have average throughput requirements that range from 5 Mbit/s up to 100 Mbit/s, and peak rates from 20Mbit/s to 200 Mbit/s. The required latency also varies from 50ms down to sub 10ms.

|  |  |  |  |
| --- | --- | --- | --- |
| Type of Small Cell | Average Capacity | Peak Capacity | Required Latency |
| Dual 2.4 / 5 GHz Wi-Fi Access Point | 5 Mbit/s | 20 Mbit/s | <50ms |
| 3G Microcell (HSPA) | 8 Mbit/s | 26 Mbit/s | <50ms |
| 10 MHz FDD Single Carrier LTE Release 8/9 | 30 Mbit/s | 70 Mbit/s | <20ms |
| 20 MHz TD-LTE Single Carrier LTE Release 8/9 | 50 Mbit/s | 100 Mbit/s | <20ms |
| LTE-Advanced, 2 x 20 MHz CA TD-LTE Release 10 | 100 Mbit/s | 200 Mbit/s | <10ms |

As the 802.16 basestation is located at the Macro cell site and this site has trusted backhaul then the 802.16 small cell backhaul can also be considered trusted. This potentially allows the deployment of the indoor small cells without the need for a security gateway and/or the use of IP SEC for the backhaul links (depending on the small cell in question). This can reduce the bandwidths required (avoiding the overhead of the IPSEC traffic).

TBD.

* 1. Deployment Scenario 2– Mobile Carrier, Backhaul for Indoor LTE Enterprise Small Cell Deployment.
     1. Short Description

As part of an LTE heterogeneous network there is a need to provide backhaul for a layer of cells deployed indoors in shopping malls, stadiums, and into large, and small/medium enterprises facilities etc. These small cell layers is deployed to increase coverage in these locations and provide dedicated capacity in these extreme high usage locations, which is driven by large numbers of users in a very dense locations. A typical scenario would be an office block where the enterprise has a corporate deal with a carrier and this results in tens or hundreds of users on the same carrier network.

Wireless backhaul is provided to the building direct from the mobile carriers network by feeding from existing macro-sites. Distribution to indoor eNBs can be made through Ethernet or Fibre LAN within the building, or in some locations the 802.16 small cell backhaul is directly integrated into the indoor enterprise pico or femto cell and backhaul operates on a NLOS basis with first wall penetration.



Figure 1Typical Enterprise Small Cell Backhaul Scenario

* + 1. Actors

Indoor small eNB, small NodeB or Wi-Fi Access Point

Building to be covered using indoor eNB, or Wi-Fi Access Points

Existing mobile carrier macro-cell site, or street-side access from fibered street assets.

* + 1. Pre-conditions

Macro cell sites able to accommodate 802.16 backhaul feeder node.

Sub-6GHz (NLOS) Licensed spectrum available for backhaul.

Demand for service inside an Enterprise or High density Indoor location.

* + 1. Post-conditions

Improved in-building coverage and capacity for small cells within target locations.

Improved economics when compared with using wired backhaul solutions

* + 1. Normal Flow

The deployment of high capacity mobile broadband services indoors to large numbers of users requires the indoor small cells to have a high capacity backhaul. If small cells are not deployed the concentrated density of users creates capacity issues on serving macro cells and provide a poor QoE for the users in the Enterprise or indoor location. The 802.16 small cell backhaul is deployed either external (typically on the roof) or internally (if RF conditions permit this). The 802.16 radio interface permits deployment in NLOS conditions and even NLOS conditions with signal losses from first wall penetration. The 802.16 small cell backhaul links provide high capacity links with low latency (as per requirements in the 6.1.5 use case).

1. Use Cases (Informative)
   1. Use Case 1 - Shared Wireless Backhaul
      1. Short Description

A shared wireless backhaul system could be provided by an independent backhaul provider offering backhaul services to a variety of customers based on connectivity at a Carrier Ethernet port. The independent backhaul provider is responsible to configure the port as part of a Ethernet Virtual Connection, or interconnected with another Carrier Ethernet Network as part of an Operator Virtual Connection. A user may attach a small cell at the Carrier Ethernet port. The small cell may support of multiplicity of technologies. In some cases, the small cell may be managed by a single retail service provider in support of that provider’s customers. In other cases, the small cell may provide services to a multiplicity of retail service providers.

The backhaul network is operated by the independent backhaul provider, who is responsible for the installation, commissioning, and ongoing maintenance of the backhaul transport network and the Carrier Ethernet connectivity to remote customer ports comprising the Ethernet Virtual Connection or Operator Virtual Connection.

* + 1. Actors

Carrier Ethernet port. ENNI connection to Carrier Ethernet network supporting remaining ports in Ethernet Virtual Connection.

* + 1. Pre-conditions

Macro-cell site able to accommodate IEEE 802.16 backhaul feeder node.

Sub-6 GHz (NLOS) licensed spectrum available for backhaul.

* + 1. Post-conditions

Ethernet Virtual Connection connectivity provided to a variety of Carrier Ethernet physical and virtual ports. Separation of customer traffic flows separable by VLAN, with capacity sliced per customer and per customer service, with differentiated and manageable QoS.

* + 1. Normal Flow

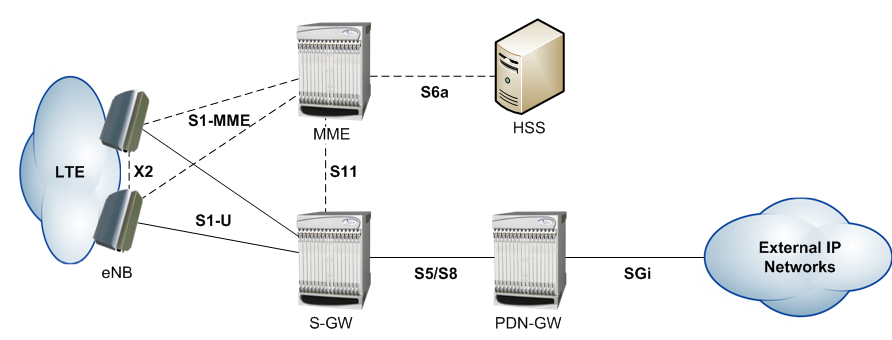
Ethernet Virtual Connection connectivity provided to a variety of Carrier Ethernet physical and virtual ports. Connectivity provided among small cells without requiring transport over the backhaul. QoS management by means of controllable mapping of flows to transport connections.

* + 1. Alternative Flow

TBD.

1. Architecture

The reference architecture to support an LTE air interface as defined in the 3GPP specifications is shown below. This is an example of one type of small cell.



The communication paths and associated protocols between the LTE access nodes (eNodeBs) and core network are shown in greater detail below.



Small cell backhaul shall support communication between eNodeBs using the X2 protocol, as well as communication to the core network (typically the S1 interface). A summary is provided below.

* S1-MME; control plane interface between eNodeB & MME, using SCTP over IP.
* S1-U; user plane interface between eNodeB & S-GW, using GTP over UDP.
* X2-U; user plane interface between eNodeB, using GTP over UDP
* X2-C; control plane interface between eNodeB, using SCTP over IP
* MGMT; management plane interface between eNodeB & EMS.

It is envisaged that some X2 connections are carried over the backhaul network.

* 1. Convergence Sublayer

The connectivity provided by the 802.16 small cell backhaul is typically provided as a layer 2 Ethernet service and as such requires the support of the ETH-CS convergence sub-layer.

* 1. Bridged Ethernet Support

The point to multipoint support of the 802.16r small cell backhaul requires full support for Bridged Ethernet services.

1. Requirements (Conditional Normative)
   1. Mandatory Requirements

The key requirements for the 802.16r small cell backhaul are as follows;

* Backwards compatibility with IEEE 802.16-2012 [Needs softening]
* Support for ETH-CS and VLAN mapping / classification of traffic
* Improved spectral efficiency allowing higher order modulation on Downlink and Uplink up to 1024 QAM (r=5/6).
* Support for channel sizes between 3 MHz and 20 MHz.
* Support for low latency with frame sizes of 2.5ms and 5ms (final target: one-way traffic latency of <5ms)
* One to One mapping / End to End QoS for LTE QCI (QoS Class Identifiers)

Support for 1588v2 PTP and SyncE traffic

* 1. Optional Requirements
  2. Network Requirements
  3. Air Interface Requirements
     1. Overview

When considering small cell backhaul, operators will generally opt for licensed spectrum for the following key reasons:

* Maintaining CoS / QoS from core to user equipment. Licensed spectrum provides the means to deliver against an SLA by means of a controlled RF interference environment.
* Avoiding external interference to allow a scalable high capacity backhaul network.

Sub-6GHz has been used primarily for wireless access services where it’s ability to operate in harsh mobile non-line of sight (NLOS) propagation environments make it an ideal choice over higher frequency bands. The same characteristics also make it well suited to the backhaul of small cells deployed in locations where high capacity NLOS connectivity is required. Licensed frequency bands in the sub-6GHz range vary by geography. Particular allocations are fully occupied for mobile access services, however there are many allocations currently under utilised. These include small fragmented unpaired allocations, as well as frequency ranges above 3GHz which, due to higher propagation losses, are sub optimal for providing mobile connectivity to handsets. These spectrum allocations are ideally suited to NLOS small-cell backhaul (SCB) applications. The use of beam-switching / beam-forming, network wide synchronisation and highly directional antennas with sophisticated algorithms, delivers large spectral efficiency gains and enables n=1 frequency re-use, typically doubling or tripling the real-world capacities. This means that a small amount of licensed spectrum goes a long way.

* + 1. Spectrum and Licensing

Frequency ranges can be broadly considered as follows:

|  |  |
| --- | --- |
| Sub1GHz | Mostly fully utilized for mobile access using paired allocations. TVWS provides lightly licensed unpaired spectrum suitable for SCB in rural locations. |
| 1GHz to 2GHz | Largely used for mobile access using paired allocations. However small unpaired allocations, held by some operators, are unused and ideally suited to SCB. |
| 2GHz to 3GHz | Paired allocations recently or currently being auctioned primarily for mobile access. However, small unpaired allocations are available and ideally suited to SCB. |
| 3GHz to 5GHz | Largely under utilised and licensed for paired or unpaired operation. Due to propagation losses, this frequency range is more suited to fixed applications such as SCB than mobile access applications. Lightly licensed allocations are available also in this frequency range in some countries (eg. 3.65GHz in the USA) |
| 5GHz to 6GHz | Primarily non-exclusive bands, with restrictions on transmit power and requirements for DFS. |

In some cases, >40MHz allocations are available, however this is unusual in the sub-5GHz bands. Generally allocations range from 5MHz to 20MHz.

Available licensed spectrum in the sub 5GHz bands varies from country to country. However it is generally licensed on a regional or nationwide basis allowing an operator to deploy large scale networks with contiguous coverage. An area, regional, or nationwide licensing regime allows an operator to roll out a network most rapidly. This is clearly advantageous when deploying a small-cell network, and the ability to lay down SCB coverage across a target area significantly speeds up the deployment of small-cell nodes.

Most spectrum regulators limit the power (EiRP) limits permitted by unlicensed spectrum. Sub 5GHz licensed bands allow much higher EiRP limits. Typically EiRPs in sub 6GHz license exempt bands are limited to +33dBm or +36dBm, whereas licensed sub 6GHz bands typically permit up to +60dBm or at least +50dBm. This gives a 14-30dB link budget advantage which can be practically leveraged for SCB using symmetric links.

* 1. Security Requirements
* Support for WIMAX mutual authentication
* RF interface Encryption using WIMAX Network / Security architecture
  1. Management Requirements
  2. Performance Requirements
     1. Capacity

The capacity of a wireless link is determined by its spectral efficiency multiplied by the channel size. Further to this, the capacity of a wireless system is determined by the “link” capacity multiplied by the system’s ability to re-use frequency channels.

Licensed sub-5GHz spectrum offers the opportunity to manage interference levels to leverage high order modulation and coding schemes such as 256QAM (and later 1024QAM). In addition, its NLOS propagation characteristics allow multi-path techniques such as MIMO to be used. These both increase the “link” spectral efficiency. Today’s SCB solutions use 256QAM and 2x2 MIMO to yield a net spectral efficiency in the order of 14b/s/Hz over the air. Future extensions are expected to use 1024QAM and 4x4 MIMO increasing net spectral efficiency to 35b/s/Hz. These typically equate to net TCP/IP channel capacities of 170Mbps and 425Mbps respectively when operating a 20MHz TDD channel which can be delivered on a point to multi-point or point to point basis.

OFDMA based frequency re-use schemes applied to downlink and uplink, combined with interference aware scheduling algorithms and smart steerable antenna technology promise the ability to deploy a SCB network in sub-5GHz licensed spectrum using a single channel allocation.

A point to multipoint SCB network running in a 20MHz sub-6GHz licensed spectrum allocation consisting of 50 backhaul “hub” nodes, is expected to provide a peak capacity of 9Gbps using today’s technology. With 1024QAM and 4x4 MIMO extensions, this can potentially be increased to 22Gbps.

Network-wide optimization and interference aware algorithms are required to achieve these capacities, and the ability to schedule traffic in frequency, time and space are fundamental to maximizing the spectral efficiencies. OFDMA and smart steerable antennas are being adopted by SCB vendors to achieve this.

It should be noted that the dimensioning of a point to multi-point backhaul solution is calculated differently to a traditional uncontended point to point solution. The ability of the system’s QoS to deliver bursty data rates to multiple locations (depending on instantaneous demand) allows for network dimensioning to be based on statistical multiplexing.

* + 1. Latency

SCB systems designed for sub-6GHz Licensed spectrum are mostly PtMP, where traffic scheduling is centrally coordinated. In such systems, the latency is dominated by air interface frame structures and scheduling algorithms. 15ms one way latency is typical of today’s solutions and sub 10ms one way latency is targeted with technology evolution. However, it should be noted that latency and QoS are closely coupled. Not all traffic requires the minimum latency and overall network capacity increases if real-time services are handled differently to traffic that is not latency sensitive. Latency aware scheduling is a key feature for systems deploying contended backhaul. A close integration of the backhaul with the access QoS is critical to ensuring delivery of real time services.

* + 1. Coverage

Sub-6GHz Licensed spectrum provides the means to achieve reliable NLOS coverage as well as LOS between network nodes. SCB systems using this spectrum are expected to be deployed in order to cover a target area rather than on a node by node basis.

Two basic deployment models are possible depending on whether network POPs are at street level or high-sites such as existing macro-sites. With street level POPs, NLOS backhaul is used between adjacent street poles where small cells are located. In this case, NLOS technology is advantageous in order to accommodate local clutter such as trees. Where high-site POPs are available, a point to multi-point “cellular” coverage of small cell backhaul can be deployed. Both of these models result in very different backhaul link distances, or POP spacing.

The link budget of the SCB solution is critical to achieving maximum coverage. A typical solution operating in 3.5GHz would have a system link budget greater than 160dB. In the interest of form factor and MIMO performance, unlike microwave point to point solutions, antenna gains cannot be simply increased to achieve these link budgets.

Typical POP spacings are shown below:

|  |  |  |
| --- | --- | --- |
| **Environment** | **Coverage Type** | **Typical POP Spacing** |
|  |  |  |
| Urban | “Cellular Coverage” | 3km |
| Sub-urban | “Cellular Coverage” | 5km |
| Rural | “Spotty Coverage” | 15-20km |

1. Guidance and Recommendation to other Standards Organizations

Annex A Document History (*Informative)*

|  |  |  |
| --- | --- | --- |
| **Date** | **Subject History** | **Version** |
| 2013-03-20 | Initial template including ToC | 00 |
| 2013-05-16 | Incorporate 802.16-13-0092 | 01 |
| 2013-07-17 | Incorporate 802.16-13-0144-01 | 02 |
| 2013-07-18 | Moved Architecture section, moved some text | 03 |
| 2013-11-14 | Incorporate 802.16-13-166-03-000r | 04 |
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