Need for Small-Cell Backhaul (SCB) Enhancements to WirelessMAN-OFDMA

Document Number:

    IEEE 802.16-12-0451-00-Shet

Date Submitted:

    2012-07-11

Source:

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Re:

    Call for Contributions toward IEEE 802.16's Session #80, IEEE 802.16's HetNet Study Group (IEEE 802.16-12-0390-01-Gdoc)

Base Contribution:

    None, but see also IEEE 802.16-12-0452-00-Shet

Abstract:

This document explains the value of enhancing WirelessMAN-OFDMA to specifically address Small Cell Backhaul (SCB) applications. It presents the case that Wireless SCB is becoming increasingly important and that standardization of Wireless SCB is critical to its success. It argues that WirelessMAN-OFDMA is an excellent basis for Wireless SCB and presents a list of key enhancements required to optimize for that scenario.

Purpose:

To support a decision of the HetNet Study Group to proceed with actions toward initiating a project, including issuing a Call for Contributions toward Session #81. Note: The contributors request that this proposal be addressed on 19 July, after work on topics carried forward from Session #80 is addressed.

Notice:

Need for Small-Cell Backhaul (SCB) Enhancements to WirelessMAN-OFDMA

11 July 2012

Paul Trubridge (Airspan Networks, Inc.)
Roger Marks (Consensii LLC; Airspan Networks, Inc.)

Abstract

This document explains the value of enhancing WirelessMAN-OFDMA to specifically address Small Cell Backhaul (SCB) applications. It presents the case that Wireless SCB is becoming increasingly important and that standardization of Wireless SCB is critical to its success. It argues that WirelessMAN-OFDMA is an excellent basis for Wireless SCB and presents a list of key enhancements required to optimize for that scenario.

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Content

Market Demand for:

- *Small Cells*

- Small Cell *Backhaul* (SCB)

- *Wireless* SCB

- *Standardization* of Wireless SCB

- *WirelessMAN-OFDMA* for Standardization of Wireless SCB

- *Enhancements* to WirelessMAN-OFDMA for Standardization of Wireless SCB

Market Demand for Small Cells

Market Demand for:

- *Small Cells*

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Mobile Data Growth: An unstoppable trend…

Industry Forecasts of Mobile Data Traffic

Traffic Relative to 2009

Legend:
- Cisco
- Coda
- Yankee Group
- Average

Source: FCC OBI Technical Paper No. 6
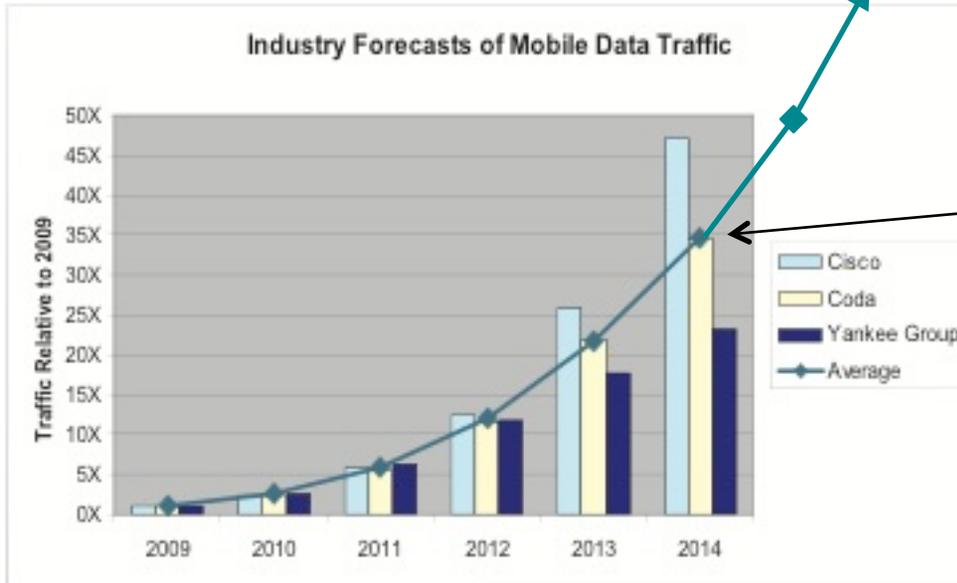
35x Data Growth 2009-2014!
(will hit 100x in 8 years, at this rate)

Only 3x Improvement in 5 years

Air-Interface Technology improvement **cannot** deliver improvements fast enough, other solutions are needed….

Downlink spectral efficiency by technology
Bps/Hz

| GPRS	EDGE	WCDMA	HSDPA, Rel 5	HSPA, Rel 6	HSPA, Rel 7	LTE
0.03	0.09	0.16-0.24	0.480	0.720	1.08-1.29	1.36-1.5
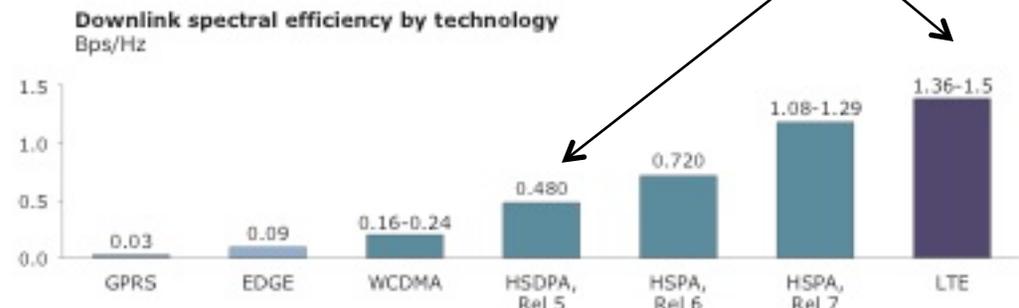
The "Mobile Broadband Capacity Chasm"

- 3G and 4G Macro base stations deliver high capacity and peak speeds close to the base station. In these locations, broadband applications can work well (depending on load).

- Femtocells and Wi-Fi access points give high capacity and peak speeds at home, at the office, and in hot spots. In these locations, broadband applications work well.

- Peak speed and capacity drops by more than an order of magnitude at cell edge (especially at 2.x GHz). **Broadband applications don't work well in these areas**.

bit/s/Hz

x10

x1

The "Capacity Chasm"

Cell Edge

At Home - At Work

The Last Mile

4G Macro Base Station
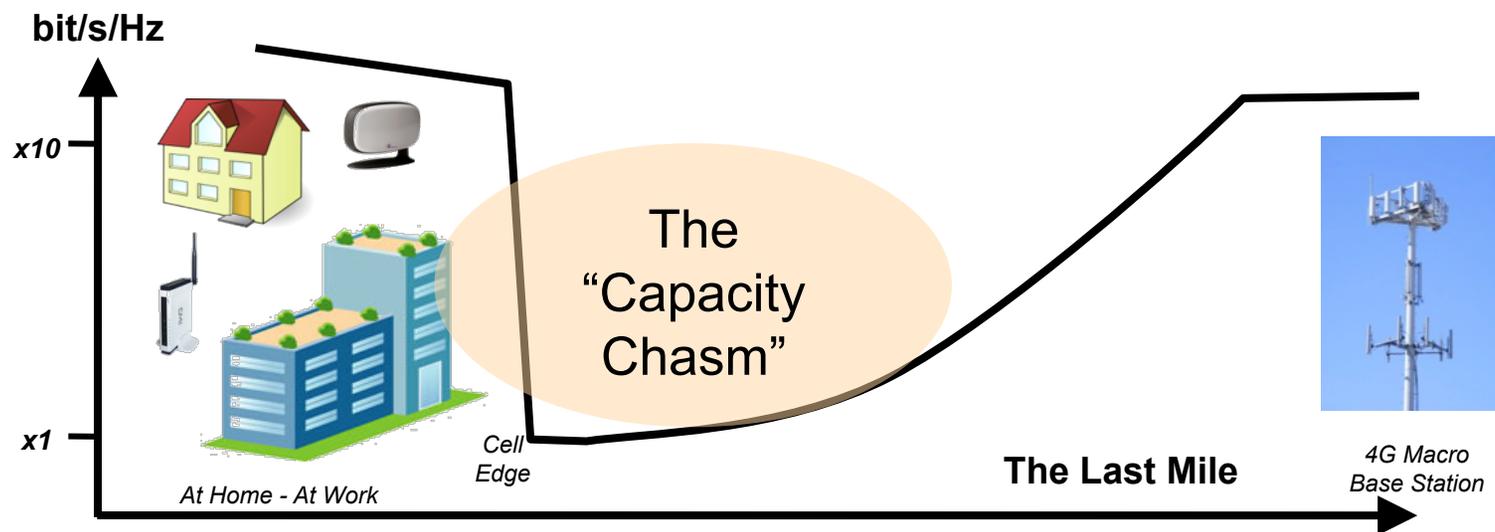
The Need For Small Cells

- The deployment of **small cells** can fill the broadband chasm by enabling a mobile carrier to deliver broadband service / data offload infrastructure <u>where</u> it's needed:

  - Locating nodes close to users enables usage of high order modulations and MIMO techniques present in 4G technologies.

  - Off-loading data traffic from the macro network to relieve congestion.

  - Deploying on existing street furniture (e.g. utility poles and lamp posts) to save site acquisition costs and ongoing OPEX.

  - Solving coverage constraints due to challenging terrain in rural applications.
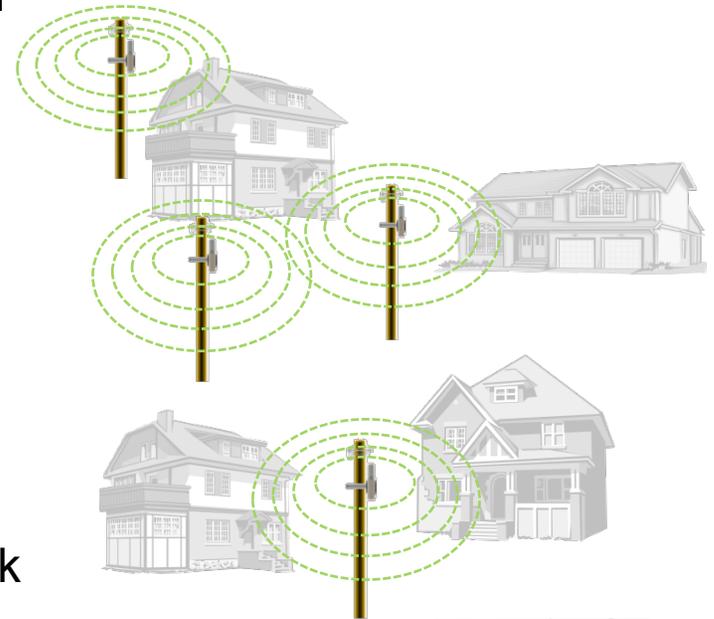
Small Cell Infrastructures: When and How much?

- Small cell market definition is still immature

- Many solutions and architectures

- Small cells are a major trend in the 4G radio access network.

Outdoor Picocells Market Expected To Reach $8 Billion by 2016

LONDON - August 12, 2011

ABIresearch
technology market intelligence

The outdoor picocell market, which is still in the early stages of development, is projected to reach $8 billion in global revenues by 2016.

Currently, while many outdoor microcells are in operation, outdoor picocells are undergoing operator trials, with several companies, including Alcatel-Lucent, Huawei, Bel-Air, Airspan, and NEC focusing their attention on these new lower cost and easier-to-deploy alternatives. Other vendors working on developing solutions include NSN, Ericsson, and ZTE.

Research: Picocell revenues to make up 9% of LTE eNode B revenues by 2015

DG DELL'ORO GROUP

A new report from the Dell'Oro Group forecasts the mobile infrastructure LTE equipment market to grow at a compound annual growth rate (CAGR) of 81 percent during the next five years and reach $8 billion by 2015.
In addition, the firm forecasts picocell revenues will reach 9 percent of total LTE eNode B revenues during the same period.

Industry pundits predicting small cells as major new market segment, reaching $8 Billion by 2016

What Industry Bodies are saying… NGMN

Where will they be?

Congestion on fully upgraded macro sites

↓ **Need to densify**

No rooftop space left smaller units needed to fit available locations

↓ **Smaller unit = less power = shorter range**

Small, low power cells close to users Near street level

Macrosite

Small cell

Small cells

• **Small cell sites typically 4-6 m above street level, on sides of buildings or street furniture**

Julius Robson, Wireless Technology Consultant and Leader, NGMN Small Cell Backhaul Requirements Group

Market Demand for Small Cell Backhaul (SCB)

Market Demand for:

- *Small Cells*

- Small Cell *Backhaul* (SCB)

- *Wireless* SCB

- *Standardization* of Wireless SCB

- *WirelessMAN-OFDMA* for Standardization of Wireless SCB

- *Enhancements* to WirelessMAN-OFDMA for Standardization of Wireless SCB

What Operators are saying… T-Mobile

Key challenges of outdoor pico cells deployment

Key enablers	Challenges
Deployment aspects — Site acquisition	• Traditional acquisition methods for macro site e.g. individual contracts would be too expensive. • Reduction of acquisition cost e.g. <20% of the cost for macro sites
Deployment aspects — Backhaul	• Low cost • Allow flexibility in selection of site location
Deployment aspects — Traffic hotspots/hotzones detection	• Detection or prediction of hotzones/hotspot locations
Technology aspects — Product availability	• Availability of a range of low cost small cell BTS types suitable for different deployment scenarios
Technology aspects — Macro/Pico spectrum re-use	• No need for extra spectrum carriers for small cells, at least for hotzone/hotspot scenarios • For pico network layer scenario, a separate carrier can be used.

• The deployment aspects are most challenging. Effective solutions are not yet available.

·· **T**· ·

Deutsche Telekom   29.09.2011   8

What Industry Bodies are saying… Small Cell Forum

BT is chairing the backhaul Special Interest Group in the Small Cell Forum

SMALL CELL FORUM
HOME | ENTERPRISE | URBAN | RURAL

- The Femto forum was renamed to Small Cell Forum (SCF) to reflect the operators interests to deploy outdoor small cells as well as indoor femtocells.
- Backhaul at the capacity required with right economics was seen as one of the biggest challenges to deployment of small cells.
- SCF backhaul Special Interest Group (SIG) was set up to
  - define small cell use cases and scenarios (hotspots, coverage, QoE enhancement)
  - requirements profile on backhaul for each (capacity, latency, availability..)
  - analyse backhaul solutions (wireless, wired, satellite,..)
  - To provide recommendations and identify challenges with each use case.

- The target output is an industry white paper providing insight into backhaul options for small cells.

Small Cell Forum has formed a backhaul requirements group
– mission critical to outdoor small cell deployment

What Operators are saying… BT

Two key challenges for urban small cells: sites and backhaul.

Small cell sites

- How to identify site location?
- How to acquire sites?
- How to manage sites cost effectively?
- How to manage teams and field force?
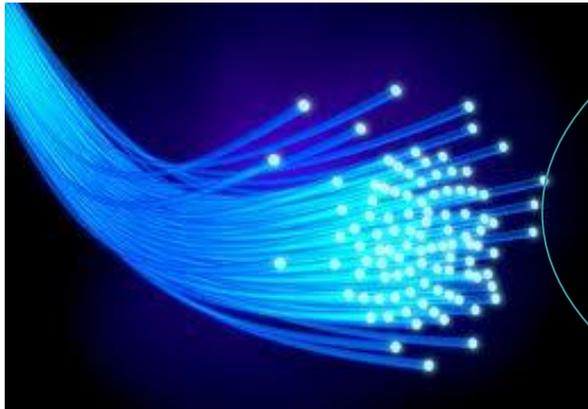
Backhaul

- What is the most cost effective backhaul option?
- How do I ensure consistent user experience?
- How to minimise cost of OSS and management of backhaul?
- What is the clear upgrade path to LTE?

6

BT wholesale

- Viraj Abhayawardhana – BT Wholesale

Market Demand for <u>Wireless</u> SCB

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What Operators are saying… Vodafone

Small Cell Deployment - So What Have We Learnt?

- The concept is strong – Small cell deployment will deliver many benefits and the capacity gains can be significant.

- Initial findings indicate that low cost, compact products can be developed to meet our network requirements.

But…………..

- Seamless Heterogeneous Network operation (2G/3G/LTE) is a must if small cells are to be successful

- Interference mitigation techniques provided by next generation technologies such as ICIC will be critical to deliver optimum performance.

- Although easier to deploy, Omni-directional antenna solutions will require further work due to a more challenging interference environment.

- Backhaul remains a significant challenge to the concept, wireless solutions are a key site and proposition enabler. Progress has been seen but more work is required if they are to be realised.

There is still work to do!

2G Macro

3G/LTE Macro

LTE small cells

Voice and Data Proposition   Data Proposition
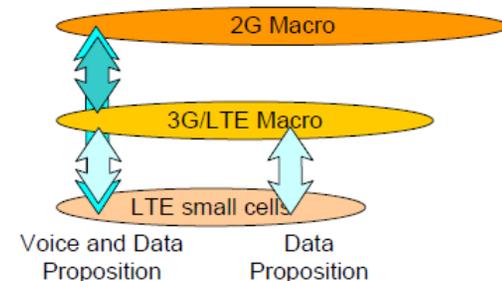
# What Operators are saying… T-Mobile

Key challenges for realization of heterogeneous networks

- Availability of large number of low cost sites for micro/pico networks
- Backhaul
  - Wireless backhaul (inband, outband) is a key enabler.
- Interference avoidance and cancellation between network layers
- Seamless mobility between different technologies, spectrum bands and network layers
  - Users should not notice which technology, spectrum or network layer he is using.
- Single, simple (for users) authentication scheme
- Low cost, plug-and-play (SON) base stations
- Cope with changing UL/DL traffic asymmetry

Zhongrong Liu, Ole Klein (DTAG)   11.03.2010   10

Metrozone Deployment Topology Vision

Node types
RH: Rooftop hub
SH: Street-level hub
AP: Access point
R: Backhaul repeater

Backhaul link types
- - - - NLoS wireless
- - - - LoS wireless
▮ Fiber / cable

RH2 is two PTP radios, possibly in the same package

Tree is blocking LoS from AP4 to AP3

Building is blocking LoS from AP1 to AP2

SH is backhauled by either a fiber/cable or a high capacity LoS link to RH

Tree is blocking LoS from AP9 to AP8

Tree is blocking LoS from SH1 to AP6

Highly Integrated (SoC based) LTE radios with Fiber/LOS/NLOS wireless backhaul

15

- Pete Gelbman – Clearwire

Clearwire

What Operators are saying… BT

Extra backhaul capacity available in FTTC/P could be used to aggregate a few additional small cell sites via wireless aggregation.

Small cell (3G/LTE)

GPS or OTT
Packet based timing?

P2MP aggregation

Wireless backhaul
unit

Fibre or VDSL

To wireless
backhaul unit

To small cell
on site

DC power

Backhaul CPE

Power
converter

Power unit

Power

Fibre or VDSL
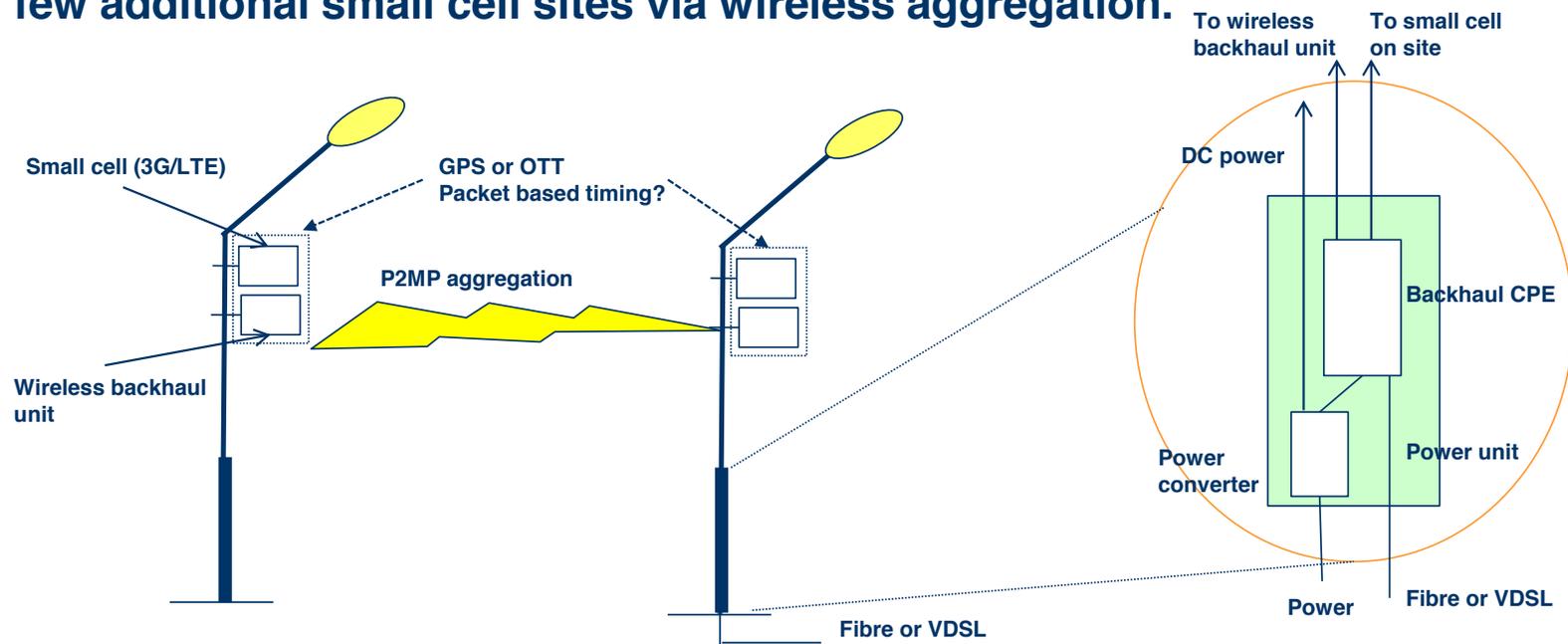
Backhaul CPE(s) can be miniaturised to be placed in sites (e.g. street lamps)

- Wireless aggregation used to connect several small cells over single backhaul link.
- Wireless hub would need to be either integrated with small cell or has zero footprint in street lamp.

Small size requires chipsets

- Viraj Abhayawardhana – BT Wholesale

Small cell backhaul

Everything Everywhere perspective as a competitive operator
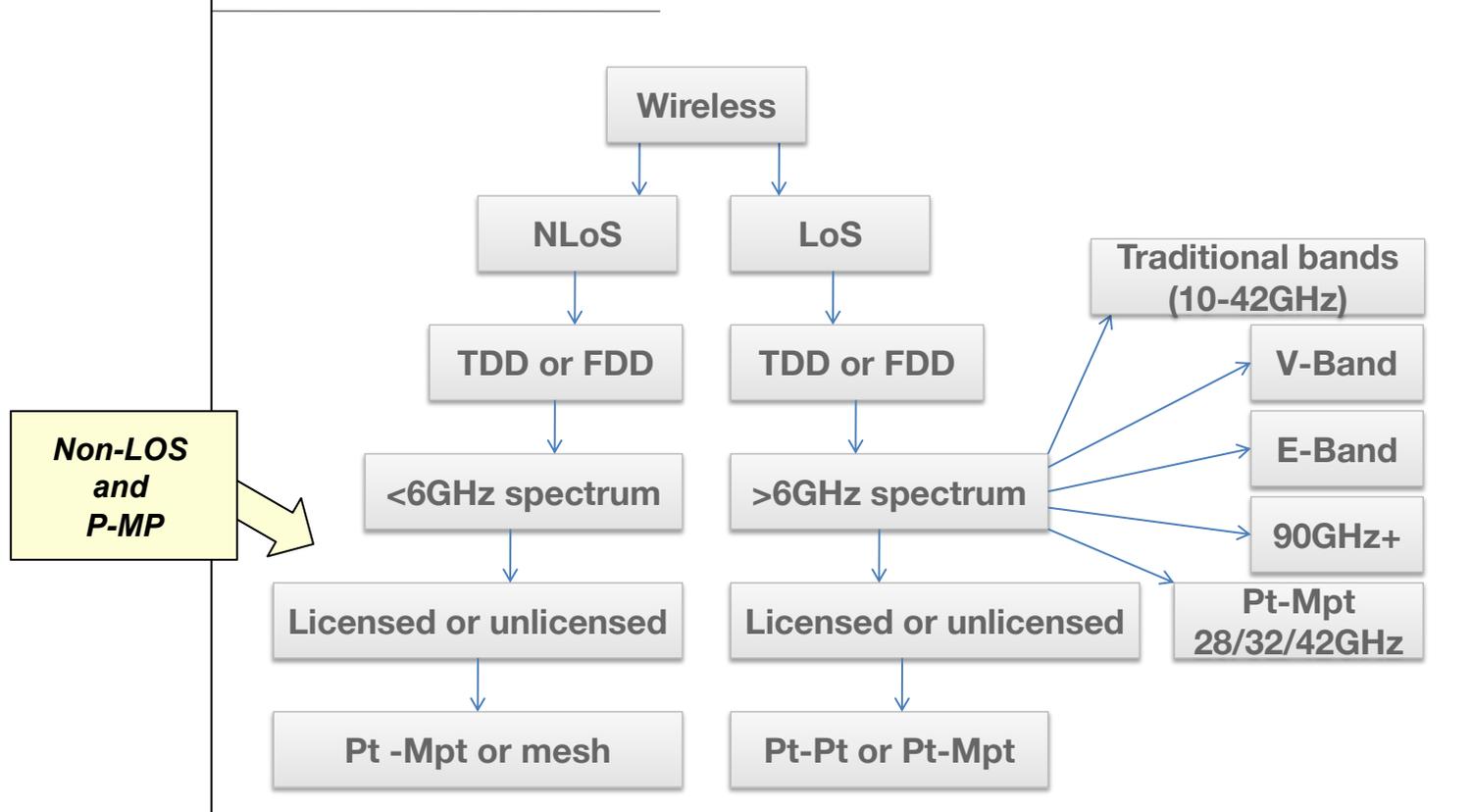
- Andy Sutton

  Principal Network Architect (Everything Everywhere – T-Mobile / Orange)

Market Demand for <u>Standardization</u> of Wireless SCB

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Standardization of Wireless SCB

Why do we need standards for Wireless Small Cell Backhaul?

- **Tens of millions** of outdoor small cells within the next 10 years

- Majority of these will use wireless backhaul

- Small cell access points will be provided by many vendors

- Small cell access point vendors will focus on cell performance

  - They need to build to a standard backhaul interface.

  - They do not want to focus on the backhaul any more than an manufacturer of a Wi-Fi access point wants to focus on the Ethernet WAN port.

- An interoperable small cell backhaul interface will enable the entire small cell marketplace.

What Operators are saying… Everything Everywhere

Summary

- There are several use cases for small cells, all are valid
- Small cells will be rolled out in volume to support mobile network evolution
- Initial momentum behind 3G small cells however LTE in the future
- Small cell sites must have a very low TCO (Total Cost of Ownership), in the region of 10% of that associated with traditional macro sites
- Small cell backhaul is a challenge from a technical and economical perspective
- Several backhaul solutions will be required to meet all likely deployment scenarios
  - A toolkit approach…
- Backhaul solution must meet today's requirements of 3G small cells whilst having a clear and cost-effective evolution path to support future LTE small cells

Low Cost needs a standard and eco-system

- Andy Sutton

  Principal Network Architect (Everything Everywhere – T-Mobile / Orange)

What Operators are saying… Sprint

Of all the small cell concerns, backhaul has become one of the main business case issues

- *Most carriers don't have facilities-based wireline access networks and must procure backhaul for each site, making small cell deployments competitively more expensive.*

- *Most small cell deployments will not be in line of site with each other or with aggregation points.*

  Must be NLOS

- *Solutions are needed that provide low cost & high capacity backhaul and access for massive number of small cells.*

  Low Cost needs a standard – Capacity needs an evolution of a standard

- *Other key small cell business case concerns include:*
  - *Total cost of deployment for flexible and easy installation.*
  - *IOT in a multi-vendor deployment for plug-play equipment and standardized interfaces.*

  Standard Interface; Multi-Vendor Interoperability Test (IOT)

- Jeff Sopha
  Technology Development & Strategy - CTO Office

WirelessMAN-OFDMA for Standardization of SCB

Market Demand for:

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Key Features of *WirelessMAN-OFDMA* for SCB

- Wireless Point-to-Multipoint

- Full QoS management support

- Supports Layer 2 Ethernet bridging using Ethernet Convergence Sublayer, fully interoperable and available in today's vendor solutions
  - Not included in other wireless standards such as 3GPP

- Non-line-of-sight

- OFDMA on UL as well as DL
  - Performance advantage in small cell environment over single-carrier UL like LTE

- Widely deployed, including by leading cellular carriers
  - Well known in cellular industry via IMT-2000

- Rich, established ecosystem of vendors of base stations, core network, silicon
  - WiMAX Forum support for ecosystem

- Support for fixed, B2B wireless has been in 802.16 since IEEE Std 802.16-2001

- Easy to enhance for higher spectral efficiency

Quality of Service over Backhaul

Small Cell Backhaul – QoS is king!

- Operators want consumer QoE to be independent of the access topology
- Backhaul QoS should be driven by services offered
- Some aspects of backhaul QoS may change according to deployment scenario:

Aspect of backhaul QoS	Small cell deployed primarily for…	
	New coverage @Not Spot	**Easing congestion @Hot Spot**
Availability	same as macro	relaxed
Delay (Latency, jitter)	same as macro	same as macro
Capacity provisioning	relaxed	greater than small cell
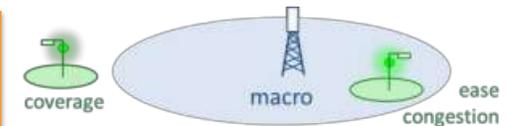
Where easing congestion, RAN capacity should not be limited by the backhaul

Where coverage overlaps, macro layer acts as fall back for small cells

coverage   macro   ease congestion

"Macrocells might be 'quality not quantity'

….but the reverse is not true for small cells"

Julius Robson, Wireless Technology Consultant and Leader, NGMN Small Cell Backhaul Requirements Group

Cost and performance tradeoffs: challenging decisions

What is the lowest-cost small-cell backhaul solution? There is no single answer. Exploring different ways to assess the cost implications is crucial for developing a solid small-cell backahul strategy.

Sub-6 GHz solutions have a lower TCO compared to 60 GHz and e-band (top graph) on a per-link basis. But 60 GHz and e-band have a much lower TCO per mbps (bottom graph). Capacity is cheaper with millimeter wave spectrum, coverage with sub-6 GHz spectrum.

In the report, we present a model that looks at these tradeoffs and discusses how operators may navigate through them differently, depending on their deployment plans and on the environment in which they operate.

Cost savings from e-band

Equipment, Capex, Opex, Overall
■ 60 GHz ■ Sub-6 GHz, licensed ■ Sub-6 GHz, unlicensed

TCO per mbps

e-band, 60 GHz, sub-6 GHz licensed, sub-6 GHz unlicensed
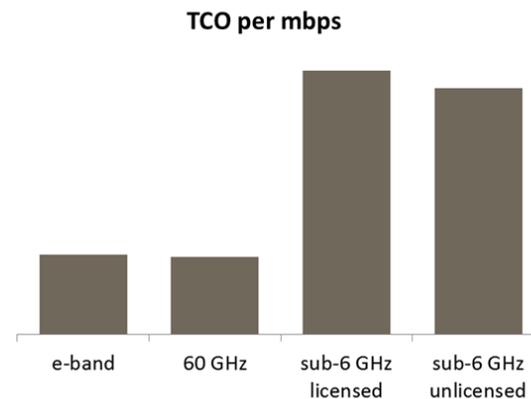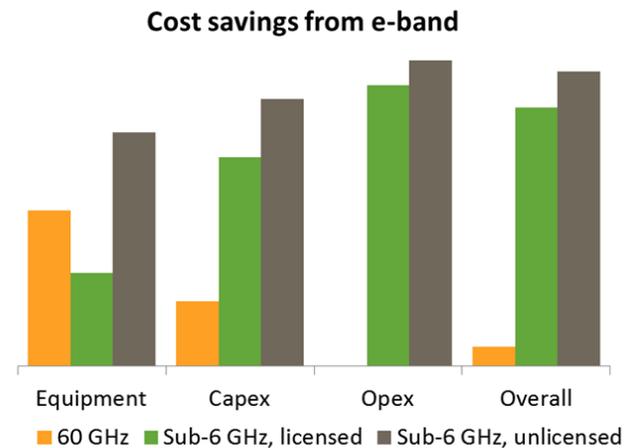
Sub 6 GHz Licensed is the sweet-spot for Small Cell Backhaul because is provides universal deploy-ability…. Not the case with E-Band. Long term both are required

Note: "e-band" is an informal reference to bands in the range of 70-90 GHz.

Source: Senza Fili

LOS or NLOS Backhaul for Small Cells

- High Frequency backhaul technologies, operating in bands from 10-80 GHz, offer the attraction of **very high capacity,** and in bands above 40 GHz, **license-free deployment**

- High Frequencies require Line-of-Sight (LOS) between the fiber connection location (typically the Macro cell site) and the location of the small cell.

- **Critical Issue: What percentage of small cell locations can LOS backhaul technology serve?**

Coverage that penetrates into Clutter
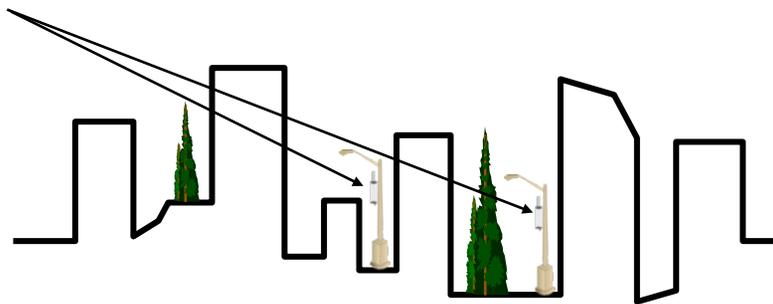
Coverage only to the edge of the Clutter

*NLOS Small Cell Backhaul*
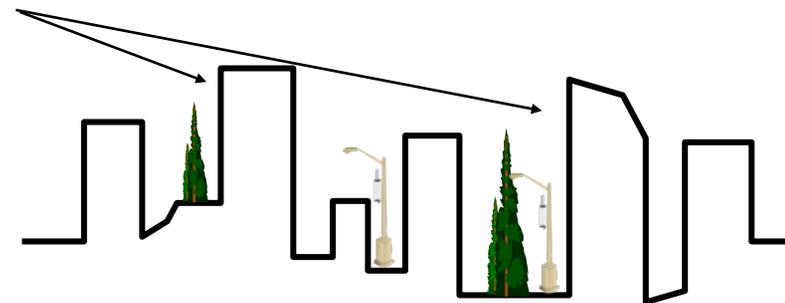
LOS Small Cell Backhaul

Line-of-Sight or Non-Line Sight Backhaul?

- **Objective**: Assess if high frequency LOS backhaul could provide high capacity backhaul to typical picocell locations
  - Down to 5 m

- RF planning used 5 m building height and clutter database (LIDAR)

- Comparison of P-MP **28 GHz** LMDS-like solution vs. P-MP **3.5 GHz** NLOS OFDMA.
  - Both solutions capable of delivering greater than 50 Mbit/s to a picocell

Dataset supports 3D ray-tracing propagation modeling

LOS vs. NLOS: Picocells at 20 m

Assumptions:

- Macro Cells - Tower or Rooftop site (10 m above average clutter)
- LOS Radio @ 28 GHz
- NLOS Radio @ 3.5 GHz (OFDMA)
- 5 m dataset with building outline data (5 m classification)

~70% Coverage with LOS

LOS vs. NLOS: Picocells at 15 m

0 2.5 5
kilometers
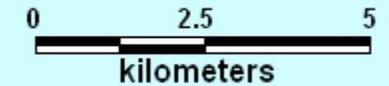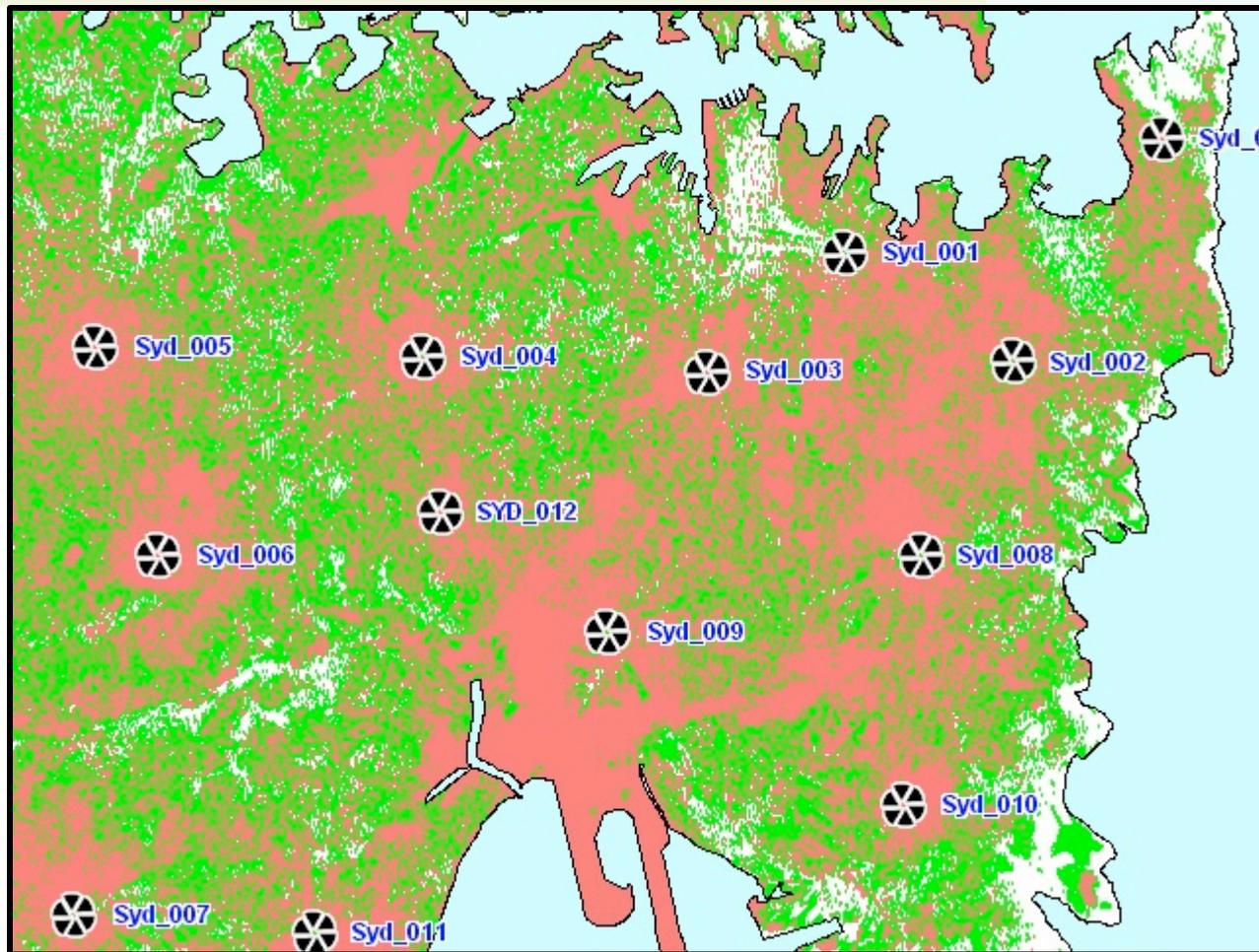
LOS Radio > 50 Mbit/s

NLOS Radio >50 Mbit/s

Assumptions:

- Macro Cells - Tower or Rooftop site (10 m above average clutter)
- LOS Radio @ 28GHz
- NLOS Radio @ 3.5 GHz (OFDMA)
- 5 m dataset with building outline data (5 m classification)

~40% Coverage with LOS

LOS vs. NLOS: Picocells at 10 m

Assumptions:

- Macro Cells - Tower or Rooftop site (10 m above average clutter)
- LOS Radio @ 28GHz
- NLOS Radio @ 3.5 GHz (OFDMA)
- 5 m dataset with building outline data (5 m classification)

~20% Coverage with LOS

LOS vs. NLOS: Picocells at 5 m

0   2.5   5
kilometers
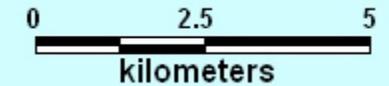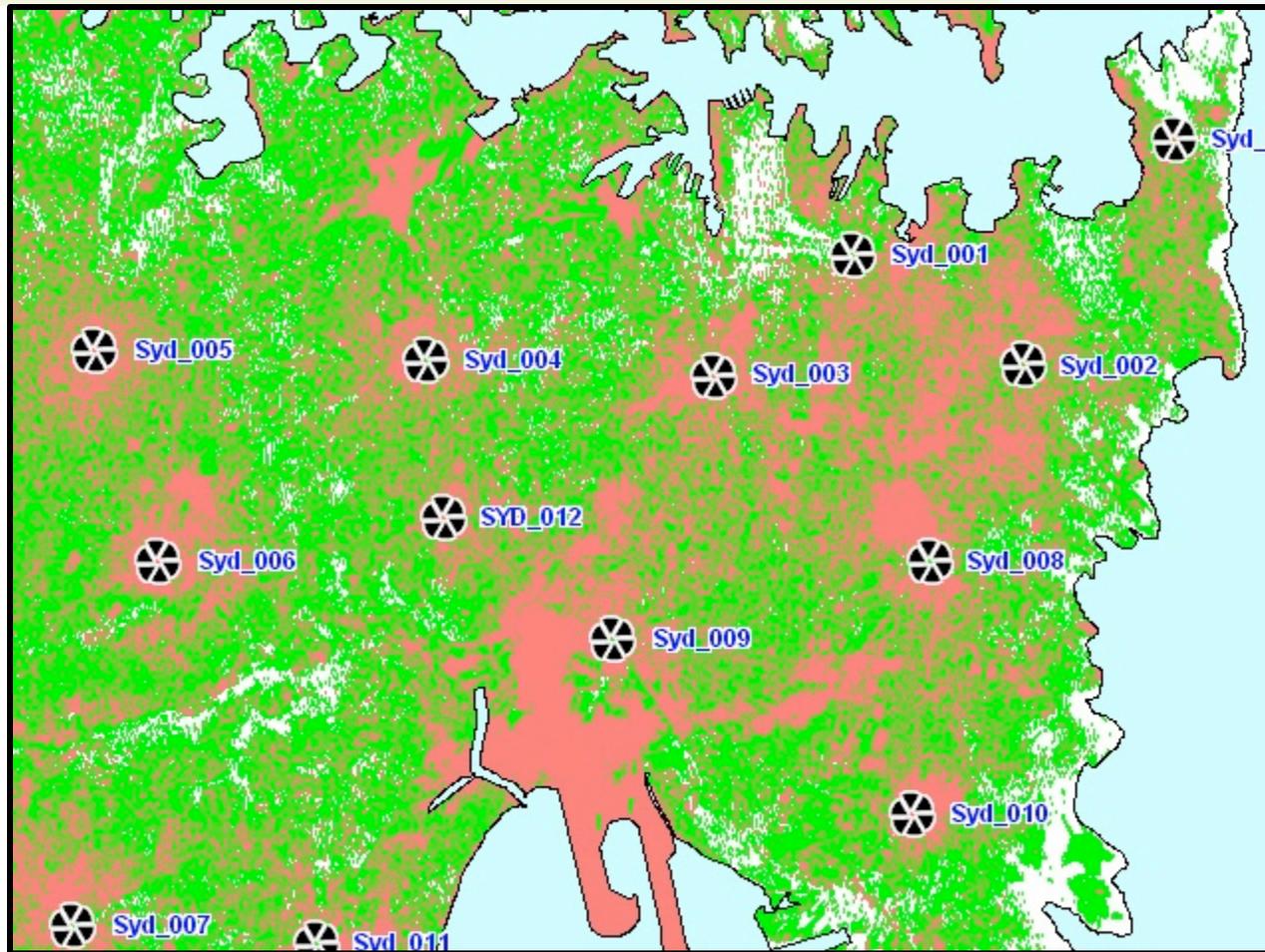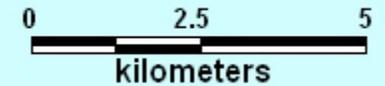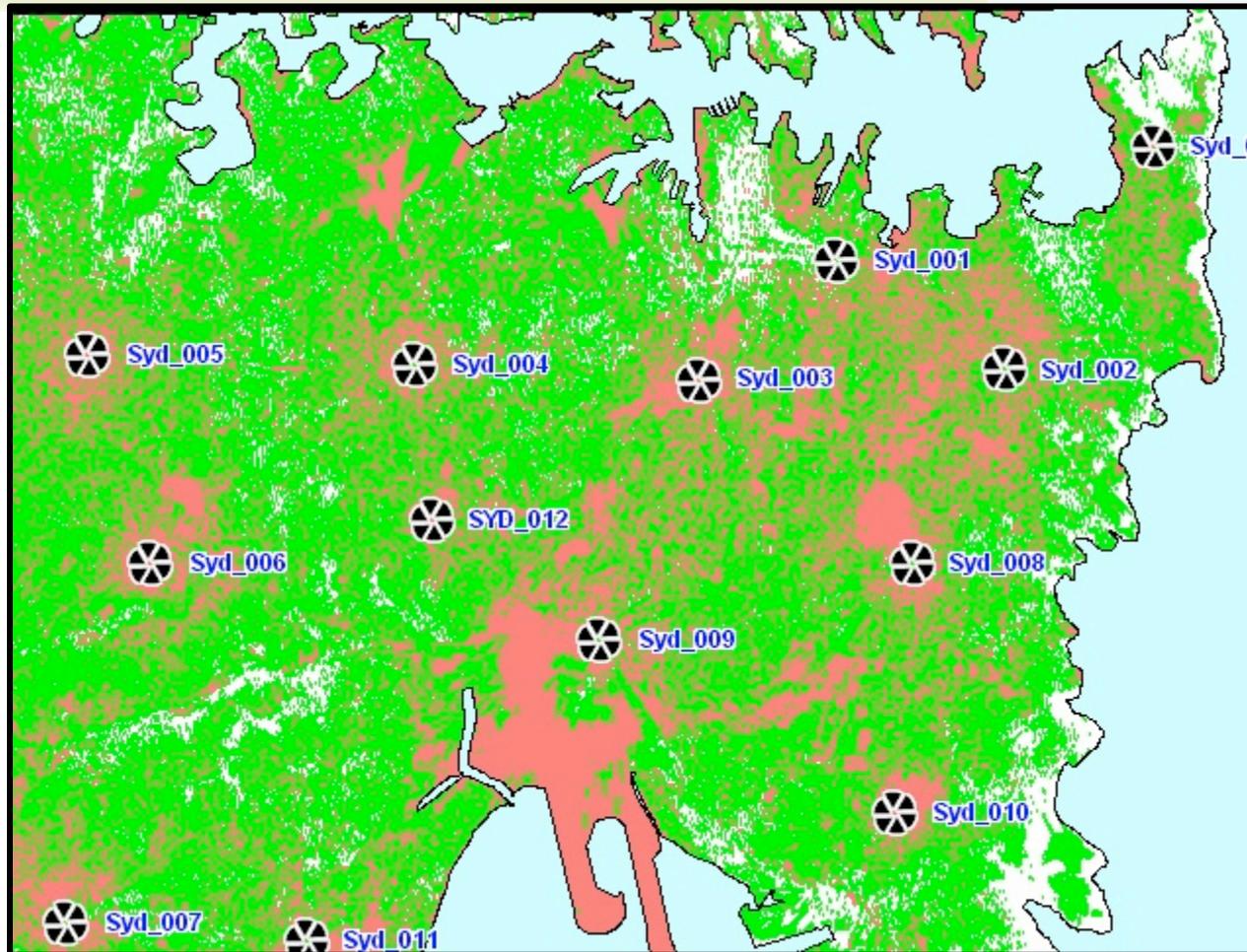
LOS Radio

NLOS Radio

Assumptions:

- Macro Cells - Tower or Rooftop site (10 m above average clutter)

- LOS Radio @ 28 GHz

- NLOS Radio @ 3.5 GHz (OFDMA)

- 5 m dataset with building outline data (5 m classification)

~10% Coverage with LOS

LOS vs. NLOS: Conclusions

- **High Frequency, LOS backhaul technology not suitable for mass picocell deployment**
  - But can be used in some locations on a tactical "in-fill" basis, feeding Relay or OFDMA backhaul nodes with high capacity

- **OFDMA Non-LOS technology provides good coverage even in highly cluttered environments (penetrating past buildings and vegetation)**
  - Mass deployment of picocells viable only using NLOS backhaul technology.

- **Even NLOS OFDMA 3.5 GHz fails to provide coverage to some locations**
  - Relay or Mesh networking between locations is required.

LOS 28 GHz limited to locations close to BS

Syd_004

Syd_

SYD_012

006

Syd_009

No coverage from NLOS 3.5 GHz OFDMA
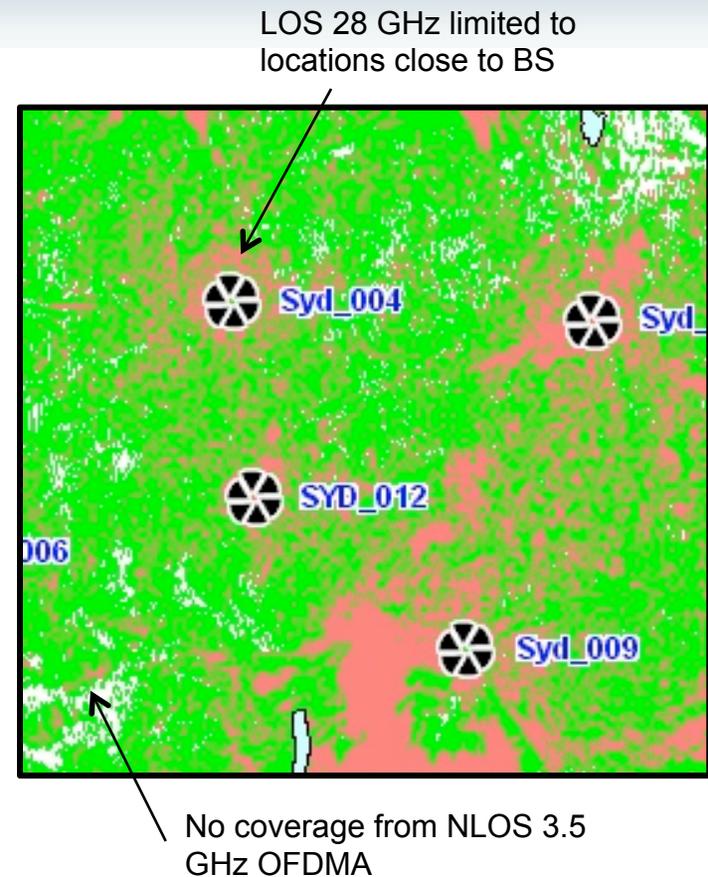
Non Line-of-Sight OFDMA is ideal for small cell backhaul

Enhancements to WirelessMAN-OFDMA for SCB

Market Demand for:

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- *Enhancements* to WirelessMAN-OFDMA for Standardization of Wireless SCB

Enhancements to *WirelessMAN-OFDMA* for SCB

- Focus on bands below 11 GHz, particularly below 6 GHz (target: 3.5 GHz)

- PHY spectral efficiency improvement: target >14 bits/Hz/sector over the air
  - 256QAM or better, both DL & UL
    - 512 and 1024 QAM options
  - Spatial Multiplexing, Uplink Matrix B MIMO
    - Start with DL & UL 2x2; add 4x4 option

- Small cell PHY optimizations, such as cyclic prefix

- Latency Optimization
  - Target <10 ms; consider focus on 5 ms frame

- Network Architecture Considerations
  - Layer 2 – Focus on Ethernet Convergence Sublayer
  - Design and optimize for fixed operation, without mobility

- Seek compatibility with *WirelessMAN-OFDMA R1 Reference System* (per IEEE 802.16.1)

- Future considerations
  - 11-80 GHz
  - WirelessMAN-Advanced basis

Wireless SCB in the HetNet Study Group

- HetNet Study Group has considered:
  - Multi-RAT networks: OmniRAN
  - Multi-Tier networks: P802.16q PAR proposal

- Wireless SCB is an element of a multi-tier network
  - P802.16q considers WirelessMAN-OFDMA deployments with mixture of macro and small cells
  - The Wireless SCB application can address multi-tier networks using non-802.16 RANs

Conclusions

- Demand for Small Cells will surge.

- Small Cells will require standard wireless backhaul solution.

- WirelessMAN-OFDMA is excellent basis for a wireless backhaul standard.

- IEEE 802.16 should quickly move to enhance WirelessMAN-OFDMA to address the Small Cell Backhaul (SCB) market.

- Wireless SCB is within the scope of the HetNet Study Group.

- The HetNet Study Group should begin planning to initiate a PAR to amend IEEE Std 802.16 for Wireless SCB.