Neighborhood Small Cells & UltraSON OPEN For 3G
Overview
Strong Mobile Data Demand Requires Extra Capacity

Overall Mobile Data Traffic Growth

Exabytes per Month

2011: 0.6 EB  
2012: 1.3 EB  
2013: 2.4 EB  
2014: 4.2 EB  
2015: 6.9 EB  
2016: 10.8 EB

78% CAGR 2011-2016

MOBILE NETWORKS NEED TO PREPARE FOR 1000X TRAFFIC GROWTH!

Source: Cisco VNI Mobile, 2012
Small Cells & Extra Spectrum Are Critical For Reaching 1000x

MORE SPECTRUM
IN LOW AND HIGHER BANDS

MORE SMALL CELLS
EVERYWHERE!

MORE INDOOR CELLS
INSIDE-OUT DEPLOYMENT

Evolve 3G/4G/Wi-Fi
HetNets Interference Mgmt/SON
Intelligently Access 3G/4G/Wi-Fi

HIGHER EFFICIENCY
Progressive Introduction Of Small Cells To Build Dense Carrier-Grade Network

Macros

+ planned small cells

+ dense unplanned* small cells

BRING CARRIER-GRADE NETWORK CLOSER TO USER FOR NEXT LEAP OF PERFORMANCE

* Small cells will be deployed in areas of high demand without detailed RF planning.

Combined network managed by operator

Planned small cell

Unplanned small cell
A New Network Deployment Model: Hyper-dense Neighborhood Small Cells (NSC)

**HIGH CAPACITY**
- Significant capacity gains compared to macro-only deployment

**SCALABLE DEPLOYMENT**
- Minimal CapEx & OpEx
- Leverages existing premises and backhaul

**INTEGRATED NETWORK**
- Plug-n-play small cells with SON
- Unplanned yet operator-managed
Good Outdoor Coverage Even with Low Small Cell Penetration

- Commercial 3G small (femto) cells in a suburban neighborhood with 7% penetration on dedicated channel provides good outdoor coverage
  - 10 mW pilot TX power*

*Small cells deployed on a channel different from macrocells

RSCP [dBm]

-115 to -105
-105 to -95
-95 to -85
-85 to -75
-75 to -65
-65 to -55

- RSCP= -115dBm results in ~700kbps in thermal noise limited case
- Points with RSCP less than -115dBm is not shown on the plots
Neighborhood Small Cell OTA Network in San Diego

Live since Nov 2011

- 20 indoor sites (Dedicated spectrum, 20dBm max transmit power)
- Substantial outdoor coverage – high throughput
- Key UltraSON features for self-configuration, mobility and interference management demonstrated
Neighborhood Small Cells Overview

Capacity Gains
- Cell splitting
- SINR improvement
  - User closer to serving cell
  - Wall isolation for indoor users
- More spectrum
  - High frequency band operation

Challenges
- Mobility
  - User experience
  - Network signaling load
- Unplanned deployment / self configuration
- Shared backhaul and QoS
- Spectrum availability

Capacity Analysis

UltraSON Development
Simulation Results
Neighborhood Small Cells 3G Capacity Simulations

Baseline Vs. Dedicated Channel Deployments

**Baseline Macro Deployment**
Rel 9 UMTS, 2-carriers deployment with 10 MHz spectrum

**Dedicated Channel Deployment**
Rel 9 UMTS, total of 10 MHz spectrum macro and small cell deployed on different carriers
Dense Urban Neighborhood Small Cells Simulation

Assumptions

Parameter | Value
---|---
Macrocell ISD | 500m
Population Density | 20000 per sq km
Number of Apartments per Macrocell (2 subs per Apt.) | 720
User Distribution | 70% Indoors/30% Outdoors; Randomly dropped

Notes:

a) Small cells are randomly dropped in a apartment statistically independent of other small cells’ locations
b) At most one small cell is dropped in any apartment
Neighborhood Small Cells Capacity Simulation

*Dense Urban Model Configuration*

- Multi-floor apartment blocks placed in a 3-cell macro area
- Each apartment block has two buildings with a street in the middle
- 10 apartments in each floor in each building
  - Two rows of 5 apts
  - Each apt is 10m x 10m with a 1m-wide balcony
- Detailed RF propagation modeling for indoors and outdoors
  - Indoor propagation based on Keenan-Motley multi-wall model
  - Explicit modeling of internal and external walls, windows and floor losses
    - Internal wall loss: 8dB
    - External wall loss: 20dB
    - Floor loss: 18.3dB (indoor users only)
Neighborhood Small Cells Provide Significant DL Capacity Gains

**Neighborhood Small Cells Offer Scalable Capacity As Demand Increases**

- 500m ISD, 720 apartments/cell, 2 subs/apartment. Users randomly dropped, 70% indoor and 30% outdoor
- Gains shown are relative to macro baseline with same amount of spectrum.
- Small cell penetration is percentage of total apartments with a small cell.

**DL Median Throughput Gain**
(dense urban, relative to macro-only)

- 8 UEs/macro
- 48 UEs/macro
- 288 UEs/macro

**Graph Details**
- DL Median Throughput Gain (x)
- Small Cell Penetration (%)
- (72 small cells) (360 small cells)
- 2.4 6.3 7.4 7.5
- 37.4 21.3 34.6 38.1
- 124.8 124.8

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SON Features For 3G NSC
# UltraSON Features for NSC Deployments

## Mobility Management
- Optimize handover performance and signaling load
  - Frequent Handover Mitigation
  - PSC selection and neighbor discovery

## Radio Resource and Interference Management
- Optimize capacity and user experience via managing radio resources and interference
  - Co-channel and adjacent channel interference mitigation
  - Short-term and long-term load balancing

## Tx Power Management
- Optimize network capacity while minimizing pilot pollution
  - Network Listen based Tx power management
  - UE-assisted Tx power management
  - Adaption to dynamic network topology

## Backhaul Management (for consumer-grade backhaul)
- Optimize capacity offload and user experience under backhaul constraints
  - Estimate available backhaul
  - Prioritize preferred users (enterprise/residential)
SON Features Help Small Cells Deliver Carrier-Grade Performance

- In an unplanned/semi-planned deployment, RF environment around each small cell is different and dynamic
- Small cell needs to be able to respond when it is turned on and continue to adapt to the changing environment

**AT STARTUP**
- Calibrate Tx power
- Select PSC and configure neighbor list
- Optimize idle re-selection parameters and paging area

**AFTER STARTUP**
- Adapt Tx power & update neighbor list
- Monitor backhaul quality & prioritize preferred users
- Balance load among different cells
Main Considerations for Mobility Management for NSC

- Facilitate handover to small cells to maximize traffic offload
- Key Issues:
  - Mobile UEs on small cell layer likely to cross cell boundary frequently
  - Excessive handovers create signaling load and potential outage and hence should be avoided
Pilot Pollution

• Pilot pollution results in:
  – Outdoor pedestrian/vehicular users to perform many frequent handovers
  – Reduction in SNR

• Goal:
  – Minimize number of handovers for outdoor users with minimal impact on coverage

• Solution:
  – NSCs detect pilot pollution and adapt transmit power
Network Listen based Tx Power Management

- Pilot pollution can be reduced by Tx power management

- Baseline Network Listen Based Algorithm:
  - Two-tiered coverage depending on strength of nearby small cells
    - Extended coverage (high power)
    - Confined coverage (low power)
  - Power dynamically adapts to changes in network topology

Baseline Tx Power Management Algorithm

- Make NL measurements of other small cells

- Is total RSCP from small cells with $P_{\text{high}}$ above threshold?
  - YES: Set power to $P_{\text{low}}$
  - NO: Set power to $P_{\text{high}}$
Frequent Handover Mitigation: Ping Pong Handovers

- Frequent handovers impact user experience and increase risk of call drop
- Even stationary users can experience frequent handovers when they observe many small cells with similar strength

**Diagram:**
- Small Cell A
- Small Cell B
- Small Cell C
- Small Cell D

**Flowchart:**

- **A → B → C → B → A → C**
- UE moves to D

**Left Side:**
- Frequent handovers: Cell ID is repeated in recent UE H/O history
- Categorize as ping-pong UE
- Adjust H/O parameters of UE to prevent ping pong

**Right Side:**
- Cell ID is not repeated in recent H/O history
- Categorize as non-ping pong UE
- Reset H/O parameters for that UE back to default
Frequent Handover Mitigation: High Mobility Handovers

- Fast moving users cross small cell coverage boundaries frequently and require many handovers
- These users are best served on the macro layer

Very frequent handovers
Cell IDs of past serving cells unique

Categorize as fast moving UE

Handover to macro layer
PSC Selection

- PSC re-use amongst small cells can lead to PSC collision and confusion
  - PSC pool limited by neighbor list size constraints in 3G
  - Collision results in interference
  - Confusion causes handover issues

- PSC selection needed to minimize collision and confusion
  - Avoid PSCs detected by Network Listen
  - Utilize mobiles to prevent collision/confusion with farther neighbors
Neighborhood Discovery

- Target PSC and Cell ID need to be discovered to enable handover
  - Network Listen alone cannot detect all neighboring target cells for handover
- Mobile reports can be utilized to enhance the neighbor cell list determined via Network Listen
  - Enables reliable handover from small cell to another small cell or macrocell
Backhaul Estimation

- Bandwidth available to the residence is time-varying and limited due to competition from neighbors.
- Need to ensure priority for backhaul owner traffic (both UE and non UEs).
- NSC needs to estimate available backhaul to determine how much bandwidth can be used.