Qualcomm Research

Neighborhood Small Cells & UltraSON OPEN For 3G

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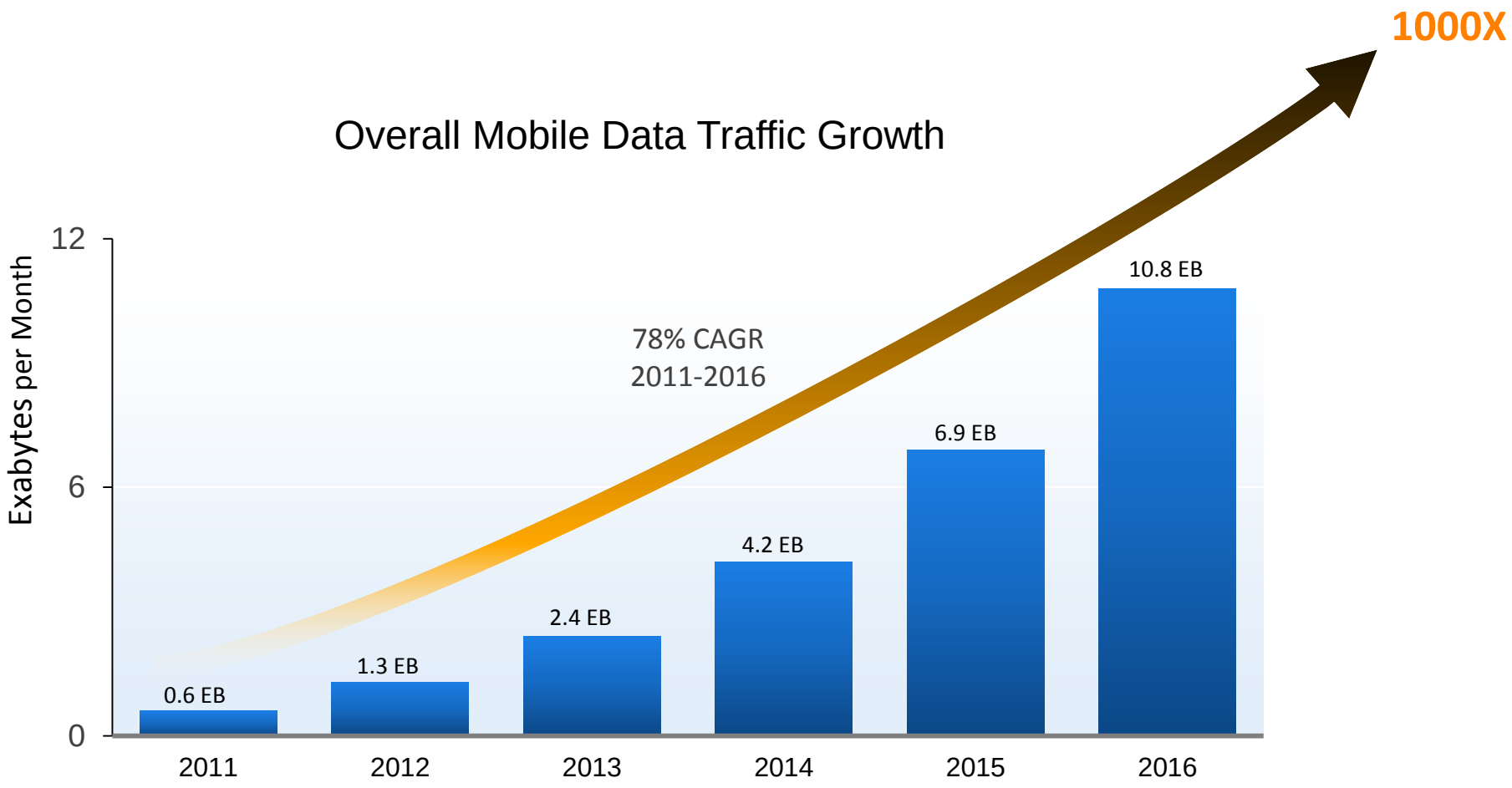
Overview

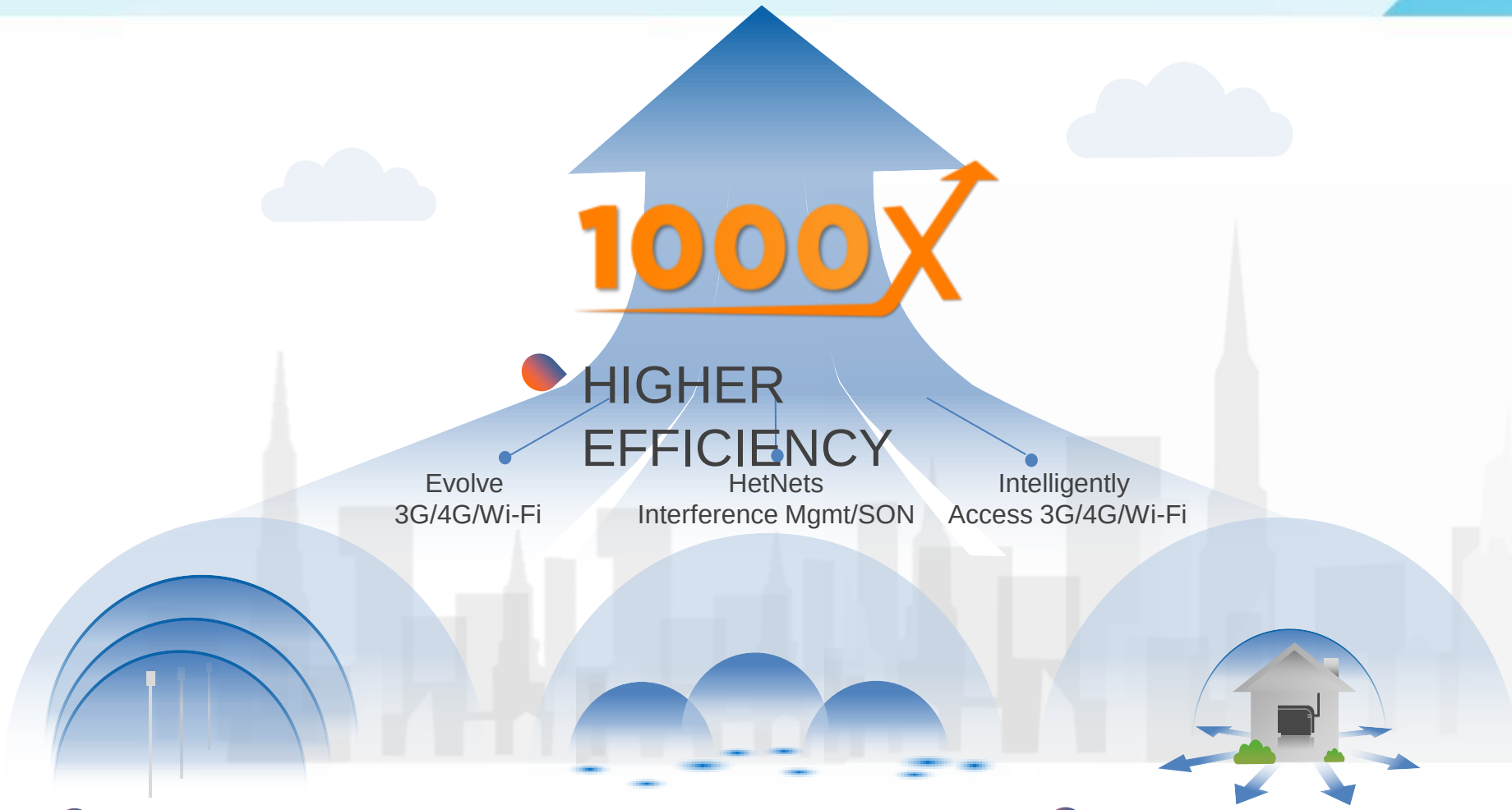
Strong Mobile Data Demand Requires Extra Capacity



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

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

Macros

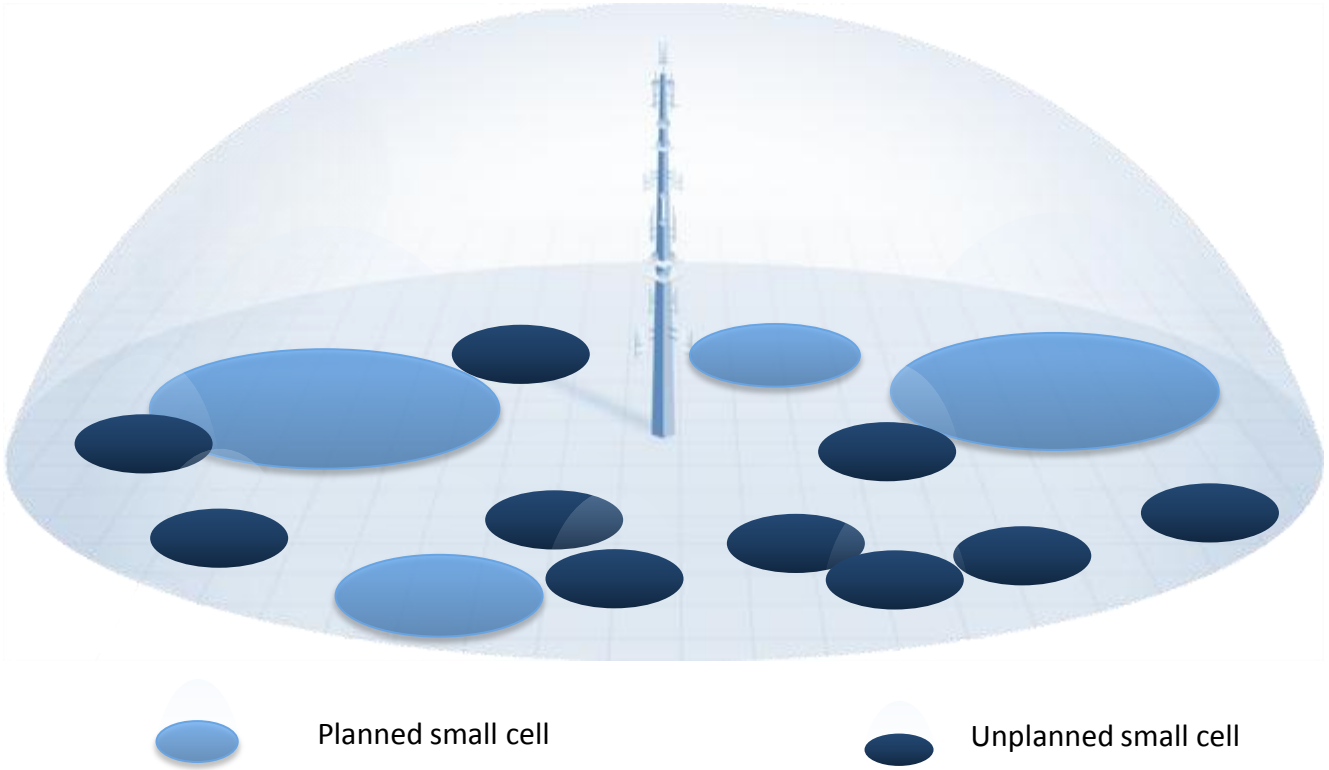
+

planned small cells

+

dense unplanned* small cells

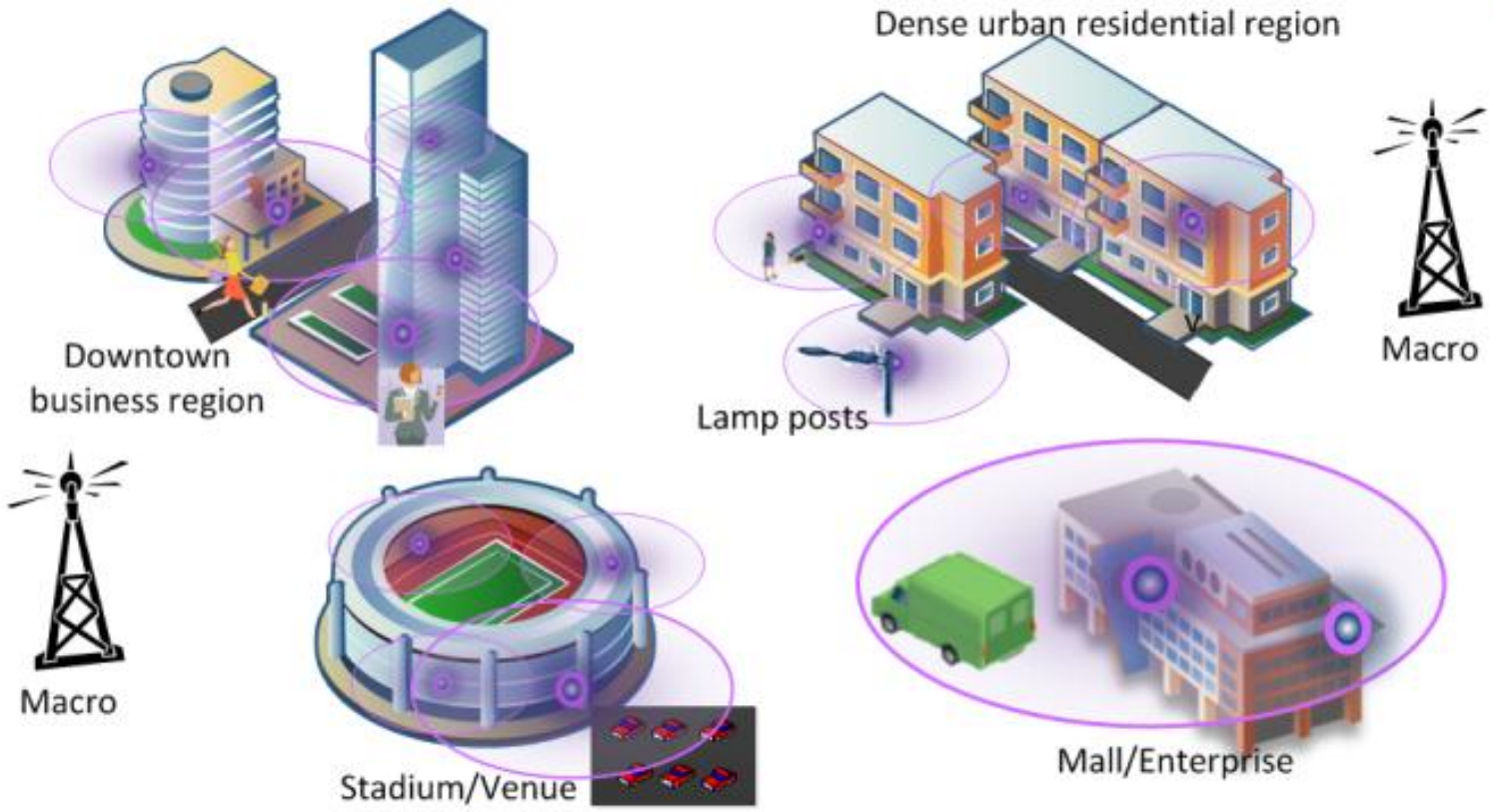
Combined network managed by operator



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.

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*

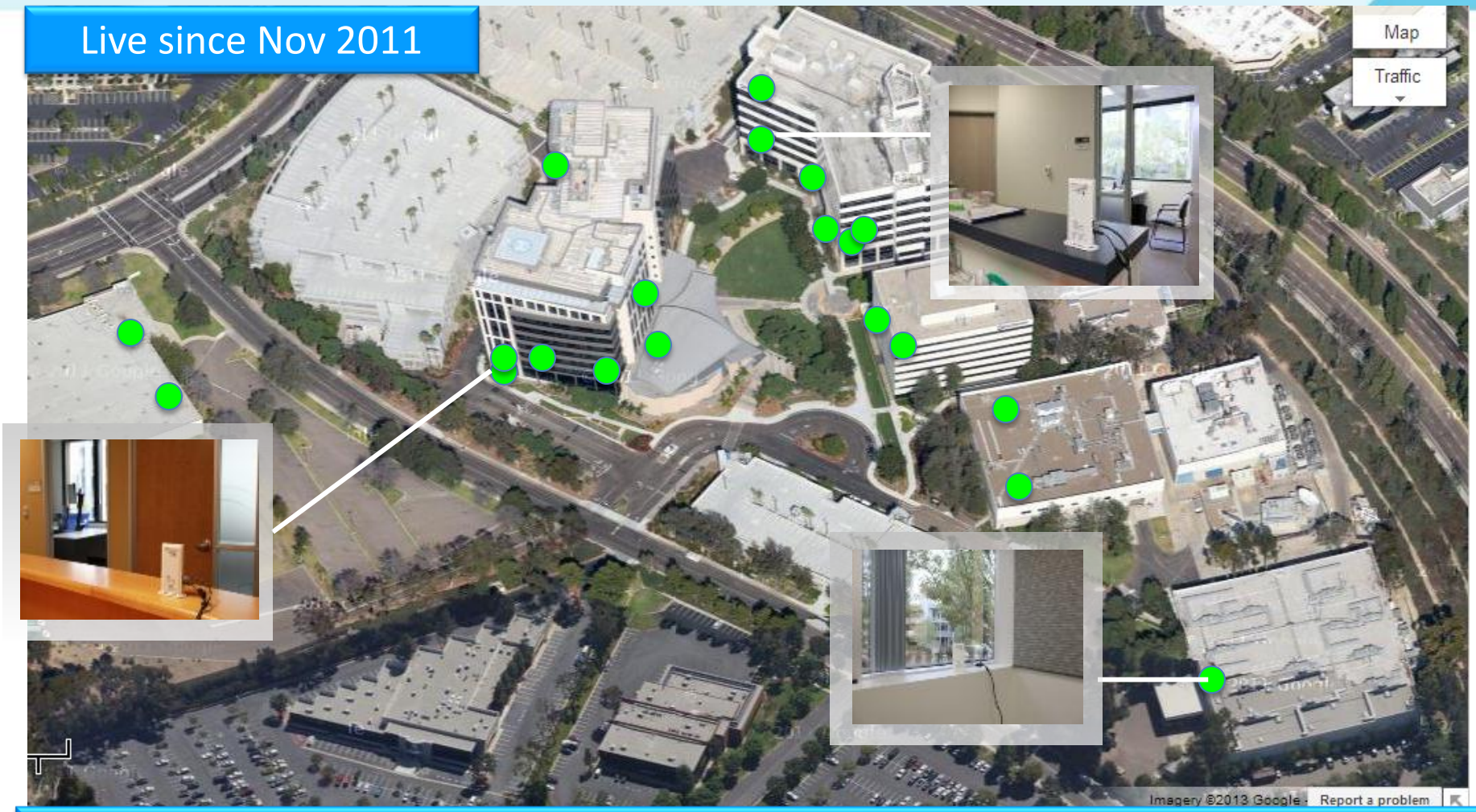
RSCP [dBm]	
	-115 to -105
	-105 to -95
	-95 to -85
	-85 to -75
	-75 to -65
	-65 to -55

- RSCP= -115dBm results in ~700kbps in thermal noise limited case
- Points with RSCP less than -115dBm is not shown on the plots

Small cell

*Small cells deployed on a channel different from macrocells

Neighborhood Small Cell OTA Network in San Diego



- 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

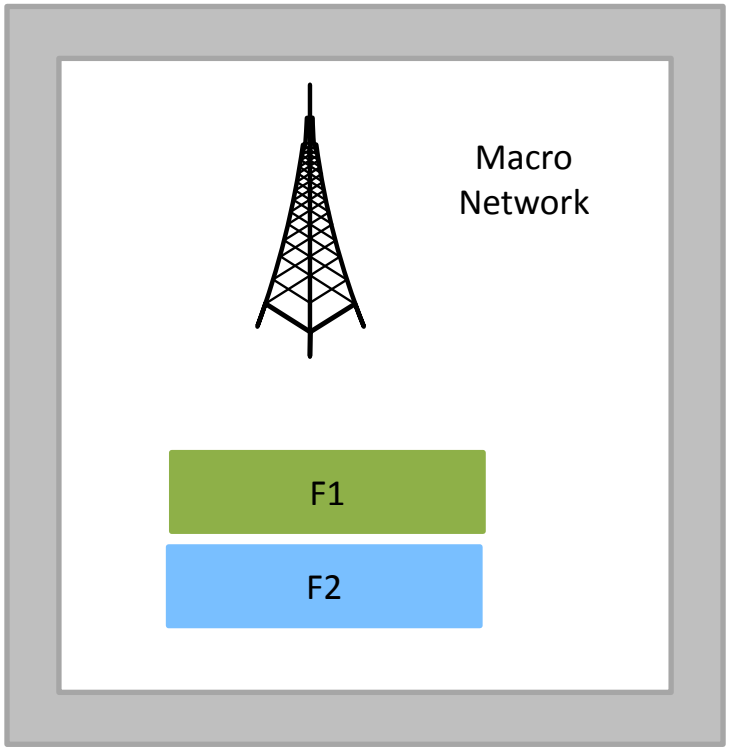
Capacity Analysis

UltraSON Development

Simulation Results

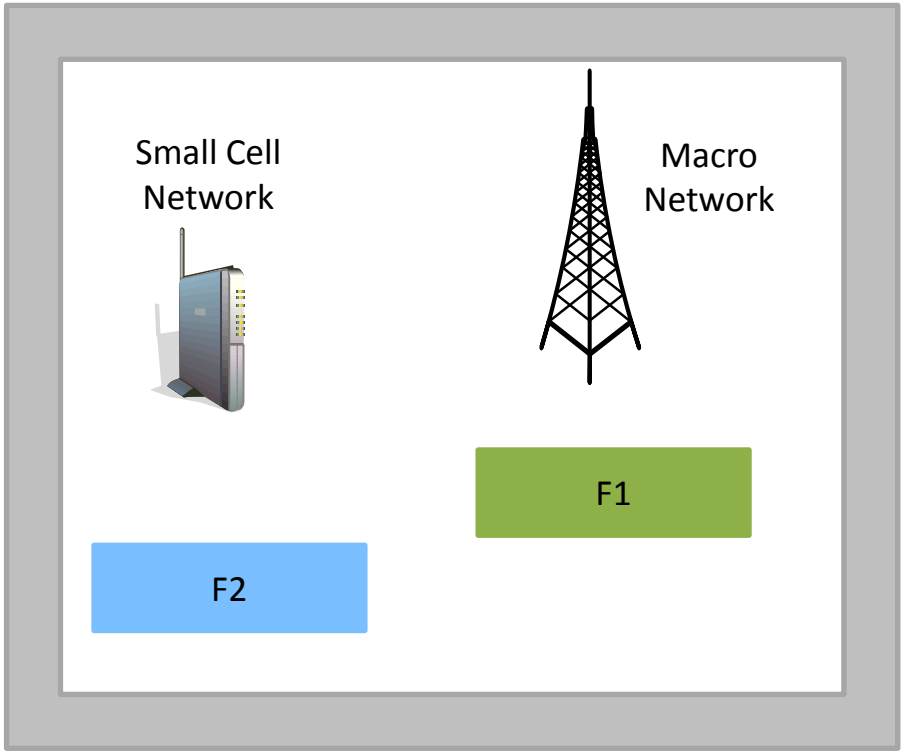
Neighborhood Small Cells 3G Capacity Simulations

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

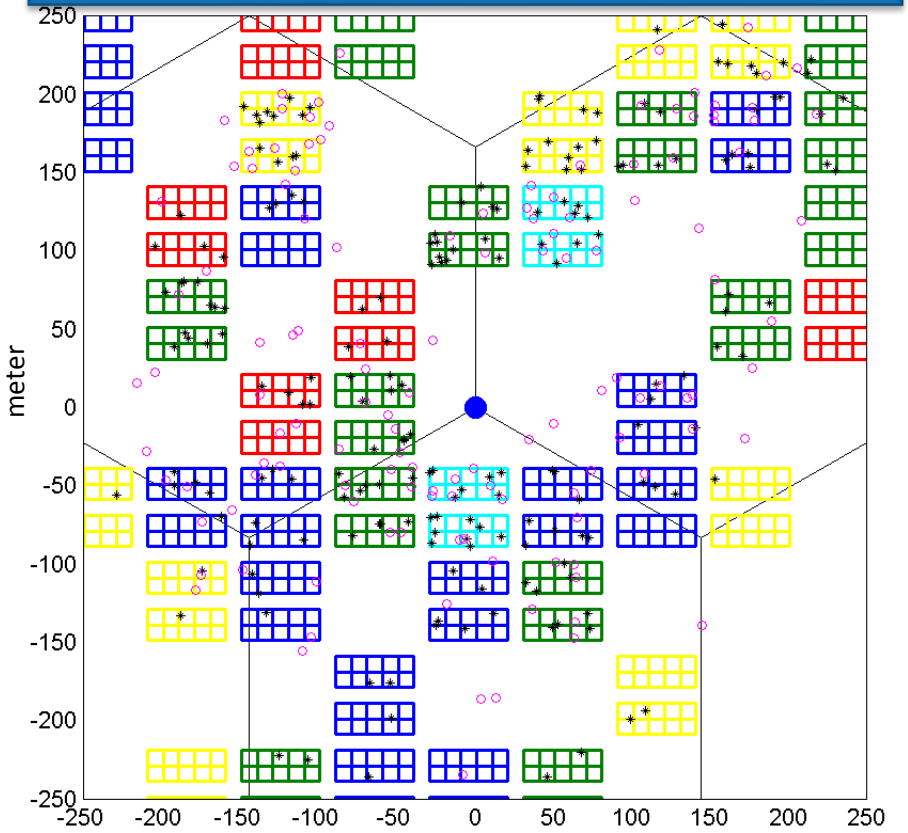
Parameter	Value
Macrocell ISD	500m
Population Density	20000 per sq km
Number of Apartments per Macrocell (2 subs per Apt.)	720
User Distribution	70% Indoors/ 30% Outdoors; Randomly dropped

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

Dense-Urban Area
(Simulation with Apartment Buildings)



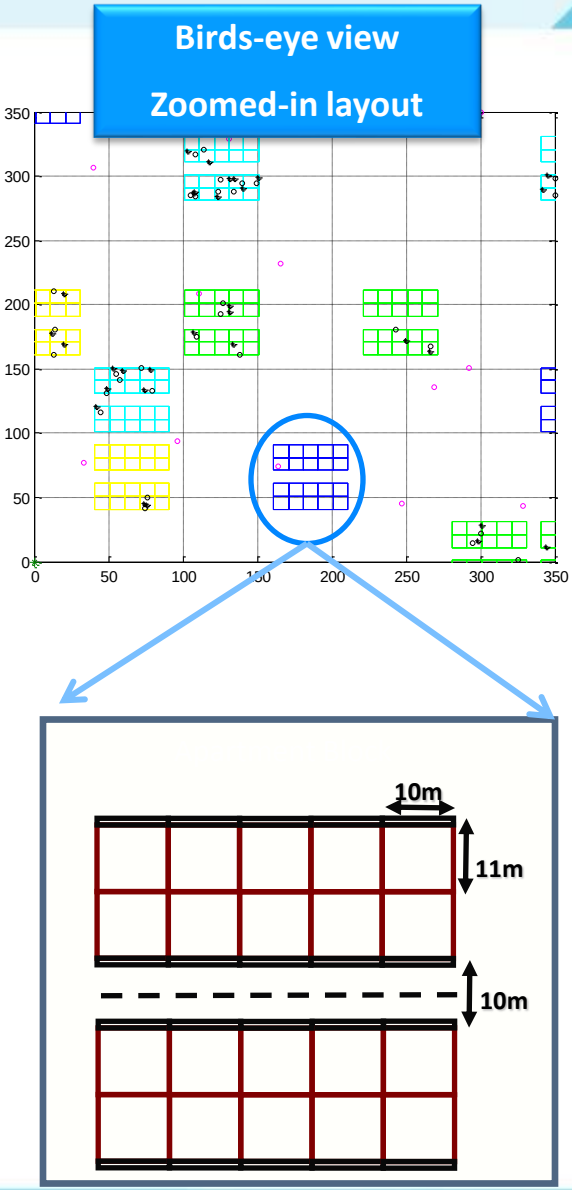
Red: 2 story bldg
Blue: 3 story bldg
Green: 4 story bldg
Cyan: 5 story bldg
Yellow: 6 story bldg

Black star: Small cell
Magenta Circle: Mobile
Blue circle: Macrocell

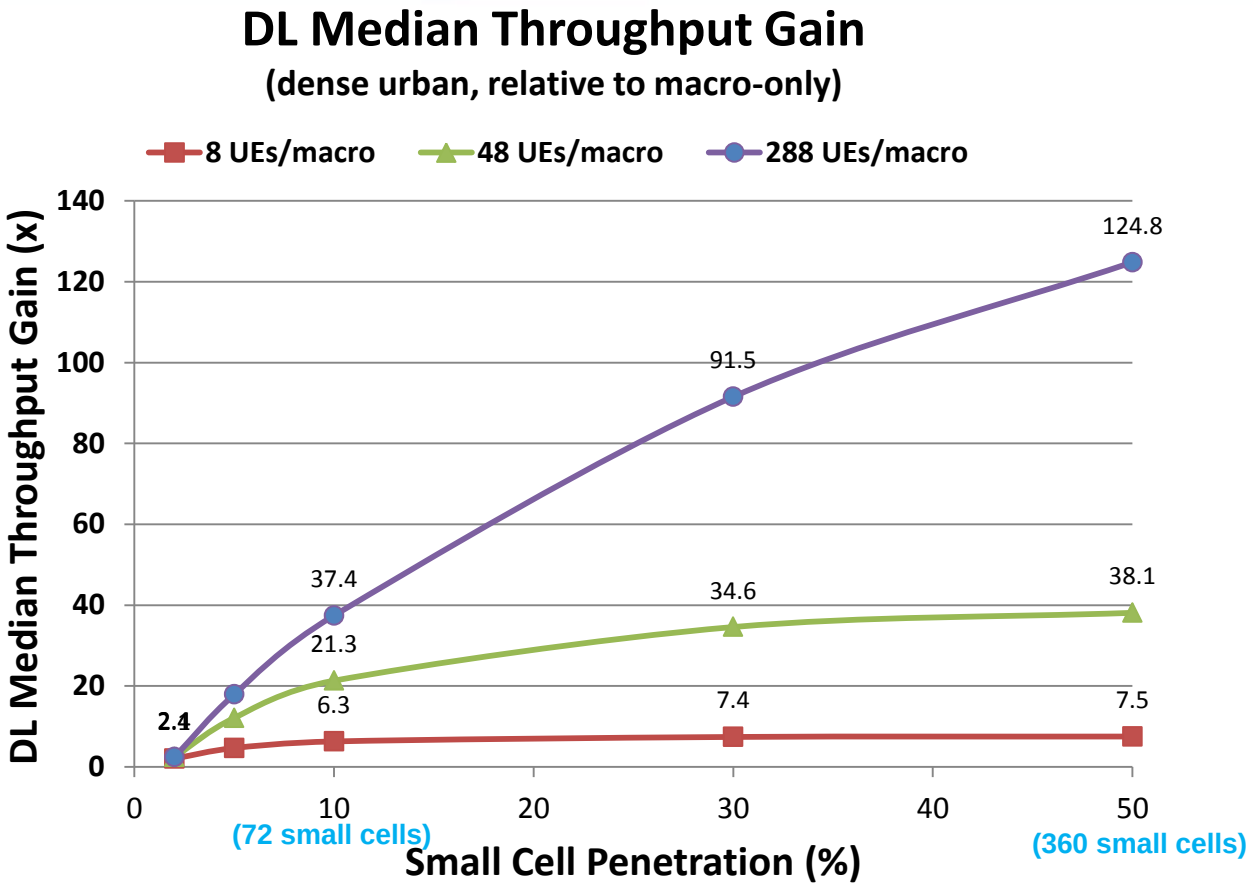
Neighborhood Small Cells Capacity Simulation

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.

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

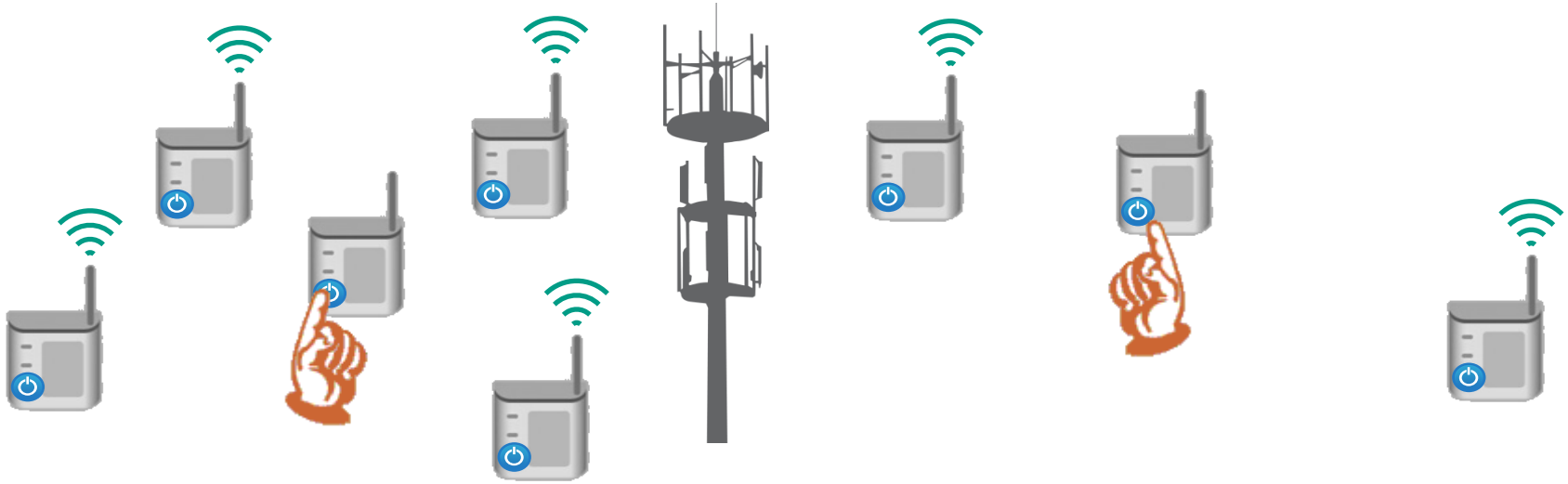
- Optimize network capacity while minimizing pilot pollution
  - Network Listen based Tx power management
  - UE-assisted Tx power management
  - Adaption to dynamic network topology

Backhaul Management (for consumer-grade backhaul)

- Optimize capacity offload and user experience under backhaul constraints
  - Estimate available backhaul
  - Prioritize preferred users (enterprise/residential)

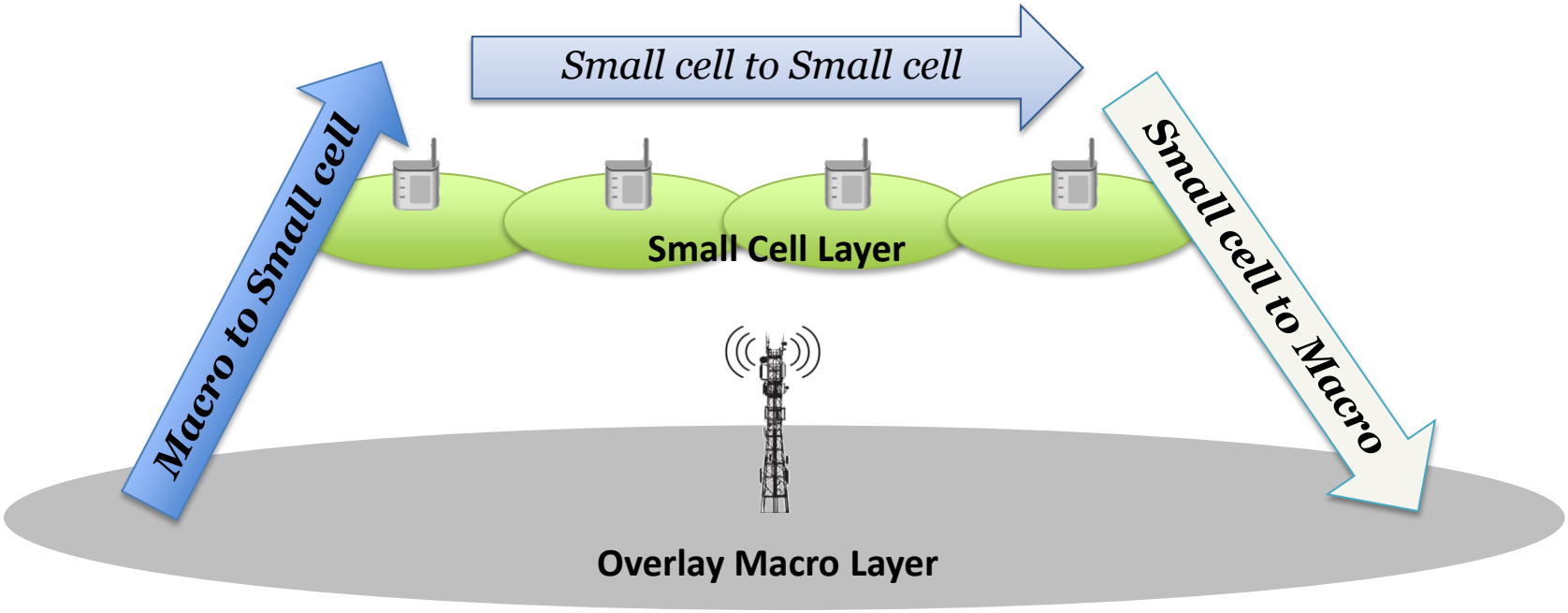
SON Features Help Small Cells Deliver Carrier-Grade Performance

- 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	AFTER STARTUP
• Calibrate Tx power • Select PSC and configure neighbor list • Optimize idle re-selection parameters and paging area	• Adapt Tx power & update neighbor list • Monitor backhaul quality & prioritize preferred users • Balance load among different cells

Main Considerations for Mobility Management for NSC

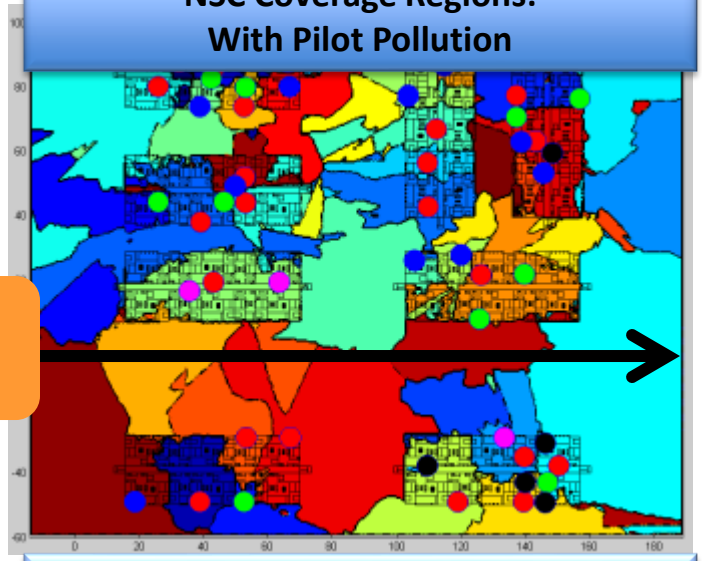


- Facilitate handover to small cells to maximize traffic offload
- Key Issues:
  - Mobile UEs on small cell layer likely to cross cell boundary frequently
  - Excessive handovers create signaling load and potential outage and hence should be avoided

Pilot Pollution

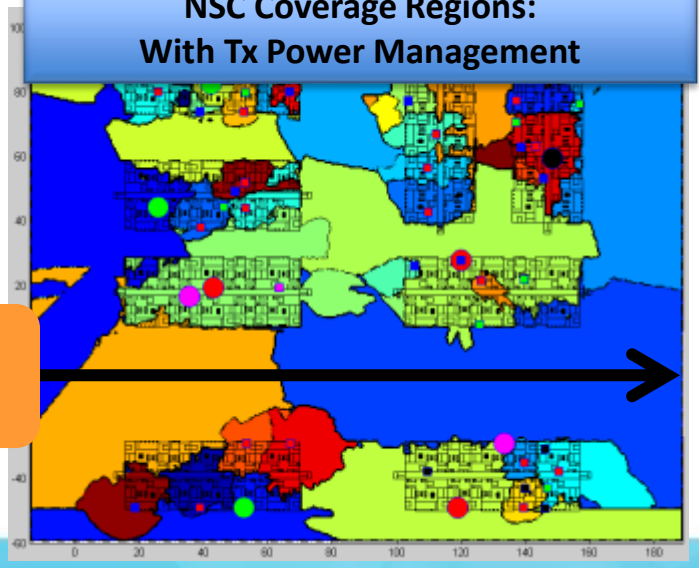
- Pilot pollution results in:
  - Outdoor pedestrian/vehicular users to perform many frequent handovers
  - Reduction in SNR
- Goal:
  - Minimize number of handovers for outdoor users with minimal impact on coverage
- Solution:
  - NSCs detect pilot pollution and adapt transmit power

NSC Coverage Regions: With Pilot Pollution



6 Hard Handovers along route

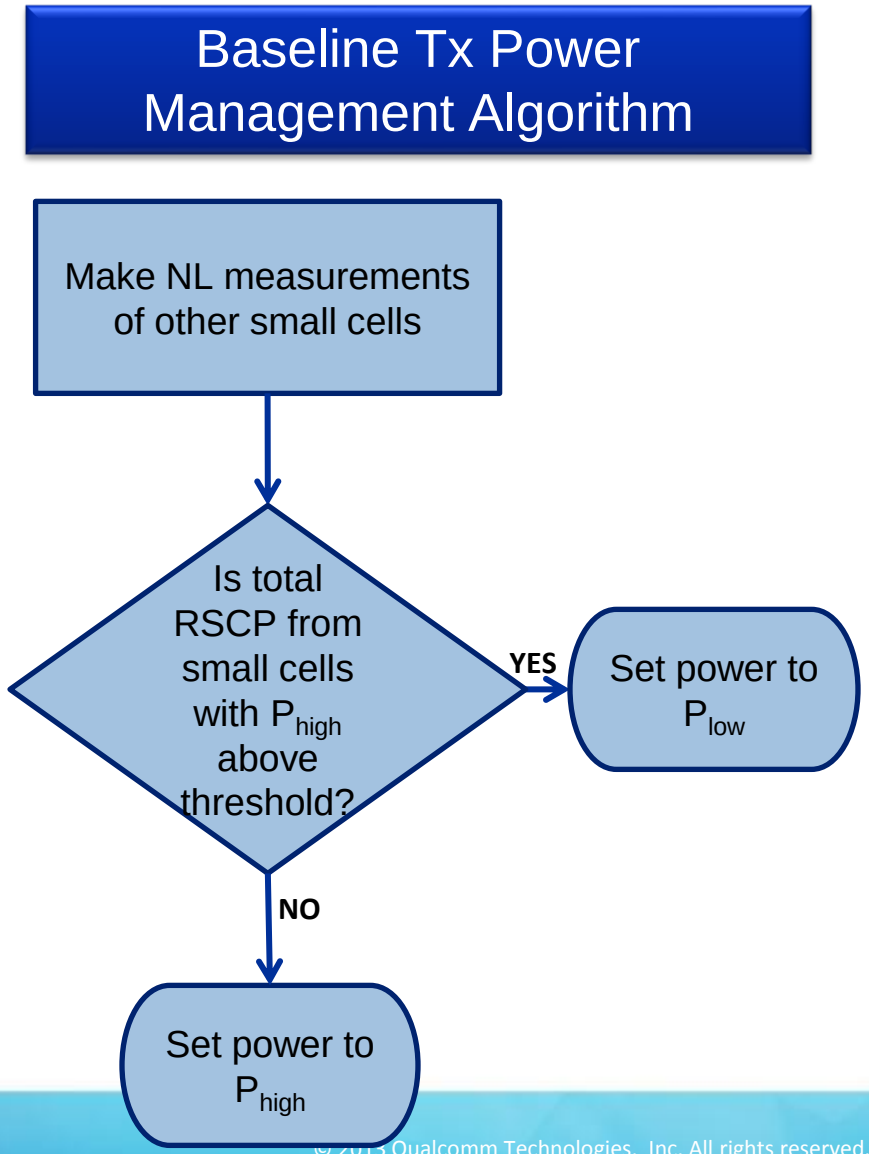
NSC Coverage Regions: With Tx Power Management



2 Hard Handovers along route

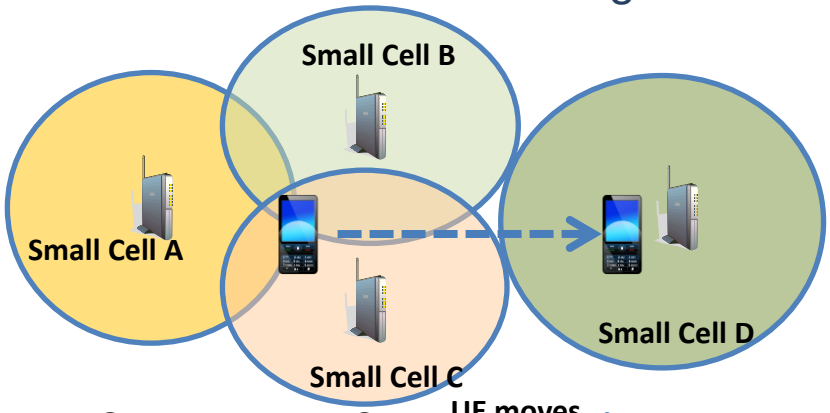
Network Listen based Tx Power Management

- 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



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



UE in handover region

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

UE moving across cells

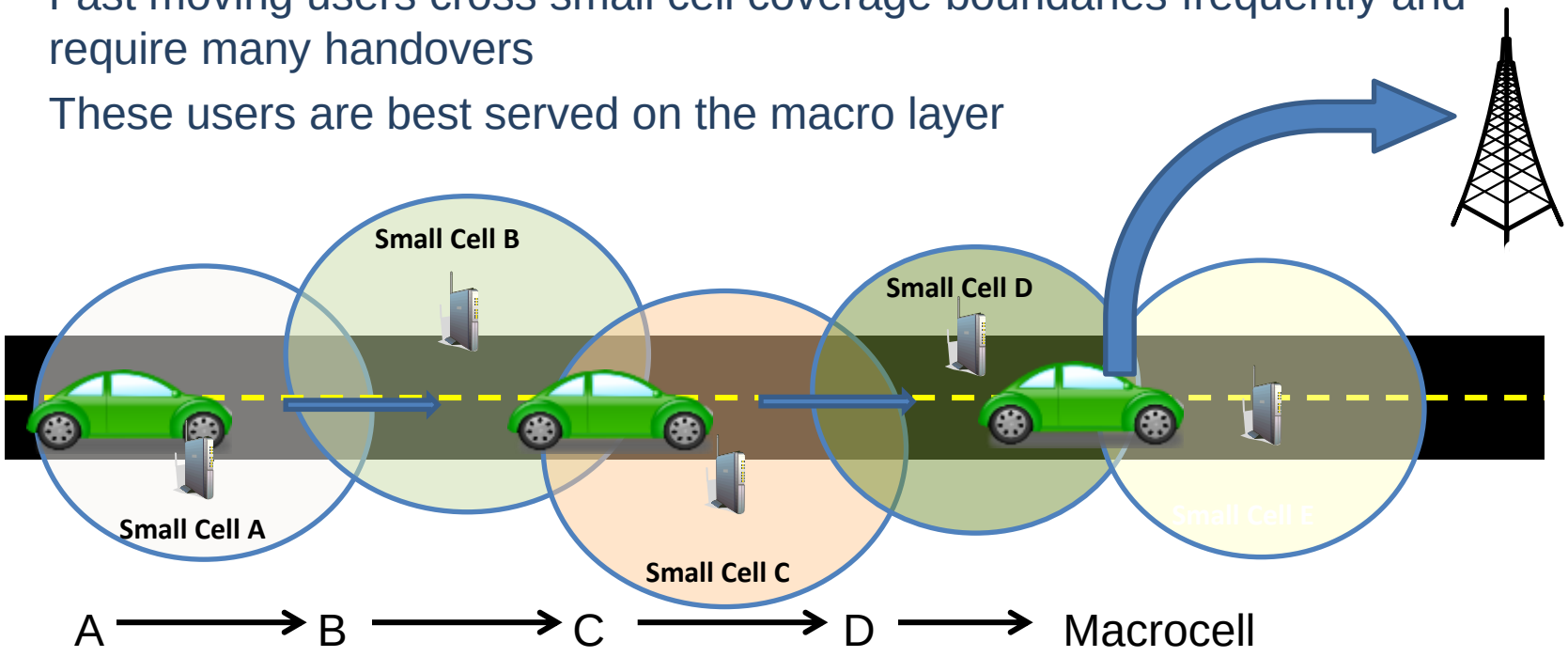
Cell ID is not repeated in recent H/O history

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



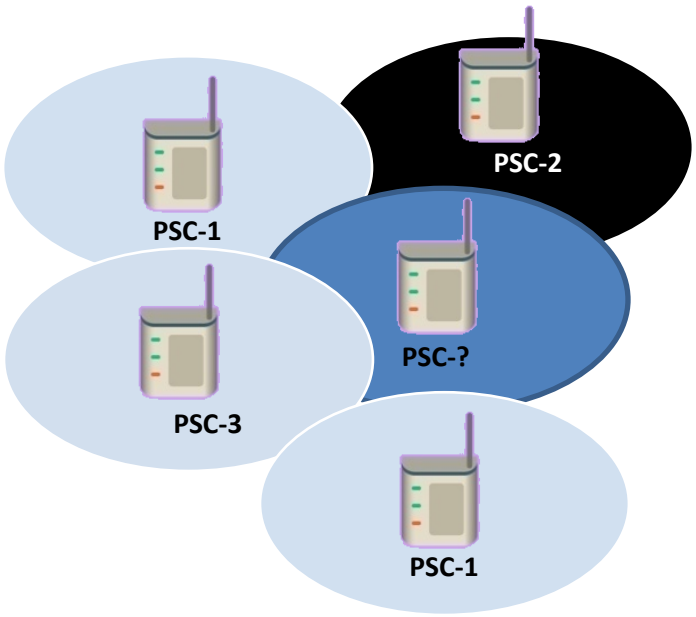
Very frequent handovers

Cell IDs of past serving cells unique

Categorize as fast moving UE

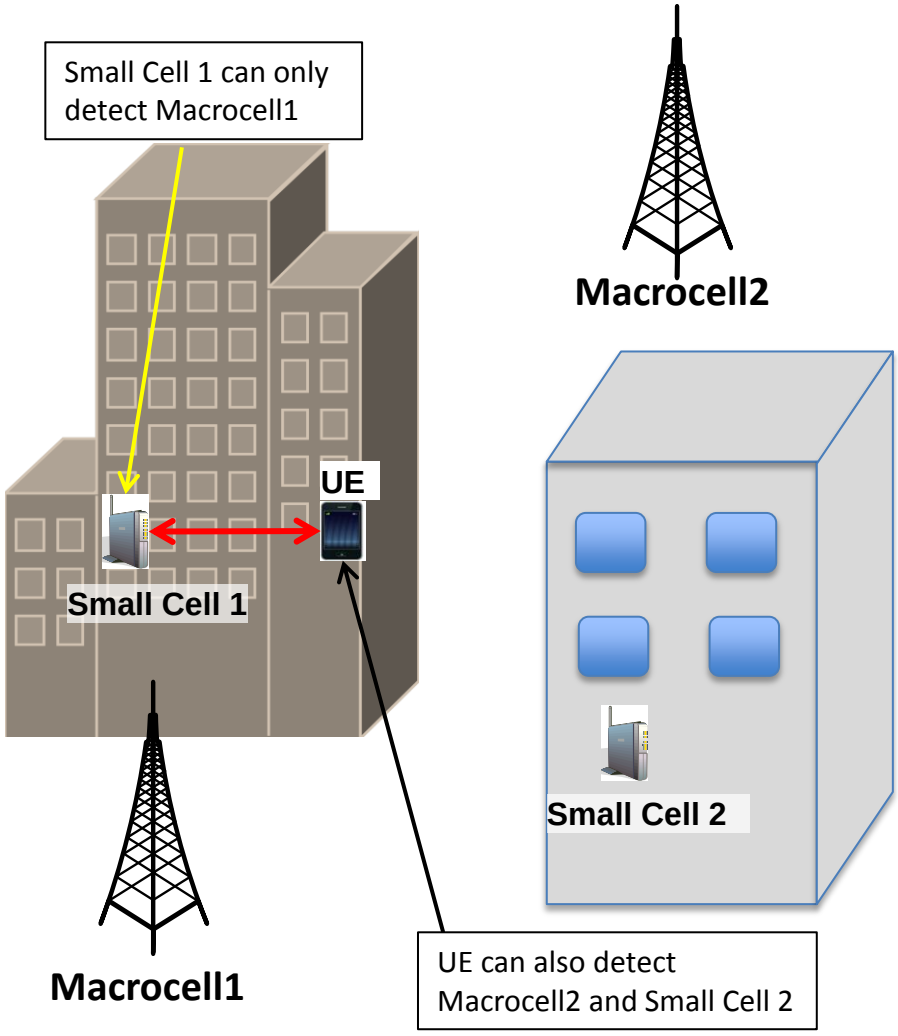
Handover to macro layer

PSC Selection



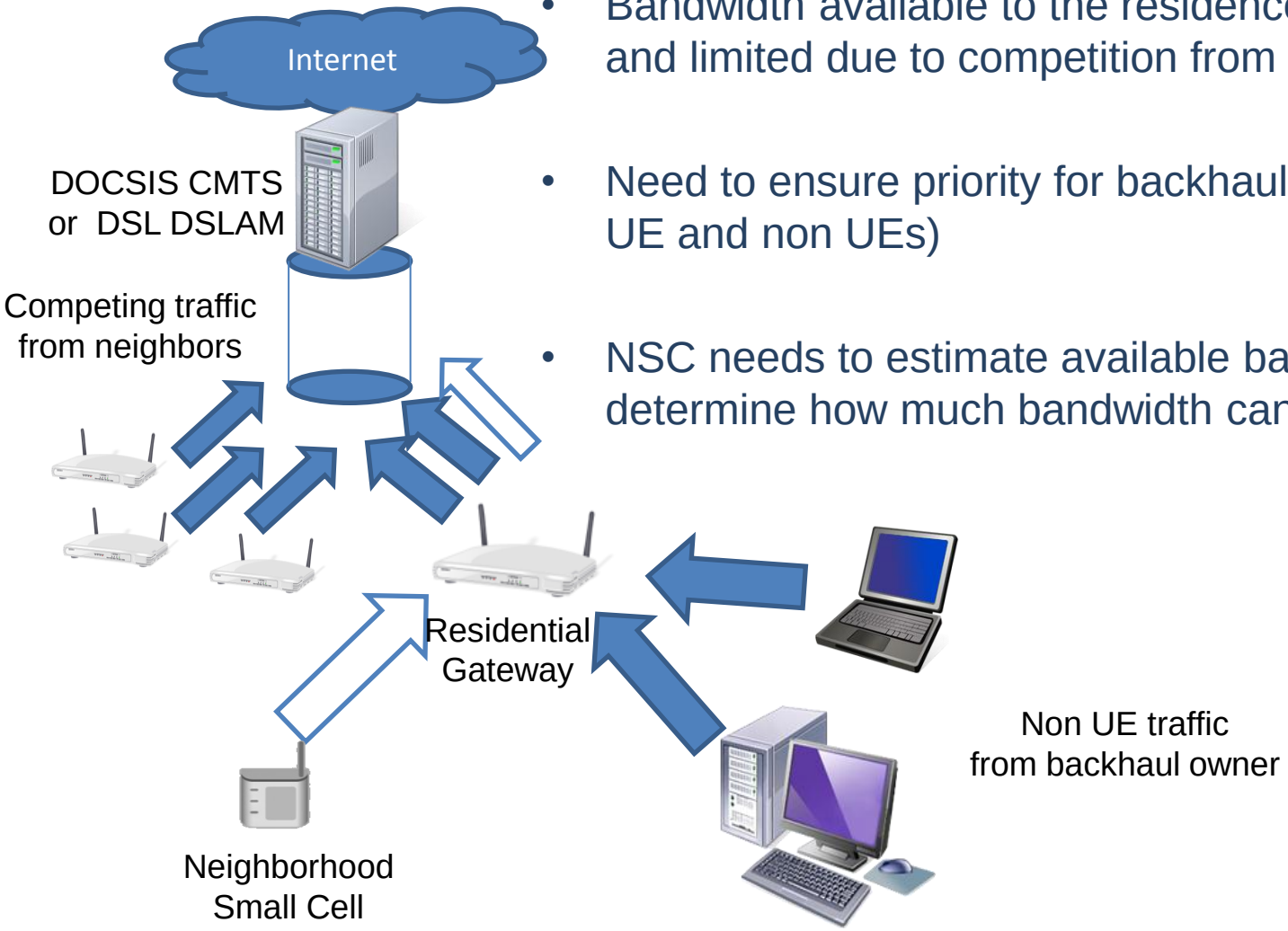
- PSC re-use amongst small cells can lead to PSC collision and confusion
  - PSC pool limited by neighbor list size constraints in 3G
  - Collision results in interference
  - Confusion causes handover issues
- PSC selection needed to minimize collision and confusion
  - Avoid PSCs detected by Network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

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