Qualcomm Research

Neighborhood Small Cells & UltraSON Open For LTE

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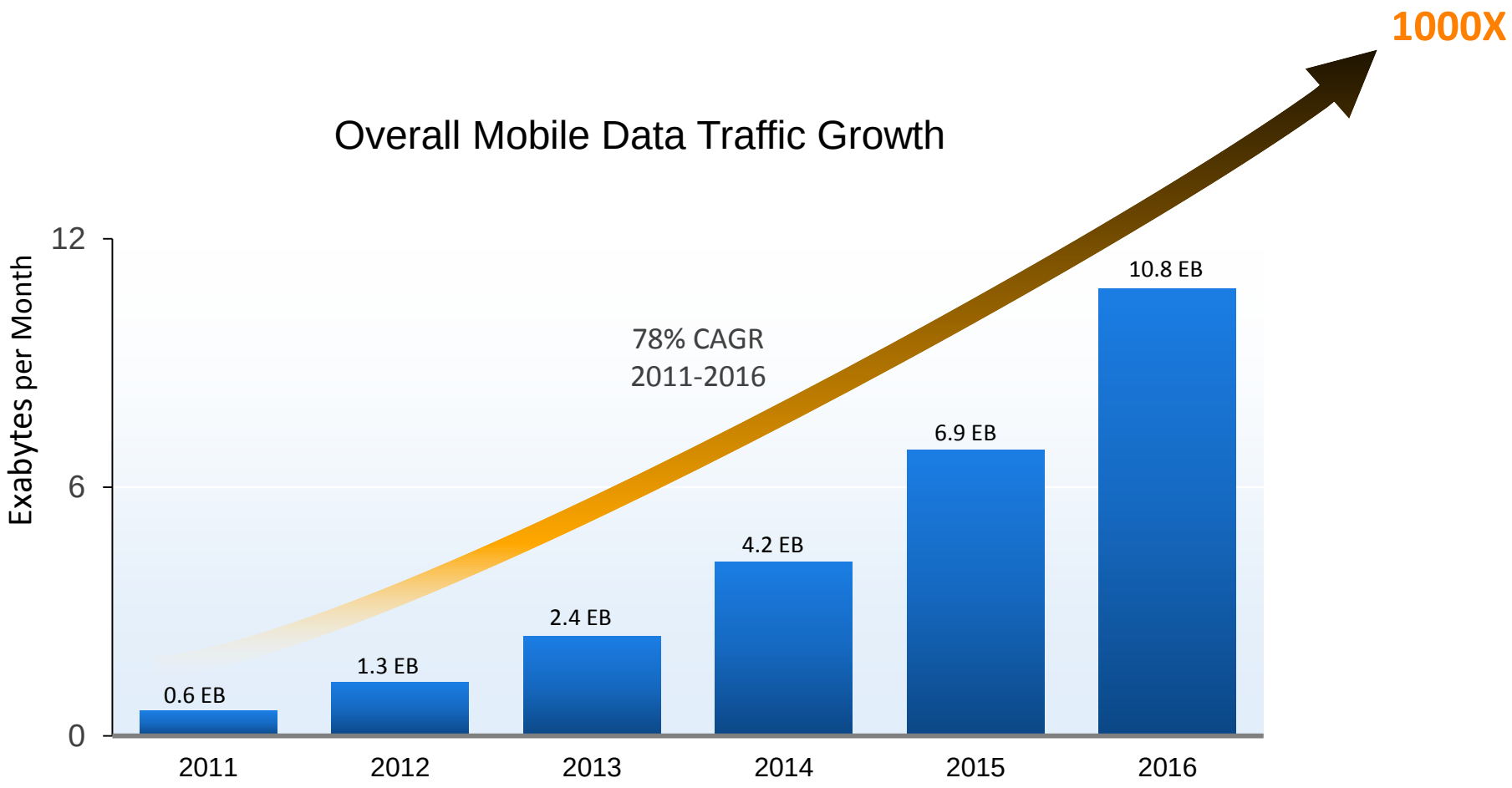
Overview

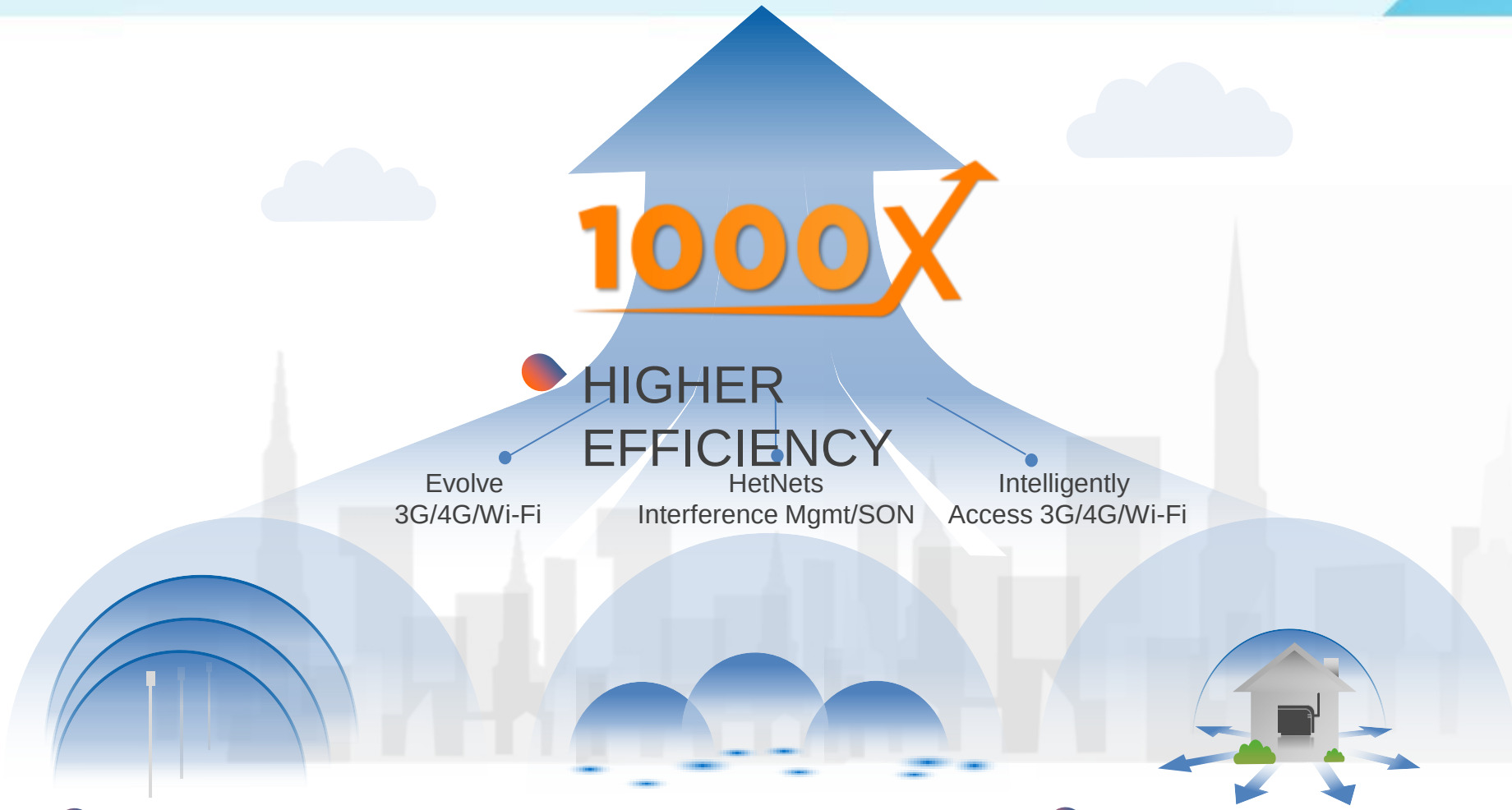
Strong Mobile Data Demand Requires Extra Capacity



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

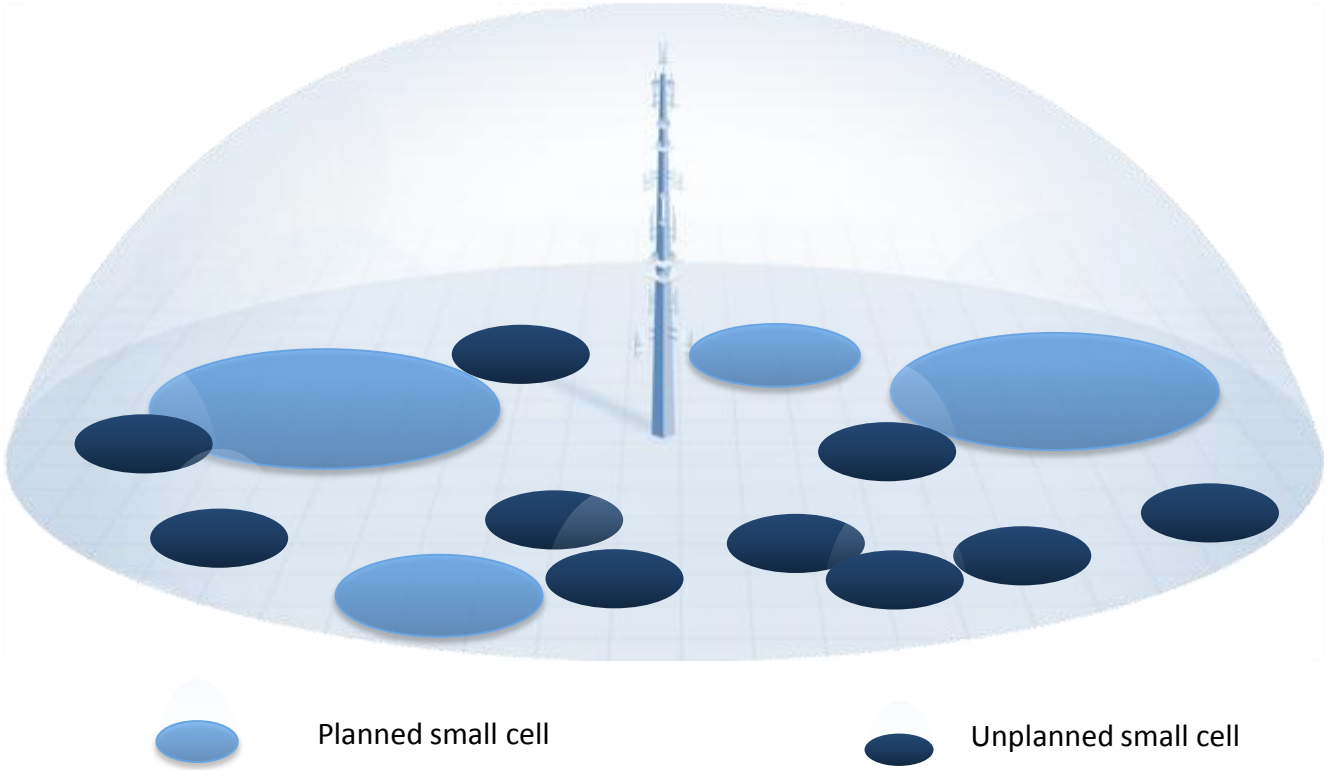
+

planned small cells

+

dense unplanned* small cells

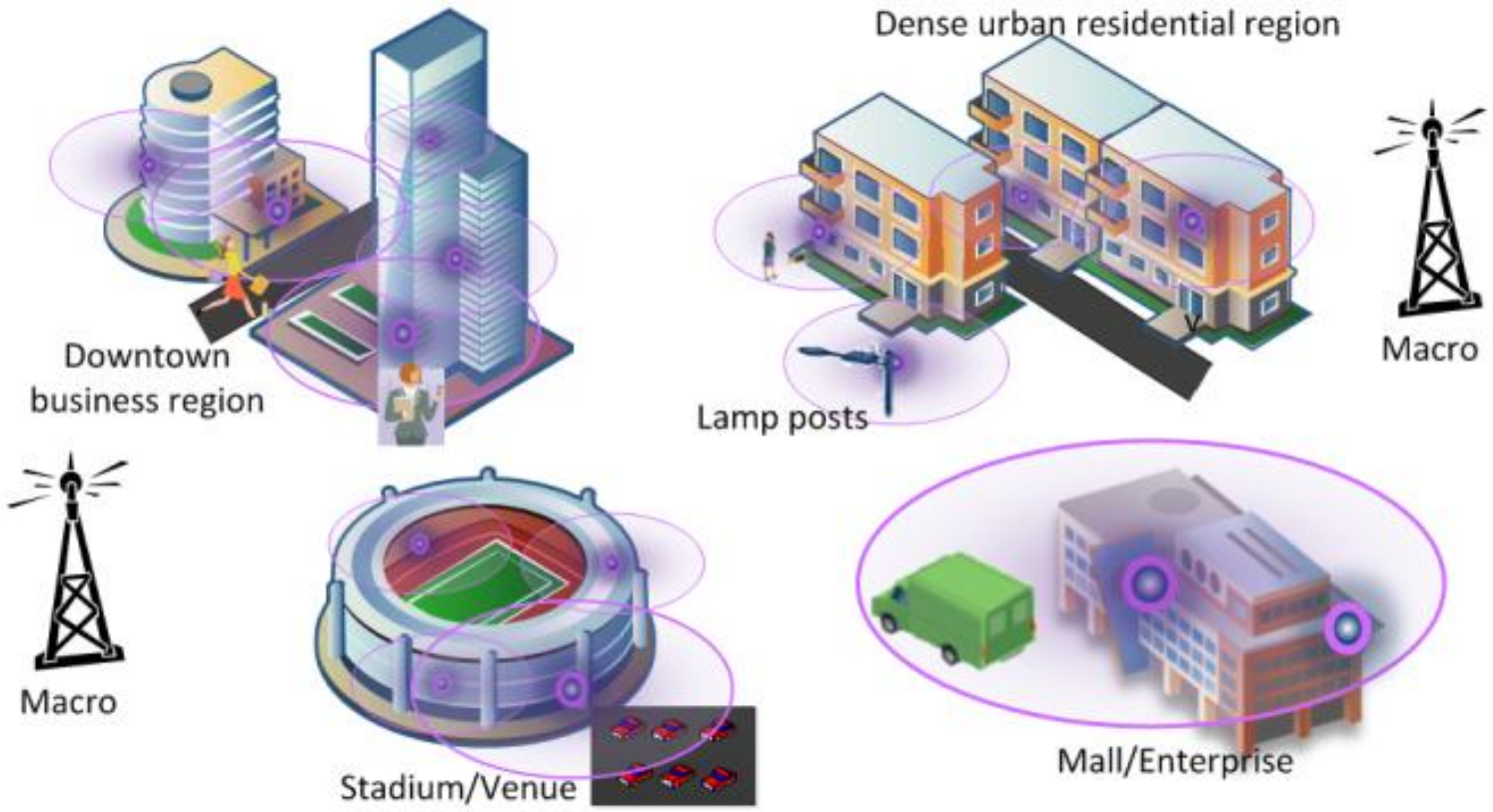
Combined network managed by operator



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

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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*

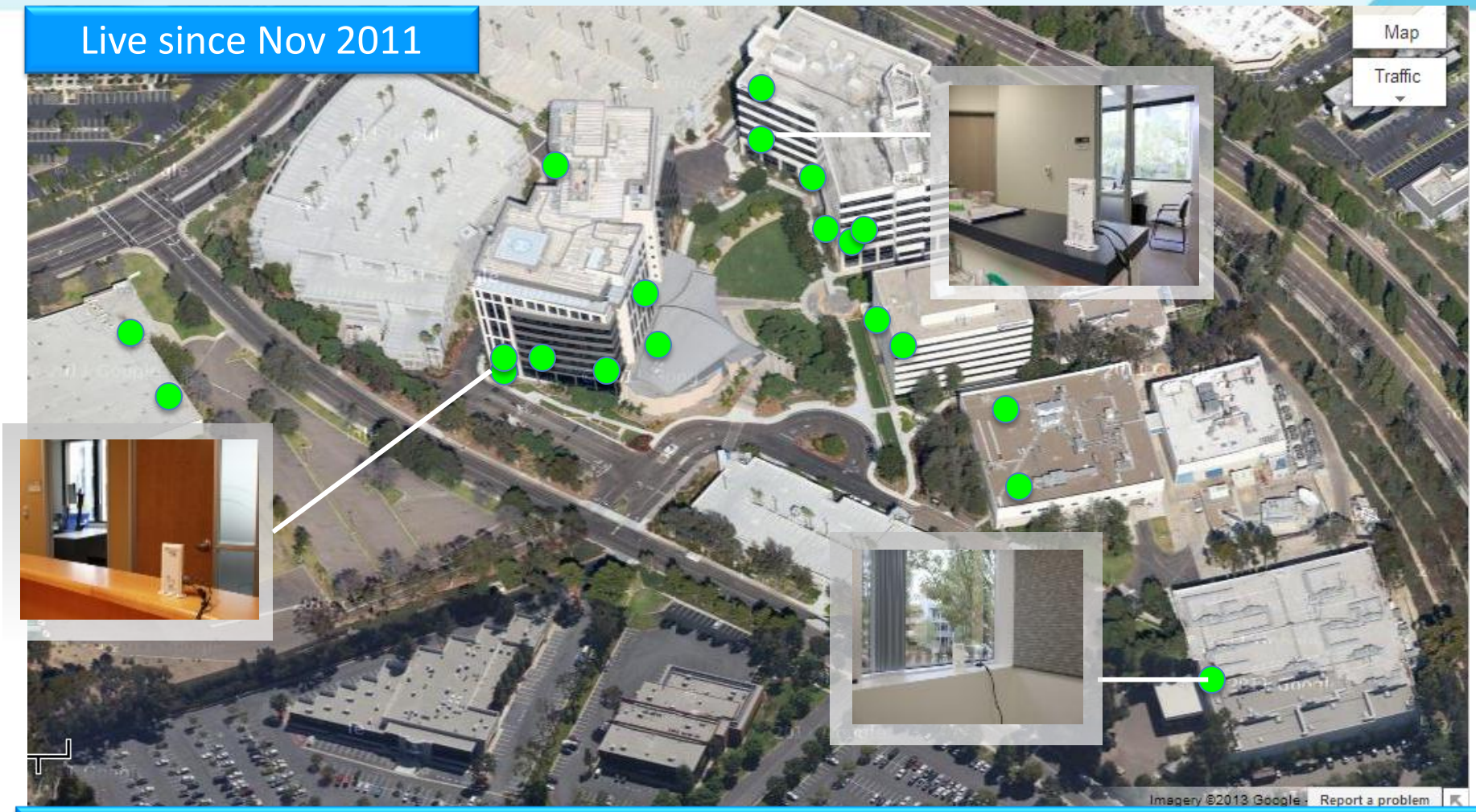
RSCP [dBm]	
	-115 to -105
	-105 to -95
	-95 to -85
	-85 to -75
	-75 to -65
	-65 to -55

- 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

Dense Urban Neighborhood Small Cells Simulation

Assumptions

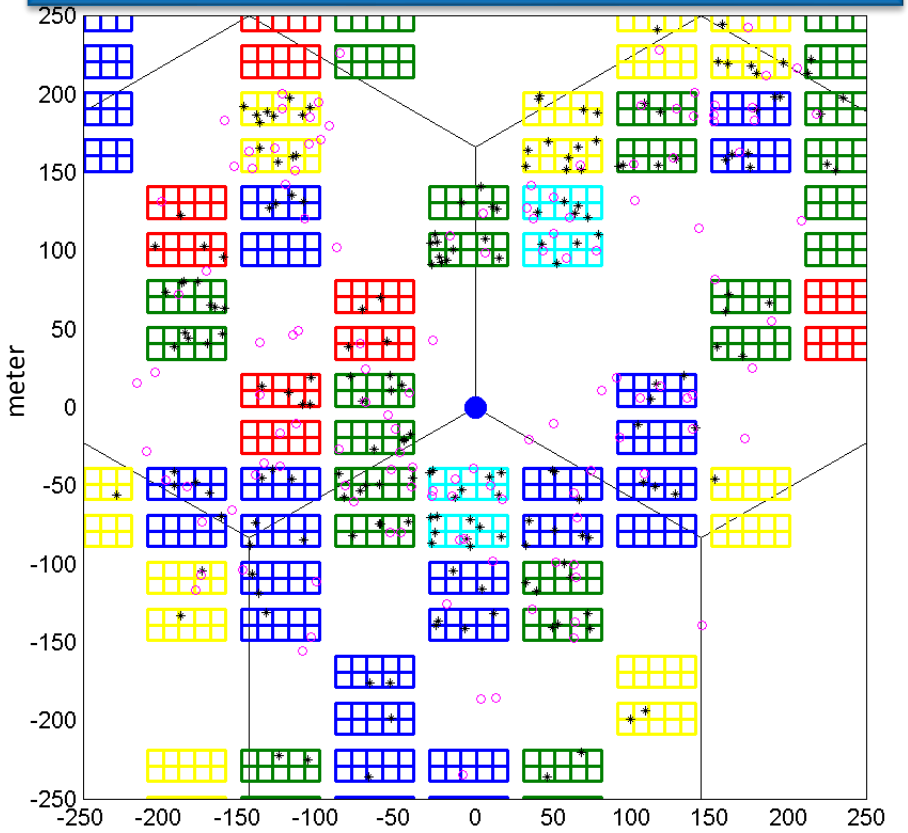
Parameter	Value
Macrocell ISD	500m
Population Density	20000 per sq km
Number of Apartments per Macrocell (2 subs per Apt.)	720
User Distribution	70% Indoors/ 30% Outdoors; Randomly dropped

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)



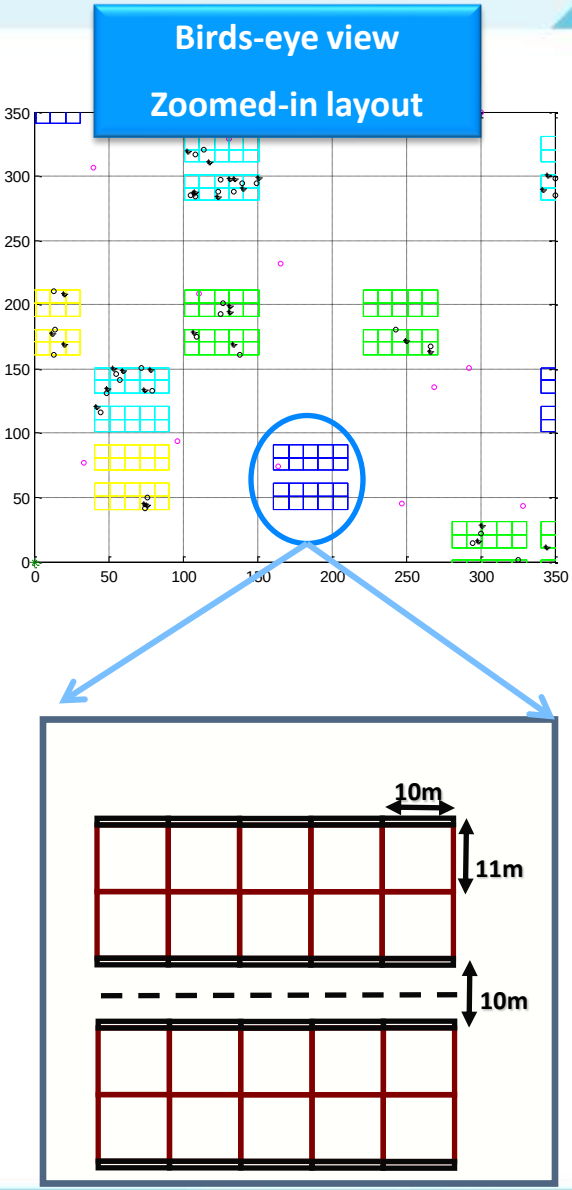
Red: 2 story bldg
Blue: 3 story bldg
Green: 4 story bldg
Cyan: 5 story bldg
Yellow: 6 story bldg

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

Neighborhood Small Cell Capacity Simulation

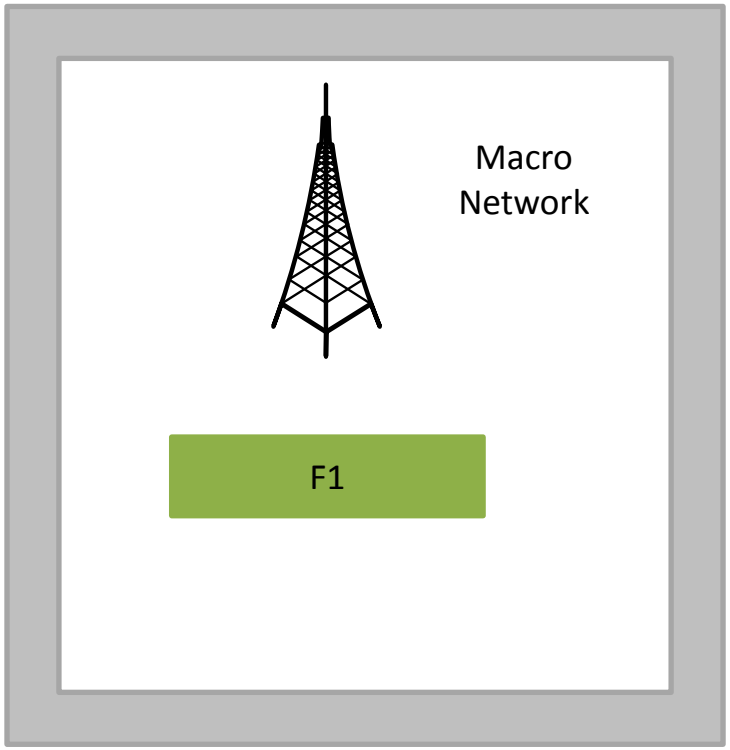
Dense Urban Model Configuration

- 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)



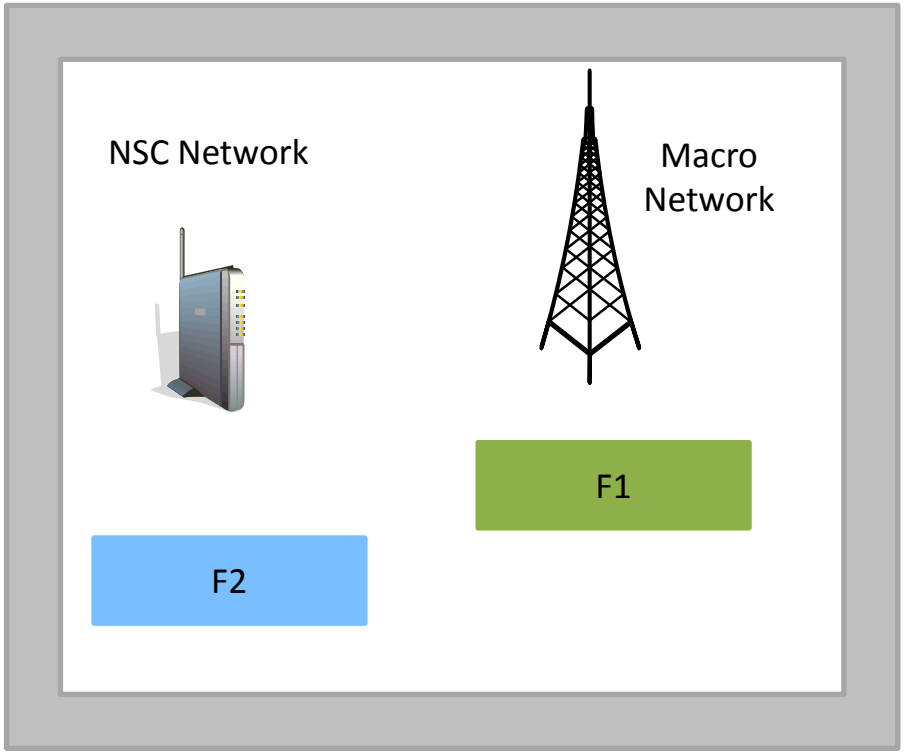
Neighborhood Small Cells Capacity Simulation

Baseline (macro-only) vs. Macro+Small Cells Deployments



Baseline Macro Deployment

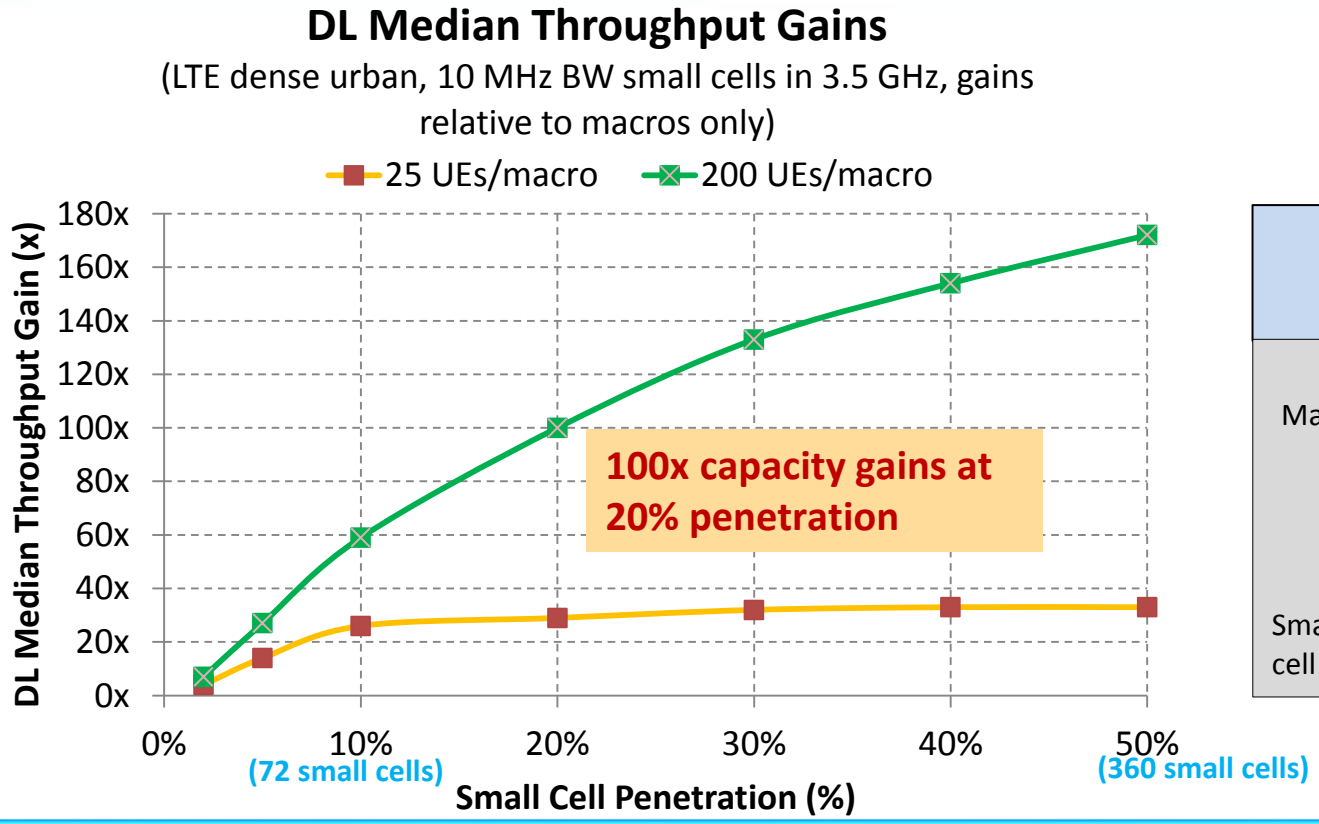
Rel 8 LTE, single 10 MHz LTE carrier at 2 GHz carrier frequency

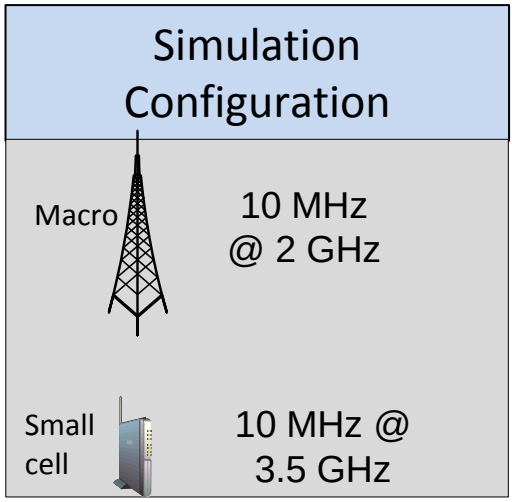


Macro + Small Cells Deployment

Rel 8 LTE, 10 MHz carrier for macros at 2 GHz while small cells are deployed in 3.5 GHz

Neighborhood Small Cells Provide Significant DL Capacity Gains for LTE

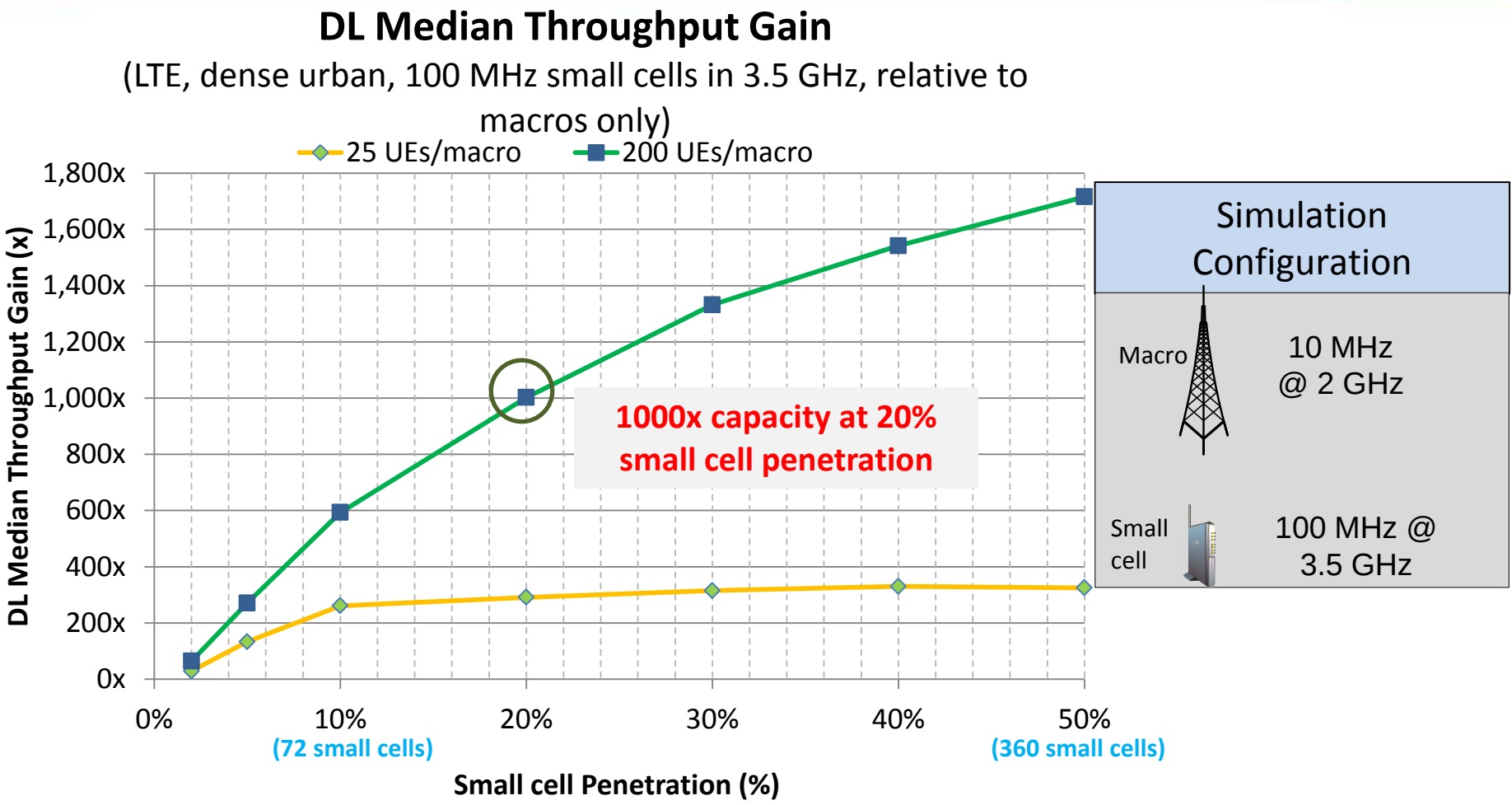




Neighborhood Small Cells Offer Scalable Capacity As Demand Increases

- 500m ISD, 720 apartments/cell, 2 subs/apartment. Users randomly dropped, 70% indoor and 30% outdoor, 2x2 MIMO
- Gains shown are relative to macro-only baseline. Macros deployed in 10 MHz bandwidth at 2 GHz. Small cells deployed at 3.5 GHz with 10 MHz bandwidth.
- Small cell penetration is percentage of total apartments per macrocell (720) with a small cell. For a particular operator, this number cannot exceed its own market share. For example, an operator with 30% market share can at most have 216 small cells in a macro (assuming no small cell is deployed outside customer premise by the operator).

Exceeding 1000x Capacity Gain With Dense Neighborhood Small Cells And More Spectrum



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SON Features For LTE NSC

LTE UltraSON™ Overview

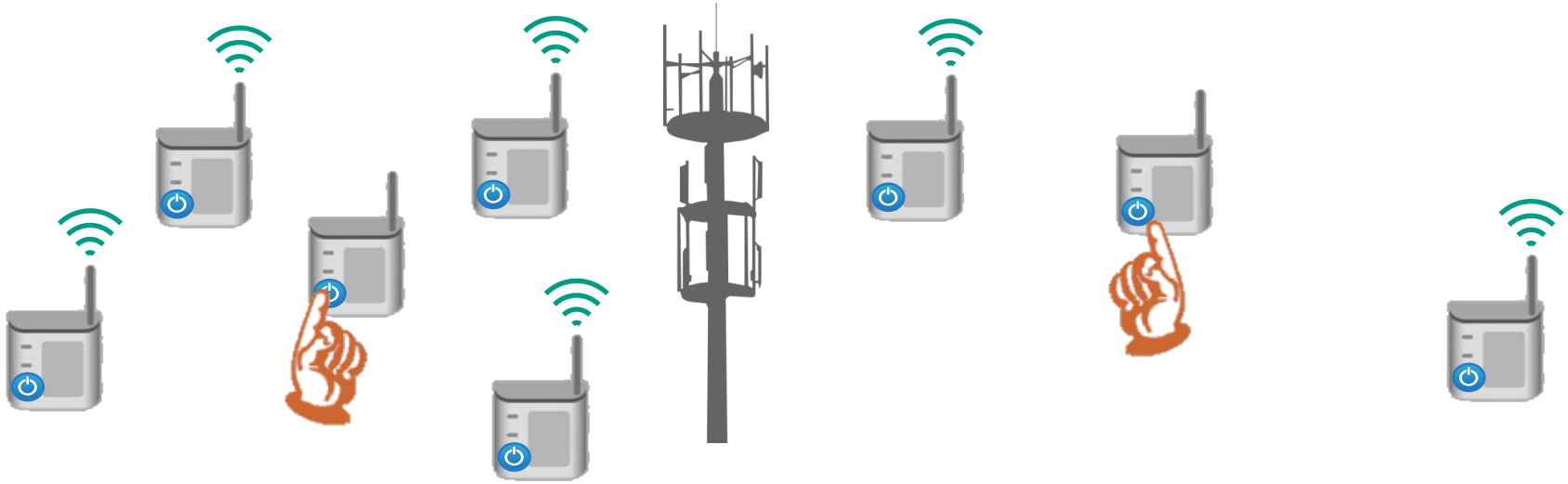
OBJECTIVE

- Optimize Handover performance and signaling load
- Optimize capacity and user experience
- Minimize pilot pollution
- Handle backhaul constraints

CATEGORY	UltraSON FEATURES
Mobility Management	• Frequent Handover Mitigation • Forward handover • Robust mobility signaling • Automatic neighbor discovery
Tx Power Management	• Network listen based Tx power Mgmnt. • UE-assisted Tx power management
Resource and Interference Management	• Resource partitioning and coordination • Load balancing between macro and small cell layer
Backhaul Management	• User prioritization based on backhaul • Load balancing based on backhaul

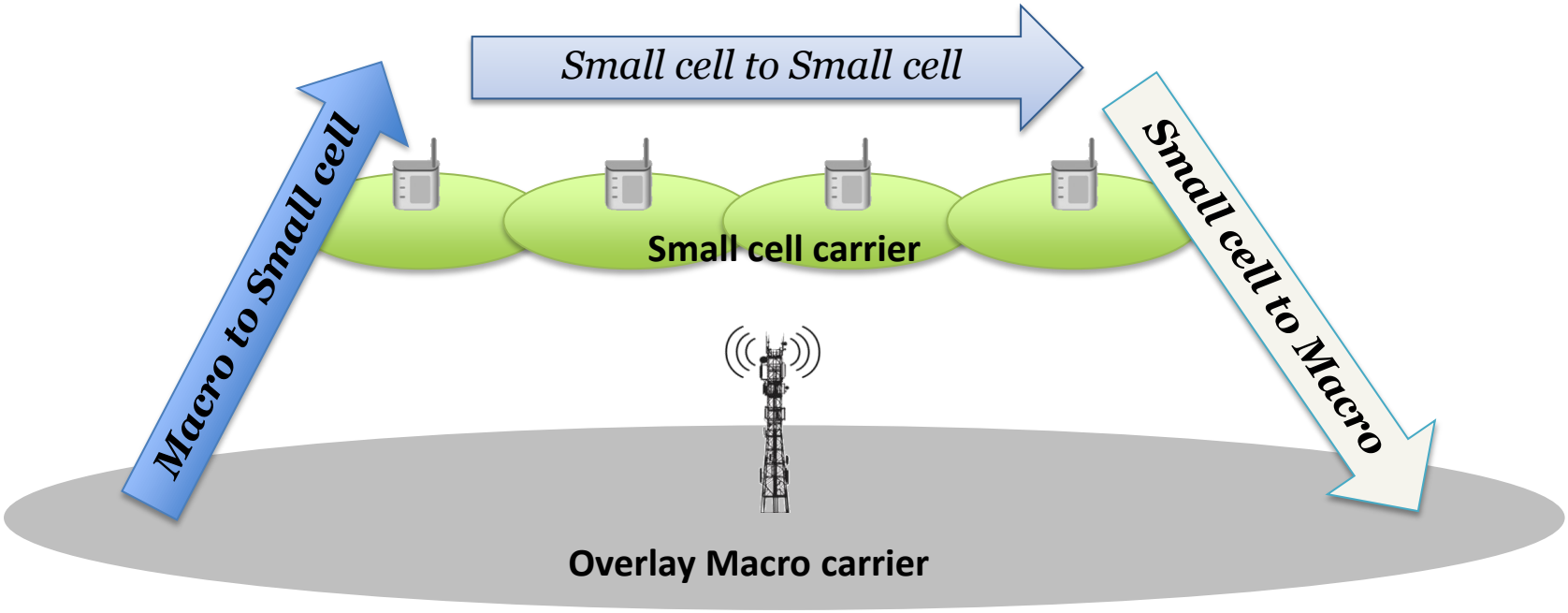
SON Features Help Small Cells Deliver Carrier-Grade Performance

- 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
• Select PCI and configure neighbor list • Calibrate Tx power • Optimize idle re-selection parameters and paging area	• Adapt Tx power & update neighbor list • Coordinate & partition resources with other cells • Monitor backhaul quality & prioritize preferred users • Balance load among different cells

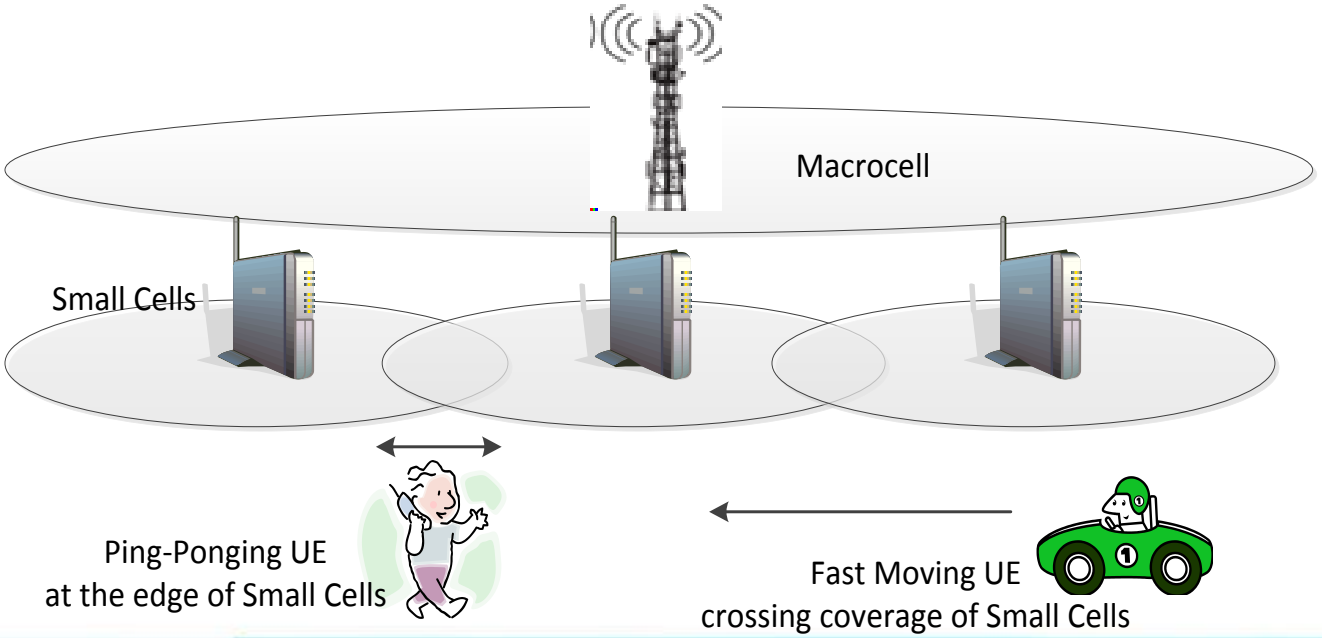
Main Considerations for Mobility Management for NSC



- 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

Frequent Handover Mitigation

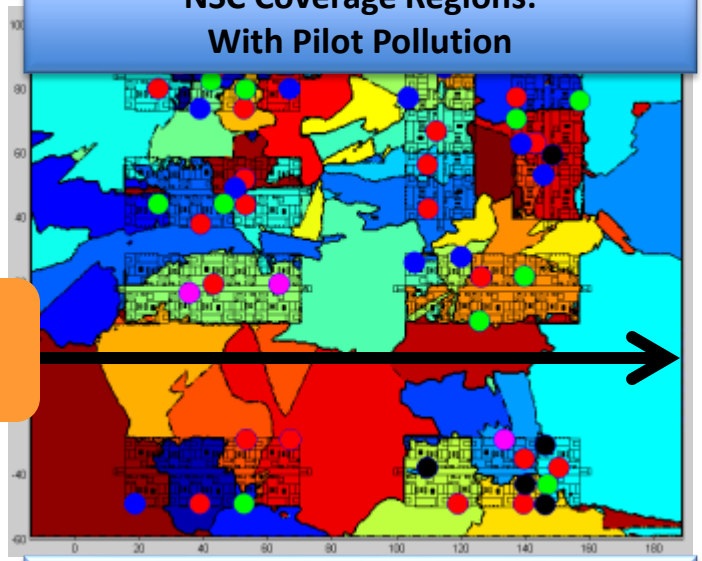
- Frequent handovers impact user experience and increased risk of call drop
- Classify users as high speed or ping-pong users based on handover history
- Handover high mobility users to macro layer
  - Ping-pong users handed over to macro layer if ping-pongs cannot be avoided through handover parameter adjustment
- In addition, leverage MRO framework for mobility parameter optimization for improved handover performance



Tx Power and Resource Management

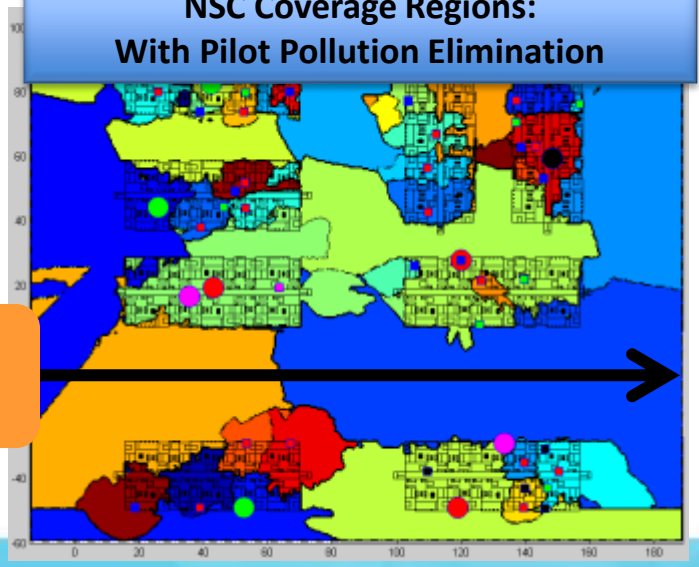
- Dense small cell deployment results in:
  - Frequent handovers due to pilot pollution
  - Degradation of SINR due to inter-SC interference
- NSC Tx power management to eliminate pilot pollution
  - Minimize number of handovers with minimal impact on coverage
- NSC resource management to maximize capacity
  - Resource/interference coordination to improve user SINR

NSC Coverage Regions: With Pilot Pollution



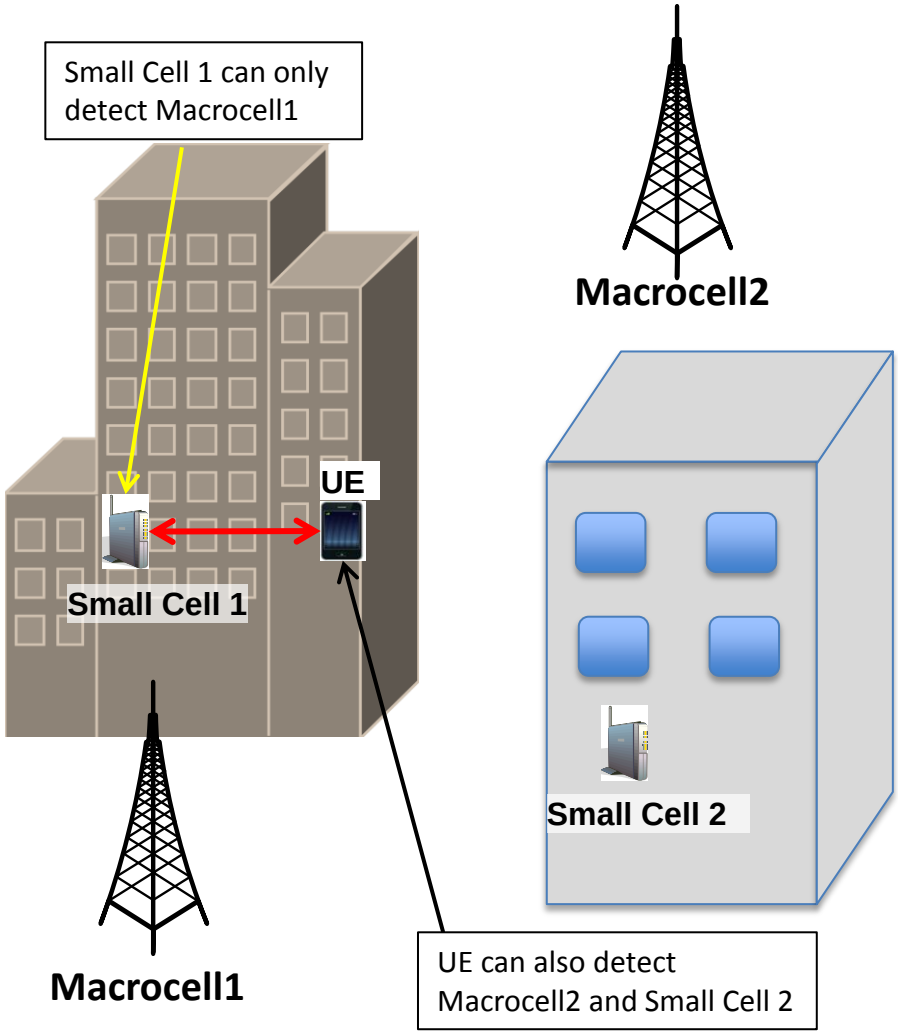
6 Hard Handovers along route

NSC Coverage Regions: With Pilot Pollution Elimination



2 Hard Handovers along route

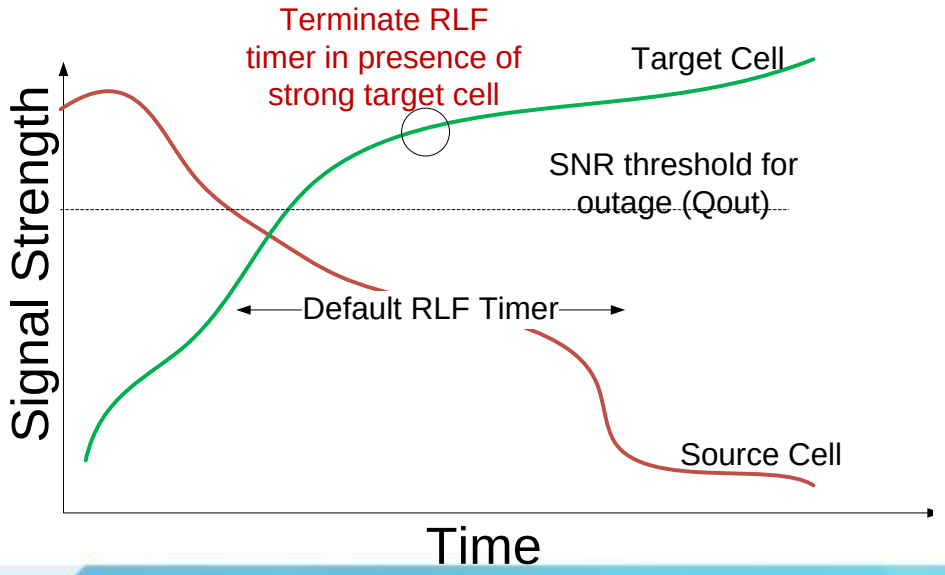
Neighborhood Discovery



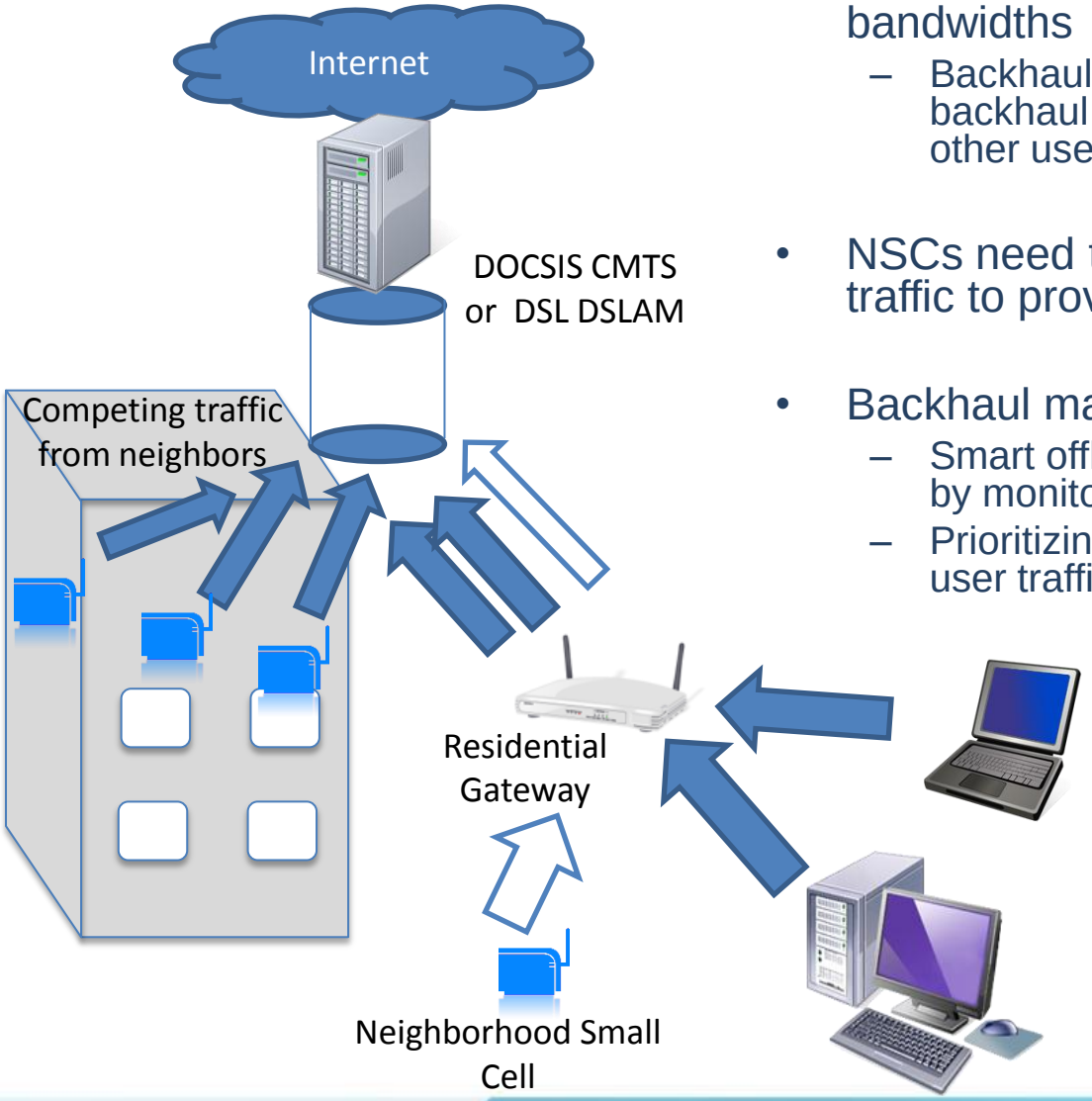
- Target PCI to Cell ID mapping need to be discovered to enable handover
  - Network Listen alone cannot detect all neighboring target cells for handover
- Mobile reports and X2 message exchange can be utilized to enhance the neighbor cell list determined via Network Listen
  - Leverage the ANR framework

Signaling Enhancements For More Robust Handover

- Allow early termination of T310 timer at UE when strong HO candidate is available
  - UE can be served by the stronger target cell sooner without getting stuck at source cell
- Target cell to fetch UE context from source cell via X2 in case it is not already prepared for HO
  - Forward Handover



Backhaul Management



- NSCs leverage existing backhaul with varying bandwidths
  - Backhaul bandwidth availability varies due to backhaul sharing with other traffic (e.g., WiFi) and other users
- NSCs need to ensure priority to backhaul owner traffic to provide optimal user experience
- Backhaul management is done via:
  - Smart offloading between small cells and macros by monitoring backhaul quality
  - Prioritizing home/enterprise user traffic over other user traffic

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