Femtocells

August 2011

A Low Cost Solution To Increase Indoor Coverage and Capacity

Femtocell

Improved Voice, Higher Data Rate, Macro Offload
With existing devices

Expands Beyond Hot-Spot—to Femto Networks
To enable dense, large scale residential and enterprise deployments

Requires Innovative Interference Management
Due to restricted access but also for large scale open access deployments

Qualcomm: Industry Leading Femto Platform
Comprehensive, highly integrated solution with state of the art UltraSON interference management

Data Usage Increasing Rapidly—Majority of Voice and Data Usage Indoors

" More deployed 3G Femtos than 3G Macros "
- *Informa June 2011*

" Mobile data traffic more than doubled in 2010, and predicted to grow 10-12x from 2010-2015 "
- *Strategy Analytics, March 2011*

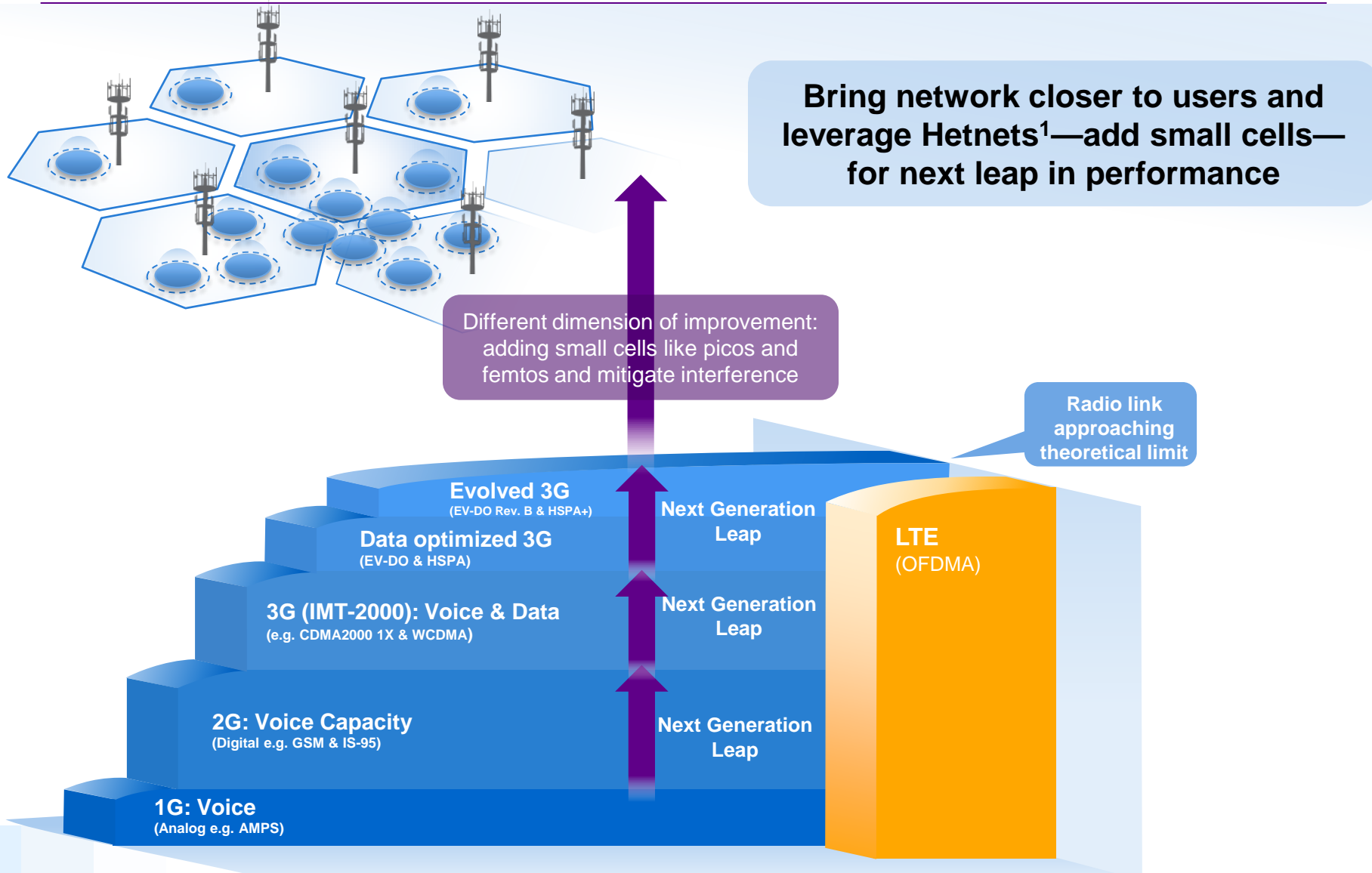" 70% of all voice and data traffic indoor in 2008[1] "
- *Informa 2008*

FEMTOCELLS ARE A LOW COST SOLUTION TO IMPROVE INDOOR VOICE & DATA

[1]Includes both data and voice traffic , indoor includes both home and office

Small Cells Will Provide
The Next Leap In Performance

Bring network closer to users and leverage Hetnets[1]—add small cells—for next leap in performance

Different dimension of improvement: adding small cells like picos and femtos and mitigate interference

Radio link approaching theoretical limit

Evolved 3G
(EV-DO Rev. B & HSPA+)

Data optimized 3G
(EV-DO & HSPA)

3G (IMT-2000): Voice & Data
(e.g. CDMA2000 1X & WCDMA)

2G: Voice Capacity
(Digital e.g. GSM & IS-95)

1G: Voice
(Analog e.g. AMPS)

Next Generation Leap

Next Generation Leap

Next Generation Leap

LTE
(OFDMA)

[1]Leveraging heterogeneous network topology: macro network with added small cells like picocells and femtocells

Femtocells Evolve To Femto Networks

RESIDENTIAL   SMALL ENTERPRISE   LARGER SCALE ENTERPRISE / RESIDENTIAL

Initially: Indoor Hot-Spots

FEMTOCELLS USED AS TRADITIONAL PICOCELLS

Next: Denser Indoor And Even Outdoor Deployments

- Deployed by user—"unplanned"
- Supports restricted access
- User's broadband connection
- Scalable Femto network architecture

- Also deployed by operator
- More enterprise and open access
- Inter-Femto service continuity (soft HO)
- Interference coordination

Femtocells Deliver Both End-User and Operator Values—With Existing Devices

OPERATOR BENEFITS

Enhanced Coverage and Capacity
OFFLOADS MACRO NETWORK

Reduced Churn and Cost
INDOOR COVERAGE MAIN CHURN REASON.
REDUCE BACKHAUL, SITE COST

New Revenue and Services
ADDITIONAL ARPU – FEMTO, TARIFFS,
BUNDLES, FEMTO ZONE SERVICES

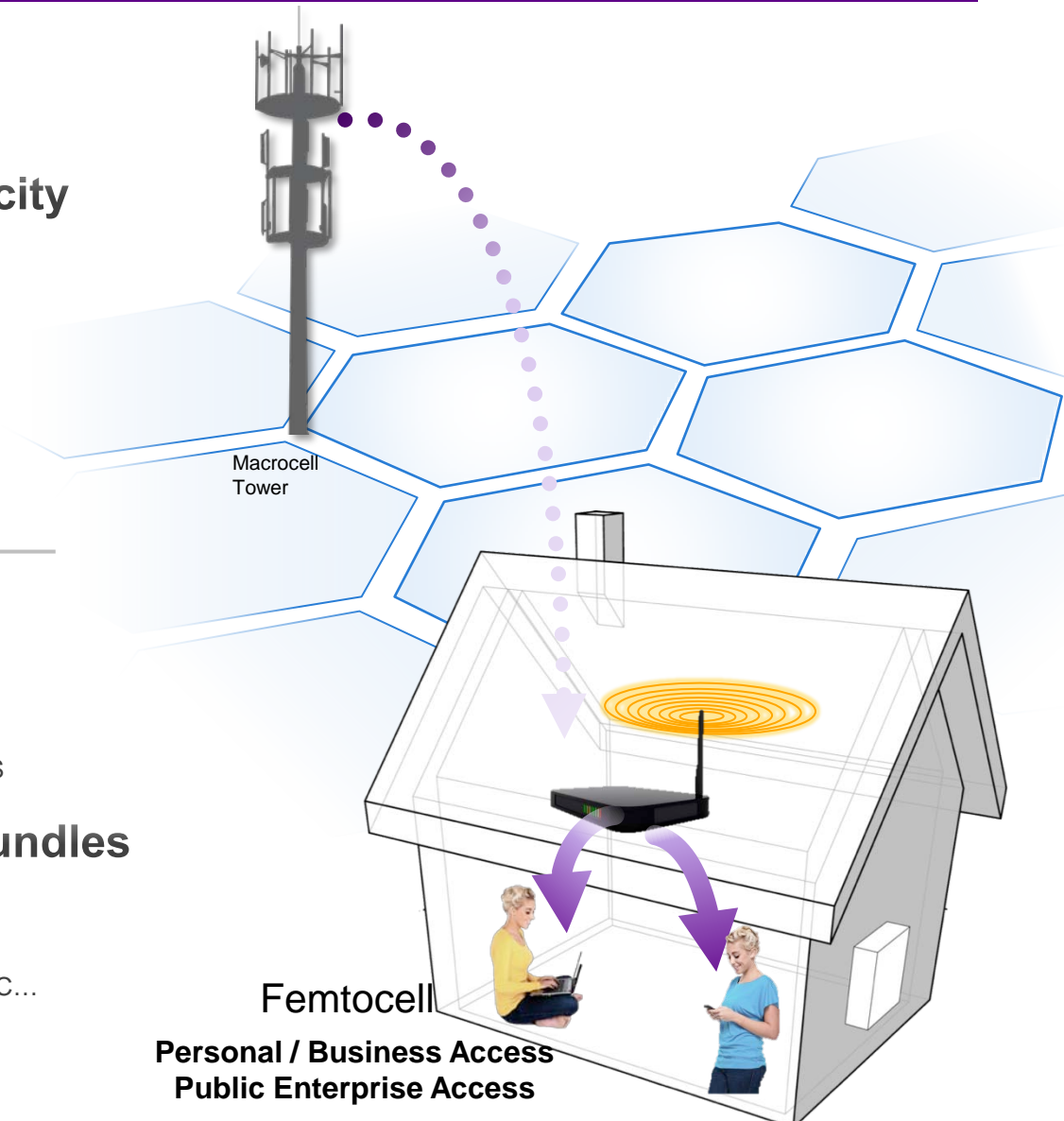## END-USER BENEFITS

Enhanced User Experience
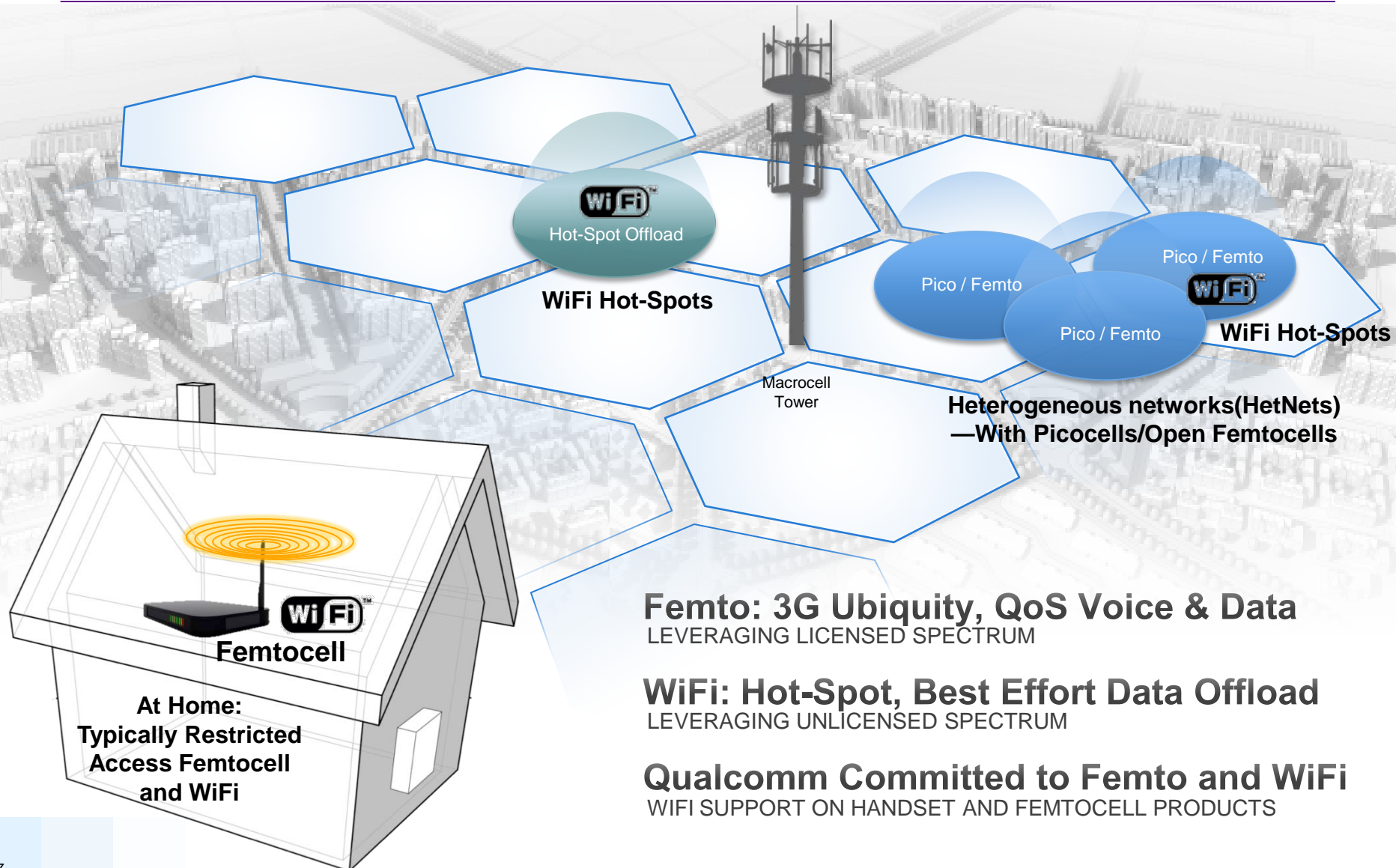IMPROVED VOICE QUALITY AND HIGHER DATA RATES

Attractive Femto Tariffs and Bundles
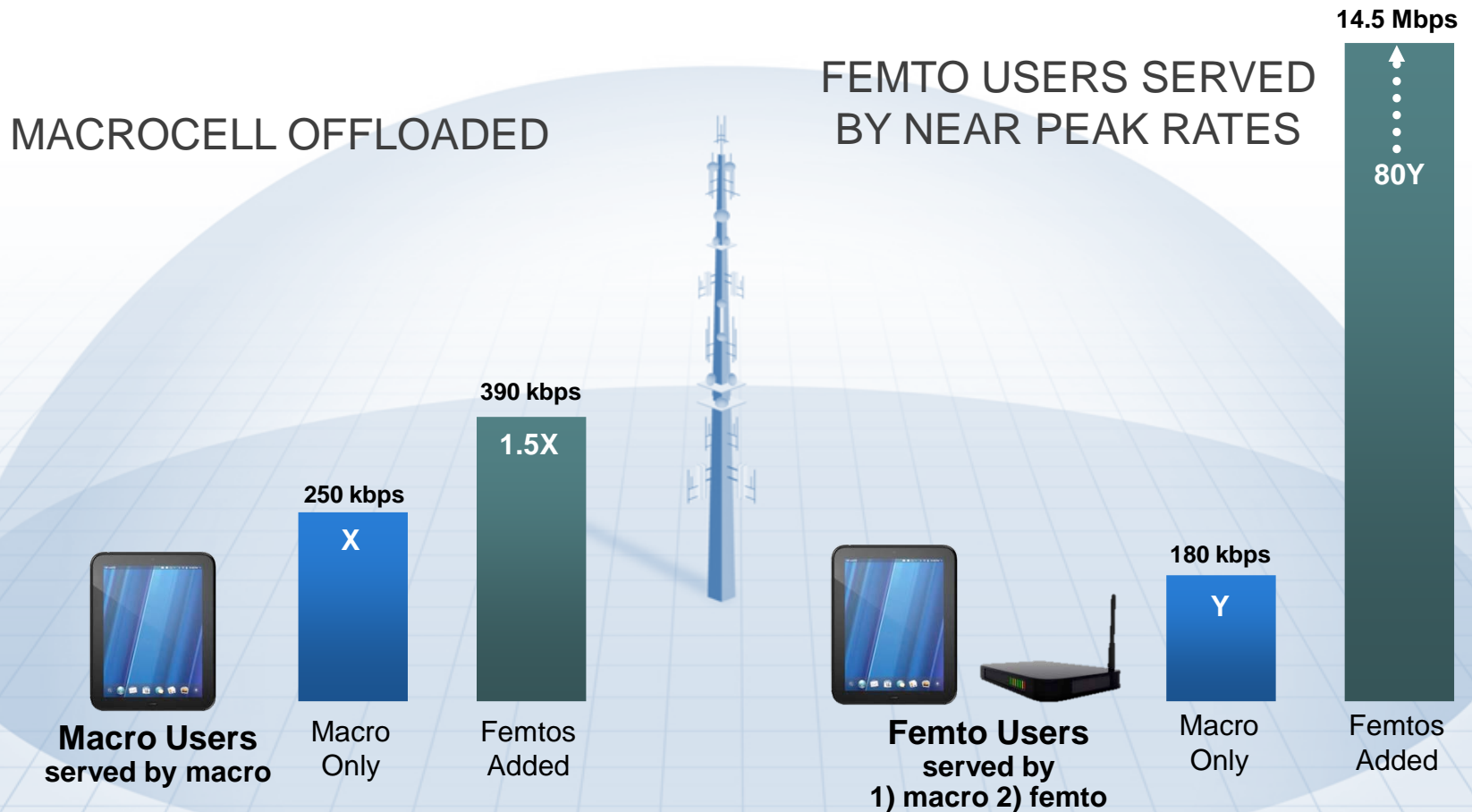ENABLES WIRELES SUBSTITUTION

New Femto Zone Services
BASED ON LOCATION, INTERACTION WITH MEDIA, ETC…

Macrocell
Tower

Femtocell

Personal / Business Access
Public Enterprise Access

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WiFi Complements Femtocells

WiFi Hot-Spots

Hot-Spot Offload

Macrocell Tower

Pico / Femto

Pico / Femto

Pico / Femto

WiFi Hot-Spots

**Heterogeneous networks(HetNets)
—With Picocells/Open Femtocells**

Femtocell

**At Home:
Typically Restricted
Access Femtocell
and WiFi**

Femto: 3G Ubiquity, QoS Voice & Data
LEVERAGING LICENSED SPECTRUM

WiFi: Hot-Spot, Best Effort Data Offload
LEVERAGING UNLICENSED SPECTRUM

Qualcomm Committed to Femto and WiFi
WIFI SUPPORT ON HANDSET AND FEMTOCELL PRODUCTS

Femtocells Offload the Macro Network and Enable High Data Rates

MACROCELL OFFLOADED

FEMTO USERS SERVED BY NEAR PEAK RATES

14.5 Mbps
80Y
Femtos Added

390 kbps
1.5X
Femtos Added

250 kbps
X
Macro Only

180 kbps
Y
Macro Only

Macro Users
served by macro

Femto Users
served by
1) macro 2) femto

Handset Advanced Receivers Even More Beneficial for Femto Deployments

RECEIVE DIVERSITY AND EQUALIZER IMPROVES QUALITY AND CAPACITY

ALL MACRO USERS IMPROVED

390 kbps
>3X

140 kbps
X

1 RX antenna

2 RX antennas and Equalizer
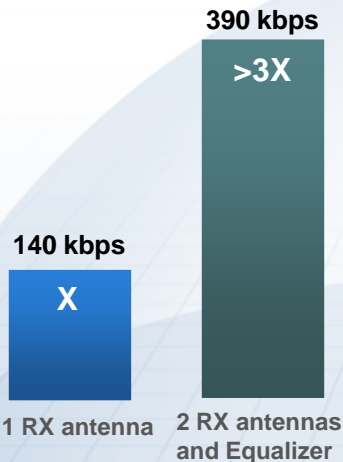
Median DL data rates macro users

'WORST' FEMTO USERS IMPROVED MOST

6.2 Mbps
2X

3.2 Mbps
X

1 RX antenna

2 RX antennas and Equalizer
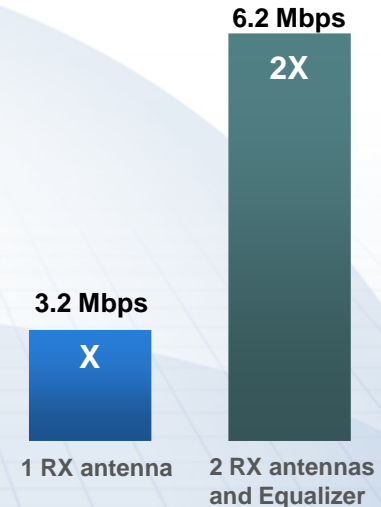
10% worst femto users' DL median data rates

Close Macro User impacted
(Restricted Access)

Home Users Impacted
By Neighbor Femto

Assumptions: Dense urban system simulation for HSPA+. 16 Users per cell: 10 macro users and 6 home users served either by macrocell or added femto cells. Rx diversity and MMSE Equalizer used. The median user data rates are shown for macro users and the 10% percentile for the 'worst' femto users.

Femtocells Require Innovative Interference and Mobility Management
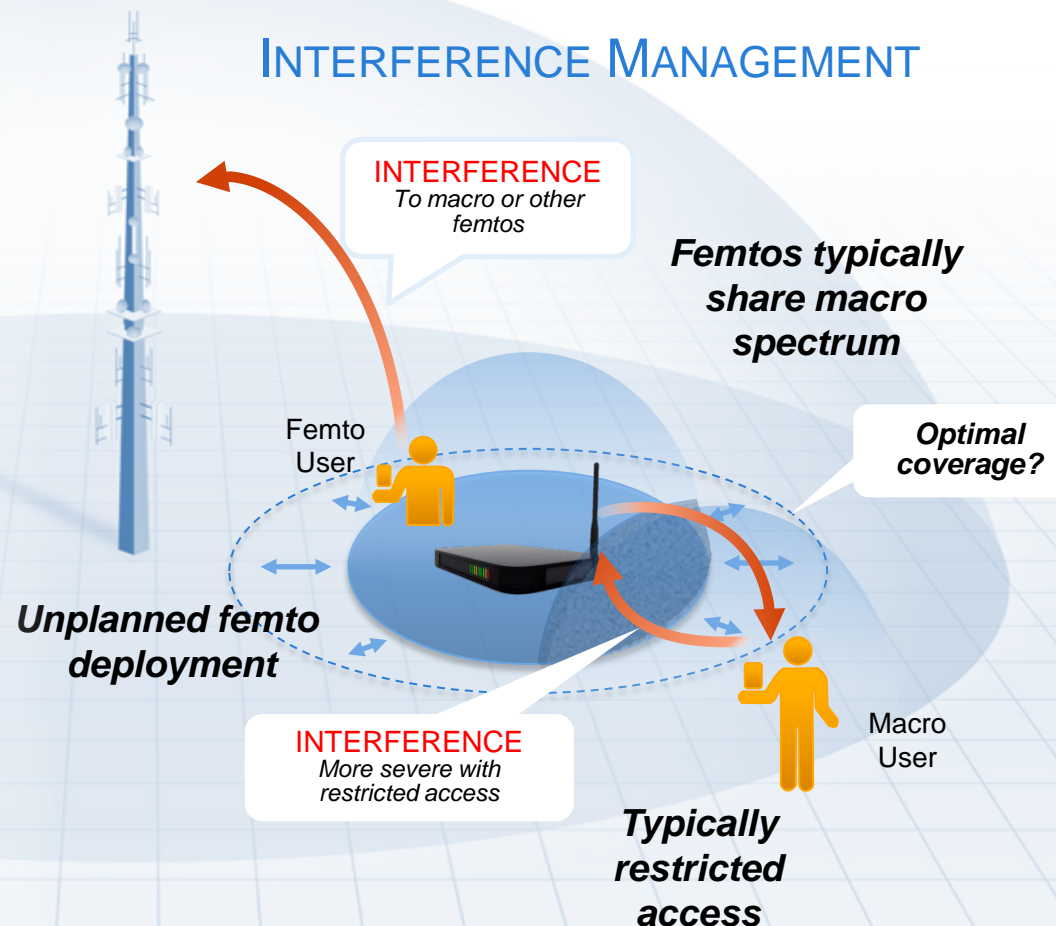
ENABLING LARGE SCALE DEPLOYMENTS

MOBILITY MANAGEMENT

- Need to discover femto
  (with femto beacon supporting legacy devices)

- Need reliable macro/femto handovers
  (e.g. femto beacon assisted hand-in)

ALL PART OF QUALCOMM'S UltraSON

INTERFERENCE MANAGEMENT

INTERFERENCE
To macro or other femtos

Femtos typically share macro spectrum

Optimal coverage?

Femto User

Unplanned femto deployment

INTERFERENCE
More severe with restricted access

Typically restricted access

Macro User

Qualcomm's Innovative Interference Management—Part of UltraSON

ENABLING LARGE SCALE DEPLOYMENTS

INITIAL SELF-CALIBRATION

- Network listen to select carrier, set femto transmit power etc.

FEMTO RANGE TUNING

- Fine tune range with handset assistance
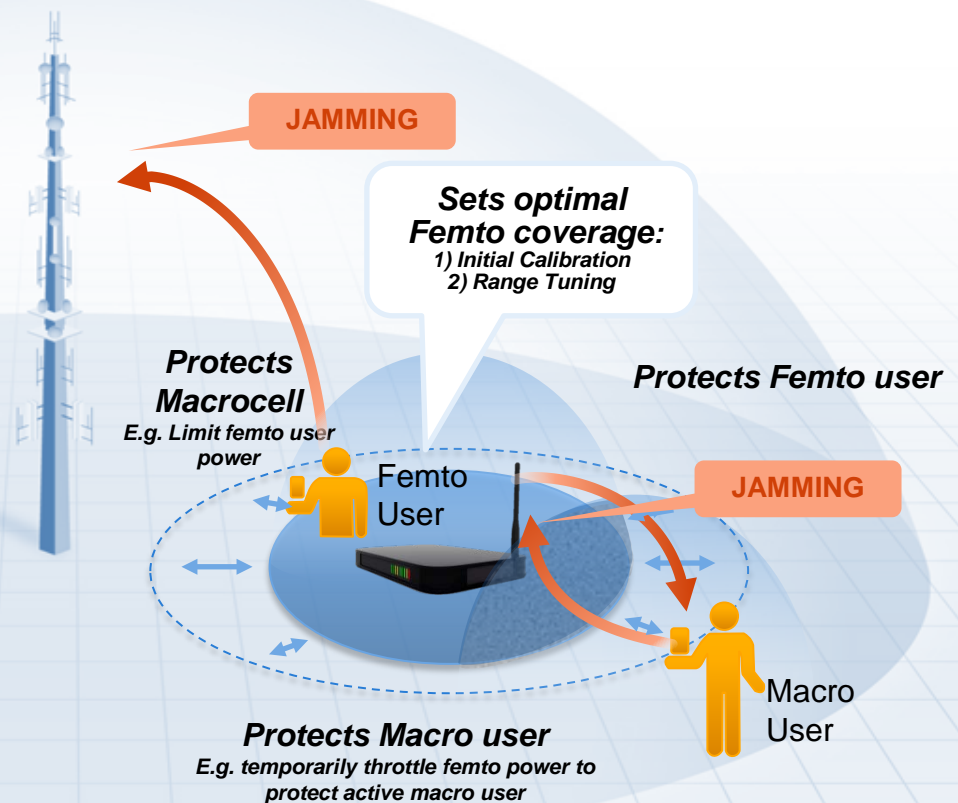- Technician assisted for Enterprise femtos

FEMTO USER PROTECTION

- Set appropriate femto noise rise threshold based on femto location

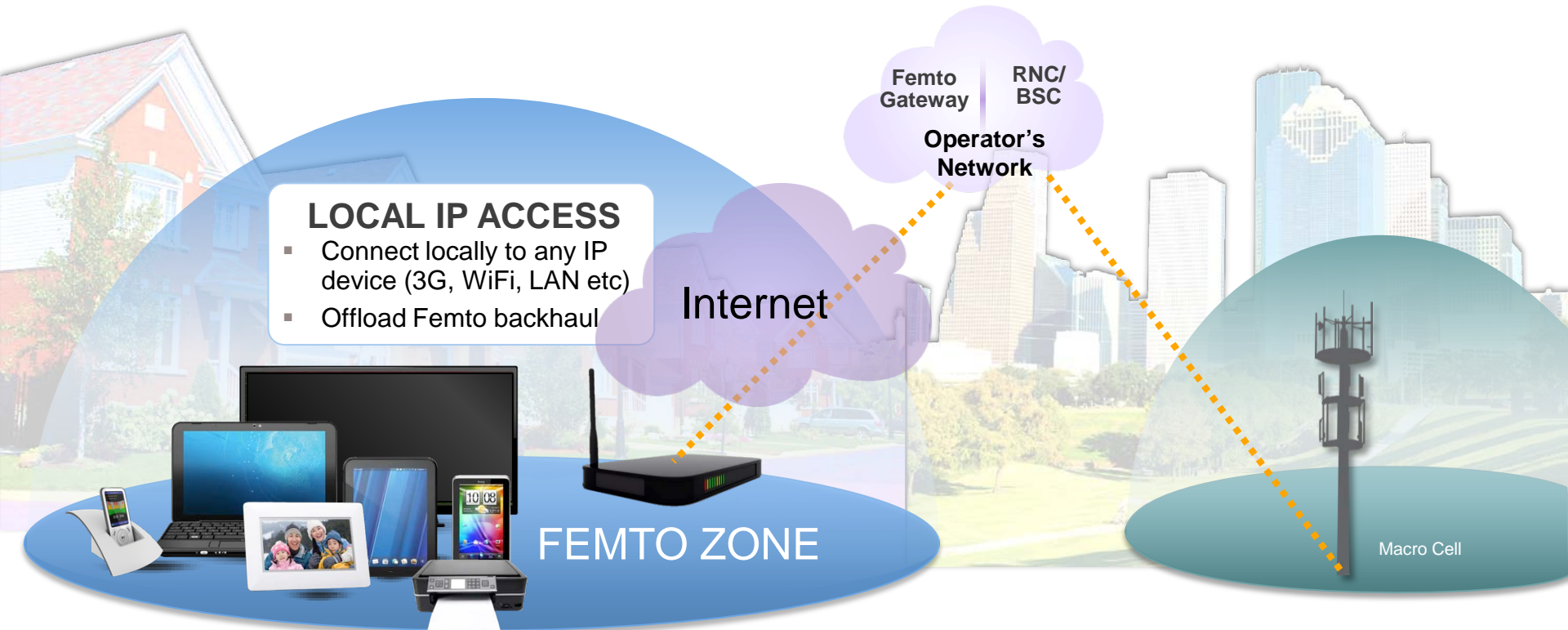### GUEST / NEARBY MACRO USER PROTECTION

- Detect active guests/macro users to temporarily throttle femto power

MACROCELL PROTECTION

- Limit femto user transmit power
- Set appropriate femto noise rise threshold based on femto location

JAMMING

Sets optimal Femto coverage:
1) Initial Calibration
2) Range Tuning

Protects Macrocell
E.g. Limit femto user power

Protects Femto user

JAMMING

Femto User

Macro User

Protects Macro user
E.g. temporarily throttle femto power to protect active macro user

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Enables New Femto Zone Services

Femto Gateway

RNC/BSC

Operator's Network

LOCAL IP ACCESS
- Connect locally to any IP device (3G, WiFi, LAN etc)
- Offload Femto backhaul

Internet

FEMTO ZONE

Macro Cell

FEMTO ZONE SERVICES

- Leverage location, relationship etc. for new services
- Synch with local media/data servers (music, videos, data)
- Stream to/from local media servers, screens, printers
- Push services to Femto zone, remote control
- Additional Enterprise opportunities such as integrated IP-PBX services and desk phone substitution

REMOTE ACCESS[2]

- Access Femto zone remotely
- Remotely control media servers, appliances…

Examples—Femto Zone Services
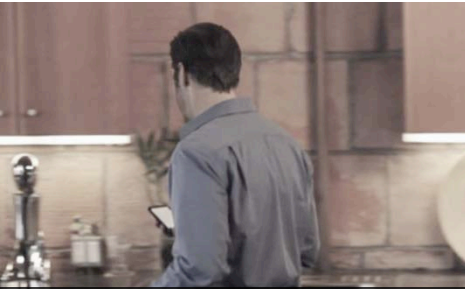
Location Based

- Alert family members when a family member enters the femto zone
- Virtual home number— call all mobile devices in home zone
- Interact with social media—update presence and location information automatically when entering femto zone

Synch & Stream

- Automatic synchronization between mobile device and home media servers (music, videos, data, etc)
- Stream media (music, videos etc.) to/from mobile device and home entertainments system, screens, etc.

Remote Control

- Use mobile device as remote control for the media servers, TV etc.
- Use mobile device for home controls appliances and home settings like temperature and lights for the connected home

Push

- Push content to femto based on location, context and customer relationship
- Femtocells can utilize unique knowledge of femto usage pattern and subscriber relationship to push personalized services
- A business can deploy femtocells and push location based advertisement

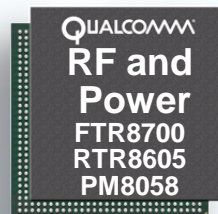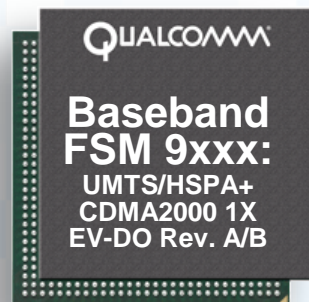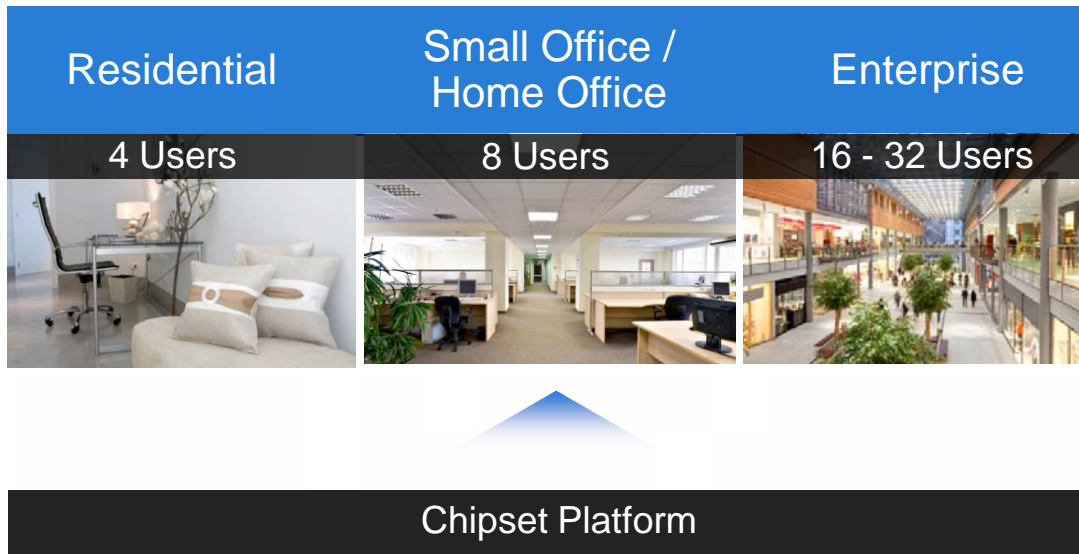# The Residential Femtocell Can Evolve to a Home Entertainment Gateway

Personal 3G Access → **Integrated Router** → **Home Entertainment Gateway**

Femtocell	Other Access (e.g. WiFi)	Home Backhaul (Router with DSL/Cable)	Media Consumption (e.g. IPTV)	Media Storage (e.g. DVR)	More…

INTEGRATED NETWORKING, ENTERTAINMENT HARDWARE, ETC.

Home Gateway

INTEGRATED SERVICES

Home Zone Services	Push Services	Personalization based on usage and user profile	Home Control	More…

New Home Zone Services → **Personalized services** → **Connected Home** →

Up Next: Large Scale Enterprise Femtocell Deployments

Typically Multiple Femtos To Cover a Floor

- **UltraSON enables large scale enterprise deployments**

- **Requires technician assisted coverage planning/range tuning**
  - Different challenges than residential deployments, such as larger interference variations
  - Technician assisted range tuning helps to set optimal femto coverage with least macro impact

- **Inter-femto soft handover ensures voice quality (or transmit diversity)**
  - Frequent Hard Handovers (HHO) can disrupt voice calls in an enterprise environment
  - Soft handover (SHO) reduces HHO rate, or if SHO is not available, use femto transmit diversity

Qualcomm: Industry Leading Femto Platform

Residential	Small Office / Home Office	Enterprise
4 Users	8 Users	16 - 32 Users

Chipset Platform

Baseband FSM 9xxx:
UMTS/HSPA+
CDMA2000 1X
EV-DO Rev. A/B

RF and Power
FTR8700
RTR8605
PM8058

- **Comprehensive, highly integrated solution**
  - Baseband, RF & power mgmt, integrated GPS
  - Common UMTS/HSPA+ & EV-DO/1X platform
  - 1GHz CPU based on Snapdragon
  - Transmit/Receive diversity and 2 x 2 MIMO
  - WiFi support

- **Enables very small form factor, low power products**

- **State-of-the-Art UltraSON interference, mobility and discovery management**
  - With integrated multiband network listen
  - Support for pilot beacons and active hand-in

- **Commercial FSM Products Launched in 2011**

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Comprehensive, highly integrated solution with state of the art UltraSON interference management

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http://www.qualcomm.com/blog/contributors/prakash-sangam

> Thank You

Qualcomm's Innovative Interference management —Part of UltraSON

Qualcomm's Innovative Interference Management—Part of UltraSON

INITIAL SELF-CALIBRATION
- Network listen to select carrier, set femto transmit power etc.

FEMTO RANGE TUNING
- Fine tune range with handset assistance
- Technician assisted for Enterprise femtos

FEMTO USER PROTECTION
- Set appropriate femto noise rise threshold based on femto location
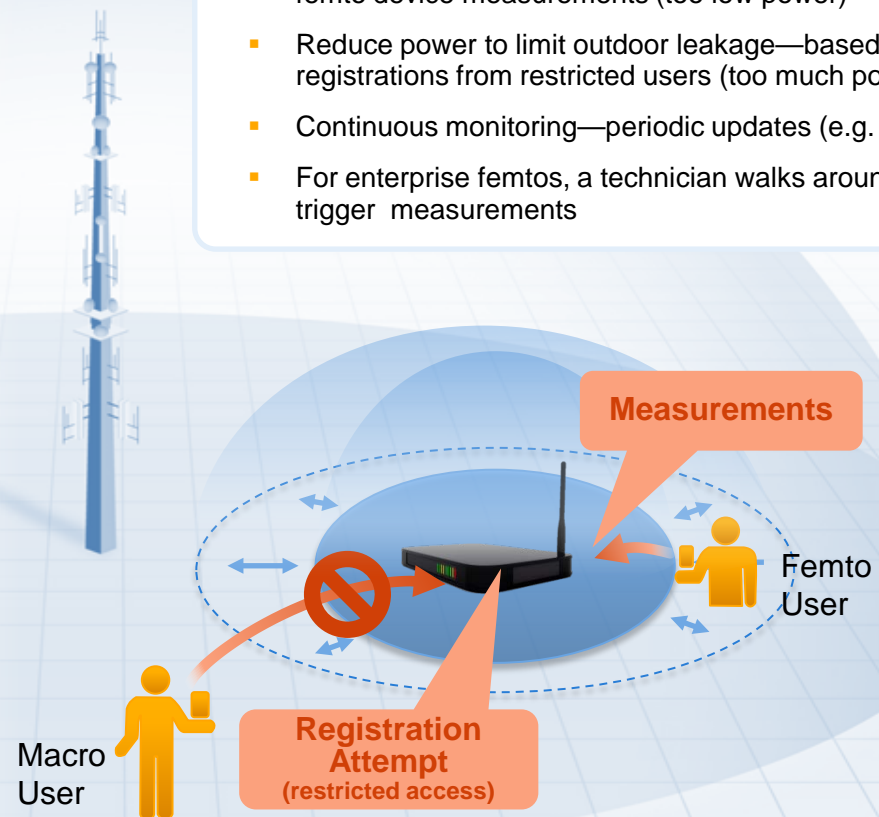
GUEST / MACRO USER PROTECTION
- Detect active guests/macro users to temporarily throttle femto power

MACROCELL PROTECTION
- Limit femto user transmit power
- Set appropriate femto noise rise threshold based on femto location

Sets proper femto coverage and minimizes impact on macrocell
- Measure strength of macro signal (and other femto cells)
- Power is set to achieve fixed femtocell coverage

Qualcomm's Innovative Interference Management—Part of UltraSON

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Fine tune femto range with handset assistance

- Increase power to improve indoor coverage—based on femto device measurements (too low power)
- Reduce power to limit outdoor leakage—based on registrations from restricted users (too much power)
- Continuous monitoring—periodic updates (e.g. daily)
- For enterprise femtos, a technician walks around to trigger measurements

Measurements

Femto User

Macro User

Registration Attempt (restricted access)

Qualcomm's Innovative Interference Management—Part of UltraSON

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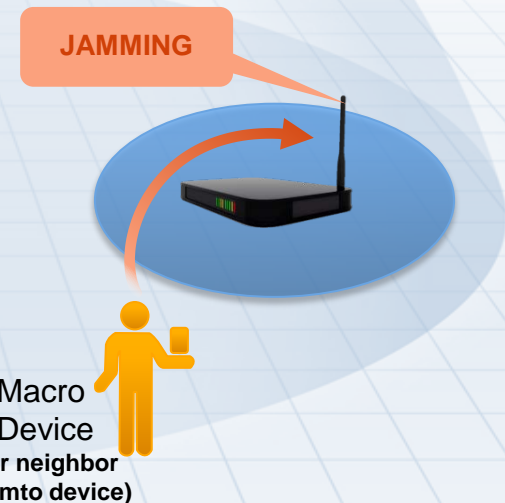
GUEST / MACRO USER PROTECTION

- Detect active guests/macro users to temporarily throttle femto power (especially for restricted access)

MACROCELL PROTECTION

- Limit femto user transmit power
- Set appropriate femto noise rise threshold based on femto location

Location based femto noise rise

- A femto closer to the cell edge is set to higher noise rise threshold to mitigate interference created by a nearby macro user (protecting the femto user)

JAMMING

Macro Device
(or neighbor femto device)

Qualcomm's Innovative Interference Management—Part of UltraSON

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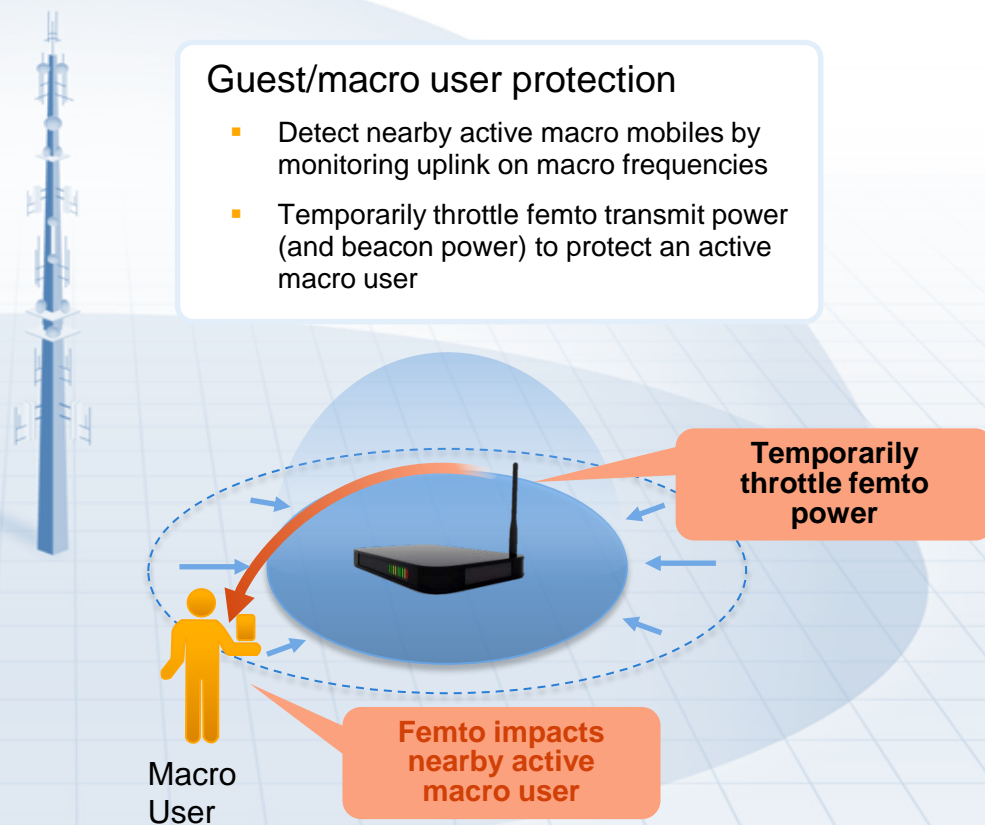
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MACROCELL PROTECTION

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Guest/macro user protection

- Detect nearby active macro mobiles by monitoring uplink on macro frequencies
- Temporarily throttle femto transmit power (and beacon power) to protect an active macro user

Temporarily throttle femto power

Femto impacts nearby active macro user

Macro User

Qualcomm's Innovative Interference Management—Part of UltraSON

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- Set appropriate femto noise rise threshold based on femto location

JAMMING

Limit femto user transmit power
- Cap device power dynamically, based on path loss to nearest macro, to keep uplink interference below noise floor of macrocell

Femto User

Location based femto noise rise
- A femto closer to the macro is set to lower noise rise threshold to limit the interference created by the user trying to access the femtocell (To protect macro users)

Qualcomm's Pilot Beacon for Femtocell Discovery —Part of UltraSON

Femto Beacons Ensure Efficient Femtocell Discovery for Legacy Devices

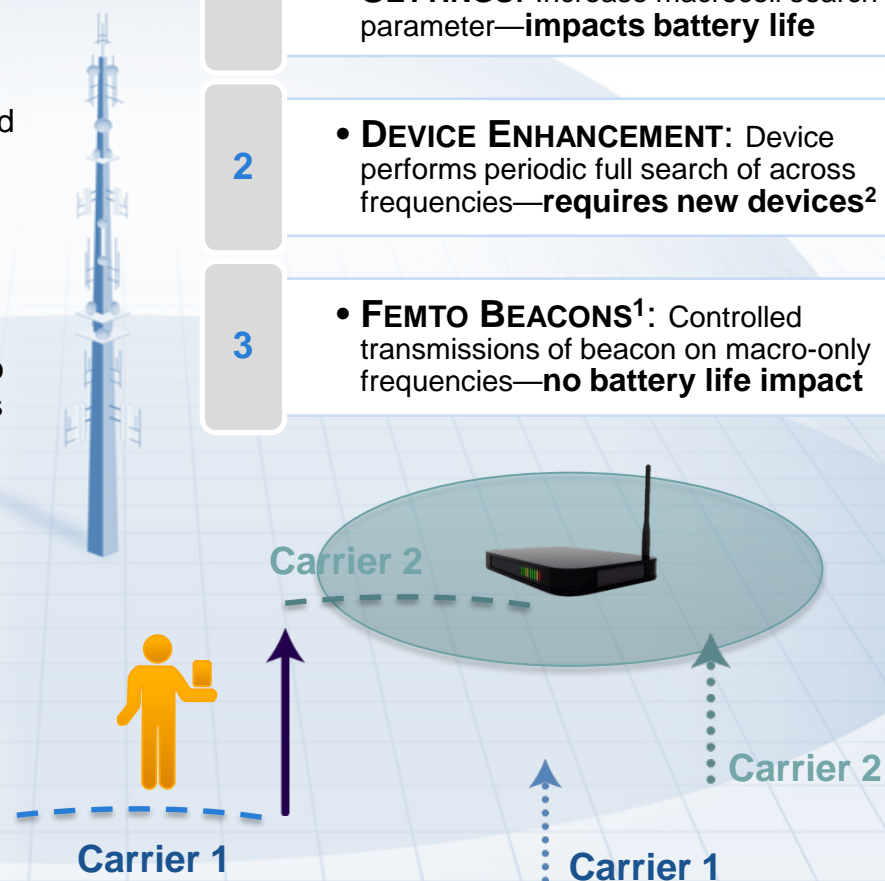**Options to find femtocell**

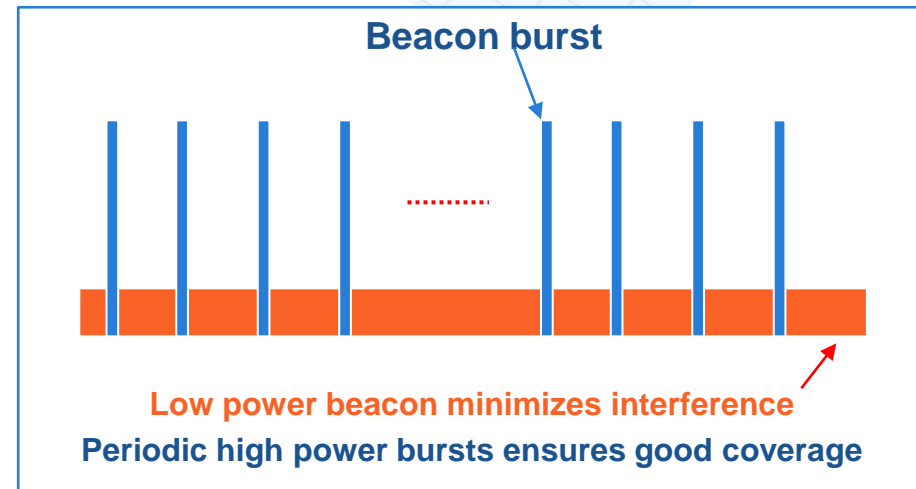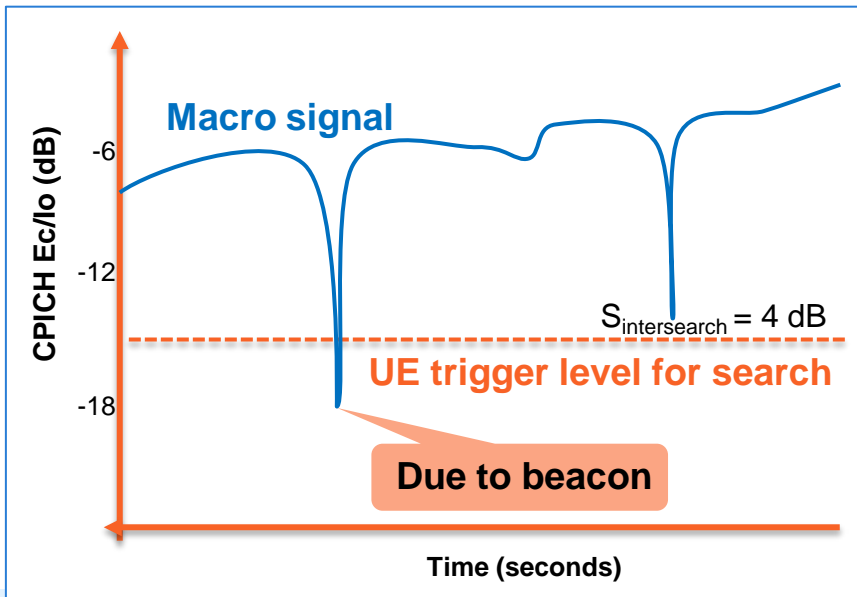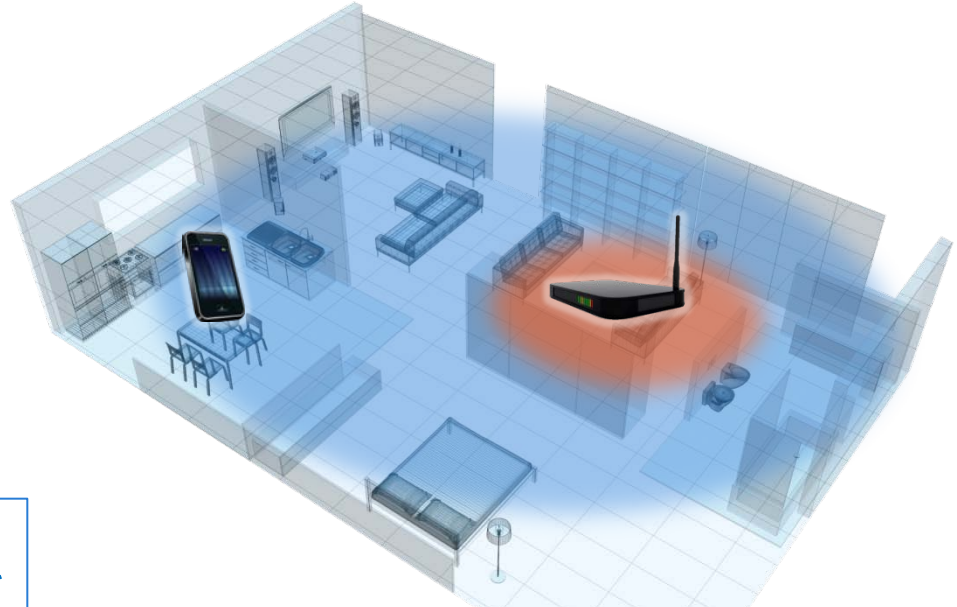|	
1	• **CHANGES TO MACRO NETWORK SETTINGS**: Increase macrocell search parameter—**impacts battery life**
2	• **DEVICE ENHANCEMENT**: Device performs periodic full search of across frequencies—**requires new devices**[2]
3	• **FEMTO BEACONS**[1]: Controlled transmissions of beacon on macro-only frequencies—**no battery life impact**

PROBLEM: FEMTO DISCOVERY

- User may never discover its femtocell in in good macro coverage—reselection may not be triggered

SOLUTION: FEMTO BEACONS[1]

- Minimize discovery time without battery impact
- Voice quality not affected and no impact on macro user's throughput with properly designed beacons

FEMTO BEACONS ALSO ENABLE EFFICIENT INTER-FREQUENCY ACTIVE HAND-IN

- Active hand-in reduces call drops and ensures that the femto is used whenever possible

Carrier 2

Carrier 2

Carrier 1

Carrier 1

[1]Femto beacon transmits on macro carriers not used by femto. [2]Future standards enhancements will enable new devices to find femto faster, but not as efficient as beacons.

Femtocell Beacons Transmit On Macro Frequencies to Trigger Search

- **Beacon triggers inter frequency search**
  - Temporarily reduces Macro Ecp/Io in the vicinity of the femtocell
  - Voice quality not affected, no impact on macro user's throughput with properly designed beacons

Macro signal

CPICH Ec/Io (dB)

-6

-12

$S_{intersearch} = 4 \text{ dB}$

UE trigger level for search

-18

Due to beacon

Time (seconds)

Beacon burst

Low power beacon minimizes interference
Periodic high power bursts ensures good coverage

Summary: Qualcomm's UltraSON

	FEATURE	DESCRIPTION
Femtocell Transmit Power Calibration Suite	Network Listen Based transmit Power Calibration **(NLPC)**	Location aware transmit power calibration after femtocell is installed
	Mobile Assisted Range Tuning **(MART)**	Optimized *residential femto* transmit power calibration based on mobile reports and registrations
	Supervised Mobile Assisted Range Tuning **(SMART)**	Optimized *enterprise femto* transmit power calibration based on mobile reports via a technician walk
	Guest Mobile Protection **(GUMP)**	Transmit power throttling based on uplink RSSI measurements to protect nearby active macro mobiles
Uplink Interference Management Suite	Controlled Limit on Mobile Power **(CLIP)**	Dynamic capping of femto mobile transmit power to limit uplink impact to macro
	Macro Aware Rise Setting **(MARS)**	Femto noise rise setting to protect femto/macro mobiles uplink throughput
	Receive Diversity	Dual femto receive antennas to improve the uplink throughput of the femto user and also to reduce the interference to macro network
Mobility Management Suite	Idle Mode Femtocell Discovery	Fast and reliable femtocell discovery via pilot beacon transmission
	Active Hand-in	Reliable macro to femto handover via pilot beacon for active mode service continuity
	Mobile Assisted Self Configuration **(MASC)**	Enhancement of femto Neighbor cell List configuration for reliable femto to macro handover
	Transmit Diversity	Dual femto transmit antennas to reduce number of handovers and improve voice quality via diversity