



University of  
Bedfordshire



# ICC 2009 Panel

## **Femtocells: Deployment and Applications**

*Organiser:*

**Prof. Jie Zhang**

Head of Centre for Wireless Network Design (CWIND)

University of Bedfordshire, UK

Email: [jie.zhang@beds.ac.uk](mailto:jie.zhang@beds.ac.uk)

*Dresden, 16 June, 2009*

# Agenda

- The chair will give
  - A short introduction to the rationales behind this panel
  - A very brief introduction to the panelists
- Each panelist will give some 10 min presentation to address some aspects of **femtocell deployment and applications.**
- Q&A
  - The engagement of audience is important. **You are part of this panel session!**

# Reasons to organise this panel

- Femtocell is a **missed opportunity** for academia.
- There is a big gap between the enthusiasm of the mobile communications industry (chip producers, vendors, operators) and the interests from the academic institutions.
- Femtocell is not only a small-sized base station, it also brings many interesting and challenging research problems.

# Reasons to organise this panel

- Femtocell **deployment** gives rise to many challenging research topics:
  - Interference (co-channel deployment) between indoor  $\Leftrightarrow$  outdoor
  - SON
  - Mobility management due to different access methods.
  - ...
- **Applications** matter to users and are vital for creating business models
  - Many great wireless technologies do not succeed because of the lack of viable business models.



# What is femtocell?

- Femtocells, also known as “**home base station**”, are cellular network access points that connect standard mobile devices to a mobile operator’s network using residential DSL, cable broadband connections, optical fibre or future wireless last-mile access technologies.
- A femtocell network = fixed network + cellular access points
  - Cable operators can deploy a femto only mobile network (roaming agreement with other operators).

# Short history and development

- **Femtocell/small cell** (then called access point base station) was first investigated in **1999** by Bell Labs. The original design was intended to provide a direct equivalent to a WiFi access point, but for mobile cellular networks such as GSM and UMTS.
- **By 2005**, the idea had become more widely recognized. More companies started to develop femtocells.
- **By early 2007**, the idea had become **mainstream**, with a number of major companies publicly demonstrating systems at the Mobile World Congress in Barcelona **in February 2007**.
- **In July 2007**, the Femto Forum ([www.femtoforum.org/](http://www.femtoforum.org/)) was founded to promote femtocell deployment worldwide. As of Dec. 2008, the forum includes more than 100 telecom hardware and software vendors, mobile operators, content providers and start-ups.
- **Home Node-B / Home eNode-B** were introduced in 3GPP release 8

# Why is femtocell important?

- 90% of data services and 2/3 of calls occurs indoor.
  - In the future, the most important part of the network to optimize is **indoor**.
- It is not a good idea to provide indoor coverage using outdoor macro/micro cells, in particular, for high bit rate services – the key drive of mobile broadband.
  - High penetration loss
  - Higher modulation and coding schemes require high quality radio links.

# Why is femtocell important?

- Exponential growth in mobile data, yet the price to end user is being driven down by competition.
- Air interface spectral efficiency is not growing at sufficient rate.
- Focusing on **topology** (Spatial Frequency Reuse) to complement the technology is pivotal to address a number of key points such as **cost (both CAPEX and OPEX), efficiency, ease of deployment** and indeed the **green** side.
- Some large operators have obligation to cut energy consumption by 50% by 2020.
  - Power bills account for some 10% of OPEX in developed countries
  - Up to 65% of OPEX in developing countries where infrastructure is not available.
- Small cells require less power to deliver the same data in comparison with macro network.
  - No air-conditioning or backup is needed.
  - Can be switched on and off.

# Why is femtocell important?

- Provide a cost effective roll-out plan with much reduced financial risks for **operators**.
- Deliver a seamless **user** experience across outdoor and indoor environments.
- Provide a basis for next-generation **converged services** that combine voice, video, and data services to a mobile device.
- Ideal for Fixed Mobile Convergence (FMC)
  - “The future cellular network is fixed network (IP) with a radio air interface.” – Hartmut Kremling, ICC 2009, Kennote speech.

# Why is femtocell important?

- Last but not least, it means **collaboration**, **funding** and **jobs** for you. This little thing concerns:
  - Chip producers
  - Telecom vendors
  - Telecom operators and
  - Users (who use applications and buy services) – the **X Factor**

# The Panellists

- Dr Andy Tiller (VP, Ip.access)
- Dr Holger Claussen (Alcatel-Lucent)
  - Head of Autonomous System and Engineering Research group.
  - PIMRC papers widely cited.
- Dr Guillaume de la Roche (CWIND, University of Bedfordshire)
  - Marie Curie Research Fellow
  - A lead author of femtocell book “Femtocells: Technologies and Deployment”, Wiley, Q3 2009.
- John Raw (Huawei).
- Prof. Simon Saunders (Chairman, The Femto Forum), who can't come, his presentation will be delivered by Andy Tiller.

# Thanks!

**Prof. Jie Zhang**  
**Centre for Wireless Network Design**  
**University of Bedfordshire**  
Tel. +44 (0) 1582 743288  
Email : **[jie.zhang@beds.ac.uk](mailto:jie.zhang@beds.ac.uk)**  
Web: **[www.cwind.org](http://www.cwind.org)**





driving convergence worldwide

# Femtocells

## *Delivering the Mobile Broadband Vision to Homes and Offices*

Dr. Andy Tiller

Vice-chair Marketing, **Femto Forum**

VP Marketing, **ip.access Ltd.**



ICC

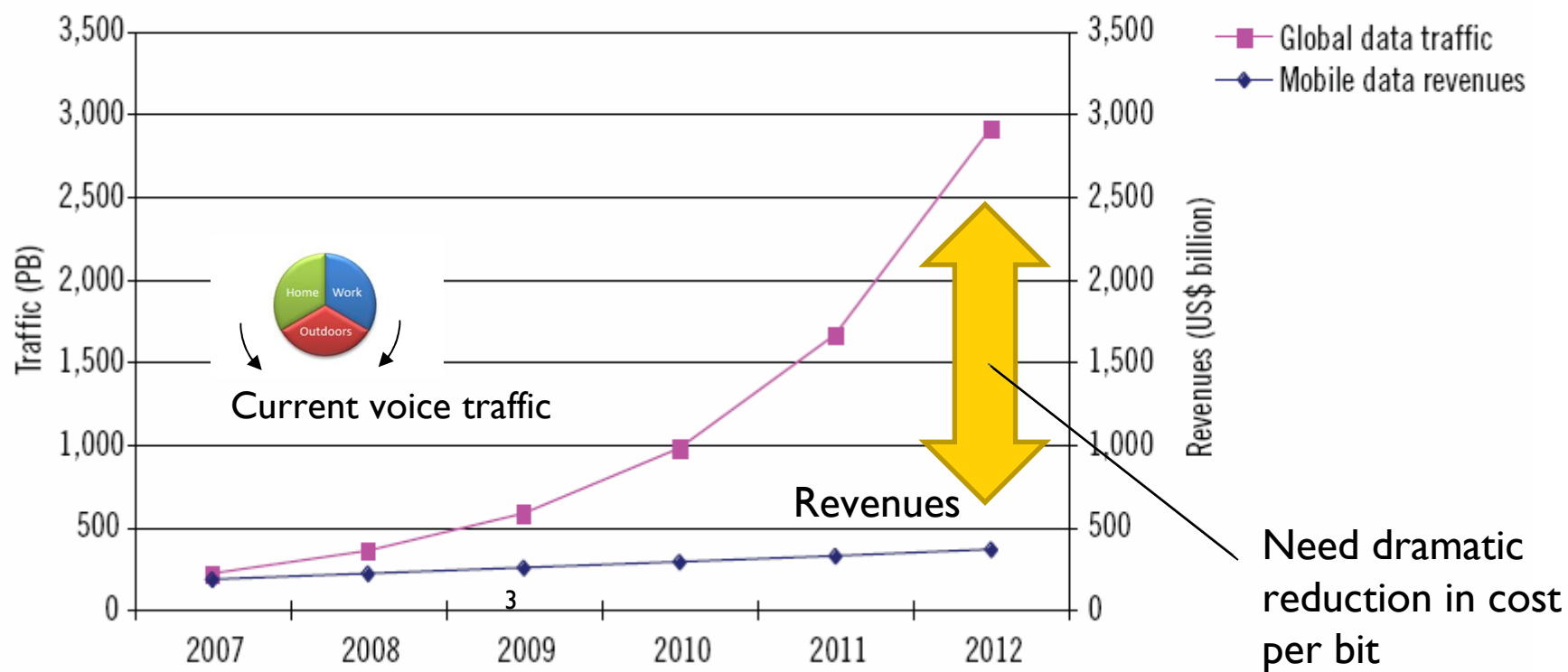
# ip.access overview

- **Cambridge (UK) company**
  - Shipping picocells since 2002
  - £18 million annual revenues, 150+ employees
- **Leading supplier of in-building cell infrastructure**
  - Coverage & capacity for homes, enterprises, SMEs & public spaces
- **Products**
  - nanoGSM® - the world's most deployed picocell
  - Oyster 3G™ - multi-award winning 3G femtocell
  - nano3G™ - next generation 3G IP picocell
- **All our in-building cells connect to the mobile operator's core network over IP links (hence "ip.access")**



# A compelling and urgent need

Figure 1.4: Global mobile data revenues and traffic, 2007-2012



Source: Informa, 2008

# Mobile data traffic is mostly generated indoors

- 42% of US mobile data is consumed at home <sup>1</sup>
- 44% of smartphone data usage occurs at home <sup>2</sup>
- 46% of UK 18-34 year olds watch mobile video & TV at home <sup>3</sup>
- 50% of US 18-24 year olds want to watch mobile TV at home <sup>1</sup>
- 60% of mobile data traffic will be generated in the home by 2013 <sup>4</sup>
- 75% of UK mobile broadband users access the internet via their dongle while at home <sup>5</sup>
- 75% of mobile traffic will be generated indoors by 2015, and 95% of that traffic will be data <sup>6</sup>



1 Gordon Mansfield, Director of RAN planning at AT&T, Jun 08

2 Nokia smartphone survey, Dec 07

3 Market Tools survey of over 650 mobile phone users, May 08

4 Informa Telecoms & Media, Mobile Broadband Access at Home, Aug 08

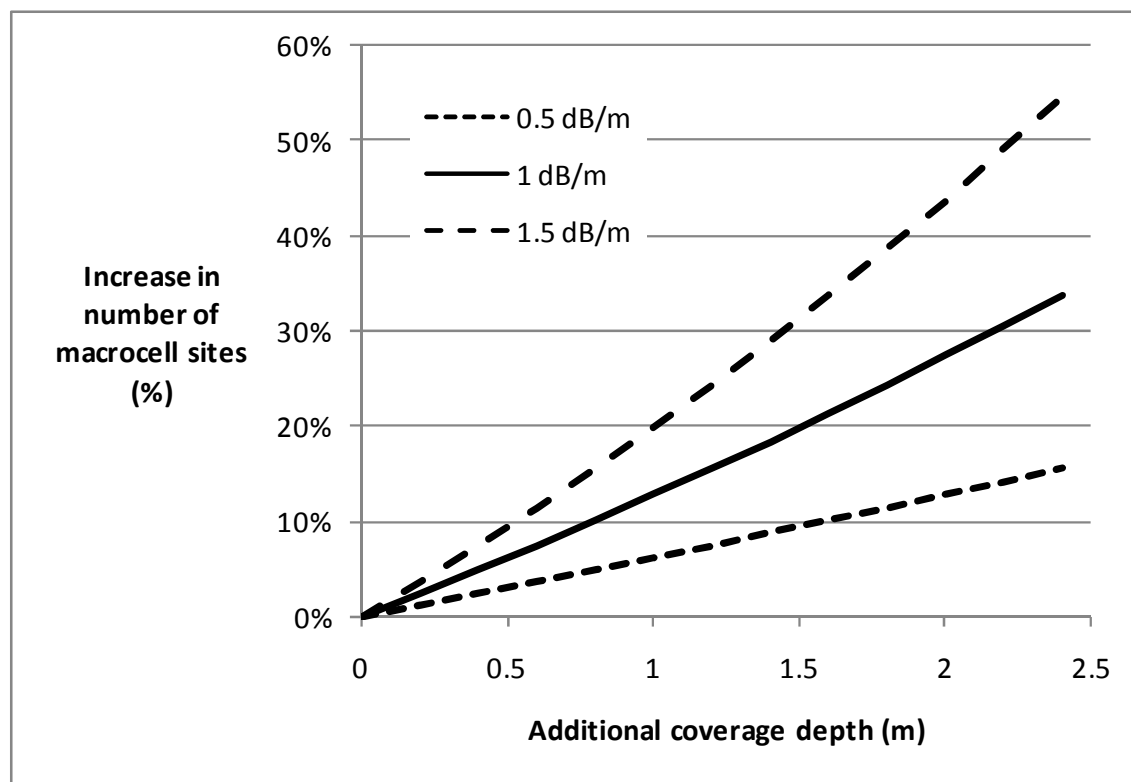
5 Ofcom report, Aug 08

6 Analysys Mason, Apr 09

## Coverage: outside in?

- Macrocell site numbers needed increase very rapidly to provide deep indoor domestic coverage for high-rate services
- Very costly: approx €308M for 1 metre extra coverage depth into building

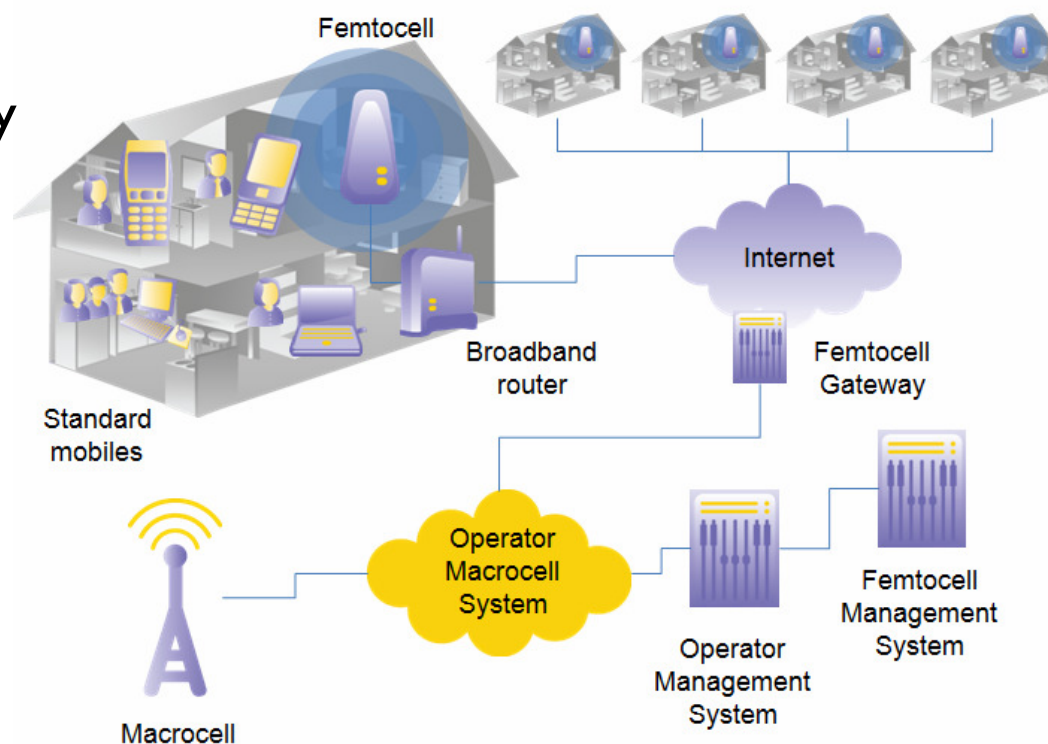
Increase in macrocell sites required for deeper coverage



Assumes 5000 initial sites, €225k NPV per site, 1 dB/m internal penetration loss

# What are femtocells?

Low-power access points...  
 ...using mature mobile technology  
 ...in licensed spectrum  
 ...generating coverage & capacity  
 ...over internet-grade backhaul  
 ...at low prices  
 ...with full operator management  
 ...self-organising, self-managing



# What's the point of femtocells?

## 1. Great 3G user experience in homes / offices

- Especially for high-speed data

## 2. Cost-effective service delivery

- Radio network installed by customer
- Free backhaul via consumer broadband

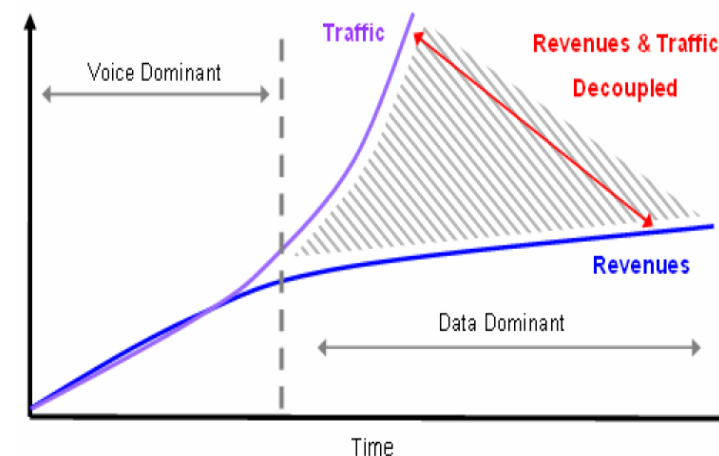
## 3. Platform for innovative new services

- Home presence
- Connected Home

### Probability of Coverage by bearer channel

	Urban	Suburban
Outdoor PoC	98%	98%
Indoor PoCs		
12.2kbps (inbuilding PoC)	70%	72%
384kbps (inbuilding PoC)	28%	22%

Source: Signals Research Group, LLC

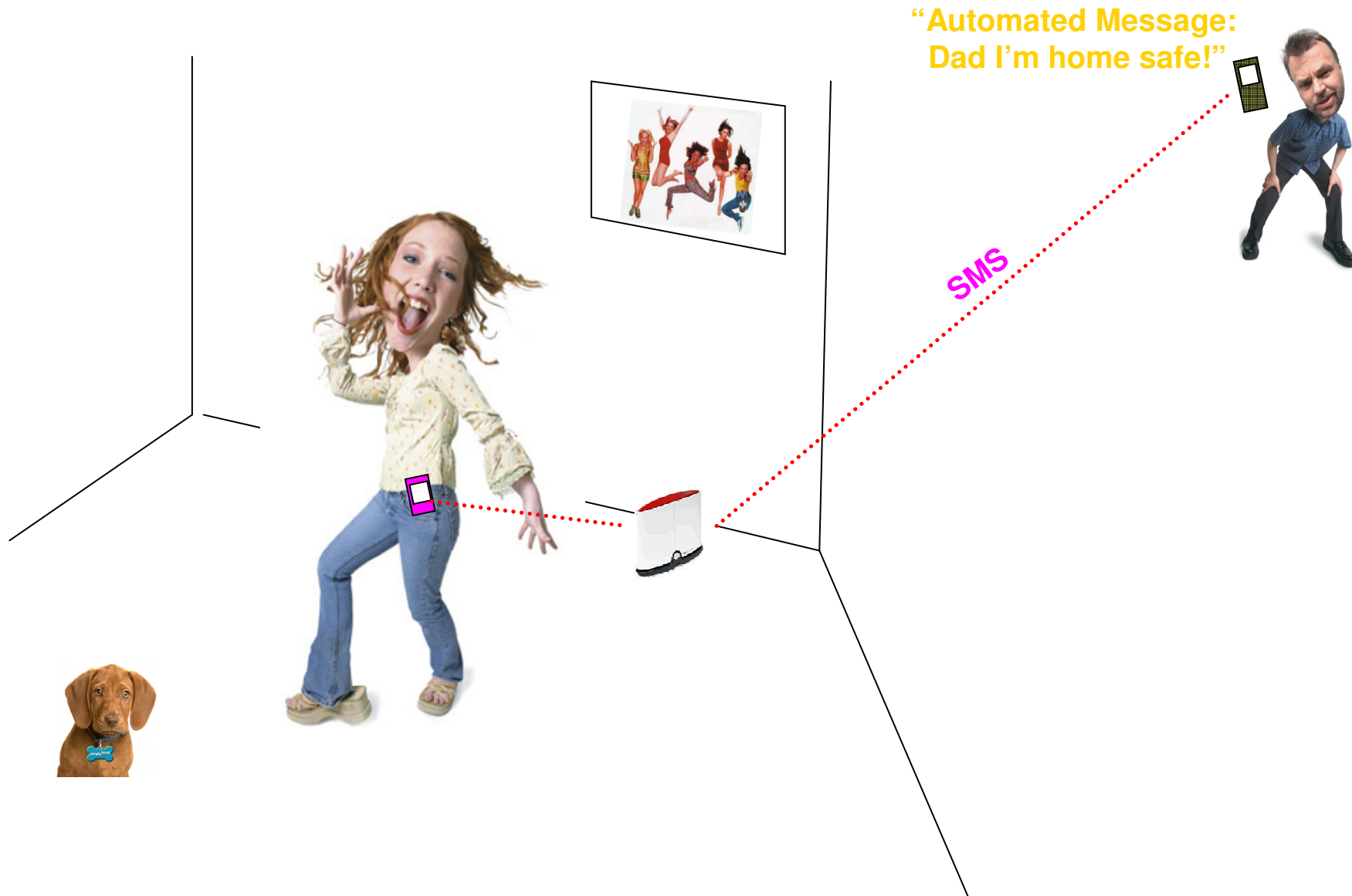


# Virtual home number

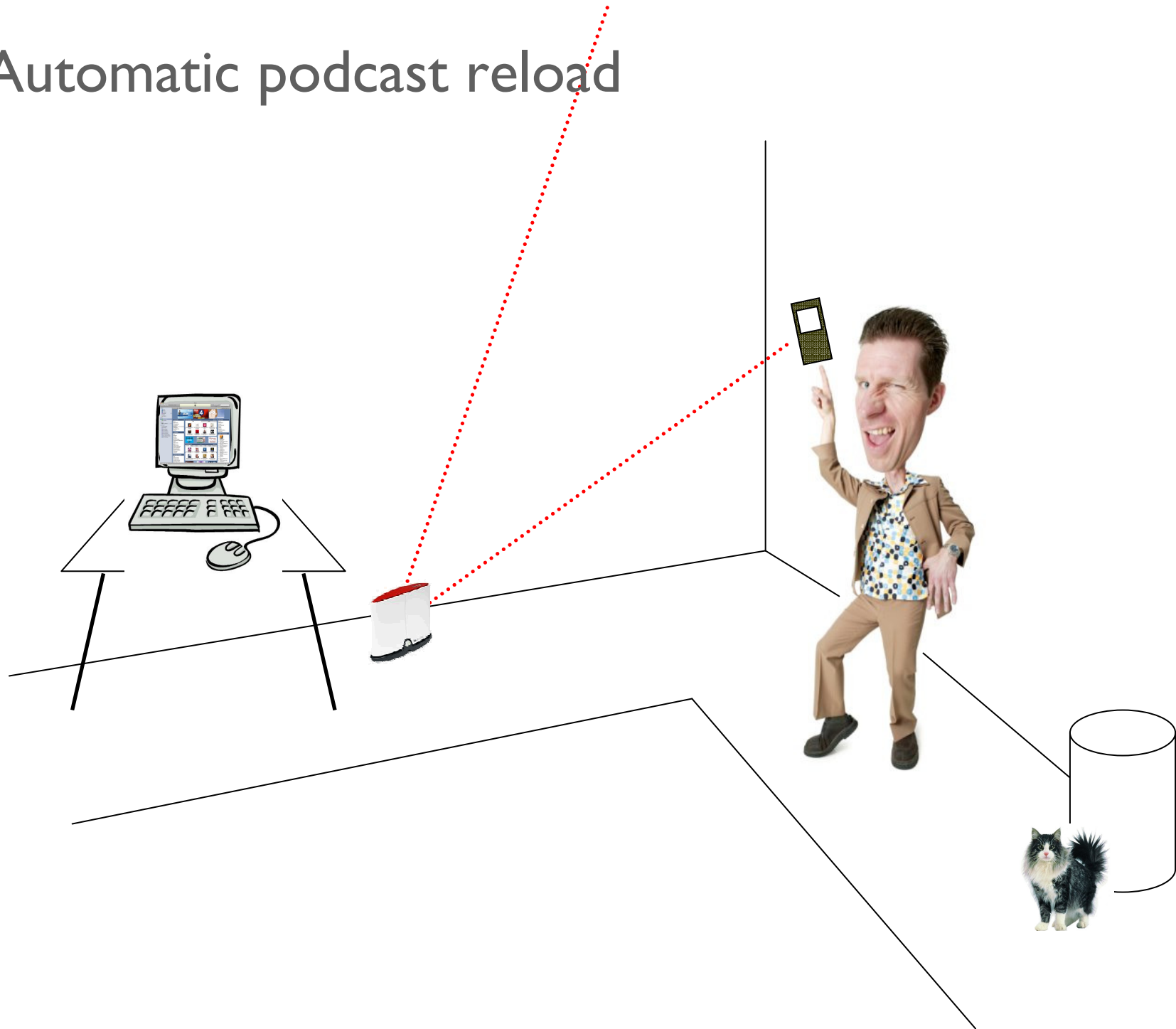




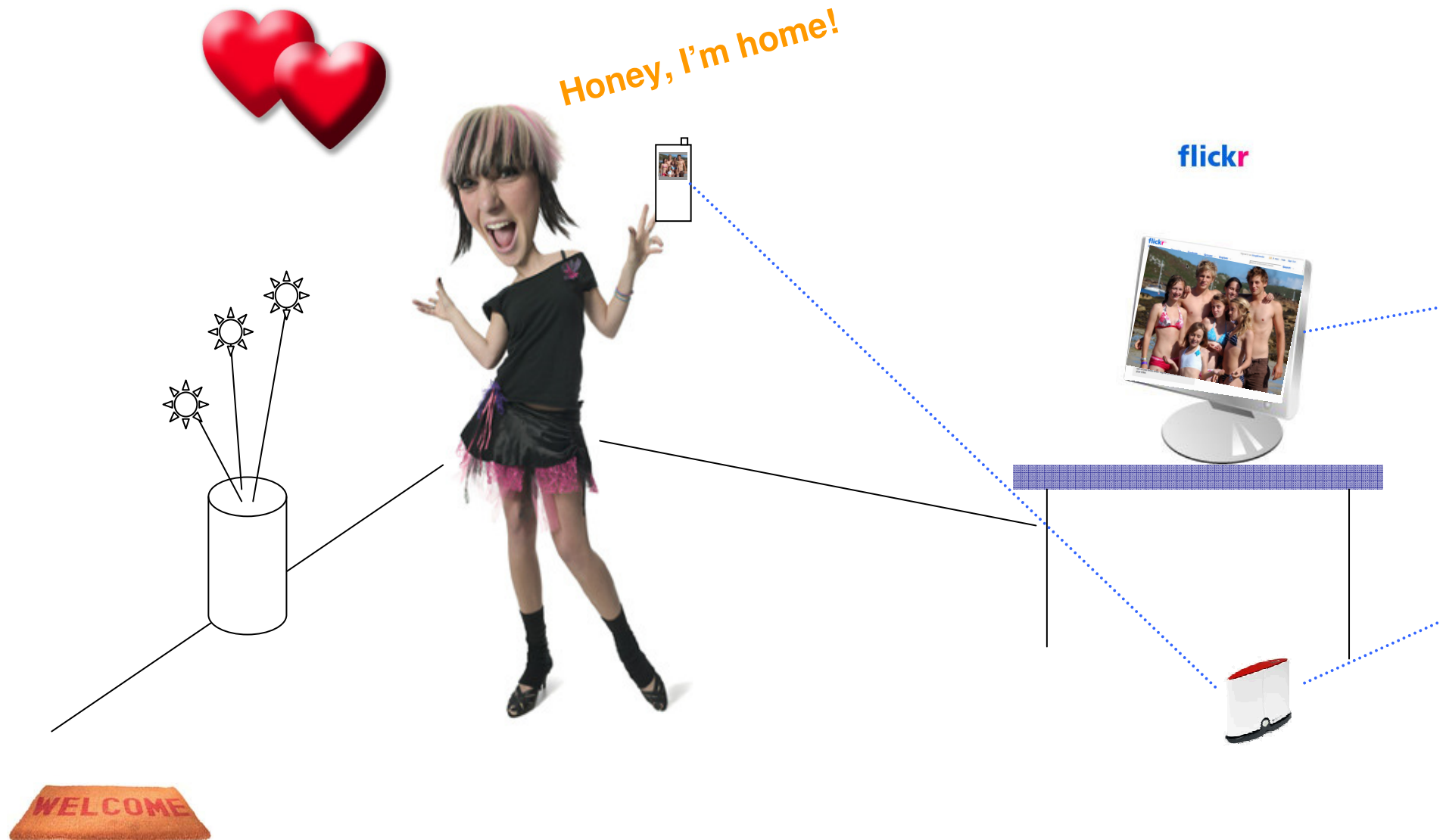
# Peace of mind for working parents



# Automatic podcast reload



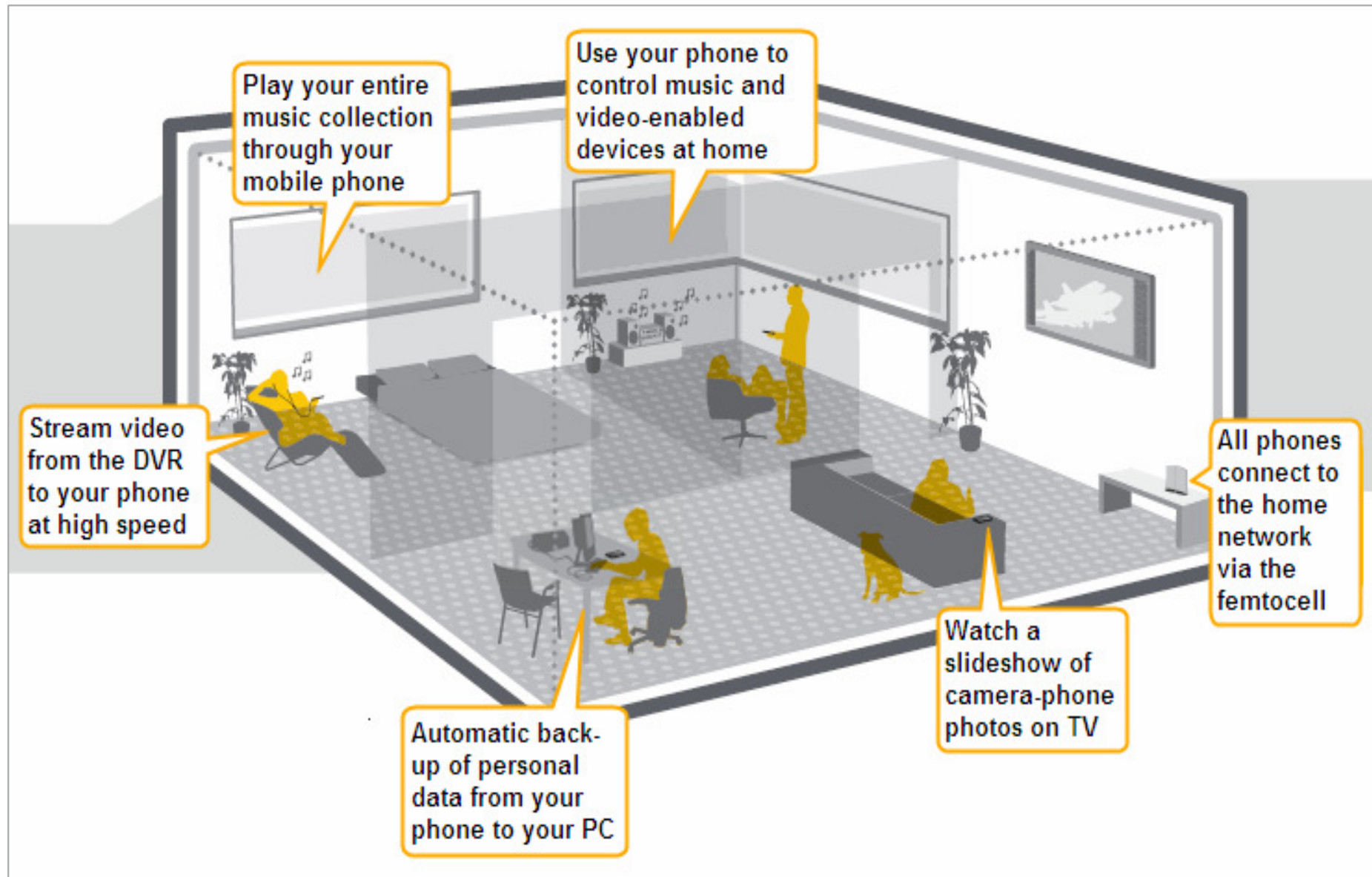
# Automatic photo sharing / blogging



# Facebook “virtual fridge notes”

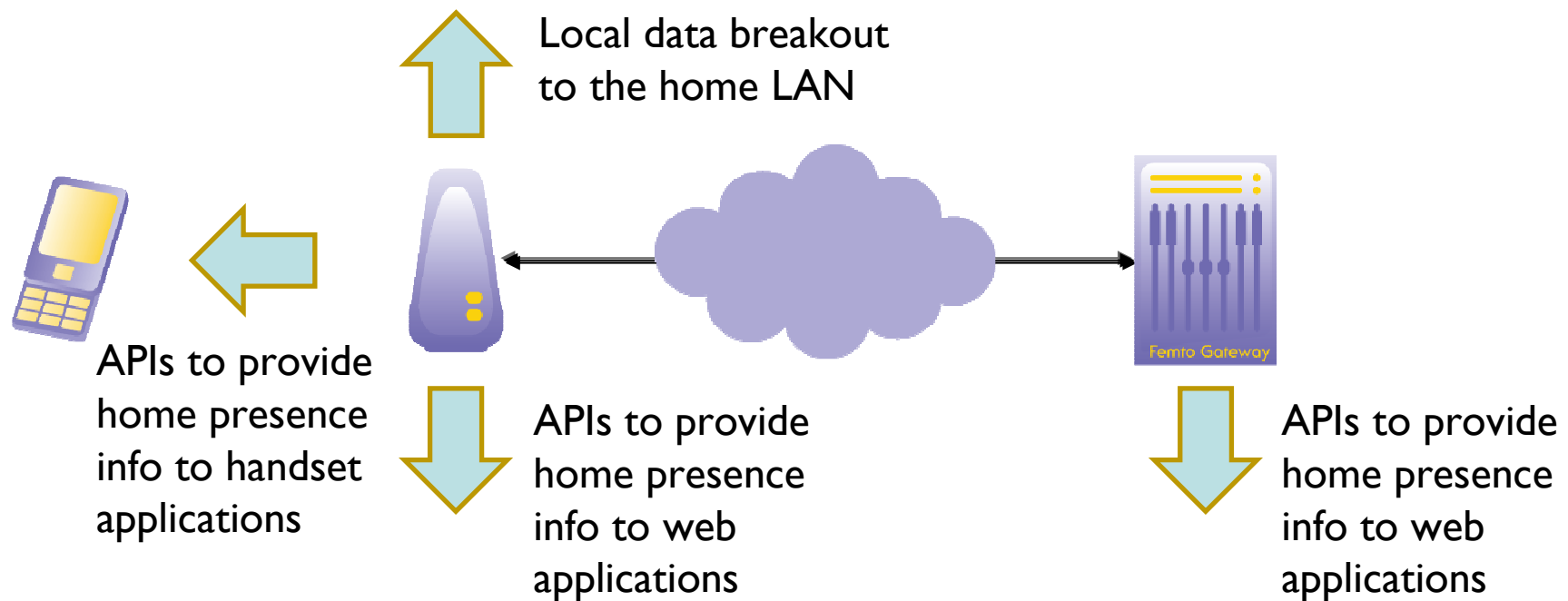


# Femtocells and the Connected Home



# Femtocell service enablers

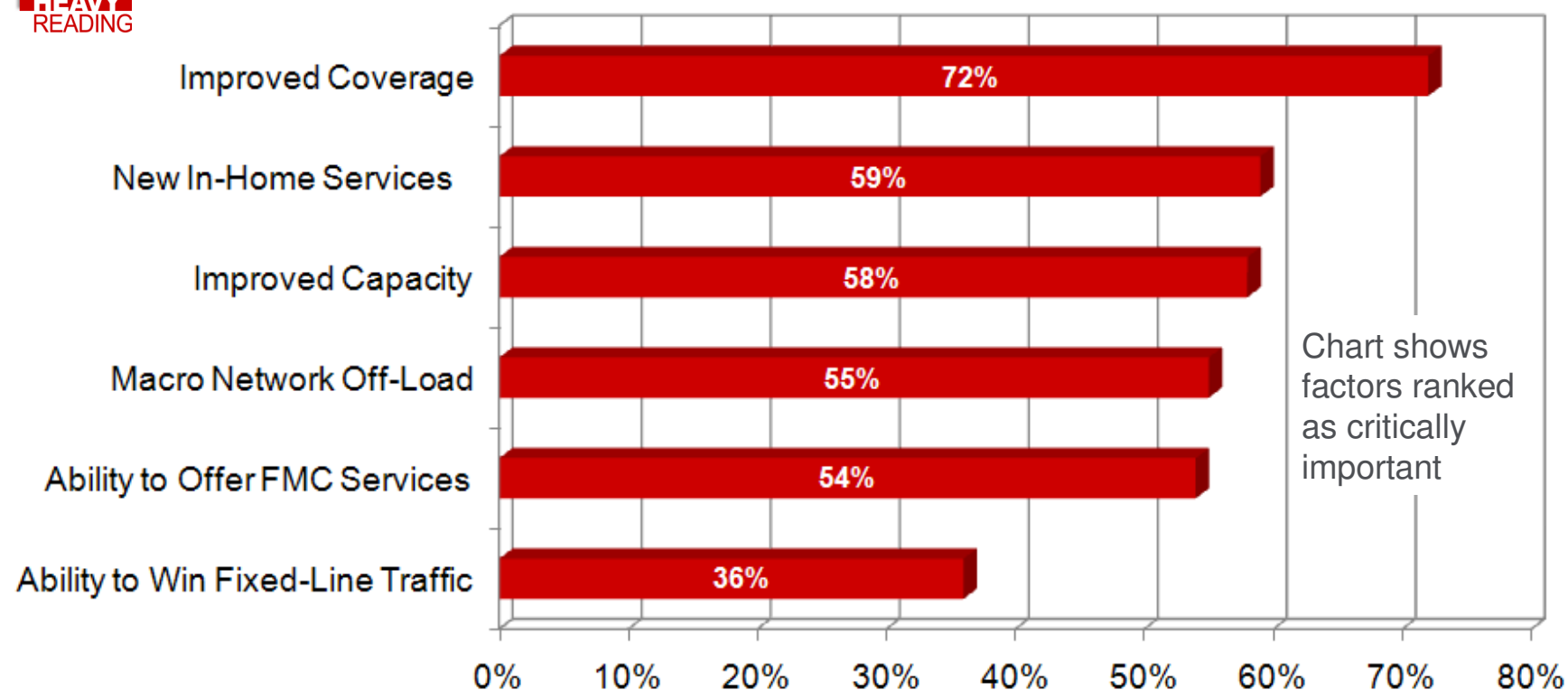
1. Femtocells know who is at home (and when they arrive at home)
2. Femtocells provide full-speed data at very low cost
3. Femtocells provide a connection to the home LAN



# Femtocell market drivers today



## *Factors in establishing the business case for femtocell deployment...*

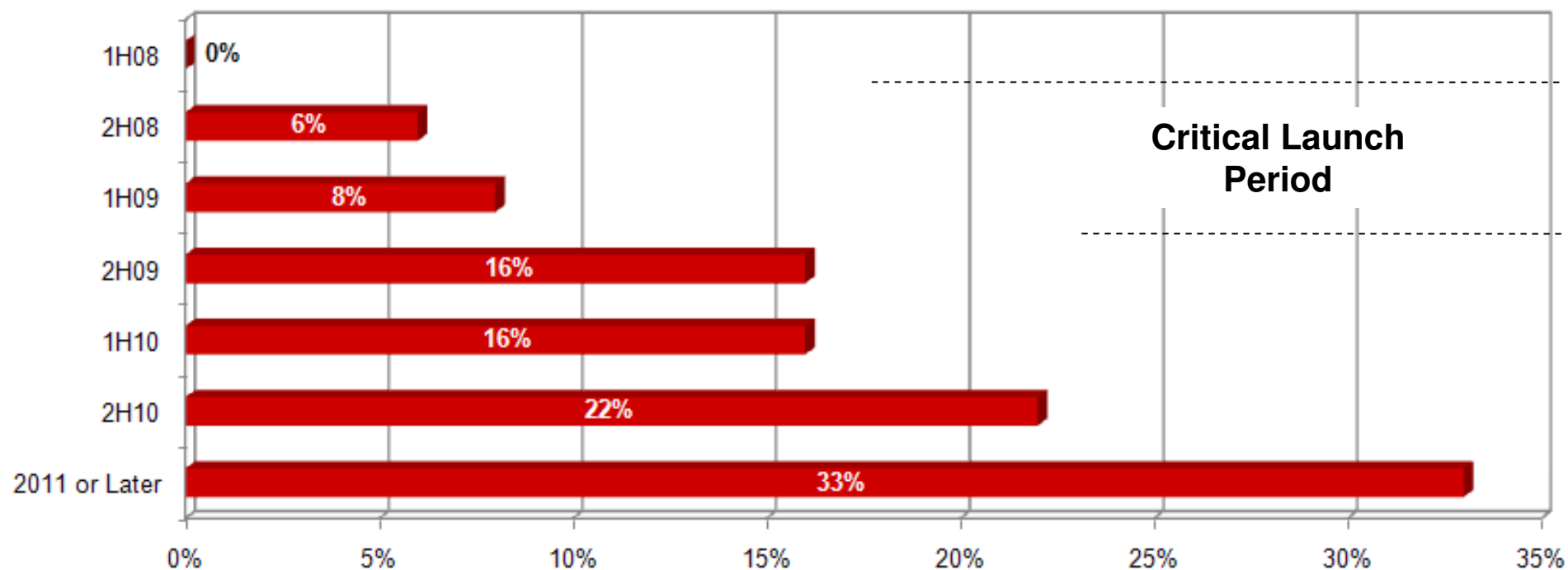


Heavy Reading Femtocell Deployment & Market Perception Survey of 111 professionals from 79 operators, published August 2008

# Femtocell commercial launch timescales



*What is your company's most likely timeframe for commercial launch of femtocells?*







driving convergence worldwide

# The Femto Forum

- Femtocell industry body, founded in 2007 to promote the deployment of femtocells worldwide

## Ecosystem Development

- Large number of members
- Geographical and technological spread

## Market Education

- Spreading awareness
- Increasing informed coverage

## Driving open standards

- **Not** a standards-setting body
- Building voluntary consensus
- Close interactions with standards bodies



driving convergence worldwide

## Femto Forum membership

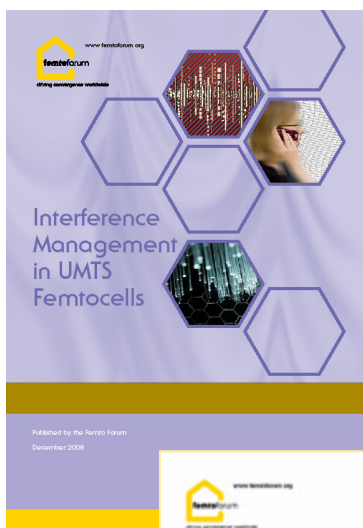


- 50 operators covering 1.308 billion mobile subscribers
- 65 providers of femtocell technology and fixed line operators

# Femto Forum key achievements

## *Overcoming barriers to early market adoption*

- Achieved consensus on WCDMA architectures and management protocols; supported the first femtocell standards in 3GPP Rel 8
- Interference management study created certainty of capacity and quality enhancements
- Delivered business model, demonstrating business case in wide range of situations
- Increased clarity of regulation

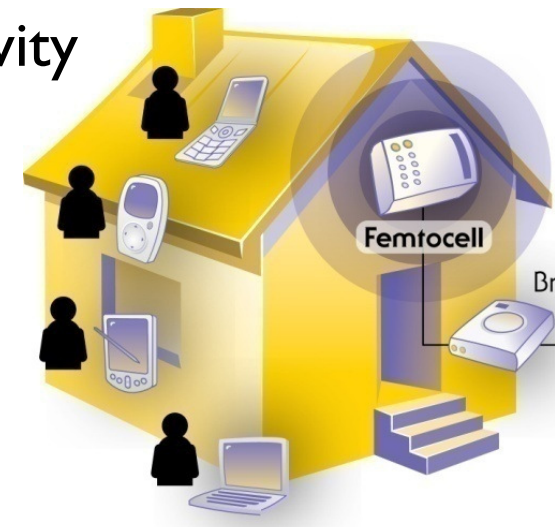


# Femto Forum Research Initiative

- Objectives
  - Create a “long term research agenda” and encourage high quality, precompetitive research aligned to long-term vision of the role of femtocells in the evolution of mobile networks
- Scope
  - Support for research into technical, economic, regulatory, business, management, manufacturing and environmental factors
- Status
  - Call for capability statements, to help us build an understanding of the capabilities of research institutions globally who have an active programme or a strong capability to perform research in this area
  - Research presentations at Femtocell World Summit, London, 24 June
- See [www.femtoforum.org](http://www.femtoforum.org) for more details

## Conclusions

- In 2008 the barriers to femtocell deployment were overcome, demonstrated by real market activity
- In 2009 we are focusing on
  - Maximising potential
  - Enabling rapid growth
  - Expanding the range of femtocell applications
- In 2010 femtocells will accelerate in volume and evolve towards next-generation systems





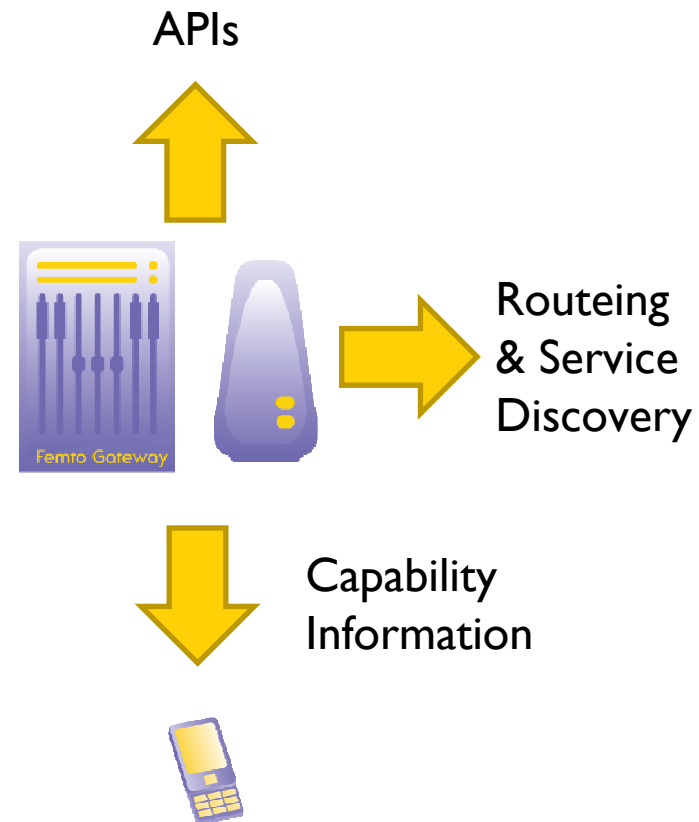
driving convergence worldwide

# Thank you



# What do femtocells provide?

- Presence information
  - When I get home, when I am at home and when I leave home.
- Capability information
  - “14.4Mbps available here”.
- Local routing
  - My mobile and home PC can find each other.
- Service discovery
  - My mobile can find my networked TV and control it.
- Secure remote access
  - A secure tunnel from a mobile back to the home/office.



## 2009 Priorities

**Main goal: *Enable rapid take-up of femtocells across a broad range of applications***

1. Femto Services - Enable new business via femtocell-enhanced services
  - Develop femto services API specifications
  - Foster applications ecosystem in partnership with other industry bodies
2. Achieve completion of 3GPP R8 and R9 with sufficient scope
3. Address critical factors for next-generation femtocells (LTE (TDD & FDD), WiMAX)
4. Encourage a wider ecosystem across a broad standards base
  - 3GPP, 3GPP2, WiMAX
  - User equipment and application developers
5. Articulate and drive 'greater femtocell' usage (enterprise, public, rural/emerging markets)
6. Regulation - Achieve greater certainty and avoid delays
7. Interoperability testing strategy defined and initial testing started
8. Ensure wide market recognition and clarity on market status & progress
9. Drive cost reduction through standards, volume, openness and reuse





driving convergence worldwide

## 2009 Initiatives

- Femtocells for rural environments and developing markets
- Femto Research Initiative
- Femto-friendly handsets
- Femtocell industry awards





driving convergence worldwide

## Forthcoming Events and Information



Femtocells Global Summit, Femto Forum awards and Femtocell Applications Live  
London Heathrow, 23<sup>rd</sup> -25<sup>th</sup> June

FEMTOCELL  
APPLICATIONS *Live*



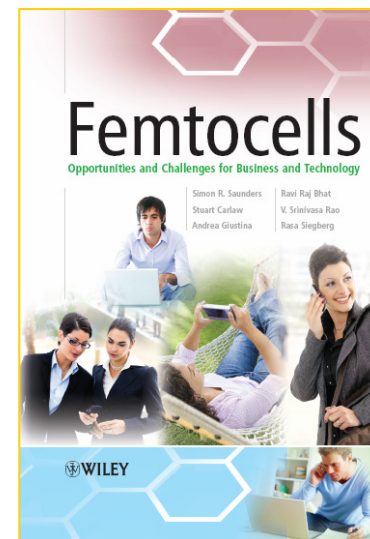
FF Europe Plenary  
Lisbon, 22<sup>nd</sup>-25<sup>th</sup> September



China Femtocells Symposium  
Beijing, 15<sup>th</sup> October



Femtocells USA and FF Plenary,  
San Diego, 16<sup>th</sup> – 20<sup>th</sup> November



See [www.femtoforum.org](http://www.femtoforum.org) for further information

[www.femtocellbook.com](http://www.femtocellbook.com)



driving convergence worldwide

# Qualcomm Sees the Potential in Femtocells

“the improvement of wireless links that enhance user throughputs is reaching its limit...

there is another method: **densely deploying base stations** to shorten the distance between base stations and mobile terminals. **Femtocell**, which is often discussed in these days, is an example of this concept.

According to the results of our research, this effort will possibly result in **eight times higher throughput per user**.

In retrospect, an eight-times improvement is **equivalent to that brought by the cell phone's shift from analog to digital**. This is really an exciting fact.”



Paul E Jacobs  
CEO of Qualcomm Inc

[http://techon.nikkeibp.co.jp/english/NEWS\\_EN/20080905/157548/?P=](http://techon.nikkeibp.co.jp/english/NEWS_EN/20080905/157548/?P=)



## Ofcom recognise femtocells



- UK communications regulator Ofcom recently produced its assessment of the mobile sector, including many references to the significance of femtocells:

“...major structural shifts – 2G giving way to mobile broadband, new technologies like femtocell domestic base stations”

“At this point, they form part of a vanguard of a long-promised technology that has the potential to enable new forms of competition across communications networks: fixed-mobile convergence.”

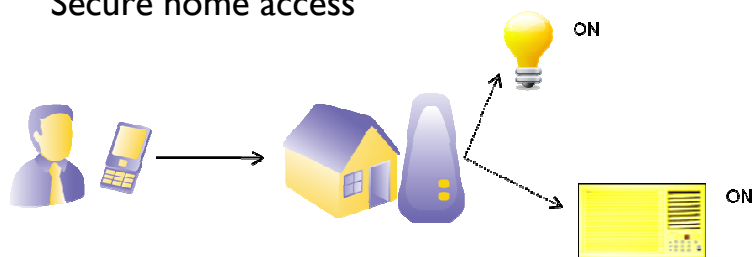
<http://www.ofcom.org.uk/consult/condocs/msa08/>



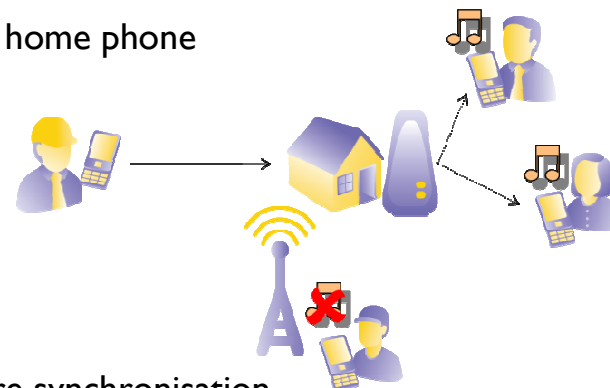
# What are femtocell applications?

Simple, useful & fun

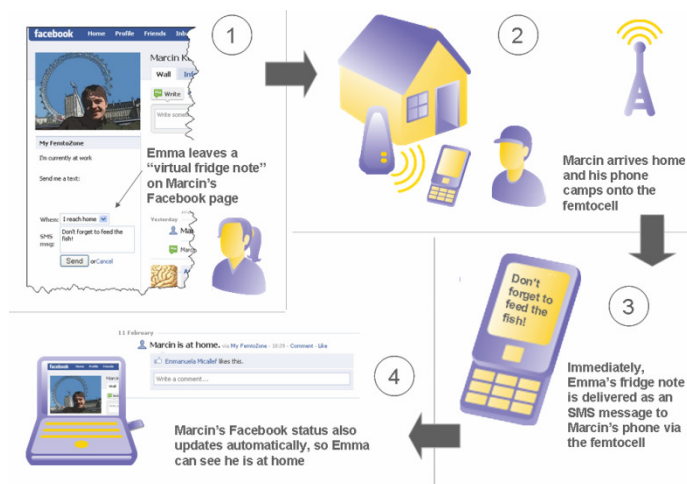
Secure home access



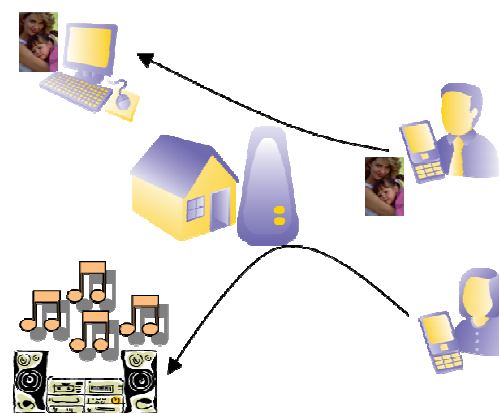
Virtual home phone



Virtual fridge notes



Picture synchronisation & remote control



## Economic Impact

Revenue impact	Time-to-market	Cost savings
<ul style="list-style-type: none"><li>• New revenue streams from value-added services</li><li>• Location-specific tariffs without leakage</li><li>• Family contracts</li></ul>	<ul style="list-style-type: none"><li>• Rapid deployment of upgraded technologies (HSPA, LTE, WiMAX...)</li><li>• Rapid provisioning of new services</li></ul>	<ul style="list-style-type: none"><li>• Deferred and reduced macro roll-out</li><li>• Operational savings – especially power, backhaul, site rental</li><li>• Churn reduction – contract extension</li></ul>

Substantial value to be created, challenging preconceptions of cellular economics

---

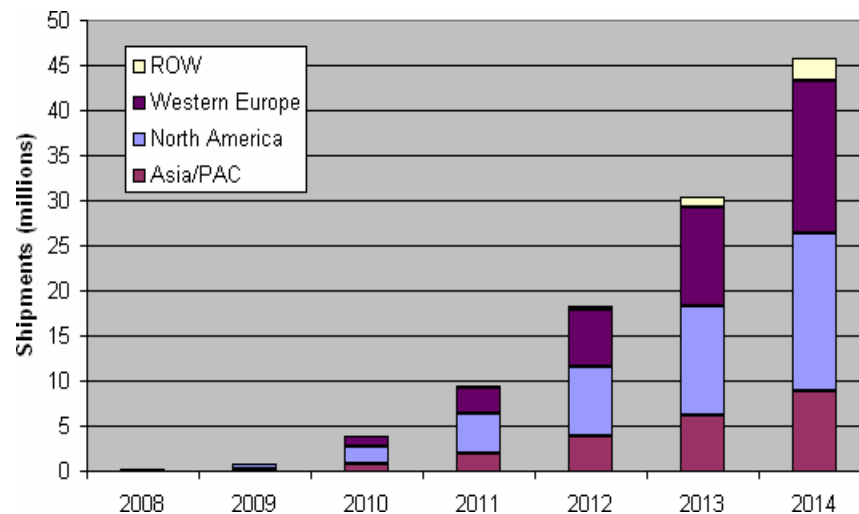
## Femtocell market – operator status

- Sprint – AIRAVE launched
- Verizon – Wireless Network Extender launched
- AT&T – consumer trial
- SoftBank – commercial launch
- StarHub – limited commercial launch
- Chunghwa Telecom – 3000 APs ordered
- Vodafone – preparing launch in Spain & UK
- T-Mobile – plans for commercial femto rollout in Germany
- Orange France – enterprise trial
- Telefonica O2 – trials in Spain
- Many other trials announced (China Mobile, Korea Telecom, SKT, TDC, Mobilkom, Portugal Telecom, Telecom NZ, Cellcom...)

## Recent market forecasts

### – ABI Research

- 18 million shipments in 2012
- 30 million shipments in 2013
- Associated revenues will be \$4 bn in 2013



### – In-Stat

- Femtocells, picocells, and microcells are expected to surpass 15 million units by 2013
- Worldwide annual femtocell semiconductor revenue will approach \$400 million by 2013

### – Infonetics Research

- Sales of femtocell & FMC network equipment will grow to \$8 billion in 2013





## Relationships with other key bodies

Femto Forum members see eye-to-eye on femtocell architecture

London, UK – 21st May 2008

To aid this drive towards common practices, the forum **has been accepted as a Market Representation Partner (MRP)** with key industry standards bodies, 3GPP, 3GPP2 and established cooperation agreements with the DSL Forum and the GSMA,



Market  
Representation  
Partner



Liaison agreement



Market  
Representation  
Partner



Cooperation Agreement



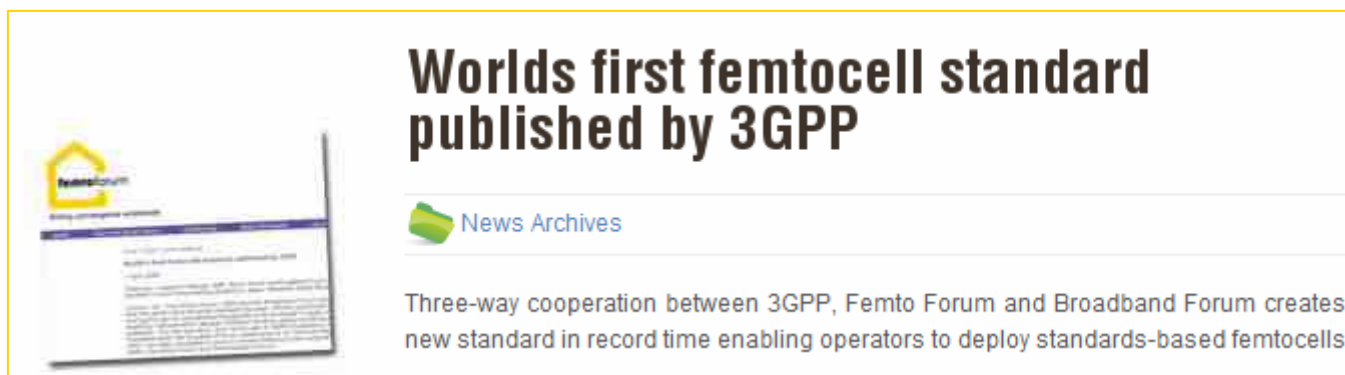
Partnership  
Agreement



Partnership Agreement

## 3GPP Release 8 Completion

- The completion of the release 8 Home Node-B (UMTS femtocell) specification was a major achievement for the industry, providing clarity on the roadmap and enabling operator deployments in the short term
- Outcome from a close collaboration between 3GPP, Femto Forum & Broadband Forum



**New femtocell standard to drive mass-market rollouts – industry bodies**



**3GPP flies femto standard**



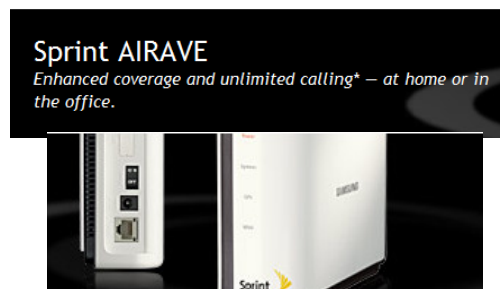
**World's First Femtocell Standard Published by 3GPP**

**ElectronicsWeekly.com**



# Market Developments on Course

- In June 2007 we said:
  - Femtocell technology would be ready for detailed technical evaluation in the first half of 2008...
  - ...ready for customer trials in mid-2008
  - ...with technology ready for commercial deployment in late 2008 and early 2009
  - ..with more launches occurring during the course of 2009...
  - ... and volumes building onwards into 2010, supported by standards-based products
- All on course, with more launch announcements widely anticipated



## StarHub launches world's first 3G femtocell service

“StarHub has today announced what it claims to be the world's first commercial 3G femtocell service in Singapore. “

Japan's SoftBank first to launch 3G femtocells  
22 September 2008

## Verizon Wireless Network Extender Enhances In-Home Call Capabilities



## AT&T 3G Microcell

- Plug and Play
- Use with any 3GPhone
- In Employee Trial
- Customer Trial Upcoming
- Available later this year





## Interference mitigation techniques

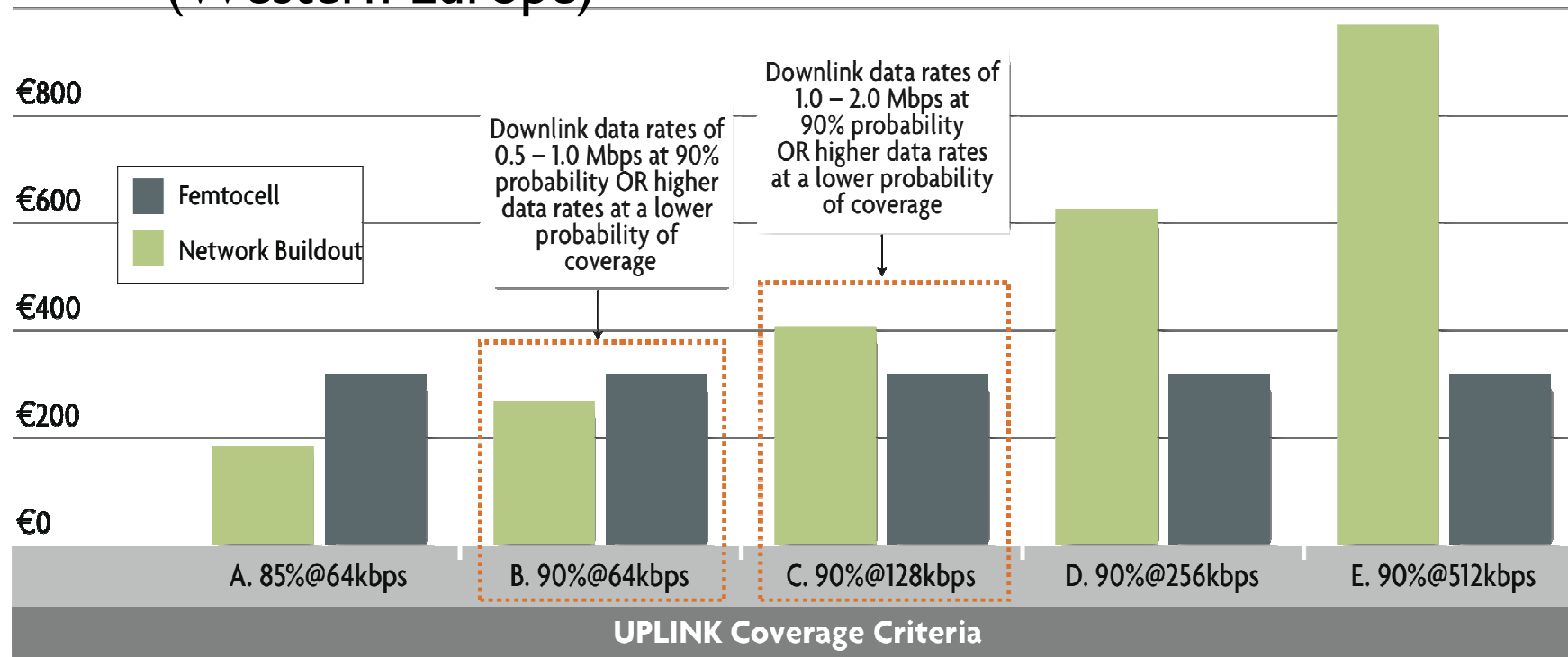
- Adaptive Pilot Power Control, whereby the femtocell dynamically adjusts its transmit power in response to the current level of signals from surrounding cells and the desired coverage area.
- Extended Tests for Dynamic Range, to ensure that femtocell designs are able to operate reliably even in the presence of nearby high power mobile phones connected to the macro network (this test has already been incorporated into the latest 3GPP Release 8 25.104 specification).
- Uplink power capping of the mobile phone when operating in the femtocell environment, ensuring that, even in difficult radio conditions, the phone hands-off to the macro network before its transmit power increases to the point where macro noise rise is a problem.
- Dynamic receiver gain management in the femtocell (Automatic Gain Control or adaptive attenuation), to ensure that femtocells can offer good service to both near and far mobile phones without unnecessarily increasing the phone transmit power, therefore keeping the noise rise to a minimum.





# HSPA network investment for deep indoor coverage

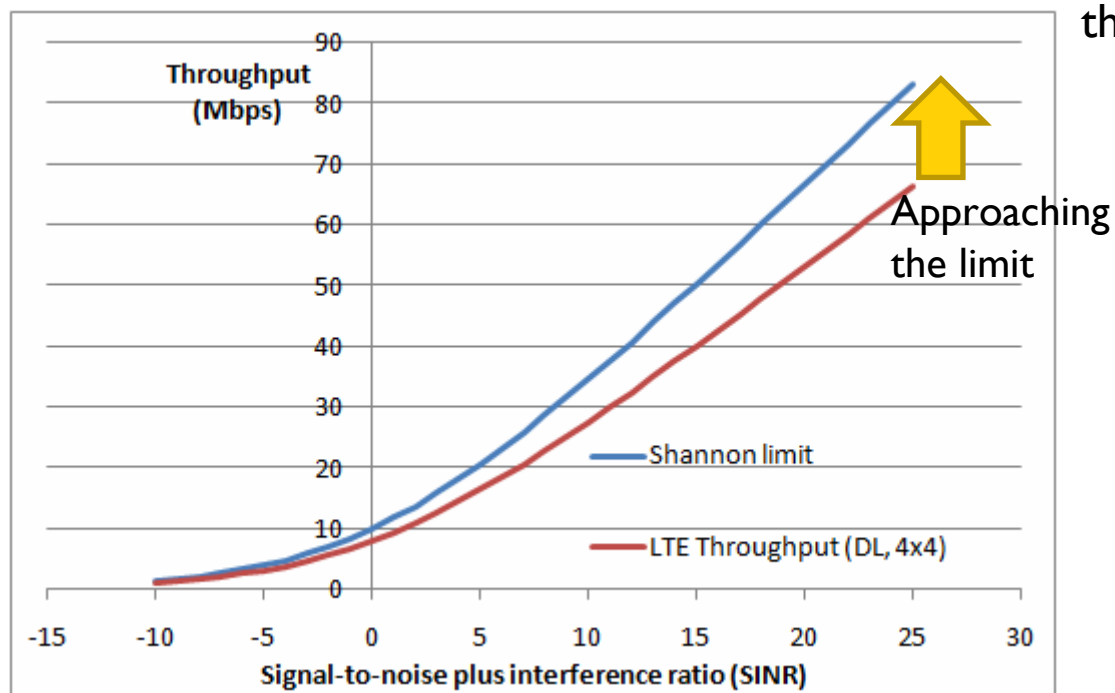
(Western Europe)



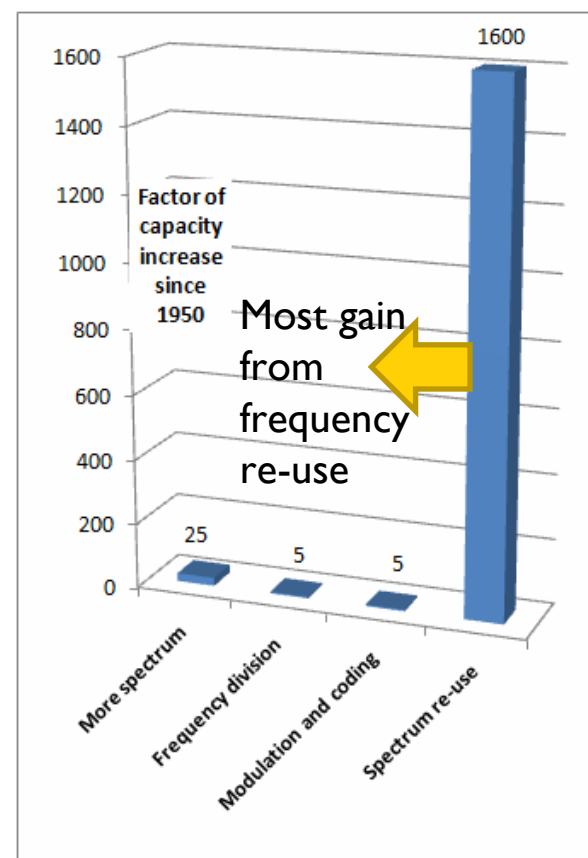
*Network investment purely for coverage is difficult to justify in the 2100 MHz band for a depth of coverage greater than that of scenarios “B” or “C.” The graph compares the incremental industry investment to the cost of placing a femtocell in each coverage-challenged household.*

## Capacity – Reaching Limits?

- Next-generation system performance is close to the Shannon bound
- Cooper's Law suggests that increasing the number of cells has always been the main means of adding capacity



- Need *more cells* and *tighter interference control* to continue to increase capacity



# Femtocells enabling customer propositions



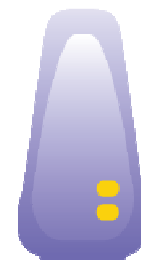
Great  
home  
coverage

Femtozone  
call tariffs  
for all

Fast data,  
high call  
quality

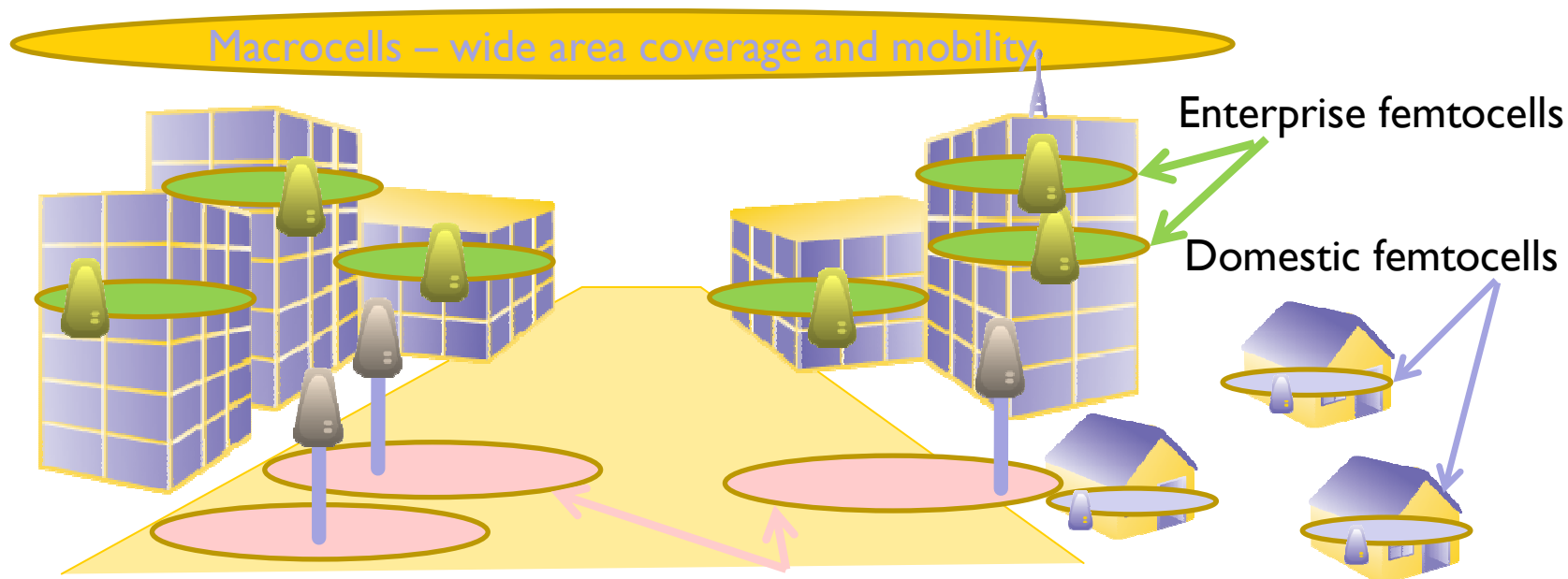
Unlimited  
data  
services

Compelling  
new  
femtozone  
services



## ‘Greater’ femtocells – beyond the home

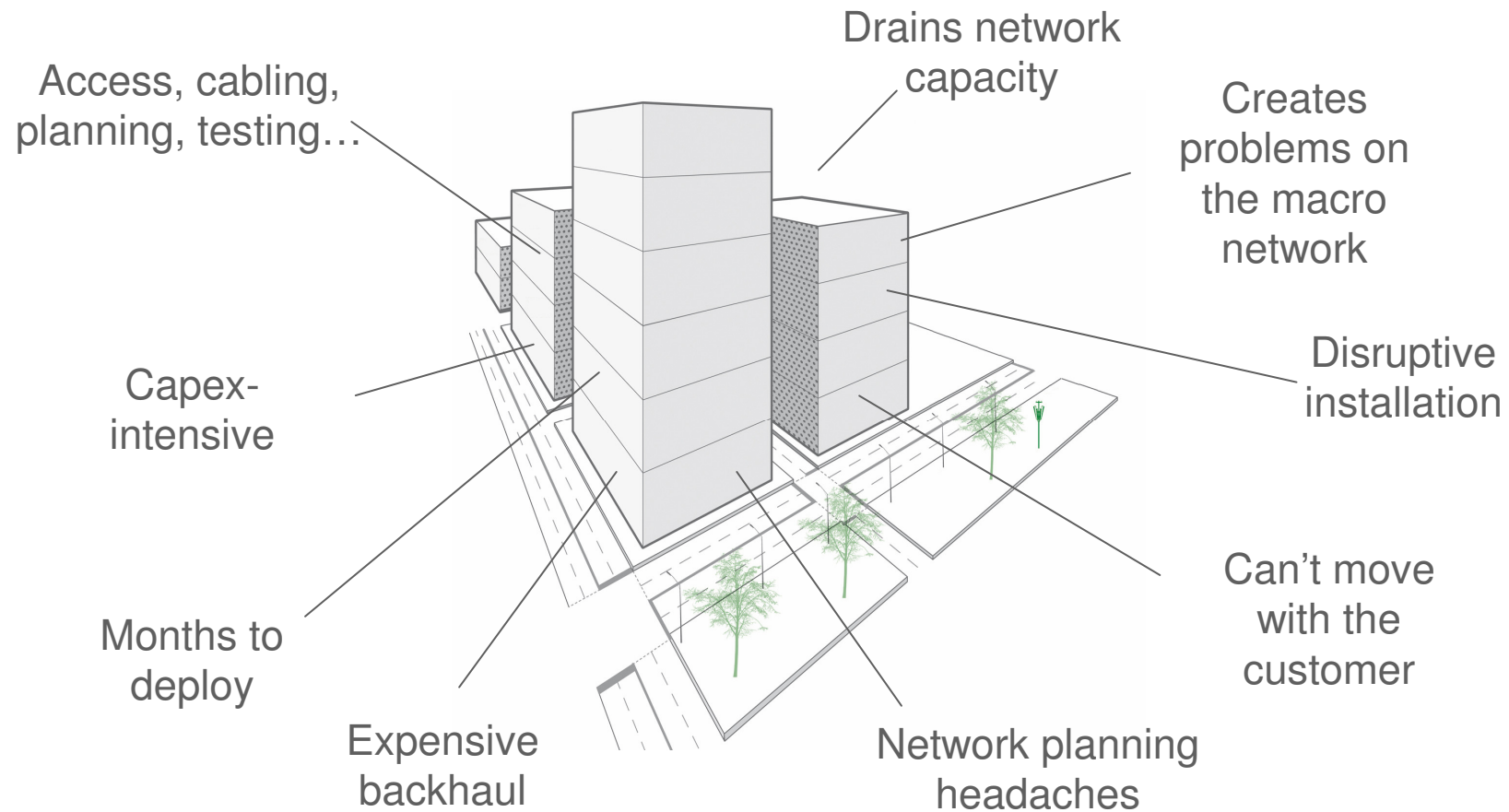
- Femtos in the enterprise and metrozone
  - Femtocell economies of scale can deliver cost-effective deployments in offices and in high-traffic or low coverage locations
- Rural and developing markets via appropriate backhaul solutions





# Traditional in-building systems

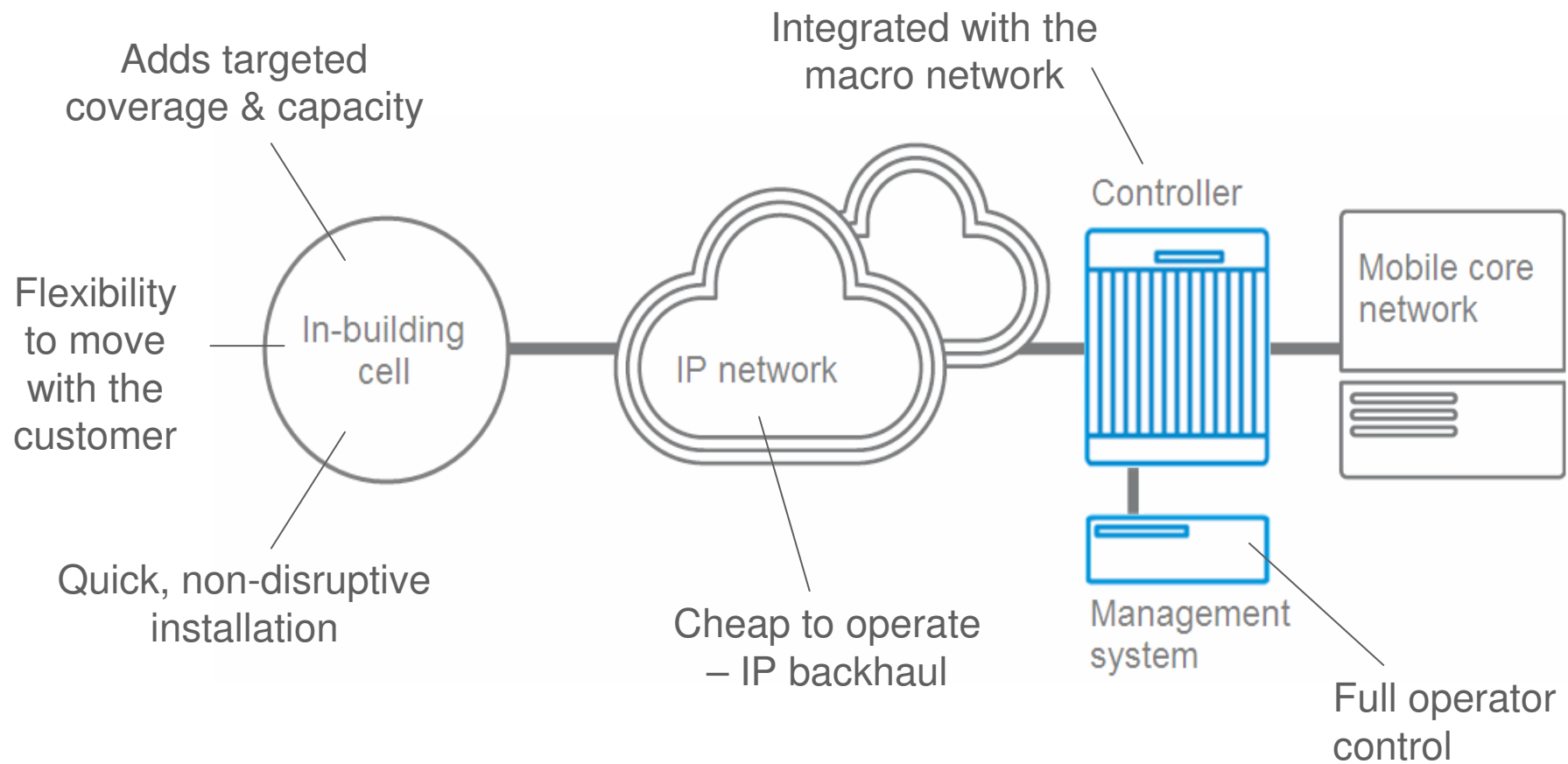
Too expensive, too slow, too many network issues





driving convergence worldwide

## Femtocell advantages





University of  
Bedfordshire



# A femtocell deployment tool: objectives, functionalities and examples

*Dr Guillaume de la Roche*

ICC 2009, Dresden, Germany, June 2009

# Overview

- Why a simulator ?
- Which functionalities ?
- Examples

# Why a simulator-based femtocell deployment tool?

- The performance evaluation of femtocell networks is important for both operators and vendors:
  - For operators
    - To evaluate the impact of femtocells on the macrocell layer
    - To test different configuration: frequency/slot/power allocation
  - For vendors
    - To test their algorithms before a real implementation (ex: sensing, self-configuration, use of directional antennas)

# Why a simulator-based femtocell deployment tool?

- The performance evaluation of femtocell networks is important for both operators and vendors:
  - For operators
    - To evaluate the impact of femtocells on the macrocell layer
    - To test different configuration: frequency/slot/power allocation
  - For vendors
    - To test their algorithms before a real implementation (ex: sensing, self-configuration, use of directional antennas)
- Solutions:
  - Real measurements: But currently few large scale deployments
  - RF Channel simulator: Expensive
  - Software: Fast and cheap

# Functionalities of a femtocell simulation software

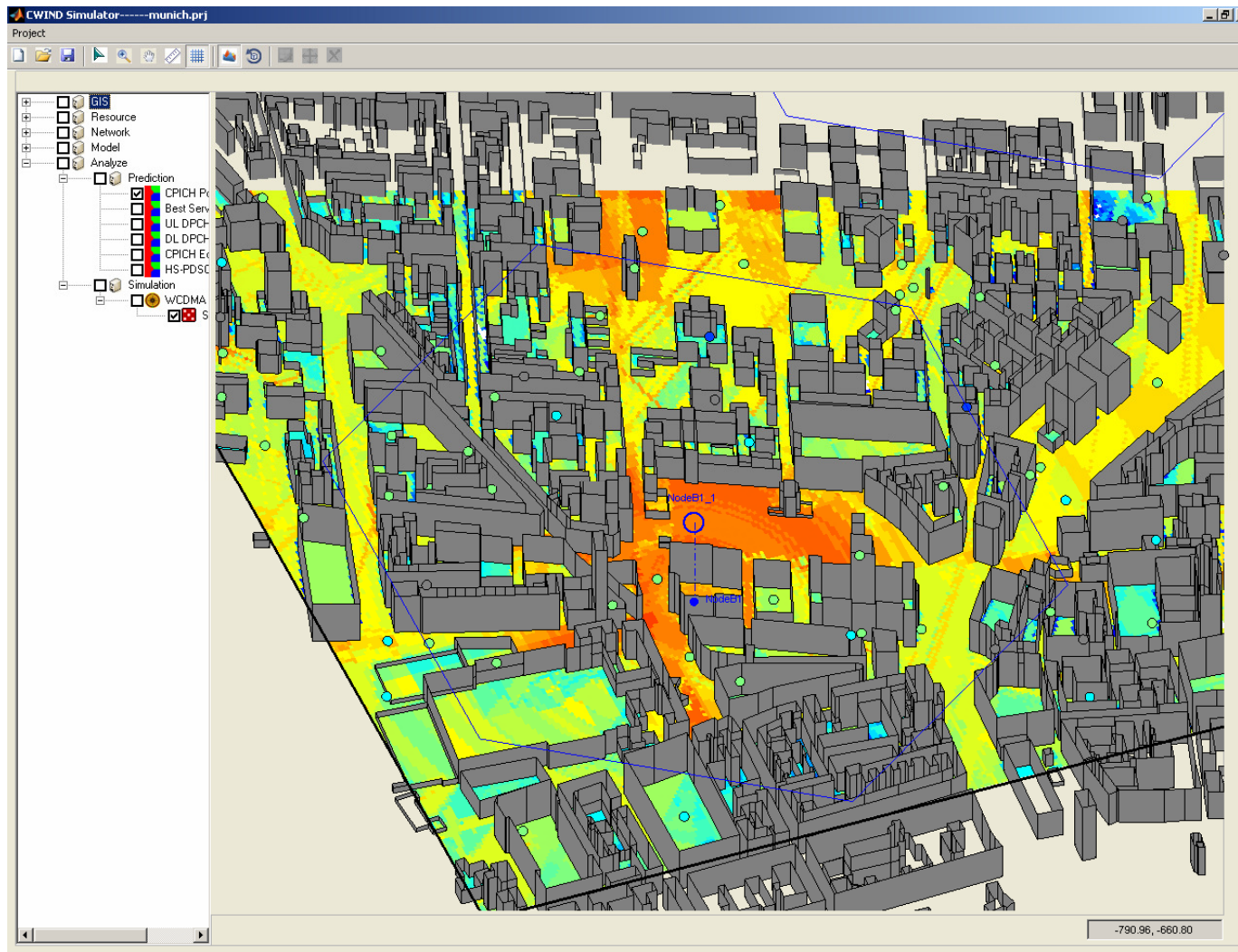
- Propagation tool:
  - A typical femtocell deployment scenario needs to take into account both outdoor and indoor environments;
  - Outdoor: GIS (e.g. 2.5D city data) / Indoor: building structure (e.g. dxf)
  - Indoor – outdoor radio propagation models: 3D Ray tracing/launching (outdoor and indoor), FDTD (indoor and fading estimation), ...
  - Possibility to calibrate with measurements

# Functionalities of a femtocell simulation software

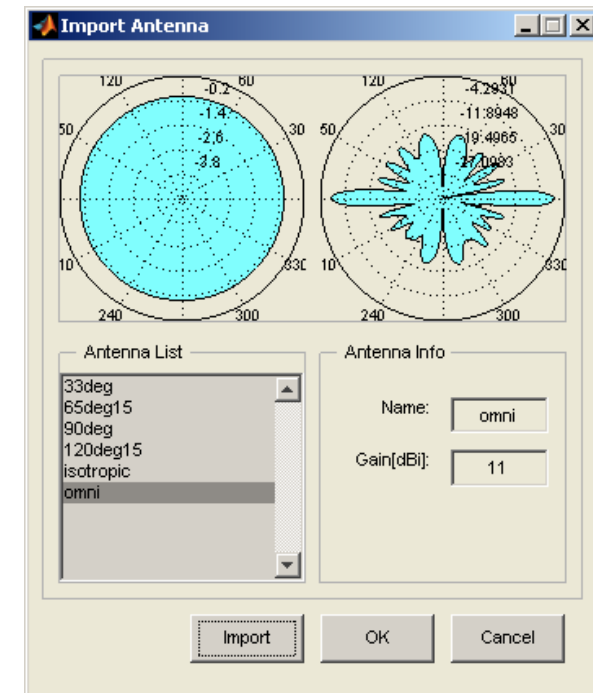
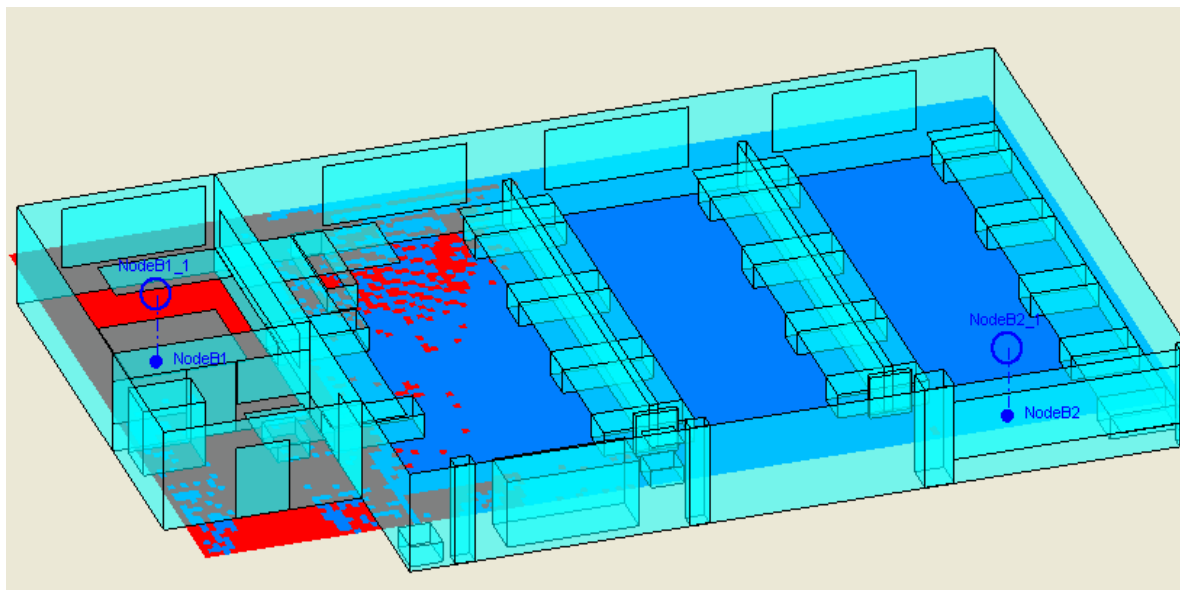
- Propagation tool:
  - A typical femtocell deployment scenario needs to take into account both outdoor and indoor environments;
  - Outdoor: GIS ... / Indoor: building structure (e.g. dxf)
  - Indoor – outdoor radio propagation models: 3D Ray tracing/launching (outdoor and indoor), FDTD (indoor and fading estimation), ...
  - Possibility to calibrate with measurements
- System level simulation tool:
  - Standards: UMTS/HSPA, WiMAX, LTE
  - Static vs dynamic
  - Performance analysis (throughput, QoS)



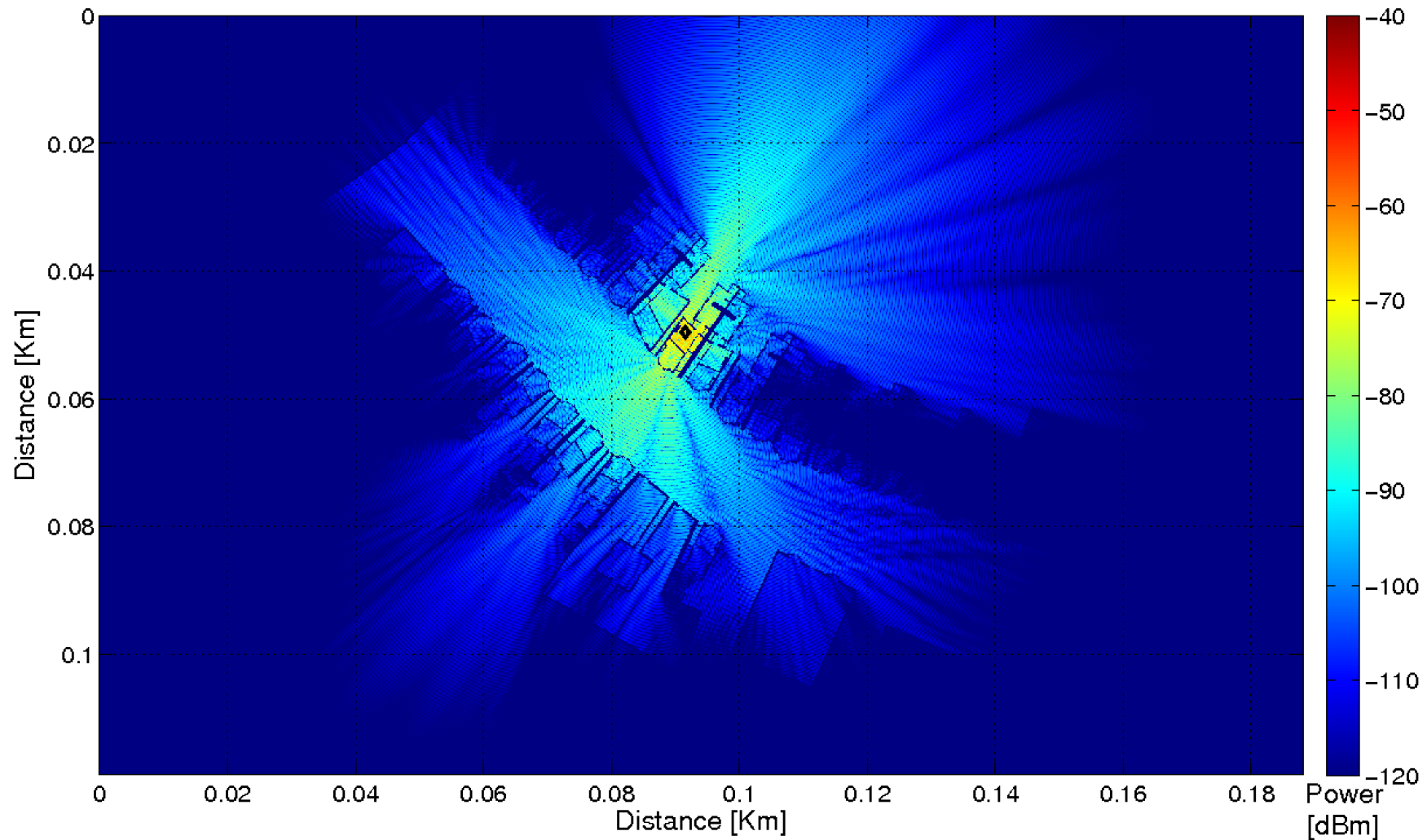
# Platform Overview - Outdoor



# Platform Overview - Indoor

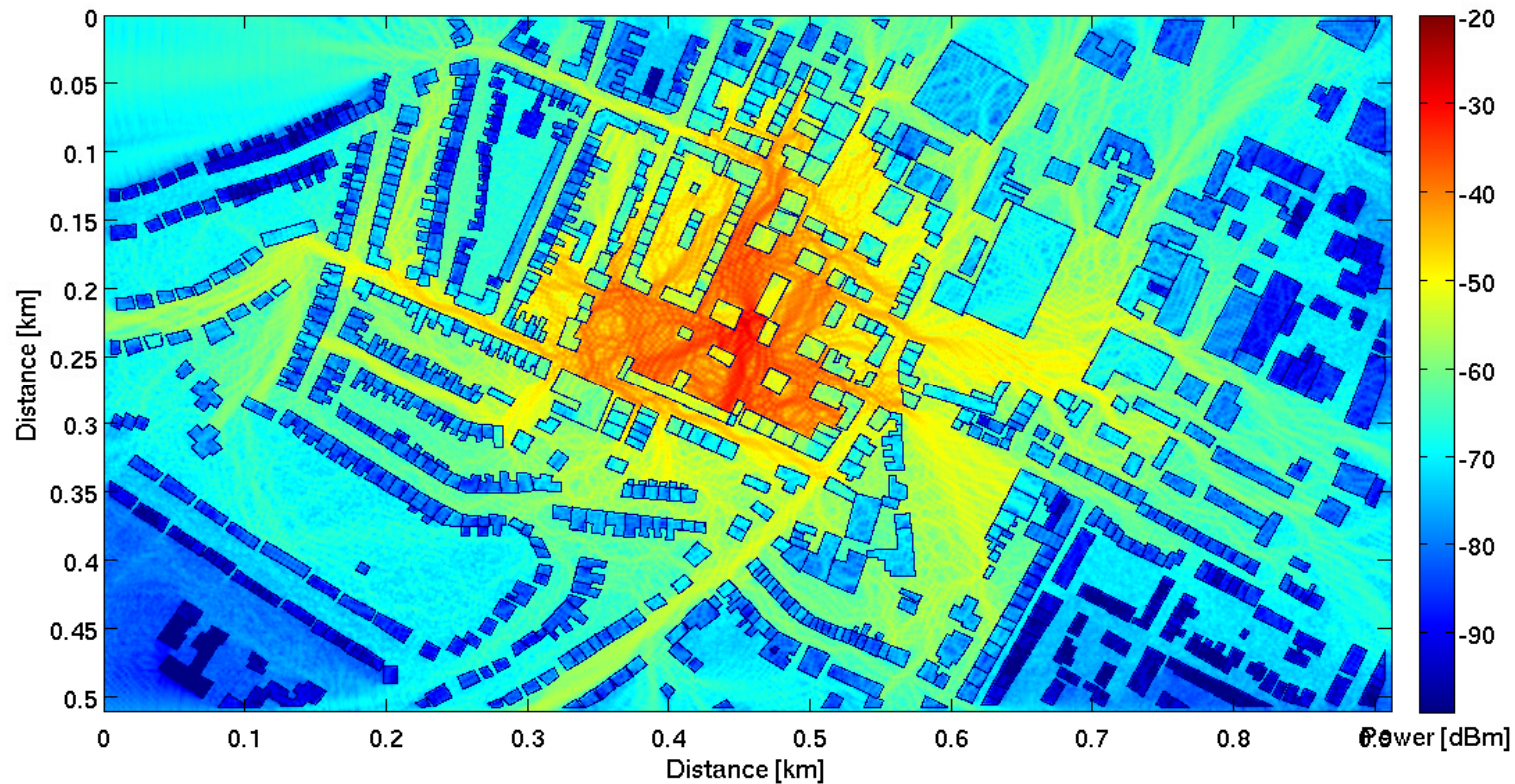


# Coverage prediction of one femtocell

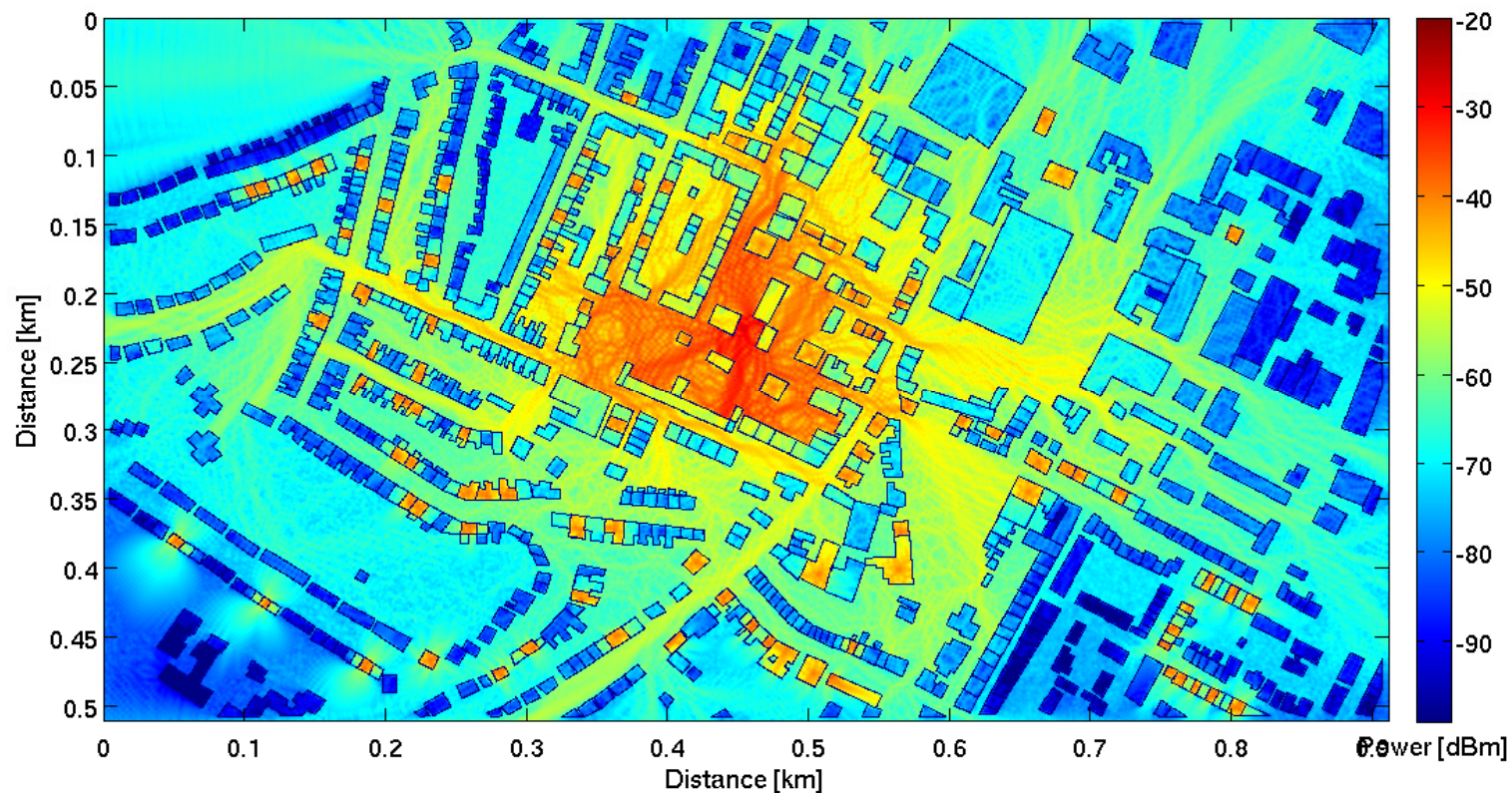




# Coverage of femto/macrocells



# Coverage of femto/macrocells



# Examples

- OFDMA femtocells
- Residential scenario (Luton)
- 3 examples:
  - CSG vs open access
  - Frequency planning
  - Mobility

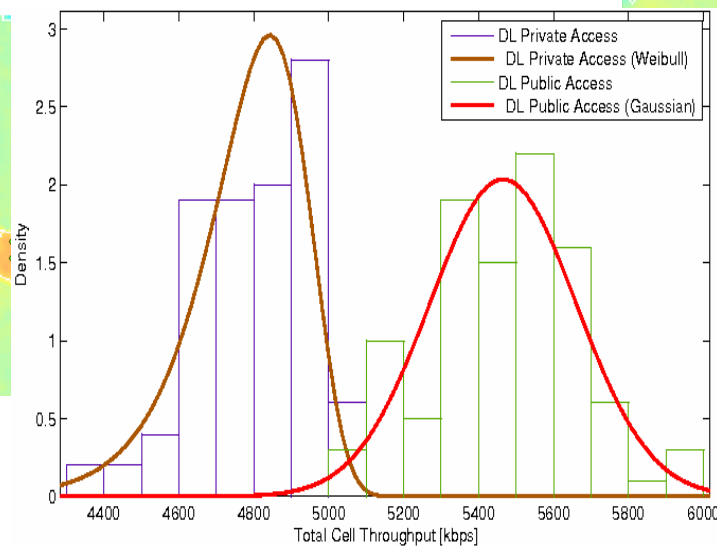
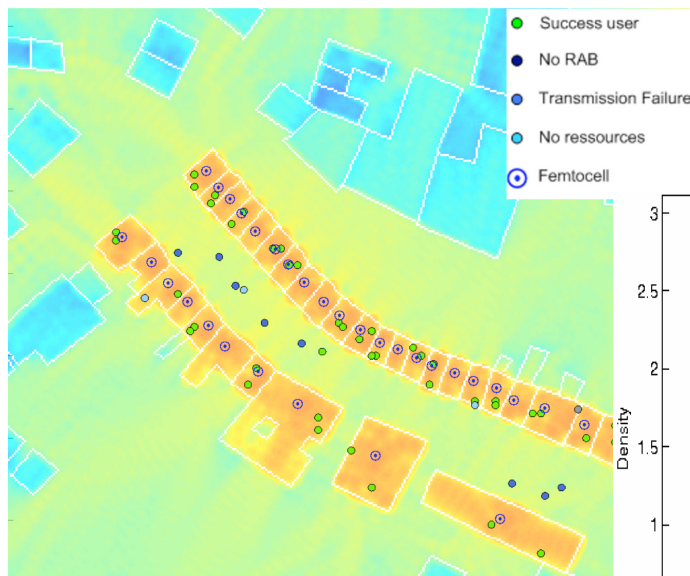
# Example 1: CSG vs Open

- CSG (Closed subscriber group)
  - Non subscribers: can connect to the macrocell only
  - subscribers: can connect to their femtocell or the macrocell
- Open access
  - Outdoor and indoor users have the same rights to connect to both macro and femtocells

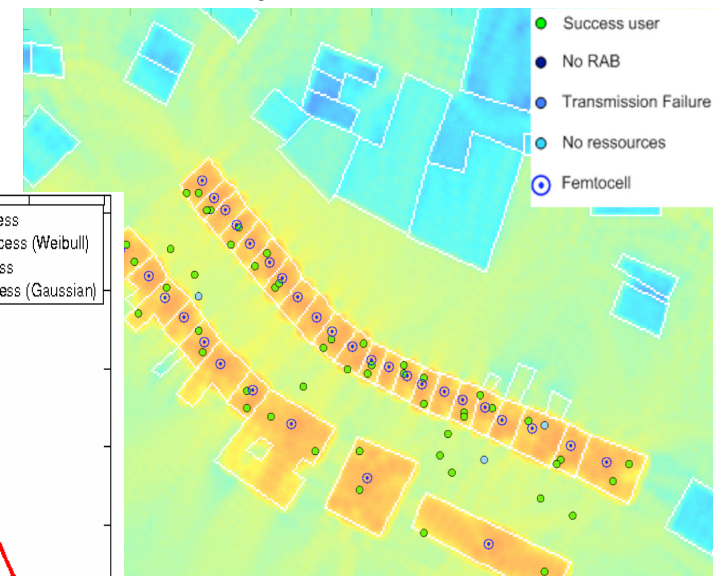


# Example 1: Results

CSG Access



Open Access



ACCESS METHOD STATISTICS

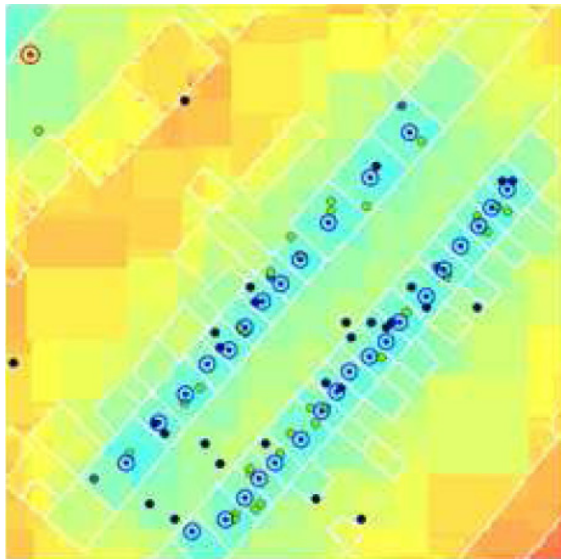
	Public Access	Private Access
Users with errors in transmission	6.2%	6.8%
Users without RAB	0.2%	6.8%



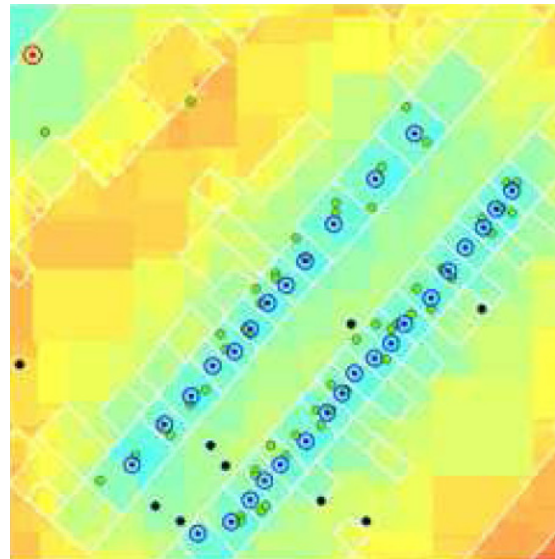
## Example 2: Frequency allocation

- Frequency planning strategies:
  - Orthogonal channel assignment
  - Co-channel assignment
- Choice of the channel:
  - Random
  - FRSx (spectrum divided into x fragments)
  - Self-Optimized (centralized, use of sensing)

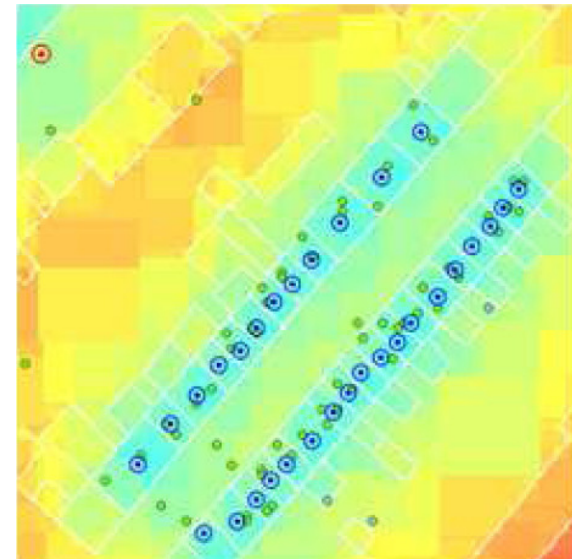
# Example 2: Results



Same channel  
Throughput=3168kbps



Random channel  
Throughput=5707kbps

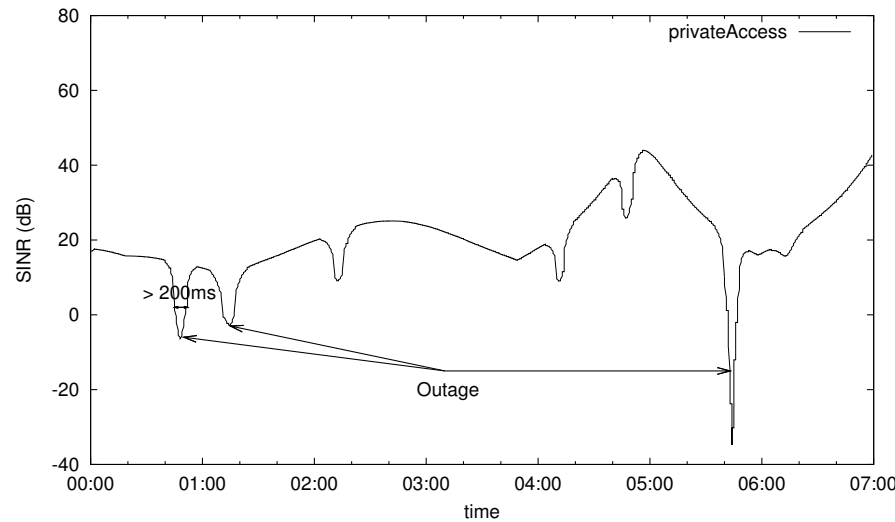


Optimized channel  
Throughput=6652kbps

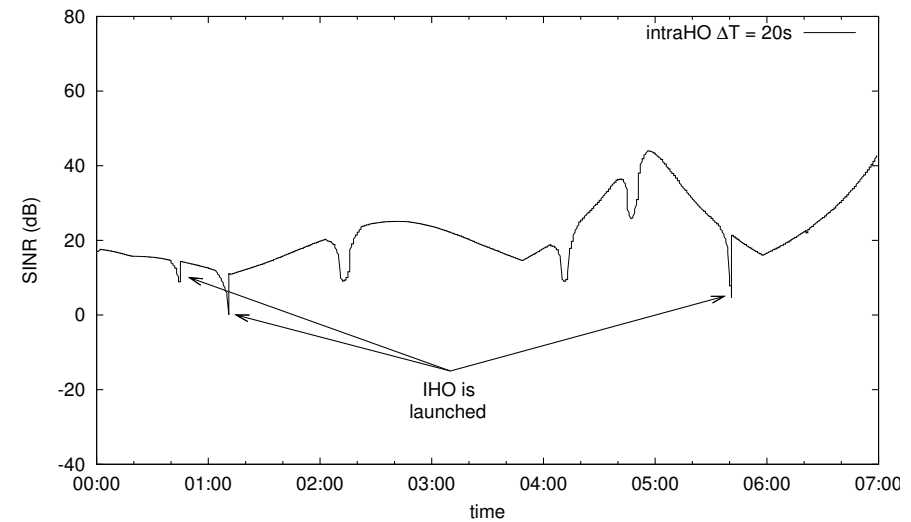
# Example 3: Study of mobility

- Different strategies to perform handover
  - Thresholds, delays...
  - Macro to femto, femto to macro, femto to femto (open access only)
- Use of dynamic system level simulation
  - Outdoor users moving in the street.
  - CSG access mode

# Example 3: results



Standard Handover



Improved solution (delays +  
intra-cell handover)

# More information

- **Book:**

**“Femtocells – Technologies and Deployment”, Wiley, Q3 2009.** (Lead authors: Prof. Jie Zhang and Dr Guillaume de la Roche ; Contributing authors: Alvaro Valcarce, David Lopez, Enjie Liu and Hui Song)

- **Journal/conference Publications**

[1] D. López-Pérez, A. Valcarce, G. De La Roche and J. Zhang, "OFDMA femtocells: A roadmap on interference avoidance," in IEEE Communications Magazine, 2009.

(accepted and to appear)

[2] A. Valcarce, G. De La Roche, A. Juttner, D. López-Pérez and J. Zhang, "Applying FDTD to the coverage prediction of WiMAX femtocells," in EURASIP Journal of Wireless Communications and Networking. Volume 2009, Article ID 308606, 13 pages.

[3] A. Valcarce, D. López-Pérez, G. De La Roche and J. Zhang, "Predicting small-scale fading distributions with Finite-Difference methods in Indoor-to-Outdoor scenarios," in IEEE Vehicular Technology Conference (VTC) 2009-Spring, Barcelona, April 2009.

[4] D. López-Pérez, A. Valcarce, G. De La Roche and J. Zhang, "Access Methods to WiMAX Femtocells: A downlink system-level case study," in IEEE International Conference on Communication Systems (ICCS), Guangzhou, China, November 2008.

[5] D. López-Pérez, G. De La Roche, A. Valcarce, A. Jüttner and J. Zhang, "Interference Avoidance and Dynamic Frequency Planning for WiMAX Femtocells Networks," in IEEE International Conference on Communication Systems (ICCS), Guangzhou, China, November 2008.

# Challenges under investigation

- Self-organization
- Timing
- Security
- Location
- Access methods
- Applications
- Health issues

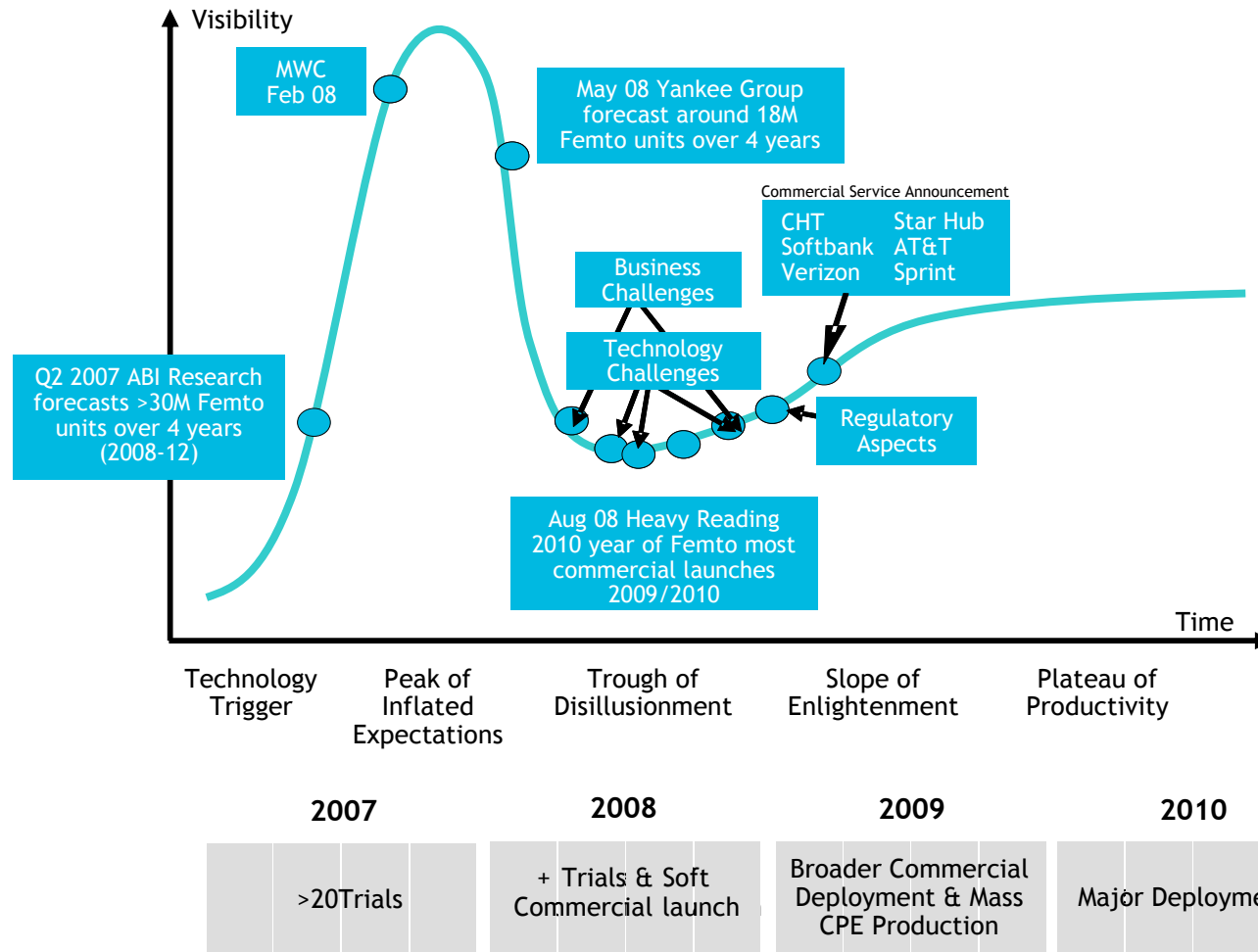
# Future Evolution of Femtocell Deployments



Holger Claussen

Bell Labs

## Femto Market View



Source: Gartner Group's emerging technology curve customized by Alcatel-Lucent for FEMTO

**Question: How will Femtocell deployments evolve in the future?**



## Improving spectral efficiency per area

### Separate carrier for femtocells

- private access
- public access



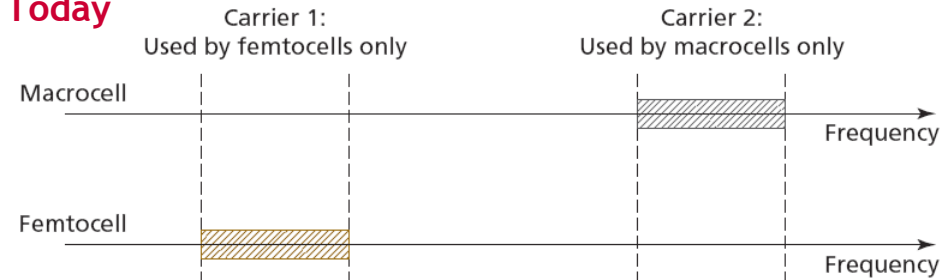
### Co-channel operation of macro- and femtocells on a single shared carrier

- private access NOT FEASIBLE due to high interference - coverage holes exist around femtocells with restricted access if no alternative carrier is available
- public access

### Co-channel operation of macro- and femtocells with one shared & one clean macrocell carrier

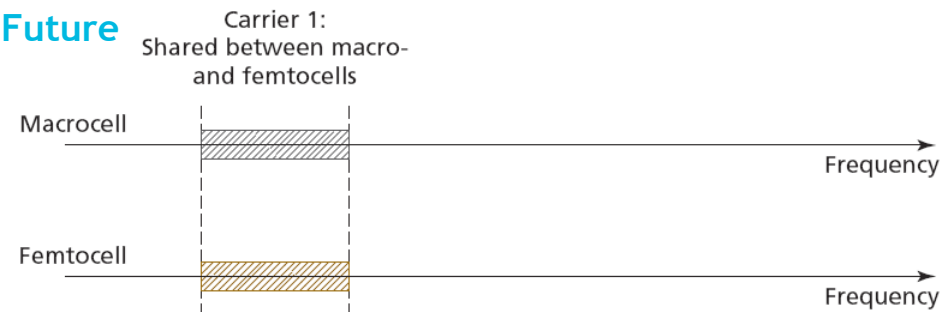
- private access - requires one clean macrocell carrier to serve UEs that are in range of femtocells with restricted access
- public access - optionally all carriers can be shared

#### Today

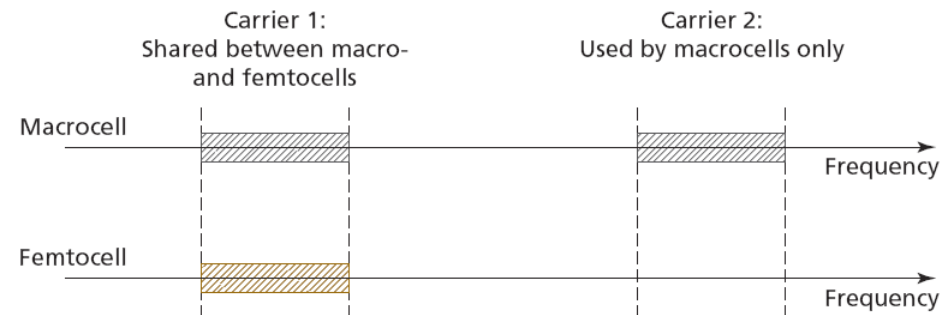


(a) Separate carriers

#### Future



(b) Shared carrier

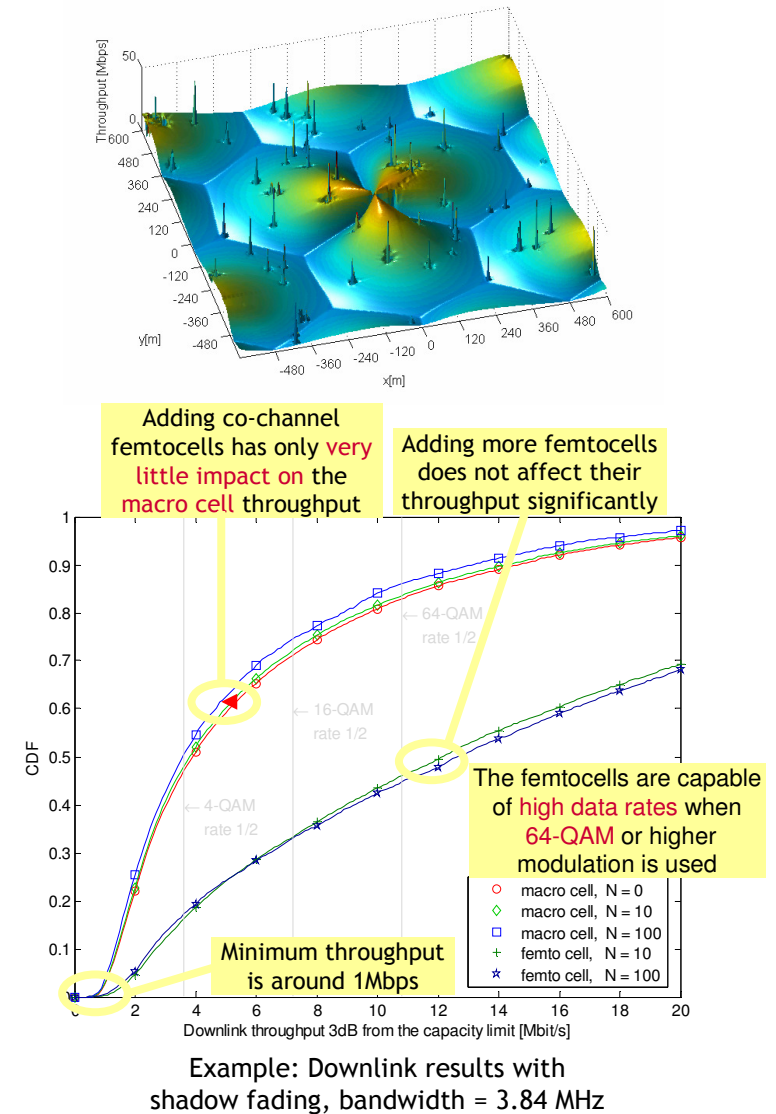


(c) Partially shared carriers

## Technical feasibility of co-channel operation (2007)

### Results

- **Co-channel deployment** of femtocells in a macrocellular network is possible **without significant impact on the macrocell performance**.
- This allows efficient **spatial frequency re-use**.
- **Femtocell throughputs** indoors are **very high** since the wall separation to interference sources results in a high SINR. 64-QAM support recommended.
- **Power self-optimization** for both DL and UL of the femtocell is **necessary to ensure a low impact** on the macrocellular network and to achieve a **consistent cell range** independent from the distance to the macrocell.
- For **co-channel operation** with only **one available carrier**, **public access** for femtocells is **required**.



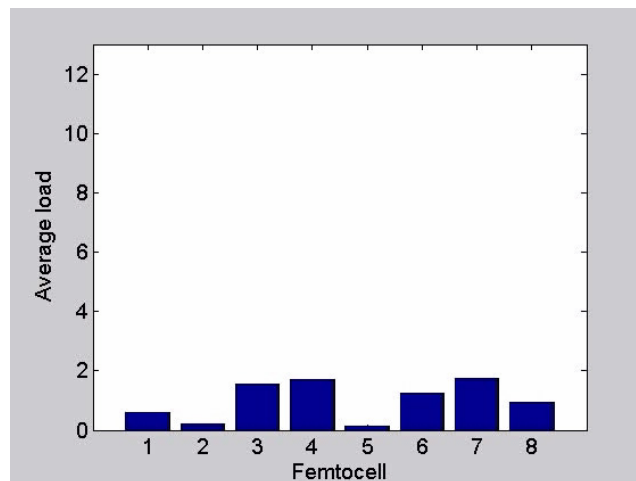
# Enterprise Femtocells

The femtocell concept will be extended to support enterprise applications

This requires several changes:

- Support for more active users (8-16)
- Higher power (~250mW)
- Different self-optimization algorithms
- Connects via Ethernet

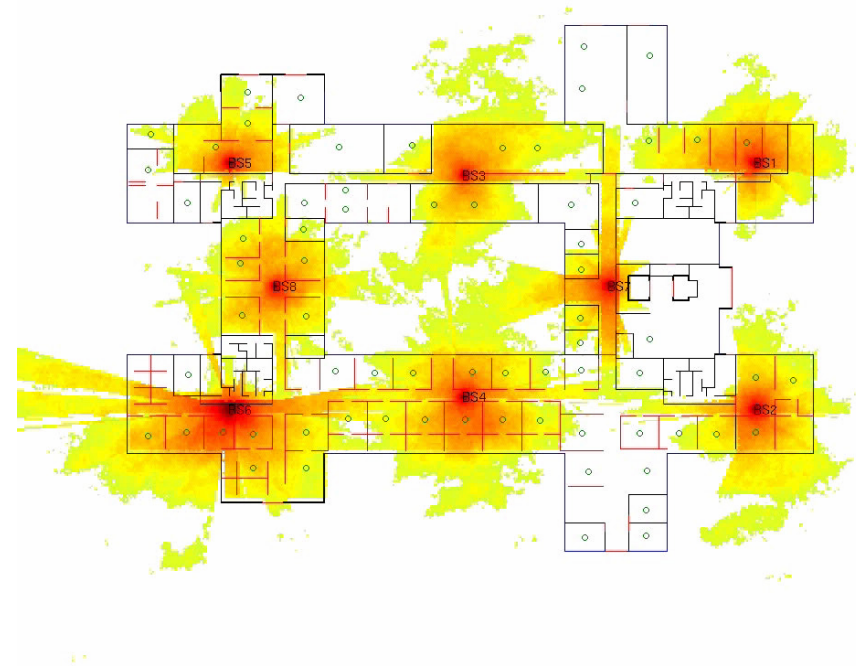
Plug-and-Play deployment model will remain unchanged!



## Example: Distributed Coverage Optimization

Algorithm uses local measurements as inputs and adjusts coverage to balance the needs of following objectives:

- minimise coverage holes
- balance load
- minimise overlap and leakage



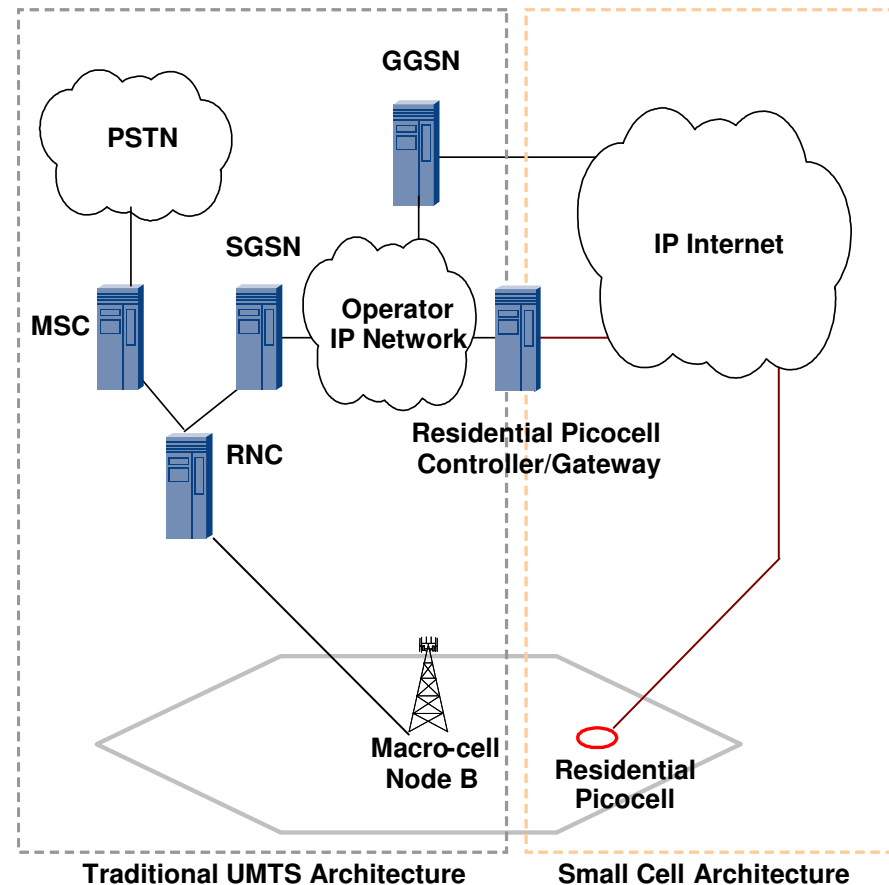
# Future small cell deployments

## The concept

- Slightly increase coverage of Femtocells to a cell radius of around 60m (Residential Picocells)
- Increase support to 8 users.
- Use small cell deployed by the user to supplement macrocell coverage
- Use the user's internet connection as backhaul
- Allow public access for users of the same operator
- This results in no costs for the cell deployment, the site, electricity, and backhaul for the operator

## Questions:

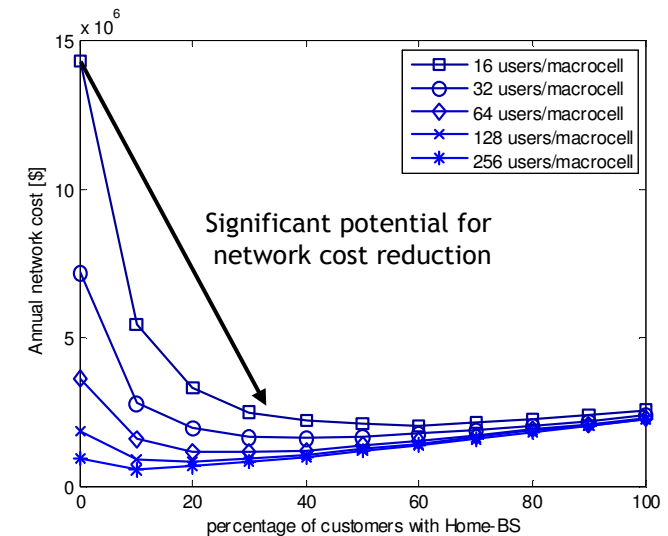
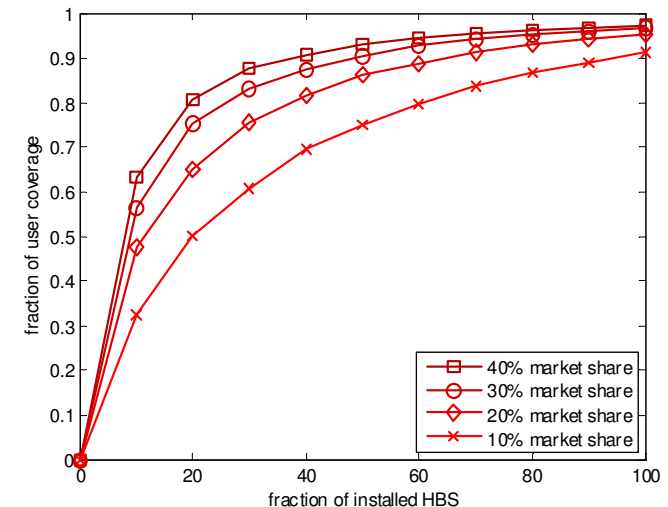
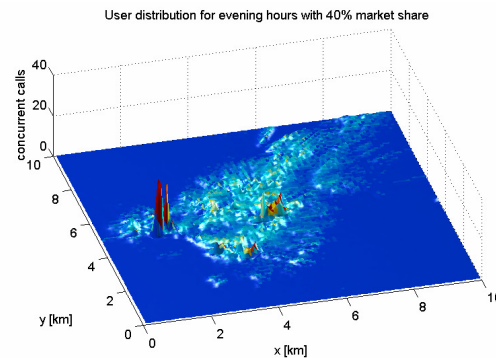
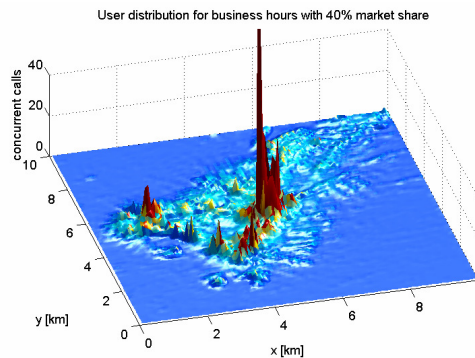
- What is the financial impact?
- What is the impact on the total energy consumption of the network?



# Future small cell deployments can significantly reduce the total annual network costs (2006)

## Results

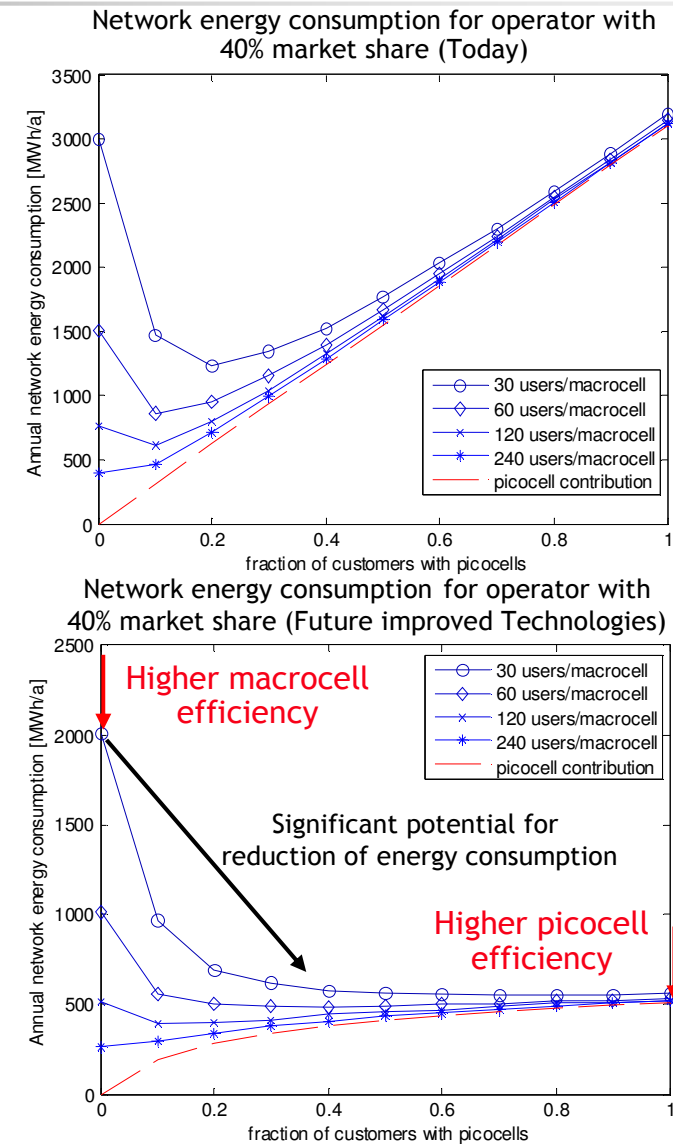
- Macro-cellular networks become less economically viable with an increasing demand of high data rate services due to high operational expenses
- This problem can be addressed by user-deployed publicly accessible residential picocells
- A large fraction of the user demand can be covered by installing home base stations in only a small fraction of the customer's homes
- Residential picocell deployment in combination with a macro-cellular network for area coverage can potentially reduce the annual network costs by 30% to 70%.



# Future small cell deployments enable significant improvements in energy efficiency of cellular networks (2008)

## Results

- A mixed macro- and residential picocell architecture can significantly reduce the energy consumption of cellular networks for high data rate user demand in urban areas where macrocells are capacity limited
- Based on today's technology the power consumption can be reduced by up to 60% for high data rate demand in urban areas.
- Effect expected to increase in the future when both technologies mature
- Operators with high market share benefit more from the advantages since high small cell coverage is achieved with a lower fraction of customers with small cells.
- A joint macro- small cell architecture is also attractive for operators since energy consumed by picocells is paid for by the customer



## Summary

---

**Reserving carriers for femtocells will not be acceptable** in the future since this restricts the macrocellular capacity too much.

- **Co-channel operation** with a macrocellular network is feasible and **solves this problem**.
- **Partial frequency re-use** for femtocells is **most likely** due the flexibility of this approach.

The femtocell concept will be **extended to Enterprise applications**

- **More capable hardware platform** (more supported users, higher power).
- Need for **advanced self-optimization** that allows joint optimization of multiple cells.
- **Same plug-and-play deployment model** as residential femtocells.

A promising direction for the future evolution of femtocells is to **change their objective** from providing coverage in the home **to supplementing macrocellular coverage**.

- **Increased coverage, supported users, allow public access**.
- This can **significantly reduce** the **total network costs** and the **total energy consumption** in urban areas when the demand for high data services increases.





# Femto Cell End to End Solutions

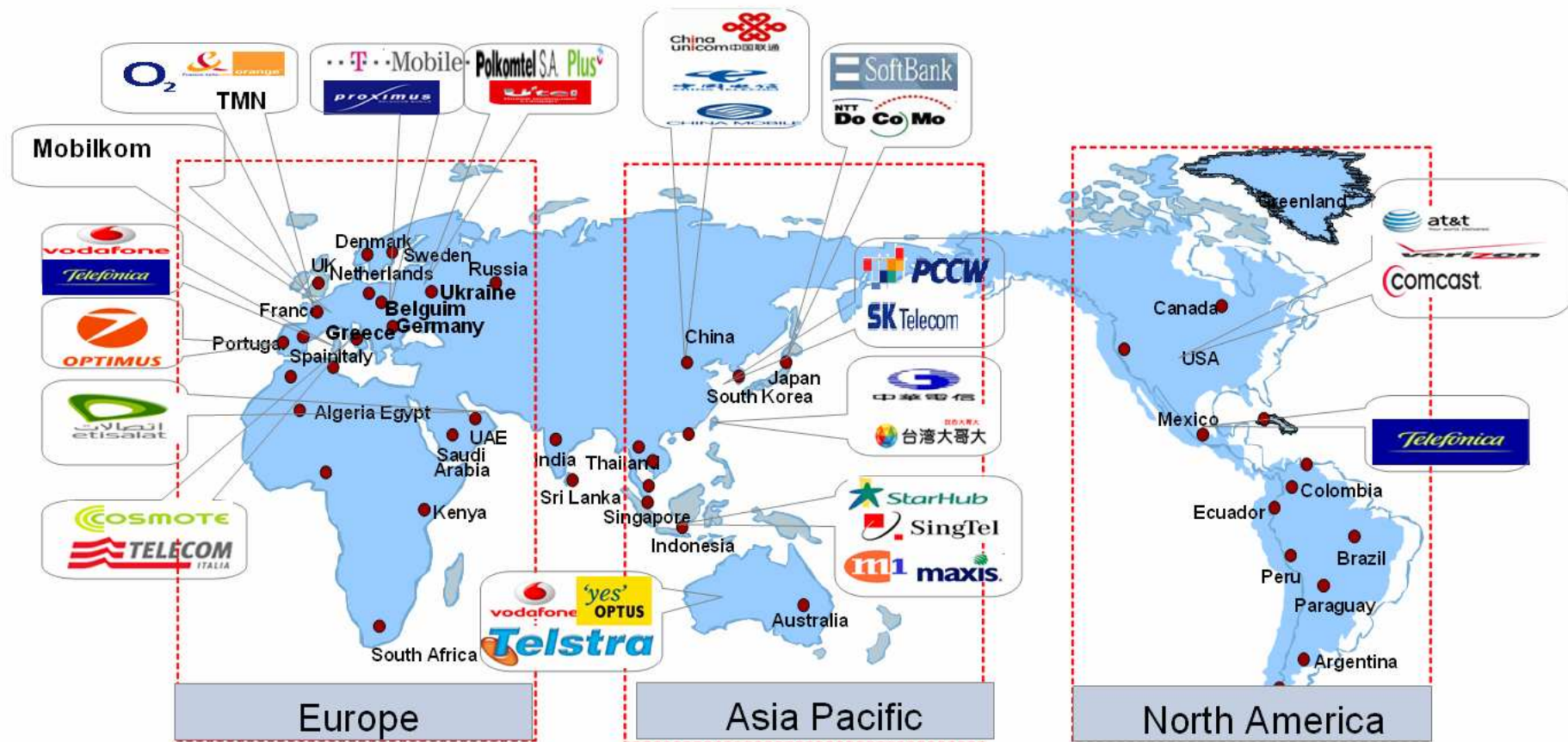
John Raw C.Eng MIET  
+447920870541  
[john.raw@huawei.com](mailto:john.raw@huawei.com)

[www.huawei.com](http://www.huawei.com)

HUAWEI TECHNOLOGIES CO., LTD.

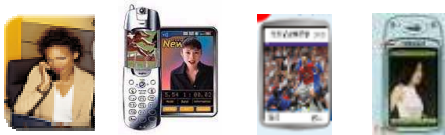


# Huawei Global Experience



# Huawei uBro Key Features overview

## 1 All UMTS Services & Terminals



## 2 Access control

Multiple access control modes:

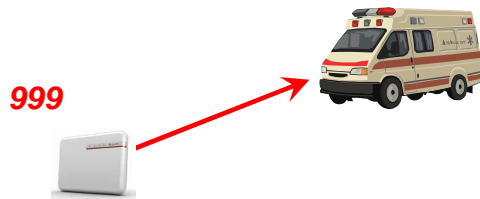
- Open: all users
- Closed: only authorised users
- Community: Groups

## 3 Location indication

Indicates if user is in home zone



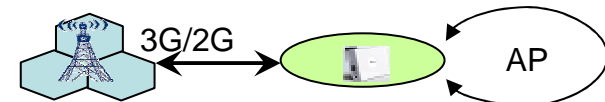
## 8 Emergency call



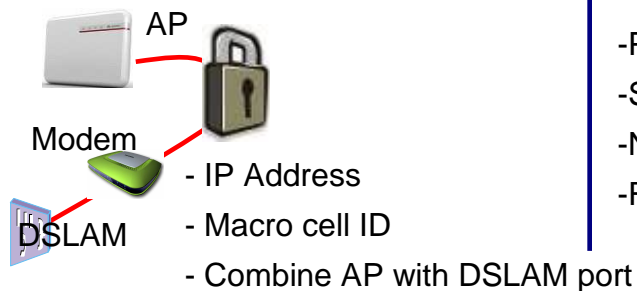
## Key Features

## 4 Mobility

- handover from AP to 3G/2G
- handover from 2G/3G to AP
- Support handover between APs



## 7 Location lock



## 6 Auto-configuration

- Pilot Power auto. adjustment
- Scrambling code auto assign
- Neighbouring cell auto sense
- Radio parameter profile

## 5 IP Clock Sync. & Air Sync.



If no macro coverage, clock server provides IP clock synchronization

# Plug and Play



## All the end user needs to do is:

1. Get the AP (at shop or posted)
2. Connect Ethernet cable to DSL Router.
3. Power on

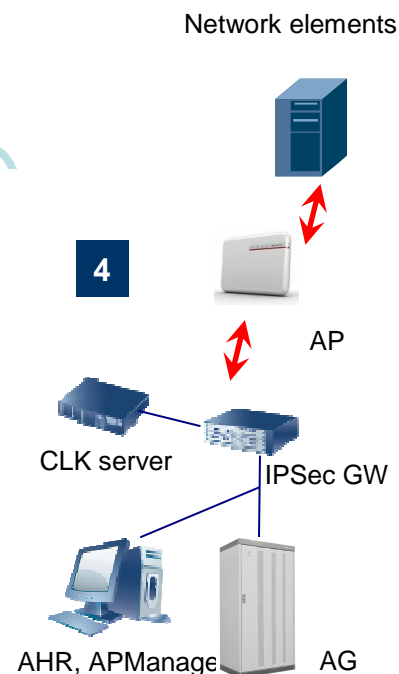
## **AP auto setup and auto configuration:**

4a. AP automatically finds the DNS, SEGW, AG servers

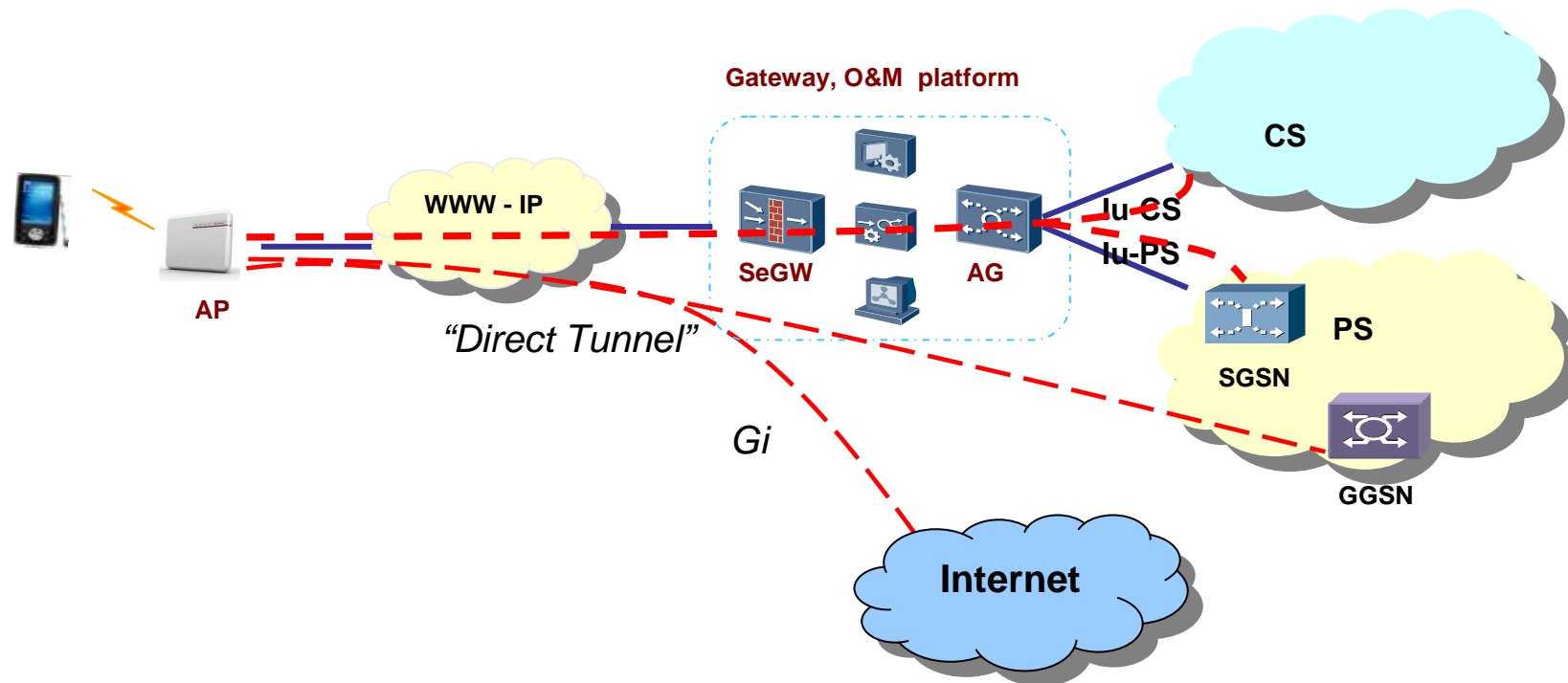
4b. Auto discovery to set up connections with other entities e.g. IPCLK server

### Auto Configuration:

- Carrier auto selection
- Scrambling code auto selection
- Neighbouring cell auto sense (2G & 3G)
- Pilot power auto adjustment
- Radio parameter profile configuration



# Traffic Flow and Offload Strategy



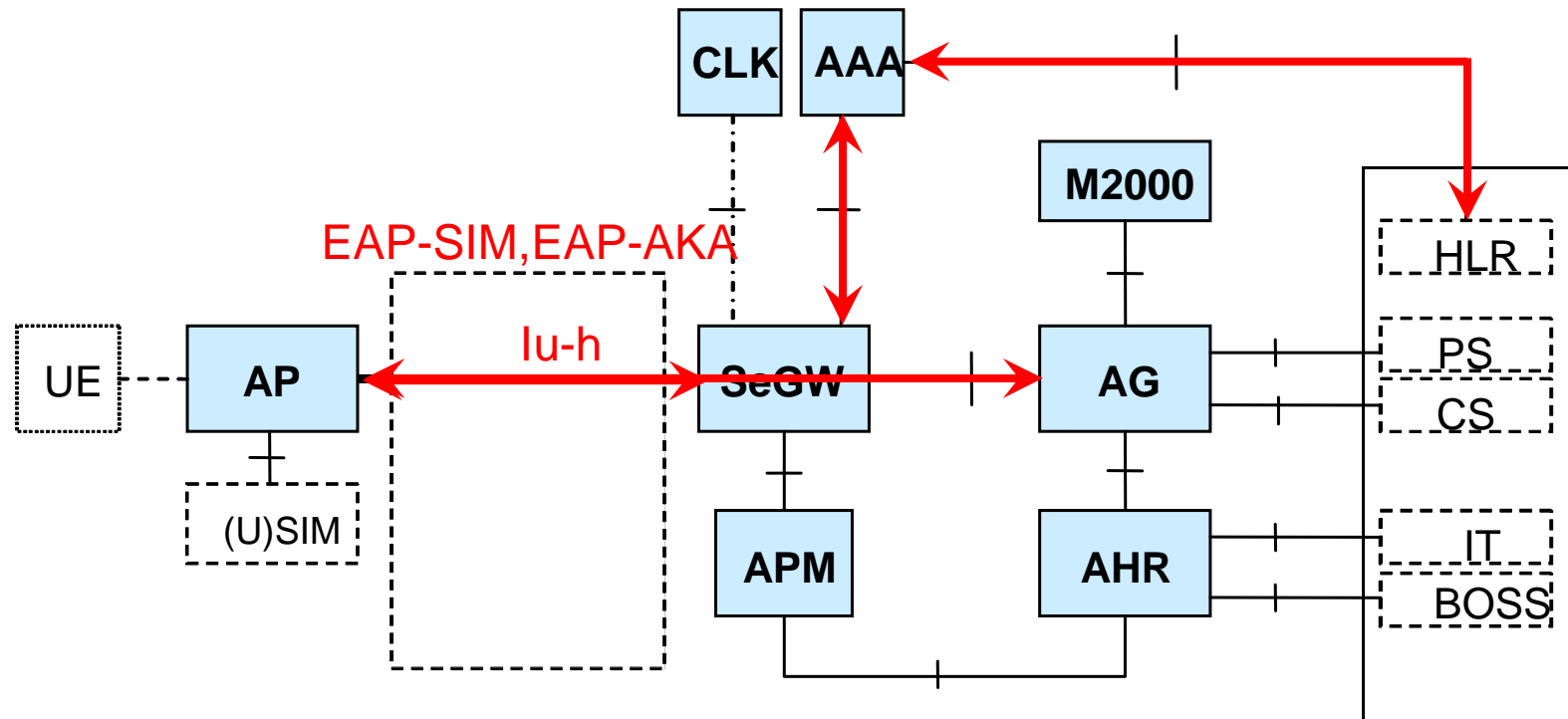
## Primary Traffic Routing

- All traffic is passed to core network via standard Iu-CS and Iu-PS

## Traffic Routing Evolution

- Support Direct Tunnel - skip SGSN to go directly to GGSN
- Direct Gi for local traffic- skips all infrastructure !

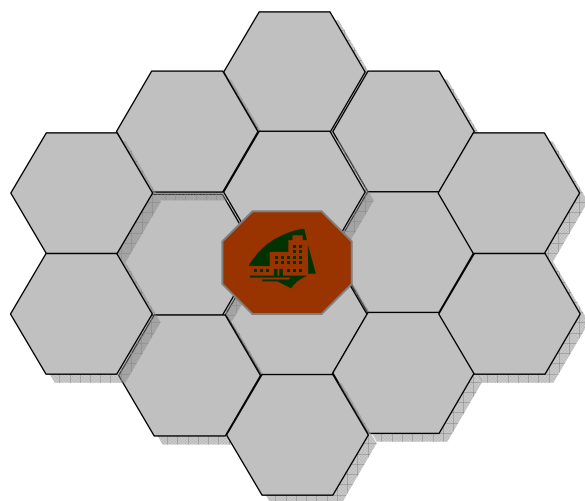
# System Architecture and Interface (1)



**AP:** Radio Access (Node B and RNC)  
**AG:** AP concentrator & CN interface  
**AHR:** Control DB for uBro access control  
**SeGW:** IPSec tunnel and IKEV2 security

**AAA:** Authentication for SIM/USIM used in AP  
**AP Manager:** OMC system for AP  
**M2000:** OMC system  
**Clock server:** IP clock synchronization.

# Deployment: Mobility Principles



## Femto Enterprise-oriented Mobility

### Femto Home-oriented Mobility

#### Idle Mobility:

Femto Solution based on automatic neighbour detection  
2G & 3G sniffer capabilities

#### Outgoing Mobility:

Femto Solution based on automatic neighbour detection 2G  
& 3G sniffer capabilities

Handover to another AP is required for seamless coverage

#### Incoming Mobility:

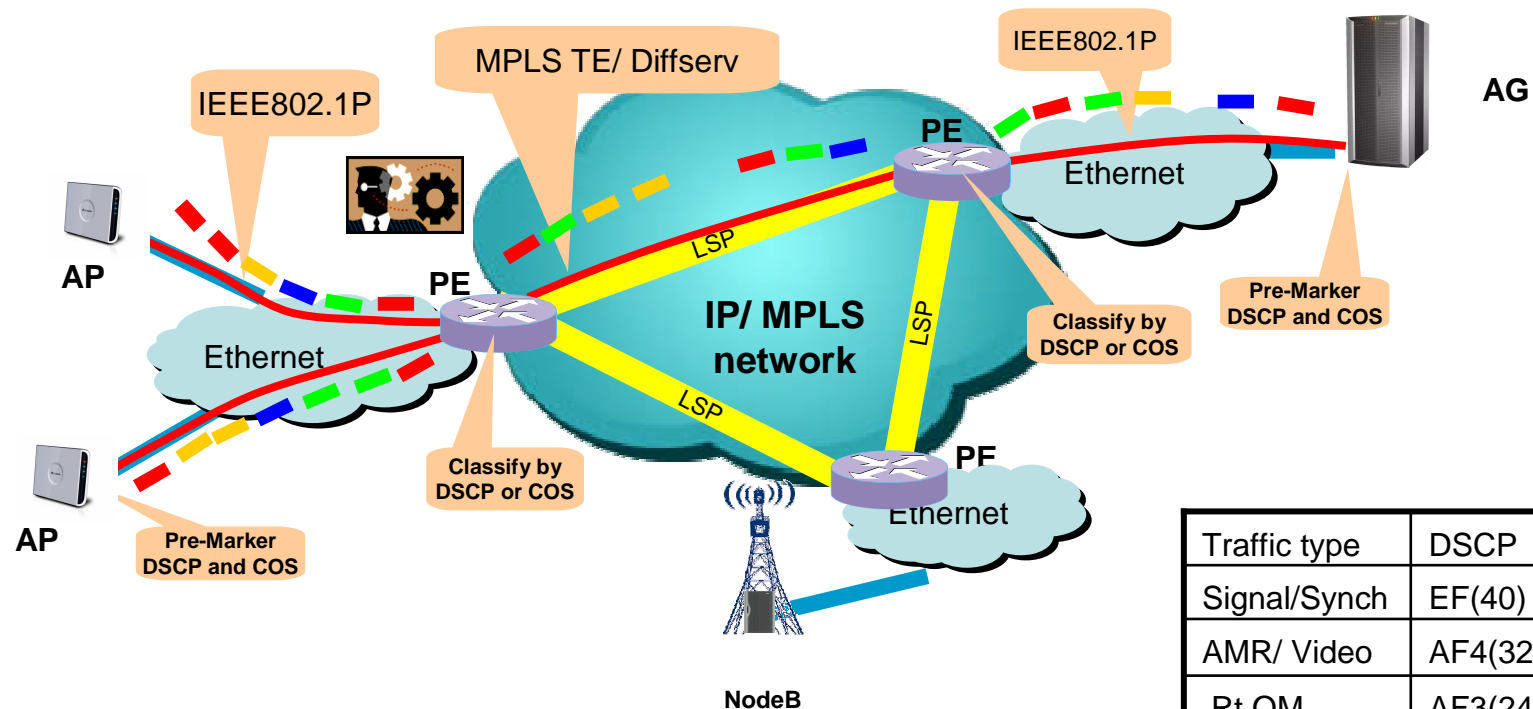
Requires support in the Macro Network

Requires configuration to Identify Target Cell

Applicable only to Open Mode

Handover from APs required for Seamless coverage

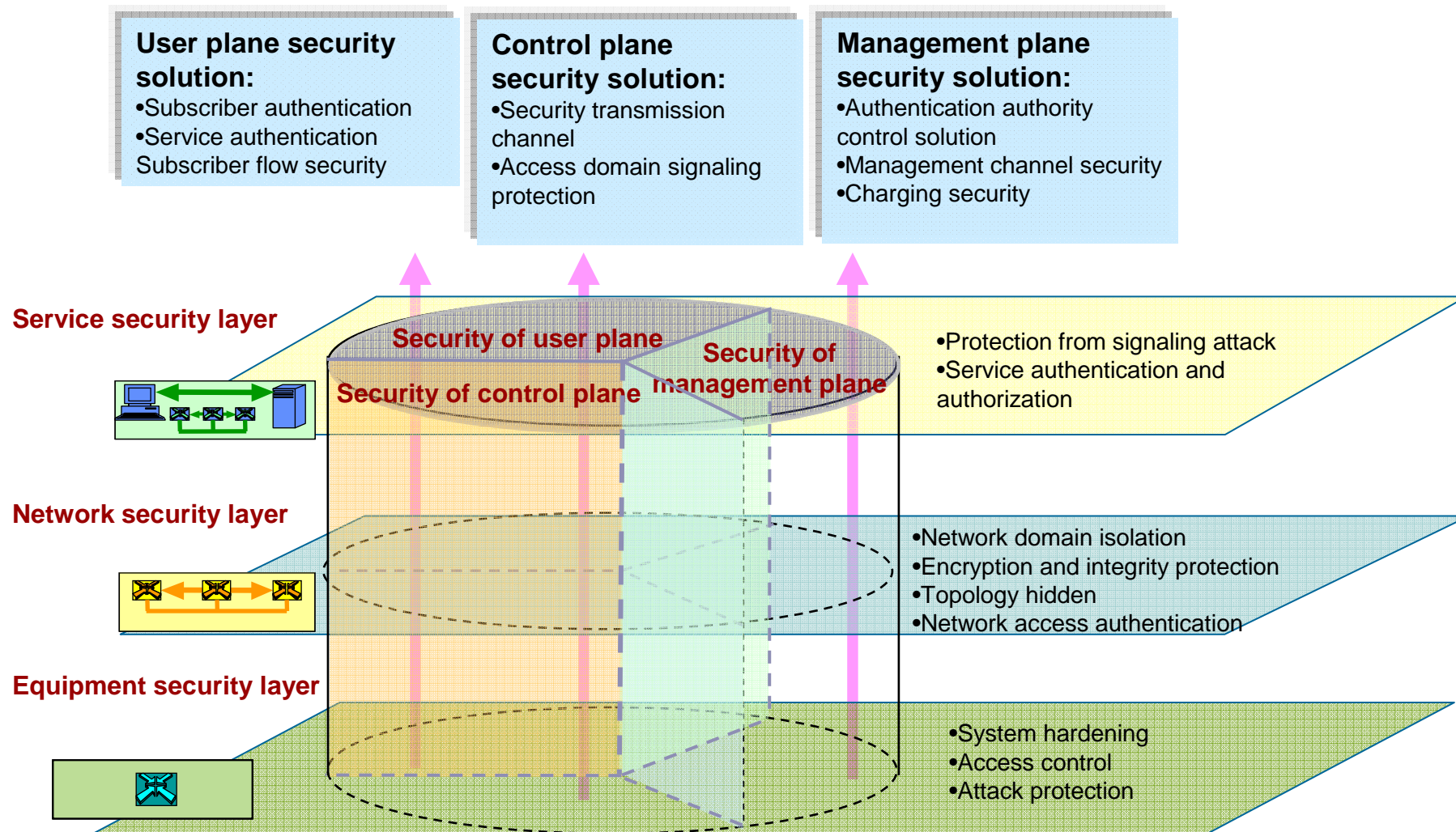
# QoS Strategy and Management



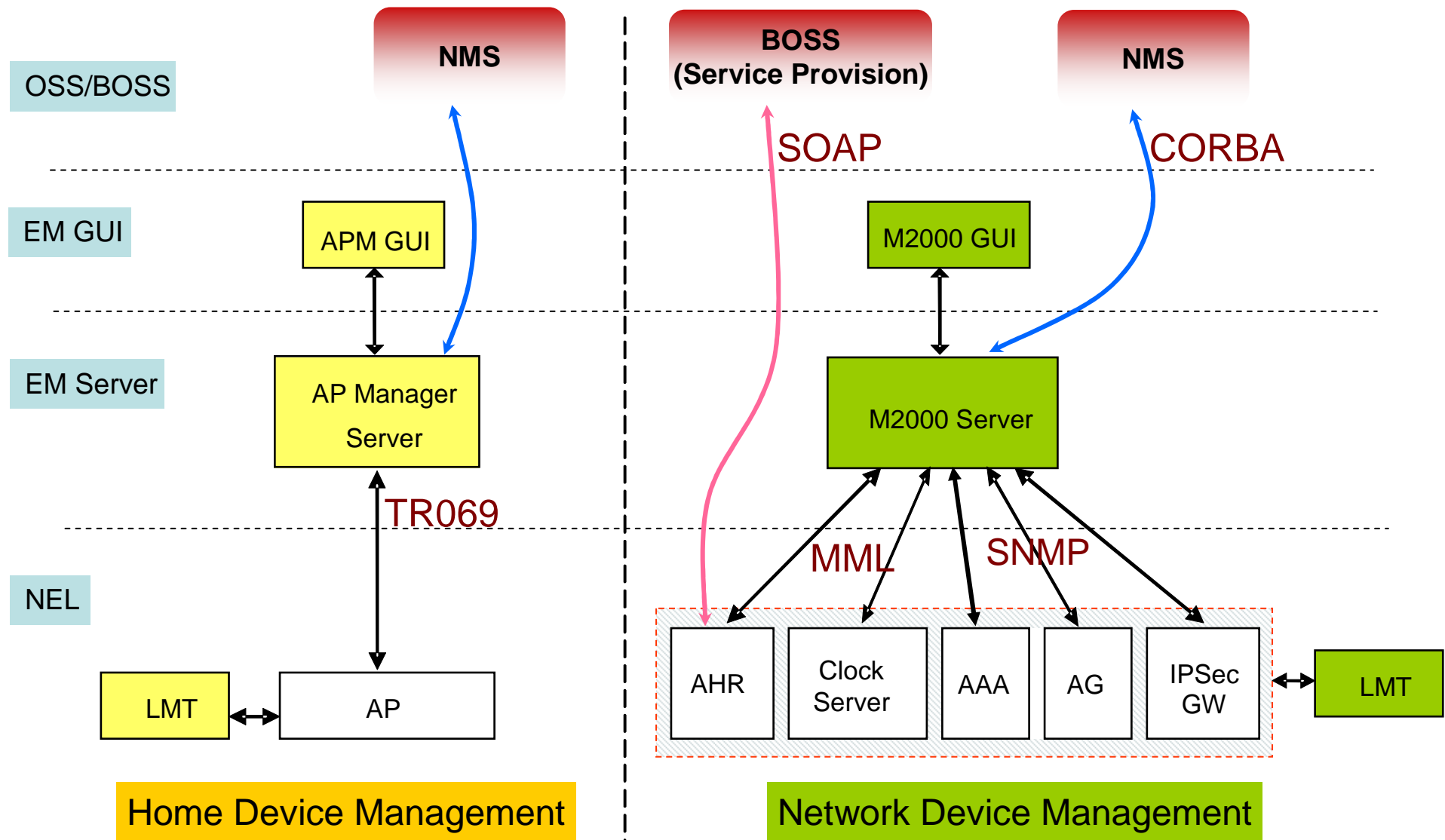
Traffic type	DSCP	CoS
Signal/Synch	EF(40)	5
AMR/ Video	AF4(32)	4
Rt OM	AF3(24)	3
Streaming	AF2(16)	2
Non-Rt OM	AF1(8)	1
I/B	BE(0)	0



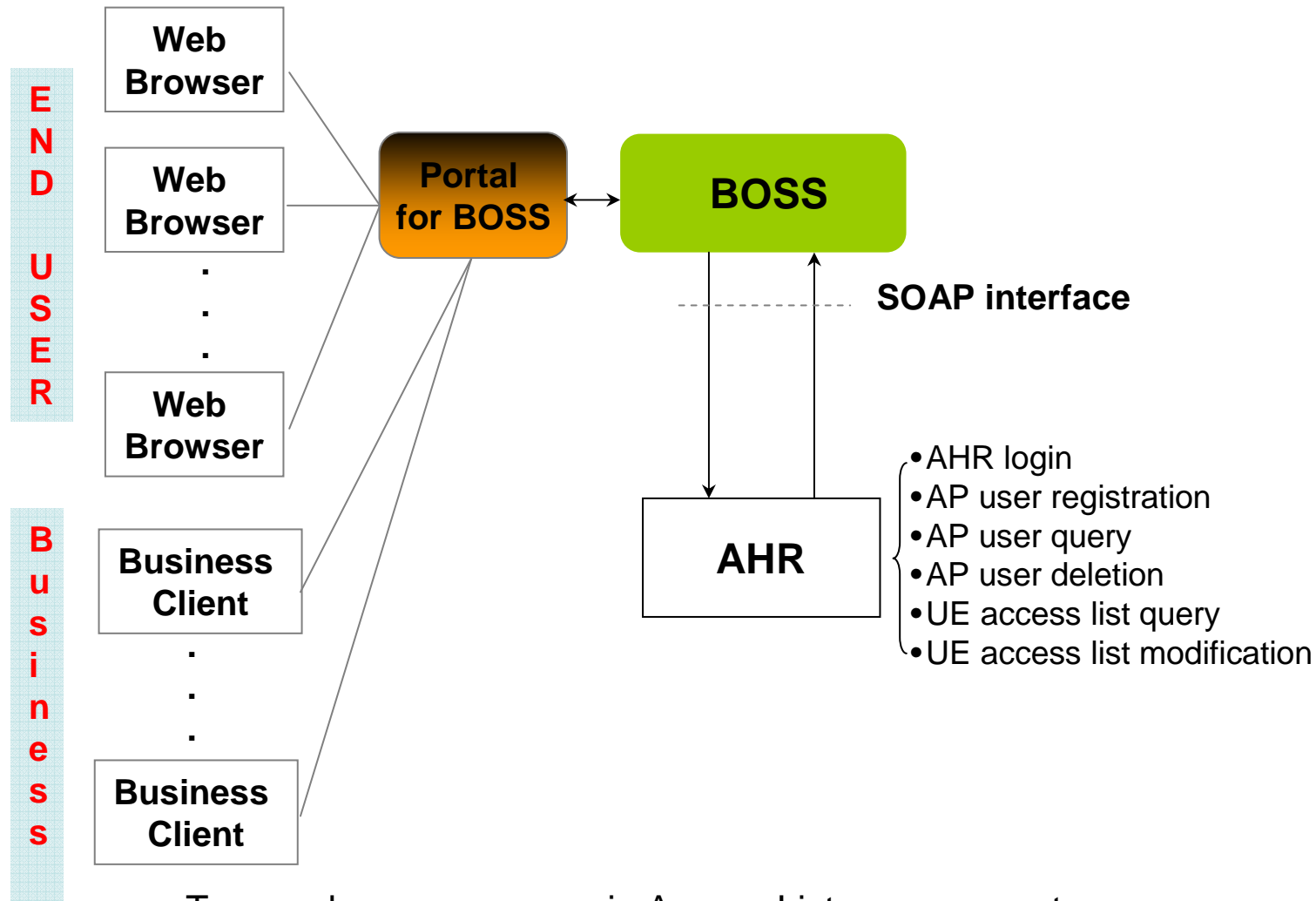
# uBro Security Solution



# Femto cell OM Structure

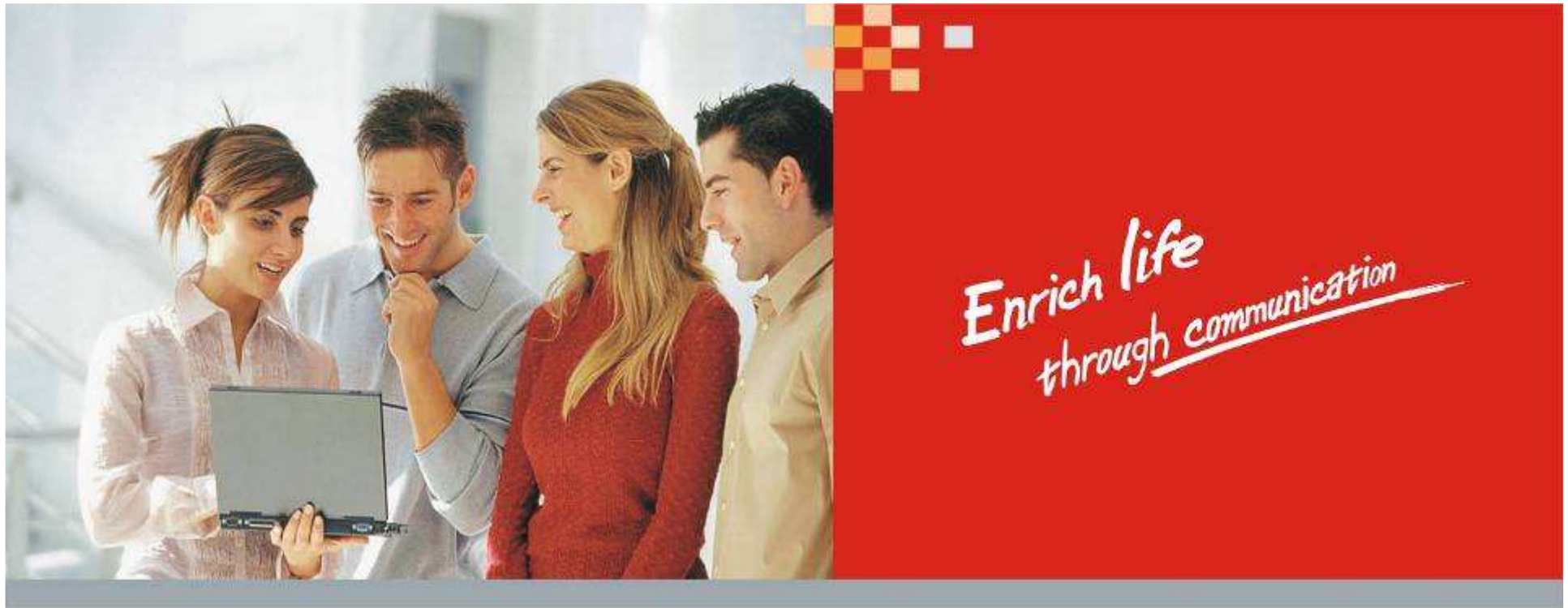


# Recommended Architecture for Provisioning



To save human resource in Access List management

•The “End User” should modify the AP access list using Web, USSD, SMS, DTMF etc.



*Enrich life  
through communication*

# Thanks

Copyright©2008 Huawei Technologies Co., Ltd. All Rights Reserved.  
The information contained in this document is for reference purpose only, and is subject to  
change or withdrawal according to specific customer requirements and conditions.