CTVR / the telecommunications research centre

Small Cells and their Technological Challenges

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What is a small cell?

Macro Cells

Micro Cells

Pico Cells

Femto Cells

Super-Femto Cells

Metro Cells

LTE Small Cells

"small cells"

I'll focus mostly on femtocells and LTE small cells systems

Challenges of

- Very large numbers of cells
- Not operator controlled

Why go smaller?

- Capacity: Greater Spectral reuse
  scales with the number of cells (also becomes more efficient)
- Costs: Reduced Operator costs
  May not be paying for backhaul
  May not be paying for energy
- Costs: improved energy efficiency
  RF energy dissipates as r^3 (or worse)
- Costs: smaller, cheaper, sites
  smaller cells, lower power, easier to find sites.

State of the Game

- 3GPP standards for femtocells
- LTE compatible and may be best implemented with small cells

- Commercial solutions available

  Alcatel Lucent 9360
  Texas Instruments
  Broadcom
  Picochip
  Ubiquisys

- Interference issues seem to be well managed

- Vodafone selling “SureSignal” and operators deploying in-fill cells and remote RF heads.

- Estimated to be 2.3m 3G femtocells deployed worldwide (*Informa*)

Challenges

- Interference/RF Frontends
- DSP and upgrade paths
- Management
- Backhaul Issues
- Energy Efficiency
- Reliability and Maintenance
- Security

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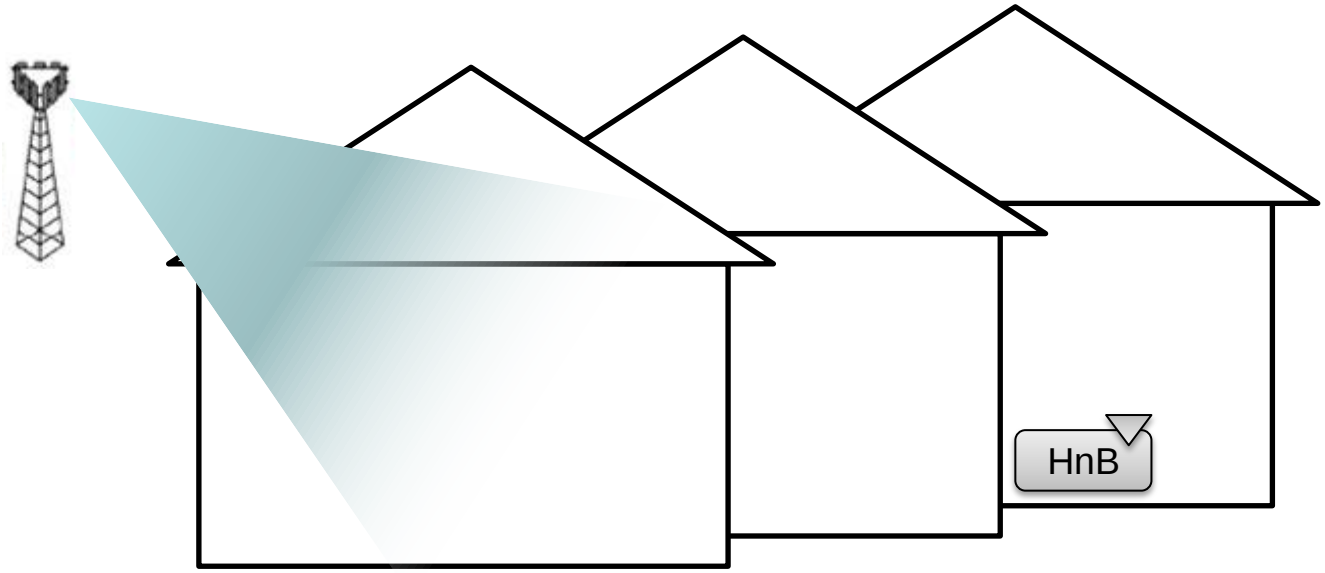
All of these can be solved or avoided

but the challenges are in finding an optimal combination for

cost
energy
ownership

Interference & RF Frontend



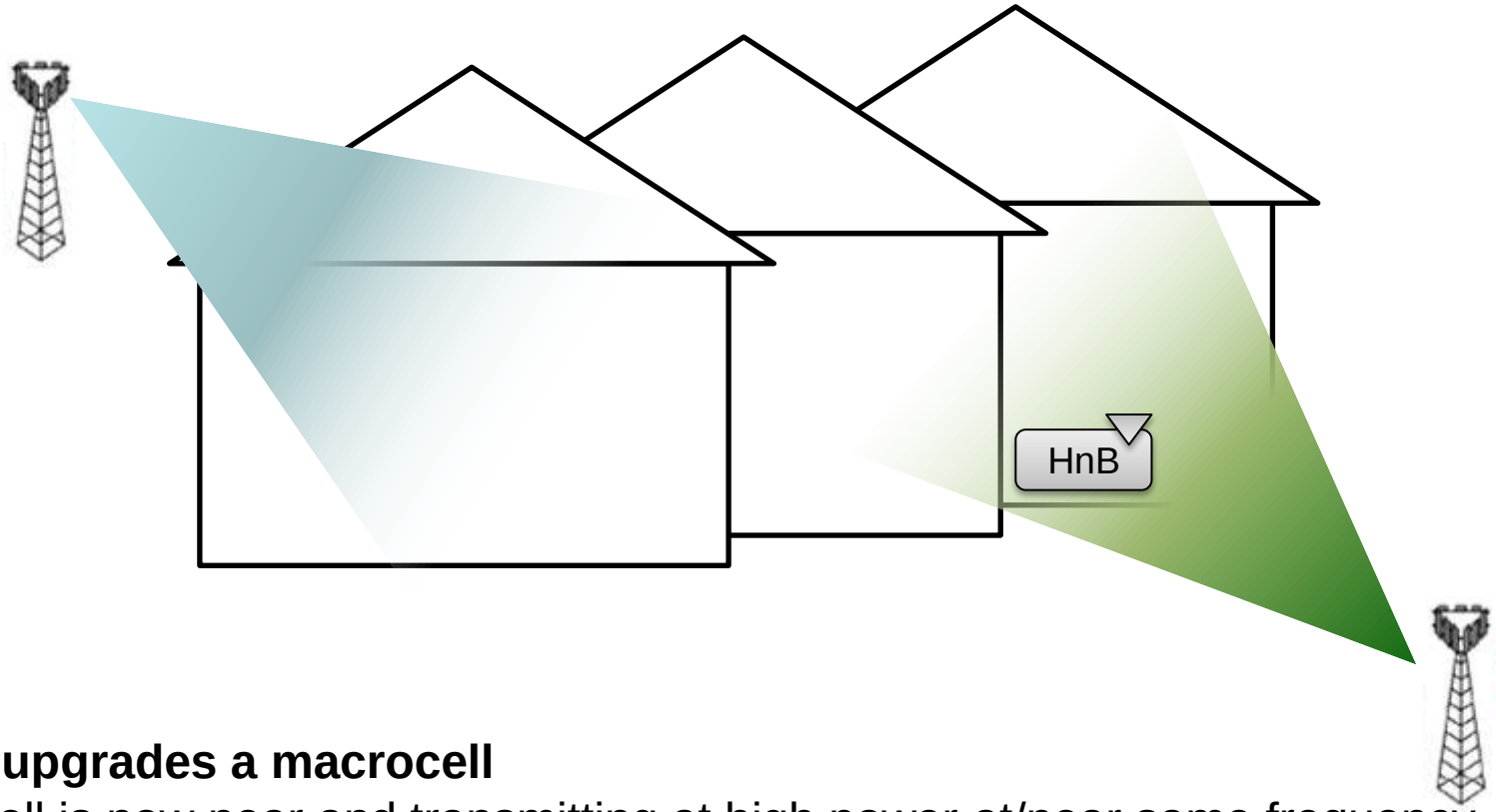
Ideal case:

Macrocell is “far” away and coverage is poor.

HnB reuses the same frequency at low power, no interference issues

Easily checked using “sniffers” on the HnB

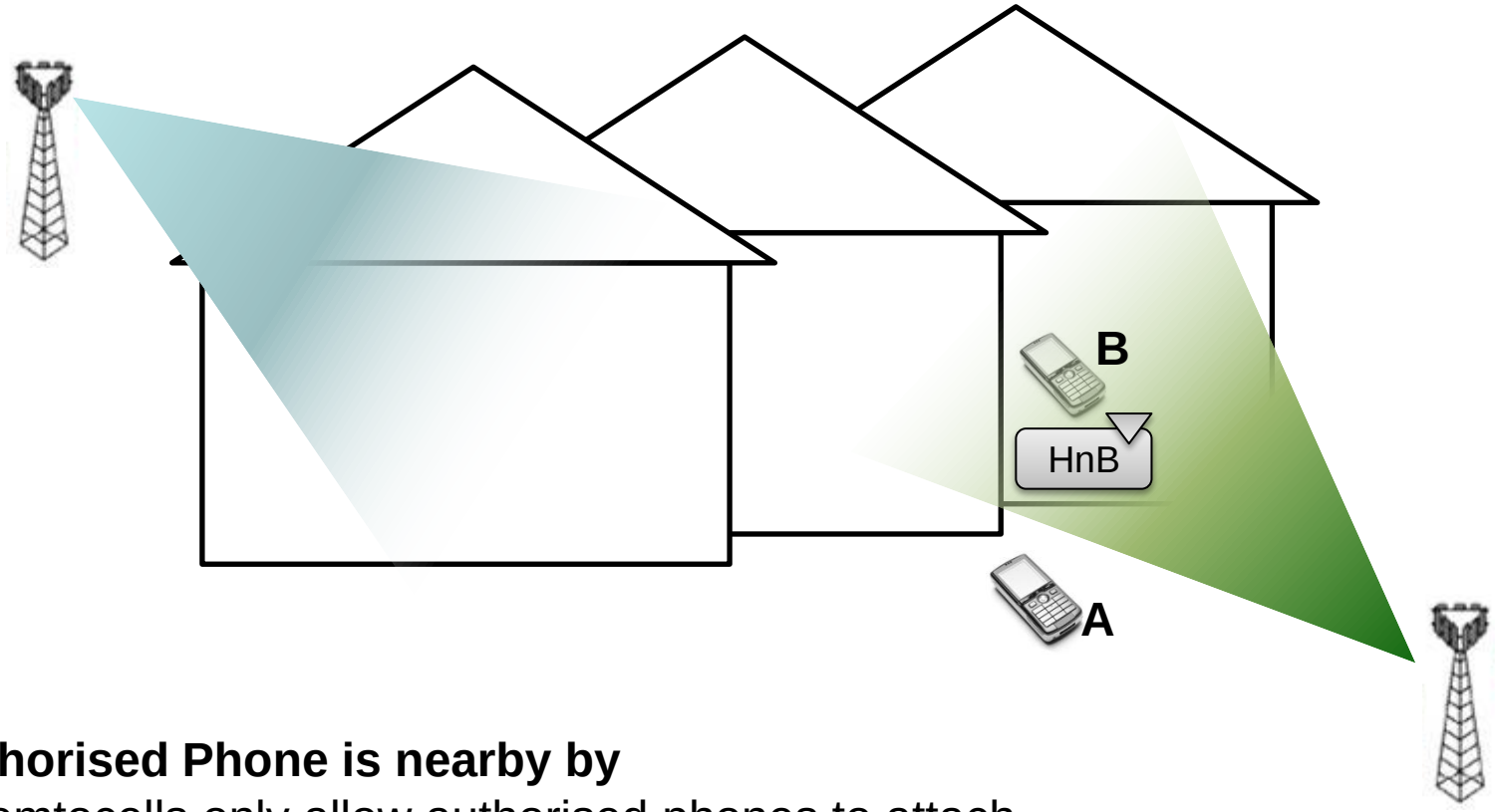
Interference & RF Frontend



Operator upgrades a macrocell

- Macrocell is now near and transmitting at high power at/near same frequency
- The HnB is no longer in a shadow and there is mutual interference
- Effects can vary, but none are nice.
- Which cell is going to change frequency??

Interference & RF Frontend



An unauthorised Phone is nearby by

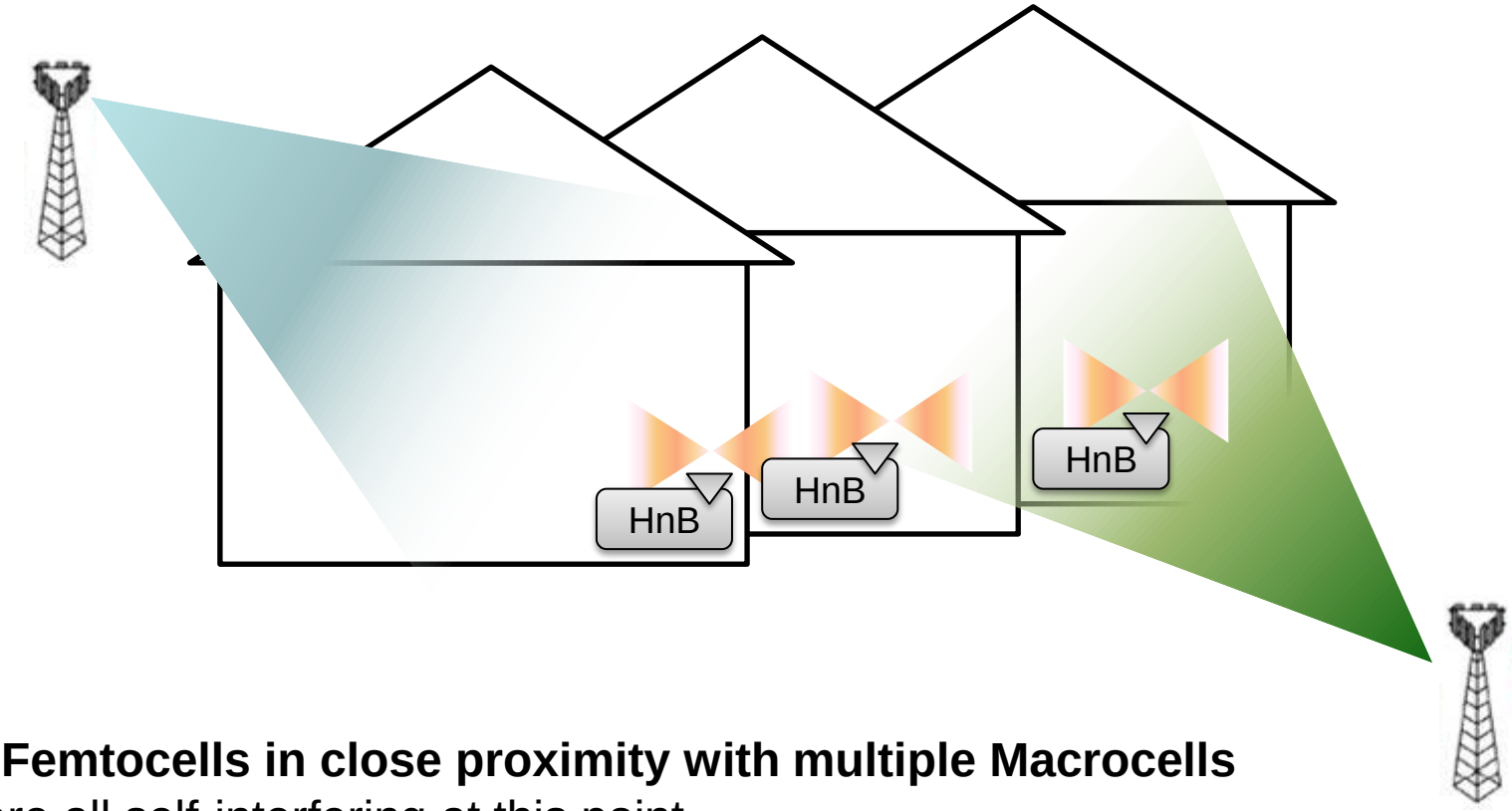
Many femtocells only allow authorised phones to attach.

Another phone is in the room, or just outside... Transmitting at max power

Very powerful interferer, demanding high dynamic range on Receiver

Which cell is going to change frequency??

Interference & RF Frontend

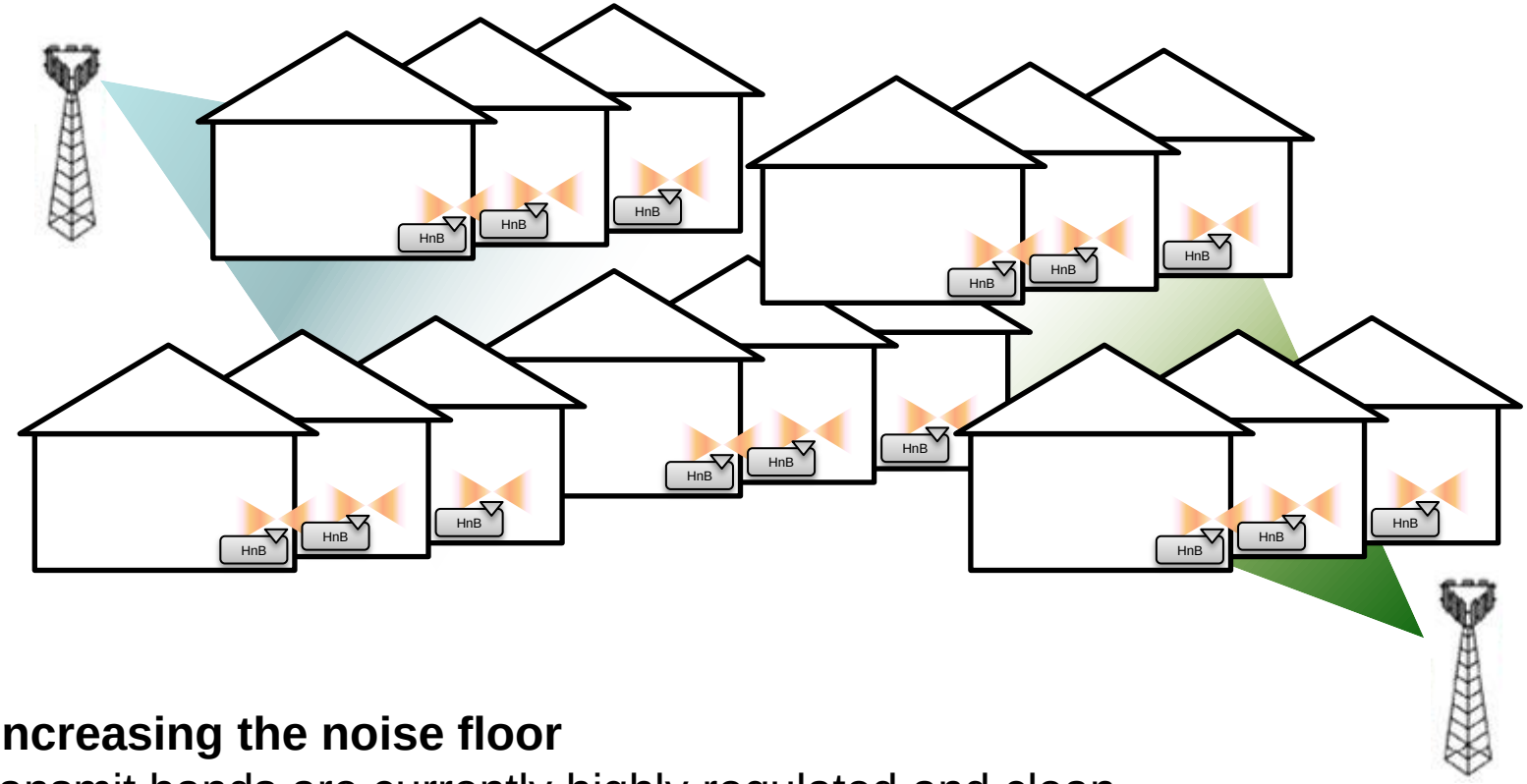


Multiple Femtocells in close proximity with multiple Macrocells

- They are all self-interfering at this point
- Need to have some form of self-organising structure
- If user placed, then no guarantee where they will end up
- Problem gets worse if we're not reusing frequency (from an RF perspective)

With varying propagation effects, this is a dynamic problem.

Interference & RF Frontend



Simply increasing the noise floor

The transmit bands are currently highly regulated and clean.

We may flood the spectrum with unsynchronised transmissions

Individually low power, but causing interference and raising the noise floor

Could degrade macrocell coverage or performance at the margins.

(when outside a femtocell range but at the limit of a Macrocell)

Existing Solutions

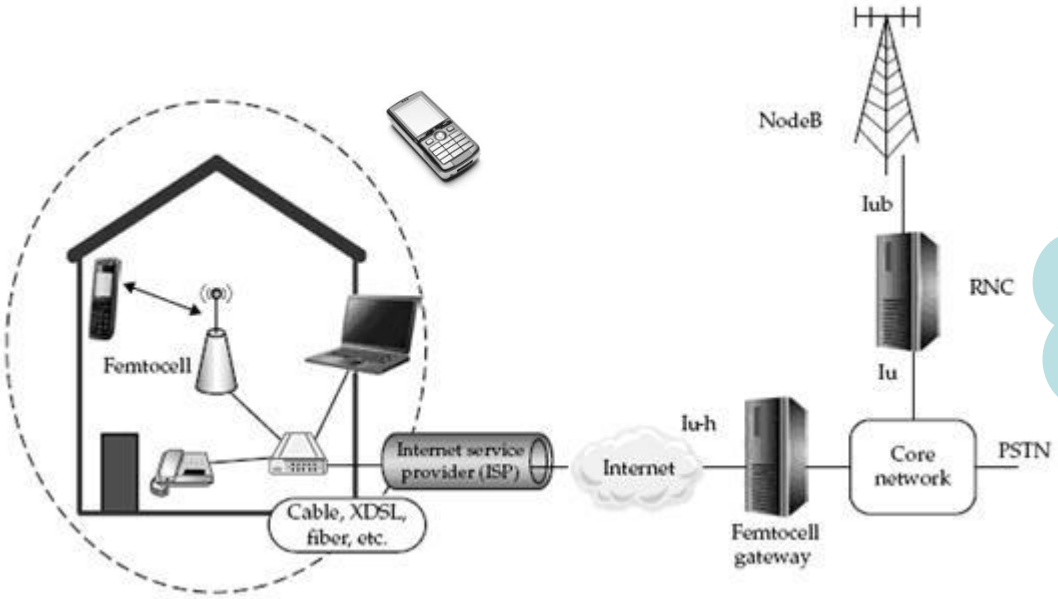
Adaptive Pilot Power Control / Self-Organising Networks: detect neighbours and dynamically adjusts its own transmitter power to avoid interfering. SON's are an advanced version of this.

Dynamic femtocell receiver gain management: allowing mobiles to operate without increasing their transmitted output power any more than is absolutely necessary. This will keep any increase in noise and interference to a minimum.

Open Femtocells and phone power capping: ensures that all phones will hand off to the appropriate cell before its transmitter power rises

Extended femtocell receiver dynamic range: Cells must have a very high dynamic range. Specific tests have been includes as part of Release 8 of the 3GPP standards (25.104)

Backhaul Issues



Backhaul is "trivial and invisible"??

A voice call is about 8-12 kbps, a 4 user system = 48 kbps **TRIVIAL!**

But

for data hotspots, offering up to 7.2 Mbps for users **NON-TRIVIAL!**

why should the ISP supply high quality connectivity for free? **NON-TRIVIAL!**

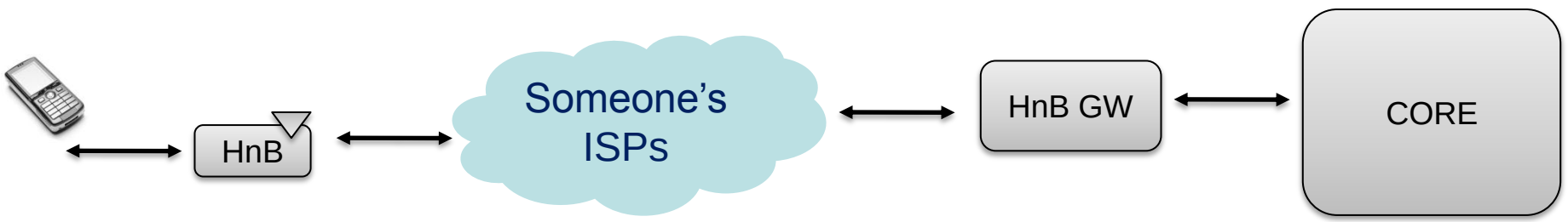
Backhaul and Capacity

Average Broadband Speeds (2011)

- Japan (8.5 Mbps)
- S. Korea (14Mbps)
- Finland (32 Mbps)
- Sweden (16 Mbps)
- UK (6.2 Mbps)
- USA (3.9 Mbps)
- Ireland (~3Mbps)

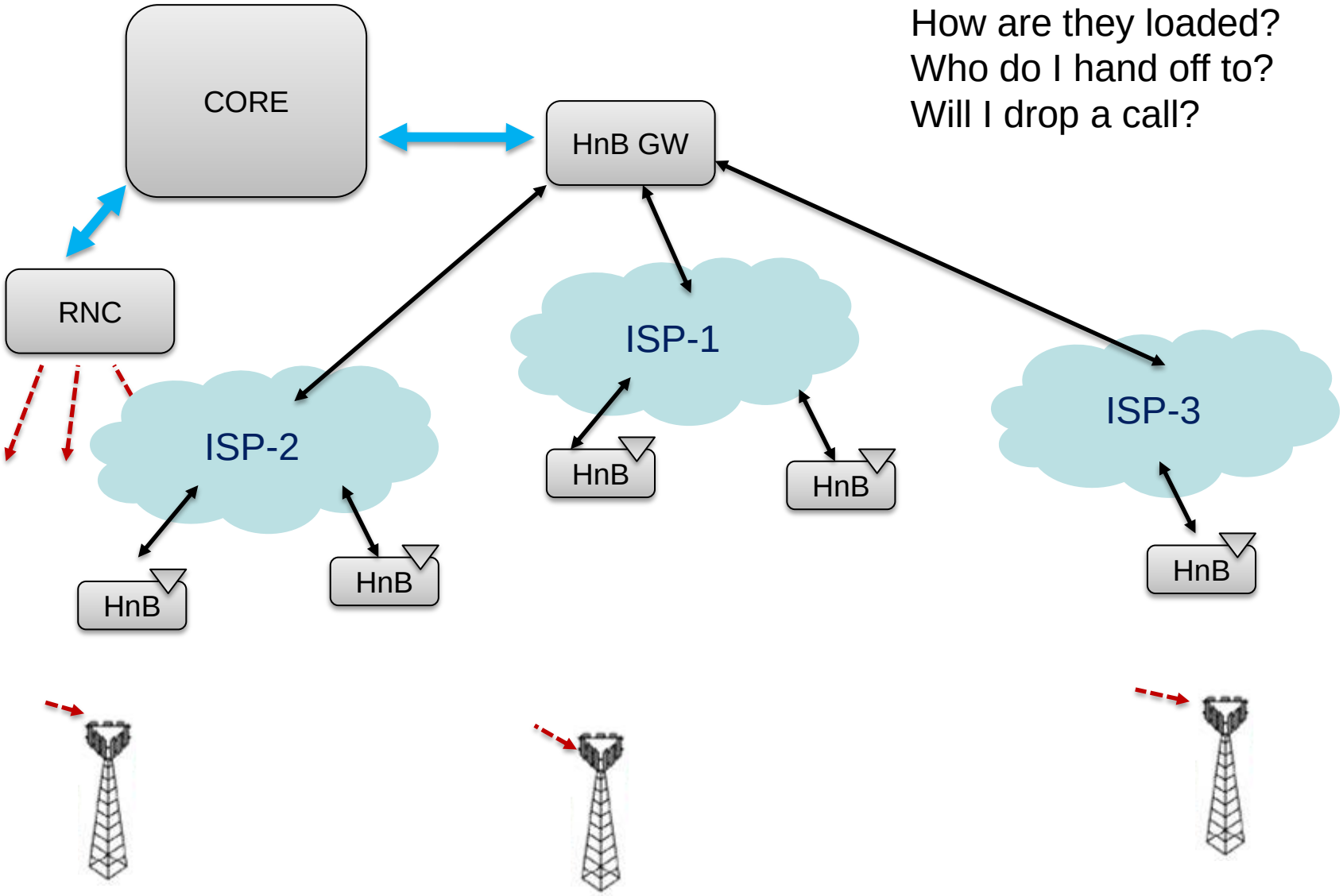
Is QoS supported?

Experienced “Speed” and quality of service is more than just bits... It also depends on latency, contention ratio, consistency. This varies greatly depending on ISP (dsl, satellite, WiMAX/FWA, cable)



Management and Signalling

Which cells are available?
How are they loaded?
Who do I hand off to?
Will I drop a call?



Macro/Femto & Femto/Femto Handoff Issues

Questions:

- how does the mobile user know where all the femto's are (lists, discovery)
- is the handset allowed to register to femto (moving in)
- how do you signal the femto to manage the handover (ISP vulnerability)
- reasonably straightforward for nomadic users
- normally only hard handover supported

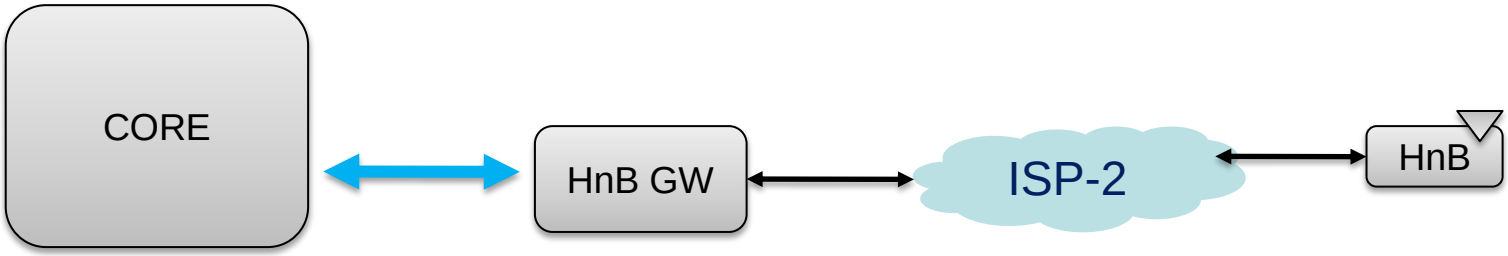
Backhaul Quality

- does it have QoS or traffic prioritisation?
- is latency <100ms (inspired by WiFi VOIP specs)?
- how do contention ratios effect your performance (network and other users)?
- are you throttled or traffic-shaped by ISP?

Impact

- if solving a problem, then no harm
- basic network functionality now dependent on networks outside your control
- dropped or interrupted calls are likely
- misleading promises on capacity.

DSP Challenges



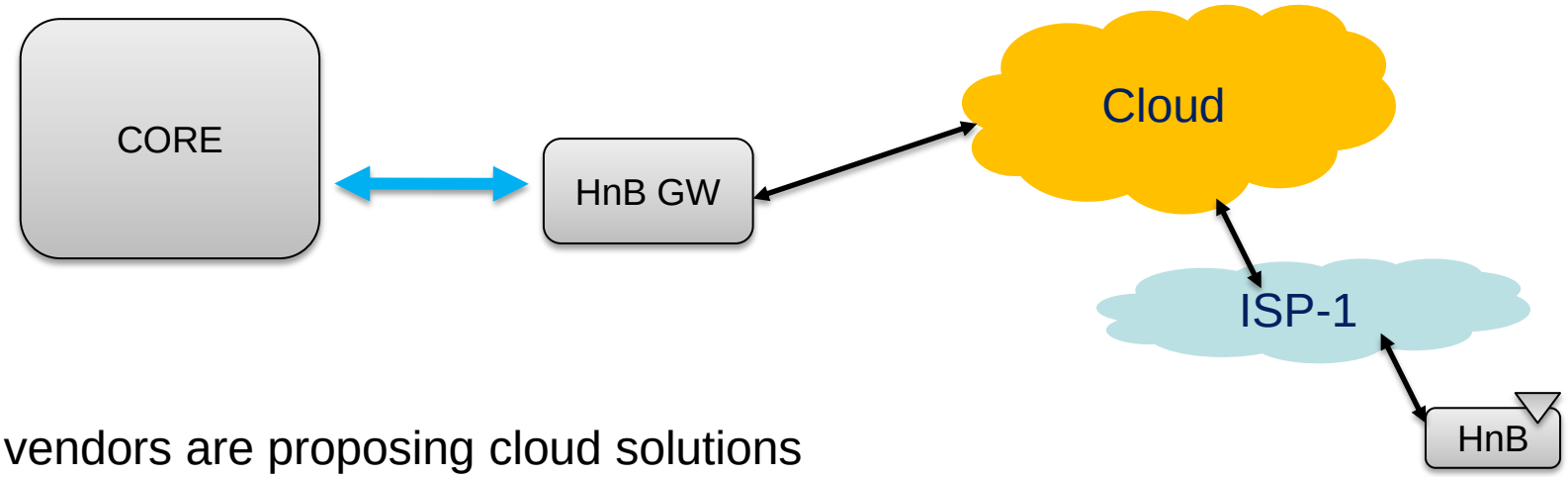
There are several commercial offerings
They have several things in common

- Software Radio Engines
- Support a limited number of modes
- Simplified processing solutions

But standards are evolving rapidly, with new features

- can small cells be upgraded?
- will you be stuck with legacy devices in the network?

Cloud to the Rescue



Several vendors are proposing cloud solutions

- all higher level and baseband processing takes place remotely
- only modulated baseband data sent to cell
- logical evolution from remote-RF heads

Several vendors are proposing cloud solutions

- PHY is mostly static now, so this preserves full upgrade path
- Simplifies the small cell
- efficiency and scalability
- need more bandwidth with greater reliability (8 times bandwidth)

Security and Reliability

- **Do you trust the backhaul connection?**
  what happens if it keeps dropping?

- **Security 101: “never trust the client”**
  physical access to the data, registration details
  denial of service attacks (deliberate misconfiguration)
  malicious sensing and signalling (disrupt macrocell behaviour)

- **Which cells are allowed on and where?**
  Can a customer take his femtocell and use it in his new house??
  Can he bring one from another country?

- **Damaged and aging components**
  How do you handle frequency shifts from the oscillators
  How do you handle distortion from aging amplifiers?
  Who is responsible for detecting and repairing?

Summary

Femtocells can be built and offer benefits

The backhaul is their greatest weakness

Managing the RF environment is a challenging dynamic problem

Long-term aging and reliability effects need to be addressed for consumer eq.

Question:

Small cells for LTE is a good and viable idea

But

if femtocells use mixed networks for backhaul, why not use mixed wireless access protocols too. Shed the load across different wireless modes. Most smartphones already do this.