GREEN 3G femto prototype

Ivaylo Haratcherev / ALU Bell Labs France

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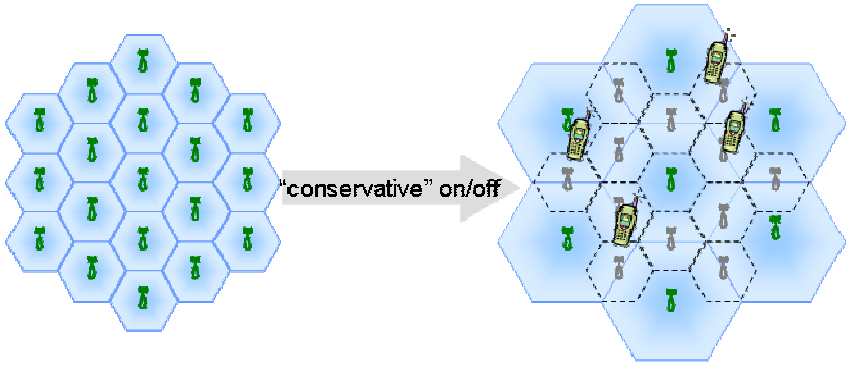
Addressed problem: always-tx cells

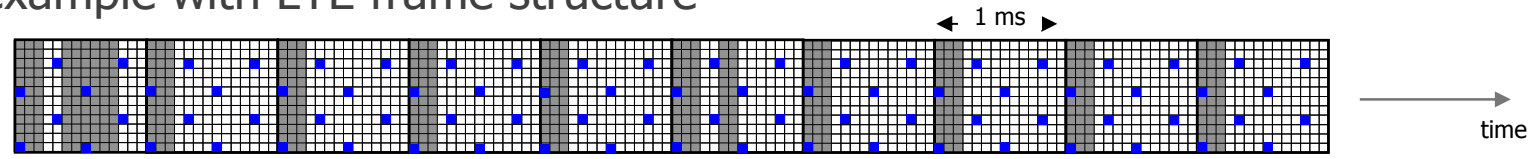
- Current cellular systems

  Permanent service advertisement: always-tx cells (pilots, signaling, sys info)

  (over) dimensioned for peak-hour traffic: most of the time cells are < 100% load



- An example with LTE frame structure

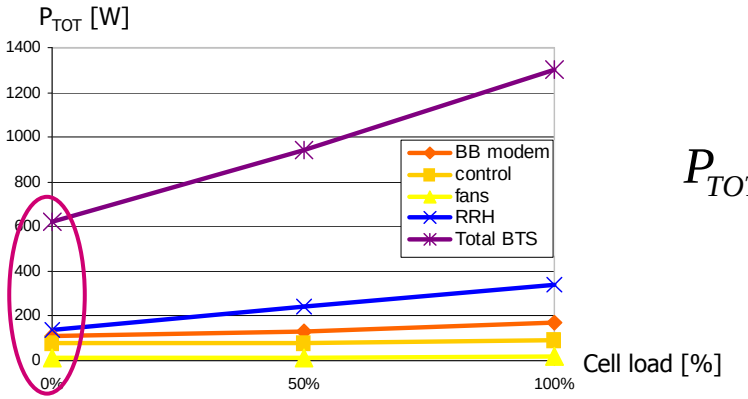


- The result is :

  Energy wasting

  Inter-cell interferences

  Unnecessary RF radiation



ALU LTE RRH 2x40W 3 sectors 2.6GHz (real data)

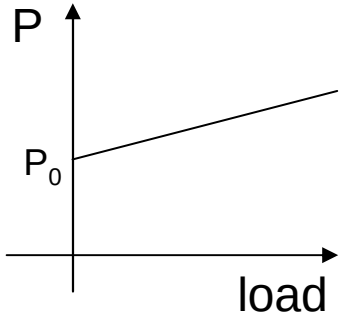
$$P_{TOT} = P_0 + \alpha \cdot P_u$$

$$P_0 = 50\% \cdot P_{MAX}$$

Our focus

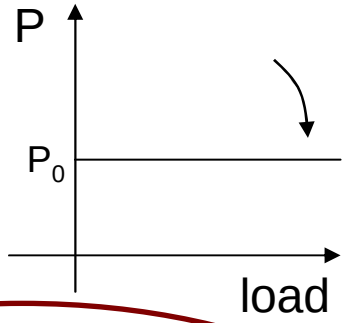
macro

femto



$$P_{TOT} = P_0 + \alpha \cdot P_u$$

$\alpha \rightarrow 0$



Large Cell size

- A large set of strategies:
  - ERP control, smart antenna flavours…
  - Minimize P_0
  - …

Small Cell size ⇒ frequent inactivity:

- Reasonable strategy:
  - Eliminate P_0 (standby mode)

Our experimental research

What?

- Implement a novel stand-by mode on ALU 3G Femto
- Introduce a UE → Femto wake-up/probe channel (secondary channel on WiFi)

How?

1. Analysis of Femto HW and SW
2. Assessment of Femto power consumption and on-off possibilities
3. Stand-by mode implementation
4. Wake-up channel introduction
5. Run tests and refine scenarios

FEMTO STANDBY MODE ANALYSIS

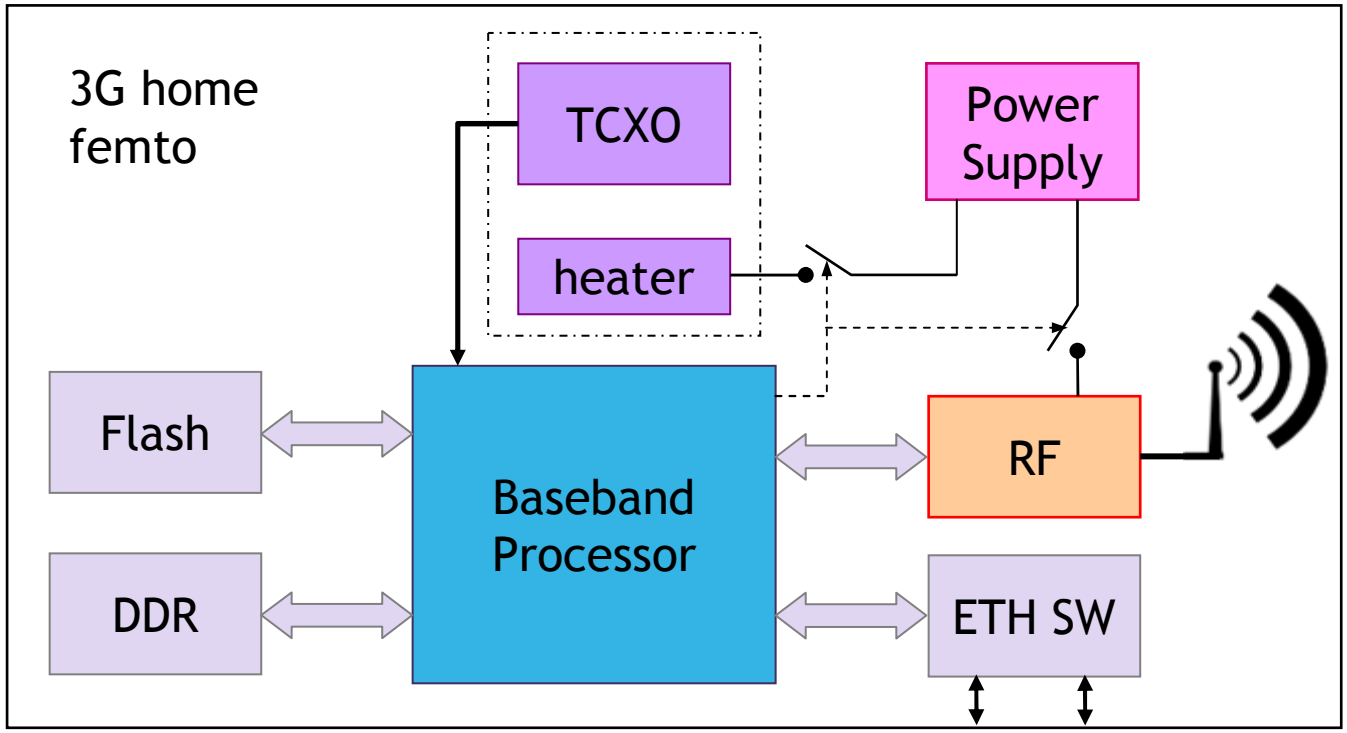
Questions:

- What elements/subsystems can we switch off?
- What is the gain in terms of Electrical Power saved.
- What is the penalty in terms of:
  - Wakeup delay
  - Design+Implementation effort

Approach:

- Detailed study of each element (datasheet, registers, power-down/up sequence)
- Detailed study of the power distribution in the femto (schematics)
- Power measurements (energy meter/logger, multimeter, DAQ)
- SW + HW modifications
- Standby modes assessment

HW STRUCTURE

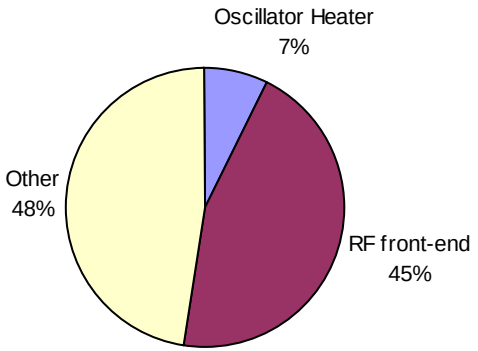


- HW almost ready for sleep modes: standby enabled in most ICs, RF DC/DC converter can be powered down
- … but some supply lines have to be rerouted
- RF electrical power consumption (almost) invariable with ERP => No use of ERP control just for electrical power saving!!!

Femto standby mode analysis results

Parts we can switch off (implemented):

- RF - most beneficial in terms of gain/penalty ratio:
  - Over 45% electrical power saved + low wakeup delay
  - There is need for re-initialization and re-calibration on each wakeup
- TCXO heater also has good gain/penalty ratio:
  - 7% electrical power saved + very easy to switch off/on
  - TCXO stability might be compromised



Parts we want to switch off, but we shouldn't:

- ETH switch (consumes a lot, but we cannot wakeup femto via backhaul)
- Parts of BB processor (huge redesign penalty)

Parts we don't need to switch off (low gain or/and high penalty):

- Memory/Logic (low power), Oscillators, DC/DC conv. (low quiescent current)

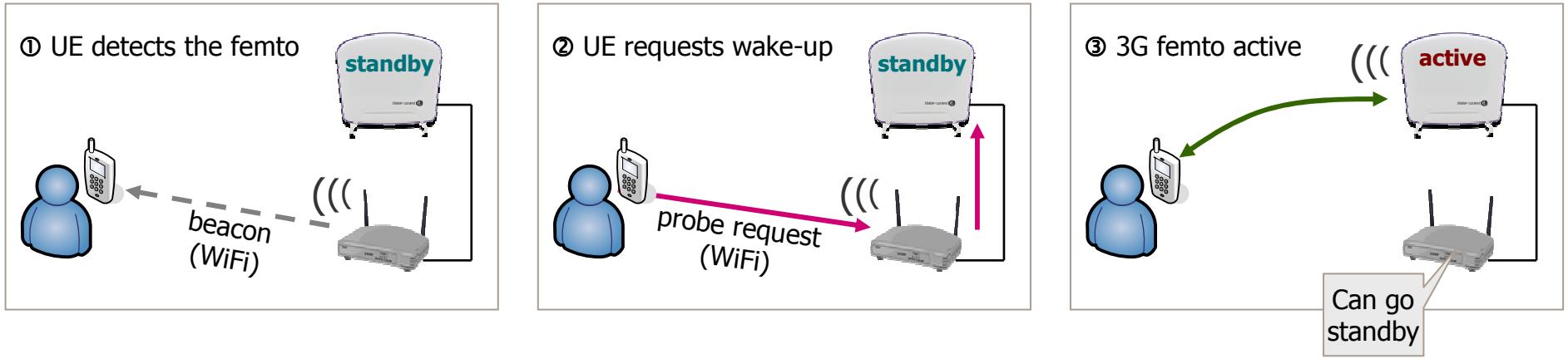
GREEN 3G FEMTO PoC

What we did

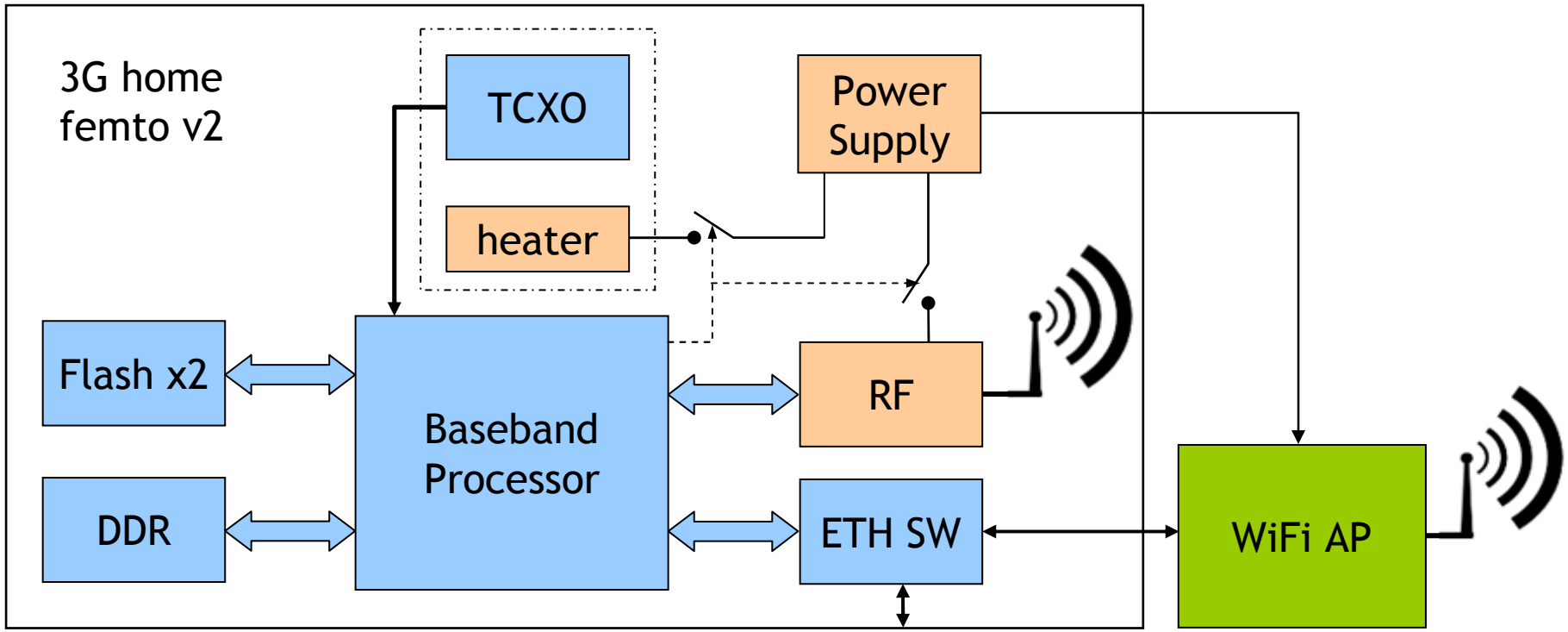
- modify 3G femto code + HW to enable stand-by mode (RF + TCXO heat. off)
- add a WiFi module to receive the wake-up message from UE
- exploit dual radio (WiFi/3G) capability of terminals for the operations

Operation

- 3G stays on as long as UE "at home" (even in idle-mode) – UE is registered
- On -> off = all UEs de-registered from the Femto (can be IMSI selective)
- 3G off = no registered UEs + no wake-up
- Off -> on = wake-up by a secondary channel (WiFi)



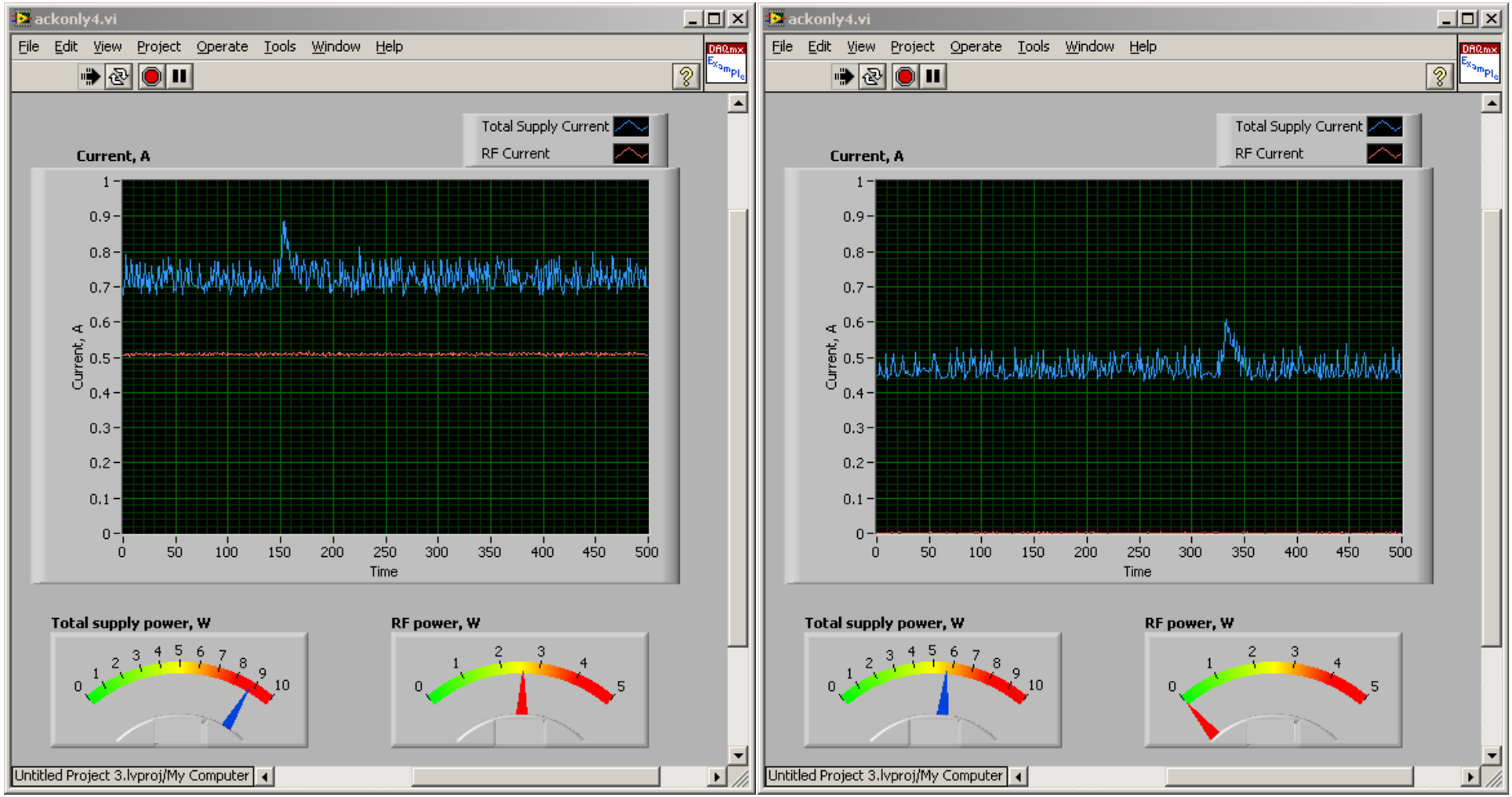
GREEN 3G FEMTO PROTOTYPE HW



Do we gain something in standby mode?

- The 3G femto RF consumes about 4 W on average
- The WiFi router consumes about 2 W on average
  - expected to go down to about 1 W with a power-efficient WiFi module

GREEN 3G FEMTO PROTOTYPE – first results



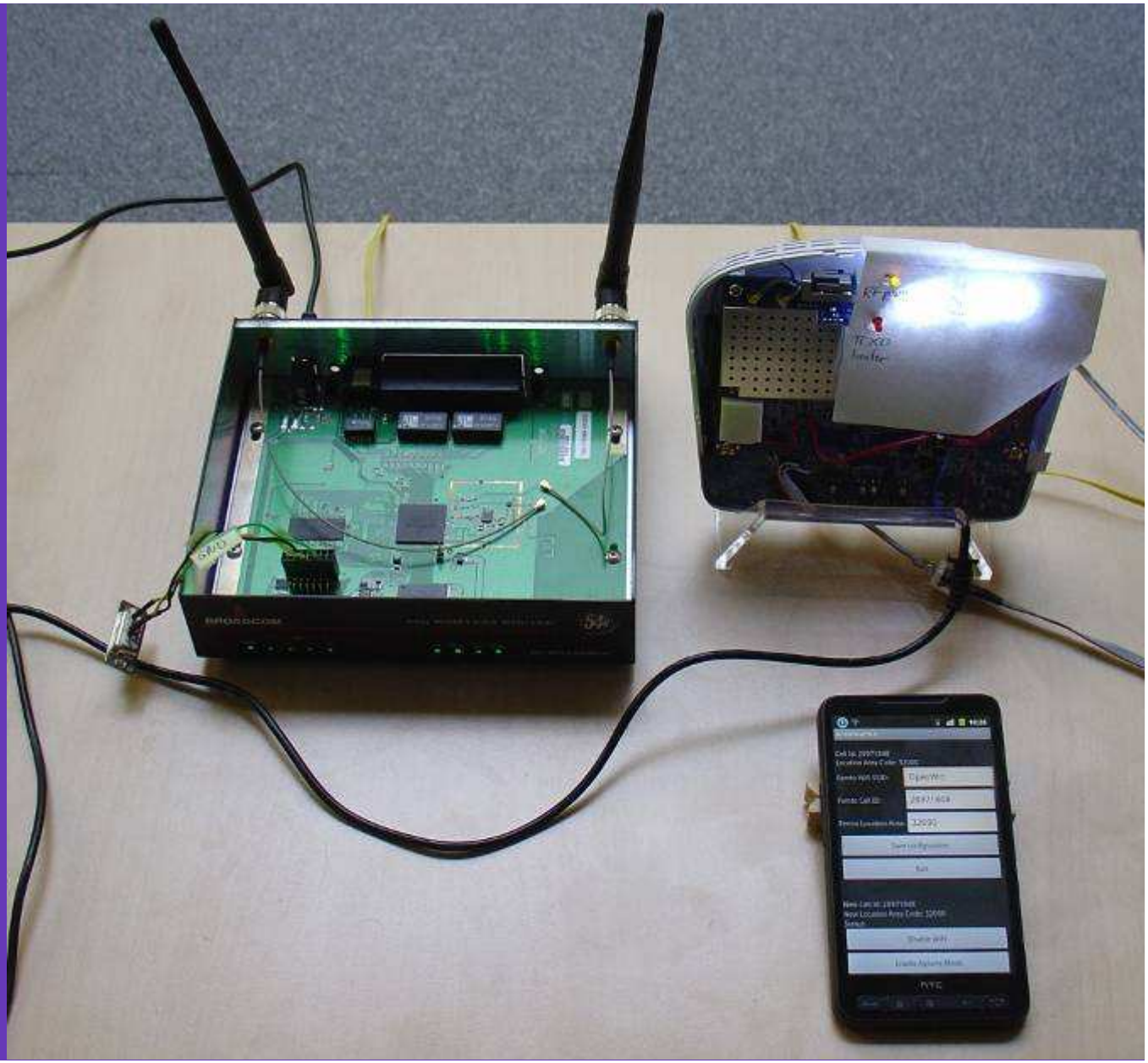
- Real-time measurements in active and standby modes

Status

- Where we are
  - Prototype fully functional:
    - Stand-by mode on Femto = RF module off + TCXO heater off
    - Wake-up by WiFi after probe request (WiFi net scanning) from UE
    - time(RF_module off $\rightarrow$ on) < 1s
    - Still some issues to fix (occasional long UE registration time)

- Next steps
  - Add power self-measure capabilities
  - WiFi power-save mode?
  - Refine 3G stand-by mode entry
  - Other wakeup triggers:
    - UE localization (in addition or instead of WiFi sensing)
    - Explicit by user
    - Macro (3G network) assisted

AT THE SPEED OF IDEAS™



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