Cell-Lab: A Femtocell-based Cellular Network Testbed

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Introduction of Cell-Lab

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Motivation

- Many wireless network testbeds so far
  - ORBIT, APE, MIT Roofnet, ..
    - No cellular-based testbed in spite of its worldwide popularity (e.g., Google Android)
    - Due to cost and license issues in constructing cellular base stations for network research testbed
- Femtocell technologies to build a cellular-based testbed
  - Originally designed as a small base station to extend the service coverage indoors in a residential setting
    - ➔ feasible to construct a testbed due to low cost and small coverage

Requirements of cellular-based testbed (1/3)

- It should implement core elements of cellular network for simplified emulation
  - In terms of architecture
    - RNC, Node-B, SGSN/GGSN, IMS, …
  - In terms of protocols
    - Various transport/logical channel types
      - BCH, FACH, PCH, DCF, HS-DSCH, …
    - AMC, Power control, HARQ, CDMA

Requirements of cellular-based testbed (2/3)

- It should provide independent BS-MS point-to-point links for each experiment
  - Multiple experiments simultaneously
    - By virtualization
  - Real link layer technologies
    - link adaptation techniques
    - handover capability among BSs

Requirements of cellular-based testbed (3/3)

- It should provide various MS profiles
  - The characteristics of wireless channels change depending on the distance, mobile speed, obstacles
  - Cell-Lab's MS profile is not fully controllable

Implication of Cell-Lab

- Cell-Lab provides testing environments for mobile wireless network
  - Especially network and transport layer protocols
    - C.f. Android is for mobile applications
- Potential test purposes
  1. To evaluate protocols suitable to *wireless link* characteristics
  2. To evaluate protocols that supports *mobility*

Implementation

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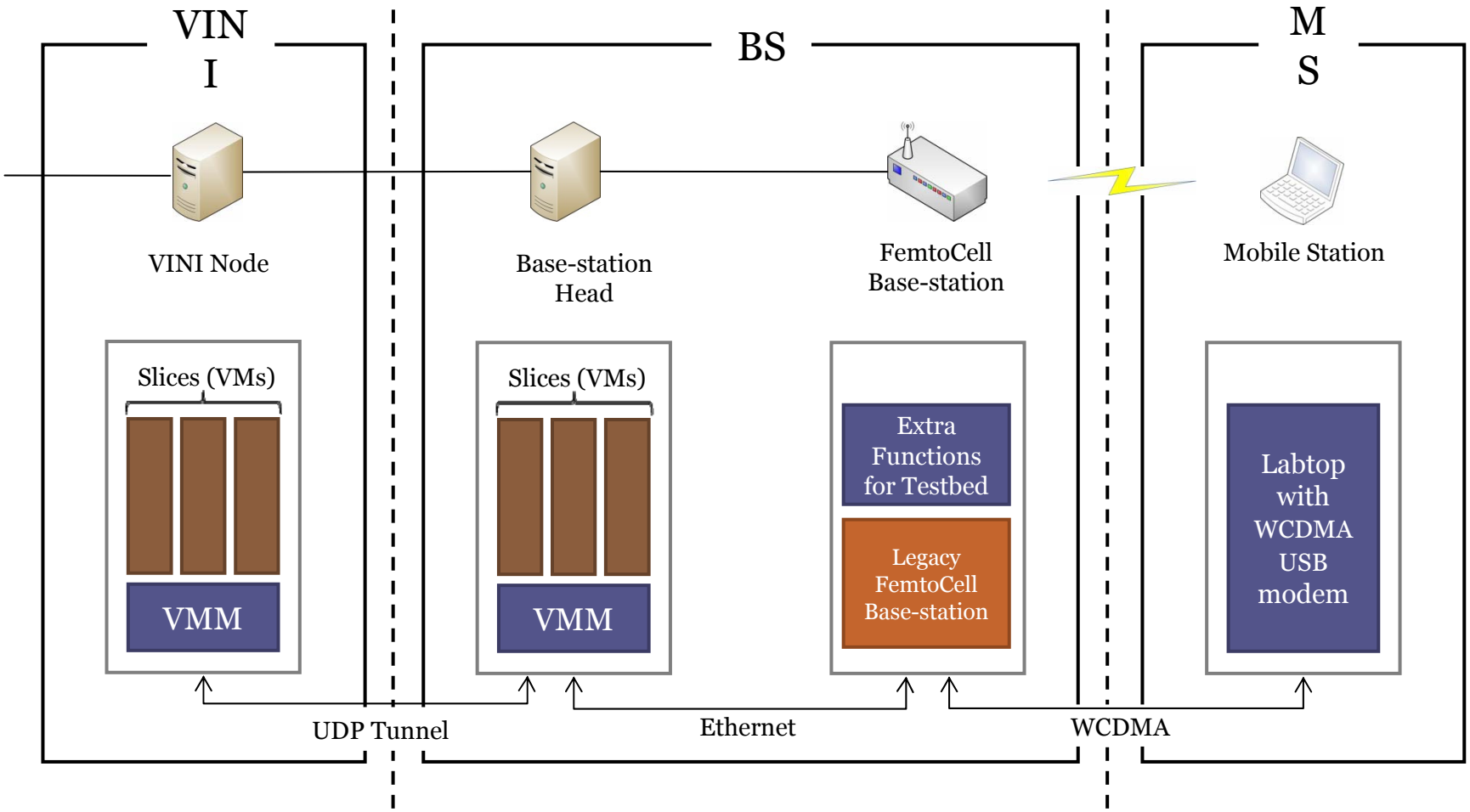
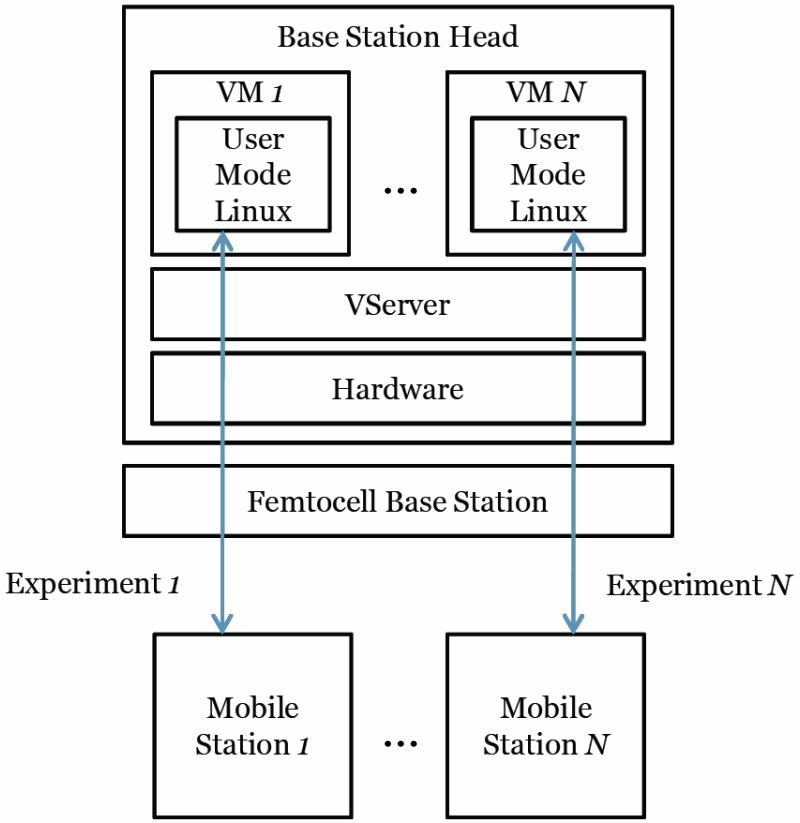
Testbed outline

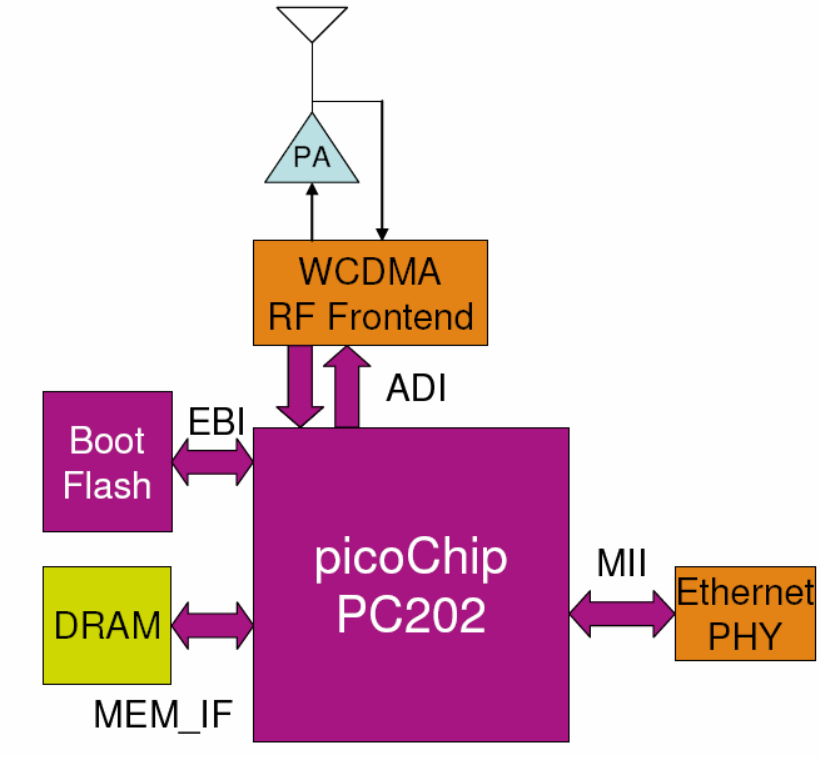


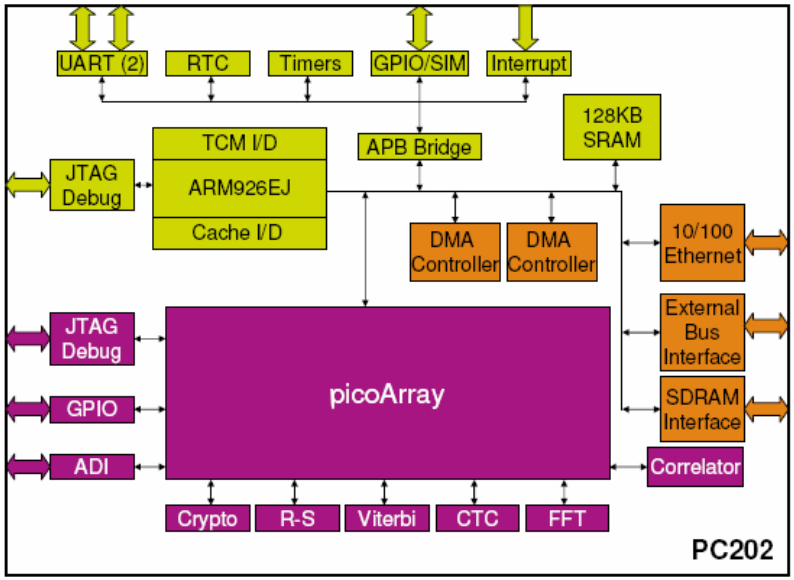
BS Virtualization

- BS head is virtualized instead of low end femtocell BS
- VServer
  - provides root access to Cell-Lab users while isolating users from each other
- User Mode Linux (UML)
  - is a full-featured Linux Kernel running as a user process
  - makes a development process faster



HSDPA WCDMA Femtocell H/W





PC8208 Software Reference Design

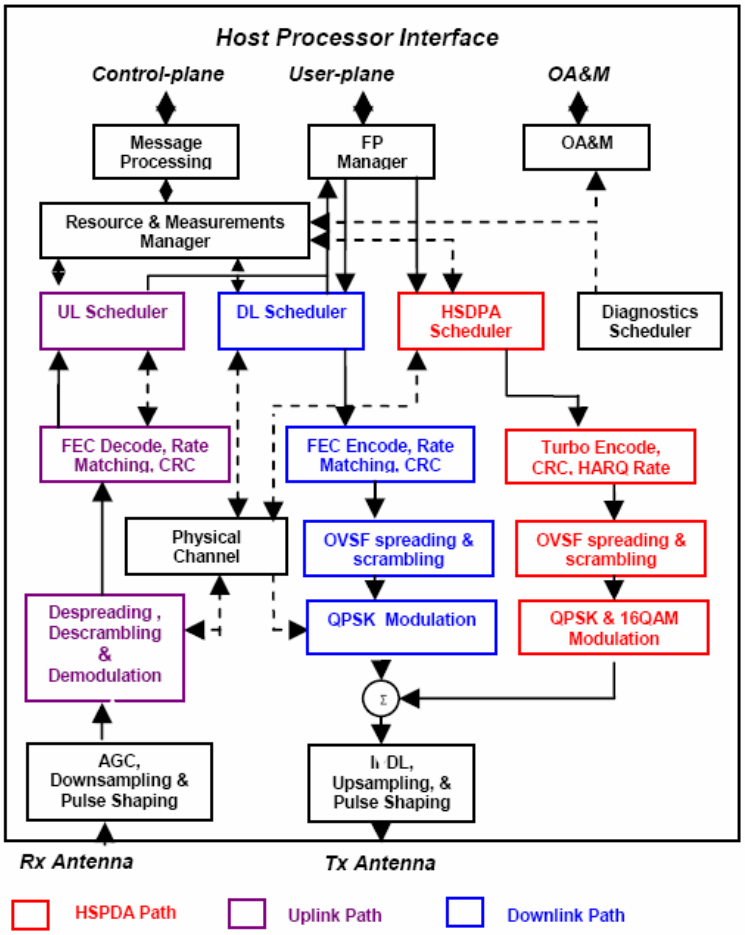
- A software-defined implementation for 3GPP Rel. 5 FDD WCDMA PHY including support for HSDPA
- 1 x PC202 with an integrated ARM9
- Suitable for all backhaul architectures
- Upgradeable to support HSUPA

Parameter	Value
Cell Radius	≤ 200m
Maximum UE Speed	10km/h
Max. Traffic Capacity	4 12.2kbit AMR voice OR 4 HSDPA PS data† OR 4 64kbit CS/PS data OR 2 144kbit CS/PS data OR 1 384kbit CS/PS data
Peak HSDPA Data rate	7.21 Mbit/s††
Rake Fingers	4 per DCH/HSDPA user

Table 1: PC8208 Dimensioning Summary

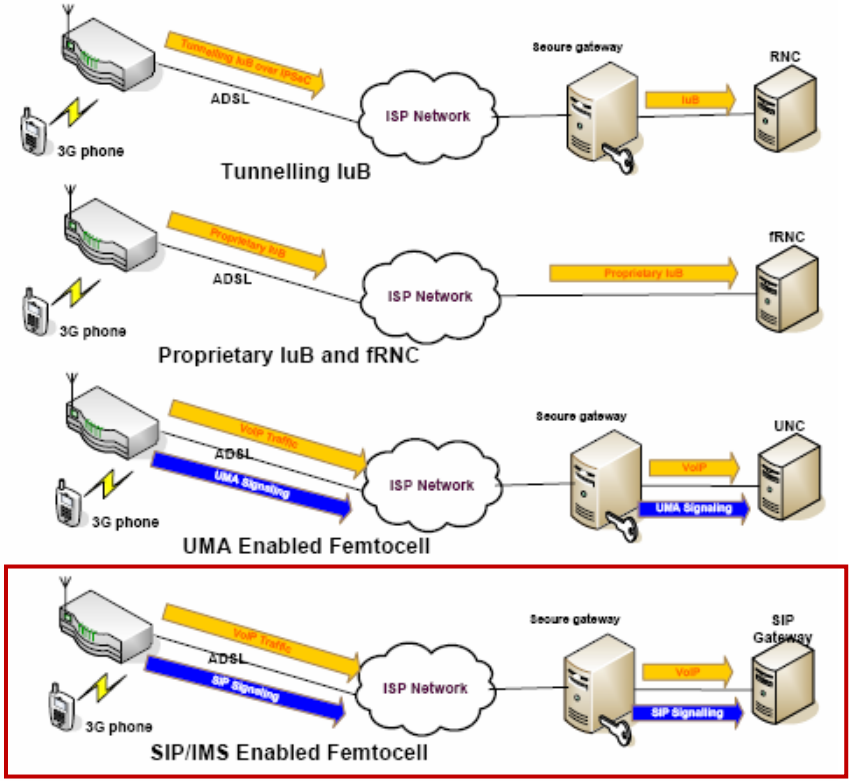
PC8208 Block Diagram

- Management of the modem resources
- Collection and reporting of physical layer measurements and OA&M alarms
- MAC-hs that allocates data to HS-DSCH channels and generates HS-SCCH channels
- MAC-b that supports broadcast messages over the BCH
- Buffer management
- CQI and HARQ

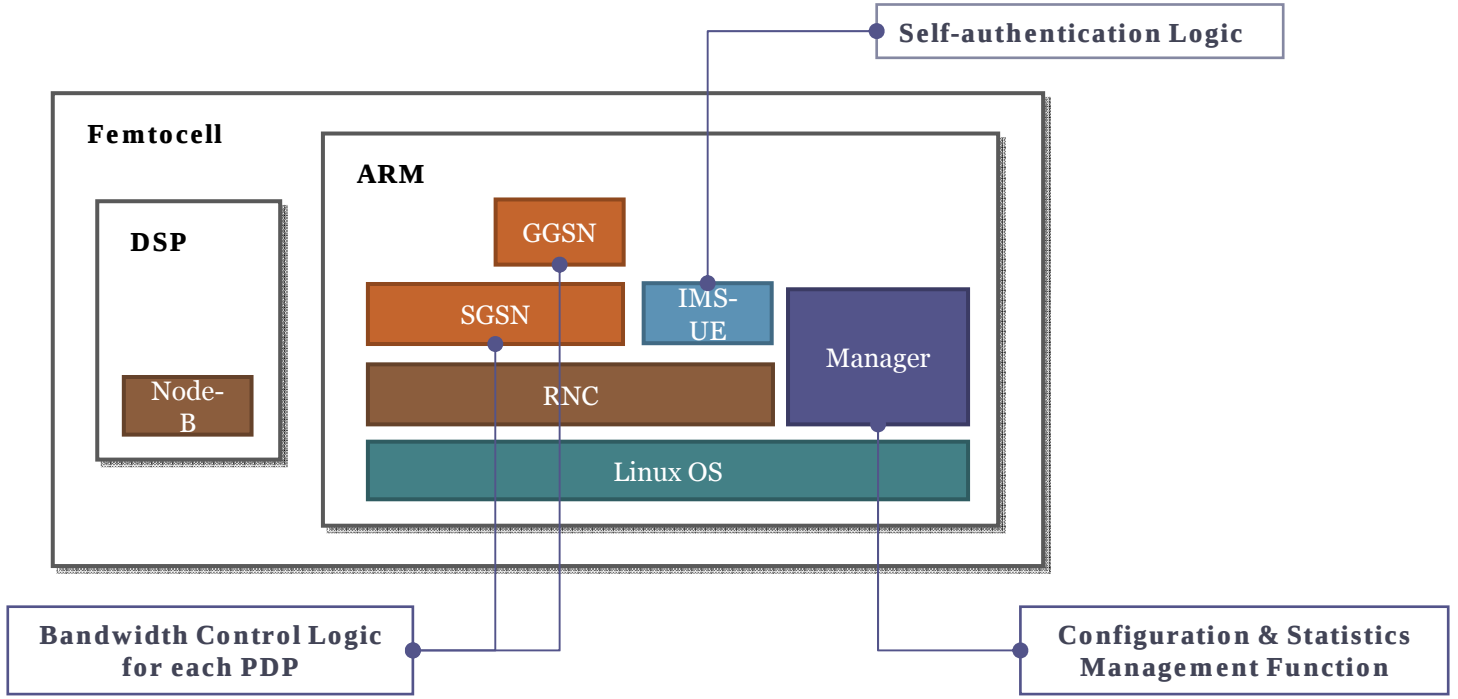


Backhaul Architecture

- Tunneling luB: Node B
- Proprietary fRNC: Node B
- UMA (unlicensed mobile access) Enabled Femtocell: Node B + RNC
- SIP/IMS Enabled Femtocell: Node B + RNC + a core network



Femtocell BS Architecture



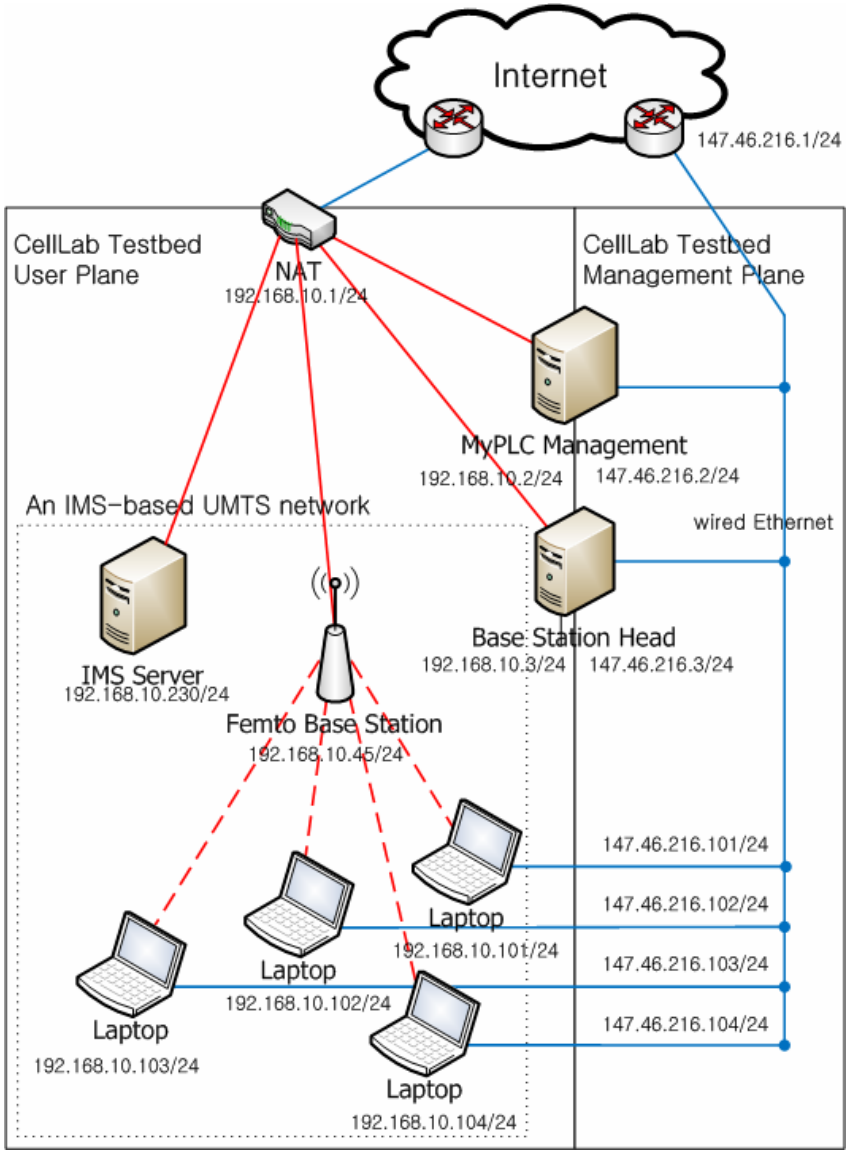
- For self-authentication, a part of IMS core logic is included
  - IMS server exists separately
- Management functions handled by SNMP-like protocol
- Bandwidth control functions for each PDP context can be implemented
  - Unimportant feature because of using dedicated channel in current version

Mobile Stations

- Lock-free HSDPA USB modem
  - HUAWEI E220 HSDPA USB modem
    - Supports HSDPA/UMTS: 3GPP R99, R5
    - Maximum transmission rate of 3.6Mbps
    - Running on Linux

Cell-lab Network

- Cell-lab network is divided into public and private areas
  - public area for management purpose
  - private area for experiment purpose
- Thorough routing setup is necessary
  - in order to guarantee that the packet of MS will visit the appropriate VM in base station head, and vice versa



Weakness

- Limited capacity of femtocell base station
  - High mobility experiment is impossible
    - Small cell coverage and mobility (<30m, <10km/h)
  - Maximum simultaneous (WCDMA)UEs: 4
    - Virtualization of MS can be a solution
- Unstable performance for Testbed yet
  - Need for debugging continually

Future direction

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Issues for open testbed

- Stability
  - Reliable experiment environment should be offered to users
- Features to be added
  - User account & scheduling of experiments
    - Isolation among experiments should be maintained through virtualization & synchronization
  - User interface
    - In addition to ssh connection, various user interfaces for the experiment should be provided
    - Ex) ORBIT's script-based experiment
  - Statistics
    - Should be collected from many points
      - such as the femtocell BS, BS head, MS
    - Should be displayed appropriately
      - what to show, what to hide, how to show