RAN platform for LTE research

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Outline

- MCN contribution
- LTE Overview
- OpenEPC – LTE core solution
- VirtualRAN – LTE RAN solution
- Load Balancing
- Conclusion
Mobile Cloud Networking
Mobile Cloud Networking

- Mobile Cloud Networking has the vision to
  - develop a novel cloud-based network architecture for mobile communication systems;
  - extend cloud computing so as to support on-demand and elastic provisioning of novel mobile services.

- The MCN approach requires
  - extensions towards higher decentralisation & scale based on load;
  - composition & operation of virtual end-to-end infrastructure;
  - management of physical infrastructure by different network providers.

- University of Bern is involved in:
  - WP3 – Wireless cloud, Radio Access Network
  - WP4 – Mobility management and prediction
  - WP5 – Distributed content management
Radio Access Network experimentation platform

What do we want to have?
- Platform to test diversity of mechanisms for mobility management, resource management, content distribution, QoS monitoring, etc.
- Both performance of core and radio access networks should be observed

What is already there?
- Core functionality – OpenEPC
- Radio access – several LTE simulators for ns3 and OPNET

What can we do?
- Interface a simulated radio access model with core testing platform
- Introduce emulation to existing simulated radio access models – user equipment vs base stations, available hardware
Load balancing in the RAN

- between radio resources & radio management (base stations)
- based on decentralised and self-organising mechanisms that can
  - identify available spectrum (of the same and different systems, e.g., LTE and WiFi) and temporal and geographical traffic variations
  - distribute resources by multi-technology BBU-pools over incoming service requests
LTE Overview
3GPP Evolved Packet System (EPS)
LTE Overview

- EPS realises a separation between E-UTRAN and EPC
- Target
  - packet optimized system with higher data rates & lower latency
  - support for multiple radio access technologies
- Functions separation

<table>
<thead>
<tr>
<th>Evolved UTRAN (E-UTRAN)</th>
<th>Evolved Packet Core (EPC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>eNodeB (eNB)</td>
<td>Mobility Management Entity (MME)</td>
</tr>
<tr>
<td>Serving Gateway (S-Gw)</td>
<td>Packet Data Network (PDN-Gw)</td>
</tr>
<tr>
<td>intra-3GPP mobility</td>
<td>IP address allocation, Packet filtering Inter-3GPP mobility</td>
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</tbody>
</table>
LTE Overview

- Radio Access Network – the protocol stack
  - Independent RAN protocol stack
  - Independent core stack (towards MME and SGW)
  - eNodeB does translation
LTE Overview

- Radio Access Network – E-UTRAN architecture
  - Distributed approach towards base stations
  - eNodeB can consist of
    - A Base Band Unit (BBU)
    - One or more Remote Radio Heads (RRH)
  - Increased radio resource flexibility
OpenEPC
OpenEPC

- Core network testing framework
  - All core functionalities are implemented

OpenEPC integrates with
- 3GPP networks
  - LTE – third party eNodeB
  - HSPA/UMTS – third party NodeB
  - EDGE/GPRS – third party BTS/BSC

- Trusted non-3GPP (WiMAX)
  - AAA and packet network connectivity

- Untrusted non-3GPP (WiFi)
  - AAA and packet network connectivity

Figure is courtesy to Fraunhofer FOKUS
Emulation of the 3GPP radio accesses

- Operates without RAN equipment using public spectrum (WiFi)
- eNodeB behaves as an eNodeB towards OpenEPC (implements NAS)
- eNodeB behaves as an access point towards the UE

To do

- None of the RAN protocols are yet implemented
- No operability with existing radio access simulators is supported

Figure is courtesy to Fraunhofer FOKUS
VirtualRAN
Available simulation models

- **ns3 LENA**
  - LTE Specialized Model
    - open source
    - Most functionalities are validated
  - Includes
    - PHY layer functionality (outdoor channel models, CQI, BLER modulation curves, ACM)
    - MAC layer functionality (buffer status, DL scheduling, channel mapping)
    - Radio Resource Control (RRC)
    - X2 implementation supporting handover
Available simulation models

- **OPNET**
  - LTE Specialized Model
    - OPNET Modeler® Wireless Suite
    - OPNET Modeler® Wireless Suite for Defense
  - Includes
    - PHY layer functionality (interference and path loss models, CQI, BLER modulation curves)
    - MAC layer functionality (buffer status, scheduling, channel mapping)
    - NAS (admission control, session and location management)
VirtualRAN

- Objective
  - Support the development and testing of mechanisms for the LTE RAN (inter-related to core functionality)

- Requirements
  - Represent the behaviour of the radio channel
  - Represent the behaviour of the communicating parties – mobile users and eNodeBs
  - Represent interaction with the core functionalities

- Approaches
  - Simulation of both radio channel and communicating parties
  - Emulation of communicating parties
  - For both cases, interaction with the core should be possible
VirtualRAN

Development directions

Simulation model

Phase 1
- Application
- Simulated UE

Phase 2a
- Application
- Virtual UE

Phase 2b
- Application
- Real UE

Radio Channel / PHY

Simulated eNodeB

Interfacing with OpenEPC
To do

Simulation
- Determine best LTE simulation model (LENA favorite)
- Familiarize in detail with the model’s modules
- Identify missing functionalities for implementation, e.g., uplink scheduling, radio propagation models

Emulation
- Study emulation support in each simulator framework
- Introduce emulation to the simulation model

Interface with OpenEPC
- Appropriately passing of RAN information
Load Balancing
Load balancing

- **Advantages**
  - Higher flexibility and optimisation of operation
  - Global best-service offer to users

- **Disadvantages**
  - Increased complexity of the management
  - Operators/network owners need to cooperate

- **Challenges**
  - The current dedicated radio spectrum needs to transform to a shared one
  - Radio resources need to be appropriately represented for a global management scheme
  - Several strategies towards resource sharing may exist
Load balancing

- Radio Access Network (RAN)
  - Load balancing between radio bearers
    - In the scope of a single eNodeB
    - Performed by the eNodeB scheduling mechanism
    - May require intra-eNodeB handover
  - Load balancing between eNodeBs
    - In the scope of different eNodeBs
    - Performed with the MME and the eNodeB participation
    - May require inter-eNodeB handover
Load balancing

- Radio Access Network (RAN)
- Load balancing between technologies – managed by MME
Load balancing

- Sharing resources among technologies and operators may enable more advanced mechanisms but requires appropriate algorithms

To do
- Complete state of the art (cooperation with INOV)
- Identify most relevant current shortcomings
- Investigate on most promising approaches
Thank you
Available simulation models

- **OPNET**
  - Media Access Control Layer (MAC)
  - RRC procedures for radio bearer management
  - EPS bearer to radio bearer mapping
  - RLC TM, UM, and AM
  - Transport channels: DL-SCH, UL-SCH, L1/L2 control channel
  - Random access
  - Scheduling requests
  - Channel dependent scheduling
  - Buffer status reporting
  - Rate adaptation
  - FDD and TDD operation
Available simulation models

- **OPNET**
  - **Non-Access Stratum (NAS) Layer**
  - Location management: LTE_ACTIVE state, IN_SYNC sub-state
  - Session management: EPS bearer handling
  - Admission control
  - PDCP
  - Single-cell downlink broadcast
Available simulation models

- **OPNET**
  - **Physical Layer (PHY)**
  - OFDMA for downlink/SC-FDMA for uplink
  - Physical channels: PDDCH, PUCCH, PHICH, PDSCH, PUSCH, PRACH
  - BLER modulation curves with turbo coding and circular buffer rate matching algorithm: for each modulation and coding scheme (MCS)
  - Multiple path loss models
  - Multipath channel model for uplink and downlink
  - Intra- and inter-cell interference
  - HARQ: Type-II Incremental Redundancy
  - Channel Quality Indicator (CQI)
  - MIMO: Space Time Coding
Available simulation models

- **OPNET**
  
  - **General features**
  
  - Nodes: UE (end-node or router), eNodeB, (single-or multi-sector), EPC
  
  - Handover mechanisms for mobility (Intra-E-UTRAN)
    - Inter- and intra-frequency
    - With S1 or X2 interfaces
  
  - GGSN services by EPC to legacy SGSNs
  
  - MBMS (Multimedia Broadcast Multicast Service)
  
  - Initial cell selection by UEs
  
  - Efficiency mode to disable PHY layer
  
  - Energy consumption model
  
  - Dynamic failure/recovery of base stations