LTE/5G Self-Backhauling with Open Air Interface

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Wireless Networks Group (WNG) @UPC

- 7 Faculty Members
- 2 Postdocs, 10 PhD students
- Standardization works @IETF, IEEE 802.11
- +50 R&D projects completed
Softwarized Cellular Networks @WNG

- OpenBTS (2G)
- OpenUMTS (3G)
- Open Air Interface (4G)
OAI @WNG

- LTE-WiFi Aggregation (LWA)
- SDN integration (OVS, OF) to OAI
- Wireless LTE Backhauling
LTE/5G Self-Backhauling

• The access and the backhaul links share the wireless channel resources
LTE/5G Self-Backhauling: Why?

• Physical limitations for wired BH
• To reduce CAPEX/OPEX
  • Wireless cheaper than fiber
  • Use of same radio hardware for access/BH
  • Same O&M systems
• Higher spectrum efficiency
  • Reuse of wireless channel resources
• New applications:
  • Cells on wheels, Drone BS, etc.
LTE/5G Self-Backhauling: Challenges

• Resource scheduling between access and BH
• Access-BH interference
  • Less problematic for mmWave-based access/BH considered in 5G
• FH capacity/delay requirements
  • New functional splits relaxes these requirements
Scientific Literature on Self-BH

• Enhanced UEs (eUEs) [1] to relay eNB traffic, by forwarding L2/MAC packets
  • Requires significant changes at UE
  • Incentive and cooperation mechanism for battery-powered UEs to relay traffic for eNBs are challenges

• Enhanced evolved NodeB (e2NB) [2] targets a wireless mesh between e2NBs
  • Defines virtualized UEs@eNB, each communicating with a neighbor eNB
  • MME and HSS components of EPC is also included in e2NB to allow standalone functioning
  • The developed solution is experimented with an LTE emulator/simulator, showing its feasibility
  • Requires changes at eNBs, calls for a copy of HSS to individual eNBs (with the UEs that can connect), not 3GPPP-compliant
  • No physical experimentations

LTE Self-Backhauling in 3GPP

• To extend the radio coverage or increase the capacity of 4G networks, the concept of *relaying* was defined in Rel. 10

![Table showing different relay types](image)

- **Inband**
  - **Half-duplex**: Type 1
  - **Full-duplex**: Type 1b
  - **L2 Relay**: Type 2
  - **Outband**: Type 1a

• RN has to have UE functionality towards DeNB

• The uptake of *relaying* has been limited
  - Due to the densification targets of the operators (e.g., through small cell deployments), there is a fresh interest in wireless backhauling solutions
Self-BH Implementation
Network Configuration

Diagram showing network configuration with various components such as UE, SDR, PC3: RN, LTE Dongle, PC1: DeNB, PC2: EPC, MME, HSS, SGW, and PGW. Connections and IP addresses are indicated for Uu, S1-C, S1-U, and S6a interfaces.
Double GTP Encapsulation Problem
Double GTP Encapsulation: Wireshark

Packets @ S-GW

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>Length</th>
<th>Info</th>
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</thead>
<tbody>
<tr>
<td>312</td>
<td>102.94934211 172.16.0.2</td>
<td>8.8.8.8</td>
<td>GTP &lt;DNS&gt;</td>
<td>115</td>
<td>Standard query 0x139a AAAA accounts.google.com</td>
<td></td>
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<tr>
<td>313</td>
<td>102.9493445 8.8.8.8</td>
<td>172.16.0.2</td>
<td>GTP &lt;DNS&gt;</td>
<td>143</td>
<td>Standard query response 0x139a AAAA accounts.google.com AAAA 2a00:1450:4063:804::200d</td>
<td></td>
</tr>
</tbody>
</table>

Frame 374: 160 bytes on wire (1280 bits), 160 bytes captured (1280 bits) on interface 0
- Ethernet II, Src: 6iga-8yt.4c1:e2:7b (1c:1b:0d:4c:1e:2:7b), Dst: Dell_cc:50:fb (00:1e:4f:cc:50:ff)
- User Datagram Protocol, Src Port: 2152, Dst Port: 2152
- GPRS Tunneling Protocol
- User Datagram Protocol, Src Port: 2152, Dst Port: 2152
- GPRS Tunneling Protocol
- Internet Protocol Version 4, Src: 172.16.0.4, Dst: 8.8.8.8
- User Datagram Protocol, Src Port: 65516, Dst Port: 53

Domain Name System (query)
Final Implementation
Inband vs. Outband Frequency Settings

Conventional LTE Network and In-band Self-backhauling

Out-band Self-backhauling

7/11/2017 LTE/5G Self-Backhauling w/ OAI
Conventional LTE Setup Performance

**Downlink**

**Uplink**
Self-Backhauling: Type 1b RN

**Downlink**

**Uplink**

<table>
<thead>
<tr>
<th>Bandwidth (MHz)</th>
<th>DeNB Gain (dB)</th>
<th>RN Gain (dB)</th>
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<tbody>
<tr>
<td>5</td>
<td>70 75 80 85 90</td>
<td></td>
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<tr>
<td>10</td>
<td>8 10 12 14 14</td>
<td>11 10</td>
</tr>
<tr>
<td>20</td>
<td>6 8 9 11 13</td>
<td>10</td>
</tr>
</tbody>
</table>
Self-Backhauling: Type 1a RN

Downlink

Uplink

CQI Levels for Outband Self-Backhauling at Different Tx Gains

<table>
<thead>
<tr>
<th>Bandwidth (MHz)</th>
<th>DeNB Gain (dB) 70</th>
<th>DeNB Gain (dB) 75</th>
<th>DeNB Gain (dB) 80</th>
<th>DeNB Gain (dB) 85</th>
<th>DeNB Gain (dB) 90</th>
<th>RN Gain (dB) 75</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
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Conclusions

• Self-Backhauling can extend the radio coverage and network capacity of the LTE networks

• Better performance enhancements are expected in a real setup with more idealistic antenna setups

• Access-BH interference is a challenge
  • In mmWave access and BH, interference will be less of a challenge

• A potential future work is the efficient scheduling of resources for inband (Type 1 or 1b) RN solutions