LWIR: LTE-WLAN Integration at RLC Layer with Virtual LTE-WLAN Scheduler for Efficient Aggregation

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1 3GPP LTE-WLAN Aggregation

2 RAN Level Integration of LTE WiFi
   - LTE-WiFi Integration Architecture
   - LWIP: LTE-WLAN Radio Level Integration Using IPsec Tunnel
   - LWA: LTE-WLAN Aggregation at PDCP Layer
   - Problems with Existing Aggregation Architectures

3 Proposed LTE-WLAN Integration Architecture
   - LWIR: LTE-WLAN Integration at RLC Layer
   - Virtual WLAN Scheduler

4 LWIR: Performance Results
   - Simulation Setup
   - LWIR Performance Evaluation

5 Conclusions and Future Work
LTE and WiFi Interworking

- **LTE:**
  - Operates in licensed spectrum
  - Spectrum is limited and too costly

- **WiFi:**
  - Operates in unlicensed spectrum
  - Random access and no guarantee for QoS

- Interworking schemes for WLAN offloading
  - IP Flow Mobility (IFOM)
  - NBIFOM Protocols (PMIPv6)
  - Not efficient for link utilization and system performance
Outline

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eNB serves as an anchor for both user plane (S1-U) and control plane (S1-MME)

No WLAN-specific core network is needed

No changes to MME and S-GW/P-GW

Realized at different layers of LTE protocol stack of eNB
Advantages of RAN Level Aggregation of LTE and WiFi

- Dynamic resource allocation based on network conditions
- Unified network control and real-time load balancing
- Minimal or no changes in core network
- Better user and system throughput
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**LWIP Architecture**

- **LTE-WLAN Integration at IP Layer**
- A secure IP tunnel between LWIP node and UE to ensure security for communication over WiFi interface
- No changes required at the UE protocol stack
- No packet re-ordering at IP layer
- No support for Packet Level traffic steering

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**3GPP LWIP Architecture**

- LWIP
- RRC
- NAS
- UserPlane
- UE
- PHY
- MAC
- RLC
- PDCP
- LWIP
- LWIP Tunnel
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LWA Architecture

- LTE-WLAN Integration at PDCP layer
- Changes required at both eNB and UE
- Packet re-ordering at PDCP layer

3GPP LWA architecture for collocated scenario
Granularity of Traffic Steering

- Traffic steering - moving data at different granularity (packets or flows) across different radio interfaces
  - Switched Bearer (flow level)
  - Split Bearer (packet level)

Split and Switch bearer in LWA from 3GPP
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TCP Performance with LWA

- Split bearer causes delay and out-of-order packet delivery at receiver
- Congestion window drops frequently (lower than that in ”Only LTE” scenario)

![Graph showing variation in congestion window size in LTE and LWA]
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LWIR Architecture

- Both eNB and WiFi AP functionality in single box (LWIR Node)
- Byte stream level traffic steering
- VWS selects data from RLC buffer based on user selection scheme
Traffic Steering at Different Layers of Protocol Stack

- **LWIP** - Packets are steered to both LTE and WiFi interfaces at IP layer of eNB
- **LWA** - PSDUs (PDCP Service Data Unit) are tunnelled to WiFi AP in form of MSDUs (MAC SDUs)
- **LWIR** - Byte from scheduler segmented into a packet sent over WiFi in the form of MSDUs
Traffic Steering at Different Layers of Protocol Stack (cont...)

- LWIP and LWA cause waiting delay in WiFi queue
- LWIR does steering at granularity of byte stream level
- Byte stream level gives finer control than packet, flow, and bearer level
- In LWIR, no waiting time in WiFi queue
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Virtual WLAN Scheduler (VWS)

Feedback from WiFi - amount of data being sent over WiFi to LTE scheduler
LTE scheduling remains unchanged
Virtually scheduling done for both links
Ensures at most one packet in the WiFi MAC queue to ensure maximum link utilization

WiFi user selection schemes

- Min CQI First
- Max CQI First
- Max RLC Buffer First
- Max RLC Buffer with Min CQI
- Max RLC Buffer with Max CQI
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Simulation Setup

Macro

LWA

UE

Simulation Setup
### NS-3 Simulation Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTE Scheduler</td>
<td>Proportional Fair</td>
</tr>
<tr>
<td>Tx power of Macro and LWIR/LWIP/LWA node</td>
<td>43 dBm, 16 dBm</td>
</tr>
<tr>
<td>TCP</td>
<td>New Reno</td>
</tr>
<tr>
<td>LTE Mode</td>
<td>FDD with 100 RBs</td>
</tr>
<tr>
<td>Distance b/w UEs and LWA/LWIP/LWIR node</td>
<td>50m</td>
</tr>
<tr>
<td>Number of UEs per LWA/LWIP/LWIR node</td>
<td>30</td>
</tr>
<tr>
<td>IEEE 802.11a Bandwidth</td>
<td>20 MHz</td>
</tr>
<tr>
<td>Number of Seeds</td>
<td>10</td>
</tr>
<tr>
<td>PDCP Re-ordering Timer</td>
<td>5, 20, 50 msec</td>
</tr>
<tr>
<td>MTU Size</td>
<td>1500, 2300 Bytes</td>
</tr>
<tr>
<td>Simulation duration</td>
<td>30 seconds</td>
</tr>
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LWIP (only flow split) - very less out-of-order packets resulting less triple DUPACKS

LWIR - all the data is taken from the front of the RLC buffer, so a continuous flow is maintained for TCP during the transmission

Using WiFi opportunistically leads to less 3DUPACKS
TCP Throughput for LWIR

- LWA - performs poor because of high out-of-order packet delivery.
- LWIP - flow level traffic steering able to achieve combine capacity of LTE and WiFi.
- LWIR - out performed LWIP and LWA because of the efficient packet routing without queuing at WiFi.
TCP throughput for LWIR (MTU=1500)

Max RLC Buffer with Max CQI performs better than other schemes
Min CQI First scheme gives less throughput - users having high interference will be served by WiFi
LWIR with VWS has throughput improvement of 50% (Min CQI First) to 65% (Max RLC Buffer with Max CQI) over LWA
TCP Throughput for LWIR (MTU = 2300)

Same trends follow as in MTU size 1500
Throughput increases as MTU size is increased
The throughput improvement from 60% to 85% over LWA
Conclusions and Future Work

- Proposed a unique RLC layer integration architecture LWIR with Virtual WLAN Scheduler (VWS)

- Different user selection schemes allow efficient utilization of WiFi network

- LWIR with VWS gives up to 85% TCP throughput improvement over the LWAs packet-level traffic steering approaches

- Future work: Study of LWIR architecture on uplink flows and non-collocated scenario
Questions

Any Queries?

Thank You!!!