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

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Globecom 2016
December 7, 2016

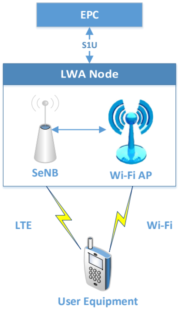
Outline

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

Specifications of LTE-WiFi Integration



- 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

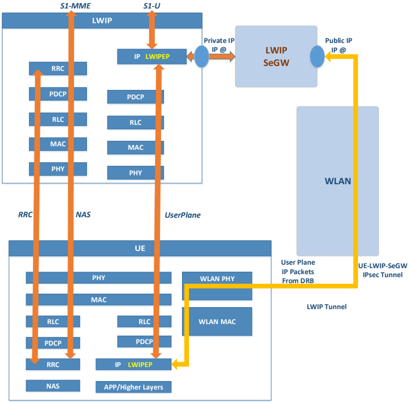
Advantages of RAN Level Aggregation of LTE and WiFi

- 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

Outline

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

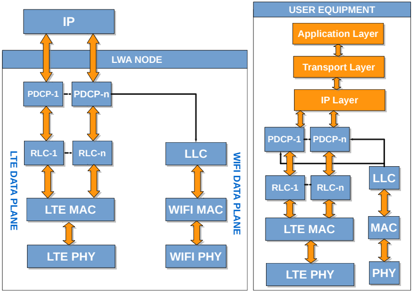


3GPP LWIP Architecture

Outline

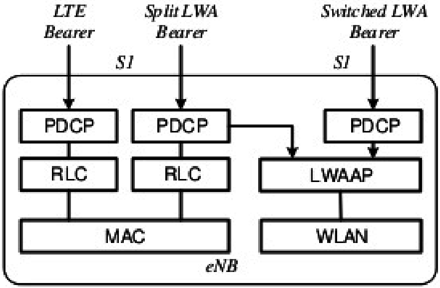
LWA Architecture

- 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



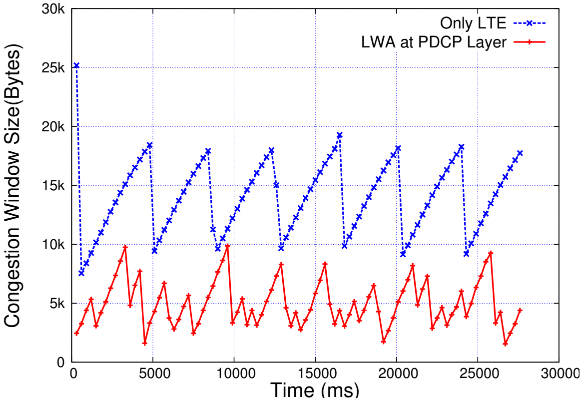
Split and Switch bearer in LWA from 3GPP

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

Outline

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)

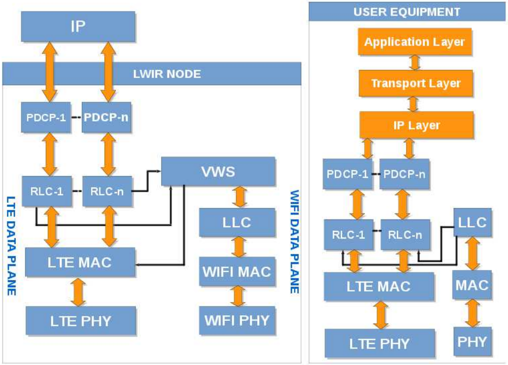


Variation in congestion window size in LTE and LWA

Outline

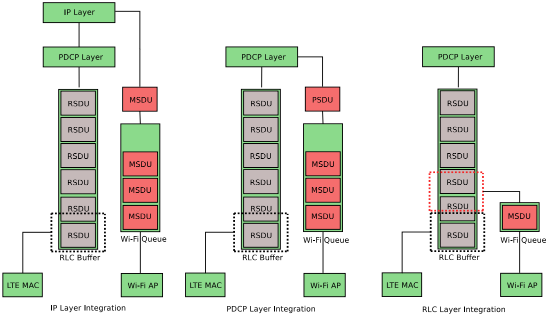
LWIR Architecture

- 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



LWIR Architecture with VWS

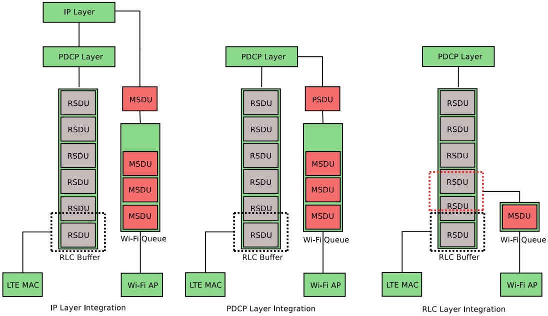
Traffic Steering at Different Layers of Protocol Stack



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...)



Traffic Steering at Different Layers of Protocol Stack

- 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

Outline

Virtual WLAN Scheduler (VWS)

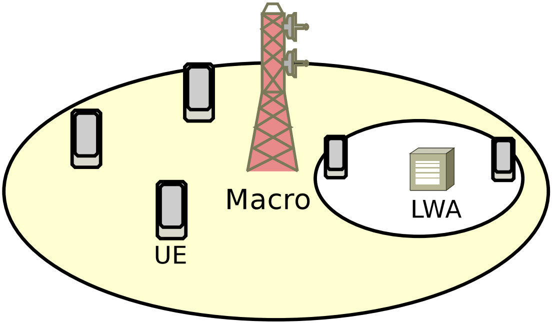
- Feedback from WiFi - amount of data being sent over WiFi to LTE scheduler
- LTE scheduling remains unchanged
- Virtually scheduling done for both links
- Ensures at most one packet in the WiFi MAC queue to ensure maximum link utilization

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

Outline

Simulation Setup



Simulation Setup

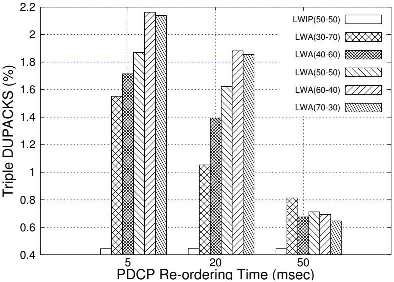
NS-3 Simulation Parameters

Simulation Parameters

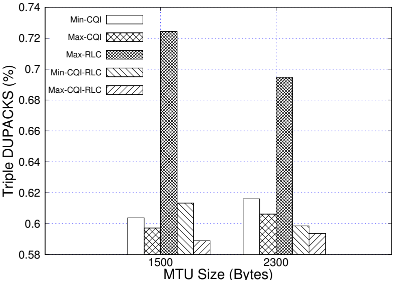
Parameter	**Value**
LTE Scheduler	Proportional Fair
Tx power of Macro and LWIR/LWIP/LWA node	43 dBm, 16 dBm
TCP	New Reno
LTE Mode	FDD with 100 RBs
Distance b/w UEs and LWA/LWIP/LWIR node	50m
Number of UEs per LWA/LWIP/LWIR node	30
IEEE 802.11a Bandwidth	20 MHz
Number of Seeds	10
PDCP Re-ordering Timer	5, 20, 50 msec
MTU Size	1500, 2300 Bytes
Simulation duration	30 seconds

Outline

Triple DUPACKS in LWIP, LWA and LWIR



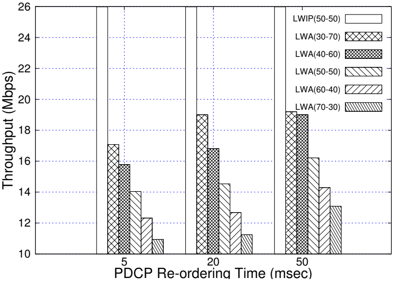
Triple DUPACKS in LWIP and LWA



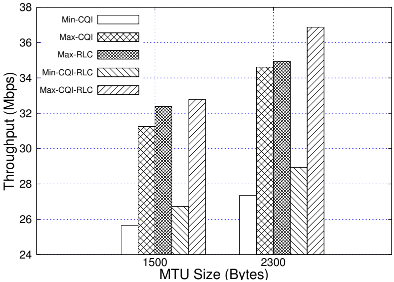
Triple DUPACKS in LWIR

- 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 Throughputs in LWIP LWA and LWIR



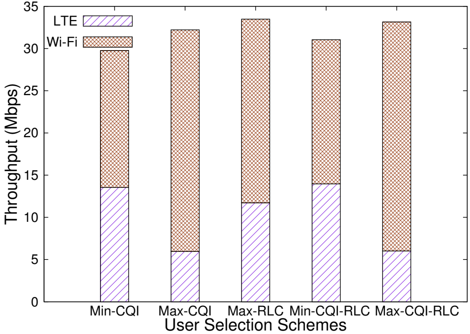
TCP Throughputs in LWIP and LWA



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

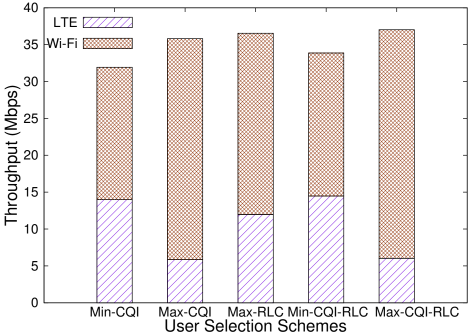
TCP throughput for LWIR (MTU=1500)



TCP Throughput for LWIR with Feedback mechanism (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)



TCP Throughput for LWIR with Feedback mechanism (MTU=2300)

- Same trends follows 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 upto 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!!!