A Framework for Integrating MPTCP over LWA - A Testbed Evaluation

Thomas Santhappan, Nabhasmita Sen, Venkatarami Reddy, Bheemarjuna Reddy Tamma, and Antony Franklin

Networked Wireless Systems Lab (NeWS Lab)
Department of Computer Science and Engineering
Indian Institute of Technology Hyderabad

भारतीय प्रौद्योगिकी संस्थान हैदराबाद
Indian Institute of Technology Hyderabad

Outline

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- IMT-2020 envisions
  - 20x hike in peak data rate
  - 100x hike in area traffic capacity
  - 10x hike in connection density
  - 10x low latency
- Crunch for licensed band
- High cost of license spectrum
- Exponential growth in data demand

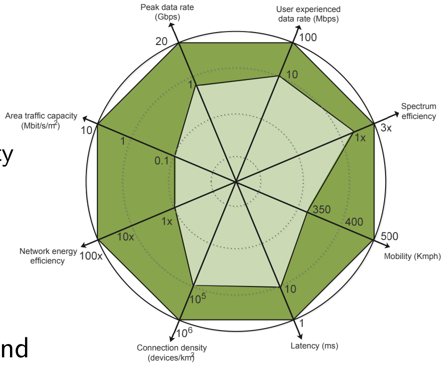


Figure 1 : IMT-2020 vision.

Outline

Multi-RAT Aggregation

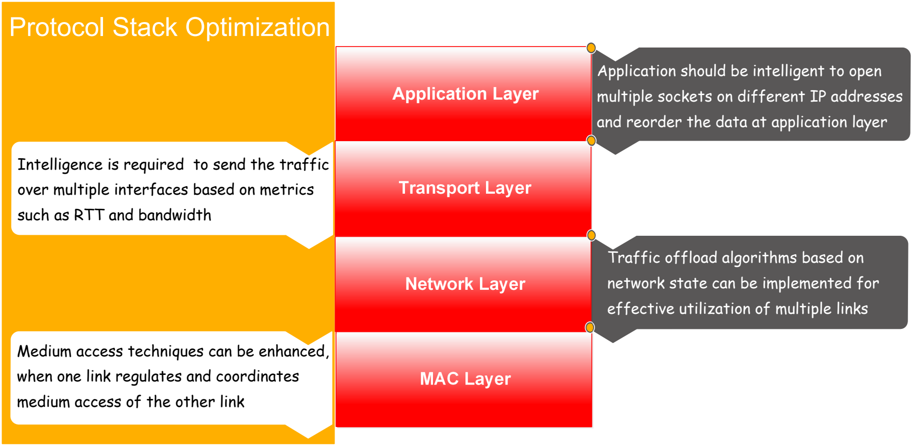
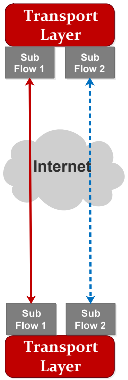
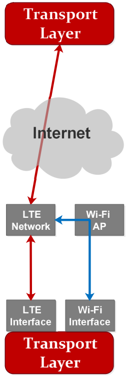


Figure 2 : Realize Aggregation at different layers of protocol stack.

Multi-RAT Aggregation at Transport vs Link layer



(a) Aggregation at Transport Layer (MPTCP).



(b) Aggregation at Link Layer (LWA).

- Multiple subflows.
- End-to-End decisions.

- Diverse link steering.
- Link level decisions.

MPTCP vs LWA

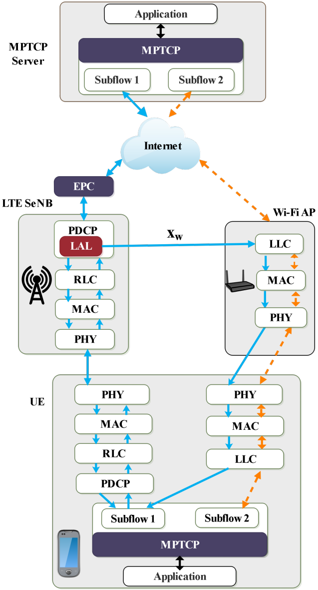
MPTCP	LWA
Enables multiple path routing at transport layer.	Enables traffic steering at link layer.
Conservative in congestion window growth to prevent network congestion	Faster switching across different links
Reroute to a new path when congested	Limited to available links

Does MPTCP competes or complements with LWA?

1. Does MPTCP compete with radio level aggregation?
   - How does MPTCP and LWA react to packet losses in the network?
   - How does MPTCP and LWA react to high contentions in medium access?
   - How does MPTCP and LWA react to network loss and high contention?
2. Does MPTCP complement with radio level aggregation when integrated?
   - Does co-operative MPTCP and LWA solution withstand packet losses and high contentions?

Outline

Architecture for Integrating MPTCP over LWA (MLWA)



MLWA Architecture

1. MLWA architecture supports link level and transport layer steering.
2. Adapting the solutions for network and link level problems with one architecture.

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Testbed Setup

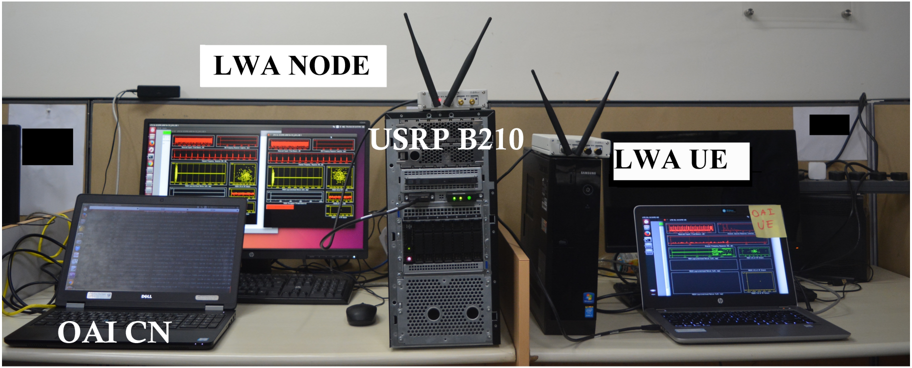

Figure 3 : LTE Wi-Fi Aggregation testbed.

Realizing LWA

- LWA module is realized by introducing link aggregation layer (LAL) at OAI-eNB.
- Link Aggregation layer enables steering the traffic across LTE and Wi-Fi links.
- Implemented UDP tunnel to carry the traffic from LTE eNB to LTE UE through Wi-Fi.
- Traffic steering at LWA node based on link round trip time (LRTT).
- Probe packets were sent periodically to estimate the LRTT.

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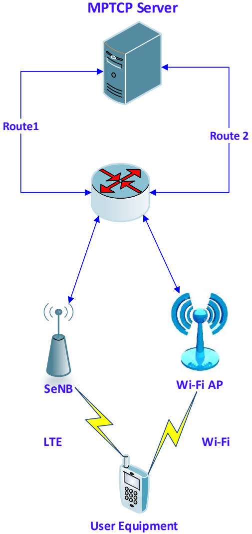
Performance Evaluation

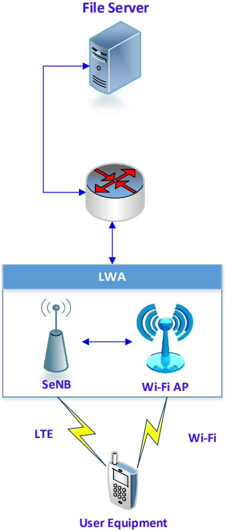
Experimental Parameters

Parameter	Value
LTE eNB bandwidth	5 MHz
LTE downlink, uplink frequency	2.66 GHz, 2.54 GHz
Number of resource blocks	25
Wi-Fi transmit power	20 dBm
LTE MAC Scheduler	Round Robin
Wi-Fi frequency, bandwidth	2.4 GHz, 20 MHz
Wi-Fi standard	IEEE 802.11g
Backhaul delay	80 msec
Packet loss rate	$10^{-4}, 10^{-3}$, and 10^{-2}
Download file size	16, 32, 64 MB

Experimental setup of MPTCP and LWA



(a) MPTCP.



(b) LWA.

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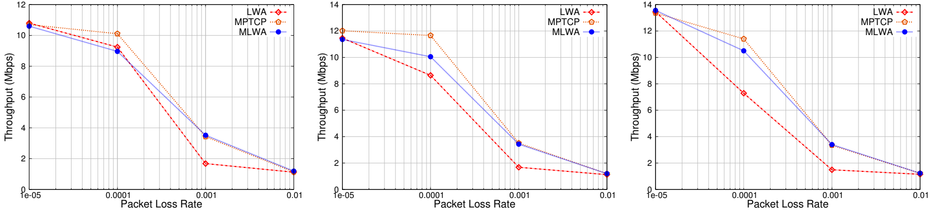
Case 1: Network Congestion (Throughput)

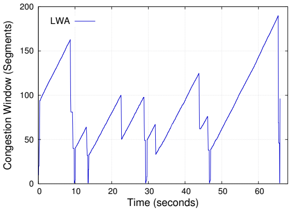


(a) File size: 16 MB.   (b) File size: 32 MB.   (c) File size: 64 MB.

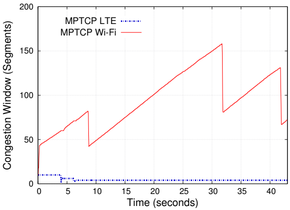
Figure 4 : Throughput observed in case of LWA, MPTCP, and MLWA by varying congestion losses in the network.

Low and medium congestion, MPTCP efficiently handles the packet loss.

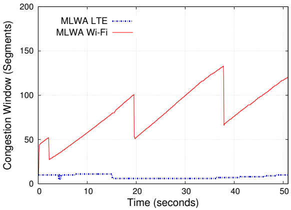
Case 1: Network Congestion (Congestion Window)



(a) LWA.



(b) MPTCP.



(c) MLWA.

The LWA fails to handle network level losses, whereas MPTCP sustains.

Ratio of packets through LTE and Wi-Fi are in order of 1 : 4, and 1 : 27 in case of LWA and MPTCP.

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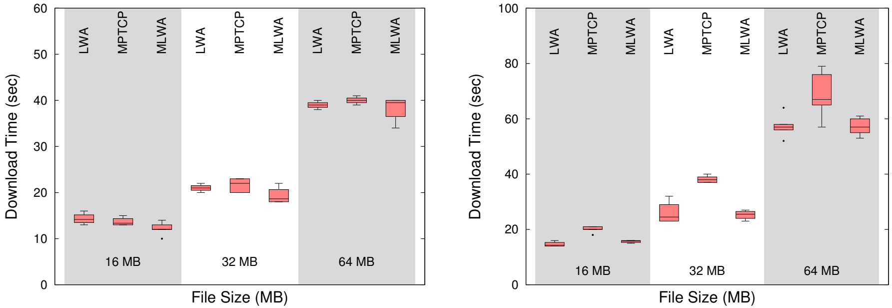
Case 2: Wi-Fi Channel Contention (Download Time)



(a) Low contention in Wi-Fi channel. (b) High contention in Wi-Fi channel.

Figure 6 : Time to download observed in case of LWA, MPTCP, and MLWA by varying file sizes.

LWA works phenomenal when the channel congestion is high as compared to MPTCP and MLWA.

Case 2: Channel Contention in Wi-Fi (Channel Busy Time)

(a) Low contention.

(b) High contention.

Figure 7 : Channel busy time observed on Wi-Fi channel when one 32 MB file was downloaded.

LWA allows effective utilization of Wi-Fi channel and provides more airtime for native Wi-Fi nodes to transmit.

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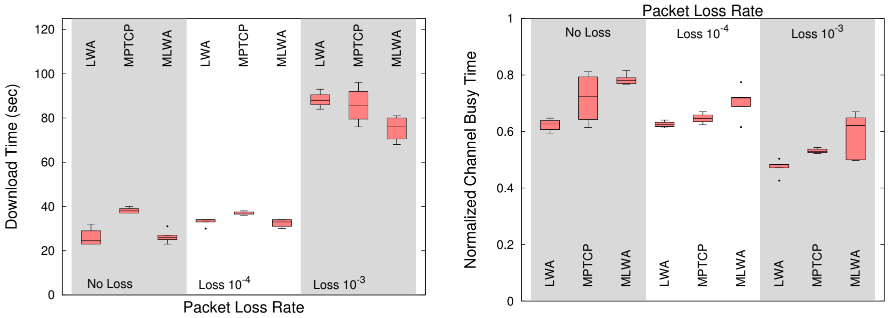
Case 3: Network Congestion and Wi-Fi Channel Contention



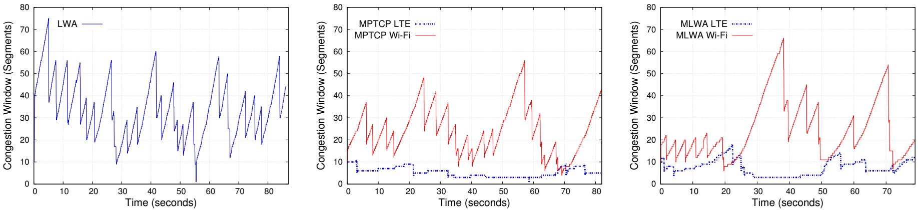
(a) Time to download.

(b) Channel busy time.

Figure 8 : Performance observed for 32 MB file download with network congestion and high channel contention.

MLWA withstands network losses and channel congestion.

Case 3: Network Congestion and Wi-Fi Channel Contention



(a) LWA. (b) MPTCP. (c) MLWA.

Figure 9 : Congestion window observed for 32 MB file download with 10^{-3} loss rate and high channel contention.

MLWA sustains whereas the congestion window drops frequently for LWA and MPTCP.

Outline

Conclusions

- MPTCP is an ideal solution to effectively handle the network level losses.
- LWA fails to aggregate link capacities when congestion in the network exist.
- LWA is highly preferable for small files download (less than 1 MB, Web traffic).
- With channel contentions, LWA not only improves the performance of LWA users but also improves overall performance of all users on the Wi-Fi channel.
- MLWA is robust and exhibits significant performance in both congestion losses and Wi-Fi channel contentions.

Acknowledgements

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For Further Queries Contact US

cs13p1002@iith.ac.in

www.thomasvalerrianpasca.in

GitHub

https://github.com/ThomasValerrianPasca/