OASIS : A Framework for Enhanced Live Video Streaming over Integrated LTE Wi-Fi Networks

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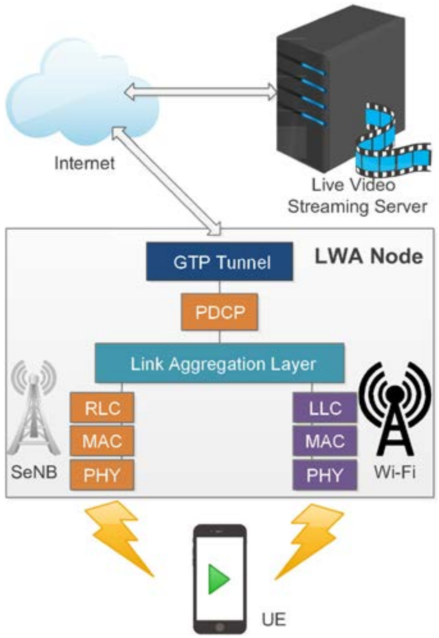
Live Video

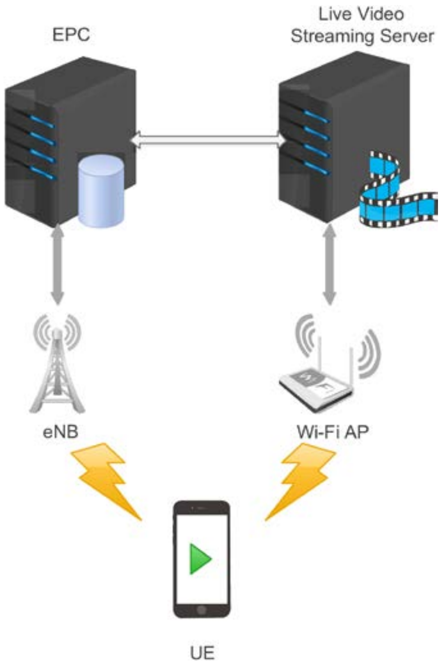
- Live and interactive video allows users to interact with each other in real-time
  - Facebook live, Linkedin Live, FaceTime, Skype, WhatsApp Video Calling
  - WebEx, Skye for Business, etc
- Live and interactive video imposes strict delay requirements
  - It requires one-way latency of up to 150ms[1] to be interactive

Live Video over Multipath Techniques



Live video streaming over LWA

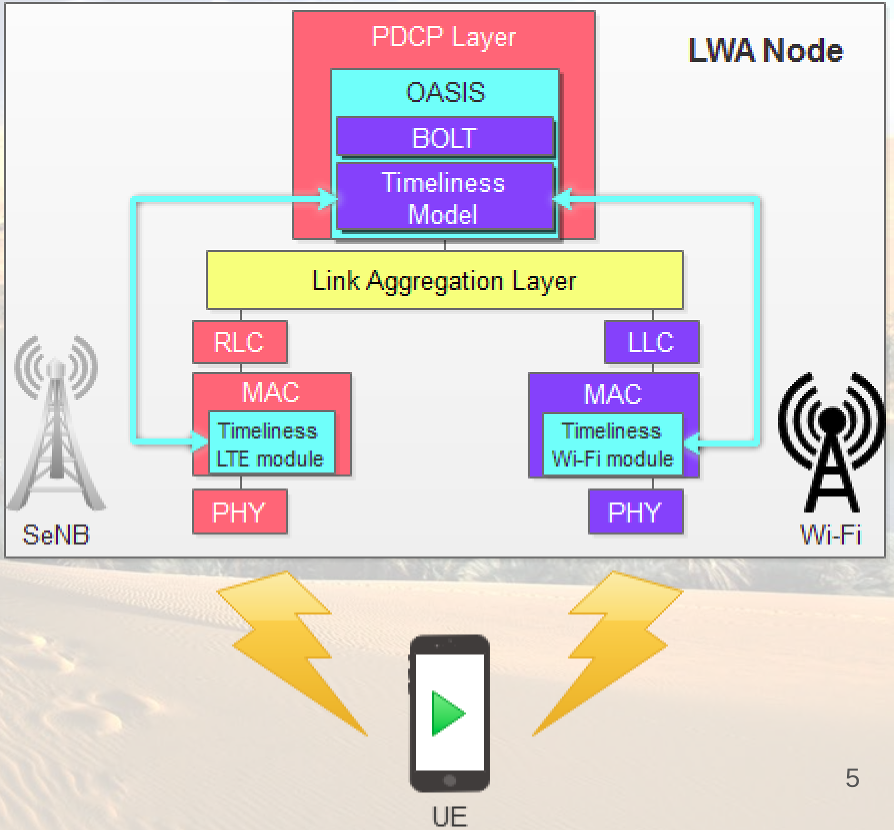
- Multipath techniques like MPTCP[2], MPRTP[3], LWA[4] etc. increase resource utilisation and provide increased throughput.
- MPTCP/ MPRTP establish multiple TCP/UDP connections from the server to the client.
- LWA maintains a single connection.
  - Traffic is split at the eNB over LTE and Wi-Fi links.
- But multipath techniques are not optimized for the low latency requirement of Live Video.



Live video streaming over MPRTP

OASIS : A Framework for Live Video Streaming

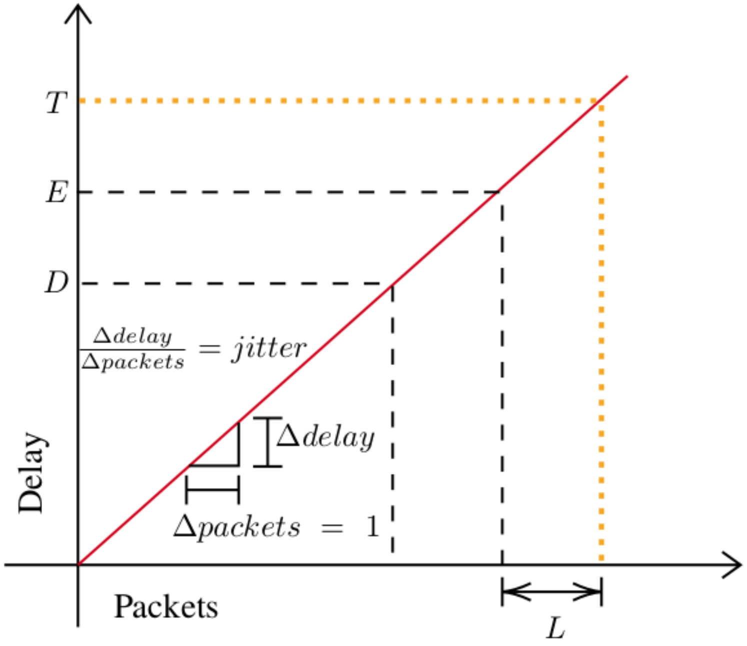
- **OASIS (bOunded delAy baSed steerIng with timelineSs):** A framework which allows streaming of live video with low latency.
- OASIS comprises of two components.
  - **BOLT** (bOunded delAy baSed steerIng) : a novel traffic steering algorithm
  - **Timeliness model** : It prioritizes I-frames, to ensure their intime delivery.
- OASIS works under UDP (User Datagram Protocol).
  - UDP supports sub-second latency required for live video streaming while TCP doesn't.



OASIS component #1 : BOLT

- BOLT is a novel packet steering algorithm.
- BOLT runs at the PDCP layer of the LWA node.
- It steers traffic according to the traffic load each link (LTE, Wi-Fi) can accommodate before exceeding the delay threshold.
- BOLT requires the receiver (smartphone) to send periodic updates regarding the delay and the jitter experienced by the packets.

BOLT working



Per Packet Delay Curve

$$E_i = D_i + J_i \times (S_i - R_i); i \in \{lte, wifi\}$$

Symbol	Description
T	The delay threshold, above which a frame expires.
E	The estimated delay of the last packet sent on the link that is yet to be received
D	The delay experienced by the last packet that was sent on the link.
L	The traffic load that can be transmitted on each link without exceeding T.

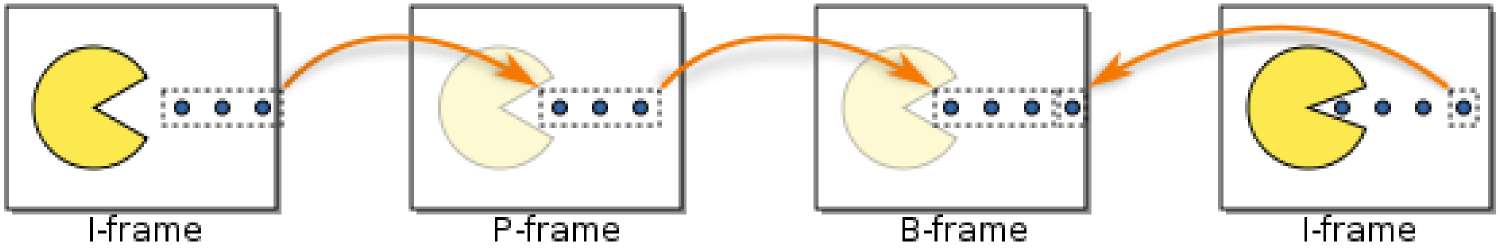
BOLT calculates load (L) for both LTE and Wi-Fi links and then decides steering ratio:

$$L_i = \frac{T - E_i}{J_i}; i \in \{lte, wifi\}$$

Steering Ratio= $\frac{L_{lte}}{L_{wifi}}$

I Frames

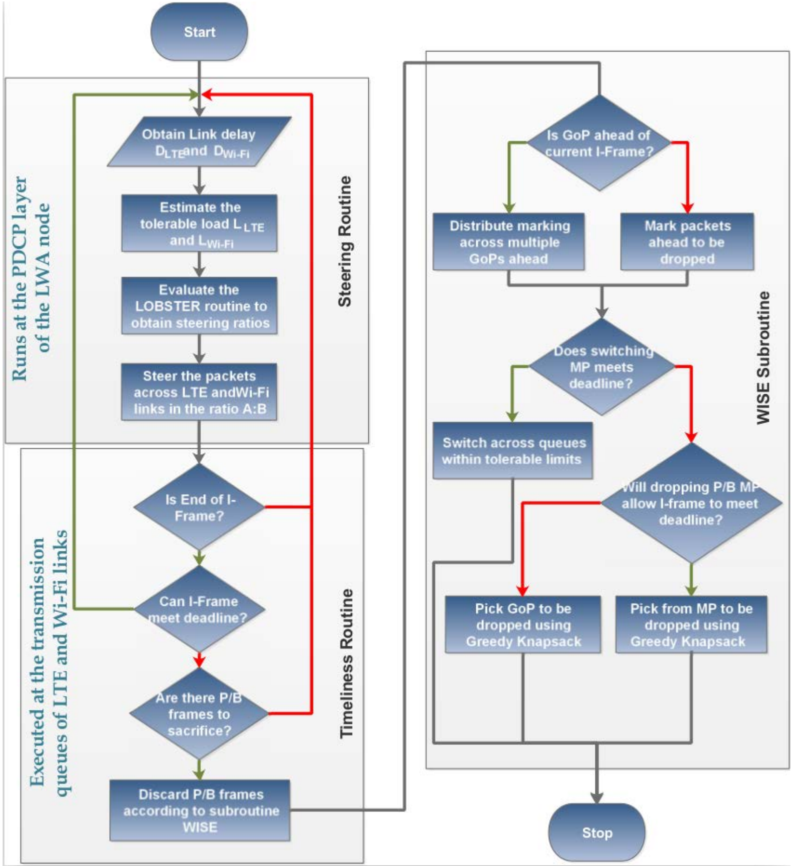
- Videos are compressed using various codecs like MPEG-4, H.264, WMV
- There are 3 types of pictures that are used in video compression.
  - I Frame (Intra coded Picture): It is a complete image (Least compressible)
  - P Frame (Predicted Picture): Holds only the changes from the previous frame.
  - B Frame (Bidirectional Predicted Picture): Holds the changes with respect to the preceding and following frames.



Source : Wikipedia

OASIS component #2 : Timeliness Model

- Timeliness model prioritizes I-frame packets.
- It ensures that they are delivered in time by sacrificing other frame packets.



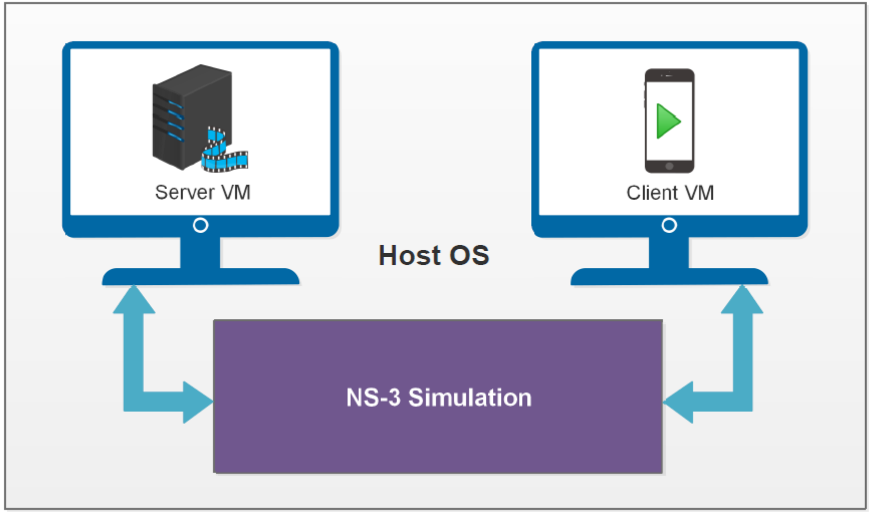
Reordering in OASIS

- Whenever multiple paths are involved, packets arrive out of order at the receiver (e.g., smartphone).
- This results in garbled video during playback.
- To solve this problem the packets are held for a duration at the transport layer before being forwarded to the application layer (i.e., video the player).

$$Holding\ Time = Delay\ Threshold + Sending\ Time - Receiving\ Time$$

- This allows packets to be sent to the application layer at the same rate with which they were streamed in.

Experimental Setup



NS-3 Experiment Parameters

LTE Parameter	Value
LTE eNB bandwidth	5 MHz
Resource Blocks	25
Tx power	20 dBm
Path Loss Model	Log Distance
Fading Model	Trace Fading Model
MAC Scheduler	Proportional Fair

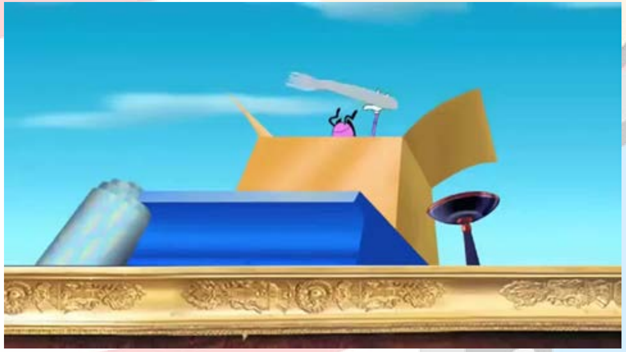
Wi-Fi Parameter	Value
Frequency, bandwidth	2.4 GHz, 20 MHz
Standard	IEEE 802.11 g
Propagation Delay Model	Constant Speed
Propagation Loss Model	Log Distance

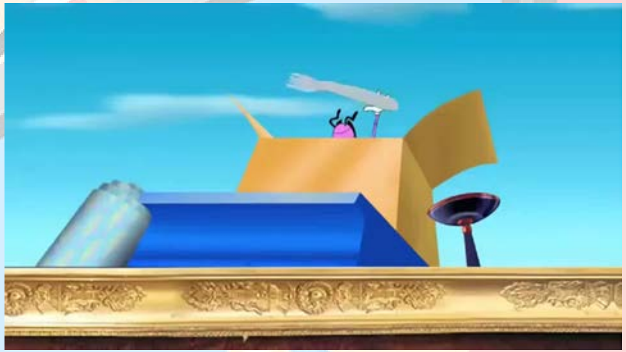
Video Parameter	Value
Resolution	1280 × 720
Bitrate, FPS	1742 Kbps, 25
Codec	H.264

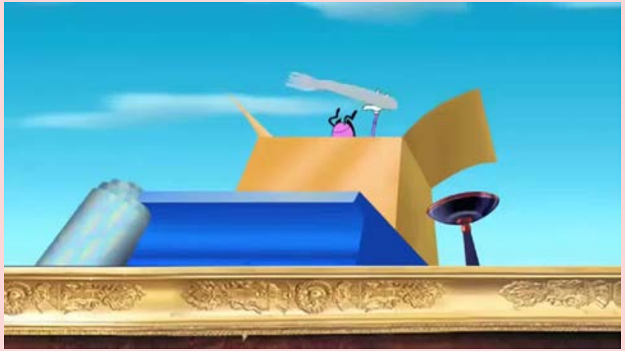
Scenarios to test OASIS performance

- **Scenario #1 :** UE is made to oscillate between the eNB and the Wi-Fi AP. This scenario creates the following conditions
    - Good Conditions : When UE is closer to one of the networks
    - Bad Conditions : When UE is farther from one of the networks
- **Scenario #2 :** Variable background traffic is added on both LTE and Wi-Fi links.
- **Scenario #3 :** Only LTE link is usable, Wi-Fi link is unusable (i.e., it has high latency).
- **Scenario #4 :** Only Wi-Fi link is usable. LTE link is unusable (i.e., it has high latency).

Video Comparison for Scenario #1







OASIS

VMAF : 78

Regular LWA

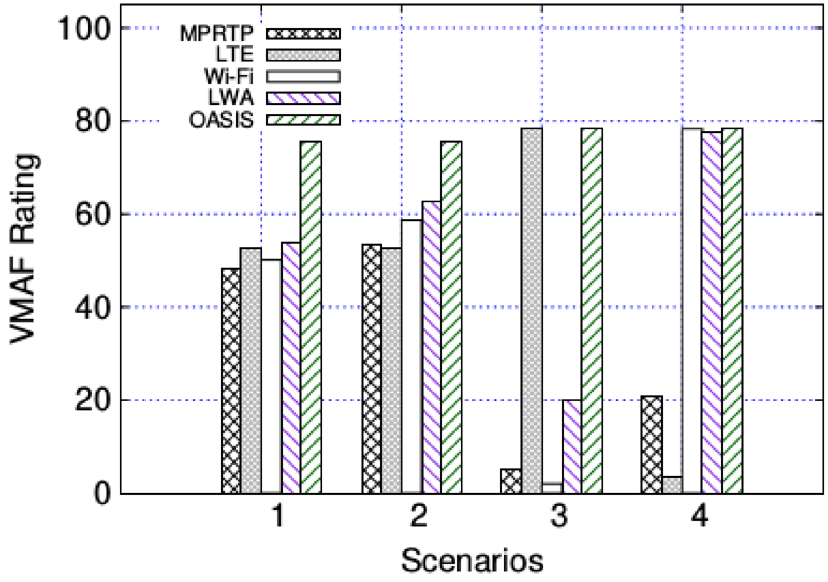
VMAF : 62

MPRTP

VMAF : 53

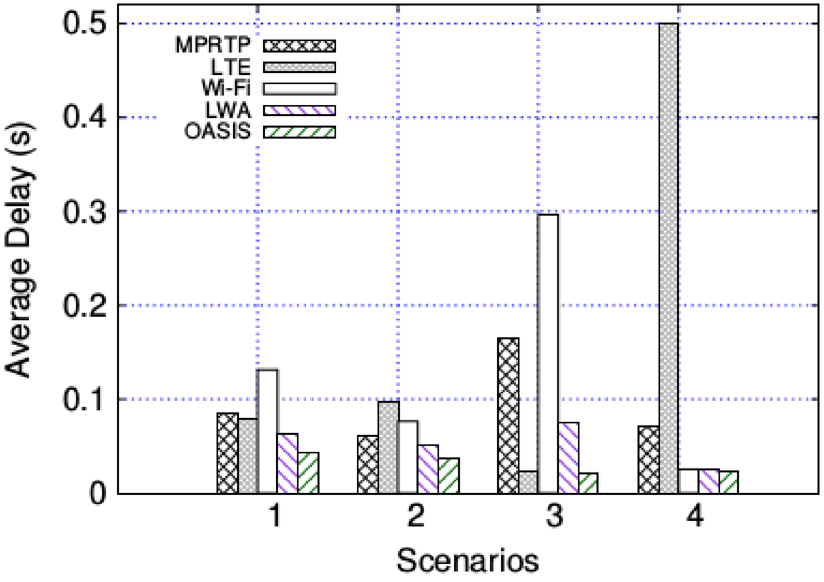
Results #1

Comparing OASIS with MPRTP, regular LWA, LTE only, and Wi-Fi only.



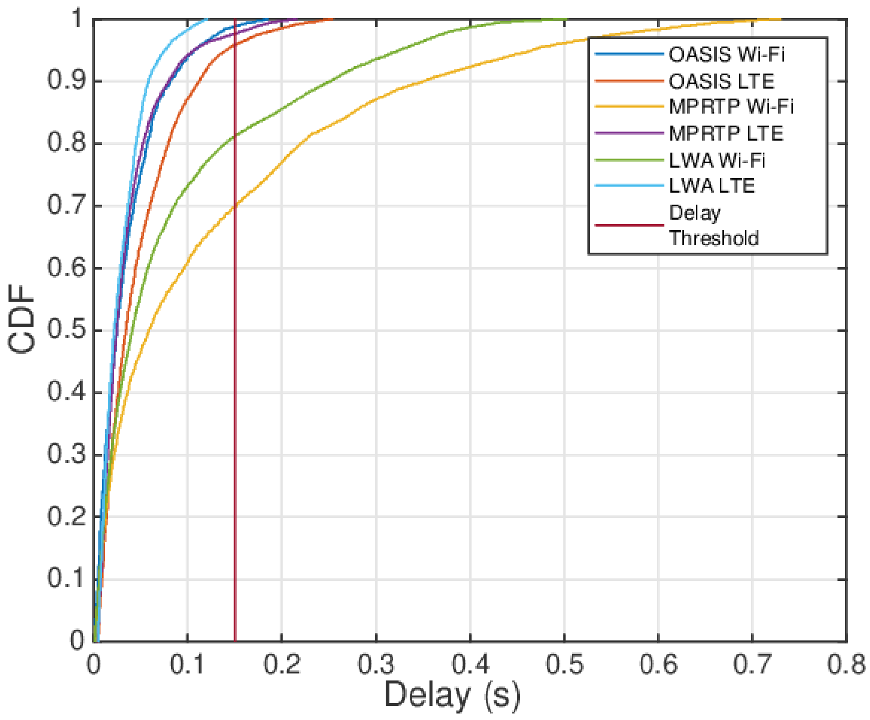
VMAF ratings comparison for all the scenarios.

Video Multimethod Assessment Fusion (VMAF)

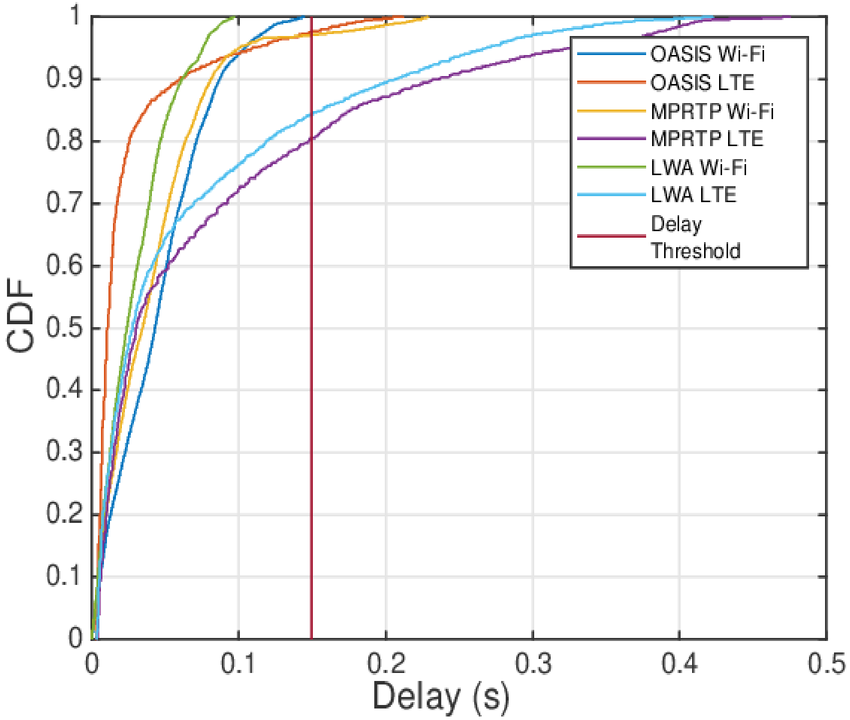


Average Delay comparison for all the scenarios.

Results #2

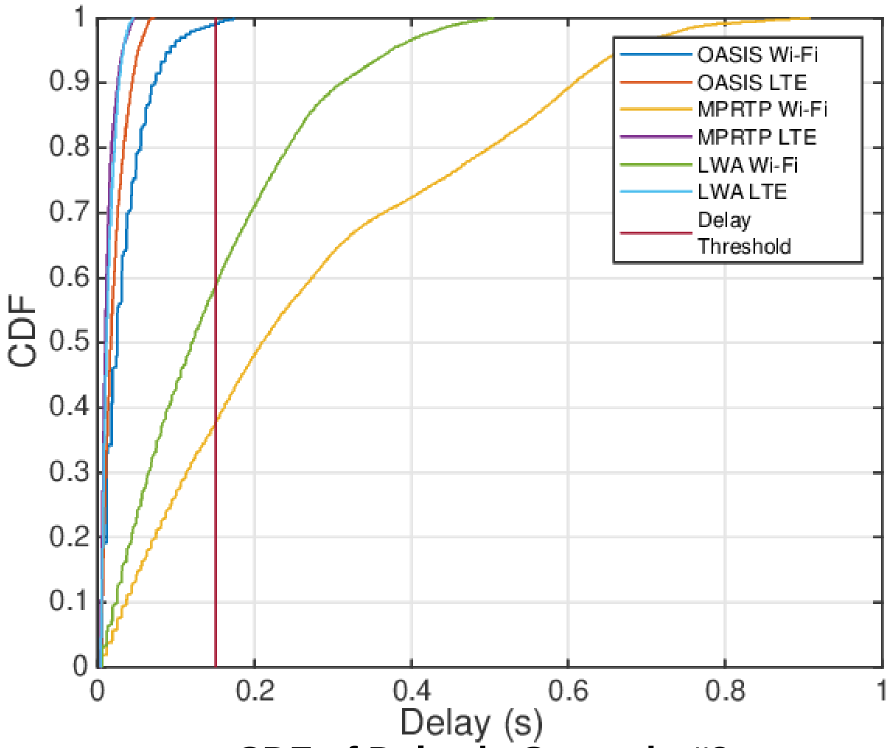


CDF of Delay in Scenario #1

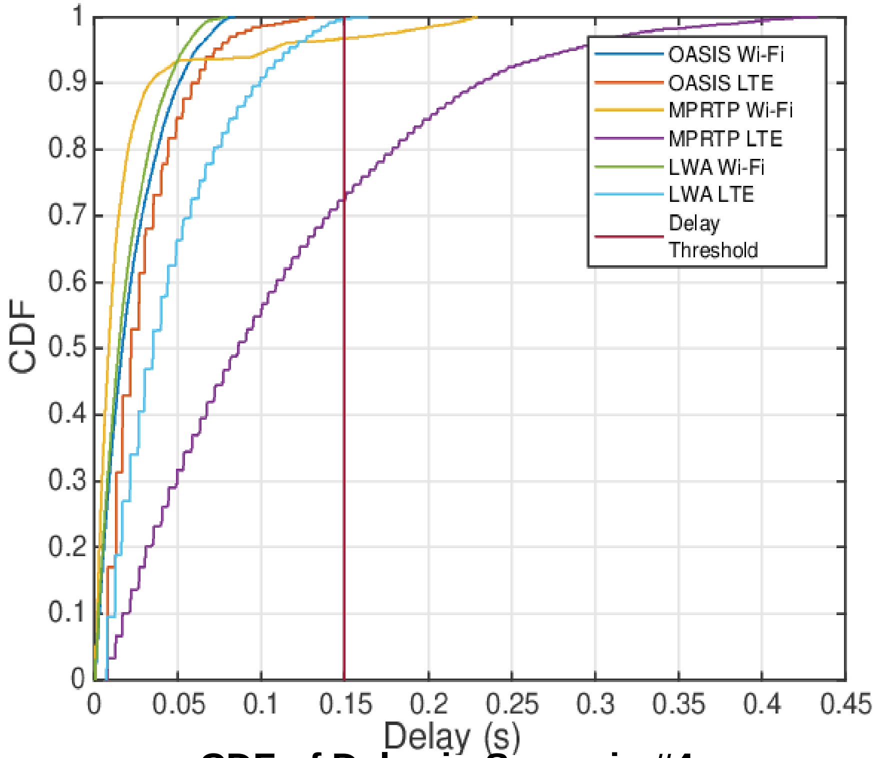


CDF of Delay in Scenario #2

Results #3



CDF of Delay in Scenario #3



CDF of Delay in Scenario #4

Results #4

The effect of adding timeliness model:

	OASIS without Timeliness Model	OASIS with Timeliness Model
Total Lost Packets	62	56
I-Frame Packets Lost	60	12
VMAF Rating	68.057	75.43

Note: Results were only collected for Scenario #1.

Conclusions

- The steering algorithm of OASIS, BOLT, aggregated the links effectively and outperformed MPRTP and LWA.
- Thus OASIS successfully enhanced the live video streaming over LWA by 1.4x as compared to MPRTP.

Future Wok:

- Streaming DASH videos over LWA using BOLT as the traffic steering algorithm
- Adapting video quality using Scalable Video Coding (SVC)
  - Enhancement Layer packets can be discarded if the bandwidth is not available.
- Work can be extended to streaming 360 degree videos over LWA

References

[1] T. Szigeti and C. Hattingh, End-to-end QoS network design: quality of service in LANs, WANs, and VPNs. Cisco Press, 2010.

[2] A. Ford et al., “Architectural guidelines for multipath TCP development,” IETF, Tech. Rep. RFC 6182, 2011.

[3] Varun Singh, Saba Ahsan, and Jörg Ott. 2013. MPRTP: multipath considerations for real-time media. In Proceedings of the 4th ACM Multimedia Systems Conference (MMSys '13). ACM, New York, NY, USA, 190-201. DOI=http://dx.doi.org/10.1145/2483977.2484002

[4] 3GPP, “LTE-WLAN Aggregation Adaptation Protocol,” 3GPP, Tech. Rep. 36.360, 2017.

Acknowledgements

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