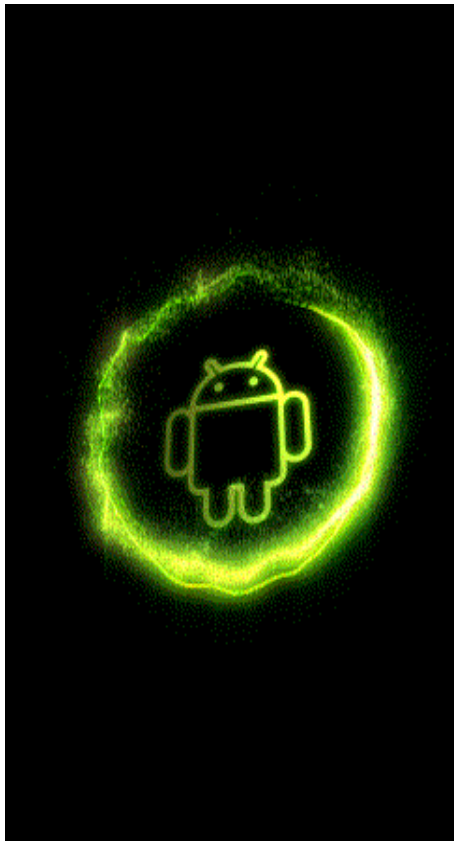

Enhancing the Real-Time Traffic Latency in Wi-Fi Networks: A Smartphone Perspective

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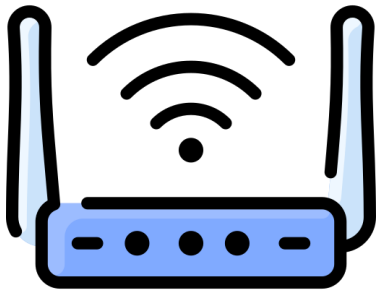
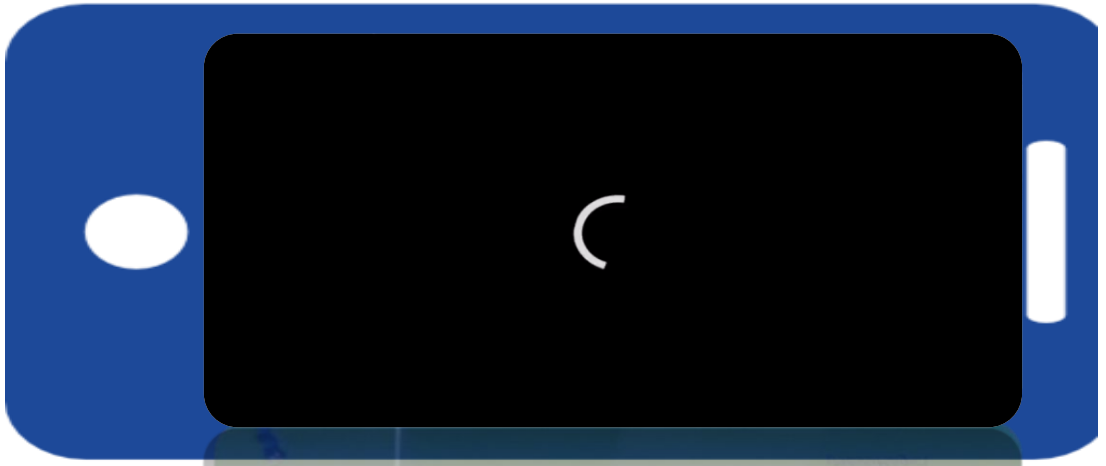
Real time traffic – The interesting swift

- Widespread adoption of smartphones has transformed ➔ Communicate, work, and entertain ourselves.
- As the demand for seamless and high-quality user experiences surges, ensuring **efficient Quality of Service (QoS)** for smartphone applications becomes critical to mobile computing.
- Different service levels ➔ different types of traffic ➔ different requirements.
- **Latency, throughput, packet loss, and jitter**, which significantly impact user satisfaction and the overall usability of applications.
- Smartphone applications ➔ Increase in real-time traffic 3x during and post pandemic
- The QoS requirements for each of the above services are different. For example,
  - **Online mobile gaming and video conferencing:** low latency and minimal packet loss are paramount to ensure a smooth and immersive experience.
  - **Web browsing/Downloads:** Throughput is the priority over low latency.

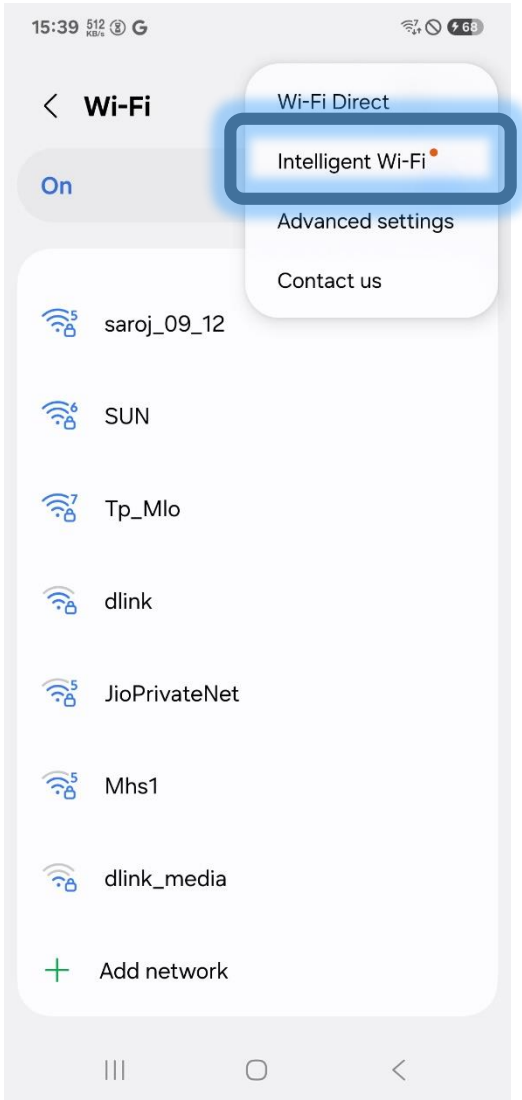
A day-to-day scenario

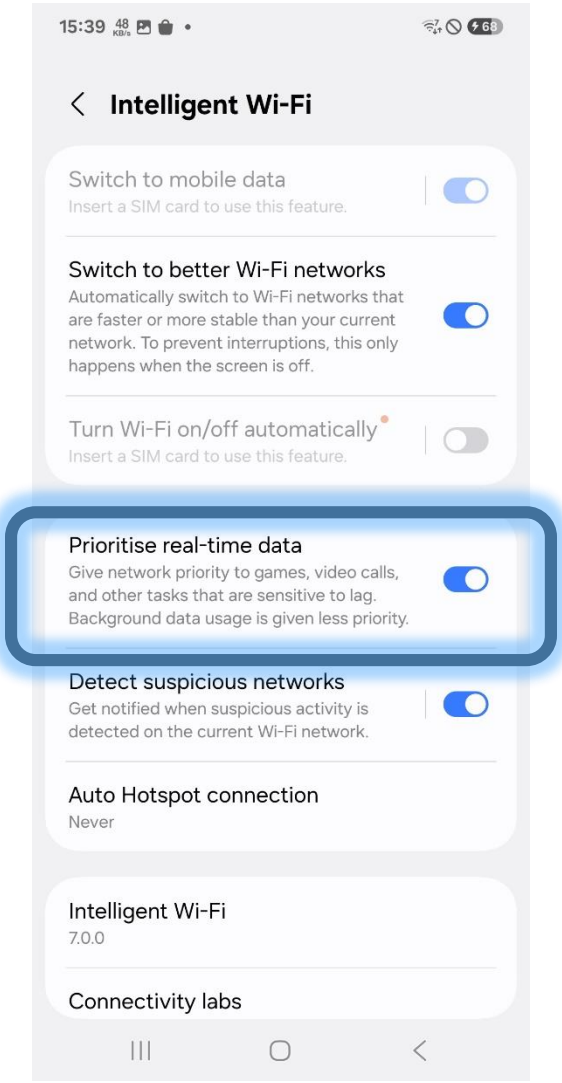




Bandwidth is shared by different client running multiple traffic

Wi-Fi QoS Management: UE/STA/Smartphone only





- Due to auto-download policy or background downloads → Race in same device
- Best-effort dominates the Real-time traffic
- **Video can be spotty, online game can face delay**
- Since, both traffic are in same device → Control the downlink traffic
- Control?? Delay/Drop/Shape packets or ack or playaround with ACK/Windows
- Pros: Server and Middlebox independent
  Cons: Other BE traffic can dominate in shared medium. Not very common case in smartphone

M. R. Kanagarathinam, K. M. Sivalingam and G. K. Choudhary, "Application Prioritization Engine for Enhancing Real-Time Performance in Smartphones," in IEEE Transactions on Network and Service Management, vol. 21, no. 1, pp. 773-788, Feb. 2024, doi: 10.1109/TNSM.2023.3291706.

Wi-Fi QoS Management: STA + AP

- A common challenge smartphone users face is the **inconsistency** in QoS among different applications.

- Wi-Fi QoS Management:
  a) Stream Classification Service (SCS)
  b) Mirrored Stream Classification Service (MSCS)
  c) Differentiated Service Code Point (DSCP) Mapping/Policy

- **Today → IEEE 802.11e Quality of Service Standard: 'DSCP and Access Categories (AC)'**

- Four defined AC – Voice, Video, Best Effort, and Background

- **RFC 8325:** Mapping Diffserv (DSCP) to IEEE 802.11 User priority (UP)

- The **real-time** video and gaming should be in **CS4→ VI**

TABLE I
NETWORK CLASS TO WI-FI ACCESS CATEGORY MAPPING

IETF Network Class	PHB	Category
Network Control	CS6	VO
Voice	EF, VA	VO
Signalling	CS5	VI
Multimedia Conference	AF4X	VI
Real-time Interactive	CS4	VI
Multimedia Streaming	AF3X	VI
Broadcast Video	CS3	VI
Low latency data, OAM, High throughput, Best Effort	AF2X, CS2, AF1X, DF	BE
Low Priority Data	CS1	BG

DSCP and AC of top-chart apps

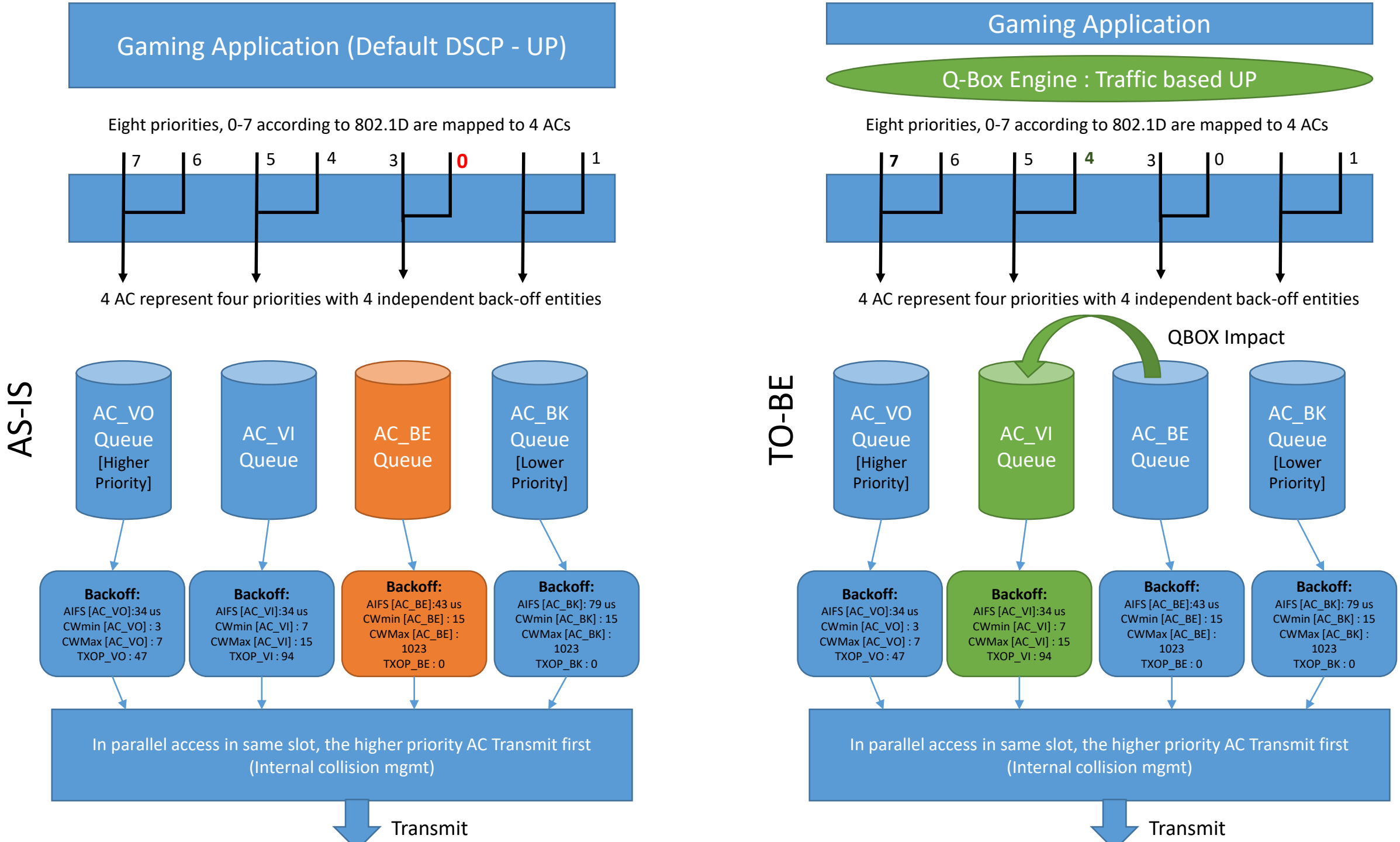
- From our experiment, we found that **most of the RT traffic does not set proper DSCP** value and hence, the **Wi-Fi UP is Best effort (Be)** by default. However, the recommended UP is Video (Vi).

- We aim to enhance the QoS for smartphone applications, particularly those requiring **real-time responsiveness.**

Application	UL: AC	UL: DSCP	DL: AC	DL: DSCP
PUBG Mobile	Best effort (0)	0x00	Background (1)	0x20
Call of Duty	Best effort (0)	0x00	Background (1)	0x20
Free Fire	Best effort (0)	0x00	Background (1)	0x20
Clash Royale	Best effort (0)	0x00	Background (1)	0x20
Snake	Best effort (0)	0x00	Background (1)	0x20
Google Meet	Best effort (0)	0x00	Excellent effort (3)	0x60
Microsoft Teams	Best effort (0)	0x00	Background (1)	0x20
Zoom	Best effort(0)	0x00	Background (1)	0x20
Cisco WebEx	Controlled Load (4)	0x88	Background (1)	0xb8

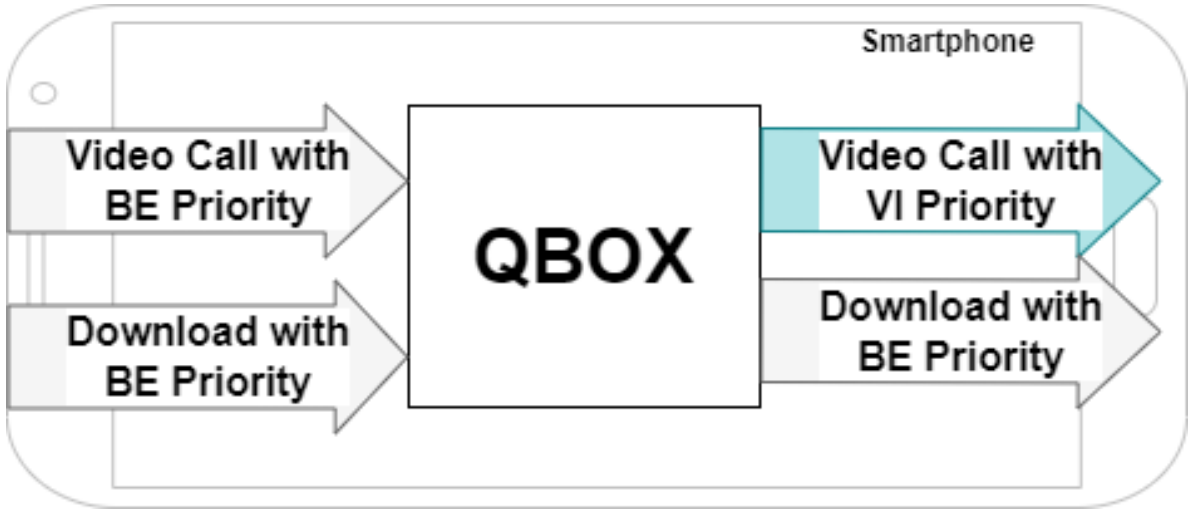
*Test conducted this 2nd week of Dec 2024 in India. A similar result was in 2022, 2023 as well

802.11e : Wi-Fi Multimedia Standard Contd.



Quality Box (QBOX) for App-Agnostic latency improvement

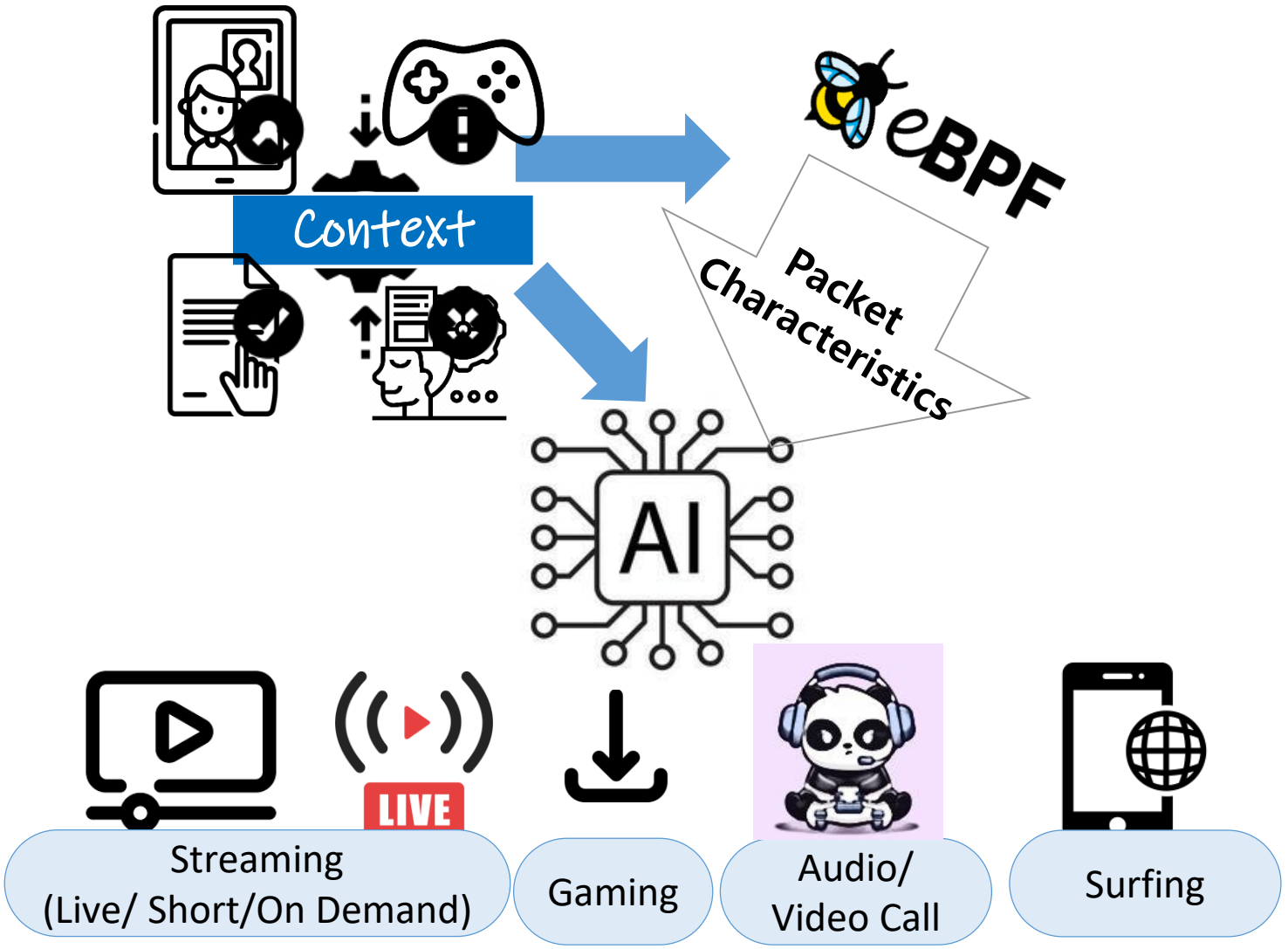
- We introduce QBOX (Quality Box): An app agnostic Wi-Fi UP mangler
- QBOX Uses **eBPF**, to inspect, filter, and **modify** incoming and outgoing packets **DSCP/UP** in real-time.
- Upon detection of inappropriate QoS values, QBOX intervenes and dynamically modifies the ToS value of the packets to reflect the application's real-time requirements accurately.
- Additionally, to ensure prioritized transmission, QBOX upgrades the Wi-Fi access category from **Best Effort to Video**, giving real-time applications preferential treatment during data transmission.



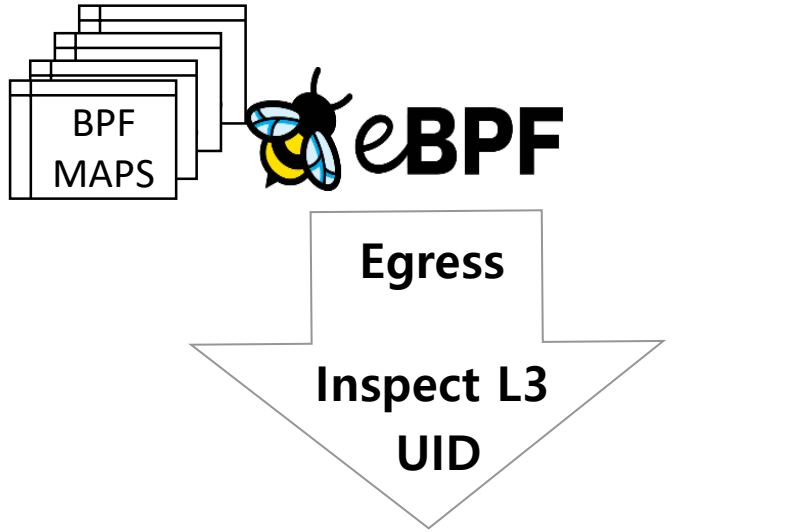
Egress Video Call packets are upgraded from BE to VI

What do we require?

Step 1: Classify the real-time traffic



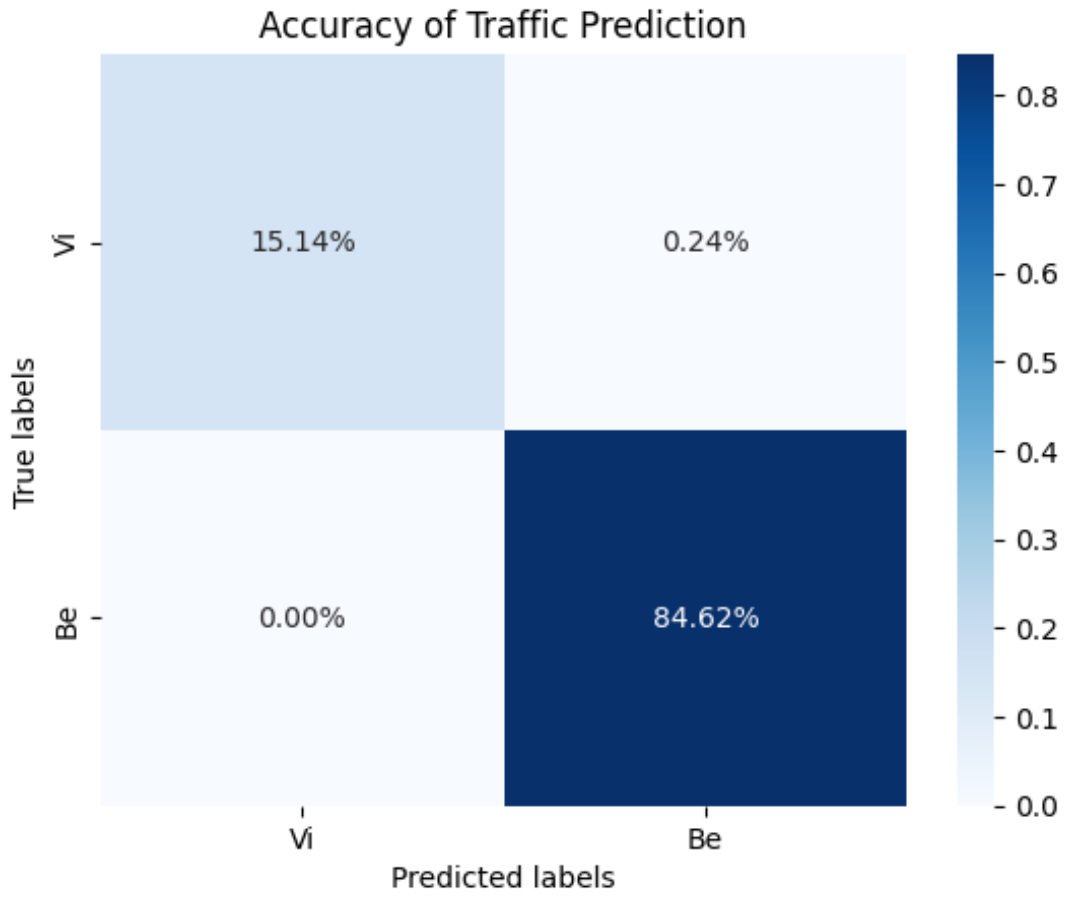
Step 2: Mangle the Wi-Fi AC



Upgrade or Downgrade (DSCP ➔ AC)

Detection Accuracy

- Upon successful detection of real-time applications, the QBOX architecture proceeded to enhance the QoS by dynamically modifying the Type of Service (ToS) and Wi-Fi Priority (DSCP) values to Video (VI) as expected.
- The figure shows the confusion matrix of the overall accuracy of the traffic prediction. We found that none of the BE traffic was upgraded to VI.
- There were just 0.24% of the VI packets still continued to be BE priority. This is mainly the initial packet due to the delay in the events.
- Hence, we can conclude that the QBOX never caused any negative impact. Except for the first few initial packets, the QBOX always upgrades the Wi-Fi priority of the required traffic.



Quantifying the QoE for RT traffic

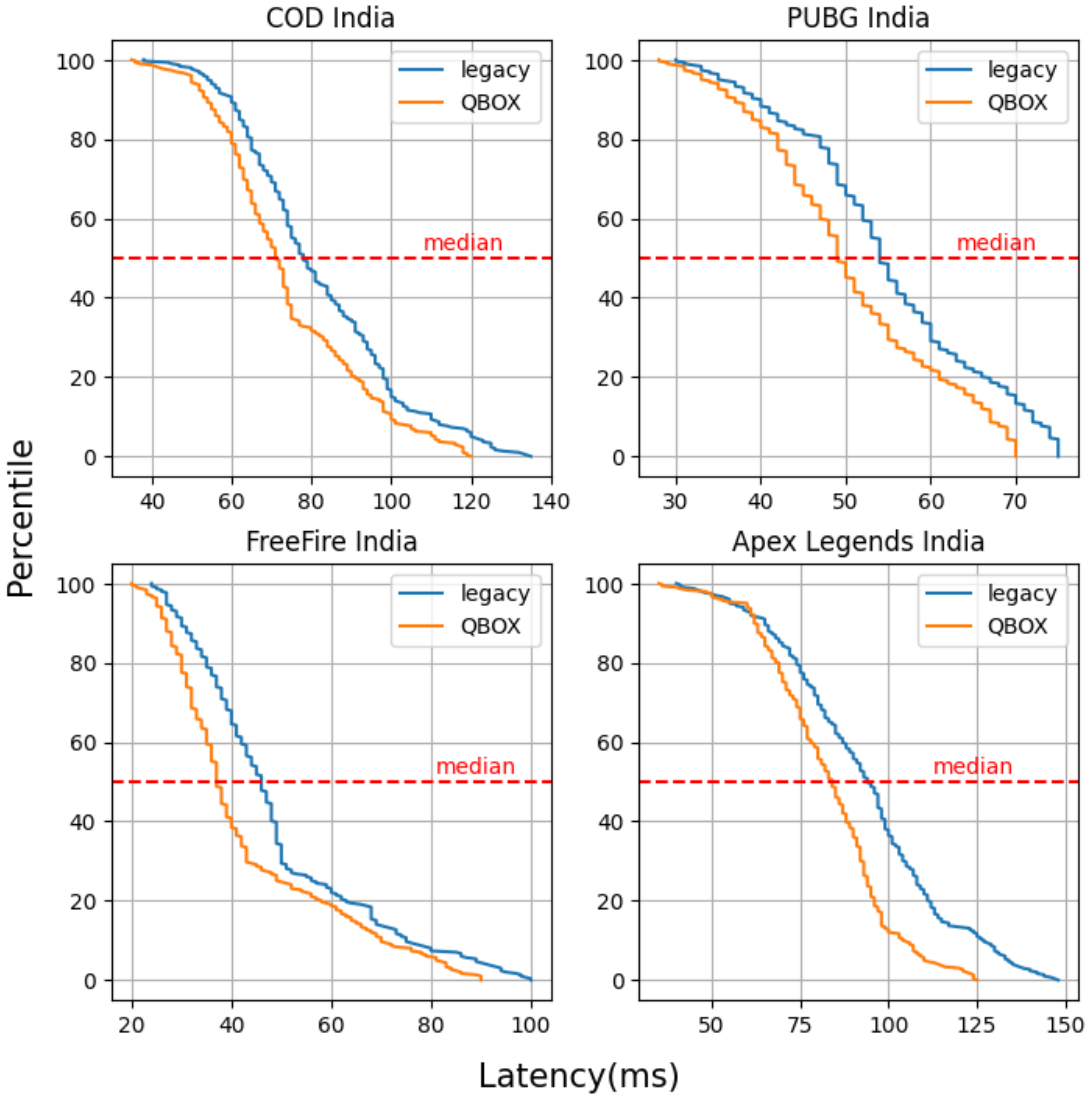
- Video calling app → We found Bitrate highly correlated to QoE
- For gaming → No correlation
- Use TCP connection of the game → Low correlation
- Most of the application displays one way latency to the server → Prop methods
- Can we use this as metric to determine the QoE?
- Screen capture → OCR → Latency Extract → Evaluate

J. R. Kovvuri, M. R. Kanagarathinam, K. M. Sivalingam and S. Lee, "Game Stabilizer: Enhancing Mobile Gaming with Intelligent Bandwidth Optimization," ICC 2024 - IEEE International Conference on Communications, Denver, CO, USA, 2024, pp. 764-769, doi: 10.1109/ICC51166.2024.10622997.

Latency improvement in gaming

Scenario 1: Middle box that replicates the TOS value

Up-to 24% reduction in latency in saturated network

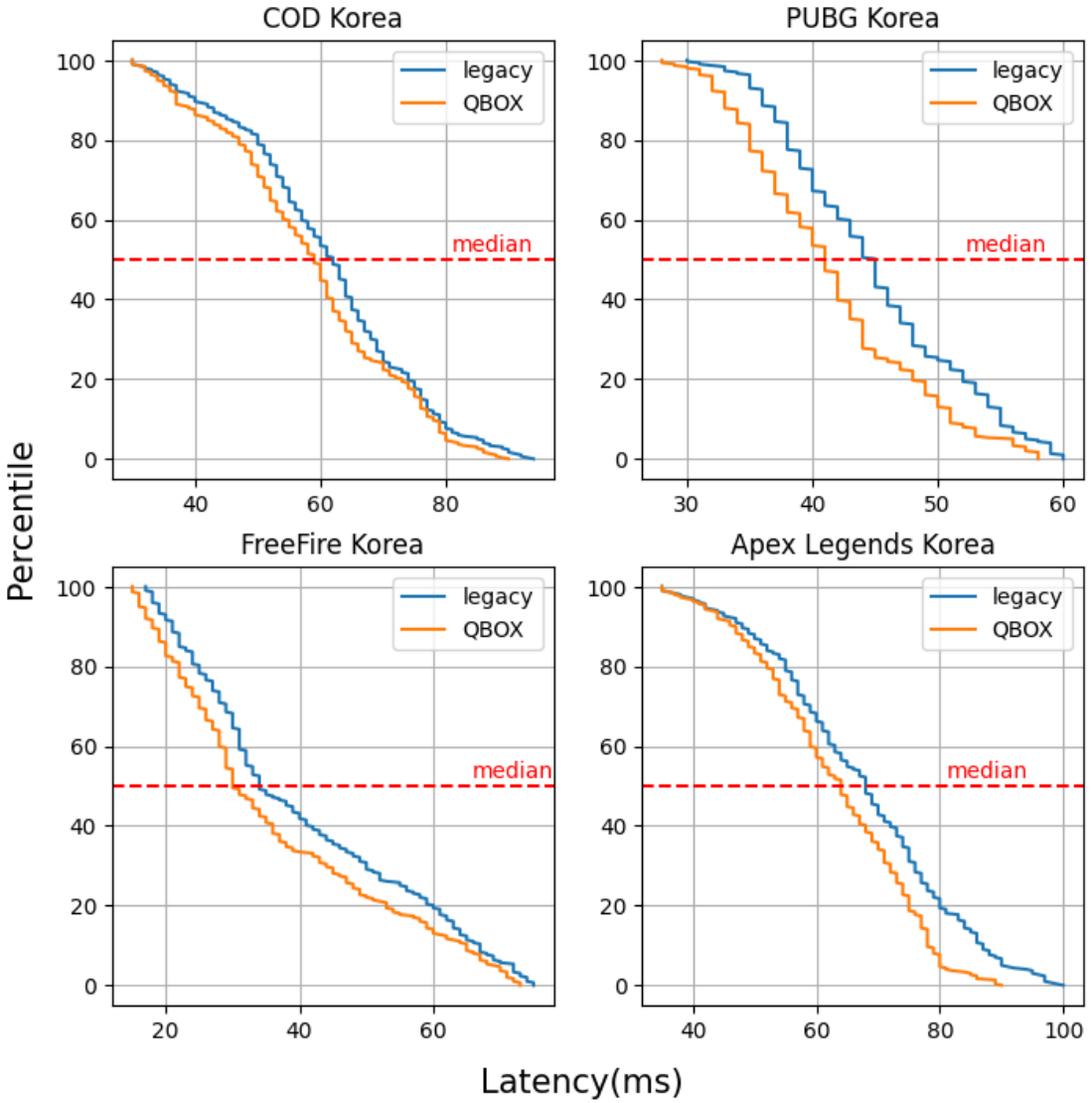


M. R. Kanagarathinam, K. M. Sivalingam, J. R. Kovvuri and S. Lee, "QBOX - Policing Smartphone App Experience with Dynamic QoS Enhancement," 2023 IEEE Globecom Workshops (GC Wkshps), Kuala Lumpur, Malaysia, 2023, pp. 973-978, doi: 10.1109/GCWkshps58843.2023.10464434.

Latency improvement in gaming

Scenario 2: Only UL priority

Up-to 10% reduction in latency in saturated network



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Towards Understanding Latency 4.0

3.0 - Summary

→STA only (App-Agonistic)

→STA with AP partial support (App-Agonistic)

4.0 (The wish list)

→Device with AP full support – SCS and MSCS, Hybrid Schedulers (FQ-Codel, Cake, etc.), Multi link operation, Dynamic Configurations

→End-to-end latency support – L4S, TSN, App-Aware, etc.

THANK YOU