



Characterization and troubleshooting of cloud gaming applications on mobile networks

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There is therefore a need to **collect, identify and analyze** metrics specific to low-latency applications in network equipment (switches, base stations, UEs...) for **efficient troubleshooting** of user QoE degradation purposes.

[illegible]

The diagram illustrates the Mahimahi architecture. At the top, a large grey rounded rectangle represents the **Livebox**. Inside it is a blue rounded rectangle labeled **Namespace Mahimahi**. Within this namespace is a pink rectangle labeled **Link-X**, which contains a **UL queue** (uplink) and a **DL queue** (downlink). To the left of the namespace, a line labeled **Connected to the Windows client** enters through a diamond labeled **emq429** into the **UL queue**. From the **DL queue**, a line exits through a diamond labeled **egress Link-X**. To the right of the namespace, a line labeled **Connected to the FTTH box** enters through a diamond labeled **emq250** into the **DL queue**. From the **UL queue**, a line exits through a diamond labeled **ingress Link-X**. In the center of the Livebox is an orange dashed oval labeled **NAT Iptables**, which is connected to the **ingress Link-X** and **egress Link-X** diamonds. Below the Livebox, the network topology is shown: a **Windows CG Client** (with STADIA and NVIDIA logos) is connected to a **Mahimahi LinkShell** box, which is connected to the **Livebox** (represented by a wireless router icon). The **Livebox** is connected to the **Internet** (cloud icon), which is connected to the **CG Server** (server rack icon). An orange callout box points to the **Livebox** with the text: **Use a FTTH Box to avoid creation of a bottleneck**.

Conditions	Throughput (Mbps)	Location
File 1	220	Orange
File 2	160	Orange
File 3	120	Brélèvenez
File 4	80	Brélèvenez
File 5	40	Pleumeur-Bodou
File 6 (Highway)	45	Guingamp - Lannion

Figure 10 consists of six subplots arranged in a 3x2 grid. The left column (a, b, c) shows mean throughput, and the right column (d, e, f) shows the CDF of inter-transaction times.

- (a) Mean Downlink Throughput of 10:10 Mix:** A line plot showing throughput (Mbps) on the y-axis (0 to 400) versus Net Demand (G) on the x-axis (0 to 100). The throughput fluctuates between approximately 100 and 350 Mbps.
- (b) Mean Uplink Throughput of 10:10 Mix:** A line plot showing throughput (Mbps) on the y-axis (0 to 400) versus Net Demand (G) on the x-axis (0 to 100). The throughput fluctuates between approximately 100 and 350 Mbps.
- (c) Mean Downlink Throughput of 40:10 Mix:** A line plot showing throughput (Mbps) on the y-axis (0 to 120) versus Net Demand (G) on the x-axis (0 to 100). The throughput fluctuates between approximately 20 and 100 Mbps.
- (d) Mean Uplink Throughput of 40:10 Mix:** A line plot showing throughput (Mbps) on the y-axis (0 to 120) versus Net Demand (G) on the x-axis (0 to 100). The throughput fluctuates between approximately 20 and 100 Mbps.
- (e) CDF of Inter txops time (10:10 Mix):** A line plot showing the CDF on the y-axis (0.75 to 1.00) versus Inter txops time on the x-axis (0 to 35). The 'uplink' curve (blue) rises sharply from 0.75 at time 0 to 1.00 by time 5. The 'downlink' curve (orange) rises more gradually, reaching 1.00 by time 15.
- (f) CDF of Inter txops time (40:10 Mix):** A line plot showing the CDF on the y-axis (0.50 to 1.00) versus Inter txops time on the x-axis (0 to 30). The 'uplink' curve (blue) rises sharply from 0.50 at time 0 to 1.00 by time 5. The 'downlink' curve (orange) rises more gradually, reaching 1.00 by time 15.

The txops files data are available in **OpenData** at the following link: <https://cloud-gaming-traces.lhs.loria.fr/cellular.html>

- [1] Keith Winstein. Saturatr tool. <https://github.com/keithw/multisend>.
- [2] Ravi Netravali. Mahimahi. <https://github.com/ravinet/mahimahi>.

The diagram illustrates the proposed framework for anomaly detection and root cause analysis. It begins with **Multivariate Time-Series** data as the **Input**. This data is processed through **Data Processing** and **Unsupervised ML/DL learning** (represented by a neural network icon). The output of the learning phase is **Anomaly Detection**, which identifies a specific point in the time series. This leads to the **Output**, which is a detailed view of the time series with a green vertical line marking the anomaly. Finally, **Root Cause Analysis** identifies the causes of the anomaly, shown as **Cause 1**, **Cause 2**, ..., **Cause p-1**, and **Cause p**.

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