TestDevLab

iMind: A/V Pilot

Video App Benchmarking

iMind | Google Meet

Introduction to TestDevLab

- 10 years in business
- 500 employees, 8 offices across 4 countries (Latvia, Estonia, North Macedonia, Spain)
- Clients include both startups and Fortune 500 companies
- Products that we test are being used by 4.5 billion people every day
- We offer QA services, testing labs (such as Audio/ Video quality testing) and products
- ISO 27001 certified
- >2500 actual devices to test against

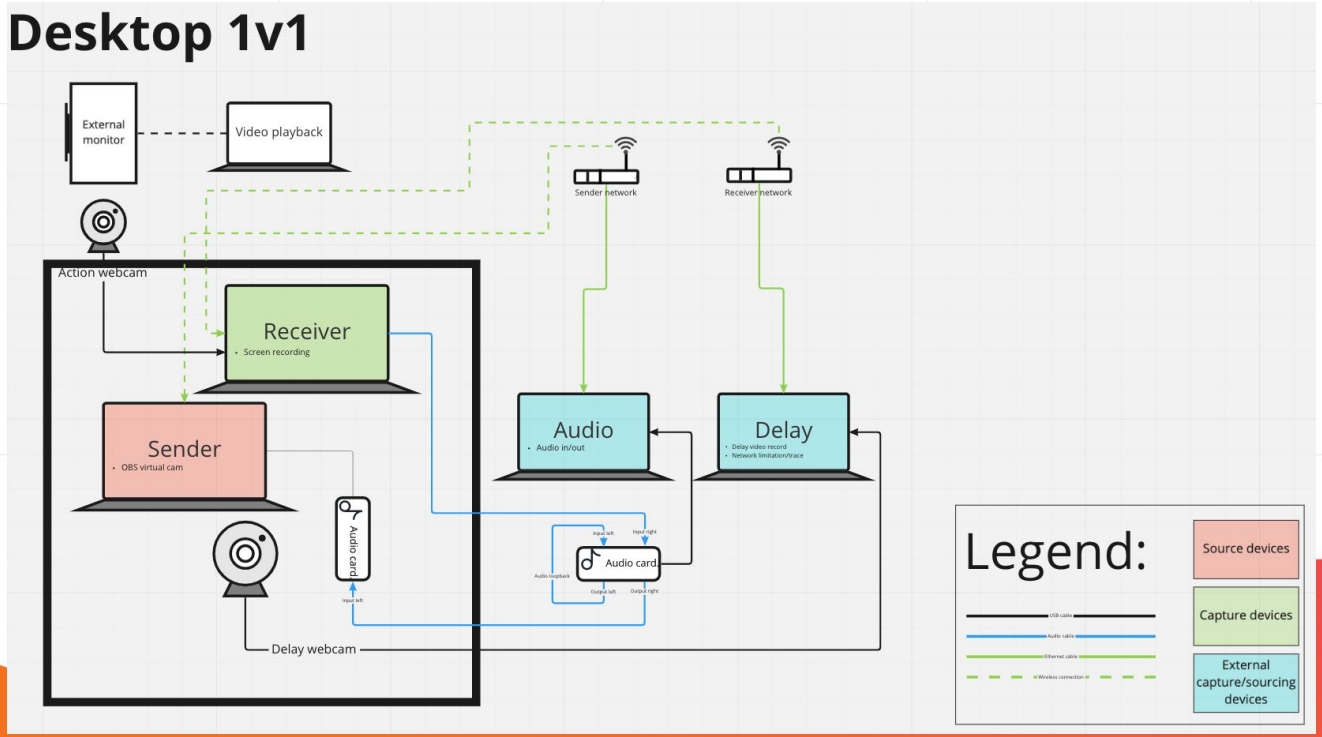
Trusted by: Microsoft WorldRemit skype Telefónica twilio orange and others

What we could offer

- Functional/Regression Testing
- Accessibility tests
- Performance Benchmarking (Battery/CPU/GPU/RAM/)
- Load Testing
- VOIP communications
- Video Conferencing/Streaming/VOD (video on demand) Testing
- iOT (internet of things)
- Automation / manual testing

Benchmark Program Goals

- Benchmark iMind quality vs Google Meet
- Review behavior in different network conditions (Changing BW, Changing PL, Changing Latency & Jitter)



Two participants connect to the call.

Playback of reference files(audio and video) start on the sender side.

At the same time screen and audio recording starts on the constrained participant.

Testing process & Schema

Benchmark Test Scope

Applications

iMind

Google Meet

Platforms

Sender:

WinChrome

Receiver:

WinChrome

Network Constraints

Sender:

None

Receiver:

Changing Bandwidth tests

Unlimited->2M->500K->200K ->500K->2M->Unlimited

Changing Packet loss tests

Unlimited->10%->20%->45%->20%->10%->Unlimited

Changing Latency & Jitter tests

0/0-100/30-500/90-1500/270-500/90-100/30-0/0

Each limitation lasts 60 seconds which sums up to 7 min long tests

Test device/app versions

Windows 10 PRO 19044.1288

Google Chrome 108.0.5359.125

iMind

Google Meet

108.0.5359.125

Metrics explanation

Audio metrics

- **POLQA** - (Perceptual Objective Listening Quality Analysis) Full reference audio quality measurement standard in MOS scale. Documentation link
- **Audio Delay** - End to end latency between the audio signal being sent and getting received
- **VISQOL** - (Virtual Speech Quality Objective Listener) is an objective, full-reference metric for perceived audio quality. It uses a spectro-temporal measure of similarity between a reference and a test speech signal to produce a MOS-LQO (Mean Opinion Score - Listening Quality Objective) score. Documentation link
- **Audio and Video Synchronization** - The difference in milliseconds between audio and video signals being received that were sent at the same time.

Metrics explanation

Video metrics

- **VQTDL** - NO-REFERENCE ALGORITHM FOR VIDEO QUALITY ASSESSMENT DEVELOPED BY TESTDEVLAB. Video Quality Testing with Deep Learning—or VQTDL—is a no-reference algorithm for video quality assessment. This solution produces image quality predictions that correlate well with human perception and offers good performance under diverse circumstances, such as various network conditions, platforms and applications.

- **Full reference metrics:**
  - **VMAF** - full reference video quality metric developed by Netflix
  - **PSNR** - Peak signal to noise ratio Documentation link
  - **SSIM** - Structural similarity index measure Documentation link
- **FPS** - Frames per second, shows how fluid the video is
- **Video Delay** - End to end latency between the video frames being sent to them getting received.
- **Freezes count** - The count of each individual freeze that appears.
- **Freezes between** - The average time between two freezes.
- **Freezes total time** - The sum of values from all freeze's length.
- **Freezes average time** - The time calculated by (Freezes total time/Freezes count)

VQTDL - our own machine learning algorithm

VQTDL: is based on a convolutional neural network with Resnet50 as a backbone. Which is a 50 layer neural network with very rich feature representation. Moreover it uses a transformer encoder to handle different resolutions which translates into a much more robust algorithm for IQA. Prediction values are more stable and closer to the subjective than BRISQUE. Scores from 1 to 5

VQTDL	
>4	Video is very clear.
3.6 - 4	Video looks fairly good, although it's not great in most cases.
3 - 3.6	Video will have many artefacts and low resolution.
2.3 - 3	Poor video quality
<2.3	Very bad, not acceptable in most cases.

Documentation link

FPS

- **FPS:** calculated using QR codes - the combination of qr codes is changing 30 times per second

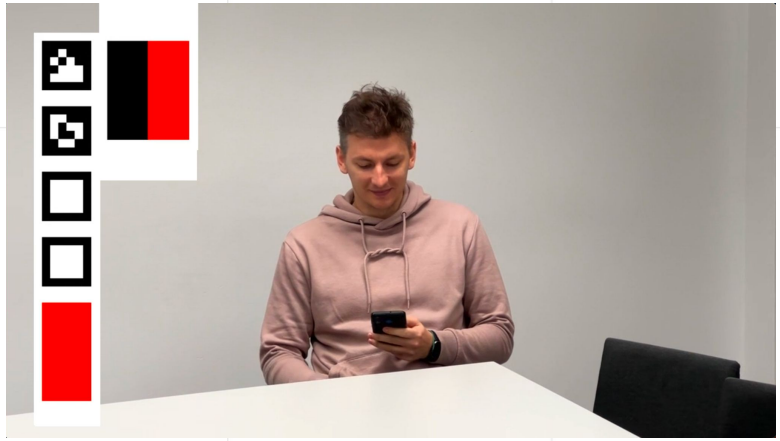
QR codes - used to calculate FPS

VMAF Image Evaluation

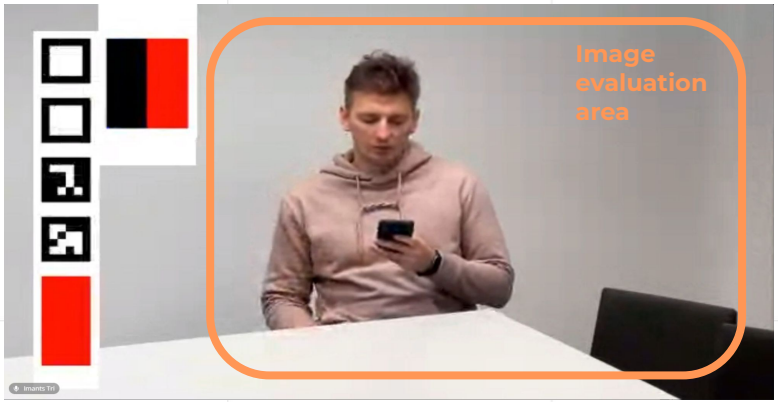
- Full Reference
- Represents the quality difference between two videos
- Developed and maintained by Netflix

VMAF	
80-100	Excellent
60-80	Good
40-60	Fair
20-40	Poor
0-20	Bad

Documentation link



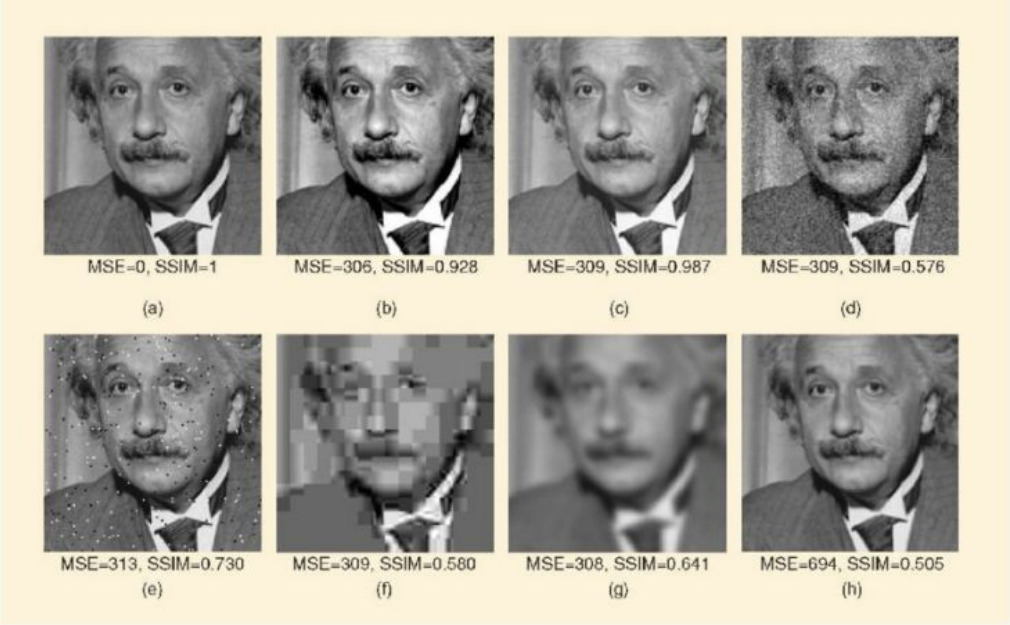
Original

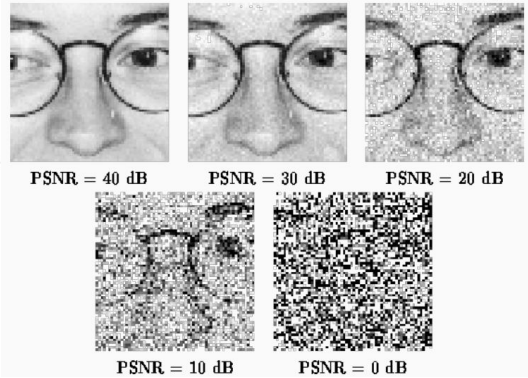


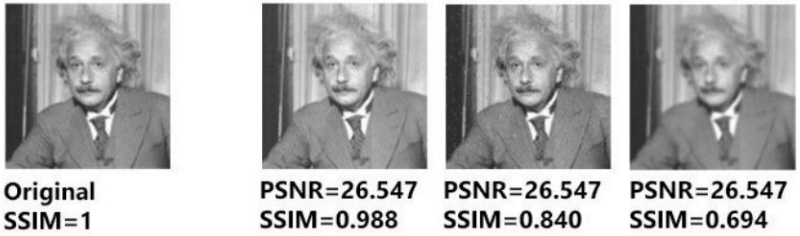
Degraded

Full reference metrics explanation

- Full reference Video Analysis compares the original reference video with a degraded one to get different video quality metrics







Metrics explanation

Network metrics

- Sender trace
- Receiver trace

Performance metrics

- **CPU Utilization** - Percentage of total CPU used by the specified process.
- **GPU Utilization** - Percentage of total GPU used by the specified process.
- **RAM Utilization** - Total Memory used by the specified process.

Key findings

Summary of findings

Video

#1: Video Delay spikes/drops during Changing Packet Loss tests
#2: Received video freezes a lot on Changing Packet Loss
#3: Disconnects on Changing Packet Loss
#4: Video quality is affected by network dual behavior on Changing Bandwidth
#5: Better performance on Jitter/Latency condition in comparison to Google Meet
#6: Video fluency and audio quality are affected by network behavior

Performance

#9: Lower sender memory usage in comparison to competitor

Audio & Network

(#4): Video quality is affected by network dual behavior on Changing Bandwidth
(#6): Audio quality and video fluency are affected by network behavior
#7: Sender Bitrate wasn't affected by Receiver limitation
#8: Receiver bitrate shows dual behavior in Changing Jitter/Latency condition

Findings

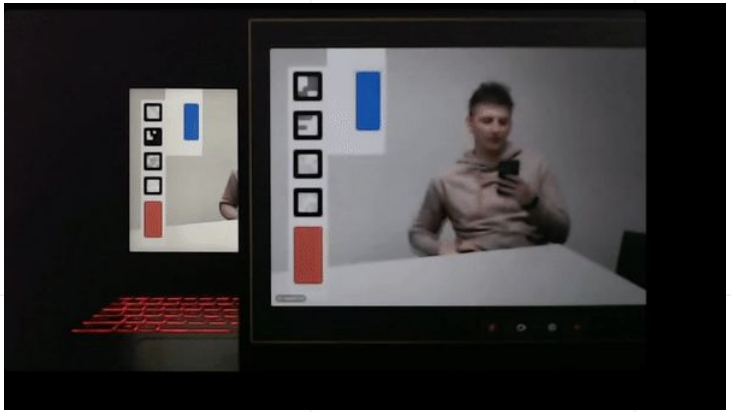
Video

#1: Video Delay spikes/drops during Changing Packet Loss tests
#2: Received video freezes a lot on Changing Packet Loss
#3: Disconnects on Changing Packet Loss
#4: Video quality is affected by network dual behavior on Changing Bandwidth
#5: Better performance on Jitter/Latency condition in comparison to Google Meet
#6: Video fluency and audio quality are affected by network behavior

Audio & Network

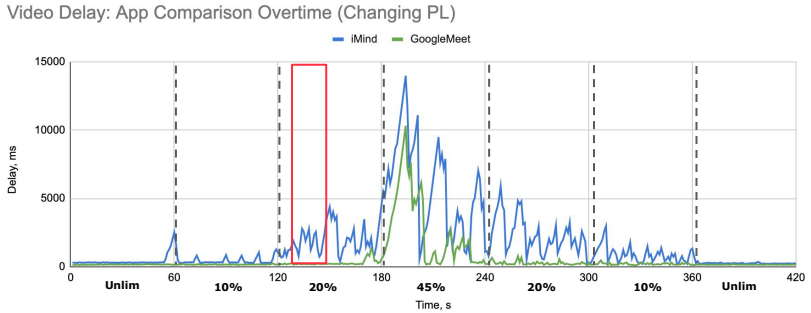
(#4): Video quality is affected by network dual behavior on Changing Bandwidth
(#6): Audio quality and video fluency are affected by network behavior
#7: Sender Bitrate wasn't affected by Receiver limitation
#8: Receiver bitrate shows dual behavior in Changing Jitter/Latency condition

#1: Video delay spikes/drops during Changing PL tests



Test1 Delay Video

Received video slows-down, freezes and then speed-up many times during higher PL



Findings

#2: Freezes a lot in Packet loss condition

Video

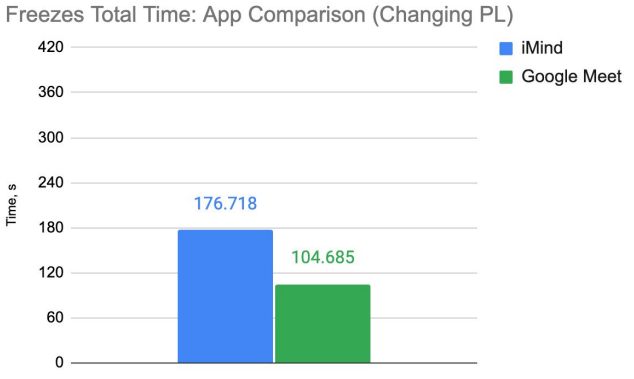
#1: Video Delay spikes/drops during Changing Packet Loss tests
#2: Received video freezes a lot on Changing Packet Loss
#3: Disconnects on Changing Packet Loss
#4: Video quality is affected by network dual behavior on Changing Bandwidth
#5: Better performance on Jitter/Latency condition in comparison to Google Meet
#6: Video fluency and audio quality are affected by network behavior

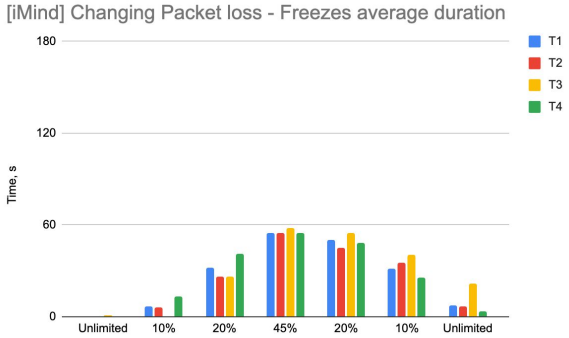
Audio & Network

(#4): Video quality is affected by network dual behavior on Changing Bandwidth
(#6): Audio quality and video fluency are affected by network behavior
#7: Sender Bitrate wasn't affected by Receiver limitation
#8: Receiver bitrate shows dual behavior in Changing Jitter/Latency condition

On average, in each **iMind** test, the video freezes for a total of **~180 seconds**.

And this is **~42.8%** of the entire test video and it's higher than in **Google Meets** tests.





Findings

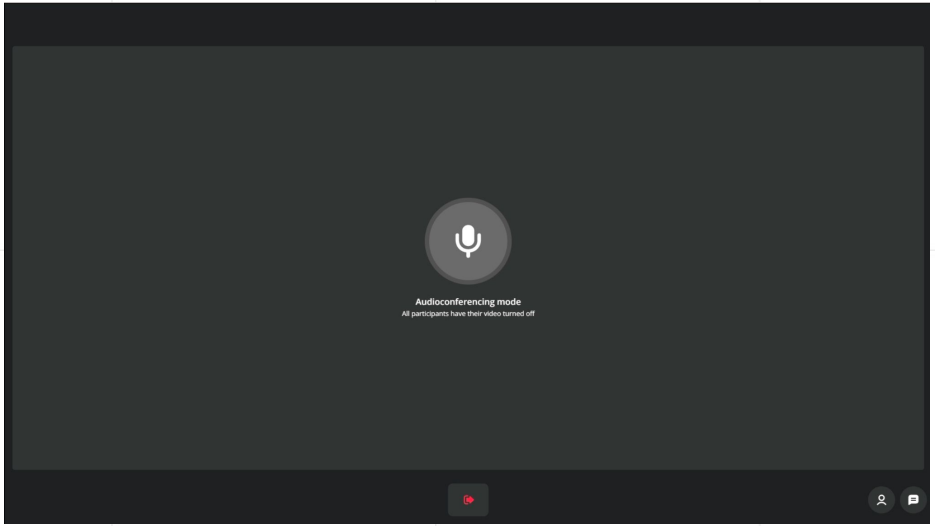
Video

#1: Video Delay spikes/drops during Changing Packet Loss tests
#2: Received video freezes a lot on Changing Packet Loss
#3: Disconnects on Changing Packet Loss
#4: Video quality is affected by network dual behavior on Changing Bandwidth
#5: Better performance on Jitter/Latency condition in comparison to Google Meet
#6: Video fluency and audio quality are affected by network behavior

Audio & Network

(#4): Video quality is affected by network dual behavior on Changing Bandwidth
(#6): Audio quality and video fluency are affected by network behavior
#7: Sender Bitrate wasn't affected by Receiver limitation
#8: Receiver bitrate shows dual behavior in Changing Jitter/Latency condition

#3: Disconnects on Changing Packet Loss condition



In the Packet loss tests, Receiver has a probability in **28%** to disconnecting from the call.

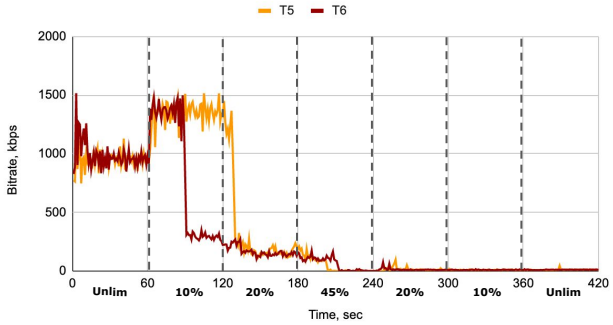
* More details about disconnects see in the next slide

#3: Disconnects on Changing Packet Loss condition

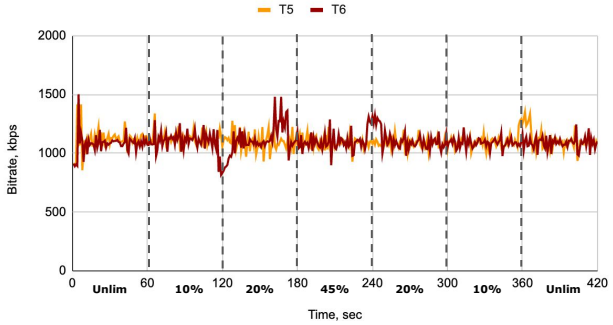
On **Changing Packet Loss** condition in **2 test cases out of 7** Receiver device disconnects from the call.
Audio and video streams are interrupted and Receiver bitrate drops.

To keep **iMind** tests comparable, these 2 tests are selected as invalid, because there are no disconnects in **Google Meet** tests.

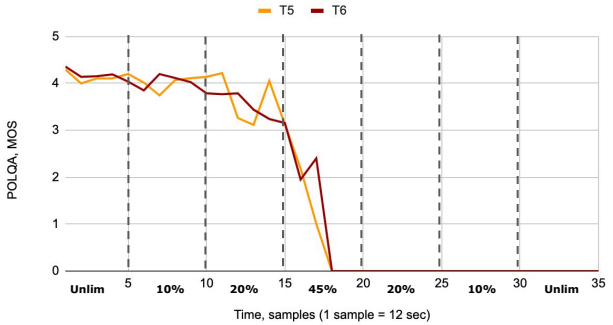
[iMind] Changing Packet Loss - Receiver Bitrate



[iMind] Changing Packet Loss - Sender Bitrate



[iMind] Changing Packet Loss - POLQA



While Sender bitrate **does not change**, it continues to send the data stream in the same volume. Check finding #5

Findings

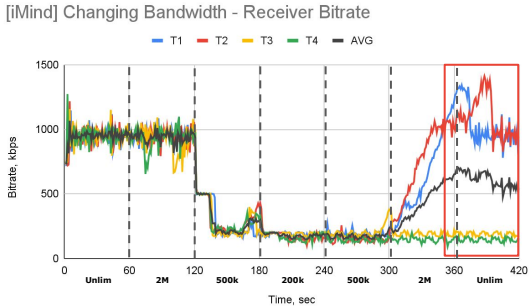
Video

#1: Video Delay spikes/drops during Changing Packet Loss tests
#2: Received video freezes a lot on Changing Packet Loss
#3: Disconnects on Changing Packet Loss
#4: Video quality is affected by network dual behavior on Changing Bandwidth
#5: Better performance on Jitter/Latency condition in comparison to Google Meet
#6: Video fluency and audio quality are affected by network behavior

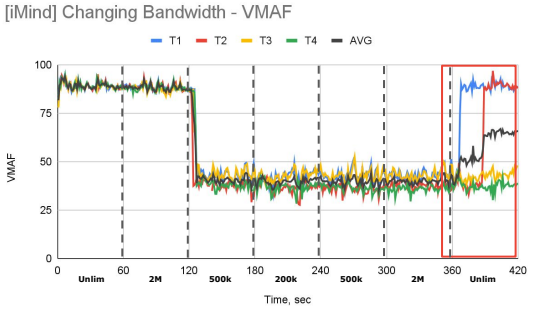
Audio & Network

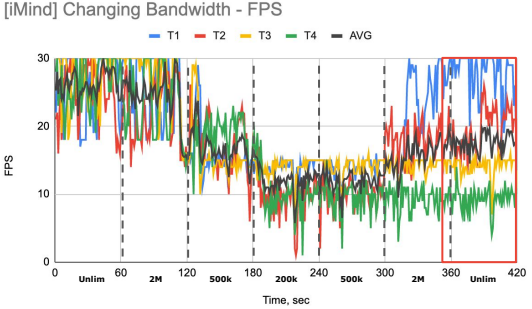
(#4): Video quality is affected by network dual behavior on Changing Bandwidth
(#6): Audio quality and video fluency are affected by network behavior
#7: Sender Bitrate wasn't affected by Receiver limitation
#8: Receiver bitrate shows dual behavior in Changing Jitter/Latency condition

#4: Video quality is affected by network dual behavior on Changing Bandwidth



Receiver network show dual behavior in the end of tests, which affect video quality. **Test1** and **test2** **increase** network consumption and video **quality after available network is unlimited**, but **test3** and **test4** **do not**.





Findings

#5: Better performance on Jitter/Latency condition in comparison to Google Meet

Video

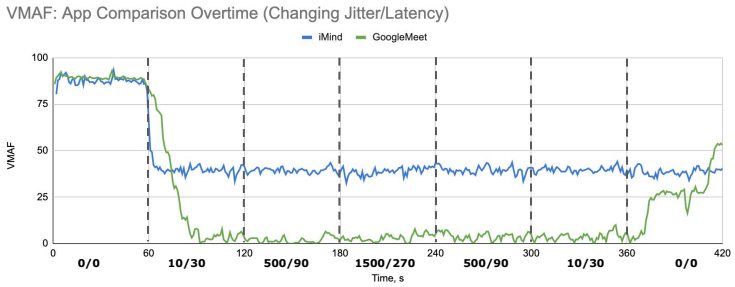
#1: Video Delay spikes/drops during Changing Packet Loss tests
#2: Received video freezes a lot on Changing Packet Loss
#3: Disconnects on Changing Packet Loss
#4: Video quality is affected by network dual behavior on Changing Bandwidth
#5: Better performance on Jitter/Latency condition in comparison to Google Meet
#6: Video fluency and audio quality are affected by network behavior

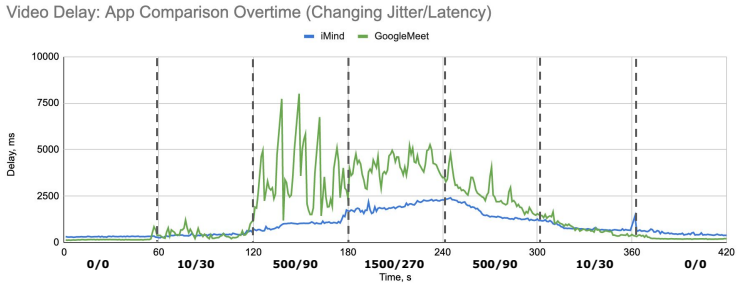
Audio & Network

(#4): Video quality is affected by network dual behavior on Changing Bandwidth
(#6): Audio quality and video fluency are affected by network behavior
#7: Sender Bitrate wasn't affected by Receiver limitation
#8: Receiver bitrate shows dual behavior in Changing Jitter/Latency condition

iMind keeps call usable – **has higher image quality and video fluency** even with higher **Jitter and Latency limitation** than **Google Meet**.

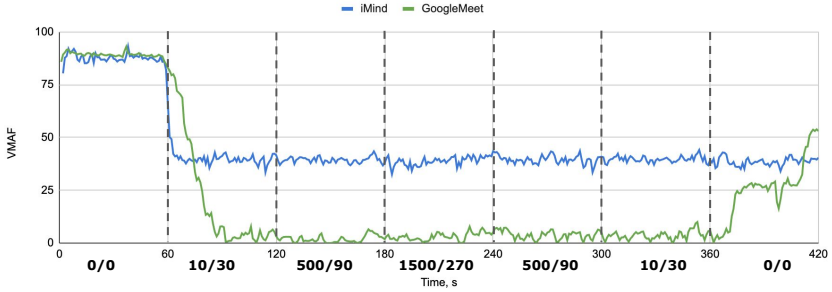
Audio quality stays on par, but **Google Meet** has many POLQA drops, while **iMind** **keep quality more stable**



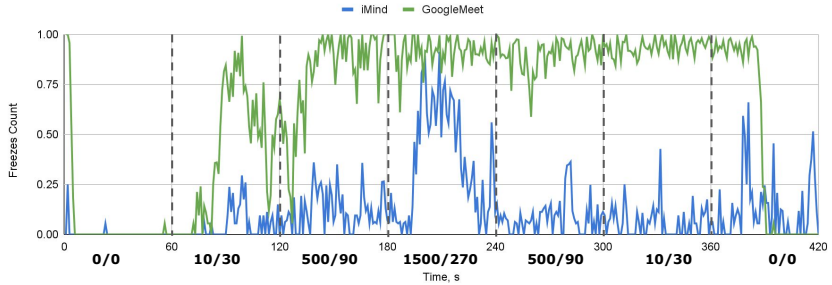


#5: Better performance on Jitter/Latency condition in comparison to Google Meet

VMAF: App Comparison Overtime (Changing Jitter/Latency)



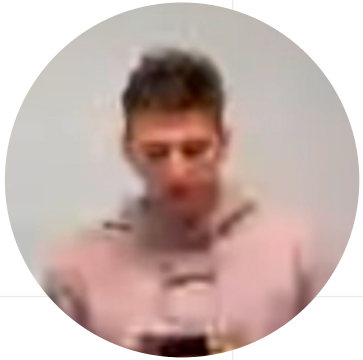
Freezes count: App Comparison Overtime (Changing Jitter/Latency)



Google Meet
145 sec
500/90
VMAF ~5

iMind
145 sec
500/90
VMAF ~40

Google Meet
201 sec
1500/270
VMAF ~2



iMind
205 sec
1500/270
VMAF ~38

Findings

Video

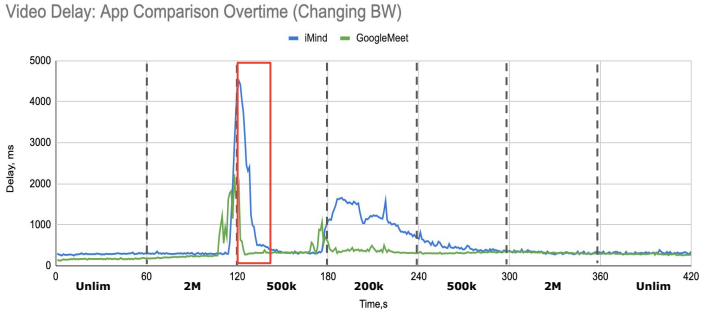
#1: Video Delay spikes/drops during Changing Packet Loss tests
#2: Received video freezes a lot on Changing Packet Loss
#3: Disconnects on Changing Packet Loss
#4: Video quality is affected by network dual behavior on Changing Bandwidth
#5: Better performance on Jitter/Latency condition in comparison to Google Meet
#6: Video fluency and audio quality are affected by network behavior

Audio & Network

(#4): Video quality is affected by network dual behavior on Changing Bandwidth
(#6): Audio quality and video fluency are affected by network behavior
#7: Sender Bitrate wasn't affected by Receiver limitation
#8: Receiver bitrate shows dual behavior in Changing Jitter/Latency condition

#6: Audio quality and video fluency are affected by network behavior

In **Changing Bandwidth** tests is noted that, when available network changes to **500kbps**, receiver network consumption stays **500kbps** for ~20 seconds and then drops to **~200kbps**.

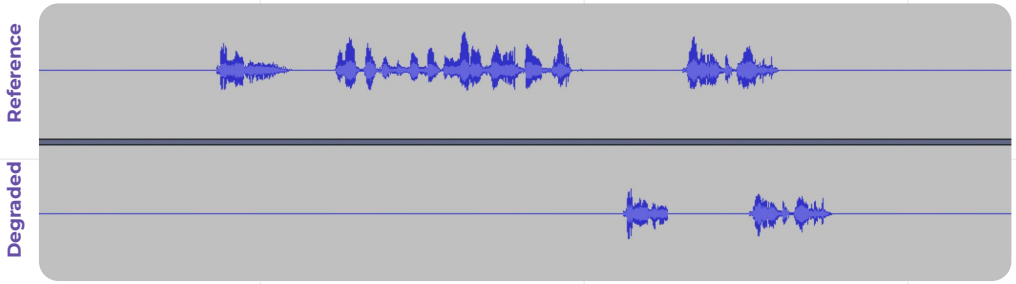


During these 20 seconds **video fluency and audio quality decreases** and recover back, when consumption is 200kbps

* More details about audio quality see in the next slide

#6: Audio quality and video fluency are affected by network behavior

During limitation change POLQA is dropping and Audio Delay also increases:

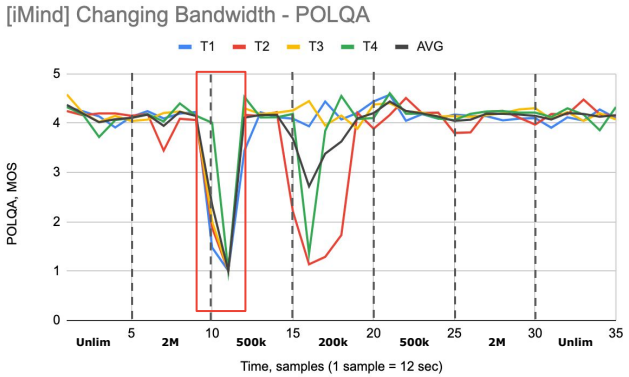


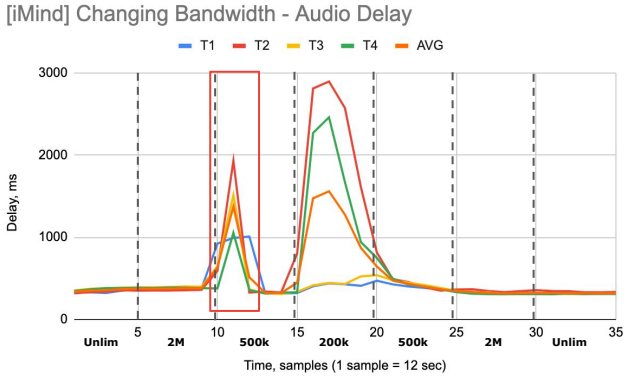
Test 2 Sample 11

Degraded audio contains only 1st and 3rd reference audio part. 2nd phrase is cutted off by app due to limitation change

Reference audio

Degraded audio
POLQA – 1.01





Findings

Video

#1: Video Delay spikes/drops during Changing Packet Loss tests
#2: Received video freezes a lot on Changing Packet Loss
#3: Disconnects on Changing Packet Loss
#4: Video quality is affected by network dual behavior on Changing Bandwidth
#5: Better performance on Jitter/Latency condition in comparison to Google Meet
#6: Video fluency and audio quality are affected by network behavior

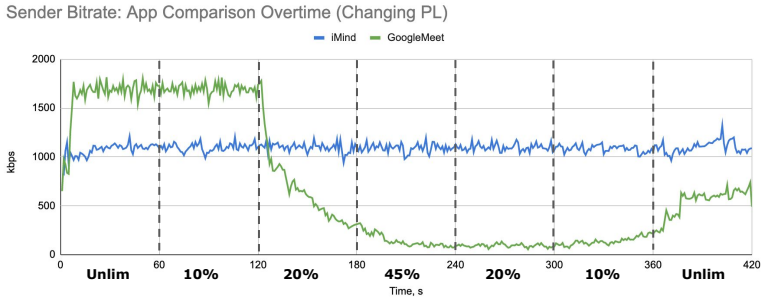
Audio & Network

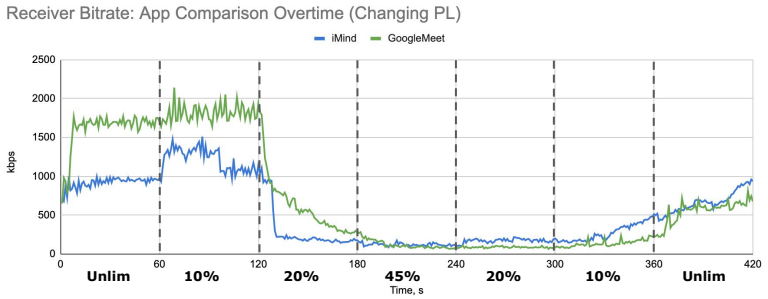
(#4): Video quality is affected by network dual behavior on Changing Bandwidth
(#6): Audio quality and video fluency are affected by network behavior
#7: Sender Bitrate wasn't affected by Receiver limitation
#8: Receiver bitrate shows dual behavior in Changing Jitter/Latency condition

#7: Sender Bitrate wasn't affected by Receiver limitation

In **iMind** tests Sender Bitrate does not adapt to Receiver network constraints.

While in **Google Meet** tests Sender and Receiver bitrates has the same pattern.





Findings

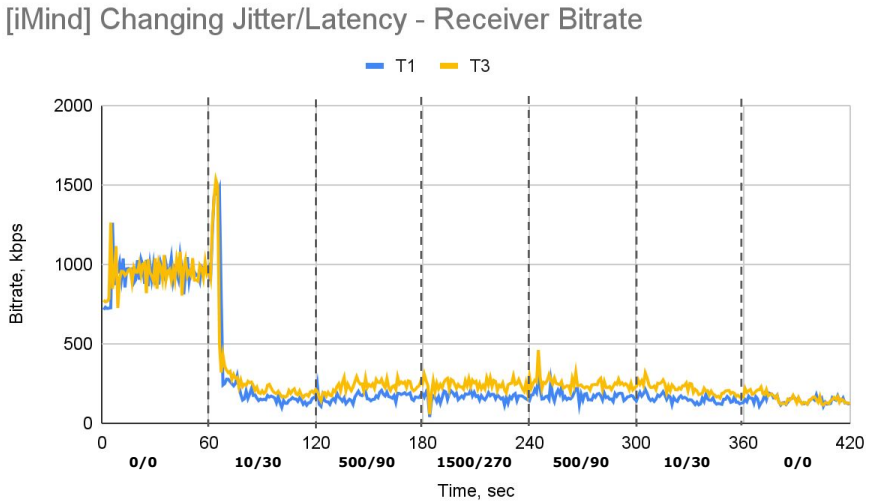
Video

#1: Video Delay spikes/drops during Changing Packet Loss tests
#2: Received video freezes a lot on Changing Packet Loss
#3: Disconnects on Changing Packet Loss
#4: Video quality is affected by network dual behavior on Changing Bandwidth
#5: Better performance on Jitter/Latency condition in comparison to Google Meet
#6: Video fluency and audio quality are affected by network behavior

Audio & Network

(#4): Video quality is affected by network dual behavior on Changing Bandwidth
(#6): Audio quality and video fluency are affected by network behavior
#7: Sender Bitrate wasn't affected by Receiver limitation
#8: Receiver bitrate shows dual behavior in Changing Jitter/Latency condition

#8: Receiver bitrate shows dual behavior in Changing Jitter/Latency condition



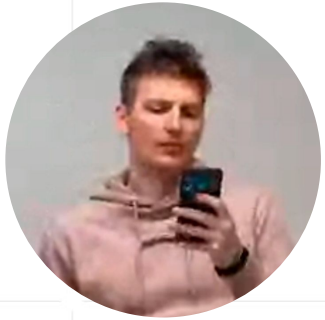
Network **shows dual behavior** after first limitation change. **Video quality is affected**.

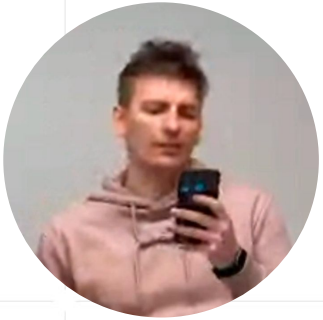
More details in the next slide.

#8: Receiver bitrate dual behavior in Changing Jitter/Latency condition

Test1 81 sec
Image is a bit more distorted, less blurry and brighter in comparison to test3 image

VMAF – 34
10/30 AVG bitrate – 297 kbps



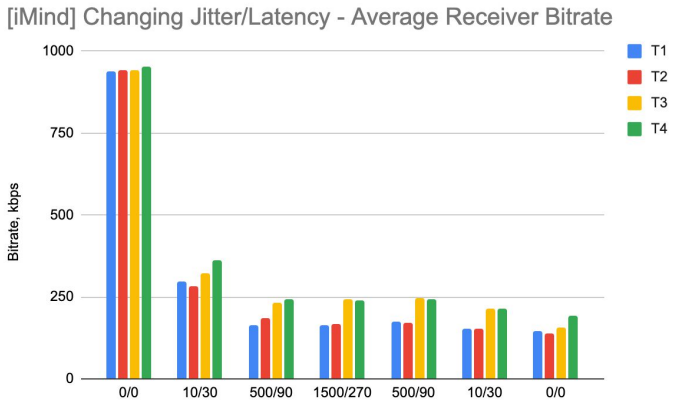


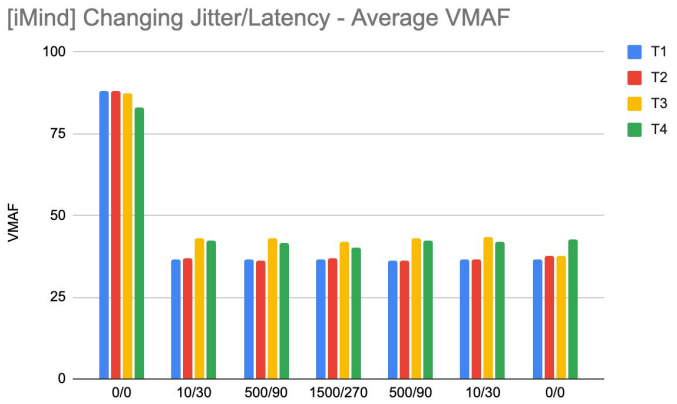
Test3 81 sec
Image is more blurry, but less blocky/distorted. Image is darker in comparison to test1

VMAF – 43
10/30 AVG bitrate – 323 kbps

In **Changing Jitter/Latency** tests is noted that **test 3** and **test 4** have higher network consumption after limitation change in comparison to **test 1** and **test 2**. As a result, image quality and video fluency also show dual behavior.

This behavior occurs **starting from first limitation change until available network is unlimited again.**





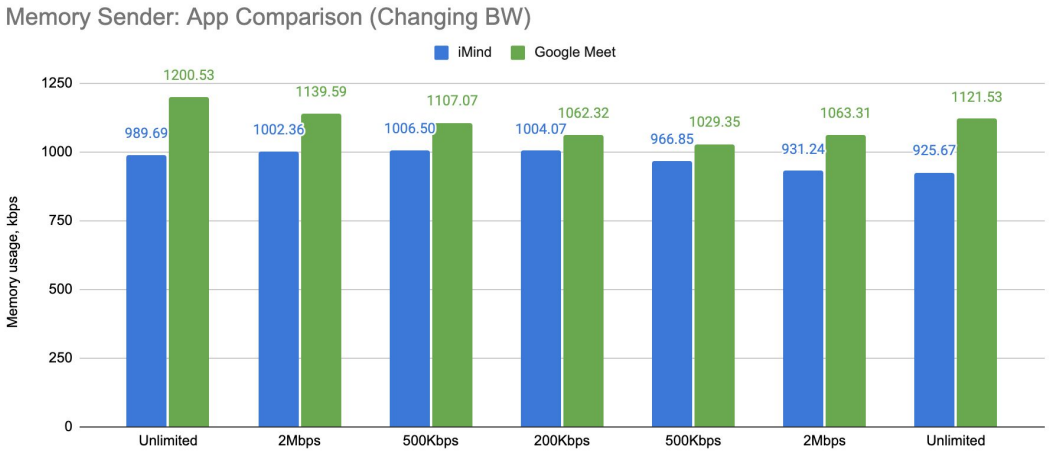
Findings

Performance

#9: Lower sender memory usage in comparison to competitor

#9: Lower sender memory usage in comparison to competitor

Sender in **iMind** tests uses less Memory compared to **Google Meet**



This behaviour noted in all network conditions.

iMind performance against Google Meets

Windows platform

	Changing Bitrate	Changing Packet Loss	Changing Jitter/Latency
Video quality	**Lower ⬇️** FPS - 25% VQTDL - 8% VMAF - 22% Video Delay - 67%	**On par/ Lower ⬇️** FPS - 32% VQTDL + 6% VMAF +2.5% Video Delay - 208%	**Higher ⬆️** FPS + 45% VQTDL + 17% VMAF +117% Video Delay +44%
Audio quality	**Lower ⬇️** POLQA - 6% Audio Delay -23%	**Lower ⬇️** POLQA - 6% Audio Delay -20%	**On par ↔** POLQA + 0.48% Audio Delay - 6%
Network	**Lower ⬆️** Receiver Bitrate +42.14% Sender Bitrate -24% AV Sync +104% Freeze Total Time -22%	**Higher ⬇️** Receiver Bitrate +25% Sender Bitrate -57% AV Sync -486% Freeze Total Time -78%	**Lower ⬆️** Receiver bitrate +10% Sender Bitrate -200% AV Sync +111% Freeze Total Time +82%

TestDevLab

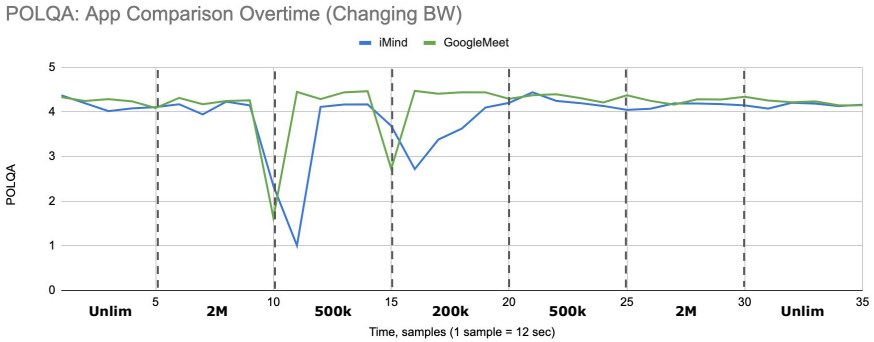
Video App Benchmarking

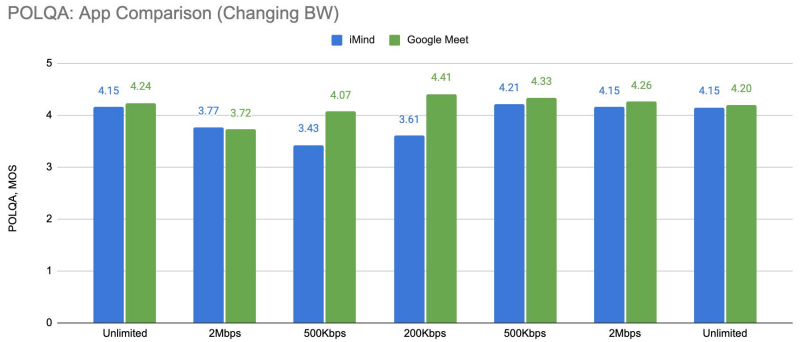
CHANGING BANDWIDTH

Changing Bandwidth Test Process

1. Sender creates a room
2. Receiver starts recording the screen and performance/delay data
3. Sender starts playing the video on OBS
4. Audio script along with network trace capture and “Changing Packet Loss” script are executed with conditions:
    1. Unlimited limitation enabled for 1 minute
    2. 2 Mbps limitation enabled for 1 minute
    3. 500Kbps limitation enabled for 1 minute
    4. 200Kbps limitation enabled for 1 minute
    5. 500Kbps limitation enabled for 1 minute
    6. 2 Mbps limitation enabled for 1 minute
    7. Unlimited limitation enabled for 1 minute
5. Test ends when the sender video reaches white screen, delay video recording and network trace capturing is stopped
6. Receiver device leaves the room/call
7. Sender disconnects from the room/call and the chrome browser is restarted

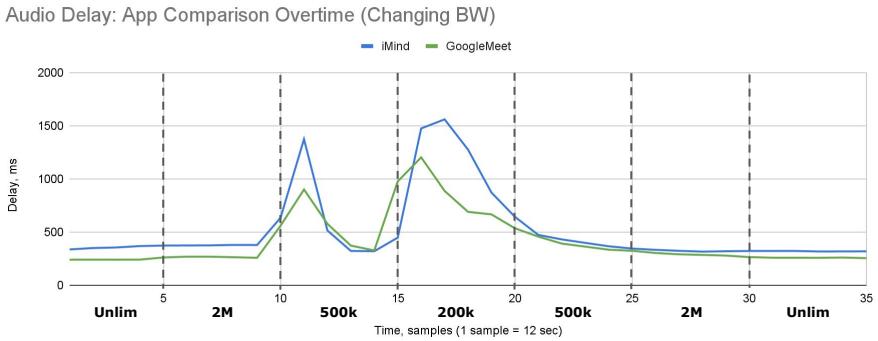
POLQA comparison

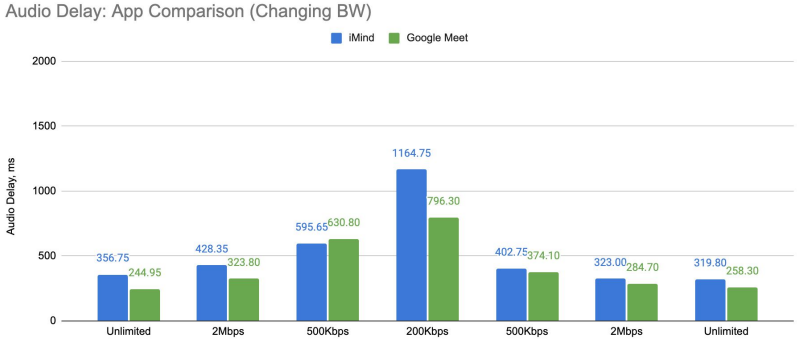




Overall POLQA has similar behavior pattern on both apps. iMind have more significant drop at 500kbps. On average, Google Meet has higher POLQA results

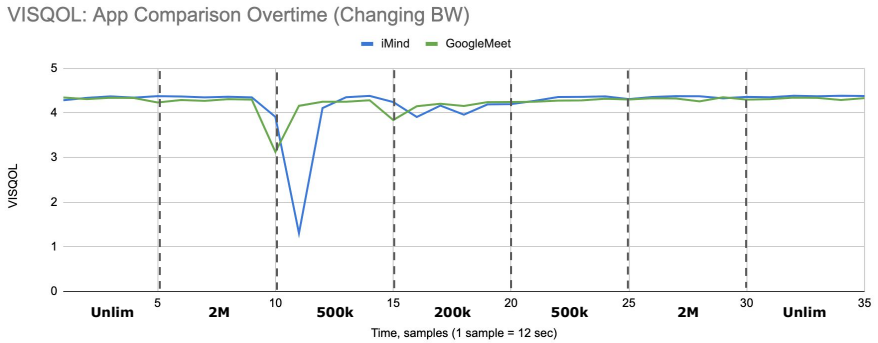
Audio Delay comparison

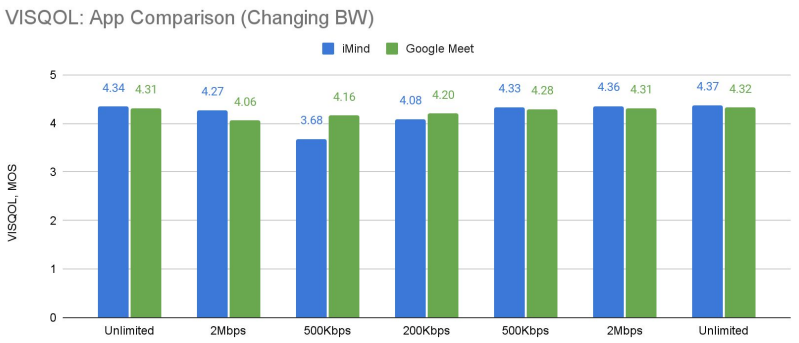




Audio Delay adapts to network constraints. iMind overall has higher Audio Delay

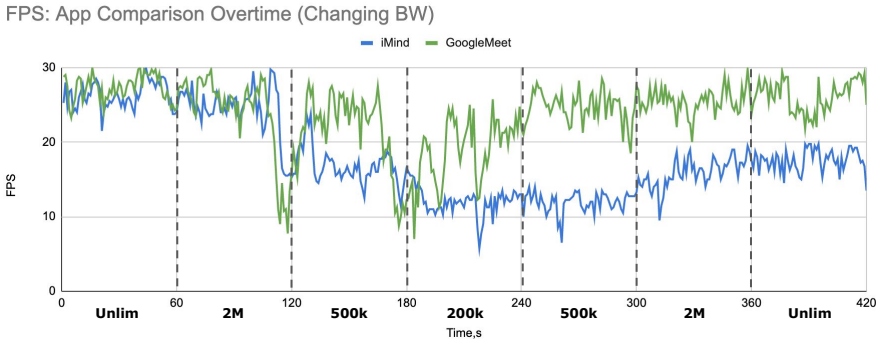
VISQOL comparison

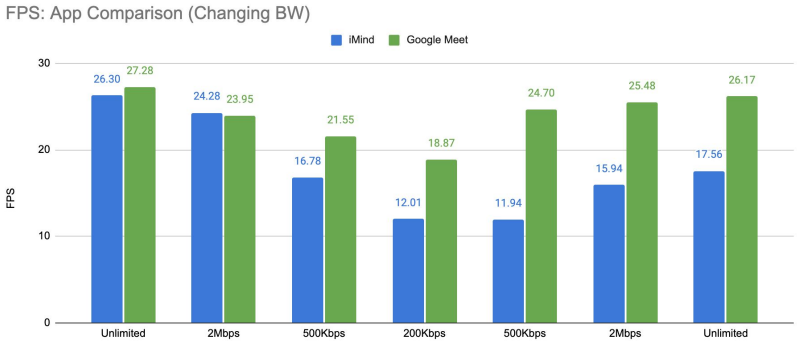




Similar behavior pattern to POLQA, less significantly affected by limitation change to 200kbps

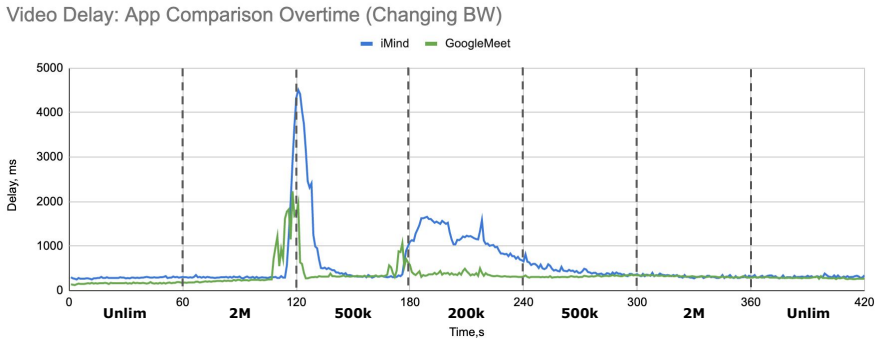
FPS comparison

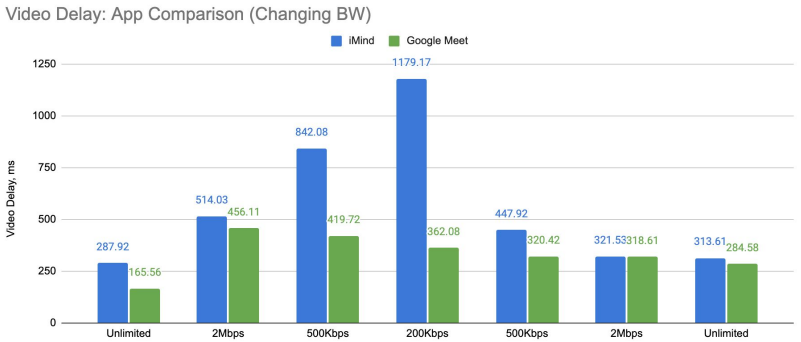




After limitation changes to 500kbps iMind drops FPS and slowly recovers back. At the baseline in the end of test iMind has lower FPS, which is similar to 500kbps limitation results in the beginning

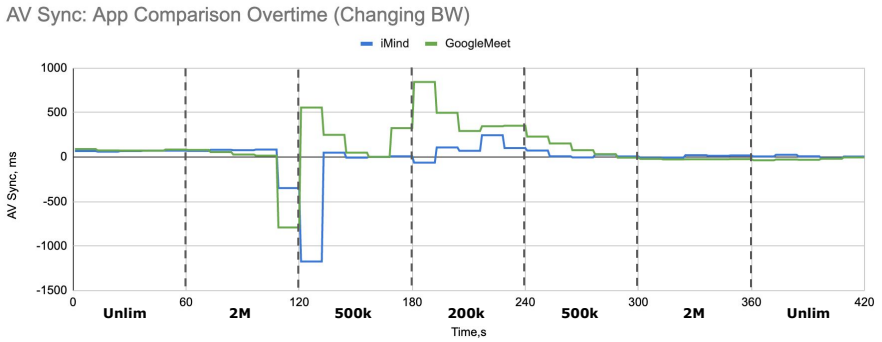
Video Delay comparison

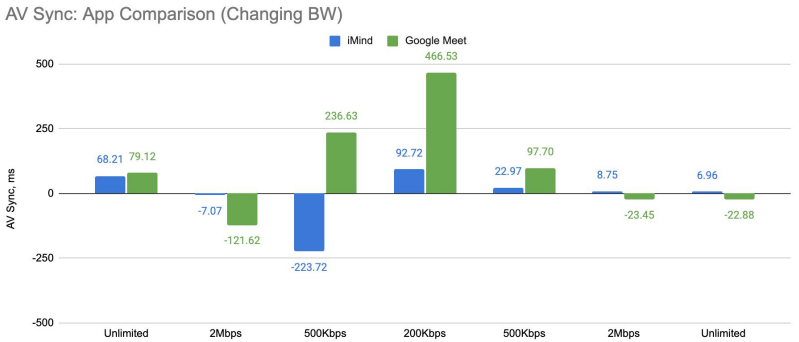




Video Delay in iMind tests is more sensitive to lower network. At 200kbps delay stays high until available network is 500kbps again

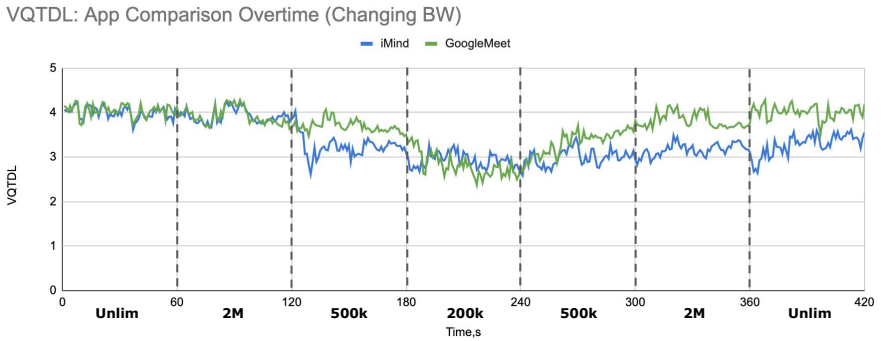
Audio and Video synchronization comparison

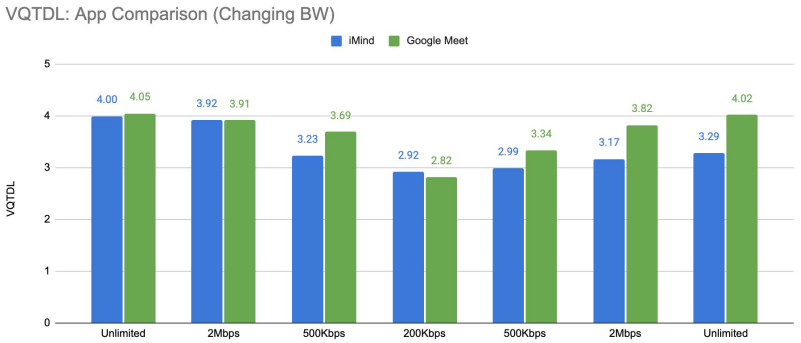




Overall iMind has better A/V Synchronization

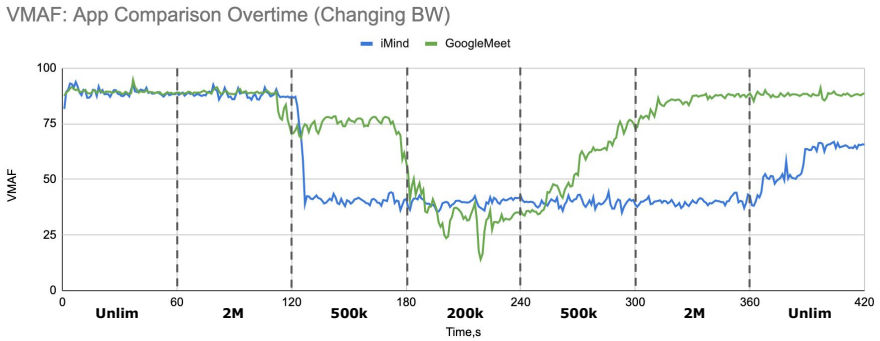
VQTDL comparison

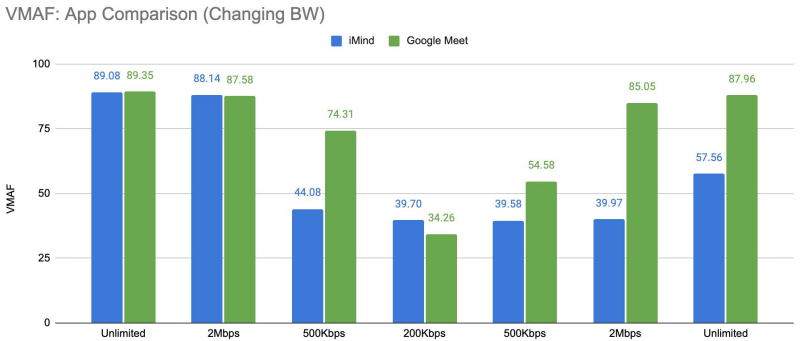




Similar pattern to FPS: iMind drops quality after network is limited to 500kbps and then very slowly recovers quality back. But even at the baseline in the end of test VQTDL result is similar to the result at 500kbps in the beginning of tests

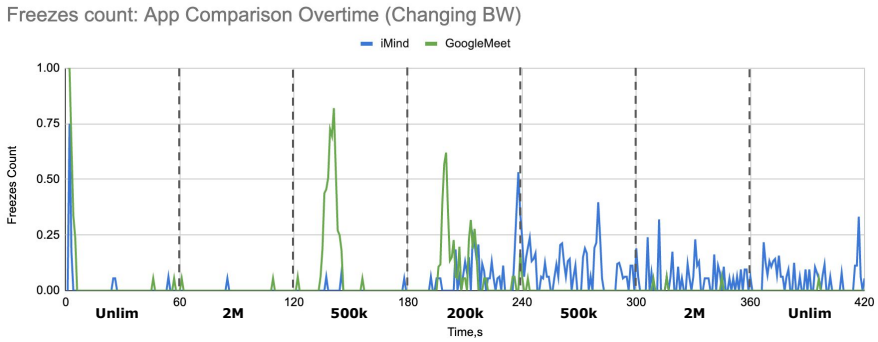
VMAF comparison

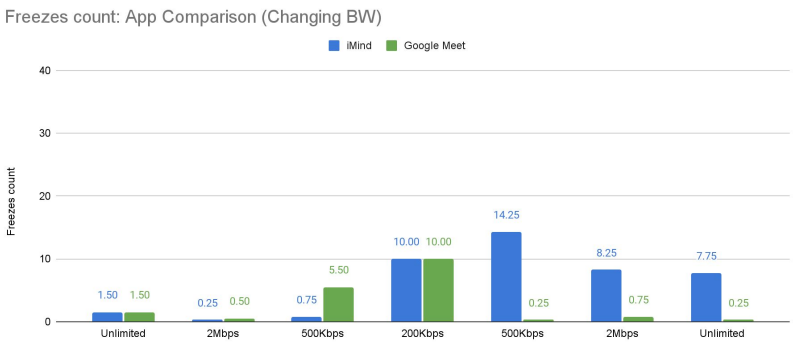




iMind drop VMAF at 500kbps and then score stays stable until network is unlimited again. Google Meet recovers quality faster, but iMind has higher VMAF at 200kbps limitation

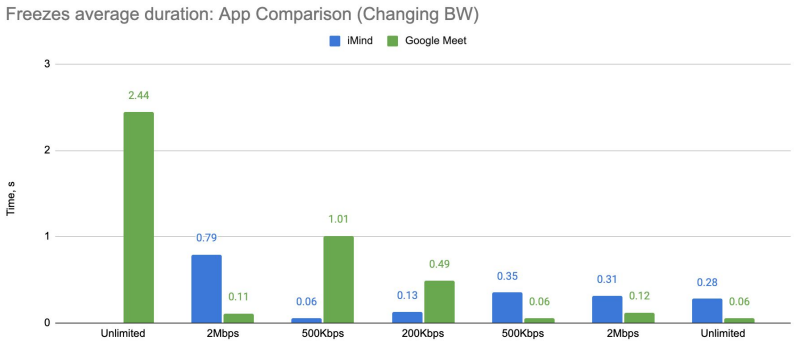
Freeze count comparison

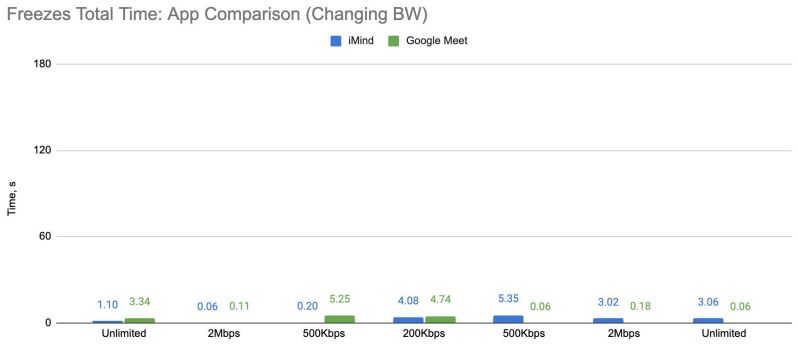




Overall iMind is on par with Google Meet in the first part of tests, even has less freezes at 500kbps. In the 2nd part of tests Google Meet recovers back, but iMind freezes more than in the beginning, even at the baseline

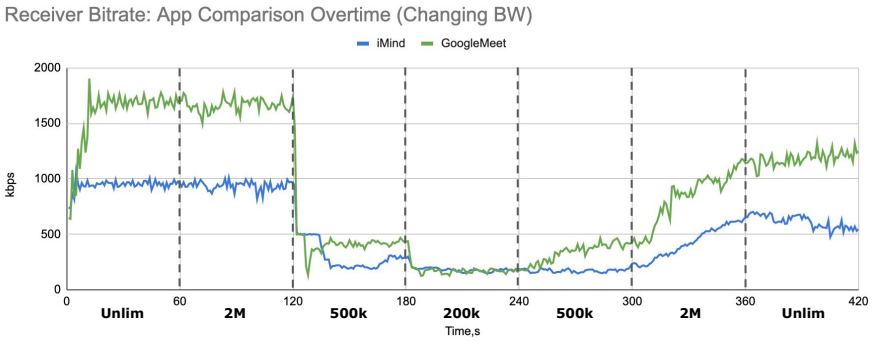
Freeze duration and total length comparison

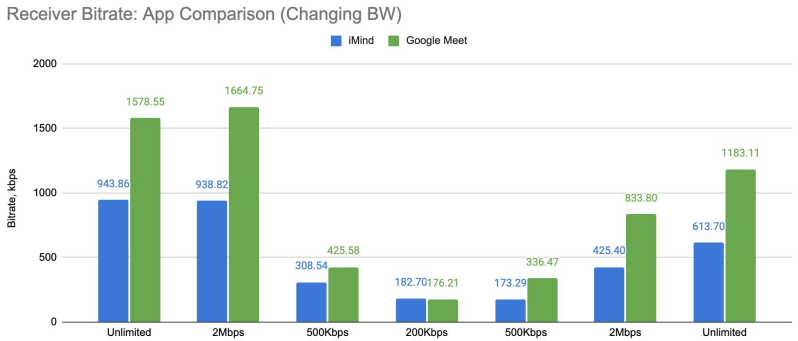




Google Meet has the highest freezes duration in the first part of tests, in the second part iMind freezes more

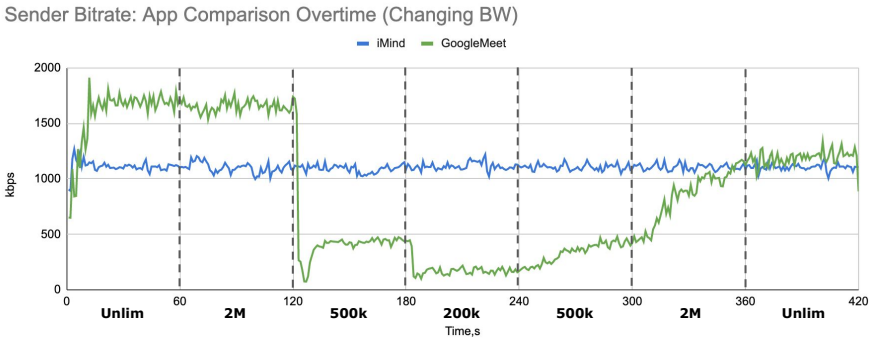
Receiver bitrate comparison

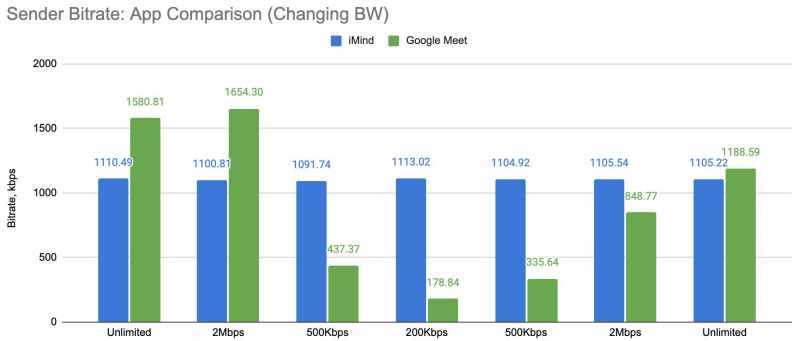




iMund uses less bitrate in comparison to Google Meet, but uses less than 700kbps in the end, while uses ~1Mbps in the beginning. Quality metrics are affected by this behavior

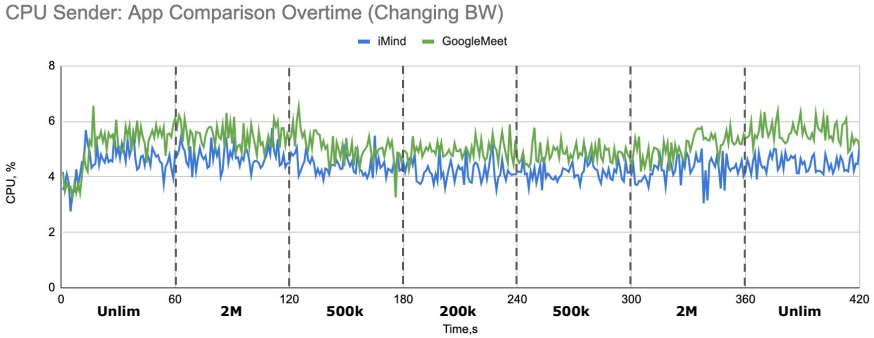
Sender bitrate comparison

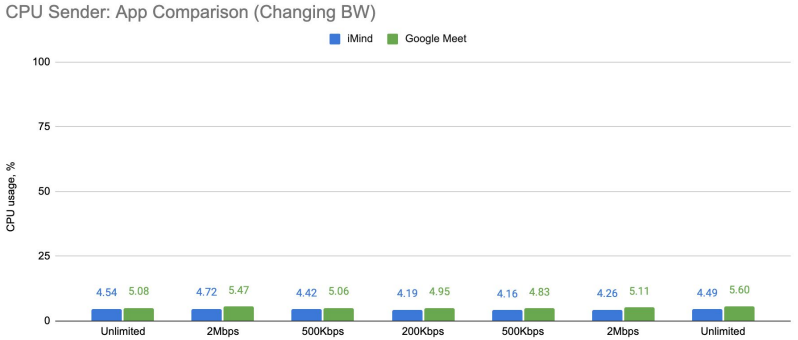


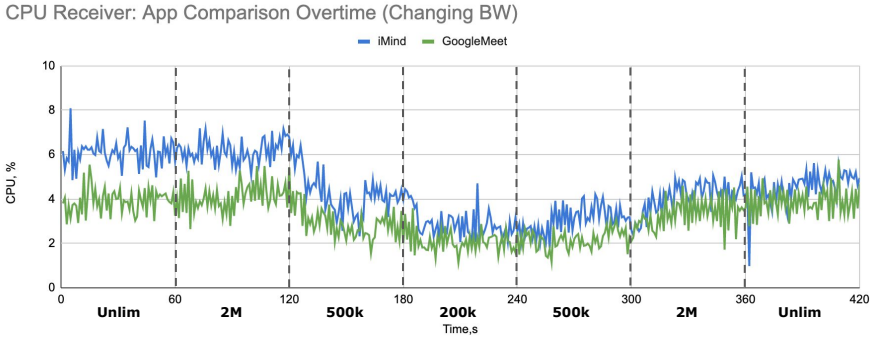


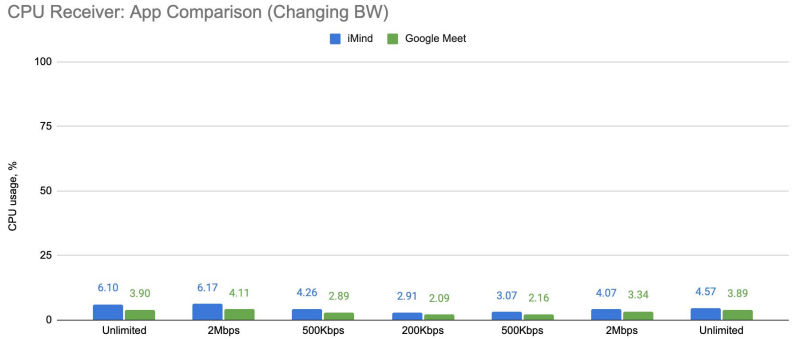
Sender doesn't adapt to Receiver network constraints, as a result network consumption stays stable during tests. iMind uses less network tham Google Meet at the baseline

CPU comparison



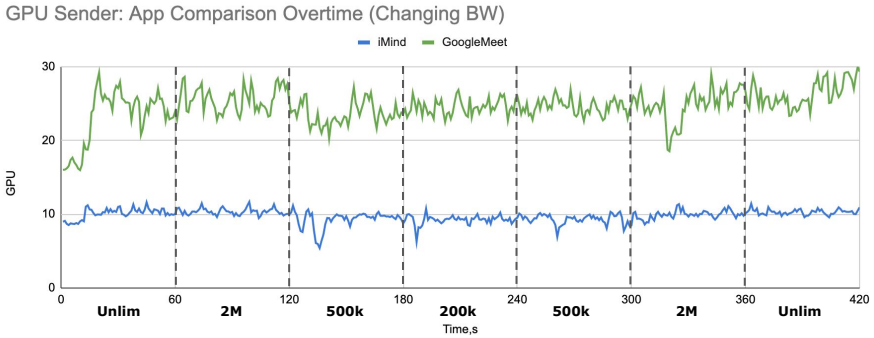


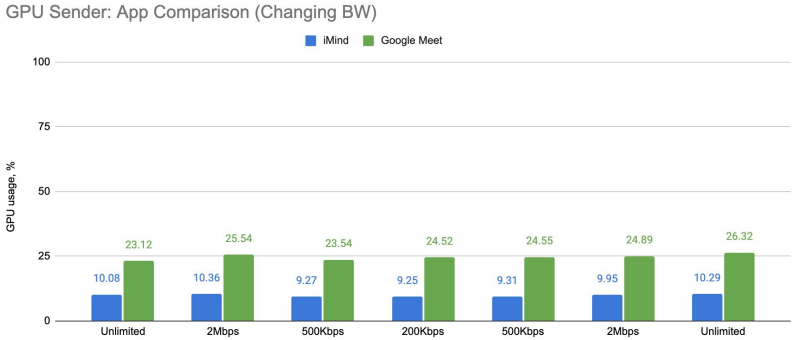


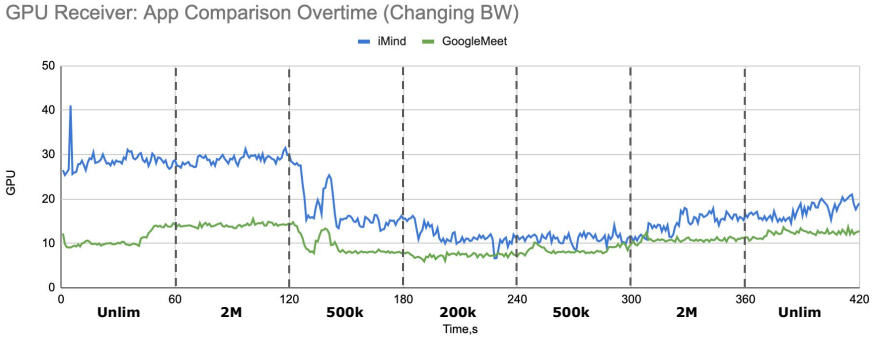


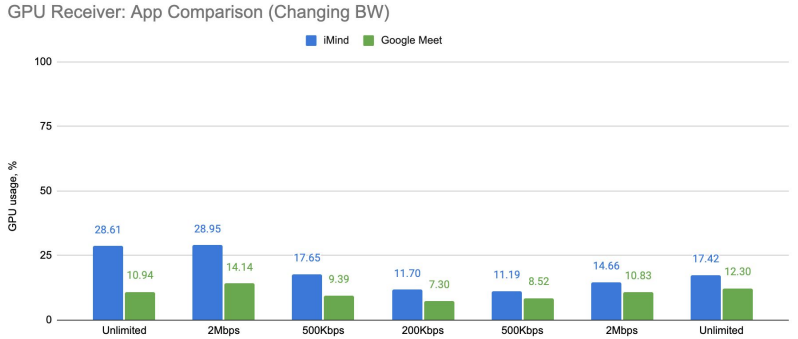
CPU usage is overall the same, a bit more iMind uses for Receiver device

GPU comparison



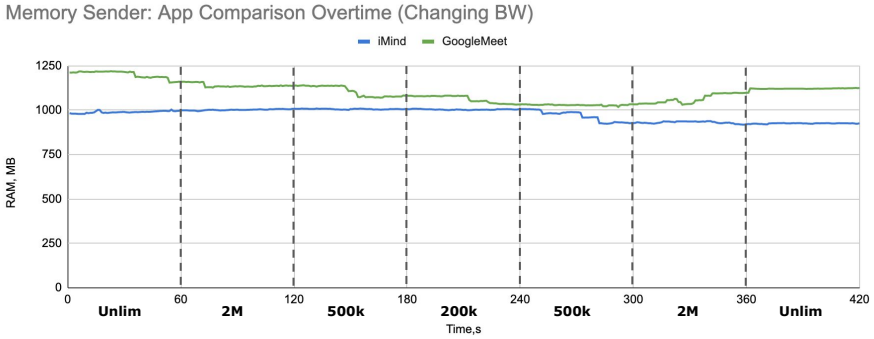


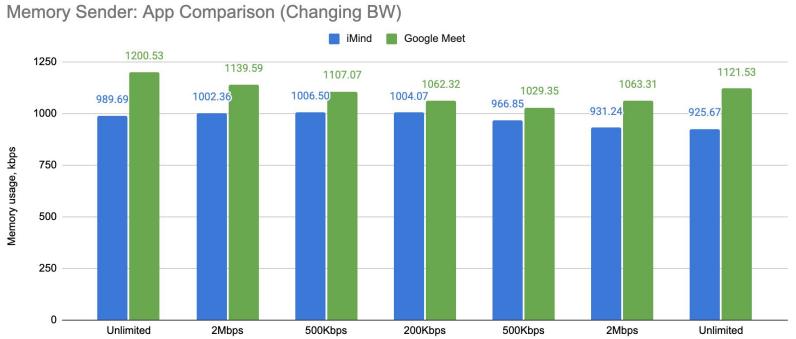


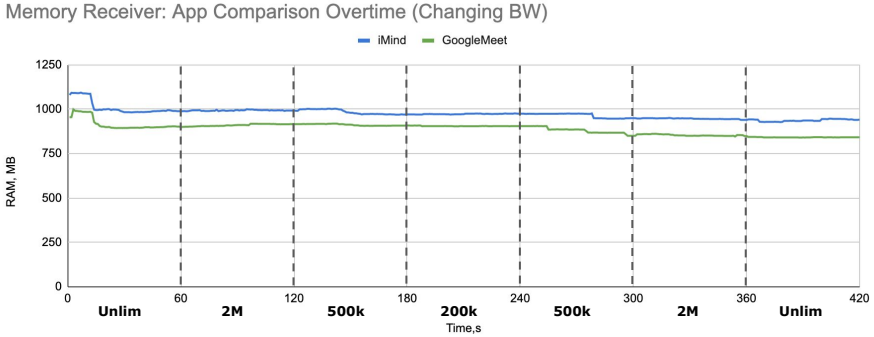


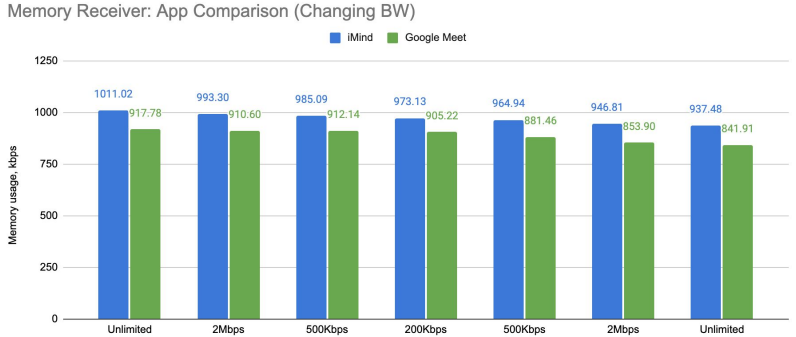
iMind uses less Sender GPU and more Receiver GPU

Memory comparison









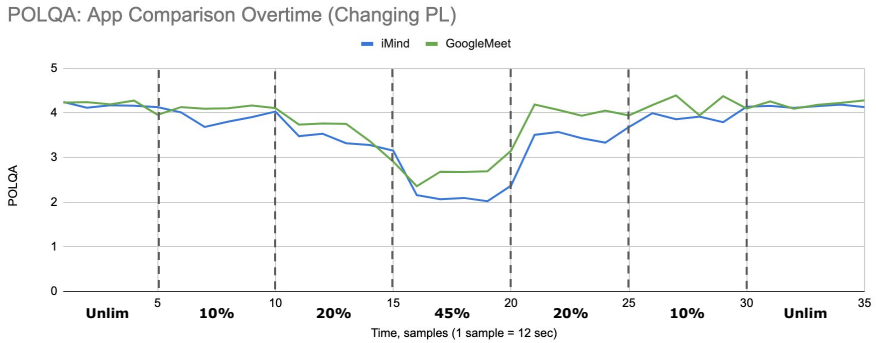
iMind uses less Sender Memory and more Receiver Memory

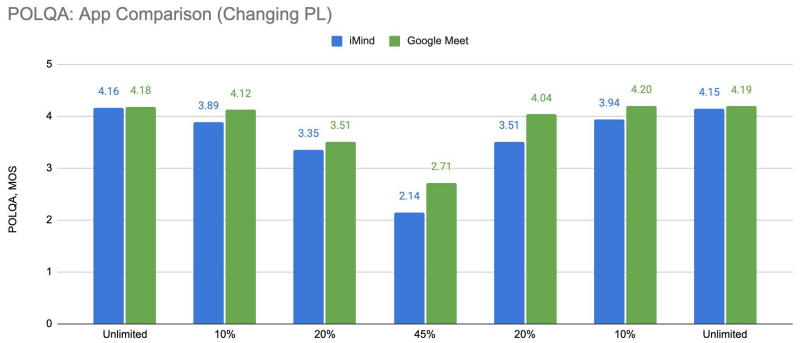
CHANGING PACKET LOSS

Changing Packet Loss Test Process

1. Sender creates a room
2. Receiver starts recording the screen and performance/delay data
3. Sender starts playing the video using OBS
4. Audio script along with network trace capture and “Changing Packet Loss” script are executed with conditions:
    1. Unlimited limitation enabled for 1 minute
    2. 10% limitation enabled for 1 minute
    3. 20% limitation enabled for 1 minute
    4. 45% limitation enabled for 1 minute
    5. 20% limitation enabled for 1 minute
    6. 10% limitation enabled for 1 minute
    7. Unlimited limitation enabled for 1 minute
5. Test ends when the sender video reaches white screen, delay video recording and network trace capturing is stopped
6. Receiver device leaves the room/call
7. Sender disconnects from the room/call and the chrome browser is restarted

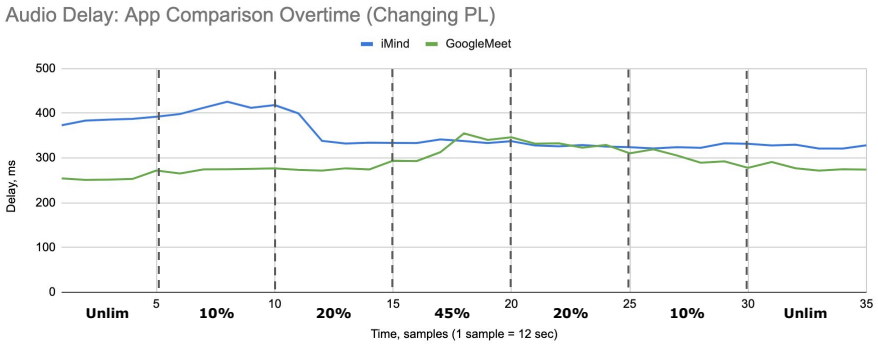
POLQA comparison

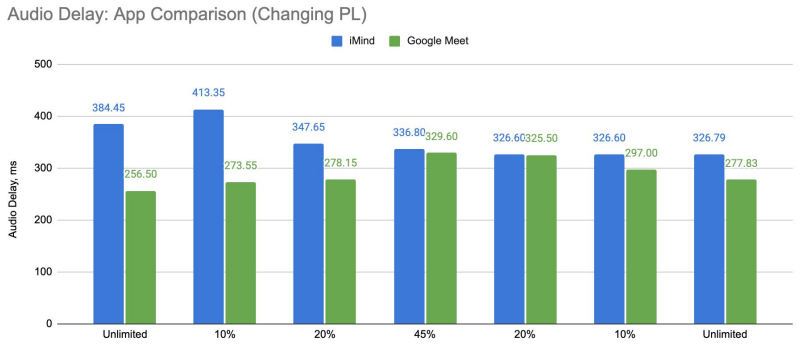




iMind has the same audio quality at the baseline and lower POLQA score in packet loss

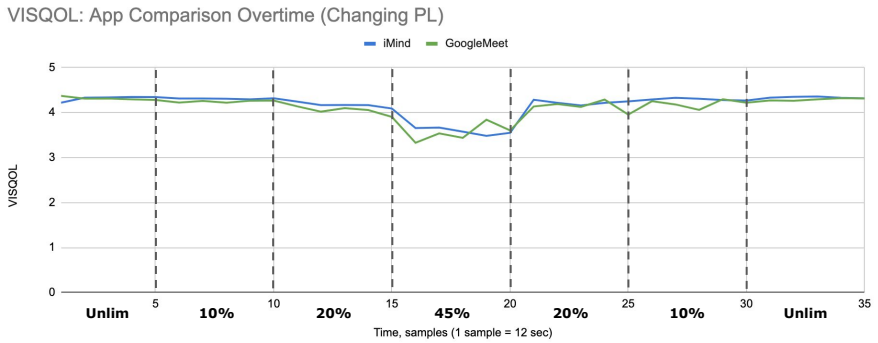
Audio Delay comparison

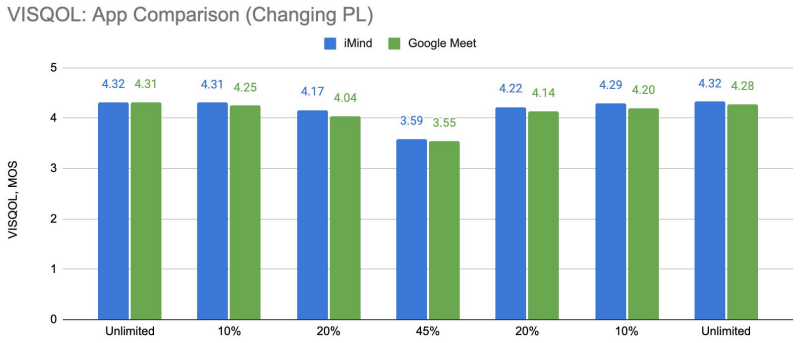




iMind has higher Audio Delay compared to Google Meet in all network conditions.

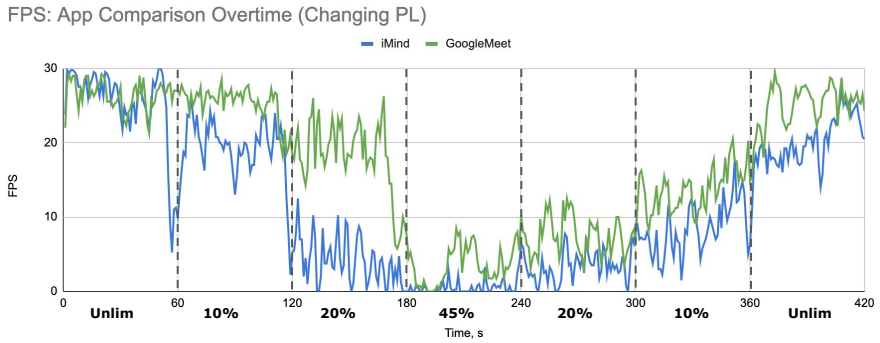
VISQOL comparison

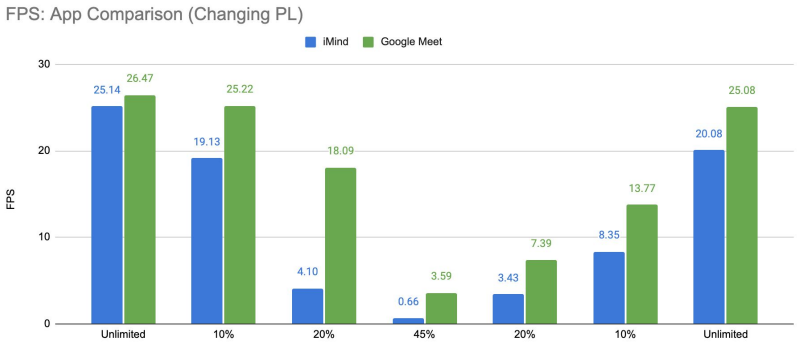




In all network conditions
iMind has slightly higher VISQOL results than Google Meet.

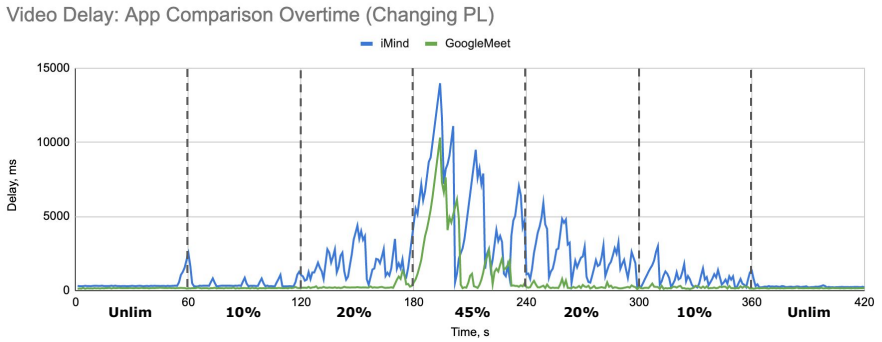
FPS comparison

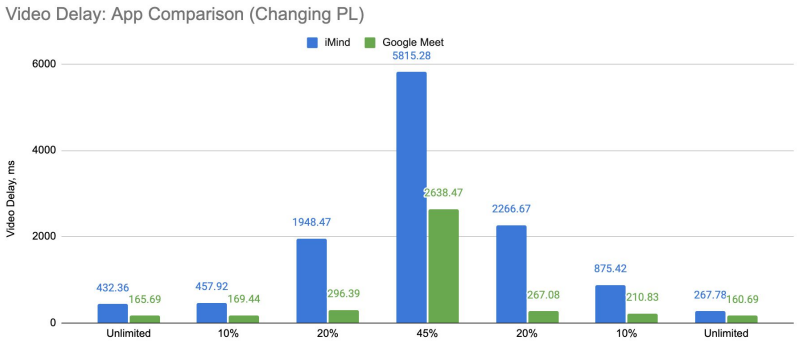




iMind has approximately the same FPS than Google Meet in the beginning of tests, but lower FPS in all packet loss conditions.

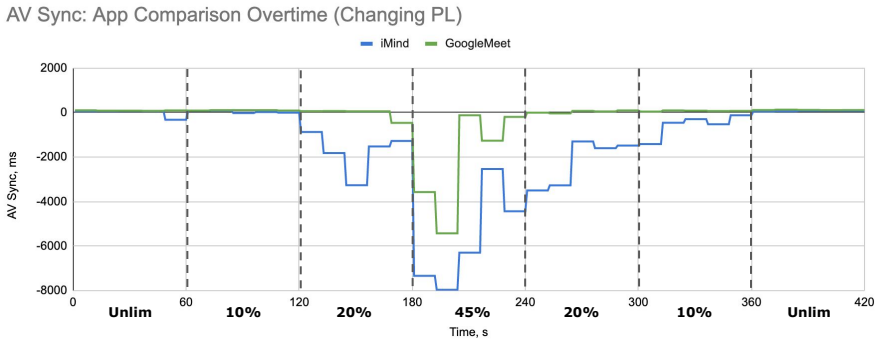
Video Delay comparison

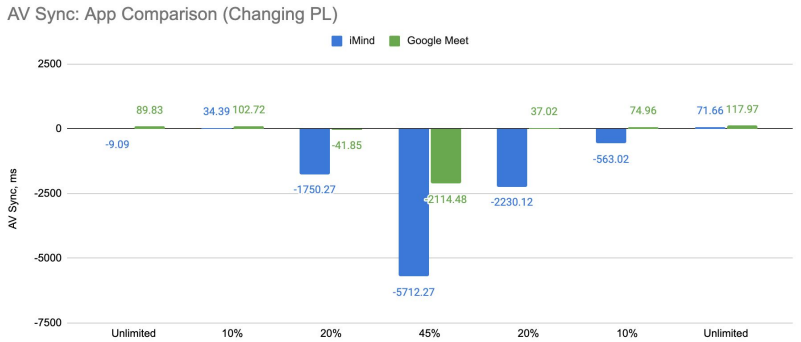




iMind has higher Video Delay at the baseline and in all packet loss conditions.

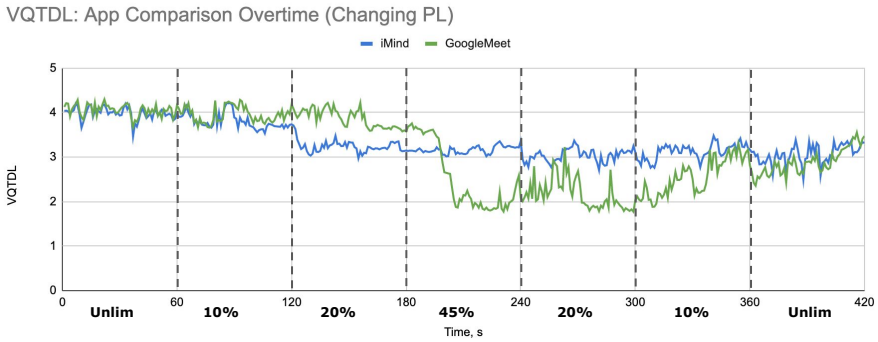
Audio and Video synchronization comparison

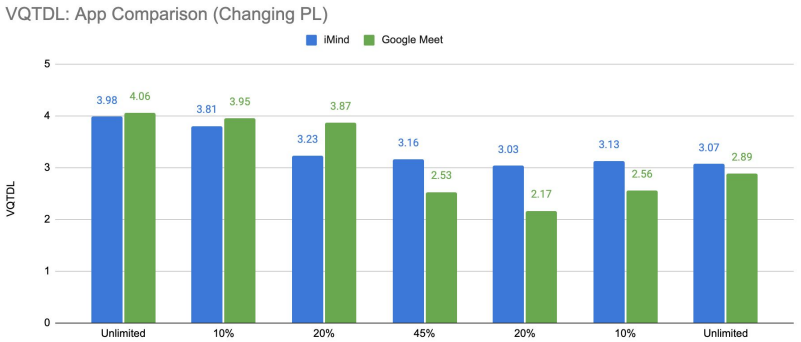




iMind has better A/V synchronization in two first minutes of tests, but after 20% Packet loss condition it get worse.

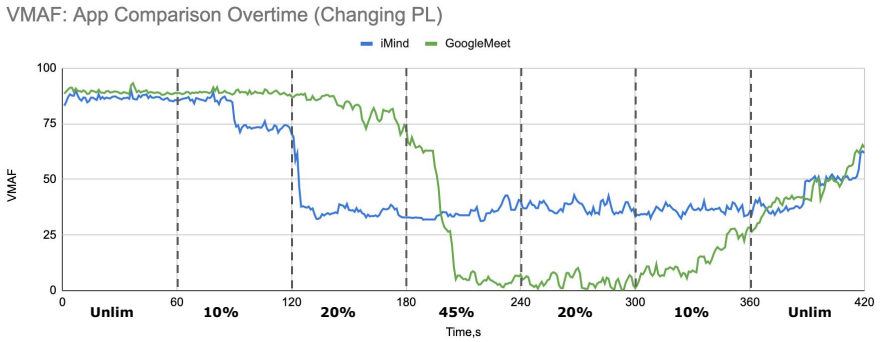
VQTDL comparison

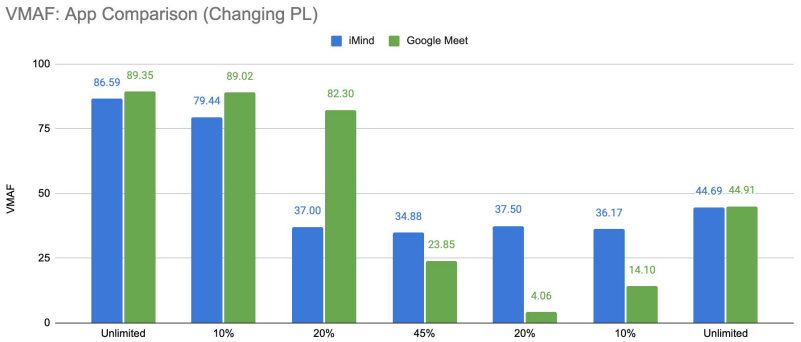




iMind has stable VQTDL score after network changes to 20%PL until the end of tests. Overall has better image quality in high Packet loss condition.

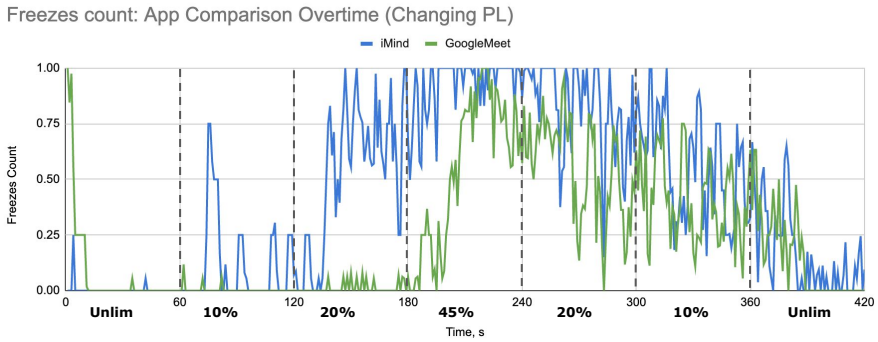
VMAF comparison

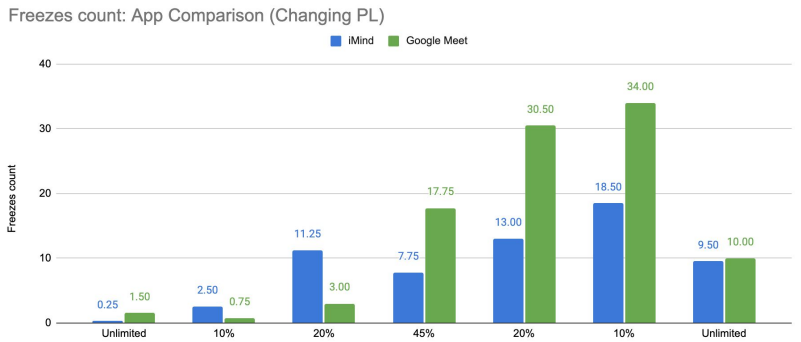




iMind drops video quality at 20% Packet loss condition and keeps stable quality during all test.

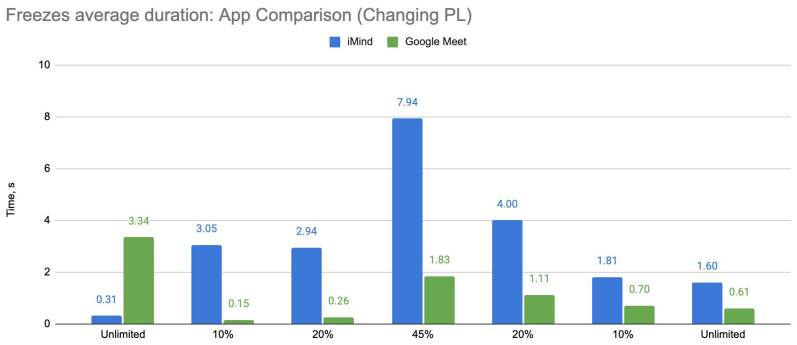
Freeze count comparison

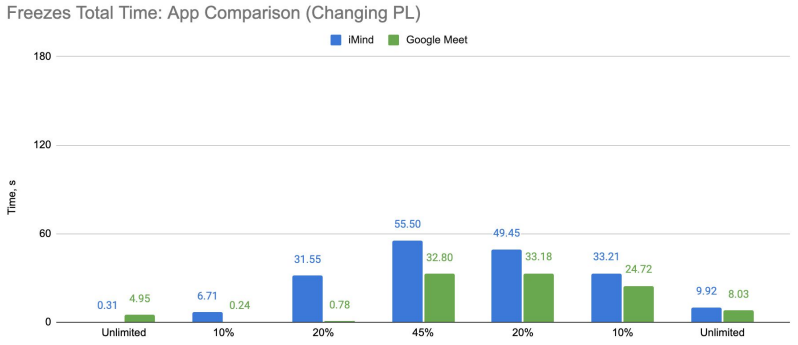




iMind has long freezes in all Packet loss conditions, while Google Meet starts freezing only at 45% of Packet loss.

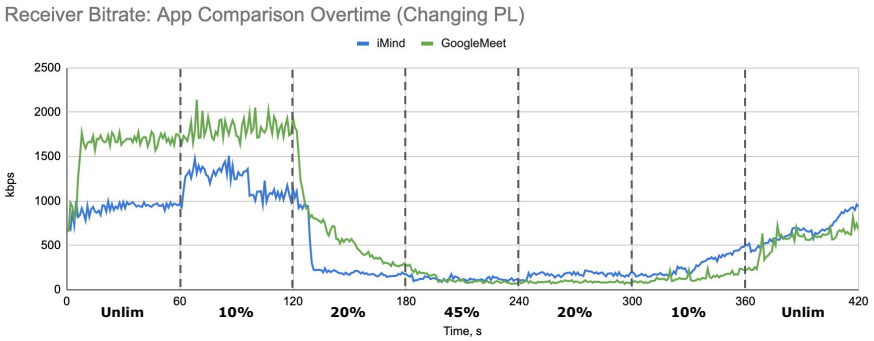
Freeze duration and total length comparison

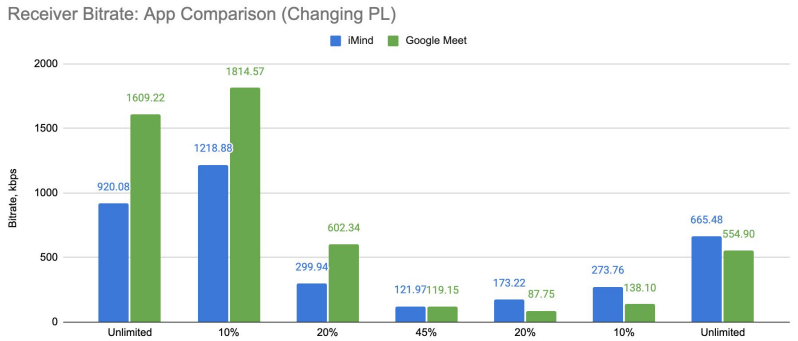




iMind freezes for a longer amount of time during the entire test, compared to Google Meet, shorter at the baseline

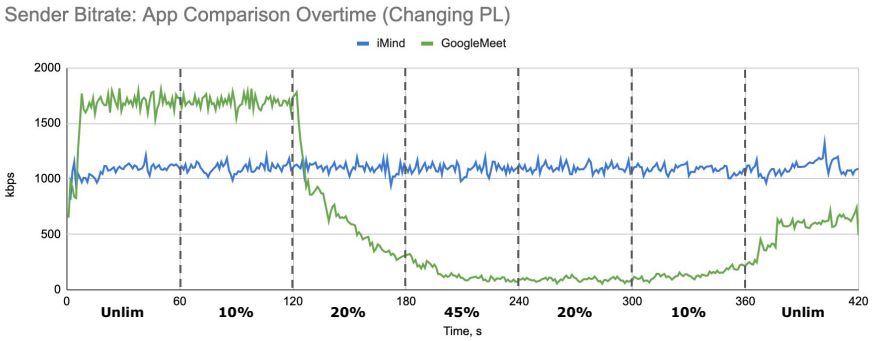
Receiver bitrate comparison

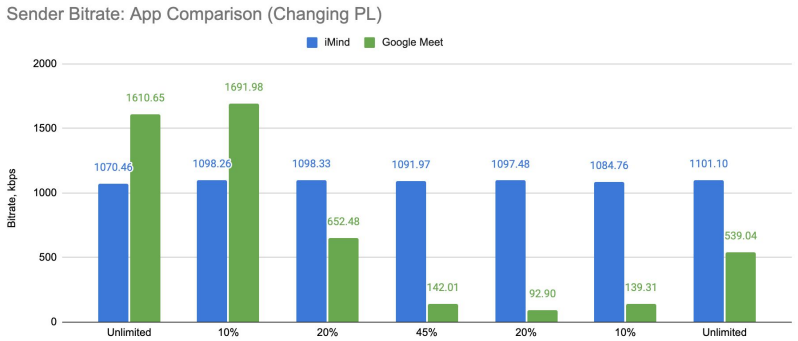




iMind has lower network consumption at the baseline. The same as Google Meet, iMind increase Receiver bitrate at the 10% and decrease at 20% of Packet loss.

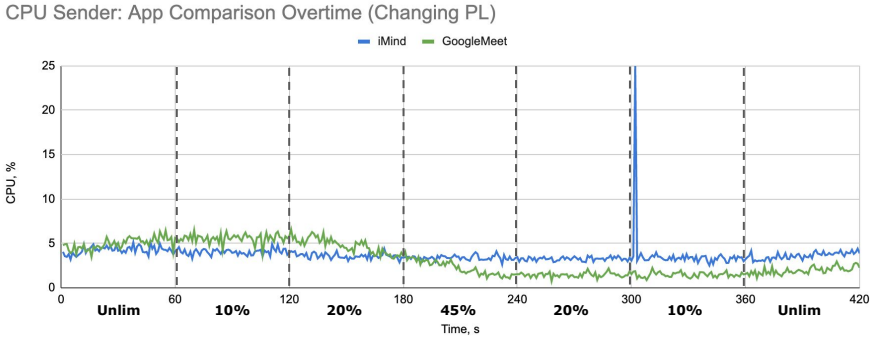
Sender bitrate comparison

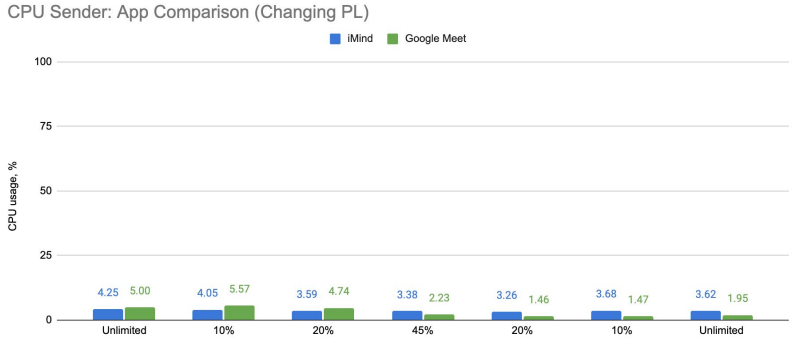


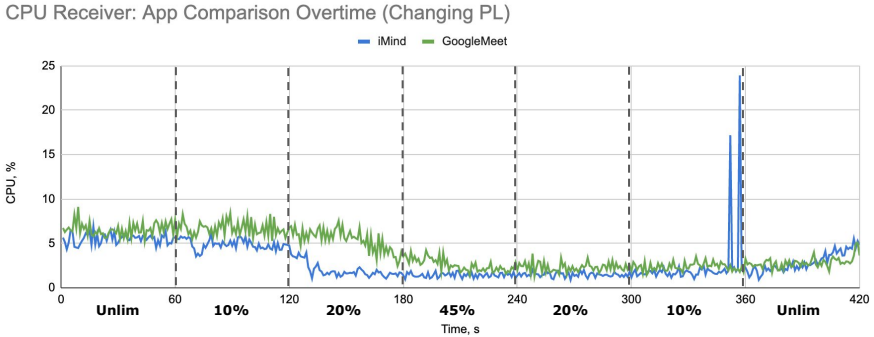


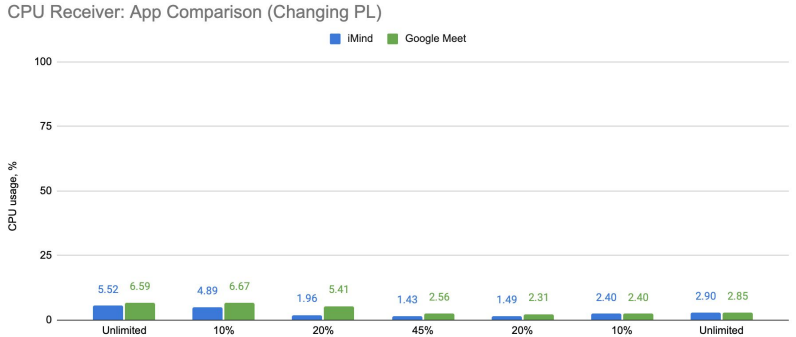
iMind keeps Sender Bitrate stable throughout the test, while Google Meet adapts Sender bitrate to Receiver network limitation.

CPU comparison



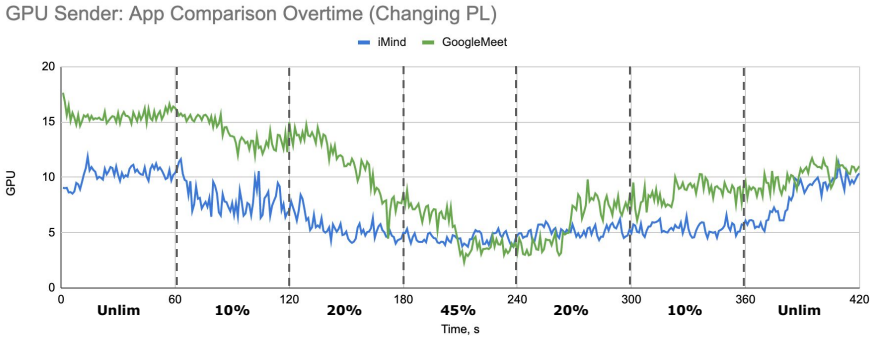


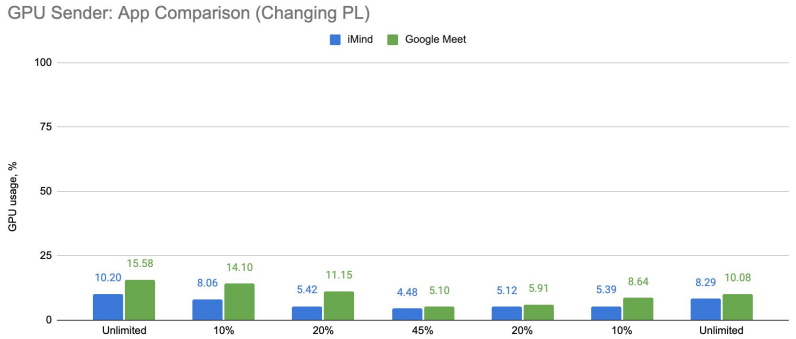


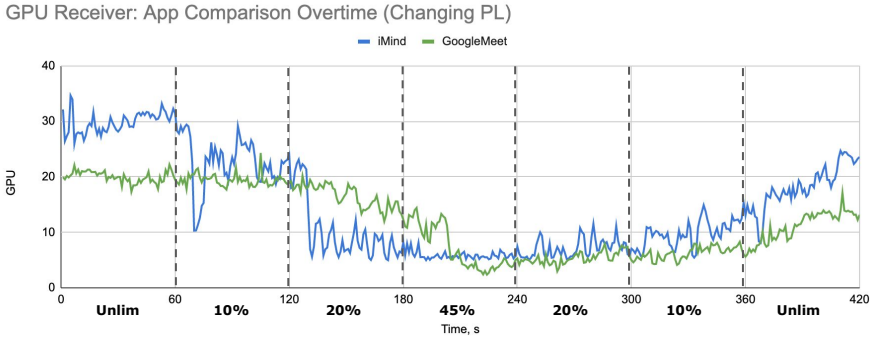


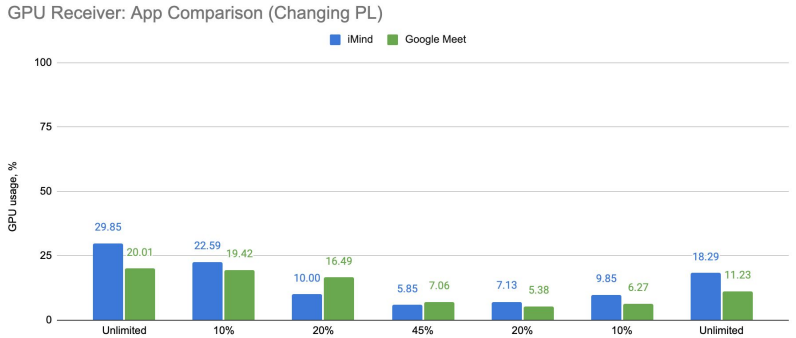
Sender has stable CPU usage during the test and Receiver consumes according to network limitation in iMind tests.

GPU comparison



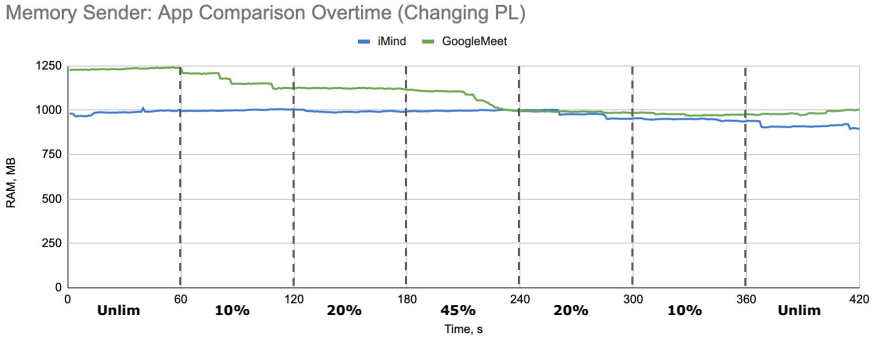


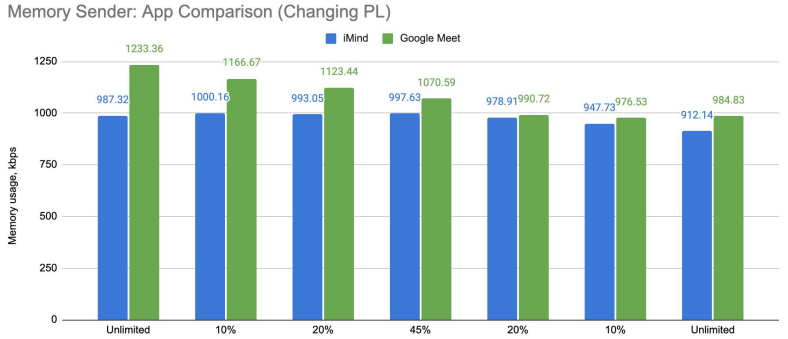


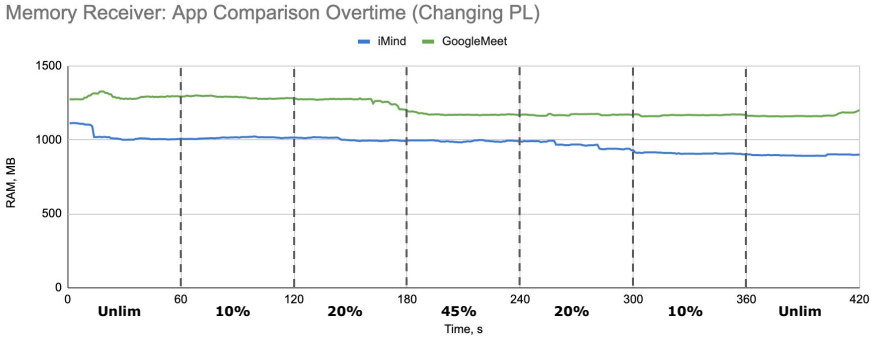


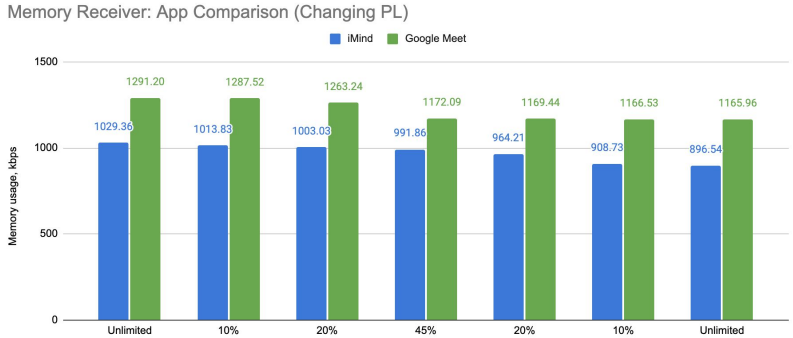
In iMind tests Sender has lower GPU usage and Receiver overall higher than Google Meet.

Memory comparison









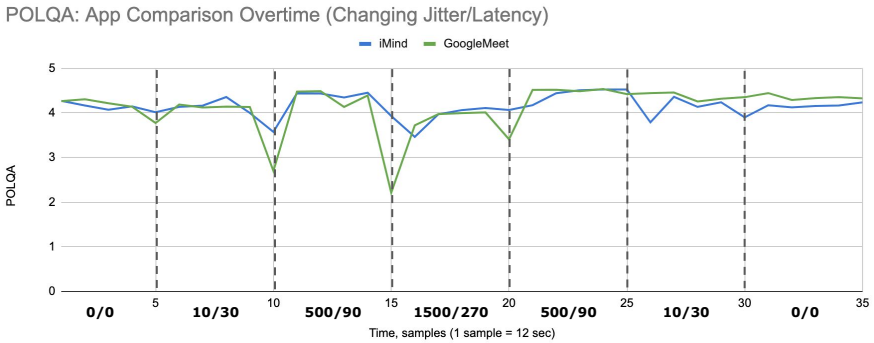
Sender and Receiver uses less Memory in iMind tests.

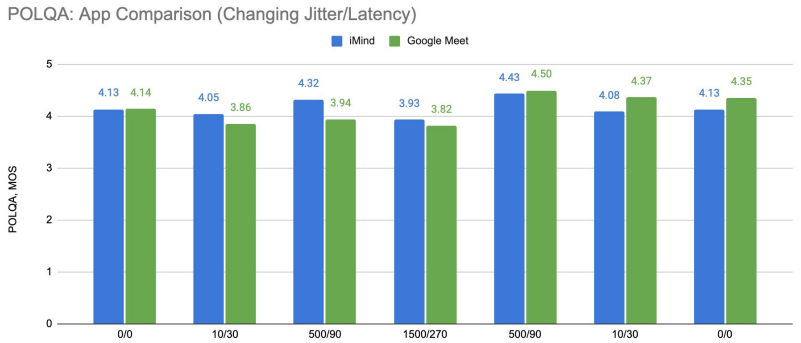
CHANGING LATENCY AND JITTER

Changing Latency and Jitter Test Process

1. Sender creates a room
2. Receiver starts recording the screen and performance/delay data
3. Sender starts playing the video on OBS
4. Audio script along with network trace capture and “Changing Packet Loss” script are executed with conditions:
    1. 0/0 ms limitation enabled for 1 minute
    2. 10/30 ms limitation enabled for 1 minute
    3. 500/90 ms limitation enabled for 1 minute
    4. 1500/270 ms limitation enabled for 1 minute
    5. 500/90 ms limitation enabled for 1 minute
    6. 10/30 ms limitation enabled for 1 minute
    7. 0/0 ms limitation enabled for 1 minute
5. Test ends when the sender video reaches white screen, delay video recording and network trace capturing is stopped
6. Receiver device leaves the room/call
7. Sender disconnects from the room/call and the chrome browser is restarted

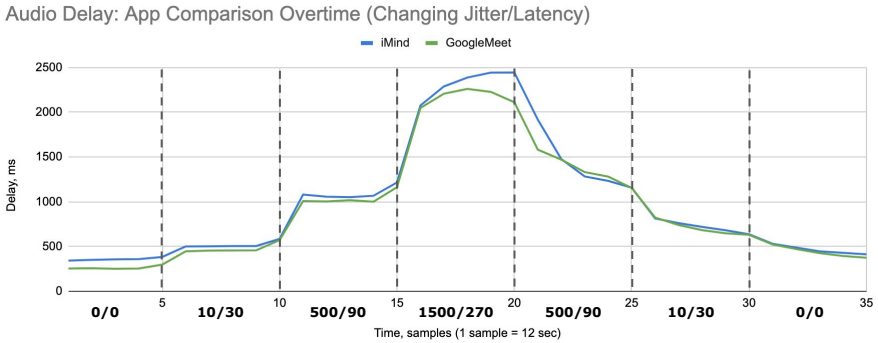
POLQA comparison

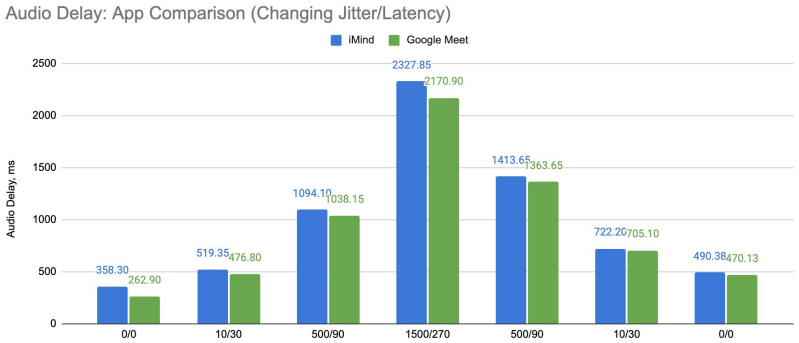




iMind has more stable audio quality and has less significant POLQA drops during limitation changes. Has higher POLQA in the first part of test until ~240 second

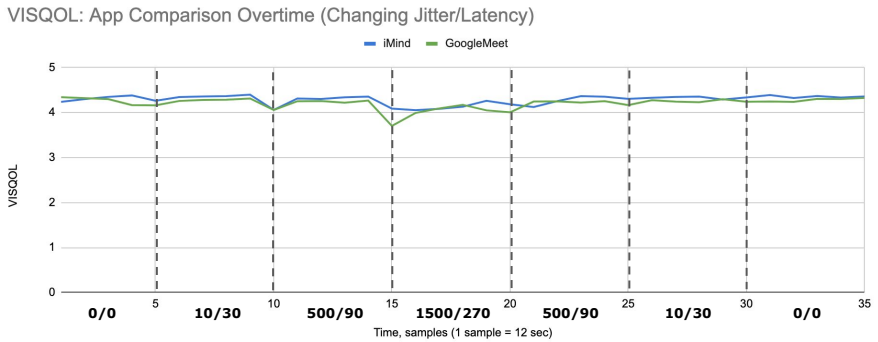
Audio Delay comparison

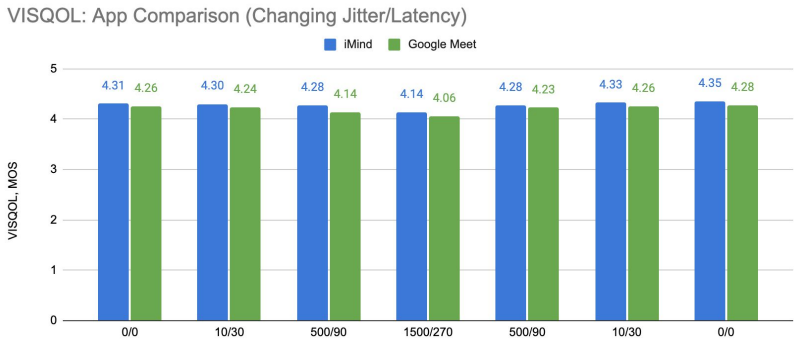




Competitors are overall on par, but iMind has slightly higher Audio Delay in comparison to Google Meet

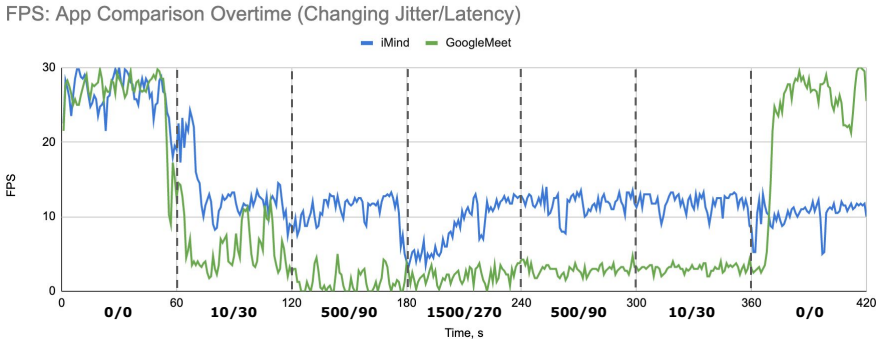
VISQOL comparison

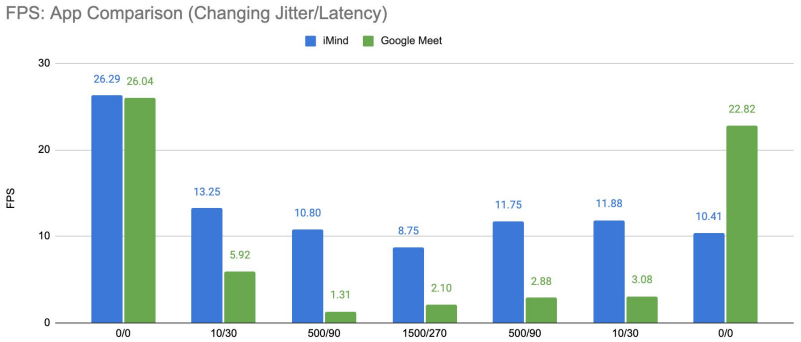




iMind has higher VISQOL results during entire tests

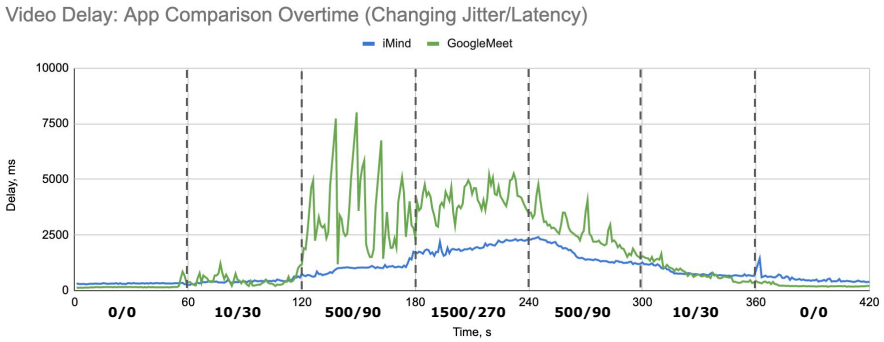
FPS comparison

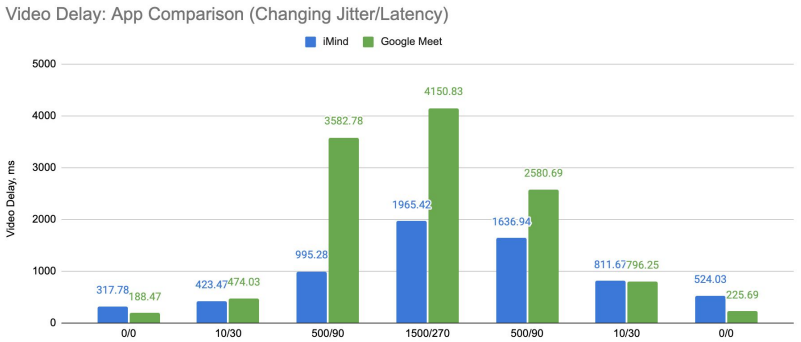




iMind has higher FPS results until network is unlimited again. Than Google Meet recovers FPS back and has 2x higher result, while iMind keeps stable FPS until the end

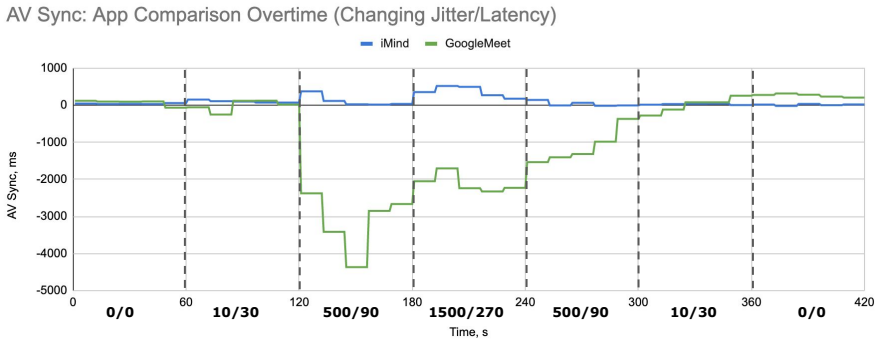
Video Delay comparison

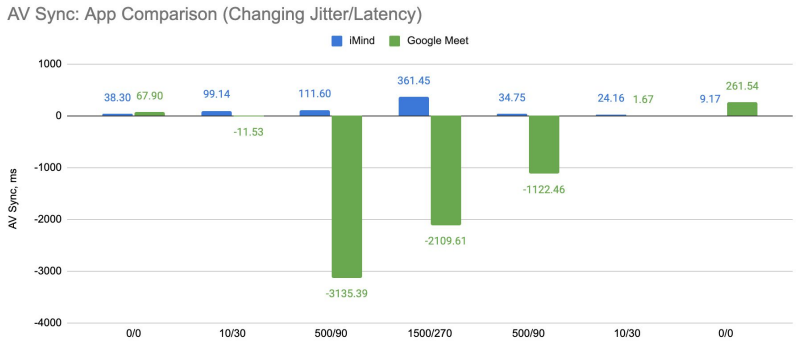




iMind Video Delay is lower and has more stable behavior pattern without any huge spikes

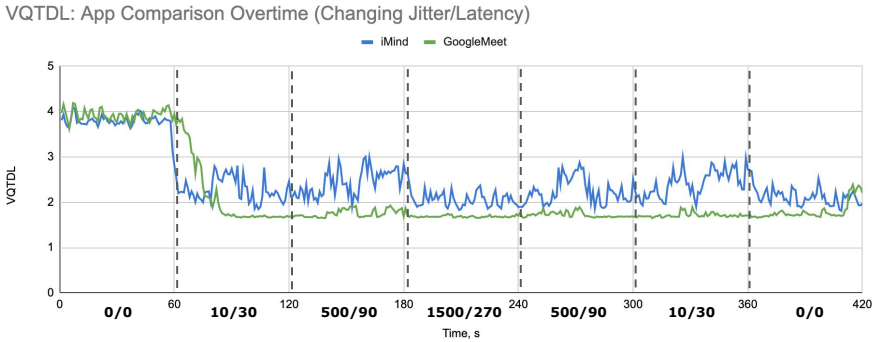
Audio and Video synchronization comparison

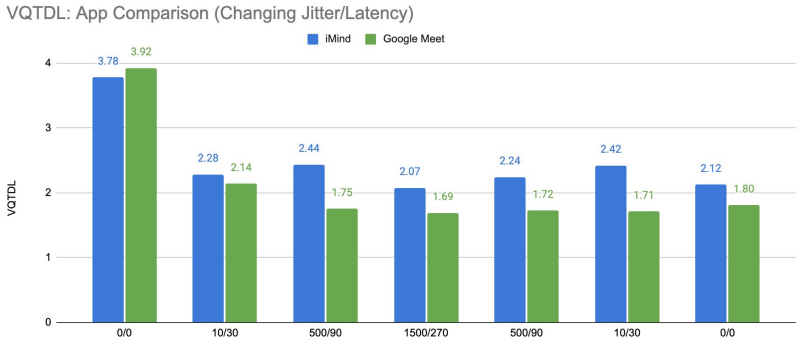




iMind has better A/V Synchronization

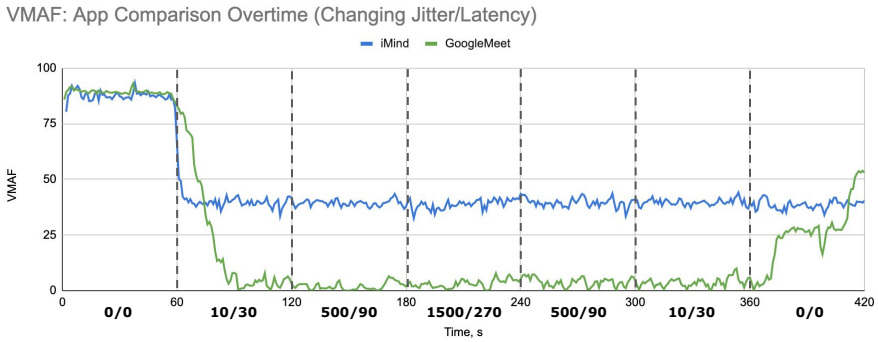
VQTDL comparison

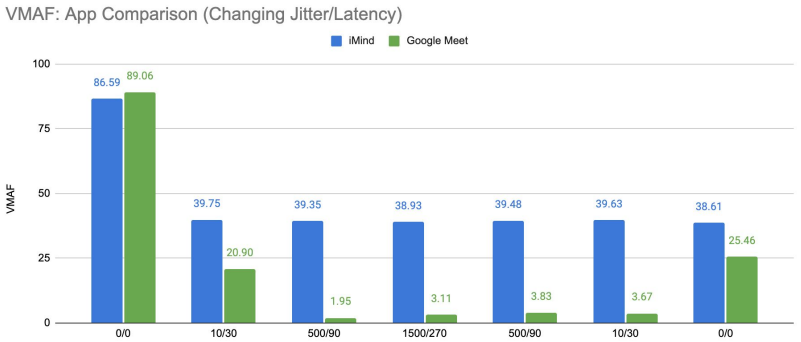




iMind shows higher VQTDL results

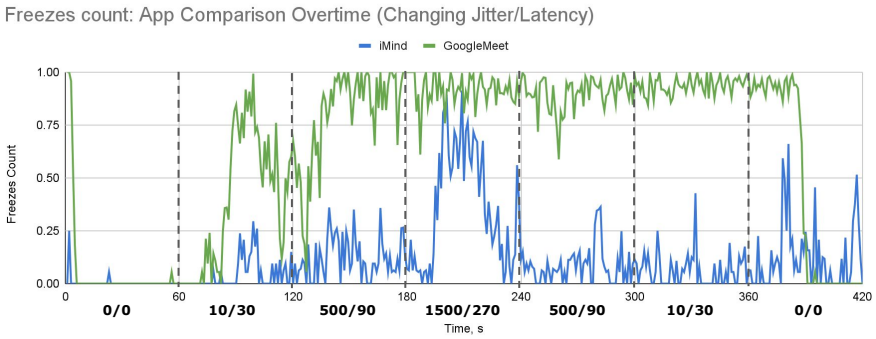
VMAF comparison

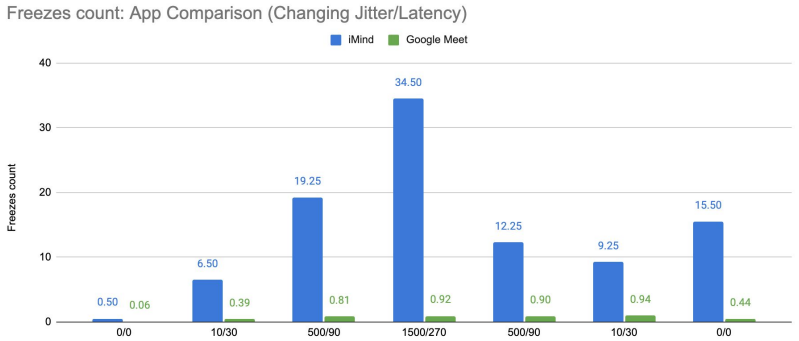




iMind shows higher VMAF results

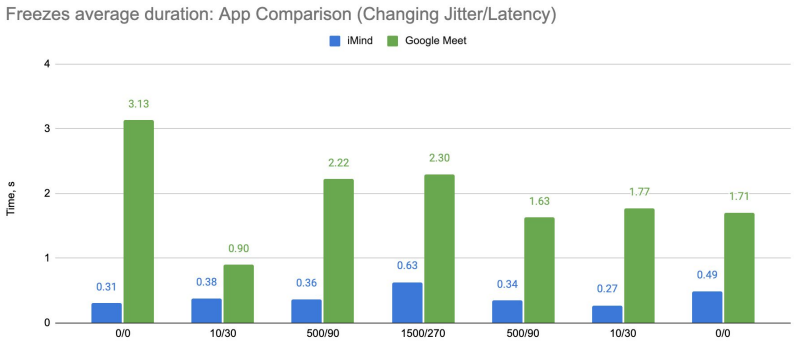
Freeze count comparison

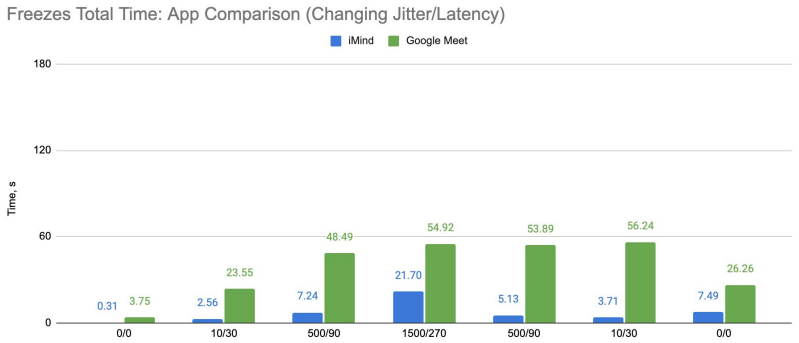




iMind has more freezes in comparison to Google Meet, because they are shorter

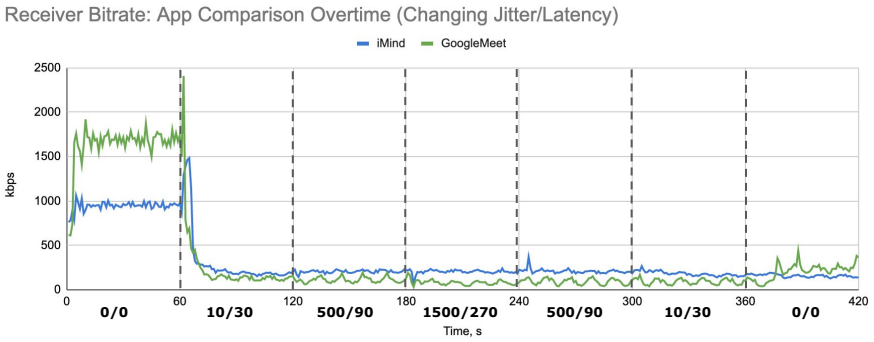
Freeze duration and total length comparison

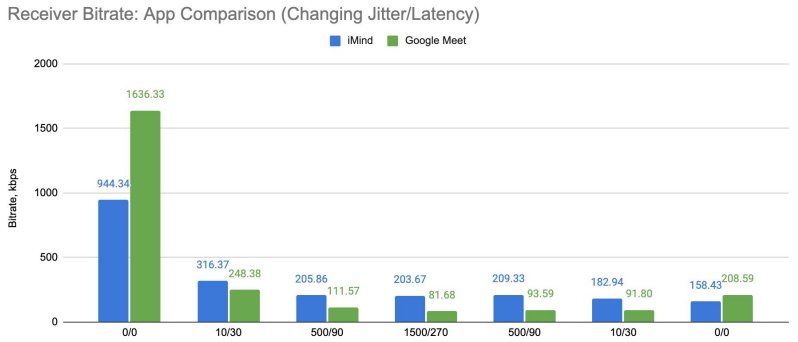




iMind has shorter freezes in comparison to Google Meet

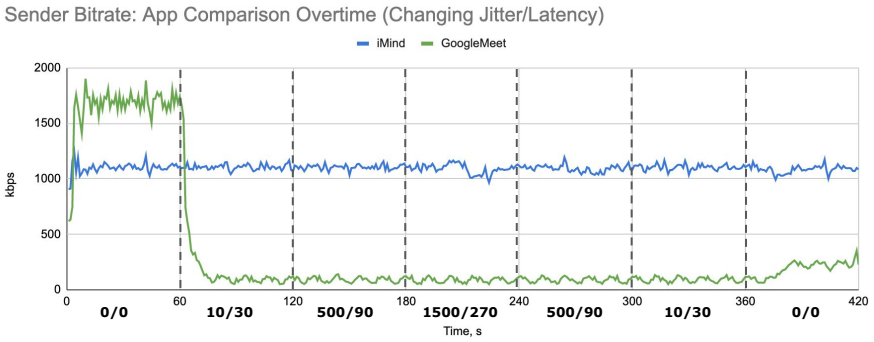
Receiver bitrate comparison

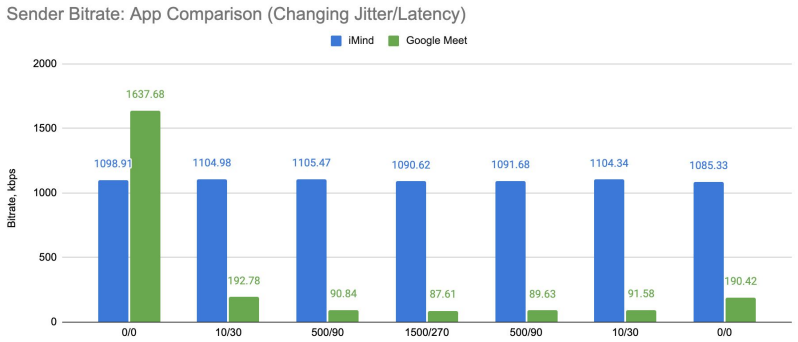




iMind has lower Receiver network consumption. Both applications doesn't recovers back the consumption in the end of tests

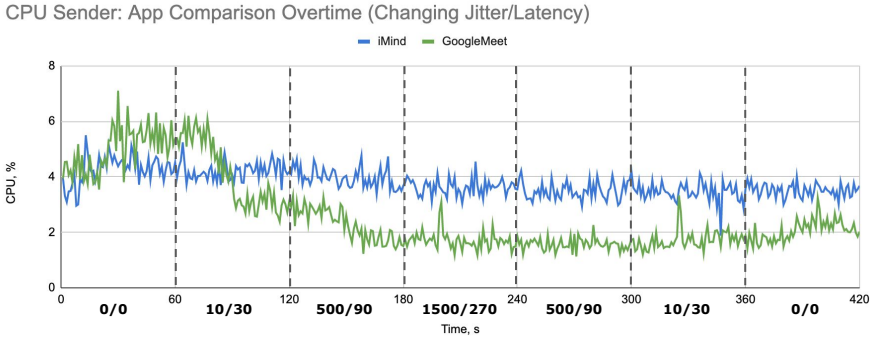
Sender bitrate comparison

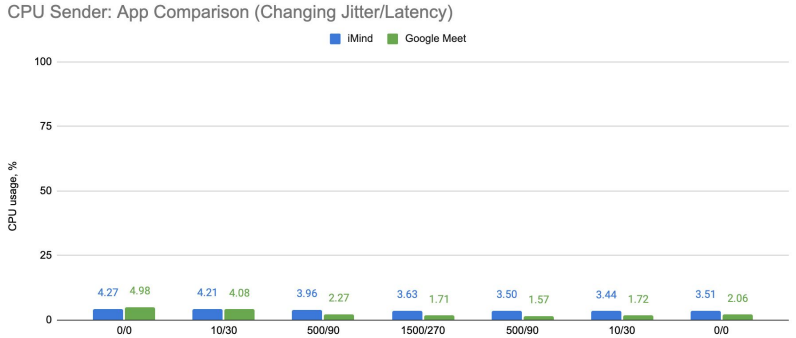


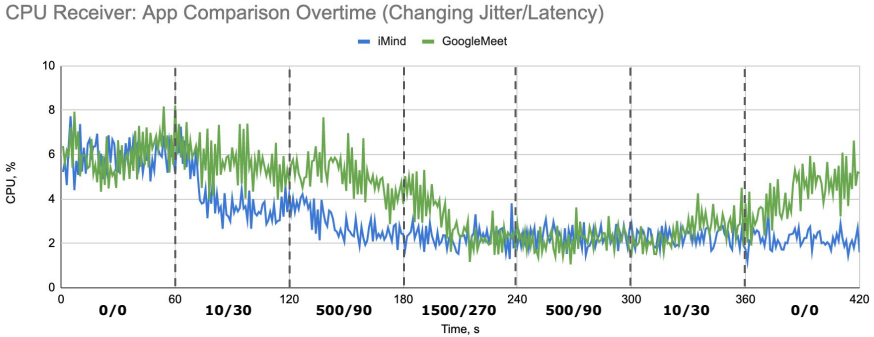


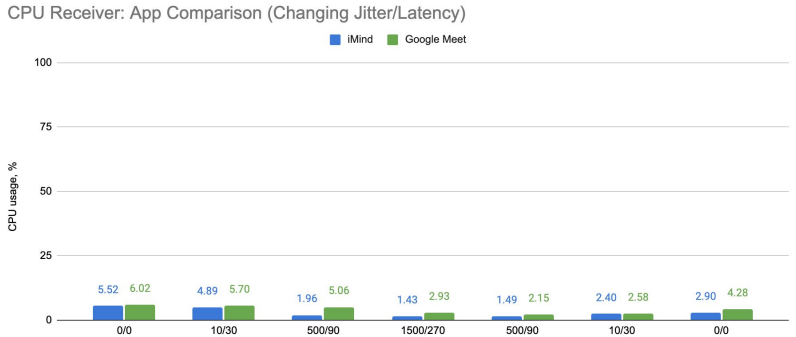
Sender bitrate is not adapting to Receiver network limitations.
iMind has less sender network consumption than Google Meet at the baseline

CPU comparison



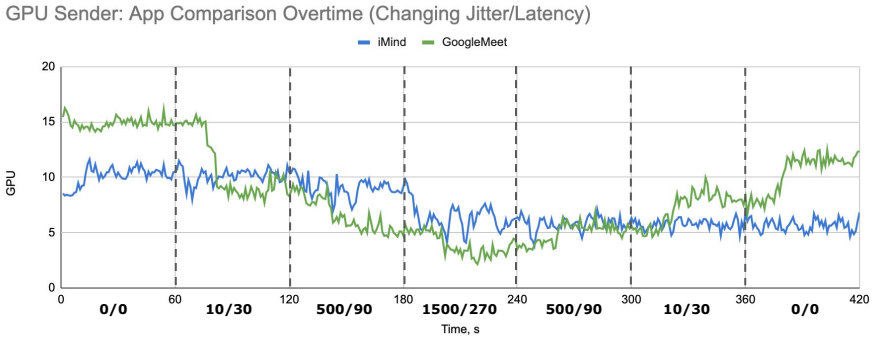


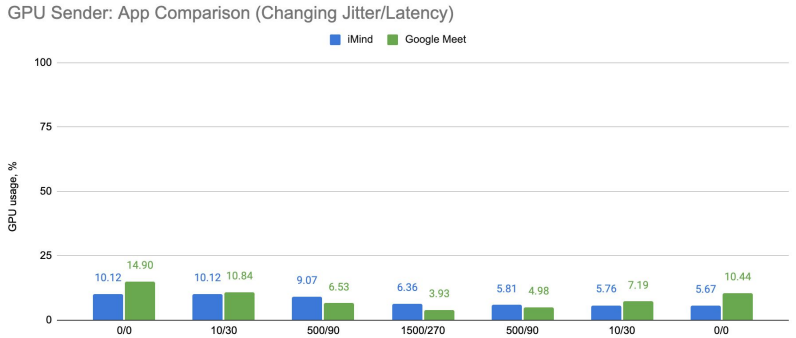


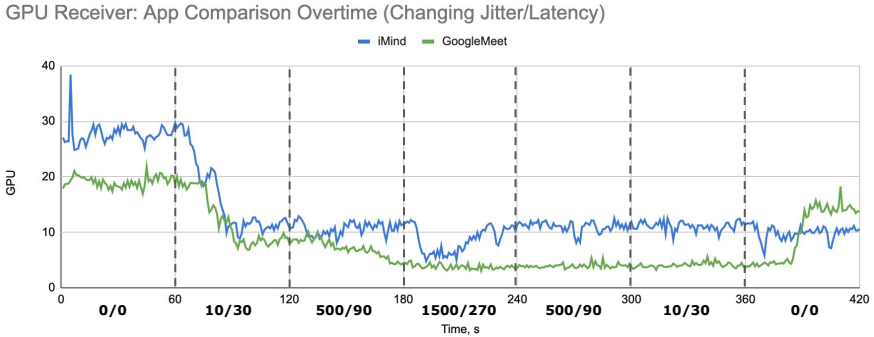


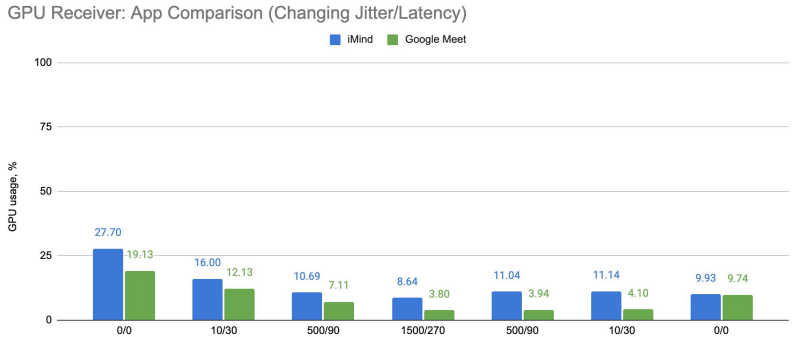
iMind uses less Receiver CPU and and more Sender CPU

GPU comparison



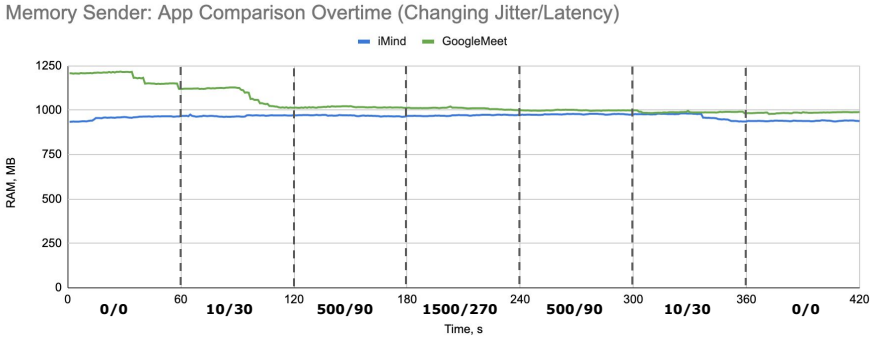


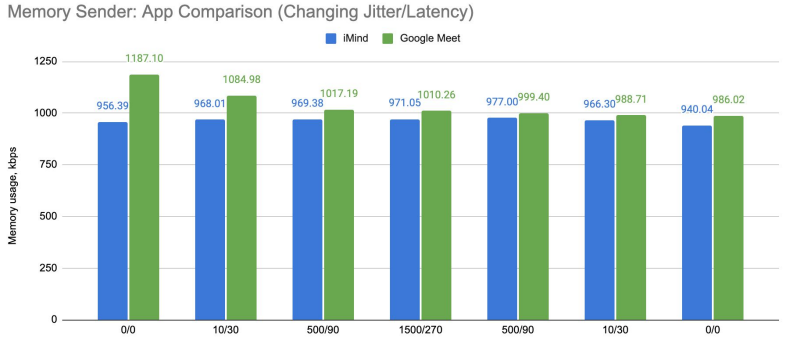


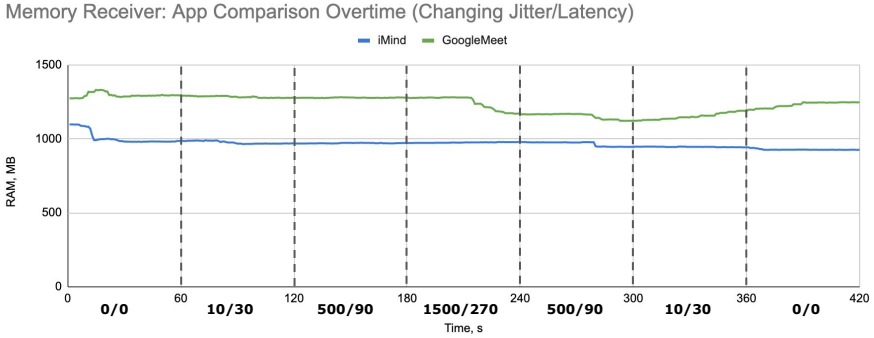


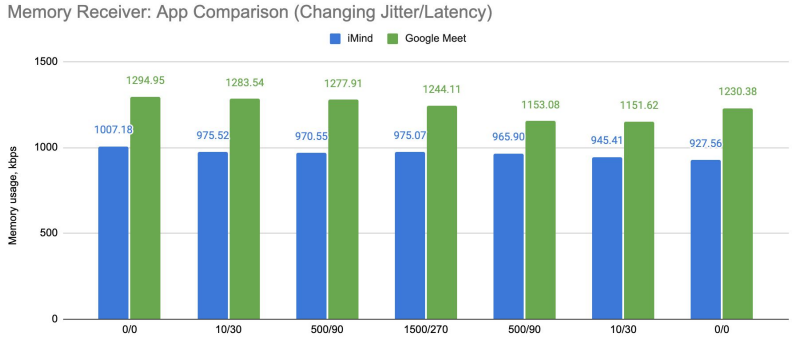
iMind uses more Receiver CPU, Sender CPU is stable – doesn't adapt to Receiver

Memory comparison









iMind uses less Memory in comparison to Google Meet

HEATMAPS

Changing Bandwidth

Win-Win	iMind	Google Meet
FPS	17.83	24.00
VQTDL	3.36	3.67
Video Delay	558.04	332.44
VMAF	56.88	73.30
PSNR	35.11	39.29
SSIM	0.956	0.982
Freeze count	8.50	3.75
POLQA	3.92	4.18
Audio Delay	513.01	416.14
Receiver Network	512.33	885.50
Sender Network	1104.53	889.19
CPU_Sender	4.40	5.16
GPU_Sender	9.80	24.67
RAM_Sender	974.64	1103.63
CPU_Receiver	4.45	3.21
GPU_Receiver	18.61	10.51
RAM_Receiver	972.76	888.45
CPU_Sender	4.40	5.16

Changing Packet Loss

Win-Win	iMind	Google Meet
FPS	11.56	17.09
VQTDL	3.35	3.15
Video Delay	1723.41	558.37
VMAF	50.90	49.66
PSNR	34.62	35.98
SSIM	0.953	0.951
Freeze count	12.10	19.40
POLQA	3.59	3.85
Audio Delay	351.61	291.16
AV SYNC	-1451.25	-247.69
Receiver Network	524.76	703.72
Sender Network	1091.77	695.48
CPU_Sender	3.70	3.20
GPU_Sender	6.75	10.09
RAM_Sender	972.97	1077.18
CPU_Receiver	2.96	4.11
GPU_Receiver	14.91	12.29
RAM_Receiver	971.65	1216.44

Changing Jitter/Latency

Win-Win	iMind	Google Meet
FPS	13.30	9.16
VQTDL	2.48	2.11
Video Delay	953.51	1714.11
VMAF	46.05	21.14
PSNR	33.28	31.63
SSIM	0.944	0.914
Freeze count	19.50	30.50
POLQA	4.16	4.14
Audio Delay	985.23	922.23
AV SYNC	96.94	-863.98
Receiver Network	317.28	353.13
Sender Network	1097.33	340.08
CPU_Sender	3.79	2.62
GPU_Sender	7.54	8.44
RAM_Sender	963.77	1038.50
CPU_Receiver	3.11	4.12
GPU_Receiver	13.56	8.63
RAM_Receiver	966.26	1233.82