International Conference of Modern Systems Engineering Solutions
MODERN SYSTEMS 2025
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"Development of a WebRTC-based Video Calling Application to predict Quality of Service Patterns Using an Artificial Neural Network"

Ph.D Carlos Moreno. UCV, Venezuela
carlosmanuel.moreno.ucv@gmail.com

Ing. Ezequiel Frias. UCV, Venezuela
ezequieljfrias20@gmail.com

Ph.D. Vinod Kumar Verma. SLIET, India.
vinod5881@gmail.com

PhD. Eric Gamess. JSU, USA
egamess@jsu.edu

METAOIT Special Track

IARIA

Carlos Moreno received his Ph.D. in Telecommunications and Computer Science from **Telecom SudParis** jointly with the **University of Paris VI – Pierre et Marie Curie**, France, in 2009.
He completed a **Postdoctoral Research Fellowship** funded by the **Carolina Foundation** of Spain at the **Polytechnic University of Madrid**, Spain, in 2022.
He earned a **Master's Degree in Big Data & Business Intelligence** from **Next Educación** in collaboration with the **University Isabel I**, Spain, in 2024.
He holds an **MBA** from **IESA, Venezuela** (2017).
He also obtained both a **Specialist** and a **Master's Degree in Data Networks** from the **Central University of Venezuela** (2001 and 2005).
He graduated as an **Electronics Engineer** from the **Simón Bolívar University**, Venezuela, in 1998. He is currently Professor at **Central University of Venezuela** and Teacher in Collaboration with **Universidad Internacional de La Rioja – UNIR** (La Rioja, Spain), **OBS Business School** (Barcelona, Spain) and **NextEducación** (Madrid, Spain)

PhD. Carlos Moreno

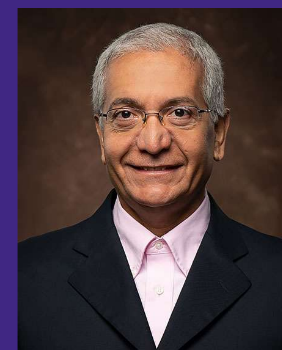
Video and audio over IP networks, QoS, Cibersecurity. Big Data, IoT and AI

Eng. Ezequiel Frias.

Python and Javascript Developer. AI architectures. QoS in IP networks.

PhD. Vinod Kumar Verma

Big Data, IoT, AI, Sensor Networks, Trustworthiness, Cibersecurity

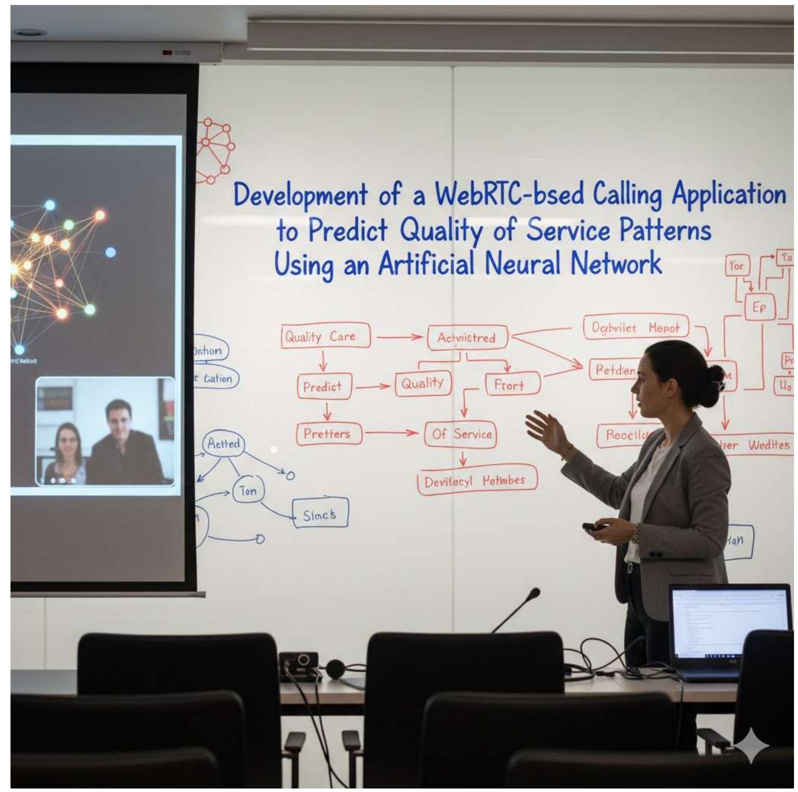


PhD. Eric Gamess

IP Networks, IPv6, Cibersecurity, VANET, SDN, SCADA

Outline

- **Motivation**
- **State of the art**
  - ✓ WebRTC studies without IA
  - ✓ WebRTC studies with IA
- **Problem formulation**
  - ✓ Research questions
  - ✓ Dissertation context
- **Methodology**
  - ✓ Description of scenarios
  - ✓ Development of neural network
  - ✓ Evaluation of the neural network
  - ✓ Prediction of QoS indicators
- **Results and analysis**
- **Conclusion and future work**
- **Questions and answers**



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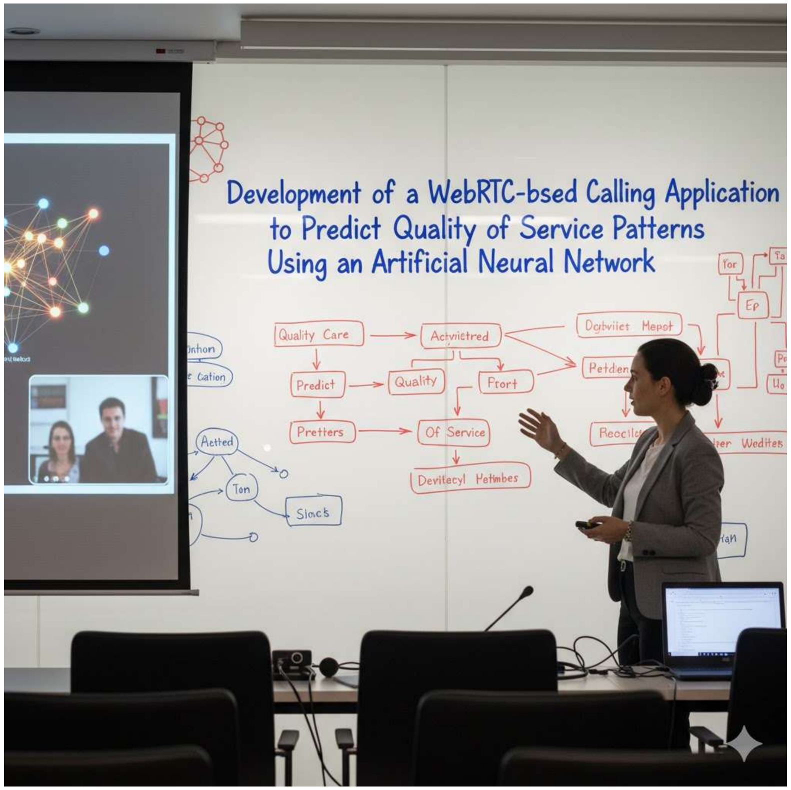

Motivation

Evolution of video call

P2P Technologies (1996)

SIP (Session Initiation Protocol, 1999-2002)

WebRTC (Google) 2018 (Stable)- 2021 (W3C)

P2P

IETF

IETF

Motivation

Evolution of AI in video calls

QoS

Jitter
Latency
Packet Loss
Throughput

QoE

- MOS
- Call Completion Ratio

- Lineal Regression
- SVM
- Decision Trees

- Supervised Machine Learning

(2015-2018)

- CNN
- LSTM

Deep Learning, (2019-2022)

QoE

- MOS
- PSNR
- SSIM

Deep Learning In WebRTC

-Reinforcement Learning

-Hybrid Models

-Dynamic Adaptation of WebRTC (bitrate, resolution, FEC)

-Experimental models: attention, transformers

(2023-now)

Web RTC

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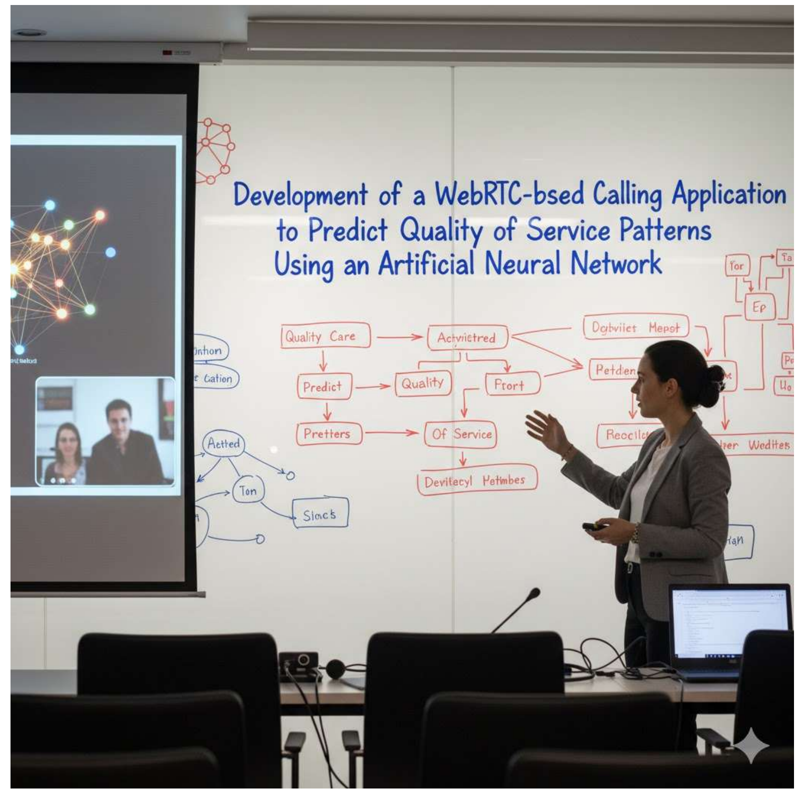
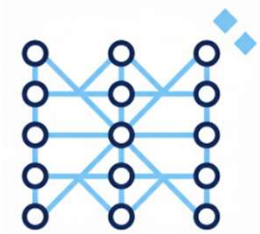


State of the art

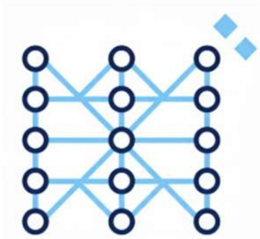
Prediction in non-WebRTC with Machine Learning / Deep Learning

- S. Ness, V. Eswarakrishnan, H. Sridharan, V. Shinde, N. Venkata Prasad Janapareddy, and V. Dhanawat, “Anomaly Detection in Network Traffic Using Advanced Machine Learning Techniques”, IEEE Access, vol. 13, pp. 16133–16145, August 2025, doi: 10.1109/ACCESS.2025.3526988.

- Y. Wang, Z. Jia, X. Zhang, B. Shao, H. Wang, and X. Xing, “TAQ-GRNN: A Topology-Aware QoS Prediction Model Based on Gated Recurrent Neural Networks”, 2024 IEEE 13th Data Driven Control and Learning Systems Conference (DDCLS 2024), August. 2024, pp. 303-308, doi:10.1109/ DDCLS61622.2024.10606915.



- M. Di Mauro, G. Galatro, F. Postiglione, W. Song, and A. Liotta, “Evaluating Recurrent Neural Networks for Prediction of Multi-Variate Time Series VoIP Metrics”, 2024 22nd Mediterranean Communication and Computer Networking Conference (MedComNet 2024), Nice, France, 2024, pp. 1-8, doi: 10.1109/MedComNet62012.2024.10578296.



State of the art

Prediction in non-WebRTC with Machine Learning / Deep Learning

- W. A. Aziz, I. I. Ioannou, M. Lestas, H. K. Qureshi, A. Iqbal, and V. Vassiliou, “Content-Aware Network Traffic Prediction Framework for Quality of Service-Aware Dynamic Network Resource Management”, IEEE Access, vol. 11, pp. 99716–99733, August 2023, doi: 10.1109/ACCESS.2023.3309002.
- Z. Wu, Y.-N. Dong, X. Qiu, and J. Jin, “Online Multimedia Traffic Classification from the QoS Perspective Using Deep Learning”, Computer Network, vol. 204, pp. 1–13, Elsevier, January 2022, doi: 10.1016/j.comnet.2021.108716.
- P. Zhang, J. Ren, W. Huang, Y. Chen, Q. Zhao, and H. Zhu, “A Deep-Learning Model for Service QoS Prediction Based on Feature Mapping and Inference”, IEEE Transactions on Services Computing, vol. 17, no. 4, pp. 1311–1325, August 2024, doi: 10.1109/TSC.2023.3326208.

State of the art

Prediction in WebRTC with Machine Learning / Deep Learning

- "Optimizing RTC Bandwidth Estimation with Machine Learning", https://engineering.fb.com/2024/03/20/ networking-traffic/optimizing-rtc-bandwidth-estimation-machine-learning/
- K. Sakakibara, S. Ohzahata, and R. Yamamoto, "Deep Learning-Based No-Reference Video Streaming QoE Estimation Using WebRTC Statistics", 2024 IEEE International Conference on Artificial Intelligence in Information and Communication (ICAIIC 2024), February 2024, pp.1-7, doi: 10.1109/ICAIIC60209.2024.10463278
- G. Bingol, "Advancing Video Communication: From WebRTC Quality Prediction to Green Appplications", Ph.D. Dissertation, Department of Electrical and Electronical Engineering, University of Cagliari, Cagliari, Italia, 2025.

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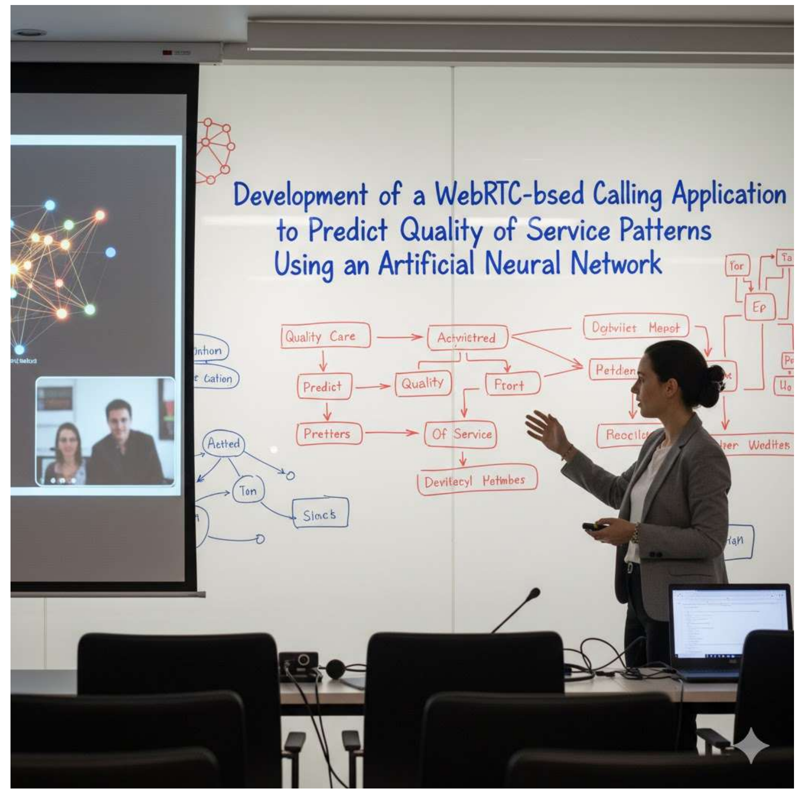

Problem formulation

Research questions

- **Question 1: Which QoS metrics can be considered to measure, analyze, and predict QoS patterns?**
- **Question 2: Which specific type of neural network predicts better QoS in a WebRTC-based video call?**

Context

- **Universidad Central de Venezuela has research lines related to: Effect of cybersecurity over QoS in videocalls with WebRTC**
- **SLIET has research lines related to IoT , Cloud Computing, Trustworthiness, Machine Learning and Deep Learning**
- **JSU has research lines related to Big Data and Cibersecurity**

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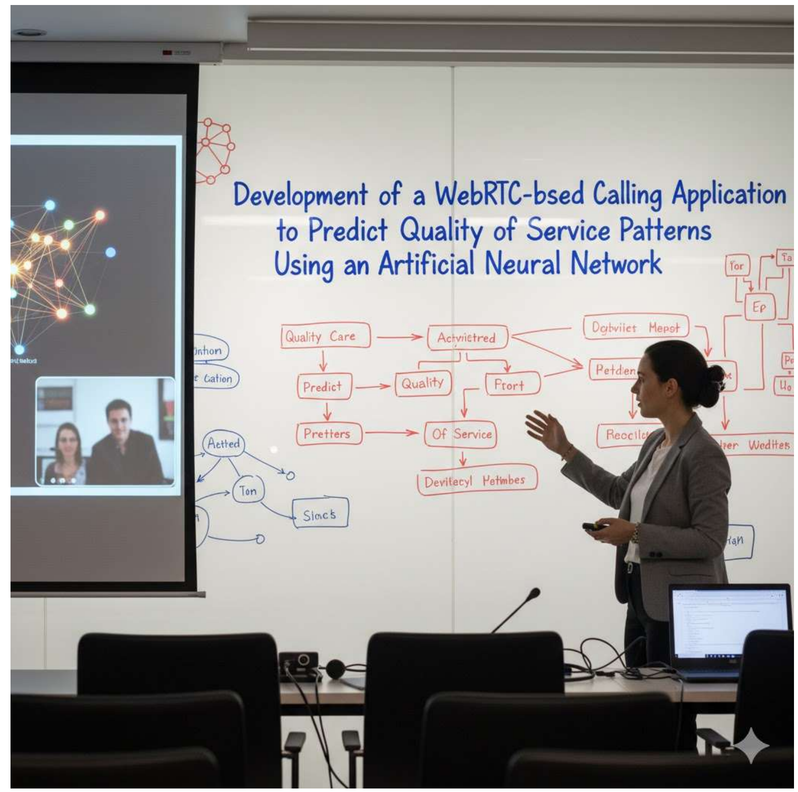
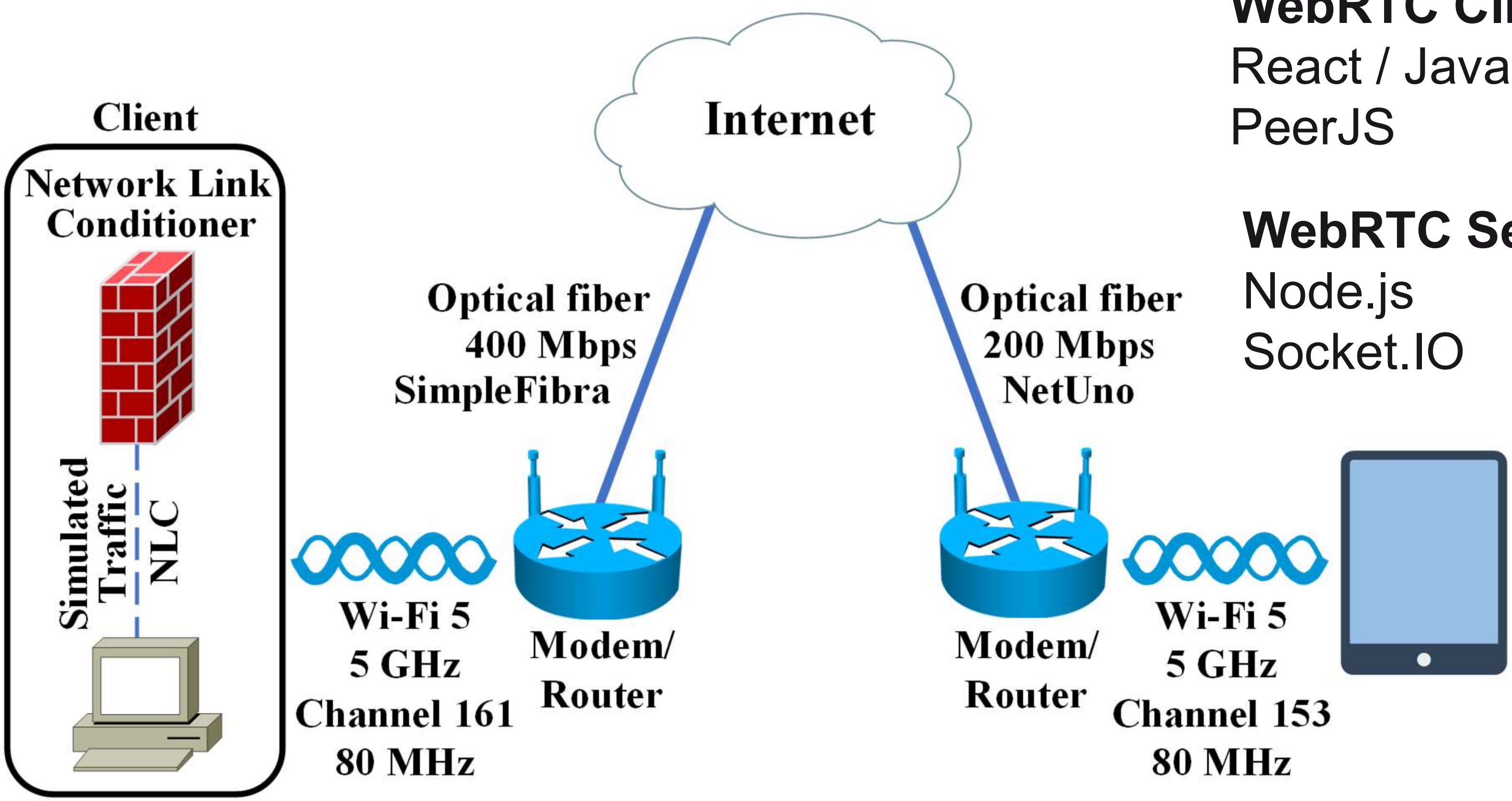


Description of Scenarios

Testbed with 4 scenarios



WebRTC Client:
React / JavaScript / PeerJS

WebRTC Server:
Node.js
Socket.IO

Critical QoS parameters in WebRTC: latency, jitter, packet loss rate

Description of Scenarios

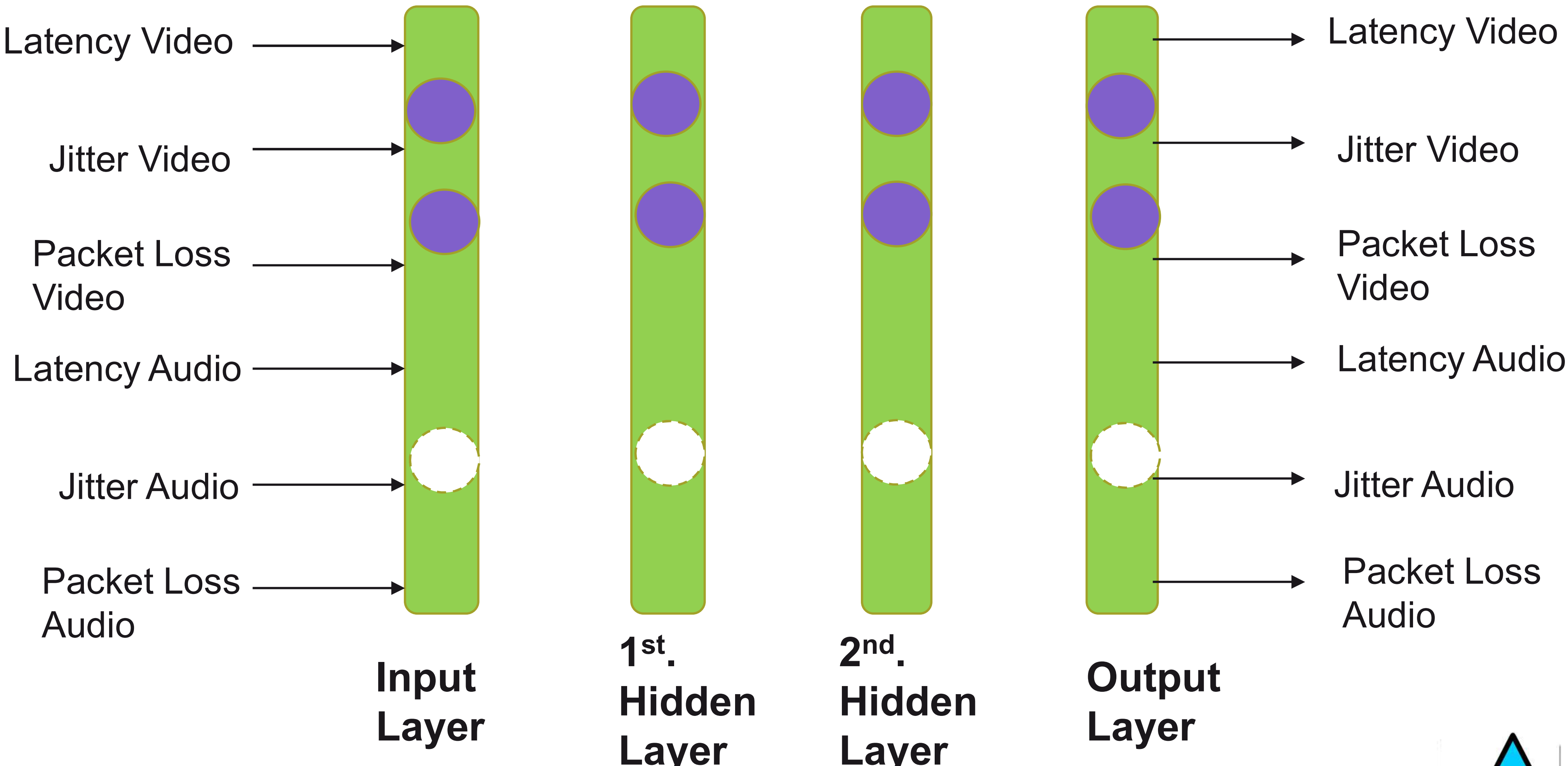
4 Scenarios

Scenario	Bandwidth	Latency	PLR	Description
(1) Acceptable Quality	50 Mbps	20 ms	0%	Acceptable
(2) Moderate Degradation	2 Mbps	100 ms	3%	Congestion
(3) Critical Quality	0.8 Mbps	200 ms	10%	Deficient
(4) Extreme Conditions	0.3 Mbps	500 ms	20%	Degraded

Tool: Network Link Conditioner (scenarios produced by Apple Laptop)

Development of Neural Network

Architecture of Neural Network



Evaluation of Neural Network

Architecture of Neural Network

Hyperparameter	GRU-1	GRU-M	LSTM-1	LSTM-M
Output (steps)	1	30	1	30
LSTM Layers	2	2	2	2
Neurons per Layer	128	128	128	128
Optimizer	Adam	Adam	Adam	Adam
Learning Rate	0.001	0.001	0.001	0.001
Epochs	12	11	32	25
Batch Size	16	16	16	16

Training Set (80%) for the 4 scenarios (1 hour all scenarios)
Testing Set (20%) for each scenario (1 call of 5 minutes per scenario)

GRU-1	GRU-M	LSTM-1	LSTM-M
Gated Recurrent Unit	Gated Recurrent Unit	Long Short-Term Memory	Long Short-Term Memory
Single Output	Multiple Output	Single Output	Multiple Output

Evaluation of Neural Network

Architecture of Neural Network

Hyperparameter	GRU-1	GRU-M	LSTM-1	LSTM-M
MAE (Mean Absolute Error)	0.1154	0.1365	0.0601	0.1205
MSE (Mean Squared Error)	0.0424	0.0540	0.0098	0.0418
RMSE (Root Mean Squared Error)	0.2059	0.2324	0.0994	0.2044

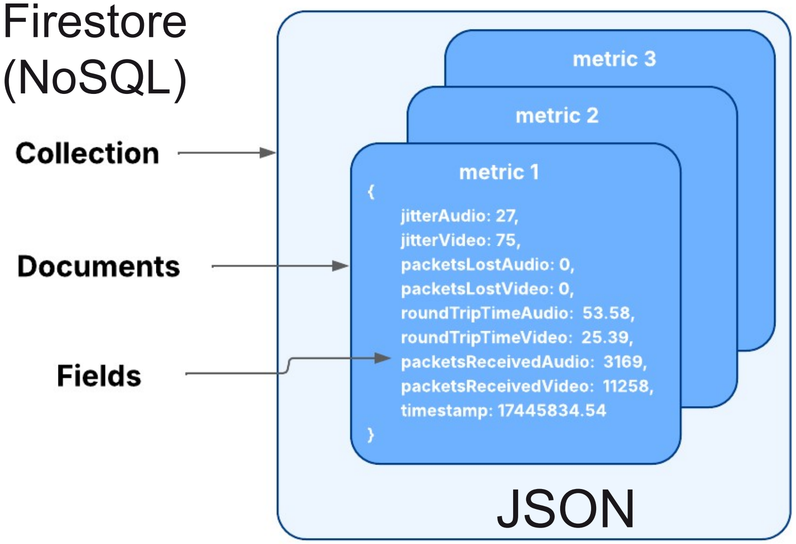
Function: getStats

Web RTC

API: PeerJS

FireBase
Firestore
(NoSQL)

Metrics

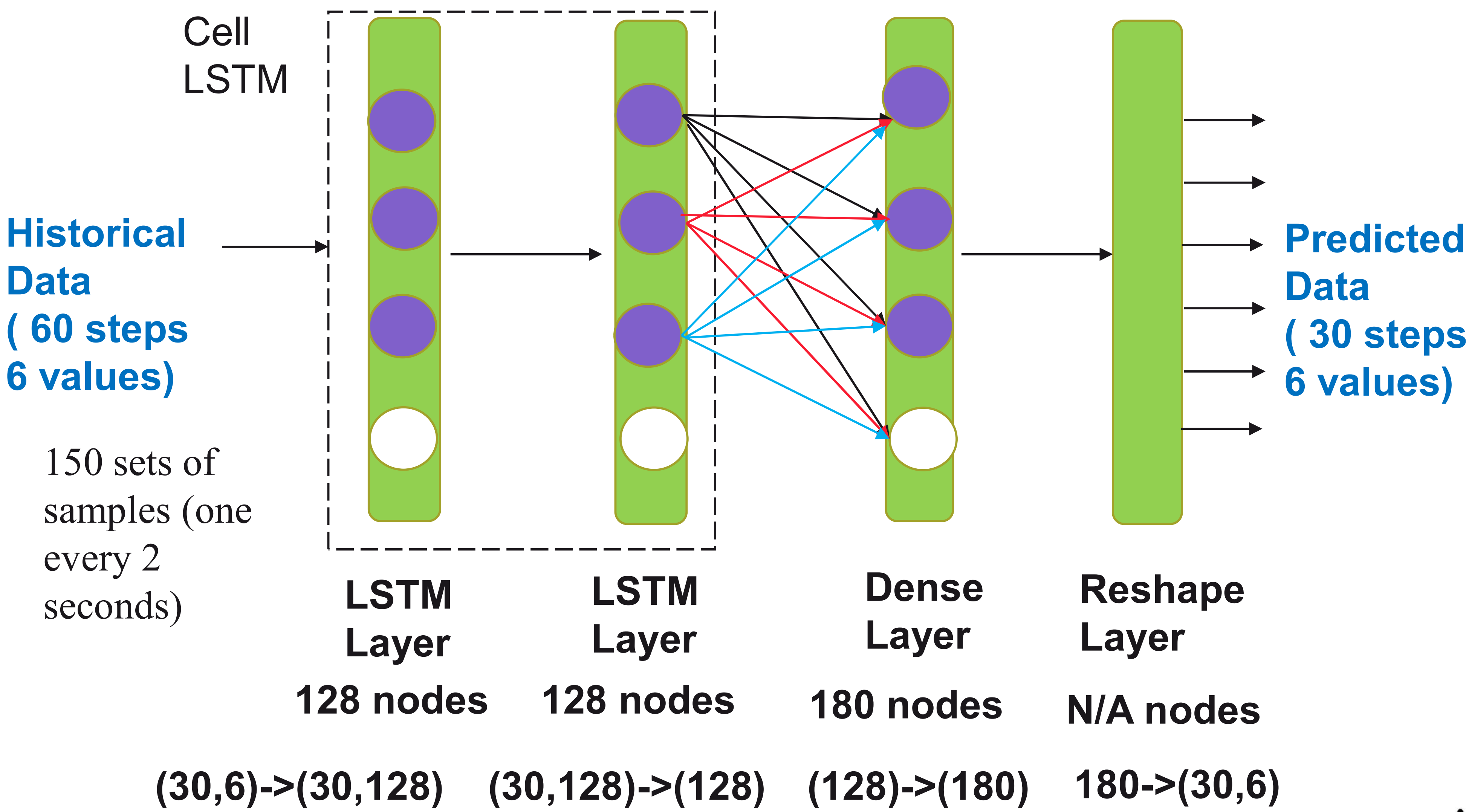


Pandas

python

ELT: Extraction / Loading / Transformation

Prediction of QoS indicators



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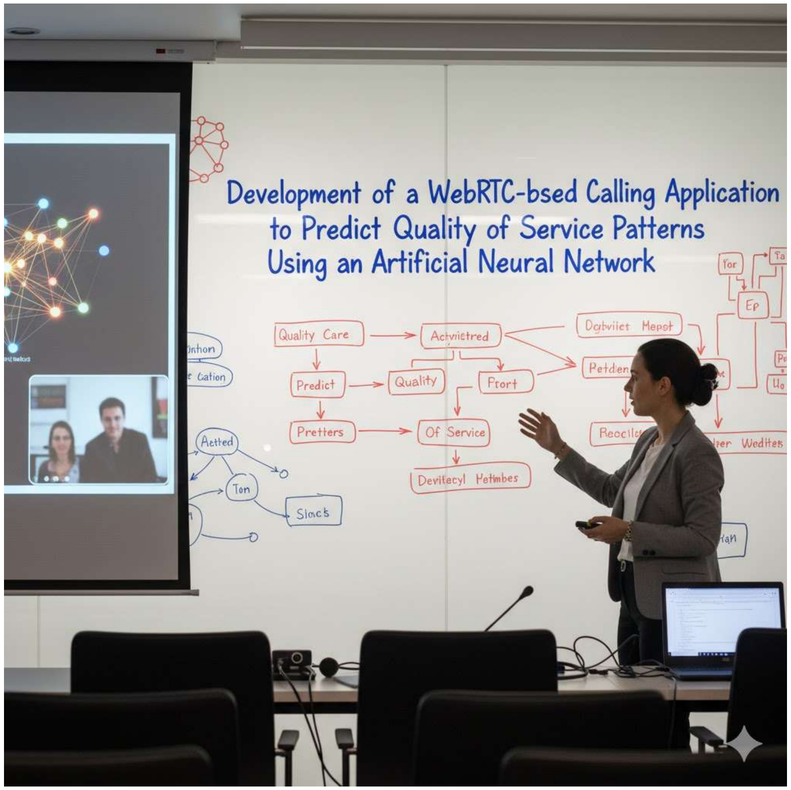
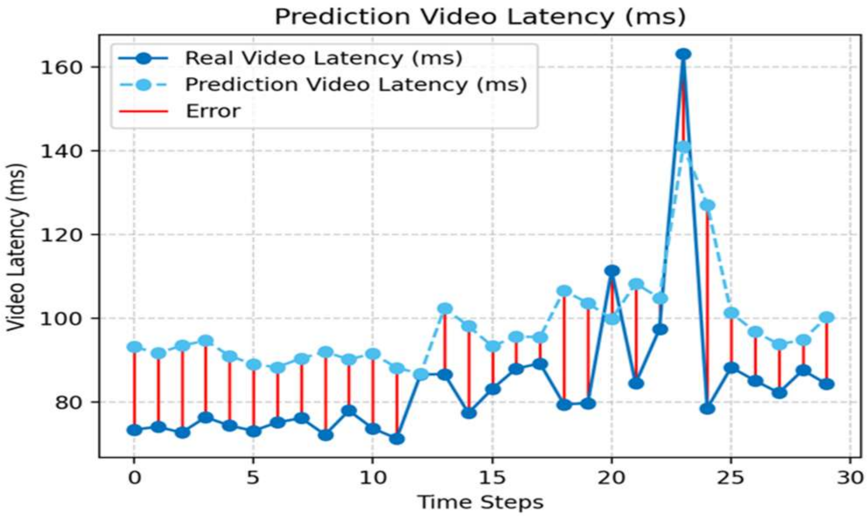
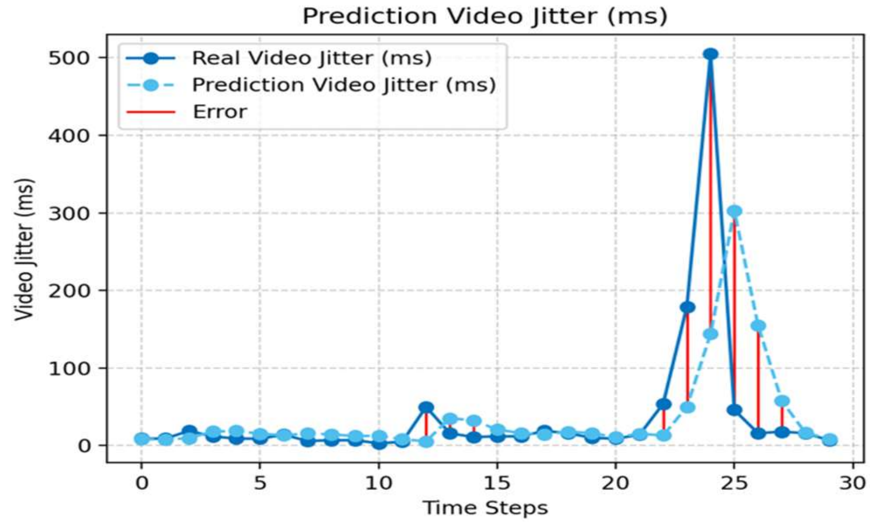
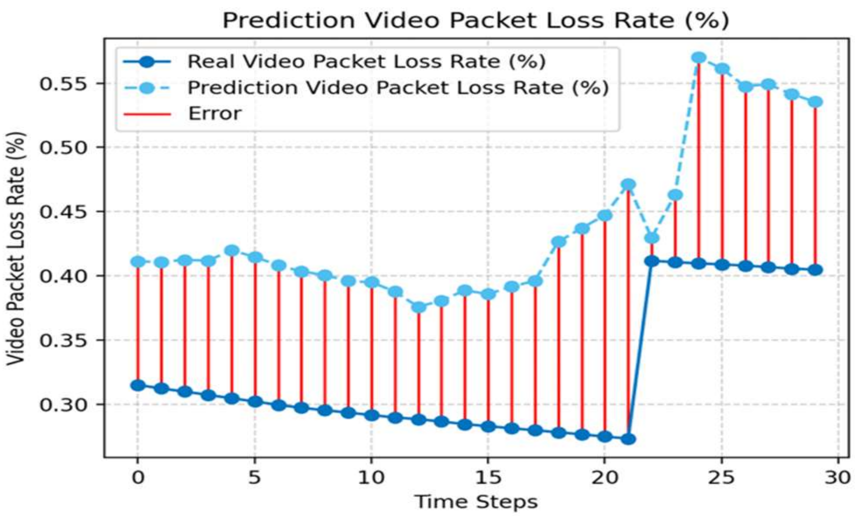


Results and analysis

- Scenario 1 - Acceptable Quality (Video)

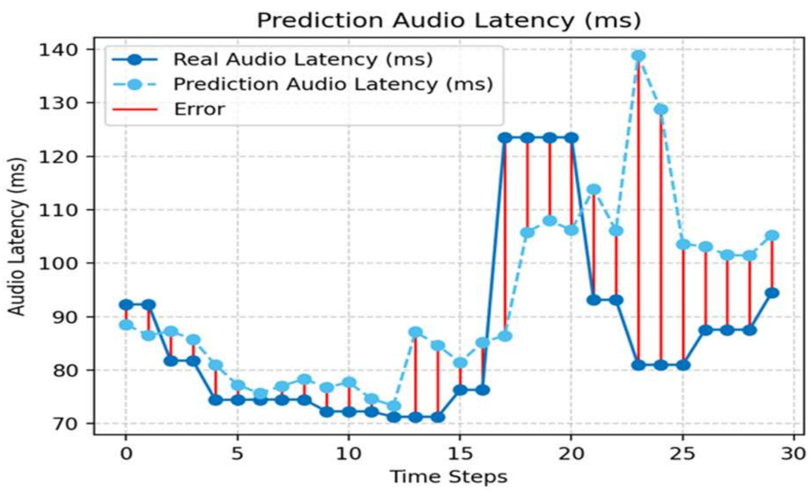


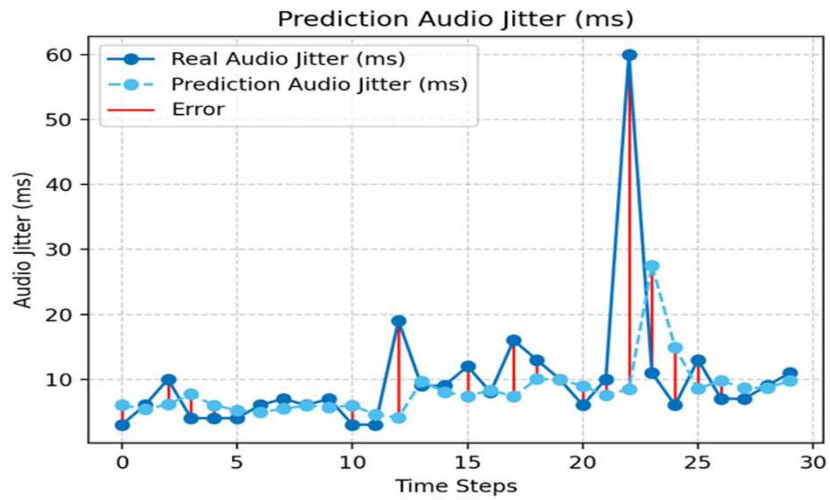


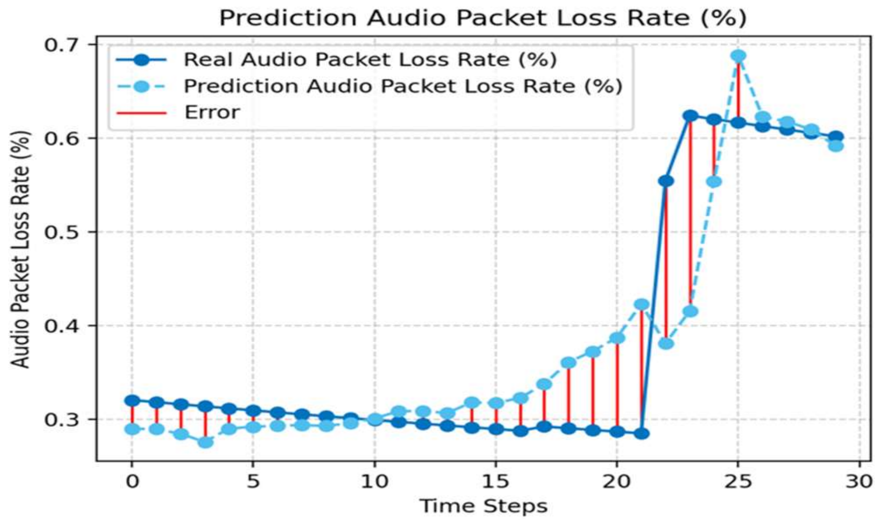


Results and analysis

❑ Scenario 1- Acceptable Quality (Audio)

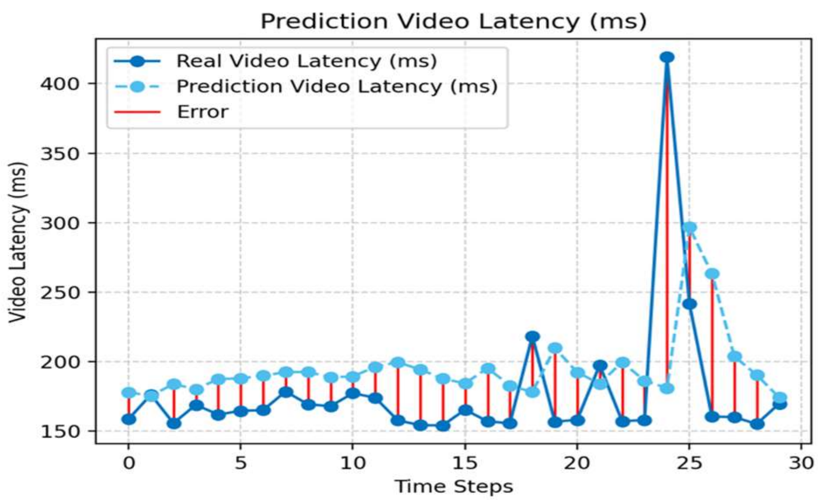


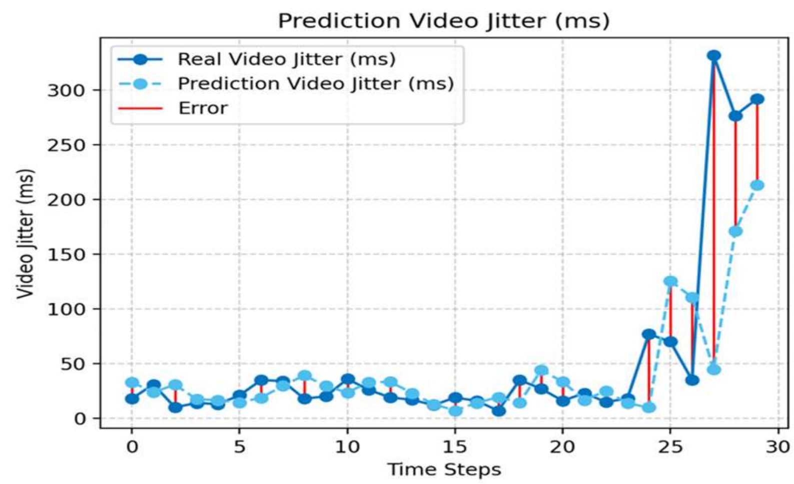


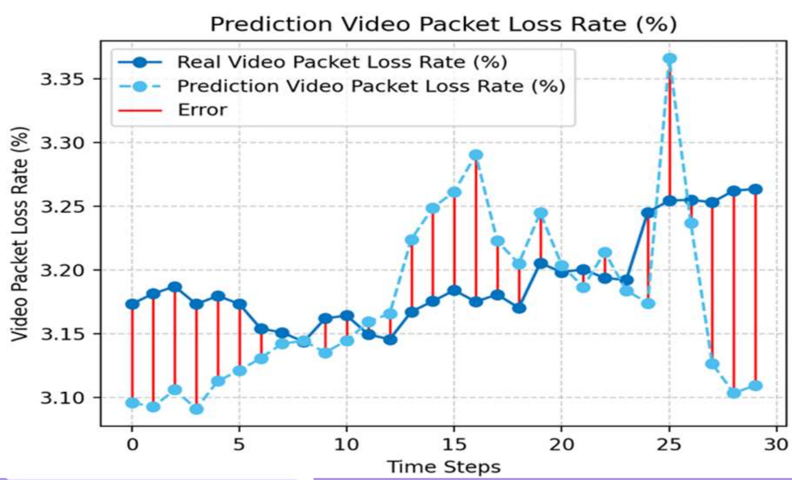


Results and analysis

❑ Scenario 2 - Moderate Degradation (Video)







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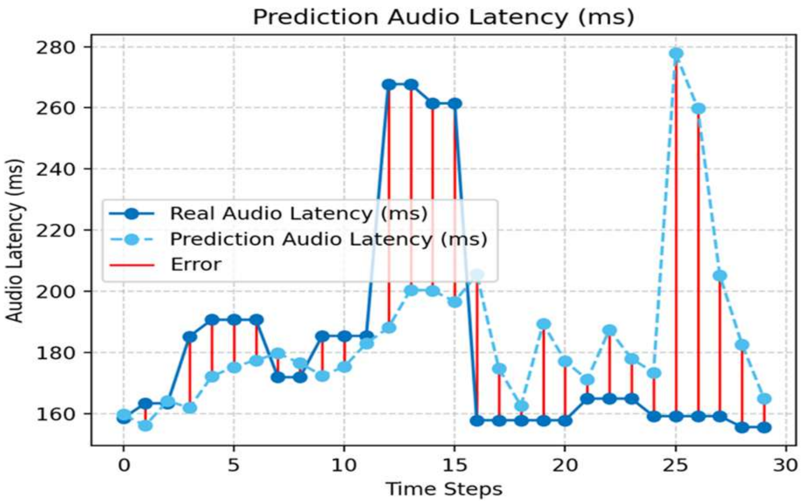
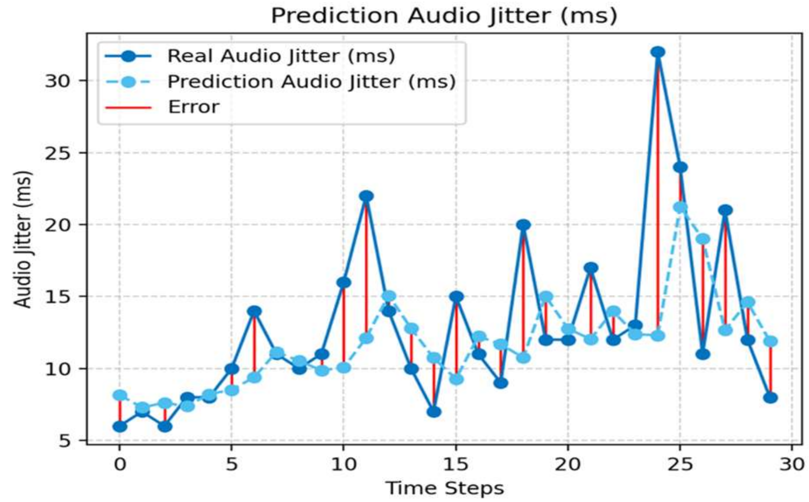
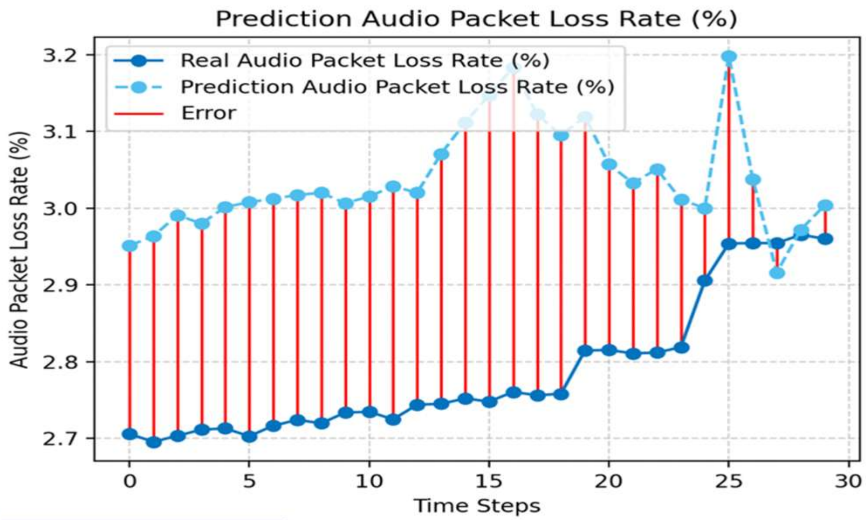
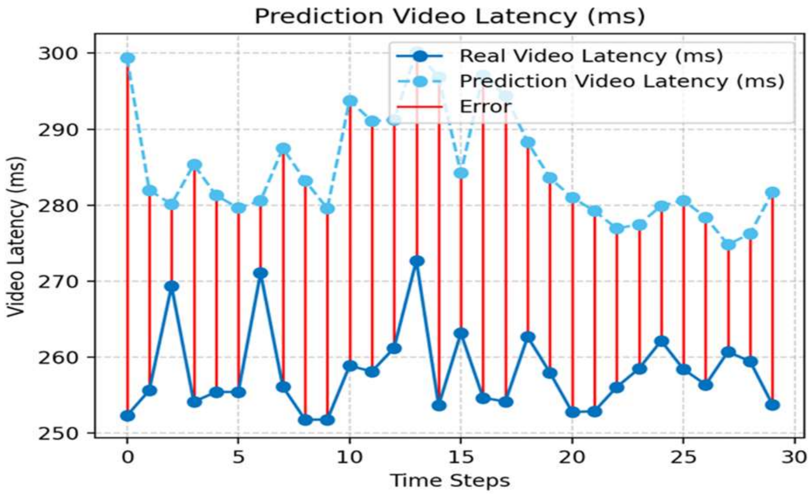


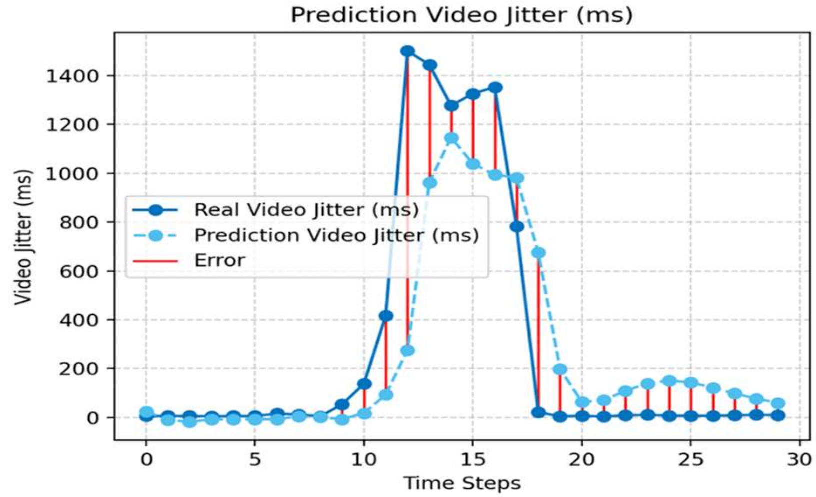


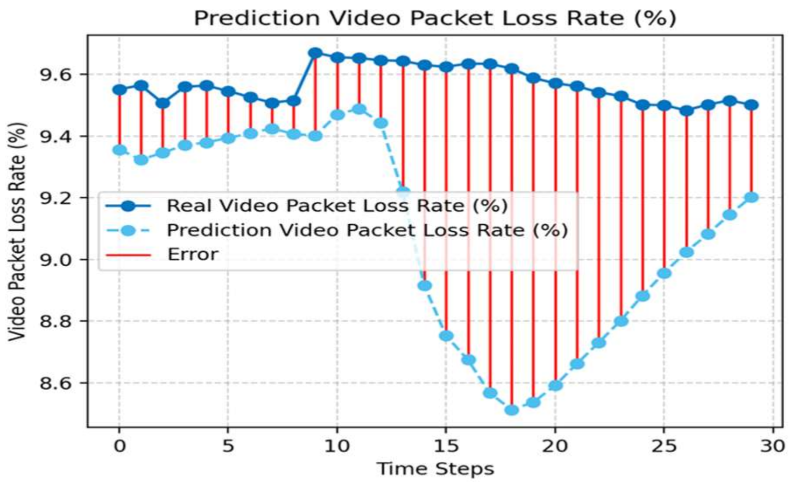


Results and analysis

❑ Scenario 3 - Critical Quality (Video)

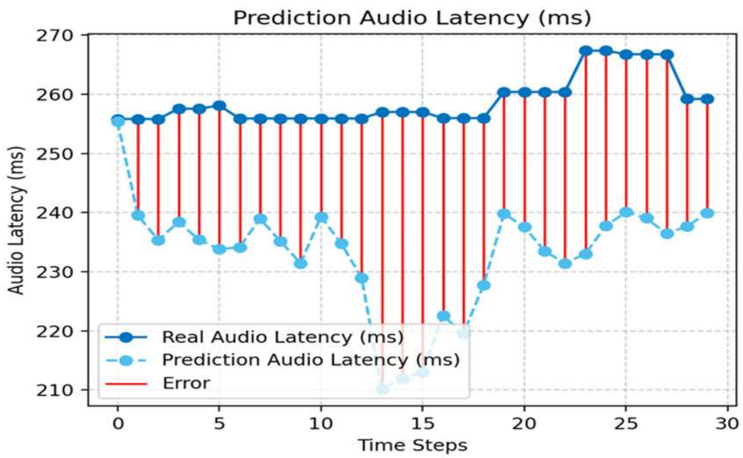


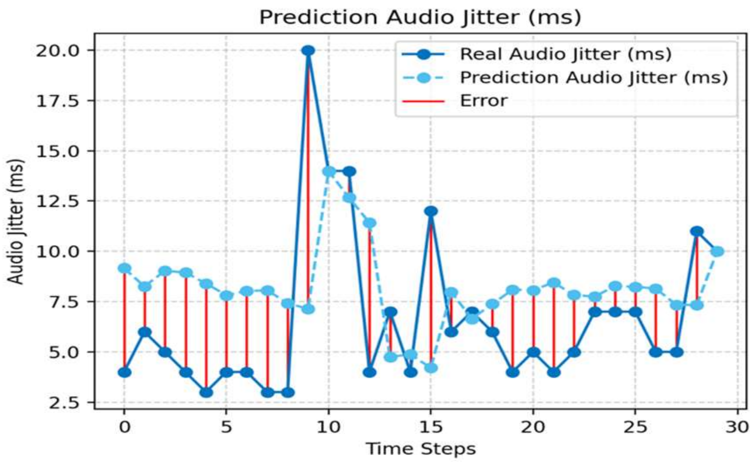


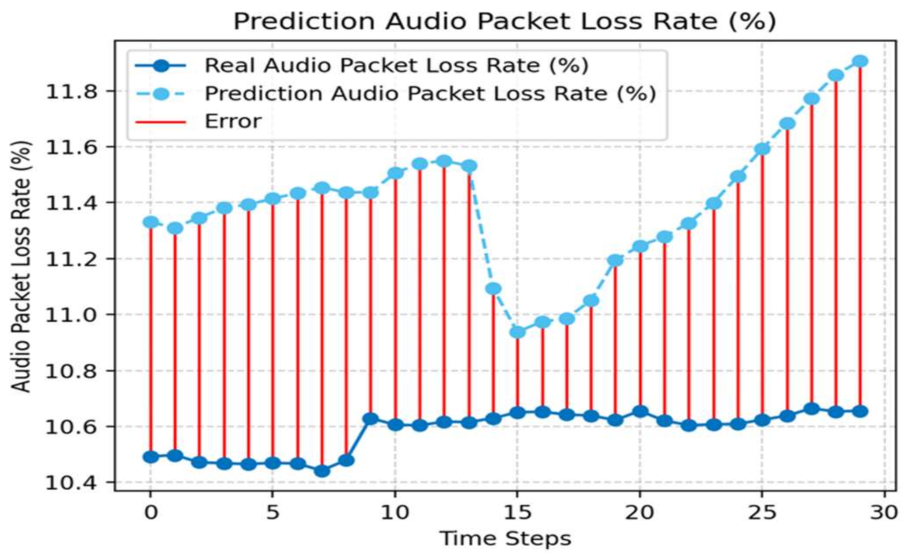


Results and analysis

❑ Scenario 3 - Critical Quality (Audio)

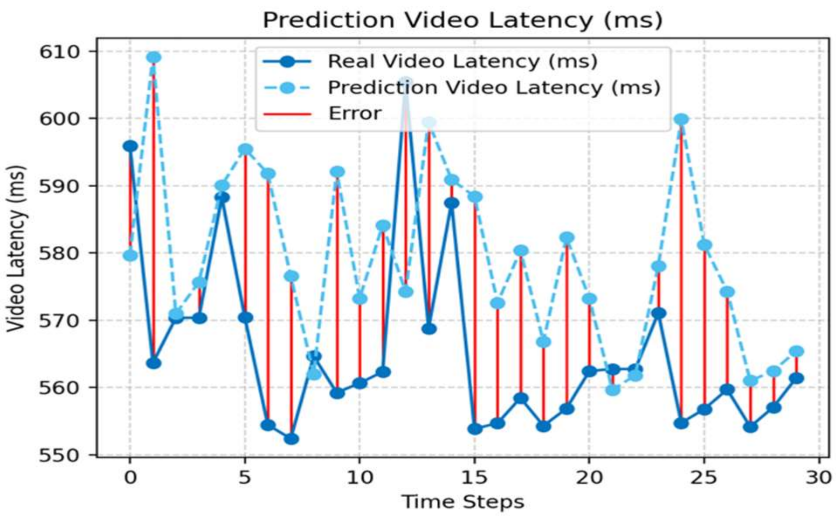


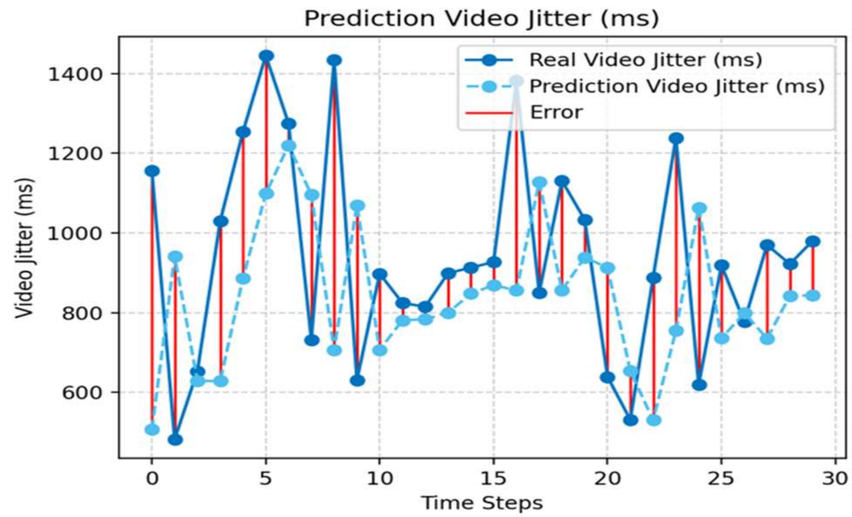


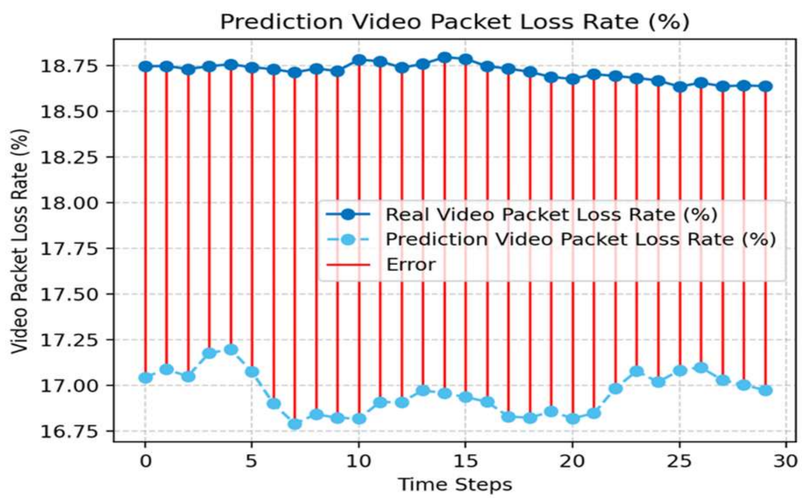


Results and analysis

Scenario 4 - Extreme Condition (Video)

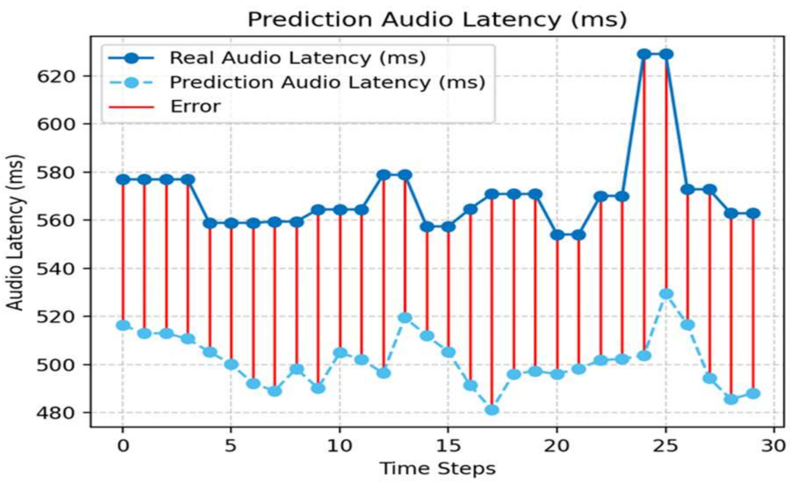


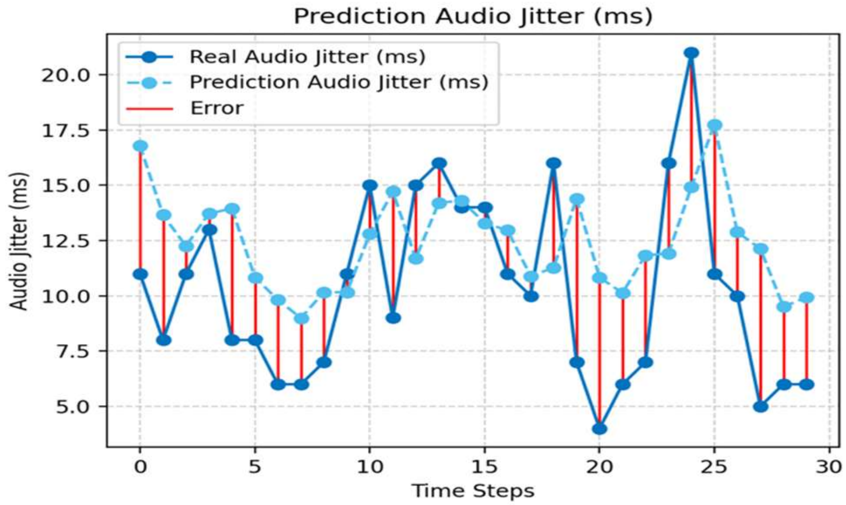


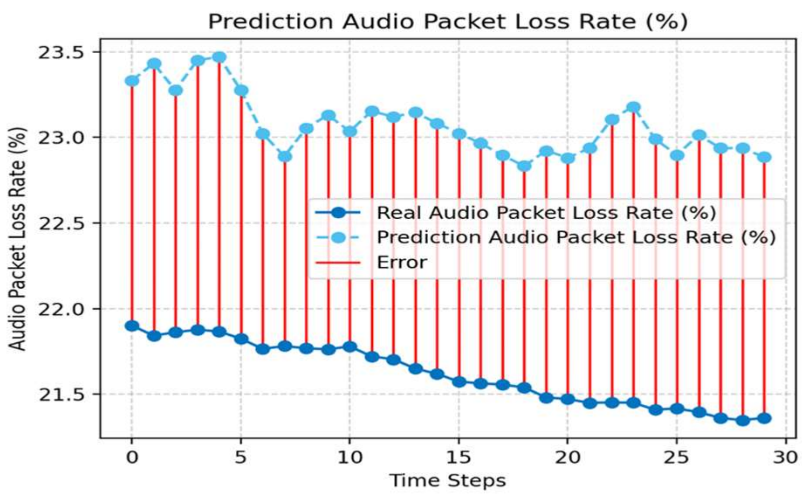


Results and analysis

❑ Scenario 4 - Extreme Condition (Audio)







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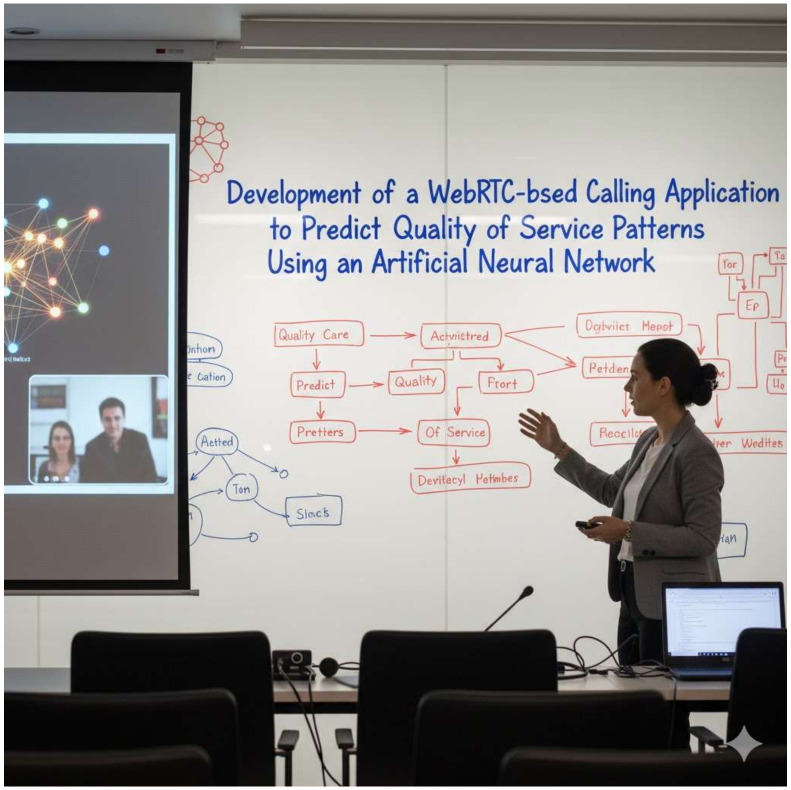

Conclusion

- The integration of technologies such as WebRTC and RNNs represents a viable and modern alternative for addressing the problem of QoS prediction in video-call applications.

- WebRTC, as a base technology, facilitates the creation of real-time communication environments with measurement and adaptation capabilities, removing previous technological barriers.

- LSTM-type neural networks are capable of capturing the temporal behavior of the evaluated metrics (latency, jitter, and packet loss rate), allowing the anticipation of their future evolution with an acceptable level of accuracy, especially under stable or moderately degraded conditions.

Conclusion

- **One of the most significant contributions of this work was demonstrating that a deep-learning-based model can be fed with the first few minutes of a call to generate reliable predictions of its future behavior.**

- **The adopted predictive approach demonstrated robustness when trained across multiple network scenarios, which allowed the neural network to learn diverse patterns and therefore generalize better under new conditions.**

Future Work

- The following recommendations are proposed to strengthen the developed solution and encourage future research:

- **Expansion of the dataset.**
- **Inclusion of new QoS and QoE metrics.**
- **Implementation of the model in real production environments.**
- **Exploration of more complex architectures.**
- **Design of autonomous network management systems.**

Questions

"The important thing is not to stop questioning."

Albert Einstein

PhD. Carlos Moreno.

Universidad Central de Venezuela.

Universidad de La Rioja

OBS Business School

carlosmanuel.moreno.ucv@gmail.com

+58-414-9191033

TELECIENTIFICA **@CarlosMorenoPhD**

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