Q-AIMD: A New Video Quality Based Congestion Aware Mechanism

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Alcatel·Lucent

About TCP AIMD congestion control

The main objective is to prevent network congestion

How?

- > The sender monitors the network state
- > Packet losses (or delay increase) as congestion indicator
- > AIMD principle is driven by losses and RTT
  - Additive Increase (AI) the congestion window (i.e., bit rate) if no packet losses are observed
  - Multiplicative Decrease (MD) the congestion window if packet losses occur

What we get: fairness among competing flows **in terms of throughput**

Does this remain consistent for multimedia flows?
Does throughput is the optimal metric to control for multimedia flows?

Existing proposals

- **Throughput based**
  - > Scalable Streaming Video Protocol (SSVP) [1]
  - > Multimedia streaming TCP-friendly protocol (MSTFP) [2]
- **Quality based**
  - > Resource-aware and quality-fair video streaming using multiple adaptive TCP connections [3]
  - > AIMD-like media-aware congestion control [4]
  - > Quality-centric congestion control for multimedia streaming [5]

[1] P. Papadimitriou et al., "SSVP : A congestion control scheme for real-time video streaming"

[2] Q. Zhang et al., "Resource allocation for multimedia streaming over the internet,"

[3] Y. Jung et al., "Resource-aware and quality-fair video-streaming using multiple adaptive TCP connections"

[4] O. Habachi et al., "Online learning based congestion control for adaptive multimedia transmission"

[5] H.-P. Shiang et al., "A quality-centric TCP-friendly congestion control for multimedia transmission"

Proposed Solution

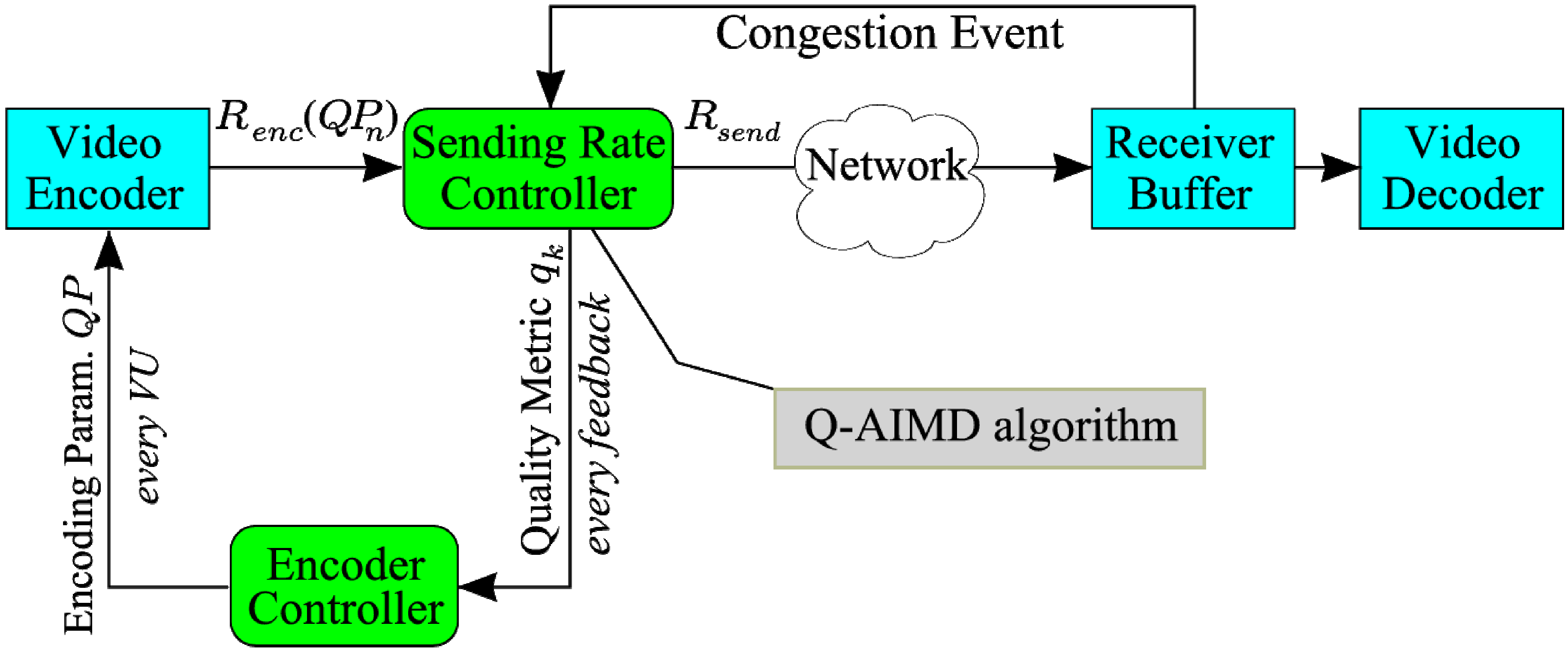
We propose Quality-AIMD (Q-AIMD)

- Targeting **video quality fairness** between multiple video sessions
- Low complexity congestion aware algorithm
- Generic algorithm for any video quality metrics

Rest of the presentation:

- Q-AIMD system description
- Q-AIMD algorithm
- Q-AIMD control granularity
- Possible video quality metrics
- Simulation results
- Conclusion

System description



- **Issues**
  - Control granularity of the Q-AIMD and encoder controllers
  - Quality metric for fairness constraint

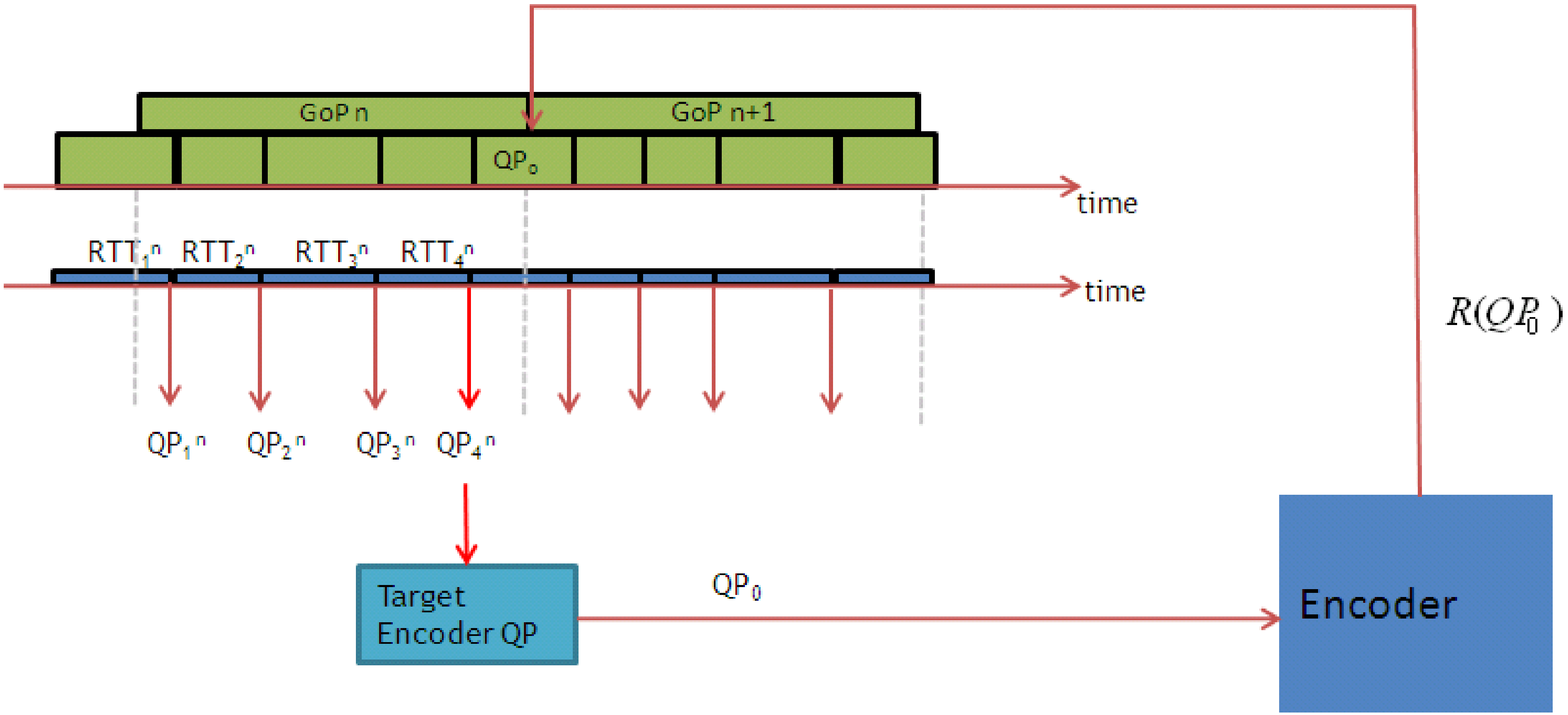
Q-AIMD algorithm

- Quality range [q_{worst}, q_{best}] (e.g., [30,45] dB in PSNR)
- Additive Increase: α_q(quality quantitive)
- Multiplicative Decrease: β_q ($0< \beta_q<1$)

Algorithm: Generic quality-AIMD algorithm

```
Upon reception of feedback from the receiver
if CongestionEvent then
    if q < q_worst then
        q = q_worst
    else
        q = q_worst + (q − q_worst)* β_q
    end if
else
    q = q + α_q
    if q > q_best then
        q = q_best
    end if
end if
```

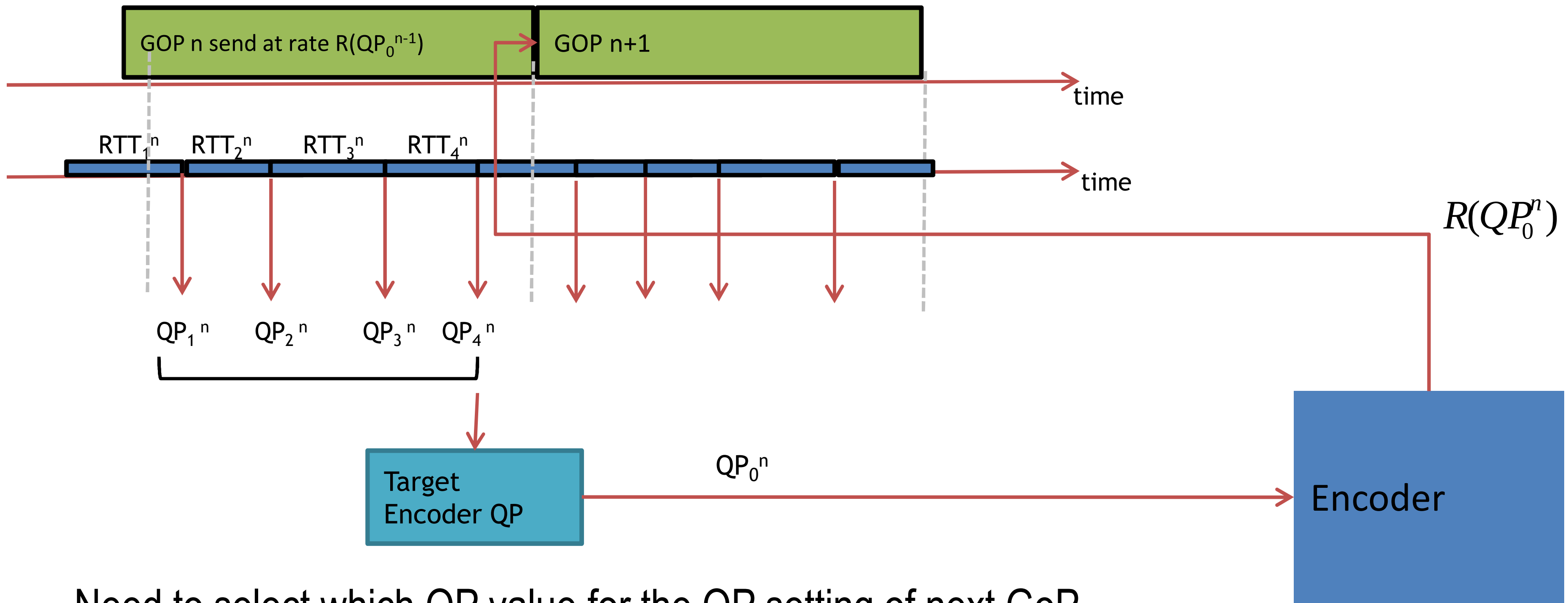
Granularity: fast adaptation at RTT scale



Need to:

- Check how to change QP setting at sub GoP level for every RTT_i
- Take care of mismatch between GoP and RTT boundaries!

Granularity: slow adaptation at GoP scale



Need to select which QP value for the QP setting of next GoP

Possibilities:

- Average QP
- Last QP
- If increase observed over $\{QP_i^n\}$, then set QP_0^n to $\lfloor \max QP_i^n \rfloor$
- If decrease observed over $\{QP_i^n\}$ then set QP_0^n to $\lfloor \min QP_i^n \rfloor$

Quality metrics

- Quantization Parameter (QP)
  - Not quality metric but video encoder input
- Peak Signal to Noise Ratio (PSNR)
  - Require Rate↔PSNR model
- Video Quality Metric (VQM)
  - Consideration of the spatial and temporal resolution

$$VQM = \alpha.PSNR + \beta.M_A.(30 - FR) + \frac{\delta}{\gamma + e^{-\omega x}} + \xi$$

> α, β, δ, ω, ξ, γ: model parameters
> FR, MA, x: frame rate, motion activity and height of the spatial resolution

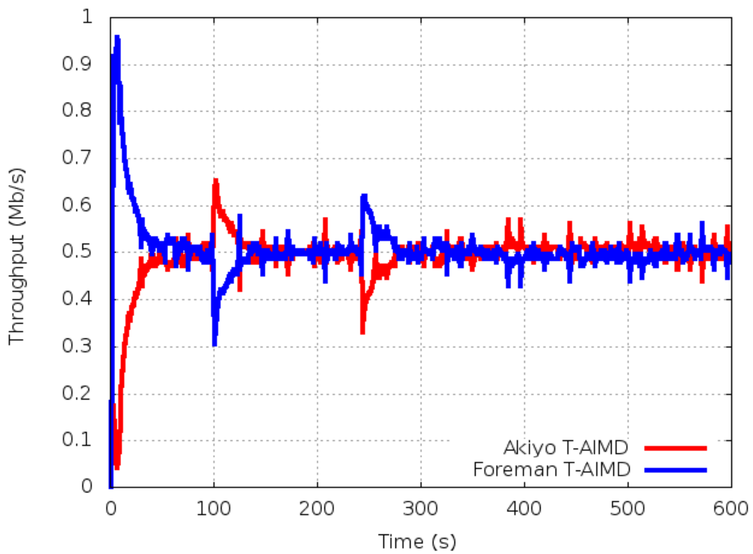
Experiment settings

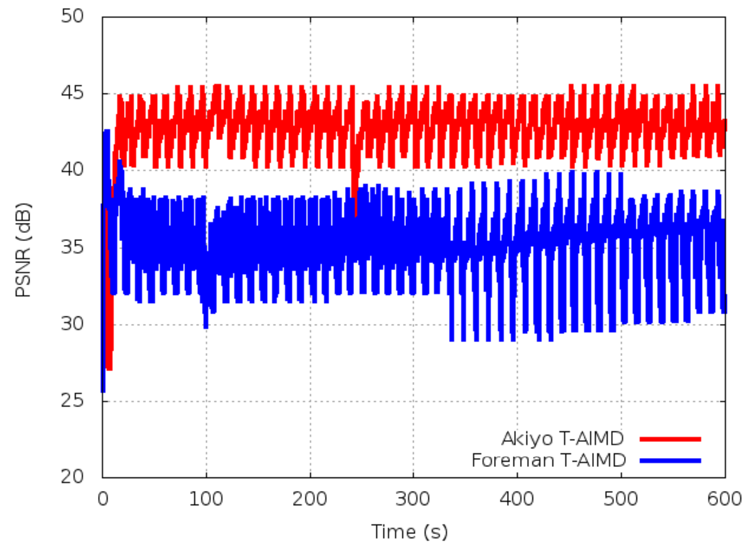
- Tool: ns-2
- Base RTT: 100ms
- Simulation duration: 600 seconds
- All flows start and stop at the same time
- Q-AIMD variants: PSNR-AIMD, QP-AIMD, VQM-AIMD
- Reference case: throughput based AIMD (T-AIMD)
- Video settings: 25 Hz with GoP size of 5 images

Parameters	PSNR-AIMD	QP-AIMD	VQM-AIMD
(q_{worst}, q_{best})	(30,50) dB	(50,1)	(30,100)
(α_q, β_q)	(0.15,0.85)	(-1.0,0.85)	(1.0,0.85)

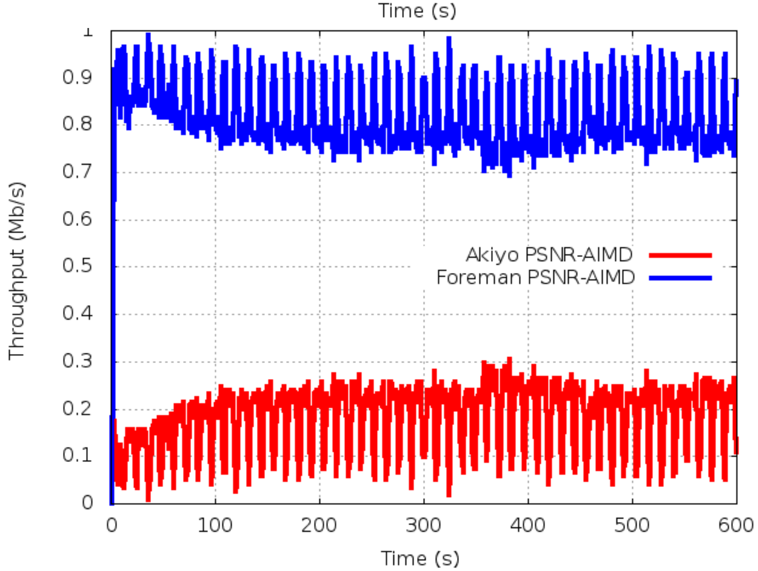
Two videos with same spatial resolution CIF

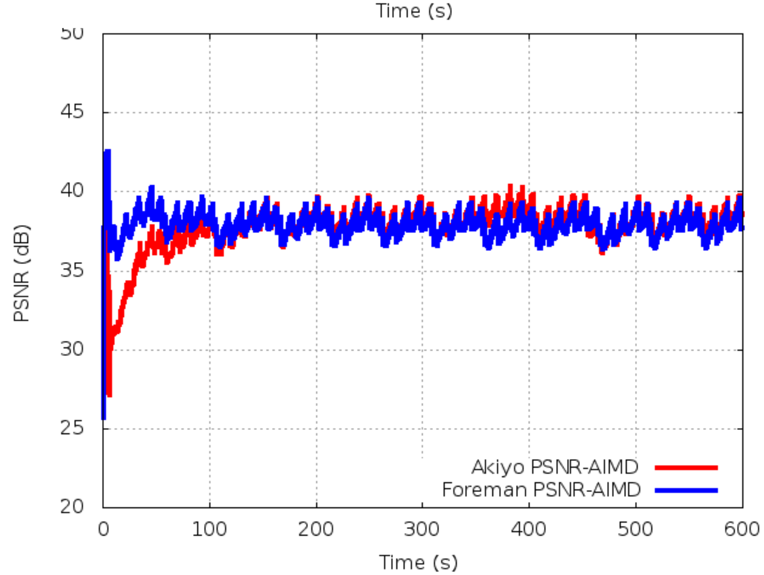
T-AIMD





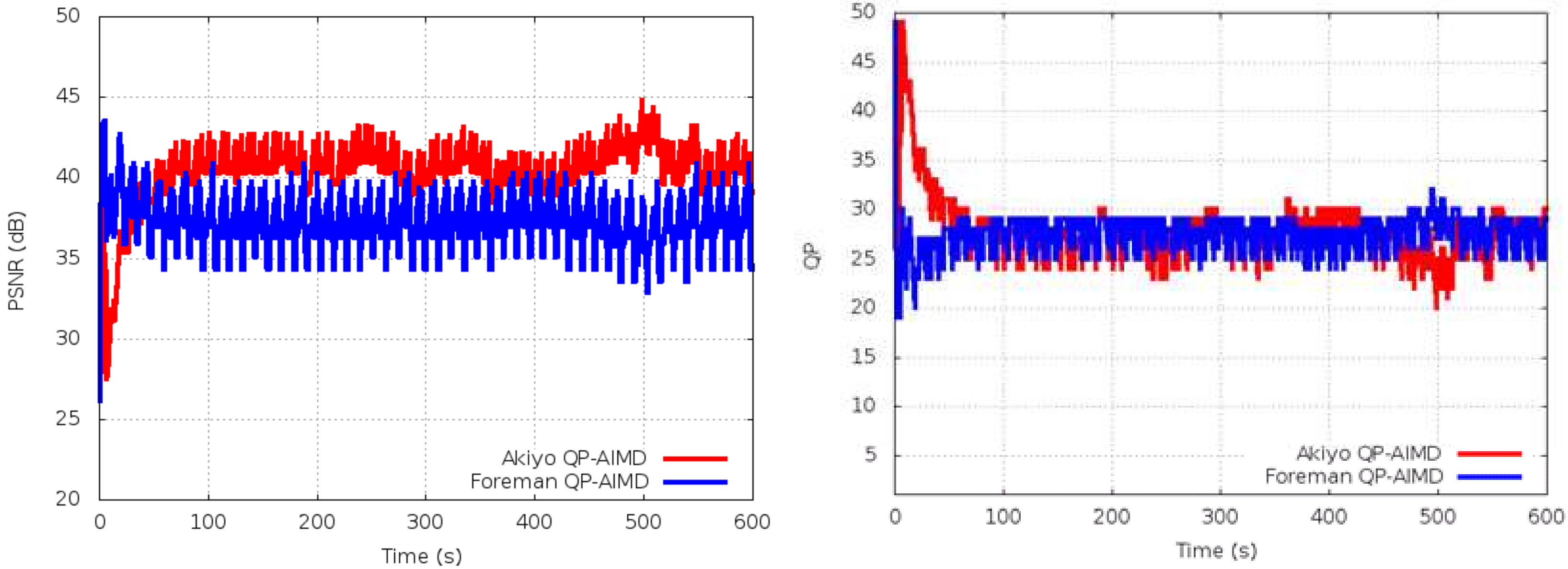
PSNR-AIMD





Two videos with same spatial resolution CIF

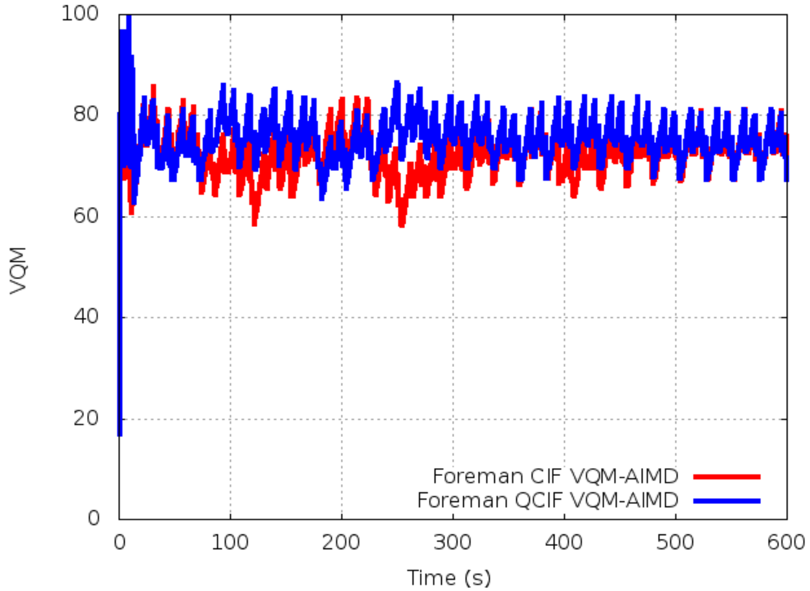
QP-AIMD

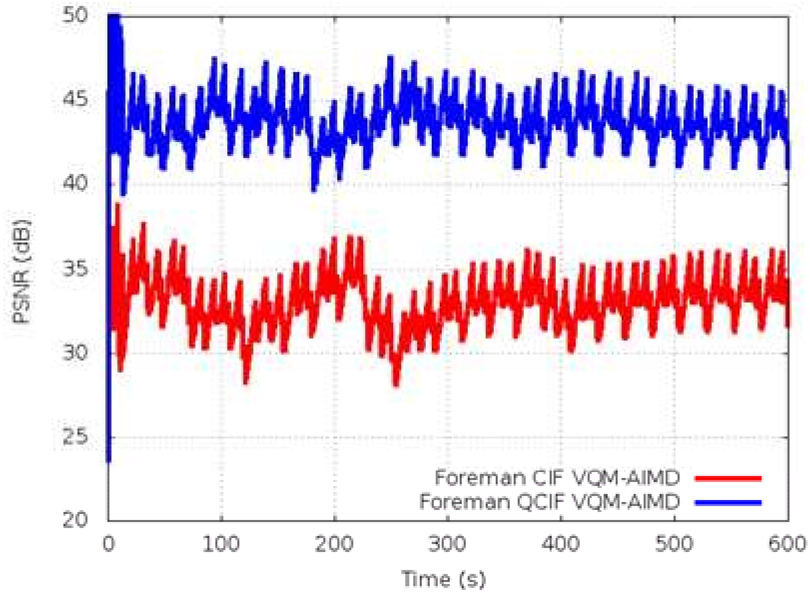


	PSNR (dB)			Throughput (Mb/s)	
	Akiyo	Foreman	Delta	Akiyo	Foreman
PSNR-AIMD	37.75	37.93	**0.18**	0.18	0.82
QP-AIMD	40.32	37.09	**3.23**	0.28	0.72
VQM-AIMD	38.91	37.79	**1.12**	0.21	0.78
T-AIMD	42.76	34.95	**7.81**	0.49	0.51

Two videos with different spatial resolutions

VQM-AIMD





	PSNR (dB)			VQM			Throughput (Mb/s)	
	CIF	QCIF	Delta	CIF	QCIF	Delta	CIF	QCIF
PSNR-AIMD	37.27	38.35	1.08	84.62	59.64	**24.98**	0.72	0.27
QP-AIMD	36.71	38.32	1.61	82.98	59.55	**23.43**	0.70	0.30
VQM-AIMD	33.00	43.74	10.74	72.24	75.27	**3.03**	0.34	0.66
T-AIMD	34.67	41.54	6.87	77.08	68.91	**8.17**	0.48	0.51

Six videos with same spatial resolution

	Akiyo	Coastguard	Foreman	Hall	Mother	Silent	Max Delta
PSNR-AIMD	36.44	**35.01**	35.74	35.60	**36.48**	35.62	**1.47**
QP-AIMD	**40.41**	**33.70**	35.83	37.36	39.67	35.39	**6.71**
VQM-AIMD	**37.83**	**34.67**	35.14	35.62	37.34	35.25	**3.16**
T-AIMD	**42.73**	**31.06**	34.74	36.92	41.68	34.63	**11.67**

Six videos with different spatial resolutions

	CIF			QCIF			
	Akiyo	Coastguard	Foreman	Akiyo	Coastguard	Foreman	
			PSNR (dB)				**Max Delta**
PSNR-AIMD	36.95	**36.07**	36.61	**37.54**	36.55	36.69	**1.47**
QP-AIMD	41.17	**35.21**	36.99	**41.21**	36.25	38.07	**6.0**
VQM-AIMD	35.63	**32.76**	33.82	**43.96**	42.13	42.65	**11.2**
T-AIMD	42.64	**30.99**	34.74	**49.20**	37.91	41.21	**18.21**
			VQM				**Max Delta**
PSNR-AIMD	**83.69**	81.13	82.71	57.29	**54.43**	54.85	**29.26**
QP-AIMD	**95.93**	78.63	83.80	67.93	**53.55**	58.82	**42.38**
VQM-AIMD	**79.85**	71.52	74.62	75.90	**70.61**	72.12	**9.24**
T-AIMD	**100.18**	66.40	77.26	91.11	**58.37**	67.95	**41.81**

Conclusions and future work

Conclusions

- Targeted video quality metric as fairness convergence criteria based on AIMD principle
- System to deploy Q-AIMD and its control granularity
- Obtained an important decrease in the video quality discrepancies between the different transmitted video flows
- Evaluated video quality using different metrics

Future work

- Analyze the convergence of the algorithm and study the fairness against different TCP variants
- Use the erasure codes to protect from packet losses and evaluate the video quality at the receiver side

Thank you for your attention!

Questions?

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