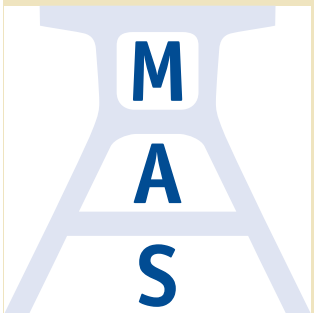


UNIVERSITÄT
DUISBURG
ESSEN

Open-Minded

A Comprehensive End-to-End Lag Model for Online and Cloud Video Gaming

Florian Metzger, Albert Rafetseder, Christian Schwartz

Games and Frames

CS:GO gameplay at 30fps (Competitively played at 120+)

scene from `https://www.youtube.com/watch?v=02I5vVxlJhU`

Games and Frames

same scene at 6fps

scene from `https://www.youtube.com/watch?v=02I5vVxlJhU`

Motivation and Past Issues

- Increasing research interest for (networked) video game QoS and QoE
- Increasing focus on and demands of **competitive games**
- But: past user studies treated video games akin to video streaming:

Motivation and Past Issues

- Increasing research interest for (networked) video game QoS and QoE
- Increasing focus on and demands of **competitive games**
- But: past user studies treated video games akin to video streaming:
  - Insufficient framerates (e.g. $\leq$ 15 Hz)
  - Wrong choice of metrics to detect effects of lag (e.g. time-scale wise)
  - Focus just on network delay, not full E2E lag
  - Often short observation periods
  - Influences of gameplay mechanics not considered
  - Difficulties to generalize results from individual games to whole “genres”

Motivation and Past Issues

- Increasing research interest for (networked) video game QoS and QoE
- Increasing focus on and demands of **competitive games**
- But: past user studies treated video games akin to video streaming:
  - Insufficient framerates (e.g. $\leq$ 15 Hz)
  - Wrong choice of metrics to detect effects of lag (e.g. time-scale wise)
  - Focus just on network delay, not full E2E lag
  - Often short observation periods
  - Influences of gameplay mechanics not considered
  - Difficulties to generalize results from individual games to whole "genres"
- Many interlocked mechanics in play, we need to understand their effects!
- Specifically: framerate and tickrate

$\Rightarrow$ Set up a small simulation to investiate the impact of the framerate

Framerate and Frametime (or Duration)

Rate at which the game renders distinct images. Frametime is the duration a frame is displayed.

Frame- and Tickrates

Framerate and Frametime (or Duration)

Rate at which the game renders distinct images. Frametime is the duration a frame is displayed.

Tickrate

Rate at which the server in a client/server-game updates its game simulation state.

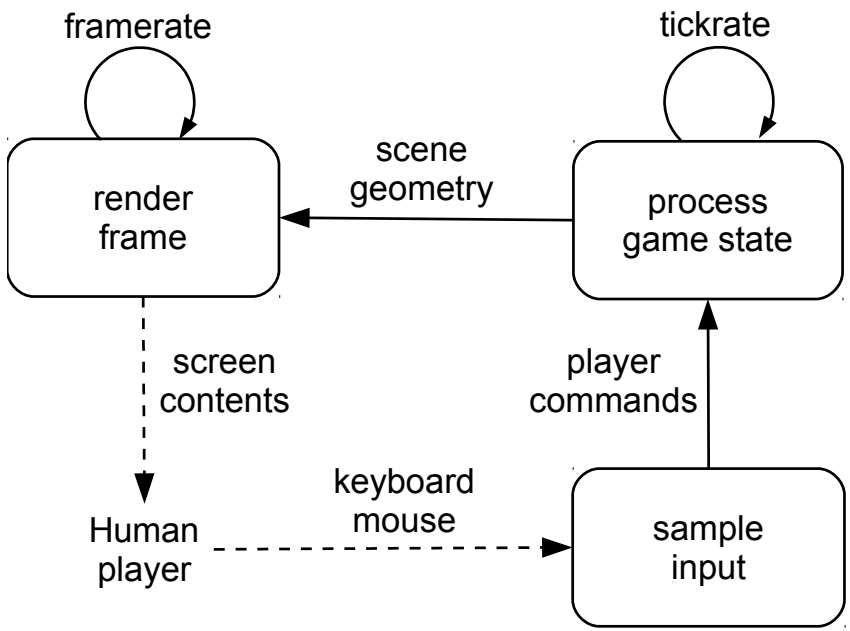
Frame- and Tickrates

Framerate and Frametime (or Duration)

Rate at which the game renders distinct images. Frametime is the duration a frame is displayed.

Tickrate

Rate at which the server in a client/server-game updates its game simulation state.

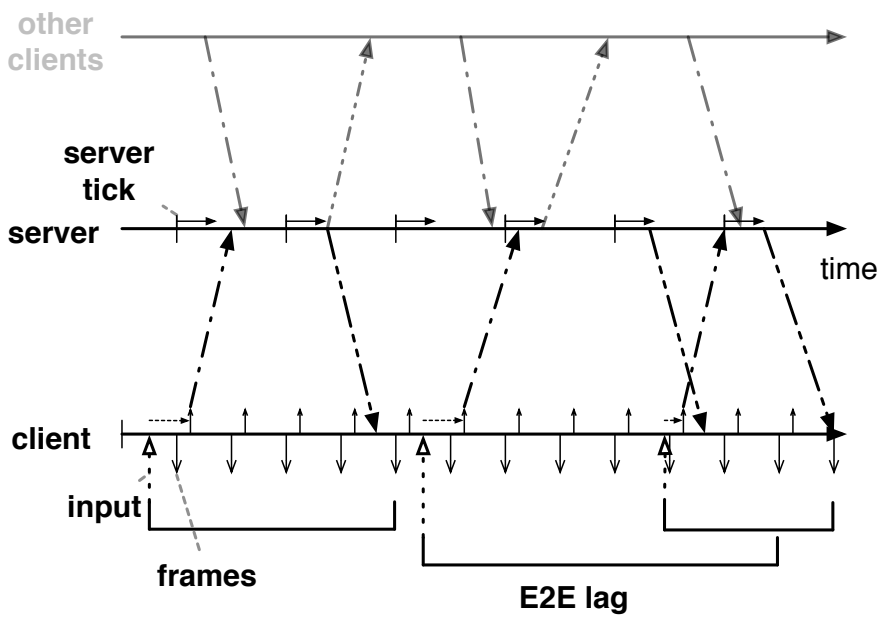


End-to-End (E2E) Lag

- Perceived delay and delay variation between input action and visible reaction
- **Cause**: various sources, including network QoS, I/O devices, game engine, game mechanics
- But also through the **interplay of framerate and tickrate**
- Examples of tickrates in c/s-games: CS:GO 64 Hz to 128 Hz; Dota 2 30 Hz; Overwatch 60 Hz

End-to-End (E2E) Lag

- Perceived delay and delay variation between input action and visible reaction
- **Cause**: various sources, including network QoS, I/O devices, game engine, game mechanics
- But also through the **interplay of framerate and tickrate**
- Examples of tickrates in c/s-games: CS:GO 64 Hz to 128 Hz; Dota 2 30 Hz; Overwatch 60 Hz



Information Deficit through Low Framerate

Low framerates are a source of lag

http://blog.logicalincrements.com/2015/04/does-fps-matter-decide-for-yourself/

Attributes and Measures of Lag

- Lag affects reaction and timings in gameplay ⇒ player performance

⇒ Potentially largest **QoE** influencer

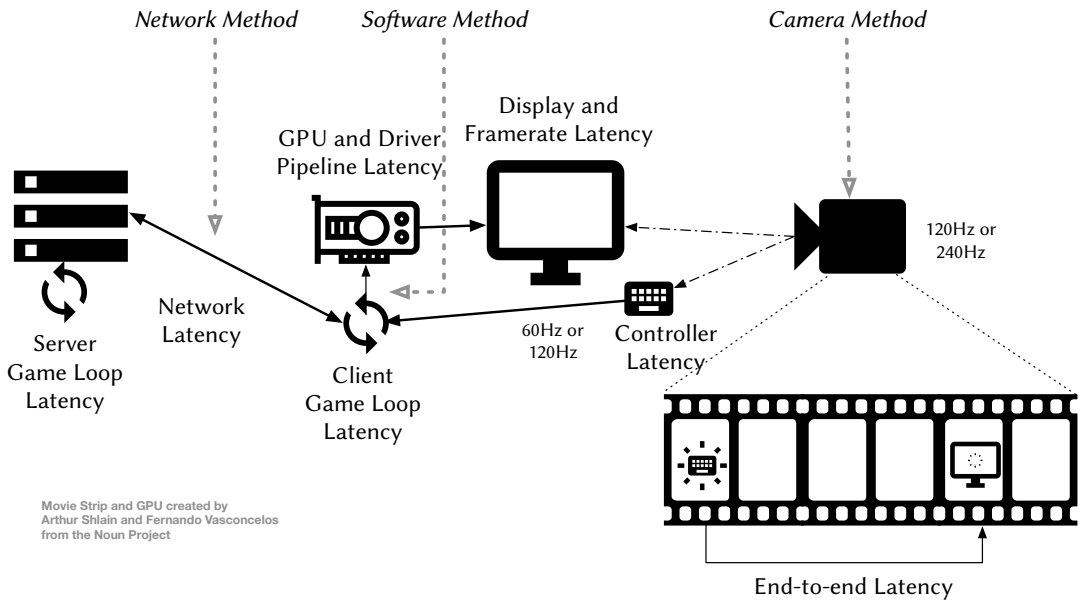
- Every game, every gameplay action, can behave differently under lag
- Difficult to observe E2E lag and attribute to individual lag sources

Attributes and Measures of Lag

- Lag affects reaction and timings in gameplay ⇒ player performance

⇒ Potentially largest **QoE** influencer

- Every game, every gameplay action, can behave differently under lag
- Difficult to observe E2E lag and attribute to individual lag sources

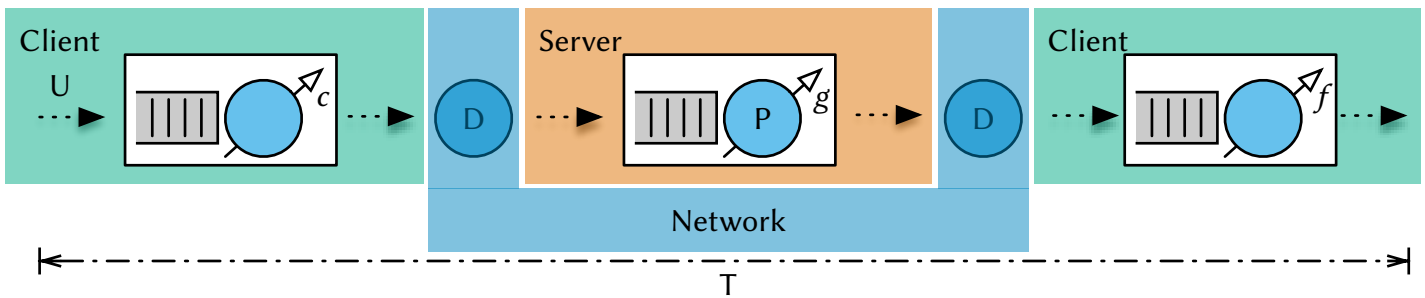


Modeling and Simulating Lag

- Instead of measurements: lag sources modeled in a queuing system
- **Goal**: investigate lag sources not typically attributed to lag
  - Especially: frame- and tickrate; but also: message rates, input and display devices, …
- Frame- and tickrate modeled as independent, clocked processes

Modeling and Simulating Lag

- Instead of measurements: lag sources modeled in a queuing system
- **Goal**: investigate lag sources not typically attributed to lag
  - Especially: frame- and tickrate; but also: message rates, input and display devices, …
- Frame- and tickrate modeled as independent, clocked processes



- Implemented as an R simulation[1]
- Evaluated for several scenarios and parameter combinations

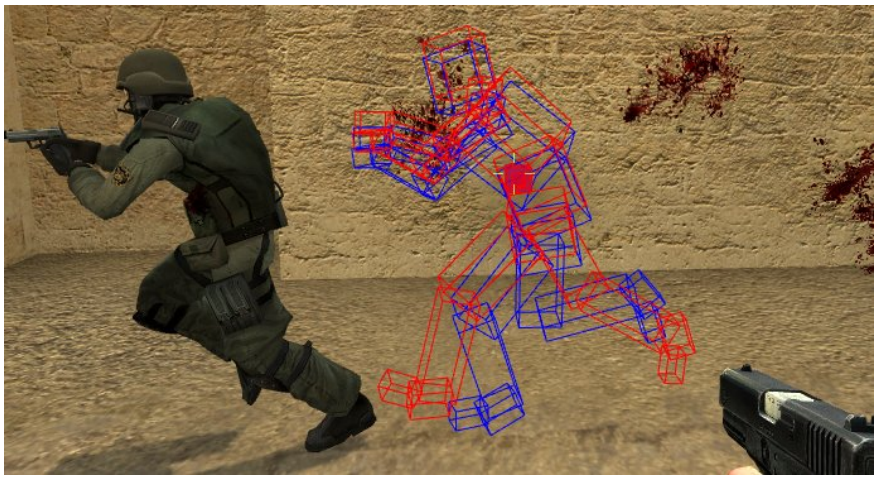
[1] `https://github.com/mas-ude/onlinegame-lag-sim`

Model Limitations and Caveats

Lag-Concealing Features in Games

Examples of features that can reduce lag impact in games, but are not considered in the model and sim:

- Immediate visualization and output of object actions through client-side **prediction** (e.g. player movement) without waiting for authoritative answer
  - Roll back action if prediction wrong
- **Interpolate** motion between consecutive game simulation snapshots from the server, or extrapolate from last two snapshots
- Lag **compensation** by doing hit detection on object positions slightly in the past

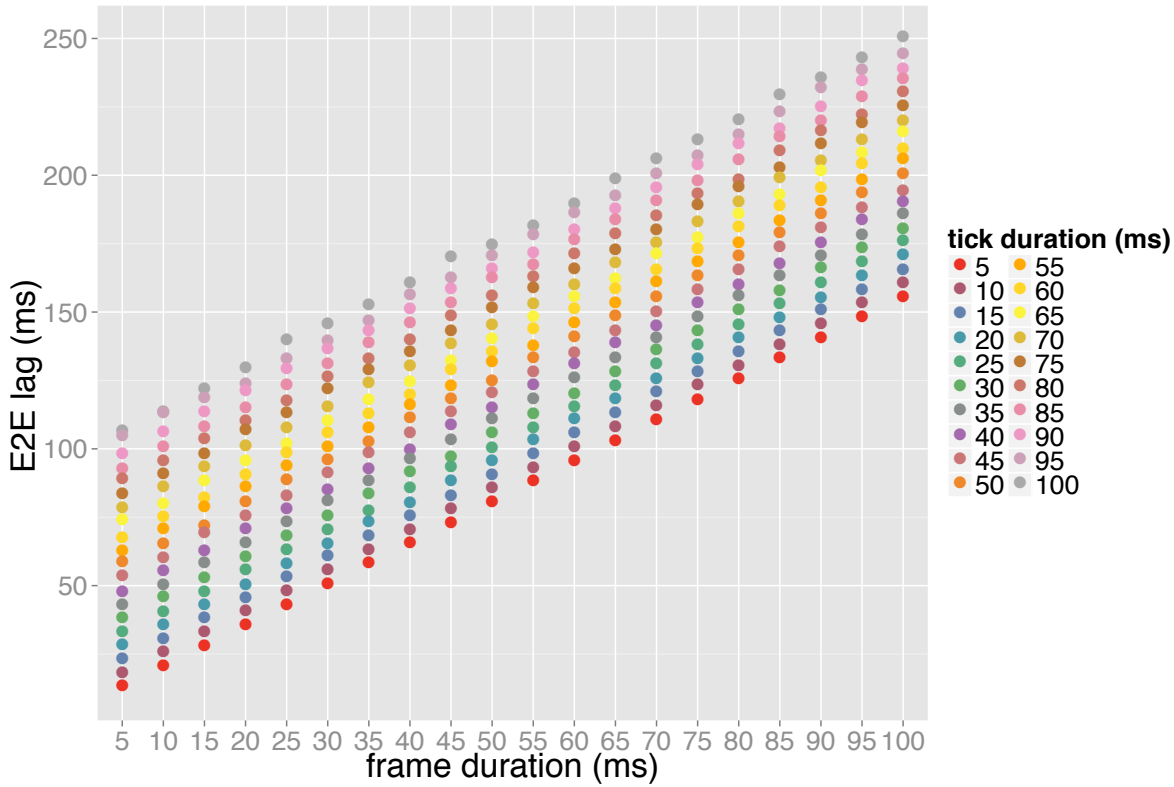


`developer.valvesoftware.com/wiki/Lag_compensation`

Local Game Simulation

A.K.A.: Best Case Lag Scenario

Locally running C/S-game, no network interactions involved, average of 1000 runs.

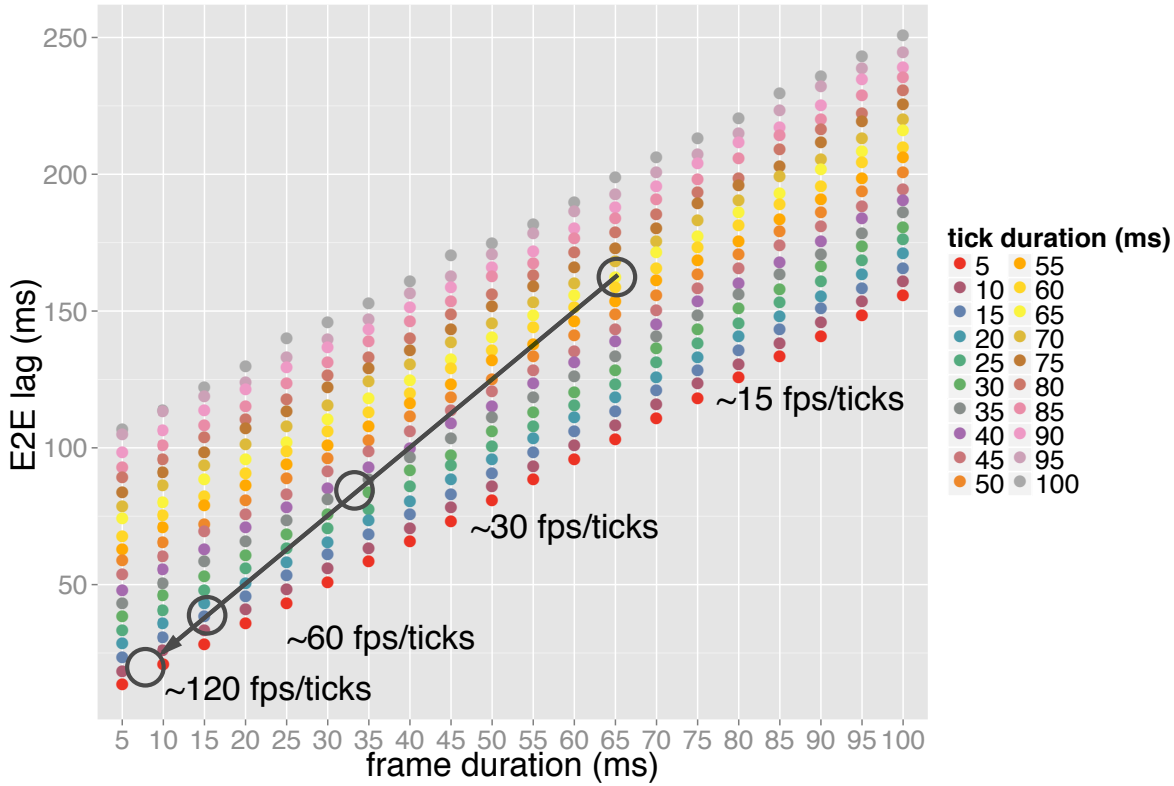


(Note 16.67 ms frame duration $\hat{=}$ 60 Hz framerate)

Local Game Simulation

A.K.A.: Best Case Lag Scenario

Locally running C/S-game, no network interactions involved, average of 1000 runs.



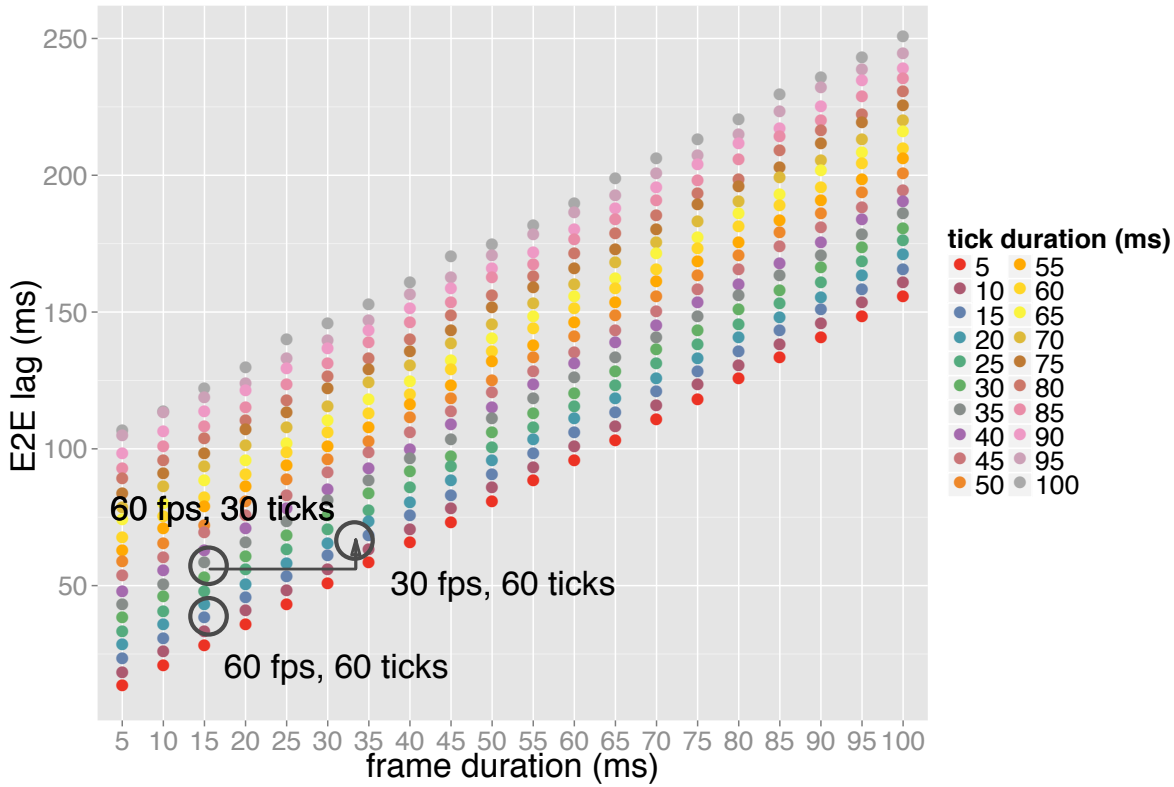
Linear decrease of E2E lag

e.g.: 50 ms less when going from 30 to 60 fps and ticks.

Local Game Simulation

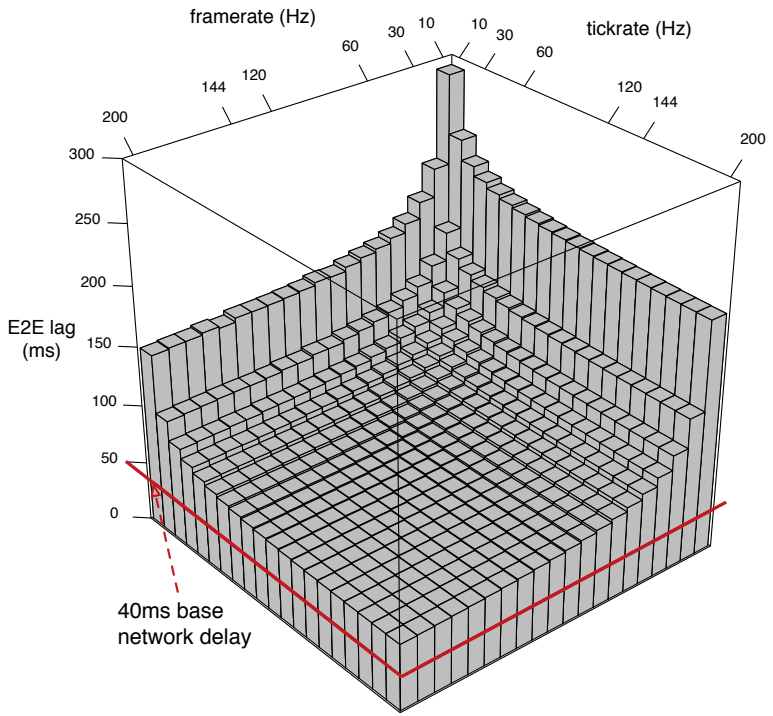
A.K.A.: Best Case Lag Scenario

Locally running C/S-game, no network interactions involved, average of 1000 runs.



Bigger impact of framerate than tickrate!

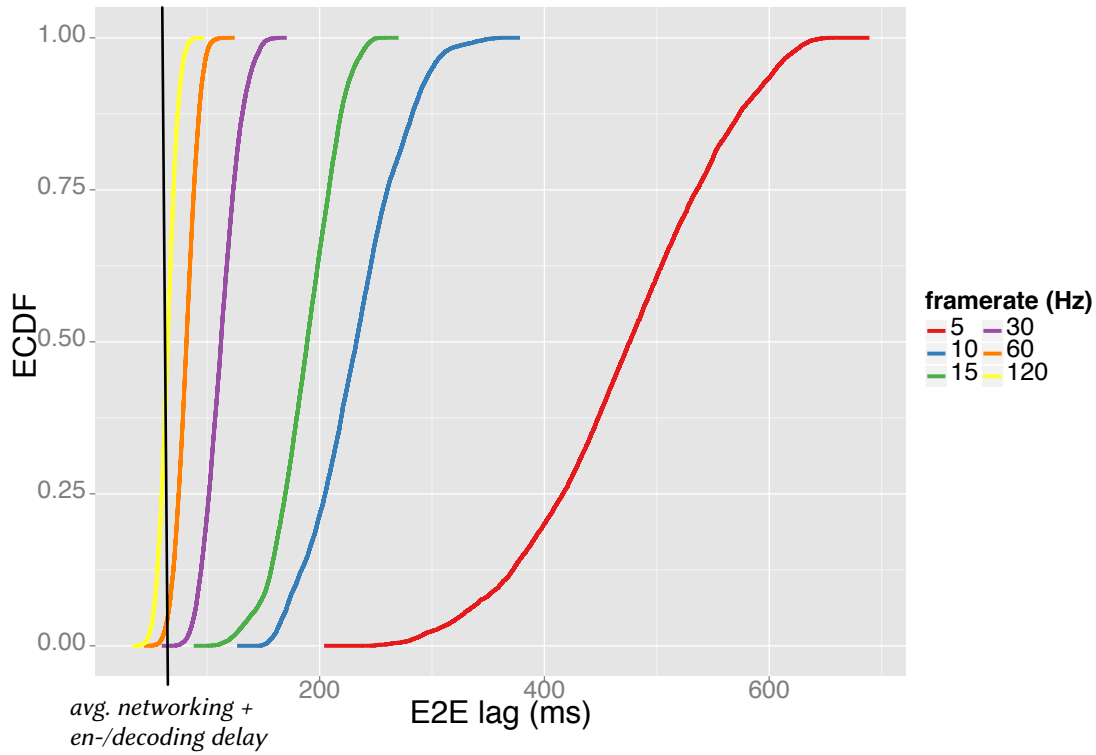
Median lag of a networked game at 10 Hz to 200 Hz frame- and tickrates



Network is not the main source of lag at low frame-/tickrates!

Cloud Game Simulation

Similar to networked C/S but with added video en-/decoding delay and frame transmission times.



Large E2E lag and wide spread of lag values

⇒ **Gameplay actions appear to be “stuttering”!**

Conclusions

Recap:

- Examining framerates and tickrates as a large QoE factor
- Simplified simulation of typical gaming scenarios
- Complex scenario due to interactivity and diversity of video games
- Larger influence of framerates than generally thought in academia
- **Keep lag sources other than network in mind!**

Conclusions

Recap:

- Examining framerates and tickrates as a large QoE factor
- Simplified simulation of typical gaming scenarios
- Complex scenario due to interactivity and diversity of video games
- Larger influence of framerates than generally thought in academia
- **Keep lag sources other than network in mind!**

In the future:

- More extensive simulation setup (more influence factors, variable framerates, triple buffering, ...)
- Focus on frametimes and resulting stuttering
- Cross-check with real world E2E lag measurements
- Derive guidelines for future gaming user studies

Questions?

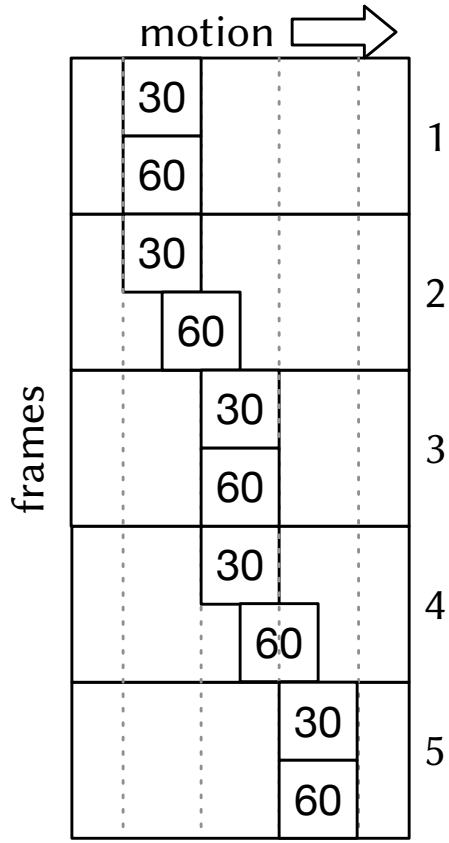
`https://github.com/mas-ude/onlinegame-lag-sim`

Contact: `florian.metzger@uni-due.de`

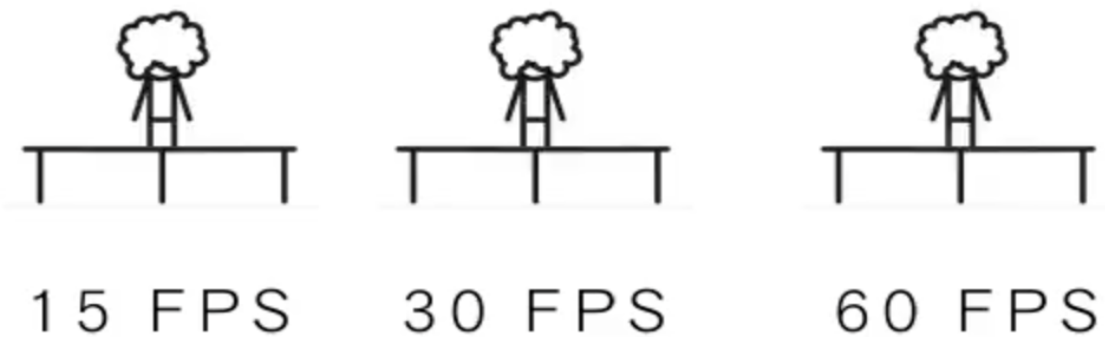
Key fingerprint: `C98A 32B7 554F C5CC 4E5A 60FB 1CE5 B541 7B20 99C7`

Appendix

Static Framerate Figure

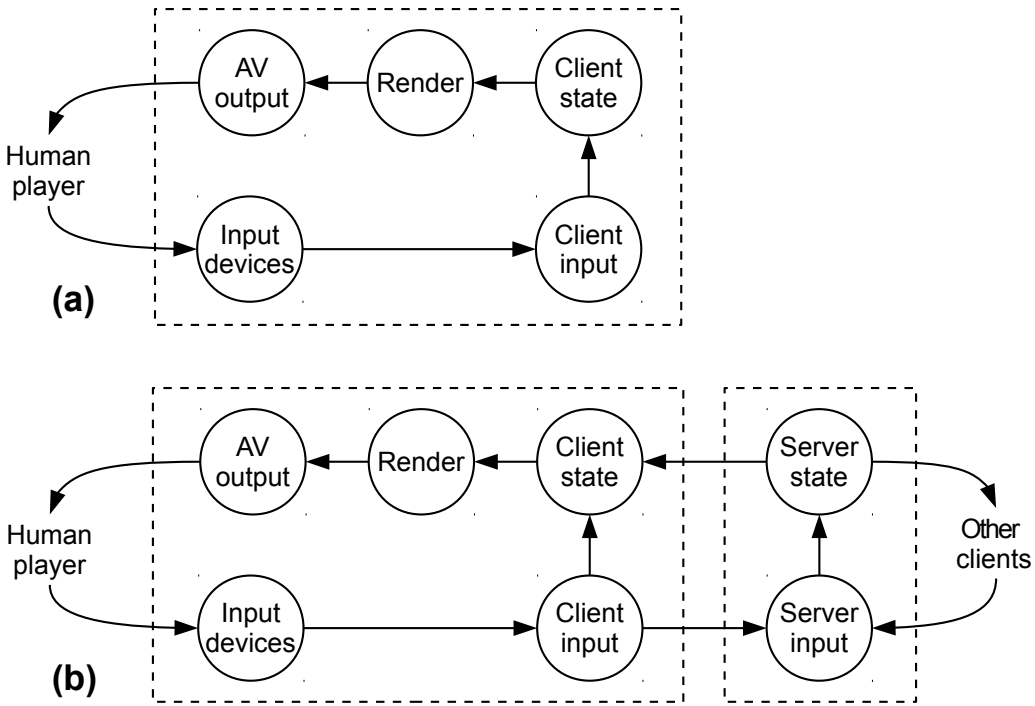


Alternate Framerate Animation



http://hugelol.com/lol/364250

Simplified Video Game Main Loops



(a) local game, *(b)* networked game, *(c)* cloud game

Tickrates in Video Games

Command message rates and client update rates can differ from server tickrates

Video Game	Tickrate
CS: GO	Configurable 64 Hz/128 Hz
Battlefield 4	Configurable 60 Hz/120 Hz; previously 30 Hz with 10 Hz for state outside of close proximity
Minecraft	max. 20 Hz
League of Legends	30 Hz
Dota 2	30 Hz
StarCraft II	supposedly either 16 Hz or 32 Hz
Eve Online	1 Hz
Overwatch	60 (client update rate previously was 20)

Note: Values are not verified and may be unreliable

References I

G. Armitage. "An experimental estimation of latency sensitivity in multiplayer Quake 3."
In: *Networks, 2003. ICON2003. The 11th IEEE International Conference on.* Sept. 2003, pp. 137–141.

Michael Bredel and Markus Fidler. "A Measurement Study Regarding Quality of Service and Its Impact on Multiplayer Online Games."
In: *Proceedings of the 9th Annual Workshop on Network and Systems Support for Games.* NetGames '10. Taipei, Taiwan: IEEE Press, 2010, 1:1–1:6. ISBN: 978-1-4244-8355-6.

Mark Claypool and Kajal Claypool. "Latency and Player Actions in Online Games."
In: *Commun. ACM* 49.11 (Nov. 2006), pp. 40–45. ISSN: 0001-0782.

KajalT. Claypool and Mark Claypool.
"On frame rate and player performance in first person shooter games."
In: *Multimedia Systems* 13.1 (2007), pp. 3–17. ISSN: 0942-4962.

References II

Kuan-Ta Chen, Polly Huang, and Chin-Laung Lei.

"Effect of Network Quality on Player Departure Behavior in Online Games."

In: *Parallel and Distributed Systems, IEEE Transactions on* 20.5 (May 2009), pp. 593–606.

ISSN: 1045-9219.

V. Clincy and B. Wilgor.

"Subjective Evaluation of Latency and Packet Loss in a Cloud-Based Game."

In: *Information Technology: New Generations (ITNG), 2013 Tenth International Conference on.*

Apr. 2013, pp. 473–476.

Zenja Ivkovic, Ian Stavness, Carl Gutwin, and Steven Sutcliffe. "Quantifying and Mitigating the Negative Effects of Local Latencies on Aiming in 3D Shooter Games."

In: *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems.*

CHI '15. Seoul, Republic of Korea: ACM, 2015, pp. 135–144. ISBN: 978-1-4503-3145-6.

References III

M. Jarschel, D. Schlosser, S. Scheuring, and T. Hossfeld.

"An Evaluation of QoE in Cloud Gaming Based on Subjective Tests." In: *Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS), 2011 Fifth International Conference on.* June 2011, pp. 330–335.

Florian Metzger, Albert Rafetseder, Christian Schwartz, and Tobias Hoßfeld.

"Games and Frames: A Strange Tale of QoE Studies."

In: *Proceedings of the 8th International Conference on Quality of Multimedia Experience.* QoMEX 2016. June 2016.

Sebastian Möller et al.

"Towards a New ITU-T Recommendation for Subjective Methods Evaluating Gaming QoE."

In: (2015).

References IV

M. Ries, P. Svoboda, and M. Rupp.

"Empirical study of subjective quality for Massive Multiplayer Games."

In: *Systems, Signals and Image Processing, 2008. IWSSIP 2008. 15th International Conference on.* June 2008, pp. 181–184.

Colin Ware and Ravin Balakrishnan.

"Reaching for Objects in VR Displays: Lag and Frame Rate."

In: *ACM Trans. Comput.-Hum. Interact.* 1.4 (Dec. 1994), pp. 331–356. ISSN: 1073-0516.

Max Wertheimer. "Experimentelle Studien über das Sehen von Bewegung." PhD thesis. 1912.