Quantitative Analysis Of Cosmos Blockchain

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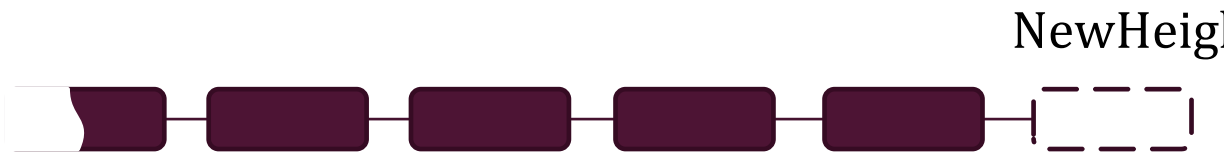
Background: What is Cosmos?

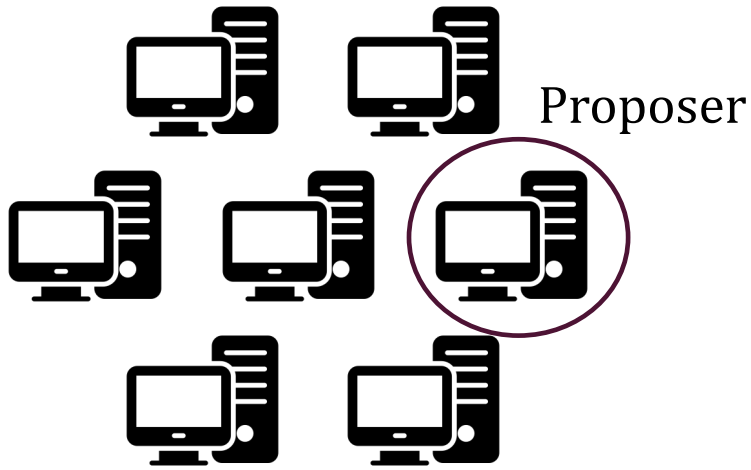
- Network of blockchain networks
- PoS-driven
- CosmosBFT (Tendermint) consensus
- InterBlockchain Communication

Consensus

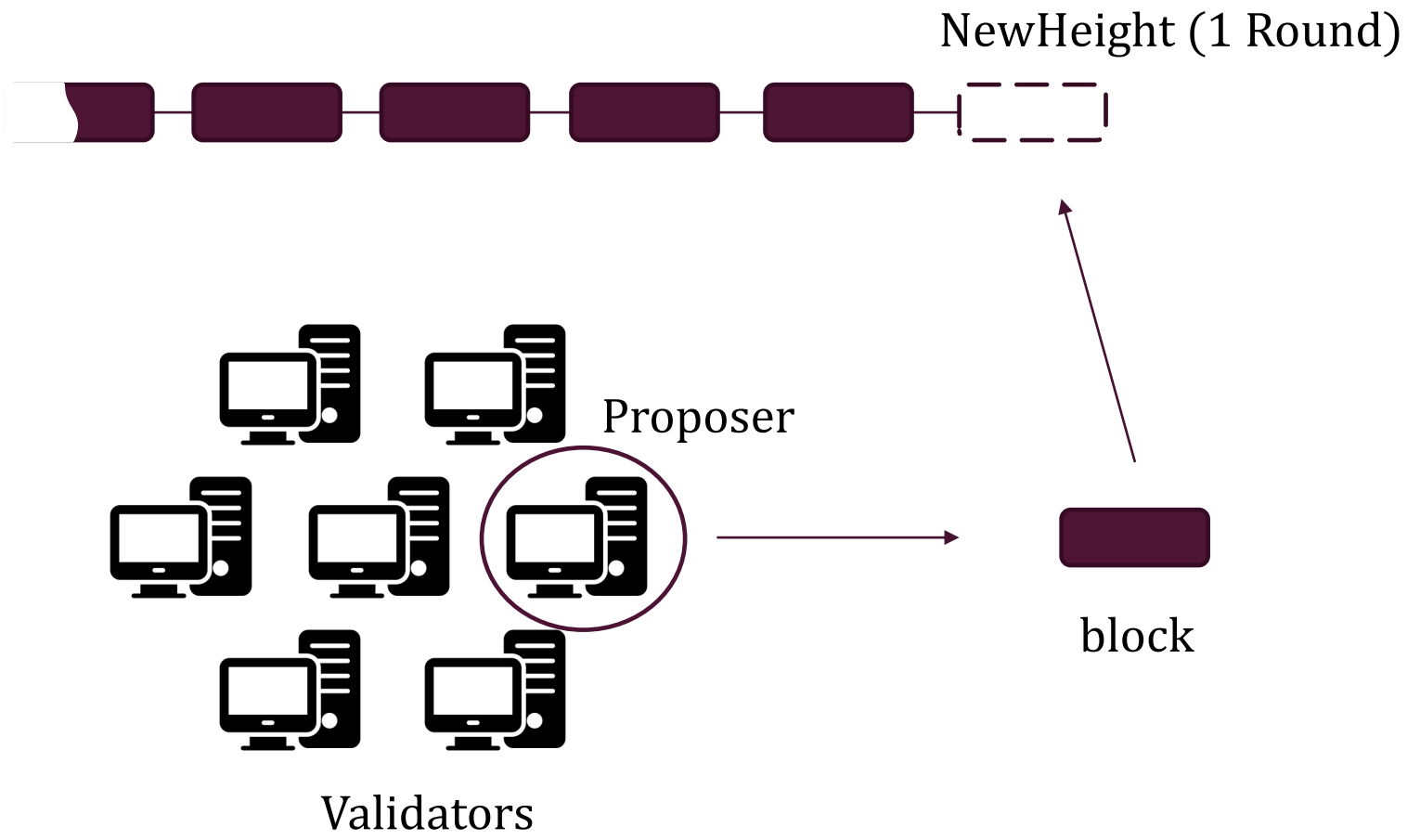
$$NewHeight \rightarrow \underbrace{(Propose \rightarrow Prevote \rightarrow Precommit)^{\geq 1}}_{Round} \rightarrow Commit \rightarrow$$

Consensus

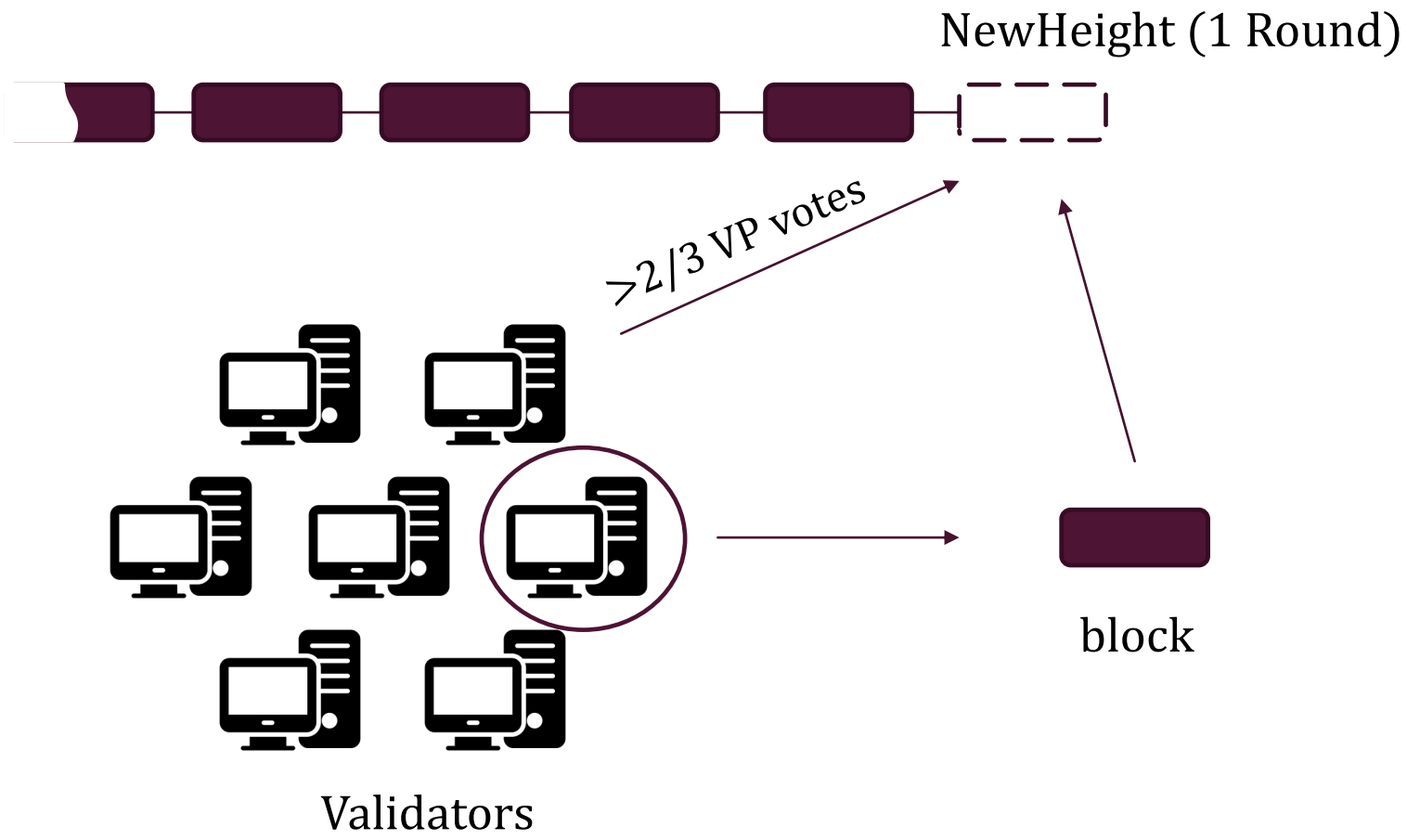




Consensus

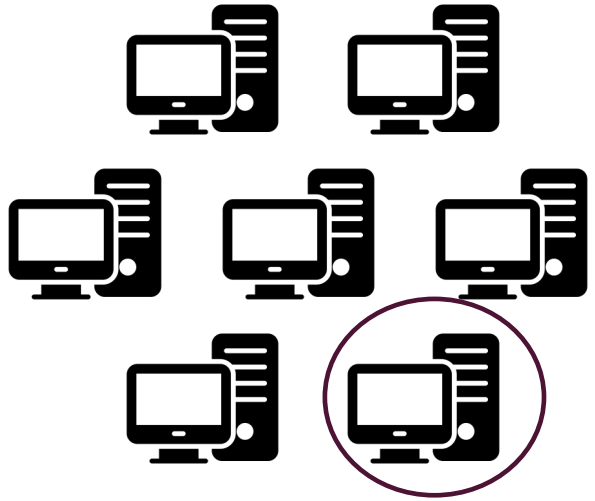


Consensus



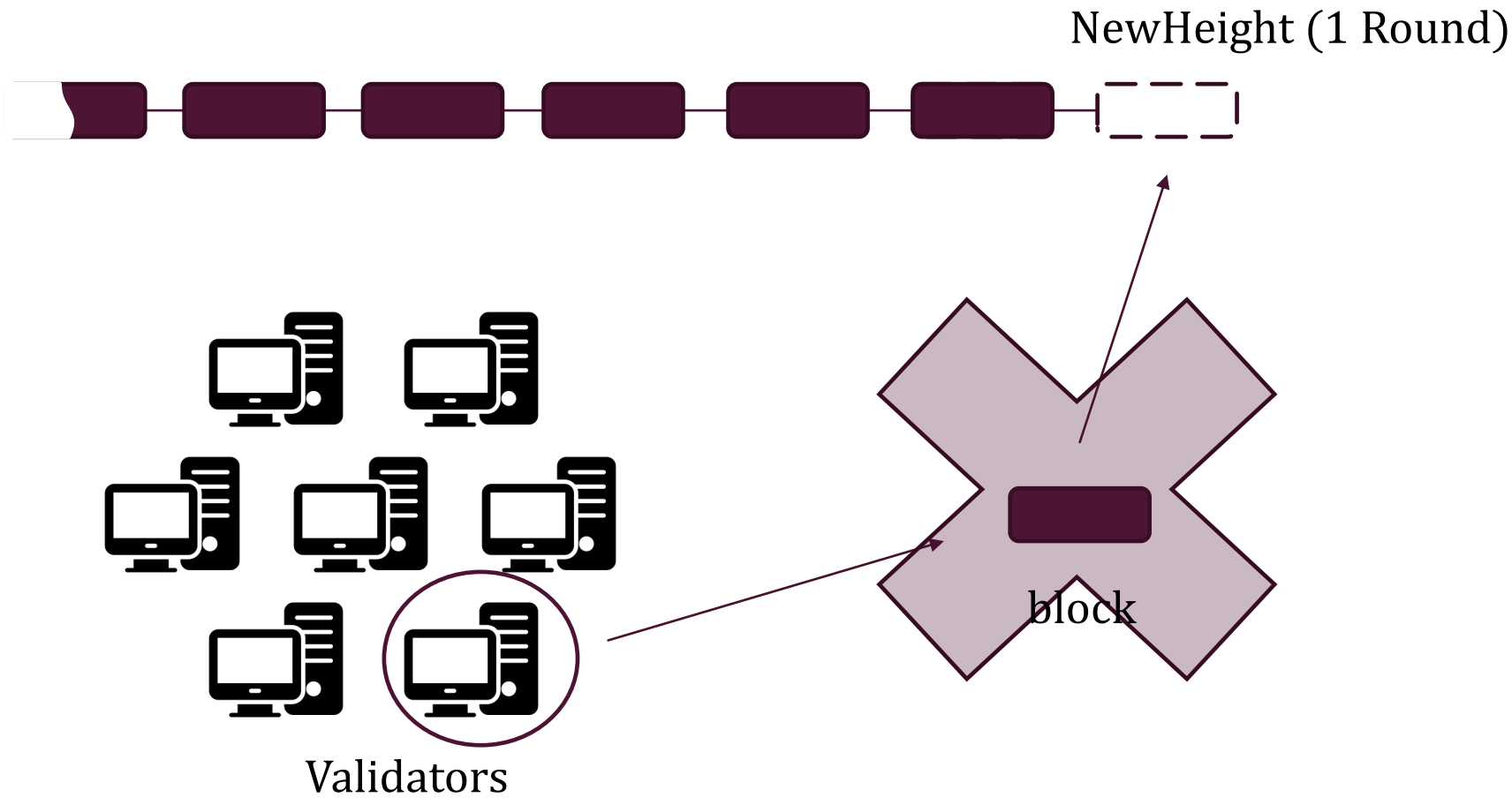
Consensus

NewHeight (1 Round)

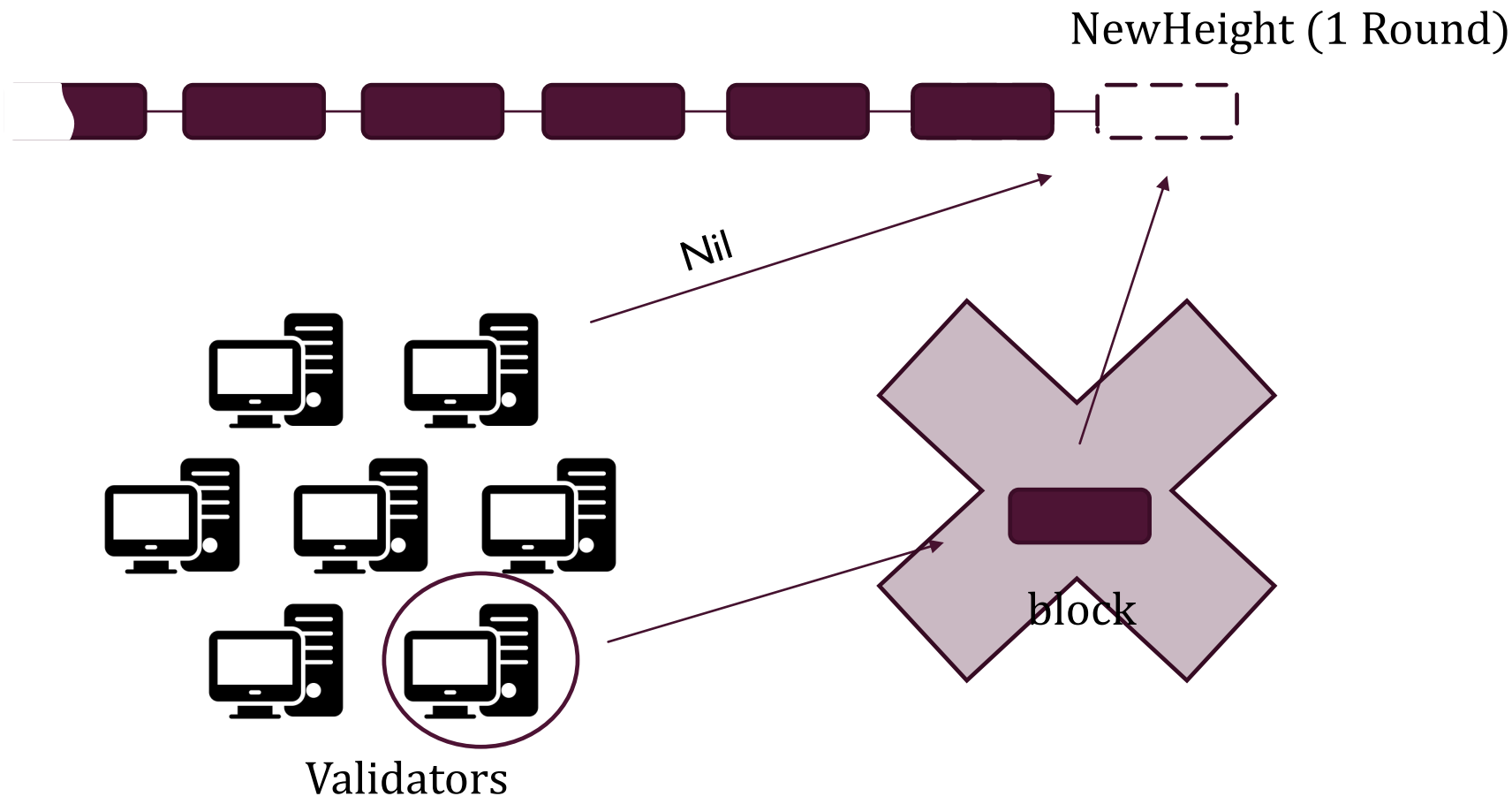


Validators

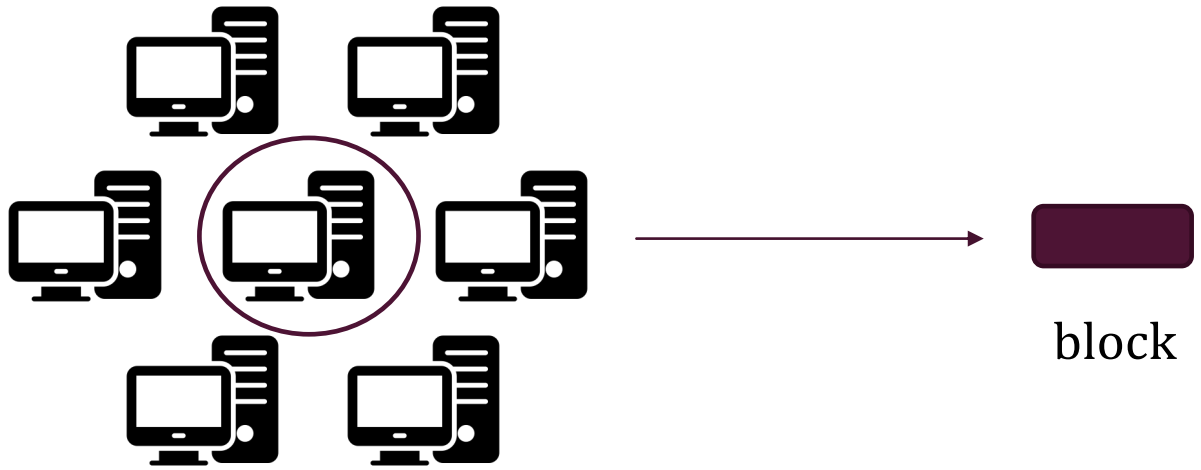
Consensus



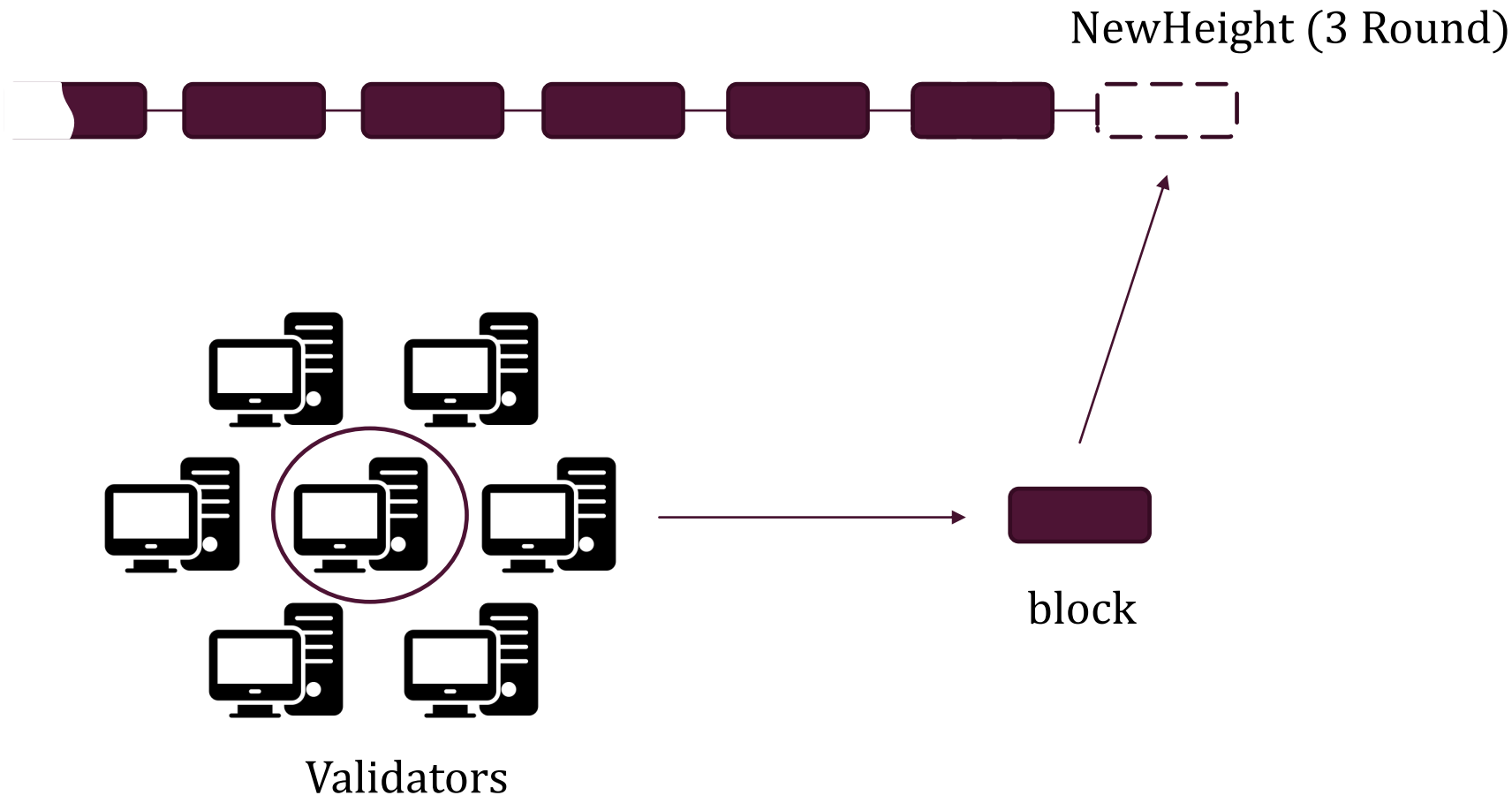
Consensus



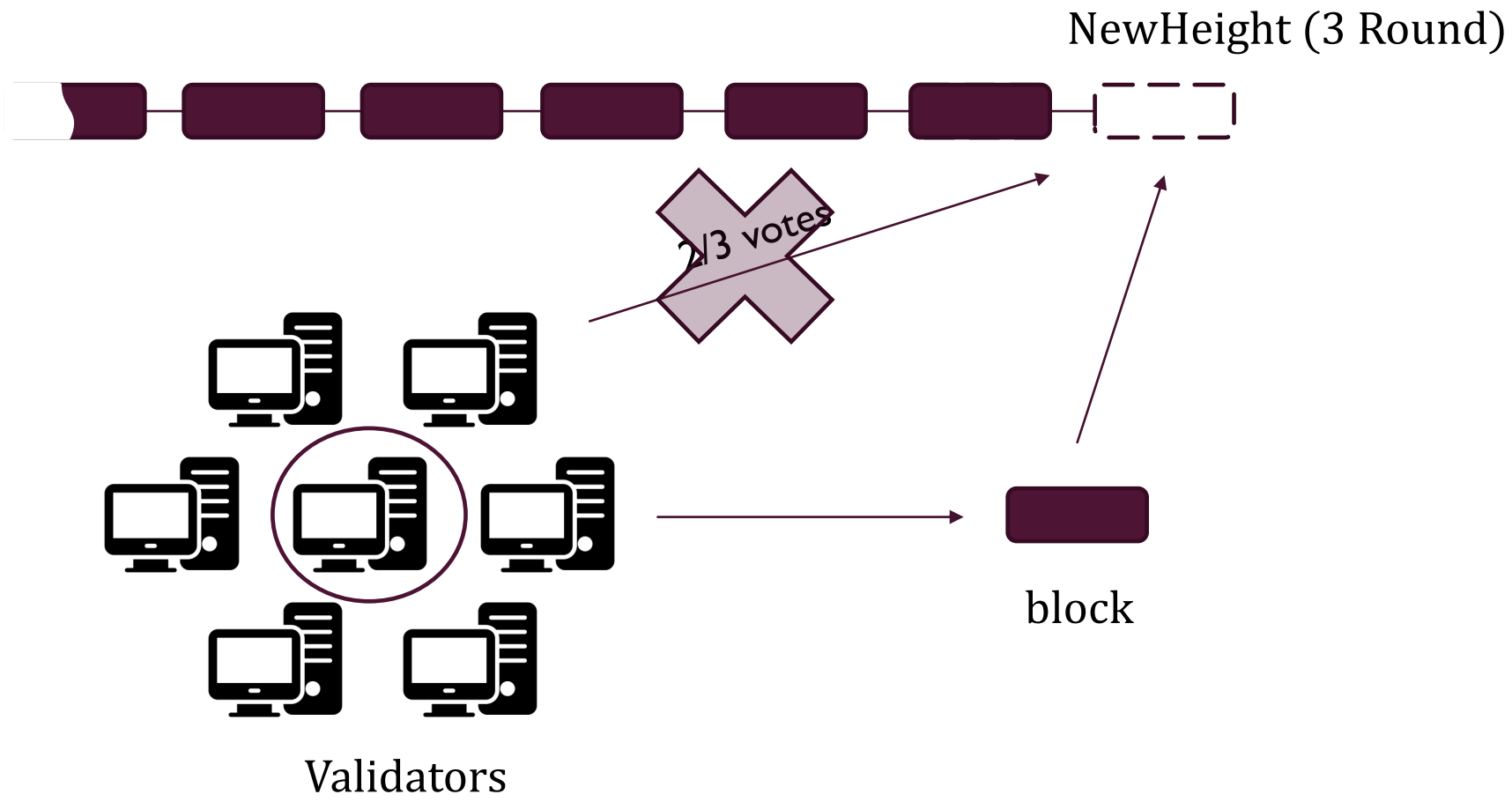
Consensus



Consensus



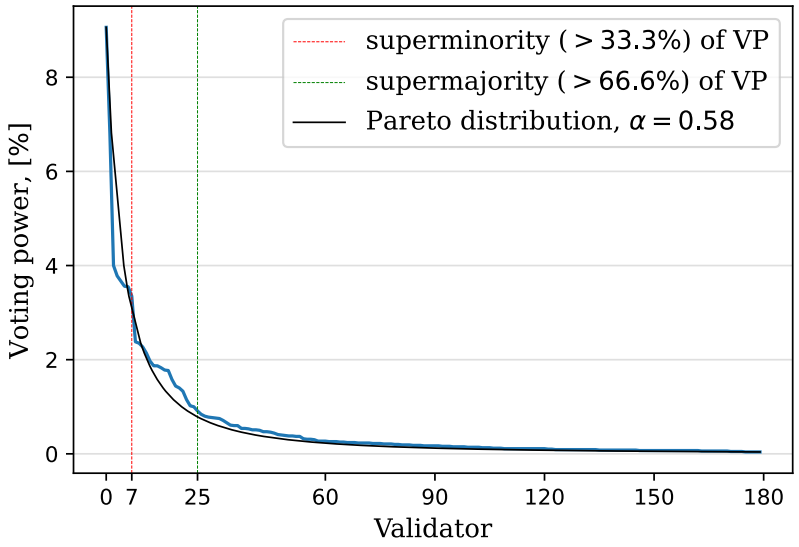
Consensus



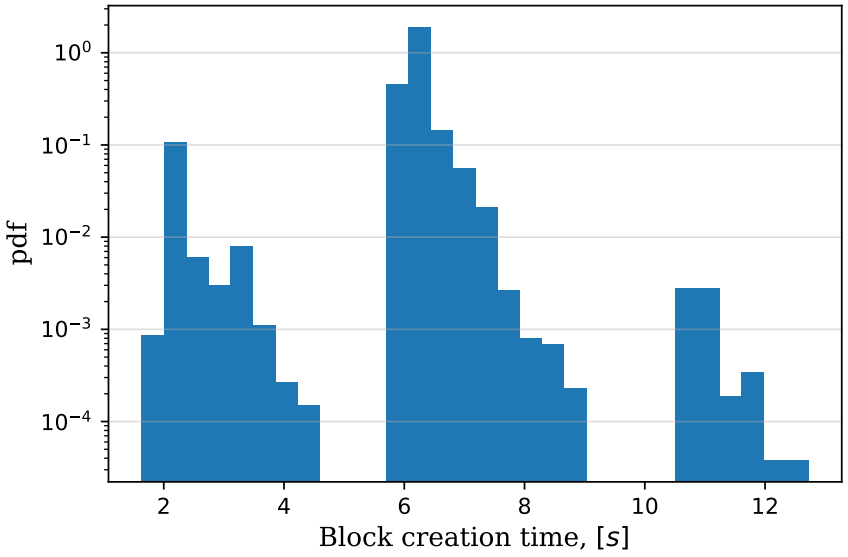
Problem statement

Assess the performance of Cosmos blockchain using quantitative analysis

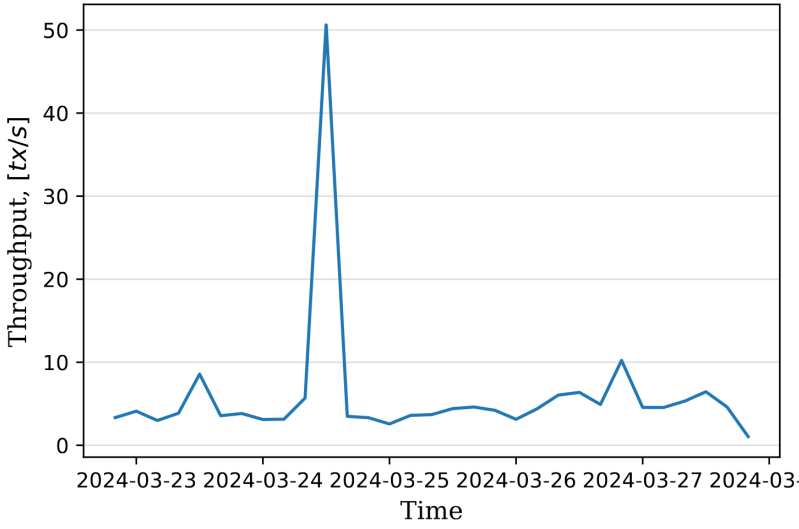
Cosmos blockchain



Voting Power distribution in Cosmos



pdf of block creation time



Transaction throughput with 4 hours granularity

Performance Evaluation Process Algebra (PEPA)

Operators:

$$P ::= P \underset{L}{\bowtie} P \mid P/L \mid S$$

Cooperation Hiding

$$S ::= (\alpha, r).S \mid S + S \mid A$$

Prefix Choice

- α - action type
- r - activity rate
- τ - unknown action type
- $\top$ - unspecified rate
- L - cooperation set

- P - model component
- S - sequential component
- A - countable set of constants

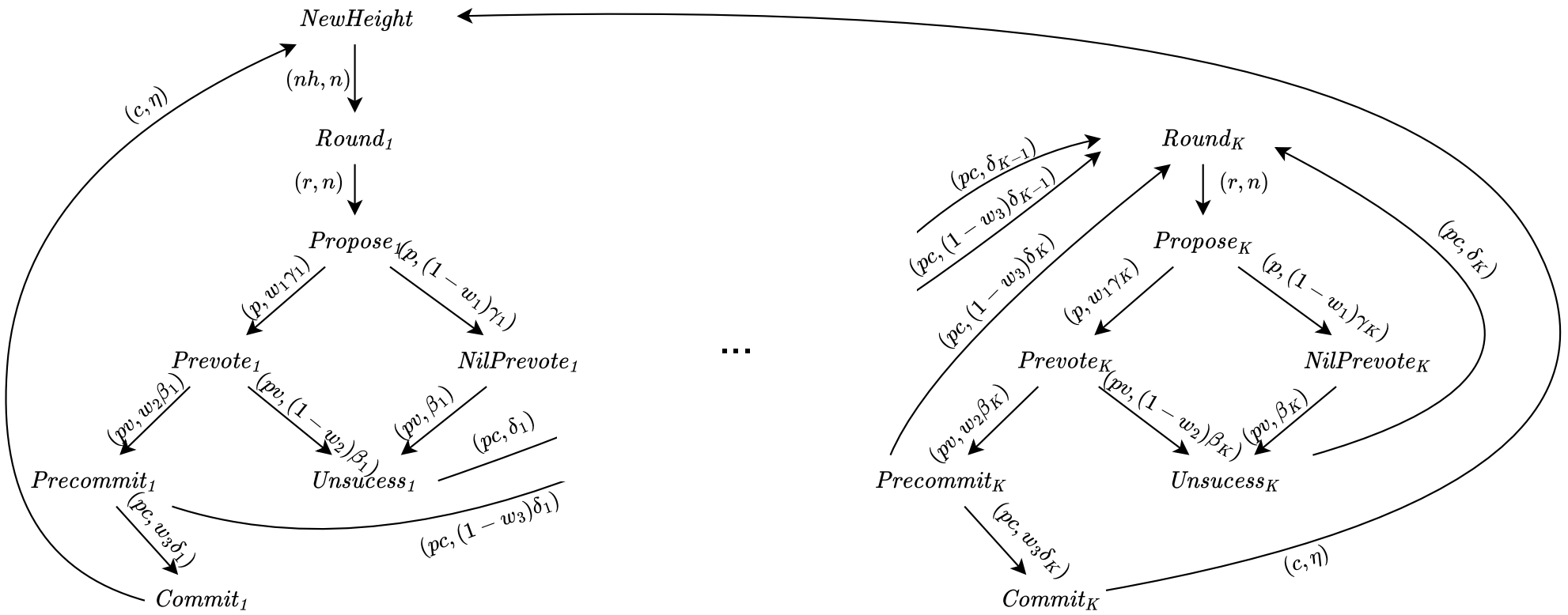
PEPA model of the consensus process with homogeneous proposers in Cosmos ecosystem

$$
\begin{array}{lcl}
NewHeight & \stackrel{def}{=} & (nh, n).Round_1 \\
\hline
Round_i & \stackrel{def}{=} & (r, n).Propose_i \\
Propose_i & \stackrel{def}{=} & (p, w_1\gamma_i).Prevote_i + (p, (1-w_1)\gamma_i).NilPrevote_i \\
Prevote_i & \stackrel{def}{=} & (pv, w_2\beta_i).Precommit_i + (pv, (1-w_2)\beta_i).Unsuccess_i \\
NilPrevote_i & \stackrel{def}{=} & (pv, \beta_i).Unsuccess_i \\
Unsuccess_i & \stackrel{def}{=} & (pc, \delta_i).Round_{i+1} \\
Precommit_i & \stackrel{def}{=} & (pc, w_3\delta_i).Commit_i + (pc, (1-w_3)\delta_i).Round_{i+1} \\
Commit_i & \stackrel{def}{=} & (c_i, \eta).NewHeight \\
\hline
Round_K & \stackrel{def}{=} & (r, n).NewHeight
\end{array}
$$

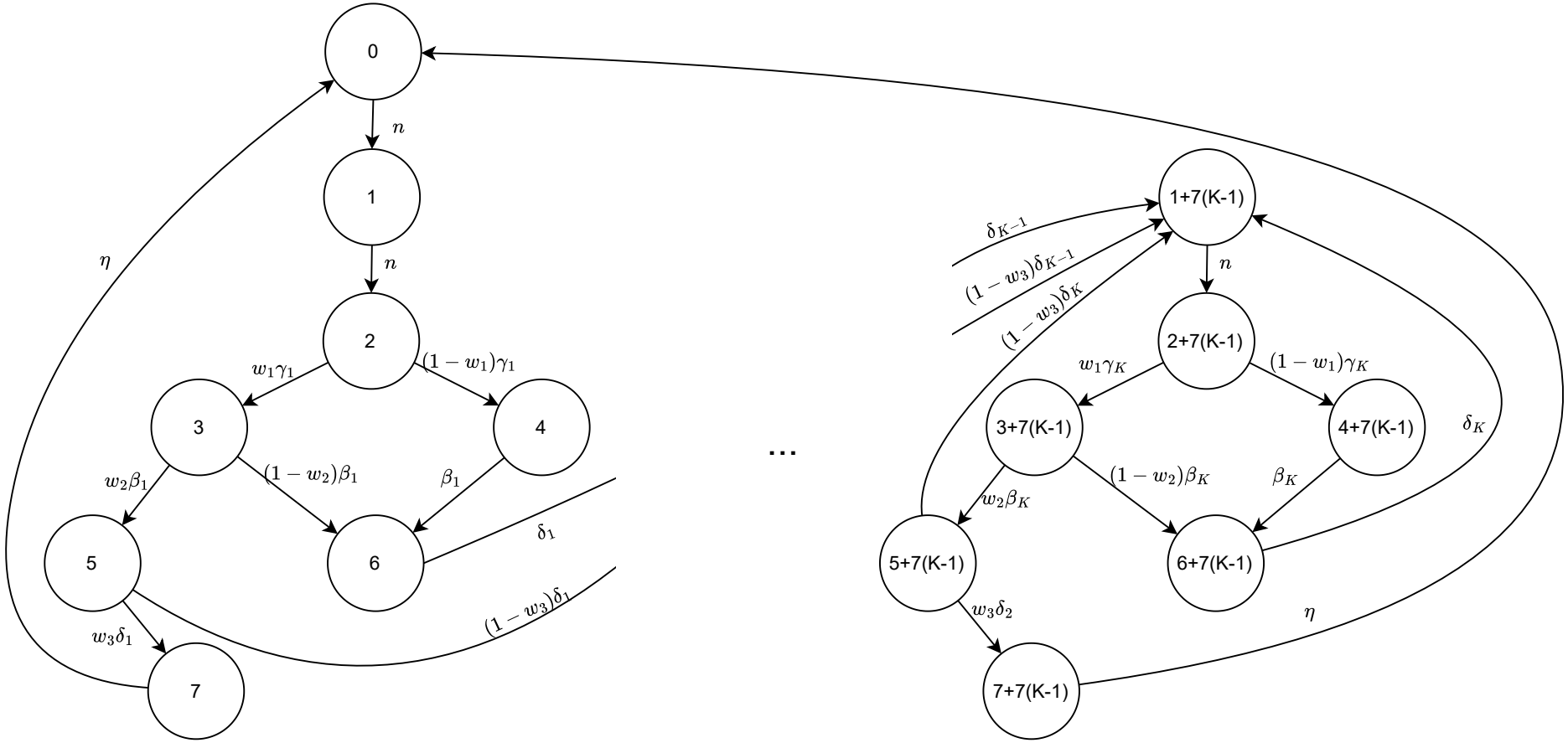
where $\gamma_i = max\left(\frac{1}{t_1}, \frac{1}{T_1 + (i-1)g}\right)^a$, $\beta_i = max\left(\frac{1}{t_2}, \frac{1}{T_2 + (i-1)g}\right)$, $\delta_i = \frac{1}{T_3 + (i-1)g}$,

$i \in \{1, \ldots, R\}$, and $\eta = \frac{1}{T_4}$

Derivation graph



Markov chain



Rates and parameters assigned

Name	Duration
Propose timeout, (T_1)	3s
Prevote timeout, (T_2)	1s
Precommit timeout, (T_3)	1s
Timeout increase, (g)	0.5s
Commit timeout, (T_4)	1s

$$w_1 = Pr[X_1 \leq T_1] = 1 - e^{-\frac{1}{t_1}T_1}$$

$$w_2 = Pr[X_2 \leq T_2] = 1 - e^{-\frac{1}{t_2}T_2}$$

$$w_3 \to 1$$

$$\gamma_i = max\left(\frac{1}{t_1}, \frac{1}{T_1 + (i-1)g}\right)$$

$$\beta_i = max\left(\frac{1}{t_2}, \frac{1}{T_2 + (i-1)g}\right)$$

PEPA model of the consensus process with non-homogeneous proposers in Cosmos ecosystem

$$
\begin{array}{lcl}
NewHeight & \stackrel{def}{=} & (nh, n).Round_1 \\
\hline
Round_i & \stackrel{def}{=} & (r, p_{FF}\, n).Propose_{i_{FF}} + (r, p_F\, n).Propose_{i_F} + (r, p_S\, n).Propose_{i_S} \\
Propose_{i_{FF}} & \stackrel{def}{=} & (p, w_{1_{FF}} \gamma_{i_{FF}}).Prevote_i + (p, (1 - w_{1_{FF}})\gamma_{i_{FF}}).NilPrevote_i \\
Propose_{i_F} & \stackrel{def}{=} & (p, w_{1_F} \gamma_{i_F}).Prevote_i + (p, (1 - w_{1_F})\gamma_{i_F}).NilPrevote_i \\
Propose_{i_S} & \stackrel{def}{=} & (p, w_{1_S} \gamma_{i_S}).Prevote_i + (p, (1 - w_{1_S})\gamma_{i_S}).NilPrevote_i \\
Prevote_i & \stackrel{def}{=} & (pv, w_2 \beta_i).Precommit_i + (pv, (1 - w_2)\beta_i).Unsuccess_i \\
NilPrevote_i & \stackrel{def}{=} & (pv, \beta_i).Unsuccess_i \\
Unsuccess_i & \stackrel{def}{=} & (pc, \delta_i).Round_{i+1} \\
Precommit_i & \stackrel{def}{=} & (pc, w_3 \delta_i).Commit_i + (pc, (1 - w_3)\delta_i).Round_{i+1} \\
Commit_i & \stackrel{def}{=} & (c_i, \eta).NewHeight \\
\hline
Round_K & \stackrel{def}{=} & (r, n).NewHeight \\
\hline
\end{array}
$$

where $\gamma_{i_{FF/F/S}} = max\left(\frac{1}{t_{1_{FF/F/S}}}, \frac{1}{T_1 + (i-1)g}\right)$, $\beta_i = \frac{1}{T_2 + (i-1)g}$,

$\delta_i = \frac{1}{T_3 + (i-1)g}$, $i \in \{1, \ldots, R\}$, and $\eta = \frac{1}{T_4}$ while $p_{FF} = p_F = p_S = \frac{1}{3}$

Rates and parameters assigned

Name	Duration
Propose timeout, (T_1)	3s
Prevote timeout, (T_2)	1s
Precommit timeout, (T_3)	1s
Timeout increase, (g)	0.5s
Commit timeout, (T_4)	1s

$$w_{1_{FF}} = Pr[X_{1_{FF}} \leq T_1] = 1 - e^{-\frac{T_1}{t_{1_{FF}}}}$$

$$w_{1_F} = Pr[X_{1_F} \leq T_1] = 1 - e^{-\frac{T_1}{t_{1_F}}}$$

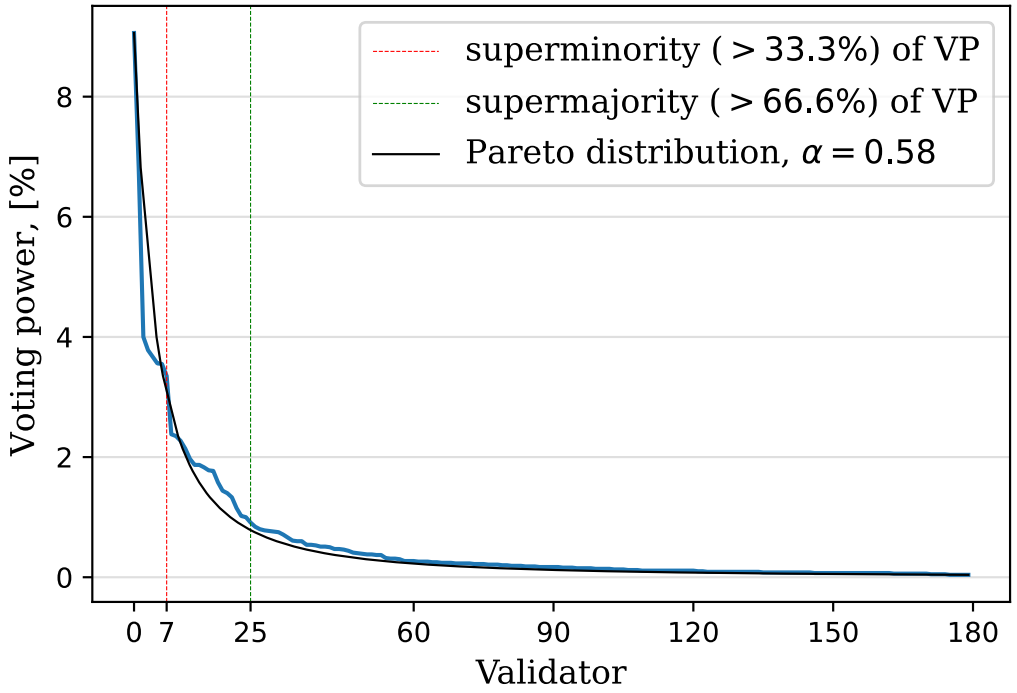
$$w_{1_S} = Pr[X_{1_S} \leq T_1] = 1 - e^{-\frac{T_1}{t_{1_S}}}$$

$$w_2 = Pr[X_2 \leq T_2] = 1 - e^{-\frac{1}{t_2}T_2}$$

$$w_3 \to 1$$

Rates and parameters assigned

$$\overline{VP}_{FF} = 0.0483, \quad \overline{VP}_{F} = 0.0184, \quad \overline{VP}_{S} = 0.0021$$

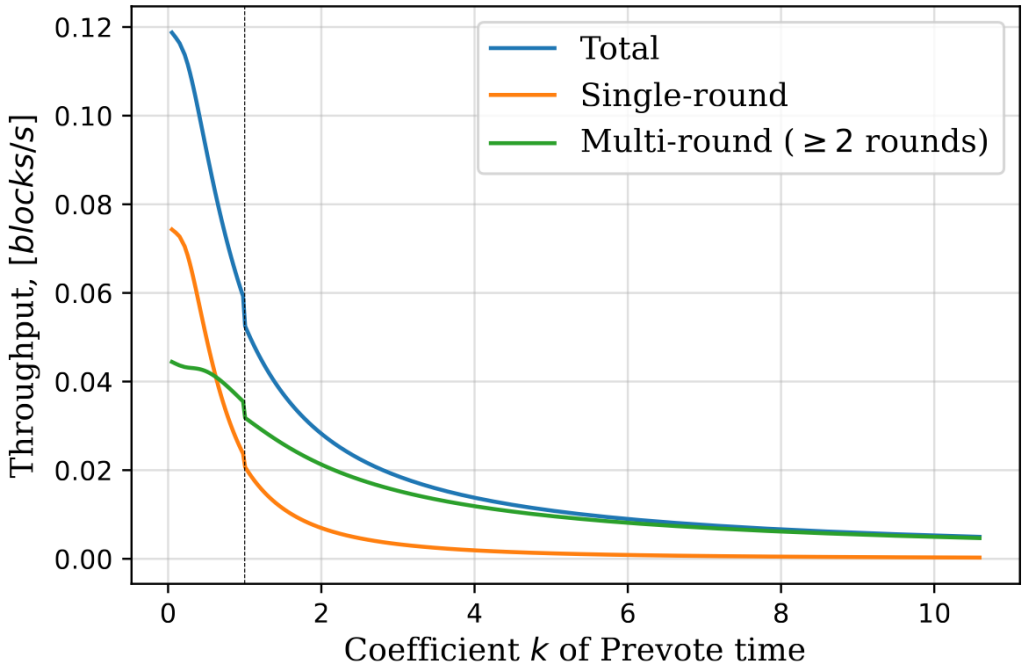


$$t_{1_{FF}}^{-1} = \frac{\overline{VP}_{FF}}{\overline{VP}_{F}} \frac{1}{3}, \quad t_{1_{F}}^{-1} = \frac{\overline{VP}_{F}}{\overline{VP}_{F}} \frac{1}{3}, \quad t_{1_{S}}^{-1} = \frac{\overline{VP}_{S}}{\overline{VP}_{F}} \frac{1}{3}$$

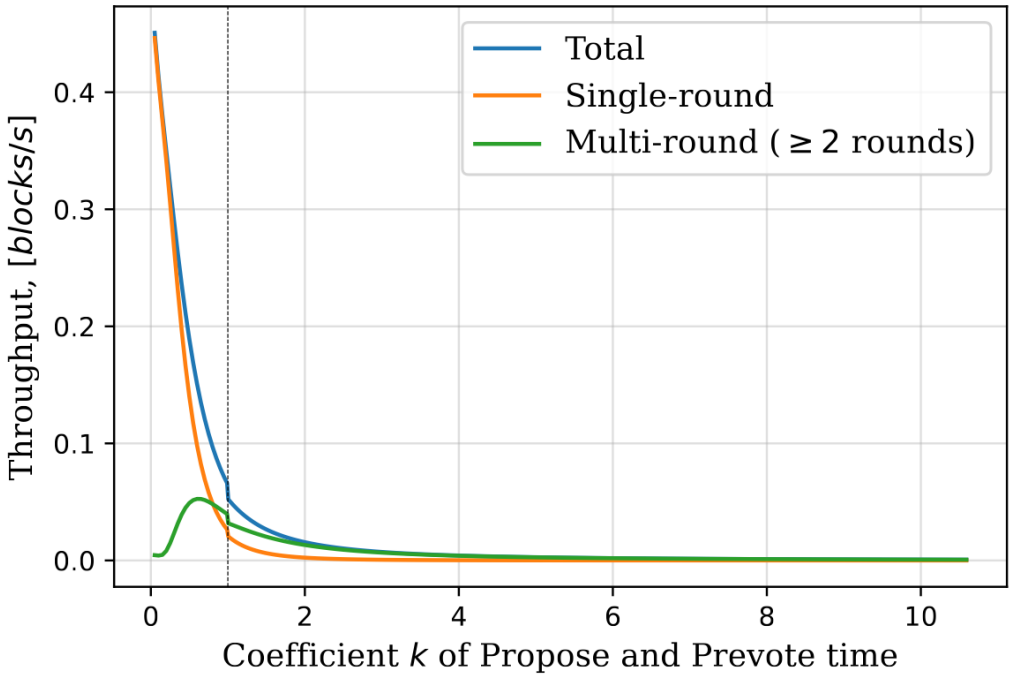
$$t_{1_{FF}} = 3\frac{\overline{VP}_{F}}{\overline{VP}_{FF}}, \quad t_{1_{F}} = 3\frac{\overline{VP}_{F}}{\overline{VP}_{F}}, \quad t_{1_{S}} = 3\frac{\overline{VP}_{F}}{\overline{VP}_{S}}$$

Network throughput as a function of coefficient k: Homogeneous model

$$t_1 = kT_1 \text{ and } t_2 = kT_2 \implies w_1 = w_2 = 1 - e^{-\frac{1}{k}}$$



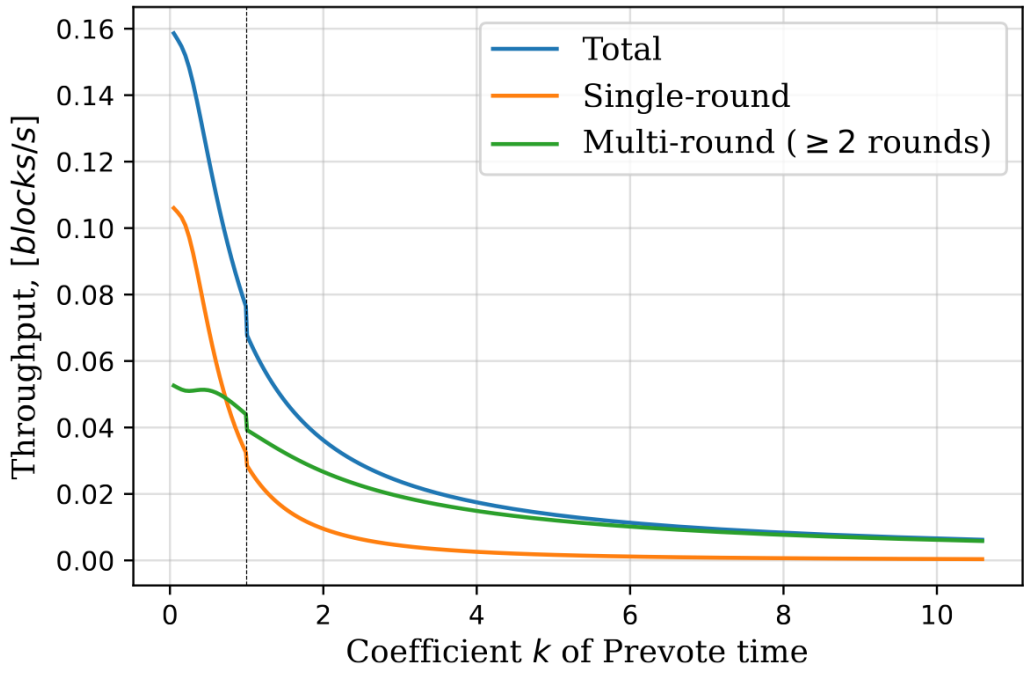
For Prevote time with fixed $w_1 = 0.63$



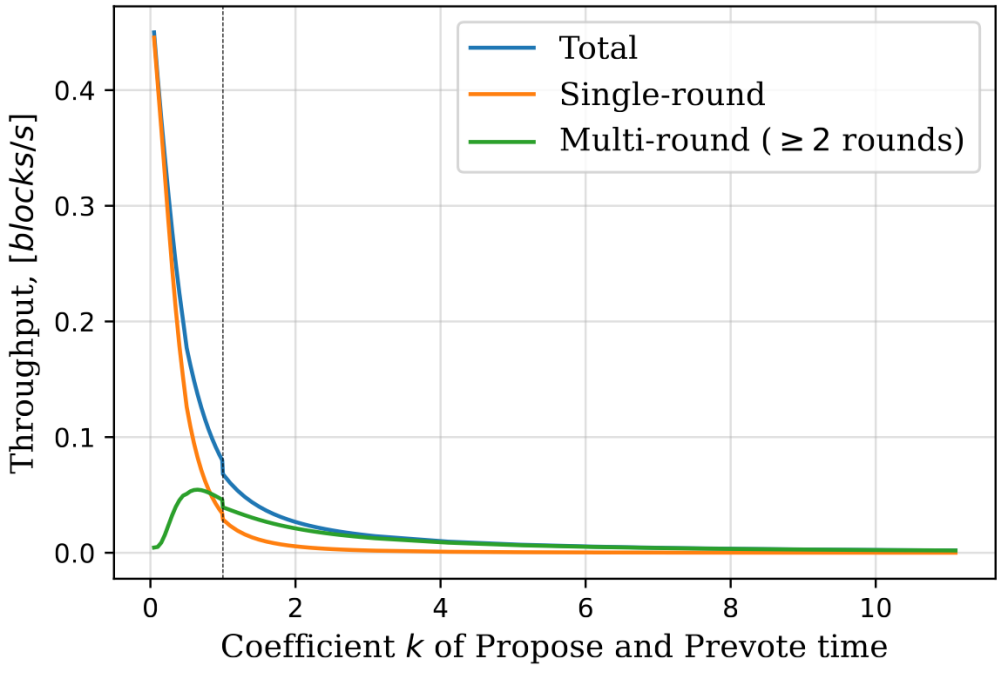
For Propose and Prevote

Network throughput as a function of coefficient k: Non-homogeneous model

$$t_1 = kT_1 \text{ and } t_2 = kT_2 \implies w_1 = w_2 = 1 - e^{-\frac{1}{k}}$$



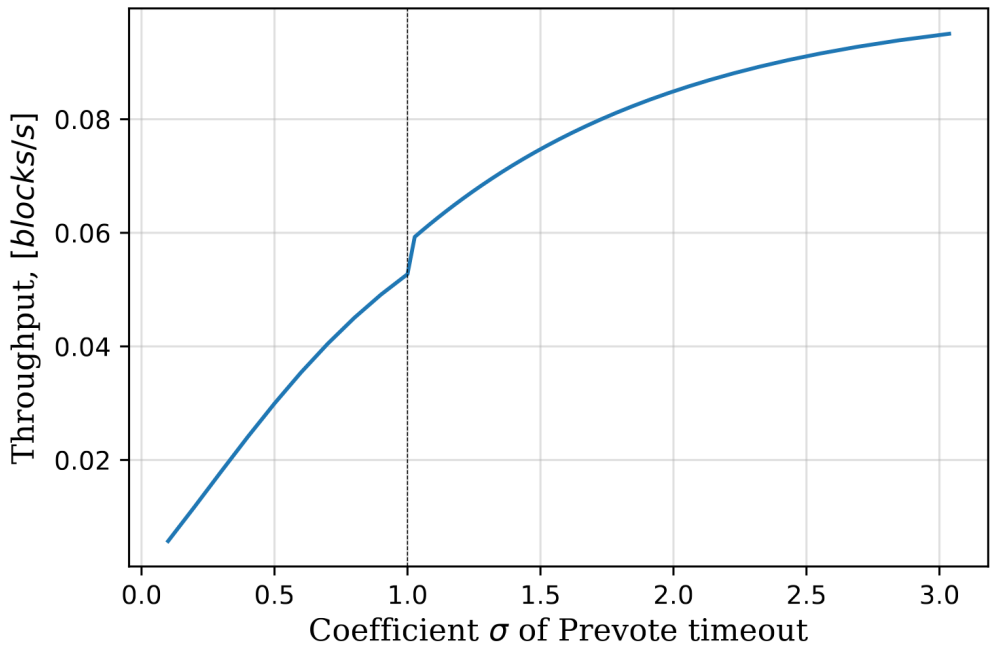
For Prevote time with fixed $w_1 = 0.63$



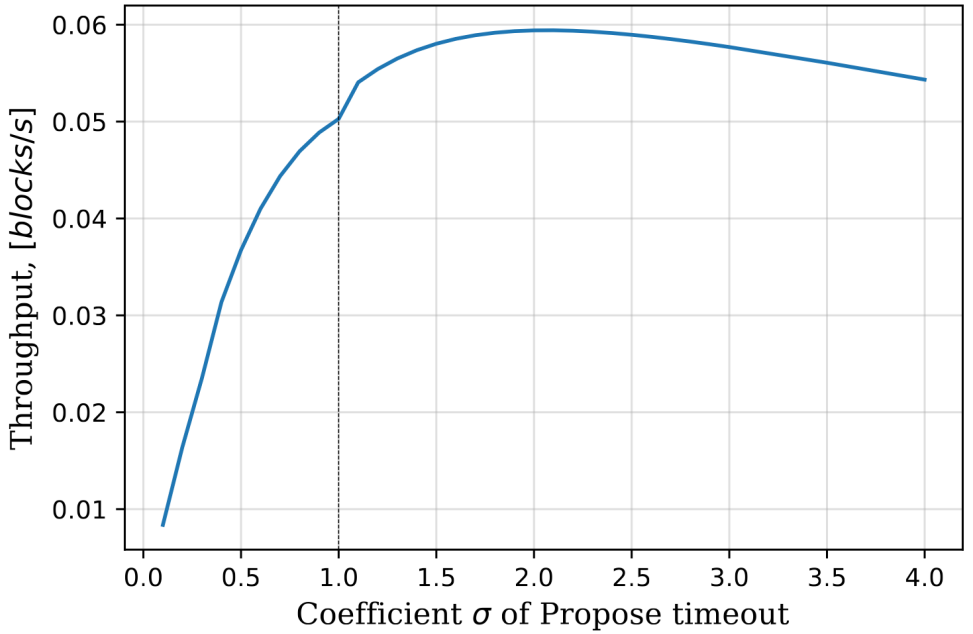
For Propose and Prevote

Network throughput as a function of coefficient σ

$$T_1^* = \sigma t_1^* \text{ and } T_2^* = \sigma t_2^* \implies w_1^* = w_2^* = 1 - e^{-\sigma}$$

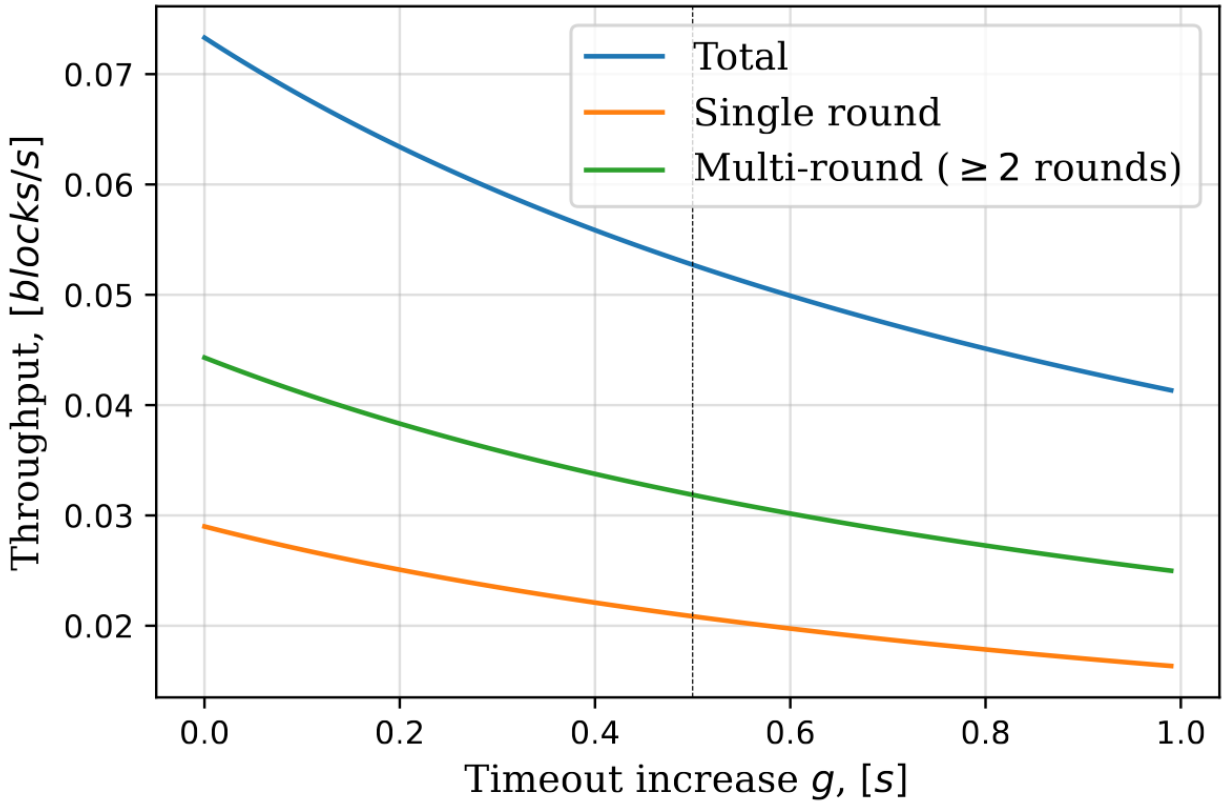


Of Prevote timeout fixed at $w_1 = 0.63$



Of Propose timeout

Network throughput as a function of timeout increase



Conclusion

- We assessed the performance of Cosmos blockchain studying:
  - Different verification time of round steps
  - Optimal timeout for better throughput
  - Timeout increase dynamics
- Future work includes comprehesive analysis of other network within Cosmos ecosystem


Thank you!
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