Linking Policies for the Permanent Web

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Drexel University CCI & Internet Archive

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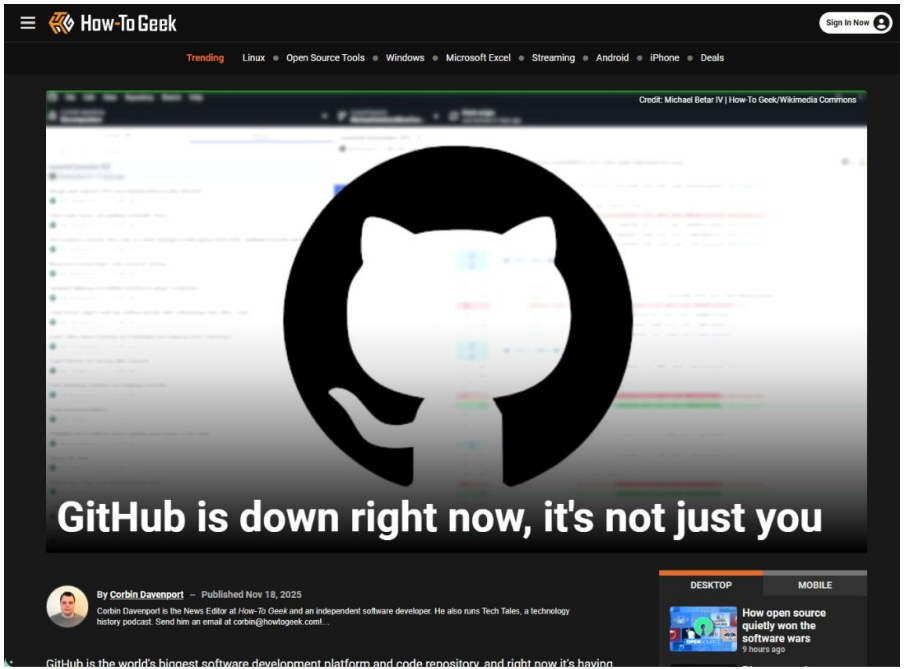
A Senior Capstone Project at Drexel University

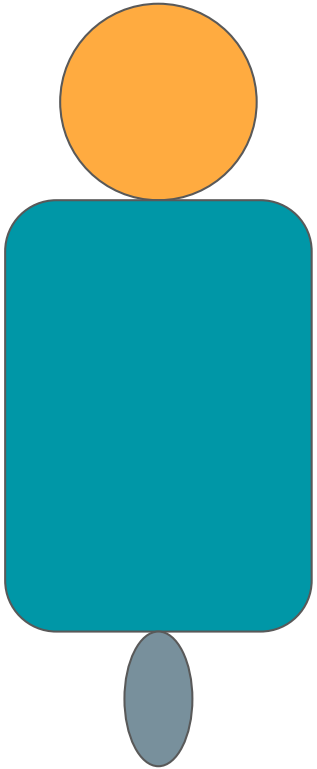
Why Decentralize Versioning



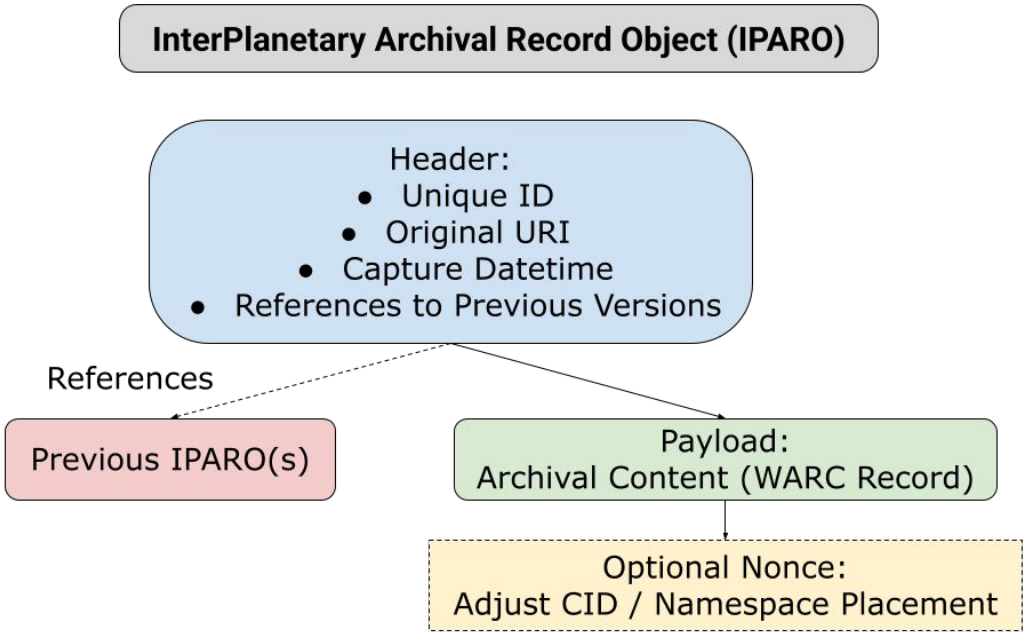
https://www.howtogeek.com/github-is-down-its-not-just-you/

https://www.theverge.com/2024/10/14/24269741/internet-archive-online-read-only-data-breach-outage

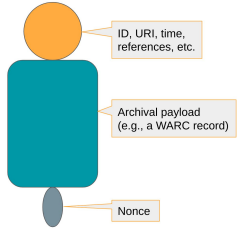
Building Blocks of Decentralized Archiving

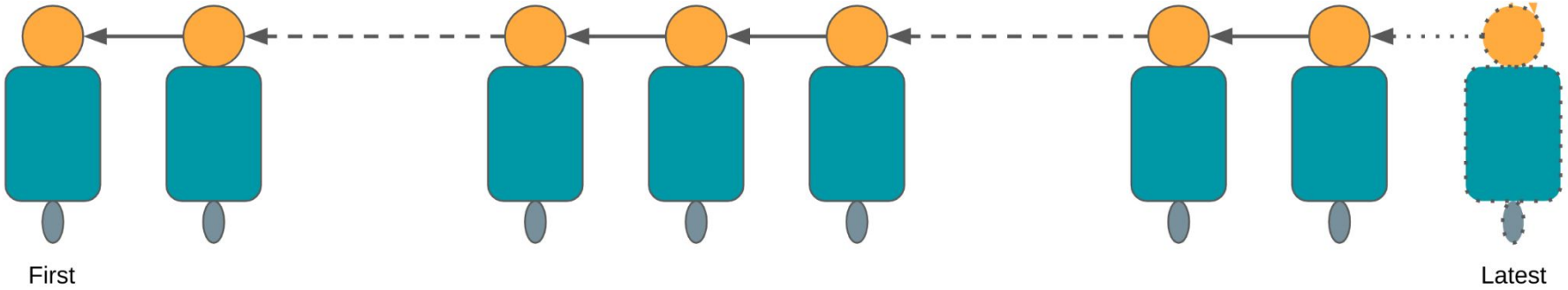


What is an IPARO?



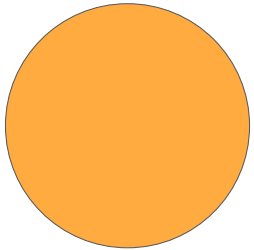
Linking IPAROs Over Time





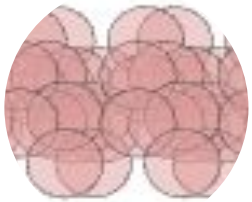
Sawood Alam, "IPARO: InterPlanetary Archival Record Object for Decentralized Web Archiving and Replay," in iPRES 2023.

Methodology



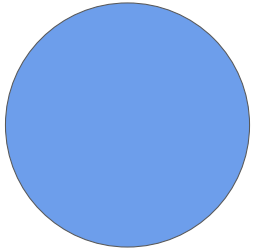
Volume

How many versions for a given object?



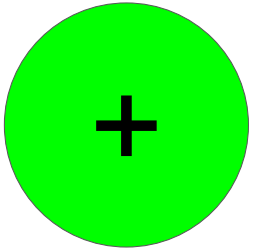
Density

How often are versions recorded?



Linking Strategy

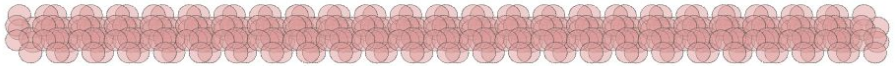
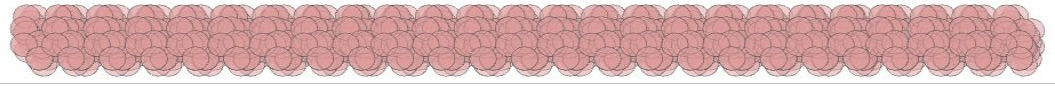
How does each object link to the prior versions?



Operations

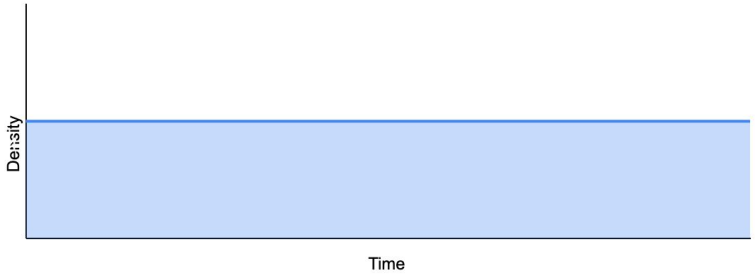
What operations do we perform on these objects?

Version Volumes

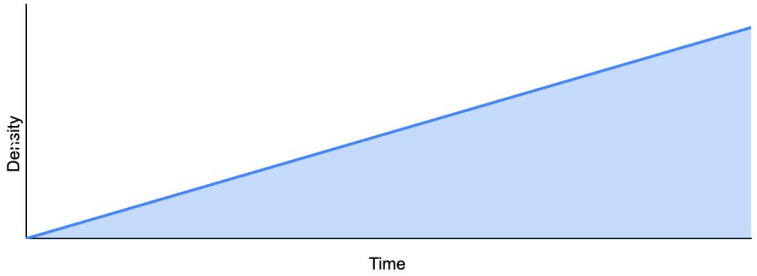
Volume	Range	Example Chain
Single	1	
Tiny	2-9	
Small	10-99	
Medium	100-999	
Large	1000-9999	
Huge	10000+	

Version Densities

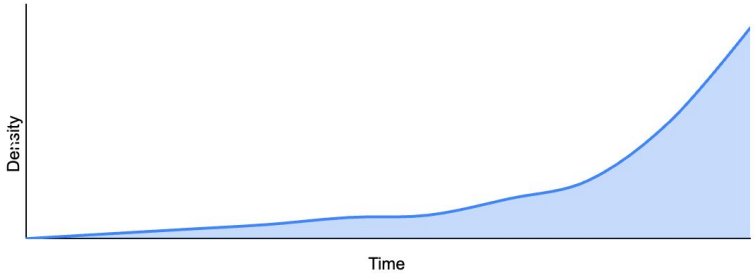
Uniform



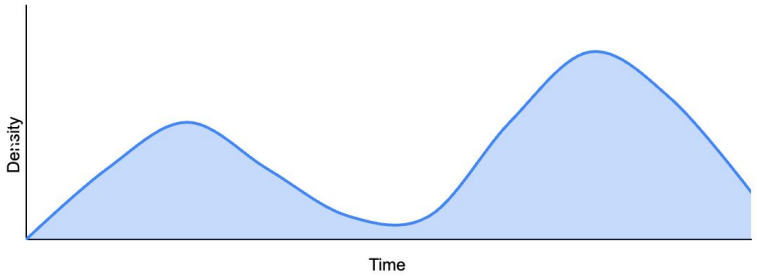
Linear



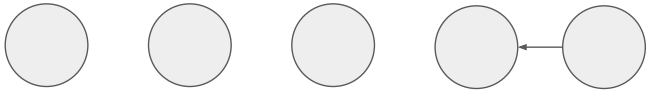
Big Head Long Tail (BHLT)



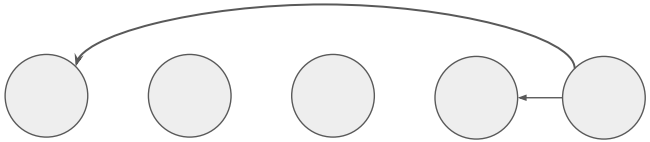
Multipeak



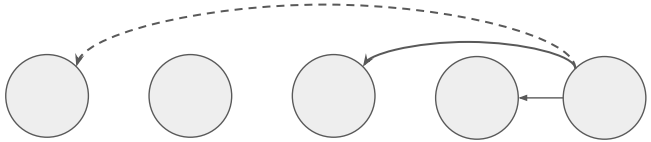
Linking Strategies: Basic



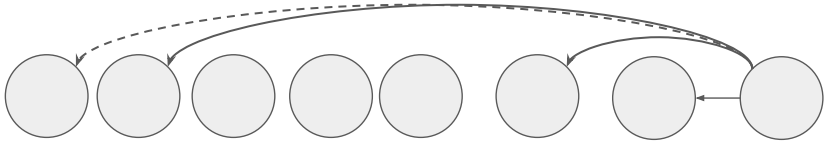
Single



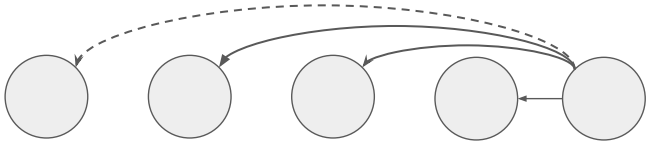
Previous (Baseline)



K-Previous

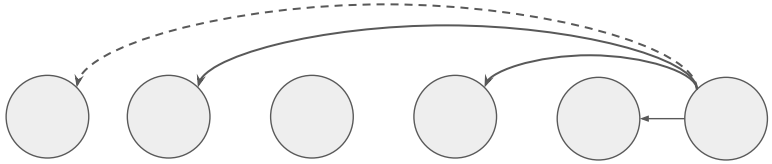


K-Random

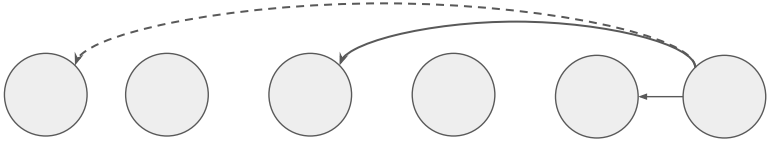


Comprehensive

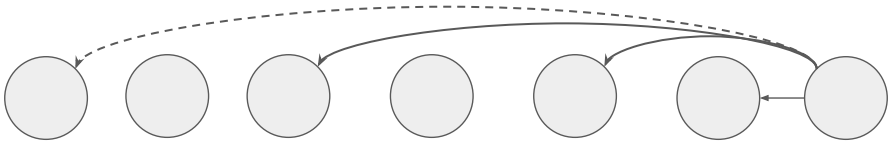
Linking Strategies: Sequential



Sequential K-Uniform

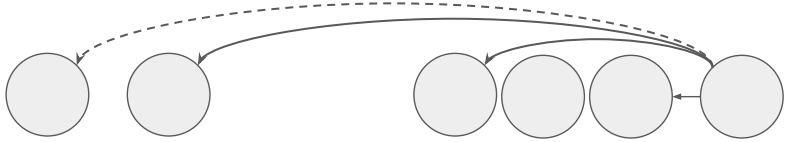


Sequential S-Max-Gap

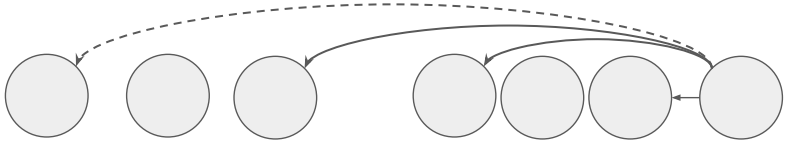


Sequential Exponential (Base B)

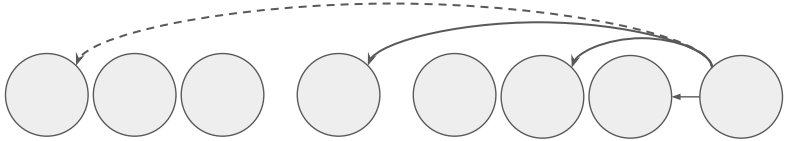
Linking Strategies: Temporal



Temporal K-Uniform



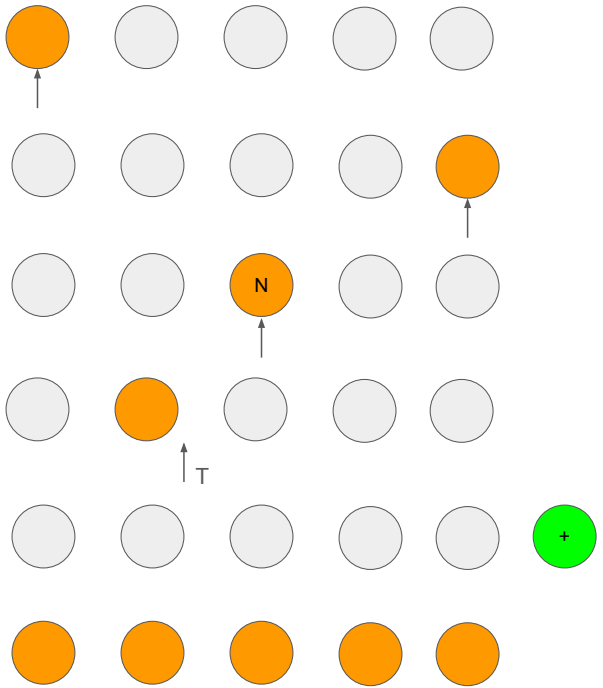
Temporal T-Min-Gap



Temporal Exponential (Base B)

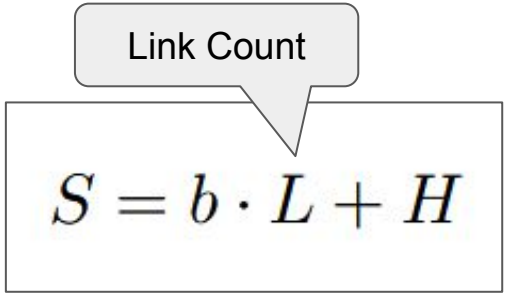
Operations

- Retrieve First
- Retrieve Latest
- Retrieve By Sequence Number (RBSN)
- Retrieve By Time (RBT)
- Add New
- List All

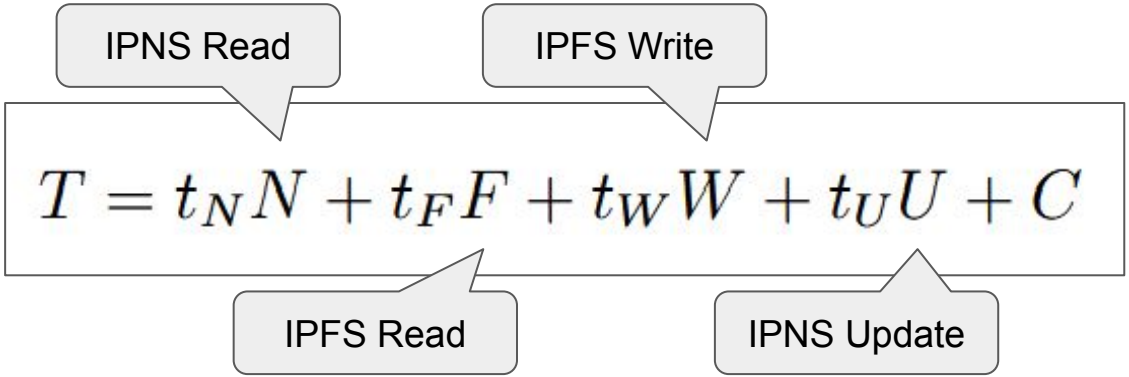


Costs

Storage Cost



Time Cost



Complexities

Strategy	Links Per Node	Add Node	RBT	RBSN	List All
Single	1	1	N	N	N
Previous	1	1	N	N	N
Comprehensive	N	1	1	1	1
K-Previous	K	K	N'	N'	N'
K-Random	K	$\sqrt{NK}$	$\sqrt{N'}$	$\sqrt{N'}$	N'
Sequential K-Uniform	K	K	N'	N'	N'
Sequential S-Max-Gap	N/S	N/S	S	S	S
Sequential Base B Exponential	$\log N$	$\log^2 N$	$\log N$	$\log N$	N
Temporal K-Uniform	K	N'	$N_{T'}$	$N_{T'}$	N
Temporal T-Min-Gap	$\bar{T}$	$\bar{T}$	$\bar{T} + N_T$	$\bar{T} + N_T$	N
Temp-Exp Base B (Time Unit T)	$\log(\bar{T})$	$N_T \log \bar{T}$	N_T	N_T	$N_T \log \bar{T}$

- N' = N/K
- T* measures time between first and latest node
- T' = T*/K
- $\bar{T}$ = T*/T
- N_T is the maximum nodes for time window T.

Complexities

Strategy	Links Per Node	Add Node	RBT	RBSN	List All
Single	1	1	N	N	N
Previous	1	1	N	N	N
Comprehensive	N	1	1	1	1
K-Previous	K	K	N'	N'	N'
K-Random	K	$\sqrt{NK}$	$\sqrt{N'}$	$\sqrt{N'}$	N'
Sequential K-Uniform	K	K	N'	N'	N'
Sequential S-Max-Gap	N/S	N/S	S	S	S
Sequential Base B Exponential	$\log N$	$\log^2 N$	$\log N$	$\log N$	N
Temporal K-Uniform	K	N'	$N_{T'}$	$N_{T'}$	N
Temporal T-Min-Gap	$\bar{T}$	$\bar{T}$	$\bar{T} + N_T$	$\bar{T} + N_T$	N
Temp-Exp Base B (Time Unit T)	$\log(\bar{T})$	$N_T \log \bar{T}$	N_T	N_T	$N_T \log \bar{T}$

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Sequential K-Uniform	K	K	N'	N'	N'
Sequential S-Max-Gap	N/S	N/S	S	S	S
Sequential Base B Exponential	$\log N$	$\log^2 N$	$\log N$	$\log N$	N
Temporal K-Uniform	K	N'	$N_{T'}$	$N_{T'}$	N
Temporal T-Min-Gap	$\bar{T}$	$\bar{T}$	$\bar{T} + N_T$	$\bar{T} + N_T$	N
Temp-Exp Base B (Time Unit T)	$\log(\bar{T})$	$N_T \log \bar{T}$	N_T	N_T	$N_T \log \bar{T}$

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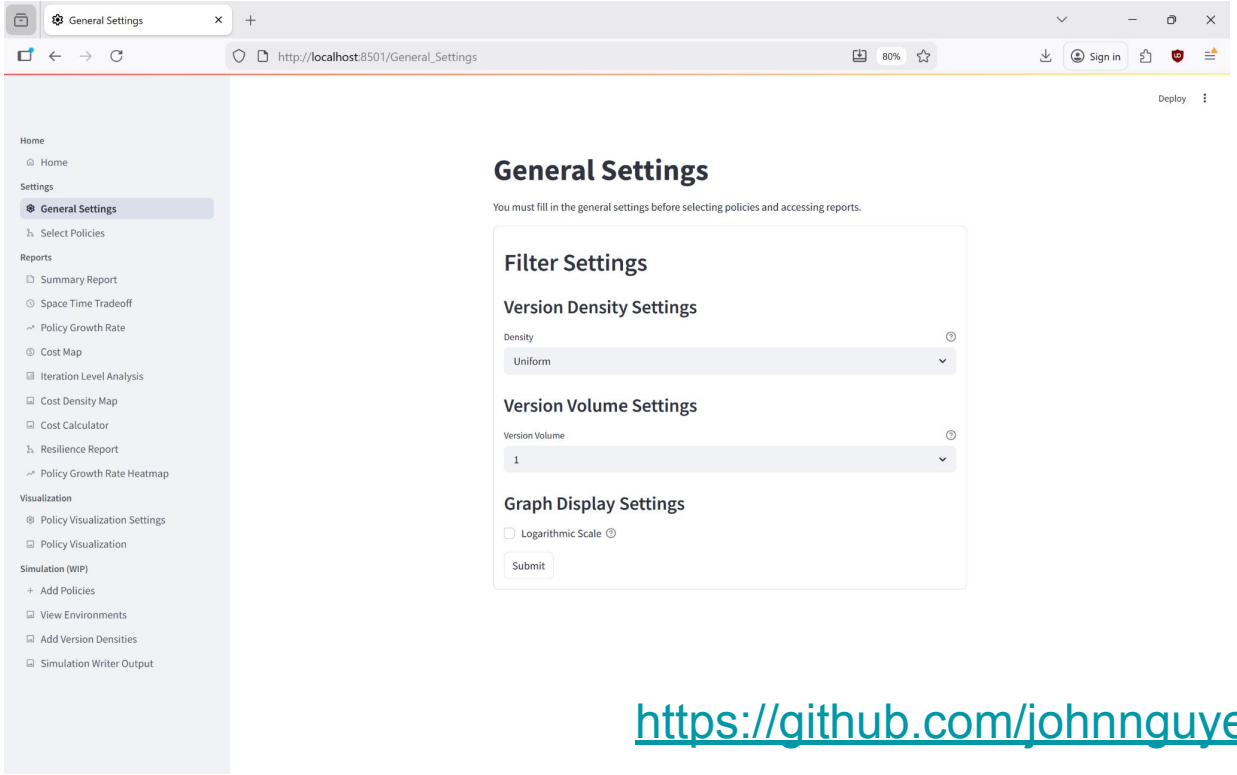
Experimental System

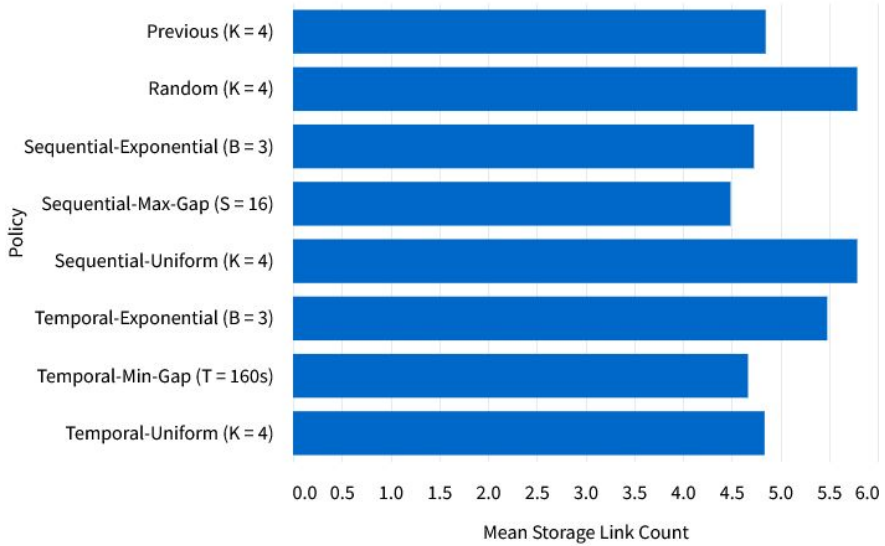


https://github.com/johnnguyenn77/iparo

Experimental Setup

- Windows 11 PC, 8 cores
- Chains have length 100
- 10 iterations per operation

Chosen Strategies



Experimental Storage and Time Cost

	Single	Comprehensive	Exponential
Retrieve First	100	2	2
Retrieve Latest	1	1	1
Retrieve By Seq. #	54	2	4.5
Retrieve By Time	54.4	2	4
Add New	0.99	0.99	6.65
List All	99	1	49
Links Per Node	0.99	49.5	6.65

Nodes: 100, Density: Uniform, Exp. Base: 2

Experimental Storage and Time Cost

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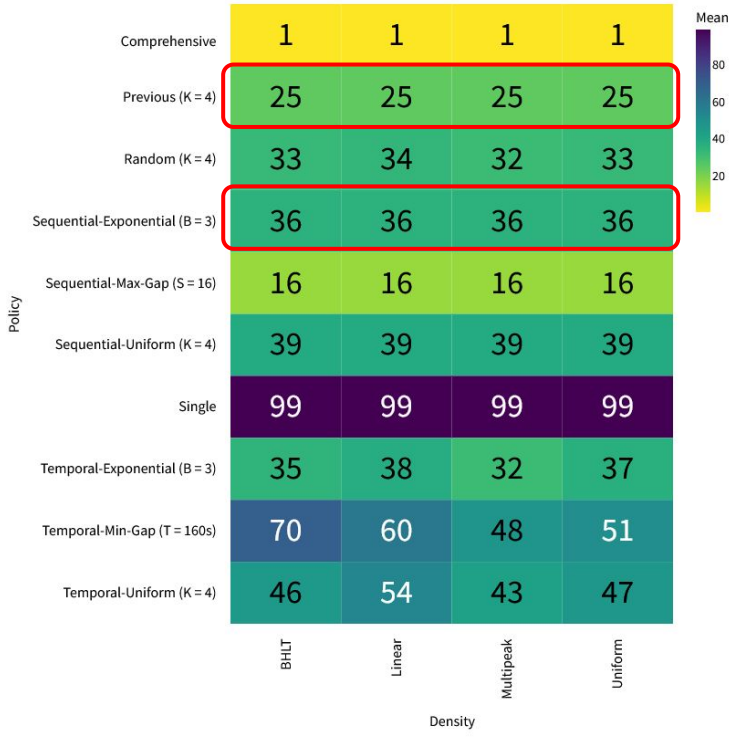

Conclusion and Future Work

- Which strategies to use?
  - Exponential: General Purpose
  - K-Previous: Many List All operations

- Future Work
  - Sampling other distributions
  - Which strategies are the most resilient?

Summary

Decentralized Versioning	System Configurations	Cost Analysis
IPFS IPNS IPARO	6 Volumes 4 Densities 11 Strategies 6 Operations 4 Parameters	Storage (for links) Time (for operations) Theoretical Complexities Experimental Results

https://github.com/johnnguyenn77/iparo