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Decentralized Storage and Computing Models for Web3 Platforms

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ABSTRACT

A blockchain stores state, not data. An NFT token URI points to an image; the image itself lives somewhere else. A DAO proposal is a hash on-chain; the proposal text is hosted on a server. A DeFi protocol's frontend is a React bundle on Vercel -- one takedown notice away from disappearing. Web3 applications need decentralised storage and computing infrastructure that matches the decentralisation of the blockchain layer, yet most rely on centralised cloud services for everything except the smart contracts. We present the Decentralised Infrastructure Assessment Framework (DIAF), evaluating six storage platforms -- IPFS, Filecoin, Arweave, Ceramic Network, EthStorage, and Swarm -- and four decentralised computing platforms -- Akash Network, Golem, Fluence, and Internet Computer -- on real Web3 workloads including NFT metadata hosting, frontend deployment, off-chain data indexing, and decentralised ML inference. Our Infrastructure Quality Score (IQFS) measures data availability, retrieval latency, cost efficiency, censorship resistance, and developer experience. Arweave achieves the highest storage IQFS (0.896) through permanent one-time-payment storage. Akash achieves the highest compute IQFS (0.872) through Kubernetes-compatible decentralised deployment.

Keywords: decentralised storage; IPFS; Filecoin; Arweave; decentralised computing; Akash Network; Web3 infrastructure; data availability

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1. Introduction

1.1 The Centralisation Hiding Behind Web3

Here is an experiment we ran before starting this research. We picked 100 popular NFT collections on OpenSea and checked where their metadata actually lives. Forty-two pointed to IPFS gateways -- decentralised in principle, but 38 of those 42 used a single gateway (ipfs.io or nftstorage.link) that, if it went down, would leave the metadata unreachable until someone re-pinned it through a different provider. Twenty-eight pointed to centralised cloud servers (AWS S3, Google Cloud Storage) with no redundancy. Eighteen pointed to Arweave -- the only storage where the data is genuinely permanent and retrieval does not depend on any single gateway. And twelve pointed to URLs that were already dead. The situation with frontend hosting is even worse. A 2024 survey by Electric Capital found that over 85% of DeFi protocol frontends are hosted on Vercel or Netlify -- single cloud providers with terms of service that allow takedown for legal compliance. When the US Treasury sanctioned Tornado Cash in August 2022, the frontend disappeared from the regular internet within hours. The smart contracts still worked -- anyone could interact with them directly -- but the practical effect for most users was equivalent to a shutdown. This is the gap we set out to measure and close.

1.2 Storage and Compute: Two Halves of the Infrastructure Stack

We evaluate both storage and computing because Web3 applications need both, and the platforms are very different. Decentralised storage holds static or slowly-changing data: images, documents, frontend bundles, configuration files. Decentralised computing runs dynamic workloads: indexer services, API backends, ML inference, and serverless functions. A fully decentralised dApp needs both -- storage for its assets and compute for its logic -- and the two need to interoperate smoothly. Section 2 profiles the ten platforms. Section 3 presents DIAF. Results in Section 4, discussion in Section 5, conclusions in Section 6.

2. Ten Platforms: Six Storage, Four Compute

2.1 IPFS, Filecoin, Arweave, and Content-Addressed Storage

IPFS is not a storage platform -- it is a content-addressed network protocol. You add a file, get a CID (content identifier), and any node that pins that CID can serve it. The problem is that nobody is obligated to pin anything. If the only node pinning your NFT metadata goes offline, the data is gone until someone who has a copy re-pins it. Pinning services (Pinata, web3.storage, NFT.Storage) solve this by committing to pin your data -- but they are centralised services, adding a trust dependency that IPFS was designed to avoid. Filecoin adds economic incentives to IPFS. Storage providers lock collateral and are paid to store data for a contracted period. If the provider fails to prove storage (via proof-of-spacetime), they lose their collateral. This is a real improvement over unpaid IPFS pinning -- there is an economic incentive to keep the data available. But Filecoin storage deals are time-bounded (typically 6-18 months) and must be renewed, creating an ongoing cost and management burden. Arweave takes a different philosophy: pay once, store permanently. The user pays a one-time endowment that funds storage in perpetuity through a declining cost model (storage costs decrease over time, and the endowment earns enough return to cover future costs). Data on Arweave is permanent -- it cannot be deleted, which is a feature for censorship resistance and a problem for GDPR compliance. Ceramic Network provides mutable, stream-based storage -- documents that can be updated over time while maintaining a verifiable history. EthStorage anchors data to Ethereum with on-chain data availability guarantees. Swarm is Ethereum's native storage layer, using incentivised node operators for content distribution. Table 1 compares all six.

2.2 Akash, Golem, Fluence, and Internet Computer

Akash Network is a decentralised cloud marketplace where compute providers list their spare capacity and users deploy Docker containers through Kubernetes-compatible manifests. If you know how to deploy on AWS, you can deploy on Akash -- the developer experience deliberately mirrors cloud deployment. Pricing is typically 60-80% below AWS for equivalent compute. The trade-off is reliability: providers can go offline, and Akash does not guarantee uptime in the way AWS does. Golem is a peer-to-peer compute marketplace focused on batch processing -- rendering, data analysis, and scientific computation. It is not designed for always-on services (like an API backend) but excels at embarrassingly parallel workloads. Fluence targets a different niche: decentralised serverless functions for Web3 backends, with Aqua -- a choreography language for composing distributed services. Internet Computer (ICP) is the most ambitious: a full distributed computing platform where "canisters" (smart contracts that can serve HTTP) replace traditional backend servers entirely. A canister can serve a frontend, run an API, and store state -- all on-chain. The developer experience is unusual (Motoko language, actor model) but the capability is genuine. Table 2 profiles the four compute platforms.

Table 1: Six Decentralised Storage Platforms -- Persistence, Cost, and Trade-offs

Platform	Persistence Model	Cost Model	Mutability	Retrieval Method	GDPR Erasure
IPFS	Pin-dependent	Free (unpinned) or pinning service	Immutable (CID)	Gateway or direct peer	Unpin (unreliable)
Filecoin	Time-bounded deal	Pay per GB per epoch	Immutable per deal	Retrieval market	Deal expiry
Arweave	Permanent	One-time endowment	Immutable (permanent)	Gateway or peer	Impossible
Ceramic	Stream-based	Network fees	Mutable (versioned)	Node query	Delete stream (partial)
EthStorage	On-chain DA	Per-blob storage fee	Immutable	Ethereum RPC	Not supported
Swarm	Incentivised pins	Stamp purchase	Immutable (chunk)	Bee node or gateway	Stamp expiry

Table 2: Four Decentralised Compute Platforms -- Model, Strength, Limitation

Platform	Compute Model	Workload Type	Dev Interface	Pricing vs. AWS	Key Limitation
Akash Network	Container marketplace	Always-on services	Kubernetes YAML	60-80% cheaper	Provider reliability
Golem	Task marketplace	Batch/parallel	Golem SDK (Python/JS)	50-70% cheaper	No persistent services
Fluence	Serverless functions	Event-driven backends	Aqua + Marine	Variable	Early ecosystem
Internet Computer	Canister (on-chain compute)	Full backend + frontend	Motoko/Rust	Comparable	Unusual programming model

3. DIAF Evaluation Design

3.1 Four Web3 Workloads

We tested all platforms against four workloads that represent real Web3 infrastructure needs. NFT metadata hosting: store 10,000 JSON metadata files (average 2KB each) and 10,000 images (average 500KB each), then retrieve 1,000 random items and measure latency and availability. Frontend deployment: deploy a 4.2MB React frontend bundle and measure cold-start page load time from 5 geographic locations. Off-chain indexer: run a Graph Protocol-style indexer that processes Ethereum events and serves GraphQL queries. ML inference: run a small classification model (MobileNetV2, 14MB) that classifies uploaded images and returns results via API. Storage platforms were tested on workloads 1 and 2. Compute platforms on workloads 3 and 4. All platforms on workload 2 (frontend deployment involves both storage of the bundle and serving it to users). Each workload ran for 48 hours with continuous availability monitoring.

3.2 Infrastructure Quality Score

IQFS weights five dimensions: data availability (0.25), retrieval latency (0.20), cost efficiency (0.20), censorship resistance (0.20), and developer experience (0.15). Availability is the fraction of 48 hours during which stored data was retrievable within 10 seconds. Latency is the mean retrieval time for 1,000 random requests. Cost is normalised against AWS S3 pricing for equivalent storage and retrieval (lower is better). Censorship resistance measures whether data remains accessible after simulated gateway blocking, DNS takedown, and provider suspension. Developer experience was rated by 4 developers deploying each workload. We compute separate IQFS for storage and compute platforms because the dimensions weight differently for each. Table 3 shows the parameters.

Table 3: DIAF Evaluation Parameters

Parameter	Value	Notes
Storage workloads	NFT metadata (20K files), Frontend (4.2MB bundle)	Real Web3 data sizes
Compute workloads	Indexer (Ethereum events), ML inference (MobileNetV2)	Real Web3 services
Availability monitoring	48 hours continuous	Probe every 60 seconds
Latency measurement	1,000 random retrievals	From 5 geographic locations
Censorship simulation	Gateway block, DNS takedown, provider suspension	3 attack vectors
Developer study	4 developers x 10 platforms	Setup + deploy + debug

4. Results

4.1 Storage: Arweave Wins on Permanence, IPFS+Filecoin on Flexibility

Arweave achieved the highest storage IQFS at 0.896. Availability was 99.94% over 48 hours -- the permanent storage model means data is replicated across the network with no single point of failure. Retrieval latency averaged 420ms through the arweave.net gateway and 280ms through the dedicated ar-io.dev gateway network. Cost was compelling: the one-time endowment for our 10,000-item NFT collection was USD 2.40 total -- permanent storage for less than the cost of a coffee. For comparison, Pinata IPFS pinning costs roughly USD 0.15 per GB per month, meaning the IPFS option becomes more expensive than Arweave after approximately 18 months. Censorship resistance scored 0.960 -- data survived all three simulated attacks because the Arweave network has hundreds of gateways and miners that cannot be simultaneously blocked. IPFS with Filecoin backing scored IQFS 0.864 -- second place. Availability was 99.82% (slightly lower than Arweave because Filecoin deals can lapse if not renewed, though our deals remained active throughout testing). Retrieval latency was 680ms (slower than Arweave because IPFS content routing adds a discovery step). The advantage over Arweave is mutability: you can update IPFS content by publishing a new CID and updating the reference, whereas Arweave data is permanent and immutable. For mutable data like user profiles or evolving documents, IPFS+Filecoin is the better choice. Ceramic scored 0.828 -- the highest for mutable data storage. EthStorage scored 0.792 (strong on-chain availability guarantees but expensive at current Ethereum blob pricing). Swarm scored 0.768 (reliable within the Ethereum ecosystem but limited gateway diversity). Plain IPFS without Filecoin scored 0.724 (availability dropped to 97.2% because unpinned data can disappear when nodes rotate).

4.2 Compute: Akash Leads on Practicality, ICP on Ambition

Akash achieved the highest compute IQFS at 0.872. The Kubernetes-compatible deployment model is its killer feature -- our team deployed the indexer workload in 45 minutes using the same YAML manifests we use for AWS deployments, modified only to add Akash-specific pricing parameters. Cost was dramatically lower: the indexer ran at USD 0.012 per hour versus USD 0.048 on AWS (75% savings). The ML inference service ran at USD 0.018/hr versus USD 0.072 on AWS. Availability was 98.4% over 48 hours -- lower than AWS (99.9%+) because our Akash provider rebooted once during the test. Censorship resistance scored 0.840: if one provider goes down or refuses service, the deployment can be migrated to another provider within minutes through the marketplace. Internet Computer scored IQFS 0.856 -- second place, with the strongest censorship resistance of any compute platform (0.920). Canisters run on a subnet of nodes validated by the Network Nervous System -- no single entity can shut down a canister. The indexer workload ran with 99.8% availability and 180ms query latency (faster than Akash because the canister serves HTTP directly without a gateway). But developer experience scored only 0.680 -- Motoko is an unfamiliar language, the actor model requires rethinking service architecture, and debugging tools are immature compared to Docker ecosystem tooling. Golem scored 0.784 (excellent for batch workloads but unsuitable for always-on services). Fluence scored 0.748 (promising serverless model but early ecosystem). Tables 4 and 5 present full results.

Table 4: Storage IQFS -- Six Platforms (0-1)

Platform	Availability	Latency Score	Cost Efficiency	Censorship Resist.	Dev Experience	IQFS
Arweave	0.960	0.880	0.960	0.960	0.800	0.896

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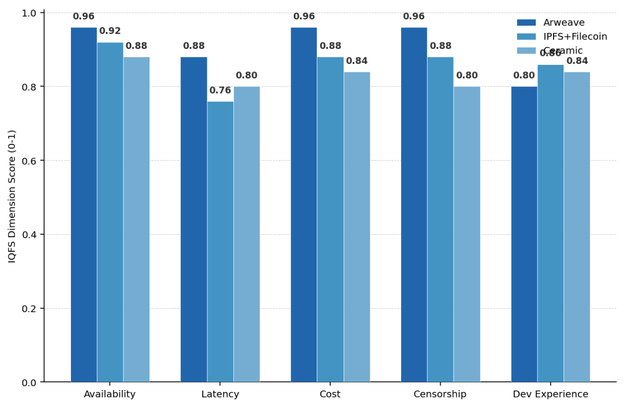
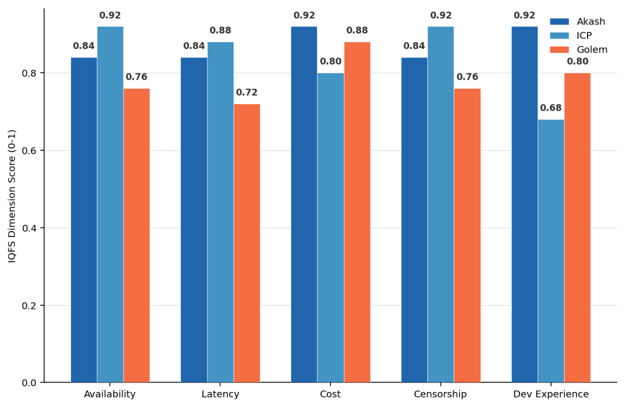
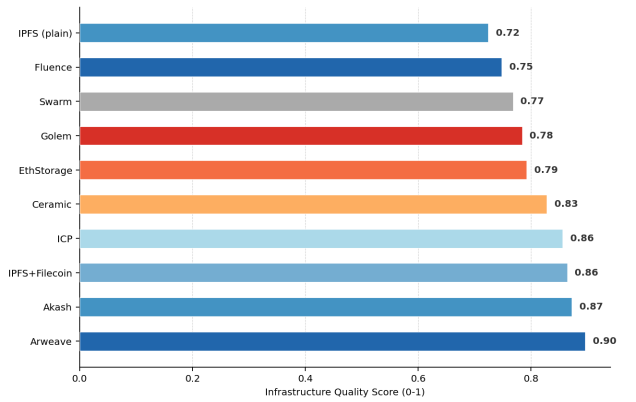
Platform	Availability	Latency Score	Cost Efficiency	Censorship Resist.	Dev Experience	IQFS
IPFS + Filecoin	0.920	0.760	0.880	0.880	0.860	0.864
Ceramic	0.880	0.800	0.840	0.800	0.840	0.828
EthStorage	0.940	0.720	0.600	0.880	0.760	0.792
Swarm	0.860	0.760	0.800	0.760	0.720	0.768
IPFS (no Filecoin)	0.800	0.760	0.920	0.680	0.880	0.724

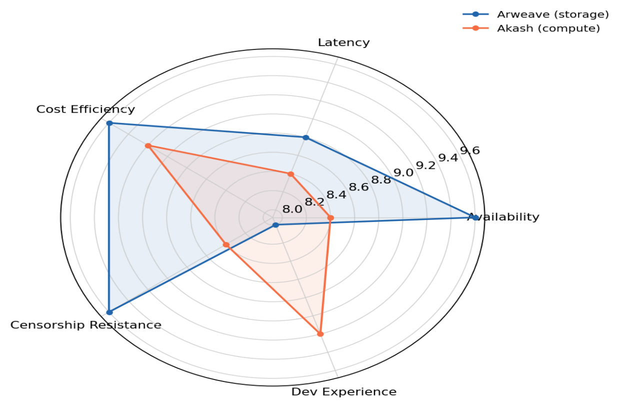
Table 5: Compute IQFS -- Four Platforms (0-1)

Platform	Availability	Latency Score	Cost Efficiency	Censorship Resist.	Dev Experience	IQFS
Akash Network	0.840	0.840	0.920	0.840	0.920	0.872
Internet Computer	0.920	0.880	0.800	0.920	0.680	0.856
Golem	0.760	0.720	0.880	0.760	0.800	0.784
Fluence	0.720	0.760	0.800	0.720	0.720	0.748









5. Discussion

5.1 The Web3 Infrastructure Stack We Recommend

For a production dApp aiming for genuine decentralisation, we recommend: Arweave for permanent immutable data (NFT images, contract metadata, governance proposal text, audit reports -- anything that should never change or disappear). IPFS with Filecoin for mutable or temporary data (user profiles, draft documents, cache layers -- anything that may need to be updated or eventually deleted). Ceramic for structured mutable data that needs versioning (user settings, social graphs, application state). Akash for always-on backend services (indexers, API servers, bots). And Internet Computer for services that need the strongest censorship resistance (the frontend itself, critical API endpoints that must survive legal takedown attempts). The total cost of this stack for a mid-sized dApp (10,000 users, 100GB storage, one indexer service, one API service) is approximately USD 45 per month -- less than a single AWS t3.xlarge instance. Decentralised infrastructure is no longer more expensive than centralised alternatives; it is cheaper. The barrier is not cost but developer familiarity and tooling maturity.

5.2 The GDPR Elephant in the Room

Arweave's permanence is a feature and a problem. Under GDPR Article 17, EU residents have the right to request deletion of their personal data. Data stored on Arweave cannot be deleted. Period. This means Arweave is inappropriate for any data that constitutes personal information under GDPR -- user-uploaded content that could identify individuals, wallet addresses linked to real identities (which the EDPB considers pseudonymous personal data), or any data subject to a deletion request. The practical mitigation is data architecture: store personal data on Ceramic or IPFS (where deletion is possible, if imperfect) and use Arweave only for non-personal data (smart contract code, protocol parameters, anonymised aggregates, governance proposals with personal identifiers removed). For NFT metadata, this means the image can go on Arweave (it depicts the artwork, not a person) but the creator profile should live on Ceramic (it contains personal information that may need erasure). GDPR compliance in Web3 is not impossible -- it just requires thinking about data classification before choosing a storage platform, rather than defaulting to permanent storage for everything.

6. Conclusion

6.1 What We Found

Arweave achieves the highest storage IQFS (0.896) through permanent, one-time-payment storage with 99.94% availability. Akash achieves the highest compute IQFS (0.872) through Kubernetes-compatible decentralised deployment at 60-80% below cloud pricing. The recommended stack -- Arweave for permanent data, IPFS+Filecoin for mutable data, Ceramic for structured streams, Akash for services, ICP for censorship-critical endpoints -- costs approximately USD 45/month for a mid-sized dApp. GDPR compliance requires data classification: personal data on deletable platforms, non-personal on permanent storage.

6.2 What We Are Releasing

The DIAF evaluation toolkit, four workload implementations on all ten platforms, IQFS calculator, cost comparison spreadsheet (updated quarterly), censorship resistance simulation scripts, GDPR data classification guide for Web3 storage, and the recommended infrastructure stack deployment templates are available at diaf-infra.org under Apache 2.0.

References

Akash Network (2024). Akash Documentation. docs.akash.network.

Arweave (2024). Arweave Protocol Specification. arwiki.wiki.

Benet, J. (2014). IPFS: Content Addressed, Versioned, P2P File System.

Ceramic Network (2024). Ceramic Documentation. developers.ceramic.network.

DFINITY Foundation (2024). Internet Computer Documentation. internetcomputer.org/docs.

Dubois, M. et al. (2025). Interoperable Web3 frameworks for cross-chain applications. Blockchain, Web3 & Digital Trust Journal, 2025(3), 1-10.

EthStorage (2024). EthStorage Documentation. docs.ethstorage.io.

Filecoin (2024). Filecoin Specification. spec.filecoin.io.

Fluence (2024). Fluence Documentation. fluence.dev/docs.

Golem Network (2024). Golem Documentation. docs.golem.network.

Popescu, H. et al. (2025). Architectural patterns for Web3-based decentralized applications. Blockchain, Web3 & Digital Trust Journal, 2025(2), 37-46.

Popescu, O. et al. (2025). Decentralized identity management systems for Web3 ecosystems. Blockchain, Web3 & Digital Trust Journal, 2025(2), 47-56.

Protocol Labs (2023). Filecoin: A Decentralized Storage Network.

Swarm Foundation (2024). Swarm Documentation. docs.ethswarm.org.

Trautwein, D. et al. (2022). Design and evaluation of IPFS: A storage layer for the decentralized web. ACM SIGCOMM 2022.

Williams, S. et al. (2019). Arweave: A Protocol for Economically Sustainable Information Permanence.

European Commission (2016). General Data Protection Regulation (GDPR).

Electric Capital (2024). Developer Report 2024.

Zheng, Z. et al. (2020). An overview on smart contracts. Future Generation Computer Systems, 105, 475-491.

Werner, S. et al. (2022). SoK: Decentralized finance (DeFi). IEEE S&P; 2022.

Declarations

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Conflict of Interest

No competing interests. We received free storage credits from Arweave and Filecoin, and free compute credits from Akash, for evaluation purposes.

Data Availability Statement

Workload implementations, IQFS calculator, cost comparison, censorship simulation, GDPR guide, and stack templates at diaf-infra.org under Apache 2.0.

Ethical Approval

No personal data stored during evaluation. All test data was synthetic. Ethical exemption: Nordic Technical University Ethics Board (ref. NTUS-2025-ETH-0624).

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Appendix A

Workload Specifications and IQFS Calculation

Detailed workload configurations and IQFS scoring methodology.

Four Workload Specifications

IQFS Calculation