mythos

DePIN Deep Dive: Bridging To The Real World

Table of Contents

Introduction

Decentralized Physical Infrastructure Networks (DePINs) represent an innovative application of blockchain technology to disrupt the traditional, centralized model of physical infrastructure development and management. Historically, the physical infrastructure space is dominated by large corporations and governments with significant financial resources, such as big software or telecommunication companies - DePIN applications aim to challenge this status quo.

DePIN Networks use crypto-incentives to coordinate the operation of their underlying infrastructure efficiently.

DePINs proposed a paradigm shift towards a decentralized system empowered by individual participation and incentivized through cryptocurrency tokens for the first time in a decade. In short, DePINs create a future where infrastructure like wireless networks, computing, data storage, and even sensor data are built and maintained not by singular entities but by collaborative networks of individuals. This is achieved through a combination of key elements:

- ***Blockchain as the Foundation:*** Blockchain technology serves as the core infrastructure for DePINs, providing a secure and transparent platform for tracking contributions, managing token rewards, and ensuring fair governance within the network.
- ***Tokenized Incentives:*** DePIN networks oftentimes leverage cryptocurrency tokens to reward individuals who contribute physical resources to the infrastructure. This can incentivize actions such as deploying a wireless node in one's home to bolster internet coverage or sharing excess storage capacity on a personal computer to contribute to a decentralized cloud network.
- ***Integration with Decentralized Finance (DeFi):*** DePINs seamlessly integrate with DeFi principles, creating a self-sustaining ecosystem. Token holders can stake their holdings to earn rewards, further incentivizing participation and organic network growth.

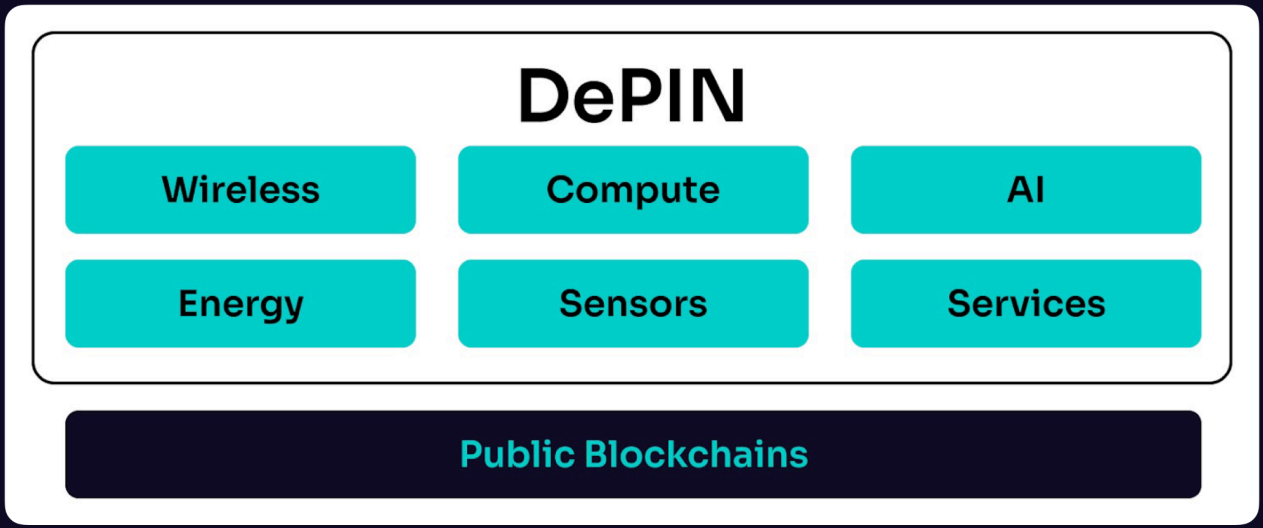
DePINs can be classified in many ways, with compute, wireless, and sensors being some of the key verticals.

DePIN Sectors

The core concept of DePINs revolves around rewarding users for actively participating in building and maintaining the physical assets of the Networks. These contributions can encompass a wide range of infrastructure elements, including:

1. ***Decentralized Storage Solutions:*** Individuals with unused storage space on their personal computers can contribute to the DePIN, creating a decentralized storage network. This can offer cost-effective and scalable storage solutions for various applications within the DePIN ecosystem.
2. ***Shared Computing Power:*** By sharing excess computing power, users can contribute to resource-intensive tasks required by the DePIN network. This can range from data processing and analysis to running decentralized applications that rely on distributed computing power.
3. ***Wireless Infrastructure Expansion:*** To strengthen the network's coverage and capacity, users can contribute by deploying wireless access points, such as home routers. This fosters a more ubiquitous and reliable network presence, particularly in underserved regions.
4. ***Sensor Network Integration:*** Users can contribute by installing sensors that collect environmental data relevant to the network's operation. This data can be crucial for optimizing network performance, monitoring resource utilization, and even enabling new applications based on real-world data collection.

Figure 1: Overview of DePIN Verticals



DePIN Fundamentals

The idea behind DePIN was introduced long before its naming of DePIN itself. DePIN originates from the belief of Web3 developers that people worldwide can collaborate to build an infrastructure network that is independent of third parties and does not require mutual trust. After establishing a decentralized physical infrastructure network, it will attract user participation and contribute to the development of the network. Members involved in building and operating the network will be rewarded with fees from the network, typically in the form of tokens. Thus, forming perpetual mutual benefits for both parties.

Trends and Developments

From the Bitcoin Whitepaper in 2008 to the $66 billion business, here's the development of what is known as DePINs now:

📅 2014: The dawn of decentralized storage arrived with Filecoin, Storj, and Sia, pioneering a new paradigm for data management. This development marks the beginning of a broader DePINs ecosystem.

📅 2017: Decentralization extended beyond data, with the emergence of Akash, Livepeer, and Render as the first decentralized computing networks. This marked a significant step towards a more distributed infrastructure landscape.

📅 2019: The year witnessed the birth of MachineFi, aiming to establish a "machine economy" where connected devices could actively participate in the financial system. This concept, built on the IoTeX blockchain, laid the foundation for DePIN by empowering users to monetize their device data. Helium also entered the scene, pioneering decentralized bandwidth networks. This marked another crucial step towards a more distributed infrastructure ecosystem, showcasing the growing potential of DePINs.

📅 2020: The evolution of DePINs accelerated with the introduction of the Neural Internet by Bittensor, the first Decentralized AI Services Network. This further broadened the scope of decentralized infrastructure.

📅 2021: Sensor networks joined the DePINs revolution with the arrival of Dimo and Hivemapper. These projects showcased the potential for decentralized data collection and management in various sectors.

📅 2022: This year witnessed a surge in DePINs activity. The innovative Proof of Physical Work (PoPW) consensus mechanism emerged, incentivizing users to contribute physical resources like wireless networks, mobile infrastructure, and storage solutions. This concept empowered users to become active participants in building the very infrastructure they rely on.

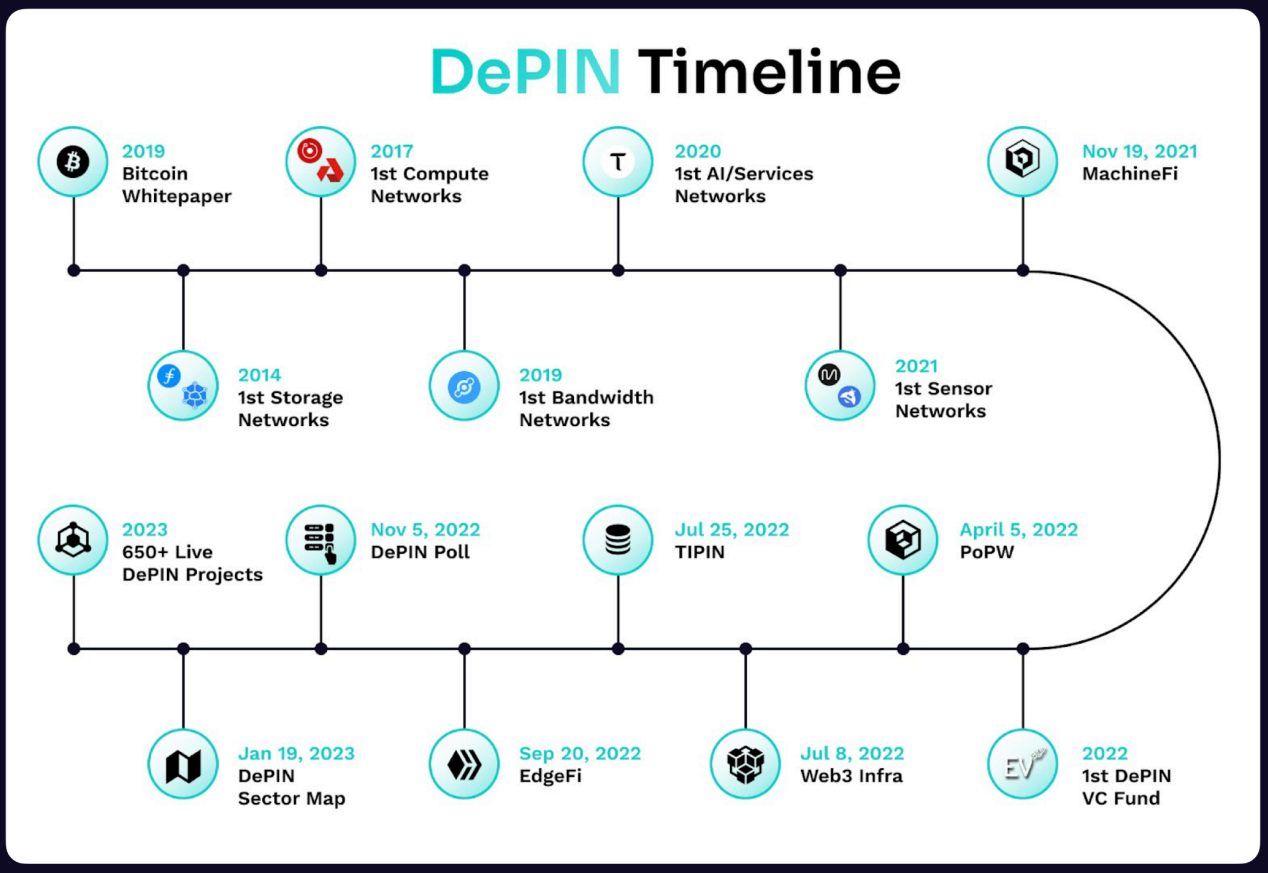
📅 Mid-2022: Token-incentivized physical Infrastructure Networks (TIPIN) emerged, further promoting user engagement through token-based rewards for deploying and managing physical infrastructure. This approach aimed to create a more equitable and decentralized model than traditional, centralized infrastructure management.

📅 September 2022: EdgeFi entered the scene, focusing on the strategic deployment of hardware resources at the network edge, specifically near end-users. This addressed the growing demand for efficient data processing amidst the proliferation of IoT devices.

📅 2023-Present: The DePIN ecosystem continues flourishing, with over 650 live projects and a market capitalization exceeding $20 billion. This rapid growth underscores the immense potential of DePINs to reshape how physical infrastructure is built, managed, and utilized.

📅 Present: A new wave of innovative projects is emerging. Projects such as Aethir aim to revolutionize DePINs with key improvements, such as their distributed enterprise-grade GPU-based compute infrastructure tailored for AI and gaming solutions.

Figure 2: Timeline of DePIN Innovation



How DePIN works

Figure 3: Centralized vs. Decentralized Comparison

Feature	Centralized System	Decentralized System
Single Point of Failure	Yes	No
Transparency	Limited	Increased
User Control	Limited	Enhanced
Censorship Risk	High	Reduced

DePIN's Operational Principles and Consensus Mechanism

Imagine a digital marketplace where users contribute resources like storage space, computing power, or even internet connectivity, and earn rewards for doing so. These are the operational principles behind DePINs projects. These projects function like resource ecosystems. They identify valuable resources individuals possess, like unused computer storage, and connect them with those who need them. A clear incentive system is the engine that keeps these ecosystems running. Users who contribute resources and provide reliable services are rewarded with the project's digital tokens. For example, Filecoin, a leading DePIN project, focuses on cloud storage and uses the FIL token to compensate storage providers.

To ensure quality and disincentivized malicious behavior, some projects require providers to put up a "security deposit" in the form of tokens. If a provider fails to deliver promised services or engages in harmful activities, they risk losing this deposit or even being excluded from the network.

Conversely, users leverage these tokens to pay for the resources they need. For example, FIL can be used to purchase storage space on Filecoin. By creating a marketplace for resources and incentivizing participation, DePINs pave the way for a more decentralized and user-driven digital infrastructure.

Interestingly, no singular consensus mechanism is universally adopted across DePIN projects. However, one commonality is that most DePIN projects aim to achieve Byzantine Fault Tolerance (BFT). BFT ensures a distributed system can operate correctly even if some nodes malfunction or exhibit malicious behavior. BFT is critical for achieving consensus among participants in a blockchain network, guaranteeing transaction security and validity. While BFT is a core principle, each DePIN project may leverage its own approach to achieve network agreement. This can include, but is not limited to:

- Established Options: Proven consensus mechanisms like Proof of Work (PoW) and Proof of Stake (PoS) might be adapted for DePINs. These adaptations likely focus on incentivizing physical infrastructure contributions while maintaining security and efficiency.

- Hybrid Approaches: DePIN projects could evolve towards a combination of existing models. This could involve elements from Proof of Work (PoW) or a variant like Proof of Physical Work (PoPW) integrated with Proof of Stake (PoS). The consensus must align with the project's ambitions and goals.

Examples of consensus mechanisms used by DePINs :

- Helium Network utilizes a unique "Proof of Coverage" (PoC) to verify that Hotspots accurately represent their location, configuration, and the wireless coverage they create. Proof of Coverage incentivizes Hotspot Operators to deploy Hotspots in underserved areas and

report their deployments accurately so that users of the Helium Network can see where coverage is likely to be available.

- Aethir is following a different approach to support a high-performance network architecture. Since Aethir needs to guarantee a fast connection and low latency rendering service, the global network is divided into distinct regional side chains. The main chain is called the Aethir Blockchain Hub, and the side chains are simply called Aethir Session Zones. Dividing side chains and submitting session information by region relieves real-time, main chain concurrency, and storage pressure. Consensus is first achieved on the side chain, after which the information is uploaded to the main chain. The consensus mechanism utilized by Aethir is called “Proof of Rendering Capacity”. Aethir will randomly select 30–40 validator nodes from all containers that have staked the required amount of Aethir Tokens. For this service, the validators receive a corresponding consensus reward at the end of the Epoch.

- Hivemapper Network called their consensus mechanisms “Proof of Locations.” Trustworthy data collection is crucial for their street-level imagery project. They employ a three-layered verification system to ensure the location accuracy of uploaded data. This system incorporates GPS, Helium's LoRaWAN network, and post-collection Map Image QA, offering redundancy and protection against potential failure in any single layer.

Verification and Reward Distribution

The specific implementation details of Consensus Mechanisms may vary depending on the DePINs network in question. However, the general framework involves users providing verifiable proof of their physical contributions. This verification process could involve:

1. Secure Registration: Users securely register their physical infrastructure with the DePIN network, providing details and specifications of their contributing resources.

2. Verifiable Evidence: Users demonstrate their ongoing contributions through various means. This could involve network logs for wireless access points, tamper-proof data storage solutions, secure verification of computing power contribution, or sensor data that prove their participation.

Successful verification of physical contribution leads to rewards in the form of tokens (which could be the DePIN's native tokens). This incentivizes users to actively participate in building and maintaining the network, creating a user-driven and collaborative approach to infrastructure development.

DePINs represent a transformative paradigm shift in infrastructure development. They are rooted in the foundational principles of the Internet of Things (IoT) and leverage blockchain technology and cryptocurrencies to build global collaboration in constructing, maintaining, and operating physical infrastructure networks. This innovative approach eliminates the need for reliance on third-party intermediaries, building a more inclusive and user-driven ecosystem. To function efficiently, DePINs rely upon four pillar principles:

1. Physical Infrastructure: This underpins the core functionality of DePINs, encompassing tangible assets such as mobile and wireless network infrastructure (base stations, routers), and server infrastructure for cloud networks, sensors, and many other tangible physical infrastructure. These components form the backbone of the decentralized network, enabling seamless service provision.

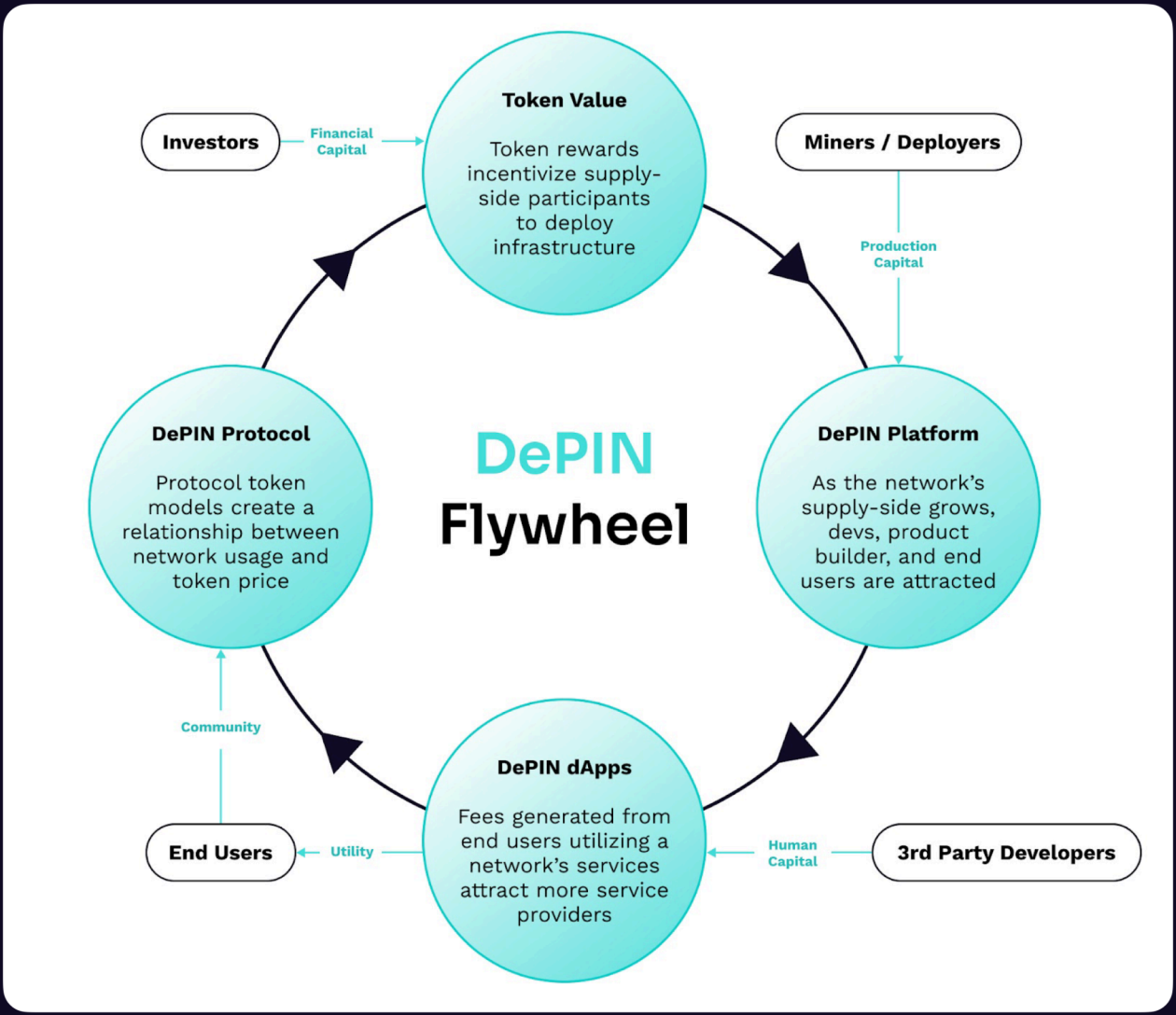
2. Off-Chain Computing Infrastructure: The off-chain computing infrastructure plays a crucial role as a vital bridge between the physical world and the blockchain. This component facilitates the

recording of user activities in the real world, the subsequent distribution of fees users pay within the real world, and the subsequent distribution of fees paid by users to hardware providers. Additionally, it enables the aggregation of this data for diverse use cases on the blockchain, for further analysis and application development.

3. Token Incentives: A cornerstone of the DePIN framework, token incentives serve as an effective tool for rewarding network participation. By offering token rewards to individuals actively contributing to the network's construction and maintenance, DePINs attract users and encourage collaborative network building, even before the project generates sustainable revenue from user demand. This initial phase of network development is crucial for establishing a strong foundation upon which the network can grow.

4. End Users: Once the DePIN is established and operational, a final crucial component emerges: end users. These individuals represent the beneficiaries of the decentralized infrastructure, utilizing the services provided by the network. End users contribute to the network's sustainability through convenient and secure payment mechanisms.

Figure 4: The DePIN Flywheel



Benefits of DePIN Integration

By harnessing the power of decentralization, DePINs offer a bunch of advantages over traditional, centralized infrastructure models:

1. Enhanced Resilience: DePINs exhibit inherent resistance to disruptions due to their distributed nature. Unlike centralized systems susceptible to single points of failure, DePINs ensure continued

service availability despite localized issues.

2. Increased Security: Blockchain technology's distributed control framework and tamper-proof nature contribute to enhanced security within DePINs. This approach mitigates risks associated with cyberattacks and data breaches, fostering a more secure and trustworthy infrastructure platform.

3. User-Driven Development: DePINs empower individuals to actively participate in network development and governance actively, building a sense of ownership and engagement among stakeholders. This user-centric approach creates a dynamic and responsive ecosystem that can adapt readily to evolving user needs and priorities.

DePINs represent a glimpse into the future of infrastructure development, offering a more resilient, scalable, and inclusive approach than traditional centralized models. By leveraging the combined power of IoT, blockchain technology, and tokenized incentives, DePINs pave the way for a future where individuals can actively contribute to and benefit from the infrastructure that shapes their digital and physical worlds.

Challenges of building DePINs

DePINs require a robust and secure consensus mechanism to maintain network integrity and ensure fair participation. While Proof of Physical Work (PoPW) offers a unique approach, it faces challenges verifying the validity and value of diverse contributions across different resource types. Designing a consensus mechanism that effectively incentivizes a wide range of contributions while ensuring efficient verification and fair reward distribution remains an ongoing area of research and development. There are additional challenges when it comes to building DePIN projects.

- Scalability: As DePINs gain traction and user bases expand, scaling the network becomes critical. Managing the increasing complexity of a

decentralized network, accommodating growing data storage needs, and ensuring efficient transaction processing present significant technical hurdles.

- Regulatory: The regulatory landscape surrounding DePINs is still evolving, lacking clear guidelines and established frameworks. The absence of clear regulations can hinder DePIN development and adoption by creating uncertainty for investors and developers. Establishing a regulatory framework is crucial for the sustainable growth of DePINs.

- Initial Investment: Building the initial physical infrastructure for DePINs requires significant upfront investment. This can delay the network's ability to generate sustainable revenue and offer competitive service costs compared to established, centralized infrastructure providers. Balancing the need for an initial investment with the ability to attract users and generate revenue through efficient service provision is a key challenge for DePIN in its early stages of development.

- Token Volatility: Since many DePIN projects utilize token-based incentive structures, the volatile nature of cryptocurrency markets can impact user incentives and potentially lead to network instability. Mitigating the impact of token price fluctuations and exploring alternative incentive structures that are less susceptible to market volatility is crucial to designing the best tokenomics possible.

Benefit		Challenges	
Lightning Fast Scaling	DePINs leverage crowdsourced physical infrastructure, enabling rapid network scaling at a fraction of the traditional cost.	Scalability	Ensuring fast transaction processing requires overcoming significant technical hurdles.

Community Ownership	DePINs empower communities to own and manage the network infrastructure, aligning stakeholder interests for long-term adoption and growth.	Regulatory	The evolving regulatory landscape with unclear guidelines and frameworks can hinder DePIN development and adoption.
Open Governance	DePINs operate with open, democratic, and accessible governance, allowing communities to shape the network's direction.	Initial Investment	Significant upfront investment is required to build the initial physical infrastructure, potentially delaying revenue generation.
No Gatekeeping	DePINs are permissionless, open, and censorship-resistant. No centralized entity can deny network access.	Token Volatility	The volatile nature of cryptocurrency markets can impact user incentives and lead to network instability.

Figure 5: Benefits and Challenges of DePIN Applications

Thankfully, DePINs do have a lot going for them on that front. Offering a variety of competitive edges over the traditional model:

- Hardware and telecom Companies must invest billions in capital expenditures in infrastructure and real estate to host it and keep thousands of employees to manage it. DePINs incentivize network members to take care of this while everyone profits.

- DePINs offer their members secure peer-to-peer payments without relying on a payments processor intermediary taking a cut, which is the perfect use case for blockchain utility.

- DePINs also grant the network participants direct access to various Web3 tools and DeFi services, such as financing new hardware, that can unlock even more revenue streams for them.

- DePINs reduce the barriers to entry and bring new competition into various industries that have been lacking innovation for a while, incentivizing innovation across the board.

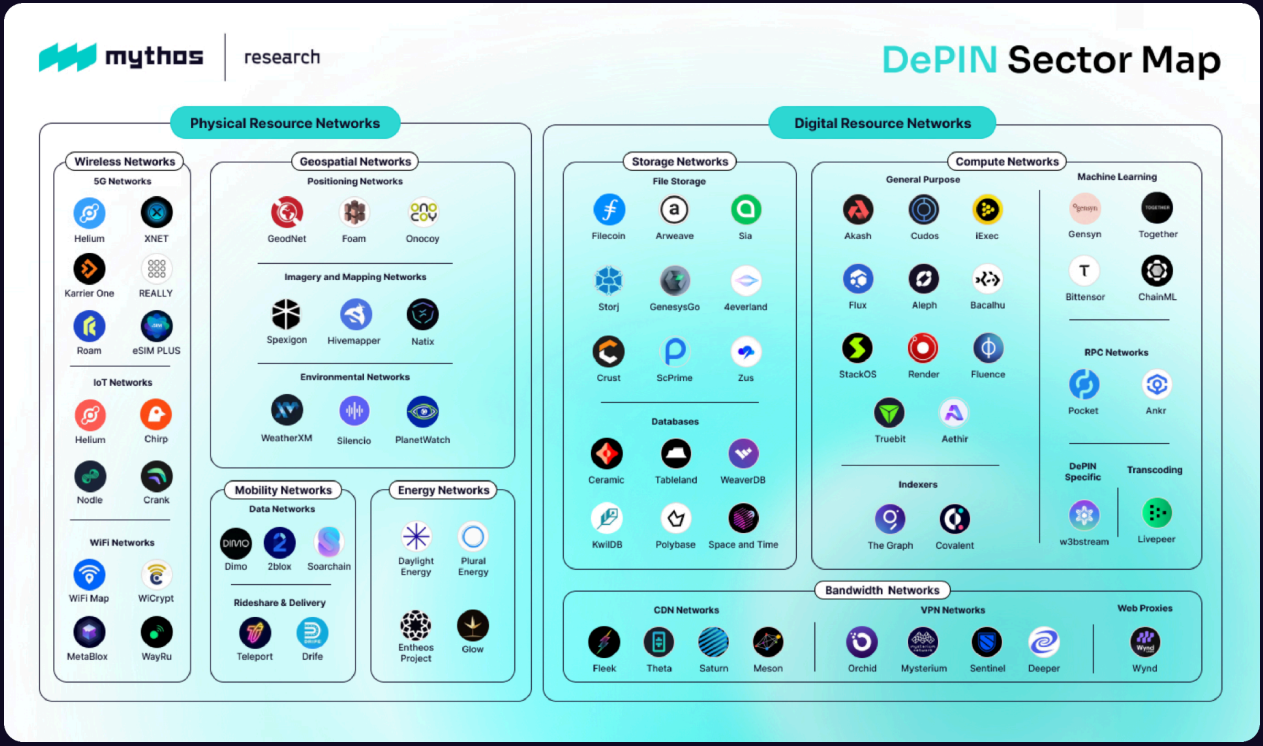
Figure 6: Comparison between Centralized Infrastructure and DePIN applications

Criteria	Centralized Infrastructure	DePIN
CapEx	Massive up-front capital requirements — high barrier to entry.	Crowdsourced CapEx by users — motivated by transparent & fair token incentives.
OpEx	Inefficient, bureaucratic processes — depress operating margins.	Onchain settlements reduce admin overhead and transparency on a shared ledger.
Single Point of Failure	Security & reliability depend entirely on a handful of opaque infra providers.	Decentralized networks reduce single-points-of-failure risks — at least, make them more transparent.
Innovation	Zero innovation culture; new tech takes years to roll out & integrate.	The pace is high because of experimentation in the open & being permissionless.

Overview

More than 650 projects are being built in the DePIN space. While we expect this number to increase significantly over the coming years, there are a few leaders to highlight. While most of the market share is with projects that have been established for a long time, we see a lot of innovation and expect the landscape to change quickly.

Figure 7: DePIN Sector Map



As mentioned above, we want to highlight some sectors within the DePIN space.

Decentralized Storage

In the ever-expanding digital realm, data storage has become a vital concern. From personal memories captured as photos and videos to critical business records, a big amount of information requires a secure and reliable haven. This is where decentralized storage emerges as a revolutionary alternative to traditional, centralized storage systems. Imagine a colossal warehouse where a single corporation controls access, security measures, and pricing structures. This explains the concept of centralized storage.

Figure 8: Strengths and Weaknesses of Decentralized Storage

Decentralized storage overcomes a lot of the downside of a centralized storage system by introducing a peer-to-peer (P2P) network. Instead of a

single entity wielding control, individual users contribute storage space on their personal computers, acting as storage providers (SPs) or miners. This distributed network offers a multitude of benefits:

- Decentralized storage eliminates the requirement for a central server. Instead, users connect directly with each other over a blockchain, which maintains a secure and transparent record of transactions on the network.

- Regular users with unused storage capacity can participate in the network by offering their unused space. These users are known as SPs or miners. Users get incentivized.

- To ensure data security and privacy, decentralized storage systems encrypt the user's data before storing it. Additionally, the data is split into smaller fragments or shards and distributed across various SPs on the network. This process minimizes the risk of data loss or corruption, as no single SP holds the complete data.

- With data dispersed across the network, accessibility is enhanced. Even if a few SPs go offline, the remaining nodes can still fulfill data retrieval requests. This redundancy also safeguards against data loss due to hardware failures.

Ultimately, as more users participate in the network, the decentralized system's overall storage capacity and processing power can grow significantly.

While decentralized storage offers exciting possibilities, it's important to acknowledge some potential challenges. Due to the distributed nature of the network, retrieving data can sometimes be slower than centralized storage. Setting up and managing data on decentralized platforms might require more technical expertise than user-friendly centralized storage solutions. Decentralized storage is a relatively new technology; some platforms are

still developing. This can lead to potential risks associated with project stability and adoption.

Despite the exploding demand for data storage within Web3, the adoption of Decentralized Storage solutions remains quite slow. Currently, most Decentralized Storage users are other crypto networks. This indicates a need for more awareness and understanding of Decentralized Storage benefits among retail users, both those familiar with Web2 and those actively participating in Web3.

Filecoin has had some good results in attracting Web2 data, and its storage utilization has skyrocketed by 650% from 2022 to 2023. However, this growth is overshadowed by an 85% decrease in revenue per terabyte stored. This suggests a potential misalignment between the network's capacity and ability to attract a broader user base, particularly retail users. Increased demand from retail users typically translates to price appreciation for the network's native token.

Huge storage demands can be seen on every edge of Web3. Oracle networks, like the Chainlink process, secure over 10 billion data points. Layer 1 blockchains, for instance, Solana, store data roughly equivalent to 200 terabytes.

Decentralized Storage holds immense potential to revolutionize data ownership and security. However, to bridge the gap between this potential and widespread adoption, Decentralized Storage solutions must address the challenges of user awareness, tokenomics optimization, and scalability. By capitalizing on the increasing data storage needs of the blockchain ecosystem, Decentralized Storage networks can evolve and secure a crucial role in the future of web3.

Case Study: Filecoin

Imagine Filecoin as a giant digital marketplace for storage. Here, users with data to store (clients) meet miners who offer unused space on their computers. This marketplace is transparent, meaning everyone can see the deals being made. Clients can find storage solutions to their needs, specifying how long they need storage, how many copies they want of their data (redundancy), and the price they're willing to pay. On the other hand, miners set their prices based on factors like how much space they have available, how reliable their connection is, and where they're located. Filecoin also has a retrieval market, where clients pay miners to access their stored data. This system rewards miners for providing fast and reliable access, ensuring you can get your data back quickly when needed.

These two markets, combined with Filecoin's unique security mechanisms (proof-of-replication and proof-of-spacetime), ensure your data is stored securely and retrievable across the network. This innovative approach makes Filecoin a more dynamic and efficient data storage option than traditional cloud providers.

Filecoin disrupts traditional cloud storage by creating a decentralized marketplace for data. This marketplace connects users with storage providers (miners), offering unused computer storage space. Users pay miners in $FIL tokens to store and retrieve their data, while miners earn $FIL for providing this service.

Decentralized Compute

Decentralized Compute distributes computational tasks across a network of individual computers. Users with idle processing power (Suppliers) can contribute their resources to the network, while the required processing power (requester or users) can access them securely and transparently. Traditionally, centralized cloud providers like Amazon Web Services and Google Cloud have dominated this space, offering access to vast computing power. This decentralized compute narrative creates a two-sided marketplace where suppliers are incentivized to contribute their idle resources.

Adapting to the decentralized network can offer a more efficient and secure cloud computing environment. As more users participate in the network, the collective processing power scales dynamically, ready to adapt to the fluctuating demand for computing power.

Case Study: Aethir

The tech world relies heavily on powerful graphics cards (GPUs) for everything from artificial intelligence (AI) to gaming. Lately, demand for these GPUs has skyrocketed, outpacing production and causing a shortage. This scarcity drives up prices and makes it difficult for researchers, gamers, and businesses to get the necessary equipment. One major factor in this shortage is the rapid growth of complex AI models like ChatGPT. These models require immense processing power, pushing the limits of current GPU technology.

Built on the Arbitrum network, Aethir offers a solution to this global challenge. Their network acts like a giant pool of computing power, cleverly collecting unused or under-utilized GPUs from businesses, data centers, cryptocurrency miners, and regular consumers. The average data center in the US only uses 10-15% of its GPU capacity. Aethir taps into this hidden potential. Aethir boasts a significant infrastructure advantage, reportedly possessing 20x more GPUs and 45x greater compute power (TFLOPS) compared to the RNDR Network. Additionally, Aethir claims to have dedicated 31x more infrastructure capital than the combined investment of Akash Network and RNDR Network.

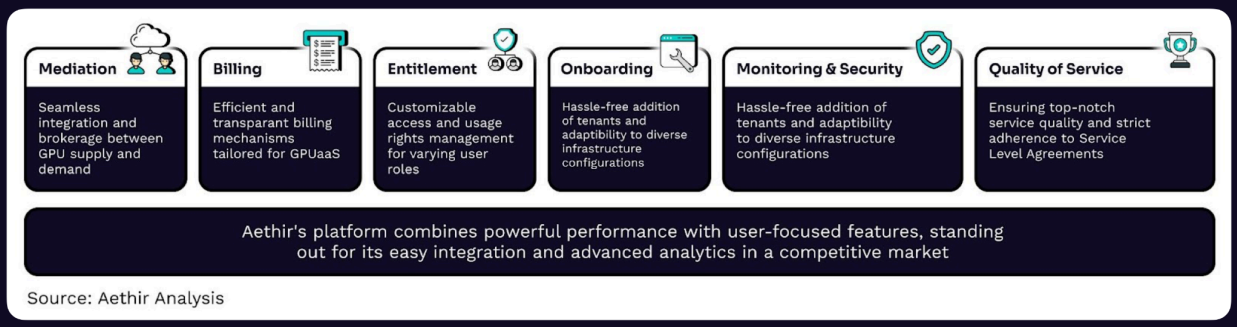
By connecting those who need processing power with those who have it to spare, Aethir can:

- Boost access to existing GPUs: Instead of waiting for new chips, researchers and businesses can utilize the network's pool of underutilized GPUs.

- Reduce risk for new investments: Companies can avoid the high costs and uncertainty of buying new GPUs upfront.

- Dramatically increase global GPU compute power: Aethir estimates their solution could potentially multiply the world's available GPU processing power by more than 10 times.

Aethir's innovative approach offers a win-win for everyone. It helps businesses and researchers access the power they need to innovate while allowing individuals to monetize their unused resources.



Wireless Networks

Global data transfer has compounded at a staggering 30-35% CAGR (Compound Annual Growth Rate) for the past 25 years, with no signs of slowing down. This surge is primarily driven by mobile video traffic. Projections estimate wireless data transfer from Wi-Fi alone to reach 10 million petabytes by 2027.

The rise of 5G connectivity is fueling this demand. By 2027, nearly 70% of wireless connections are expected to utilize 5G, generating a staggering $1.5 trillion annual revenue for wireless network service providers.

Figure 9: Overview of Wireless Network Markets

	Mobile	Fixed	WiFi
Market Size	$1T+ Global Annual Revenue	$400B Global Annual Revenue	$100B Global Annual Revenue
Key Unlocks	eSIM	PtMP & mmWave	WiFi7 & MVNO offload
Pro	Highest Revenues per GB	High User Retention	Most Used Wireless Types
Cons	Extremely Competitive	Lower Revenue per GB	Difficult to monetize
Crypto Leaders	eSIM+, Helium, Really	Andrena, Althea, Quantum	WiFi Map, WiCrypt

The fundamental difference lies in who builds and manages the network. Traditional wireless networks rely on large, well-funded telecommunication companies to handle infrastructure. This creates a centralized system with limited players controlling the industry.

Decentralized Wireless Networks flips this model. By using cryptographic incentives, Decentralized Wireless Networks empowers individuals and organizations to participate in building and maintaining network infrastructure. This collaborative approach lowers the barrier to entry and paves the way for a more decentralized, potentially more affordable wireless future.

Case Study: eSIM+

Mobile internet benefits person-to-person, building the next iteration of data ownership and growth. In contrast to that, fixed internet connects place-to-place. WiFi is the most widely-used connectivity protocol on earth and access to it is a key component for economic growth, freedom, and sovereignty.

As a response to this, new projects such as eSIM+ are emerging, helping to build the foundational layer of access for projects by providing services such as eSIMs, VPNs, and mobile phone numbers. Combining these services with a Digital Identity (DID) allows eSIM+ to create a trustless access system and build a foundational layer of internet access.

As an already existing business with millions of users, the crypto pivot allows eSIM+ to decentralize project ownership while simultaneously addressing coverage issues by enabling community members to contribute to the overall wifi mapping.

Implementing crypto elements allows eSIM+ to reward users and contributors, growing and validating the network while allowing users to participate in the overall growth of the project due to their profit-sharing mechanism.

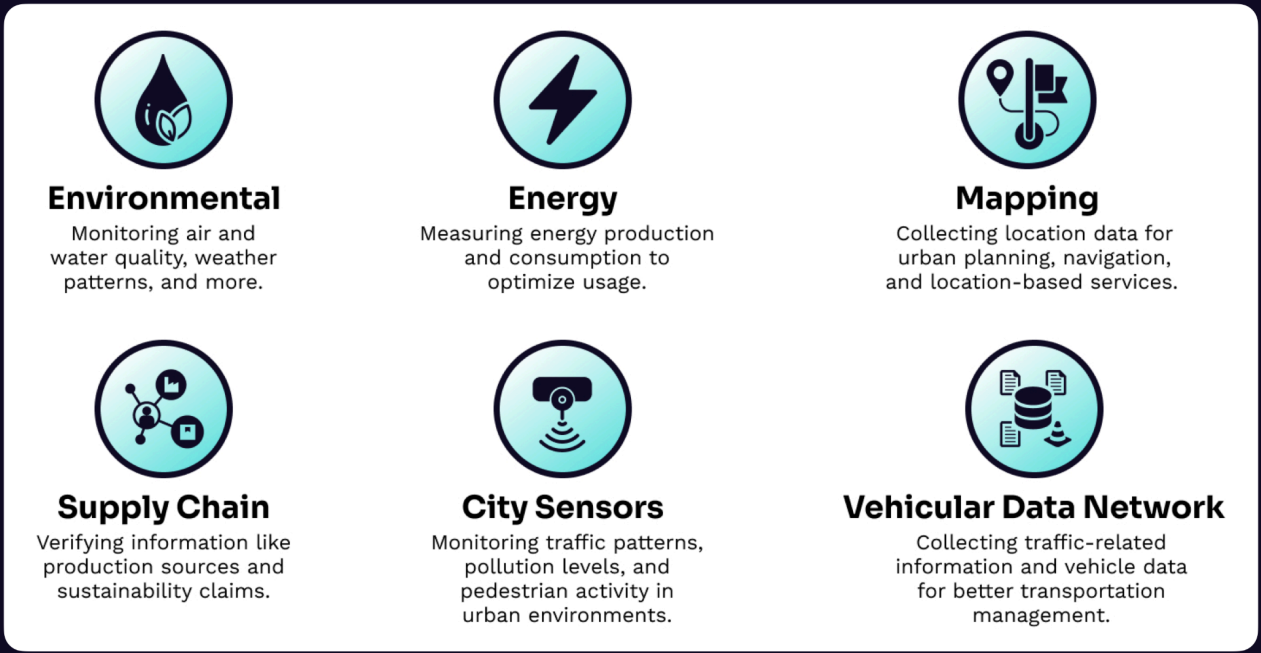
Sensors

Imagine a network of tiny, powerful sensors scattered throughout our environment, collecting data on everything from traffic flow to air quality. That's the core idea behind decentralized sensor networks. These networks

ditch the traditional "central authority" model like GoogleMaps and empower individual sensors to work together securely and transparently.

These networks specialize in collecting various types of data through different sub-sectors:

Figure 10: Types of Sub-Sectors



Decentralized sensor networks hold immense potential for a future where data collection is secure and transparent, empowering us to harness the power of information in new and innovative

Case Study: Hivemapper

The Hivemapper Network leverages its HONEY token to incentivize real-world contributions that turn information from dashcam into physical map creation. This collaborative approach enables faster, more cost-effective construction of digital infrastructure, finely tuned to meet global market needs.

Hivemapper empowers thousands of individuals to work together and create a comprehensive global map. Contributors participate in various ways:

- Dashcam Drivers: Capture real-world footage while driving, providing valuable visual data.
- AI Trainers: Analyze these images, helping train AI systems to understand the world as humans do.
- Mobile App Users: Report real-time issues they encounter, keeping the map constantly updated.

By working together, the Hivemapper community benefits from a shared reward: a fresh, detailed world map.

Traditional map data collection methods, often expensive and time-consuming, struggle to keep pace with a rapidly changing world. This results in outdated information, a significant hurdle for various applications. For instance, current maps, designed for human drivers, lack the crucial detail and freshness required by autonomous and semi-autonomous vehicles. Businesses are also burdened by high costs and limited options when integrating maps into their products, restricting innovation for smaller players.

Furthermore, existing maps often lack context for traffic slowdowns. They can't distinguish between minor inconveniences and major delays, hindering efficient route planning. User reported issues also face limitations, as users lack the ability to verify the situation visually. Finally, current mapmaking practices often rely on user-generated data without compensation or transparency regarding its commercialization.

The Hivemapper Network tackles these challenges. Its innovative approach creates a collaborative environment where users are incentivized for their contributions, ensuring fresh, detailed maps that benefit everyone.

DePIN Tokenomics

Like any business needs a well-defined financial plan, successful crypto projects require a carefully crafted roadmap - Token Economics or, in its famous terms, Tokenomics. Think of it as the rulebook that governs how cryptocurrencies or a blockchain project function.

For a DePINs project to thrive in the long run, it needs a good strategy for generating token supply and, more importantly, genuine demand for its product. Without a strong demand for the project's utility, the token's value becomes purely speculative.

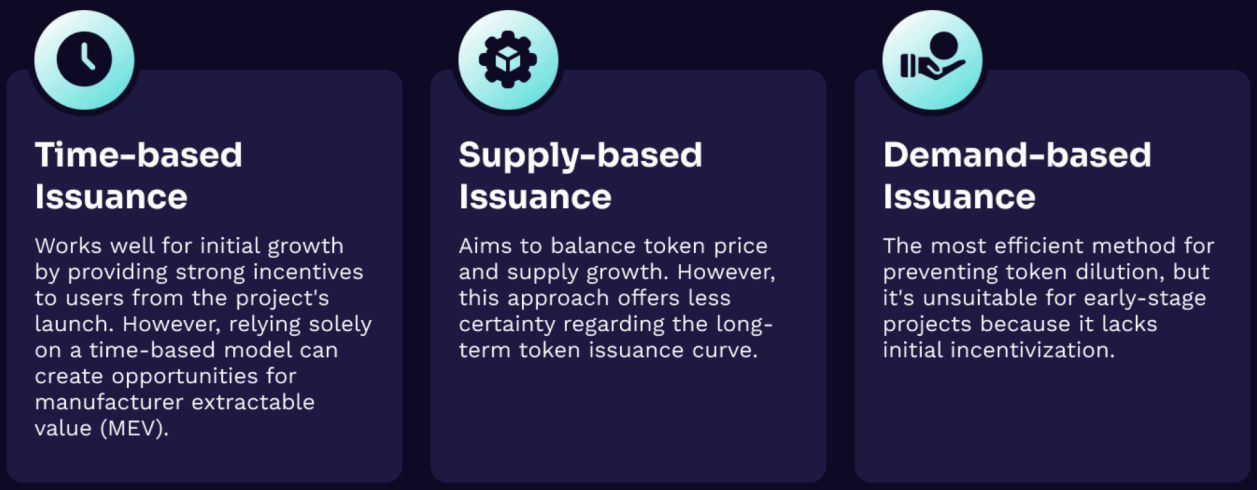
With the right tools, creating a token supply isn't overly complex. In simple terms, projects reward users for their contributions. The real challenge lies in determining the optimal amount of tokens to distribute. It's crucial to avoid over-distribution that depletes the tokens supply for future growth while ensuring enough tokens are available to attract participants. Newer projects often face an additional hurdle of the "cold start" problem, “a newborn network with limited contributors offers minimal value”. Reaching a desired number of users is essential before the network can even begin servicing demand.

Thus, some projects applied a gamification scheme to achieve that number even before the token generation. Hardware DePINs like Hivemapper, Helium, and Geodnet utilize "point boost" mechanisms to incentivize specific activities. In essence, users are drawn to projects that offer rewards for their contributions, leading to higher user retention and loyalty.
Most DePIN projects utilize four key dimensions for their dynamic reward systems.

Figure 11: DePINs Four Dimensions of Dynamic Reward Systems

There are three primary approaches to token issuance: time-based, supply-based, and demand-based. In practice, most DePIN projects combine elements of all three, utilizing different issuance schedules for various token allocations at specific times.

Figure 12: Three Primary Approaches to Token Issuance



By carefully crafting tokenomics that incentivizes user participation and balances supply with genuine demand, DePIN projects can build sustainable infrastructure that benefits both users and the network as a whole. This focus on long-term value creation will be crucial for DePINs to fulfill their goal of revolutionizing how people manage physical infrastructure.

Figure 13: Value Capture Overview

Three Primary Approaches to Token Issuance

Protocol	Token Model	Token Supply	Price of Services	Network Token Burn	Commodity Like	Token Governance
Filecoin	Stake-of-Access	Fixed Cap	Market Rate	Yes	Yes	No
Livepeer	Stake-of-Access	Inflationary	Market Rate	No	Yes	Yes
Chainlink	Stake-of-Access	Fixed Cap	Market Rate	No	Yes	No
The Graph	Stake-of-Access	Inflationary	Market Rate	Yes	Yes	No
Pocket	Stake-of-Access	Inflationary	Fixed	In Future	Yes	No
Helium	Burn-and-Mint	Inflationary	Fixed	Yes	No	Yes
Render	Burn-and-Mint	Inflationary	Fixed	Yes	No	Yes
Akash	Burn-and-Mint	Inflationary	Market Rate	Yes	No	Yes
Arweave	Endowment Model	Inflationary	Dynamic	No	Yes	No

When designing tokenomics for DePIN projects, it's important to differentiate between hardware and software projects. Whereas hardware DePINs mainly reward through mining rewards and contributions, software DePINs work best with point systems.

Figure 14: Hardware DePINs vs Software DePINs

Hardware DePINs vs. Software DePINs

Aspect	Hardware DePINs	Software DePINs
Type of Infrastructure	Physical hardware infrastructure (data storage, wireless connectivity, positioning, mapping, etc.)	Software-based infrastructure (data, bandwidth, protocols, etc.)
Incentive Mechanisms	Targeted bursts/boosts for mining rewards	Provision of points with potential to convert into tokens
User Adoption Strategy	Encourage high-value deployments through off-chain data & decisions incentivization	Scaling to tens or hundreds of thousands of active users before launching a token
Monetization	Benefits from using off-chain data and decisions to incentivize high-value deployments, potential revenue from hardware usage fees, mining rewards, or token value appreciation	Revenue generation through software services, including data sales, service fees, or other value-added offerings
Projects	Helium, GeodNet, Hivemapper	Grass, Silencio, Natix

Key Trends and Innovation

DePIN and AI

The ability to verify computations securely on the blockchain with Zero-Knowledge Verifiable Proofs or ZK is nearing reality. This paves the way for an "on-chain economy," where AI models can be used directly within blockchain applications. This decentralization disrupts the current dominance of centralized AI providers like Google's Gemini, which offers limited access (60 queries per minute) to capture user data for training purposes.

However, decentralized AI presents its challenges. Securely verifying AI computations currently comes at a significant cost – 75 times more expensive than traditional trusted methods. This is problematic for developers who want to integrate advanced AI into smart contracts on the blockchain. Lowering these overhead costs is crucial to unlock the full potential of on-chain AI.

Several Decentralized AI projects like Ritual, Spectral, Upshot, Modulus, and Giza are already emerging. As DePINs mature and ZK verification becomes cheaper, we can expect on-chain AI to become a powerful tool for developers.

DePIN and Beyond

A fascinating intersection is emerging between real-world infrastructure and on-chain gaming. This fusion is happening faster than anticipated, creating exciting new possibilities:
Beyond the advancements in AI and gamified infrastructure, DePINs hold immense potential for disrupting other critical sectors. One such area is the realm of trust and verification. Decentralized Random Number Generation protocols could eliminate the need for centralized entities to generate

random numbers, enhancing security for online games, online gambling platforms, blockchain protocols, and cryptography. This would create a tamper-proof system, building greater trust and fairness within these applications.

Another exciting possibility lies in Decentralized Advertising Data. Decentralized Advertising Data empowers users to control and monetize their advertising data. Data would be securely stored on the blockchain, preventing manipulation by third parties and giving users greater control over how their data is used. This shift towards user-centric data management could revolutionize advertising, promoting transparency and user empowerment.

DePINs could even transform how we verify physical assets. Imagine a decentralized mileage counter embedded within a car. This tamper-proof record of a vehicle's mileage would be accessible to potential buyers on the blockchain, preventing odometer fraud and creating trust in the used car market. Similar DePIN applications could be applied to real estate deeds, medical records, or even national election tallies, creating a secure and transparent record-keeping system that minimizes manipulation and ensures data integrity.

By creating innovation and solving the challenges in these areas and beyond, DePINs can reshape entire industries, ushering in a new era of trust, security, and user empowerment.

Conclusion

Decentralized Physical Infrastructure Networks are emerging as a game-changer, leveraging blockchain technology and crypto incentives to create a collaborative ecosystem. Traditionally, infrastructure development and management have been dominated by large corporations, often leading to centralized control and limited user participation. DePINs disrupt this model. By enabling individuals to contribute physical resources like storage space, computing power, or wireless network connectivity, DePINs create a more distributed and resilient infrastructure landscape. Users are incentivized through token rewards, creating a win-win situation: individuals earn for sharing resources, while the network benefits from a wider resource pool.

At the heart of DePINs lies blockchain technology. This distributed ledger system ensures secure and transparent network operation. Every transaction is immutably recorded, building trust and accountability. DePINs integrate seamlessly with Decentralized Finance, creating a self-sustaining ecosystem where tokens earned can be used within the broader DeFi landscape.

Relying on various consensus mechanisms to ensure network stability and validate transactions, DePINS often employed established mechanisms like Proof of Work (PoW) and Proof of Stake (PoS). However, DePINs also leverage unique mechanisms tailored to specific resource contributions. Proof of Coverage (PoC), for instance, is used in networks like Helium to verify wireless network coverage provided by users.

While DePINs hold immense promise, there are challenges to overcome. Identifying the optimal consensus mechanism that effectively incentivizes diverse contributions remains an ongoing pursuit. The evolving regulatory landscape surrounding DePINs necessitates ongoing adaptation.

Additionally, token value volatility can also present challenges.

However, the potential benefits of DePINs far outweigh the challenges. The distributed nature of DePINs significantly enhances network resilience, minimizing the impact of single points of failure. Blockchain technology safeguards DePINs from cyberattacks, creating a more secure environment. Open governance empowers communities to actively participate in shaping the network's future. DePINs offer rapid and cost-effective scaling potential, as the network can leverage the ever-growing pool of user-contributed resources.

As DePIN technology matures, we expect a surge of innovative applications across various industries. DePINs have the potential to democratize infrastructure, building a more inclusive and user-owned future. This report serves as a stepping stone to further exploration and adoption of DePINs, paving the way for a more resilient, collaborative, and empowering infrastructure landscape for all.