Proceedings of the 35th European Safety and Reliability & the 33rd Society for Risk Analysis Europe Conference
Edited by Eirik Bjorheim Abrahamsen, Terje Aven, Frederic Bouder, Roger Flage, Marja Ylönen
 Published by Research Publishing, Singapore.
doi: 10.3850/978-981-94-3281-3_ESREL-SRA-E2025-P3352-cd

Decentralized Physical Infrastructure Networks: A Catalyst for Critical Infrastructure Resilience?

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The growing complexity and interdependency of Critical Infrastructure (CI) systems have worsened their vulnerability to disruptions, and put their resilience as a key focus in both academic discourse and industrial practices. In recent years, Decentralized Physical Infrastructure Network (DePIN) has emerged as a concept that combines physical infrastructure with blockchain technology to create decentralized networks for various applications. It applies the principles of Web3 (decentralized internet) to the physical world. DePIN aims to establish decentralized networks for managing physical assets and services more efficiently, transparently, and securely. Unlike traditional centralized infrastructure, DePIN distributes decision-making, resource management, and system control across a network of sovereign (autonomously owned) but functionally interconnected nodes. This paper examines the impact of DePIN on CI resilience by analyzing how decentralization can enhance the ability of CI systems to cope with disruptions. We explore the potential benefits of improved flexibility, redundancy, and adaptability on CI resilience. In the first step, we examine the key characteristics of DePIN and its resilience-enhancing features. Subsequently, we examine real-world applications of DePIN in sectors such as energy, transportation, healthcare, and supply chain to assess its practical impact on resilience. By looking from the perspectives of Complex Adaptive Systems (CAS) theory and Resilience Engineering, we gain a deeper understanding of DePIN's potential to enhance CI resilience. While DePIN presents significant potential in improving resilience, there are also challenges and limitations related to coordination, interoperability, and governance that must be addressed to fully realize these benefits. The paper also outlines the current advantages and drawbacks of infrastructure decentralization, considering potentially associated economic and social impacts. Finally, we identify future research directions that can help leverage DePINs characteristics and design principles to develop the next generation of resilient, adaptable, and sustainable infrastructure systems.

Keywords: Decentralized Physical Infrastructure Network (DePIN), Critical Infrastructure, Resilience

1. Introduction

Critical Infrastructure (CI) systems play a vital role in sustaining the economy and community well-being through the provision of essential services such as electricity, transport, telecommunications and healthcare. Traditionally, large public companies have been responsible for establishing and managing essential physical infrastructure, including electricity grids, transport, water and waste management systems. CI systems have now reached a high level of connectivity and interaction and are merged into a system-of-systems. A disruption of one of the infrastructure systems easily propagates through other CI systems, affecting the entire economy and society. Thus, the resilience of these systems is paramount to ensuring continuity of services and mitigating the impact of disruptions.

In recent years, Decentralized Physical Infrastructure (DePIN) has emerged as a concept that combines physical infrastructure with blockchain technology to create decentralized networks for various applications (Ballandies et al., 2023). DePINs establish decentralized networks for managing physical assets and services more efficiently, transparently, and securely. Unlike traditional centralized infrastructure, DePIN distributes system control, decision-making and , resource management across a network of sovereign (autonomously owned) but functionally interconnected nodes.

This paper examines the impact of DePIN on CI resilience by analyzing how decentralization can enhance the ability of CI systems to cope with disruptions. We first examine the characteristics of DePIN and its resilience-enhancing features.

Subsequently, we examine real-world applications of DePIN to assess its practical impact on CI resilience. By looking from the perspectives of Complex Adaptive Systems (CAS) theory and Resilience Engineering, we gain a deeper understanding of DePIN's potential to enhance CI resilience. The paper also outlines the current advantages and drawbacks of infrastructure decentralization, considering potentially associated economic and social impacts. Finally, we identify future research directions that can help leverage DePINs characteristics and design principles to develop the next generation of resilient, adaptable, and sustainable infrastructure systems

2. Decentralized Physical Infrastructure Networks: Definition and Characteristics

DePINs are networks where physical infrastructure is managed, owned, or operated in a decentralized manner, typically leveraging blockchain technology and token-based incentives (Figure 1). Unlike traditional infrastructure controlled by centralized entities, DePINs distribute control, maintenance, and benefits among a wide array of participants. This approach reimagines the financing, construction, operation and maintenance of infrastructure and the vital services they provide. DePIN extends the principles of decentralization from digital (Web3 – decentralized internet) to the physical world, enabling new business models and access to CI (Wadhwani, 2025).

DePINs are dynamically coordinated networks of local elements (service providers) aiming to decentralize the control and ownership of physical assets, creating not only new opportunities but also challenges. The physical assets within a DePIN can range from telecommunications infrastructure, such as wireless networks and internet towers, to energy grids, transportation systems, and more.

2.1. *The role of Blockchain in DePIN*

DePIN uses blockchain technology to create a secure, transparent, and immutable record of ownership and operations. Blockchain-enabled decentralization also ensures that no single entity has control over the network. The main contributions of blockchain tech to DePIN include:

(i) **Transparency:** Blockchain ensures that all transactions in the network are recorded on a public ledger, making them visible and auditable by anyone, fostering trust and accountability.

(ii) **Security:** The decentralized nature of blockchain makes DePIN highly secure, as there is no single point of failure. The recorded data cannot be altered, ensuring data integrity.

(iii) **Smart Contracts:** These self-executing contracts enable automated agreements when predefined conditions are met. Within DePIN are used to automate processes, such as payments or governance decisions, without the need for intermediaries.

(iv) **Tokenization:** Blockchain enables the creation and management of DePIN crypto tokens, which are essential for the network's operation.

2.2. *DePIN Tokenization*

Digital tokens play several crucial roles within the DePINs ecosystem to enhance their functionality, governance, and economic model.

Governance. Token holders often have voting rights on network decisions, from protocol upgrades to community initiatives, fostering a governance model where those contributing to or using the network have a say in its direction.

Incentivization. Tokens are used to reward individuals or entities for contributing resources (physical infrastructure or services), for their engagement, performance, economic investment, network expansion, or community building.

Access to Services. Tokens facilitate transactions, so users might need to spend tokens to use services within the network. This function creates a demand for the token, which helps maintain its value.

"Tokenomics" refers to the economic model behind a token, encompassing its creation, distribution, and management. For example, tokenization allows for crowd-sourced funding of infrastructure projects without traditional financial intermediaries. The token's value can reflect the health, demand, and utility of the network, providing a market-driven metric for the infrastructure's worth.

Fig. 1. Fundamental components of DePIN

2.3. *Key Aspects of DePIN*

DePINs embody several key aspects that distinguish them from traditional centralized systems, as summarized in Table 1.

Distributed Ownership and Control. DePIN are in possession and control of independent actors. There may be a formal agreement to co-operate, but co-operating actors can also be competitors in the market. Instead of a single company or government controlling infrastructure, decisions might be made by individual operators, local communities, or through decentralized governance systems like Decentralized Autonomous Organizations (DAOs) (Petrenj & Trucco, 2023).

Peer-to-Peer (P2P), Local and On-demand Services. DePINs facilitate direct interaction between users for services, reducing or eliminating intermediaries, and reducing dependency on centralized providers. This can lead to lower costs, increased efficiency, and personalized services.

Use of Blockchain and Smart Contracts. Blockchain is used for transparent, tamper-proof record-keeping of transactions, ownership, or usage. Smart Contracts enforce rules of the network, manage payments, or distribute rewards without intermediaries. These technologies ensure trust, and automate agreements.

Tokens are commonly used for governance, rewards, and decentralized transactions, but their primary functions align with their sector-specific needs. For example, energy tokens focus on trading, grid management, and sustainability incentives, while supply chain tokens emphasize traceability, data monetization, and automation.

Table 1. Traditional Infrastructure vs. DePIN (adapted from Vilkenson, 2024)

	Traditional Infrastructure	**DePINs**
Ownership	Consolidated	Distributed
Governance	Centralized	Decentralized
Cyber Security	Centralized security measures	Decentralized protocols, encryption
Privacy	Providers handle data, GDPR	Privacy and data sovereignty.
Technology	Conventional, limited	Blockchain, Smart contracts
Transparency	Policy-dependent	Built-in high transparency
Incentives	Contract, salary	Token rewards

3. Study Methodology

The methodology for identifying and selecting the examples of CI systems working as DePINs involved several steps and criteria. The focus was on the cases of CI with evident:

- **Decentralization** – where control, maintenance, or operations are distributed across a network rather than centralized;
- **Physical Infrastructure –** projects that involve tangible or real-world entities like energy, transport, or health services;
- **Use of tokens** – to incentivize participation or as part of the system's operational model.

The first step focused on initial screening. We conducted a broad review of literature, including academic papers, industry reports, white papers, news articles and technology blogs discussing real-world applications of DePIN. The preference was given to projects/cases:

- Operational or in advanced stages of development towards real-world application;
- With evidence of real-world impact or practical applicability within the context of CI;
- With innovative aspects that bring something new or solve longstanding issues in a CI sector through decentralization;
- Able to demonstrate how decentralization impacts resilience in comparison to traditional centralized systems.

This methodology ensures that the chosen examples are both illustrative of the DePIN concept in action and relevant in the CI domain. The final selection includes the outstanding showcases of DePINs' impact on CI resilience.

3.1. *Theoretical frameworks for analyzing CI Resilience*

CI resilience is understood as the ability of the system to withstand, adapt to, and recover from adverse events of any kind (Kozine et al., 2018).

The first viewpoint, Resilience Engineering (RE), shifts from traditional safety engineering, which aims to prevent failures, to understanding how systems can remain effective under stress or disruptions. Resilience, in this context, is a system's capacity for flexibility, robustness, and adaptability in response to dynamic environment so that performance and safety are maintained at the desired level (Woods, 2015). RE emphasizes (i) adapting to changing circumstances and recovering from disturbances; (ii) the ability of a system to extend its capacity or functionality under stress, modify goals and priorities; (iii) decisions at the level where they are most effective, enhancing responsiveness (decentralized control) - Table 2.

Complex Adaptive Systems (CAS) theory considers the self-organization capability of a system. CAS are systems composed of multiple interacting components or agents (like individuals, organizations, or even software entities) that adapt their behavior based on experience, learning from interactions, and environmental feedback. Concepts such as emergent behavior, adaptability, self-organization, co-evolution, and nonlinearity (Table 3) are key tenets of CAS theory (Oughton et al., 2018). This perspective aligns well with the decentralized and participatory nature of DePINs, so CAS theory provides a suitable framework to analyze DePIN resilience characteristics in complex, unpredictable operating environments.

4. Real-world applications of decentralized CI

In this section, we briefly describe prominent real-world applications of DePIN, outlining their impact on CI resilience.

4.1. *Energy Sector: Decentralized Renewable Energy Grids*

Traditional energy systems rely on centralized power generation. The shift to renewable energy has spurred decentralized grids that integrate distributed energy resources like solar PV, wind, fuel cells, and battery storage. These microgrids can operate independently during disruptions or connect as energy clusters for shared services, enhancing resilience and security through decentralized control (Mishra et al., 2021). The Brooklyn Microgrid operates as a DePIN enabling a P2P energy marketplace where local residents can buy and sell solar-generated electricity among themselves. Germany's energy transition policy fosters decentralized renewables by incentives for households, businesses, and communities. Decentralized systems boost grid resilience by reducing reliance on centralized plants, increasing energy security, enabling local energy management and faster local responses to disruptions. Power Ledger (powerledger.io) is a blockchain-based platform that aims to solve the problem of intermittency arising from renewable integration. It enables P2P energy trading from renewable sources and has several pilot projects, including microgrid trials, residential energy trading and electric vehicle (EV) charging monetization.

However, the integration of decentralized units into the national grid requires advanced grid management technologies and policies to ensure stability. There are also concerns about the financial sustainability of decentralized systems without substantial government subsidies.

Table 2. Dimensions of Resilience Engineering adopted in the analysis (Hollnagel, 2015; Woods 2015)

Aspect	Description
Anticipation, Monitoring, Response and Adaptation	Capabilities to: Predict potential threats and prepare for them; Monitor system performance and environmental conditions to detect anomalies; Respond effectively to disruptions; Learn from experiences to improve resilience.
Graceful Extensibility and Scalability	Ability to extend performance beyond the original design parameters when under stress, without collapsing.
Robustness vs. Resilience	Robustness (through increasing redundancy and flexibility) to withstand shocks. For true resilience, the ability to adapt and bounce back from disturbances is necessary.
Decentralized Control and Decision Making	Encourages decision-making at different levels within the system, especially closer to where the problem occurs

Table 3. Dimensions of CAS theory adopted in the analysis (Oughton et al., 2018)

Aspect	Description
Emergent behavior and Non-linearity	System-level behaviors arise from the interactions of individual agents. Small changes in one part of the system can lead to disproportionate effects on the system level.
Adaptation and Learning	Agents can learn and adapt their behavior based on feedback from their environment.
Self-organization	Without central control, coordination emerges from the collective interactions.
Diversity and Redundancy	Building in different ways to achieve the same function or having backup systems and processes to ensure continuity of service.
Co-evolution	Agents evolve together, alongside its environment, with interdependent changes (agents' changes influence other agents).

4.2. *Transport Sector*

Traditional centralized transport systems often face challenges such as congestion, single points of failure, and limited adaptability to disruptions. Decentralized transport refers to a system where transport services or infrastructure are managed or provided by a network of independent or small-scale entities rather than a centralized authority or large corporation.

DePIN in ride-sharing is growing, with platforms like Drife(.io) gaining traction in India and the City of Dubai.

In smart city traffic management, DePIN decentralizes data collection and control for resilience and scalability. Atlas Navi (atlasnavi.com) creates a real-time digital twin of infrastructure, using AI and smartphone cameras to detect road conditions, accidents, and available parking. NATIX.network builds an open geospatial intelligence network via AI and the "Internet of Cameras." Hivemapper(.com) incentivizes drivers with tokens to map roads with dashcams, while DIMO(.org) lets vehicle owners collect and monetize car data. Charge(.xyz) enhances EV charging accessibility through community-owned stations.

Demand-Responsive Transport (DRT) systems are decentralized approaches (usually non-blockchain based) to urban transport, by offering flexible routing and scheduling of shared vehicles in response to user demand. Cities across the world have implemented such systems (e.g. Radiobus in Milan) to enhance mobility, reduce congestion and reliance on a single mode of transport. Decentralized urban mobility systems include networks of bike-sharing stations or electric scooters integrated with public transport.

Helium(.com) is a decentralized wireless network primarily for IoT devices, providing coverage where cellular networks might be lacking or costly. It incentivizing individuals to deploy "hotspots" and earn tokens. In San Francisco, Helium's network was used to connect various IoT devices, including smart parking sensors to provide real-time data on parking space availability without the need for extensive centralized infrastructure.

4.3. *Healthcare Sector: Decentralized Telemedicine Networks*

Decentralized telemedicine networks connect patients with healthcare providers through digital platforms, reducing the need for physical visits. This improved healthcare access has reduced the burden on hospitals and clinics during the Covid-19 pandemic. Challenges include ensuring the security and privacy of patient data, maintaining the quality of care, and addressing technological disparities among patients. There is also a need for regulatory frameworks to standardize telemedicine practices.

MediBloc(.com) uses blockchain to give patients control over their medical data, allowing secure data sharing between patients and healthcare providers as needed. In South Korea, MediBloc partnered with several hospitals to enable patients manage their health records and share data for research or second opinions while maintaining privacy.

4.4. *Supply Chain Management*

VeChain(.org) enhances supply chain transparency and traceability. By tokenizing products or components, VeChain allows for real-time tracking from the manufacturer to the end consumer. Any disruption in the supply chain can be quickly identified and addressed, enhancing resilience by providing a verifiable, immutable record of product movement. Applications include traceability of food products for Walmart China and clinical trial supply chains for Bayer China, vehicle data storage and sharing for BMW, tracking luxury leather goods for LVMH.

DePINs can decentralize data and operations, leading to fewer single points of failure in supply chains. Stakeholders gain unprecedented visibility, which is key to managing and responding to disruptions.

5. Discussion

Both theories, RE and CAS, aim to understand and enhance how systems can thrive in dynamic, unpredictable environments, but they approach it from different angles: CAS from a systemic and evolutionary perspective, understanding how emergent properties arise from the interactions of individual components; RE from an operational and practical standpoint focused on maintaining or restoring functionality under unexpected conditions. The approaches are complementary and we combine them to provide a comprehensive analysis of DePIN potential advantages over traditional physical infrastructure for enhancing CI resilience, summarized in Table 4.

5.1. *DePIN from RE perspective*

Anticipation (Proactive Risk Management). DePINs can incorporate predictive analytics to improve the ability to foresee potential threats and vulnerabilities in CI. Despite their rigidity, data dependence, exploit risks, and legal uncertainties, smart contracts can anticipate disruptions by setting conditions that trigger preventive actions or resource allocation. For example, *Atlas Navi* integrates AI and smartphone cameras to enable predictive risk management in smart cities using digital twins, and proactively reroute drivers to avoid disruptions. *Power Ledger* anticipates fluctuations and employs smart contracts in its energy-trading platform, enabling preemptive energy allocation during peak demand or outages.

Monitoring (Real-Time Awareness). By integrating IoT devices and decentralized data collection, DePINs enhance situational awareness allowing for quick detection of anomalies or performance issues. For example, *Hivemapper* and *NATIX* provide real-time road conditions. *Helium* allows for a decentralized monitoring of CI like parking sensors and air quality. *VeChain* enhances supply chain transparency ensuring anomalies like delays or spoilage are quickly identified and traced.

Response (Robust Action). DePINs distribute decision-making, enabling rapid and localized response and recovery from disruptions. This reduces dependency on centralized systems, which are often bottlenecks during crises, while immediate action can significantly reduce downtime and damage. For example, *Brooklyn Microgrid* enables rapid local energy redistribution during grid failures, reducing reliance on centralized utilities.

Learning, Adaptation (Long-Term) and Sustainability. DePINs encourage iterative learning from past disruptions through community feedback or token-based incentives for improvements. The incentives can also reward contributions aimed to improve long-term resilience and sustainability goals. *Hivemapper* incentivizes drivers with tokens to update road maps, learning from traffic patterns to improve routing over time, enhancing sustainability in transport. Transparent ledger records enable post-event analysis and learning. *Germany's energy policy* incentives support long-term sustainability.

DePINs inherently build in redundancy and flexibility, allowing the system to absorb shocks by rerouting or redistributing load across the network. They also emphasize **resilience** - token-based economy ensures that there is a continuous drive towards resilience-building activities and adaptation. *MediBloc* ensures continuous healthcare data availability even if hospital systems experience cyberattacks or outages and enables sharing records with alternative providers during hospital disruptions. *Charge.xyz* decentralizes EV charging infrastructure, ensuring that electric vehicles can find community-owned charging stations even if large providers face disruptions.

Table 4. Summary of DePIN positive impacts on CI systems' resilience

Positive Impacts	Description
Redundancy and Fault Tolerance	Distribution across multiple nodes/locations reduces the risk of a single point of failure. Redundancy of data and control, in some cases of service and infrastructure.
Reduced Vulnerability	Decentralized systems are less vulnerable to attacks, as there is no central point of control or data storage. Geo-distribution reduces the impact of localized disasters.
Improved Security	Many DePINs employ blockchain, which enhances security against cyber-attacks.
Trust and transparency	Tamper-proof and transparent data fosters trust among users and stakeholders, crucial for coordinated and effective responses to crises.
Local Autonomy	Nodes operate independently ensuring that local issues do not disrupt the entire system
Localized Response and Recovery	Local entities respond to disruptions more rapidly, minimizing downtime and damage. Decisions made closer to the impact, leading to more relevant and effective solutions.
Scalability, flexibility,innovation	Decentralized systems can be scaled simply by adding new nodes without system redesign, adapting to changing demands and new technologies.
Cost reduction, efficiency and sustainability	Costs lowered by eliminating intermediaries and central management. More efficient resource use, as local production and consumption can be better matched, and more equitable access to resources.

Extensibility and Scalability. DePINs can scale by adding more nodes or resources without a proportional increase in complexity or cost, and the system can extend its functionality under stress. *Helium* expands network coverage dynamically through user-deployed hotspots. *Power Ledger* supports microgrid scalability by enabling peer-to-peer energy trading across regions.

Decentralized Control and Decision Making. DePINs naturally support systems that can make decisions at various levels through their decentralized governance models, where decisions can be made closer to the point of impact. *Power Ledger* users govern trading rules via token voting so communities can decide on pricing, renewable prioritization, or emergency allocation protocols. *Helium's* governance is managed through a DAO where token holders vote on network upgrades, coverage priorities, or reward structures.

5.2. *DePIN from CAS perspective*

DePINs facilitate **self-organization** as participants can independently decide to contribute, expand, or modify the infrastructure based on local or global needs, fostering a system that can reorganize in response to external pressures without centralized control. For example, *Helium* enables individuals to deploy hotspots and expand network coverage autonomously, creating a self-organizing decentralized IoT network.

DePINs promote rapid **adaptation** to evolving threats and real-time conditions by leveraging distributed sensors and data inputs from diverse stakeholders. This can include adapting service offerings, infrastructure maintenance, or network configurations in response to disruptions or changes in demand. This adaptability enhances the system's ability to handle uncertainty and emergent challenges, such as cascading failures in CI. For example, *VeChain* allows businesses to quickly react to supply chain disruptions. The use of tokens and community governance in DePINs creates **feedback loops** where participants are incentivized to respond to system needs, enhancing resilience by continuously adjusting to maintain or restore functionality. *Hivemapper* rewards users for contributing up-to-date mapping data, ensuring maps remain accurate without relying on centralized updates.

By distributing infrastructure across numerous independent agents and locations (e.g., nodes, stakeholders), DePINs inherently introduce **redundancy and diversity**, reducing the likelihood of system-wide failure due to the failure of any single node. By providing alternative local solutions (e.g., different types of connectivity, transports, or energy solutions) DePIN enhances spatial-temporal reconfigurability to maintain functionality during disruptions. Decentralization can also improve security making it more difficult for malicious actors to target critical components. Distributed systems employ advanced security protocols based on blockchain technology, to ensure data integrity and prevent unauthorized access. *MediBloc* secures healthcare data across distributed nodes, reducing cyber risks with blockchain encryption.

The interconnectedness of DePINs allows for **emergent behaviors** that could improve resilience, such as cooperative recovery strategies following disruptions, new service models or unexpected solutions to infrastructure challenges. *Helium's* decentralized network has organically grown in unexpected ways, enabling novel IoT applications beyond its initial scope. However, nonlinear interactions, not predictable from the parts alone, also introduce risks such as system-wide instabilities if coordination mechanisms fail.

Finally, DePIN provides access to service and connectivity to geographically-disadvantaged communities, thereby increasing inclusion and promoting technological advancement outside cities. *Charge.xyz* extends EV charging to underserved areas, while *Mediblock* improves healthcare access in remote areas. By better matching the local needs and encouraging the optimal use of existing local resources via peer-to-peer collaboration, DePIN also enhances sustainability and promotes circular economy.

5.3. *Challenges and drawbacks*

Numerous challenges and drawbacks remain to be addressed before deploying DePIN at larger scale and fully exploiting their advantages. A key challenge of decentralized systems is the complexity of coordinating numerous components, which requires sophisticated management and communication protocols. There are also challenges with the integration and interoperability of DePIN with existing infrastructure, that might use systems or standards that do not easily interface with decentralized networks. This can lead to technical incompatibilities, requiring significant adaptations or middleware solutions.

Service consistency, reliability: and quality in DePIN can vary since nodes might not hold the same standards. Maintaining these aspects across a network of independent operators is challenging. Multiple DePIN solutions might lead to fragmentation, potentially reducing efficiency or increasing costs due to overlap. Inefficiencies can also be caused by an underuse of the infrastructure.

Implementing DePIN often incurs higher initial costs due to the need for deploying multiple units, establishing communication networks, and integrating advanced coordination technologies. As with every innovation, adoption barriers might occur, requiring user education and trust-building. Some technologies or applications might not be mature enough for decentralized models, especially where real-time responsiveness or high system integration is needed.

While decentralization mitigates the impact of a single point of failure, it can also introduce vulnerabilities to localized disruptions. For example, if a particular region experiences a severe event, the local decentralized units may all be affected simultaneously.

Finally, considering long-term development, the challenge lies in ensuring that DePIN incentives and governance mechanisms promote sustainability rather than just short-term economic gain. This requires thoughtful tokenomics, clear guidelines or regulatory frameworks.

6. Conclusion and future research

From both RE and CAS theory perspectives, DePINs offer significant potential to enhance CI resilience through their adaptive and self-organizing capabilities. By embracing decentralized decision-making, DePINs can address both the complexity and unpredictability of modern resilience challenges. Furthermore, DePIN encourages new business models where infrastructure services can be more accessible, customizably priced, and operated in ways not feasible under traditional centralized models. Future research should conduct in-depth empirical studies to quantitatively measure the impact of DePIN on resilience aspects compared to traditional non-DePIN systems.

Still, realizing this potential requires careful design, implementation, and governance to navigate the trade-offs and challenges. Interdisciplinary research must further study the economic impacts, cost-benefit analysis, sustainability, public perception and acceptance of DePIN. Research should also focus on policy and regulatory frameworks that could facilitate the integration of DePIN into existing systems, including the harmonization of standards for the interoperability. AI and Machine Learning can advance DePIN by optimizing the coordination and management of decentralized components, as decision-support systems. DePIN implementation strategy must be based on collaboration between developers, end-users, existing infrastructure managers and regulators, to ensure benefits. DePIN has started a potential transformation in how we develop and manage CI. As the technology matures and social acceptance grows, we can expect to see more projects covering CI sectors and integrating more real world assets (RWA), enhancing DePINs scope and impact.

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