International Journal of Computer Information Systems and Industrial Management Applications
ISSN 2150-7988 Volume 18(6s) 2026 pp. 187-195
https://doi.org/10.70917/ijcisim-2026-2878
Article

From Connectivity Monetization to Network Developer Ecosystems: A Conceptual Framework for Reclaiming the 6G Value Layer

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Abstract: Background: Communication Service Providers have historically attempted to monetize mobile networks through connectivity pricing, premium bandwidth tiers, enterprise service bundles, and infrastructure differentiation. The 5G era showed the limitations of this approach: while operators invested heavily in spectrum, radio access networks, and core infrastructure, much of the application-layer value was captured by cloud platforms, device ecosystems, app stores, and software intermediaries.
Objective: This article develops a conceptual framework for understanding 6G network monetization as a developer ecosystem problem rather than a connectivity-pricing problem.
Methods: A targeted integrative review was conducted across recent standards, industry reports, and peer-reviewed literature on IMT-2030/6G, network APIs, multi-access edge computing, platform ecosystems, and edge artificial intelligence. Sources were selected for authenticity, recency, relevance to Communication Service Provider monetization, and direct contribution to the proposed framework.
Results: The synthesis identifies four interdependent layers required for Communication Service Provider value capture in the 6G era: network infrastructure, programmability, developer experience, and application monetization. The analysis shows that APIs, software development kits, edge-local compute, quality-on-demand controls, network exposure functions, and developer marketplaces are core mechanisms through which operators can convert technical network capability into ecosystem value.
Conclusion: Communication Service Providers are unlikely to reclaim the 6G value layer through faster connectivity alone. Their monetization prospects depend on whether they can become developer-facing platforms that expose network capabilities as programmable, interoperable, and commercially usable application primitives.

Keywords: 6G, IMT-2030, network monetization, Communication Service Providers, network APIs, developer ecosystem, edge computing, multi-access edge computing, platform strategy, edge AI

1. Introduction

The transition from 5G to 6G is often framed through technical performance indicators such as peak data rate, latency, reliability, coverage, sensing capability, positioning accuracy, energy efficiency, and artificial intelligence integration. The ITU-R IMT-2030 framework formally describes the objectives and envisaged capabilities for International Mobile Telecommunications systems beyond 2030, while ITU-R M.2516 identifies future technology trends for terrestrial IMT systems toward 2030 and beyond [1,2]. From an operator perspective, 6G is also expected to support new service experiences, enhanced network intelligence, sustainability goals, and tighter integration between connectivity, computing, and data-driven services [3].

However, the central commercial question is not only what 6G networks can technically deliver. The more important question is how Communication Service Providers (CSPs) can convert technical capabilities into durable value capture. The 5G era exposed a structural weakness in the traditional telecom monetization model. CSPs invested heavily in spectrum, coverage, radio access networks (RANs), and core-network upgrades, yet much of the downstream economic value moved to cloud platforms, device ecosystems, app stores, and software platforms. These firms captured developer attention, application distribution, user engagement, and transaction revenue, while CSPs often remained positioned as connectivity providers.

Recent industry initiatives suggest that telecom operators are beginning to recognize this gap. GSMA Open Gateway seeks to expose common mobile network capabilities through standardized application programming interfaces (APIs) for developers [4]. CAMARA, an open-source Linux Foundation project, develops and tests APIs for network capability exposure across operators and countries [5]. GSMA Intelligence reports continuing market development around Open Gateway, with growing attention to developer demand, use-case segmentation, and API categories beyond fraud and security [6]. These developments indicate a strategic shift from network-as-transport toward network-as-programmable-platform.

Multi-access edge computing (MEC) further strengthens this shift. ETSI MEC application developer guidance emphasizes developer access to service APIs and the need to align API exposure across standards bodies, open-source communities, and industry initiatives [7]. ETSI MEC architecture defines the role of MEC hosts, MEC platforms, and MEC applications within operator-managed edge environments, while ETSI MEC application enablement specifications describe APIs that allow applications to discover, consume, and manage MEC services [8,9]. These standards provide an architectural basis for treating the network edge as part of the application runtime.

The theoretical basis for this article lies in digital platform and ecosystem scholarship. Digital platforms create and capture value not only through owned assets but through the orchestration of complementors, interfaces, governance rules, and network effects [10]. Platform ecosystems can be understood as modular, interdependent systems in which platform sponsors coordinate innovation by external actors through design rules and shared value propositions [11]. Platform competition literature also shows that ecosystem control, complementor adoption, and governance choices shape long-term competitive advantage [12]. These insights are directly relevant to CSPs because the 6G monetization problem is not only technical; it is also organizational and ecosystemic.

The research gap is therefore clear. Standards and telecom industry literature increasingly discuss 6G capabilities, network APIs, and edge computing. Platform literature explains how ecosystems create value through developers and complementors. Yet fewer works integrate these perspectives into a CSP-specific monetization framework for the 6G era. McKinsey analysis of network APIs similarly argues that telcos must generate both supply and demand and then shape ecosystems and market structures around API value [13]. This article extends that argument by positioning the CSP network as a developer ecosystem in which 6G capabilities become programmable components of application design.

The objective of this article is to develop a conceptual framework for 6G network monetization based on developer ecosystem ownership. The article asks: how can CSPs convert 6G network capabilities into monetizable ecosystem value by becoming developer-facing platforms rather than connectivity-only providers?

2. Methodology

2.1 Study design

This article uses a targeted integrative conceptual review design. The purpose is not to conduct a systematic review or meta-analysis, but to synthesize recent standards, industry evidence, and scholarly literature into a conceptual framework for CSP monetization in the 6G era.

This approach is appropriate because the subject is emerging, cross-disciplinary, and not yet supported by a mature empirical literature. The relevant evidence base spans telecommunications standards, open-source API initiatives, industry market reports, edge-computing architectures, platform strategy scholarship, and edge AI research.

2.2 Evidence sources and selection logic

Sources were selected from five categories: official 6G and IMT-2030 standards or position documents; network API and telecom developer ecosystem initiatives; MEC and edge-computing standards; peer-reviewed platform ecosystem and platform competition literature; and peer-reviewed or technically credible edge AI and 6G intelligence literature.

The evidence domains used for synthesis are summarized in Table 1.

Table 1: Evidence domains used for the integrative conceptual synthesis

Evidence domain	Source type	Contribution to the manuscript
IMT-2030 and 6G direction	ITU-R recommendations, ITU-R reports, operator position papers	Establishes the technical and strategic background of 6G [1-3]
Network APIs and telecom API commercialization	GSMA, CAMARA, GSMA Intelligence, McKinsey	Supports the developer-facing network programmability argument [4-6,13-15]
Multi-access edge computing	ETSI white paper and MEC specifications	Provides the architectural basis for local application hosting and service API exposure [7-9]
Platform ecosystems	Peer-reviewed management and strategy literature	Provides theoretical framing for developer ecosystems, complementors, and value capture [10-12]
Edge AI and 6G intelligence	Peer-reviewed technical literature and selected preprints	Supports the claim that future workloads require distributed intelligence, low latency, and edge execution [17-22]

2.3 Inclusion and exclusion criteria

Sources were included if they met at least three of the following criteria: publication within the last five years, relevance to 6G or IMT-2030, relevance to network APIs or telecom programmability, relevance to edge computing or edge AI, relevance to digital platform ecosystems, authenticity through an official standards body or publisher, and direct usefulness for CSP monetization analysis.

Sources were excluded if they were unverifiable, outdated unless theoretically essential, vendor-marketing-only without analytical value, or unrelated to the proposed framework. Sources that could not be authenticated through official standards bodies, publisher records, DOI records, or recognized industry institutions were removed from the final reference list.

2.4 Analytical procedure

The analysis followed a seven-step workflow. First, the research problem and guiding question were defined. Second, relevant evidence domains were selected. Third, sources were assessed for quality, authenticity, recency, and relevance. Fourth, key themes were extracted through thematic analysis. Fifth, themes were synthesized into a conceptual framework. Sixth, framework elements were mapped to value-creation and monetization pathways. Seventh, limitations and future research directions were identified.

The methodological workflow is illustrated in Figure 1.

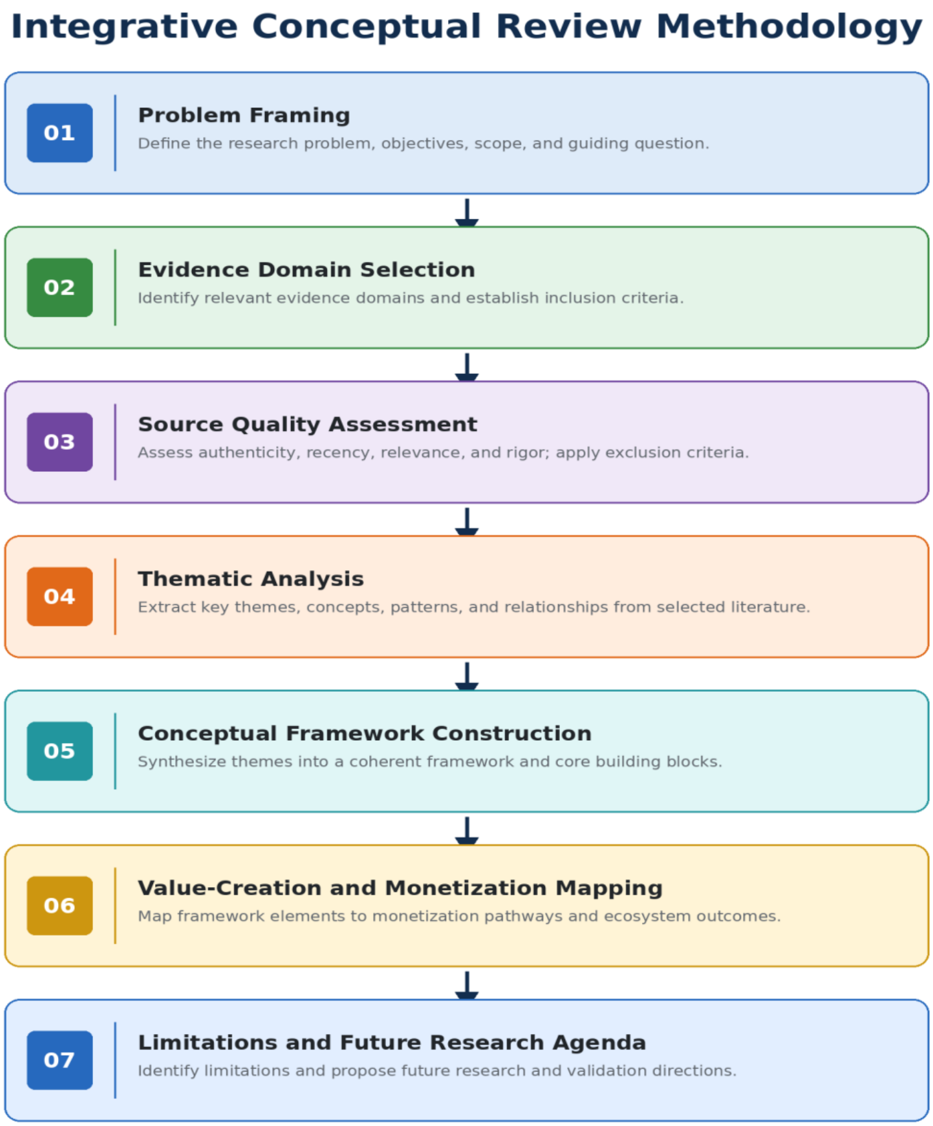

Figure 1: Methodological workflow for the integrative conceptual synthesis

3. Results: Conceptual Synthesis

The integrative synthesis produced three principal findings. First, 6G monetization cannot be reduced to connectivity pricing because the value of future networks will depend on their integration into application architecture. Second, network APIs and MEC provide a practical mechanism for converting operator-controlled capabilities into developer-consumable services. Third, CSPs require platform governance, developer experience, and marketplace structures if they are to capture ecosystem value rather than remain wholesale infrastructure providers.

3.1 Developer-facing network programmability is becoming the central monetization interface

The evidence indicates that network APIs are emerging as the practical interface between telecom capability and application innovation. GSMA Open Gateway and CAMARA both seek to reduce operator fragmentation by exposing standardized APIs across networks [4,5]. In particular, CAMARA Quality on Demand and QoS Profiles demonstrate how network performance characteristics such as latency, throughput, and priority can be represented as programmable resources for application developers [14,15].

This matters because developers do not adopt infrastructure in its raw form. They adopt abstractions that are documented, testable, interoperable, and economically predictable. If CSP capabilities remain accessible only through bilateral enterprise contracts or operator-specific interfaces, developer adoption will remain limited. If those capabilities become accessible through common APIs, software development kits (SDKs), sandboxes, and marketplaces, they can become part of application design.

3.2 Commercial aggregation is required to overcome operator fragmentation

A single operator API program is insufficient for most software developers. Applications often need multi-market reach, cross-operator consistency, and predictable behavior across geographies. GSMA Intelligence Open Gateway market analysis shows that network API demand is beginning to diversify beyond fraud and security into categories such as quality on demand, device information, and location-based information [6]. Ericsson's completion of the Aduna transaction further signals the industry movement toward aggregated network API commercialization across multiple CSPs [16].

This finding is important because developer ecosystems require scale. A fragmented market of operator-specific APIs would replicate a common failure of telecom innovation: technical capability without adoption simplicity. Aggregation and interoperability are therefore not peripheral; they are necessary conditions for network API monetization.

3.3 Edge AI and real-time applications strengthen the case for CSP-controlled local infrastructure

The technical literature on edge AI and 6G intelligence supports the argument that future applications will increasingly require distributed intelligence, low-latency processing, and coordination between communication and computation. Edge AI has been identified as a key enabler for integrating communication, computation, and intelligence in 6G systems [17]. Research on 6G-enabled edge intelligence also links edge computing with ultra-reliable low-latency applications such as autonomous vehicles, holographic communication, drones, and telesurgery [18]. Broader edge AI surveys identify latency, privacy, energy efficiency, resource management, and distributed inference as central design considerations [19,20]. Reinforcement-learning-based mobile edge computing research further illustrates the need for adaptive orchestration in dynamic wireless and edge environments [21].

These findings support the view that centralized hyperscale cloud architectures will remain essential but insufficient for every emerging 6G workload. Some applications will require execution closer to users, sensors, vehicles, robots, or industrial systems. This creates a structural opportunity for CSPs because they control local network conditions, radio access, mobility context, and distributed infrastructure.

3.4 The network can be conceptualized as an application runtime

The synthesis supports a conceptual shift from network-as-transport to network-as-application-runtime. In this model, the network does not merely deliver packets between endpoints. Instead, it exposes capabilities that applications can request, observe, adapt to, and monetize.

The proposed CSP developer ecosystem model is shown in Figure 2. The mapping between network capabilities and ecosystem implications is presented in Table 2.

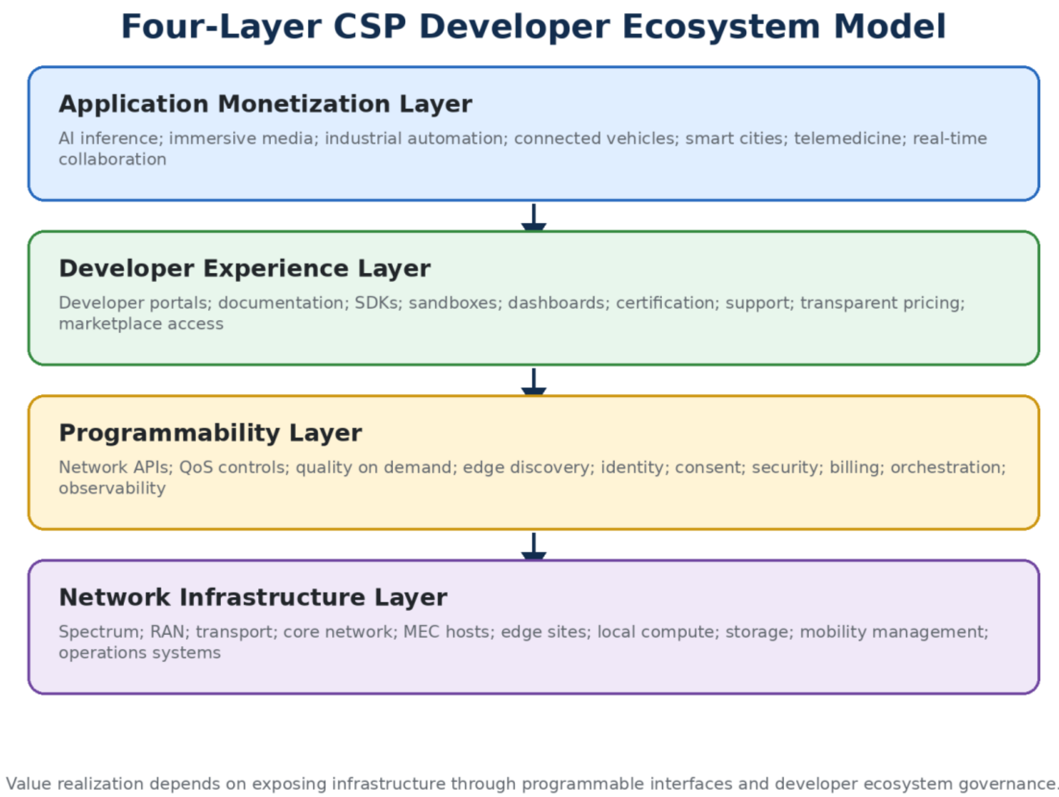

Figure 2. Four-layer CSP developer ecosystem model for 6G monetization

Table 2. Mapping 6G capabilities to developer ecosystem implications

6G/network capability	Developer-facing abstraction	Application implication	Monetization implication
Low latency	Quality on demand; QoS profile; edge placement	Real-time collaboration; industrial control; immersive media	Performance-based pricing
High uplink capacity	Uplink optimization; session quality API	Video intelligence; creator streaming; sensor ingestion	Premium application performance
Edge-local compute	MEC hosting; edge discovery; local execution	AI inference; robotics; telemedicine; smart cities	Edge hosting and execution revenue
Network awareness	Connectivity insights; session insights; congestion signals	Adaptive application behavior	API-based revenue
Identity and device context	Number verification; device status; consent APIs	Fraud reduction; authentication; compliance	Transaction and risk-service revenue
Mobility management	Location; reachability; handover-aware services	Connected vehicles; logistics; field operations	Vertical platform revenue
Data locality	Local processing; policy-aware orchestration	Data sovereignty and regulated workloads	Compliance-oriented infrastructure revenue

4. Discussion

The central implication of this analysis is that CSP monetization should be reframed as a platform strategy problem. Platform theory shows that value creation in digital ecosystems depends on complementors, modular interfaces, governance rules, and network effects [10-12]. For CSPs, developers are the crucial complementors.

Without developers embedding network capabilities into applications, even advanced 6G features risk remaining commercially invisible.

This interpretation challenges the traditional telecom assumption that better network performance automatically produces better monetization. Performance is necessary, but it is not sufficient. Developers need consumable abstractions, economic incentives, integration support, and market access. The CSP that offers the technically superior network but the inferior developer experience may still lose the value layer to platforms that make application development easier.

Network APIs are the most immediate mechanism for CSPs to expose value, but APIs alone will not create an ecosystem. The history of platform competition suggests that interfaces must be embedded in governance systems: documentation, version control, pricing, certification, trust, revenue sharing, compliance management, and dispute resolution [10-12]. In the telecom context, these governance functions are especially important because API behavior may be shaped by spectrum conditions, local regulation, subscriber consent, security requirements, and operator-specific policies.

This means CSPs should avoid treating Open Gateway or CAMARA APIs as purely technical deliverables. Their success depends on whether developers experience them as reliable products. A well-defined API that requires months of contracting, lacks sandbox support, or behaves differently across operators will not generate meaningful ecosystem adoption.

The edge-computing and edge AI literature strengthens the case for CSP participation in application runtime design. Applications such as video intelligence, robotics, connected vehicles, telemedicine, immersive collaboration, and industrial automation often require low latency, local execution, and context-aware adaptation [17-21]. These conditions align with CSP assets: RAN control, distributed network infrastructure, mobility information, local regulatory presence, and service-level management.

However, the existence of these assets does not guarantee monetization. CSPs must expose these assets through developer-consumable services. The distinction is critical. A central office, edge node, or RAN control function is not a platform by itself. It becomes part of a platform only when external developers can build with it predictably, securely, and profitably.

Hyperscalers will remain essential participants in the 6G ecosystem. They provide mature developer tooling, global cloud platforms, AI infrastructure, marketplace distribution, and enterprise relationships. CSPs should therefore partner with hyperscalers where appropriate. The risk is that CSPs may repeat the 5G pattern by allowing hyperscalers to own the developer relationship while operators provide only the underlying infrastructure.

A defensible CSP strategy should therefore be based on co-opetition rather than passive dependence. CSP capabilities should be consumable through hyperscaler platforms, aggregators, and enterprise software channels, but the operator's differentiated assets - quality control, local network intelligence, edge execution, identity, consent, and policy control - must remain visible, measurable, and monetizable. Li et al. similarly frame 6G open networks and generative AI around API-centric platforms and monetization models, reinforcing the need to treat programmable network capability as an ecosystem asset rather than a hidden infrastructure input [22].

The proposed monetization pathways and governance requirements are summarized in Table 3. These pathways show that CSP monetization should shift from charging for generic data movement to charging for application-relevant outcomes. The value proposition must be expressed in terms that developers and enterprises understand: fewer failed sessions, lower fraud, improved latency, reliable uplink, local inference, compliance assurance, and measurable service quality.

Table 3: Proposed monetization pathways and governance requirements for CSP developer ecosystems

Monetization pathway	Revenue mechanism	Required CSP capability	Principal risk
API-based monetization	Per-call, subscription, usage-tier, or outcome-linked API pricing	Standardized APIs; billing; observability; consent management	Fragmented implementation across operators
Edge hosting	Compute, storage, and local execution fees	MEC infrastructure; workload orchestration; deployment tooling	Low utilization or unclear developer demand
Performance-based pricing	Charges for latency, reliability, throughput, or session quality	QoS enforcement; telemetry; SLA monitoring	Inability to verify or guarantee performance consistently

Monetization pathway	Revenue mechanism	Required CSP capability	Principal risk
Transaction participation	Revenue share from applications using network services	Marketplace; partner contracts; settlement systems	Weak platform governance or poor developer economics
Vertical enterprise platforms	Industry-specific bundles for healthcare, logistics, manufacturing, media, smart cities	Domain integration; compliance; security; support	Over-customization and lack of repeatability
Data-sovereign services	Localized processing and compliance-oriented infrastructure	Local edge execution; auditability; policy controls	Regulatory complexity and high assurance burden
Developer marketplace	Listing, certification, distribution, and revenue sharing	Portal; certification; discovery; billing; support	Failure to reach sufficient developer scale

5. Conclusion

This article developed a conceptual framework for CSP network monetization in the 6G era. The central argument is that CSPs cannot reclaim the value layer by selling faster connectivity alone. The 5G era demonstrated that infrastructure ownership does not automatically lead to ecosystem control. Value is captured by the platforms on which developers build, deploy, distribute, and monetize applications.

The transition to 6G creates a new opening because future applications are likely to be more latency-sensitive, uplink-heavy, AI-enabled, edge-dependent, and network-aware. These requirements align with CSP assets, including RAN control, local infrastructure, mobility context, quality-of-service management, and regulated local presence. Yet these assets become commercially meaningful only when exposed through developer-facing platforms.

The proposed four-layer model - network infrastructure, programmability, developer experience, and application monetization - offers a structured way to understand how CSPs can move from connectivity providers to ecosystem orchestrators. The core implication is that 6G monetization is not simply a technical challenge or a pricing challenge. It is a platform governance challenge.

The winners of the 6G era will not necessarily be the operators with the fastest networks. They will be the operators that make their networks programmable, interoperable, developer-friendly, and economically useful for the next generation of real-time applications.

6. Limitations

This manuscript is a conceptual integrative review rather than an empirical study. It does not include primary data, statistical modeling, operator financial datasets, developer surveys, or API usage telemetry.

The framework is based on currently available standards, industry reports, and scholarly literature. Because 6G standardization and network API commercialization are still evolving, some assumptions may change as technical specifications, commercial aggregators, and regulatory models mature.

The analysis focuses primarily on CSP strategy and developer ecosystem design. It does not deeply model spectrum economics, capital expenditure constraints, security architecture, regulatory compliance, or cross-border data governance.

The article also does not compare operator-specific API platforms in detail. Such comparison would require commercial data that is not consistently available in the public domain.

7. Future Directions

Future research should empirically test whether standardized network APIs increase developer adoption, application performance, and CSP revenue.

Longitudinal studies should examine whether Open Gateway, CAMARA, Aduna, and MEC-based developer initiatives generate sustained commercial traction beyond early pilots.

Future work should develop measurable indicators of CSP developer ecosystem health, including active developers, sandbox-to-production conversion, API retention, application revenue, marketplace liquidity, and enterprise adoption.

Technical research should benchmark edge-local execution against centralized cloud execution for latency-sensitive workloads such as AI inference, industrial automation, telemedicine, immersive media, and connected vehicles.

Economic research should evaluate pricing models for quality on demand, edge hosting, performance guarantees, and transaction-based network services.

Governance research should examine how CSPs can balance openness, interoperability, security, regulatory compliance, consent management, and commercial control.

Acknowledgment

The author acknowledges the standards bodies, open-source communities, and industry research organizations whose publicly available work informed this conceptual synthesis.

Funding statement

No external funding was received for this work.

Conflict of interest statement

The author declares no conflict of interest

Ethics Statement

This article is a conceptual review based on publicly available standards, industry reports, and scholarly literature. It does not involve human participants, animal subjects, personal data, or clinical data. Formal ethics approval was therefore not required.

Data Availability Statement

No datasets were generated or analyzed during the preparation of this manuscript.

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