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The evolution and trends of hyperconvergence in the telecommunications sector: a competitive intelligence review

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Abstract
This research analyzes and identifies the evolution and trends in the telecommunications sector to successfully implement a hyperconverged solution. The approach was qualitative through a document review, exploring the best practices of consulting firms, the technology community, and manufacturers in the sector. The Gartner Magic Quadrant for Hyperconverged Infrastructure in 2022 was used as a basis to achieve this objective. The leading vendors successfully implementing their solutions in the telecommunications sector were identified. Subsequently, the information gathered by consulting firms, the technology community, and experts in the field was contrasted to corroborate the evolution, advantages, and market trends. Finally, it was concluded that organizations' decision-making should consider economic and commercial criteria and evaluate aspects of greater depth and relevance, such as field evidence, technological innovation, and customer experience described by third parties.

Keywords: hyperconvergence; hypervisor; bare-metal; virtualization; cloud-native; telco cloud; SDDC; 5G.

Evolución y tendencias de la hiperconvergencia en el sector de las telecomunicaciones: una revisión de la inteligencia competitiva

Resumen
Esta investigación analiza e identifica la evolución y tendencias en el sector de las telecomunicaciones para implantar con éxito una solución hiperconvergente. El enfoque fue cualitativo a través de la revisión documental, se analizaron las mejores prácticas de las consultoras, la comunidad tecnológica y fabricantes del sector. Para lograr este objetivo, se tomó como base el Cuadrante Mágico de Gartner para Infraestructura Hiperconvergente en 2022, luego se identificó los proveedores líderes que implantan con éxito sus soluciones en el sector de las telecomunicaciones. Posteriormente, se contrasto la información recopilada por consultoras, comunidad tecnológica y expertos en la materia para corroborar la evolución, ventajas y tendencias del mercado. Por último, se concluyó que la toma de decisiones de las organizaciones debe considerar no sólo criterios económicos y comerciales, sino también evaluar aspectos de mayor profundidad y relevancia, como la evidencia de campo, innovación tecnológica y experiencia del cliente descrita por terceros.

Palabras clave: hiperconvergencia; hipervisor; metal desnudo; virtualización; nube nativa; nube de telecomunicaciones; SDDC; 5G

1. Introduction

The digital era has brought a Hyperconverged Infrastructure (HCI) boom thanks to virtualization, hardware, networking, and software storage solutions. Lee [1] identified that by 2019 it was estimated that 30% of data storage would be within a hyperconverged solution.

This is why the hyperconvergence phenomenon has evolved in Information Technology (IT) administration. New skills, competencies, and abilities have been acquired to ensure the proper functioning and use of infrastructure resources, which must be a constant and dynamic task. The dynamism of modern infrastructures gave rise to the term Software-Defined Data Center (SDDC), which consisted of virtualizing servers, storage, and network natively to maximize and obtain more value from the resources and

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storage [2], thus creating an infrastructure of integrated components that later became known as HCI, which offered high availability, better performance and resource allocation [3].

Thanks to these benefits, as well as reduced technology infrastructure acquisition budgets (CapEx), linked administration services (OpEx), and a simple, unified, agile, rapid implementation and centralized framework [3,4], the business sector has adopted hyperconvergence solutions en masse since 2016.

As a consequence of this phenomenon, hyperconvergence solutions have had an accelerated expansion process for different industries. The telecommunications sector, for example, is adopting new business models to manage operations more efficiently in light of 5G network growth; the exponential growth of data traffic is demanding higher latency, better performance, and optimal use of the technological infrastructure but keeping investment levels always within the company's budget (CapEx). This new approach, along with the emergence of various architectures that seek to meet the demand of these organizations, is the subject of the following study.

Therefore, the goal of this study is to understand the evolution and trends of HCI technology based on the review of studies conducted by expert consulting firms in the area, technological communities, and best practices documented by the leading technology manufacturers in the industry, together with academic research available in the literature to achieve a better understanding of the subject, providing an overview and a roadmap of the trends required by telecommunications service operators and companies in general.

The objective of this research is to discover what is the evolution, advantages, and market trends of hyperconvergence. The idea is to propose a line of research to clarify the problem in this study: the gap between the evolution and trends that telecommunications companies should consider implementing a hyperconverged solution successfully.

2. Literature review

In academia, a broad library of studies addresses different dimensions of hyperconvergence. Among those studies is the research of Popek and Goldberg [4], which established the formal requirements for third-generation virtualized architectures leveraging either native or bare-metal hypervisors (type 1) and hosted hypervisors (type 2) based on HCI.

Type 1 hypervisors run directly on the host hardware to control the computer and manage guest operating systems. For this reason, they are sometimes called bare-metal hypervisors [5]. The first hypervisors, developed by IBM in the 1960s, were native [6]. Technology manufacturers like Ericsson invest in research and development to develop solutions on this platform, such as Red Hat [7].

Kominos, et al. [5] mentioned that the main benefit of bare metal-based solutions is licensing. Bare metal-based solutions are based on an open-source platform allowing organizations to contribute to improving their CapEx. However, the researchers need to specify the impact of the upgrade process, release of new versions, and operational management on the operation due to this platform's lack of an orchestrator (hypervisor).

From the perspective of hosted hypervisors (type 2), research, such as that carried out by Halabi [8], identifies this technology as a software platform with a virtualization layer (hypervisor) with nodes interconnected through an array. Desai, et al. [9] conceptualize it as integrating components or layers (compute, virtualization, network, and software-defined storage) unified in an architecture. Depending on the manufacturer, compute nodes, which can vary in quantity depending on the size of the requirements and configuration, are incorporated within the architecture.

Computing nodes are nothing more than servers, which, due to their technology, are organized in groups (clusters), where each node has the capacity for processing, management of Random-Access Memory (RAM), and data storage [10]. Additionally, Chiueh and Brook [11] identified that each node must have virtualization software that assumes the role of a hypervisor.

Jhingran [12] asserts that hyperconverged solutions must enable the pooling and automation of resources and services. I.e., HCI solutions must coexist with SDDCs to ensure all functionalities and technologies are presented as services.

In the software-defined world, all technology infrastructure components (processing, storage, management, and networking) are virtualized and presented as a service on servers and industry components.

From these concepts, the leading manufacturers in the industry have put into practice the SDDC model, leaving room for different structures with a variety of components, among which are Software-Defined Networking (SDN) and Software-Defined Storage (SDS) [13,14].

Gelberger, et al. [15] identified that SDN solutions offer reduced workload for network administrators, easier deployments, reduced OpEx, increased security, and improved application performance. On the other hand, ONF [16] mentions that SDN offers an agile network environment and centralized management based on open and programmable standards.

SDS-based solutions offer a scalable, secure, and easy-to-manage structure and independent operation of the virtualized architecture [17]. SDN and SDS solutions solve storage provisioning and management issues [14].

Moreover, leading manufacturers in the industry have highlighted and documented the advantages and benefits of HCI-based solutions: 1) Low cost through improved return on investment when compared to traditional (licensed) technologies; 2) Scalability and efficiency because they enable horizontal and vertical growth, making it easier for companies to stagger their investment decision-making processes; 3) Process automation, thanks to the centralized management of all their components through a hypervisor; 4) Easy implementation, as they are designed to plug and play [18-21].

However, HCI-based solutions have some limitations, such as 1) Performance degradation, since, being consolidated structures, assembled and configured in the factory, their components are not always state-of-the-art and require testing and verification to certify the compatibility of the elements [18,20,21]; 2) Inflexible scaling, because some applications may require growth in storage, but not necessarily because they need an increase in processing, which is a limitation since this infrastructure is based on nodes that add processing and storage to the structure [19,21]; and 3) The acquisition process since the purchase of an HCI infrastructure from a specific manufacturer implies that the organization, due to technological renewal issues, generates loyalty that may lead to a dependence on a particular manufacturer [2].

This literature review of documentation from consulting firms, leading technology manufacturers, communities of experts, and academia was designed to determine the best solution according to the business requirements in the digital era and to take the criteria demanded by telecommunications operators as a model.

3. Research methodology

The research was conducted under a qualitative-descriptive approach since it sought to develop the object under investigation, seeking regularities and relationships between the components of the study [22]. Additionally, it established a subcategory within the descriptive approach, which identified the properties and characteristics of the subject matter related to the importance of the different software-defined hyperconvergence solutions, thus explaining the trend of the study population [23].

Barrantes [24] established that the documentary review not only includes data collection but also allows the verification of the company's documentary assets, such as case studies, reports, and documents. These assets' contents can be linked to the subjects of investigations. As a result, the documentary review strengthens research by comparing studies with best practices documented in field studies conducted by leading consulting firms in the industry, technical information from significant technology manufacturers, and expert judgment written by the international technology community. In this case, the documentary review examined assets and studies on hyperconvergence solutions in the telecommunications sector.

The documentary review process was carried out employing a digital search to find outstanding information related to the research topic, using online databases, such as Business Source Complete, EBSCOhost, Emerald, ScienceDirect, Scopus, Pro-Quest Central, Web of Science, and the Internet engines of authors, communities of experts and suppliers. The search only included articles, documents, blogs, and official websites written in English and Spanish.

Finally, the selection criteria leveraged the Gartner Magic Quadrant for Hyperconverged Infrastructure Software in the 2022 [25]. The documentary review examined the relationship between the leading technology manufacturers of hyperconverged solutions internationally. This comparison made it possible to establish the roadmap for analysis.

From there, a review was made of the significant technological advances and publicly documented research and development processes of the leading technology manufacturers in this industry, with particular emphasis on technical solutions that met the requirements of the telecommunications operators, together with the criteria, opinions and documented expert judgment of the international technology community. That information was contrasted with the results of field studies, recognitions, and awards granted since 2021 and up to the present by consulting firms and technological communities at the international level. Thus, the discussion reinforced the documentary review with empirical evidence of the evolution and trend of hyperconvergence solutions in the telecommunications sector.

4. Results and discussion

To be in Gartner's Magic Quadrant (Fig. 1), HCI solutions must be software-defined based on this definition. Comparing the capabilities of platforms mentioned in this report with the literature review findings can provide a blueprint for telecom companies searching for new infrastructure to handle their changing requirements.

However, Gartner [25] mentions other, more modern categories for Converged Infrastructure (CI) solutions that offer management, scaling, and enhanced integration solutions. Use cases in this category tend to be performance oriented.

Among CI's leading technology solutions providers are Hewlett Packard Enterprise (HPE) with disaggregated HCI (dHCI) and Pure Storage FlashStack, whose solution combines software and hardware. For example, HPE dHCI includes ProLiant servers coupled with HPE Nimble or HPE Alletra Storage with some flexibility in the network layer. On the other hand, Pure Storage combines its solution with the Cisco Unified Computing System (UCS), which gives the advantage of a complete architecture but only offers independent solutions at the software level if it is tied to the manufacturer's HPE [26].

Figure 1. Gartner Magic Quadrant for Hyperconvergence.
Source: Own Elaboration

Turner [27] highlights that organizations currently evaluate between a software-defined HCI solution and a modern CI, often run on a bare-metal server.

In the software-defined HCI scenario, companies with the following capabilities, according to Turner [27], offer competitive advantages that align with telecoms companies' needs:

1. "(HCI) combines storage, computing, and networking into one simplified, secure, easily managed solution – unlike legacy silos. HCI is, therefore, often the choice for companies refreshing their servers and storage."
2. Hardware and firmware upgrades are easy to perform, helping to prevent data breaches.
3. A hypervisor, based on a virtual machine platform, is free to customers. This combination becomes a complementary advantage for organizations currently paying for virtual machine capabilities.
4. Like most industry platforms, multi-platform use only supports one virtual machine vendor.
5. Additional features for file, object, and data protection.
6. Applications to make scaling the solution easier than other options.
7. Integration with major public cloud providers.

Robust solutions also offer telecom companies a management platform that allows administrators to perform non-disruptive operations on their nodes and data storage [19].

Among the technical requirements of the vendors supporting the HCI solution, an important aspect is handling high workload capacities, high availability, testing model, certification processes, and integration of robust solutions [20,28].

At the other extreme is the modern CI, which builds on the strengths of HCI vendors and adds flexibility when scaling servers, storage, and data management capabilities [29].

Turner (27) also highlights modern CI capabilities, which include:

1. Independent computational and storage capacity
2. Data-management functions, such as replication, compression, and encryption, are offloaded onto a storage array, freeing up server processor resources.
3. A minimum of two nodes, making it easy for Small and Medium-sized Businesses (SMBs) to start up on demand and scale as required.
4. Easy-to-perform upgrades.
5. It can work in new and existing environments; some existing networks can also be used, which is useful when servers, storage, and network are upgraded at different times.
6. And finally, HPE dHCI is only compatible with VMware.

Table 1 shows a comparative table of the main attributes of bare-metal and hypervisor approaches to infrastructure [5,30,31].

Undoubtedly, both approaches demonstrate great attributes and functionalities, highlighting why Gartner includes the vendors above in its Magic Quadrant report.

Therefore, both HCI and CI solutions have their advantages and disadvantages, but both solutions seek to offer organizations a common approach and the following benefits:

Table 1.
A comparison of pure bare-metal vs. hypervisor approaches.

	Bare-metal	**Hypervisor**
Performance	Same latency	Same latency (Some cases of better throughput
Hardware Optimization	Single Operating System (OS) per system	Mixand match different workloads with different OS
Unlock Trapped Capacity	Resources sit idle most of the time	Shared resources and greater pod density
Security	Containers alone are inadequate security boundaries	Additional layers of security
Accelerated Time to Market	Service delivery can't be automated across the network	Service delivery reduced from days/weeks to hours
Ease of Life Cycle Management	Complex scale up and down, update, and rollback process	Automation and repeatability. No need to take assets offline
Reduced Operational Complexity	Siloed resource islands	Sharedtools across the network – no workload islands
Clear Visualization	The patchwork of telemetry and visualization is time-consuming and costly	Cross-resource visualization, analytics, planning and control
Ease of Life Cycle Management	Containers / Kubernetes alone do not provide adequate security or isolation of workloads	Logically isolate workloads to prevent workload encroachment. Restrict access between workloads
Reduced Operational Complexity	It does not recover nodes automatically	Better resiliency and faster recovery

Source: Own Elaboration

1. **Ease of use:** In day-to-day operations, updates, visibility, predictive capability, and processing modeling, any solution must provide more with less.
2. **Security:** Meeting the organization's needs is essential for evaluating any product.
3. **Independent scaling of storage and compute:** When choosing a CI solution, it is necessary to consider independent scaling if the organization's use cases grow to compute and storage at different rates. Otherwise, you will duplicate the entire HCI stack, which is much more costly.
4. **Performance:** You need to assess the application's critical performance requirements and ensure the solution can maintain the necessary performance over time as it grows.
5. A consumption-based purchasing option can help stretch the organization's budget.

Comparing HCI and CI solutions' capabilities to telecommunications operators' requirements and documentary review findings can highlight how operators should proceed when modernizing infrastructure. In operators' environments, infrastructure requirements are based more on Operations Technology (OT) than on Information Technology (IT) environments since the levels of needs, mission-critical systems, and response times are more demanding [32,33].

ABI-Research [34] conducted a field analysis of the different solutions in the industry to evaluate the requirements of telecommunications providers for 5G networks and recommend the best platform in the market, taking into consideration additional variables and approaches such as response times, innovation, and compliance with operators' OT requirements. Two vendors emerged as leaders in this research. Both solutions enable telecom operators to pair Kubernetes with 5G technology, according to the needs of the industry [6,31]. The capabilities of the virtual machine-based solution include:

- Reduced latency
- Optimized hardware utilization
- Unlocking stranded capacity
- Better security postures
- Accelerated time to market
- Ease of lifecycle management
- Reduced operational complexity
- Clear visualization
- Multitenancy
- Improved Resiliency

The bare metal-based vendor offers similar capabilities but with a commercial licensing strategy based on open source for specific solutions [34-36]. This licensing strategy favors customers by comparing CapEx versus OpEx [37,38].

However, as James [39] comments, solutions based on bare metal are an obsolete technology since telecommunications operators are looking for solutions that allow them to quickly and easily manage their operations and even incorporate the automation of functions and processes to reduce resilience and increase the ability to adapt and change with each upgrade and release process of network functions in the native 5G cloud.

Undoubtedly, comparing which platform is better for a telecom operator (bare metal versus virtualization) is still an active debate. James [40] indicates that bare metal is not an optimal platform for cloud-native computing because of the complexity of Orchestration and Service Management (SMO) from an operation and maintenance perspective. Cloud-native computing may be crucial for the future of the telecoms industry, as it allows telecommunications companies to manage their budgets efficiently (CapEx) and Operating Expenses (OpEx) while meeting the exponential demand for video, voice, and data, along with custom-designed services to maintain user experience and satisfaction.

Giallorenzo, et al. [31] take a different view, as they indicate that the operator must visualize its financial and operational strategy in the short, medium, and long term to avoid being tied to a solution that is not easy to migrate or orchestrate in a long time. Trakadas, et al. [41] state that 5G will establish strict and diverse requirements for developing and efficiently managing Network Services (NS).

The only way to determine which platform is better at meeting the needs of telecommunications operators is through demonstrable evidence with Proof of Concepts (PoC), field studies conducted by objective third parties, or evaluations conducted by the industry, as in the case of awards recognition at industry trade shows, such as FutureNet World in London and Interop in Japan in 2022.

Finally, technology in hyperconverged solutions is advancing rapidly, along with the demands of 5G networks and the demanding requirements of the telecommunications sector that are increasingly strict in meeting both financial and operational metrics, with demonstrable evidence of the operating performance of each of the technological solutions being the main element to be considered to meet the minimum requirements of communications operators.

5. Conclusions

The different characteristics, properties, and functionalities of hyperconvergence solutions have been discussed throughout this research. However, today there needs to be a guide on the steps companies must follow to adopt a particular technological solution for a specific provider. Many organizations need more knowledge, experience, or expertise in the digital maturity model that allows them to select the best solution according to their business requirements.

To solve this problem, organizations, especially the telecommunications sector, must have precise requirements to ensure successful implementation, including 1) technical knowledge. Suppose an organization does not possess its technical ability. In that case, it can rely instead on the international technology community to visualize a possible roadmap based on technological and market trends, along with field evidence (PoC) of the various manufacturers that demonstrate the correct functionality of the proposed solution. 2) The functionality of the current and future infrastructure, designed under an OT model rather than an IT-based model, ensures easy, agile, scalable deployment with the expected performance according to operational requirements.

However, there are currently different hyperconverged solutions and platforms in the market, making it difficult for organizations to select a technology closer to their business needs. In combination with technical ignorance and lack of experience, the array of available solutions often leads to organizations selecting a solution inappropriate for the company's needs.

Many organizations currently base their decisions on the commercial speeches of technology manufacturers and the value of a commercial offer that positively impacts CapEx in the short term and do not consider the future impact on the operation.

Based on the results and discussion of this study, it is recommended that telecommunications operators establish their decision-making processes for the acquisition of hyperconverged solutions not only on financial criteria and commercial discourse of the manufacturers but also on other variables, such as proof of concept of the functionality, performance, stability, and scalability of the technology platform; documented user experiences, and the technology manufacturer's capacity to invest in research and development in emerging technologies such as artificial intelligence.

Additionally, the international technology community is observing and evaluating technological trends through consulting firms that show the best technological solutions according to the requirements of specialized operators, along with awards and prizes of worldwide prestige (FutureNet) that distinguish technical leaders in solutions such as hyperconvergence, thus becoming an additional input to be taken into consideration in the decision-making process of organizations.

On the other hand, as we can observe, hyperconverged systems offer telecommunications operators benefits such as better control of the complexity of 5G networks since having the use of a hypervisor as part of its technology platform will reduce development times, implementation, and support of the enterprise network, since its primary role is to carry the orchestration and control, while bare metal systems, not having the element of orchestration, make the administration, management, and support of 5G networks more complex for telecommunications operators.

Another essential aspect to take into consideration is the impact from the financial perspective for the company because although it is true that at the beginning, the bare metal solutions can be attractive from the CapEx perspective, due to the reduction in software licensing costs, this saving will be impacted in the OpEx. After all, if the network begins to evolve, grow, or change due to market requirements, context, or other variables, then the operator's business model will become unprofitable from a financial perspective, losing any savings generated by economies of scope and scale, as they will have to incur in the use of professional services through skilled labor to incorporate these market requirements as soon as possible, thus affecting not only the operation but also the finances and corporate image.

Finally, there is no doubt that the different cloud technologies are offering great benefits and a competitive advantage to industries, as is the case of the telecommunications sector, which has been characterized in recent years as a futuristic area that is in constant search of cutting-edge solutions that allow them to be increasingly competitive.

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