FUTUREWEI Technologies

Whitepaper

Next Generation HCI

V1.0	March 2022

Trademarks and Permissions

and other Futurewei® trademarks are trademarks of Futurewei® Technologies. Huawei trademarks are trademarks of Huawei Technologies Co., Ltd. All other trademarks and trade names mentioned in this document are the property of their respective holders.

Notice

The purchased products, services, and features are stipulated by the contract made between Huawei and the customer. All or part of the products, services, and features described in this document may not be within the purchase scope or the usage scope. Unless otherwise specified in the contract, all statements, information, and recommendations in this document are provided "AS IS" without warranties, guarantees, or representations of any kind, either express or implied.

The information in this document is subject to change without notice. Every effort has been made in the preparation of this document to ensure accuracy of the contents, but all statements, information, and recommendations in this document do not constitute a warranty of any kind, express or implied.

FUTUREWEI® TECHNOLOGIES, INC.

Boston Research Center

Address: 111 Speen Street, Suite 114
Framingham, MA 01701
United States of America

Website: http://www.futurewei.com/

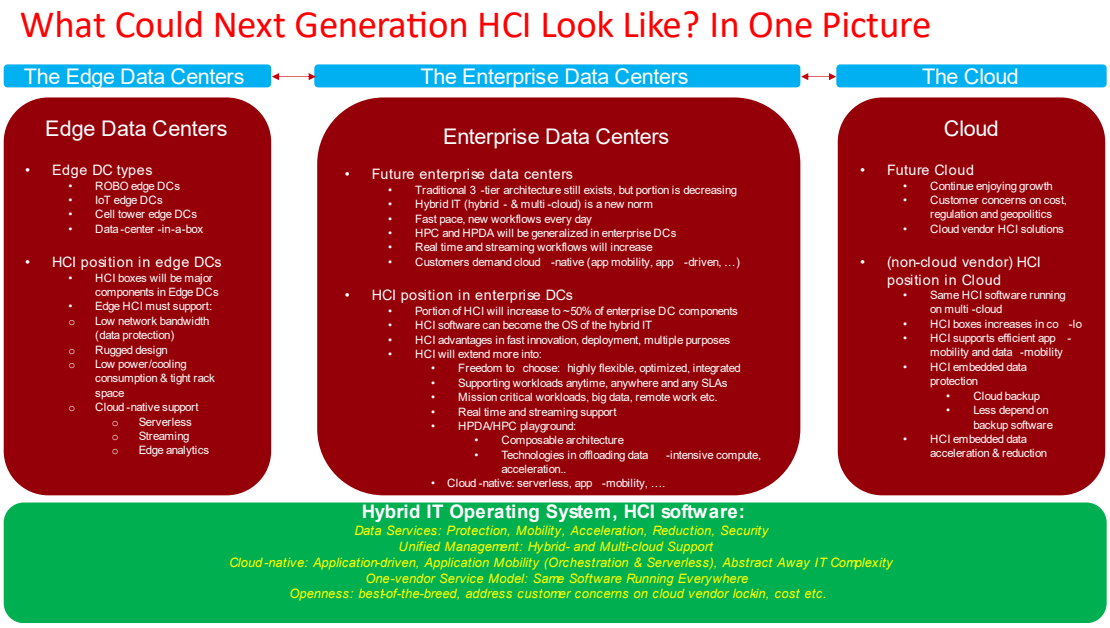
Contents

1 EXECUTIVE SUMMARY

Hyper-Converged Infrastructure (HCI) as a relative mature technology will continue enjoying significant market growth in next few years according to various market research reports. However, the new IT challenges, requirements from next generation of data centers, as well as ever growing and new workflows do require HCI vendors to rethink the next generation of HCI, and what areas could be improved. Here is the summary of the key points from this white paper:

1. **HCI is the by-far the faster growing storage sector**
    1. The CAGR is at least twice of the second fastest growing storage sector
    2. Estimated global HCI market size is $50.97 billion USD in 2028 with CAGR of 27.43%
2. **Next generation HCI software can become the OS of the hybrid IT**
    1. Running same HCI software at edge, data centers and multi clouds
    2. Efficient data mobility and embedded data protection and reduction
    3. AI and automation in O&M
    4. Vendors who have server business or own hypervisor do not necessarily have advantages over other HCI vendors
3. **Next generation composable high performance HCI has bright future**
    1. Composable with DPU, GPU, FPGA, persistent memory, InfiniBand, all-flash etc.
    2. High Performance Data Analytics (HPDA – HPC meets big data, is expected to reach USD 345.9 billion by 2028, growing at a CAGR of 23.6% during the forecast period) and beyond.
    3. Offload compute from compute servers
    4. Technology can be generalized in storage
4. **HCI vendor's market position is especially important**
    1. Gartner®'s Magic Quadrant of HCI vendors
    2. GigaOm®'s Radar for HCI vendors
5. **HCI fits important future trends in the post pandemic digital-first world very well**
    1. Cloud adoption, edge computing, hybrid work, skill challenge, and optimizing cost
6. **Next generation HCI must support different workloads anytime, anywhere, any SLAs**
    1. Multi cloud, big data, mission critical applications, real time and streaming, remote work
7. **Next generation HCI must enable advanced and modern services**
    1. Containers, serverless, edge (ROBO and IoT), data protection, secondary storage, and AI-driven O&M automation
8. **Hypervisor vendor dominance in HCI will be gradually decreased**
    1. Enterprises move to cloud-native technology like containerization
    2. HCI software become the OS of the hybrid cloud
9. **Huge architecture changes to support the complete version of dHCI and composable HCI (except the ones with high priced and high-performance**

components) might not worth it



10. **What could be the differentiating technologies in the next generation of HCI?**
    Summary:
    1. **Technologies to Offloading Data-intensive Computations from Server**
        - Data-intensive computations
            - Compression, Deduplication, Encryption, AI training, Analytics
        - Offload target
            - DPU, SmartNic, FPGA, GPU, Persistent memory etc.
        - HPDA/HPC playground
            - Composable architecture
            - Ecosystem
    1. **HCI software: OS of the Hybrid IT**
        - Data Services: Protection, Mobility, Acceleration, Reduction, Security
        - Unified Management: Hybrid- and Multi-cloud Support
        - Cloud-native: Application-driven, Application Mobility (Orchestration & Serverless), Abstract Away IT Complexity
        - One-vendor Service Model: Same Software Running Everywhere
        - Openness: best-of-the-breed, address customer concerns on cloud vendor lock-in, cost etc.
    2. **Real-time Streaming Support**
        - Developing the streaming platform
        - HCI integration
    3. **Extend HCI to Mission Critical**
        - EMR, CRM, ERP, Databases, SAP HANNA etc.

- Expand into vertical ecosystems
- Performance is the key

4. **Be the Best of Edge and ROBO HCI vendor**
    - Develop edge and ROBO HCI based on different use cases
    - Rugged/compact design, low power/cooling consumption, work well under low network bandwidth
    - Ecosystem integration: IoT, ROBO and cell tower etc. edge data centers
5. **Be the Best of Hybrid Work support**
    - VDI acceleration via GPU
    - Ecosystem integration

2 BRIEF INTRODUCTION OF HCI

2.1.1 What is HCI

Hyper-converged infrastructure is a software-centric architecture that tightly integrates compute, storage, and virtualization resources in a single system. In short, HCI consolidates servers, storage, the virtualization in hypervisor and/or container, and some network functions into a software-centric solution deployed on commodity and/or optimized hardware.

2.1.2 What Problems Does HCI Try to Solve

2.1.2.1 Data Center Complexity

Modern businesses rely on the data center to provide the computing, storage, networking, and management resources that are necessary to host vital enterprise workloads and data. But data centers can be notoriously complex places where a multitude of vendors compete to deliver myriad different devices, systems, and software. This heterogeneous mix often struggles to interoperate -- and rarely delivers peak performance for the business without careful, time-consuming optimizations. Today, IT teams simply do not have the time to wrestle with the deployment, integration and data center management challenges posed by traditional heterogeneous environments.

2.1.2.2 Customers' Need for Heterogeneous Data Centers

Heterogeneous data centers evolved because every enterprise has computing problems that must be solved, but the answer is rarely the same for every company or every problem. The promise of heterogeneity frees an enterprise to choose between low-cost product options and best-of-breed ones -- and everything in between -- all while keeping the data center largely free of vendor lock-in.

But heterogeneity has a price. Constructing an effective heterogeneous data center infrastructure requires time and effort. Hardware and software must be individually procured, integrated, configured, optimized -- if possible -- and then managed through tools that are often unique to a vendor's own products. Thus, managing a diverse infrastructure usually requires expertise in multiple tools that IT staff must master and maintain. This causes additional time and integration challenges when the infrastructure had to be changed or scaled up. Traditional heterogeneous IT simply is not particularly agile.

2.1.2.3 Faster Pace of Business Change

Today, business changes at a much faster pace. IT must respond to the demands of business much faster; provisioning new resources for emerging workloads on-demand and adding new resources often just in time to keep enterprise applications running and secure, yet IT must also eliminate systems management errors and oversights that might leave critical systems vulnerable. And all of this must be accomplished with ever-shrinking IT budgets and staff. Hyper-converged infrastructure is all about deployment speed and agility.

HCI draws on the same benefits that made homogeneous data center environments popular: single-vendor platforms that ensured compatibility, interoperability, and consistent management, while providing "one vendor's throat to choke" when something went wrong. But HCI goes deeper to deliver compute, storage and network resources that are organized using software-defined and virtualization technologies. The resources are tightly integrated and pre-optimized, and the hardware and software are packaged into convenient appliances -- or nodes -- which can be deployed singularly to start and then quickly and easily scaled out as resource demands increase.

2.1.3 Different Generations of HCI: CI, HCI, dHCI (HCI 2.0), Composable HCI

2.1.3.1 CI: Converged Infrastructure

The notion of *convergence* originally arose as a means of addressing the challenges of heterogeneity. Early on, a single vendor would gather the systems and software of different vendors into a single pre-configured and optimized set of equipment and tools that was sold as a package. This was known as *converged infrastructure*, or *CI*.

2.1.3.2 HCI: Hyper-Converged Infrastructure

Vendors (started from startups like Nutanix®, SimpliVity® around 2009) took the next step to design and produce their own line of prepackaged and highly integrated compute, storage, and network gear for the data center. It was an evolutionary step now called *hyper-converged infrastructure*, or *HCI*.

2.1.3.3 dHCI or HCI 2.0: Disaggregated Hyper-Converged Infrastructure

Some hyper-converged vendors have figured out there is a need for a more configurable resource buffet that retains the management benefits of HCI. These offerings, referred to as disaggregated HCI, provide customers with more granularity around the ratio of compute to storage. Rather than monolithic all-in-one nodes, dHCI products ship separate compute and storage nodes so you can decide the right mix of each without scaling compute and storage linearly in lockstep. Disaggregated HCI works well for those who need more control over their resource allocation but still want operational ease.

In our view, dHCI is just an offering and deployment option that does not represent a major evolution step like it from CI to HCI.

2.1.3.4 Composable HCI

Composable architecture is an IT infrastructure type getting a lot of hype lately. Several vendor examples are Fungible®, Liqid®, VMWare® Monterey Project and HPE® Synergy. It goes a step beyond hyper-convergence by providing a fluid platform in which all resources are pooled together and tightly managed with software. The resulting fabric enables quick creation of workload operating environments in which the administrator does not have to mess around with hardware beyond initial deployment.
Although it sounds promising, but it might be hard to expand to general IT market for composable HCI. In the enterprise, how many IT shops really reconfigure their hardware every day? Change is risk and enterprise is not ready to dynamically rebuild your infrastructure unless they are 100% certain. The automation requirement needed by composable is extremely high, most of IT organizations are not ready.

However, enterprises using expensive general compute and GPU servers and facing a need to support widely different workloads will see server utilization going up and down as workloads change and drive overall utilization up. This applies to HPC/HPDA data centers and to co-location/managed service suppliers facing workload variability as tenant workloads come and go. Composable fit very well in these use cases.
In short, we think the general market are not ready to accept composable HCI yet, but it can now penetrate into HPDA/HPC market for composing expensive hardware components. With improvement in automation in coming years and we might see composable HCI to extend its market in the future.

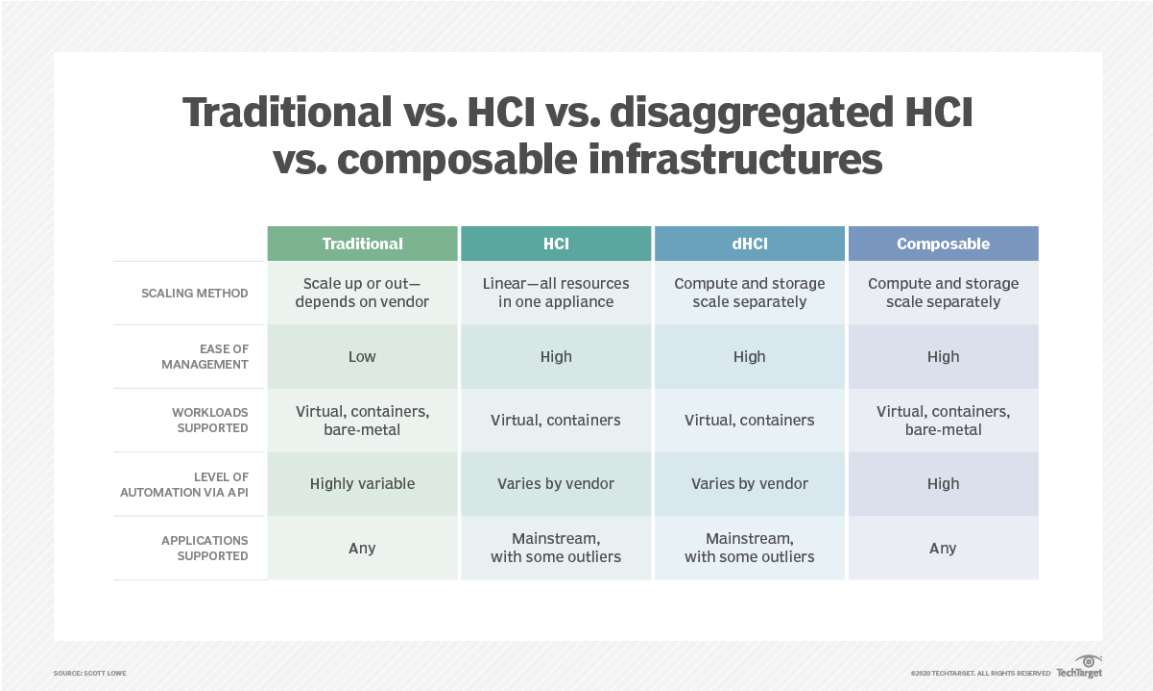


Figure 1. Comparison of Different Types of HCI [1]

3 Why is HCI Becoming More and More Important in Future Datacenter

3.1 Welcome to the Digital-First World

According to IDC®, for the first time in over 20 years, the IT industry in 2021 grew at double digit [2], and additional $1.5 trillion to the cumulative rolling 4-year forecast [3]. For most companies, the pandemic was the catalyst that drove a rapid acceleration of the shift to digital-first – influencing how broadly the need for modern technology will play out throughout the world.

Focus on business outcomes is a visible sign that digital-first is becoming a reality. Digital-first is not a business model but an organizational approach to always utilize digital to improve lives and outcomes. Digital-first is not about picking/prioritizing a

particular technology or a business model. It is an organizational aspiration that must apply across customer engagement, hybrid work, unified security, automated operations, and shared business value.
One thing is certain that more and more data will be created and analyzed to create better digital experience for customers.

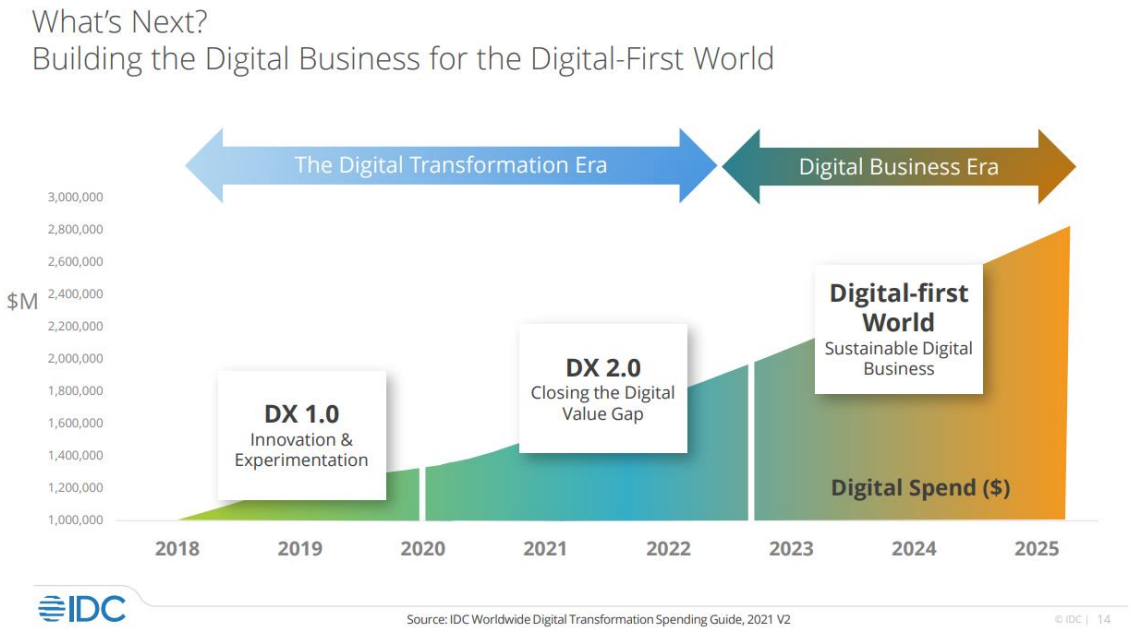


Figure 2. Digital-First World from IDC® Direction 2022 [4]

3.2 Important Trends in Post Pandemic World

3.2.1 Cloud Adoption and Growing Hybrid Cloud

There has been a dramatic increase in the amount spent on cloud in total – doubling in the last 4 years, and in the next 2 years it will almost double again. Cloud is maintaining a significant momentum.

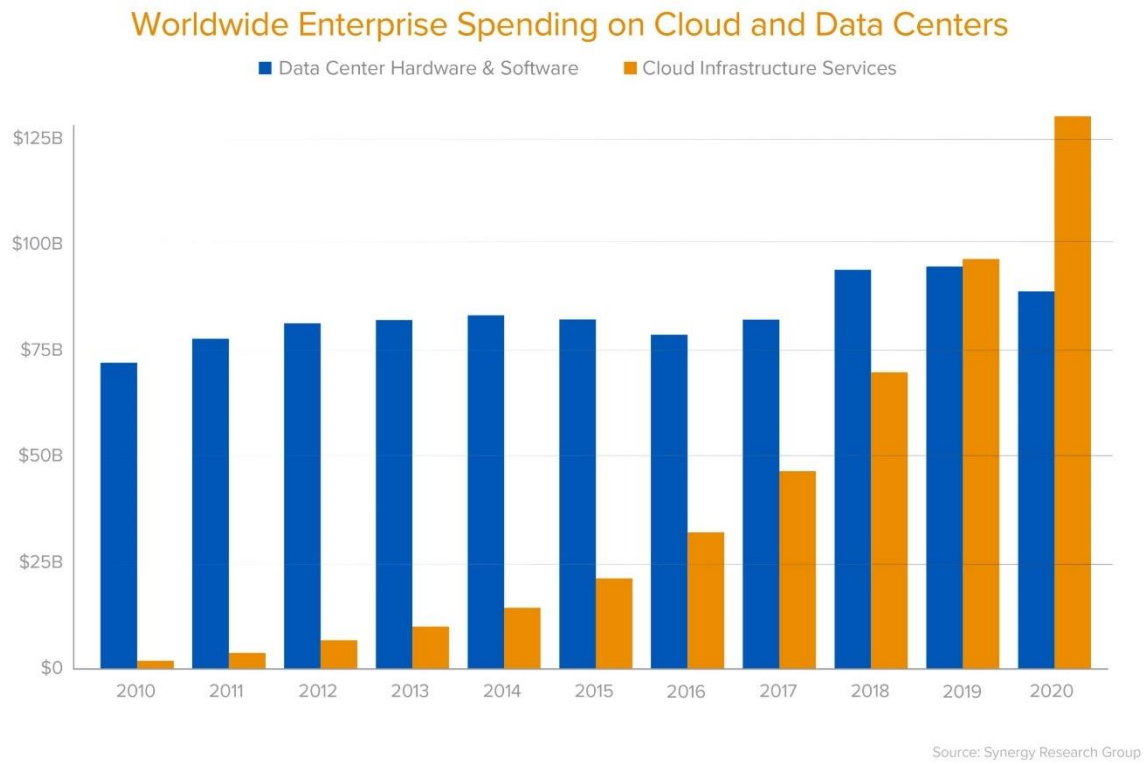


Figure 3. Worldwide Enterprise Spending on Cloud and Data Centers. [5]

However, due to following concerns over public cloud, hybrid cloud will be become a new norm in enterprise IT infrastructure, commonly called hybrid IT, covers cloud, edge, and data centers with cloud experience in the enterprise IT:

- The true cost of public cloud (see The Cost of Cloud, a Trillion Dollar Paradox) or paradox of "*You're crazy if you don't start in the cloud; you're crazy if you stay on it"* [6]
- Regulations
- Geopolitics

3.2.2 Edge Computing

The interconnected and cooperative nature of the edge has never been more apparent, from IoT to auto driving, to ROBO offices and edge data centers, The edge ecosystem has expanded rapidly in recent years, and with it, an increase in data coming from edge devices.

But many organizations that spent the past decade moving data out of their own data centers and into the cloud are realizing that it does not make sense to send all the data generated by edge to the cloud for processing. There are two main concerns with edge to cloud model:

- The cost of building cloud infrastructure and fees associated with transporting ever-growing huge amount of edge data to cloud:
- Data transmission time: The speed of sending data to the cloud, where analytics engines would process the data and then return actionable insights back to those endpoints would in many use cases take too long. Organizations need near

instantaneous results for many of their edge deployments, where even a one-second delay could be too long.

Tremendous infrastructure investments are needed to support the growing device and infrastructure edge demand. According to The Linux Foundation's estimation, between 2019 and 2028, cumulative capital expenditures of up to $800 billion USD will be spent on new and replacement IT server equipment and edge computing facilities [7]. These expenditures will be evenly split between equipment for the device and infrastructure edges.

3.2.3 Hybrid Work

Hybrid work is here to stay, employees divide their working week between being in the office and working remotely.

3.2.4 Skill Challenge

One thing that is consistent in this next decade is the ongoing concern about skills challenge. As the pace of technology advancement accelerates, the IT needs infrastructure that can

- Do more with less
- High level of automation with assistance of AI

3.2.5 Optimizing Costs

Cost saving is always in the front end of enterprise IT. With multi-billion-dollar digital transformation and digital-first projects already in progress, IT needs to justify every dime spent. This goes beyond upfront capital expenditure. You need to maximize the efficiency of every investment *over time*.

3.3 HCI Fits These Trends Like Hand in Glove

3.3.1 HCI Can Become the OS of the Hybrid Cloud

According to S&P Global Market Intelligence®'s (acquired 451 Research® in 2019) 2021 survey, there is strong correlation between HCI and hybrid cloud deployments [8]. Hybrid cloud, or hybrid IT, refers to the amalgamation of on- and off-premises infrastructure, HCI is being readily adopted to support such integrated IT environments. According to the study, 52% of organizations using HCI have hybrid IT architecture currently in place, and another 30% are in the process of implementing it.

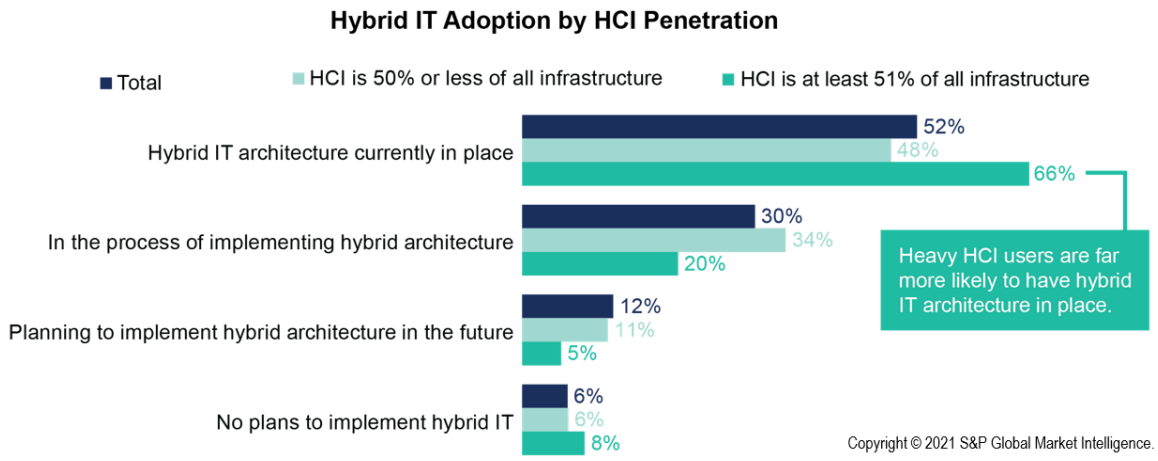


Figure 4. Hybrid IT Adoption by HCI Penetration. [8]

One of the most common complaints is managing all the various panes of glass in a complex hybrid cloud and multi-cloud IT environment. HCI can become the operating system of the hybrid cloud, so that such HCI software can not only support the ease of deployment and management, also could run the same software across different infrastructures for more efficient data movement.

We think these are at the root of the connection between HCI and hybrid cloud.

3.3.2 HCI Can Become the Main Component in Edge Data Centers

HCI continues to make inroads in organizations recognizing the need to embrace adaptive technology to solve fundamental business problems. HCI has begun to enjoy more prominent success in enterprises with edge-based Remote Office/Branch Office (ROBO) IT needs.

ROBO and edge facilities – bank branches, retail locations and field-based oil & gas work sites, for example – tend to lack personnel with the skills to manage IT systems simply and efficiently. While 36% of all HCI users cite “ease of management” as the top rationale for deploying HCI, that percentage swells to 50% for users servicing ROBO locations [8]. The last place where you want storage complexity is at the edge, where you generally do not have a lot of depth in terms of IT resources.

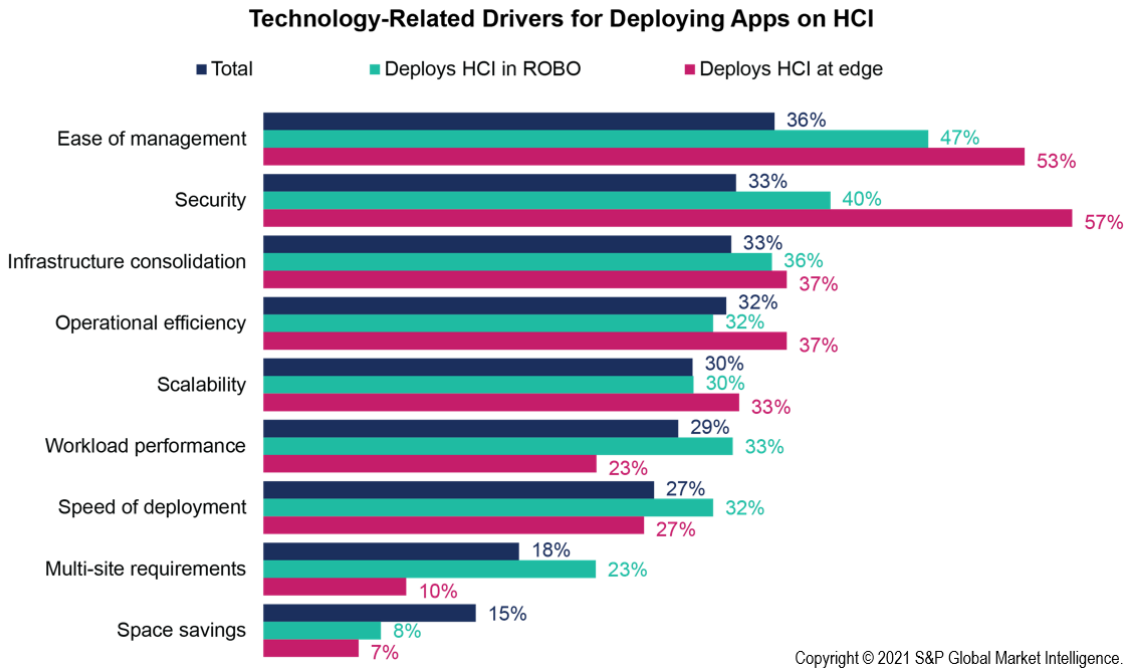


Figure 5. Technology-Related Drivers for Deploying Apps on HCI. [8]

3.3.3 HCI Is the Major Remote Work Player

Technologies like Virtual Desktop Infrastructure (VDI), Desktop as a Service (DaaS), are remote virtual machine etc. become more and more popular because of their strong security features, while these technologies fit naturally with HCI solution.

3.3.4 HCI has the Ease-of as Hallmark Feature to Ease Skill Challenges

That HCI has been shown across many circumstances to simplify system deployment and management, often greatly reduce cost, especially OpEx. In recent years, many AI features have been integrated into HCI systems, and automation also makes great progress. Due to all these, the skill requirement of operating HCI is much lower than other traditional IT systems. Therefore, HCI can help to ease of the skill challenges of IT organization.

3.3.5 HCI Has the Largest ROI

HCI is a great way to reduce both CapEx and OpEx. Reducing both means you achieve a lower overall TCO, with IDC® calculating that HCI provides a five-year return-on-investment of 524% and a 60% reduction in five-year operating costs [9].

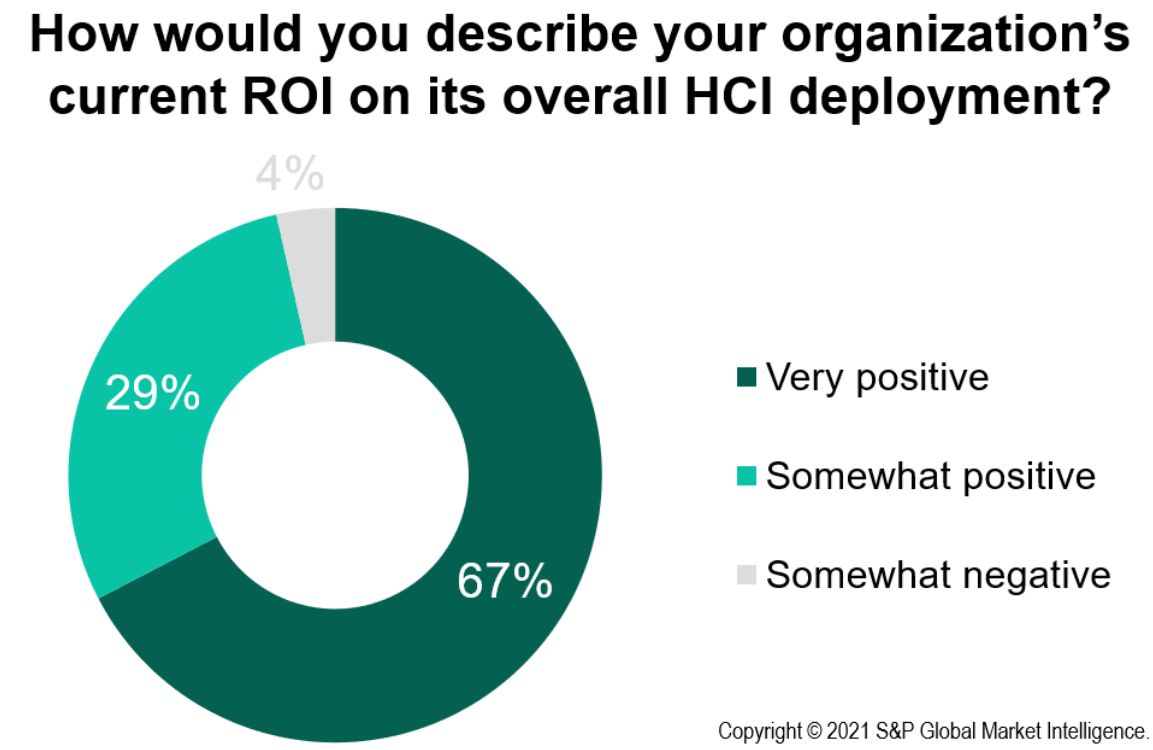


Figure 6. Customers' Satisfaction on HCI ROI. [8]

4 HCI Market Analysis and Forecast

4.1.1 HCI is the Fastest Growing Storage Sector

According to an IDC® report, the virtual SAN segment, which includes hyperconverged infrastructure (HCI) appliances, will grow the fastest across all data access segments at a CAGR of 11.6%, at least twice compared to the second fastest. By 2025, it will exceed the level of sales of the Ethernet file and object market segment. [10]

TABLE 5

Worldwide External Enterprise Storage Systems Revenue by Topology, Installation, and Data Access, 2016-2025 ($B)

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2020–2025 CAGR (%)
Direct (DAS)	1.3	1.1	1.0	0.9	1.0	1.0	0.9	0.9	0.8	0.8	-5.3
Mainframe networked (FICON)	0.9	0.7	0.7	0.8	0.6	0.5	0.5	0.5	0.4	0.4	-7.3
Open networked											
Ethernet file/object	5.7	6.0	7.4	6.9	6.8	7.6	8.0	8.2	8.4	8.4	4.5
SAN											
Fibre Channel	12.0	11.7	13.0	12.2	11.1	11.5	12.6	13.2	13.5	13.6	4.2
Virtual SAN	1.3	2.3	3.8	4.8	5.1	5.9	6.7	7.4	8.1	8.8	11.6
Ethernet block	3.1	2.9	3.0	3.6	3.7	3.6	3.9	4.1	4.1	4.2	2.7
Other	0.9	0.8	1.0	1.3	1.1	1.0	0.8	0.8	0.8	0.7	-8.5
Subtotal SAN	17.3	17.8	20.8	21.9	21.0	21.9	24.0	25.5	26.5	27.3	5.4
Subtotal open networked	23.0	23.8	28.2	28.8	27.7	29.6	32.0	33.7	34.9	35.7	5.2
Total	25.2	25.6	29.8	30.5	29.3	31.1	33.5	35.0	36.1	36.9	4.7

Note: Virtual SAN includes value of storage components in systems sold as HCI appliances. Value of other components (e.g. compute, networking and software) is excluded.

Source: IDC, 2021

Figure 7. HCI is the fastest growing storage sector in revenue. [10]

For capacity, the 2020-2025 CAGR of the virtual SAN is also the fastest among all storage sectors, reaches 42.8%. [10]

TABLE 6

Worldwide External Enterprise Storage Systems Capacity Shipped by Topology, Installation, and Data Access, 2016-2025 (PB)

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2020–2025 CAGR (%)
Direct (DAS)	3,890	4,095	4,303	4,408	4,539	5,914	5,300	5,514	5,666	5,760	4.9
Mainframe networked (FICON)	1,199	881	1,042	1,248	1,126	1,134	1,024	943	975	1,072	-1.0
Open networked											
Ethernet file/object	16,307	17,534	21,183	21,460	24,170	29,844	33,234	40,152	46,302	52,417	16.7
SAN											
Fibre Channel	18,643	19,334	23,935	22,217	22,343	25,762	28,409	36,489	42,427	48,003	16.5
Virtual SAN	1,056	1,840	3,525	5,450	7,413	12,564	20,985	27,416	40,795	44,043	42.8
Ethernet block	8,995	10,752	10,899	12,103	12,734	14,421	14,702	20,284	25,045	30,309	18.9
Other	1,709	1,721	2,507	5,239	4,947	6,016	6,168	6,498	6,668	6,741	6.4
Subtotal SAN	30,402	33,647	40,867	45,009	47,436	58,764	70,265	90,687	114,935	129,095	22.2
Subtotal open networked	46,709	51,181	62,050	66,469	71,606	88,607	103,499	130,839	161,236	181,512	20.4
Total	51,798	56,157	67,395	72,126	77,271	95,656	109,823	137,297	167,877	188,345	19.5

*Virtual SAN includes storage capacity of systems sold as HCI appliances.

Source: IDC, 2021

Figure 8. HCI is the fastest growing storage sector in capacity. [10]

4.1.2 Attractive Opportunity for HCI market: HCI Market Size Predictions to 2028

According to several market prediction research reports, in recent 3 years, HCI global market grown from 2018 $3.84 billion [11], to 2019 $6.1 billion [12], to 2020 7.8 billion [13], the three-year CAGR is 26.64% from 2018 to 2020.

For future prediction, the calculated average global market size is $50.97 Billion in 2028 with CAGR 26.1% according to these reports:

	Reported CAGR%	Reported Market Size ($ Billions)	Calculated Market Size ($ Billions) in 2028	**Average Market Size ($Billions) in 2028**	**Average CAGR%**
Meticulous Research® [14]	24.1% (2021 – 2028	42.1 (2028)	42.1	**50.97**	**27.43**
Markets and Markets® [15]	28.1% (2020 - 2025)	27.1 (2025)	56.97		
Emergen Research® [16]	26.8% (2020 – 2028)	48.17 (2028)	48.17		
Allied Market Research® [17]	30.7% (2019 - 2026)	33.16 (2026)	56.65		

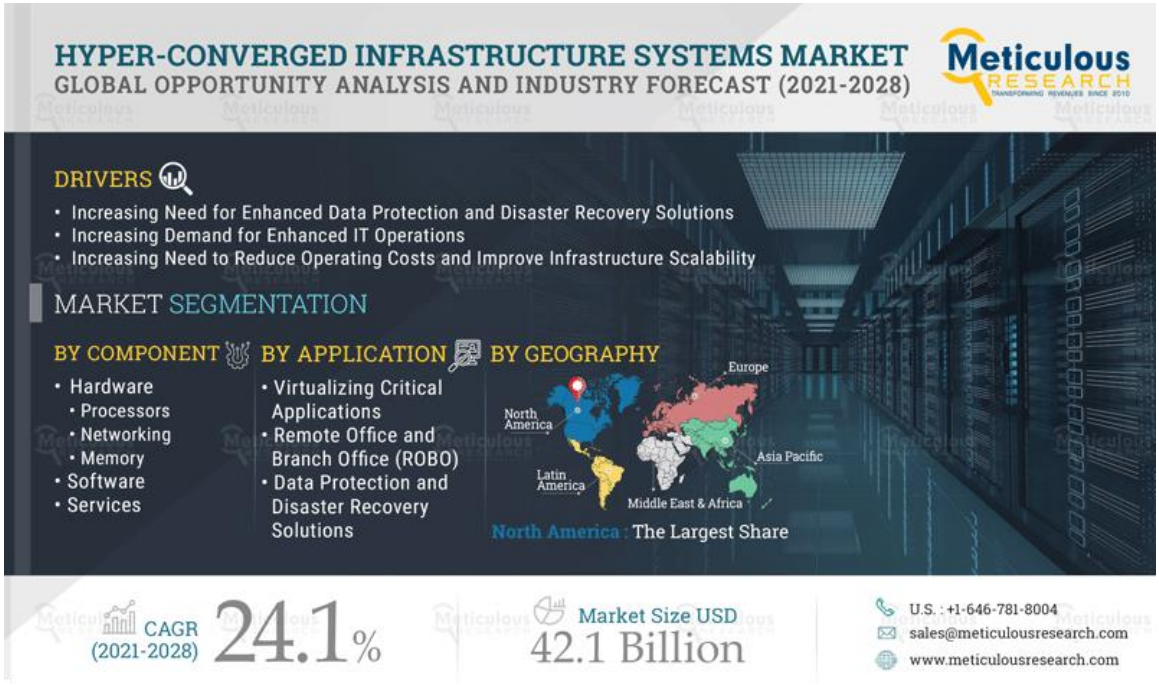


Figure 9. HCI Market Forecast Example. [14]

4.1.3 Composable HCI Potential Market: HPC and HPDA

According to IDC® report, the market for composable/disaggregated infrastructure solution will grow at a six-year CAGR of 58.2% and reach $4.7 billion in 2023 [18]. If composable can penetrate other markets, then the potential of such products can have more potential. For example, the HPC market is estimated to reach $49.4 billion in 2025

with five-year CAGR at 5.5% [19], while High Performance Data Analytics (HPDA) market has even higher value which is estimated $345.9 billion by 2028 with a CAGR of 23.6% [20]. HPDA refers to big data analytics being carried out on High-Performance Computing (HPC) methods.

5 HCI VENDOR ANALYSIS

5.1.1 Analyst View of HCI Vendors

5.1.1.1 Gartner® Magic Quadrant for Hyperconverged Infrastructure Software

According to Gartner® [21], HCI software stacks support infrastructure that spans compute, storage, networking, and management. Infrastructure and Operations (I&O) leaders should regard HCI software as a technology that addresses requirements related to the cloud-native, edge, hybrid cloud and virtual desktop infrastructure use cases

Nutanix® and VMWare® are in the leading role, while cloud vendors like Microsoft® (Azure Stack HCI) quickly catch up via their HCI products as cloud extension to on-prem data center.

Figure 10. Gartner® MQ for HCI Software. [21]

5.1.1.2 GigaOm® Radar for Enterprise and Edge HCI

Another well-known industry analyst firm GigaOm® has also been published HCI vendor analysis reports yearly. According to GigaOm®, there are two distinct hyperconverged infrastructure (HCI) markets, namely Enterprise [22] and Edge [23]. Accordingly, the analyst firm has compiled two separate "radar screens", its version of Gartner®'s Magic Quadrant.

VMware®, Nutanix® and Dell/EMC® dominate Enterprise hyperconverged systems by revenues. But for the purposes of the GigaOm® radar screen, it sets market share aside and concentrates on technology.

According to GigaOm®, hyperconvergence for the enterprise market is both mature and consolidated. VMware® Cloud Foundation (VCF) holds the lion's share of the market in terms of deployments and enjoys technology leadership. At the same time, alternative solution stacks are gaining popularity by offering compelling value and innovative approaches.

The interest has shifted from core virtualization features to the platform ecosystem and integration of core, cloud, and edge components. Other aspects of hyperconvergence infrastructure (HCI) that are quickly gaining traction include automation and orchestration, as well as integration with Kubernetes. The final goal is to build hybrid cloud infrastructures that can provide a consistent user experience across different environments while enabling applications and data mobility.

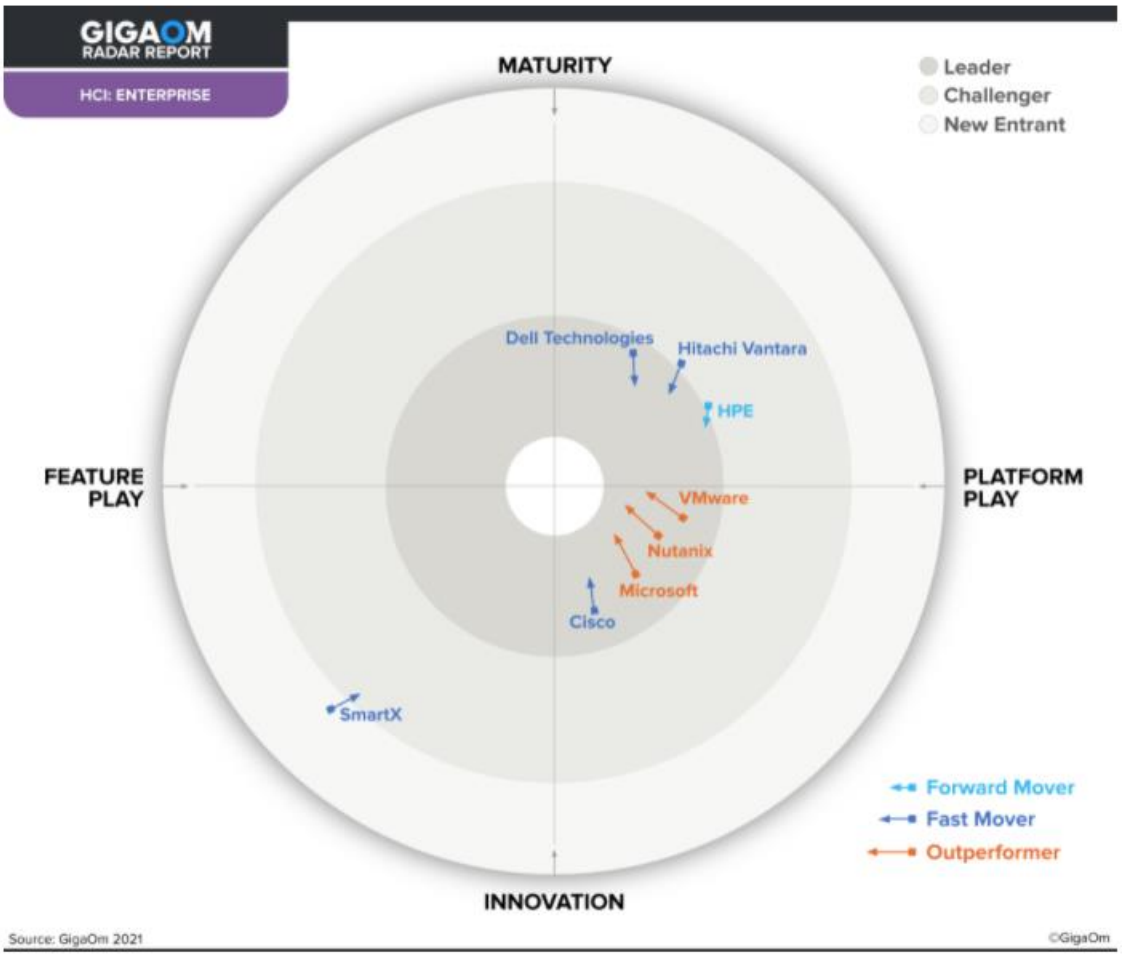


Figure 11. GigaOm® Radar Report on HCI Enterprise 2021. [22]

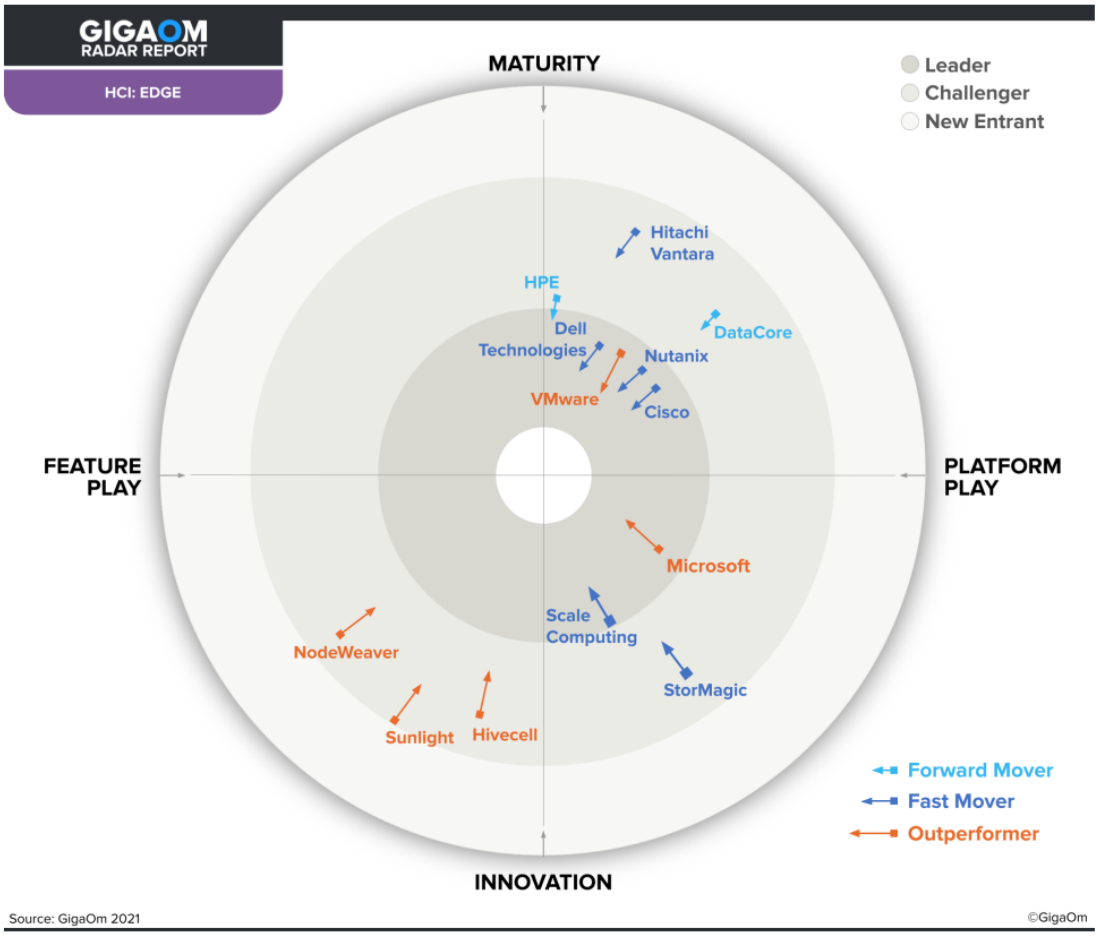


Figure 1. GigaOm Radar for Edge HCI

Figure 12. GigaOm® Radar Report on HCI Edge 2021. [23]

5.1.2 Nutanix®

Strengths:

- Nutanix® has one of the most compelling HCI solutions in the market.
- Nutanix® goes beyond core HCI, by offering a complete list of additional storage services (including scale-out file and object storage), integrated backup and disaster recovery tools, an end-to-end monitoring and analytics platform, automation, and orchestration tools. All of this is available while keeping the user experience extremely consistent with a strong user interface.
- Karbon (K8S) platform is aimed at delivering the same user experience across hybrid and multi-cloud environments.

Challenges:

- Need time to prove it is a successful move to move to a pure HCI software company
- Low profit margin

5.1.3 Dell-EMC-VMWare®

Strengths:

- Dell/EMC® has its flagship product, the VxRail appliance, is part of a broad product lineup that includes VSAN-ready nodes and solutions for Microsoft® Hyper-V. VxRail offers one of the best and most consistent user experiences in the HCI space.
- VMWare® has its flagship HCI solution, VMware® Cloud Foundation (VCF), providing customers an integrated stack including compute, storage and networking virtualization, advanced management, and SDDC Manager for complete lifecycle management.
- End-to-end integrated stack with tools to simplify and improve operations at any scale.
- Market leader with solutions for all use cases and possessing a vast ecosystem. VMware® still innovates through internal product development and acquisitions when necessary.

Challenges:

- CloudIQ, the analytics platform that works across all Dell® storage systems, is not supported on VxRail.
- VMWare® solution can be expensive at times and customers have concerns on vendor lock-in.

5.1.4 HPE®

Strengths:

- HPE® has a complete product line covering HCI (Simplivity) and Nimble Storage dHCI.
- The HPE® dHCI platform is also available through the GreenLake cloud-like subscription for customers wanting to move from CapEx to OpEx models for their budgeting.
- Solid, easy-to-use, and efficient solution with a best-in-class analytics platform via InfoSight.
- Market leader with solutions for all use cases and possessing a vast ecosystem. VMware® still innovates through internal product development and acquisitions when necessary.

Challenges:

- Confusion and inconsistency related to different product lines (via acquisition) and architecture.

5.1.5 Cloud Vendors

Big public cloud vendors now all have their own HCI solutions

- Microsoft® Azure Stack HCI
- Amazon® AWS Outposts
- Google® GCP Anthos

Although these products provide customers unified cloud experience and comprehensive managed services, customers do have concern on vendor lock-in, cost, and the requirement to support hybrid and multi clouds.

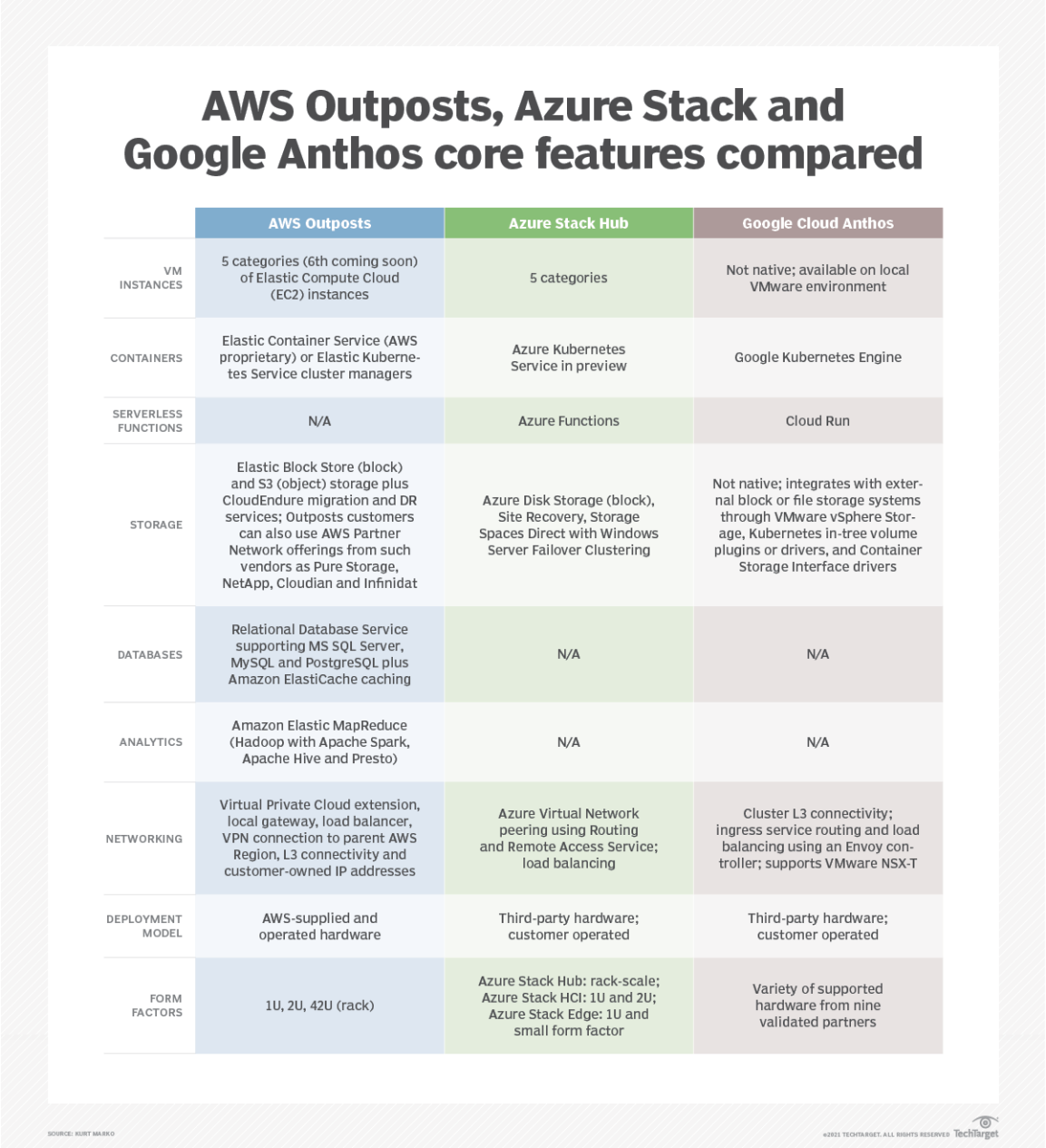


Figure 13. Cloud HCI Products Comparation. [24]

Among these big three, Microsoft® has the leading role:

5.1.5.1 Microsoft®

Strengths:

- Microsoft® Azure Stack HCI can be used as an extension of Microsoft Azure Cloud to provide unified experience for Azure Cloud customers.
- Microsoft® has improved the core of Azure Stack HCI also. Its distributed storage layer (Storage Spaces Direct, or S2D) has been optimized for enhanced

performance and reduced resource consumption, while native backup and disaster recovery services are integrated in the stack. Infrastructure lifecycle management, including firmware upgrades, is possible via select hardware vendors.
- It runs AKS services directly on Azure Stack HCI, helping to bring Kubernetes to the edge. The AKS control plane resides on the local HCI system, enabling disconnected use without continuous access to Azure Cloud.
- Aggressive and cost-effective pricing.

Challenges:

- Even though Microsoft® has a long list of vendors supporting Azure stack HCI, this solution can be limiting for users who want integrated appliances and single point of contact for support and maintenance.

5.1.6 Composable Vendors

Composable infrastructure fits well with the use case that customers need repurpose hardware components, especially the expensive ones like GPU, DPU (Data Process Unit) etc., because constant change of applications.

For composable vendors, we can put them into three categories:

- Nvidia® BlueField (SmartNic/DPU) ecosystem vendors, the representative is VMWare® Monterey Project
- Self-made DPU, such as Fungible® and Pandando®
- Software composable vendor, such as Liqid®

5.1.6.1 Nvidia® BlueField (SmartNic/DPU) ecosystem vendors

The following picture described major players in Nvidia® BlueField ecosystems, here we just present one example in the VMWare® Monterey Project.

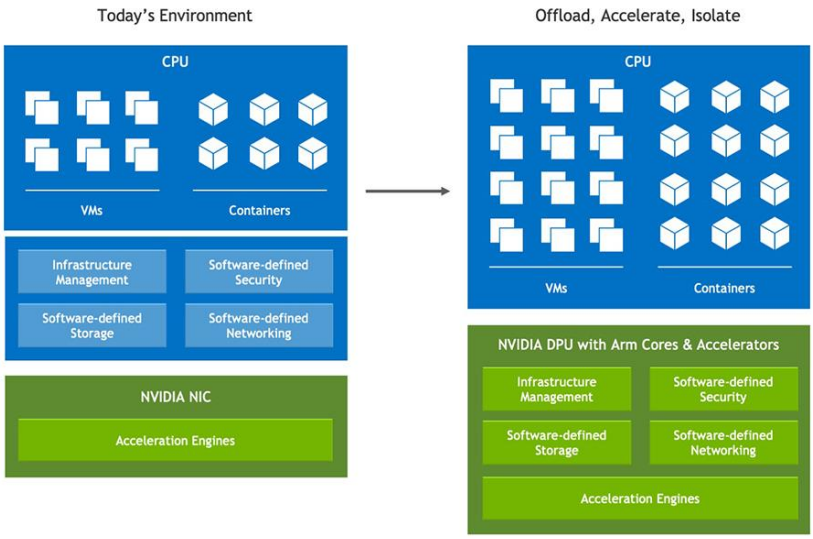


Figure 14. Nvidia® DPU: Data centers evolve to be software-defined, containerized, and composable. Offloading infrastructure tasks to the DPU improves server performance, efficiency, and security. [25]

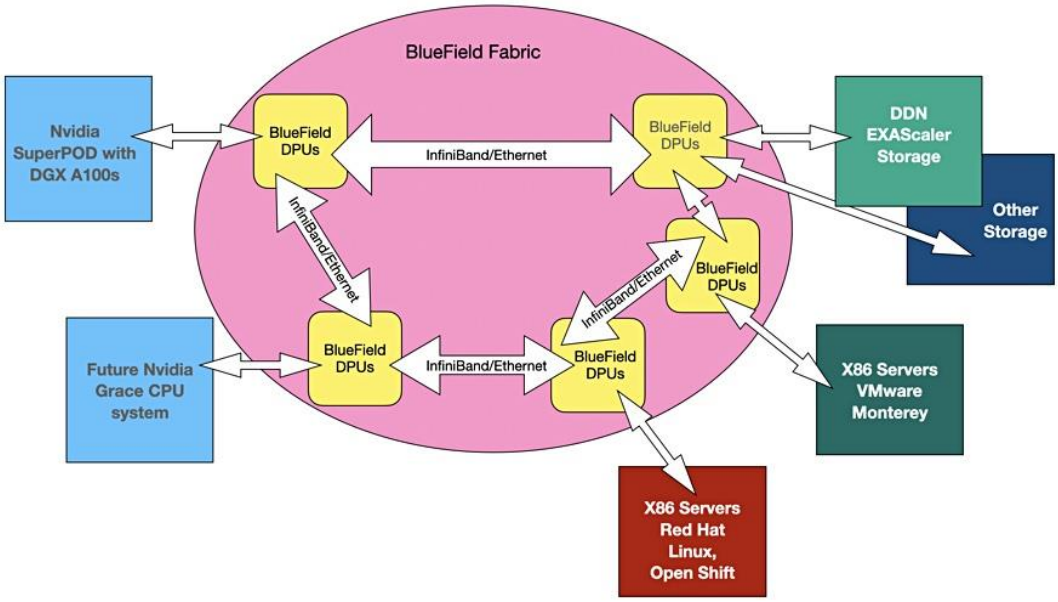


Figure 15. Blocks & Files diagram of a BlueField composability fabric. [26]

VMWare® Monterey Project

The project [27] introduces a new model that offloads hypervisor, networking, security, and storage tasks from the CPU to the DPU. The aim is to offload hypervisor, networking, security, and storage tasks from a host CPU to Nvidia®'s BlueField data processing unit (DPU). This should be useful for AI, machine learning, and high-throughput, data-centric applications, according to the companies.

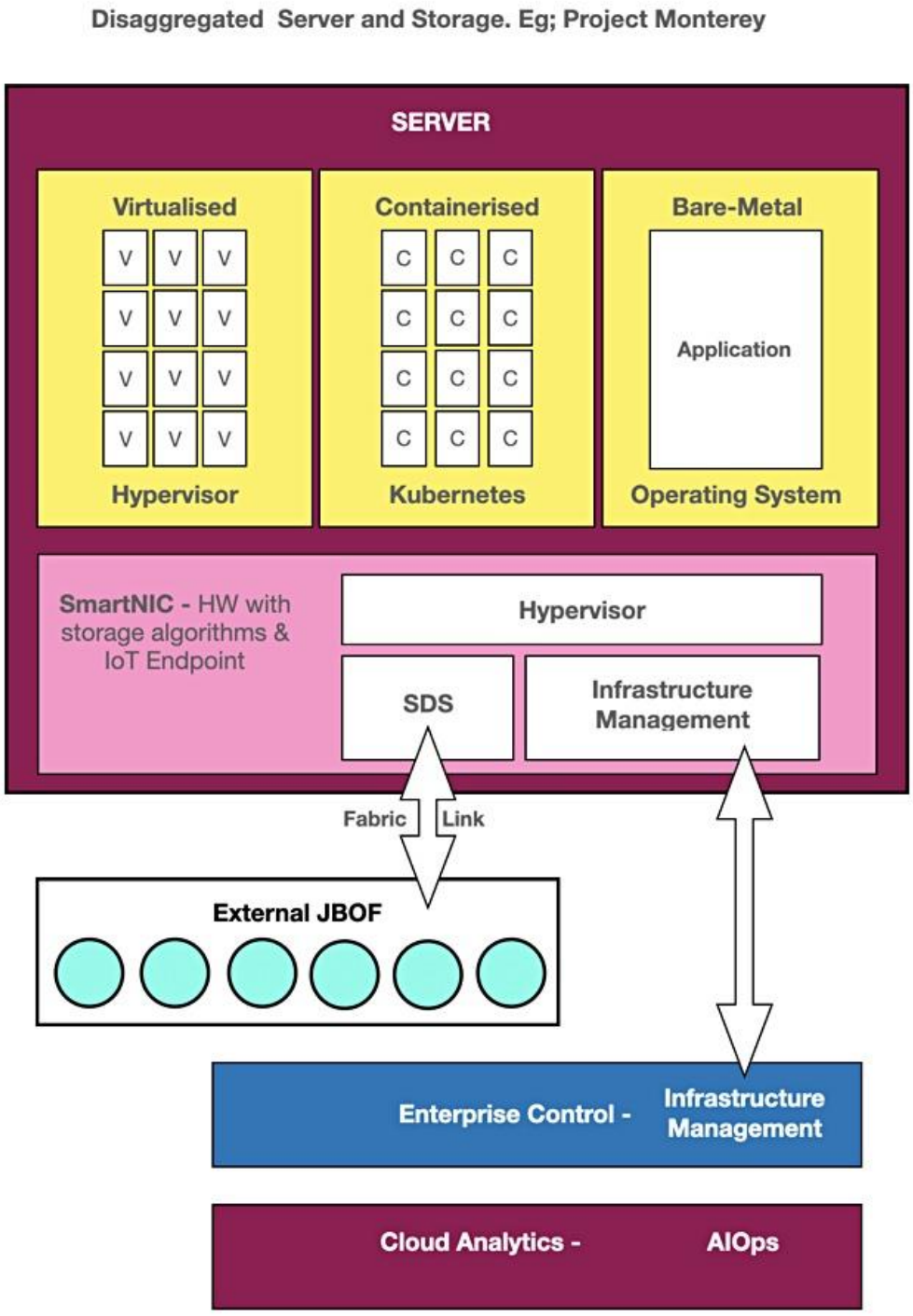


Figure 16. Disaggregated Server and Storage, Eg.; Project Monterey. [28]

5.1.6.2 Fungible®

Fungible® has developed DPU (Data Processing Unit) chips and used them to power its storage node. Dutch high-performance computing (HPC) researchers have reported a Fungible® storage node delivering 6.55 million random read IOPS to a single server

[29]. Fungible® claims this is the world's highest performance between a single server reading data and a single storage target.

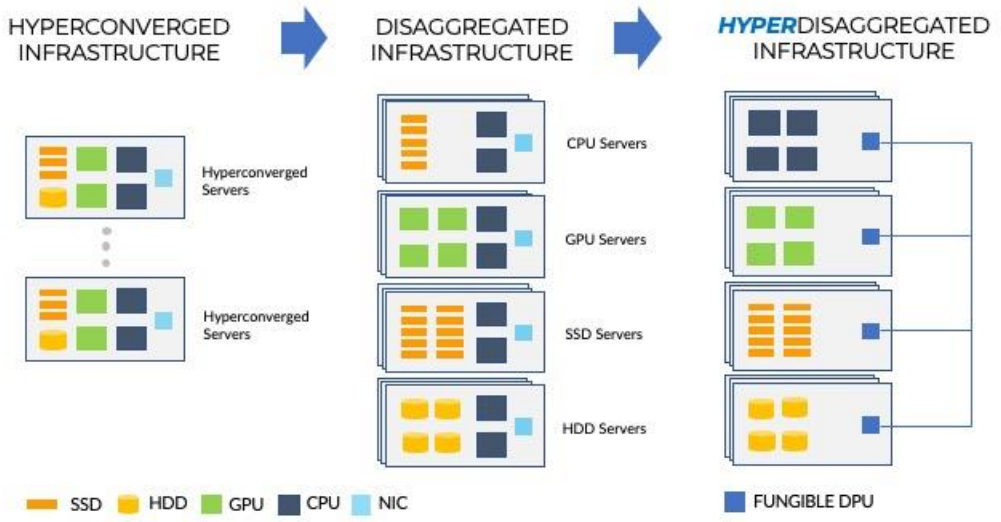


Figure 17. Fungible® Composable Architecture. [30]

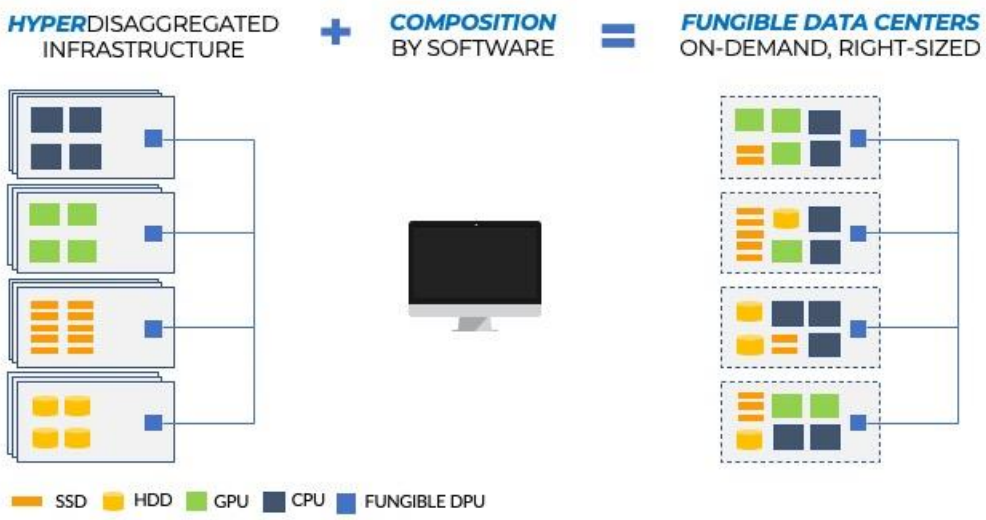


Figure 18. Fungible® Composable Architecture (2). [30]

5.1.6.3 Liqid®

Its technology is based around its CDI (Composable Disaggregated Infrastructure) orchestration software which composes server CPUs+DRAM, GPUs, FPGAs, NVMe SSDs, networking, and storage-class memory using the PCIe bus (generations 3 and 4) as its connectivity, to create software-defined, bare metal servers on demand.

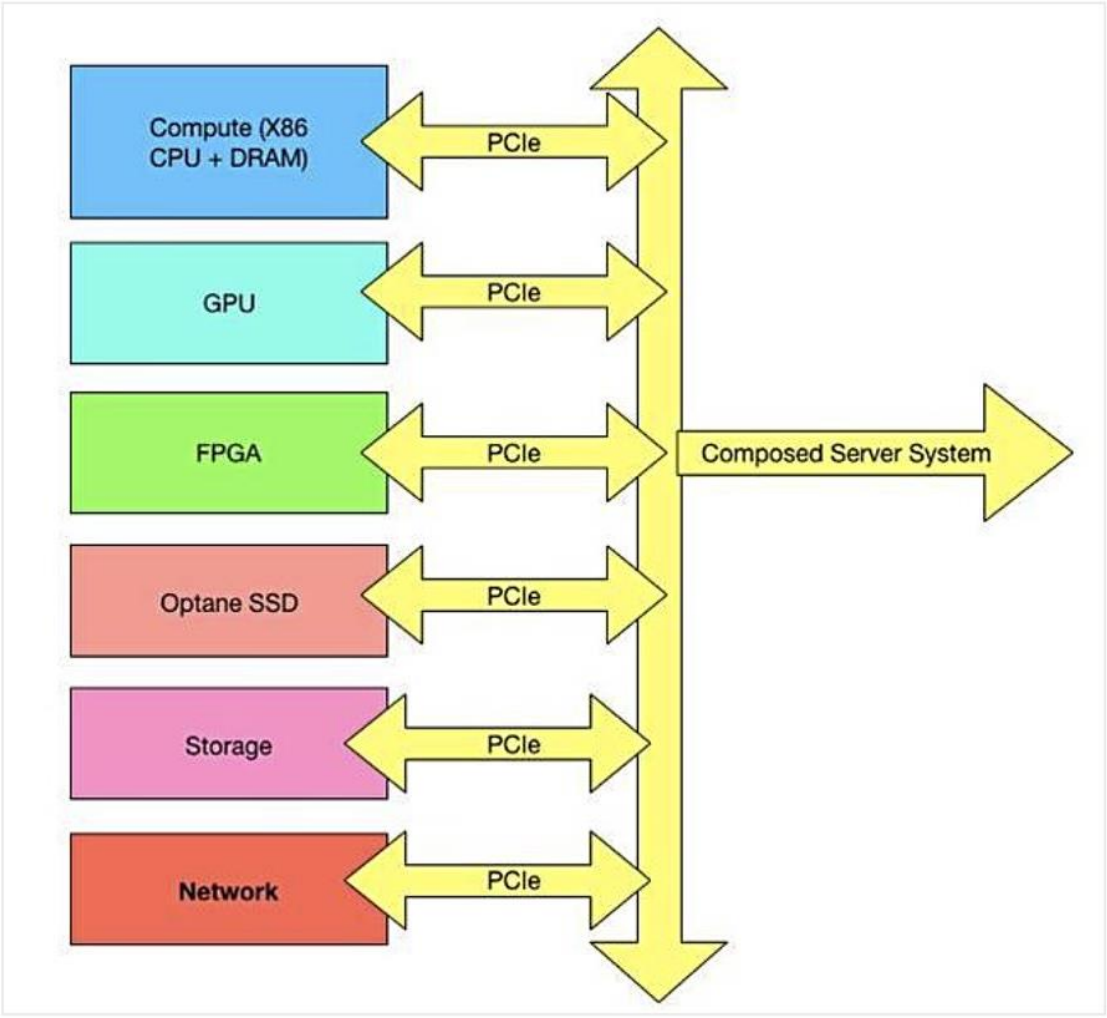


Figure 19. Liqid® Composable Architecture. [31]

6 NEXT GENERATION OF HCI

6.1.1 Freedom to Choose

Every organization is unique. Some operate workloads that may allow complete adoption of HCI vs. traditional vs. converged vs. disaggregated HCI vs. composable infrastructures. Others operate application stacks that are siloed, where hyper-convergence may be perfect on a per-application basis, running alongside traditional environments, composable offerings and hybrid cloud deployments. As with everything, the critical elements lie in the outcomes you aim to achieve. Regardless of which direction you go, make sure your selected infrastructure path -- or paths -- adheres to your organization's workload needs, disaster recovery goals and transformation requirements.

For HCI vendors, they must provide the freedom to choose for customers, but this does not mean each vendor need develop different HCI product lines or totally architectures to support HCI, dHCI and composable HCI; dHCI and composable HCI can be an existing HCI with different configurations that are fully tested and verified.

6.1.2 Supporting Workloads Anytime, Anywhere, Any SLAs

There was a misconception in the past, to get the best of HCI performance, HCI had to be designed as an appliance to fit only certain workloads, for example, you will have two different HCIs to support VDI and databases, because these two workloads have distinct characteristics, even different hardware requirement. VDI might need GPUs on the HCI system.

This proves to be not true, most VDI vendors now can design generic purpose HCI software that can be flexible enough to support different configurations, this characteristic must be carried over to the next generation of HCI. In short, next generation HCI must support multiple workloads which is required by the modern data centers.

6.1.2.1 Operating Workloads in Multi Clouds

Workloads today run across many different environments. They may run in an on-premises datacenter or in multiple public, private, or hybrid cloud environments. Next generation hyperconverged infrastructure (HCI) enables the enterprise cloud, so you do not have to settle on just one location to host your critical workloads. Even better, next-generation HCI can help you manage the chaos that often ensues in the world of multi-cloud by providing simplified and centralized management for workloads and components that may reside in various locations.

6.1.2.2 Supporting Big Data

Big data comes in many forms and requires a variety of storage service to work, from block to file to object storage. Most HCI solutions support running virtual machines (VMs) and containers. Next generation of HCI might want to support native file, block, and object storage services, as well as analytical services. A next-generation HCI solution breaks out of the traditional limitation and becomes a platform that provides native storage services without forcing you to build a VM or container construct.

6.1.2.3 Mission Critical Workloads

In the early days of HCI, there was concern about whether the use of hyperconverged infrastructure would become a hindrance and negatively affect workloads. This concern quickly faded as the technology proved itself and particularly once nodes started being outfitted with all-flash storage. Organizations began deploying mission-critical workloads on HCI, such as electronic medical records (EMR), customer relationship management (CRM), e-commerce, databases, and enterprise resource planning (ERP) systems such as SAP HANNA.

Next-generation HCI is fully supported by most critical applications today and the solution can provide a less expensive and more efficient operating environment, helping organizations save money while realizing better outcomes

6.1.2.4 Real time and Streaming Support

Data streaming in from all places including edge continues to grow exponentially. With the influx of devices like security cameras, drones, and mobile apps, even the most established organizations can feel like they are bursting at the seams. With this massive influx of data, enterprise need a data streaming platform in conjunction with storage like HCI to ingest, store and analyze continuously streaming data in real-time, to deliver next-generation business insights from valuable streaming data with little effort.
Some HCI vendors just started this journey, such as Dell/EMC® in combining Dell® Streaming Data Platform [32] with VxRail [33]. There are a lot more that can be developed for the next generation of HCI.

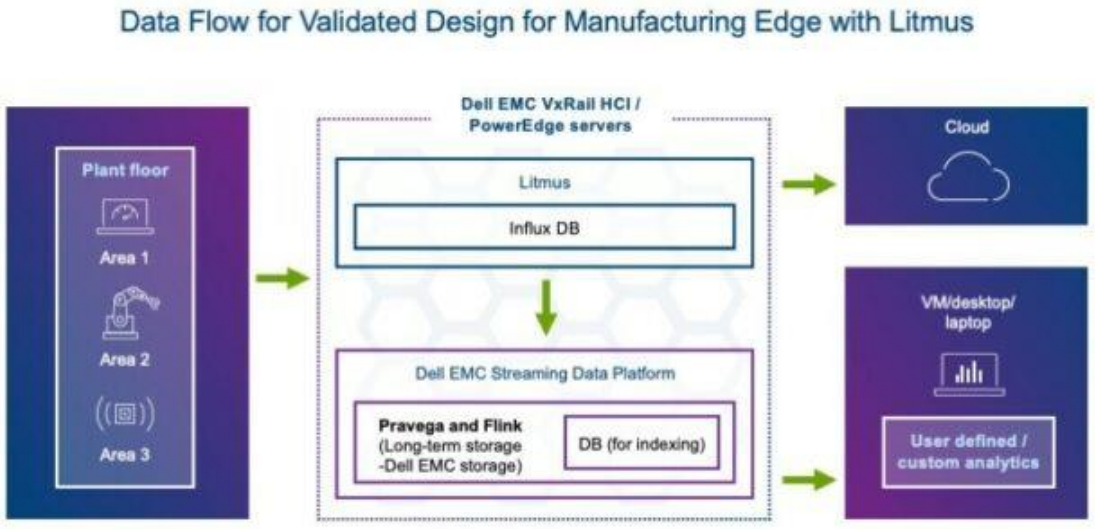


Figure 20. Dell® SDP and VxRail HCI. [33]

6.1.2.5 Remote Work Support

Impacted by pandemic, remote work support has increased significantly. Early in its evolution, HCI was the go-to technology to support virtual desktop infrastructure (VDI) deployments. However, VDI was getting a bad rap because of the poor storage choices that were available at the time.
Now with flexibility of configuration, HCI vendors can add performance of flash storage and GPUs to accelerate VDI performance, and VDI has once again emerged as a viable enterprise desktop solution.
Next-generation HCI solutions can also enable a new paradigm for enterprise desktop computing delivered in the cloud or on prem: desktop as a service (DaaS). DaaS provides a complete turnkey solution for virtual desktops, simplifying desktop administration within the enterprise.

6.1.3 HCI Software Can Become the OS of the Hybrid IT

Just as the virtual machine hypervisor has become the operating system for the data center, but there is no corollary for the hybrid cloud. A single hyperconverged infrastructure that lives in both places, gets rid of the storage and network administration, it can become the next OS for the hybrid cloud.

Although cloud vender HCI solutions have certain advantages, such as strong ecosystems and comprehensive managed services etc., customers do have concerns over vendor lock-in, fees associated with cloud, and have the need to support multi-cloud. General HCI vendors might eventually win out in this battle.
This will mean the same HCI software can be run on edge, on-prem data centers and clouds, the data movement among these will become much more efficient to support multiple workflows. The native features of HCI like data protection and data reduction technologies etc. will be much more cost effective compared to cloud offerings.

6.1.4 HPDA/HPC Playground

Although high performance composable infrastructure just started, but the immense potential (HPDA market size and the fast CAGR growth) is obvious. The breakthrough of the next generation of HCI might come from this field.
It is a way to increase resource utilization and assign resources to an application from disaggregated pools of compute, storage, and networking, with more sophisticated offerings delivering GPU, DPU, FPGA, and storage memory accelerators that can also be provisioned as needed. A single programmable API manages all of IT through one single pane-of-glass application. This software defined management layer is used to discover, assign, and manage the pools of disaggregated data center devices, ensuring that the right resources are in the right place at the right time.
To invest in this field, HCI vendor can:

- Develop technologies to offload data-intensive compute, such as compression, deduplication, encryption, AI training, analytics etc. from server to DPU and FPGA etc.
- Develop composable and acceleration technologies that might be generalized in storage advancement.
- Develop more generic high performance next generation data centers, in related to the fact that most of the HPCs/HPDA today are only in specialized super-compute data centers,

6.1.5 Enable Advanced and Modern Services

6.1.5.1 Native Container, Orchestration and Serverless

A next-generation HCI solution must support containers and orchestration platform like Kubernetes or OpenShift. This can be done in a couple of ways. The first is to deploy a VM that itself becomes a container host. The second is to use a platform that provides native container orchestration, automation, and management with integrated persistent storage services. The second option fits better to most of HCI vendors.
Serverless is another feature that has not been seen in on-prem HCI product yet, this could be a unique feature to own, it will provide customers a flexible way to program needed functions running on the HCI nodes directly for near data processing.

6.1.5.2 Enable edge: ROBO and IoT

6.1.5.2.1 Remote office and branch office (ROBO)

ROBO environments are key areas in need of improvement. ROBO environments include branch sales offices for large corporations, doctor’s offices and urgent care clinics,

restaurant chains and coffee shops, retail outlets and mall kiosks, gas stations, ocean floor oil drilling platforms and more. These locations all need computing power and storage capacity, but typically not as much as the headquarters location. In the past, these ROBO locations often had full stacks of three-tier infrastructure deployed because that is all that was reasonably available. Of course, three-tier environments have challenges. These issues are multiplied when you deploy infrastructure into remote environments without full IT support.
Next-generation HCI has emerged as a viable solution for these locations. Now, rather than a bulky, expensive deployment, companies can deploy smaller hyperconverged clusters that provide exponentially higher levels of availability and better central management capabilities. When you are dealing with thousands of locations, the savings can be enormous.
Supporting ROBO HCI can potentially also help HCI vendors to improve sustainability of the HCI products:

- Low power consumption
- Rugged design
- Low cooling requirement
- Tight rack space

Some edge places like field-based oil & gas work sites might have low network bandwidth, some even only use satellite connections, the HCI product must support this kind of use cases, so that certain workflow like remote backup etc. must function normally.

All these will also help next generation HCI to increase footprint in next generation of data centers.

6.1.5.2.2 IoT

No next-generation solution would be complete without support for what has emerged as a force unto itself: the Internet of Things (IoT).
IoT has serious data needs. For that, you need serious capacity. Many IoT services depend on AI/ML capabilities to analyze the mass of data that runs through IoT-centric workflows. There is simply too much data for a human to realistically ingest and derive insights from. The AI/ML-centric portions of the workflow require computing resources at the edge locations in which IoT devices often reside. AI/ML can be pretty compute-intensive, so many organizations naturally turn to the cloud to deliver the CPU cycles and storage capacity that is necessary to process these workloads. In these scenarios, IoT gateways become key as IoT devices direct their traffic through them, with the cloud being the ultimate analysis destination.
This approach is not always feasible. Sometimes you have too much data to push to the cloud, which would result in an unacceptable latency period for analysis. In other cases, network latency itself can be a factor. Thus, organizations are seeking to embrace hybrid cloud services that enable some immediate processing at the edge with longer-term processing being pushed to the cloud. For immediate decisions, you allow edge services to do the work. For analysis that may take longer or that you do not need immediately, the workload is sent off to the stratosphere.

The following figure gives an example on how Nutanix® Xi IoT enables a hybrid-cloud IoT workflow with analysis capabilities present at both the edge and in the cloud. Xi IoT delivers cloud-based services using next-generation HCI, thus providing Nutanix® customers with a similar experience and operating model as their on-premises environment.

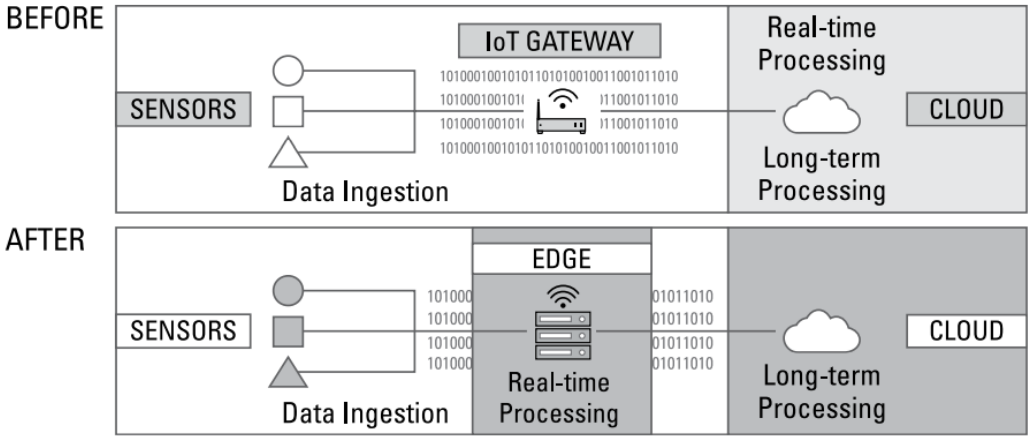


FIGURE 4-1: Before and after Nutanix Xi IoT deployment.

Figure 21. Example in Enabling IoT with HCI: Nutanix®. [34]

6.1.5.3 Native Data Protection & Embracing Secondary Storage

The next generation of HCI must have native data protection support, it means that it allows customers to quickly do backup, archive, rollback and recover in one-click of button with HCI software, it will save customers' investment to secondary storage. But in case customers still need third party backup and archive solutions, such as Veeam, Commvault etc. next generation of HCI must embrace the secondary storage.

6.1.5.4 O&M Automation via ML

This refers to cloud-based O&M analytics and automation platform like HPE®'s InfoSight [35], Dell® CloudIQ [36], and Huawei®'s DME [37]. These platforms support multi-cloud application orchestration and management framework that provides application-level orchestration to transform how you deploy and manage IT operations. They provide application automation, AI-driven proactive insight, and lifecycle management natively integrated into the HCI platform.

7 BIBLIOGRAPHY

[1] A. M. Scott D. Lowe. [Online]. Available: https://searchconvergedinfrastructure.techtarget.com/opinion/HCI-vs-traditional-IT-vs-dHCI-vs-composable-infrastructure.

[2] "idc_uk," [Online]. Available: https://idc-cio.dk/the-path-ahead-for-the-digital-first-enterprise/.

[3] C. D. Prete, "Welcome to Directions," [Online]. Available: https://www.idc.com/getdoc.jsp?containerId=DR2022_GS1_CDP.

[4] P. Carter, "From DX to Digital First Equals Sustainable Digital Business: The CEO Imperative in the Digital-First World," [Online]. Available: https://www.idc.com/getdoc.jsp?containerId=DR2022_GS4_PC_SN.

[5] Synergy, "2020 – The Year that Cloud Service Revenues Finally Dwarfed Enterprise Spending on Data Centers," [Online]. Available: https://www.srgresearch.com/articles/2020-the-year-that-cloud-service-revenues-finally-dwarfed-enterprise-spending-on-data-centers.

[6] S. W. a. M. Casado. [Online]. Available: https://a16z.com/2021/05/27/cost-of-cloud-paradox-market-cap-cloud-lifecycle-scale-growth-repatriation-optimization/.

[7] T. L. F. Report. [Online]. Available: https://stateoftheedge.com/reports/state-of-the-edge-report-2021/.

[8] A. CRANIN. [Online]. Available: https://blog.451alliance.com/hcis-growing-role-in-hybrid-it-and-edge-computing/.

[9] "Why Hyperconverged Infrastructure Can Mean Hyper-reduced Lifetime Costs," [Online]. Available: https://www.computerworld.com/article/3609111/why-hyperconverged-infrastructure-reduces-lifetime-costs.html#:~:text=HCI%20is%20a%20great%20way,Nutanix%20Enterprise%20Cloud%20platform%20solutions..

[10] P. G. K. S. Natalya Yezhkova, "Worldwide and U.S. External Enterprise Storage Systems 2021-2025," [Online]. Available: https://www.idc.com/getdoc.jsp?containerId=US48454421.

[11] "Hyper-Converged Infrastructure Market," [Online]. Available: https://www.alliedmarketresearch.com/hyper-converged-infrastructure-market.

[1] "Hyper-Converged Infrastructure Market Sales Revenue, Key Players Analysis, Business Advancements and Top-Vendor Landscape to 2030," [Online]. Available:

[12] https://www.marketwatch.com/press-release/hyper-converged-infrastructure-market-sales-revenue-key-players-analysis-business-advancements-and-top-vendor-landscape-to-2030-2022-03-01.

[13] "The global HCI market size is expected to grow from USD 7.8 billion in 2020 to USD 27.1 billion by 2025, at a Compound Annual Growth Rate (CAGR) of 28.1%," [Online]. Available: https://www.globenewswire.com/news-release/2020/08/07/2074871/0/en/The-global-HCI-market-size-is-expected-to-grow-from-USD-7-8-billion-in-2020-to-USD-27-1-billion-by-2025-at-a-Compound-Annual-Growth-Rate-CAGR-of-28-1.html.

[14] "2. Meticulous Research," [Online]. Available: https://www.meticulousresearch.com/product/hyper-converged-infrastructure-systems-market-5176.

[15] "Markets and Markets," [Online]. Available: https://www.marketsandmarkets.com/Market-Reports/hyper-converged-infrastructure-market-149796579.html.

[16] "Emergen Research," [Online]. Available: https://www.emergenresearch.com/industry-report/hyper-converged-infrastructure-market.

[17] "alliedmarketresearch," [Online]. Available: https://www.alliedmarketresearch.com/hyper-converged-infrastructure-market.

[18] "IDC report," [Online]. Available: https://pages.fungible.com/20210330-IDC-Spotlight_20210330-IDC-Spotlight-LP.html.

[19] "High Performance Computing (HPC) Market by Component (Solutions (Servers, Storage, Networking Devices, and Software) and Services), Deployment Type, Organization Size, Server Prices Band, Application Area, and Region - Global Forecast to 2025," [Online]. Available: https://www.marketsandmarkets.com/Market-Reports/Quantum-High-Performance-Computing-Market-631.html#:~:text=%5B198%20Pages%20Report%5D%20The%20HPC,5.5%25%20during%20the%20forecast%20period..

[20] "High Performance Data Analytics Market - Market Size & Forecasting (2017-2028)," [Online]. Available: https://www.researchandmarkets.com/reports/5450161/high-performance-data-analytics-market-market.

[21] "gartner mq HCI," [Online]. Available: https://www.nutanix.com/go/gartner-2021-magic-quadrant-for-hyperconverged-infrastructure-software.

["enterprise hci gigaom," [Online]. Available:
2 https://www.smartx.com/blog/2021/12/smartx-named-a-fast-mover-in-gigaom-radar-
2 for-enterprise-hci/.
]
["edge gigaom," [Online]. Available: https://www.scalecomputing.com/landing-
2 pages/gigaom-radar.
3
]
[M. Kurt Marko, "AWS Outposts vs. Azure Stack vs. Google Anthos hybrid storage,"
2 [Online]. Available: https://www.techtarget.com/searchstorage/feature/AWS-
4 Outposts-vs-Azure-Stack-vs-Google-Anthos-hybrid-storage.
]
["Nvidia DPU," [Online]. Available: https://developer.nvidia.com/blog/offloading-and-
2 isolating-data-center-workloads-with-bluefield-dpu/.
5
]
["Nvidia BlueField goes SuperPODDING – with composability in its sights," [Online].
2 Available: https://blocksandfiles.com/2021/04/16/nvidia-bluefield-goes-
6 superpodding/.
]
["montere project," [Online]. Available:
2 https://blogs.vmware.com/vsphere/2021/10/project-monterey-updates.html.
7
]
["OK, SANshine, how do you position Nebulon against external arrays, HCI,
2 SmartNIC and DPU storage?," [Online]. Available:
8 https://blocksandfiles.com/2021/04/27/positioning-nebulon-against-external-arrays-
] hci-smartnic-and-dpu-storage/.
["Fungible claims fastest storage node on the market, at 6.55 million IOPS," [Online].
2 Available: https://blocksandfiles.com/2021/07/01/fungible-claims-fastest-storage-
9 node-on-the-market-at-6-55-million-iops/.
]
["Scale-Out Data Centers: The Best is Yet to Come," [Online]. Available:
3 https://www.datacenterknowledge.com/industry-perspectives/scale-out-data-centers-
0 best-yet-come.
]
["Compose yourself: Liqid gets unicorn-class funding boost," [Online]. Available:
3 https://blocksandfiles.com/2021/12/07/compose-yourself-liqid-gets-unicorn-class-
1 funding-boost/.
]
["Dell Streaming Data Platform," [Online]. Available: https://www.dell.com/en-
3 us/dt/storage/streaming-data-platform.htm.
2
]

[33] "Unify IT, OT, and Business for Smart Manufacturing Outcomes," [Online]. Available: https://www.dell.com/ko-kr/blog/unify-it-ot-and-business-for-smart-manufacturing-outcomes/.

[34] "next-gen-hci-for-dummies," [Online]. Available: https://www.nutanix.com/go/next-gen-hci-for-dummies.

[35] "InfoSight HPE," [Online]. Available: https://www.hpe.com/us/en/solutions/infosight.html?jumpid=ps_irysqpt7n2_aid-520061466&ef_id=Cj0KCQjw3IqSBhCoARIsAMBkTb1J-23QZsr4jzOK68GGYJ-RQxZWYpKS6yarHGFmdm9YaIuTzujMuksaAnteEALw_wcB:G:s&s_kwcid=AL!13472!3!534136956188!e!!g!!infosight!13921241176!124985.

[36] "CloudIQ Dell," [Online]. Available: https://www.dell.com/en-us/dt/storage/cloudiq.htm?gacd=9650523-1033-5761040-266691960-0&dgc=st&gclid=Cj0KCQjw3IqSBhCoARIsAMBkTb25KgdpQjf6G_5wODU6Tfo6xUsqTu6I_XMHVEcKRVtjGUT8KEA3VI4aAio7EALw_wcB&gclsrc=aw.ds&nclid=PQSTj6z9FrIERbjUvRx7VKPcSce1CBiOwSrC8rfWpP.

[37] "DME Huawei," [Online]. Available: https://e.huawei.com/en/products/storage/data-management/data-management-engine.

[38] "The global HCI market size is expected to grow from USD 4.1 billion in 2018 to USD 17.1 billion by 2023, at a Compound Annual Growth Rate (CAGR) of 32.9%," [Online]. Available: https://www.prnewswire.com/news-releases/the-global-hci-market-size-is-expected-to-grow-from-usd-4-1-billion-in-2018-to-usd-17-1-billion-by-2023--at-a-compound-annual-growth-rate-cagr-of-32-9-300777557.html.

[39] "Roll-your-own server crew at Liqid add vCentre composable server plug-in," [Online]. Available: https://blocksandfiles.com/2021/06/11/liqid-adds-vcentre-composable-server-plug-in/.