Top 10 Technologies That Will Drive the Future of Infrastructure and Operations

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Initiatives:Technology Innovation

Enabling innovation through an agile, scalable and intelligent infrastructure is vital for digital organizations. We highlight the 10 most compelling early-stage technologies that enterprise architecture and technology innovation leaders should use to drive infrastructure innovation through 2024.

More on This Topic

This is part of an in-depth collection of research. See the collection:

- Dare to Disrupt With ILD: A Gartner Trend Insight Report

Overview

Key Findings

- There continues to exist significant technical debt in infrastructure and operations (I&O) due to complex legacy applications and outdated processes, which cripple agility, enhance business risks and often result in bloated costs.
- There is a clear market shift in innovation — from legacy IT infrastructure vendors to cloud providers and open-source communities — that are heralding the next wave of infrastructure innovation.
- Technology innovation leaders struggle to increase their ability to absorb, deploy and scale technological innovations.

Recommendations

Enterprise architecture and technology innovation leaders driving innovation should:

- Ideate with business leaders and I&O leaders on potential use cases where these technologies can be applied to enhance business value.
- Develop a decision map on which of these technologies are relevant within their organization and a timeline for its implementation.
- Improve the scale and efficiency of innovation by identifying internal champions both within I&O and business units to lead these efforts, incentivize them, measure accurately the

success/failure and iterate toward continuous improvement.

- Invest beyond technology, as technology isn't a silver bullet and needs to be complemented by process automation, skills training and cultural hacks to ensure that these projects don't fail.

Analysis

The needs of digital business are forcing technology innovation leaders to rethink infrastructure strategies for next-generation workloads. To succeed in the digital business era, innovation leaders need to drive "creative destruction," often willing to fundamentally rethink the technology architecture, deployment environment and operating models. We have analyzed many transformative technologies and selected the 10 that we believe will have the greatest impact on I&O (see Figure 1). These technologies are all highly transformative and will mature within the next five years. As an enterprise architecture (EA) and technology innovation leader, you must assess how your organization could exploit these technologies.

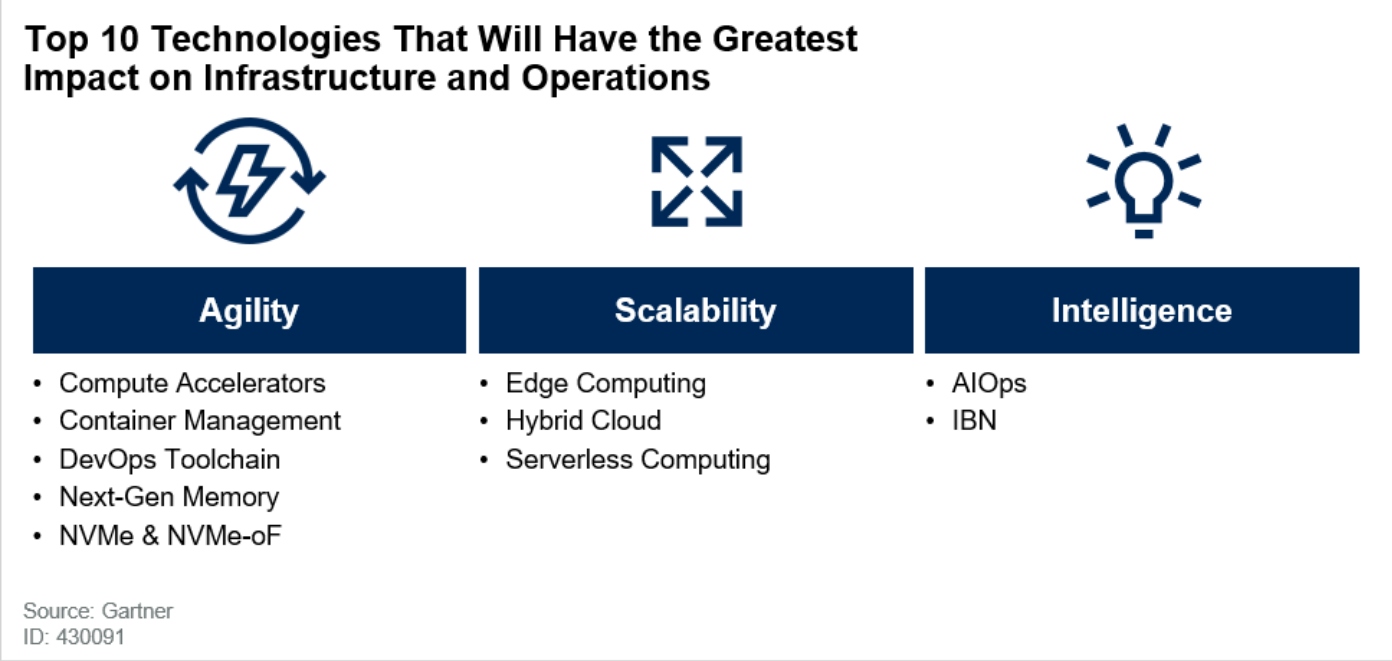

Figure 1. Top 10 Technologies That Will Have the Greatest Impact on Infrastructure and Operations

Source: Gartner (October 2019)

In this research, we define each technology, predict its market adoption, assess why you should care and list some of the imperatives that you should be aware of. Although this research focuses on individual technologies, you should be alert for opportunities that arise when two or more of these trends combine to enable new capabilities.

Technology No. 1: Artificial Intelligence for IT Operations (AIOps) Platforms

Description: AIOps platforms combine big data and machine learning to support several primary IT operations functions. They do so through the scalable ingestion and analysis of the ever-

increasing volume, variety and velocity of data that IT operations generate. These platforms enable the concurrent use of multiple data sources, data collection methods, and analytical and presentation technologies.

Why EA and Technology Innovation Leaders Should Care: AIOps platforms bring:

- **Agility and productivity gains.** They do so by analyzing both IT and business data, yielding insights on user interaction, business activity and supporting IT system behavior.
- **Service improvement and cost reduction.** They do so by significantly cutting the time and effort required to identify the cause of uptime and performance issues. Behavior-prediction-informed forecasting can support resource optimization efforts.
- **Risk mitigation.** They do so by analyzing monitoring, configuration and service desk data. They identify anomalies from both operations and security perspectives.
- **Competitive differentiation/disruption.** They do so through superior responsiveness to market and end-user demand based on machine-based analysis of shifts.

Prediction: By 2022, at least 25% of large enterprises will be using artificial intelligence for IT operations (AIOps) platforms and digital experience monitoring (DEM) technology exclusively to monitor the nonlegacy segments of their IT estates, up from 2% in 2018.

Maturity: Emerging; market adoption is 5% to 20%.

AIOps platform vendors have a broad range of capabilities, such as event correlation, anomaly detection, root cause and optimization analysis, that continues to grow. However, vendors differ in their data-ingest and out-of-the-box use cases made available with minimal configuration. Building your own AIOps platform requires a high degree of operational, analytical and data science skills.

What You Should Know: AIOps skills and IT operations maturity are the usual inhibitors in ensuring quick time to value when using these tools, followed by data quality as an emerging challenge for some of the more mature deployments. The market is experiencing broad “analytics” confusion, intentional obfuscation by vendors and rising costs associated with increasing data volumes. Cultural barriers exist and end users must acquire new skills to use AIOps platforms. Before planning to adopt an AIOps platform, decide whether a monitoring tool that uses machine learning would be a sufficient alternative.

Sample Vendors: BigPanda; BMC; Devo; Elastic (Elasticsearch); Loom Systems; Moogsoft; Splunk; StackState; Sumo Logic.

Technology No. 2: Compute Accelerators

Description: Compute accelerators are composed of:

- **Graphics processing unit (GPU) accelerators.** These use a GPU to accelerate highly parallel compute-intensive portions of workloads in conjunction with a CPU.
- **Deep neural network (DNN) application-specific integrated circuits (ASICs).** These purpose-specific processors accelerate DNN computations.
- **Field-programmable gate array (FPGA) accelerators.** These server-based reconfigurable computing accelerators deliver extreme high performance by enabling programmable hardware-level application acceleration.

Why EA and Technology Innovation Leaders Should Care: Compute accelerators bring extreme performance and power efficiency. GPU-accelerators can deliver extreme performance for highly parallel compute-intensive workloads in HPC, DNN training and inferencing. GPU computing is also available as a cloud service and may be economical for applications where utilization is low but time to market needs are high. DNN ASICs will enable neural-network-based systems to address more opportunities in your business through improved cost and performance. Use cases that can benefit from DNNs include speech-to-text, image recognition and natural-language processing.

FPGA accelerators can enable dramatic performance improvements within significantly smaller energy consumption footprints than comparable mainstream technologies. FPGA accelerators are well suited to artificial intelligence (AI) inference workloads, as they excel in low-precision processing capabilities in energy-efficient footprints.

Prediction: Through 2022, computational resources used in AI will increase by at least 4x from 2018, making AI the top category of workloads driving infrastructure decisions.

Maturity: GPUs are most mature (5% to 20% market adoption) followed by ASICs and FPGAs, which are adolescent and early mainstream, respectively (1% to 5% market adoption).

GPU subsystems are actively deployed in HPC and AI. In AI, DNN technologies are maturing quickly, and most of the DNN frameworks support GPU acceleration. Gartner describes GPU accelerators as a mature mainstream technology.

Gartner expects that the market for DNN ASICs will mature quickly, possibly within the three-year depreciation horizon of new systems. FPGAs are typically configured using hardware programming languages that are very complex to use, which has held back widespread adoption of FPGA accelerators. Gartner describes FPGA accelerators as an early mainstream technology.

What You Should Know: Widespread use of DNN ASICs will require the standardization of neural network architectures and support across diverse DNN frameworks. Choose DNN ASICs that offer or support the broadest set of DNN frameworks to deliver business value faster.

For GPU accelerators, selecting the right GPU compute platforms that offer the most mature software stack can be challenging. Optimize infrastructure costs by evaluating cloud-hosted GPU

environments for proof-of-concept and prototype phases. Identify the costs associated with the skills necessary for FPGAs and with the programming challenges of FPGAs. Use cloud-based FPGA services to accelerate development.

Sample Vendors: We have broken down our list by accelerator type:

- **GPU accelerators:** AMD; Cray; Dell; Hewlett Packard Enterprise; IBM; Lenovo; NVIDIA; Supermicro
- **DNN ASICs:** Amazon; Google; Graphcore; Intel; SambaNova Systems; Wave Computing
- **FPGA accelerators:** Amazon Web Services; Baidu; Intel; Microsoft Azure; Xilinx

Technology No. 3: Container Management (Orchestration)

Description: Container management software supports the management of containers at scale in production environments. It includes container runtimes, container orchestration, job scheduling and resource management. Container management software brokers the communication between the continuous integration/continuous deployment pipeline and the infrastructure via APIs. It also aids in the life cycle management of containers.

Why EA and Technology Innovation Leaders Should Care: Container runtimes make it easier to exploit container functions, such as providing integration with DevOps tools and workflows. Containers provide productivity and agility benefits, including:

- The ability to accelerate and simplify the application life cycle
- Workload portability between different environments
- Improved efficiency of resource utilization

Container management software also makes it easier to achieve scalability and production readiness, and to optimize the environment to meet business SLAs.

Prediction: By 2022, more than 75% of global organizations will be running containerized applications in production, which is a significant increase from fewer than 30% in 2018.

Maturity: Adolescent; 5%-20% market adoption.

Grassroots adoption of containers from individual developers has been significant. These developers will use containers with increasing frequency in development and testing, particularly for Linux. Gartner expects container management software to remain an adolescent technology through 2020 and possibly 2021.

What You Should Know: Explore container technology for packaging and deploying Linux applications and beware that Windows containers lag behind in maturity and ecosystem integration. Container management may be appropriate for you if your organization:

- Is DevOps-oriented or plans to become so
- Has high-volume, scale-out applications with a willingness to adopt microservices architecture or large-scale batch workloads
- Has aspirational goals of increased software velocity and immutable infrastructure
- Prioritizes provisioning and scaling time to be critical (measured in seconds, not minutes like VMs)

Sample Vendors: Amazon Web Services; D2IQ; Docker; Google Cloud Platform; IBM; Microsoft Azure; Pivotal; Rancher Labs; Red Hat; VMware.

Technology No. 4: DevOps Toolchain

Description: A DevOps toolchain is composed of tools for supporting DevOps pipeline activity and providing fast feedback as part of the software development life cycle. It typically covers six main activities: plan, create, verify, release, configure and monitor. Pipeline activities have started with discrete tools for various steps, but vendors are delivering solutions across the application development and delivery cycle.

Why EA and Technology Innovation Leaders Should Care: A well-designed, integrated and automated DevOps toolchain enables development and operations team members to work together, with common objectives and metrics. This helps to ensure quality, on-time application delivery to the business. Of particular interest to operations teams are tools that do continuous configuration automation (such as Chef, Puppet, Ansible and SaltStack), APM/infrastructure management (such as Cisco AppDynamics, Datadog, Dynatrace, Elastic, New Relic and Splunk) and release automation tools (such as CloudBees, Microsoft and XebiaLabs).

Prediction: By 2022, at least 30% of enterprises will adopt a standard set of tools across their DevOps practices, up from less than 10% in 2018.

Maturity: Adolescent; 5%-20% market adoption.

The market is rapidly evolving through acquisitions, the emergence of open-source and new commercial products, and the continued development of cloud architecture. Competition between the largest vendors, particularly of cloud platforms, will continue to disrupt the market.

What You Should Know: DevOps toolchains can include dozens of unintegrated tools, which makes automation a technically complex and arduous task. We recommend that IT organizations develop a toolchain strategy that establishes business objectives, identifies practices to achieve those objectives and then selects tools to support those practices. If your organization supports more than a single unified delivery platform (such as cloud, mainframe, mobile apps and packaged applications), you'll require a variety of tools from multiple vendors. The toolchain should focus on removing execution barriers and automating the development and continuous delivery process.

Remember that even open-source tools aren't free. There's a cost attached to learning, integrating and (especially when they're integrated) replacing them.

Sample Vendors: Atlassian; CloudBees; GitLab; Harness; Microsoft; Red Hat; ServiceNow; XebiaLabs.

Technology No. 5: Edge Computing

Description: Edge computing is a distributed computing topology that places information processing close to the things or people that produce or consume that information. It aims to:

- Keep traffic and processing local and off the center of the network
- Reduce latency and unnecessary traffic
- Establish a hub for interconnection between interested peers
- Establish a hub for the data thinning of complex media types or computationally heavy loads

Why EA and Technology Innovation Leaders Should Care: Edge computing solves many urgent issues, such as unacceptable latency and bandwidth and cost limitations, given a massive increase in edge-located data. Edge computing will enable aspects of the Internet of Things (IoT) and digital business well into the very near future.

Prediction: By 2022, more than 50% of enterprise-generated data will be created and processed outside the data center or cloud.

Maturity: Adolescent; 5%-20% market adoption.

Most of the technology for creating the physical infrastructure of edge is readily available. However, widespread application of the topology and explicit application and networking architectures are common only in vertical applications, such as retail and manufacturing. The increase in demand for the IoT and the proliferation of its use cases has dramatically increased interest in edge technologies and architectures. This is because edge computing is the IoT's accepted topological design pattern (namely, the "where" a "thing" is placed in an overall architecture). The still-nascent state of non-IoT edge applications has prevented wider adoption.

What You Should Know: Don't risk being left behind — begin considering edge design patterns in your medium- to longer-term infrastructure architectures. Expect to do more planning and experimentation with data thinning and cloud interconnection than with applications, such as client-facing web properties and branch office solutions. You must become familiar with an emerging application model, in which edge gateways and hubs serve as the linchpins for deploying heterogeneous, multicloud and multiendpoint applications.

Sample Vendors: Akamai; Amazon; Cisco; Cloudflare; HPE; Microsoft; Pixeom; Vapor IO; Verizon; ZEDEDA.

Technology No. 6: Hybrid Cloud

Description: Hybrid cloud is the integration of private and public cloud services to support parallel, integrated or complementary tasks. Hybrid cloud computing needs integration between two or more internal or external environments at the data, process, management or security layers.

Why EA and Technology Innovation Leaders Should Care: Hybrid cloud offers enterprises the best of both worlds — the cost optimization, agility, flexibility, scalability and elasticity benefits of public cloud, in conjunction with the control, compliance, security and reliability of private cloud. The solutions that hybrid cloud provides include service integration, availability/disaster recovery, cross-service security, policy-based workload placement and runtime optimization, and cloud service composition and dynamic execution (for example, cloudbursting).

Prediction: By 2022, more than 80% of organizations will have deployed a hybrid cloud or multicloud model for their IT needs.

Maturity: Adolescent; 5%-20% market adoption.

Organizations have started adopting foundational technologies (such as cloud management tools and continuous integration tools), but full-blown implementations still are riddled with complexity. Leading cloud IaaS providers have either released products or made announcements for hybrid and multicloud deployments in the past few years. Among the most notable of these are Azure Stack from Microsoft, VMC from AWS/VMware, Anthos from Google and Outposts from AWS. Gartner expects this to be an area of intense competition and innovation in the coming years.

What You Should Know: When using hybrid cloud computing services, establish security, management, and governance guidelines and standards to coordinate the use of these services with internal (or external) applications and services to form a hybrid environment. Approach sophisticated cloudbursting and dynamic execution cautiously because these are the least mature and most problematic hybrid approaches. To encourage experimentation and cost savings, and to prevent inappropriately risky implementations, create guidelines/policies on the appropriate use of the different hybrid cloud models.

Sample Vendors: Amazon Web Services (AWS); Google; Hewlett Packard Enterprise (HPE); IBM; Microsoft; Nutanix; OpenStack; Rackspace; Flexera (RightScale); VMware.

Technology No. 7: Intent-Based Networking

Description: An intent-based networking system (IBNS) provides:

- **Translation and validation:** It can take a higher-level business policy as input from end users and convert it to the required network configuration.
- **Automation:** It can configure appropriate network changes across existing network infrastructure.

- **State awareness:** The system ingests real-time network status for systems under its control.
- **Assurance and dynamic optimization:** The system continuously validates that business intent is being met and can take corrective action when it isn't.

Why EA and Technology Innovation Leaders Should Care: Intent-based networking can transform network operations. IBNSs improve network agility and availability and support unified intent and policy across heterogenous infrastructures. When the technology matures, a full IBNS implementation will reduce the time to deliver network infrastructure services to business leaders by 50% to 90%. It will also reduce the number and duration of outages by at least 50%. IBNSs also:

- Reduce operating expenditure
- Optimize performance
- Cut dedicated tooling costs
- Enhance documentation
- Improve compliance

Prediction: By 2022, more than 1,500 large enterprises will use intent-based networking systems in production, up from less than 15 today.

Maturity: Emerging; less than 1% market adoption.

Unfortunately, the technology is massively overhyped, and things such as automation and programmability are "washed" with intent. However, real-world enterprise adoption of IBNSs was nascent as of early 2019, and Gartner estimated fewer than 50 full deployments. Through 2019, early rollouts are likely to be in larger-scale environments for well-defined and specific use cases, such as spine/leaf data center networks. We don't expect the number of commercial enterprise deployments will reach the hundreds until the end of 2020. Adoption will be pragmatic, associated with new build-outs or network refresh initiatives.

What You Should Know: IBNSs require the ability to abstract and model network behavior, which has proved difficult, particularly in multivendor environments. IBNSs also require a substantial cultural shift in the design and operation of networks. This will create barriers to adoption in many risk-averse organizations. Choose an IBNS that supports multivendor network infrastructures and extends into public cloud environments to support a broader range of use cases and avoid vendor lock-in. Deploy IBNSs in phases.

Sample Vendors: Apstra; Cisco; Forward Networks; Gluware; Huawei; Intentionet; Juniper Networks; NetYCE; Veriflow Systems.

Technology No. 8: Next-Generation Memory

Description: Next-generation memory is a type of nonvolatile memory capable of displacing DRAM in servers. It has the density and manufacturing cost close to flash memory, but is fast enough to augment DRAM, or even replace it over time.

Why EA and Technology Innovation Leaders Should Care: Next-generation memory enables a five to 10 times increase in fast, local storage capacity. This means scale-up computing systems can perform faster or handle larger analytics workloads. The nonvolatile storage will be significantly faster than any solid-state drive (SSD) but limited by PCIe interface when used as storage. Alternatively, this type of memory can provide greater consolidation, reducing costs by shrinking the data center space required. When used as persistent memory, it has the potential to accelerate the adoption of in-memory computing architectures.

Prediction: By 2022, 20% of CPU socket servers with two or more sockets will ship with 3D XPoint NVDIMMs, up from less than 1% in 2018.

Maturity: Emerging; 1%-5% market adoption.

Gartner describes next-generation memory as an adolescent technology. Next-generation memory techniques include Hewlett Packard Enterprise's (HPE's) ion migration memristor and Intel-Micron's 3D XPoint phase change and spin-transfer torque memory. Only these three technologies have a viable opportunity between the cost, reliability and performance attributes of DRAM and flash memory. Of the three, Intel-Micron's 3D XPoint technology is the furthest along and will probably hold off the competition through 2020. Reducing the cost of keeping data in the "main memory" and simplifying high-availability architecture can accelerate the mainstream organization adoption of in-memory computing architectures.

What You Should Know: The 3D XPoint memory cell technology is shipping in less demanding Peripheral Component Interconnect Express (PCIe) and NVM Express (NVMe) solid-state storage devices, where memory management is far simpler. These devices — because of their low-write latency — exhibit high-transaction rates compared with flash-based SSDs. Fully exploiting these performance attributes requires changes to software and drivers.

Sample Vendors: Dell; Hewlett Packard Enterprise; Inspur; Intel; Lenovo; Supermicro.

Technology No. 9: NVMe and NVMe-oF

Description: Nonvolatile memory express (NVMe) and nonvolatile memory express over fabrics (NVMe-oF) are host controller and network protocols that are taking advantage of the parallel-access and low-latency features of solid-state storage and the PCIe bus. NVMe-oF extends access to nonvolatile memory (NVM) remote storage subsystems across a network.

Why EA and Technology Innovation Leaders Should Care: NVMe and NVMe-oF offerings can have a dramatic impact on business use cases where low-latency requirements are critical to the bottom line. Though requiring potential infrastructure enhancements, the clear benefits these technologies can provide will immediately attract high-performance computing and OLTP use cases where

clients can quickly show a positive ROI. The easiest way to consume these technologies will be through acquisition of modern solid-state arrays (SSAs) that support these.

Prediction: By 2022, over 20% of new SSA shipments will utilize NVMe-oF to optimize performance, latency and effective bandwidth, up from 1% today.

Maturity: Emerging; 1%-5% market adoption.

NVMe is a fast-growing storage protocol that is being used internally within SSAs and servers. However, NVMe-oF, which requires a storage network, is still emerging and developing at different rates, depending on the network encapsulation method. There are many NVMe-oF offerings that use fifth-generation and/or sixth-generation Fibre Channel (FC) NVMe available, but adoption of NVMe-oF within 25/40/50/100 Gigabit Ethernet is slower. In November 2018, the NVMe standards body ratified NVMe/TCP as a new transport mechanism. In the future, it's likely that TCP/IP will evolve to be an important data center transport for NVMe.

What You Should Know: Buyers should clearly identify workloads where the scalability and performance of NVMe-based SSA and NVMe-oF justify the premium cost of an end-to-end NVMe-deployed SSA, such as AI/ML or transaction processing. Next, identify appropriate potential array, network interface card (NIC)/host bus adapter (HBA) and network fabric suppliers to verify that interoperability testing has been performed and that reference customers are available. During the next 12 months, most SSA vendors will offer SSAs with internal NVMe storage, followed by support of NVMe-oF connectivity to the compute hosts.

Sample Vendors: Dell EMC; Excelero; IBM; Kaminario; NetApp; Pavilion Data Systems; Pure Storage.

Technology No. 10: Serverless Computing

Description: Serverless computing is a model of IT service delivery. It uses the underlying enabling resources as an opaque, almost unlimited, shared pool that is continuously available without advance provisioning. The price of the pool is included in the cost of the consumed IT service. Serverless computing automatically provisions and operates the runtime environment.

Why EA and Technology Innovation Leaders Should Care: Serverless computing enables organizations to build applications quickly and deploy them at a large scale. It's suitable when a quick response and dynamic scalability are vital. It can enable organizations to exploit new application architectures, such as microservices patterns, which can bring competitive differentiation. Serverless computing can be economical for variable workloads because it provisions and consumes infrastructure resources only when necessary. Serverless computing is transformational in terms of flexibility and reduced operating costs.

Prediction: More than 30% of global enterprises will have deployed serverless computing technologies by 2022, which is an increase from fewer than 5% today.

Maturity: Emerging; 1%-5% market adoption.

Serverless delivery of IT services has gained attention since Amazon popularized its Amazon Web Services (AWS) Lambda function platform as a service (fPaaS). However, the significance of serverless computing, as demonstrated by the leading vendors (including Amazon, Google and Microsoft), extends beyond functions. Many PaaS capabilities will be delivered with serverless characteristics, and some are already (such as Amazon Athena). Serverless fPaaS capabilities are also starting to converge on Kubernetes, with the Knative project having potential to be the underlying abstraction to enable it. However, on-premises implementations are uncommon because of data integration and scalability challenges.

What You Should Know: Serverless computing represents a broad set of technologies, but the most transformative and widely used flavor of serverless computing is fPaaS. With fPaaS, fine-grained units of custom application logic are packaged as functions, which are executed when triggered by events. Serverless computing demands substantial transformation management. Instead of managing physical infrastructures, you'll have to:

- Take an application-centric view and understand the interdependencies between application components and whether their design enhances scalability, reliability, security and performance.
- Factor in API gateway, network egress and other costs. Exceptions such as workloads with heavy invocations can make API gateway costs high.
- Revise data classification policies and controls because objects in a content store can now also represent code, as well as data.
- Rethink IT operations from infrastructure management to application governance to ensure you can secure, monitor and debug, and meet application SLAs.

Sample Vendors: Amazon; Cloudflare; Google; IBM; Iguazio; Microsoft Azure; Oracle; Pivotal; Red Hat.

Evidence

Gartner analysts combed through hundreds of Hype Cycle profiles to select early-stage technologies that would offer significant long-term benefits to customers over the next five-year period. Detailed discussions on the list were also held within Gartner research communities with participation from a broad set of analysts.

Market adoption is expressed as a percentage of all companies that have adopted that technology.

Explanation of Maturity Levels:

Table 1: Maturity Level

Maturity Level	Status	Products/Vendors
Emerging	■ Commercialization by vendors ■ Pilots and deployments by industry leaders	■ First generation ■ High price ■ Much customization
Adolescent	■ Maturing technology capabilities and process understanding ■ Uptake beyond early adopters	■ Second generation ■ Less customization
Early mainstream	■ Proven technology ■ Vendors, technology and adoption rapidly evolving	■ Third generation ■ More out-of-box methodologies
Mature mainstream	■ Robust technology ■ Not much evolution in vendors or technology	■ Several dominant vendors

Source: Gartner (October 2019)

Recommended by the Authors

Market Guide for AIOps Platforms

How to Build and Evolve Your DevOps Toolchains

Top Emerging Trends in Cloud-Native Infrastructure

Best Practices for Running Containers and Kubernetes in Production

2019 Strategic Roadmap for Networking

2019 Strategic Roadmap for Compute Infrastructure

An I&O Leader's Guide to Serverless Computing

Recommended For You

The Top 10 Wireless Technologies and Trends That Will Drive Innovation

Top 10 User Experience Technologies That Will Drive Innovation

Hype Cycle for Display and Vision, 2019

Hype Cycle for Semiconductors and Electronics Technologies, 2019

Market Guide for Technologies Supporting a DTO