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Chapter 10

Performance monitoring and troubleshooting in hybrid infrastructure

Ravi Kumar Vankayalapati

Cloud AI ML Engineer, Equinix, Dallas, USA.
ravikumar.vankayalapti.research@gmail.com

Abstract

Performance monitoring and troubleshooting in hybrid cloud infrastructures are essential for ensuring optimal operation across both public and private cloud environments. This abstract explores the challenges of maintaining consistent performance and identifying issues in a hybrid setup, where resources are distributed across multiple platforms. Key strategies include implementing centralized monitoring tools, real-time analytics, and automated alerts to detect bottlenecks and anomalies. It also discusses the importance of effective troubleshooting techniques, such as log aggregation and root cause analysis, to quickly address performance issues. By leveraging these approaches, organizations can maintain high availability, reliability, and efficiency in their hybrid cloud systems.

Keywords

Performance Monitoring, Troubleshooting, Hybrid Cloud, Hybrid Infrastructure, Cloud Performance, Cloud Management, Real-Time Analytics, Monitoring Tools, Root Cause Analysis, Bottleneck Detection, Log Aggregation, Cloud Reliability, Cloud Optimization, Infrastructure Efficiency, Availability, Cloud Troubleshooting, Performance Issues.

10.1. Introduction

Today, the business paradigm is increasingly moving towards consuming external cloud resources. However, for most traditional IT organizations, a full transition to the cloud is not expected. This leads to the coexistence of on-premises resources and cloud-based services, where on-prem resources may contain existing systems or specific workloads that are not suitable for the cloud or for which the transition is costly (Ramanakar et al.,

2024). As a cloud strategy is adapted, the cloud vendor may change due to various reasons including offerings available, pricing, and business agreements. Furthermore, some workloads may be transferred from a cloud provider to an on-prem infrastructure if it is more cost-effective. In all cases, cloud providers should interact with existing on-prem systems for various reasons such as replication, file synchronization, system monitoring, and security policies.

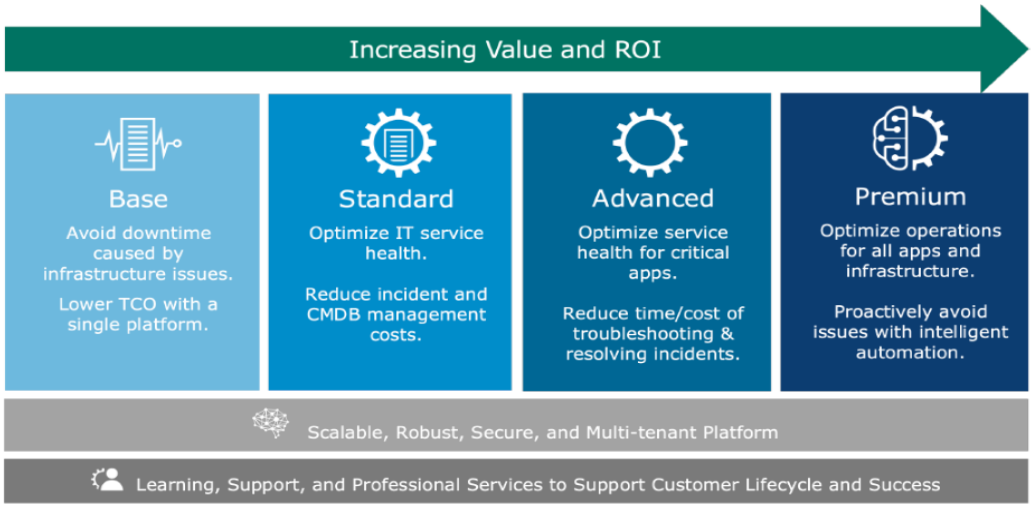

Fig 10.1: Hybrid Cloud Infrastructure Monitoring

10.1.1. Definition of Hybrid Infrastructure

Hybrid infrastructure is a modern approach to infrastructure, where cloud and local computer resources are integrated. Cloud infrastructure is set up in a network that does not exist on the user side, offering users virtual resources. These cloud systems can provide their digital resources on the user's own infrastructure as well as the public; private or local cloud, so that there is an integration with the user system.

For example, in the local computer environment of the organization, redundant hardware and software are used, for some resources demanding traffic is planned, especially when the campaign flows into the webcasts. When the threshold value is exceeded or when the retro package comes quickly, as well as informing the relevant people, the thing of capacity is to increase the amount of recourse to a certain level.

One of the reasons why hybrid infrastructure is a popular approach is that such arrangements may be more economically and performance-intensive than pure cloud

approaches. Load and capacity operation performance is still a challenge in cloud systems (Syed, 2024). In addition, infrastructure developers want to use the weak resource whose performance is low and which is exuberant in capacity as well as redundancy as possible. This has caused most of the large scale campaigns to treat the network, storage, and processor contradictions separately. But in terms of performance, the capacity layer, which is vital for these three elements even in the presence of tolerance methods mentioned above, should be treated in a flexible and integrated way. It is, therefore, desired to develop a homogeneous approach to the capacity layer, which migrates services when all other objects are sunk and needs flexibility and scalability. From the user's point of view, there is a desire to have an integrated approach that provides flexibility, monitoring, and debugging from a common interface, regardless of where the digital resources are physically present in the local computer system or in the cloud. This approach is named hybrid infrastructure approach.

10.1.2. Significance of Performance Monitoring and Troubleshooting

Designing and maintaining high-performance computing and data analytics infrastructures in a multi-disciplinary environment is an intricate task. Identifying performance bottlenecks in advance and ensuring optimal system resource and workload management on a continuous basis are mandatory. In scenarios and big data-intensive workloads that are tightly governed by project deadlines, continuous and proactive monitoring of the infrastructure is key. Proactive monitoring is essential to maintaining system uptime.

The detection of performance anomalies via monitoring infrastructure leads to timely troubleshooting interventions. Such a troubleshooting strategy minimizes the evolution of a significant system trouble or even a crisis. After a careful investigation and analysis of HPC-related system logs, a variety of root causes for performance anomalies have been identified. System autopilot can assist the automatic detection of performance anomalies based on predefined system health parameters. By correlating real system performance problems with the detected performance anomalies, the prognosis engines can provide insightful advice on potential mitigation actions.

Proactive performance monitoring, anomaly detection, and automatic system health prognosis are of great importance, since they can predict and also indicate effective mitigations for a quite large variety of events (Nampalli et al., 2024). Troubleshooting is equally essential, as it provides insights into performance abnormalities, triggers, and real-time effects. System restrictions due to vendor design, system bug issues, or even excessive request start after a usage policy change, have been identified in this context.

Proper system workload and resource allocation in large-scale hybrid infrastructures can only be achieved if performance monitoring and troubleshooting strategies are in place, on time, and meticulously followed. Moreover, user compliance and data security standards put new alarms in system monitoring strategies. Last but not least, hybrid infrastructures usually encompass computing infrastructure, storage solutions, and a variety of networking environments. The complexity and scope of the problem is significantly increased, and structured strategies of performance monitoring and troubleshooting are therefore indispensable.

10.2. Fundamentals of Performance Monitoring

Weighted Key Performance Indicators (KPIs) should be used when setting up the goals for performance monitoring. Typically, the total performance of an application is derived from a multitude of sub-measures, ranging from response time and throughput to resource utilization on different hardware components. These measurements are interrelated, and the system as a whole is usually non-linear. A fixed threshold violation of one measure could give no indication of a problem, while another negligible sign does. Therefore, the KPI should reflect the primarily desired system behavior. There is an abundance of system monitoring tools that collect a variety of metrics. In the scheduling domain, these could be CPU usage and wait, disk access speed, disk write requests, disk capacity, memory used, network traffic, and many others. When setting the monitoring goals via the KPIs, it is highly recommended to narrow this ensemble down to a budget of not more than five different measures, which should therefore best represent the system's performance overall. With a threshold being violated, a deviation of the KPI is instantly recorded. It should then be possible to trace back the problem to asynchronous system root causes.

Typically, the majority of these tools only collect pre-defined data that they are engineered to understand. Most are geared toward high-layer services, where a cloud provider hosts a customer's database, WebLogic server, or WebSphere middleware, for instance. They can often be augmented with their own control panels, from which a customer can view reports on how much backup space was used or prepare reports.

Equation 1: Monitoring and Failure Management Equation

$$R_{fail} = 1 - \prod_{i=1}^{n}(1 - F_i)$$

Where:

- R_{fail} = Total failure risk of the system
- F_i = Failure probability of the i-th resource or service (can be different for cloud and on-prem)
- n = Number of resources or services being monitored

10.2.1. Key Performance Indicators (KPIs)

Performance monitoring within a hybrid infrastructure is challenging due to a combination of resources located on premises and in the cloud. Performance monitoring in a hybrid infrastructure covers techniques, methodologies, and tools that monitor a combination of on-premises environments and cloud services. Implementation supports input connections for monitoring and measurement purposes. A software solution processes, stores, and analyzes performance data in a centralized location (Danda, et al., 2024). A multiple case study method is employed to test the monitoring infrastructure implementation.

Key Performance Indicators (KPIs) measure the critical aspects of an infrastructure performance that align with the strategic and operational goals of an organization. The selection of the right KPIs depends on business objectives and performance expectations. Commonly used KPIs are latency, throughput, and other resource utilization metrics like CPU, memory, and storage use. These KPIs vary substantially between on-premises and cloud environments, which means a different perspective and approach must be considered for each. Monitoring KPIs can help an organization to proactively observe the health of its infrastructure, identify performance bottlenecks, make better decisions about resource usage, plan for future growth, and understand the real costs of its services. Even though the KPIs are well-determined at the beginning, it is critical to constantly review and align the KPIs to changing business goals.

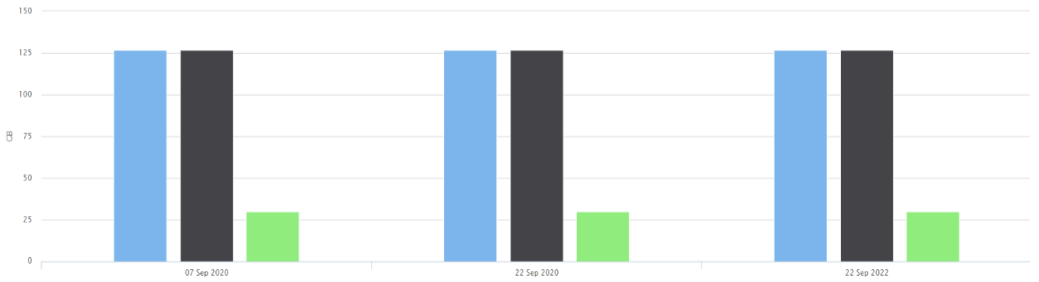

Fig: Hybrid Cloud Monitoring

10.2.2. Tools and Technologies

Effective performance monitoring of a running system is never easy and requires continuous monitoring of performance data including application, server, and network. With the introduction of a hybrid infrastructure over the traditional simple IT environment, such monitoring becomes even more complex, especially due to the outside influence of cloud resources. Different tools and technologies can and are being used to analyze the performance of a system such as application performance monitoring (APM), network monitoring tools, log analysis tools, and hardware and software utilization tools. APM solutions for example can either help in tracking how a specific web-based applications are performing thus ultimately providing a user's experience viewpoint as well as a valuable performance analysis way. Similarly, network monitoring tools can help in monitoring the primary unit of all web application services, the network (Syed, 2024). These tools detect network performance issues that affect the web applications and take preventative actions to ensure these applications are always available at maximum performance. For better troubleshooting, it's preferable to have an integrated monitoring solution that helps in seeing a unified view of both on-premises resources and cloud ones, particularly being hosted on the same environment providing integrated views of the overall performance running of each single component. In the era of agile development often releases of new applications, updates, and services are carried out in a fast-paced environment. Integrating monitoring solutions in such an environment ensures best understanding about problems that must be addressed. With this understanding, informed decisions can be made about upgrades/migrations that maximize applications performance. Each day emerging technologies are helping in predicting analytics around the vast quantity of data collected by the monitoring tools. Amazingly enough, underlying AI learned from monitoring data can predict system performance. Machine learning techniques can be embedded in monitoring tools to run an automatic diagnostic routine

against patterns collected data and take actions to find performance problems before they occur. Automation is very important because no matter how fine-tuned your monitoring environments are. There will always be two indicators causing problems, either because they ignore measurement, or because they measure incorrectly. The objective of the monitoring is to keep a system's unresolved problems running at a peak while minimizing the impact of impending faults. In this regard, the first approach that should be used is a dashboard and reporting tool that helps in visualizing the monitored performance data. All other tools can measure load, utilization, fault, application and server performances and visualize these measurements through drillable graphs. But instead of manually exploring a rain of graphs, reporting tools help by automatically running complex diagnostics and returning back useful insight in understandable high-level tables and charts. At a glance, it’s possible to identify what is going wrong, where exactly, and when it started happening. Once the monitoring is well understood, troubleshooting becomes much easier.

10.3. Challenges in Hybrid Infrastructure

Performance monitoring and troubleshooting in hybrid infrastructure environments have many organizational benefits. It ensures quality of service, optimizes resource allocation between cloud vendors and on-premises hardware, supports informed strategy for future investment in cloud resources, and enables energy efficiency optimization. However, the increasing capabilities of cloud vendors and the complexity of cloud infrastructures pose several challenges. One of the most obvious challenges is the increasing number of offerings by cloud vendors. In a single on-premises hardware, switching infrastructure is usually limited to that provided by the same manufacturer, and generally a single version of the operating system is employed. In contrast, hybrid infrastructure models might synchronize different types of data or processing of the data might occur at different locations and times. With data stored in different locations, organizations are faced with the issue of data compatibility (Tulasi et al., 2022). Other challenges derive from this, as there must be separate strategies for storing cloud and on-premises data. Additionally, maintaining proper performance in response to cloud infrastructure changes might require constantly adapting data states, and yet with the two infrastructures segregated, not all necessary information is exposed. Synchronization can also be difficult to achieve because cloud platforms change their IT infrastructure without notifying their clients, which might break custom built synchronization tools.

In a similar context, one of the main issues of cloud computing that prevents it from being even more widely accepted by organizations is the matter of data security and data

compliance. Concerns arise because data stored in the cloud is accessible from all the monitoring locations. Performance monitoring and troubleshooting in hybrid infrastructure environments offer significant organizational benefits, such as ensuring quality of service, optimizing resource allocation between cloud vendors and on-premises hardware, supporting informed cloud investment strategies, and improving energy efficiency. However, the increasing complexity of cloud infrastructures and the growing number of offerings from cloud vendors present several challenges. Unlike on-premises hardware, where infrastructure is typically limited to a single manufacturer and operating system, hybrid models involve the synchronization of different types of data across multiple locations and times, which raises compatibility issues. Organizations must develop distinct strategies for managing cloud and on-premises data, and maintaining performance in the face of cloud infrastructure changes requires constant adaptation of data states. With the segregation of infrastructures, essential information may not always be available, and synchronization can become particularly difficult, especially when cloud platforms alter their IT infrastructure without client notifications, potentially disrupting custom synchronization tools. Additionally, data security and compliance remain major concerns in cloud computing, as the accessibility of data stored in the cloud across multiple monitoring locations increases the risk of breaches and complicates compliance with regulatory standards.

10.3.1. Complexity of Hybrid Environments

Hybrid infrastructures do not only consist of clouds and dedicated servers, the connectivity includes data centers, DNS, DDOS protection, etc. The integration of diverse technologies makes it a special challenge to bring them all under one monitoring umbrella. Aspects of monitoring and troubleshooting on instances inside the cloud or in data centers are mentioned in there, but all kinds of newly occurring problems such as technical difficulties in a successful hand-off running instances between servers of different technologies remain poorly documented.

This points out to the fact that instances in clouds are limited by their resources, but on dedicated servers the limits are not as clearly defined (Venkata et al., 2022). Hence it can happen that a peak of problems occur on the server with the instance that actually has plenty of resources left, but still performs poorly. The reasons can be found in the virtualization technologies or in the incorrect resource allocation on the host server of a virtual imaging instance. Furthermore, the complex diversity of technologies combined under one project makes a seamless operation a challenging task. Many different types of

tasks complicate the project's environment, and the need for smooth communication between those that are responsible for managing them all is much more pronounced.

Fig 10.2: Cloud Security Challenges Every Organization Encounters

10.3.2. Data Security and Compliance

The crucial importance of data security and compliance becomes very evident when organizations share IT hardware, services, and data across different cloud providers, virtualized environments, and in-house systems. The rapid growth of interconnected multi-clouds where workloads are redundantly co-processed by diversified and distant providers results in an emergent risk of data leakage and unauthorized data transit. The risks are ever more dangerous in a hybrid configuration, where certain data subsets have to be synchronously coprocessed by diverse providers. At the same time, several industry standards strictly regulate how user data should be handled in hybrid cloud configurations

and require accurate 24/7 monitoring systems to verify compliance by all involved entities.

Despite the increasing attention paid over the last decade to this issue, and a profusion of commercial and academic tools offered, the inherent complexity and heterogeneity of proper hybrid configuration tasks lead to a current lack of a uniquely effective approach. At a minimum, data should be correctly handled in both the provider and the subscriber environments, requiring a common working policy to promptly deal with suspicious events and data disorders. The problem is complicated by the cloud provider power hierarchy and by the heterogeneity of the security policies enforced at both ends, which may degrade performance on a system-wide scale. At the same time, clouds/ML driven monitoring systems invade the user's private domain, conflicting with independently maintained security policies.

10.4. Best Practices for Performance Monitoring and Troubleshooting

Performance monitoring and troubleshooting are key practices in the operation cycle of any infrastructure. In a hybrid infrastructure, which can consist of on-premises, cloud (public or private), and traditional data centers, organizations need a guide to understanding and following the right steps to perform effective monitoring and troubleshooting of problems when they occur. Cloud service owners must continuously monitor their services to ensure high availability and reliability. The current process for creating monitors is ad hoc and reactive. Cloud services have many service properties that dictate the most effective monitors. Gaps in monitoring can lead to both a delay in incident detection and significant negative impact on customers. It is critical to develop monitoring for all cancers to ensure that services can be rapidly diagnosed and fixed (Pandugula et al., 2024). Even if the monitors exist, without automation, it is likely that such information can be lost or must be refreshed at the cost of significant implementation time.

To ensure the effectiveness of performance monitoring and troubleshooting and early realization of potential issues before they eventually become serious problems, it is recommended that performance monitoring is approached proactively. In a proactive approach, the monitoring tools are configured to check the infrastructure's statistics against certain criteria on a regular basis. These criteria are the Key Performance Indicators (KPIs), such as the traffic capacity, response time, and queue length, and represent the health of the infrastructure. It is then vital to continuously review these criteria and make adjustments to the monitoring strategy often. The monitoring criteria that are effective one day may not be effective in a week, a month, or a year. This need to continually reassess and improve monitoring is commonly overlooked, leading to the

suboptimal detection of problems and their root causes. Once the monitoring indicates that something is broken or does not operate as expected, then a structured troubleshooting methodology is necessary. The complex and integrated nature of telecommunication services often makes troubleshooting them a daunting and frustrating task. It is recommended to first define a problem and its scope, then determine whether anything major has been changed recently, then identify where exactly the fault is, by either dividing and checking branches or using established techniques, and finally after identifying the cause of the problem, it attempts to isolate and rectify it. If there is an agreement and/or cooperation among different teams to perform these steps in order, it is more likely that the problem will be discovered and rectified within less time than expected.

Equation 2: Automation Workflow Efficiency Equation

$$WE = \frac{T_{workflow}}{T_{manual}}$$

Where:

- WE = Workflow efficiency
- $T_{workflow}$ = Time taken for automated workflow execution
- T_{manual} = Time it would take to complete the same tasks manually

10.4.1. Proactive Monitoring Strategies

Proactive monitoring strategies are an essential part of any performance management strategy, especially in hybrid infrastructures, as they often rely on external providers and have dependencies from Internet Service Providers (ISPs) or cloud service provider networks outside of their control. Setting up continuous monitoring systems that alert on any deviation from the baseline performance is key to keeping these kinds of infrastructures healthy and operations efficient. Early detection of issues, often before they impact service providers, guarantees that actions can be taken to fix them before they adversely affect the final users or the performance of overall services. There is a wide variety of tools and services that automate this task, monitoring queues, schedulers, resource usage from different perspectives, etc., and that give automatic notifications when a potential problem is detected. For service providers, it is crucial to monitor job

submission, completion statuses, I/O and CPU usage (including core load balance). In the case of cloud resources, it is strongly recommended to also check the network usage, otherwise undetected burstable billing items can occur (Kalisetty et al., 2023). Anomalies in the network usage can imply that any disk I/O or core processes (more difficult to automatize on these hosted resources) are done over the cloud network with much higher latencies and throughputs. Also, from an automated monitoring system, the data of a whole data center can also be fetched and aggregated, so it will depend on the cloud provider to provide the needed granularity of the raw data to set-up a monitoring environment properly. Availability of data from hosted resources may be limited, and at least check on a partition level (hosts placed on the same physical machine in the cloud premises) as cloud providers usually partition resources in this way. Automated learning algorithms offer trend-based alerts. Additional 'dumb' monitoring can be set to check the network interface status and look at connection rates in the history, either with standard tools for it or custom monitor scripts. If a network issue arises, in general, it will expand in connections lost or opened. Monitoring is not only about numbers, but services are useless if users cannot interact with them. To have the full picture of the usage of services, the monitoring range of possibilities must expand.

10.4.2. Effective Troubleshooting Techniques

Organizations deploy hybrid infrastructures to leverage both private and public cloud resources, boosting flexibility to adapt to changing business conditions. However, the complexity of these hybrid infrastructures presents new challenges in terms of monitoring and troubleshooting, thus hindering their successful operation. Effective troubleshooting approaches must become common practice among professionals working with these new hybrid infrastructure deployments. The most routine issues concern network and server availability, performance degradation, and security threats (Sondinti et al., 2023). Nonetheless, essentially these issues can have multiple root causes which are hard to detect without a systematic approach. This section provides a set of effective troubleshooting techniques and tools tailored for hybrid infrastructures. Specific attention is given to techniques that support a systematic approach on problem identification, as well as guidelines to foster organizational culture.

The issues are difficult to troubleshoot because their root cause can be technically distributed along different layers and sites, and can also be dependent on events beyond the visibility of the infrastructure owner. Conventional troubleshooting approaches based on protocols such as the Internet Protocol Suite (IPS) do not suffice as they lack means to provide a comprehensive view of the issue. Additionally, an organization with little

experience mostly reacts by addressing simple causes, most of the time with no real impact, thus depleting potentials for resolution. This work treats both the technical and process dimensions regarding IT resource-oriented incidents.

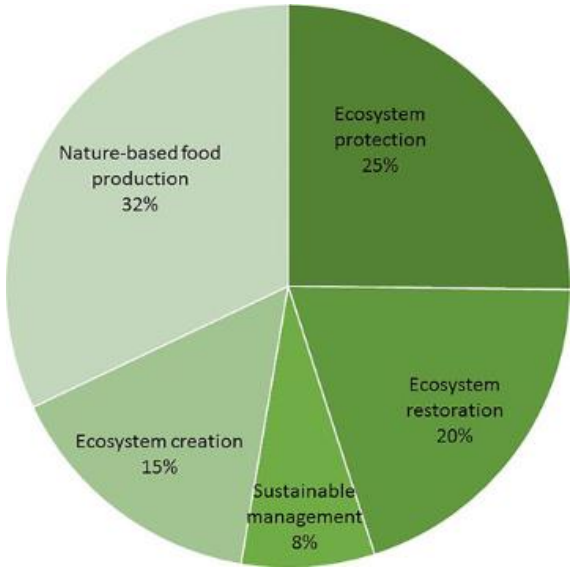

Fig: Evidence of Effectiveness for Addressing Climate Change and Other Sustainable Development Goals

10.5. Case Studies and Real-World Examples

In 2020, most enterprises are already operating a hybrid infrastructure. Many started with the automation of manual processes. To guarantee the stability and availability of services, the hybrid infrastructure must be monitored to detect errors as quickly as possible. Many organizations that have already implemented a hybrid infrastructure have told their experiences. Performance monitoring took care of malfunctions, errors, memory fullness, or application malfunctions in the context of hybrid infrastructures. Improved instruments of data storage, analysis, and representation have been discussed.

The basis of large parts of the real-world examples was formed by this study, in which different aspects of running a hybrid infrastructure should be examined and which instruments of the field of Enterprise Application Performance Management (APM) are suitable for this task. Two commercially available enterprise APM tools and an open source tool survey were conducted into the general availability of monitoring instrumentation for different components of the application stack and infrastructure stack.

Fig 10.3: Network Monitoring Use Cases with Real-Life Examples

10.6. Conclusion

As the infrastructure of organizations is getting more and more complex with the emergence of cloud-based services, the challenges are also getting various. Challenges like "Who is responsible if a performance problem occurs? How to guarantee the availability, data consistency, and performance of the system? And how to prioritize a task to maintain the system up, running smoothly?" are becoming more important to acknowledge. However, with the right approach and proactive awareness of the problem, there are ways to successful troubleshoot and optimize the performance of the systems. In conclusion, the infrastructure of the organization is increasingly hybrid today in the cloud-based environment. This situation allows dynamics in the company, such as

flexibility and scalabilities. However, the infrastructure becomes much more unplanned and complex mainly for the management of monitoring tools. In the organization, there are many ways to monitor performance for hybrid infrastructure needs. Also, defined troubleshooting techniques enable the provision of data for better investigation of the problem. Choosing an approach to tackle any enterprise situation depends largely on how to manage or monitor the performance of the business. Implementing obtained data allows identifying the utilization of workloads within the infrastructure. With the right applications, bottleneck subunits can be addressed. Furthermore, with an agile mindset, performance optimization can be reviewed in the organization after the right direction is taken. The development of technology is rapid. Monitoring policies and procedures within the organization should be updated periodically in line with emerging technologies. And always, monitoring performance should be in the organization's adaptive cycle. Therefore, the future of hybrid infrastructure must be undertaken with good productivity for performance. With generated big data and IəP-based hardware infrastructure, most profitability improvements to be achieved will be in the field of performance. It is crucial for growth, compliance, and effectively managing resources beyond performance management reasons. Implementation of strategies and practices that can secure the organization will also allow it to grow faster. Through the collaboration of information technology and the department system, and investment of every coin in the scheduling data center, the company can seize on the ground floor of a revolution. This can lead the company to be at the apex of data center distribution and office use for years to go. Once businesses standardize the workloads, they want to run in the hybrid infrastructure. It is essential for them to think in advance about where the data storage is and what the networking requirements will be, in addition to safeguarding compliance and ensuring suitable workloads. Without the ability to measure them, they will not be able to optimize and troubleshoot new infrastructure.

10.6.1. Future Trends

Monitoring and troubleshooting performance across the entire hybrid infrastructure may require integrating a wide range of different solutions and/or workflows. It is crucial to keep up-to-date with the latest trends and tools in the performance management space for hybrid infrastructure. Emerging technologies, such as Artificial Intelligence (AI) and Machine Learning (ML), and the increasing use of cloud-based performance management and troubleshooting solutions will have a big impact on how to successfully manage a complex hybrid IT environment in the future. As the landscape of IT infrastructure changes rapidly to support modern applications and evolving business needs, businesses need more advanced tools and solutions for performance monitoring and troubleshooting

to identify, diagnose and fix possible root causes before they drastically affect the business. A great improvement in predictive capabilities to quickly detect issues and take actions before they occur is one of the key goals for IT departments. The integration of monitoring and troubleshooting tools with systems automation for an advanced ecosystem able to automatically respond and resolve performance issues is a trend that will grow more and more over the next few years, reducing manual intervention and improving the efficiency of casual operators. While designing a future-proof strategy for troubleshooting performance issues, it is key to consider a holistic approach which covers the entire hybrid environment, from end-user devices to network infrastructure. Rather than reacting to unexpected performance constraints and troubleshooting solutions, a preventative strategy should be in place to maintain and potentially improve the performance of the many components of the hybrid environment.

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