Technical Report

FlexPod for Electronic Health Record Systems

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Abstract

The document describes how the application components of an electronic health record (EHR) system and various components of the FlexPod® architecture can come together to provide a high-performing, flexible, scalable, hybrid/cloud ready, and reliable infrastructure platform for all the environments of EHR system.

In partnership with

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Introduction

The healthcare system is complex. The complexity increases exponentially when healthcare faces market competition and changing policies. The decentralized healthcare system functions within a framework of heavy regulations and quality oversight. Today's challenges in the healthcare system require that all the segments of the system work in unison. It is no longer sufficient to just care for the critically ill because the communal spread of highly infectious diseases has pushed healthcare's capacity to its threshold. Healthcare workers are currently overworked and cannot sustain the current care demands. Physician fatigue was already a key factor before the communal spread of infectious diseases, and the fatigue of healthcare workers has reached new heights and is approaching a breaking point. Existing patient care processes have been proven inefficient. Healthcare technology is not innovating at the same rate as the demands of the healthcare industry.

Under the stress of infectious diseases, the current healthcare system has shown innumerable weak points. To add to the problem, healthcare services are split between various service providers; consequently, public health activities are not well coordinated and vary greatly across geographic regions. Standardization of clinical pathways and integration of the pathways into the everyday workflows within the hospitals is a foundational element. After diagnosed, the practice of standardized clinical protocols for treatment becomes the second foundational element. As ideal as it might sound, achieving the same is not straightforward. Another challenge in the foreseeable future is that EHR systems hold the clinical data hostage. Every EHR system has a set of unique capabilities; however, when it comes to their ability to make the data available where needed, they all have the same fundamental weakness. EHRs generally lack the ability to make the data available when needed, where it's needed, and at the scale it's needed. NetApp has invested in solving the data availability problem by bridging expertise in data management to address the critical need of accessing and protecting patient data. Global healthcare providers have entrusted NetApp to protect and manage their most valuable asset—healthcare data.

NetApp understands the challenges faced by worldwide healthcare organizations. It is this ability to understand healthcare challenges that makes NetApp a keystone in solving many data management problems that healthcare organizations face. The latest innovation within the FlexPod architecture makes the clinical data available where and when it's needed. In addition to availability, clinical data must be accessible at scale and speed that tomorrow's clinical capabilities demand. Tomorrow's clinical data analytics capabilities will require data to be accessible at much higher throughput rates and with lower latency. From a data ingest standpoint, clinical data collected by devices such as medical wearables will need to be processed at the edge and sent to core infrastructure components at a much higher rate than is the case today.

It's important to understand the state of the current healthcare system and how it evolved to that state. With regards to the health information systems used by the healthcare organizations, the question of whether to build versus buy tends to have a monotone answer—buy. Reasons for this answer are many and they are quite subjective. Decades of buying decisions result in information systems that are extremely heterogeneous in nature. Each system has a specific set of requirements for the platform they should be deployed on. The main issue is the large set of diverse storage protocols and performance levels that the vast set of information systems demand. This environment makes platform standardization and optimal operational efficiency an everyday challenge. Healthcare organizations aren't focusing on mission-critical aspects of the organization because their focus is spread too thin by managing trivial operations that require a diversified set of skills.

In summary, the challenges can be classified into the following categories:

- Heterogeneous storage needs
- Departmental silos
- IT operational complexity
- Cloud connectivity
- Cybersecurity

- Artificial intelligence and deep learning

For more than 10 years, FlexPod has been delivering a trusted, global platform for innovation, with unmatched versatility, driving best-in-class converged infrastructure solutions that support enterprises and enable service providers to meet the needs of diverse workloads.

By running an EHR environment on the FlexPod architectural foundation, your healthcare organization can expect to see an improvement in staff productivity and a decrease in capital and operating expenses. FlexPod provides a prevalidated, rigorously tested converged infrastructure from the strategic partnership of Cisco and NetApp, and it is engineered and designed specifically to deliver predictable low-latency system performance and high availability. This approach results in high comfort levels and optimal response time for users of an EHR system.

With FlexPod, you get a single platform that supports Fibre Channel (FC), Fibre Channel over Ethernet (FCoE), internet small computer systems interface (iSCSI), network file system (NFS), parallel network file system (pNFS), Server Message Block (SMB), Common Internet File System (CIFS), and so on from a single platform. People, process, and technology are the three pillars to achieve excellence in IT that are part of the DNA that FlexPod is designed and built upon. FlexPod's adaptive quality of service (QoS) helps break down the departmental silos by supporting multiple mission-critical clinical systems from the same underlying FlexPod platform. FlexPod is FedRAMP certified and FIPS 140-2 certified. Additionally, healthcare organizations are faced with opportunities to try and support artificial intelligence and deep learning activities. FlexPod and NetApp solve these challenges by making the data available where it is needed, on-premises or in a hybrid multicloud in a standardized and simpler platform. For more information and to learn more about our proud set of customer success stories, see FlexPod Healthcare.

The FDA is beginning to approve AI-based imaging solutions for clinical use. The health information system infrastructure must perform to, and in many cases outperform, the design considerations that these systems were built on. One such consideration is making clinical data available to analytical tools that are located on-premises, are cloud-based, or are hybrid in nature. The FlexPod converged infrastructure system from NetApp and Cisco provide an industry-proven infrastructure that can help organizations expand their current on-premises capabilities and integrate cloud-based clinical capabilities seamlessly at scale and speed. FlexPod is offered with a single point of support; therefore, healthcare IT departments can avoid the headache of managing different support requests to different support teams.

Here are some additional challenges that healthcare organizations face and how the FlexPod solution can help solve them today and in the years to come:

- The healthcare industry is strained by tremendous operational overheads due to COVID-19, and healthcare organizations are being forced to rethink their operational strategy. The $2 trillion federal relief bill passed in March 2020 is roughly 10% of the U.S. annual gross domestic product. The impact of COVID-19 on healthcare will have lasting effects on how care is delivered. Telemedicine is expected to take a front seat in the years to come. Virtual desktop infrastructure (VDI) is one of the primary ways to deploy telemedicine capabilities. For full information about the advantages of deploying VDI on FlexPod, see FlexPod for Virtual Desktop Infrastructure (VDI) Solutions.
- Centralized anonymization capability will help healthcare organizations to collaborate better with the rest of the industry in rapidly developing cures for pandemics such as COVID-19. Healthcare organizations are racing to find optimal clinical pathways and protocols to develop a vaccine for COVID-19. FlexPod solutions give organizations the ability to run both transactional and analytical databases on the same system. No clinical capability suffers from the load of the others, thanks to FlexPod and the NetApp® ONTAP® guaranteed QoS capability. With the capabilities of NetApp FlexCache® and the data fabric powered by NetApp, QoS can be applied to on-premises, hybrid cloud, and cloud-based clinical capabilities seamlessly.
- Healthcare organizations continue to implement Internet of Things (IoT) based medical devices that collect patient-consented data to enable patient-reported outcomes. IoT data is not only integrated with the patient medical record but is also used to execute predictive and prescriptive clinical analytical models. FlexPod clinical models can take advantage of both CPU-bound and GPU-bound AI algorithms with equal ease. The ability of healthcare organizations to generate IoT-based patient

medical data far exceeds the ability to understand and act on the data. Organizations can safely deploy IoT messaging platforms onto the same FlexPod system as their EHR, which maximizes the use of infrastructure at the same time guarantees that workloads do not compete for storage level input/output operations, typically measured in input/output operations per second (IOPS).

- Healthcare organizations are leveraging population health management (PHM) based hospital information systems. PHM systems require data that is located on-premises, in the cloud, or in a hybrid setup. With a data fabric powered by NetApp, organizations can make data available where it's needed. Making data available to clinical decision support systems is crucial to improving patient care.
- A recent JAMA study reports wastage of 25% in the U.S. healthcare system. EHR systems are among the biggest budget line items for healthcare organizations. This technical report describes how healthcare organizations can improve operational efficiency when clinical systems are implemented on a FlexPod infrastructure, both on premise and in the cloud or hybrid setup.
- Population Health Management System (PHMS) and population health indicators are a key metric to improve patient care and wellness. PHMS systems require high volumes of data both in batch and real-time from the healthcare organizations. FlexPod enables PHMS systems to span data centers and be hybrid cloud capable.

With FlexPod, most industry storage protocols are available from a single storage system. FlexPod makes it possible to configure multiple data storage tiers from a single storage system. This improves efficiency, increases standardization of support processes, and reduces errors. In summary, data management personnel are not challenged to manage a diversified set of platforms and they are stretched in their length and breadth of knowledge of the platform. Platform management personnel can trust that they are getting a platform that is used and trusted globally.

Scope

This document is a technical overview of a Cisco Unified Computing System (Cisco UCS) and NetApp ONTAP based FlexPod infrastructure for hosting one or more EHR solutions.

Audience

This document is intended for technical leaders in the healthcare industry and for Cisco and NetApp partner solutions engineers and professional services personnel. NetApp assumes that the reader has a good understanding of compute and storage sizing concepts as well as technical familiarity with an EHR system, Cisco UCS, and NetApp storage systems.

Solution benefits

The FlexPod infrastructure is a modular, converged, optionally virtualized, scalable (scale out and scale up), and cost-effective platform. With the FlexPod platform, you can independently scale out compute, network, and storage to accelerate your application deployment. And the modular architecture enables nondisruptive operations even during your system scale-out and upgrade activities.

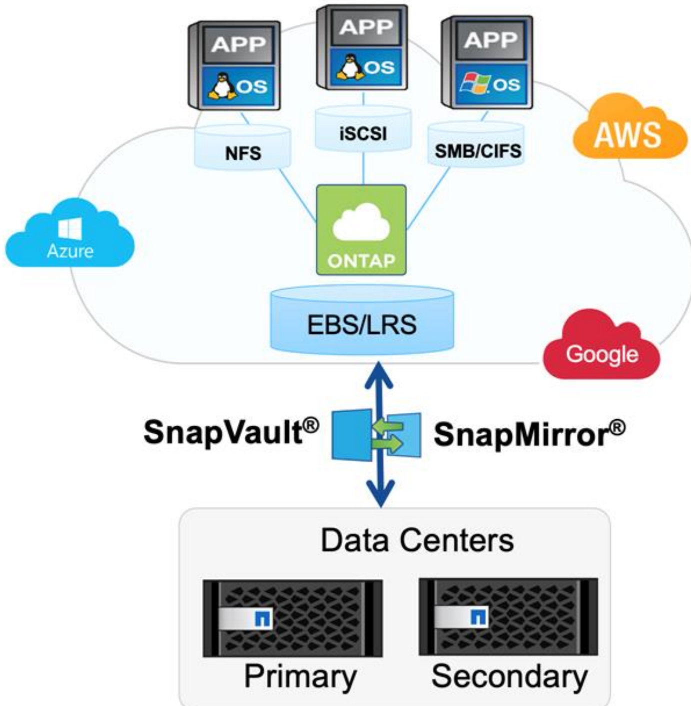
Different components of an EHR system require data to be stored in SMB/CIFS, NFS, Ext4, and NTFS file systems. This requirement means that the infrastructure must provide data access over the NFS, CIFS, and SAN protocols. A single NetApp storage system can support all of these protocols, eliminating the need for the legacy practice of protocol-specific storage systems. Additionally, a single NetApp storage system can support non-EHR workloads such as PACS or VNA, genomics, VDI, and more, with guaranteed and configurable performance levels for EHR and non-EHR workloads.

FlexPod with an EHR delivers several benefits that are specific to the healthcare industry:

- **Modular architecture**. FlexPod components are connected through a clustered server and storage management fabric and a cohesive management toolset.

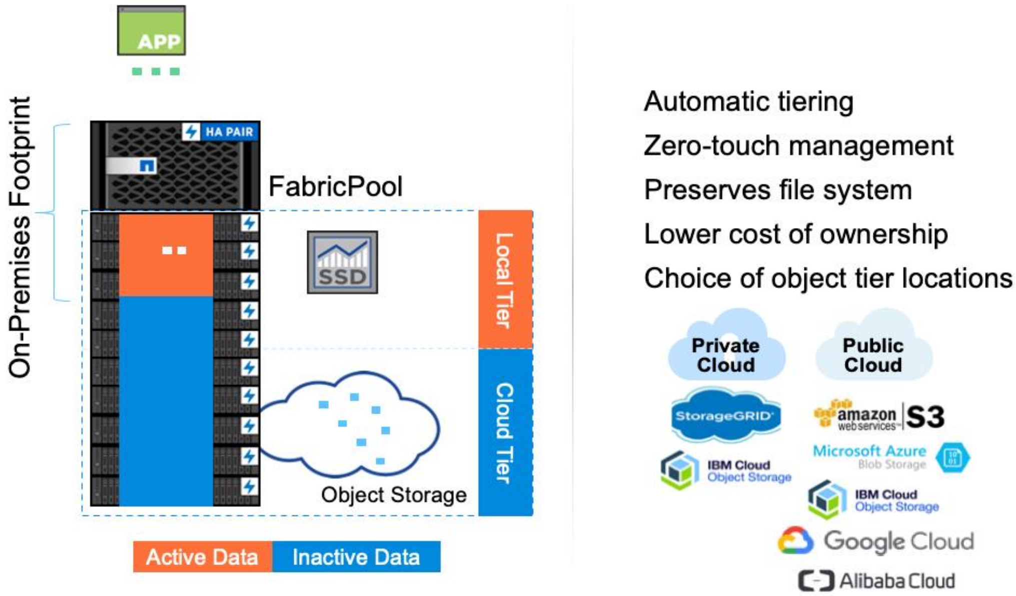
- **Faster deployment of infrastructure**. Whether it's in an existing data center or a remote location, the integrated and tested design of FlexPod Datacenter enables you to get the new infrastructure up and running in less time, with less effort.
- **Accelerated application deployment**. A prevalidated architecture reduces implementation integration time and risk for any workload, and NetApp technology automates infrastructure deployment. Whether you use the solution for an initial rollout of an EHR, a hardware refresh, or expansion, you can shift more resources to the business value of the project.
- **Simplified operations and lower costs**. You can eliminate the expense and complexity of legacy proprietary platforms by replacing them with a more efficient and scalable shared resource that can meet the dynamic needs of your workload. This solution delivers higher infrastructure resource utilization for greater return on investment.
- **Scale-out architecture**. You can scale SAN and NAS from terabytes (TB) to tens of petabytes (PB) without reconfiguring running applications.
- **Nondisruptive operations**. You can perform storage maintenance, hardware lifecycle operations, and software upgrades without interrupting your business.
- **Secure multitenancy**. Supports the increased needs of virtualized server and storage shared infrastructure, enabling secure multitenancy of facility-specific information, particularly when hosting multiple instances of databases and software.
- **Pooled resource optimization**. Helps you reduce physical server and storage controller counts, load balance workload demands, and boost utilization while improving performance.
- **QoS**. FlexPod offers QoS on the entire stack. The industry-leading QoS storage policies enable differentiated service levels in a shared environment. These policies help optimize performance for workloads and help in isolating and controlling runaway applications.
- **Support for storage tier SLAs by using QoS**. You don't have to deploy different storage systems for the different storage tiers that an EHR environment typically requires. A single storage cluster with multiple NetApp FlexVol® volumes with specific QoS for different tiers can serve that purpose. With this approach, storage infrastructure can be shared by dynamically accommodating the changing needs of a particular storage tier. NetApp AFF can support different SLAs for storage tiers by allowing QoS at FlexVol volumes, eliminating the need for different storage systems for different storage tiers for the application.
- **Storage efficiency**. You can reduce storage costs with NetApp storage efficiency features such as deduplication (inline and on demand), data compression, and data compaction.
- **Agility**. With the industry-leading workflow automation, orchestration, and management tools that FlexPod systems offer, your IT team can be far more responsive to business requests. These requests can range from EHR backup and provisioning of additional test and training environments to analytics database replications for population health management initiatives.
- **Higher productivity**. You can quickly deploy and scale this solution for optimal clinician end-user experiences.
- **Data fabric**. Your data fabric powered by NetApp ONTAP weaves data together across sites, beyond physical boundaries, and across applications. Your data fabric is built for data-driven enterprises in a data-centric world. Data is created and used in multiple locations, and it often needs to be leveraged and shared with other locations, applications, and infrastructures, so you need a consistent and integrated way to manage your data. This solution offers a way to manage data that puts your IT team in control and that simplifies ever-increasing IT complexity. Here's a quick glance of the Data Fabric capability from a backup and restore standpoint, as shown in Figure 1.

Figure 1) Data Fabric capability from a backup and restore standpoint.



- **FabricPool.** NetApp ONTAP FabricPool helps reduce storage costs without compromising performance, efficiency, security, or protection. FabricPool is transparent to enterprise applications and capitalizes on cloud efficiencies by lowering storage TCO without the need to rearchitect the application infrastructure. FlexPod can benefit from the storage tiering capabilities of FabricPool to make more efficient use of ONTAP flash storage. For full information, see [FlexPod with FabricPool](). Figure 2 provides a high-level overview of FabricPool and its benefits.

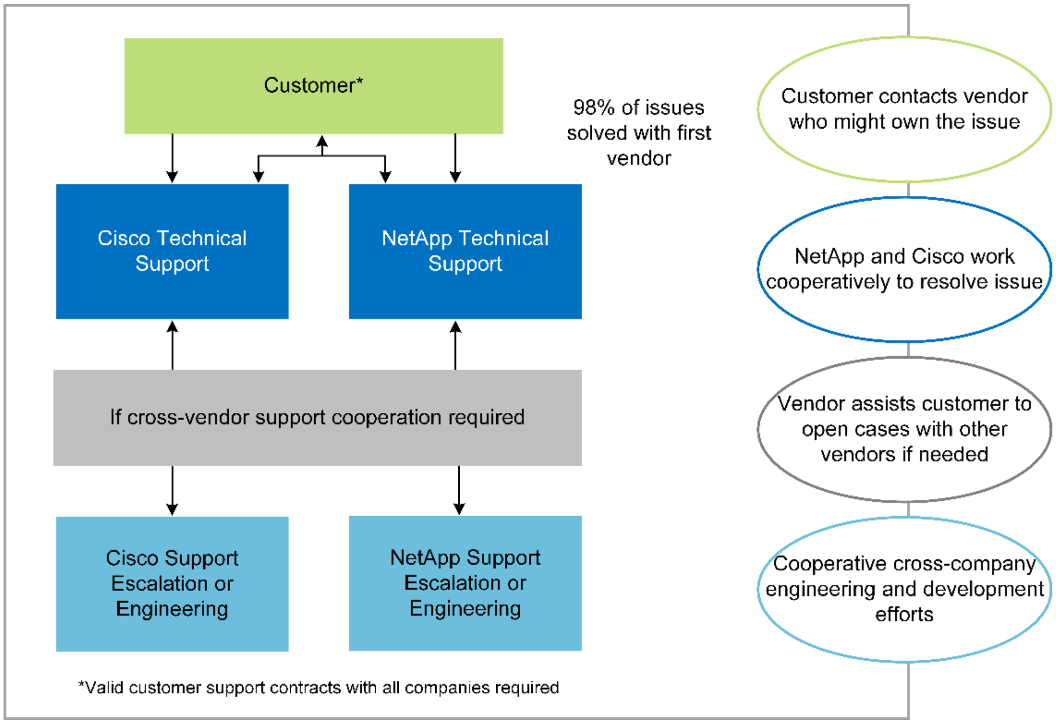
Figure 2) FabricPool and its benefits.



- **FlexPod security.** Security is at the very foundation of FlexPod. In the past few years, ransomware has become a threat. Ransomware is a type of malware that is based on cryptovirology, the use of cryptography to build malicious software. This malware can use both symmetric and asymmetric key encryption to lock a victim's data and demand a ransom to provide the key to decrypt the data. To learn how FlexPod helps mitigate threats like ransomware, see The Solution to Ransomware. FlexPod infrastructure components are also Federal Information Processing Standard (FIPS) 140-2 compliant.
- **FlexPod Cooperative Support.** NetApp and Cisco have established FlexPod Cooperative Support, a strong, scalable, and flexible support model to meet the unique support requirements of the FlexPod converged infrastructure. This model uses the combined experience, resources, and technical support expertise of NetApp and Cisco to offer a streamlined process for identifying and resolving FlexPod support issues, regardless of where the problem resides. The FlexPod Cooperative Support model helps confirm that your FlexPod system is operating efficiently and is benefiting from the most up-to-date technology, and also provides an experienced team to help resolve integration issues.

  FlexPod Cooperative Support is especially valuable if your healthcare organization runs business-critical applications. Figure 3 is an overview of the FlexPod Cooperative Support model.

Figure 3) FlexPod Cooperative Support model.



EHR

Clinicians use an EHR system to help manage critical patient data by providing secure access to patient data in real time. This document does not list all the clinical capabilities of an EHR; however, it does describe the core clinical capabilities.

An enterprise EHR supports an enterprise-wide view of clinical information, which is crucial in coordinating patient care and documenting the point at which care is delivered in both acute in-patient and out-patient settings. It gives providers access to the right information at the right time, helping them to make the best possible decisions. EHR also includes powerful decision support capabilities that use predictive algorithms to trigger rules and alerts that inform physicians about patient safety. Predictive algorithms can run inside the EHR on-premises, hybrid cloud, or on a cloud.

Enterprise EHRs help see patient information across the care continuum. EHRs use a simple but integrated application to document and access critical patient data, streamlining workflows that help improve patient safety. Let's attempt to list and understand some clinical capabilities offered by a typical EHRs.

Clinical capabilities

- **EHR patient portal and mobile application**. A patient-facing application that enables patients access to their medical records. The following is a list of capabilities:
  - Patient record summary, detailed medical history and results
  - Current medications
  - Provider lookup
  - Appointment scheduling
  - Video visits
  - Patient record access and ability to audit who all accessed your patient record
  - Clinician direct messaging and prescription refill requests

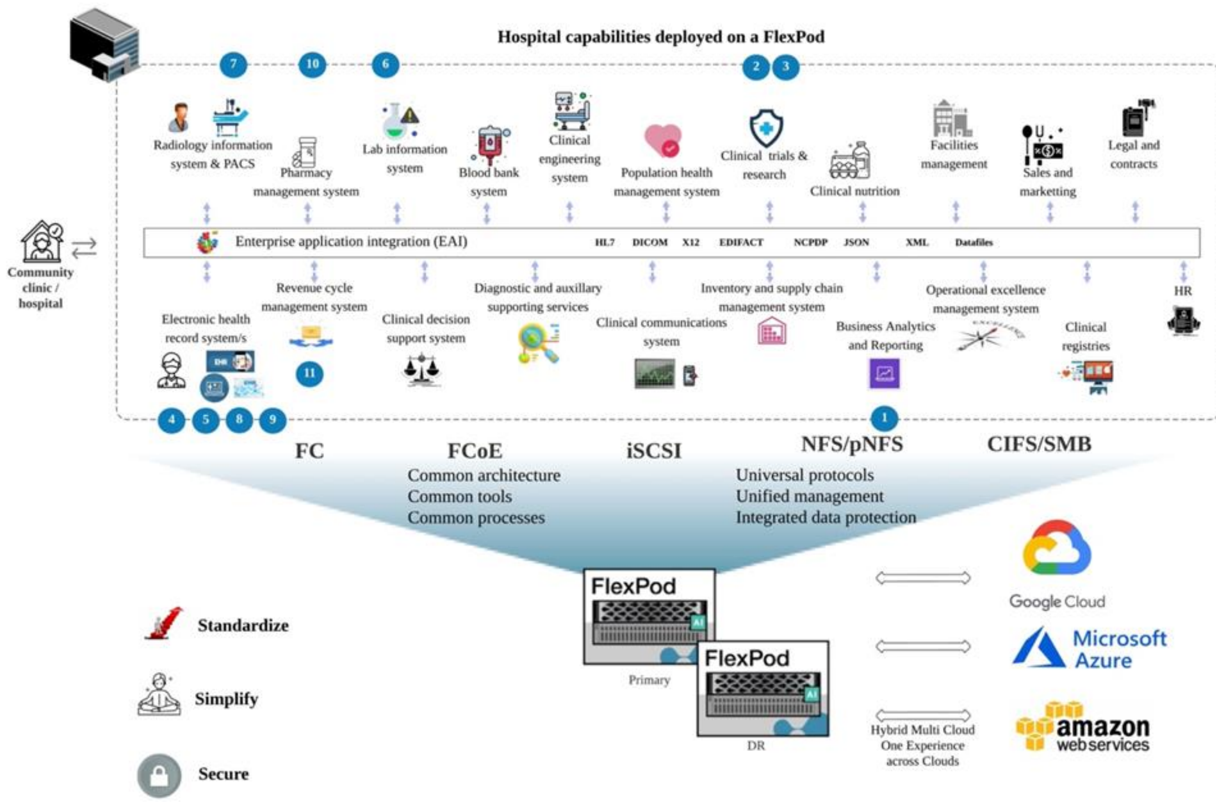
  - Treatment plans
  - Bill payments
  - Drug and prescription price lookup
  - Ability to review and merge IoT-based health information into the patients electronic medical record
- **Clinical decision support**. Clinical decision supports systems enable clinicians to make the most accurate clinical diagnosis and treatment protocol consistently. Clinical decision support systems can be broadly classified into two types based on the underlying implementation technology:
  - Implemented using rules based expert systems
  - Implemented using Artificial Intelligence capabilities
- **Emergency department**. EHRs have the capability for effective and safe management of the emergency department. This capability supports functions such as adult and pediatric ED and trauma, air transport, ground ambulance, and so on.
- **EHR hospital operations**. Improve patient outcomes with a capability that uses information from time and attendance systems to help make staffing decisions.
- **Medical imaging**. Some EHR systems have native support for medical imaging and radiology information systems. Medical imaging also supports multimedia such as scanned documents during registration, and media such as scanned pictures taken of patients or in a clinic. This capability streamlines radiology workflows and radiology imaging capabilities. An enterprise best practice for imaging is to have a centralized enterprise medical imaging system. For more information about how to deploy an enterprise medical imaging system on a FlexPod system, see TR-4865: FlexPod for Medical Imaging. Enterprise imaging capabilities have support for the following functions:
  - Computer tomography
  - Diagnostic radiology without interventional procedures
  - Interventional radiology
  - Magnetic resonance imaging
  - Mammography
  - Nuclear medicine
  - Positron emission tomography (PET)
  - Ultrasound
- **Document management system**. Some EHRs have a built-in document management system for managing patient registration and insurance documents.
- **Population health management**. EHRs might include functions that help manage clinical health outcomes of a defined group of individuals through improved care coordination and patient engagement.
- **Clinical trials management**. EHRs might have capabilities to manage clinical trials life cycle, research studies, patient enrollment and monitoring, research protocols, workflows for clinical research coordination, trials reporting, and so on.
- **Clinical registries**. EHRs can have capabilities to perform reporting functions to fulfill local state and federal compliance requirements and to enable broad clinical innovation efforts. EHRs might have the capability to tag patients to be part of one or more registries for reporting purposes.
- **Laboratory information system (LIS)**. Some EHRs also have native laboratory information systems with capabilities such as clinical financial and managerial capabilities in the clinical laboratory to improve the service experience for users and patients. Information is linked seamlessly between the EHR and LIS. LIS systems might also have support for automation of laboratory logistics such as courier routes and allows tracking of specimens for better management.

- **Medical device integration**. EHRs also have the capability to Integrate both bedside and nonbedside medical devices using standard integration patterns such as HL7, SOAP/JSON. EHRs can also have built-in capabilities to manage and validate medical device integration.
- **Enterprise application integration and interoperability**. Some EHRs have native support for enterprise application integration and interoperability. Hence enabling secure capabilities to integrate with other clinical systems within the same organization or other healthcare organization using HL7, FHIR, SOAP/JSON, and so on. One of the key capabilities of the EHR system is to exchange patient medical records with other hospitals electronically using clinical document architecture (CDA).
- **Order management**. EHRs include a computerized physician order entry (CPOE) capability with enhanced capabilities such as physician preference lists and order sets.
- **Charting and in-patient**. EHRs have the ability to manage patient chart information by different personas such as physicians, nurses, nurse practitioners, and so on. The charting capability enables physicians and nurses to securely document patient care on a smart device. Supports natural language processing-based dictation. Typically, this capability supports the following hospital functions:
  - Acute care
  - Critical care
  - Intensive care
  - Intermediate care
  - Observation
- **Operating theaters and anesthesia.** EHRs have workflow capabilities along with the ability to manage physician picklists for procedures. Capabilities can also include various dashboard capabilities to optimize operational traits of a typical operating room (OR) department.
- **Outpatient or ambulatory clinic management capability**. EHRs provide unique workflow capabilities to support operations of an ambulatory clinic. EHRs help automate ambulatory clinic workflows and clinical functions of physicians, care teams and clinic managers.
- **Treatment plans**. Some EHRs have the ability to facilitate treatment plans such as chemotherapy and similar types of treatments.
- **Clinical analytics**. EHRs have clinical analytics capabilities using retrospective and real-time data. Clinical analytics require that the EHR data be made available at scale for analytics on premises, hybrid cloud, or in the cloud.
- **EHR physician portal**. EHRs have the ability to access patient data through a secure web portal. This capability is typically provided to enable community physicians to refer patients and review order results and images.
- **Patient transportation**. EHRs have the patient transportation capability to manage patient movement from various parts of the hospital such as in-patient, procedure areas, imaging, labs, and so on.
- **Radiology information system (RIS)**. EHRs can also have native support for radiology department capabilities such as film tracking and image viewing.
- **Revenue cycle management**. EHRs can have the ability to perform revenue cycle functions such as charge capture, coding, billing, claims management, and so on.
- **Pharmacy**. EHR systems can have capabilities to manage pharmacy functions such as retail pharmacy, central fill pharmacy, experimental medication trials and pharmacy, inpatient pharmacy, prescription services (e-prescribing), specialty medication pharmacy, and so on.
- **Clinical engineering**. EHRs can have the ability to manage medical devices and medical device metadata and or library updates.
- **Infection prevention and control**. EHRs can have the ability to develop infection prevention and control education programs for hospital staff, manage infection prevention, and control policies and procedures.

- **Clinical communications**. EHRs can have the ability to send page messages to nurses and physicians from within human clinical workflows manually and automatic pages initiated by automated processes. EHRs can also provide secure texting capability to the clinicians.

Figure 4 illustrates the typical hospital capabilities deployed on a FlexPod system. A FlexPod architecture helps hospitals standardize, simplify, and secure healthcare capabilities at scale. FlexPod enables EHR systems to have the ability to naturally extend to the cloud with the capabilities of data fabric powered by NetApp.

Figure 4) Clinical and IT workflows.



The following workflow is typical in a hospital's organization:

Note the various clinical and IT workflows and how a FlexPod system enables the personnel involved to implement them seamlessly with no downtime, as shown in Figure 4.

1. The physician uses clinical analytics capabilities of the EHR and develops a new chronic obstructive pulmonary disease (COPD) risk score model. FlexPod enables the organization by providing composable compute, networking, storage, and AI from the same unified platform that scales up and out with ease.
2. The physician creates a clinical trial in the clinical trials management system (CTMS). With FlexPod QoS, EHR and non-EHR workloads can run on the same underlying platform with guaranteed multitenancy. CTMS can run side by side with the EHR with no impact to either systems' performance. FlexPod and NetApp ONTAP® hybrid cloud data fabric capabilities enable the healthcare organization to collaborate with other healthcare entities and compliance entities with ease.
3. The physician's clinical research coordinators work with the patients for consent to participate in the clinical research trial and enrolls the patient into the clinical trial. Healthcare organizations can implement HL7 messaging platforms on FlexPod Datacenter with ease. One more added benefit of

standardizing on the FlexPod platform. The FlexPod and ONTAP hybrid cloud data fabric capabilities enable healthcare organizations to implement data interoperability with cloud-based registries and population health management systems with ease.

4. The patient visits the ER or ambulatory clinic with symptoms that are similar to COPD. The patient provides information, and the patient is assessed. The clinical systems used in the ER and trauma departments must be up 24/7. FlexPod has an industry-leading, high-availability (HA) performance and proven record that helps a hospital organization to operate efficiently and allows them to trust the platform functionality under various failure scenarios.
5. After a preliminary check and vitals collection, clinicians and physicians document a reason for the visit, perform a review of systems, conduct a physical examination, and order labs and imaging for the patient by using the EHR. The FlexPod platform is used by healthcare organizations to not only host multiple PACS systems but also a Vendor Neutral Archive (VNA) system. The FlexPod architecture is a proven and trusted platform that provides increased performance and capacity features.
6. The patient visits the labs for sample collection and tests. The hospital LIS systems can run on the FlexPod platform with ease, which enables standardization.
7. The patient visits the radiology department for imaging.
8. The radiologist documents an imaging review in PACS.
9. The imaging results are integrated with PHI in EHR.
10. The physician uses EHR to review the patient’s vitals, labs, and imaging results along with the COPD risk score to prescribe a clinical protocol for treatment and recovery.
11. The physician prescribes and experimental prescription from the hospital’s pharmacy as part of the research study.
12. The hospital’s pharmacy dispenses the experimental medication to the patient.
13. A revenue cycle management system is used to code, bill, and submit the claim to the payor for the patients visit.
14. A PHI from EHR and the PACS is sent to the clinical trial software by using some interoperability technology such as CDA or FHIR.

FlexPod

Before describing the key application architecture components of an EHR, this section describes the underlying FlexPod platform and key components—and more importantly, the differentiating capabilities of a FlexPod system.

Cisco Unified Computing System

Cisco Unified Computing System (UCS) consists of a single management domain that’s interconnected with a unified I/O infrastructure. Cisco UCS for EHR environments are aligned with standard enterprise-grade EHR infrastructure recommendations and best practices so that the infrastructure can deliver critical patient information with maximum availability.

With its integrated systems management, Intel Xeon or AMD processors, and server virtualization, Cisco UCS technology is the proven compute foundation for an EHR. These integrated technologies solve data center challenges to help you meet your goals for data center design with an EHR. Cisco UCS unifies LAN, SAN, and systems management into one simplified link for rack servers, blade servers, and virtual machines (VMs). Cisco UCS consists of a redundant pair of Cisco UCS Fabric Interconnects that provide a single point of management, and a single point of control, for all I/O traffic.

Cisco UCS uses service profiles so that virtual servers in the Cisco UCS infrastructure are configured correctly and consistently. Service profiles include crucial server information about the server identity, such as LAN and SAN addressing, I/O configurations, firmware versions, boot order, network virtual LAN

(VLAN), physical port, and QoS policies. Service profiles can be dynamically created and associated with any physical server in the system in minutes rather than hours or days. The association of service profiles with physical servers is performed as a single simple operation and enables migration of identities between servers in the environment without requiring any physical configuration changes. It also facilitates rapid bare-metal provisioning of replacements for failed servers.

The use of service profiles helps confirm that servers are configured consistently throughout the enterprise. When using multiple Cisco UCS management domains, Cisco UCS Central or Cisco Intersight can use global service profiles to synchronize configuration and policy information across domains. If maintenance must be performed in one domain, the virtual infrastructure can be migrated to another domain. With this approach, even when a single domain is offline, applications continue to run with high availability.

Cisco UCS is a next-generation solution for blade and rack server computing. The system integrates a low-latency, lossless, 10/25/40/100GbE unified network fabric with enterprise-class, x86-architecture servers. The system is an integrated, scalable, multichassis platform in which all resources participate in a unified management domain. Cisco UCS accelerates the delivery of new services simply, reliably, and securely through end-to-end provisioning and migration support for both virtualized and nonvirtualized systems.

Cisco UCS offers the following features:

- Comprehensive management
- Radical simplification
- High performance
- Reduced cabling costs

Cisco UCS consists of the following components:

- **Compute.** The system is based on an entirely new class of computing system that incorporates rack-mounted and blade servers based on the Intel Xeon scalable processor product family or alternatively AMD processors.
- **Network.** The system is integrated onto a low-latency, lossless, 10/25/40/100Gbps unified network fabric. This network foundation consolidates LANs, SANs, and high-performance computing networks, which currently are separate networks. The Cisco Unified Fabric lowers costs by reducing the number of network adapters, switches, and cables, and by decreasing power and cooling requirements.
- **Virtualization.** The system unleashes the full potential of virtualization by enhancing the scalability, performance, and operational control of virtual environments. Cisco security, policy enforcement, and diagnostic features are now extended into virtualized environments to better support changing business and IT requirements.
- **Storage access.** The system provides consolidated access to both SAN storage and NAS over the Unified Fabric. It is also an ideal system for software-defined storage. By combining the benefits of a single framework to manage both the compute and storage servers, QoS can be implemented if needed to inject I/O throttling in the system. And your server administrators can preassign storage-access policies to storage resources, which simplifies storage connectivity and management and can help increase productivity. In addition to external storage, both rack and blade servers have internal storage that can be accessed through optional hardware RAID controllers. By setting up the storage profile and disk configuration policy in Cisco UCS Manager, the storage needs of the host OS and application data are fulfilled by user-defined RAID groups. The result is high availability and improved performance.
- **Management.** The system uniquely integrates all system components to enable Cisco UCS Manager to manage the entire solution as a single entity. To manage all system configuration and operations, Cisco UCS Manager has an intuitive GUI, a CLI, and a powerful scripting library module for Microsoft Windows PowerShell that are built on a robust API.

Cisco UCS fuses access layer networking and servers. This high-performance, next-generation server system gives your data center a high degree of workload agility and scalability.

Cisco UCS Manager/Intersight

Cisco UCS Manager provides unified, embedded management for all software and hardware components in Cisco UCS. By using single-connection technology, UCS Manager manages, controls, and administers multiple chassis for thousands of VMs. Through an intuitive GUI, a CLI, or an XML API, administrators use the software to manage the entire Cisco UCS as a single logical entity. Cisco UCS Manager resides on a pair of Cisco UCS 6300 Series Fabric Interconnects that use clustered, active-standby configuration for high availability.

Cisco UCS Manager offers a unified embedded management interface that integrates your servers, network, and storage. It performs autodiscovery to detect the inventory of, to manage, and to provision system components that you add or change. It offers a comprehensive set of XML APIs for third-party integration, and it exposes 9,000 points of integration. It also facilitates custom development for automation, for orchestration, and to achieve new levels of system visibility and control.

Cisco Intersight is the next generation cloud management tool that will replace all UCS Manager functionality over time. It will add capabilities for analytics that identify bottlenecks, suggest remediation strategies and implement them. It has the capability to use Cisco Connected Technical Assistance Center (TAC), which gives customers the ability to rely on Cisco to keep their environments up and running with the highest reliability.

Service profiles benefit both virtualized and nonvirtualized environments. They increase the mobility of nonvirtualized servers, such as when you move workloads from server to server or when you take a server offline for service or upgrade. You can also use profiles in conjunction with virtualization clusters to bring new resources online easily, complementing existing VM mobility.

For more information about Cisco UCS Manager, see the Cisco UCS Manager product page.

For more information about Cisco Intersight, see the Cisco Intersight product page.

Cisco UCS differentiators

Cisco UCS is revolutionizing the way that servers are managed in the data center. Here are the unique differentiators of Cisco UCS and Cisco UCS Manager:

- **Embedded management.** In Cisco UCS, the servers are managed by the embedded firmware in the Fabric Interconnects, eliminating the need for any external physical or virtual devices to manage the servers.
- **Unified Fabric.** In Cisco UCS, from blade server chassis or rack servers to Fabric Interconnects, a single Ethernet cable is used for LAN, SAN, and management traffic. This converged I/O reduces the number of cables, SFPs, and adapters that you need, in turn reducing your capital and operational expenses for the overall solution.
- **Autodiscovery.** By simply inserting the blade server in the chassis or by connecting rack servers to the Fabric Interconnects, discovery and inventory of compute resource occurs automatically without any user intervention. The combination of Unified Fabric and autodiscovery enables the wire-once architecture of Cisco UCS, so that its compute capability can be easily extended while keeping the existing external connectivity to LAN, SAN, and management networks.
- **Policy-based resource classification.** When Cisco UCS Manager discovers a compute resource, it can be automatically classified to a given resource pool based on the policies that you defined. This capability is useful in multitenant cloud computing.
- **Combined rack and blade server management.** Cisco UCS Manager can manage B-Series Blade Servers and C-Series Rack Servers under the same Cisco UCS domain. This feature, along with stateless computing, makes compute resources truly hardware form-factor–agnostic.

- **Model-based management architecture.** The Cisco UCS Manager architecture and management database are model-based and data-driven. The open XML API that is provided to operate on the management model enables easy and scalable integration of Cisco UCS Manager with other management systems.
- **Policies, pools, and templates.** The management approach in Cisco UCS Manager is based on defining policies, pools, and templates instead of a cluttered configuration. It enables a simple, loosely coupled, data-driven approach in managing compute, network, and storage resources.
- **Loose referential integrity.** In Cisco UCS Manager, a service profile, a port profile, or policies can refer to other policies or to other logical resources with loose referential integrity. A referred policy cannot exist at the time of authoring the referring policy, but a referred policy can be deleted even if other policies are referring to it. This feature enables different subject-matter experts (SMEs) to work independently from each other. You gain great flexibility by enabling different experts from different domains—such as network, storage, security, server, and virtualization—to work together to accomplish a complex task.
- **Policy resolution.** In Cisco UCS Manager, you can create a tree structure of the organizational unit hierarchy that mimics the real-life tenants and organizational relationships. You can define various policies, pools, and templates at different levels of your organizational hierarchy. A policy that refers to another policy by name is resolved in the organizational hierarchy with the closest policy match. If no policy with a specific name is found in the hierarchy of the root organization, then a special policy named “default” is searched. This policy resolution practice enables automation-friendly management APIs and provides great flexibility to the owners of the different organizations.
- **Service profiles and stateless computing.** A service profile is a logical representation of a server, carrying its various identities and policies. You can assign this logical server to any physical compute resource, as long as it meets the resource requirements. Stateless computing enables procurement of a server within minutes, a task that used to take days in legacy server management systems.
- **Built-in multitenancy support.** The combination of policies, pools, templates, a loose referential integrity, policy resolution in the organizational hierarchy, and a service-profiles-based approach to compute resources makes Cisco UCS Manager inherently friendly to multitenant environments that are typically observed in private and public clouds.
- **Extended memory.** The enterprise-class Cisco UCS B200 M5 Blade Server extends the capabilities of the Cisco UCS portfolio in a half-width blade form factor. The Cisco UCS B200 M5 harnesses the power of the latest Intel Xeon scalable-processor CPUs with up to 3TB of RAM. This feature enables the huge VM-to-physical-server ratio that many deployments need and can enable certain architectures to support large memory operations, such as big data.
- **Virtualization-aware network.** Cisco Virtual Machine Fabric Extender (VM-FEX) technology makes the access network layer aware of host virtualization. This awareness prevents pollution of compute and network domains with virtualization when a virtual network is managed by port profiles that are defined by your network administration team. VM-FEX also offloads hypervisor CPU by performing switching in the hardware, thus enabling the hypervisor CPU to perform more virtualization-related tasks. To simplify cloud management, VM-FEX technology is well integrated with VMware vCenter, Linux Kernel-Based Virtual Machine (KVM), and Microsoft Hyper-V SR-IOV.
- **Simplified QoS.** Even though FC and Ethernet are converged in the Cisco UCS, built-in support for QoS and lossless Ethernet make it seamless. By representing all system classes in one GUI panel, network QoS is simplified in Cisco UCS Manager.

Cisco Nexus IP and MDS switches

Cisco Nexus switches and Cisco MDS multilayer directors give you enterprise-class connectivity and SAN consolidation. Cisco multiprotocol storage networking helps reduce your business risk by providing flexibility and options: FC, Fiber Connection (FICON), FCoE, iSCSI, and FC over IP (FCIP).

Cisco Nexus switches offer one of the most comprehensive data center network feature sets in a single platform. They deliver high performance and density for both the data center and the campus core. They also offer a full feature set for data center aggregation, end-of-row, and data center interconnect deployments in a highly resilient modular platform.

Cisco UCS integrates compute resources with Cisco Nexus switches and a Unified Fabric that identifies and handles different types of network traffic. This traffic includes storage I/O, streamed desktop traffic, management, and access to clinical and business applications. You get:

- **Infrastructure scalability.** Virtualization, efficient power and cooling, cloud scale with automation, high density, and performance all support efficient data center growth.
- **Operational continuity.** The design integrates hardware, Cisco NX-OS software features, and management to support zero-downtime environments.
- **Transport flexibility.** You can incrementally adopt new networking technologies with this cost-effective solution.

Together, Cisco UCS with Cisco Nexus switches and MDS multilayer directors provide a compute, networking, and SAN connectivity solution for an EHR system.

NetApp all-flash and FAS storage

NetApp storage that runs ONTAP software reduces your overall storage costs while delivering the low-latency read and write response times and high IOPS that an EHR needs. To create an optimal storage system that meets the enterprise EHR system requirements, ONTAP supports all-flash, hybrid, and FAS storage configurations.

NetApp flash storage provides high performance and responsiveness to support latency-sensitive EHR operations. By creating multiple fault domains in a single cluster, NetApp technology can also isolate your production environments from your nonproduction environments. And by guaranteeing that system performance won’t drop below a certain level for workloads with ONTAP minimum QoS, NetApp reduces performance issues for your system.

An ONTAP storage cluster can have all-flash controller nodes and/or FAS controller nodes. ONTAP storage data management and data fabric capabilities are available on both all-flash and FAS storage. FAS storage can be used for workloads where larger storage capacity at lower performance is required.

NetApp ONTAP differentiators

The scale-out architecture of ONTAP software can flexibly adapt to your various I/O workloads. To deliver the throughput and low latency that clinical applications need and to provide a modular scale-out architecture, all-flash configurations are typically used in ONTAP architectures. NetApp AFF nodes can be combined in the same scale-out cluster with hybrid (HDD and flash) storage nodes, suitable for storing large datasets with high throughput. You can clone, replicate, and back up your EHR environment from expensive SSD storage to more economical HDD storage on other nodes. With NetApp cloud-enabled storage and a data fabric delivered by NetApp, you can back up to object storage on the premises or in the cloud.

ONTAP offers features that are extremely useful in EHR environments. These features simplify management, increase availability and automation, and reduce the total amount of storage that you need. You get:

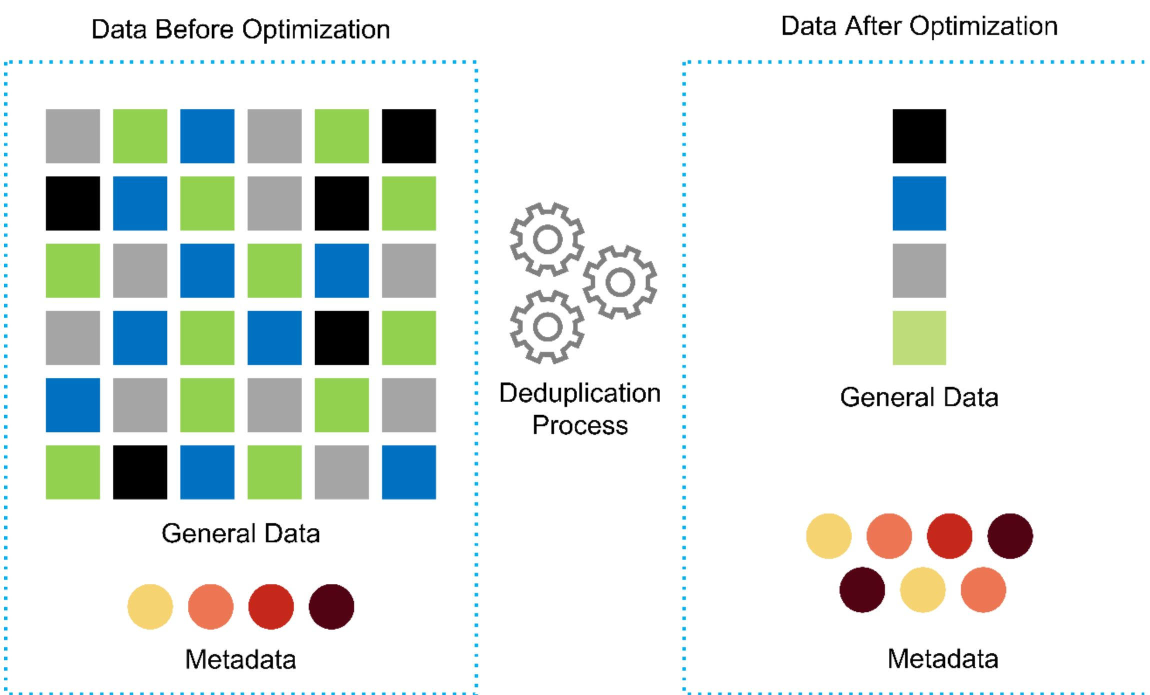
- **Multiprotocol.** A single NetApp ONTAP storage system supports multiple storage protocols, iSCSI and FC SAN protocols, and CIFS and NFS NAS protocols. This enables organizations to meet the various storage protocol requirements of EHR components from a single storage system.
- **Outstanding performance.** The NetApp AFF solution shares the same unified storage architecture, ONTAP software, management interface, rich data services, and advanced feature set as the rest of the NetApp FAS product families. This innovative combination of all-flash media with ONTAP gives you the consistent low latency and high IOPS of all-flash storage with industry-leading ONTAP software.

- **Storage efficiency.** You can reduce your total capacity requirements with deduplication, NetApp FlexClone® technology, inline compression, inline compaction, thin replication, thin provisioning, and aggregate deduplication.

NetApp deduplication provides block-level deduplication in a FlexVol volume or a data constituent. Essentially, deduplication removes duplicate blocks, storing only unique blocks in the FlexVol volume or data constituent.

Deduplication works with a high degree of granularity and operates on the active file system of the FlexVol volume or data constituent. Figure 5 shows an overview. Deduplication is application transparent; therefore, it can be used to deduplicate data originating from any application that uses the NetApp system. You can run volume deduplication as an inline process and as a background process. You can configure it to run automatically, to be scheduled, or to run manually through the CLI, NetApp ONTAP System Manager, or NetApp Active IQ® Unified Manager.

Figure 5) How NetApp deduplication works.



- **Space-efficient cloning.** With the FlexClone capability, your system can almost instantly create clones to support backup and testing environment refresh. These clones consume additional storage only as changes are made.
- **Integrated data protection.** Full data protection and disaster recovery features help you protect your crucial data assets and provide disaster recovery.
- **Nondisruptive operations.** You can perform upgrades and maintenance without taking data offline.
- **QoS.** Storage QoS helps you limit potential bully workloads. More importantly, QoS can guarantee minimum performance so that your system performance won't drop below a certain level for crucial workloads such as EHR production. And by limiting contention, NetApp QoS can also reduce performance-related issues.
- **Data fabric.** To accelerate digital transformation, your data fabric delivered by NetApp simplifies and integrates data management across cloud and on-premises environments. It delivers consistent and integrated data management services and applications for superior data visibility and insights, data access and control, and data protection and security. NetApp is integrated with large public clouds, such AWS, Azure, Google Cloud, and IBM Cloud, giving you a wide breadth of choice.

Host virtualization—VMware vSphere

FlexPod architectures are validated with VMware vSphere, which is the industry-leading virtualization platform. VMware ESXi is used to deploy and to run the VMs. vCenter Server Appliance is used to manage the ESXi hosts and VMs. Multiple ESXi hosts that run on Cisco UCS B200 M5 blades are used to form a VMware ESXi cluster. The VMware ESXi cluster pools the compute, memory, and network resources from all the cluster nodes and provides a resilient platform for the VMs that are running on the cluster. The VMware ESXi cluster features, vSphere high availability, and Distributed Resource Scheduler (DRS) all contribute to the vSphere cluster's tolerance to withstand failures, and they help distribute the resources across the VMware ESXi hosts.

The NetApp storage plug-in and the Cisco UCS plug-in integrate with VMware vCenter to enable operational workflows for your required storage and compute resources.

The VMware ESXi cluster and vCenter Server give you a centralized platform for deploying EHR environments in VMs. Your healthcare organization can realize all the benefits of an industry-leading virtual infrastructure, such as:

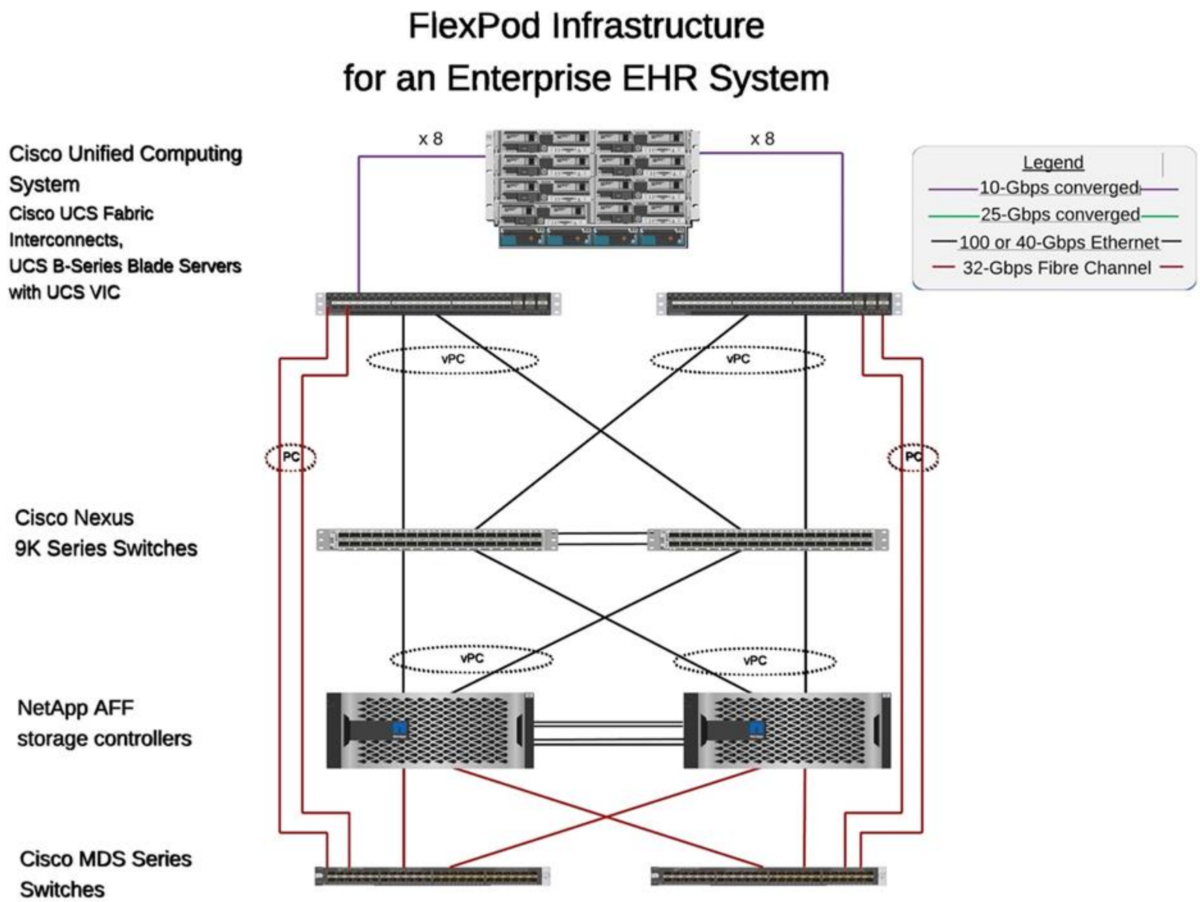
- **Simple deployment.** Quickly and easily deploy vCenter Server by using a virtual appliance.
- **Centralized control and visibility.** Administer the entire vSphere infrastructure from a single location.
- **Proactive optimization.** Allocate, optimize, and migrate resources for maximum efficiency.
- **Management.** Use powerful plug-ins and tools to simplify management and to extend control.
- **Simplified virtual desktop infrastructure (VDI).** FlexPod for VDI is fully tested and validated to provide operational simplicity.

Architecture

The FlexPod architecture is designed to provide high availability if a component or a link fails in your entire compute, network, and storage stack. Multiple network paths for client access and storage access provide load balancing and optimal resource utilization.

Figure 6 illustrates the 16Gb FC/40Gb Ethernet (40GbE) topology for an EHR solution deployment.

Figure 6) FlexPod for an EHR physical topology.



Storage architecture

Use the storage architecture guidelines in this section to configure your storage infrastructure for an EHR.

Storage tiers

Actual EHR data storage tiering requirements are not available at the time of this report. To help understand the storage platform, consider the following data storage tiers as generic requirements (Table 1).

Table 1) An EHR environment storage tiers.

Storage Tier	Requirements	NetApp Recommendation
1	1–5ms latency 35–500MBps throughput	AFF with <1ms latency AFF A400 high-availability (HA) pair with two disk shelves can handle throughput of up to ~1.6GBps
2	On premises Archive	FAS with up to 30ms latency
	Archive to cloud	SnapMirror replication to Cloud Volumes ONTAP or backup archiving with NetApp StorageGRID® software

Storage network connectivity

FC fabric:

- The FC fabric is for host OS I/O from compute to storage.
- Two FC fabrics (Fabric A and Fabric B) are connected to Cisco UCS Fabric A and UCS Fabric B, respectively.
- A storage virtual machine (SVM) with two FC logical interfaces (LIFs) is on each controller node. On each node, one LIF is connected to Fabric A and the other is connected to Fabric B.
- 16Gbps FC end-to-end connectivity is through Cisco MDS switches. A single initiator, multiple target ports, and zoning are all configured.
- FC SAN boot is used to fully achieve stateless computing. Servers are booted from LUNs in the boot volume that is hosted on the AFF storage cluster.

IP network for storage access over iSCSI, NFS, and CIFS:

- Two iSCSI LIFs are in the SVM on each controller node. On each node, one LIF is connected to Fabric A and the second is connected to Fabric B.
- Two NAS data LIFs are in the SVM on each controller node. On each node, one LIF is connected to Fabric A and the second is connected to Fabric B.
- Storage port interface groups (virtual port channel [vPC]) for 10Gbps link to switch N9k-A and for 10Gbps link to switch N9k-B.
- Workload in Ext4 or NTFS file systems from VM to storage: iSCSI protocol over IP.
- VMs hosted in NFS datastore: VM OS I/O goes over multiple Ethernet paths through Nexus switches.

In-band management (active-passive bond):

- 1Gbps link to management switch N9k-A, and 1Gbps link to management switch N9k-B.

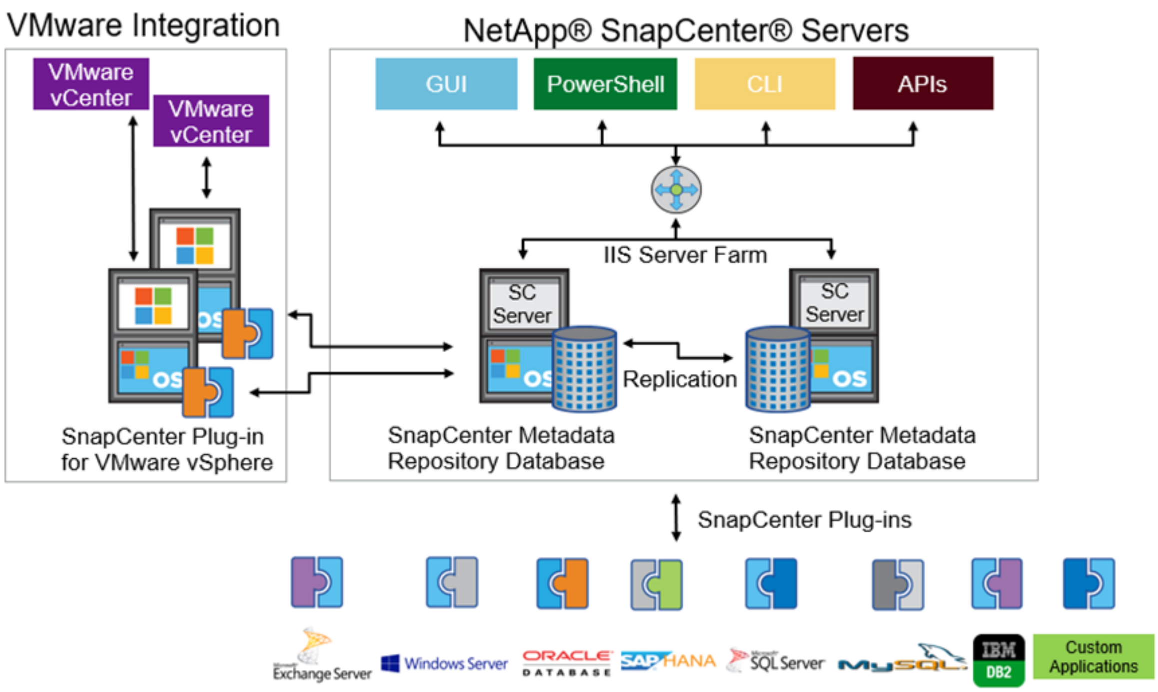
Backup and recovery

FlexPod Datacenter is built on a storage array that is managed by NetApp ONTAP data management software. ONTAP software has evolved over 20 years; it offers many data management features for VMs, Oracle or SQL Server databases, CIFS file shares, and NFS. It also provides protection technology such as NetApp Snapshot™ technology, SnapMirror technology, and NetApp FlexClone data replication technology. NetApp SnapCenter® software has a server and a GUI client to use ONTAP Snapshot, SnapRestore®, and FlexClone features for VM, CIFS file shares, NFS, and Oracle database backup and recovery.

NetApp SnapCenter software employs patented Snapshot technology to instantaneously create a backup of an entire VM or Oracle database on a NetApp storage volume. Compared with Oracle Recovery Manager (RMAN), Snapshot copies don't require a full baseline backup copy, because they are not stored as physical copies of blocks. Snapshot copies are stored as pointers to the storage blocks that exist in the current state of the ONTAP WAFL® file system when the Snapshot copies were created. Because of this tight physical relationship, the Snapshot copies are maintained on the same storage array as the original data. Snapshot copies can also be created at the file level to give you more granular control for the backup.

Snapshot technology is based on a redirect-on-write technique. It initially contains only metadata pointers and doesn't consume much space until the first data change to a storage block. If an existing block is locked by a Snapshot copy, a new block is written by the ONTAP WAFL file system as an active copy. This approach avoids the double-writes that occur with the change-on-write technique (Figure 7).

Figure 7) SnapCenter architecture.



Networking

A pair of Cisco Nexus switches provides redundant paths for IP traffic from compute to storage, and for external clients of an EHR system:

- Link aggregation that uses port channels and vPCs is employed throughout, enabling the design for higher bandwidth and high availability:
  - vPC is used between the NetApp storage array and the Cisco Nexus switches.
  - vPC is used between the Cisco UCS Fabric Interconnect and the Cisco Nexus switches.
  - Each server has virtual network interface cards (vNICs) with redundant connectivity to the Unified Fabric. NIC failover is used between Fabric Interconnects for redundancy.
  - Each server has virtual host bus adapters (vHBAs) with redundant connectivity to the Unified Fabric.
- The Cisco UCS Fabric Interconnects are configured in end-host mode as recommended, providing dynamic pinning of vNICs to uplink switches.
  - An FC storage network is provided by a pair of Cisco MDS switches.

Compute—Cisco Unified Computing System

Two Cisco UCS fabrics through different Fabric Interconnects provide two failure domains. Each fabric is connected to both IP networking switches and to different FC networking switches.

Identical service profiles for each Cisco UCS blade are created as per FlexPod best practices to run VMware ESXi. Each service profile should have the following components:

- Two vNICs (one on each fabric) to carry NFS, CIFS, and client or management traffic
- Additional required VLANs to the vNICs for NFS, CIFS, and client or management traffic
- Two vNICs (one on each fabric) to carry iSCSI traffic

- Two storage FC HBAs (one on each fabric) for FC traffic to storage
- SAN boot

Virtualization

The VMware ESXi host cluster runs workload VMs. The cluster is composed of ESXi instances running on Cisco UCS blade servers.

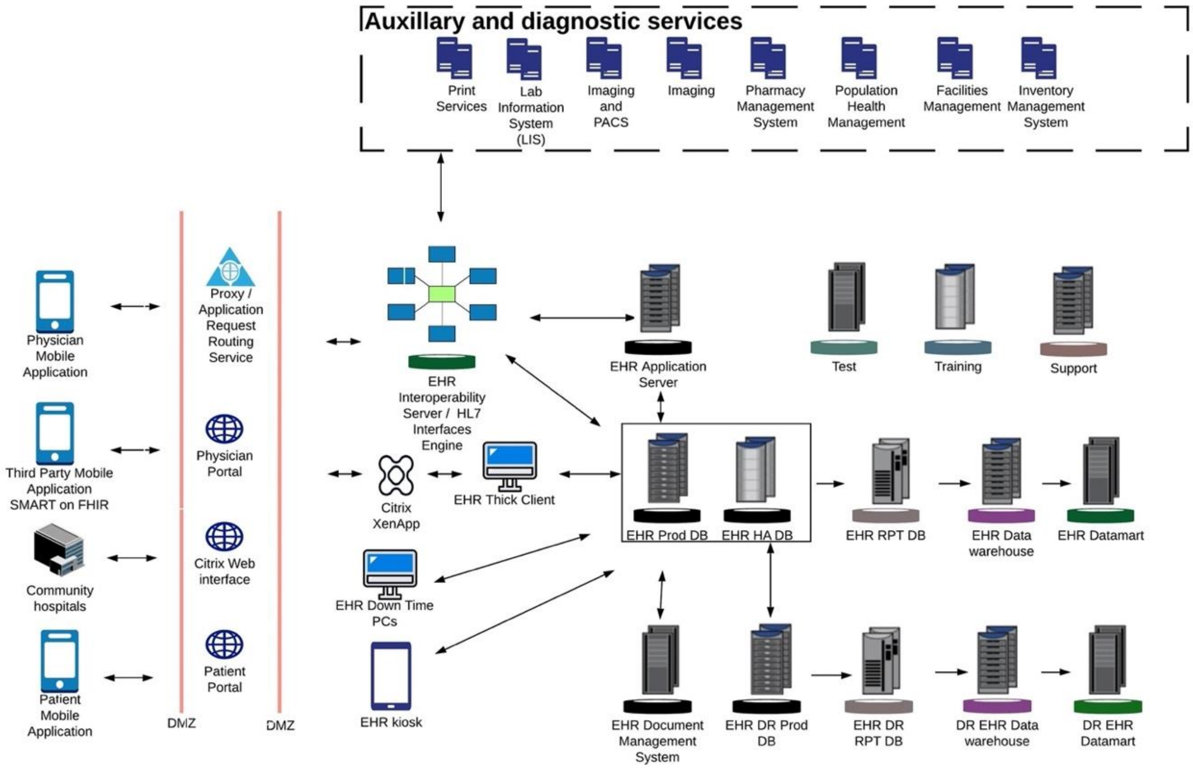
Each ESXi host includes the following network components:

- SAN boot over FC or iSCSI
- Boot LUNs on NetApp storage (in a dedicated FlexVol volume for boot OS)
- Two VMNICs (Cisco UCS vNIC) for NFS, CIFS, or management traffic
- Two storage HBAs (Cisco UCS FC vHBA) for FC traffic to storage
- Standard switch or distributed virtual switch (as needed)
- NFS datastore for workload VMs
- Management, client traffic network, and storage network port groups for VMs
- Network adapter for management, client traffic, and storage access (NFS, iSCSI, or CIFS) for each VM
- VMware DRS enabled
- Native multipathing enabled for FC or iSCSI paths to storage
- VMware snapshots for VM turned off
- NetApp SnapCenter deployed for VMware for VM backups

EHR architecture

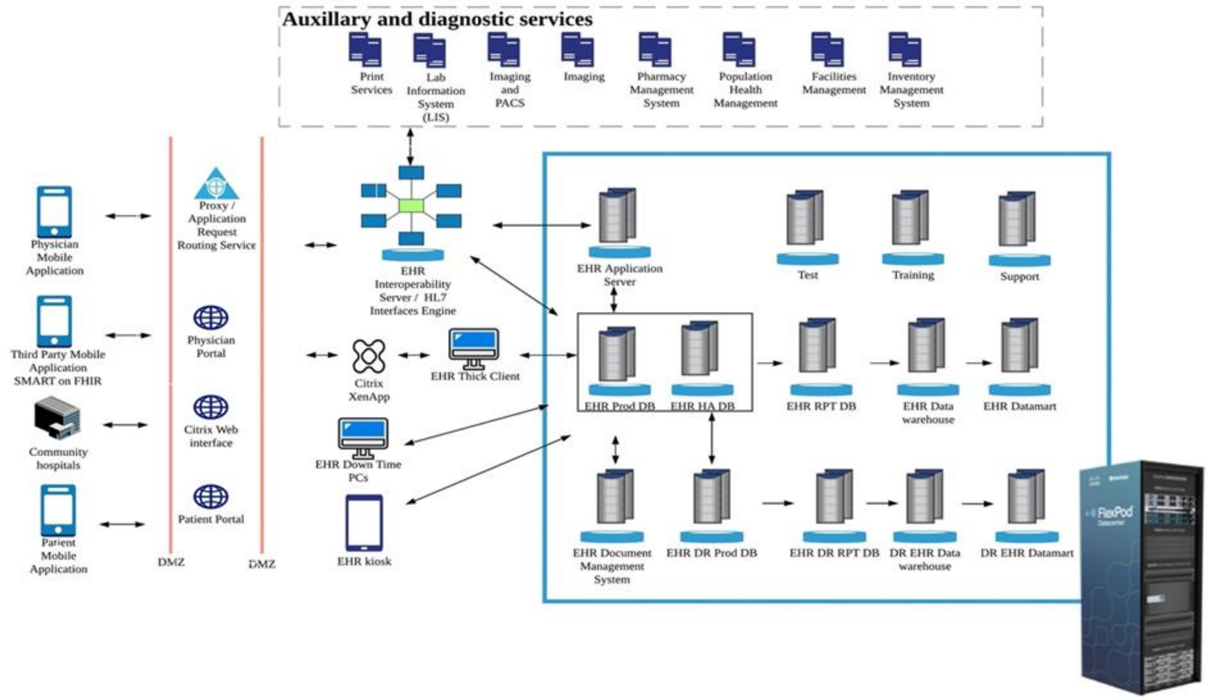
Healthcare organizations tend to have heterogeneous platforms to deploy various components of an EHR system. Depicted in various colors of the data storage below are the various types of storage platforms that healthcare organizations accumulate over a period of time, thus increasing complexity of IT operations exponentially (Figure 8).

Figure 8) EHR architecture components.



With FlexPod, healthcare organizations can deploy all the components of an EHR into a standardized FlexPod platform. Additionally, with FlexPod and NetApp ONTAP QoS and NetApp service level manager (NLSM), healthcare organizations can deploy nonproduction EHR workloads on the FlexPod platform with confidence. NetApp QoS and NLSM has been proven to provide performance that exceeds the minimum requirements of the EHR vendors, as shown in Figure 9.

Figure 9) EHR architecture components deployed on a FlexPod.



Here are the key core application architecture components of an EHR:

EHR application server. Most EHRs use an n-tiered architecture. At the core is an application server, typically either with .Net or Java stack. Application server core application functionality and requires a tier 1 level of performance from the storage platform. NetApp ONTAP delivers the performance needed by using guaranteed QoS. EHR can integrate with third-party software for document scanning. Users control the scanning process from within EHR. After they are captured, scanned documents are captured into the document management server, and document metadata is stored in the EHR database. EHRs typically offer both single and bulk document scanning capabilities.

Core application database server. EHRs have either relational or nonrelational database as the core database for OLTP transactions. Typical relational databases include, but not limited to, Oracle, MS SQL database, and so on. Some EHR applications use nonSQL databases such as InterSystems cache, Mongo DB, and so on. A typical OLTP database requires a high-performing tier 1 storage system. Ensuring availability while also lowering the IT TCO is always a top priority. FlexPod deployed core databases deliver industry-leading storage, unprecedented scalability, continuous data access, and automated data management for immediate responses to business opportunities. NetApp offers an integrated set of data protection capabilities for most code databases that deliver industry-leading reliability. Hospitals have multiple environments where EHR is deployed; the following is a list of those environments:

- Production environment
- HA production environment
- Disaster recovery production environment
- Reporting and business intelligence production environment:
  - Clinical data lake environment
  - Data warehouse environment
  - Datamart environment

- Training environment
- Production support environment
- Release testing environment

It is critical to manage the data refreshes between these various environments in a timely fashion. NetApp solutions for data protection and data replication to the disaster recovery site support both synchronous and asynchronous mirroring. A disaster recovery site can be on-premises, in the cloud, or a hybrid.

- Data protection using NetApp MetroCluster™ high-availability and disaster recovery software
  - For more information, refer to FlexPod MetroCluster IP Solutions.
- Data protection using SnapMirror and SnapCenter
  - For more information, refer to SnapCenter Plug-In for Oracle Database, SnapCenter Plug-In for MS SQL Database.

Table 2 compares MetroCluster and SnapMirror.

Table 2) Differences between MetroCluster and SnapMirror.

	Underlying Technology	Pros	Cons
MetroCluster	Synchronous mirroring of data of the entire cluster across the site	Better RPO, RTO. Distance up to 700KM.	Increased write latency up to 10ms. Replicate entire cluster data.
SnapMirror (SM-S)	Synchronous (SM-S) replication of the selected volume data	Better RPO, RTO. Replication of selected volumes.	Limited to a distance of 150KM. Increased write latency up to 10ms.
SnapMirror Async	Asynchronous replication of the selected volume data	Long-distance replication to another site or cloud. Backup-based replication of selected volumes.	RPO - Only recovery option is from the last replicated Snapshot copy.

Work with your NetApp SME to decide whether MetroCluster or SnapMirror is a good solution for your organization.

For more information about the MetroCluster and SnapMirror disaster recovery options, see the following NetApp technical reports:

- TR-4832: Three-Data-Center Disaster Recovery Using NetApp SnapMirror
- TR-4733: NetApp SnapMirror Synchronous
- TR-4592: Oracle Disaster Recovery with NetApp MetroCluster

For Oracle Database backup, Snapshot copies yield amazing time savings. For example, a backup that took 26 hours to complete by using RMAN alone can take less than two minutes to complete by using SnapCenter software. The key is that actual data restoration does not copy any data blocks, but instead flips the pointers to the application-consistent Snapshot block images when the Snapshot copy was created. Therefore, a Snapshot backup copy can be restored almost instantaneously. SnapCenter cloning creates a separate copy of metadata pointers to an existing Snapshot copy and mounts the new copy to a target host. This process is also fast and storage efficient.

Table 3 summarizes the primary differences between Oracle RMAN and NetApp SnapCenter software.

Table 3) Comparison of backup with Oracle RMAN and with NetApp SnapCenter.

	Backup	Restore	Clone	Need Full Backup	Space Usage	Off-Site Copy
RMAN	Slow	Slow	Slow	Yes	High	Yes
SnapCenter	Fast	Fast	Fast	No	Low	Yes

Enterprise application integration server. This server transports discrete and waveform data from the medical devices into the EHR for verification and filing into the patient's medical record. It requires a tier 1 storage platform, and it typically integrates bedside device monitoring interfaces with the EHR. The integration server is also used to integrate with auxiliary systems in the hospital. Integration servers play a key role in implementing real-time predictive analytics capabilities. Integration servers provide messaging-based integration with other systems in the hospital by using HL7, EDIFACT, X12, SOAP, JSON, DICOM, and so on.

Document imaging server. An EHR typically has a document management component/system that is used to store clinical media like images, video, and so on. According to an industry estimate, clinical data is doubling every 72 days. The huge volumes of imaging data require the data to be stored and made available to various clinical workflows and AI-enabled tools, either on the premises, in the cloud, or in a hybrid configuration. A data fabric delivered by NetApp makes the data available where it's needed. For more information, read the blog, Get in the Fast Lane to Hybrid Cloud with FlexPod.

Archiving large volumes of data is a challenge for healthcare organizations. Tier 2 storage would be appropriate for the new images, and archive tier storage would be appropriate for archiving images after some time. NetApp ONTAP FabricPool helps reduce storage costs without compromising performance, efficiency, security, or protection. FabricPool is transparent to enterprise applications and capitalizes on cloud efficiencies by lowering storage TCO without having to rearchitect the application infrastructure. FlexPod can benefit from the storage tiering capabilities of FabricPool to make more efficient use of ONTAP flash storage. For more information, read the NetApp technical report, TR-4801: FlexPod with FabricPool.

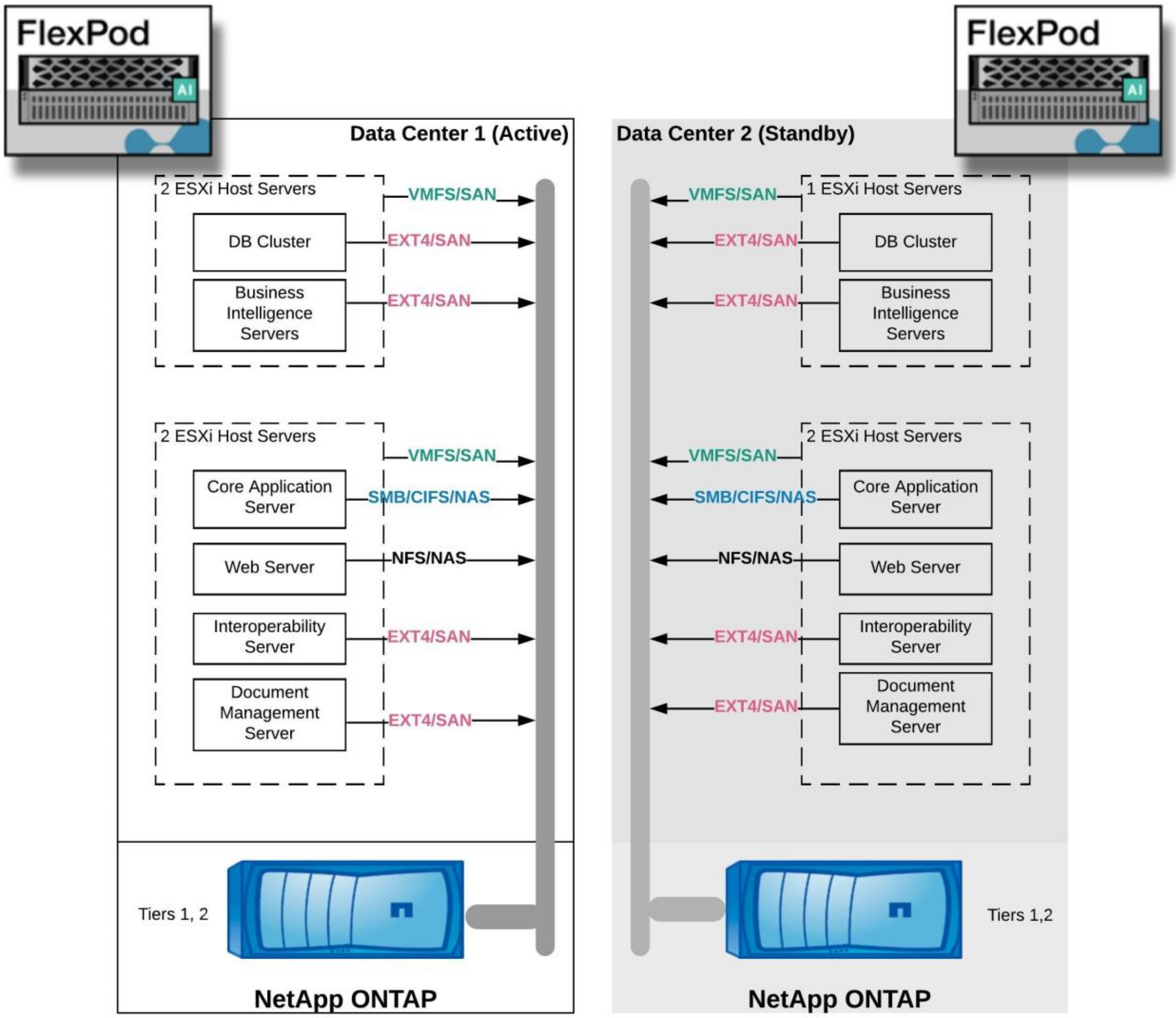
EHR thick client application. End users of the EHR system can access the application through the Citrix web interface. The EHR Windows thick client application is deployed as a Citrix XenApp application on the Citrix farm servers. As the number of telemedicine encounters increases with COVID-19, the EHR thick client is a good candidate to deploy as a virtual desktop infrastructure (VDI). For more information about the advantages of deploying VDI, see Top Five Reasons for FlexPod VDI: Digitally Transform Your Desktops.

Here are the key benefits of deploying the EHR Windows thick client application using NetApp FlexPod VDI solutions:

- Scale end-user compute device capacity quickly and easily without disruption.
- Securely increase scalability, agility, and reliability.
- Harness a software-defined experience for both IT and end users.
- Deploy a high-performance VDI solution with confidence.

EHR business continuity solution. The EHR business continuity solution is used if the EHR application becomes unavailable. Business continuity becomes critical during a down time, hence this capability is also called downtime PC. Downtime PC has a local copy of the patient's chart, usually data that was taken a few minutes (approximately three minutes) prior to the downtime, as shown on Figure 10.

Figure 10) EHR infrastructure architecture.



NetApp ONTAP on a single FlexPod system can support a wide variety of file systems. Also, ONTAP using QoS can support multiple storage tiers from a single FlexPod system.

Solution infrastructure hardware and software components

Table 4 and Table 5 list the hardware and software components respectively for FlexPod infrastructure to deploy an EHR system. The recommendations in these tables are examples; you should work with your NetApp SME to make sure that the components are suitable for your organization. Also, make sure that the components and versions are supported in the NetApp Interoperability Matrix Tool (IMT) and Cisco Hardware Compatibility List (HCL).

Table 4) Infrastructure hardware.

Layer	Product Family	Quantity and Model	Details
Compute	Cisco UCS 5108 chassis	1 or 2	Based on the number of blades required to support the number of annual studies
	Cisco UCS blade servers	B200 M5	Number of blades based on the number of annual studies Each with 2x 20 or more cores, 2.7GHz, and 128-384GB RAM
	Cisco UCS Virtual Interface Card (VIC)	Cisco UCS 1440	See the Cisco Interoperability Matrix
	2 x Cisco UCS Fabric Interconnects	6454 or later	–
Network	Cisco Nexus switches	2x Cisco Nexus 3000 Series or 9000 Series	–
Storage network	IP network for storage access over SMB/CIFS, NFS, or iSCSI protocols	Same network switches as above	–
	Storage access over FC	2x Cisco MDS 9132T	–
Storage	NetApp AFF A400 all-flash storage system	One or more HA pair	Cluster with two or more nodes
	Disk shelf	One or more DS224C or NS224 disk shelves	Fully populated with 24 drives
	SSD	>24, 1.2TB or larger capacity	–

Table 5) Infrastructure software.

Software	Product Family	Version or Release	Details
EHR	EHR	As suggested by EHR vendor	–
	Oracle Database Server	As suggested by EHR vendor	–
	IBM WebSphere	As suggested by EHR vendor	–
	Sonic MQ	As suggested by EHR vendor	–
	MS SQL	As suggested by EHR vendor	–
	Linux	Oracle Linux (64 bit), CentOS (64 bit)	–
	Windows	Windows Server 2012 R2 (64 bit)	–
Storage	NetApp ONTAP	ONTAP 9.7 or later	–
Network	Cisco UCS Fabric Interconnect	Cisco UCS Manager 4.1 or later	–

Software	Product Family	Version or Release	Details
	Cisco Ethernet 3000 or 9000 series switches	For 9000 series, 7.0(3)I7(7) or later For 3000 series, 9.2(4) or later	–
	Cisco FC: Cisco MDS 9132T	8.4(1a) or later	–
Hypervisor	Hypervisor	VMware vSphere ESXi 6.7 U2 or later	–
Management	Hypervisor management system	VMware vCenter Server 6.7 U3 (vCSA) or later	–
	NetApp Virtual Storage Console (VSC)	VSC 9.7 or later	–
	NetApp SnapCenter	SnapCenter 4.3 or later	–
	Cisco UCS Manager	4.1(1c) or later	–

Solution sizing

This section offers directional sizing guidance to enable a starting point for discussing infrastructure requirements. Healthcare organization requirements differ vastly from one to another. Work with your NetApp SME to understand sizing requirements for your healthcare organization and to work toward optimal FlexPod configuration.

Size of the healthcare organization and platform sizing

Healthcare organizations can be classified to size the platform at a high level. Accountable care organizations (ACOs) are groups of doctors, hospitals, and other health care providers who come together voluntarily to give coordinated high-quality care to their Medicare patients. Healthcare organizations can be broadly classified by using standards-based methods that help programs such as ACOs. One such classification uses the concept of a clinically integrated network (CIN). A CIN is a group of hospitals that work together and adhere to proven standard clinical protocols and pathways to improve patient care and to decrease the cost to patients. Hospitals in a CIN have controls and practices in place to onboard only physicians who follow the core values of the CIN. Following these principles, healthcare organizations can be classified into small, medium, and large.

Small healthcare organizations

A healthcare organization is small if it includes only a single hospital with ambulatory clinics and an inpatient department, but is not part of a CIN. Physicians work as caregivers and coordinate patient care on a care continuum. These small organizations typically include physician-operated facilities. They might or might not offer emergency and trauma care as integrated care for the patient. Typically, a small-size healthcare organization has fewer than 200 beds and supports about 100,000 clinical patient encounters annually.

Medium healthcare organizations

A medium-size healthcare organization includes multiple hospital systems with focused organizations, such as:

- Adult care clinics and adult inpatient hospitals
- Labor and delivery departments
- Childcare clinics and child inpatient hospitals

- A cancer treatment center
- Adult emergency departments
- Child emergency departments
- A family medicine and primary care office
- An adult trauma care center
- A child trauma care center

In a medium-size healthcare organization, physicians follow the principles of a CIN and operate as a single unit. Hospitals have separate hospital, physician, and pharmacy billing functions. Hospitals might be associated with academic research institutes and perform interventional clinical research and trials. A medium-size healthcare organization performs as many as 500,000 clinical patient encounters annually.

Large healthcare organizations

Large healthcare organizations include the traits of a medium-size healthcare organization and offer the medium-size clinical capabilities to the community in multiple geographical locations.

A large healthcare organization typically performs these functions:

- Has a central office to manage the overall functions
- Participates in joint ventures with other hospitals
- Negotiates rates with payer organizations annually
- Negotiates payer rates by state and region
- Participates in Meaningful Use programs
- Performs advanced clinical research across population health cohorts by using standards-based population health management tools
- Performs up to 1 million clinical encounters annually

Some large healthcare organizations that participate in a CIN also have AI-based imaging reading capabilities. These organizations might perform 1 million to 2 million clinical patient encounters annually.

Note: The following sizing guidelines are for the primary and disaster recovery sites.

Storage sizing

This section describes the number of encounters and their corresponding infrastructure requirements.

Actual EHR data storage tiering requirements are not available at the time of this report. To help provide a better understanding of the storage platform, this section uses generic storage tiering definitions.

The storage requirements in Table 6 assume that existing data is one year’s worth plus projected growth for one year of encounters in the primary system (tier 1). Additional storage needs for projected growth for three years (beyond the first two years) are listed separately.

Table 6) Summary of storage requirements.

	Small <250K Patient Encounters	Medium 250K–500K Patient Encounters	Large 500K–1 Million Patient Encounters
IOPS (average)	30K	75K	150K
Capacity data center 1 (tiers 1, 2) for year 1 + 4 years	480TB	1200TB	2100TB
Capacity data center 2 (tiers 1, 2) for year 1 + 4 years	480TB	1000TB	2000TB

Compute sizing

Table 7 lists the compute requirements for small, medium, and large EHR systems.

Table 7) Summary of compute requirements.

	Small <250K Patient Encounters	Medium 250K–500K Patient Encounters	Large 500K–1 Million Patient Encounters
Data center 1 (primary site)			
Number of VMs	40	60	120
Total virtual CPU (vCPU) count	180	348	716
Total memory requirement	552GB	824GB	2344GB
Physical server (blades) specs (assume 1 vCPU = 1 core)	6 servers with 40 cores and 128GB RAM each	8 servers with 56 cores and 160GB RAM each	12 servers, with 56 cores and 256GB RAM each
Data center 2 (disaster recovery site) Able to run the workload with same performance as primary. Server specs can be adjusted if the DR site can be operated with lower load and performance.			
Number of VMs	40	60	120
Total virtual CPU (vCPU) count	180	348	716
Total memory requirement	552GB	824GB	2344GB
Physical server (blades) specs (assume 1 vCPU = 1 core)	6 servers with 40 cores and 128GB RAM each	8 servers with 56 cores and 160GB RAM each	12 servers with 56 cores and 256GB RAM each

Networking and Cisco UCS infrastructure sizing

Table 8 lists the networking and Cisco UCS infrastructure requirements for small, medium, and large EHR system.

Table 8) Compute and network sizing summary.

	Small <250K Patient Encounters	Medium 250K–500K Patient Encounters	Large 500K–1 Million Patient Encounters
Data center 1 (primary site)			
Cisco UCS chassis count	1x 5108	1x 5108	2x 5108
Cisco UCS Fabric Interconnect	2x 6332/6454/ 64108	2x 6332/6454/64108	2x 6332/6454/64108
Number of ports on NetApp storage nodes	2 converged network adapters (CNAs); 2 FCs	2 CNAs; 2 FCs	2 CNAs; 2 FCs
IP network switch ports (Cisco Nexus 9000)	48-port switch	48-port switch	48-port switch
FC switch (Cisco MDS)	32-port switch	32-port switch	48-port switch
Data center 2 (disaster recovery site)			

	Small <250K Patient Encounters	Medium 250K–500K Patient Encounters	Large 500K–1 Million Patient Encounters
Cisco UCS chassis count	1x 5108	1x 5108	1x 5108
Cisco UCS Fabric Interconnect	2x 6332/6454/64108	2 x 6332/6454/64108	2x 6332/6454/64108
Number of ports on NetApp storage nodes	2 CNAs; 2 FCs	2 CNAs; 2 FCs	2 CNAs; 2 FCs
IP network switch ports (Cisco Nexus 9000)	48-port switch	48-port switch	48-port switch
FC switch (Cisco MDS)	32-port switch	32-port switch	48-port switch

Best practices

NetApp and Cisco recommend the best practices described in this section for the design and deployment of the infrastructure for EHR, and for high availability, security, and optimal performance.

Storage best practices

High availability

The NetApp storage cluster design provides high availability at every level: cluster nodes, back-end storage connectivity, NetApp RAID DP® that can sustain two disk failures, physical connectivity to two physical networks from each node, and multiple data paths to storage LUNs and volumes.

Secure multitenancy

NetApp SVMs provide a virtual storage array construct to separate your security domain, policies, and virtual networking. NetApp recommends that you create separate SVMs for each tenant organization that hosts data on the storage cluster.

NetApp storage best practices

Consider the following NetApp storage best practices:

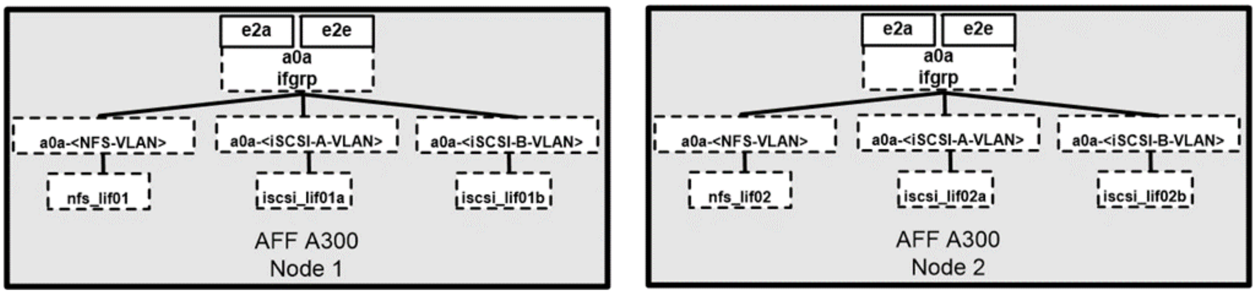
- Always enable NetApp AutoSupport® technology, which sends support summary information to NetApp through HTTPS.
- For maximum availability and mobility, make sure that a LIF is created for each SVM on each node in the NetApp ONTAP cluster. Asymmetric logical unit access (ALUA) is used to parse paths and to identify active optimized (direct) paths versus active nonoptimized paths. ALUA is used for both FC and FCoE and iSCSI.
- A volume that contains only LUNs does not need to be internally mounted at all, and a junction path is not needed for such a volume.
- If you use the Challenge-Handshake Authentication Protocol (CHAP) in ESXi for target authentication, you must also configure it in ONTAP. Use the CLI (`vserver iscsi security create`) or NetApp ONTAP System Manager (edit Initiator Security under Storage > SVMs > SVM Settings > Protocols > iSCSI).

SAN boot

NetApp recommends that you implement SAN boot for Cisco UCS Servers in the FlexPod Datacenter solution. This step enables the operating system to be safely secured by the NetApp AFF storage system, providing better performance. The design that is outlined in this solution uses iSCSI SAN boot.

In iSCSI SAN boot, each Cisco UCS Server is assigned two iSCSI vNICs (one for each SAN fabric), which provide redundant connectivity all the way to the storage. The storage ports in this example, e2a and e2e, which are connected to the Cisco Nexus switches, are grouped together to form one logical port called an interface group (ifgrp)—in this example, a0a. The iSCSI VLANs are created on the igroup, and the iSCSI LIFs are created on iSCSI port groups—in this example, a0a-<iSCSI-A-VLAN>. The iSCSI boot LUN is exposed to the servers through the iSCSI LIF by using igroups. This approach enables only the authorized server to have access to the boot LUN. For the port and LIF layout, see Figure 11.

Figure 11) iSCSI SVM port and LIF layout.



Unlike NAS network interfaces, the SAN network interfaces are not configured to fail over during a failure. Instead, if a network interface becomes unavailable, the host chooses a new optimized path to an available network interface. ALUA, a standard that is supported by NetApp, provides information about SCSI targets, which enables a host to identify the best path to the storage.

Storage efficiency and thin provisioning

NetApp leads the industry in storage efficiency innovation, such as with the first deduplication for primary workloads and with inline data compaction, which enhances compression and stores small files and I/Os efficiently. ONTAP supports both inline and background deduplication, as well as inline and background compression.

To realize the benefits of deduplication in a block environment, the LUNs must be thin provisioned. Although the VM administrator still sees the LUN as taking the provisioned capacity, the deduplication savings are returned to the volume to be used for other needs. NetApp recommends that you deploy these LUNs in FlexVol volumes that are also thin provisioned with a capacity that is twice the size of the LUN. When you deploy the LUN that way, the FlexVol volume acts merely as a quota. The storage that the LUN consumes is reported in the FlexVol volume and its containing aggregate.

For maximum deduplication savings, consider scheduling background deduplication. However, these processes use system resources when they’re running. So ideally, you should schedule them during less active times, such as weekends, or run them more frequently to reduce the amount of changed data to be processed. Automatic background deduplication on AFF systems has much less impact on foreground activities. Background compression (for hard-disk–based systems) also consumes resources, so you should consider it only for secondary workloads with limited performance requirements.

Quality of service

Systems that run ONTAP software can use the ONTAP storage QoS feature to limit throughput in megabits per second (Mbps) and to limit IOPS for different storage objects such as files, LUNs, volumes, or entire SVMs. Adaptive QoS is used to set an IOPS floor (QoS minimum) and ceiling (QoS maximum), which adjust dynamically based on the datastore capacity and used space.

Throughput limits are useful for controlling unknown or test workloads before a deployment to confirm that they don't affect other workloads. You might also use these limits to constrain a bully workload after it has been identified. Minimum levels of service based on IOPS are also supported to provide consistent performance for SAN objects in ONTAP.

With an NFS datastore, a QoS policy can be applied to the entire FlexVol volume or to individual Virtual Machine Disk (VMDK) files within it. With VMFS datastores (Cluster Shared Volumes [CSV] in Hyper-V) that use ONTAP LUNs, you can apply the QoS policies to the FlexVol volume that contains the LUNs or to the individual LUNs. However, because ONTAP has no awareness of the VMFS, you cannot apply the QoS policies to individual VMDK files. When you use VMware Virtual Volumes (VVols) with VSC 7.1 or later, you can set maximum QoS on individual VMs by using the storage capability profile.

To assign a QoS policy to a LUN, including VMFS or CSV, you can obtain the ONTAP SVM (displayed as Vserver), LUN path, and serial number from the Storage Systems menu on the VSC home page. Select the storage system (SVM), then Related Objects > SAN. Use this approach when you specify QoS by using one of the ONTAP tools.

You can set the QoS maximum throughput limit on an object in MBps and in IOPS. If you use both, the first limit that is reached is enforced by ONTAP. A workload can contain multiple objects, and a QoS policy can be applied to one or more workloads. When you apply a policy to multiple workloads, the workloads share the total limit of the policy. Nested objects are not supported; for example, for a file within a volume, they cannot each have their own policy. QoS minimums can be set only in IOPS.

Storage layout

This section describes best practices for layout of LUNs, volumes, and aggregates on storage.

Storage LUNs

For optimal performance, management, and backup, NetApp recommends the following LUN design best practices:

- Create a separate LUN to store database data and log files.
- Create a separate LUN for each instance to store Oracle Database log backups. The LUNs can be part of the same volume.
- Provision LUNs with thin provisioning (disable the Space Reservation option) for database files and log files.
- All imaging data is hosted in FC LUNs. Create these LUNs in FlexVol volumes that are spread across the aggregates that are owned by different storage controller nodes.

For placement of the LUNs in a storage volume, follow the guidelines in the next section.

Storage volumes

For optimal performance, management, and backup operations, NetApp recommends the following volume design best practices:

- Isolate databases and their respective tables with I/O-intensive queries throughout the day in different volumes and eventually have separate jobs to back them up.
- For faster recovery, place large databases and databases that have minimal recovery time objectives (RTOs) in separate volumes.
- Consolidate into a single volume your small-to-medium-size databases that are less crucial or that have fewer I/O requirements. When you back up a large number of databases that reside in the same volume, fewer Snapshot copies need to be maintained. NetApp also recommends that you

consolidate Oracle Database server instances to use the same volumes to control the number of backup Snapshot copies that are created.

- For database replicas, place the data and log files for replicas in an identical folder structure on all nodes.
- Place database files in a single FlexVol volume; don't spread them across volumes.
- When appropriate, configure a volume auto size policy to help prevent out-of-space conditions.
- If the database I/O profile consists mostly of large sequential reads, such as with decision support system workloads, enable read reallocation on the volume. Read reallocation optimizes the blocks for better performance.
- For ease of monitoring from an operational perspective, set the Snapshot copy reserve value in the volume to zero.
- Disable storage Snapshot copy schedules and retention policies. Instead, use the NetApp SnapCenter Plug-In for Oracle Database to coordinate Snapshot copies of the Oracle data volumes.
- Place user data files and log files on separate FlexVol volumes so that appropriate QoS can be configured for the respective volumes and so that different backup schedules can be created.

Aggregates

Aggregates are the primary storage containers for NetApp storage configurations; they contain one or more RAID groups that consist of both data disks and parity disks.

NetApp performed various I/O workload characterization tests by using shared and dedicated aggregates with data files and transaction log files separated. The tests show that one large aggregate with more RAID groups and drives (HDDs or SSDs) optimizes and improves storage performance and is easier for administrators to manage for two reasons:

- One large aggregate makes the I/O abilities of all drives available to all files.
- One large aggregate enables the most efficient use of disk space.

For effective disaster recovery, place the asynchronous replica on an aggregate that is part of a separate storage cluster in your disaster recovery site and use SnapMirror technology to replicate content.

For optimal storage performance, NetApp recommends that you have at least 10% free space available in an aggregate.

Storage aggregate layout guidance for AFF A400 systems (with 2 disk shelves with 24 drives) includes:

- Keep two spare drives.
- Use Advanced Drive Partitioning to create three partitions on each drive, root, and data.
- Use a total of 20 data partitions and two parity partitions for each aggregate.

Backup best practices

NetApp SnapCenter is used for VM and database backups. NetApp recommends the following backup best practices:

- When SnapCenter is deployed to create Snapshot copies for backups, turn off the Snapshot schedule for the FlexVol volume that host VMs and application data.
- Create a dedicated FlexVol volume for host boot LUNs.
- Use a similar or a single backup policy for VMs that serve the same purpose.
- Use a similar or a single backup policy per workload type; for example, use a similar policy for all database workloads. Use different policies for databases, web servers, end-user virtual desktops, and so on.
- Enable verification of the backup in SnapCenter.

- Configure archiving of the backup Snapshot copies to the NetApp SnapVault® backup solution.
- Configure retention of the backups on primary storage based on the archiving schedule.

Networking best practices

NetApp recommends the following networking best practices:

- Make sure that your system includes redundant physical NICs for production and storage traffic.
- Use separate VLANs for iSCSI, NFS, and CIFS traffic between compute and storage.

For additional networking best practices, see the FlexPod infrastructure design and deployment guides.

Compute best practices

NetApp recommends the following compute best practice:

- Make sure that each specified vCPU is supported by a physical core, for more specific on use cases like VDI, please work with your FlexPod SME.

Virtualization best practices

NetApp recommends the following virtualization best practices:

- Use VMware vSphere 6 or later.
- Create backups during off-peak hours.

EHR best practices

NetApp recommends the following EHR best practices:

- Deploy the production EHR components such as the core application, integration server, core database server, document management server on highly available infrastructure.
- Use Red Hat Enterprise Linux operating system on an x64-bit compute platform.
- Deploy the application database in active-passive mode with a separate reporting database.
- Keep the messaging server queue connections and queues open instead of repeatedly opening and closing, connecting and disconnecting.
- EHR end-user application is a thick client application that runs on the Windows 10 OS (or something similar).
- Use of secure remote connectivity and administration capabilities for support and monitoring activities.
- Implement a weekly database health check through appropriate monitoring tools.
- For healthcare organizations, use Citrix Provisioning Services (or something similar) to manage virtualized desktop environments.
- Implement business continuity solutions and test them periodically.
- For healthcare organizations, use a read-only environment for downtimes lasting one to four hours.
- For downtimes that last longer than four hours, use a disaster recovery failover site.

Conclusion

By running an EHR environment on FlexPod, your healthcare organization can expect to see an improvement in staff productivity and a decrease in capital and operating expenses. FlexPod provides a prevalidated, rigorously tested converged infrastructure from the strategic partnership of Cisco and NetApp. A FlexPod system engineered and designed to deliver predictable low-latency system performance and high availability. This approach results in a superior user experience and optimal response time for users of an EHR system.

Different components of an EHR system require data storage in CIFS, NFS, Ext4, and NTFS file systems. Therefore, your infrastructure must provide data access over NFS, CIFS, and SAN protocols. NetApp storage systems support these protocols from a single storage array.

High availability, storage efficiency, Snapshot copy-based scheduled fast backups, fast restore operations, data replication for disaster recovery, and the FlexPod storage infrastructure capabilities together provide an industry-leading data storage and management system.

Where to find additional information

To learn more about the information that is described in this document, review the following documents and websites:

- Data Now: Improving Performance in Epic EHR Environments with Cloud-Connected Flash Technology
  https://www.netapp.com/media/10809-cloud-connected-flash-wp.pdf
- FlexPod Datacenter for Epic EHR Infrastructure
  https://www.netapp.com/pdf.html?item=/media/17061-ds-3683.pdf
- FlexPod Datacenter for Epic EHR Deployment Guide
  https://www.netapp.com/media/10658-tr-4693.pdf
- FlexPod Datacenter Infrastructure for MEDITECH Software
  https://www.netapp.com/media/8552-flexpod-for-meditech-software.pdf
- The FlexPod Standard Extends to MEDITECH Software
  https://blog.netapp.com/the-flexpod-standard-extends-to-meditech-software/
- FlexPod for MEDITECH Directional Sizing Guide
  https://www.netapp.com/pdf.html?item=/media/12429-tr4774.pdf
- FlexPod for medical imaging
  https://www.netapp.com/media/19793-tr-4865.pdf
- AI in Healthcare
  https://www.netapp.com/us/media/na-369.pdf
- FlexPod for healthcare Ease Your Transformation
  https://flexpod.com/solutions/verticals/healthcare/
- Oracle Databases on ONTAP Cloud with Microsoft Azure
  https://www.netapp.com/us/media/tr-4691.pdf
- FlexPod Datacenter Infrastructure with VMware vSphere 6.7 U1, Cisco UCS 4th Generation, and NetApp AFF A-Series
  https://www.cisco.com/c/en/us/td/docs/unified_computing/ucs/UCS_CVDs/flexpod_datacenter_vmware_netappaffa.html
- FlexPod Datacenter for Microsoft SQL Server 2019 and VMware vSphere 6.7
  https://www.cisco.com/c/en/us/td/docs/unified_computing/ucs/UCS_CVDs/mssql2019_flexpod.html
- FlexPod Datacenter Oracle Database Backup with SnapCenter Solution Brief
  https://www.netapp.com/us/media/sb-3999.pdf
- FlexPod Datacenter with Oracle RAC Databases on Cisco UCS and NetApp AFF A-Series
  https://www.cisco.com/c/en/us/td/docs/unified_computing/ucs/UCS_CVDs/flexpod_orc12cr2_affaseries.html
- FlexPod Datacenter with Oracle RAC on Oracle Linux
  https://www.cisco.com/c/en/us/td/docs/unified_computing/ucs/UCS_CVDs/flexpod_orcrac_12c_bm.html

- FlexPod from Cisco and NetApp
  https://flexpod.com/
- TR-4700: SnapCenter Plug-In for Oracle Database
  https://www.netapp.com/us/media/tr-4700.pdf
- NetApp Product Documentation
  https://www.netapp.com/us/documentation/index.aspx
- FlexPod Datacenter with Oracle Real Application Clusters 12c Release 1 and NetApp All Flash FAS
  https://www.netapp.com/us/media/tr-4552.pdf
- ONTAP Recipes: Easily Create an Oracle RAC Application on SAN
  https://community.netapp.com/t5/ONTAP-Recipes/ONTAP-Recipes-Easily-create-an-Oracle-RAC-Application-on-SAN/td-p/132293
- FlexPod Datacenter with Citrix XenDesktop/XenApp 7.15 and VMware vSphere 6.5 Update 1 for 6000 Seats

  https://www.cisco.com/c/en/us/td/docs/unified_computing/ucs/UCS_CVDs/cisco_ucs_xd715esxi65u1_flexpod.html#_Toc517798387

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Disclaimer

This technical report details NetApp's knowledge on and experience with best practices for deploying an EHR on FlexPod Datacenter. There was no specific EHR vendor that was consulted for testing performance of the proposed FlexPod architecture for optimal operation of an EHR. EHR vendors have not made any recommendation or endorsement regarding this paper.

Version history

Version	Date	Document Version History
Version 1.0	December 2020	Initial release.
Version 2.0	December 2020	Cisco Review Completed
Version 3.0	December 2020	Nikhil's Review Completed
Version 3.0	January 2021	Brian Pruitt Review Completed

Refer to the Interoperability Matrix Tool (IMT) on the NetApp Support site to validate that the exact product and feature versions described in this document are supported for your specific environment. The NetApp IMT defines the product components and versions that can be used to construct configurations that are supported by NetApp. Specific results depend on each customer's installation in accordance with published specifications.

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