



Connected Imaging—Medical Image Architecture 2.0 Application Design Guide

Cisco Validated Design

February 4, 2009

Introduction

This document is intended to provide information on the implementation and configuration for the Connected Imaging—Medical Image Infrastructure solution for healthcare.

Intended Audience

The target audience for this solution is new and existing healthcare providers.

It is assumed that administrators of Connected Imaging—Medical Image Infrastructure have experience with installation and acceptance of the products covered by this network design. In addition, it is assumed that the administrator understands the procedures required to upgrade and troubleshoot networks at a basic level.

Typical users of this guide include the follow groups:

- Customers with technical staff experienced enough to perform the installation and configuration of the elements required for this solution
- Cisco SEs and Advanced Services personnel assisting customers with the implementation of the elements required for this solution
- Service Integrators and Cisco Partners assisting customers with the implementation of the elements required for this solution
- System administrators who are responsible for installing and configuring internetworking equipment, and who are familiar with Cisco IOS



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Solution Overview

Executive Summary

The Connected Imaging—Medical Image Infrastructure solution is based on the Cisco and partner technologies that provide a highly available and scalable infrastructure to support the various Picture Archive Communication System (PACS) used today. The Connected Imaging—Medical Image Infrastructure solution addresses scalability, application, and storage performance challenges with advanced networking, image routing, and storage technologies. This portion of the end-to-end image management solution improves image availability, and provides outstanding storage performance at low cost. Through the Cisco Medical-Grade Network (MGN), the Cisco Connected Imaging solution provides scalable imaging services and increases PACS performance, to manage today's high-bandwidth images. It supports centralized image storage for quick image access and retrieval across a distributed storage environment.

The applications of these products are produced through direct consultation with radiology or imaging services providers to address many key concerns as the growth and complexity of imaging services increases exponentially. By addressing these issues, CI can provide direct value to clinical leadership and have the clinical leadership include advanced infrastructure technologies in imaging services budgets.

Solution Description

PACS is at the core of medical image management. PACS is comprised of a cluster of application, database and web servers. The PACS architecture will dictate the quantity and function of the servers, but they will all require high availability, typically greater than 99.99%. When more than a single PACS server and/or multiple modalities are present, a situation is created where it is often difficult to provide high availability and fault tolerance.

By coupling Cisco core technologies with DICOM Services Grid™ software from Acuo Technologies® we can effectively enhance image management performance. The AcuoMed™ Image Manager is a secure, open-system software solution for transporting, storing, tracking and retrieving digital images across an entire storage system network. It is a DICOM 3.0 Level 2 compliant solution which uses Microsoft Windows® 2000, 2003 Server or Microsoft Windows® XP Professional on a recommended AMD platform. AcuoMed™ works in conjunction with AcuoStore™, a digital asset manager. AcuoStore™ serves as a digital vault, communicating the instructions of AcuoMed™ with the diverse DICOM storage devices in which digital DICOM image and patient information is contained.

Each Acuo system works in concert with other DICOM devices to create local intelligent workflow using its dynamic router, enabling a single view of the entire DICOM network through its peer-aware collaboration feature. Acuo's Next Generation technology offers local caching of image data, seamless integration of legacy data and interoperability with the available information systems for real-time image reconciliation and RIS/PACS synchronization.

There are 3 deployment options of the solution available. All 3 options provide optimized traffic Routing using DICOM Services Grid™ software from Acuo Technologies® as well as dynamic load balancing and stateful failover providing high availability and increased performance. With the addition of the Cisco ACE module and WAAS services, the solution can easily support a large Data Center or multi-site implementation.

Deployment Option 1 (Version 1.0)

In Version 1, sitting in front of these DICOM routers (DICOM Services Grid™) is the Cisco Content Services Switch which dynamically load balances the traffic between the DICOM routers in the grid. This is accomplished through the use of the Acuo Load Optimizer, which monitors the work queues on each DICOM router and sends updates to the Cisco Content Services Switch when a particular router is loaded beyond a pre-defined threshold. When this happens, the Cisco Content Services Switch lowers the weight of that particular router and sends the data to one of the others in the configuration.

Version 1 is intended to enhance operations in a clinic or remote radiology site or small to mid-size hospitals.

Deployment Options 2 and 3 (Version 2.0)

In Version 2, the Cisco Application Control Engine (ACE) module/appliance is added to the overall solution to create a more robust service offering. In the solution testbed, the ACE module was inserted into the Cisco 6500 Catalyst switch to provide the load balancing functionality for data center type deployments. The Cisco ACE module dynamically load balances the traffic between the DICOM routers in the grid. This is accomplished through the use of the Acuo Load Optimizer, which monitors the work queues on each DICOM router and sends updates to the Cisco Content Services Switch when a particular router is loaded beyond a pre-defined threshold. When this happens, the Cisco ACE module lowers the weight of that particular router and sends the data to one of the others in the configuration.

For more information on the ACE module, refer to the following URL:

http://www/en/US/products/ps6906/tsd_products_support_model_home.html

In addition, the Cisco Wide-area Application Engine (WAE) is also added to the Version 2 configuration. The WAE is part of Cisco Wide Area Application Services (WAAS), which includes best of breed caching, compression and protocol optimizations technology that overcome bandwidth and latency limitations associated with TCP/IP and client-server protocols.

Cisco WAAS is an application acceleration and WAN optimization solution for the branch office, remote clinic or remote data center that improves the performance of any TCP-based application operating in a WAN environment. With Cisco WAAS, IT organizations can consolidate PACS deep archive servers and storage into centrally managed data centers, and deploy PACs storage systems directly from a data center, while offering LAN-like application performance for the remote users. For more information about the Cisco WAAS, refer to the following URL:

http://www/en/US/products/ps5680/Products_Sub_Category_Home.html

Version 2 is intended for enterprise or multi-site customers looking to centralize their imaging operations and enhance the scalability and performance of their existing implementation. Three different deployment models are included, each intended to enhance operations in a clinic or remote radiology site, or small to mid-size hospitals.

The dynamic load-balancing integration between the Cisco Content Services Switch or the Cisco ACE and the Acuo DICOM routers makes this solution unique in the healthcare market.

Target Market

This solution has three deployment options. While the Medical Image Infrastructure Deployment Option 1 (Version 1.0) focused on small to medium size hospitals and radiology clinics, deployment Options 2 and 3 (Version 2.0) is targeted at large clinics, enterprise, and multi-site hospitals.

For this solution, the size of the hospital is based upon the number of modalities, size of the images scanned, number of images /exam and the exams per year. The following numbers are averages based upon feedback from organizations that reflect the sizing for each. The following shows the approximate number of modalities and images per year for each size hospital or clinic. For details on how these numbers were conceived, please see Sec. 5.2 for more information.

Small Hospital or Remote Clinic:

- 11 Modalities
- 100,000 Exams / Year

Mid-Size Hospital or Large Clinic

- 28 Modalities
- 300,000 Exams / Year

Large Hospital

- 86 Modalities
- 1,000,000 Exams / Year

The interested party at a customer site for this solution is most likely the CIO or CTO, as well as the IT management. Because it is primarily targeted at enhancing the backend storage, network, and imaging workflow solutions, as well as the availability and management of those products, they are most likely to understand the benefits of the solution.

It is not likely that radiologists or radiology departments will be the *primary* target, because the particulars of this solution deal with the availability of the storage device, as well as imaging workflow and network issues. However, because there are other functions that the Acuo DICOM Services Grid can provide (for example, image cache), and the solution does enhance the performance of the availability of the image in the overall workflow, they should not be ignored.

Solution Benefits

The Connected Imaging—Medical Image Infrastructure solution improves the performance and scalability of the multi-vendor PACS systems used by healthcare providers. Modern imaging requires large amounts of resources because of the size of the images, sometimes in the gigabit range. To complicate the issue, each vendor has their own proprietary protocol.

In Deployment Option 1, the Cisco Content Services Switch improves the overall scalability by intelligently load balancing the PACS/DICOM traffic to the Acuo DICOM Services Grid™.

Deployment Options 2 and 3 add the benefit of using the ACE Module and 6500 to improve the overall scalability by intelligently load balancing the PACS/DICOM traffic to the Acuo DICOM Services Grid.

The addition of the Cisco WAAS/WAE improves the overall performance by optimizing the Wide Area Network (WAN).

Testing was done by a combination of teams in Germany to study the effects of WAAS/WAE on DICOM traffic. Here is a synopsis of those test results:

- The percentage of improvement was virtually identical despite testing done using different bandwidths
- The differences were minimal between tests using DICOM specific WAAS settings and standard out-of-the-box WAAS settings

- Mammography and CR studies showed the best results, probably because of the high percentage of black-values in those studies
- As expected, latency on the network did have an effect on the overall outcome of the tests. The lower the latency on the network, the less effect that WAAS/WAE had on the overall test. The testing that was done was over a network with a 40 ms latency.
- Highlights of the testing done:
 - Mammography studies were 4.5x faster (2.5 seconds with WAS versus 11 seconds without)
 - CR studies were 2.4x faster
 - CT studies were 1.75x faster
 - MR studies were 1.53x faster

Faster studies means less impact on existing infrastructures and existing applications

The details of the test and the results can be found in the appendices of this document.

The Acuo DICOM Services Grid is an enabling open-systems software solution that facilitates a DICOM infrastructure built on a services-oriented architecture that can aggregate/federate DICOM objects and query results, virtualize and replicate storage assets; and is built on a collaborative and extensible grid computing model.

The Cisco Connected Imaging—Medical Image Infrastructure solution provides the ability to connect proprietary PACS systems such that they operate together seamlessly. It also allows images to be routed based on metadata contained in the DICOM header. The Acuo DICOM Services Grid™ directs the image traffic based on a set of business rules, and provides image storage services by either placing into storage or forwarding to the diagnostic workstation.

Solution Features

The Connected Imaging—Medical Image Infrastructure solution addresses multiple challenges in healthcare today. It enables healthcare organizations to reduce patient scan times, effects a high availability application environment, and improves patient satisfactions. The solution solves these challenges by configuring the components in the solution to allow for the following:

- Highly available single point of access for modalities
- Eliminates single points of failure
- Physical and virtual IP redundancy
- Real-time adaptive load optimization through integration between Cisco CSS or Cisco ACE module with the Acuo DICOM Services Grid
- Wide Area Network optimization to minimize impact on other applications
- PACs deployment at data centers to consolidate applications into a single or multi-centralized deployment

Scope of the Solution

The scope of this solution is limited to workflows for modality image acquisition, to PACs storage.

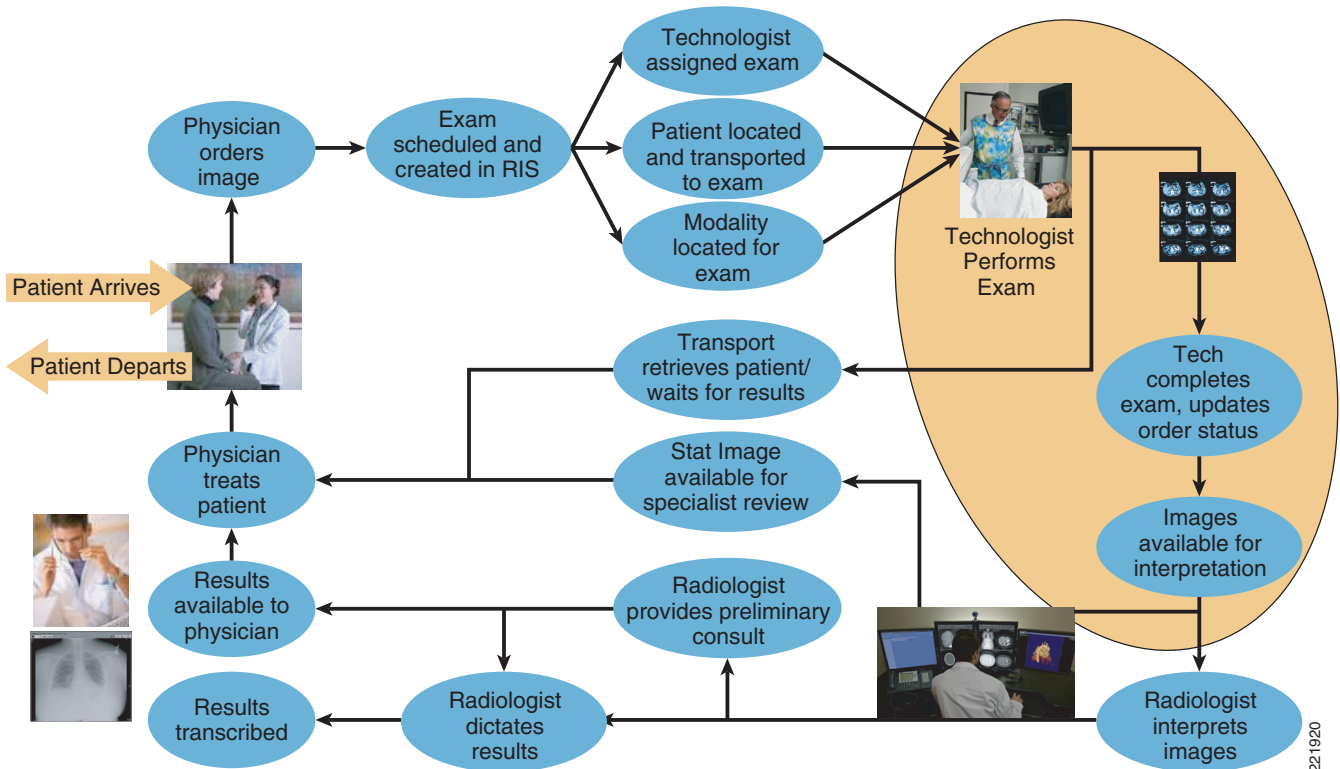
This document is intended to provide implementation and configuration information for the components required to provide intelligent load balancing of DICOM images using Cisco Content Services Switches or Cisco ACE Modules and Acuo DICOM routers. Information has been provided to allow for capacity

planning as well as extensibility and scaling. As the solution is easily extensible, care should be taken in the design to allow for baseline projections and then a gradual implementation to allow for adequate bandwidth and processing to support the imaging environment. For more information, refer to the Acuo Technologies® re: sizing Acuo DICOM Services Grid™ implementations at the following URL:

<http://www.acuotech.com>

The radiology workflow is a multi-step process with large file transfers and multiple communications and this solution is focused on the steps highlighted in the Figure 1.

Figure 1 Radiology Workflow



Through the implementation of a DICOM Services layer, we can more effectively route DICOM traffic making the workflow more efficient. It allows for intelligent routing of the images based on information in the DICOM header and business rules that are configured in the Acuo DICOM Services Grid™ software. Additional capabilities of the DICOM Services layer, although not included in this phase of the solution, include caching, better performance on image retrievals, and allow for expanded collaboration within the imaging environment.

This workflow represents a typical, in-house radiologist workflow. In the case of a multi-entity customer, you could potentially be moving large amounts of data across the WAN, depending on where your central PACS system, modalities, and diagnostic workstations are located.

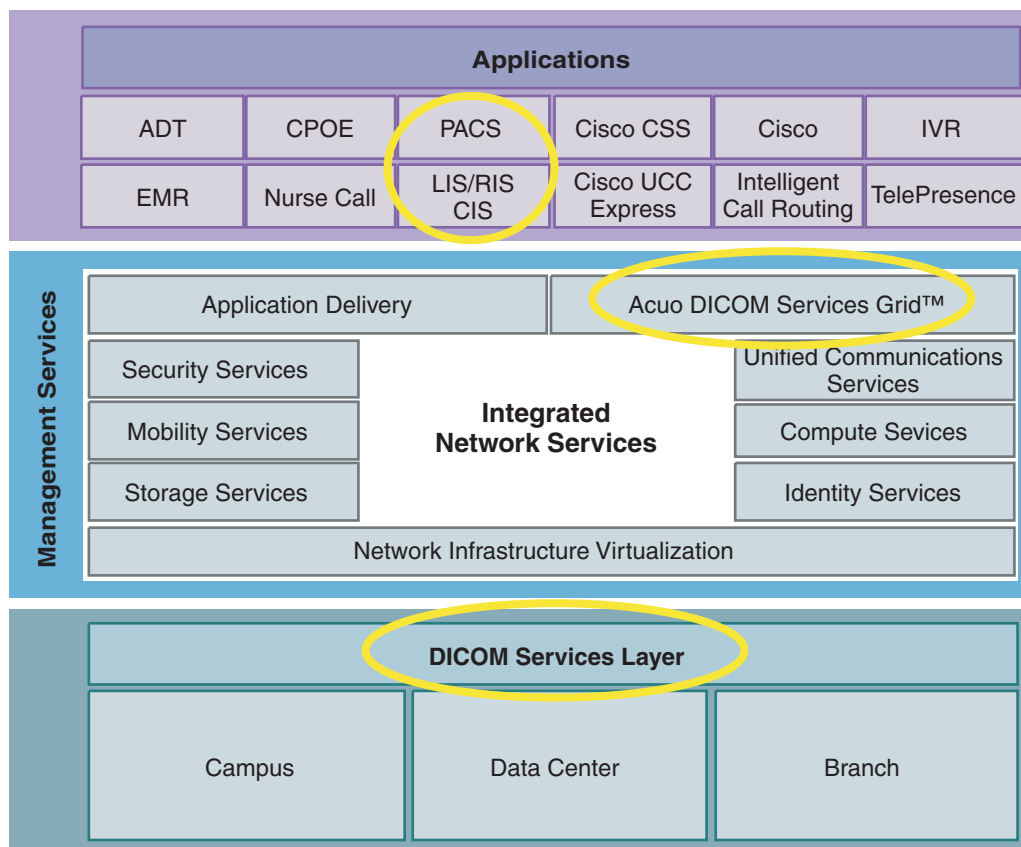
High Level Architecture

The Cisco Service-Oriented Network Architecture (SONA) provides a foundation for the Connected Imaging—Medical Image Infrastructure solution. This architecture identifies an end-to-end system offering to provide adaptive image routing to medical facilities that require better care for their patients.

The Connected Imaging—Medical Image Infrastructure solution is an integrated solution of Cisco and partner products to provide a highly available foundation for image routing in the healthcare environment.

The SONA architecture (see [Figure 2](#)) shows how these components come together in the solution. The modalities and diagnostic image viewers can exist practically anywhere in the network. The core of the solution along with the storage subsystem or PACS system would typically exist in the data center or imaging center.

Figure 2 *DICOM Services within the Cisco SONA model*



The following three layers provide the architectural foundations of the Connected Imaging—Medical Image Infrastructure solution that deliver an innovative solution offering to solve the challenges image routing in healthcare today:

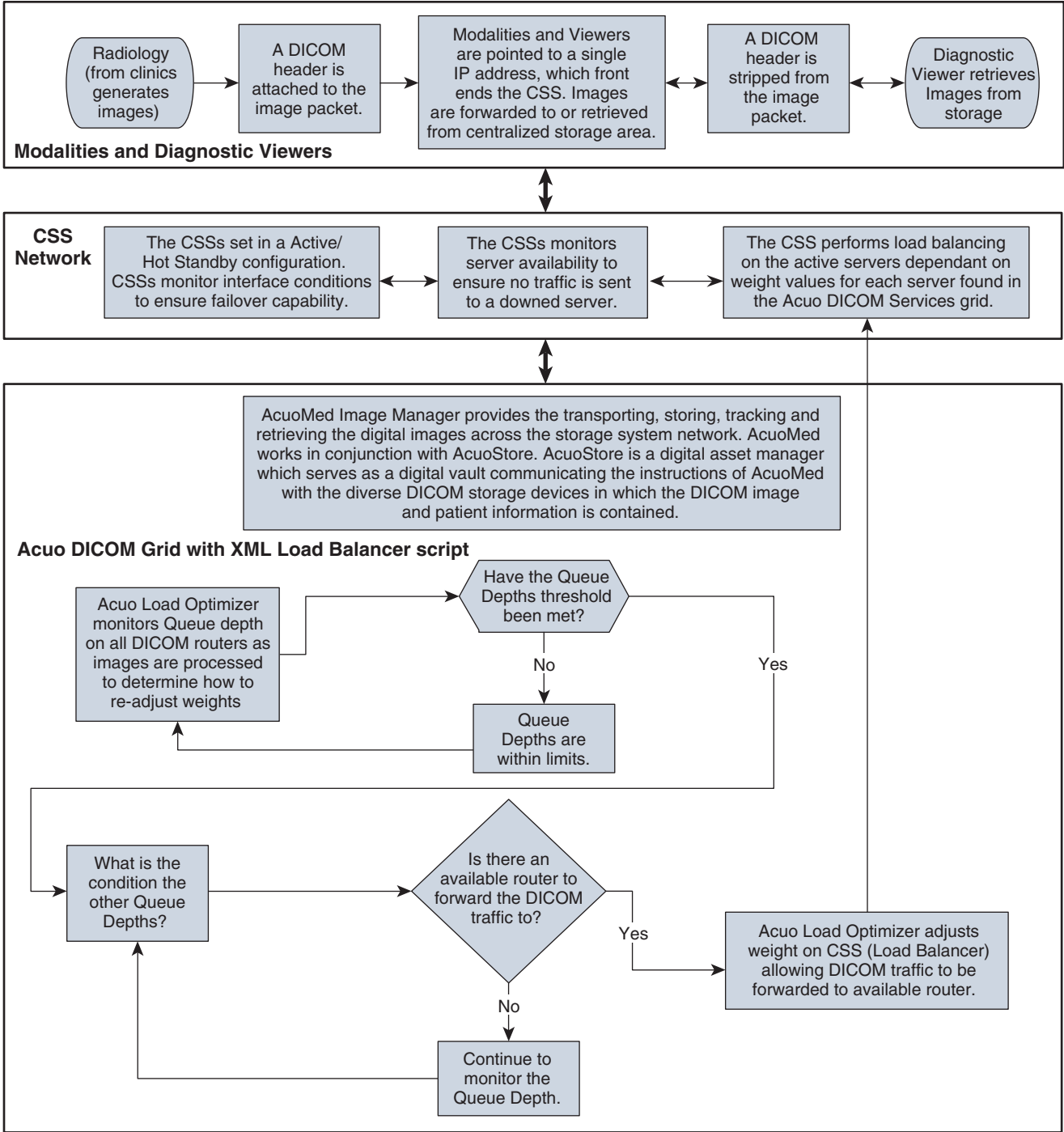
- **Network infrastructure layer**—Covers the various network locations from which images may originate, are read, or are stored. These locations include specific locations inside a hospital where the design follows a campus or branch office design. In particular, the larger implementations would be based upon the Data Center architecture, which include server optimization and virtualization as well as security best practices.
- **Interactive services layer**—Brings in the Acuo DICOM Services Grid to add the agent for the DICOM Services layer previously discussed.
- **Application Layer**—Combines the PACS systems, diagnostic stations, and modalities through the adaptive image routing provided by the Acuo DICOM Services Grid software.

For more information on DICOM Services or to reference the DICOM 3.0 Specification, see the following URL:

<http://www.rsna.org/Technology/DICOM>

Process Flow

Figure 3 Process Flow



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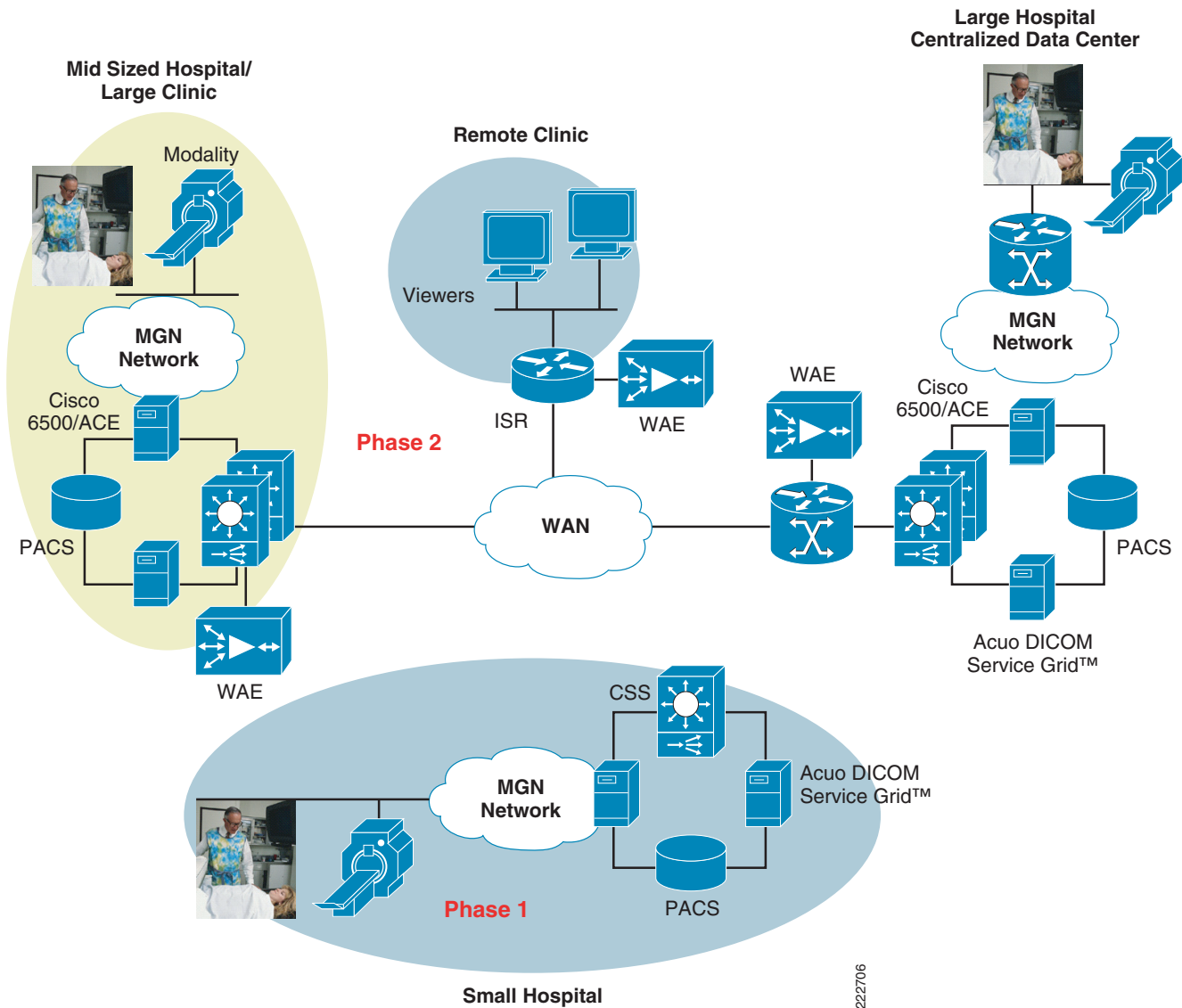
Solution Architecture

Network Architecture

The Cisco Medical Image Infrastructure version 2 solution plays a critical part in providing optimal traffic management for the transport of images from modalities to PACs storage components. The architecture for this solution (Figure 4) is based on Cisco's Medical-Grade Network (MGN) architecture, thus providing high availability as well as scalability. It is beyond the scope of this document to discuss the Cisco MGN architecture in detail. For more information about the MGN architecture, refer to the following URL:

http://www.cisco.com/web/strategy/docs/healthcare/MGN_Architecture.pdf

Figure 4 Overall Medical Image Infrastructure Architecture



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Figure 4 illustrates the high level architecture of the Connected Imaging—Medical Image Infrastructure solution. The following key functional blocks are represented:

- **Small Hospitals**

Small hospitals (performing on average of 100,000 exams per year) may have their own dedicated PACs and storage systems to serve the technologies and radiologists. Local modality endpoints ingest images from CTI, Mammo, and Catscan into the PACs systems. Usually the infrastructure consists of basic IP connectivity and switching capabilities. This is represented by the Medical Grade Network (MGN). The Cisco Content Switch is used to perform load balancing to the ACUO servers that front-end the storage PACs devices.
- **Remote Clinics**

Remote clinics may only house viewers to image examination, without any modalities. In this case, the clinic use a WAN link back to the centralized PACs systems. A wide area acceleration engine is used to perform DICOM traffic acceleration over the WAN.
- **Mid Size Hospitals and Large Clinics**

A mid-size hospital is generally large enough to own its own PACs systems and MGN infrastructure. In this case, both modality and viewing services would be located at the campus. An MGN architecture could be deployed at this size hospital along with the ACUO DICOM Grid servers. If the campus supports a local data center with a 6500, then an ACE module and could be used to handle the load balancing functions to the ACUO DICOM Grid.
- **Large Hospitals and Centralized Data Centers**

A large size hospital will own the PACs system, as well as serve both modalities and viewers within the hospital infrastructure. For very large operations, the hospital may support a centralized data center that supports large storage systems for images. In this type of deployment model, remote clinics send or retrieve images over the wide area network. In addition mid or small size clinics/hospitals may also use the centralized PACs storage.
- **Modalities**

Diagnostic equipment used to capture images such as X-rays, CTs, etc.
- **Viewers**

Image views enables radiologists and physicians to view high-resolution images stations. Images are accessed from the manufacturer's PACS systems.
- **Wide Area Networks**

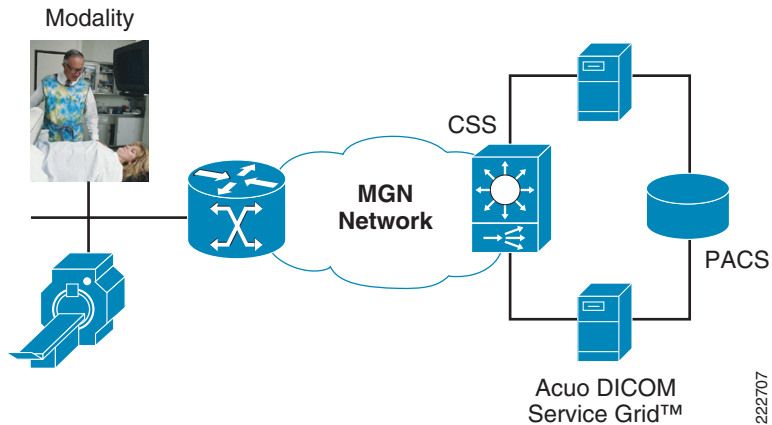
Network that connects remote locations to the the data center.

Deployment Models

Deployment Model A: Small Hospital/Standalone Clinic using CSS

Deployment model A (see Figure 5) is used for small hospital and/or standalone clinics where modality/viewer endpoints are distributed locally at a single location. Here, the content services switch (CSS) is used for load balancing functionality and distribution to the ACUO Services Grid. The PACs system is located behind the ACUO grid. Since this is a single context type of deployment, the CSS is recommended for environments that do not have aggregation or core size switches (for example, 6500). This is the main deployment model supported included from Version 1 of the solution.

Figure 5 **Deployment Model A**

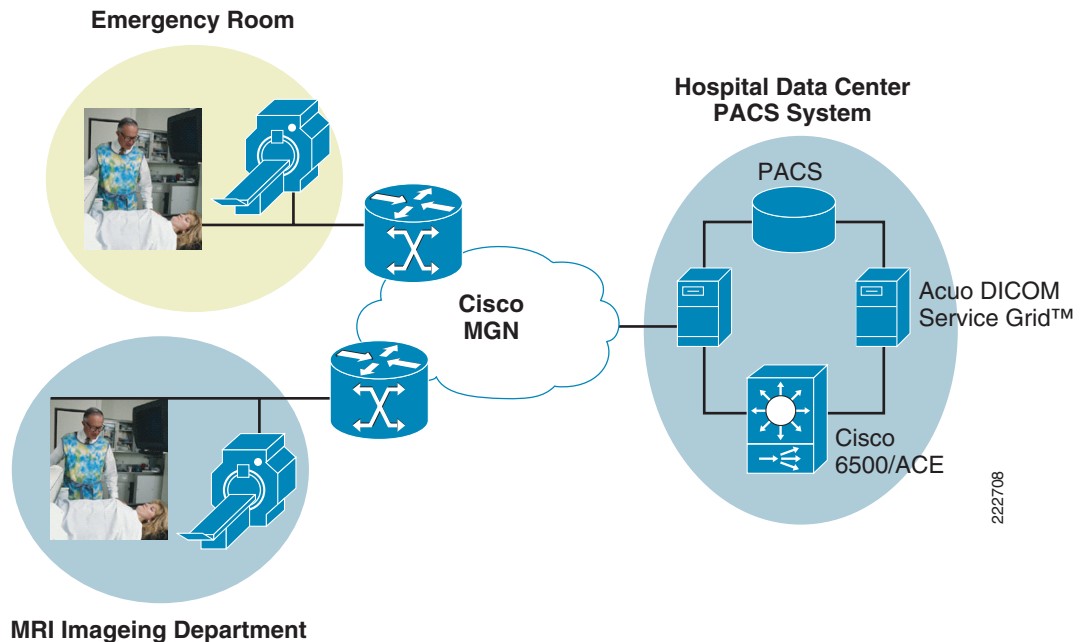


Deployment Model B: Medium Size Hospital/Large Clinic using 6500 and ACE module

Deployment model B (see [Figure 6](#)) is used for a medium size hospital and/or large clinics, where modality/viewer endpoints may be distributed locally at a single location, but may also have a centralized data center on campus with. Here, the 6500 is used with the Application Control Engine (ACE) module to perform the load balancing functions and distribution to the ACUO Services Grid. The PACs system is located behind the ACUO grid.

The ACE module supports up to 256 separate contexts, which allows multiple administrators within a hospital to manage the contexts that they individual own. For example, if the data center has an ACE module to perform SSL acceleration, you can add a new context for DICOM load balancing to the PACs application without disrupting the existing services.

Figure 6 **Deployment Model B**

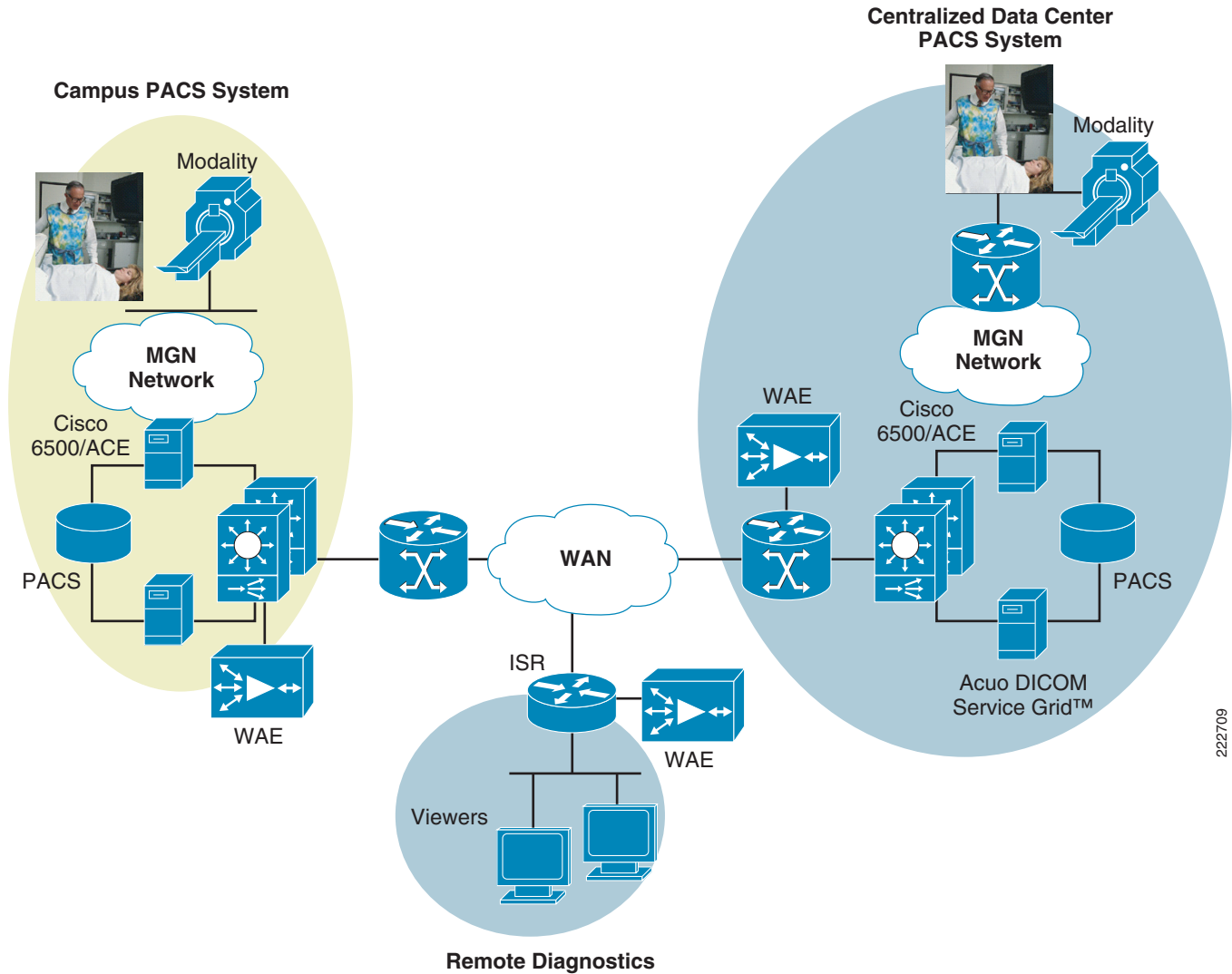


Deployment Model C: Large Hospital/Multiple Clinic using 6500, ACE module and WAE

Deployment model C (see [Figure 7](#)) is used for a large size hospitals and/or multi-site clinics, where modality/viewer endpoints may be distributed locally at remote different locations, and may meshed back to a centralized data center. Here, the 6500 is used with the ACE module to perform the load balancing functions and distribution to the ACUO Services Grid. The PACs system is located behind the ACUO grid.

At the remote locations, wide area acceleration engines are used in conjunction with the edge routers, typically the Cisco ISR 1800/2800/3800s to perform the necessary DICOM traffic compression and optimization across the WAN. The WAE is also deployed at the central data center site behind the 6500 aggregation device.

Figure 7 Deployment Model C



Interconnection and Interoperability

Once an image is captured at a modality, it is stored locally in its cache until it can off-load it to the PACS system. Typically, the modality is configured to point directly at the PACS system. If the PACS system is unavailable, the images must remain in local cache until they can be off-loaded.

In the Connected Imaging—Medical Image Infrastructure solution, the modality is pointed to the virtual IP address hosted by the Cisco CSS or Cisco ACE module (depending on the deployment model implemented) via the Cisco MGN. When it attempts to transfer the image, the content switch looks at its weight table and determines the least busy Acuo DICOM router in place and opens a conversation with that server. At this point, the image is off-loaded to the Acuo DICOM router, which then forwards it to the appropriate PACS system based on the business rules in the system. If the PACS server is not available, the image will remain on the Acuo DICOM router until it can be transferred, but once the

image is on the Acuo DICOM router, a commit is sent back to the modality so that the image can be purged from the local cache. In this case, the Acuo DICOM router is acting as a proxy for the PACS systems so that the images do not backup on the modality.

In the case of a multi-campus implementation, the image capture and transfer to a local Acuo DICOM router or PACS system happens as described above. If the image is to be read locally, it will be kept local for a period of time. If not, the image would be transferred back to the central site. In this case, the image would go from the local Acuo DICOM router or PACS system, through the WAE where it would be compressed if the image is not already compressed, and transferred across the WAN, where it is received by the WAE and transferred to the Acuo DICOM router or PACS system on the other side, based on the business rules in the system.

If there is a request from a local diagnostic workstation, the request would be made to the Acuo DICOM router, which would transfer the image to the workstation, if it is still cached locally; or it would transfer that image to the workstation for reading.

If the request comes from a diagnostic workstation remote to the PACS system or remote to the location of the image, the request would go through the Acuo DICOM router, which retrieves the image from its current location and transfer that image to the diagnostic workstation for reading.

Solution Features and Components

The Connected Imaging—Medical Image Infrastructure solution contains the following equipment, software, and architectural designs:

- Cisco Medical-Grade Network (MGN)
http://www.cisco.com/web/strategy/docs/healthcare/MGN_Architecture.pdf
- Cisco Data Center Infrastructure 2.1 Design Guide
<http://www.cisco.com/univercd/cc/td/doc/solution/dcidg21.pdf>
- Cisco Catalyst Ethernet switches

The Cisco Catalyst Ethernet switches provide the Layer 3 to the MGN and the Layer 2 connectivity to the CSS and Acuo servers supporting interface speeds ranging from 10 to 1000 Mbps. Catalyst Ethernet switches also provide segmentation of traffic via the use of VLANs and supported EtherChannel and HRSP for redundancy purposes.

The following Cisco Catalyst Ethernet switches are used for the Connected Imaging—Medical Image Infrastructure Architecture solution:

- Cisco Catalyst 4948 Intelligent Ethernet switches—Supporting 24 to 48 ports that can range in speeds from 10 Mbps to 1 Gbps, Layer 2 and 3 functionality. The 4948 is a non-blocking switch, and provides wire rate forwarding on all ports.
- 6500 with ACE module —Provides the L4 WRR load balancing to the server grid.
- Wide Area Acceleration Engine (WAE) – 612, 512, or WAE module
- Branch Router – 2800 and 3800 ISR routers
- Third-party application software—Required for DICOM traffic transport, retrieval, tracking, storage, and asset management:
- AcuoMed—The AcuoMed Image Manager is a DICOM 3.0 Level 2-compliant solution that uses secure, open-system software for transporting, storing, tracking, and retrieving digital images across an entire storage system network.

- AcuoStore—Digital asset manager that serves as a digital vault, communicating the instructions of AcuoMed with the diverse DICOM storage devices in which digital DICOM image and patient information is contained.
- Third-party database software—Required for AcuoMed and AcuoStore
- Microsoft SQL Server

Hardware Components

Table 1 provides the hardware components of this solution.

Table 1 **Hardware Components**

Product	Chassis	Modules	Interfaces	Memory/Flash
Cisco Catalyst 4948-10GE	WS-C4948-10GE	N/A	48 10/100/1000 Ethernet	256 Mbytes/64 Mbytes
Cisco Catalyst 3750	WS-C3750-48	N/A	48 10/100/1000 Ethernet	120 Mbytes/16 Mbytes
Cisco Catalyst 6500	WS-6500			
Cisco Application Control Engine (ACE) Module	ACE20-MOD-K9			
Cisco Content Services Switch	CSS 11503	CSS5-SCM-2GEHD IOM-2GE	Four GigabitEthernet ports supporting fiber or copper connectivity	256M RDRAM per module disk 0—1024 Mbytes disk 1—1024 Mbytes
WAE-612 Cisco Wide Area Application Engine	WAE-612			

Software Components

Table 2 lists the software used in this solution.

Table 2 **Software Components**

Product	Software/Code Version
Cisco Catalyst 3750	c3750-ipservicesk9-mz.122-35.SE2.bin
Cisco Catalyst 4948-10GE	cat4500-entservices-mz.122-31.SGA.bin
6500 Catalyst Switch with ACE Module	s72033_rp-ADVENTERPRISEK9_WAN-M
WAE-612	WAAS 4.0.13

Table 2 **Software Components (continued)**

Product	Software/Code Version
Acuo DICOM Services Grid	6.0
Acuo Load Optimizer	1.0
Microsoft SQL	2005 w/latest Service Pack

Features and Functionality

Table 3 lists the features and functionality of the solution.

Table 3 **Features and Functionality**

Product	Supported Feature(s)	Functional Role
WS-C4948-10GE ¹	Layer 2 and Layer 3	The WS-C4948-10GE acts as an L3 router providing support for routing protocols (OSPF for this solution) and also acts as an L2 switch providing support for VLAN traffic. Note that the WS-C4948-10GE also provides redundancy for the L2 and L3 with the use of an EtherChannel between the two WS-C4948-10GEs and HSRP for the routed interface.
WS-C4948-10GE ¹	Layer 2	The WS-C4948-10GE acts as an access layer switch that includes redundancy between the two WS-C4948-10GEs via an EtherChannel.
6500/ACE	Layer 4 load balancer	The ACE and 6500 provides L4 load balancing based on load balancer updates from ACUO that adjust queue weights
AcuoMed Image Manager	DICOM 3.0 Level 2 compliant Image Manager	AcuoMed Manager provides transport, storing, tracking, and retrieving of digital images.
AcuoStore Asset Manager	Digital asset manager	AcuoStore communicates the instructions of AcuoMed with the diverse DICOM storage devices in which digital content is contained.
Acuo Load Optimizer	Monitor service for dynamic load optimization of Content Services Switch	During normal operations, the weights are set equally, usually at 5. From there, the service monitors the queue depth of the servers. As a server becomes congested, the service changes its weight on the CSS to lower than 5. The value is determined by the amount of depth in the queue that the server is handling. At the same time, the service finds the least congested server and changes the weight value from 5 to 10, depending on the load.

1. Note that other Cisco switches support the listed features and functions similar to the WS-C4948-10GE and may be used, but testing and validation of the solution was performed with the WS-C4948-10GE.

Features, Services, and Application Design Considerations

- Single point of access to any modality regardless of the location of the PACS system

- Dynamic adaptive load sharing across a DICOM Services Grid
- Easily extensible and expandable without an outage
- Provides a highly available environment
- Store and forward is supported in the case of a PACS or storage outage

Designing the Solution

Scalability and Capacity Planning

The design includes a pair of Cisco Content Services Switches (CS11503) or Cisco ACE modules and multiple Acuo DICOM Routers for redundancy. The throughput of the solution is based on the throughput of the Cisco CSS or Cisco ACE module and the ability for the Acuo DICOM routers to handle the load.

You do not need to have separate pairs of CSS or ACE modules for this deployment, you can run on existing hardware as long as there is bandwidth and processor available. The benefit of ACE over CSS is not only throughput, but you can create multiple contexts within the ACE environment to effectively virtualize your DICOM traffic. This is not possible in CSS. The benefit of the virtualization is that you can process without affecting other traffic outside of the virtual environment (context) created.

Cisco CSS

Total throughput of the CSS is based on the configuration deployed. Use the following as a reference to determine the proper configuration for your deployment.

	Cisco CSS11501 and Cisco CSS11501S-C	Cisco CSS11503	Cisco CSS11506
Bandwidth Aggregate	6 Gbps	20 Gbps	40 Gbps

For more information about the Cisco CSS options is available, refer to the following: http://www.cisco.com/en/US/products/hw/contnetw/ps792/products_data_sheet0900aecd800f851e.htm

Cisco ACE Module

Total throughput of the Cisco ACE is based on the configuration and license deployed. Use the information in Table 4 to determine the ACE configuration necessary.

Table 4 ACE Configuration

Configuration	Throughput (Gbps)	Max L4 Setups and Teardowns per sec
4 Cisco ACE Modules with 16-Gbps license	64	1,392,000
3 Cisco ACE Modules with 16-Gbps license	48	1,044,000
2 Cisco ACE Modules with 16-Gbps license	32	696,000

Table 4 ACE Configuration

Configuration	Throughput (Gbps)	Max L4 Setups and Teardowns per sec
Cisco ACE Modules with 16-Gbps license	16	348,000
Cisco ACE Modules with 8-Gbps license	8	348,000
Cisco ACE Modules with 4-Gbps license	4	348,000

Acuo DICOM Router

Total throughput of the Acuo DICOM router is based on the hardware platform on which it was deployed, and is affected by processor type and size, amount of memory, etc. Additional information on sizing the Acuo DICOM router is available from Acuo Technologies.

If any of these devices are unable to handle the volume of images being produced by the modalities, the solution allows for the addition of one or more devices to handle the increased load.

Anticipated Volumes of DICOM traffic

The [Table 5](#), [Table 6](#), and [Table 7](#) provide sample network traffic volume that you can see in a given hospital or clinic. The tables also provide sample image sizes that are used in various size hospitals. You can use these tables as a reference to determine what type of traffic patterns you will see and need to plan for given a particular size clinic, or you can use the tools available from Acuo Technologies to perform a more complete capacity plan, including data storage necessary for the Acuo products.

Table 5 Small Hospital or Remote Clinic

# of Scanners	Modality	Matrix			Bits Stored	Image Capture	MB/ Image	Images/ Exam	MB/ Exam	Exams/ Year	Exam/ Day	Images/ Day	MB/ Day	MB/ Year
	DSA	1,024	X	1,024	16	DICOM	2		0		0	0	0	0
1	NUCLEAR	256	X	256	24	DICOM	0	10	2	3,000	8	82	16	5,898
2	ULTRASOUND 12bit	512	X	512	16	DICOM	1	30	16	7,000	19	575	302	110,100
	ULTRASOUND 12bit	512	X	512	16	DICOM	1		0		0	0	0	0
1	CT - Standard	512	X	512	16	DICOM	1	60	31	8,000	22	1,315	689	251,658
1	MRI	256	X	256	16	DICOM	0	160	21	10,000	27	4,384	575	209,715
	Digitizer	2,048	X	2,560	16	DICOM	10		0		0	0	0	0
3	Comp. Rad (CR)	2,048	X	2,560	16	DICOM	10	3	26	65,000	178	445	4,668	1,703,936
1	CT 16-Slice	512	X	512	16	DICOM	1	200	105	4,000	11	2,192	1,149	419,430
	CT 64-Slice	512	X	512	16	DICOM	1		0		0	0	0	0
	XA	512	X	512	16	DICOM	1		0		0	0	0	0
	MRI	512	X	512	16	DICOM	1		0		0	0	0	0
	Digital Mammo	4,096	X	5,624	16	DICOM	46		0		0	0	0	0
	Cath Lab	1,024	X	1,024	16	DICOM	2		0		0	0	0	0
1	Special Procedures	1,024	X	1,024	16	DICOM	2	15	31	1,000	3	41	86	31,457
1	Echo's	512	X	512	16	DICOM	1	130	68	2,000	5	712	373	136,315
11										100,000	274	9,747	7,859	2,868,511

Table 6 Mid-Size Hospital or Large Clinic

# of Scanners	Modality	Matrix			Bits Stored	Image Capture	MB/ Image	Images/ Exam	MB / Exam	Exams/ Year	Exams / Day	Images / Day	MB / Day	MB/ Year
	DSA	1,024	X	1,024	16	DICOM	2		0		0	0	0	0
3	NUCLEAR	256	X	256	24	DICOM	0	10	2	9,000	25	247	48	17,695
4	ULTRASOUND 12bit	512	X	512	16	DICOM	1	30	16	18,000	49	1,479	776	283,116
	ULTRASOUND 12bit	512	X	512	16	DICOM	1		0		0	0	0	0
	CT - Standard	512	X	512	16	DICOM	1		0		0	0	0	0
3	MRI	256	X	256	16	DICOM	0	160	21	27,000	74	11,836	1,551	566,231
	Digitizer	2,048	X	2,560	16	DICOM	10		0		0	0	0	0
6	Comp. Rad (CR)	2,048	X	2,560	16	DICOM	10	3	26	180,000	493	1,233	12,928	4,718,592
2	CT 16-Slice	512	X	512	16	DICOM	1	200	105	24,000	66	13,151	6,895	2,516,582
1	CT 64-Slice	512	X	512	16	DICOM	1	2,000	1,049	12,000	33	65,753	34,474	12,582,912
1	PET	512	X	512	16	DICOM	1	90	47	6,000	16	1,479	776	283,116
	XA	512	X	512	16	DICOM	1		0		0	0	0	0
	MRI	512	X	512	16	DICOM	1		0		0	0	0	0
2	Digital Mammo	4,096	X	5,624	16	DICOM	46	4	184	9,000	25	99	4,544	1,658,585
2	Cath Lab	1,024	X	1,024	16	DICOM	2	70	147	6,000	16	1,151	2,413	880,804
2	Special Procedures	1,024	X	1,024	16	DICOM	2	15	31	3,000	8	123	259	94,372
2	Echo's	512	X	512	16	DICOM	1	130	68	6,000	16	2,137	1,120	408,945
28										300,000	822	98,688	65,783	24,010,949

Table 7 Large Hospital / Multiple Clinics

# of Scanners	Modality	Matrix			Bits Stored	Image Capture	MB / Image	Image/ Exam	MB / Exam	Exams / Year	Exams / Day	Images / Day	MB / Day	MB / Year
	DSA	1,024	X	1,024	16	DICOM	2		0		0	0	0	0
9	NUCLEAR	256	X	256	24	DICOM	0	10	2	30,000	82	822	162	58,982
8	ULTRASOUND 12bit	512	X	512	16	DICOM	1	30	16	60,000	164	4,932	2,586	943,718
	ULTRASOUND 12bit	512	X	512	16	DICOM	1		0		0	0	0	0
	CT - Standard	512	X	512	16	DICOM	1		0		0	0	0	0
10	MRI	256	X	256	16	DICOM	0	160	21	90,000	247	39,452	5,171	1,887,437
	Digitizer	2,048	X	2,560	16	DICOM	10		0		0	0	0	0
20	Comp. Rad (CR)	2,048	X	2,560	16	DICOM	10	3	26	600,000	1,644	4,110	43,092	15,728,640
8	CT 16-Slice	512	X	512	16	DICOM	1	200	105	80,000	219	43,836	22,982	8,388,608
3	CT 64-Slice	512	X	512	16	DICOM	1	2,000	1,049	40,000	110	219,178	114,912	41,943,040
4	PET	512	X	512	16	DICOM	1	90	47	20,000	55	4,932	2,586	943,718
	MRI	512	X	512	16	DICOM	1		0		0	0	0	0
6	Digital Mammo	4,096	X	5,624	16	DICOM	46	4	184	30,000	82	329	15,147	5,528,617
6	Cath Lab	1,024	X	1,024	16	DICOM	2	70	147	20,000	55	3,836	8,044	2,936,013
6	Special Procedures	1,024	X	1,024	16	DICOM	2	15	31	10,000	27	411	862	314,573

Table 7 *Large Hospital / Multiple Clinics*

6	Echo's	512	X	512	16	DICOM	1	130	68	20,000	55	7,123	3,735	1,363,149
86								2,712		1,000,000	2,740	328,959	219,278	80,036,495

Performance Considerations

Performance testing is outside of the scope of this solution because of the complexities associated with different types of modalities, PACS systems and other traffic on the network. If you use the tables provided as a guideline for amount of traffic, you should be able to provide a solution that performs acceptably; however, you mileage may vary.

The complexities are due in large part to the specific implementation of the different systems. For instance, some PACS systems will compress their images before they send them to a diagnostic workstation, and the workstation will de-compress the image. Some modalities will do the same as they send images to the PACS systems.

Additionally, it will depend on the type of images you are sending as to what effect the WAAS/WAE will have on your network. If you are sending an ultrasound, for example, there is a lot of black space surrounding the image that will be compressed out. However, an X-ray, even though it is gray-scale, may not compress as well. You can also expect to see improvement when moving images between Acuo DICOM routers, as they have a proprietary compression algorithm that they use when moving images between systems.

In general, you need to understand the systems being connected, the images they are sending and make sure you test specifically the areas where the bottlenecks occur so that tuning can be done.

Quality of Service

Because of the varied devices that one could run into when deploying a solution such as this, no specific QoS design considerations were tested. The volume of traffic anticipated should be used as a guide to size and understand the impact on existing networks and QoS of other traffic should be marked accordingly.

High Availability

Based on the Cisco MGN, the solution has been designed with high availability in mind. Deployment Option 1 of the solution includes a pair of Cisco Content Services Switches configured in active/passive mode. If the primary fails, the secondary CSS continues to direct traffic to the appropriate Acuo DICOM router. Deployment Options 2 and 3 of the solution includes a pair of ACE modules configured in active/active mode. If the primary fails, the secondary continues to direct traffic to the appropriate Acuo DICOM router.

The high availability piece of the solution also include the Acuo load optimizer running on one of the Acuo DICOM routers in the grid. This service monitors the work queues on each of the Acuo DICOM routers and adjusts the weight of each router accordingly in the Cisco Content Services Switch or Cisco ACE module. If one of the Acuo DICOM routers becomes unavailable, the load optimizer removes that router from the rotation by lowering the weight of the device, allowing the others to consume the load.

Security

While security is not specifically covered in this phase of the solution, there are specific tests to validate that basic access security is in place on each of the devices. Additional security design including path isolation will be included in future phases.

Implementing and Configuring the Solution

Implementation or Testing Approach

The following deployment models were tested as part of the lab validation testing

- Campus 6500 with ACE module and Acuo Dicom Grid

This implementation simulates a campus or local data center type deployment.

- Branch to Remote Data Center using wide area acceleration (WAE) and Acuo Dicom Grid

This implementation simulates a remote branch office connecting over WAN into a remote local data center type deployment.

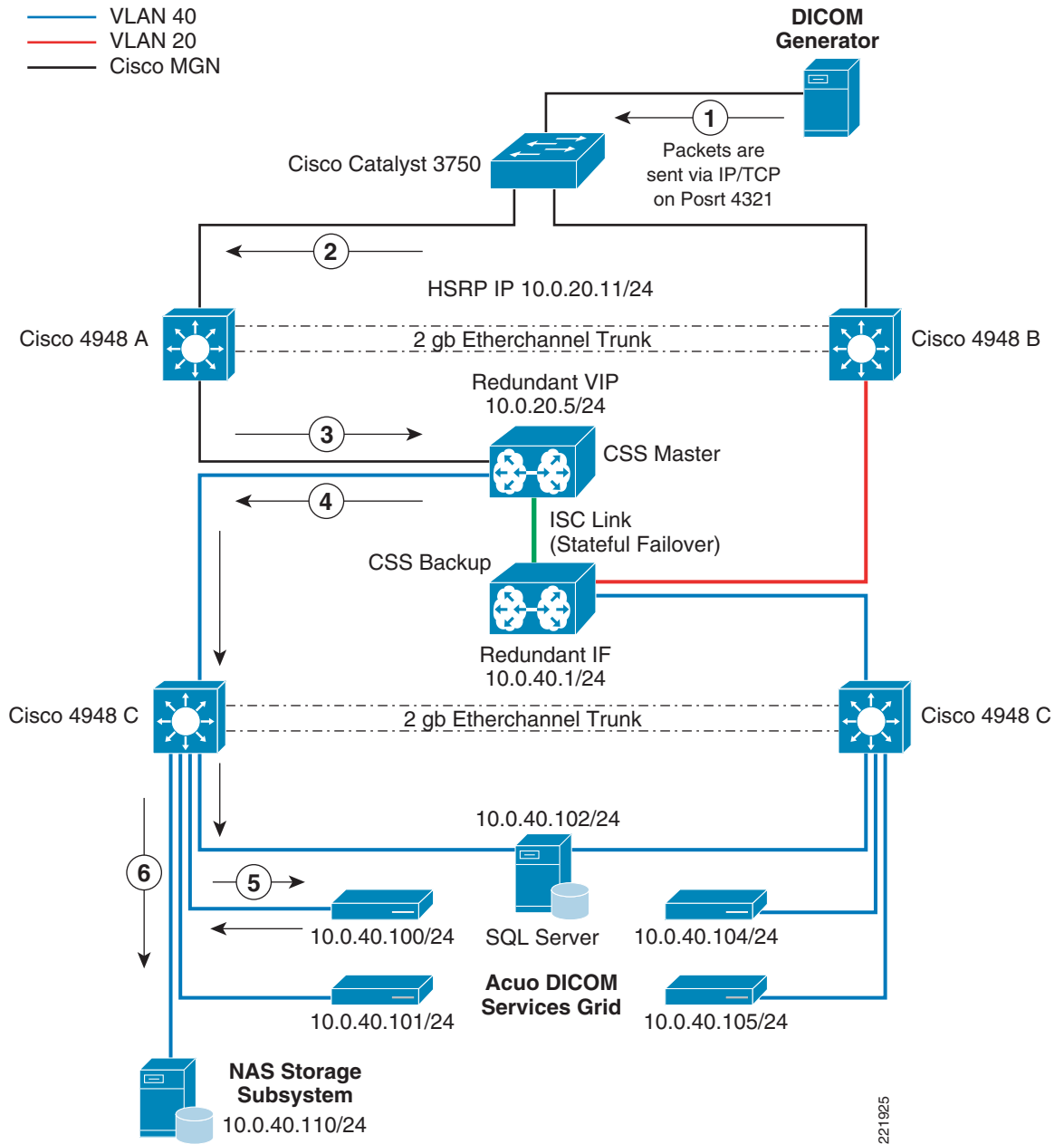
What was Implemented/Tested

The following key features and services were implemented:

- Weighted Round Robin Layer 4 load balancing
- ACE Module XML CLI
- Acuo-to-CSS XML scripting
- Acuo-to-ACE XML scripting
- Layer 2 EtherChannel and Spanning Tree
- Layer 3 functionality of the WS-C4948-10GE
- DICOM transporting, tracking, storage, and retrieval
- Active to hot standby failover of the CSS

Test Topology A: CSS Implementation

Figure 8 Test Topology A: CSS Implementation



The sequence is as follows:

1. The image data is formatted with a DICOM header (this is accomplished with Testman, a DICOM Generator used for testing purposes) that flows through the Cisco Medical-Grade Network (Cisco MGN) to the 4948A.

2. The 4948A is matched with another 4948B to provide redundancy in case of unit failure via Hot Standby Routing Protocol (HSRP). The 4948A and 4948B provide Layer 3 and Layer 2 capabilities, where the Layer 3 side provides routing into the MGN and the Layer 2 side provides connectivity to the front-end of the CSS.
3. The modalities and diagnostic viewers connect to the CSSs via a single IP address (virtual) provided by the CSSs. Using the virtual IP address on the CSSs allows the modalities and diagnostic viewers to remain connected when the active CSS fails over to the hot standby CSS. The CSSs use an Inter-Switch Communications (ISC) link to allow the CSS peers to exchange flow state information in an Adaptive Session Redundancy (ASR) configuration. If the master CSS fails, the backup CSS already has the flow state information necessary to continue the current flows without interruption. Using ISC, CSSs exchange state information as follows:
 - For existing flows, at boot-up time and at VIP redundancy failover
 - For new flows, in real time (after the CSS receives a SYN/ACK from the server)

The CSSs monitor their respective interfaces to ensure redundancy as an interface/link fails.

4. A service is created on the CSS for each server found on the DICOM Services Grid. These services contain the following information regarding the servers:
 - Server name
 - Server IP address
 - Server weight
 - Server port
 - Server keepalive

The service monitors the connectivity to the servers via an ICMP keepalive to ensure that traffic is not sent to a downed or inactive server. The CSS uses Weighted Round Robin (WRR) to forward the image traffic to the Acuo DICOM Services Grid. The Acuo Load Optimizer service running on the primary server in the Acuo DICOM Services Grid monitors the queue depth of each of the servers in the grid and updates the service on each of the CSSs based on the load on each server. As the queue depth of a server becomes longer, the Acuo Load Optimizer service connects to the CSS and changes the weight to a lower value for that server. This causes the incoming image traffic to connect and flow to other servers that have higher weight values in the CSS and shorter queues on the DICOM router.

5. The Acuo DICOM Services Grid consists of Windows 2003 Server with an internal SQL database or an external SQL database. The Acuo DICOM Services Grid is used to enhance image management performance. The AcuoMed Image Manager is a DICOM 3.0 Level 2-compliant solution that uses secure, open-system software for the transporting, storing, tracking, and retrieving of digital images across an entire storage system network. Each Acuo system works in concert with other DICOM devices to create local intelligent workflow using its dynamic router, enabling a single view of the entire DICOM network through its peer-aware collaboration feature. AcuoMed works in conjunction with AcuoStore, a digital asset manager. AcuoStore serves as a digital vault, communicating the instructions of AcuoMed with the diverse DICOM storage devices in which digital DICOM image and patient information is contained.
6. As the image traffic flows in or out of the Acuo DICOM Services Grid, AcuoMed ensures the transport of the image traffic from the storage device to the viewer, and from the modality to the storage device. AcuoStore ensures that the communications between AcuoMed and the storage device is properly maintained.

Redundancy in the Acuo Services Grid is dependant on the number of Acuo servers deployed in the solution. A minimum of two servers are required. The SQL server can be placed on the Acuo servers, which is the recommended topology.

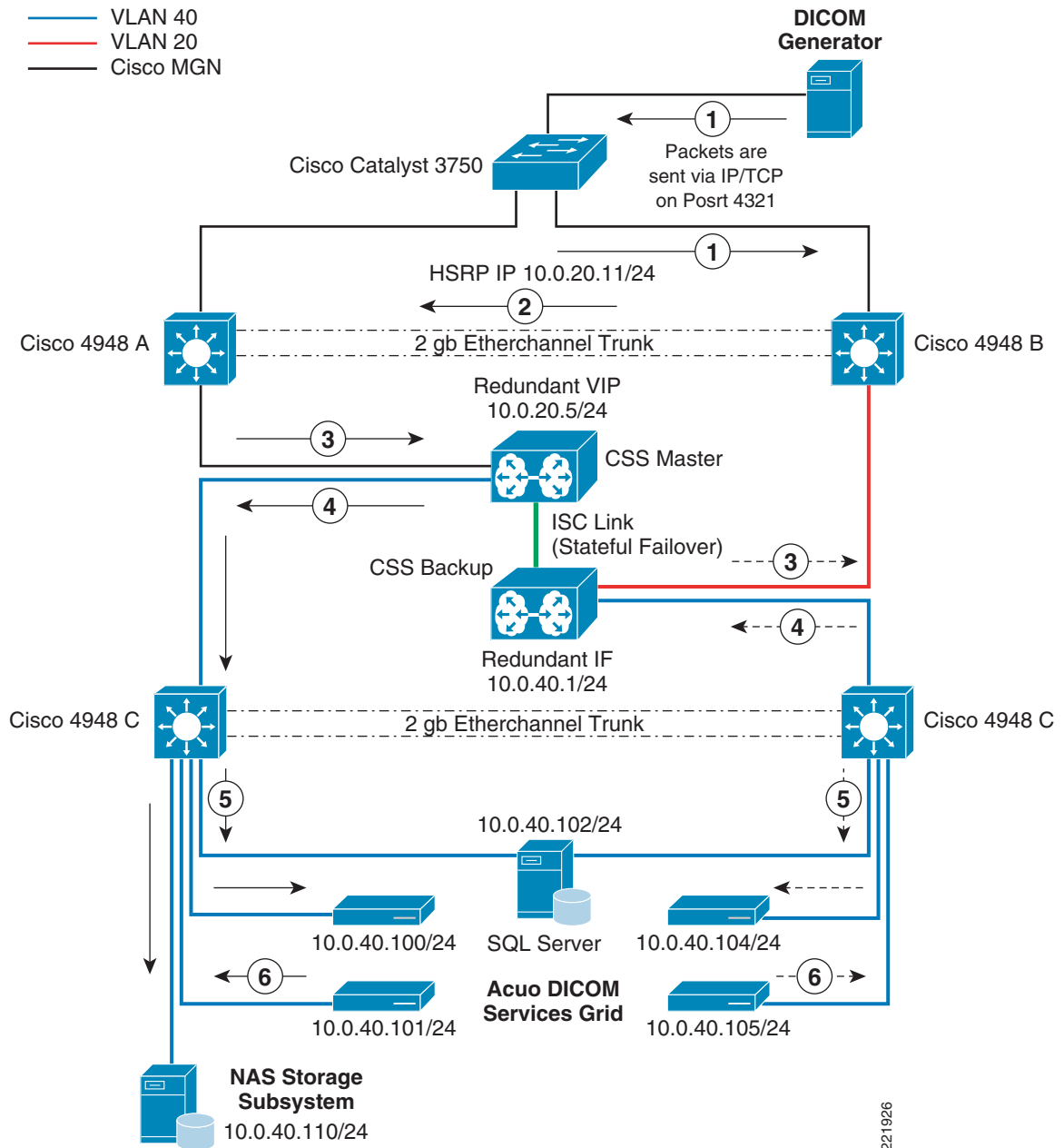
The storage device can be a network-attached storage (NAS) device, or an independent storage device can be located in the following places:

- Off network. However, the data (image) traffic must be secured because of the sensitivity of the information. The Acuo servers and SQL databases must be able to communicate with the storage devices. Because of the image data re-traversing the CSS routes, this is not a recommended method because it can be a cause of congestion
- On the same server that is running the AcuoMed and AcuoStore application. This configuration is not recommended because of the size of the images and the relative amount of internal hard drive space required.
- On the same network as the Acuo DICOM Services Grid (as shown in [Figure 9](#)). This is the recommended design because it alleviates congestion of image data traversing the CSS routes. This should be performed in the evening hours if offsite storage is required for the backup of data from the local storage device.

Failover of a Switch and/or CSS

Figure 9 shows the sequence of events for a failover of a switch and/or a CSS.

Figure 9 Failover Sequence



The sequence is as follows:

1. The image data is formatted with a DICOM header (this accomplished with Testman, a DICOM generator used for testing purposes) that flows through the MGN to the 4948B.
2. The 4948B is matched with another 4948A to provide redundancy in case of unit failure via HSRP. The follow failure scenarios determine the flow of traffic:

- a. 4948B MGN port connection failure—Because the link to the active CSS is operational, traffic is sent from the MGN to the redundant 4948A. The traffic then traverses across the EtherChannel to the 4948B (with the bad port) and flows to the active CSS.
 - b. 4948A CSS port failure or complete unit failure—Because the link to the active CSS master has failed, either by unit failure or port failure, the active CSS master goes into standby mode, forcing the CSS backup to become active. The traffic now flows from the MGN to the redundant 4948B and then to the CSS backup. Because this is a stateful connection, there is no loss of data or connection and the data flow continues from the point where it left off on the failed device.
3. The modalities and diagnostic viewers connect to the CSSs via a single IP address (virtual) provided by the CSSs. Using the virtual IP address on the CSSs allows the modalities and diagnostic viewers to remain connected when the active CSS fails over to the hot standby CSS. The CSSs use an ISC link to allow the CSS peers to exchange flow state information in an ASR configuration. If the master CSS fails, the backup CSS already has the flow state information necessary to continue the current flows without interruption. Using ISC, CSSs exchange state information as follows:
 - For existing flows, at boot-up time and at VIP redundancy failover
 - For new flows, in real time (after the CSS receives a SYN/ACK from the server)

The CSSs monitor their respective interfaces to ensure redundancy as an interface/link fails.

4. A service is created on the CSS that contains all the servers found in the Acuo DICOM Services Grid. This service contains the following server information:
 - Server name
 - Server IP address
 - Server weight
 - Server port
 - Server keepalive

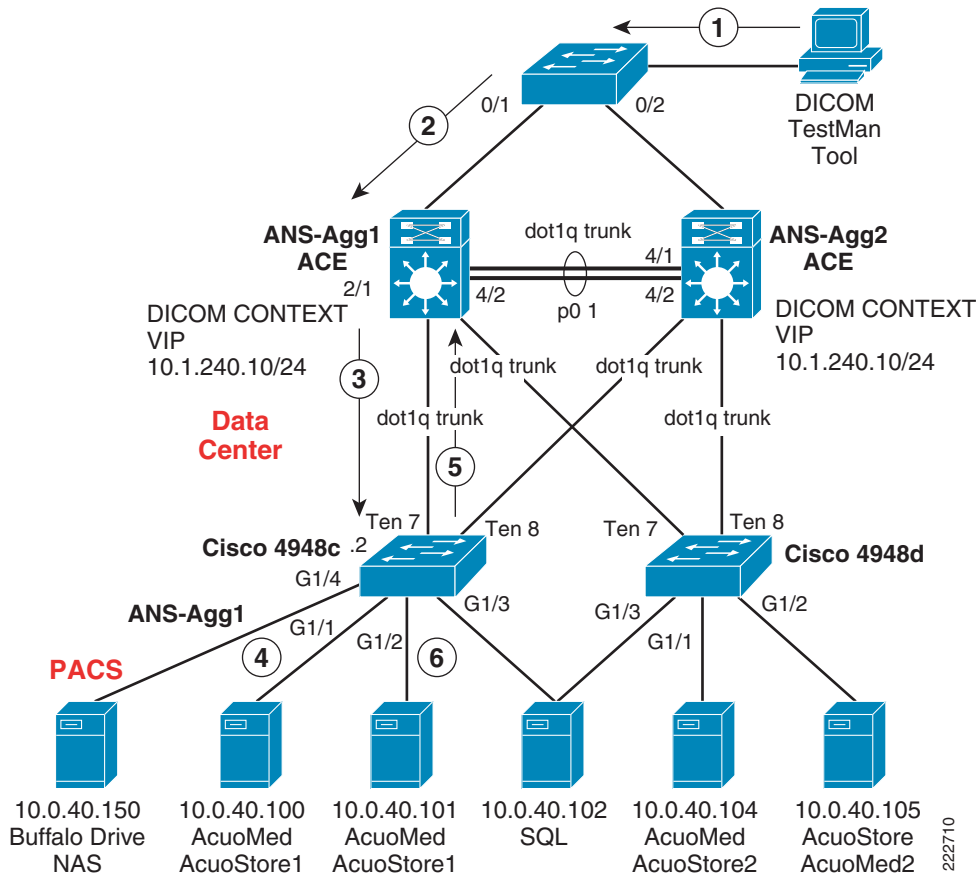
The service monitors the connectivity to the servers via an ICMP keepalive to ensure that traffic is not sent to a downed or inactive server. The CSS uses WRR to forward the image traffic to the Acuo DICOM Services Grid. The Acuo Load Optimizer service running on the primary server in the Acuo DICOM Services Grid monitors the queue depth of each of the servers in the grid and updates the service on the CSSs based on the load on each server. As the queue depth of a server becomes longer, the Acuo Load Optimizer service connects to the CSS and changes the weight to a lower value for that server. This causes the incoming image traffic to connect and flow to other servers that have higher weight values in the CSS and shorter queues on the DICOM router.

5. The Acuo DICOM Services Grid consists of a Windows 2003 Server with an internal SQL database or an external SQL database. The Acuo Services Grid is used to enhance image management performance. The AcuoMed Image Manager is a DICOM 3.0 Level 2-compliant solution that uses secure, open-system software for the transporting, storing, tracking, and retrieving digital images across an entire storage system network. Each Acuo system works in concert with other DICOM devices to create local intelligent workflow using its dynamic router, enabling a single view of the entire DICOM network through its peer-aware collaboration feature. AcuoMed works in conjunction with AcuoStore, a digital asset manager. AcuoStore serves as a digital vault, communicating the instructions of AcuoMed with the diverse DICOM storage devices in which digital DICOM image and patient information is contained.
6. As the image traffic flows in or out of the Acuo Services grid, AcuoMed ensures the transport of the image traffic from the storage device to the viewer and from modality to the storage device. AcuoStore ensures that the communications between AcuoMed and the storage device is properly maintained.

Test Topology B: ACE and 6500 Implementation

Topology B (see Figure 10) represents the Deployment Model B: Medium Size Hospital/Large Clinic using 6500 and ACE module.

Figure 10 Test Topology B: ACE/6500



The following flows were tested, simulating a local data center deployment type:

1. The image data is formatted with a DICOM header using the Testman DICOM generator tool. The DICOM packet is sent to the virtual IP address 10.1.240.10 using the following script:


```
testman.exe -r100 -s -t10.1.240.10 -eAcuoMedStore01 -ns1 -ne1 -ni1 -i5000
```
2. The 4948 sends the packet to the ACE module and into the relevant context. The modalities and diagnostic viewers connect to the ACE module via a single IP address (virtual) provided by the ACE module.. Using the virtual IP address on the ACE allows the modalities and diagnostic viewers to remain connected when the active ACE fails over to the redundancy ACE.
3. The service is created on the ACE module for each server on the DICOM services grid. These services contain information regarding the servers:
 - Server Name
 - Server IP Address
 - Server Weight

222710

– Server Port

For example:

```
rserver host AcuoMed1
  ip address 10.0.40.100
  inservice
rserver host AcuoMed2
  ip address 10.0.40.104
  inservice
rserver host AcuoStore1
  ip address 10.0.40.101
  inservice
rserver host AcuoStore2
  ip address 10.0.40.105
  inservice

serverfarm host DICOM
  predictor leastconns
  probe PING
  rserver AcuoMed1
    inservice
  rserver AcuoMed2
    inservice
  rserver AcuoStore1
    inservice
  rserver AcuoStore2
    inservice
```

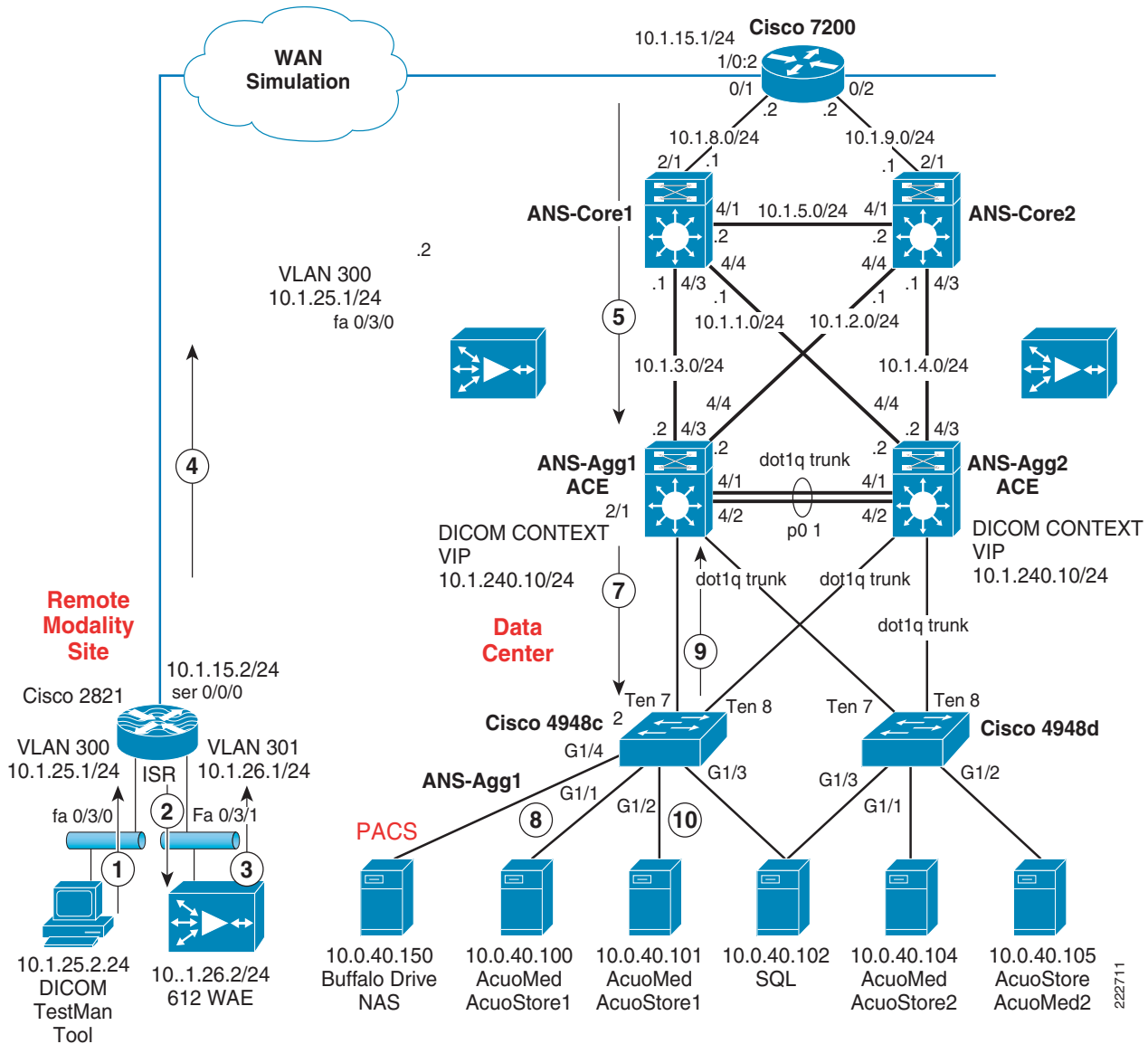
4. The ACUO Load Optimizer service running on the primary server in the Acuo DICOM Services Grid monitors the queue depth of each of the servers in the grid and updates the service on the ACE based on the load on each server.
5. As the queue depth of a server becomes longer (for example, AcuoMed1 and 10.0.40.100), the Acuo Load Optimizer service connects to the ACE and changes the weight to a lower value for that server.
6. The traffic flows to the other server (for example, AcuoStore1, 10.0.40.101) that has a higher weight values in the ACE and shorter queues on the DICOM. AcuoMed ensures the transport of the image traffic from the storage device to the viewer and from modality to the storage device. AcuoStore ensures that the communications between AcuoMed and the storage device is properly maintained.

In the lab setup, all servers performed both AcuoMed and AcuoStore functions.

Test Topology C: ACE and 6500 and WAAS Implementation

Topology C (see [Figure 11](#)) [Deployment Model C: Large Hospital/Multiple Clinic using 6500, ACE module and WAE](#).

Figure 11 Test Topology C: 6500/ACE and WAAS



The following flows were tested, simulating a wide area acceleration deployment over a simulated WAN.

1. The image data is formatted with a DICOM header using the Testman DICOM generator tool. The DICOM packet is sent to the VIP ip address 10.1.240.10 using the following script.

```
testman.exe -r100 -s -t10.1.240.10 -eAcuoMedStore01 -ns1 -ne1 -ni1 -i5000
```
2. The DICOM traffic is redirected to the WAE interface for application acceleration processing by the 612 WAE.
3. The traffic is sent back to the ISR for routing out the wan interface.
4. The traffic is sent over WAN destined for the VIP ip address of the ACE module
5. The ANS Core 6500 sends the packet to the ACE module and into the relevant context
6. The modalities and diagnostic viewers connect to the ACE module via a single IP address (virtual) provided by the ACE module.. Using the virtual IP address on the ACE allows the modalities and diagnostic viewers to remain connected when the active ACE fails over to the redundancy ACE

7. The service is created on the ACE module for each server on the DICOM services grid. These services contain information regarding the servers:
 - Server Name
 - Server IP Address
 - Server Weight
 - Server Port

For example:

```
rserver host AcuoMed1
  ip address 10.0.40.100
  inservice
rserver host AcuoMed2
  ip address 10.0.40.104
  inservice
rserver host AcuoStore1
  ip address 10.0.40.101
  inservice
rserver host AcuoStore2
  ip address 10.0.40.105
  inservice

serverfarm host DICOM
  predictor leastconns
  probe PING
  rserver AcuoMed1
    inservice
  rserver AcuoMed2
    inservice
  rserver AcuoStore1
    inservice
  rserver AcuoStore2
    inservice
```

8. The ACUO Load Optimizer service running on the primary server in the Acuo DICOM Services Grid monitors the queue depth of each of the servers in the grid and updates the service on the ACE based on the load on each server.
9. As the queue depth of a server becomes longer (for example, AcuoMed1 and 10.0.40.100), the Acuo Load Optimizer service connects to the ACE and changes the weight to a lower value for that server.
10. The traffic flows to the other server (for example, AcuoStore1 and 10.0.40.101) that has a higher weight values in the ACE and shorter queues on the DICOM. AcuoMed ensures the transport of the image traffic from the storage device to the viewer and from modality to the storage device. AcuoStore ensures that the communications between AcuoMed and the storage device is properly maintained.

In the lab setup, all servers performed both AcuoMed and AcuoStore functions.

Solution Components Tested

Hardware Tested

Table 8 lists the hardware used in the testing of this solution.

Table 8 **Hardware Tested**

Product	Identifier	Hardware Configuration (List Cards, Blades, Memory, CPU)	Functional Description
WS-C4948-10GE	4948c, 4948d	Cisco WS-C4948-10GE (MPC8540) processor (revision 5) with 262144K bytes of memory. Processor board ID FOX10450404 MPC8540 CPU at 667Mhz, Fixed Module Last reset from Reload 2 Virtual Ethernet interfaces 48 Gigabit Ethernet interfaces 2 Ten Gigabit Ethernet interfaces 511K bytes of non-volatile configuration memory.	Layer 2 and Layer 3 switch
WS-C4948-10GE	4948a, 4948b	Cisco WS-C4948-10GE (MPC8540) processor (revision 5) with 262144K bytes of memory. Processor board ID FOX10450404 MPC8540 CPU at 667Mhz, Fixed Module Last reset from Reload 2 Virtual Ethernet interfaces 48 Gigabit Ethernet interfaces 2 Ten Gigabit Ethernet interfaces 511K bytes of non-volatile configuration memory.	Access Layer switch
Catalyst 6500	6500-1, 6500-2	xxx	Layer 4 Load Balancer using Weighted Round Robin
Application Control Engine (ACE) Module	ACE Mod1		

Table 8 **Hardware Tested (continued)**

Integrated Service Router (ISR) 2821	ISR 2821		
Wide Area Engine (WAE) 612	WAE 612		
HP DL380 Server	AcuoMed1, AcuoMed2, AcuoStore1, AcuoStore2, Test Server, SQL	4 Intel Xeon CPUs @ 3.00 Ghz 3.25 G of RAM	Four servers were used for the AcuoMed and AcuoStore tool. One server was used as a test server using only AcuoMed and one server used for the SQL database
Buffalo LS-GL6F7	NAS	500G Network attached storage device	Network-attached storage device

Software Tested

[Table 9](#) lists the software that was tested with this solution.

Table 9 **Software Tested**

Product	Software Revision Used
WS-C4948-10GE	WS-C4948-10GE
HP DL380	MS-2003 Standard Server (service pack 1) AcuoMed and AcuoStore 5.0, 6.0 Acuo Load Optimizer 1.0 Testman 5.01 MS-SQL 2000

Configuration Task Lists

The following information was required before configuration of the equipment for the CSS (see [Table 10](#)):

- Access VLAN for connectivity to the Acuo Services Grid and CSS.
- Upstream VLAN for the CSS.
- IP addresses required:
 - IP range for the servers in the Acuo Services Grid and CSS downstream interface

- Default gateway address for the servers in the Acuo Services Grid (which is also the redundant interface IP address on the downstream connection of the CSS)
- IP address for the VIP on the CSS (should be on the VLAN 20 IP address subnet)
- IP address for the redundant interface (in the VLAN 20 IP address subnet) for the upstream connection on the CSS
- IP addresses for the VLAN 20 connections (includes the CSS upstream interface, VLAN 20 interface)
- Obtain the IP addresses from the Cisco MGN
- TCP listening port that is used on the AcuoMed Manager.
- Install AcuoMed and AcuoStore according to the Acuo installation guide on the servers located in the Acuo DICOM Services Grid
- Install SQL database according to Microsoft installation guide on the server dedicated for the SQL database found in the Acuo services grid. Note this server should be NIC teamed for connectivity to 4948c and 4948d.

Table 10 Configuration Task List

Equipment	Configuration Task	Command Line
4948a, 4948b	Enable IP routing	IP routing
	Configure VLAN 20 interface including HSRP (note: ensure that the VLAN is in the VLAN database)	Interface vlan 20 Ip address x.x.x.x y.y.y.y Standby 1 ip x.x.x.x Standby 1 timers 1 3 Standby 1 priority 51 Standby 1 preempt delay min 120
	Configure routing	Router OSPF 10 Network x.x.x.x y.255.255.255 area 10
	Configure interface to CSS	Interface GE (or) FE x/y/z Switchport access vlan 20 Switchport mode access
	Configure interfaces used for the EtherChannel	Interfaces GE or FE x/y/z (must be two interfaces) Channel-group 3 mode desirable
	Configure port channel (EtherChannel)	Interface port-channel 3 Switchport trunk encapsulation dot1q Switchport trunk allowed vlan 1,20 Switchport mode trunk
Configure interface for connection to the Cisco MGN	Interface x/y/z No switchport Ip address x.x.x.x y.y.y.y	

Table 10 Configuration Task List (continued)

4948c, 4948d	Configure VLAN 40 interface (note: ensure that the VLAN is in the VLAN database)	Interface vlan 40
	Configure interface(s) to the servers in the Acuo Services Grid	Interface GE or FE range x/y – z Switchport access vlan 40 Switchport mode access
	Configure interface to CSS	Interface GE or FE x/y/z Switchport access vlan 40 Switchport mode access
	Configure interfaces used for the EtherChannel	Interfaces GE or FE x/y/z (must be two interfaces) Channel-group 5 mode desirable
	Configure port channel (EtherChannel)	Interface port-channel 5 Switchport trunk encapsulation dot1q Switchport trunk allowed vlan 1,40 Switchport mode trunk
CSS1, CSS2	Allow XML, web management, default route	No restrict XML No restrict web-mgmt IProute 0.0.0.0 0.0.0.0 x.x.x.x
	Configure physical interfaces	Interface 1/1 Bridge vlan 20 Interface 1/2 Bridge vlan 40 Interface 2/2 Isc-port-one
	Configure circuits	Circuit VLAN 20 IP address x.x.x.x IP virtual-router 1 priority 200 IP redundant-interface 1 Y.Y.Y.Y Circuit VLAN 40 IP address x.x.x.x IP virtual-router 2 priority 200 IP redundant-interface 2 x.x.x.x
	Configure reporter	Reporter Farm Type vrid-peering Vrid y.y.y.y 1 Vrid x.x.x.x 2 Active Reporter Links Type critical-phy-all-up PHY 1/1 PHY 1/2 Active

Table 10 Configuration Task List (continued)

	Configure services	Service (name) - note should be a service per server IP address z.z.z.z Port (port number) Redundant-index xxxx Keepalive type tcp Keepalive port (port number) Weight 5 Active Service upstream-access IP address y.y.y.y
	Configure owner	Owner (name) Content (name) VIP address x.x.x.x Protocol tcp Port (number) Redundant-index www Add service (name) Balance weightedrr No persistent Active
	Complete configuration of circuits	Circuit VLAN 20 IP address x.x.x.x IP redundant-vip 1 z.z.z.z IP critical-reporter 1 Links IP critical-service 1 upstream-access Circuit VLAN 40 IP address x.x.x.x IP critical-reporter 2 Links IP critical-service 2 upstream-access
	Configure app session if configuration sync is used	App App session c.c.c.c

Configuration and Menus

See [Appendix D—IOS Configurations](#) for the final IOS for the ACE and WAAS configurations.

See [Appendix E—ACUO Configuration](#) for the relevant ACUO configuration screen shots.

Caveats or Limitations

Caveats, limitations, and workarounds are as follows:

- Component (hardware/software) limitation—The maximum concurrent connections per I/O module are 200,000 with 256 MB DRAM, and the maximum supported keepalives are 2048 when using the WebNS Software Version 8.10.
 - *Workaround or resolution*—N/A

- The Acuo Load Optimizer can run only on a single Acuo DICOM router at a time. It typically runs on the primary router in the DICOM Services Grid; however, it can be installed on multiple routers at the same time.
- *Workaround or resolution*—I
- If the router where the Acuo Load Optimizer is running fails, or if the service itself fails, it must be manually restarted on an alternate DICOM router.
- Inter-switch communications (ISC) link
 - *Workaround or resolution*—Only one ISC link is allowed per paired CSS
- Weighted Round Robin algorithm on the Content Services Switch (11503) works in the following manner:

If Server A and Server B are weighted as 4, and server C is weighted as 3, the Content Services Switch sends 4 connections to Server A, 4 Connections to Server B, and 3 connections to Server C, then starts the process again. At the end of 11 connections, the connection count look like AAAABBBBCCCC.

 - *Workaround or resolution*—The algorithm does not evenly place the connections to the servers; instead, it follows the weights and sends the number of connections to the server based on the weight. Over time, this balances out and provides higher service levels to the overall radiology systems.

This is masked somewhat by the Acuo Load Optimize because it monitors the load on the server queues and updates the weight tables accordingly.
- Windows Server Network Interface Cards (NIC) and Cisco switches—Auto-negotiation between a Cisco switch and a NIC on a Windows Server may not always succeed or may cause delays in traffic response times. This is a known Windows issue.
 - *Workaround or resolution*—To work around this problem, leave either the Cisco switch or the Windows NIC to auto-negotiate and manually set the speed and the duplex values of the other component.

Appendix A—DICOM Definition

Digital Imaging and Communications in Medicine (DICOM) is a standard for handling, storing, printing, and transmitting information in medical imaging. It includes a file format definition and a network communications protocol. The communication protocol is an application protocol that uses TCP/IP to communicate between systems. DICOM files can be exchanged between two entities that are capable of receiving image and patient data in DICOM format. The National Electrical Manufacturers Association (NEMA) holds the copyright to this standard. It was developed by the DICOM Standards Committee whose members are also partly members of NEMA.

For more information refer to the following link:

http://en.wikipedia.org/wiki/Digital_Imaging_and_Communications_in_Medicine#_note-0#_note-0

http://en.wikipedia.org/wiki/Digital_Imaging_and_Communications_in_Medicine#_note-1#_note-1

http://en.wikipedia.org/wiki/Digital_Imaging_and_Communications_in_Medicine#_note-2#_note-2

DICOM enables the integration of scanners, servers, workstations, printers, and network hardware from multiple manufacturers into a picture archiving and communication system. The different devices come with DICOM conformance statements which clearly state the DICOM classes they support. DICOM has been widely adopted by hospitals and is making inroads in smaller applications like dentists' and doctors' offices.

Appendix B—DICOM Header Information

The following information is from <http://www.sph.sc.edu/comd/rorden/dicom.html> and is provided for informational purposes.

Figure 12 shows a hypothetical DICOM image file. In this example, the first 794 bytes are used for a DICOM format header, which describes the image dimensions and retains other text information about the scan. The size of this header varies depending on how much header information is stored. Here, the header defines an image which has the dimensions 109x91x2 voxels, with a data resolution of 1 byte per voxel (so the total image size will be 19838). The image data follows the header information (the header and the image data are stored in the same file).

Figure 12 Hypothetical DICOM Image File

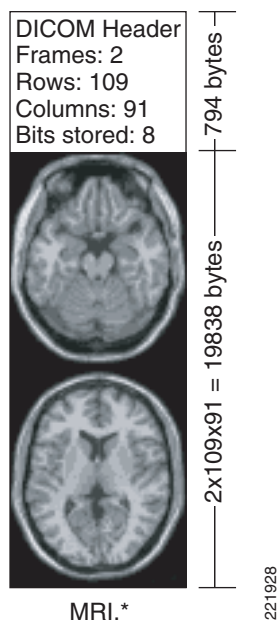


Figure 13 shows a more detailed list of the DICOM header as displayed by the software. Note that DICOM requires a 128-byte preamble (these 128 bytes are usually all set to zero), followed by the letters 'D', 'I', 'C', 'M'. This is followed by the header information, which is organized in 'groups'. For example, the group 0002hex is the file meta information group. The example on the left contains three elements: one defines the group length, one stores the file version and the third stores the transfer syntax.

Figure 13 Detailed DICOM Header

```

First 128 bytes: unused by DICOM format
Followed by the characters 'D','I','C','M'
This preamble is followed by extra information e.g.:

0002,0000,File Meta Elements Group Len: 132
0002,0001,File Meta Info Version: 256
0002,0010,Transfer Syntax UID: 1.2.840.10008.1.2.1.
0008,0000,Identifying Group Length: 152
0008,0060,Modality: MR
0008,0070,Manufacturer: MRIcro
0018,0000,Acquisition Group Length: 28
0018,0050,Slice Thickness: 2.00
0018,1020,Software Version: 46\64\37
0028,0000,Image Presentation Group Length: 148
0028,0002,Samples Per Pixel: 1
0028,0004,Photometric Interpretation: MONOCHROME2.
0028,0008,Number of Frames: 2
0028,0010,Rows: 109
0028,0011,Columns: 91
0028,0030,Pixel Spacing: 2.00\2.00
0028,0100,Bits Allocated: 8
0028,0101,Bits Stored: 8
0028,0102,High Bit: 7
0028,0103,Pixel Representation: 0
0028,1052,Rescale Intercept: 0.00
0028,1053,Rescale Slope: 0.00392157
7FE0,0000,Pixel Data Group Length: 19850
7FE0,0010,Pixel Data: 19838

```

The DICOM elements required depends on the image type, and are listed in part 3 of the DICOM standard. For example, this image modality is 'MR' (see group: element 0008:0060), so it should have elements to describe the MRI echo time. The absence of this information in this image is a violation of the DICOM standard. In practice, most DICOM format viewers (including MRIcro and ezDICOM) do not check for the presence of most of these elements, extracting only the header information which describes the image size.

The NEMA standard preceded DICOM, and the structure is very similar, with many of the same elements. The main difference is that the NEMA format does not have the 128-byte data offset buffer or the lead characters 'DICM'. In addition, NEMA did not explicitly define multi-frame (3D) images, so element 0028,0008 was not present.

Of particular importance is group: element 0002:0010. This defines the DICOM standard. This value reports the structure of the image data, revealing whether the data has been compressed. Note that many DICOM viewers can only handle uncompressed raw data. DICOM images can be compressed both by the common lossy JPEG compression scheme (where some high frequency information is lost) as well as a lossless JPEG scheme that is rarely seen outside of medical imaging (this is the original and rare Huffman lossless JPEG, *not* the more recent and efficient JPEG-LS algorithm). These codes are described in Part 5 of the DICOM standard (see <ftp://medical.nema.org/medical/dicom/2000/draft/>). An introduction to this the transfer syntax is provided at www.barre.nom.fr.

Table 11 *Transfer Syntax UID*

Transfer Syntax UID	Definition
1.2.840.10008.1.2	Raw data, Implicit VR, Little Endian
1.2.840.10008.1.2.x	Raw data, Explicit VR x = 1: Little Endian x = 2: Big Endian
1.2.840.10008.1.2.4.xx	PEG compression xx = 50-64: Lossy JPEG xx = 65-70: Lossless JPEG
1.2.840.10008.1.2.5	Lossless Run Length Encoding

Note that as well as reporting the compression technique (if any), the Transfer Syntax UID also reports the byte order for raw data. Different computers store integer values differently, so called 'big endian' and 'little endian' ordering. Consider a 16-bit integer with the value 257, the most significant byte stores the value 01 (=255) and the least significant byte stores the value 02. Some computers would save this value as 01:02, while others will store it as 02:01. Therefore, for data with more than 8-bits per sample, a DICOM viewer may need to swap the byte-order of the data to match the ordering used by your computer.

In addition to the Transfer Syntax UID (Table 11), the image is also specified by the Samples Per Pixel (0028:0002), Photometric Interpretation (0028:0004), the Bits Allocated (0028:0100). For most MRI and CT images, the photometric interpretation is a continuous monochrome (e.g. typically depicted with pixels in grayscale). In DICOM, these monochrome images are given a photometric interpretation of 'MONOCHROME1' (low values=bright, high values=dim) or 'MONOCHROME2' (low values=dark, high values=bright). However, many ultrasound images and medical photographs include color, and these are described by different photometric interpretations (e.g. Palette, RGB, CMYK, YBR, etc). Some color images (e.g. RGB) store three-samples per pixel (one each for red, green and blue), while monochrome and paletted images typically store only one sample per image. Each images store 8-bits (256 levels) or 16-bits per sample (65,535 levels), though some scanners save data in 12-bit or 32-bit resolution. So a RGB image that stores 3 samples per pixel at 8-bits per can potentially describe 16 million colors (256 cubed).

Appendix C—DICOM / WAAS Test Results

WAAS/WAE was tested with DICOM in Germany in cooperation with Dimension Data and DFC Systems. This section describes the outcome of that testing.

Testing was done by sending DICOM images from a modality to a PACS workstation. Data sets from the following modalities were included in the test: MR, CT, CR and Digital Mammography. Both compressed and uncompressed Lossless images were part of the study. Multiple bandwidths were tested, including 64, 128, 256 and 512 Kbps and 1, 2, 6 and 10 Mbps. All tests were performed with 40ms latency.

The results:

- Mammography studies showed improvements of up to 4.5 times faster through WAAS. The test set included 10 images in a single study, image size was 8Mbyte (Lossless compressed). The percentage of improvement was consistent across different bandwidths.

- CR showed improvements of up to 2.4 times faster through WAAS. The test set included 28 images within 10 studies, image size between 7Mbyte and 40Mbyte (12Mbyte average) The percentage of improvement was consistent across different bandwidths.
- CT showed improvements of up to 1.75 times faster through WAAS. The test set included an average of 300 images per study within 11 studies, with an image size of 512Kbyte. The percentage of improvement was consistent across different bandwidths.
- MR showed improvements of up to 1.53 times faster through WAAS. The test set included an average of 100 images per study within 15 studies, with an image size of 265Kbyte. The percentage of improvement was consistent across different bandwidths.
- We only used the Standard WAAS settings; the WAAS-DICOM Settings didn't show significant improvements
- There was almost no difference between the different available bandwidth

All testing was done with empty WAE caches. If the cache was not cleared, the performance improvements were considerably faster, but this does not represent real-world scenarios.

Mammography and CR studies showed the best results probably because of the large percentage of black values in those images.

One additional test showed that the percentage of improvement increased as the latency went up. Improvements may not be as dramatic across a campus as they would across a Wide Area Network.

Appendix D—IOS Configurations

ACE Module Configuration

```
ACE1-Slot3 login: admin
Password:
Cisco Application Control Software (ACSW)
TAC support: http://www.cisco.com/tac
Copyright (c) 2002-2006, Cisco Systems, Inc. All rights reserved.
The copyrights to certain works contained herein are owned by
other third parties and are used and distributed under license.
Some parts of this software are covered under the GNU Public
License. A copy of the license is available at
http://www.gnu.org/licenses/gpl.html.
ACE1-Slot3/Admin# show context
```

Number of Contexts = 5

```
Name: Admin , Id: 0
Description:
Resource-class: default
FT Auto-sync running-cfg configured state: enabled
FT Auto-sync running-cfg actual state: enabled
FT Auto-sync startup-cfg configured state: enabled
FT Auto-sync startup-cfg actual state: enabled
```

```
Name: context1, Id: 1
Description: SharePoint Testing
Resource-class: default
Vlans: Vlan82, Vlan210-211
FT Auto-sync running-cfg configured state: enabled
FT Auto-sync running-cfg actual state: enabled
FT Auto-sync startup-cfg configured state: enabled
FT Auto-sync startup-cfg actual state: enabled
```

```
Name: context2, Id: 2
Description: Web Logic Testing
Resource-class: Gold
Vlans:  Vlan220-221
FT Auto-sync running-cfg configured state: enabled
FT Auto-sync running-cfg actual state: enabled
FT Auto-sync startup-cfg configured state: enabled
FT Auto-sync startup-cfg actual state: enabled
```

```
Name: context3, Id: 3
Description: Web Sphere Testing
Resource-class: default
Vlans:  Vlan230-231
FT Auto-sync running-cfg configured state: enabled
FT Auto-sync running-cfg actual state: enabled
FT Auto-sync startup-cfg configured state: enabled
FT Auto-sync startup-cfg actual state: enabled
```

```
Name: dicom , Id: 4
Description: Dicom Testing
Resource-class: default
Vlans:  Vlan240-241
FT Auto-sync running-cfg configured state: enabled
FT Auto-sync running-cfg actual state: enabled
FT Auto-sync startup-cfg configured state: enabled
FT Auto-sync startup-cfg actual state: enabled
```

```
ACE1-Slot3/Admin# change ?
  Admin
  dicom
  context1
  context2
  context3
ACE1-Slot3/Admin# change dicom
ACE1-Slot3/dicom# sh run
Generating configuration....
```

```
login timeout 60
```

```
access-list ANYONE line 10 extended permit ip any any
access-list ANYONE line 20 extended permit icmp any any
```

```
probe icmp PING
  interval 2
  faildetect 2
probe tcp PROBE-TCP
  interval 2
  faildetect 2
  passdetect interval 10
  passdetect count 2
```

```
rserver host AcuoMed1
  ip address 10.0.40.100
  inservice
```

```

rserver host AcuoMed2
  ip address 10.0.40.104
  inservice
rserver host AcuoStore1
  ip address 10.0.40.101
  inservice
rserver host AcuoStore2
  ip address 10.0.40.105
  inservice

serverfarm host DICOM
  predictor leastconns
  probe PING
  rserver AcuoMed1
    inservice
  rserver AcuoMed2
    inservice
  rserver AcuoStore1
    inservice
  rserver AcuoStore2
    inservice

class-map type management match-any REMOTE-MANAGEMENT
  2 match protocol telnet any
  3 match protocol icmp any
  4 match protocol ssh any
  5 match protocol snmp any
  6 match protocol http any
  7 match protocol https any
class-map match-all VIP-HTTP-10
  2 match virtual-address 10.1.240.10 tcp eq 4321

policy-map type management first-match REMOTE-MANAGEMENT
  class REMOTE-MANAGEMENT
    permit
policy-map type loadbalance first-match VIP-POLICY-10
  class class-default
    serverfarm DICOM
policy-map multi-match LB-VIP
  class VIP-HTTP-10
    loadbalance vip inservice
    loadbalance policy VIP-POLICY-10
    loadbalance vip icmp-reply

interface vlan 240
  description Client side vlan
  ip address 10.1.240.5 255.255.255.0
  alias 10.1.240.4 255.255.255.0
  peer ip address 10.1.240.6 255.255.255.0
  access-group input ANYONE
  service-policy input LB-VIP
  service-policy input REMOTE-MANAGEMENT
  no shutdown
interface vlan 241
  description Server side vlan
  ip address 10.0.40.2 255.255.255.0
  alias 10.0.40.1 255.255.255.0
  peer ip address 10.0.40.3 255.255.255.0
  access-group input ANYONE
  service-policy input REMOTE-MANAGEMENT
  no shutdown

ip route 0.0.0.0 0.0.0.0 10.1.240.1

```



```

!
!
!
interface Loopback0
 ip address 10.1.6.3 255.255.255.255
!
interface Port-channel1
 switchport
 switchport trunk encapsulation dot1q
 switchport mode trunk
 no ip address
 spanning-tree guard loop
!
interface GigabitEthernet2/1
 description connection to ANS1-acc-1
 switchport
 switchport trunk encapsulation dot1q
 switchport trunk native vlan 100
 switchport trunk allowed vlan 1-209,211-219,221-229,231-4094
 switchport mode trunk
 no ip address
!
interface GigabitEthernet2/2
 description connection to ANS1-acc-2
 switchport
 switchport trunk encapsulation dot1q
 switchport trunk native vlan 100
 switchport trunk allowed vlan 1-209,211-219,221-229,231-4094
 switchport mode trunk
 no ip address
!
interface GigabitEthernet2/3
 description to WAAS Central Manager
 switchport
 switchport access vlan 21
 switchport mode access
 no ip address
 speed 1000
 duplex full
 spanning-tree portfast
!
!
interface GigabitEthernet2/25
 description Net QoS SuperAgent Collector SPAN Port
 switchport
 no ip address
!
interface GigabitEthernet2/26
 no ip address
 shutdown
!
interface GigabitEthernet2/27
 no ip address
 shutdown
!
interface GigabitEthernet2/28
 no ip address
 shutdown
!
interface GigabitEthernet2/29
 no ip address
 shutdown
!

```

```

interface GigabitEthernet2/30
  no ip address
  shutdown
!
interface GigabitEthernet2/31
  no ip address
  shutdown
!

interface GigabitEthernet2/44
  no ip address
  shutdown
!
interface GigabitEthernet2/45
  switchport
  switchport access vlan 100
  switchport mode access
  no ip address
  speed 1000
  duplex full
!
interface GigabitEthernet2/46
  no ip address
  shutdown
!
interface GigabitEthernet2/47
  no ip address
  shutdown
!
interface GigabitEthernet2/48
  description connection OOB
  switchport
  switchport access vlan 82
  switchport mode access
  no ip address
!
interface TenGigabitEthernet4/1
  description To ANS1-AGG-2
  switchport
  switchport trunk encapsulation dot1q
  switchport mode trunk
  no ip address
  channel-protocol lacp
  channel-group 1 mode active
!
interface TenGigabitEthernet4/2
  description To ANS1-AGG-2
  switchport
  switchport trunk encapsulation dot1q
  switchport mode trunk
  no ip address
  channel-protocol lacp
  channel-group 1 mode active
!
interface TenGigabitEthernet4/3
  description To ANS1-CORE-1
  ip address 10.1.3.2 255.255.255.0
!
interface TenGigabitEthernet4/4
  description To ANS1-CORE-2
  ip address 10.1.2.2 255.255.255.0
!
interface TenGigabitEthernet4/5
  no ip address

```

```

!
interface TenGigabitEthernet4/6
  no ip address
!
interface TenGigabitEthernet4/7
  description To DICOM 4948 Access C
  switchport
  switchport trunk encapsulation dot1q
  switchport trunk allowed vlan 1-81,83-209,211-219,221-229,231-239,241-4094
  switchport mode trunk
  no ip address
!
interface TenGigabitEthernet4/8
  description To DICOM 4948 Access D
  switchport
  switchport trunk encapsulation dot1q
  switchport trunk allowed vlan 1-81,83-209,211-219,221-229,231-239,241-4094
  switchport mode trunk
  no ip address
!
!
interface Vlan1
  no ip address
  shutdown
!
interface Vlan21
  description to WAAS Central Manager
  ip address 10.1.21.1 255.255.255.0
  ip nat inside
!
interface Vlan82
  description OOB management vlan
  ip address 172.28.196.43 255.255.255.0
  ip nat outside
!
interface Vlan100
  description General purpose Network - outside ACE
  ip address 10.1.100.2 255.255.255.0
  standby 1 ip 10.1.40.1
  standby 1 timers 1 3
  standby 1 priority 51
  standby 1 preempt delay minimum 120
  standby 100 ip 10.1.100.1
  standby 100 priority 150
  standby 100 preempt
!
interface Vlan150
  description Server VLAN 150
  ip address 10.1.50.2 255.255.255.0
  shutdown
  standby priority 150
  standby preempt
  standby 150 ip 10.1.50.1
!

interface Vlan240
  description DICOM ACE Client side connection
  ip address 10.1.240.2 255.255.255.0
  standby 240 ip 10.1.240.1
  standby 240 priority 150
  standby 240 preempt
!
!

```

```

!
dial-peer cor custom
!
!
!
alias exec s show ip interface brief
alias exec sb sh ip int brief
alias exec ss sh standby
!
line con 0
line vty 0 4
  session-timeout 60
  exec-timeout 60 0
  password cisco
  no login
line vty 5 15
  session-timeout 60
  exec-timeout 60 0
  login
!
!
monitor session 1 source vlan 100 , 210
monitor session 1 destination interface Gi2/25

no cns aaa enable
end

ANS1-AGG-1#

```

4948c Configuration

```

4948c#sh run
Building configuration...

Current configuration : 4971 bytes
!
version 12.2
no service pad
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
service compress-config
!
hostname 4948c
!
boot-start-marker
boot-end-marker
!
!
no aaa new-model
ip subnet-zero
no ip domain-lookup
!
vtp domain cisco
vtp mode transparent
!
!
!
power redundancy-mode redundant
no file verify auto
spanning-tree mode pvst

```

```

spanning-tree extend system-id
!
vlan internal allocation policy ascending
!
vlan 40,103
!
vlan 241
  name DICOM-ACE-CLIENT
!
interface Port-channel5
  switchport
  switchport trunk encapsulation dot1q
  switchport trunk allowed vlan 1,40
  switchport mode trunk
!
interface GigabitEthernet1/1
  switchport access vlan 241
  switchport mode access
  speed 100
  duplex full
!
interface GigabitEthernet1/2
  switchport access vlan 241
  switchport mode access
  speed 100
  duplex full
!
interface GigabitEthernet1/3
  switchport access vlan 241
  switchport mode access
  speed 100
  duplex full
!
interface GigabitEthernet1/4
  switchport access vlan 241
  switchport mode access
  speed 100
  duplex full
!
interface GigabitEthernet1/5
  switchport access vlan 40
  switchport mode access
!
interface GigabitEthernet1/6
  switchport access vlan 40
  switchport mode access
!
interface GigabitEthernet1/7
!
interface GigabitEthernet1/8
!
!
interface GigabitEthernet1/34
  switchport access vlan 103
  switchport mode access
!
interface GigabitEthernet1/35
!
interface GigabitEthernet1/36
!
interface GigabitEthernet1/37
!
interface GigabitEthernet1/38
!

```

```

interface GigabitEthernet1/39
!
interface GigabitEthernet1/40
  switchport access vlan 40
  switchport mode access
!
interface GigabitEthernet1/41
!
interface GigabitEthernet1/42
!
interface GigabitEthernet1/43
  switchport trunk encapsulation dot1q
  switchport mode trunk
!
interface GigabitEthernet1/44
  switchport trunk encapsulation dot1q
  switchport mode trunk
!
interface GigabitEthernet1/45
  switchport access vlan 40
  switchport mode access
!
interface GigabitEthernet1/46
  switchport trunk encapsulation dot1q
  switchport trunk allowed vlan 1,40
  switchport mode trunk
  channel-group 5 mode desirable non-silent
!
interface GigabitEthernet1/47
  switchport trunk encapsulation dot1q
  switchport trunk allowed vlan 1,40
  switchport mode trunk
  channel-group 5 mode desirable non-silent
!
interface GigabitEthernet1/48
  shutdown
!
interface TenGigabitEthernet1/49
!
interface TenGigabitEthernet1/50
!
interface Vlan1
  no ip address
!
interface Vlan40
  no ip address
!
ip default-gateway 10.0.40.1
ip route 0.0.0.0 0.0.0.0 10.0.40.1
ip http server
!
!
!
!
control-plane
!
!
line con 0
  stopbits 1
line vty 0 4
  login
line vty 5 15
  login

```

```

!
end

4948c#

4948c#sh vlan

VLAN Name                Status    Ports
-----
1    default                active   Gi1/7, Gi1/8, Gi1/9, Gi1/10
                                           Gi1/11, Gi1/12, Gi1/13, Gi1/14
                                           Gi1/15, Gi1/16, Gi1/17, Gi1/18
                                           Gi1/19, Gi1/20, Gi1/21, Gi1/22
                                           Gi1/23, Gi1/24, Gi1/25, Gi1/26
                                           Gi1/27, Gi1/28, Gi1/29, Gi1/30
                                           Gi1/31, Gi1/32, Gi1/33, Gi1/35
                                           Gi1/36, Gi1/37, Gi1/38, Gi1/39
                                           Gi1/41, Gi1/42, Gi1/43, Gi1/44
                                           Gi1/46, Gi1/48

40    VLAN0040                active   Gi1/5, Gi1/6, Gi1/40, Gi1/45
103   VLAN0103                active   Gi1/34
241   DICOM-ACE-CLIENT       active   Gi1/1, Gi1/2, Gi1/3, Gi1/4
1002  fddi-default            act/unsup
1003  token-ring-default     act/unsup
1004  fddinet-default        act/unsup
1005  trnet-default          act/unsup

```

612 WAE Configuration

Cisco Wide Area Application Services Engine Console

Username: admin

Password:

The device is configured with a well known default username/password for ease of initial configuration. This default username/password should be changed in order to avoid unwanted access to the device.

System initialization finished.

```

WAE-DICOM#sh run
! WAAS version 4.0.13 (build b12 Aug  9 2007)
!
device mode application-accelerator
!
!
hostname WAE-DICOM
!
!
!
!
!
!
primary-interface GigabitEthernet 1/0
!

```

```

!
!
interface GigabitEthernet 1/0
 ip address 10.1.26.2 255.255.255.0
 exit
interface GigabitEthernet 2/0
 shutdown
 exit
!
!
!
ip default-gateway 10.1.26.1
!
no auto-register enable
!
! ip path-mtu-discovery is disabled in WAAS by default
!
!
ip route 0.0.0.0 0.0.0.0 10.1.26.1
!
!
!
!
wccp router-list 1 10.1.26.1
wccp tcp-promiscuous router-list-num 1 password ****
wccp version 2
!
!
!
username admin password 1 bVmDmMMmZAPjY
username admin privilege 15
!
!
!
!
authentication login local enable primary
authentication configuration local enable primary
!
!
!
!
!
tfo tcp optimized-send-buffer 512
tfo tcp optimized-receive-buffer 512
!
!
no adapter epm enable
!
!
policy-engine application
 name Authentication
 name Backup
 name CAD
 name Call-Management
 name Conferencing
 name Console
 name Content-Management
 name Directory-Services
 name Email-and-Messaging
 name Enterprise-Applications
 name File-System
 name File-Transfer

```

```

name Instant-Messaging
name Name-Services
name P2P
name Printing
name Remote-Desktop
name Replication
name SQL
name SSH
name Storage
name Streaming
name Systems-Management

```

Appendix E—ACUO Configuration

The XML script required to communicate with the ACE module is below:

```

xml_cmd=<?xml version="1.0" encoding="utf-16" standalone="yes"?>
<request_xml>
  <serverfarm type="host" name="dicom">
    <rserver_sfarm name="DICOM12" port="4321">
      <weight value="5"> </weight>
      <inservice sense="yes"> </inservice>
    </rserver_sfarm>
  </serverfarm>
</request_xml>

<response_xml>
<config_command>
<command>
serverfarm host dicom
rserver DICOM12 4321
weight 5
inservice
</command>
<status code="100" text="XML_CMD_SUCCESS"/>
</config_command>
</response_xml>

```

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