

**PACS (picture archiving and communication system)**

PACS (picture archiving and communication system) is a medical imaging technology used primarily in healthcare organizations to securely store and digitally transmit electronic images and clinically-relevant reports. The use of PACS eliminates the need to manually file and store, retrieve and send sensitive information, films and reports. Instead, medical documentation and images can be securely housed in off-site servers and safely accessed essentially from anywhere in the world using PACS software, workstations and mobile devices.

Medical imaging storage technologies such as PACS are increasingly important as the volume of digital medical images grows throughout the healthcare industry and data analytics of those images becomes more prevalent.

### Who uses PACS

While radiologists have predominately used PACS -- radiology traditionally being the most prolific producer of X-ray images -- PACS technologies have been incorporated into other departments, such as nuclear medicine imaging, cardiology, pathology, oncology and dermatology.

Medical images are taken and reviewed for clinical analysis, diagnosis and treatment as part of a patient's care plan. The information collected can be used to identify any anatomical and physiological abnormalities, chart the progress of treatment and provide clinicians with a database of normal patient scans for later reference.

Having digital access to the most updated version of a patient's medical images, clinical reports and history can expedite and improve care, lessening the likelihood of treatment and prescription errors and preventing redundant testing. Digital access can also improve patient safety and save both the healthcare facility and the patient time and money.

### Development

Nearly all the major medical imaging equipment manufacturers and medical IT companies offer PACS. This system is used to store, retrieve, present and share images produced by various medical hardware modalities, such as from an X-ray, [computed tomography (CT) scan](https://whatis.techtarget.com/definition/CT-scan), magnetic resonance imaging (MRI) and ultrasound machines.

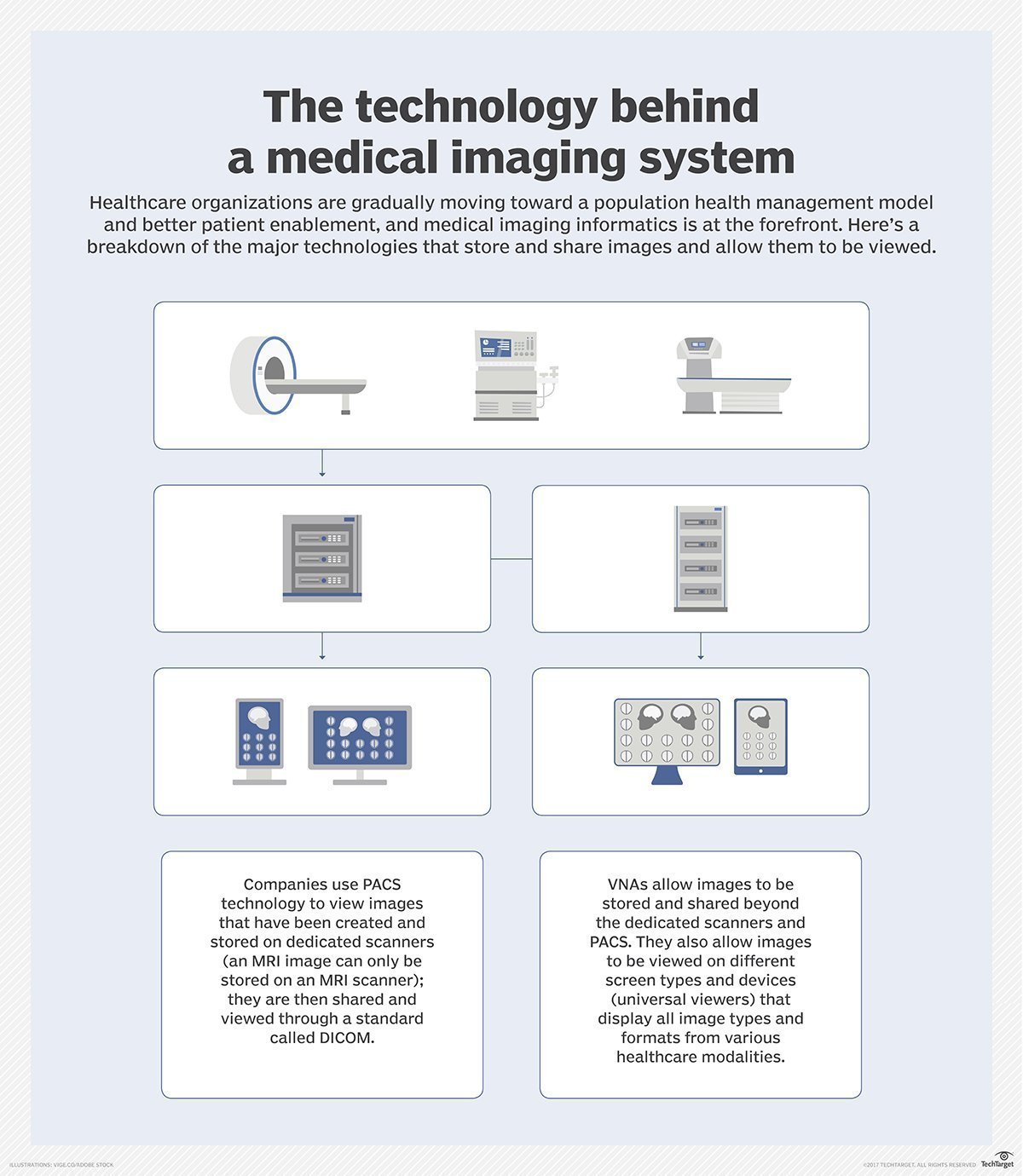
The modern use of PACS can be attributed to [DICOM](https://searchhealthit.techtarget.com/definition/DICOM-Digital-Imaging-and-Communications-in-Medicine) (Digital Imaging and Communications in Medicine), which is a standard protocol for the management and transmission of medical images and related data. DICOM was originally developed by the National Electrical Manufacturers Association (NEMA) and the American College of Radiology (ACR). In 1983, ACR and NEMA formed a joint committee in hopes of developing medical imaging technology standards and to facilitate the development and expansion of PACS.

### PACS architecture

PACS has four major components: hardware imaging machines; a secure network for the distribution and exchange of patient images; a workstation or mobile device for viewing, processing and interpreting images; and electronic archives for storing and retrieving images and related documentation and reports.

In turn, PACS has four main uses. The technology:

* replaces the need for hard-copy films and management of physical archives.
* allows for remote access, enabling clinicians in different physical locations to review the same data simultaneously.
* offers an electronic platform for images interfacing with other medical automation systems such as a hospital information system (HIS), electronic health record ([EHR](https://searchhealthit.techtarget.com/definition/electronic-health-record-EHR)), and radiology information system ([RIS](https://searchhealthit.techtarget.com/definition/Radiology-Information-System-RIS)).
* allows radiologists and other radiology and medical personnel to manage the workflow of patient exams



This illustration compares picture archiving and communication systems (PACS) and vendor neutral archives (VNA).

### Cloud-based PACS

Imaging information systems like PACS have replaced the need to store and manage hard-copy films and reports in space-consuming shelving and rooms. Instead, medical images and non-image data can be securely stored digitally on premises or in the cloud.

Cloud-based PACS store and back up an organization's medical imaging data to a secure off-site server. This is required in the U.S. by the [HIPAA](https://searchhealthit.techtarget.com/definition/HIPAA) Security Rule, which governs the privacy of patient information. A cloud PACS also enables medical staff to view medical imaging data from any approved devices, such as a smartphone.

Providers often use a [hybrid cloud](https://searchcloudcomputing.techtarget.com/definition/hybrid-cloud) system, in which primary images are stored on-premises and backups are kept in the cloud. Additional types of storage architectures may be configured and attached to the PACS server, such as direct-attached storage ([DAS](https://searchstorage.techtarget.com/definition/direct-attached-storage)), network-attached storage ([NAS](https://searchstorage.techtarget.com/definition/network-attached-storage)) or via a storage area network ([SAN](https://searchstorage.techtarget.com/definition/storage-area-network-SAN)), each allowing for upgradeability, connectivity, improved protection against failure and added security.

### Use with other medical imaging technologies

Although PACS processes are widely adopted in healthcare, vendor neutral archive ([VNA](https://searchhealthit.techtarget.com/definition/Vendor-neutral-archive-VNA)) technology has replaced PACS in some healthcare settings and integrates with PACS in others.

PACS vendors employ various syntaxes within DICOM, which makes it hard for data from one system to work in another system. VNAs enable data integration by deconstructing data from an originating PACS and then migrating the data to the new system with the proper syntax.

DICOM enables imaging technologies to connect with and transfer health data to systems at other healthcare organizations. A RIS, a networked software system for managing medical imagery and associated data, is often used with PACS and VNAs to manage image archives, image orders, record-keeping and billing.

# HIPAA (Health Insurance Portability and Accountability Act)

# HIPAA (Health Insurance Portability and Accountability Act of 1996) is United States legislation that provides...

# hybrid cloud

Hybrid cloud is a cloud computing environment that uses a mix of on-premises, private cloud and third-party, public...

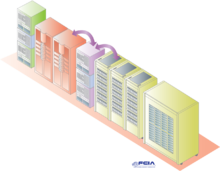
# storage area network (SAN)

A storage area network (SAN) is a dedicated high-speed network or subnetwork that interconnects and presents shared...

A **storage area network** (**SAN**) or **storage network** is a [computer network](https://en.wikipedia.org/wiki/Computer_network) which provides access to consolidated, [block-level data storage](https://en.wikipedia.org/wiki/Block_device). SANs are primarily used to access storage devices, such as [disk arrays](https://en.wikipedia.org/wiki/Disk_array) and [tape libraries](https://en.wikipedia.org/wiki/Tape_library) from [servers](https://en.wikipedia.org/wiki/Server_(computing)) so that the devices appear to the [operating system](https://en.wikipedia.org/wiki/Operating_system) as [direct-attached storage](https://en.wikipedia.org/wiki/Direct-attached_storage). A SAN typically is a dedicated network of storage devices not accessible through the [local area network](https://en.wikipedia.org/wiki/Local_area_network) (LAN).

Although a SAN provides only block-level access, [file systems](https://en.wikipedia.org/wiki/File_systems) built on top of SANs do provide file-level access and are known as [shared-disk file systems](https://en.wikipedia.org/wiki/Shared-disk_file_system).

## Storage architectures[[edit](https://en.wikipedia.org/w/index.php?title=Storage_area_network&action=edit&section=1)]

[](https://en.wikipedia.org/wiki/File:Fibre_Channel_Storage_Area_Network.png)

The Fibre Channel SAN connects servers to storage via Fibre Channel switches.

Storage area networks (SANs) are sometimes referred to as *network behind the servers*[[1]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-Tate-1):11 and historically developed out of the [centralised data storage](https://en.wikipedia.org/w/index.php?title=Centralised_data_storage&action=edit&redlink=1) model, but with its own [data network](https://en.wikipedia.org/wiki/Data_network). A SAN is, at its simplest, a dedicated network for data storage. In addition to storing data, SANs allow for the automatic [backup](https://en.wikipedia.org/wiki/Backup) of data, and the monitoring of the storage as well as the backup process.[[2]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-NIIT-2):16–17 A SAN is a combination of hardware and software.[[2]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-NIIT-2):9 It grew out of data-centric [mainframe architectures](https://en.wikipedia.org/wiki/Mainframe_computer), where clients in a network can connect to several [servers](https://en.wikipedia.org/wiki/Server_(computing)) that store different types of data.[[2]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-NIIT-2):11 To scale storage capacities as the volumes of data grew, [direct-attached storage](https://en.wikipedia.org/wiki/Direct-attached_storage) (DAS) was developed, where [disk arrays](https://en.wikipedia.org/wiki/Disk_arrays) or [just a bunch of disks](https://en.wikipedia.org/wiki/Just_a_bunch_of_disks) (JBODs) were attached to servers. In this architecture storage devices can be added to increase storage capacity. However, the server through which the storage devices are accessed is a [single point of failure](https://en.wikipedia.org/wiki/Single_point_of_failure), and a large part of the LAN network bandwidth is used for accessing, storing and backing up data. To solve the single point of failure issue, a *direct-attached shared storage* architecture was implemented, where several servers could access the same storage device.[[2]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-NIIT-2):16–17

DAS was the first network storage system and is still widely implemented where data storage requirements are not very high. Out of it developed the [network-attached storage](https://en.wikipedia.org/wiki/Network-attached_storage) (NAS) architecture, where one or more dedicated [file server](https://en.wikipedia.org/wiki/File_server) or storage devices are made available in a LAN.[[2]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-NIIT-2):18 Therefore, the transfer of data, particularly for backup, still takes place over the existing LAN. If more than a terabyte of data was stored at any one time, LAN bandwidth became a bottleneck.[[2]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-NIIT-2):21–22 Therefore, SANs were developed, where a dedicated storage network was attached to the LAN, and terabytes of data are transferred over a dedicated high speed and bandwidth network. Within the storage network, storage devices are interconnected. Transfer of data between storage devices, such as for backup, happens behind the servers and is meant to be transparent.[[2]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-NIIT-2):22 While in a NAS architecture data is transferred using the [TCP](https://en.wikipedia.org/wiki/Transmission_Control_Protocol) and [IP](https://en.wikipedia.org/wiki/Internet_Protocol) protocols over [Ethernet](https://en.wikipedia.org/wiki/Ethernet), distinct protocols were developed for SANs, such as [Fibre Channel](https://en.wikipedia.org/wiki/Fibre_Channel), [iSCSI](https://en.wikipedia.org/wiki/ISCSI), [Infiniband](https://en.wikipedia.org/wiki/InfiniBand). Therefore, SANs often have their own network and storage devices, which have to be bought, installed, and configured. This makes SANs inherently more expensive than NAS architectures.[[2]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-NIIT-2):29

## Components[[edit](https://en.wikipedia.org/w/index.php?title=Storage_area_network&action=edit&section=2)]

[](https://en.wikipedia.org/wiki/File:QLogic_QLE2562_8Gb_FC_HBA.jpg)

Dual port 8 Gb FC host bus adapter card

SANs have their own networking devices, such as SAN switches. To access the SAN so-called SAN servers are used, which in turn connect to SAN interfaces. Within the SAN a range of data storage devices may be interconnected, such as SAN capable disk arrays, JBODS and [tape libraries](https://en.wikipedia.org/wiki/Tape_libraries).[[2]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-NIIT-2):32,35–36

### Host layer[[edit](https://en.wikipedia.org/w/index.php?title=Storage_area_network&action=edit&section=3)]

Servers that allow access to the SAN and its storage devices are said to form the *host layer* of the SAN. Such servers have host bus adapters (HBAs), which are cards that attach to slots on the server main board (usually PCI slots) and run with a corresponding [firmware](https://en.wikipedia.org/wiki/Firmware) and [driver.](https://en.wikipedia.org/wiki/Device_driver) Through the host bus adapters the [operating system](https://en.wikipedia.org/wiki/Operating_system) of the server can communicate with the storage devices in the SAN.[[3]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-Dummies-3):26 A cable connects to the host bus adapter card through the gigabit interface converter (GBIC). These interface converters are also attached to switches and storage devices within the SAN, and they convert digital bits into light impulses that can then be transmitted over the Fiber Channel cables. Conversely, the GBIC converts incoming light impulses back into digital bits. The predecessor of the GBIC was called gigabit link module (GLM).[[3]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-Dummies-3):27 This is applicable for Fiber Channel deployments only.

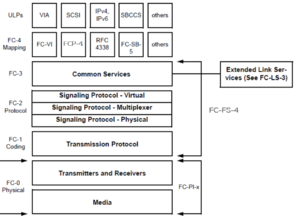
### Fabric layer[[edit](https://en.wikipedia.org/w/index.php?title=Storage_area_network&action=edit&section=4)]

[](https://en.wikipedia.org/wiki/File:ML-QLOGICNFCCONN.JPG)

[Qlogic](https://en.wikipedia.org/wiki/Qlogic) SAN-[switch](https://en.wikipedia.org/wiki/Fibre_Channel_switch) with optical [Fibre Channel](https://en.wikipedia.org/wiki/Fibre_Channel) [connectors](https://en.wikipedia.org/wiki/Electrical_connector) installed

The fabric layer consists of SAN networking devices that include [SAN switches](https://en.wikipedia.org/wiki/SAN_switch), routers, protocol bridges, gateway devices, and cables. SAN network devices move data within the SAN, or between an *initiator*, such as an HBA port of a server, and a *target*, such as the port of a storage device. SAN networks are usually built with redundancy, so SAN switches are connected with redundant links. SAN switches connect the servers with the storage devices and are typically non-blocking, thus transmitting data across all attached wires at the same time.[[3]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-Dummies-3):29 When SANs were first built, hubs were the only devices that were [Fibre Channel](https://en.wikipedia.org/wiki/Fibre_Channel) capable, but Fibre Channel switches were developed and hubs are now rarely found in SANs. Switches have the advantage over hubs that they allow all attached devices to communicate simultaneously, as a switch provides a dedicated link to connect all its ports with one another.[[3]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-Dummies-3):34 SAN switches are for redundancy purposes set up in a [meshed topology](https://en.wikipedia.org/wiki/Mesh_networking). A single SAN switch can have as few as 8 ports, up to 32 ports with modular extensions.[[3]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-Dummies-3):35 So called director class switches can have as many as 128 ports.[[3]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-Dummies-3):36 When SANs were first built Fibre Channel had to be implemented over copper cables, these days multimode [optical fibre cables](https://en.wikipedia.org/wiki/Optical_fiber) are used in SANs.[[3]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-Dummies-3):40 In switched SANs the Fibre Channel switched fabric protocol FC-SW-6 is used, where every device in the SAN has a hardcoded [World Wide Name](https://en.wikipedia.org/wiki/World_Wide_Name) (WWN) address in the host bus adapter (HBA). If a device is connected to the SAN its WWN is registered in the SAN switch name server.[[3]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-Dummies-3):47 In place of a WWN, or worldwide port name (WWPN), SAN Fibre Channel storage device vendors may also hardcode a worldwide node name (WWNN). The ports of storage devices often have an WWN starting with 5, while the bus adapters of servers start with 10 or 21.[[3]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-Dummies-3):47

### Storage layer[[edit](https://en.wikipedia.org/w/index.php?title=Storage_area_network&action=edit&section=5)]

[](https://en.wikipedia.org/wiki/File:FC_Layers-2.png)

Fibre Channel is a layered technology that starts at the physical layer and progresses through the protocols to the upper level protocols like SCSI and SBCCS.

On top of the Fibre Channel-Switched Protocol is often the serialized [Small Computer Systems Interface](https://en.wikipedia.org/wiki/Small_Computer_Systems_Interface) (SCSI) protocol, implemented in servers and SAN storage devices. It allows software applications to communicate, or encode data, for storage devices. The [internet Small Computer Systems Interface](https://en.wikipedia.org/wiki/ISCSI) (iSCSI) over [Ethernet](https://en.wikipedia.org/wiki/Ethernet) and the [Infiniband](https://en.wikipedia.org/wiki/Infiniband) protocols may also be found implemented in SANs, but are often bridged into the Fibre Channel SAN.[[3]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-Dummies-3):47 However, Infiniband and iSCSI storage devices, in particular, disk arrays, are available.[[3]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-Dummies-3):48

The various storage devices in a SAN are said to form the *storage layer*. It can include a variety of [hard disk](https://en.wikipedia.org/wiki/Hard_disk) and [magnetic tape](https://en.wikipedia.org/wiki/Magnetic_tape) devices that store data. In SANs disk arrays are joined through a [RAID](https://en.wikipedia.org/wiki/RAID), which makes a lot of hard disks look and perform like one big storage device.[[3]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-Dummies-3):48 Every storage device, or even partition on that storage device, has a [logical unit number](https://en.wikipedia.org/wiki/Logical_unit_number) (LUN) assigned to it. This is a unique number within the SAN and every node in the SAN, be it a server or another storage device, can access the storage through the LUN. The LUNs allow for the storage capacity of a SAN to be segmented and for the implementation of access controls. A particular server, or a group of servers, may, for example, be only given access to a particular part of the SAN storage layer, in the form of LUNs. When a storage device receives a request to read or write data, it will check its access list to establish whether the node, identified by its LUN, is allowed to access the storage area, also identified by a LUN.[[3]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-Dummies-3):148–149 LUN masking is a technique whereby the host bus adapter and the SAN software of a server restrict the LUNs for which commands are accepted. In doing so LUNs that should in any case not be accessed by the server are masked.[[3]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-Dummies-3):354 Another method to restrict server access to particular SAN storage devices is fabric-based access control, or zoning, which has to be implemented on the SAN networking devices and the servers. Thereby server access is restricted to storage devices that are in a particular SAN zone.[[4]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-4)

## Network protocols[[edit](https://en.wikipedia.org/w/index.php?title=Storage_area_network&action=edit&section=6)]

Most storage networks use the [SCSI](https://en.wikipedia.org/wiki/SCSI) protocol for communication between servers and disk drive devices.[[*citation needed*](https://en.wikipedia.org/wiki/Wikipedia:Citation_needed)] A mapping layer to other protocols is used to form a network:

* [ATA over Ethernet (AoE)](https://en.wikipedia.org/wiki/ATA_over_Ethernet), mapping of [ATA](https://en.wikipedia.org/wiki/AT_Attachment) over [Ethernet](https://en.wikipedia.org/wiki/Ethernet)
* [Fibre Channel Protocol](https://en.wikipedia.org/wiki/Fibre_Channel_Protocol) (FCP), the most prominent one, is a mapping of SCSI over [Fibre Channel](https://en.wikipedia.org/wiki/Fibre_Channel)
* [Fibre Channel over Ethernet](https://en.wikipedia.org/wiki/Fibre_Channel_over_Ethernet) (FCoE)
* [ESCON](https://en.wikipedia.org/wiki/ESCON) over Fibre Channel ([FICON](https://en.wikipedia.org/wiki/FICON)), used by [mainframe computers](https://en.wikipedia.org/wiki/Mainframe_computer)
* [HyperSCSI](https://en.wikipedia.org/wiki/HyperSCSI), mapping of SCSI over Ethernet
* [iFCP](https://en.wikipedia.org/wiki/IFCP)[[5]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-5) or [SANoIP](https://en.wikipedia.org/wiki/SANoIP)[[6]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-6) mapping of FCP over IP
* [iSCSI](https://en.wikipedia.org/wiki/ISCSI), mapping of SCSI over [TCP/IP](https://en.wikipedia.org/wiki/TCP/IP)
* [iSCSI Extensions for RDMA](https://en.wikipedia.org/wiki/ISCSI_Extensions_for_RDMA) (iSER), mapping of iSCSI over [InfiniBand](https://en.wikipedia.org/wiki/InfiniBand)
* [Network block device](https://en.wikipedia.org/wiki/Network_block_device), mapping [device node](https://en.wikipedia.org/wiki/Device_node) requests on [UNIX-like systems](https://en.wikipedia.org/wiki/UNIX-like) over [stream sockets](https://en.wikipedia.org/wiki/Stream_socket) like TCP/IP
* [SCSI RDMA Protocol](https://en.wikipedia.org/wiki/SCSI_RDMA_Protocol) (SRP), another SCSI implementation for RDMA transports

Storage networks may also be built using [SAS](https://en.wikipedia.org/wiki/Serial_Attached_SCSI) and [SATA](https://en.wikipedia.org/wiki/Serial_ATA) technologies. SAS evolved from SCSI direct-attached storage. SATA evolved from [IDE](https://en.wikipedia.org/wiki/Parallel_ATA) direct-attached storage. SAS and SATA devices can be networked using [SAS Expanders](https://en.wikipedia.org/wiki/Serial_Attached_SCSI#SAS_expanders).

Examples of stacked protocols using SCSI:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Applications | | | | | | |
| [SCSI](https://en.wikipedia.org/wiki/SCSI) Layer | | | | | | |
| [FCP](https://en.wikipedia.org/wiki/Fibre_Channel_Protocol) | [FCP](https://en.wikipedia.org/wiki/Fibre_Channel_Protocol) | [FCP](https://en.wikipedia.org/wiki/Fibre_Channel_Protocol) | [FCP](https://en.wikipedia.org/wiki/Fibre_Channel_Protocol) | [iSCSI](https://en.wikipedia.org/wiki/ISCSI) | [iSER](https://en.wikipedia.org/wiki/ISCSI_Extensions_for_RDMA) | [SICKLE](https://en.wikipedia.org/wiki/SCSI_RDMA_Protocol) |
| [FCIP](https://en.wikipedia.org/wiki/Fibre_Channel_over_IP) | [iFCP](https://en.wikipedia.org/wiki/Internet_Fibre_Channel_Protocol) |
| [TCP](https://en.wikipedia.org/wiki/Internet_Protocol) | | | [RDMA](https://en.wikipedia.org/wiki/Remote_direct_memory_access) Transport | |
| [FCoE](https://en.wikipedia.org/wiki/Fibre_Channel_over_Ethernet) | [IP](https://en.wikipedia.org/wiki/Internet_Protocol) | | | [IP](https://en.wikipedia.org/wiki/Internet_Protocol) or [InfiniBand](https://en.wikipedia.org/wiki/InfiniBand) Network | |
| [FC](https://en.wikipedia.org/wiki/Fibre_Channel) | [Ethernet](https://en.wikipedia.org/wiki/Ethernet) | | | | [Ethernet](https://en.wikipedia.org/wiki/Ethernet) or InfiniBand Link | |

## Software[[edit](https://en.wikipedia.org/w/index.php?title=Storage_area_network&action=edit&section=7)]

A SAN is primarily defined as a special purpose network, the [Storage Networking Industry Association](https://en.wikipedia.org/wiki/Storage_Networking_Industry_Association) (SNIA) defines a SAN as "a network whose primary purpose is the transfer of data between computer systems and storage elements". But a SAN does not just consist of a communication infrastructure, it also has a software *management layer*. This software organizes the servers, storage devices, and the network so that data can be transferred and stored. Because a SAN is not a [direct attached storage](https://en.wikipedia.org/wiki/Direct_attached_storage) (DAS), the storage devices in the SAN are not owned and managed by a server.[[1]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-Tate-1):11 Potentially the data storage capacity that can be accessed by a single server through a SAN is infinite, and this storage capacity may also be accessible by other servers.[[1]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-Tate-1):12 Moreover, SAN software must ensure that data is directly moved between storage devices within the SAN, with minimal server intervention.[[1]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-Tate-1):13

SAN management software is installed on one or more servers and management clients on the storage devices. Two approaches have developed to SAN management software: in-band management means that management data between server and storage devices is transmitted on the same network as the storage data. While out-of-band management means that management data is transmitted over dedicated links.[[1]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-Tate-1):174 SAN management software will collect management data from all storage devices in the storage layer, including info on read and write failure, storage capacity bottlenecks and failure of storage devices. SAN management software may integrate with the [Simple Network Management Protocol](https://en.wikipedia.org/wiki/Simple_Network_Management_Protocol) (SNMP).[[1]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-Tate-1):176

In 1999 an open standard was introduced for managing storage devices and provide interoperability, the Common Information Model (CIM). The web-based version of CIM is called Web-Based Enterprise Management (WBEM) and defines SAN storage device objects and process transactions. Use of these protocols involves a CIM object manager (CIMOM), to manage objects and interactions, and allows for the central management of SAN storage devices. Basic device management for SANs can also be achieved through the Storage Management Interface Specification (SMI-S), were CIM objects and processes are registered in a directory. Software applications and subsystems can then draw on this directory.[[1]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-Tate-1):177 Management software applications are also available to configure SAN storage devices, allowing, for example, the configuration of zones and logical unit numbers (LUNs).[[1]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-Tate-1):178

Ultimately SAN networking and storage devices are available from many vendors. Every SAN vendor has its own management and configuration software. Common management in SANs that include devices from different vendors is only possible if vendors make the [application programming interface](https://en.wikipedia.org/wiki/Application_programming_interface) (API) for their devices available to other vendors. In such cases, upper-level SAN management software can manage the SAN devices from other vendors.[[1]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-Tate-1):180

## Filesystems support[[edit](https://en.wikipedia.org/w/index.php?title=Storage_area_network&action=edit&section=8)]

In a SAN data is transferred, stored and accessed on a block level. As such a SAN does not provide [data file](https://en.wikipedia.org/wiki/Data_file) abstraction, only [block-level storage](https://en.wikipedia.org/wiki/Block-level_storage) and operations. But [file systems](https://en.wikipedia.org/wiki/File_systems) have been developed to work with SAN software to provide [file-level access](https://en.wikipedia.org/w/index.php?title=File-level_access&action=edit&redlink=1). These are known as [shared-disk file system](https://en.wikipedia.org/wiki/Shared-disk_file_system) (SAN file system). Server operating systems maintain their own [file systems](https://en.wikipedia.org/wiki/File_system) on their own dedicated, non-shared LUNs, as though they were local to themselves. If multiple systems were simply to attempt to share a LUN, these would interfere with each other and quickly corrupt the data. Any planned sharing of data on different computers within a LUN requires software, such as [SAN file systems](https://en.wikipedia.org/wiki/SAN_file_system) or [clustered computing](https://en.wikipedia.org/wiki/Clustered_computing).

## In media and entertainment[[edit](https://en.wikipedia.org/w/index.php?title=Storage_area_network&action=edit&section=9)]

[Video editing](https://en.wikipedia.org/wiki/Video_editing) systems require very high data transfer rates and very low latency. SANs in media and entertainment are often referred to as serverless due to the nature of the configuration which places the video workflow (ingest, editing, playout) desktop clients directly on the SAN rather than attaching to servers. Control of data flow is managed by a distributed file system such as StorNext by Quantum.[[7]](https://en.wikipedia.org/wiki/Storage_area_network#cite_note-7) Per-node bandwidth usage control, sometimes referred to as [quality of service](https://en.wikipedia.org/wiki/Quality_of_service) (QoS), is especially important in video editing as it ensures fair and prioritized bandwidth usage across the network.

## Quality of service[[edit](https://en.wikipedia.org/w/index.php?title=Storage_area_network&action=edit&section=10)]

SAN Storage QoS enables the desired storage performance to be calculated and maintained for network customers accessing the device. Some factors that affect SAN QoS are:

* [Bandwidth](https://en.wikipedia.org/wiki/Bandwidth_(computing)) – The rate of data throughput available on the system.
* [Latency](https://en.wikipedia.org/wiki/Latency_(engineering)) – The time delay for a read/write operation to execute.
* Queue depth – The number of outstanding operations waiting to execute to the underlying disks (traditional or [solid-state drives](https://en.wikipedia.org/wiki/Solid-state_drive)).

QoS can be impacted in a SAN storage system by an unexpected increase in data traffic (usage spike) from one network user that can cause performance to decrease for other users on the same network. This can be known as the "noisy neighbor effect." When QoS services are enabled in a SAN storage system, the "noisy neighbor effect" can be prevented and network storage performance can be accurately predicted.

Using SAN storage QoS is in contrast to using disk over-provisioning in a SAN environment. Over-provisioning can be used to provide additional capacity to compensate for peak network traffic loads. However, where network loads are not predictable, over-provisioning can eventually cause all bandwidth to be fully consumed and latency to increase significantly resulting in SAN performance degradation.

## Storage virtualization[[edit](https://en.wikipedia.org/w/index.php?title=Storage_area_network&action=edit&section=11)]

*Main article:*[*Storage virtualization*](https://en.wikipedia.org/wiki/Storage_virtualization)

[Storage virtualization](https://en.wikipedia.org/wiki/Storage_virtualization) is the process of abstracting logical storage from physical storage. The physical storage resources are aggregated into storage pools, from which the logical storage is created. It presents to the user a logical space for data storage and transparently handles the process of mapping it to the physical location, a concept called [location transparency](https://en.wikipedia.org/wiki/Location_transparency). This is implemented in modern disk arrays, often using vendor proprietary technology. However, the goal of storage virtualization is to group multiple disk arrays from different vendors, scattered over a network, into a single storage device. The single storage device can then be managed uniformly.[[*citation needed*](https://en.wikipedia.org/wiki/Wikipedia:Citation_needed)]

# network-attached storage (NAS)

Network-attached storage (NAS) is dedicated file storage that enables multiple users and heterogeneous client devices...

From Wikipedia, the free encyclopedia

[Jump to navigation](https://en.wikipedia.org/wiki/Network-attached_storage#mw-head)[Jump to search](https://en.wikipedia.org/wiki/Network-attached_storage#p-search)

*Not to be confused with*[*storage area network*](https://en.wikipedia.org/wiki/Storage_area_network)*.*

[](https://en.wikipedia.org/wiki/File:Netgear_ReadyNAS_NV%2B.jpg)

A Netgear NAS

**Network-attached storage** (**NAS**) is a file-level (as opposed to [block-level](https://en.wikipedia.org/wiki/Block_device)) [computer data storage](https://en.wikipedia.org/wiki/Computer_data_storage) server connected to a [computer network](https://en.wikipedia.org/wiki/Computer_network) providing data access to a [heterogeneous](https://en.wikipedia.org/wiki/Heterogeneous_computing) group of clients. NAS is specialized for [serving files](https://en.wikipedia.org/wiki/File_server) either by its hardware, software, or configuration. It is often manufactured as a [computer appliance](https://en.wikipedia.org/wiki/Computer_appliance) – a purpose-built specialized computer.[[nb 1]](https://en.wikipedia.org/wiki/Network-attached_storage#cite_note-1) NAS systems are networked appliances that contain one or more [storage drives](https://en.wikipedia.org/wiki/Hard_disk_drive), often arranged into logical, redundant storage containers or [RAID](https://en.wikipedia.org/wiki/RAID). Network-attached storage removes the responsibility of file serving from other servers on the network. They typically provide access to files using network file sharing protocols such as [NFS](https://en.wikipedia.org/wiki/Network_File_System_(protocol)), [SMB](https://en.wikipedia.org/wiki/Server_Message_Block), or [AFP](https://en.wikipedia.org/wiki/Apple_Filing_Protocol). From the mid-1990s, NAS devices began gaining popularity as a convenient method of sharing files among multiple computers. Potential benefits of dedicated network-attached storage, compared to general-purpose servers also serving files, include faster data access, easier administration, and simple configuration.[[1]](https://en.wikipedia.org/wiki/Network-attached_storage#cite_note-2)

The hard disk drives with "NAS" in their name are functionally similar to other drives but may have different firmware, vibration tolerance, or power dissipation to make them more suitable for use in RAID arrays, which are often used in NAS implementations.[[2]](https://en.wikipedia.org/wiki/Network-attached_storage#cite_note-3) For example, some NAS versions of drives support a command extension to allow extended error recovery to be disabled. In a non-RAID application, it may be important for a disk drive to go to great lengths to successfully read a problematic storage block, even if it takes several seconds. In an appropriately configured RAID array, a single bad block on a single drive can be recovered completely via the redundancy encoded across the RAID set. If a drive spends several seconds executing extensive retries it might cause the RAID controller to flag the drive as "down" whereas if it simply replied promptly that the block of data had a checksum error, the RAID controller would use the redundant data on the other drives to correct the error and continue without any problem. Such a "NAS" SATA hard disk drive can be used as an internal PC hard drive, without any problems or adjustments needed, as it simply supports additional options and may possibly be built to a higher quality standard (particularly if accompanied by a higher quoted [MTBF](https://en.wikipedia.org/wiki/MTBF) figure and higher price) than a regular consumer drive.



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## Description[[edit](https://en.wikipedia.org/w/index.php?title=Network-attached_storage&action=edit&section=1)]

A NAS unit is a computer connected to a network that provides only file-based data storage services to other devices on the network. Although it may technically be possible to run other software on a NAS unit, it is usually not designed to be a general-purpose server. For example, NAS units usually do not have a keyboard or display, and are controlled and configured over the network, often using a browser.[[3]](https://en.wikipedia.org/wiki/Network-attached_storage#cite_note-4)

A full-featured operating system is not needed on a NAS device, so often a stripped-down operating system is used. For example, [FreeNAS](https://en.wikipedia.org/wiki/FreeNAS) or [NAS4Free](https://en.wikipedia.org/wiki/NAS4Free), both [open source](https://en.wikipedia.org/wiki/Open-source_software) NAS solutions designed for commodity PC hardware, are implemented as a stripped-down version of [FreeBSD](https://en.wikipedia.org/wiki/FreeBSD).

NAS systems contain one or more hard disk drives, often arranged into logical, redundant storage containers or [RAID](https://en.wikipedia.org/wiki/RAID).

NAS uses file-based protocols such as [NFS](https://en.wikipedia.org/wiki/Network_File_System_(protocol)) (popular on [UNIX](https://en.wikipedia.org/wiki/UNIX) systems), SMB ([Server Message Block](https://en.wikipedia.org/wiki/Server_Message_Block)) (used with MS Windows systems), [AFP](https://en.wikipedia.org/wiki/Apple_Filing_Protocol) (used with [Apple Macintosh](https://en.wikipedia.org/wiki/Macintosh) computers), or NCP (used with [OES](https://en.wikipedia.org/wiki/Novell_Open_Enterprise_Server) and [Novell NetWare](https://en.wikipedia.org/wiki/NetWare)). NAS units rarely limit clients to a single protocol.

## Versus DAS[[edit](https://en.wikipedia.org/w/index.php?title=Network-attached_storage&action=edit&section=2)]

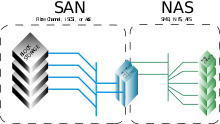
The key difference between [direct-attached storage](https://en.wikipedia.org/wiki/Direct-attached_storage) (DAS) and NAS is that DAS is simply an extension to an existing server and is not necessarily networked. NAS is designed as an easy and self-contained solution for sharing files over the network.

Both DAS and NAS can potentially increase availability of data by using [RAID](https://en.wikipedia.org/wiki/RAID) or [clustering](https://en.wikipedia.org/wiki/Cluster_(computing)).

When both are served over the network, NAS could have better performance than DAS, because the NAS device can be tuned precisely for file serving which is less likely to happen on a server responsible for other processing. Both NAS and DAS can have various amount of [cache memory](https://en.wikipedia.org/wiki/Cache_memory), which greatly affects performance. When comparing use of NAS with use of local (non-networked) DAS, the performance of NAS depends mainly on the speed of and congestion on the network.

NAS is generally not as customizable in terms of hardware (CPU, memory, storage components) or software (extensions, [plug-ins](https://en.wikipedia.org/wiki/Plug-in_(computing)), additional protocols) as a general-purpose server supplied with DAS.

## Versus SAN[[edit](https://en.wikipedia.org/w/index.php?title=Network-attached_storage&action=edit&section=3)]

[](https://en.wikipedia.org/wiki/File:SANvsNAS.svg)

Visual differentiation of NAS vs. [SAN](https://en.wikipedia.org/wiki/Storage_area_network) use in network architecture

NAS provides both storage and a [file system](https://en.wikipedia.org/wiki/File_system). This is often contrasted with SAN ([storage area network](https://en.wikipedia.org/wiki/Storage_area_network)), which provides only block-based storage and leaves file system concerns on the "client" side. SAN protocols include [Fibre Channel](https://en.wikipedia.org/wiki/Fibre_Channel), [iSCSI](https://en.wikipedia.org/wiki/ISCSI), [ATA over Ethernet](https://en.wikipedia.org/wiki/ATA_over_Ethernet) (AoE) and [HyperSCSI](https://en.wikipedia.org/wiki/HyperSCSI).

One way to loosely conceptualize the difference between a NAS and a SAN is that NAS appears to the client OS (operating system) as a [file server](https://en.wikipedia.org/wiki/File_server) (the client can map network drives to shares on that server) whereas a disk available through a SAN still appears to the client OS as a disk, visible in disk and volume management utilities (along with client's local disks), and available to be formatted with a file system and [mounted](https://en.wikipedia.org/wiki/Mount_(computing)).

Despite their differences, SAN and NAS are not mutually exclusive and may be combined as a [SAN-NAS hybrid](https://en.wikipedia.org/wiki/Storage_area_network#SAN-NAS_hybrid), offering both file-level protocols (NAS) and block-level protocols (SAN) from the same system. An example of this is [Openfiler](https://en.wikipedia.org/wiki/Openfiler), a free software product running on Linux-based systems. A [shared disk file system](https://en.wikipedia.org/wiki/Shared_disk_file_system) can also be run on top of a SAN to provide filesystem services.

## History[[edit](https://en.wikipedia.org/w/index.php?title=Network-attached_storage&action=edit&section=4)]

In the early 1980s, the "[Newcastle Connection](https://en.wikipedia.org/wiki/Newcastle_Connection)" by [Brian Randell](https://en.wikipedia.org/wiki/Brian_Randell) and his colleagues at [Newcastle University](https://en.wikipedia.org/wiki/Newcastle_University) demonstrated and developed remote file access across a set of UNIX machines.[[4]](https://en.wikipedia.org/wiki/Network-attached_storage#cite_note-Newcastle_1982-5)[[5]](https://en.wikipedia.org/wiki/Network-attached_storage#cite_note-Callaghan_2000-6) [Novell](https://en.wikipedia.org/wiki/Novell)'s [NetWare](https://en.wikipedia.org/wiki/NetWare) server operating system and [NCP](https://en.wikipedia.org/wiki/NetWare_Core_Protocol) protocol was released in 1983. Following the Newcastle Connection, [Sun Microsystems](https://en.wikipedia.org/wiki/Sun_Microsystems)' 1984 release of [NFS](https://en.wikipedia.org/wiki/Network_File_System_(protocol)) allowed network servers to share their storage space with networked clients. 3Com and [Microsoft](https://en.wikipedia.org/wiki/Microsoft) would develop the [LAN Manager](https://en.wikipedia.org/wiki/LAN_Manager) software and protocol to further this new market. [3Com](https://en.wikipedia.org/wiki/3Com)'s [3Server](https://en.wikipedia.org/wiki/3Server) and [3+Share](https://en.wikipedia.org/wiki/3%2BShare) software was the first purpose-built server (including proprietary hardware, software, and multiple disks) for open systems servers.

Inspired by the success of [file servers](https://en.wikipedia.org/wiki/File_server) from Novell, [IBM](https://en.wikipedia.org/wiki/IBM), and Sun, several firms developed dedicated file servers. While 3Com was among the first firms to build a dedicated NAS for desktop operating systems, [Auspex Systems](https://en.wikipedia.org/wiki/Auspex_Systems) was one of the first to develop a dedicated NFS server for use in the UNIX market. A group of Auspex engineers split away in the early 1990s to create the integrated [NetApp filer](https://en.wikipedia.org/wiki/NetApp_filer), which supported both the Windows SMB and the UNIX NFS protocols and had superior [scalability](https://en.wikipedia.org/wiki/Scalability) and ease of deployment. This started the market for [proprietary](https://en.wikipedia.org/wiki/Proprietary_hardware) NAS devices now led by NetApp and EMC Celerra.

Starting in the early 2000s, a series of startups emerged offering alternative solutions to single filer solutions in the form of clustered NAS – Spinnaker Networks (acquired by [NetApp](https://en.wikipedia.org/wiki/NetApp) in February 2004), [Exanet](https://en.wikipedia.org/wiki/Exanet) (acquired by [Dell](https://en.wikipedia.org/wiki/Dell) in February 2010), [Gluster](https://en.wikipedia.org/wiki/Gluster) (acquired by RedHat in 2011), [ONStor](https://en.wikipedia.org/w/index.php?title=ONStor&action=edit&redlink=1) (acquired by LSI in 2009), [IBRIX](https://en.wikipedia.org/wiki/IBRIX) (acquired by [HP](https://en.wikipedia.org/wiki/Hewlett-Packard)), [Isilon](https://en.wikipedia.org/wiki/Isilon) (acquired by EMC – November 2010), PolyServe (acquired by [HP](https://en.wikipedia.org/wiki/Hewlett-Packard) in 2007), and [Panasas](https://en.wikipedia.org/wiki/Panasas), to name a few.

In 2009, NAS vendors (notably CTERA Networks[[6]](https://en.wikipedia.org/wiki/Network-attached_storage#cite_note-cdr-7)[[7]](https://en.wikipedia.org/wiki/Network-attached_storage#cite_note-8) and [Netgear](https://en.wikipedia.org/wiki/Netgear)) began to introduce [online backup](https://en.wikipedia.org/wiki/Online_backup) solutions integrated in their NAS appliances, for online disaster recovery.[[8]](https://en.wikipedia.org/wiki/Network-attached_storage#cite_note-9)[[9]](https://en.wikipedia.org/wiki/Network-attached_storage#cite_note-10)

## Implementation[[edit](https://en.wikipedia.org/w/index.php?title=Network-attached_storage&action=edit&section=5)]

The way manufacturers make NAS devices can be classified into three types:

1. Computer-based NAS – Using a computer (Server level or a personal computer), installs FTP/SMB/AFP... software server. The power consumption of this NAS type is the largest, but its functions are the most powerful. Some large NAS manufacturers like [Synology](https://en.wikipedia.org/wiki/Synology_Inc.), [QNAP](https://en.wikipedia.org/wiki/QNAP), [Thecus](https://en.wikipedia.org/wiki/Thecus) and [Asustor](https://en.wikipedia.org/wiki/Asustor) make these types of devices. Max FTP throughput speed varies by computer CPU and amount of RAM.
2. Embedded system based NAS – Using an ARM or MIPS based processor architecture and a [real-time operating system (RTOS)](https://en.wikipedia.org/wiki/Real-time_operating_system) or an [embedded operating system](https://en.wikipedia.org/wiki/Embedded_operating_system) to run a NAS server. The power consumption of this NAS type is fair, and functions in the NAS can fit most end-user requirements. [Marvell](https://en.wikipedia.org/wiki/Marvell_Technology_Group), [Oxford](https://en.wikipedia.org/wiki/Oxford_Instruments), and Storlink make chipsets for this type of NAS. Max FTP throughput varies from 20 MB/s to 120 MB/s.
3. [ASIC](https://en.wikipedia.org/wiki/ASIC) based NAS – Provisioning NAS through the use of a single ASIC chip, using hardware to implement TCP/IP and file system. There is no OS in the chip, as all the performance-related operations are done by hardware acceleration circuits. The power consumption of this type of NAS is low, as functions are limited to only support SMB and FTP. [LayerWalker](https://en.wikipedia.org/wiki/LayerWalker) is the only chipset manufacturer for this type of NAS. Max FTP throughput is 40 MB/s.

## Uses[[edit](https://en.wikipedia.org/w/index.php?title=Network-attached_storage&action=edit&section=6)]

NAS is useful for more than just general centralized storage provided to client computers in environments with large amounts of data. NAS can enable simpler and lower cost systems such as load-balancing and fault-tolerant email and web server systems by providing storage services. The potential emerging market for NAS is the consumer market where there is a large amount of multi-media data. Such consumer market appliances are now commonly available. Unlike their [rackmounted](https://en.wikipedia.org/wiki/Rackmount) counterparts, they are generally packaged in smaller form factors. The price of NAS appliances has fallen sharply in recent years, offering flexible network-based storage to the home consumer market for little more than the cost of a regular [USB](https://en.wikipedia.org/wiki/USB) or [FireWire](https://en.wikipedia.org/wiki/FireWire) external hard disk. Many of these home consumer devices are built around [ARM](https://en.wikipedia.org/wiki/ARM_architecture), [PowerPC](https://en.wikipedia.org/wiki/PowerPC) or [MIPS](https://en.wikipedia.org/wiki/MIPS_architecture) processors running an [embedded Linux](https://en.wikipedia.org/wiki/Embedded_Linux) [operating system](https://en.wikipedia.org/wiki/Operating_system).

## Examples[[edit](https://en.wikipedia.org/w/index.php?title=Network-attached_storage&action=edit&section=7)]

### Open-source server implementations[[edit](https://en.wikipedia.org/w/index.php?title=Network-attached_storage&action=edit&section=8)]

[Open-source](https://en.wikipedia.org/wiki/Open-source_software) NAS-oriented distributions of [Linux](https://en.wikipedia.org/wiki/Linux) and [FreeBSD](https://en.wikipedia.org/wiki/FreeBSD) are available. These are designed to be easy to set up on commodity PC hardware, and are typically configured using a web browser.

They can run from a [virtual machine](https://en.wikipedia.org/wiki/Virtual_machine), [Live CD](https://en.wikipedia.org/wiki/Live_CD), [bootable](https://en.wikipedia.org/wiki/Bootable) USB flash drive ([Live USB](https://en.wikipedia.org/wiki/Live_USB)), or from one of the mounted hard drives. They run [Samba](https://en.wikipedia.org/wiki/Samba_(software)) (an [SMB](https://en.wikipedia.org/wiki/Server_Message_Block) daemon), [NFS](https://en.wikipedia.org/wiki/Network_File_System_(protocol)) daemon, and [FTP](https://en.wikipedia.org/wiki/File_Transfer_Protocol) daemons which are freely available for those operating systems.

### List of network protocols used to serve NAS[[edit](https://en.wikipedia.org/w/index.php?title=Network-attached_storage&action=edit&section=9)]

* [Andrew File System](https://en.wikipedia.org/wiki/Andrew_File_System) (AFS)
* [Apple Filing Protocol](https://en.wikipedia.org/wiki/Apple_Filing_Protocol) (AFP)
* [Server Message Block](https://en.wikipedia.org/wiki/Server_Message_Block) (SMB)
* [File Transfer Protocol](https://en.wikipedia.org/wiki/File_Transfer_Protocol) (FTP)
* [Hypertext Transfer Protocol](https://en.wikipedia.org/wiki/Hypertext_Transfer_Protocol) (HTTP)
* [Network File System](https://en.wikipedia.org/wiki/Network_File_System) (NFS)
* [rsync](https://en.wikipedia.org/wiki/Rsync)
* [SSH file transfer protocol](https://en.wikipedia.org/wiki/SSH_file_transfer_protocol) (SFTP)
* [Universal Plug and Play](https://en.wikipedia.org/wiki/Universal_Plug_and_Play) (UPnP)

## Clustered NAS[[edit](https://en.wikipedia.org/w/index.php?title=Network-attached_storage&action=edit&section=10)]

*Main article:*[*Clustered file system*](https://en.wikipedia.org/wiki/Clustered_file_system)

A **clustered NAS** is a NAS that is using a distributed file system running simultaneously on multiple servers. The key difference between a clustered and traditional NAS is the ability to distribute[[*citation needed*](https://en.wikipedia.org/wiki/Wikipedia:Citation_needed)] (e.g. stripe) data and [metadata](https://en.wikipedia.org/wiki/Metadata) across the cluster nodes or storage devices. Clustered NAS, like a traditional one, still provides unified access to the files from any of the cluster nodes, unrelated to the actual location of the data.

## See also[[edit](https://en.wikipedia.org/w/index.php?title=Network-attached_storage&action=edit&section=11)]

* [Disk enclosure](https://en.wikipedia.org/wiki/Disk_enclosure)
* [File area network](https://en.wikipedia.org/wiki/File_area_network)
* [Global Namespace](https://en.wikipedia.org/wiki/Global_Namespace)
* [List of NAS manufacturers](https://en.wikipedia.org/wiki/List_of_NAS_manufacturers)
* [Network architecture](https://en.wikipedia.org/wiki/Network_architecture)
* [Server (computing)](https://en.wikipedia.org/wiki/Server_(computing))

## Notes[[edit](https://en.wikipedia.org/w/index.php?title=Network-attached_storage&action=edit&section=12)]

* 1. [**^**](https://en.wikipedia.org/wiki/Network-attached_storage#cite_ref-1) In this article "file server" is generally used as the term contrasting to NAS, referring to the general-purpose computer used for serving files.

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  6. [**^**](https://en.wikipedia.org/wiki/Network-attached_storage#cite_ref-cdr_7-0) [CDRLab Test](http://cdrlab.pl/article_strona_9571_1.html) [Archived](https://web.archive.org/web/20101017224312/http:/cdrlab.pl/article_strona_9571_1.html) 2010-10-17 at the [Wayback Machine](https://en.wikipedia.org/wiki/Wayback_Machine) (in Polish)
  7. [**^**](https://en.wikipedia.org/wiki/Network-attached_storage#cite_ref-8) [The Age Of Computing Diversity](http://www.forrester.com/rb/Research/age_of_computing_diversity/q/id/56888/t/2). by Frank E. Gillett. Forrester Research, September 16, 2010. Page 12. "CTERA’s C200 provides a better take on network-attached storage (NAS) [...] with local Mac and PC backup built in and automated hooks to an online backup service for offsite backup in case of site disaster."

# direct-attached storage (DAS)

Direct-attached storage (DAS) is computer storage that is connected to one computer and not accessible to other...

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| [https://upload.wikimedia.org/wikipedia/en/thumb/9/99/Question_book-new.svg/50px-Question_book-new.svg.png](https://en.wikipedia.org/wiki/File:Question_book-new.svg) | This article **needs additional citations for**[**verification**](https://en.wikipedia.org/wiki/Wikipedia:Verifiability). Please help [improve this article](https://en.wikipedia.org/w/index.php?title=Direct-attached_storage&action=edit) by [adding citations to reliable sources](https://en.wikipedia.org/wiki/Help:Referencing_for_beginners). Unsourced material may be challenged and removed. *Find sources:* ["Direct-attached storage"](https://www.google.com/search?as_eq=wikipedia&q=%22Direct-attached+storage%22) – [news](https://www.google.com/search?tbm=nws&q=%22Direct-attached+storage%22+-wikipedia) **·** [newspapers](https://www.google.com/search?&q=%22Direct-attached+storage%22+site:news.google.com/newspapers&source=newspapers) **·** [books](https://www.google.com/search?tbs=bks:1&q=%22Direct-attached+storage%22+-wikipedia) **·** [scholar](https://scholar.google.com/scholar?q=%22Direct-attached+storage%22) **·** [JSTOR](https://www.jstor.org/action/doBasicSearch?Query=%22Direct-attached+storage%22&acc=on&wc=on) *(July 2011) (*[*Learn how and when to remove this template message*](https://en.wikipedia.org/wiki/Help:Maintenance_template_removal)*)* |

**Direct-attached storage** (**DAS**) is [digital storage](https://en.wikipedia.org/wiki/Data_storage_device) directly attached to the [computer](https://en.wikipedia.org/wiki/Computer) accessing it, as opposed to storage accessed over a computer network (i.e. [network-attached storage](https://en.wikipedia.org/wiki/Network-attached_storage)). Examples of DAS include [hard drives](https://en.wikipedia.org/wiki/Hard_drive), [solid-state drives](https://en.wikipedia.org/wiki/Solid-state_drive), [optical disc drives](https://en.wikipedia.org/wiki/Optical_disc_drive), and storage on [external drives](https://en.wikipedia.org/wiki/External_drive). The name "DAS" is a [retronym](https://en.wikipedia.org/wiki/Retronym) to contrast with [storage area network](https://en.wikipedia.org/wiki/Storage_area_network) (SAN) and [network-attached storage](https://en.wikipedia.org/wiki/Network-attached_storage) (NAS).



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* [2Storage features common to SAN, DAS and NAS](https://en.wikipedia.org/wiki/Direct-attached_storage#Storage_features_common_to_SAN,_DAS_and_NAS)
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* [4See also](https://en.wikipedia.org/wiki/Direct-attached_storage#See_also)
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## Features[[edit](https://en.wikipedia.org/w/index.php?title=Direct-attached_storage&action=edit&section=1)]

A typical DAS system is made of a [data storage device](https://en.wikipedia.org/wiki/Data_storage_device) (for example [enclosures](https://en.wikipedia.org/wiki/Disk_enclosure) holding a number of [hard disk drives](https://en.wikipedia.org/wiki/Hard_disk_drive)) connected directly to a computer through a [host bus adapter](https://en.wikipedia.org/wiki/Host_bus_adapter) (HBA). Between those two points there is no network device (like hub, switch, or router), and this is the main characteristic of DAS.

The main [protocols](https://en.wikipedia.org/wiki/Protocol_(computing)) used for DAS connections are [ATA](https://en.wikipedia.org/wiki/AT_Attachment), [SATA](https://en.wikipedia.org/wiki/SATA), [eSATA](https://en.wikipedia.org/wiki/ESATA),[[1]](https://en.wikipedia.org/wiki/Direct-attached_storage#cite_note-1) [NVMe](https://en.wikipedia.org/wiki/NVM_Express), [SCSI](https://en.wikipedia.org/wiki/SCSI), [SAS](https://en.wikipedia.org/wiki/Serial_Attached_SCSI), [USB](https://en.wikipedia.org/wiki/USB), [USB 3.0](https://en.wikipedia.org/wiki/USB_3.0) and [IEEE 1394](https://en.wikipedia.org/wiki/IEEE_1394).

## Storage features common to SAN, DAS and NAS[[edit](https://en.wikipedia.org/w/index.php?title=Direct-attached_storage&action=edit&section=2)]

Most functions found in modern storage do not depend on whether the storage is attached directly to servers (DAS), or via a network (SAN and NAS).

## Advantages and disadvantages[[edit](https://en.wikipedia.org/w/index.php?title=Direct-attached_storage&action=edit&section=3)]

The key difference between DAS and NAS is that DAS storage is only directly accessible from the host to which the DAS is attached. A DAS does not incorporate any network hardware and related operating environment to provide a facility to share storage resources independently. The storage presented by a DAS to a connected host can of course be shared by that host. A [SAN (storage area network)](https://en.wikipedia.org/wiki/Storage_area_network) has more in common with a DAS than a NAS with the key difference being that DAS is a 1:1 relationship between storage and host whereas SAN is many to many.

### Use with other medical imaging technologies

Although PACS processes are widely adopted in healthcare, vendor neutral archive ([VNA](https://searchhealthit.techtarget.com/definition/Vendor-neutral-archive-VNA)) technology has replaced PACS in some healthcare settings and integrates with PACS in others.

# vendor neutral archive (VNA)

A vendor neutral archive (VNA) is a technology that stores medical images in a standard format and interface, making...

# Vendor Neutral Archive

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| https://upload.wikimedia.org/wikipedia/en/thumb/b/b4/Ambox_important.svg/40px-Ambox_important.svg.png | hide**This article has multiple issues.** Please help [**improve it**](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit) or discuss these issues on the [**talk page**](https://en.wikipedia.org/w/index.php?title=Talk:Vendor_Neutral_Archive&action=edit&redlink=1). *(*[*Learn how and when to remove these template messages*](https://en.wikipedia.org/wiki/Help:Maintenance_template_removal)*)*   |  | | --- | | This article **is written like a**[**personal reflection, personal essay, or argumentative essay**](https://en.wikipedia.org/wiki/Wikipedia:What_Wikipedia_is_not#Wikipedia_is_not_a_publisher_of_original_thought) that states a Wikipedia editor's personal feelings or presents an original argument about a topic. *(August 2013)* |  |  | | --- | | This article **may be too technical for most readers to understand**. Please [help improve it](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit) to [make it understandable to non-experts](https://en.wikipedia.org/wiki/Wikipedia:Make_technical_articles_understandable), without removing the technical details. *(August 2013)* | |

A **Vendor Neutral Archive** (**VNA**) is a [medical imaging](https://en.wikipedia.org/wiki/Medical_imaging) technology in which images and documents (and potentially any file of clinical relevance) are stored (archived) in a standard format with a standard interface, such that they can be accessed in a vendor-neutral manner by other systems.

This terminology is used as distinct from a traditional [Picture Archiving and Communications Systems](https://en.wikipedia.org/wiki/Picture_Archiving_and_Communications_Systems) (PACS), although there is debate about where the boundary between a VNA and a PACS lies along the continuum of their common features.



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## Definition[[edit](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit&section=1)]

The simplest definition is "a medical device that stores medical images in a standard format with a standard interface, such that they can be accessed in a vendor-neutral manner by other systems".

So-called "vendor neutrality" is implied by the standard format and interface, and the neutrality is with respect to vendor-specific devices that produce or consume those images (e.g., for display, distribution or analysis, with or without specific workflows, such as for radiology reporting, i.e., a [PACS](https://en.wikipedia.org/wiki/Picture_Archiving_and_Communications_Systems)).

The exact definition and feature set is contentious though, and evolves as different vendors of VNAs attempt to distinguish themselves from their competitors and avoid being excluded, and customers express desires ranging from pragmatic to fantastic.

There is general agreement on the following key features:

* Storage of [DICOM](https://en.wikipedia.org/wiki/DICOM) images and related composite objects (presentation states, key objects, structured reports)
* DICOM network standard interface for storage, query and retrieval
* Administrative updates and corrections (patient ID changes and study merges)
* [Scalability](https://en.wikipedia.org/wiki/Scalability)

Each of the following features remain contentious, in the sense that some customers and vendors claim that some or all are fundamental to the concept, but others disagree:

* Storage of objects not directly related to images (such as human-generated requests and reports)
* Storage of non-DICOM content (such as [HL7](https://en.wikipedia.org/wiki/HL7) [CDA](https://en.wikipedia.org/wiki/Clinical_Document_Architecture) documents)
* Non-DICOM access protocols (such as IHE Cross-Enterprise Document Sharing ([XDS](https://en.wikipedia.org/wiki/Cross_Enterprise_Document_Sharing) and XDS-I)
* Cross-domain identity and code resolution (patient ID, accession #, procedure codes)
* Dynamic DICOM tag morphing
* [Information lifecycle management](https://en.wikipedia.org/wiki/Information_lifecycle_management)
* Exclusion of workflow management database content
* Independence from choice of database engine
* Audit trail of access

## History[[edit](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit&section=2)]

### Evolution[[edit](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit&section=3)]

Traditionally, the need to store medical images has been most common in the radiology and nuclear medicine departments, and has been implemented in the form of sub-specialty and departmental (PACS), which have combined the functions of image management and image archiving into a single solution. Whilst such systems all have standard interfaces ([DICOM](https://en.wikipedia.org/wiki/DICOM) and [IHE](https://en.wikipedia.org/wiki/Integrating_the_Healthcare_Enterprise)) for ingestion and distribution of images over the network and on physical media (like CD), typically the workflow and optimal performance for display are achieved using proprietary software and protocols. Further, the persistent storage "inside" a proprietary PACS may not be in a standard form, the PACS may not update the stored files with the latest study and demographic updates and annotations stored in the database, and it may extend, abuse or depend on specific standard and non-standard (private) DICOM attributes in the stored files.

Over time, in many implementations, the underlying storage infrastructure has been "factored" out of the traditional (PACS) at the hardware and file system ([DAS](https://en.wikipedia.org/wiki/Direct-attached_storage), [NAS](https://en.wikipedia.org/wiki/Network-attached_storage), [SAN](https://en.wikipedia.org/wiki/Storage_area_network)) level, and are supplied instead by non-domain-specific [computer data storage](https://en.wikipedia.org/wiki/Computer_data_storage) vendors.

As more medical specialties incorporate images in their practice, the need to extend image storage and distribution capability to other departments, enterprise wide. Increasingly there is a desire to inter-operate at a higher application level, separating departmental-specific workflows, display and analysis solutions from image storage infrastructure, using standard protocols that are image and metadata aware, without sacrificing display performance.

A complicating factor is that the (PACS) offerings are in a constant state of flux with respect to features and quality of service, and traditionally users will abandon one vendor and replace their product with another's every 3–5 years. This triggers the need to "migrate" the images and associated information to the new architecture without data loss, a non-trivial task despite the use of standard formats for image encoding. The concept of a VNA theoretically allows for greater stability (re-usability and less frequent migration) at the archive level, despite rapid evolution and change at the higher application-level (display and workflow). Of course, migrating from one vendor's VNA to another isn't trivial either, just hopefully less frequent.[[1]](https://en.wikipedia.org/wiki/Vendor_Neutral_Archive#cite_note-1)

An alternative term for a VNA is a "PACS Neutral Archive", which perhaps better conveys the original intent, but this term is rarely used, and for better or for worse, VNA has become the [buzzword](https://en.wikipedia.org/wiki/Buzzword) of choice amongst customers and salesmen.[[2]](https://en.wikipedia.org/wiki/Vendor_Neutral_Archive#cite_note-2)

### Literature[[edit](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit&section=4)]

As noted above, the archive of images is naturally mostly static—that is, most of the content of an archive is unchanged, with only a (relatively) small number of studies added each day, with few changes and corrections required.

From the early days of PACS, it was expected that standard interoperability boundaries would need to be defined[[3]](https://en.wikipedia.org/wiki/Vendor_Neutral_Archive#cite_note-3). The ACR-NEMA, and later DICOM, standards arose to address not only the need for a standard file format but also protocols for storage of images from acquisition modalities to archives, and to query and retrieve images from the archive. Even the first ACR-NEMA standard from 1985[[4]](https://en.wikipedia.org/wiki/Vendor_Neutral_Archive#cite_note-4) defined FIND and GET transactions[[5]](https://en.wikipedia.org/wiki/Vendor_Neutral_Archive#cite_note-5). I.e., the separation of workstations and workflow management from archives was envisaged from the beginning. The first DICOM demonstrations at RSNA beginning in 1992 made use of a so-called "central test node"[[6]](https://en.wikipedia.org/wiki/Vendor_Neutral_Archive#cite_note-6), which arguably was one of the first DICOM-based vendor neutral archives, though that label was not in use at the time. Homegrown PACS or mini-PACS typically described the archive and workstation as separate entities[[7]](https://en.wikipedia.org/wiki/Vendor_Neutral_Archive#cite_note-7). Many, but not all, monolithic commercial PACS continued to make use of proprietary protocols between their integrated workstations and archives, but the need to support separate third-party workstations for specialized work, such as 3D processing and radiotherapy planning, was always recognized, and implemented using the DICOM protocol.

In 1998, Erickson and Hangiandreou[[8]](https://en.wikipedia.org/wiki/Vendor_Neutral_Archive#cite_note-8) discussed the advantages of once again separating the archive functionality from the conventional monolithic PACS and making use of pre-fetching to populate the "interpretation storage device". They also describe query and retrieval from multiple archives (in a manner that would now be called a federated query) to provide inter-enterprise image sharing. The article noted some of the practical challenges at the time, such as the relative inefficiency of doing DICOM queries against such multiple archives and separating out those responses relevant for pre-fetching, as well as challenges of patient identifiers. Nevertheless, the ability to have images in a separate system from the workstation was felt to be an important capability. Ultimately, Erickson and colleagues developed this into a startup company, TeraMedica[[9]](https://en.wikipedia.org/wiki/Vendor_Neutral_Archive#cite_note-9) in 2000, which was purchased by Fuji Medical Systems in 2015.

In one of many blog entries[[10]](https://en.wikipedia.org/wiki/Vendor_Neutral_Archive#cite_note-10) on the subject, Michael Gray makes a reference to an early description of the concept of separating the front-end clinical applications from the back-end storage function, in an article by Nadim Daher, a Medical Imaging Market Analyst at Frost & Sullivan.[[11]](https://en.wikipedia.org/wiki/Vendor_Neutral_Archive#cite_note-11)

A long running Aunt Minnie PACS Forum thread digressed to discuss the issue of neutral archives amongst a broader audience after a response from Michael Gray.[[12]](https://en.wikipedia.org/wiki/Vendor_Neutral_Archive#cite_note-12)

A white paper from 2009 by Wayne DeJarnette [[13]](https://en.wikipedia.org/wiki/Vendor_Neutral_Archive#cite_note-13) is an early attempt to establish a definition based on a required feature set, and his company has also provided a more recent interpretation.[[14]](https://en.wikipedia.org/wiki/Vendor_Neutral_Archive#cite_note-14)

Michael Gray offers his essential ingredients of a VNA in his 2009 blog entry,[[15]](https://en.wikipedia.org/wiki/Vendor_Neutral_Archive#cite_note-15) making reference to Acuo's checklist of attributes, the most recent form of which can be found in Shannon Werb's white paper on attributes of a "true" VNA.[[16]](https://en.wikipedia.org/wiki/Vendor_Neutral_Archive#cite_note-16)

Herman Oosterwijk provides a more recent description on behalf of Teramedica, in his white paper,[[17]](https://en.wikipedia.org/wiki/Vendor_Neutral_Archive#cite_note-17) in which he offers a more detailed definition: "A Vendor Neutral Archive (VNA) is a medical device that provides scalable image and information and life cycle management so that images and related information can be queried, stored, and retrieved in a manner that is defined by open standards at multiple department, enterprise, and regional level while maintaining patient privacy and security. Characteristic for a VNA is that it provides a patient-centric approach that transcends upgrades and changes of the different viewing, acquisition, and workflow management components as they should be interchangeable without having to migrate, convert, or change the data formats or interface of the VNA."

The relationship of VNA to storage of medical images in the [cloud](https://en.wikipedia.org/wiki/Cloud_storage) is also nebulous, though offers high potential for [buzzword compliance](https://en.wikipedia.org/wiki/Buzzword_compliant), and Michael Gray provides some clarity in his paper commissioned by EMC.[[18]](https://en.wikipedia.org/wiki/Vendor_Neutral_Archive#cite_note-18)

Various alternative deployment models[[19]](https://en.wikipedia.org/wiki/Vendor_Neutral_Archive#cite_note-19) and frameworks[[20]](https://en.wikipedia.org/wiki/Vendor_Neutral_Archive#cite_note-20) have been described, which address matters of cost, value and barriers to entry.

Since the term "VNA" has been so abused as a marketing term, it has already achieved mythical status.[[21]](https://en.wikipedia.org/wiki/Vendor_Neutral_Archive#cite_note-21)

## Features[[edit](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit&section=5)]

### Administrative updates and corrections[[edit](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit&section=6)]

A passive archive will simply store what it receives, and potentially overwrite the same thing when it is received again with changes but the same (unique) identifiers. This is insufficient in a production operation, where mistakes are made, and it is necessary to correct patient demographics, or correct mistakes (wrong patient or request or side was selected during an exam and incorrect information present in the image headers).

Standards exist that cover some use cases, such as IHE Patient Information Reconciliation (PIR) and Imaging Object Change Management (IOCM).

### Cross-domain identity and code resolution[[edit](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit&section=7)]

For an archive to span departments, institutions, regions or even national boundaries, the question of identification of entities and concepts must be addressed.

In general, within a domain such as an individual institution, patient identifiers and identifiers of request, studies and reports (e.g., by accession numbers) are assigned uniquely within that domain, but not outside. Most internal systems (and most [PACS](https://en.wikipedia.org/wiki/Picture_Archiving_and_Communications_Systems)) do not manage the existence of multiple identity domains, and if identifiers are used across domains then collisions and ambiguity occur. Thus each identifier needs to either be qualified by its "assigning authority" when used (the approach taken by the [DICOM](https://en.wikipedia.org/wiki/DICOM)-based [IHE](https://en.wikipedia.org/wiki/Integrating_the_Healthcare_Enterprise) Multiple Image Manager Archive (MIMA) profile) or coerced into a single "canonical" identifier that spans the scope of the larger domain that includes all integrated cross-enterprise systems (the approach taken by IHE [Cross Enterprise Document Sharing](https://en.wikipedia.org/wiki/Cross_Enterprise_Document_Sharing). When importing outside images into the local archive, this matter also has to be addressed, usually by mapping the outside identifier into an internal identifier and re-encoding the information (coercion) in the DICOM "header" or other meta-data (such as by the manner specified in Import Reconciliation Workflow).

Whether support for this is an essential feature for a VNA depends on what environment it is intended to be deployed in (within one enterprise or across enterprises), but robust support provides insurance against future deployment configuration changes (such as enterprise mergers).

Likewise, local code sets used for such things as procedure codes (for "orderables", as opposed to billing codes), are not well standardized, and where these are useful in images to drive workflow and display (such as hanging protocols), an ability to map these too is a useful feature.

### Dynamic tag morphing[[edit](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit&section=8)]

One purpose of a VNA is to store information and serve it to multiple systems that may have different requirements for its use and expectations for very specific characteristics of the DICOM attributes and values stored in them, both standard and private.

The concept of "dynamic tag morphing" is touted as a solution to the problem of two different systems expecting different values in the same attribute. "Tag morphing" refers to changing the values in one or more attributes (usually DICOM data elements in this context). This may be done "statically", in which case only one mapping is performed, or "dynamically", in which case multiple mappings, each specific to a particular recipient, is performed.

In its degenerate form, the ability to map any tag and value to any other is inherently dangerous and undermines the value of attempting to standardize attributes in the first place, and the efforts by modality and PACS vendors to use them "properly". That said, there is variation in the installed base and even new products in how some fields are used, particularly for highly specific and advanced forms of imaging, and corresponding variation in what advanced display and analysis applications expect in their input. Accordingly this is a popular feature, despite its dangers. Some will argue strongly that it is an essential feature to be classed as a VNA.

This feature is reminiscent of what is common in the [HL7](https://en.wikipedia.org/wiki/HL7) version 2 world, a so-called Interface Engine, which is designed to map pretty much anything to anything else, depending on the source and target.

A typical use case is to change the values in Series Description supplied by acquisition modalities, in order to allow two different PACS sharing the same data to use different hanging protocol rules based in Series Description. Arguably, this could be achieved in a more standard way if modalities populated other attributes in more detail, acquisition protocols and codes for them were better standardized and hanging protocol engines were more flexible, but given the limitations of the state of the art, this technique remains useful.

Dynamic tag morphing is distinct from the specific attribute changes related to Cross-domain Identity and Code Resolution (what DICOM in PS 3.4 refers to as "coercion"), for which there are standards defined for what to change, when and how, and which often involve additional actors such as a Master Patient Index, though some proponents lump these together and some products implement them using the same mechanism.

Michael Gray was an early proponent of tag morphing and regards it an essential VNA feature.[[22]](https://en.wikipedia.org/wiki/Vendor_Neutral_Archive#cite_note-22) A description of tag morphing use-cases can be found in Wayne Dejarnette's 2010 white paper.[[23]](https://en.wikipedia.org/wiki/Vendor_Neutral_Archive#cite_note-23)

### Information lifecycle management[[edit](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit&section=9)]

Disk is cheap, though power and air-conditioning are not, but regardless, storage has a finite cost, particularly when one is paying as one goes rather than using a locally hosted capitalized infra-structure.

Accordingly, when medico-legal retention periods expire, or the clinical utility expires (such as on a patient's death), many users would like to be able to purge their storage. The rules for this are complex, and vary between jurisdictions as well as according to local policy. Given the conflicting demands of financiers, risk managers, litigators, researchers and educators, coming to agreement on such a policy may be difficult.

Regardless, a potentially useful VNA feature is support for locally customizable rule-based purging (culling) criteria, whether it be by implementing the rules directly, or responding to IHE Imaging Object Change Management (IOCM) requests from a separate rules engine.

### Non-DICOM content[[edit](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit&section=10)]

VNAs should have no difficulty storing DICOM content such images and associated information such as presentation states and so-called "evidence documents", such as DICOM Structured Reports containing such things as measurements recorded by the modality, or post-processing results such as from [CAD](https://en.wikipedia.org/wiki/Computer-aided_diagnosis).

In a clinical setting, however, other document and bulk object types may be available that it would be desirable to store. Most PACS take the approach of converting these to DICOM, in some cases using objects intended to "encapsulate" another type of object. The classic example is a scanned document stored as a PDF file and encapsulated in a DICOM PDF object along with sufficient metadata to identify it and manage it, as if it were an image. VNAs should support these type of encapsulated DICOM objects and the DICOM "header" provides a means to obtain the metadata for indexing to support query and retrieval. Michael Gray elaborates in detail on this topic in his white paper on the subject.[[24]](https://en.wikipedia.org/wiki/Vendor_Neutral_Archive#cite_note-24)

For other object types, or when there is no DICOM encapsulation object available, or when there is no need to interface with DICOM systems, as long as there is a standard means of providing the necessary metadata for indexing, such as by using HL7 version 2 messages or XDS registry services, then in theory a VNA could store anything.

Specific types of non-DICOM content, such as an HL7 CDA document instance containing, for example, a radiology report, could be stored either as a XDS, or first encapsulated in a DICOM Encapsulated CDA object and stored using DICOM services, or its content and header could be transcoded into a DICOM Structured Report instance. A fully featured VNA might have the ability to transcode any single instance into another form depending on what the requesting system needed ("object morphing", if you will).

A description of Wayne Dejarnette's approach to non-DICOM object storage in his product is described in his 2009 white paper.[[25]](https://en.wikipedia.org/wiki/Vendor_Neutral_Archive#cite_note-25)

## Interface standardization[[edit](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit&section=11)]

### Image file format on long term storage media[[edit](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit&section=12)]

There is general agreement that the use of the DICOM file format is required for images, and that where images are compressed for archival or transport, standard, not proprietary, compression schemes (transfer syntaxes) need to be used. Indeed, a distinguishing feature of most VNAs as opposed to many traditional PACS is the avoidance of proprietary internal formats ostensibly used in the past for "performance" reasons, whilst still obtaining good performance across the interfaces.

Implementations may vary in the range of supported compression schemes, whether or not reversible (lossless) compression is mandatory for medico-legal archival purposes. Implementations also vary in the range of modality-specific image types that they support; though many archives will support all DICOM image information objects in principle, some extreme cases, like whole slide pathology images and long videos may not be supported. A general feature of VNAs is to attempt to preserve all attributes as originally supplied, including private (proprietary) attributes whether from the acquisition modality or added by other intervening applications (such as QC workstations or PACS).

DICOM describes many different "Information Object Definitions" and "SOP Classes" for storage of images with specific metadata related to particular modalities and applications, and the list of these grows as technology evolves. Since the DICOM format is inherently extensible, and all new objects build upon a common encoding and pattern, a VNAs should be able to store any DICOM image object, regardless of whether the SOP Class is recognized or new. This may be achieved through the use of field-modifiable configuration to add new SOP Classes, or by analysis of the contents of the objects "header", or by the simple of approach of accepting, storing and regurgitating anything transferred via a DICOM C-STORE operation.

### Image transfer protocols[[edit](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit&section=13)]

#### Conventional DICOM[[edit](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit&section=14)]

Support of the basic DICOM C-STORE, C-FIND, C-MOVE and preferably C-GET are fundamental and not debated. The basic uncompressed transfer syntaxes including implicit and explicit VR little-endian, and the less common big-endian transfer syntax are typically supported. The range of compressed transfer syntaxes usually includes [lossless JPEG](https://en.wikipedia.org/wiki/Lossless_JPEG) and reversible and irreversible [JPEG 2000](https://en.wikipedia.org/wiki/JPEG_2000), occasionally [JPEG-LS](https://en.wikipedia.org/wiki/JPEG-LS), and usually lossy JPEG for images that were supplied that way (especially true color photographs. Support for motion compression (other than multi-frame JPEG) is less common, but perhaps more common in VNAs than in [PACSs](https://en.wikipedia.org/wiki/Picture_Archiving_and_Communications_Systems), especially for storage and regurgitation without viewing.

#### WADO[[edit](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit&section=15)]

Most would agree that an important VNA interface is the original version of [Web Access to DICOM Persistent Objects](https://en.wikipedia.org/wiki/Web_Access_to_DICOM_Persistent_Objects) (WADO), which allows single images to be retrieved with an [HTTP](https://en.wikipedia.org/wiki/HTTP) URL in either DICOM file format or pre-rendered into a consumer format like [JPEG](https://en.wikipedia.org/wiki/JPEG).

#### XDS-I.b[[edit](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit&section=16)]

The [SOAP](https://en.wikipedia.org/wiki/SOAP) [Web Service](https://en.wikipedia.org/wiki/Web_Service) based transactions of the IHE Cross Enterprise Document Sharing for Imaging are also generally considered a prerequisite for a claim to be a VNA.

### Image-related objects[[edit](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit&section=17)]

#### Presentation states[[edit](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit&section=18)]

The grayscale or color rendering transformation applied to images for display should be stored as a DICOM Presentation State object. These objects support grayscale and true color images, as well as the application of a pseudo-color [lookup table](https://en.wikipedia.org/wiki/Lookup_table) to grayscale images. Presentation states can also record any zooming and panning (displayed area selection) applied. [IHE](https://en.wikipedia.org/wiki/Integrating_the_Healthcare_Enterprise) uses these in the Consistent Presentation of Images (CPI) profile

Since many modern [PACS](https://en.wikipedia.org/wiki/Picture_Archiving_and_Communications_Systems) can also store image annotations using DICOM Presentation State objects, a VNA needs to support these, including not just storage and regurgitation, but also selection and display in any viewer supplied as a VNA component.

#### Annotations, regions of interest and measurements[[edit](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit&section=19)]

The preferred format for storage of [annotations](https://en.wikipedia.org/wiki/Annotation), [regions of interest](https://en.wikipedia.org/wiki/Region_of_Interest), and [measurements](https://en.wikipedia.org/wiki/Measurement) is the DICOM Structured Report (SR) object, which allows structure, coded and semantic information to be persisted, rather than just presentation. IHE refers to these as Evidence Documents (ED). DICOM SR objects may also be produced in the context of the IHE specifies these in the Simple Image and Numeric Report (SINR) profile.

Since many Acquisition Modalities, mammography CAD systems and quantitative image analysis workstations produce SR objects, a VNA should be capable of storing and regurgitating these. Ideally, any viewer component should be capable of a generic (if not ideal) rendering of the content of any SR, including display of coordinates on referenced images.

For specific domains, such as [Radiotherapy](https://en.wikipedia.org/wiki/Radiotherapy), an older format, the DICOM RT Structure Set, which can encode 3D patient relative coordinate [isocontours](https://en.wikipedia.org/wiki/Isocontour) (only) is used, and some non-RT workstations produce these as well instead of SRs. A VNA needs to support these too.

#### Key images and object selection[[edit](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit&section=20)]

A common concept in a PACS is for the user (such as a modality operator or interpreting radiologist) to flag some images (or other objects) as being "key", i.e., of particular interest for some reason. Though obsolete PACS may only record this as a flag in an internal database, modern PACS use the [DICOM](https://en.wikipedia.org/wiki/DICOM) Key Object Selection object (a specialized form of SR) to export this information. This usage is described in the IHE Key Image Note (KIN) profile. A VNA needs to support storage and regurgitation of KOS objects, as well as selection and display of these in any viewer.

#### Radiation dose reports[[edit](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit&section=21)]

Since many medical imaging techniques deliver non-trivial amounts of ionizing radiation to the patient, the dose exposure needs to be tracked, and in some jurisdictions this must be recorded by law. DICOM defines a specialized form of Structured Report, the Radiation Dose Structured Report (RDSR) to encode this. IHE uses these in the Radiation Exposure Management (REM) profile. A VNA must support storage and regurgitation these, and ideally, would be able to extract critical information for display in any viewer.

#### Procedure reports[[edit](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit&section=22)]

In radiology and nuclear medicine applications, the practice of dictating and transcribing (or using [speech recognition](https://en.wikipedia.org/wiki/Speech_recognition)) is well entrenched and the output of these is typically unstructured or minimally structured prose, encoded as plain text and distributed by fax or HL7 version 2 messages or some equally primitive mechanism. The persistent form of these "documents" is not well-standardized, but many customers expect a VNA to be able to accept them in whatever local format is preferred. The same principles apply as for the storage of any non-DICOM content, including the use of HL7 version 2 messages or XDS to provide metadata in lieu of a structured "header", such as in the case of reports rendered as PDF, when they have not been encapsulated in DICOM or CDA objects. Now that HL7 has promised to relax its previously closed IP policy, including offering CDA free for use, it is possible that CDA will become the preferred form of encoding, but VNAs will still need to accept (and possibly transcode) reports in a plethora of form from the installed base. DICOM defines templates for the encoding of human-generated reports as DICOM Structured Report (SR) objects, and IHE specifies these in the Simple Image and Numeric Report (SINR) profile.

#### Radiotherapy objects[[edit](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit&section=23)]

In addition to DICOM RT Structure Sets, for a VNA to be usable in an enterprise that performs Radiotherapy, the entire family of DICOM RT objects for beam, ion and [brachytherapy](https://en.wikipedia.org/wiki/Brachytherapy) need to be stored and regurgitated.

#### Raw data objects[[edit](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit&section=24)]

DICOM defines a Raw Data object that is essentially a conventional DICOM composite instance header with patient, study, series and instance information, but no payload. It was intended for the storage of the [raw data](https://en.wikipedia.org/wiki/Raw_data) that is not easily represented as an image or image-like object, such as the raw views obtained from the detectors of a CT scanner, or the [k-space](https://en.wikipedia.org/wiki/K-space_(MRI)) data from an MRI scanner, but can be used to encode anything. A VNA should be able to store and regurgitate these, even though it may be unaware of their contents and only the originating device may be able to interpret them.

#### Audio, waveform and spectroscopy objects[[edit](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit&section=25)]

Though there are many consumer formats for encoding audio in widespread use, these lack the header or metadata necessary to identify the patient and encounter. A VNA that wants to support these needs to have a means of providing such information, such as submission using XDS. [DICOM](https://en.wikipedia.org/wiki/DICOM) does define a Basic Audio object, and though it does not support the plethora of audio codecs available in the consumer world, some PACS do produce them, so a VNA should support these.

Time-based waveforms (such as ECGs) may be stored as DICOM or in a multitude of other formats, and the same principles apply as for audio; i.e., if the format is a medically oriented one, use the header meta-data for indexing during ingestion, if not, use XDS to register it.

A DICOM [MR Spectroscopy](https://en.wikipedia.org/wiki/MR_Spectroscopy) object is defined, and since some modalities produce it, a VNA should be able to store and regurgitate instances of it.

#### Private objects[[edit](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit&section=26)]

DICOM allows for the concept of Private SOP Classes, which use the DICOM encoding and transfer mechanisms but whose content is opaque. Vendors use these to good effect when necessary to encode information that has not been standardized, and also abuse them for convenience in lieu of using a standard encoding. Regardless, since their content may be important to the clinical workflow, a VNA should be configurable to accept, store and regurgitate these.

## Use cases[[edit](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit&section=27)]

* On site serving of images to multiple PACS
* Off site serving of images to multiple PACS
* Direct viewing of images (locally or externally)
* [High Availability](https://en.wikipedia.org/wiki/High_Availability)
* [Business Continuity](https://en.wikipedia.org/wiki/Business_Continuity) and [Disaster Recovery](https://en.wikipedia.org/wiki/Disaster_Recovery)

## Spectrum of vendor offerings[[edit](https://en.wikipedia.org/w/index.php?title=Vendor_Neutral_Archive&action=edit&section=28)]

Given the convoluted history, it should come as no surprise that two products claiming to be VNAs may have completely different feature sets and performance. However, there are essentially four categories of product:

* Third-party systems that have developed independently of PACS
* Offsite archival systems originally intended for BC/DR
* Central repository products that support cross-enterprise & external access
* Traditional PACS that have improved standard access to their internal archive

The heritage of any individual product line may be a significant factor when considering suitability for a different application than originally intended, despite the purported feature set as re-envisaged by a creative marketing department.