Clinical Radiology 67 (2012) 1095–1100

Contents lists available at SciVerse ScienceDirect

Clinical Radiology

journal homepage: www.clinicalradiologyonline.net

Technical Report

# Cloud computing and virtualization technology in radiology

R.P. Patel*

*Department of Radiology, The Royal United Hospital Bath, Combe Park, Bath BA1 3NG, United Kingdom*

## Introduction

The last decade has seen significant advances in information technology (IT) and medical imaging that has forever changed the way we work and communicate. The transition from hard-copy film to electronic picture archiving and communication systems (PACS) has enabled the radiology department to deliver improved patient care with current and historical imaging available to the clinician at the point of care. Radiology information systems (RIS) are used in combination with PACS to control workflow and store the generated radiology reports. The modern radiologist is increasingly required to have knowledge of the technology used in PACS and RIS in order to maximize the diagnostic opportunities offered by these systems. In addition, a better understanding of current technology enables the radiologist to play an active role in the procurement of PACS ensuring the precise needs of their department are met.

Diagnostic radiology workstations need sophisticated software and network settings to be configured in order to retrieve and review images, perform multi-planar reformats and generate a report that can be transmitted to the requesting clinician. The installation, maintenance, and upgrading of workstations is a costly and time-consuming process requiring the support of a highly skilled IT team.

"Cloud computing" and "virtualization" are terms that are commonly encountered in radiology and health informatics but not fully understood. Cloud computing centralizes the radiology infrastructure, imaging software, data storage and the network configuration which can then be delivered to any internet-based computer as a service based on user demand. Cloud computing and virtualization technology allows the rapid deployment of radiology imaging solutions to any user (client computer) as needed, whether it be to a hospital environment or to give web access to a clinician in their surgery to view radiology reports or key images. Software is accessed and downloaded as needed via the computer's web browser; additional plug-ins such as Java and ActiveX may also be required.

The cloud computing model has been successfully applied in biomedical research.[1,2] Studies have also shown how cloud computing can be implemented in medical imaging to offer advanced three-dimensional ultrasound image processing to remote facilities that use two-dimensional transducers[3] and in radiation therapy dose calculations.[4]

This article gives an overview of the basic concepts of cloud computing and virtualization technology before discussing the application of these technologies in radiology. The key benefits and some of the potential problems that cloud computing may bring to medical imaging are highlighted and explored. Examples of currently available imaging solutions based on cloud computing and virtualization technology are discussed.

## Cloud computing

The last few years have seen a considerable rise in the number of companies offering "cloud" based radiology solutions. Cloud computing is an emerging new computing paradigm that possibly reflects one of the major key innovations in the history of computing and represents a fundamental change in the way IT services will be invented, developed, deployed, scaled, maintained, and paid for within healthcare.[5]

* Guarantor and correspondent: R.P. Patel, Department of Radiology, The Royal United Hospital Bath, Combe Park, Bath BA1 3NG, United Kingdom. Tel.: +44 (0) 7920 884693.

*E-mail address:* drrakeshppatel@gmail.com

0009-9260/$ – see front matter 
doi:10.1016/j.crad.2012.03.010

Cloud computing avoids the need for a company to purchase and invest in new IT equipment and software in order to process, store and distribute data. Instead the company can outsource some of their IT needs (hardware and software) to a company providing cloud services for a subscription fee. Cloud computing is essentially an internet-based (the cloud) form of computing involving the centralization of resources, such as applications and storage, which can then be accessed by any device connected to the internet anywhere in the world when required (Fig 1). In the UK, the N3 network used by National Health Service (NHS) organizations for data transmission is available and can be utilized to provide a secure, private network through which cloud providers can offer services to connected NHS organizations. The main advantage of cloud computing is the option to pay for services as and when needed "on demand"; therefore, limiting the costly expense of software licenses and hardware, which may or may not be utilized. A variety of other payment schemes is available depending on the needs of a department, such as a yearly flat fee-based service and a tiered pricing structure dependent on volume. Cloud computing has been around for years with most people already using it through services such as Googlemail, Hotmail and Facebook.

Installing, configuring, and maintaining PACS servers and software is a costly and time-consuming task that requires lots of planning. IT continues to evolve at a phenomenal pace resulting in PACS equipment having a shorter and shorter lifespan and needing further expenditure in upgrading in order to keep up with the increasing requirements. Despite the most well thought out forecasts, it is difficult to predict IT needs accurately for the next year let alone the long term. Therefore, by outsourcing IT needs to a cloud provider, time invested building complex IT infrastructure as well as expenditure on powerful computers and software can be minimized. Computers with diagnostic clinical monitors will be required for image interpretation; however, these machines do not need to be high specification machines as the majority of the image data processing will be performed centrally. The cloud provider is responsible for providing the infrastructure, maintaining and supporting all the centralized equipment and software as well as ensuring data security and integrity. As departmental needs grow or change, additional storage and resources can be bought from the cloud provider as required. Though this approach reduces IT expenditure, basic IT personnel will still need to be available to support the hardware locally and resolve minor issues encountered on a daily basis.

Just as an organization would pay for the consumption of gas or electricity, the concept of cloud computing means that payment is only required for the service and data capacity actually used. This form of computing is often given the term "utility computing" and has also been referred to as being the fifth utility after water, electricity, gas, and telephony.[6]

## Three main models of cloud computing

*Infrastructure as a service (IaaS)*

Computer infrastructure, such as servers with operating systems pre-loaded, storage, and network access, is delivered as a service. Companies do not need to buy their own servers and are billed for the space and resources they use.

*Platform as a service (PaaS)*

In addition to the infrastructure, PaaS delivers a computing platform. Companies can rent the application environment/platform to aid the development and delivery of the applications it requires.

*Software as a service (SaaS)*

Complete software applications are downloaded/delivered as a service over the internet as required with no software required to be installed or configured on the users device/computer. Advantages are that there is no need to

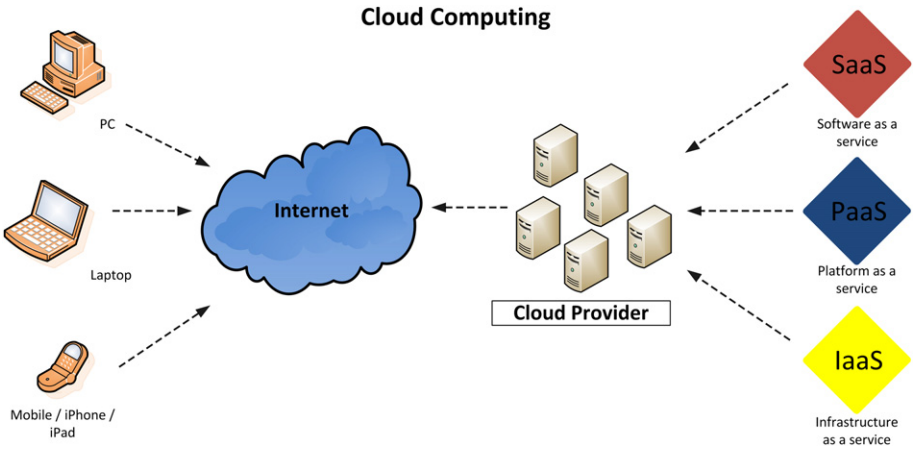


**Figure 1** A diagrammatic overview of cloud computing. The three main models of cloud computing are SaaS, PaaS, and IaaS. Devices are able to access these services using the internet (cloud).

buy a full licence and pay for the software only when needed. Upgrading and applying security patches is undertaken by the cloud provider taking away the need to upgrade individual installations on multiple machines.

## Virtualization

Virtualization technology involves the creation of a virtual (rather than actual) version of something, such as an operating system, a server, a storage device or network resources. Virtualization technology enables a single machine to run multiple platforms concurrently, for example, different versions of Windows running at the same time on a single machine.

Desktop virtualization allows multiple users to maintain customized individual desktops on a single centrally located server accessed from any device connected to the web. The user can use any device such as a mobile, iphone, tablet computer, ipad, or a computer with internet connectivity to access their desktop with minimal or no proprietary software needing to be installed. All data processing is performed on the virtual machine with minimal resources needing to be allocated by the local device.

Advances in remote image rendering has introduced the concept of image processing, such as advanced cardiac and vascular image manipulation and volume rendering being performed remotely from the desktop. This model of data processing is also known as server-side or remote image rendering. A standard PACS workstation query retrieves a complete dataset of DICOM images of the study that is being reviewed and performs any volume rendering that is required locally on the workstation. This method of data processing results in large amounts of datasets being transferred across the local area network (LAN). In the cloud computing model, the DICOM (digital imaging and communications in medicine) data is transmitted to the cloud for storage and data processing. The memory and central processing unit (CPU) intensive tasks are performed remotely and the resulting rendered two-dimensional images are then transmitted to the user's desktop for review. This method ensures that only necessary data is transferred across the network avoiding the transfer of large data sets, which would consume a vast amount bandwidth. In addition, the user does not require a high-end workstation with expensive software installed to perform the image processing locally. Cloud computing utilizing server-side image rendering also has the added benefit of the medical imaging being stored centrally within the data centre and only temporary rendered patient medical images leave the data centre to be displayed on the user's desktop. Data integrity is maintained[7] as no data resides in the user's hard drive once the session has been terminated.

## Applications of cloud computing in radiology

The range of services that a radiology cloud computing provider can offer ranges from an additional image archiving facility to a complete cloud-based radiology solution. Examples of solutions offered by radiology cloud providers are given below.

### *SaaS in radiology*

Three-dimensional visualization and quantitative analysis software tools require the purchase of a user licence and expensive powerful workstations in order to run the applications; utilization of the software is limited to that workstation. A department with reporting radiologists working in different geographical locations need to purchase multiple licenses and workstations in order to perform complex image post-processing at each location. SaaS allows access to three-dimensional software from any computer with a web client and internet access (Fig 2). The software is made available as needed, and hence payment is only required for the service used. The study DICOM images are transmitted into the "cloud" of the service provider and all data processing takes place in the cloud avoiding the need for a separate workstation. Therefore, the user is able to render the images from any web-based computer. An example of a company providing such a service is the i*N*tuition UNLIMITED™ cloud-based service offered by TeraRecon, Inc.

### *PaaS in radiology*

Transfer of patients' images between healthcare facilities and physicians has traditionally required DICOM images to be burned onto CD/DVD and then couriered, a method that is time-consuming and costly. eMix from DR Systems, Inc., and the Image Exchange Portal (IEP) in the UK are examples of cloud-based virtualized image and information sharing platforms that facilitate the transfer of radiological images and reports between institutions. As the solution is "cloud" based, the necessary software is accessed and installed via the web resulting in the system being vendor neutral (Fig 3). Institutions are billed for usage with no additional hardware or software needing to be purchased.

### *IaaS in radiology*

The amount of imaging data produced by radiology departments continues to increase at a phenomenal pace year on year. Departments are continuously expanding the storage capacities of their PACS servers to store the large volume of data produced by the increase in workload and the increased number of images produced by modern CT machines. Secure, permanent storage and archiving of medical imaging is the backbone of any imaging facility. Commercial vendors, such as InSite One and PACSDrive, offer cloud-based imaging archiving and storage solutions (Fig 4). The advantage is that institutions are billed only for the amount of storage space used with the ability to increase storage capacity instantaneously as required thus avoiding the purchase of unnecessary storage space.

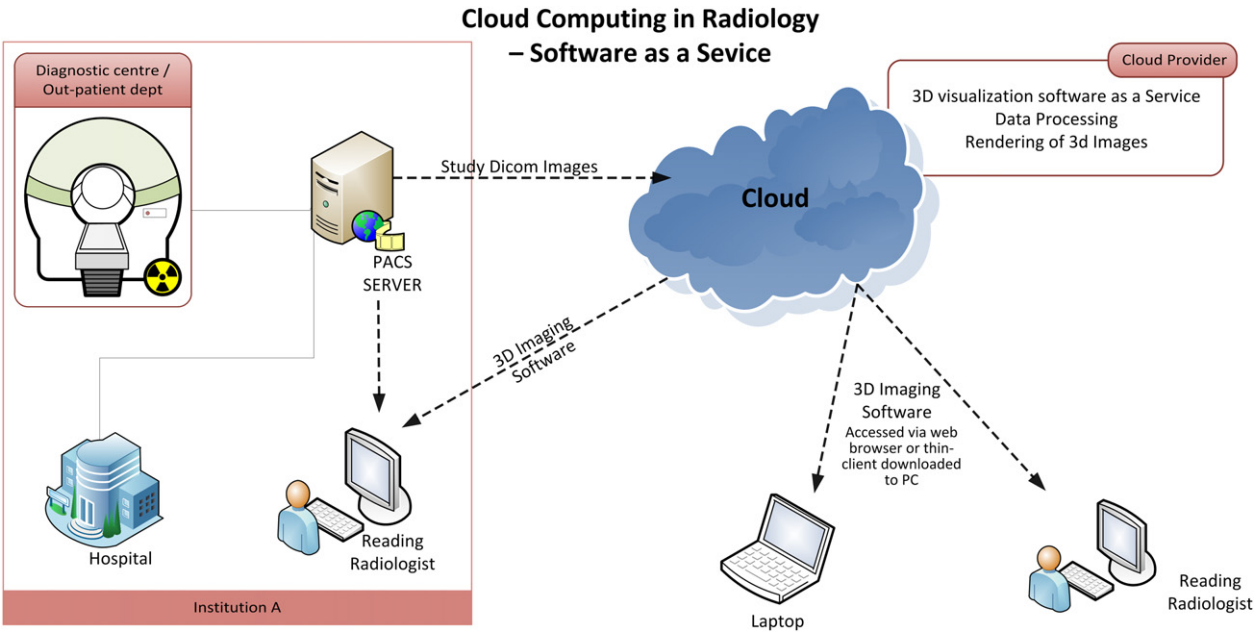


**Figure 2** SaaS. DICOM images are transferred to the cloud in order to perform advanced three-dimensional post-processing. The radiologist accesses the three-dimensional visualization software from any computer and is able to view and manipulate the rendered images.

## Cloud computing security

The various cloud computing models give rise to different types of issues regarding privacy and security of patient data.[8] Security and integrity of all patient data is essential in any implementation of a cloud computing environment. The responsibility of storage and management of patient data is shared with the cloud provider; however, this means that the institution itself will not have complete control over the enforcement of strict security policies.[9] Steps should be taken to ensure that patients' images cannot be accessed by unauthorized individuals or institutions. The originating institution is ultimately responsible for any breach of clinical data and will be required to ensure strict local and national IT governance policies are enforced and audited. Methods of ensuring data security include encrypting all data transferred over the internet using SSL (Secure Sockets Layer) encryption protocol and giving only an authorized user access to the system. Any access to patients' data should be authenticated and audited. The data centre itself should be sited in a secure physical location connected to a monitored secure network that has multiple layers of firewalls. Strict data backup protocols should be in place, the nature of the cloud allows data to be backed up at different physical

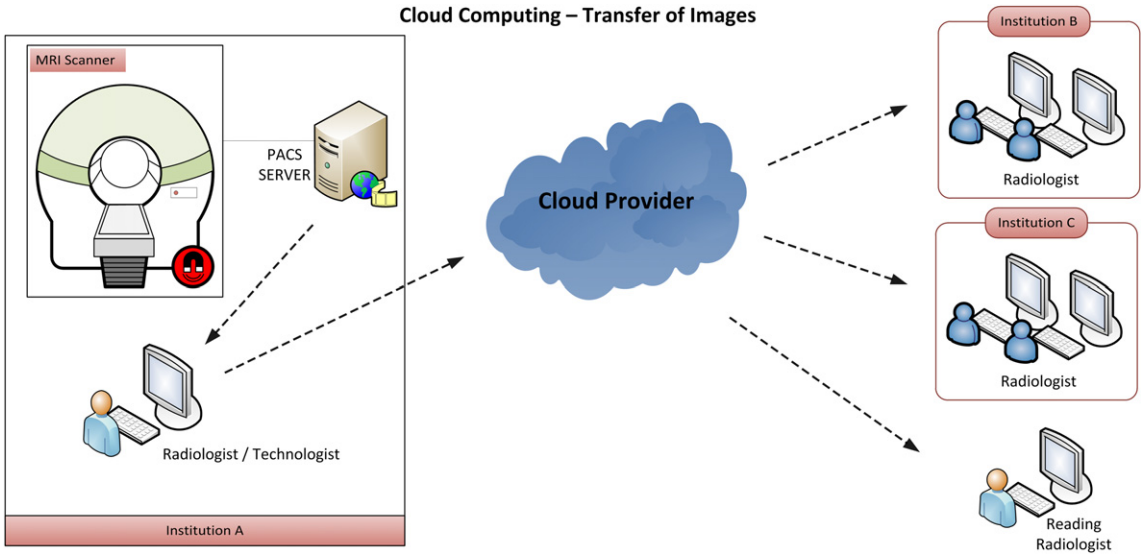


**Figure 3** PaaS. The cloud computing environment is used to transfer images to different institutions and clinicians in physically separate locations.

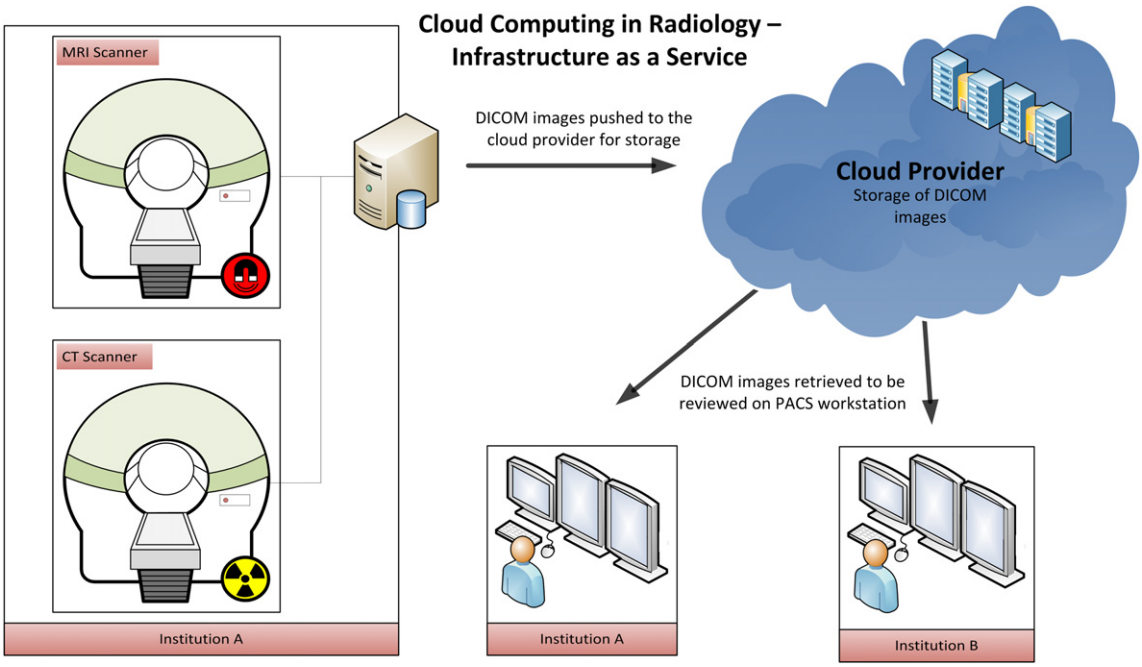


**Figure 4** IaaS. The data centre of the radiology cloud provider is used as a permanent archive to store patient's DICOM images. Institution A does not need to store the images in a PACS server locally.

locations. Only authorized personnel should be granted access to the data centre.

## Conclusion

Radiology requires the secure storage of vast quantities of data that need to be available to be accessed by clinicians, technicians and reporting radiologists in different geographical locations. A typical radiology department may have CT and MRI machines in different locations but will need to store all imaging data in a single place. For many years radiology departments have developed their IT infrastructure using traditional methodology of multiple workstations connected to a server on the departmental network. This configuration requires procurement of PACS, usually as a managed service, and also the purchase of additional licences or software for specialized three-dimensional image manipulation and processing. A dedicated skilled IT support team is needed to maintain and upgrade IT equipment. The inability to share medical imaging across multiple different institutions has been a major challenge to radiology departments with some still requiring data to be burnt onto CDs in order for outside institutions to view the images or the installation of further software/hardware.[10] Cloud computing easily enables institutions to grant temporary access to external institutions or clinicians when needed, thus avoiding any unnecessary delay in patient care. The cloud computing model can also be adopted in other aspects of healthcare, such as data storage and processing in medical research,[11] cancer imaging research and telemedicine.

The subscription-based nature of cloud-based radiology solutions will enable departments in developing third-world countries to gain access to expensive, high-end data-processing software when required without the need to pay for expensive installation and licensing costs. The financial benefits will also be gained by radiology departments in remote locations providing services to small populations.

Cloud computing offers an extremely cost-effective and flexible solution. Fixed payment plans or payment only for resources utilized with additional capacity for expansion available on demand is appealing in the current economic climate. Unquestionably steps should be taken to ensure that confidentiality and data security are maintained. Large organizations will increasingly seek to create their own radiology clouds whereas small organisation will seek the services from external service providers. As more radiology cloud providers emerge onto the market we will see a shift of radiological imaging towards the cloud.

## References

1. Kudtarkar P, Deluca TF, Fusaro VA, et al. Cost-effective cloud computing: a case study using the comparative genomics tool, roundup. *Evol Bioinform Online* 2010;**6**:197–203.
2. O'Connor BD, Merriman B, Nelson SF. SeqWare Query Engine: storing and searching sequence data in the cloud. *BMC Bioinformatics* 2010;**11**(Suppl. 12):S2.
3. Meir A, Rubinsky B. Distributed network, wireless and cloud computing enabled 3-D ultrasound; a new medical technology paradigm. *PLoS ONE* 2009;**4**:e7974. doi:10.1371/journal.pone.0007974.
4. Keyes RW, Romano C, Arnold D, et al. Radiation therapy calculations using an on-demand virtual cluster via cloud computing. *Physics med-ph* September

2010. Published online September 27, 2010. Available at http://arxiv.org/abs/1009.5282v1. Accessed 14 January 11.
5. Marston S, Li Z, Bandyopadhyay S, et al. Cloud computing — the business perspective. *Decis Support Syst* December 2010. doi:10.1016/j.dss.2010.12.006.
6. Buyya R, Yeo CS, Venugopal S, et al. Cloud computing and emerging IT platforms: vision, hype, and reality for delivering computing as the 5th utility. *Future Generat Comput Sys* 2009;**25**:599–616.
7. Philbin J, Prior F, Nagy P. Will the next generation of PACS be sitting on a cloud? *J Digit Imaging* August 2010. doi:10.1007/s10278-010-9331-4.
8. Svantesson D, Clarke R. Privacy and consumer risks in cloud computing. *Comput Law Security Rev* 2010;**26**:391–7.
9. Zissis D, Lekkas D. Addressing cloud computing security issues. *Future Generat Comput Sys* December 2010. doi:10.1016/j.future.2010.12.006. Published online December 22, 2010.
10. Sharma A, Pan T, Cambazoglu B, et al. VirtualPACS — a federating gateway to access remote image data resources over the grid. *J Digit Imaging* 2009;**22**:1–10.
11. Langer SG. Challenges for data storage in medical imaging research. *J Digit Imaging* June 2010. doi:10.1007/s10278-010-9311-8.