Medical Imaging in Cloud: A Survey on Evolution and Trends

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Abstract—With Cloud computing gaining momentum and universal acceptance of it being the future of computing and of the Internet, it can be foreseen that everybody would want to take advantage of it. Healthcare IT services also have much to gain from this revolution. Healthcare standards like DICOM recognise this, and are pushing for a paperless workflow in hospitals; making the hospitals completely digital and Cloud ready. The convergence of these technologies is eminent and many techniques to integrate them have evolved over the years. This paper tries to capture the evolution and the current trends of the same.

Keywords—Medical Imaging; Cloud; DICOM; PACS; WADO; Interoperability

I. INTRODUCTION
Healthcare IT services have been around for a long time now, and yet there seems to be a gap which needs to be bridged between the various healthcare providers and the cases where general or critical healthcare services are needed. Digital Imaging and Communications in Medicine (DICOM) is a standard which promotes exchange of Medical Images and other patient related data among various medical imaging devices and for physicians to study and maintain patient records [1, 2]. It was standardised in 1993, and has been promoted and maintained by American College of Radiology &National Electrical Manufacturers Association (ACR-NEMA) ever since. DICOM has thus, provided a platform to completely digitise the field of Medical Imagery and the way it is shared among physicians and healthcare providers alike. This has been a good starting point for paperless hospital workflow; but, it so happens that through sophistication of the modern healthcare, it has become confined to the hospital intranets. This and the complexity in accessing patient records, with the costs involved in it has rendered such healthcare services difficult for some and almost non-existent for the others.

Internet coupled with such digitised patient records have paved the way for tele-medicine and has allowed healthcare to reach out to more people than before. Specialists, like radiologists do not have to be on-site to diagnose patients – patient data is exchanged with a click of a button and faster diagnosis and treatments can be delivered remotely. But as mentioned before they are confined to hospital intranets and have restricted access from the outside.

Cloud being the next generation Internet technology, helps open up the scope of healthcare services even further. Many such technologies are flexible, adaptive and secure enough to extend that hospital network to the outside world – facilitating the healthcare providers extend reach and consumers to benefit from the services.

The scruples of what Cloud is and how it can help extend healthcare services with the help of standards like DICOM is discussed in this paper. This paper outlines the major Cloud services in the following section. The sections after that give an overview of ideas which have been brewing over the years and the latest trends. The last section summaries the paper and concludes as what to expect from the future.

II. CLOUD SERVICES
Cloud, simply put, is any IT service which is scalable, adaptable and can be which can be provided as an on-demand, pay-as-you-use service; thereby reducing cost and time in rolling out new services. It mainly targets deliverability of services in three different modes, or what some would call models:

A. Infrastructure as a Service (IaaS)
Is basically about lending hardware resources out to clients in a scalable, on-demand manner. The resources are accessed over a private network or the Internet. Physical location of the resources is unimportant to the client.

B. Platform as a Service (PaaS)
This service is about allocation of platforms, or computing environments to the client. E.g., when a client demands for a Windows Server, or a Red Hat Server environments. Hypervisors and Virtual Machines are the key to this service.

C. Software as a Service (SaaS)
The most popular Cloud service available today is, perhaps, this. Everything from Search-engines, online email services to online shopping experiences fall under this category. In this
Among the first signs of the healthcare services to leverage the power of the Internet was pondered in this paper [3]. It was years ahead of its time but the DICOM standard it seems was not ripe enough for the ideas proposed.

The author clearly implores the opportunities of expanding the capability of sharing Medical Images over the Internet making the patient records available for physicians to diagnose, remotely. Though the DICOM network of the hospital is brokered by an intermediary system, called Common Object Request Broker (COBRA), which is responsible for the secure interoperability between the World Wide Web and the private hospital network. At that time, this might have been legit, but now that the DICOM standard has evolved to introduce services like Web Access to DICOM (WADO) with the help of technologies like Representational State Transfer (REST) [1]; the convergence of the technologies seems almost natural.

Among the first signs of the healthcare services to help rapidly scale and deploy services as needed, when needed. This abstraction of responsibilities helps the healthcare services to be rapidly deployed at various sites, disregard of the costs and IT infrastructure needed. Naturally, when the services are on-demand and only how much ever needed gets utilised, the costs of such services are affordable and become accessible to all.

### III. ORIGINS

The concern next, is about the security of the data which is distributed over the Internet. Patient records are highly sensitive information and need to be made available, yes, but with proper care in maintaining the security and discreetness of what is to be shared. This too is addressed in the DICOM standard buy use of Transport Layer Security (TLS) in combination with WADO. For the more lighter clients, or thin-clients, like the sensors, we see proposals like this [8], where the security of the information exchanged is given prime importance, whilst providing remote healthcare to the patients.

With all the patient records moving to the Cloud it can be foreseen that the management of such Medical Imagery can be a challenge. This is because as the consumers of the Clinical data increase over various platforms, with equal diversity in the storage systems of this information. Adding to the complexity is the varied forms of data which is generated; for example, images are produced by X-Ray Scanners, Magnetic Resonance Imaging (MRI), etc. But on the other hand, Electrocardiography would produce waveforms, which are still clinical data. The DICOM Standard simplifies most of this but a radical idea is proposed in [9], which tries to extend beyond Picture Archiving and Communication System (PACS). PACS is a general storage system used in all DICOM networks. The limitations of these systems in backup and management is explored.

### IV. RECENT TRENDS

Fast forwarding to the recent years in the field of healthcare IT, we see this trend picking up pace. We see the previous idea of expanded healthcare network to Cloud by use of Cloud as a Service (CaaS) as described in [4]. This idea is a bit cumbersome as it still does not take in to account of the WADO services proposed in the DICOM Standard [1]. Instead by proposing CaaS, the author simply iterates the DICOM services and how they can be used in entirety as a Cloud service.

This is further pushed by the increased usage of powerful hand-held devices. This is seen in [5] where the idea of combining the DICOM services to a hand-held client is achieved by use of Hypertext Transfer Protocol (HTTP). This showcases the possibilities of information distribution to physicians either for casual diagnosis or for critical care. The remote monitoring of patients is the next big advantage of Cloud services, which is explored in [6]. This is quite an idea which will help doctors to reach-out to more patients and be updated on their health and condition.

Another use for Cloud is seen in [7], where a novel Ultrasound equipment is showcased which is mobile and can be used by physicians in the field and not just in hospitals. This further underlines the relevance of the healthcare IT’s presence in Cloud. If such products are to be seen in near future, the mobility, much like Internet of Things (IoT) and Wireless Sensors, making Medical Image and patient records available and interoperable on different platforms is inevitable.

From recognising the power of the Cloud, empower the healthcare IT, to more radical innovations in personal healthcare, and remoter patient care as the part of sensors and IoT; evidently healthcare IT is transforming for the better. The main advantages in liberating the reach of healthcare services from the bounds of a hospital are that:

#### V. SUMMARY

From the above strides in understanding the importance and relevance of Cloud in Medical Imaging, we have skimmed through what ideas we hope can affect the future of the healthcare.
• Personal healthcare becomes a reality with increase in popularity of hand-held devices
• Critical care can be provided in disaster situations from physicians remotely
• Physicians can monitor a patient’s health remotely, without hindering the patients day-to-day activities
• Paperless workflows also help in maintaining and authenticating and fool-proofing patient records across hospitals. Like Universal Healthcare systems.

With such plethora of advantages the shift towards a more open and interoperable healthcare services is indeed eminent.

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