Building a National Electronic Health Record Infrastructure on top of an Innovative Open Source Mobile Platform Using a Cloud-based Server Infrastructure

Jose Eugenio Quesada, Leo Anthony Celi

This paper describes an architecture for developing a national health record infrastructure in the Philippines using a combination of a mobile application platform, an open source medical record system and a cloud-based server infrastructure. The paper is of interest to JISFTEH as it describes a common requirement in many low resource settings and one particular solution that is already being pilot tested in one hospital in the Philippines. The paper also has describes a security architecture that is interesting as this aspect is sometimes forgotten by implementers of health information technology in low resource environments. The expert system is also of potential interest.

There are several opportunities to strengthen the paper, including the suggestions, below. I have tried to elaborate the general principle behind each point as much as possible and also offer language and grammar suggestions to assist the authors. There are also comments embedded directly in the paper using "track changes".

1. This manuscript does not address a formal research question(s) nor an actual implementation experience but, rather, a system design and architecture that could potentially scale to a national level in a low resource setting (the Philippines). The authors could consider strengthening the technical description of the system architecture and provide a well-reasoned background on the design decisions that the authors have taken and description of the existing hospital implementation. Have the authors considered other national enterprise architectures? How does this architecture compare with others that have been implemented?
2. The abstract tends to contain some material that is better suited to the introduction. The abstract should be succinct and summarize the contents of the paper, not introduce new concepts.
3. In the Introduction, it would be useful to document the actual requirements more rigorously and why this particular architecture will satisfy them. What are the functional and technical requirements for a national EHR in the Philippines? What is the rationale for including the expert system and what requirement will it fulfill?
4. It would be useful to supplement the Introduction with more details around the functional and technical requirements that need to be addressed in developing national health record applications at scale in low resource settings, particularly in the Philippines. This will help lay the foundation for the rest of the paper and the rationale for the architecture that is described. Without this, it is difficult for the reader to understand why the architecture has been developed and what problems it will address.
5. The Introduction (and the manuscript, in general) is generally lacking in scholarly research and lacks authoritative references for its main topics. It would be useful if the authors could review and include reference material around

issues such as the benefits of national EHR, the technical platforms (SANA, OMRS, cognitive system etc). The authors should provide detailed technical descriptions of SANA mobile and OpenMRS with references, where possible. It is not clear where the devices fit into the architecture, what they are doing and how their data is stored and used by the system. Wherever possible, it is preferable to reference authoritative, peer-reviewed papers from the scientific literature, rather than magazine articles and web-based material.

6. There are parts of the paper that describe work that has already been done in developing elements of the architecture and the architecture itself and there are other parts that deal with what the authors plan to do in future. It would be useful to re-structure the paper to have a section that describes the 'Current State' (description of the current requirements for national HIS, current, tools and hospital implementation) and move to the section that deals with 'Future Directions' the descriptions of the planned architecture and national implementation.
7. Many of the figures for the paper appear to have been taken directly from other sources, including the SANA Mobile brochure (Figures One and Two, refs), the technical specifications from the eSante project (http://www.sante.public.lu/fr/actualites/2011/06/14-agence-esante/20110629-eSante-Platform.pdf) (figures four and seven) and Ref 11. Note that Figures three and six are missing. The authors should, preferably, include their own figures or, if they have to use figures from other publications, use these sparingly and cite them appropriately.
8. The paper would likely be strengthened by a more systematic review of the literature and consideration of alternative technologies and architectural designs, for example:
    a. There is little description of other work in this area. The authors should consider reviewing other designs of mobile to OpenMRS, eg ODK. They should also reason why they chose to develop a new system, ie SANA Mobile and OpenMRS. What were the decision criteria? These would be useful to others considering similar implementations.
    b. The authors should consider the issue of standards and interoperability more carefully and how this is important for the immediate goal of creating an interoperable system between SANA Mobile and OpenMRS. Does SANA mobile have a messaging interface to the OpenMRS HL7 v2.x message queue? The authors could also consider the standards and interoperability requirements for the longer-term goal of creating a national scale system. What is already provided in these systems and what will be needed? Consideration should be given to various supporting standards for national architecture and how the SANA-OMRS design will fit into a national architecture, standards and interoperability framework.
    c. There are many other health information systems in the Philippines. How will the system interoperate with other systems? This will be important for scalability and a national system.
    d. Similarly, the authors should consider standards for and privacy/security in addition to HIPAA that may be less relevant in low resource settings than it is in the USA

    e. The authors could consider providing a detailed technical description of the interface between SANA mobile and OpenMRS. This will likely be of considerable interest to technical readers wishing to implement the system in their own environments.
9. The authors should avoid the use of colloquial language, eg "built on top of" and replace with technical, scientific language such as: "SANA mobile was rendered interoperable with OpenMRS by developing a data gateway, comprising of an HL7 v2.6 message envelope and harmonized data, based on a common vocabulary of terms … etc" [this is a fictitious example]. How are the systems rendered interoperable? Does SANA mobile pass data to OpenMRS? If so, what syntax is used? Is there any consideration of semantic interoperability? Is there a controlled vocabulary etc. These questions are important both for the manuscript and for considerations of national scalability in the Philippines.
10. The authors are proposing cloud-based services as a central component of the platform. However, the well-known limitation of such services in low-resource settings is the provision of connectivity and bandwidth, particularly for data services. The authors should consider supplementing the paper with details of how the platform will address these limitations in the Philippines.
11. In dealing with the matter of confidentiality of patient data and data security, the authors have not addressed the very important and contentious issue of security and access to data stored in cloud-based instances, especially those physically located in the USA that may be subject to the Patriot's Act and therefore searching by government. Where are the IBM cloud-based services stored? The authors will obviously have considered the highly contentious issue of storing national data outside of the country in a cloud-based instance. Most countries are extremely cautious of this approach. It would be very interesting to expand on the Philippines approach and why they have decided to allow patient data to be stored in the cloud and what aspects of the information, ie identified or de-identified data.
12. Regarding the choice and use of the IBM cloud-based services, the authors need to explain their choice and why this is seen to be a cost-effective solution for national implementation in the Philippines. This cost evaluation should also include a short explanation of what other cloud-based services are currently available, eg Amazon etc and why IBM was chosen.
13. The authors explain the Watson system by IBM but need to explain what they plan to use it for and how it will be deployed. The reference cited in this article refers to the application of Watson as a decision support tool for sophisticated cancer diagnostics in the developed world. This is known to be one of the most compelling uses of DSS. However, it is difficult to expect the reader to immediately apply this deep clinical example to application in a low resource setting where the challenges are likely to be more of a public health nature. The authors should explain their thinking and the inclusion of Watson in the architecture in more detail in order to convince the reader (and reviewer) that this has a place in the architecture and to avoid appearing like a simple justification for an IBM architecture.
14. It would be useful if the authors could cite the funders and sponsors of this project. Does it have national support from the Philippines national ministry of health?

Building a National Electronic Health Record Infrastructure

on top of an Innovative Open Source Mobile Platform

Using a Cloud-based Server Infrastructure

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Keywords: Open Source, eHealth, Mobile Healthcare, cloud computing

Abstract: **There have been many technical challenges in building eElectronic hHealth rRecord systems for developing countries that have been overcome and addressed in the recent past. The Sana Mobile telemedicine system provides an innovative, mobile-based, end-to-end infrastructure and platform for medical diagnosis and treatment. The system is highly customizable, with an easy to use Android-based mobile phone interface, built on top of several oOpen sSource technologies. The Philippines General Hospital is currently incorporating Sana**

Comment [CS1]: Suggest replacing 'have been' with 'are', as these technical challenges still exist

Comment [CS2]: I would say just addressed, rather than necessarily overcome, as many challenges still remain

Comment [CS3]: I suggest replacing 'built on top of' with more scientific language, such as 'developed from' or 'interfaced with', depending on what is meant.

within its current EMRS implementation. Another innovation is the advent and availability of Expert Systems that provide diagnosis and treatment options to doctors through the use of evidence based medicine and statistical analysis methods.

The next challenge ~~to hurdle~~ is to expand Sana to address data privacy and data security issues in a national context. One of the main issues in designing an eHealth system in a national context is protecting the identity and privacy of the individual person, while, at the same time, making his or her medical information available to the national government for statistical and research purposes. A second issue has to do with allowing the system to scale rapidly, once deemed necessary, to accommodate hundreds of thousands, if not millions of patient electronic medical records without suffering any performance or network degradation issues.

This paper expounds on these issues, as well as the proposed solution to ensure an effective implementation of Sana at the national level.

Comment [CS4]: Shouldn't use abbreviations in the abstract. Does this mean 'Electronic Medical record System'? If so, please spell it out. Is this the same as the electronic health record system mentioned above? If, so, decide on one terminology and use throughout the paper.

Comment [CS5]: Should this be 'anonymously available'?

Comment [CS6]: I suggest replacing 'without suffering' with 'while limiting'. There will always be a performance penalty. The aim is to limit this.

Introduction

We now live in an inter-connected world. There are over 6 billion mobile phones worldwide, for a population of 7 billion people [1], and the fastest growth of mobile users is in developing countries, reaching over 75% of the population [2].

Among the latest advancements in mobile technology are Android based smart phones. These phones allow intuitive, user-friendly applications to be built, that can capture detailed patient information and store the data on the phone. These records ~~are~~

Comment [CS7]: This is a poor reference. Firstly, one should preferably reference authoritative sources, rather than popular internet magazines. Secondly, one should try to reference the original source of the information rather than a source which is reporting another source. In this case, the actual data comes form the ITU world survey which is the original source of the data and a more authoritative source than the source cited (CNET). In summary, rather cite the original ITU source

Comment [CS8]: Similar comment as for [1], above. There are more authoritative sources of this data than PC Magazine that is imply reporting other data. Please try to find the original authoritative source of data for this statement, perhaps from the Mobile Health Alliance or some other credible organization.

Comment [CS9]: When referring to software, it is usually preferable to use the term 'developed, rather than 'built' (refers to houses). Please replace 'built' with 'developed', throughout.

can then be transmitted to a central ~~e~~Electronic ~~m~~Medical ~~r~~Record (EMR) system, through various methods of transmission.

An~~The~~ other technology that has come of age is the commercial availability of cloud based computing as a service [3]. Cloud computing allows for affordable, subscription based, instant deployment of servers for many different services, including telemedicine and eHealth systems. a~~There is a~~lso now available are~~,~~ cognitive computing systems that help doctors ~~to~~ diagnose ~~patients~~ medical illnesses, using the vast amounts of medical literature already published [4].

In order to harness these latest advances in technology for healthcare in developing countries, issues of data privacy, and data security of patient medical records have to be addressed on a national or governmental perspective. Affordability and availability of the information technology solution should also be addressed. It is these issues that this paper aims to address, and to provide a path to a resolution of the issues stated.

Components of a National eHealth System

Mobile-based open-source telemedicine deployment platform.

The first component needed for a national eHealth system is the mobile platform that will deliver the medical information from the patient to the doctor. The Sana Mobile Telemedicine System is an Android cell phone based, ~~-~~standard-focused open-source system that allows for the creation of highly customizable workflows. It connects to a back-end open-source ~~electronic Medical Record~~EMR System (OpenMRS), and allows for reliable operation on unreliable networks through its synchronization, packetization and multi-modal transfer abilities [5].

Comment [CS10]: As mentioned, above, please decide on EMR or EHR and then use throughout.

Comment [CS11]: As above, it is preferable to cite an authoritative, academic source for this statement, rather than an Internet statement. In this case, one should definitely avoid citing a quote from a vendor that also advertises its own product. This is not acceptable in a scholarly journal article.

Comment [CS12]: Same point as above. In this case, it is preferable to cite an academic source that explains the use of cognitive computing or expert systems and then to cite IBM's Watson as an example.

Comment [CS13]: It would be valuable to explain the overall requirement for the system, ie why do you want to harness this technology for healthcare and what are you trying to achieve? Would cognitive computing address any real needs? It would be valuable to explain each element of the architecture and match to a specific requirement, eg EMR to store patient records, mobile to extend to mobile health workers, cloud to ?, cognitive computing to ? etc

Comment [CS14]: I suggest replacing 'needed' with 'that can be used'.

Comment [CS15]: This first sentence needs much more explanation. What medical information is being delivered from the patient to the doctor? What workflows are being customized? How does this system work? This is a key aspect of the architecture and needs to be explained in more detail.

Comment [CS16]: You should use abbreviations for terms like electronic medical record system that are introduced earlier in the paper (above)

Comment [CS17]: This sentence needs to be explained in greater detail. I assume relaible/ureliable with reference to networks, refers to avaiability/non-availability of connectivity? How does the synchronization, packetization and multi-modal transfer do this? Does it essentially store data and then send when there is connectivity? Please explain which network this refers to? Is it the local LAN/WAN, Internet, mobile network?

The Sana Mobile Telemedicine system has the following features [6]:

- It interfaces with point-of-care diagnostic tools through the attachment of portable medical devices to the mobile phone.
- It allows guidelines, checklists, medical procedures and protocols to be saved on the phone, bringing evidence based Medicine into the hands of a health worker or nurse at a clinic.
- It streamlines triage and referral system which includes initial assessment, initiation of diagnostic procedures, appropriate physical examination, and documentation.
- It facilitates coordination of care, care standardization and quality monitoring through the use of E~~lectronic Medical Record~~MRs.

Comment [CS18]: Are PoC diagnostic tools important for the national architecture that is the main point of this paper? If so, the authors should introduce this aspect in the introduction and explain where it fits into the architecture.

Components of Sana

There are four components of Sana~~. These are~~: the Sana Android Phone client, the Mobile Dispatch Server, the SMS Server (Kannel), and the Electronic Medical Record System(OpenMRS) [6].

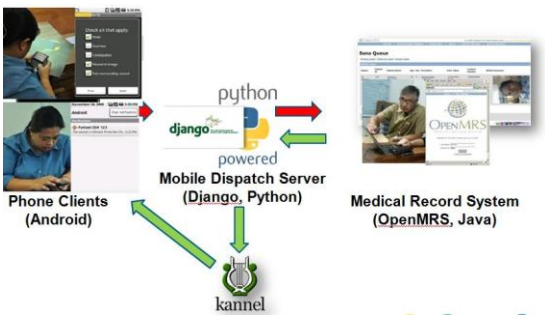

Fig. 1 Components of Sana

Phone Client – Android Phone

The Sana phone client is an application written for the Android phone. This phone client allows multiple procedures to be stored onto the phone. Examples of procedures are: Hypertension questionnaire, Shortness of Breath Evaluation. The Health care worker Opens the Sana phone clients, selects a procedure and follows the workflow hard coded into the procedure when interviewing the patient. The Sana application guides the Health Care worker through the step-by-step questionnaire [6].

Comment [CS19]: Are these procedures or workflows with questionnaires?

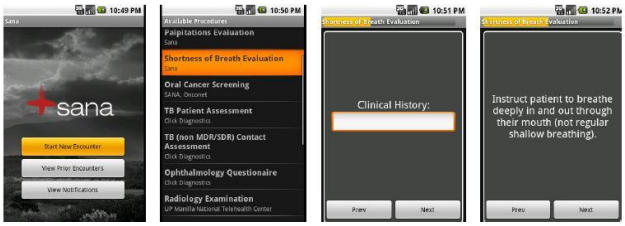

Fig. 2 Sana Phone Client phone interface screen shots

Sana provides a mobile-based telemedicine platform that is customizeable to the requirements of a particular setting. The use of open-source software makes Sana available to any organization that may want to implement the system, without having to pay for any software licenses.

System design to enable data privacy protection in a national context

A~~The~~ second component in building a~~n~~ national eHealth system is to address the data privacy and data security issues of patient medical information.

We will expand the Sana mobile-telemedicine system and incorporate the system into a set of systems that will ensure data privacy and data security in a national context.

These set of systems will comprise the eElectronic hHealth rRecord (EHR) system of a nation or government [12].

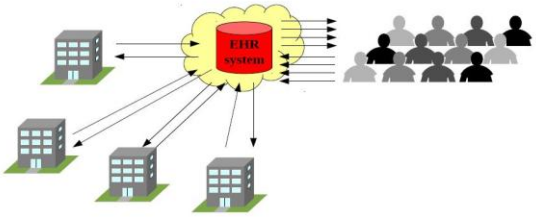

Fig. 4 Electronic Health Record system

Data privacy of Electronic Health Records

Data privacy in healthcare is currently defined and governed by laws and guidelines. The Health Information Portability and Accountability Act (HIPAA)[7] in the United States is one such law that protects a patient's privacy of his or her Protected Health Information (PHI)[8].

In the Philippines, the data privacy act of 2012 [9] was signed into law on August, 2012, which puts in place measures to protect and preserve the integrity, security and confidentiality of personal data collected by government and private entities in their operations.

Implementation of Data Privacy and Data Security measures for Electronic Health records on a national scale has only recently gained visibility and importance. We have chosen to follow the Architecture and Security of a National eHealth Platform [12].

Data privacy of Electronic Health Records can be accomplished through de-identification of personal information from the medical records of the patient [10].

Comment [CS20]: The authors should explain the difference between an EMR and an EHR. It looks to me like the EHR, in fact, is an SHR (shared health record).

Comment [CS21]: Please renumber the figures as Figure 3 is missing.

Comment [CS22]: This is more correctly cited as the 'Republic Act No. 10173 of 2012'.

Comment [CS23]: I suggest replacing 'follow' with 'implement'

Comment [CS24]: You should renumber your references: 9, 10, 11, 12

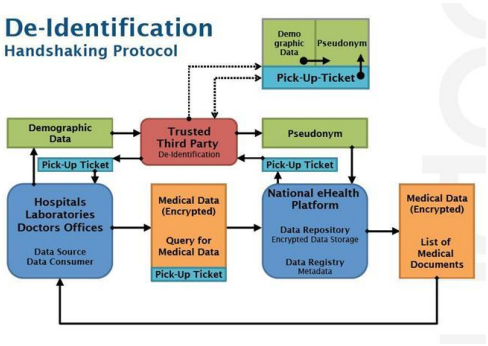

Fig. 5 De-Identification architecture

The de-identification procedure separates the medical information of a patient from his or her identity. This ~~is~~ can be accomplished through the use of pseudonyms [10]. In this strategy, t~~T~~he medical record of a patient is tagged with a pseudonym. The pseudonym and the patient identity pair are then stored at a Pseudonymized Medical Information Provider (PMIP) [12].

Data Security in Health Care

Data security in healthcare is also defined by laws and guidelines defined in each country. The HIPAA Security Rule focuses on assuring the availability, confidentiality, and integrity, of electronic protected health information through a series of administrative, physical and technical safeguards [13].

Data Security in storing medical data in multiple locations

Data security can be~~is~~ accomplished through the use of data encryption of medical data on all physical storage locations. Data encryption and decryption is done throughe the use of public and private keys using a Public Key Infrastructure and stored at a Trusted Third Party (TTP) organization [11].

The following are the different layers that can protect the privacy and security of patient medical records in this architecture. -For Data Privacy: Pseudonymization, IT consent.

For Data Security: Key Re-Encryption, Logging and Alert , Security Token, Timestamp , PKI for Signatures, Certificate Based Authentication [12].

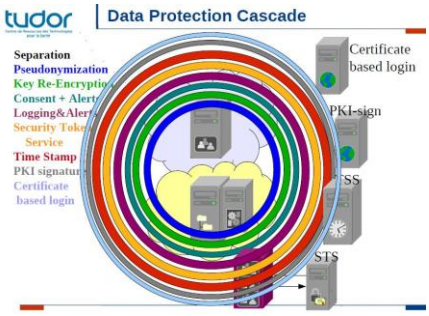

Fig. 7 Data protection layers for patient medical data

Comment [CS25]: Please renumber figures. There is no figure 6

Cloud based server infrastructure

The third component in building a~~n~~ national eHealth system is to allow for a cost efficient deployment of the systems, and allow for expansion in an affordable manner. In order for us to properly scale the set of systems on a national scale, we will test our implementation using International Business Machines (IBM) Smart Cloud Enterprise platform [3]. This cloud based server deployment will allow us to grow the capacity of our servers quickly and cost effectively as the need arises due to growing numbers of electronic records and users.

We will not be encumbered by the lack of computing power and resources to scale the systems once we are ready to grow the systems on a national scale.

Comment [CS26]: This is not a good reference to use for this statement. It seems to be only an advertisement for IBM's cloud-based services. Even the accompanying report has little facutla content. The authors should also document what aspect of 'cloud' they are using. Will they be using it to test systems, deploy system etc. In general the term 'cloud-based services' or 'in the cloud' are not accurate enough for scientific papers where readers want to know more of what this actually means from a technical implementation aspect.

Use of Expert Systems in facilitating the diagnosis of patient illness

Within the past year, IBM has put into place a set of computer systems called Watson~~,~~ that can process volumes of medical information, and provide recommended treatments

to treat patient illnesses. This expert system can be used to help doctors provide quicker, more accurate diagnosis and treatment of patient illness [14]. For a national eHealth record system to be effective in providing medical care to the majority of a population, the set of systems installed must be able to allow for the quick, accurate, and efficient processing of patient diagnosis and treatment. IBM's Watson can put into the hands of doctors, an expert system that has thousands of medical journals in its memory, to apply the appropriate treatment, based on patient history, and current symptoms reported by the patient.

Next Steps to Take

Form a project team with Integrated Open Source Solutions

In order to bring together and apply the various available technologies discussed above, the next concrete step to take is to put together a team that will build the set of systems required for the project. The group will be composed of a software development team, a software quality control team, and a server administration team. Requirements definition, analysis, design, iterative development, phases will be followed, using the agile methodology. Approximate project duration will be one year. A budget will have to be allocated for the project development. ~~Integrated Open Source Solutions [15]~~A private development compnay will lead the project and provide the manpower and project management requirements for the project.

Work with the Otorhinolarynology disivion of Philippine General Hospital

In order for us to test and gain feedback on the systems we are building, we have begun working with the Otorhinolarynology division of the Philippine General Hospital (PGH)

[16]. PGH has mandated the use of OpenMRS as the common ~~electronic medical record~~EMR system that will be used by all the divisions of the hospital, and the Otorhinolarynology division was the first adopter of OpenMRS.

Comment [CS27]: Please can you clarify where this was first? 'In the Philippines?

Use of Open Source Software to build systems

We will continue the spirit of Sana by ~~building~~ developing all of the systems necessary to achieve the stated objectives using ~~100%~~only Open Source software. This will allow the systems to be shared with others, and will allow for growth and collaboration to improve and to customize the systems in other countries.

Set up a source of trained I.T. staff

Through our partnership with Asia Pacific College [17], we will provide ~~a continuous stream of~~ I.T~~.~~ staff, trained on the various technologies that we have used. This will provide the human resource required to sustain and expand the development of a n~~N~~ational EHR~~lectronic Health record~~ system in the Philippines.

Conclusion

The use of an o~~O~~pen s~~S~~ource s~~S~~oftware development platform allows various specialized groups to collaborate and build on top of each group's expertise. This is so well characterized in the Sana Mobile Telemedicine project, which makes use of several o~~O~~pen s~~S~~ource technologies to come up with an effective, working, low-cost solution to provide r~~R~~emote m~~M~~edical d~~D~~iagnosis in low resource areas like the Philippines.

Expanding the scope of ~~of~~ the Sana telemedicine project to use it as a base technology for ~~building~~ developing a national electronic health record system is the next step required in achieving the goal of using information technology to provide affordable, accessible, universal health care in a developing country like the Philippines. The I~~.~~T~~.~~ infrastructure already exists, in the form of cloud computing services, that will allow an electronic health record system to scale rapidly, and in a cost efficient manner, to accommodate the needs of the whole population of a country. With the availability of expert systems such as IBM's Watson to assist doctors, diagnosis and treatment of thousands of patients can be accomplished in an accurate and timely manner.

Incorporating all this latest technology available, and building the set of systems required on top of an Open Source platform is the ambitious challenge facing the development team that will be part of this project. This development will be led by Integrated Open Source Solutions.

This is a project whose time has come. The dream of being able to provide universal health care can now become a reality. It is with dedication, teamwork, and collaboration that we can all make this come true.

Comment [CS28]: Suggest replacing 'on top of an Open Source platform' with 'using open source tools'.

Comment [CS29]: Not normally good practice to advertise the services of private companies in scientific articles. I suggest you exclude this sentence or say that the development will be led by "a private compnay'.

Comment [CS30]: This sentence shouldn't be included in an objective scientific paper.

Acknowledgment

My sincerest thanks go to Dr. Malina Jordanova, for giving me the opportunity to write this paper, and to Merlin Teodosia Suarez for guiding me in writing this paper. Thanks also ~~goes~~ to CS Foundation Inc., and Integrated Open Source Solutions for the continued development of the project. My thanks also goes out to IBM, for introducing me to the latest computing services that can make the realization of this vision become a

Comment [CS31]: In general, in papers, it is preferable to acknowledge others who have contributed to the content of the paper and not to thank people who have provided encouragement or support.

reality. Finally, my thanks ~~goes~~ to Asia Pacific College, for the support given with regards to the time spent working on this project.

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