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OHMF: A Query Based Optimal Healthcare Medication Framework

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Today, cloud computing infrastructure is largely being deployed in healthcare to access various healthcare services easily over the Internet on an as-needed basis. The main advantage of healthcare cloud is that it can be used as a tool for patients, medical professionals and insurance providers, to query and co-ordinate among medical departments, organizations and other healthcare related hubs. Although healthcare cloud services can enable better medication process with high responsiveness, but, the privacy and other requirements of the patients need to be ensured in the process. Patients' medical data may be required by the medical professionals, hospitals, diagnostic centers for analysis and diagnosis. However, data privacy and service quality cannot be compromised. In other words, there may exist various service providers corresponding to a specific healthcare service. The main challenge is to find the appropriate providers that comply best with patients' requirement. In this paper, we propose a query based optimal medication framework to support the patients' healthcare service accessibility comprehensively with considerable response time. The framework accepts related healthcare queries in natural language through a comprehensive user-interface and then processes the input query through a first-order logic based evaluation engine and finds all possible services satisfying the requirements. First order logic is used for modeling of user requirements and queries. The query evaluation engine is built using zChaff, a Boolean logic satisfiability solver. The efficacy and usability of the framework is evaluated with initial case studies on synthetic and real life healthcare cloud.

Keywords : Cloud Healthcare, First-order Logic, zChaff SAT.

1. INTRODUCTION

Cloud Computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (*e.g.*, networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. Recent Research by Gartner [1], on top 10 "disruptive technologies," outlined that enterprise cloud [2], power grids [3], web ecosystems, virtualization and social software are the dominant but threat-prone technologies which are being adopted largely in different countries.

Today, healthcare is undergoing enormous change and reform worldwide. With healthcare spending as a percentage of GDP rising by double digits annually in some countries [4] [5] [6], and concerns growing over medical care access and quality, governments and healthcare institutions are working to find creative new ways to address the need for improved care delivery models and payment reform.

Cloud computing [7] [8] provides efficient and cost-effective way of delivering IT services which can directly support the need to slow the growth of healthcare costs. The agility provided by on-demand, flexible cloud-based computing resources can also help empower the growth of a new generation of healthcare services and initiatives that respond more quickly and creatively to the needs of people and organizations across the continuum of health. Many healthcare providers and insurance companies today have adopted some form of elec-

Table 2
List of Requirement Attributes

Query Size	SAT translation time (msec)	SAT solver run time (msec)
200	8.23	1.2
350	8.89	1.2
1000	9.32	1.25
1500	10.12	1.26
2300	11.25	1.29
3000	11.98	1.31
3500	12.37	1.32
4000	12.89	1.33
5000	13.56	1.35

technique called Chaff [25] for finding solutions. It depends on the complexity and dependency between the Boolean clauses. This shows the power of the SAT solvers in solving Boolean formulae. Therefore, our framework is able to find the query result in considerably good time. It takes 14.91 msec to process a query with size 5000. At present, the translation of SAT results into natural language output is performed manually.

6. CONCLUSIONS

This paper presents a comprehensive query based optimal healthcare service framework that can be targeted to automate the searching of various medical information in a large hybrid healthcare cloud from different service providers. This will in turn guide the patients to take necessary and optimal decisions related to the specific healthcare service at any point of time. The framework may facilitate the service providers to design a scalable and efficient patient interaction system to choose the services as per their requirements. The major process elements of the proposed framework are as follows:

- The user validation and requirement gathering has been done through a simple and comprehensive user interactive interface.
- Query Translation module translates the user specified requirements into first order logic query. It is represented in Boolean Conjunctive Normal Form (CNF).
- The SAT solver checks the satisfiability of the translated query with the healthcare cloud backend database. For this, a Boolean model is extracted from the database.
- The SAT solver provides the possible traces of solution that satisfies the requirement. Then the result trace is provided as output through the Response Engine.
- The output is translated into natural language forms and the response engine communicates the same to the GUI.

The query evaluation engine is developed using zChaff SAT solver. The efficacy of the framework has been demonstrated through a case study. The proposed methodology has been shown to be correct and scalable. In future, the framework will be validated with various real life case studies. This work can be extended to develop an integrated patient interaction system tool for systematic retrieval of healthcare information.

REFERENCES

1. P Kacsuk. *Editorial Journal of Grid Computing*, 2004.
2. J Hasier and M Nicolett. Assessing the Security Risks of Cloud Computing, Gartner Research, *Gartner Inc*, June 2008.
3. M Ashiqur Rahaman, Padmalochan Bera and E Al-Shaer. SmartAnalyzer: A Noninvasive Security Threat Analyzer for AMI Smart Grid, 31^{st} *IEEE INFOCOM 2012*, pages 2255–2263, Orlando, Florida USA, March 2012.
4. Hillestad R, Bigelow J, Bower A, Girosi F, Meili R, Scoville R and Taylor R. Can Electronic Medical Record Systems Transform Health Care? Potential Health Benefits, Savings and Costs, *Health Affairs*, 24(5): 1103–1117, 2005.
5. Bartels A. US IT Spending Benchmarks for 2006: How to Turn the CIO's Bane into an Effective Tool for IT Budgeting, *Forrester Research Report*, www.forester.com, 2006.

6. Hasan R and Yurcik W. A Statistical Analysis of Disclosed Storage Security Breaches, *in Proceedings of* 2^{nd} *ACM Workshop on Storage Security and Survivability*, Alexandria, VA, pages 1–8, 2006.
7. N Khan, A Noraziah, T Herawan, E Ismail and Z Inayat. Cloud Computing: Architecture for Efficient Provision of Services, *in Procedings of* 15^{th} *International Conference on Network-Based Information Systems*, 2012.
8. Shirley Radack. Cloud Computing: A Review of Features, Benefits and Risks and Recommendations for Secure, Efficient Implementations, *ITL Bulletin for June 2012*.
9. Abraham C, Watson R T and Boudreau M C. Ubiquitous Access: On the Front Lines of Patient Care and Safety, *Communications of the ACM*, 51(6):95–99, 2008.
10. Kilo C M and Wasson J H. Practice Redesign and the Patient-Centered Medical Home: History, Promises and Challenges, *Health Affairs*, 29(5), 2010.
11. Microsoft HealthVault, Connected Continuous Care, White Paper, March 2011.
12. M Mohebbi, Dan Vanderkam, J Kodysh, R Schonberger, H Choi, Sanjiv Kumar. *Google Correlate Whitepaper*, June 9, 2011.
13. H Park. Report of the for Working Groups and Special Interest Groups, *IMIA Board Meeting*, April 21, 2013.
14. S M Furnell, P W Sanders. Security Management in the Health-care Environment, MEDINFO 95, *Proceedings of the Eighth World Congress on Medical Informatics Canada*, pages 675–678, 1995.
15. Sabah Mohammed, Daniel Servos and Jinan Fiaidhi. HCX: A Distributed OSGi Based Web Interaction System for Sharing Health Records in the Cloud, *IEEE/WIC/ACM International Conference on Web Intelligence and Intelligent Agent Technology*, 2010.
16. M Li, S Yu, K Ren and W Lou. Securing Personal Health Records in Cloud Computing: Patient-Centric and Fine-Grained Data Access Control in Multi-owner Settings, in SecureComm10, pages 89–106, Sept. 2010. I S Jacobs and C P Bean, Fine Particles, Thin Films and Exchange Anisotropy, in Magnetism, vol. III, G T Rado and H Suhl, Eds. New York: Academic, pages 271–350, 1963.
17. Leslie S Liu, Patrick C Shih, Gillian R Hayes. Barriers to the Adoption and Use of Personal Health Record Systems, *ACM Conference*, 2011.
18. V Koufi. Ubiquitous Access to Cloud Emergency Medical Services, *in the Proceedings of* 10^{th} *IEEE International Conference on Information Technology and Applications in Biomedicine (ITAB), Corfu, Greece*, pages 1–4, Nov. 2010.
19. Chia-Chi Teng. A Medical Image Archive Solution in the Cloud, *in the Proceedings of IEEE International Conference on Software Engineering and Service Sciences (ICSESS), Beijing, China*, pages 431–434, July 2010.
20. N Botts. Cloud Computing Architectures for the Underserved: Public Health Cyber Infrastructures Through a Network of HealthATMs, *in the Proceedings of* 43^{rd} *Hawaii International Conference on System Sciences (HICSS), Hawaii, USA,* pages 1–10, 2010.
21. S Van der Burg, E Dolstra. Software Development in a Dynamic Cloud: From Device to Service Orientation in a Hospital Environment, *In 2009 Proceedings of ICSE Workshop on Software Engineering Challenges of Cloud Computing.*
22. O Shimrat. Cloud Computing and Healthcare, San Diego Physician.org, 2009.
23. Y S Mahajan, Z Fu and S Malik. Zchaff 2004: An Efficient SATsolver, *in Proceedings of* 8^{th} *International Conference on Theory Application Satisfiability Testing,* pages 360–375, Scotland, June 2005.
24. T Hofmeister, U Schoning, R Schuler and O Watanabe. A Probabilistic3-SAT Algorithm Further Improved, *in Proceedings* 19^{th} *Annual Symposisum Theoretical Aspects Computer Science (SATACS)*, pages 192–202, 2002.
25. Matthew W Moskewicz, Conor F Madigan, Ying Zhao, Lintao Zhang and Sharad Malik. Chaff: Engineering an Efficient SAT Solver, *in Proceedings of the* 38^{th} *Annual Design Automation Conference*, pages 530–535 , New York, USA, 2001.

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