Multi-factor Authentication Framework for Cloud Computing

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Abstract—**Cloud computing is a new paradigm to deliver services over the Internet. Data Security is the most critical issues in a cloud computing environment. Authentication is a key technology for information security, which is a mechanism to establish proof of identities to get access of information in the system. Traditional password authentication does not provide enough security for information in cloud computing environment to the most modern means of attacks. In this paper, we propose a new multi-factor authentication framework for cloud computing. The proposed framework provides a feasible and a most efficient mechanism which can closely integrate with the traditional authentication system. The proposed framework is verified by developing Cloud Access Management (CAM) system which authenticates the user based on multiple factors. Also using secret-splitting and encrypted value of arithmetic captcha is innovative factor for user authentication for cloud computing environment. Prototype model for cloud computing own cloud server is implemented using open sources technology. The proposed framework shows the close agreement with the standard criteria for security.**

Keywords- Arithmetic Captcha; Multi-Factor Authentication; Out of Band Authentication; CAM System;

I. INTRODUCTION

Cloud computing is delivery model for computing services where dynamically scalable and virtualized resources are provided as a service over the Internet. In this model, various computing resources are provided as a service. It brought a lot of advantages especially in ubiquitous services where everybody can access computing services through Internet. Along with many benefits of cloud computing has to offer, the data security major bottleneck in its adoption which also makes user anxious about safety, reliability and efficiency. According to the NIST define cloud computing is a model for enabling 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. This cloud model promotes availability and is composed of five essential characteristics, three service models, and four deployment models [1]. According to NIST these five essential characteristics are: on-demand self-service, broad network access, resource pooling, rapid elasticity and measured service.

According to NIST cloud computing consists of three distinctive service models which are Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). Cloud computing instances can be operated according to four different deployment models: Private Cloud, Community Cloud, Public Cloud and Hybrid Cloud [2, 3].It provides various services over internet such as software, hardware, data storage and infrastructure. Cloud service providers deliver the applications and computing resources via Internet, which are accessed anywhere using web browsers, desktop and mobile apps. It delivers software as a service over the Internet. Cloud computing is an Internet-based model for enabling convenient, on-demand network access to a shared pool of configurable computing resources [1]. It eliminates the need of installing and running the application on the customer's own computers. PaaS is an on-demand platform service to host customer application [2, 4-7]. Cloud Service Providers (CSP): should ensure the security of their customers data and should be responsible if any security risk affects their customers service infrastructure. A cloud provider offers many services that can benefit its customers such as fast access to their data from any location, scalability, pay-for-use, data storage, data recovery, protection against hackers, on-demand security controls, and the use of network and infrastructure facilities [8]. Security issues in cloud computing: CSP can offer benefits to users, but security risks play a major role in the cloud computing environment [9]. Users who use online data sharing or network facilities are aware of the potential loss of privacy [10]. According to a recent IDCI survey [11], 74% of IT executives and CIOs stated that security was the issue of greatest concern in any cloud computing environment. Moving user data and information to clouds large data centres involves many security threats and challenges [12] such as virtualization vulnerability, accessibility vulnerability, privacy and control issues related to data accessed from a third party, integrity, confidentiality, and data loss or theft. Also authors [13,14] discuss several fundamental security challenges, such as data storage security, application security, data transmission security, and security related to third-party resources. In different cloud service models, the security responsibility between users and providers is different.

According to Amazon [15, 16], their EC2 addresses physical, environmental and virtualization security, whereas

the users remain responsible for addressing the security of the IT system, including the operating systems, applications and data. As cloud computing services have been built over the Internet, any issue that is related to internet security will also affect cloud services. Resources in the cloud are accessed through the Internet, consequently even if the cloud provider focuses on security in the cloud infrastructure, the data is still transmitted to the users through the network, which may be insecure.

In this paper, we have proposed and develop a new framework for authentication of user to access cloud computing services and resources from cloud computing server. The purpose of this proposed work is to analyse the existing security threat to the cloud computing environment and developed a new secure authentication system using dynamic secure multi-factor secret splitting approach to strengthen the security of cloud computing environment. The developed model has been analysed against various security threats and demonstrated by model CAM which is implemented using owncloud cloud computing environment and open source tools.

II. EXISTING AUTHENTICATION MECHANISMS

In this section some existing authentication schemes are reviewed, which are based on client-server architecture. Authentication is a simple function where one party presents a set of credentials to a system. If the credentials have a match on the system, the system returns a value that represents authorization; otherwise it does not. The purpose of authentication is to verify that the specific information presented represents a request to be authentic from a specified entity [1, 2][17]. Currently most of web based serviced systems have adopted a simple ID/password mechanism for achieving the goals associated with the identification and authentication. Many more technical solutions exist to uniquely identify the user [4, 5, 8, 11-16][18-21]. One of the most popular and elderly remote user authentication schemes was suggested by Lamport[22] in 1981, in which, the server stores the hashed value of a users password. In Lamport's scheme, password table was used to verify the legitimacy of users, but if this password table is compromised, stolen, or modified by an adversary, then the system could be partially or completely compromised [23]. Some more recent smart card based password authentication schemes have also been proposed in [24-27]. Shoup-Rubin [28] proposed extension of Bellare-Rogaway model which is based on three part key distribution protocol. Smartcard is used to store the long term secret key and it is assumed that the smartcard is never compromised.

So basically the scheme falls in one factor category as two factor schemes can be broken by compromising both the factors only. Liao et al. [29][24] tried to consolidate a number of passwords and smartcard based properties and proposed two factor smartcard and password authentication

scheme, which is still vulnerable to many attacks [29-30].

Cloud computing is a variant of client server architecture, where, thousands of clients use the same infrastructure at a large scale. Consequently, it needs stronger authentication than conventional client server inter-networking system.[11,21].Lee et al [3] [10] have proposed public key and mobile out of band based authentication for cloud computing.

Some systems use more complicated authentication using the smartcard system[8, 9], where a user typically has an ID, a password, and also a time-generated passkey from the smart card which changes every 60 seconds. This represents the case possessing something physically.

Biometrics authentication is more secure mechanism in which user has to demonstrate what you are. Biometrics credentials can take many dimensions, from finger prints, to retinal scans to pupil images etc.

As we can see from above, authentication is the key for information security. Most of the existing user authentication schemes have many security flaws. Password authentication is the most commonly used scheme, but this technology is vulnerable to eavesdropping, replay, exhaustive and dictionary attacks etc.

In this paper we have addressed most of the security concerns of cloud computing and have developed a secure user authentication framework for cloud computing. Most of the existing authentications are based on static passwords whereas the proposed scheme is based on dynamic secure multi-factor out-of-band secret-splitting mechanism which is more secure, efficient and user friendly.

TABLE I. LIST OF NOTATIONS

Notation	Description
U	User of Cloud Services
CSP	Cloud Server Provider
CAM	Cloud Access Management server
ID	Users unique identity
PW	User's password
OTP	One time password
K	Secret key for arithmetic captcha expression
EXP	Arithmetic captcha expression
V1	User's Arithmetic Captcha Expression Value
H	Hash function for arithmetic captcha
V0	Actual value of Arithmetic Captcha Expression
Low, Medium, High	Authentication level assign by CAM System
CA	Current authentication level of user
OOB	Out-of-band secure channel
IMEI	International Mobile Equipment Identification

III. THE PROPOSED SECURITY ARCHITECTURE

A. Key Entities

1) Cloud Services Provider(CSP): We use owncloud which is an open source cloud computing server in Linux environment.

2) Cloud Access Management (CAM) System: Which is developed using LAMP and open sources tools.

3) User: Human being who uses cloud computing services and resources for his computing needs.

4) Cloud Administrator (CloudAdmin): Responsible for overall management of CAM server and cloud computing server.

5) Internet and Browser: Is used to access CAM and CSP to access cloud computing services and resources.

6) Smart Mobile Phone and Mobile network: This smart phone, mobile phone number and network is used to exchange the authentication credentials e.g. secret key, one time password and IMEI number through SMS. The mobile network is used as out-of-band (OOB) secure channel for user authentication.

7) Email-Id: A valid email-id is used to send secret and verification code during user registration and credential change phase.
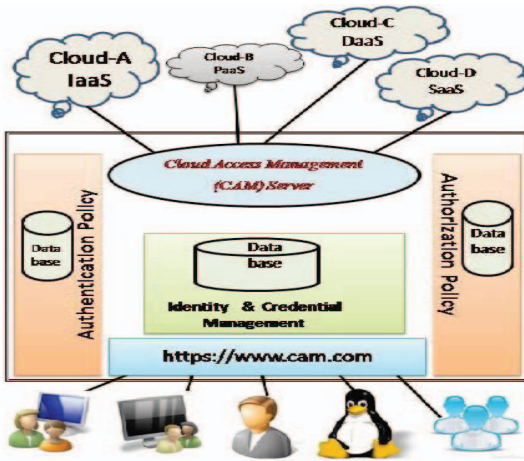

Figure 1.Framework of Proposed CAM System

B. Key Approaches Used

1) Arithmetic Captcha Expression: Arithmetic captcha expression is a simple expression with two operands (1-9) and one operator (+, -,*), generated randomly by server and displayed to user just as normal captcha. The user needs to calculate the value of captcha expression after modifying the operands with secret key. The hashed value of catpcha expression is sent just like normal captcha. This hashed value is used for user authentication by CAM server.

2) Multi-Level Authentication: In the proposed frame-work cloud services and resources are classified into three types: low, high and medium, according to risk and security level required. The user also authenticated dynamically using multi (Secret key, One Time Password and IMEI number) factors.

3) Secret Splitting of Authentication Factor: The pro-posed framework used the one time password and IMEI number of smart phone as authentication secret. These secret are split into chunks and CAM server ask to user answer some random sequences of these chunks for user authentication.

IV. ALGORITHM FOR PROPOSED FRAMEWORK

In this section the algorithm and implementation of various phases and activities of secure authentication are discussed in detail. Following are the assumptions that are not supposed to be violated during the execution of the proposed scheme. All the users and cloud service providers are supposed to be honest in the registration phase. After registration phase is complete, no user, cloud service provider is trusted. Users are required to verify themselves during login and authentication phase by providing real and exact identification details for accessing cloud services, applications and resources. Once mutual authentication is performed, the server and cloud service provider are al-ways trusted and it is assumed that the server is never compromised with the network adversaries. The proposed model consists of three phases: registration phase, login and authentication phase and change authentication credential phase.

A. Registration phase:

In the registration phase, user needs to register at the CAM server by providing appropriate identification information. The server processes user's data and registers the user mobile phone and IMEI number for authentication the algorithm for new user registration is as following:

Step-1: User requests to CAM server for new registration.

Step-2: User enters new user-ID and password and submits for registration.

Step-3: CAM server checks for uniqueness of the requested ID. If not, it goes to step-2 else proceeds to step-4.

Step-4: CAM server asks user to submit user mobile phone Number, email-id and other credentials.

Step-5: User provides all required credentials and submits.
Step-6: CAM–>U:M1, server generates a secret key (K) sends to user mobile phone, and displays an arithmetic captcha expression EXP = digit1 (+ *) digit2. User needs to send value (V1) of captcha expression.

Step-7: CAM=>U:M2, server generates a secret verification code, sends to user email-id and asks user to enter the verification code.

Step-8: U=>CAM:M1, User calculates the value of arithmetic expression V1 = h (EXP, K) and sends to server as captcha reply.

Step-9: U–>CAM:M2, User sends secret verification code

via SMS using mobile phone. *Step-10:* CAM server verifies V0=V1 if true goes to step-11, else terminates registration process.

Step-11: CAM server verifies C0=C1 if true goes to step-12, else terminates registration process.

Step-12: CAM server identifies phone number and IMEI number of mobile phone which was used to send verification and registers this mobile. This mobile information is used during authentication process.

Step-13: After all verification for user registration is complete, user information including secret key(K) ,IMEI number of mobile and other credentials are saved in user registration database.

Step-14: User registration completes.

B. Login Phase:

In this phase, user login into CAM system for authentication and to access the cloud services. Algorithm for user login is as following

Step-1: User enters ID and password for login.

Step-2: CAM System authenticates the user with id & password. If true it go to step-3 else terminates the login process.

Step-3: If the user is authenticated then the current authentication token CA is updated to 1. The user is directed to the homepage, where the user authenticated using multi-factor for high level authentication.

Step-4: If the user is not verified the login process terminates.

C. Authentication Phase

Authentication phase is processed in the CAM server where, the server will decide whether a user should be allowed to access cloud services and resources or not. To implement dynamic user authentication, all cloud computing services and resources are classified into three (Low, Medium, High) levels according to their security requirement. The user is authenticated dynamically based on three key factors. Algorithm for user authentication is as following:

1) Low Level Authentication: This authentication is based on secret key factor and arithmetic captcha expression

*Step-1:*CAM System checks for user's current authentication status If CA=1 then it goes to step-2; else terminates the authentication session.

*Step-2:*CAM System generates arithmetic captcha expression (EXP), with two operands (1 -9) and one arithmetic operator (+ -*).

*Step-3:*CAM System sends captcha expression to the user. *Step-4:*User calculates the value V1=h (Exp, K) of arithmetic captcha using secret key submit to the server.

*Step-5:*CAM System verifies V1=V0. If true, user is authenticated for low level. Server allows to access low level cloud services and resources. The current authentication token CA is updated to 2. Else terminate process.

2) Medium Level Authentication: In this Level user is authenticates using two factor first factor is arithmetic captcha and second factor is one time password (OTP).

*Step-1:*CAM System check for user's current authentication level. If CA=2 than go to step-2; Else terminate authentication session.

*Step-2:*CAM System generates one time password (OTP) and sends it to user mobile phone. *Step-3:*User enters the OTP received for authentication and submits to CAM system back.

*Step-4:*CAM System verifies (system generated) OTP=OTP' (user entered). If true, user is authenticated for medium level. Update current authentication level CA=3 and allows the user to access medium level cloud services and resources. Else terminate process.

3) High Level Authentication: In this Level user is authenticates using three factor first factor is arithmetic captcha, second factor is one time password (OTP) and third is IMEI number of user's mobile phone.

*Step-1:*CAM System checks for user's current authentication status. If CA=3 than go to step-2. Else terminate process.

Step-2: CAM System divides fifteen digit IMEI number into small chunks of two digits each and asks the user to enter three random segments of IMEI.

Step-3: User needs to submit the required segments of IMEI.

Step-4: CAM System verifies IMEI segment. If true, user is authenticated for high level. Update current authentication level CA=4 and allow the user to access high level cloud services and resources. Else, terminate process.

D. Change Authentication Secret Phase Change

Password It allows the user to change the pass- word at any time. The procedure is as follows:

*Step-1:*From authentication homepage, select and initiate a change password activity.

*Step-2:*CAM system generates arithmetic captcha expression EXP and displays to the user.

*Step-3:*User enters old password and new password.

*Step-4:*User calculates the value V1 of captcha expression and submits.

*Step-5:*CAM system verifies the old password and arithmetic captcha value V1=V0.

*Step-6:*If verification is true, then change old password with new password. Else terminate change pass-word activity.

Change Secret key It allows the user to change secret key(K) for arithmetic captcha value are as following:

Step-1: From authentication homepage, select and initiate a change secret key activity.

Step-2: CAM system generates a new secret key (K) and arithmetic captcha expression (EXP). Key send to users mobile phone.

Step-3: User calculates the value (V1) of captcha expression using new secret key and submit.

Step-4: CAM System verifies the captcha value (V1=V0). If true, then change the old secret key with new one. Else terminate activity.

Change Mobile Phone and IMEI number It allows the user to change their mobile phone number and/or IMEI number. The procedure is as follows:

Step-1: User initiate the change of phone and IMEI number activity.

Step-2: CAM system generates verification code and send to user.

Step-3: User sends verification code to server via SMS with new mobile phone.

E. Implementation Of Proposed Framework

Figure 2.User authentication system(CAM)

Figure 3.User Accessing Cloud Computing Services

F. Security Analysis Of Proposed Framework

This security analysis explain how proposed framework mitigation of possible risk.

1) Secure credential management: The CAM server stores all the credentials of the user in a secure database. Server checks the availability of unique ID for each user at the time of new registration.

2) Secure Credential Change: Proposed framework facilitates users to change password, mobile phone, IMEI number, and secret key using secure and user friendly manner, at anytime as shown in section IV (F). This change facility makes the framework inherently stronger compared to the static password based mechanism.

3) Replay attack:] Three authentication levels are based on three factors-secret key (K) and arithmetic captcha expression, one time password (OTP) and IMEI number. Also valid user login ID and password is required for authentication.

4) Man In The Middle Attack(MITM): In this framework even if attackers manage to get the user ID and password and are able to login into the system, they cannot access cloud services and resources, as the user needs authentication which requires secret key (K), one time password(OTP), mobile phone and IMEI number. These secrets are only exchanged between the user and the server using separate secure OOB channel.

5) Stolen verifier attack and unauthorized access attack: In our proposed scheme, all authentication factors are not available simultaneous. Thus, even if one credential is stolen or lost, authentication needs other parameters for login. Also the framework provides credential change facility and in case of a theft, the user can change the required parameters. Hence stolen verifier attack and unauthorized access attack is not applicable in this framework.

6) Impersonation attack: In the proposed framework, secret key for arithmetic captcha is never transmitted through the public channel. Secret key is the key factor for each authentication. Only hashed value V=h(E,X) of arithmetic captcha is transmitted to the server. Also the scheme uses high entropy OTP, delivered to user using a separate out of band channel for authentication. Hence the proposed scheme is strong and safe against impersonation attack.

7) Phishing attack: In this framework mutual authentication between the user and the CAM server, based on multi-factor credentials is performed. Secret key, OTP, IMEI and mobile phone are required for authentication. Only the genuine server can send proper authentication information. And user responses can be verified by genuine server only.

8) Password guessing attack: In the proposed framework authentication is based on multi-factors using secret key, arithmetic captcha expression, OTP and IMEI number. The use of OOB secure channel for exchange of credentials which provides more robustness to the scheme. In the proposed framework, just password guessing is not

sufficient for authentication. It also requires secret key (K), user's mobile phone and IMEI number.

V. CONCLUSION

The advantage of the ubiquitous use of smart phone is taken in the proposed work. The proposed framework provides a feasible and efficient solution by combining the traditional user ID and password based authentication with dynamic multi-factor secret-splitting based authentication approach. It designs secure authentication system which can resist many types of attacks. The basic strength of this mechanism lies in the fact that user is authenticated dynamically rather than statically. This authentication framework has many security features, such as identity and credential management, mutual dynamic authentication, session access token agreement between the user and the cloud access management server and user friendliness. The end result is a user authentication system that establishes specific level of security for the users to meet their dynamic requirement of security levels for the cloud computing services and resources.

REFERENCES

[1].Mell, P; Grance, T. *The NIST Definition of cloud computing Versiong 15 Technical Report.* Computer and Information Sci-ences. 53(6),pp.1-10. 2009.

[2]. Vaquero, L., Rodero-Merino, L., Caceres, J, & Lindner, M. (2009). *A break in the clouds: Toward a cloud definition.* ACM SIGCOMM Computer Communication Review, 39, 50-55.

[3]. Lee Badger, Robert Bohn, Shilong Chu, Mike Hogan, Fang Liu, Viktor Kaufmann, Jian. *Useful Information for Cloud Adopters.* NIST Cloud Computing Program, 2(1), pp.1-73 , 2011.

[4]. Buyya, R., Yeo,C.S. and Venugopal, S. (2008), *Market-oriented cloud computing: vision, hype, and reality for de-livering IT Services as computing utilities,* Proceedings of the 10th IEEE International Conference on High Performance Computing and Communications, pp. 5-13

[5].Buyya, R., Yeo, C., Venugopal, S., Broberg, J., & Brandic, I. (2009). *Cloud computing and emerging IT platforms: Vision, hype, and reality for delivering computing as the 5th utility.* Future Generation Computer Systems, 25, 599-616.

[6].Sharif, A.M.(2010), *Its written in the cloud: the hype and promise of cloud computing,* Journal of Enterprise Information Management, Vol. 23 No. 2, pp. 131-4.

[7].Foster, I., Zhao, Y., Raicu, I., Lu, S. (2008). *Cloud computing and grid computing 360-degree compared.* In Proceedings grid computing environments workshop: GCE 2008 (pp. 1-10).

[8].Subashini S, Kavitha V (2011)*A survey on security issues in service delivery models of cloud computing,* Journal of Network and Computer Applications: 1-11.

[9].Viega J (2009) *Cloud computing and the common man,* Com-puter 42(8):106-08.

[10].Cachin C, Keidar I, & Shraer A (2009) *Trusting the cloud,* ACM SIGACT News 40(2):81-86.

[11]. S. Lee, I. Ong, H.T. Lim, H.J. Lee, *Two factor authentication for cloud computing,* International Journal of KIMICS, vol 8, Pp. 427-

432.-33

[12].Wang C, et al. (2009) *Ensuring data storage security in cloud computing,* Proceedings of The 2009 17th International Workshop on Quality of Service (IEEE):1-9.

[13].Michael E.Whitman *In defense of the realm: understanding the threats to information security* International Journal of Information Management 24 (2004) 43-57.

[14].Dimitrios Zissis , Dimitrios Lekkas,*Addressing cloud com-puting security issues* Future Generation Computer Systems 28 (2012) 583-592.

[15].Seccombe A, Hutton A, Meisel A, Windel A, Mohammed A, Licciardi A, et al. (2009) *Security guidance for critical areas of focus in cloud computing,* Cloud Security Alliance 25:1-177.

[16].Ristenpart T, et al. (2009) Hey, *you, get off of my cloud: exploring information leakage in third-party compute clouds,* Proceedings of the 16th ACM conference on Computer and communications security (ACM):199-212.

[17].B. Lampson, Abadi, M., Burrows, M., Wobber, E.,*"Authen-ticationin Distributed Systems: Theory and Practice,"* ACM Transactions Computer Systems, vol. 10, pp. 265-310, 1992.

[18].L. Lamport,*"Password Authentication with Insecure Com-munication,"* Communications of the ACM , vol. 24, pp. 770-772, 1981.

[19].[19] C. Lin, Hwang, T.,*"A password authentication scheme with secure password updating,"* Computers & Security , vol. 22, pp. 68-72, 2003.

[20].M. Peyravian, Zunic, N.,*"Methods for Protecting Password Transmission,"* Computers & Security , vol. 19, pp. 466-469, 2000.

[21]. [M. Peyravian, Zunic, N.,*"Methods for Protecting Password Transmission,"* Computers & Security , vol. 19, pp. 466-469, 2000.

[22].Daniel Mouly (2002): Strong User Authentication, Informa-tion Systems Security, 11:2, 47-53.

[23].M.S.Hwang, and L.H. Li,*"A New Remote User Authen-tication Scheme using Smart Cards",* IEEE Transactions on Consumer Electronics 46 (1) (2000) 28-30.

[24].H.Y.Chien, J.K. Jan, Y.M. Tseng, *An efficient and prac-tical solution to remote authentication: Smart card,* Comput. Secur.21 (4) (2002) 372-375.

[25].I-En Liao, Cheng-Chi Lee, Min-Shiang Hwang, *A password authentication scheme over insecure networks,* J. Comput. System Sci. 72 (4) (2006) 727-740.

[26].E.J. Yoon, E.K. Ryu, K.Y.Yoo, *Efficient remote user au-thentication scheme based on generalized ElGamal signature scheme,* IEEE Trans. Consum. Electron. 50 (2) 2004.

[27].E.J. Yoon, K.Y. Yoo,*New authentication scheme based on a one-way hash function and DiffieHellman key exchange,* 4th International Conference of Cryptology and Network Security, CANS 2005, LNCS vol. 3810, Springer-Verlag, pp. 147-160.

[28].V.Shoup, A. Rubin, *Session key distribution using smart-cards,* in: Proc. EUROCRYPT 96, in: LNCS., vol 1070, Springer-Verlag, 1996, pp 321-333.

[29].I-En Liao, Cheng-Chi Lee, Min-Shiang Hwang, *A password authentication scheme over insecure networks,* J. Comput. System Sci. 72 (4) (2006) 727-740.

[30].G.Yang, D. S. Wong, H. Wang, X. Deng,*Two-factor mutual authentication based on smart cards and passwords,* Journal of Computer and System Sciences, vol 74, 2008, Pp. 1160-1172.