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Systematic Literature Review of Software as a Service [SaaS] in view of Security and Multitenancy

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Abstract: ***In early days of commercial software development, it was very expensive as multiple components were required such as - hardware, software, infrastructure to support mere an application development and implementation. Industry was using it with a note of burden to manage the support services. Visualizing these specific problems ICT took it as a challenge and introduces cost effective solution and bifurcated in Service components. Broadly a) Infrastructure as a Service b) Platform as a Service c) Software as a Service. Industry welcomed the approach and started handing over these services to market players and were able to focus on their key business areas. In recent development of cloud architecture these are becoming BUZZ word in industry and innovating traditional approaches.***

Keywords: IaaS, PaaS, SaaS, CaaS, Security, Multitenancy, Cloud Architecture

I. INTRODUCTION

New topology of Client-Server architecture become prominent to provide the services over network where server manages the resources and computation and client consumes the services. A file/database/application server is connected with multiple local clients who directly communicate with central server. Following is representative deployment architecture of 2-tier as known as Client-Server system:

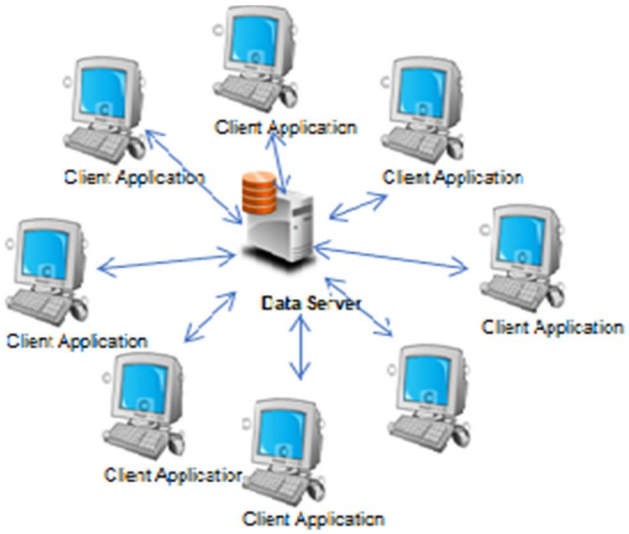

Fig 1: 2-tier architecture

The 2-tier architecture is utilized in market and provided potential benefit to market. Industry started to shift in paradigm of it. However, this architecture also contains some drawbacks, such as, heavy load and dependency on central server. On account of any change in application leads the tough replication methodology at each client. After span of time, Industry evolved the independent layer of abstraction in three tiers i.e. Data tier, Logic tier and Presentation tier. This concept was developed by John J. Donovan in Open Environment Corporation (OEC) in 1995. It gave the new direction to industry and started evolving this technique, which leads to paradigm shift from intranet: Local Area Network (LAN) to internet: Wide Area Network (WAN). This pattern proved its potency and is also being utilized till date following architecture depicts the classical three tier architecture

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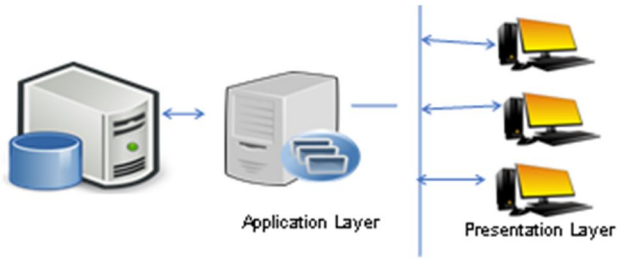

Fig 2: 3-tier architecture

After introduction of three tier architecture and successful deployment of applications leads the application developer to present their business idea in heterogeneous architecture and usage at multiple platforms by marshalling in Remote Method Invocation. In current scenario to increase the software flexibility and its reusability, developers have further layer the structure, which is also known as n-tier architecture. Though this architecture has increased the developer efforts as well as code complexity but maintenance has become quite easy. Multilayered architecture can be used by Desktop application, mobile application, embedded system and any other web application.

Under N-tier architecture each layer has a specific responsibility an upper layer is utilized as a service and consumed in lower level.

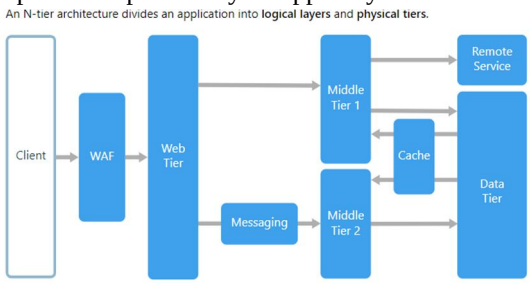

Fig 3: N-tier architecture

A. Cloud Service Models

To reduce the burden on service providers as well as customers approach of cloud service model comes into picture and its usage is growing very fast because of benefits associated with it. In general there are following 3 types of cloud service model.

1) *IaaS (Infrastructure as a Service):* As the name suggests, provides you the computing infrastructure, physical or (quite often) virtual machines and other resources like virtual-machine disk image library, block and file-based storage, firewalls, load balancers, IP addresses, virtual local area networks etc. Examples: Amazon EC2, Windows Azure, Rackspace, Google Compute Engine.
2) *PaaS (Platform as a Service):* It provides the computing platforms which typically includes operating system, programming language execution environment, database, web server etc. Examples: AWS Elastic Beanstalk, Windows Azure, Heroku, Force.com, Google App Engine, Apache Stratos.
3) *SaaS (Software as a Service):* Under this users are provided with access to application software often referred to as "on-demand software". Customer will not have to worry about the installation, setup and running of the application. Service provider will do that for you. Examples: Gmail.

Cloud computing has introduced a new concept of pay and use as per requirement. It is becoming common in industry and being offered by various service providers.

Out of all service models, SaaS model is widely and commonly used. Often, ‘SaaS’ is understood as a complete software package, which is available at web. However, ‘SaaS’ is a combination of many essential components to provide intended services.

While surveying the internet it is marked at Wikipedia - Software as a service (SaaS) is a software licensing and delivery model in which software is licensed on a subscription basis and is centrally hosted. It is sometimes referred to as "on-demand software". Further as per Stackoverflow and other internet community -SaaS eliminates the need to install and run applications on individual computers.

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Due to availability of low-cost affordable solution at web cloud various application are tailored as a ***Software as a Service 'SaaS'***. Again deployment of numerous smaller programmed slices and selection of correct slice is making the technical work wretched over Internet cloud.

Broadly a complete software package contains 1. Infrastructure as a Service(IaaS) 2. Platform as a Service(PaaS) 3. Software as a Service(SaaS) which is supported by Component as a Service(CaaS).

Any cloud architecture requires traditional front end via mean of s/w interaction interface such as web-application to display at client end and platform such as workstation, tablet, mobile screen. This frontend interface will be available on user-specific request i.e. client request which can accelerate the pre-programmed set of executable components which communicate to middleware where program repository resides and bust on request. This program is accomplished in utilization of various service platforms such as datacenter interface, firewall, Server and storage, Virtualization, Operating System, executable code, software component, application server, database server, file server etc. These platforms can communicate individually at different layer of software structure/architecture. On the basis of availability and requirement, tier architecture can be expanded or down-sized. Organization's pricing and business goal plays vital role to decide the architecture of deployment. These components in group can be represented as

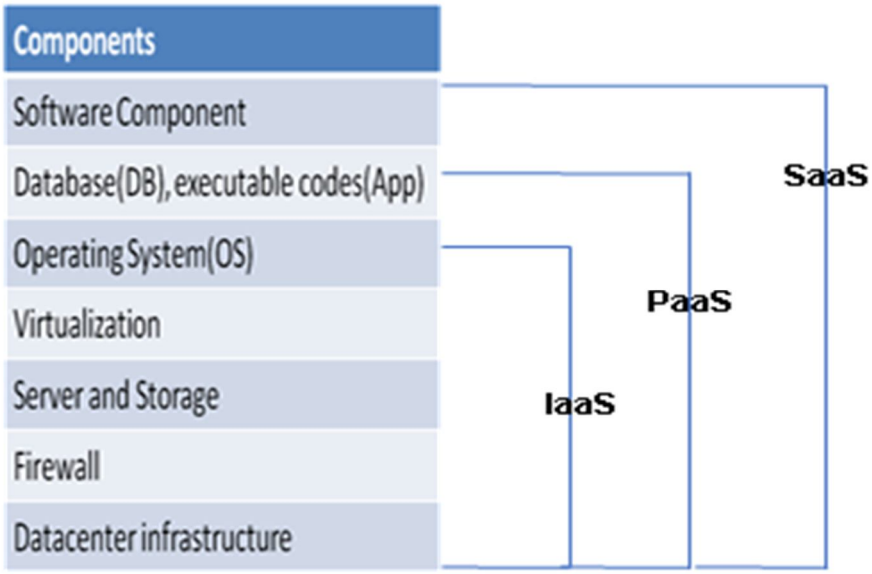

Fig 4: Service Model

In the Fig 4.0 it is clearly indicated that the area of "Software as a Service" (SaaS) includes the services offered by "Infrastructure as a Service" (IaaS) and Platform as a Service (PaaS) with Software Components i.e.

IaaS ∪ PaaS ∪ Software Component = SaaS

On it we can assume that effective SaaS application requires the efficient and mature PaaS and IaaS components.

By definition, Multitenancy refers to the mode of software operation where different customers/clients use the same application instance in a shared environment. This feature of cloud services has reduces the operating cost reasonably and helped in utilizing the resources upto optimum level. Initially it has raised the challenges of performance, security, service delivery and optimization but with each passing day technology is getting mature and cloud service providers has provided the option of dynamic resource allocation to handle the issues of Performance service delivery and optimization. Almost all cloud services providers have put latest security features and keep them updated. They implement robust cyber security measures to protect data and keep all security measures updated. Even now days, services of Artificial intelligence (AI) is also been used to check and track the vulnerabilities. Further, data is located in isolated warehouses which are ultra secure behind several firewalls and several back up of data is been taken as per policies at geographically different locations. In traditional approach, it is very hard and expensive to have such security features.

Following is the comparative assessment of saaS and traditional approach on the basis of resource sharing, price, standardization, component/resource sharing and security offered:

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S. No.	Head	SaaS	Traditional
1	Pricing	Due to multitenant usage, price of application is dynamically reduced as cost of service distributed among many partners.	Normally price is higher as cost is managed by each user with entire functions in mean of software component, Hardware, Network, Security etc.
2	Resource Sharing	Possible	Normally not allowed
3	Security	Managed by Cloud provider with continuous updates	Normally compromised with updates/upgrades.
4	Scalability	Resources can be increased on demand basis	Need to procure hardware and do permanent investment
5	Standardization	Multitenant usage forced to make application as product which can be reused with minimal customization and applicable release may be distributed as upgrade and updates. SaaS component also suggest the BPR at user end	Frequently changed and individual flavor restrict the application to become standard functions among multiple distributions.
6	Operational duty	All operational requirements managed by service provider	Need to manage installation, equipment updates, backup policy, traditional licensing management

Table 1: SaaS vs Traditional development approach

II. METHODOLOGY

For survey of literature "IEEExplore" is taken the primary source of literature availability. This paper represents the article/paper/ information available at information provider i.e. IEEExplore. However various information available at Internet and peer discussion is also mentioned in the paper.

Total 69062 article found at IEEEXplore which is distinguish in following count with search title ''Software as a Service' or 'SaaS':

Table 2: Literature for 'Software as a Service'

Publication Count as on 08-July-2021 at IEEEXplore for 'Software as a Service'		
S. No.	Published at	Count
1	Conferences	68,044
2	Journals	6,654
3	Magazines	3, 021
4	Early Accessible	460
5	Standards	279
6	Books	334
7	Courses	33

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Further drilling the word "SaaS Architecture" at IEEEXplore, received following statistics:

Publication Count as on 08-July-2021 at IEEEXplore for 'SaaS Architecture'		
S. No.	Published at	Count
1	Conferences	713
2	Journals	46
3	Magazines	23
4	Early Accessible	5
5	Courses	3

Table 3: Literature availability at IEEEXplore

Further we drill data in a ten-year gap

Key Word = 'SaaS Architecture' as on 08-July-2021		
S. No.	Publication period	Count
1	1988-1997	27
2	1998-2007	8
3	2008-2017	641
4	2017-till date	153

Table 4:Literature for 'SaaS' architecture at IEEEXplore

It is analyzed that the first article was published in IBM System Journal in year 1988 with title namely 'Application enabling in SAA'. It is also noted that all article published in year 1988 were from IBM Systems Journal.
In this paper we selected three other key words provided by author namely 'Security', 'Architecture', 'Multi-tenancy /Multitenancy /Multitenant' for detailed insight elaboration of SaaS architecture, which resulted

Keyword 'Security', 'Architecture', 'Multi-tenancy /Multitenancy /Multitenant' wise count as on 08-July-2021			
S. No.	Search Content	Publication period	Count
1	SaaS and Security	1989-1998	1
		1999-2008	13
		2009-2018	446
		2019-Aug 2021	81
2	SaaS and Architecture	1989-1998	17
		1999-2008	33
		2009-2018	656
		2019-Aug 2021	77
3	SaaS and Multi-tenancy	1989-1998	0
		1999-2008	5
		2009-2018	173

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		2019-Aug 2021	13
4	SaaS and Mutitenancy	1989-1998	0
		1999-2008	3
		2009-2018	69
		2019-Aug 2021	2
5	SaaS and Multitenant	1989-1998	0
		1999-2008	4
		2009-2018	150
		2019-Aug 2021	16

Table 5: Article with Author Key-Word -> 'SaaS' and 'Security'/ 'Architecture'/ 'Multi-tenancy'/ 'Mutitenancy'/ 'Multitenant'

III. LITERATURE REVIEW

Literature review contains following parameter on above selected keywords i.e. SaaS with Security, Architecture, Multi-Tenancy, Multitenancy and Multitenant, which has first full paper access in each ten-year bracket

1) Oldest Article
2) Latest Article
3) Most Cited Article
4) Patented Article

A. Architecture

Software as a service (SaaS) is a software distribution model in which a third-party provider hosts applications and makes them available to customers over the Internet. The cloud (or SaaS) model has no physical need for indirect distribution because it is not distributed physically and is available almost instantaneously, thereby negating the need for traditional partners and middlemen. However, as the market has grown, SaaS and managed service players have been forced to try to redefine their role. This eliminates the expense of hardware acquisition, provisioning and maintenance, as well as software licensing, installation and support. However, security and privacy issues have to be given more attention in most of these implementation environments. Basic tasks such as secure data communication, secure data storage, user management and easy-to-use interfaces are offered by the SaaS-Platform. SaaS removes the need for organizations to install and run applications on their own computers or in their own data centers. It has flexible payments rather than purchasing software to install, or additional hardware to support it. Customers subscribes to a SaaS offering. Generally, they pay for this service on a monthly basis using a pay-as-you-go model. Transitioning costs to a recurring operating expense allows many businesses to exercise better and have more predictable budgeting. Users can also terminate SaaS offerings at any time to stop those recurring costs. Cloud services like SaaS offer high scalability, which gives customers the option to access more, or fewer, services or features on-demand. Rather than purchasing new software, customers can rely on a SaaS provider to automatically perform updates and patch management. This further reduces the burden on in-house IT staff. Since SaaS applications are delivered over the Internet, users can access them from any Internet-enabled device and location.
The platform utilizes state-of-the art technologies in information and communication systems. It follows the principles of service-oriented architecture and delivers services as a SaaS. Optimizing service portfolios based on usage is not specific to Software as a Service (SaaS) products and applies to any product release offering a selection of sub-feature. Feature usage analysis becomes an important factor in SaaS products in healthcare due to the strong tie between usage and revenue. In the healthcare realm, software quality has an objective non-functional dimension (Focusing on performance, reliability, and security/privacy). Whereas subjective business functional requirements are driven by customer needs, service values, and benefits to the healthcare domain. The advancement in the healthcare solutions is strongly affected by the convergence between medicine and a series of technological progress in the information and communication technology, the increasing of requirements for the patient's quality of care and finally the raising cost pressure to both health system organizations and patients.

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Growing use of web-based user interfaces by applications continuously decreases the need for traditional client-server applications. This fact has motivated big players such as Oracle, IBM, SAP, Microsoft, Google, and Amazon to react to the revolution of the SaaS technology. They offer both SaaS services and Platform as a Service (PaaS). According to a survey by HIMSS Analytics, 83% of US IT healthcare organizations are now using cloud services with 9.3% planning to, whereas 67% of IT healthcare organizations are currently running SaaS-based applications [24].

Software Architecture comprises the two main context which is User Interface and other one is Data interface. Software Architecture defines the effective communication between User, Application and therein with database to provide the easiness of use and security of contents lead the multiple type of different architecture. SaaS architecture mainly talks about software accessibility through information flow among user, device, database and cloud i.e. virtual or public cloud. In other words, SaaS deals with licensing and delivery policy of software. Its architecture establish relationship among relevant connecting points to achieve the defined goal. The services are rendered by mean of web services such as REST, SOAP. If service is licensed, then it is provided as per usage policy opted by consumer. The most popular offering is a 'Vanilla Version' of software. Under 'Vanilla Version' the base software is least customizable [1]. In paper author Jen-Chun-Wang et. al. talks about the algorithm used recursive pyramid algorithm and AOCA architecture for ID signal and 2D image during discrete wavelet transformation and suggested segment accumulation algorithm (SAA) may provide the benefit on data structure of filter coefficient [2]. The Author Nicolus Gold, Andrew Mohan, Clarie Knight and Malcolm Munro and published in IEE SOFTWARE section [3] brought in knowledge the 'SaaS' architecture is having the revolutionary potential to change the software industry. Author quoted 'Service-oriented software lets organization create new software applications dynamically to meet rapidly changing business needs. As its construction become automated, however, Software understanding will become more difficult'. The transition of traditional software to a SaaS based software approach needs standardization, adequate legal document to enhance the user trusts, dynamic provisioning for binding and unbinding. Some problem scenario exists such as

1) Partial visibility of supply network to customer.
2) Lack of clarity of actual state of software while addressing the problem.
3) Uncertain software construction resulting the negotiation.
4) Knowledge boundary between discreet organizations.
5) Inappropriate tool.

The author Sirish Bhide et. al. focused of optimal path solution for travelling salesman problem using Boolean neural network which was published in IEEE Transactions of Computers [3]. author focuses various topologies to address fastest delivery time for optimization problem and decision problem and touched P-class, NP-class, NP-complete problem, NP-Hard problem and suggested that optimal value can be achieved if system uses the modified Boolean neural network. Author also clarify the google api as real time application and which can be used in delivery company, airlines in nutshell the problem can be addressed the most efficient route for data to travel between various nodes. Further a paper published 'The Myth of Open Web Services'- The rise of service parks was authored by Charles Petrie and Christoph Busseler [9]. The paper categorically defined the early trend of 'SaaS' based components and its distribution among end user. Further focus that end consumer commonly trusts the brand name just like toothpaste means Colgate and detergent means surf. Author also informed that SaaS industry is coming on consolidation and working as a group to be followed as a brand such as IBM, Amazon, SAP, Oracle. And this is bringing the revolution in industry also bringing some betterment and choices to industry consumers.

A Study and Performance Evaluation of the Multi-Tenant Data Tier Design Patterns for Service Oriented Computing'[7] was authored by Zhi Hu Wang et. al. in year 2008 and published in IEEE International Conference on e-Business Engineering conference. Author touched the Multitenancy under SaaS architecture and presented as key characteristics. Author provided a comprehensive illustration of 'SaaS' application's DB and application processes and presented the different security aspects. Author also described two different SaaS approach first one with different DB allocation to industry and another is comprehensive DB and Application-level distribution of access in multi-tenant scenario.

B. Security

Nowadays the word 'Security' became the vital terminology and plays a critical role to define any application's weightage and stability. It also boosts the customer confidence in organization offering solution and is having security certification. Standard certifications involve security of application software, database, hardware, communication network, file system and others. Under SaaS architecture access of application is being access through internet cloud so security plays important role.

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It is evident initially 'SaaS' application developer was focusing on application architecture instead of security. First review paper with author keyword 'Security' under 'SaaS Architecture' within IEEEXplore is found in year 2009 with title Cloud Security Issue authored by B. R. Kundukari which is also most cited and emphasized the Service Level Agreement [SLA] also mention the uptime and permissible downtime to manage the different defined parametric availability in means of information, public network, private network and infrastructure [6]. The latest available paper on security for SaaS architecture is listed with title 'Secure smart agriculture monitoring technique through isolation'. In it author George Suciuet. al. suggests the secured data communication in isolated communication between node to node. Author also proposed the future trend of multiple sensors gateway to manage the crop disease and also inform that denial of service along with access control and limit the data transmission may improvise the security [17]. Whereas the oldest available article 'Secure Enterprise Services Consumption for SaaS Technology Platform' authored by YuecelKarabulut and Ike Nassi of SAP research center in 2009 indicates the secure trust worthy SaaS based application may be obtained by using asymmetric and symmetric cryptography token[18]. YuecelKarabulut et. al. indicates in SaaS architecture there are major functionality lies between Service Consumer (SC) and Service Provider(SP) and secure communication can be achieved with complex asymmetric authentication services and rest communication with faster and easier symmetric topology. Author also mentioned various notation and protocol and used Interaction diagram to elaborate its step-by-step approach and emphasis the use of cryptography along with capability-based access control.

C. Multi-tenancy/Multitenant

The real mission of any industry viz; FMCG/Machinery/Hardware etc. is to provide the service with least functionality alteration. So after any product launch it must be packaged with standard configurations, which can be distributed between common interest groups. In Software industry we can define that multitenancy or multitenant is a structure design frame where the unique reproducible prototype of product which serves with single instance of server and being accessed by multiple client/industry users. So it can be depicted as 1-> n relation between access of 'SaaS' process and tenant/user.

Further at time of systematic review the oldest paper under multitenancy head was 'Defining Composite Configurable SaaS Application Packages Using SCA, Variability Descriptors and Multi-Tenancy Patterns' authored by Ralph Mietzner, Frank Leymann and Mike P. Papazoglou and published in 'The Third International Conference on Internet and Web Applications and Services'[15]. Ralph Mietzner et. al. elaborated various communication scenario among 'SaaS' adopters tenant, user, vendor or solution provider and its approach for distribution of requested outcome from program. Author discussed Service Component Architecture for tenants and its variety i.e. configurability at customer end and its packaging using Java Architecture. Author also indicates the approach for single instance-multitenant components, multi-instance/multitenant components.

In paper titled 'Studying the Applicability of the Intrusion Detection to Multi-tenant Container Environments' is authored by Jose Flora and Nuno Antunes and published in '15th European Dependable Computing Conference (EDCC)' [14]. The author Jose Flora et. al. mentioned the intrusion in multi-tenant environment. Mentioned mischievous intruder tries to invade the tenants to hack the valuable assignment. In article author tries to define how developer reach a secure layer to handle the situation using STIDE and BoSC algorithm in intrusion detection system by keeping inside the container for cloud use of application

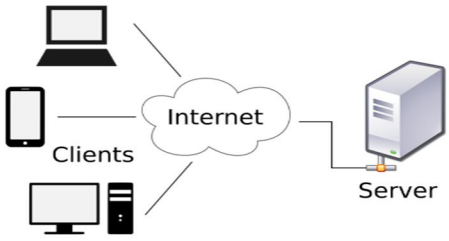

Fig 5: Cloud service architecture

This illustration represents that client is a registered user, who can access secure resources on basis of defined security parameter.

In review it is find that the multitenancy was used as Author Keyword in year 2008 only. The article "Define Composite Configurable SaaS application packages using SCA variability Descriptor and Multi-Tenancy Pattern" and authored by Ralph Mietzner et. al. Author informed that by using Multitenant approach the service provider manages the deployment part and service receptor manage the end point access only, which drastically reduced the cost of application deployment and also reduces the number of exact instance deployment.

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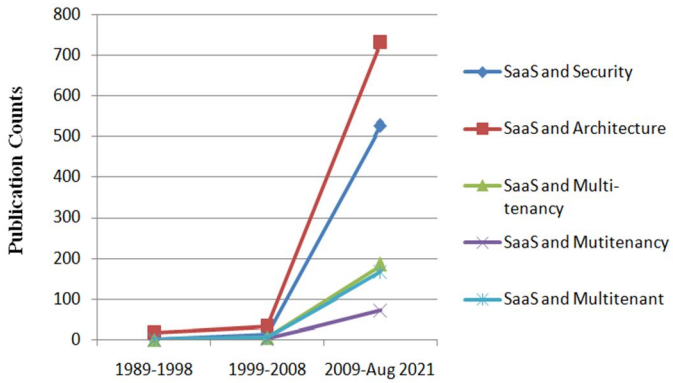
IV. SUMMARY

In early exploration of 'SaaS' community, there was no significant work on Security and Multi-tenancy. Security was having negligible presence from year 1988 to 2008 but later Security got the focus. In early days, users were not interested to invest on SaaS model. Due to low reliability and marginal difference in cost, they focus on in-house development and implementation instead of cloud. Security of legacy data may be a concern to organization which shows low presence in year 1988 to 1998 and minor presence between years 1998 to 2008. But significant development was seen in security after 2008 and also the keyword 'Multi-tenant' manages the focus and started its stamp in 'SaaS' architecture.



As per available data, finding indicates that Industry is establishing the Software Security with Deployment Architecture to ease the access of multiple tenants under SaaS. Also sharing the resources indicate that solution cost may drastically reduce with stable solution.

V. FINAL CONCLUSION AND FUTURE WORK

On basis of assessment of major benefits as per table 1 nowadays users are moderating towards 'SaaS' architecture in comparison with traditional model. This can justify that 'SaaS' based model is having edge over traditional model.

It is becoming evident that now the Organizations are trying to access the components available at Internet cloud irrespective of enterprise value or size (small/ medium/ large). Reliability of cloud services has increased exponentially and users are now acknowledging the benefits in terms of security and multitenancy. New startups as well as well-established firms want to explore new technology which is available in market. Along with-it enterprise also wants to register their presence among the unreachable arena across the world. It is becoming the duty of developer community to establish the robust and secure service-based approach for software component on which customers can show their trust.

Security and issues due to multitenancy had emerged as the major challenges in last decade but cloud services providers also matured their services to address these issues. Now reliability on these platforms has increased and organizations are moving their business on such platforms. But Security and optimum utilization is continuous growing arena and always requires emphasis on it. So, it is envisaged that in future more robust SaaS application will trend which suffice the requirement of user community with maximum fail over mechanisms.

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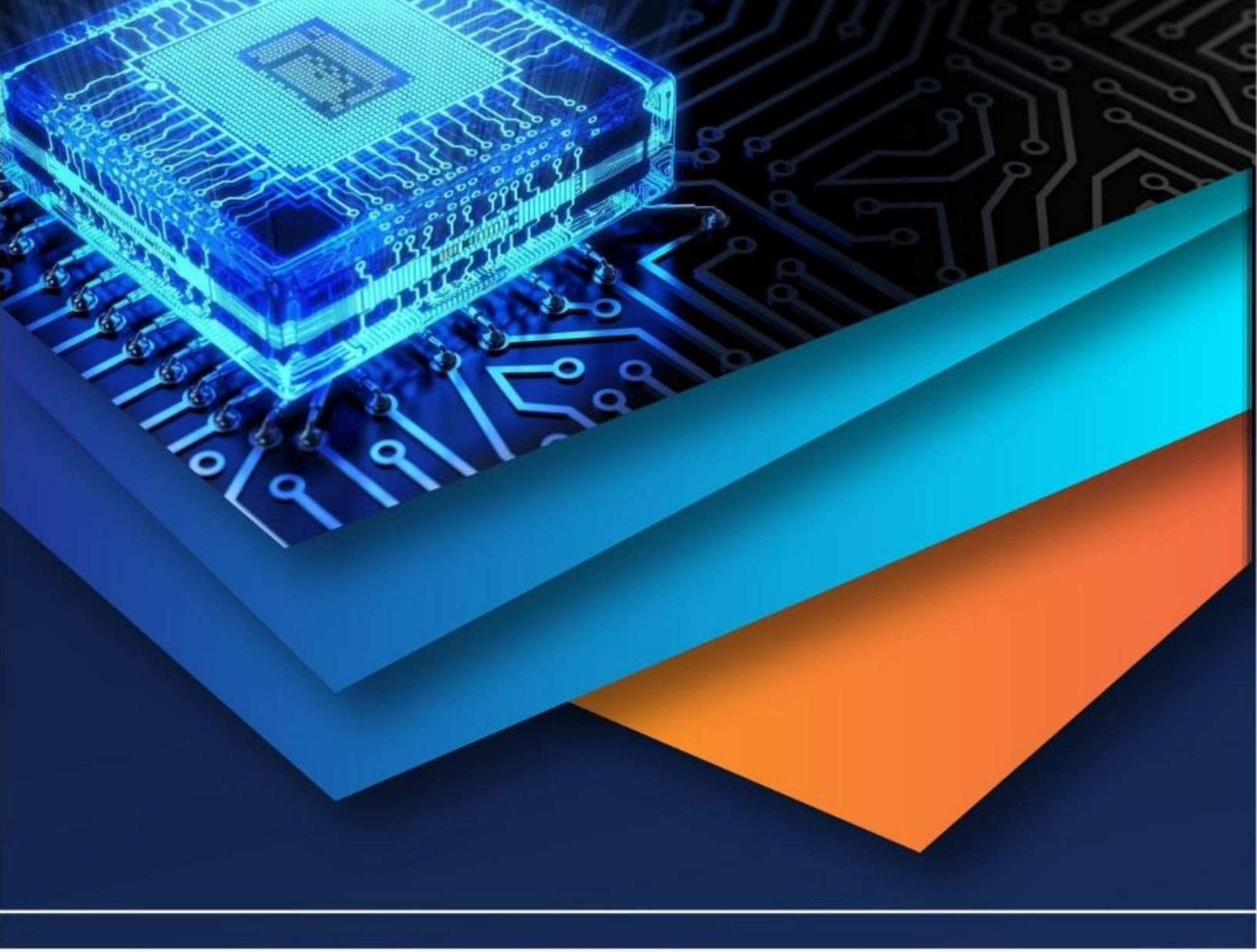

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