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Examining the Synergies and Differences Between Enterprise Architecture Frameworks: A Comparative Review

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Abstract: The Open Group Architecture Framework (TOGAF) ADM, Zachman Framework, Gartner's Enterprise Architecture Methodology (GEAM), Federal Enterprise Architecture Framework (FEAF), ISO Standard for Enterprise Modeling (ISO/IEC 19439), and the Department of Defense Architecture Framework are all examined in this comparative review paper (DoDAF). The scope, methodology, structure, and applicability of each framework are all taken into account as well as other factors. The evaluation identifies the benefits and drawbacks of each framework and offers suggestions for how to choose the best one for a variety of situations. The study comes to the conclusion that while there is no one framework that can be used for all situations, the framework that is chosen should be based on the particular requirements and objectives of the organization as well as the environment in which it operates.

Keywords: enterprise, modeling, domain, framework, guidelines, standards, architecture, methodology, structure, methods, continuum, matrix, language, systems, scope, focus, components, purpose, strategies

1. INTRODUCTION

Organizations can better align their business strategies, operational procedures, and technological infrastructure by using enterprise architecture (EA), a discipline. It offers a foundation for outlining the organization's functions, operations, and structure, allowing stakeholders to make well-informed decisions about investments and changes to the business (Zachman, 1999). Different EA frameworks have developed over time, each with unique strengths and drawbacks.

The Zachman Framework, Gartner's Enterprise Architecture Method (GEAM), Federal Enterprise Architecture Framework (FEAF), ISO Standard for Enterprise Modeling (ISO19439), and Department of Defense Architecture Framework are six of the most well-known EA frameworks that will be examined and evaluated in this comparative review paper (DoDAF). We will examine the main characteristics, advantages, and restrictions of each framework and conduct a comparative analysis of their advantages and disadvantages.

Popular and widely used, TOGAF's ADM offers a thorough method for developing enterprise applications (The Open Group, 2018). On the other side, the Zachman Framework is a descriptive framework that offers a matrix for organizing and classifying the different components of an enterprise architecture (Zachman, 1999). The goal of Gartner's GEAM is to create an enterprise architecture (EA) that supports organizational goals and objectives and is consistent with its strategic vision (Gartner, 2023). The FEAF framework, which is tailored for use by the government, places a strong emphasis on shared services, interoperability, and security for developing enterprise applications (U.S. Chief Information Officers Council, 2013). Enterprise modeling is standardized by ISO19439, with an emphasis on modeling methods, modeling languages, and modeling software (ISO, 2006). Last but not least, DoDAF is a framework created expressly for the U.S. Department of Defense, and it is centered on the creation and use of complex systems and capabilities (Department of Defense, 2010).

We hope that this comparative review paper will assist enterprises in choosing the best framework for their EA development requirements by giving a thorough analysis of the essential characteristics, advantages, and disadvantages of each framework.

2. METHODOLOGY

The research methodology for this comparative review paper was based on a systematic literature review. The paper was designed to analyze and compare the selected EA frameworks with regards to their scope, components, process, and applicability in the business world. The literature review was conducted using online databases such as Google Scholar, IEEE Xplore, ACM Digital Library, and ScienceDirect.

The search strategy included keywords such as TOGAF, Zachman, Gartner's Enterprise Architecture Method, FEAF, ISO 19439, DoDAF, Enterprise Architecture Frameworks and Comparative Review.

The retrieved articles were examined, evaluated, and used to compile this study.

3. LITERATURE REVIEW

3.1 The Open Group Architecture Framework (TOGAF)

TOGAF is a widely used enterprise architecture framework that provides a complete method to designing, planning, executing, and maintaining an organization's IT infrastructure. It is a set of best practices and standards that assist organizations in developing enterprise architecture that is aligned with their business goals.

Structure of TOGAF Framework

The TOGAF architecture consists of four main components, as illustrated in Figure 1:

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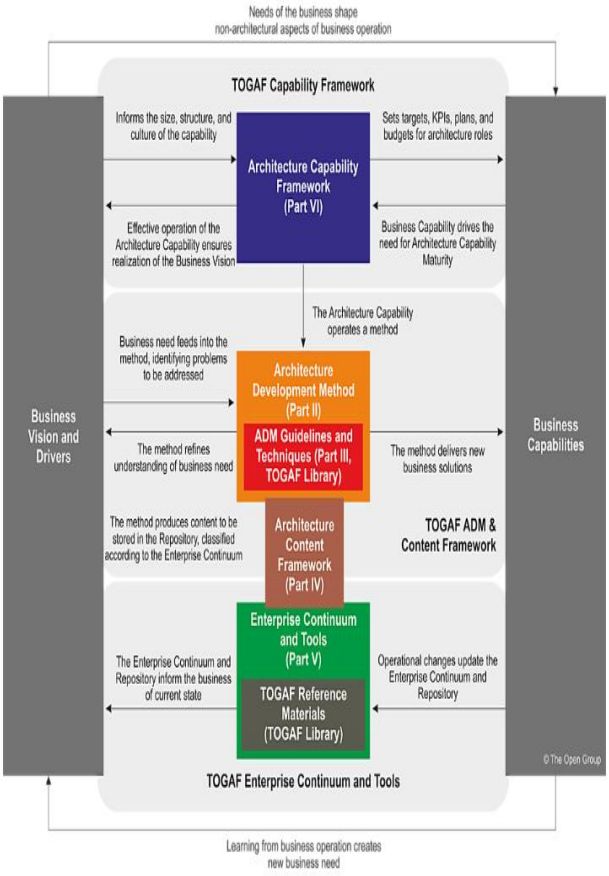

Figure 1: TOGAF Architecture Components (Source: The Open Group, 2018)

Architecture Development Method (ADM)

The TOGAF framework is built around ADM. It is a step-by-step procedure for creating corporate architecture. The ADM consists of nine iterative phases that can be adjusted to match the demands of various businesses. The phases are as follows:

1. Preliminary Phase: This phase involves defining the scope and objectives of the enterprise architecture project.
2. Architecture Vision: Creating a high-level vision of the enterprise architecture.
3. Business Architecture: Entails defining the enterprise's business processes, functions, and organizational structure.
4. Information Systems Architecture: The information systems that support the business processes are defined.
5. Technology Architecture: Technology infrastructure that supports the information systems is defined.
6. Opportunities and Solutions: Identifying opportunities for improvement and generating solutions to meet them is part of this phase.
7. Migration Planning: Planning for the transfer from the existing state architecture to the future state architecture.
8. Implementation Governance: This phase is responsible for overseeing the enterprise architecture's implementation.
9. Architecture Change Management: Managing changes to the enterprise architecture over time is part of this phase.

Architecture Content Framework

The architecture content framework standardizes how corporate architectural information is organized. It is made up of four major components: the architecture content meta-model, the content meta-model extensions, the content framework artifacts, and the content framework deliverables.

Architecture Capability Framework

The architecture capability framework provides assistance for building and operating an enterprise architecture capacity. It is made up of four major components: the architecture capability maturity model, the architecture skills framework, the architecture content framework, and the architecture governance framework.

The Enterprise Continuum

The Enterprise Continuum is a paradigm for organizing and categorizing architectural artifacts. It is divided into four levels: The Architecture Continuum, the Solutions Continuum, the Industry Continuum, and the Organizational-Specific Continuum. For architecture objects, each level delivers a different amount of depth and specificity.

Benefits of TOGAF

1. Consistency and Standardization: TOGAF provides a uniform and standardized approach to enterprise architecture that aids in ensuring alignment with the aims and objectives of the organization (The Open Group, 2018). This may result in increased efficiency, effectiveness, and agility (Gorkhali & Xu, 2017).
2. Flexibility and Adaptability: TOGAF is adaptable to various organizations, industries, and circumstances (The Open Group, 2018). This can assist firms in responding to changing business requirements, market conditions, and technological improvements (Gorkhali & Xu, 2017).
3. Cost Reduction: TOGAF can assist in cost reduction by removing redundancy, enhancing interoperability, and maximizing resource utilization (The Open Group, 2018). This can result in increased cost-effectiveness and ROI (Gorkhali & Xu, 2017).
4. Improved Communication and Collaboration: TOGAF provides a common vocabulary, framework, and methodology for enterprise architecture that helps stakeholders communicate and collaborate (The Open Group, 2018). This can result in better understanding, alignment, and buy-in (Gorkhali & Xu, 2017).
5. Risk Management: TOGAF provides a systematic way to detecting, assessing, and reducing business design risks (The Open Group, 2018). This can assist firms in avoiding or minimizing potential unfavorable business consequences (Gorkhali & Xu, 2017).

Challenges of TOGAF

1. Complexity and Overhead: TOGAF is a broad framework that includes many subjects and domains, making it challenging to learn and execute (Jeston & Nelis, 2014).
2. Lack of Flexibility: TOGAF offers a standardized approach to enterprise architecture, which can be advantageous for enterprises seeking a consistent and repeatable methodology. However, this can limit the framework's capacity to be customized to meet specific organizational demands (Gartner, 2021).
3. Difficulty in Measuring Effectiveness: While TOGAF provides a structured approach to business architecture, quantifying the impact of adopting the framework can be difficult (Gerber et al., 2020).

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TOGAF is an enterprise architecture framework that provides a uniform method to defining, planning, executing, and managing an organization's IT infrastructure. It is made up of four major parts: ADM, architecture content framework, architecture capability framework, and architecture reference models. TOGAF offers various advantages to organizations, including a consistent strategy, increased communication, better decision-making, and cost savings.

3.2 Zachman Framework

The Zachman Framework is an enterprise architectural framework that is well-known and widely used. It was created in the 1980s by John Zachman and has since been utilized by enterprises all over the world to assist them manage their information technology (IT) infrastructure. The framework offers an organized and complete approach to structuring and managing an organization's information systems. The framework is organized as a matrix, with six columns reflecting various viewpoints on the organization and its information systems and six rows representing various degrees of abstraction.

Structure of the Zachman Framework

The Zachman Framework is built on a six-by-six matrix that reflects the many components of an organization's information technology infrastructure. The Zachman Framework matrix structure is depicted in Figure 2 below, with six columns and six rows.

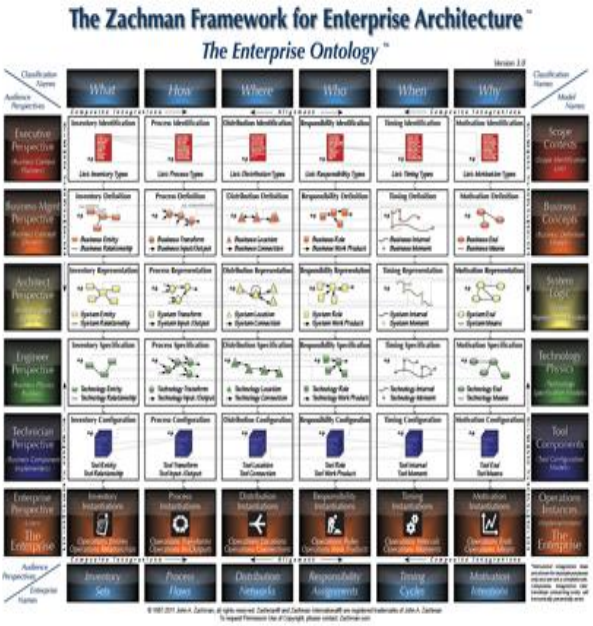

Figure 2: Zachman Framework Matrix Structure (Source: Zachman International Enterprise Architecture, 2011)

The matrix's columns reflect various perspectives on the IT infrastructure, while the rows represent various levels of abstraction. The six perspectives are as follows:

1. Who: This viewpoint focuses on the people who interact with the IT infrastructure, such as employees, customers, and partners.
2. What: This viewpoint focuses on the data used by the IT infrastructure, such as databases, files, and documents.
3. Where: This viewpoint focuses on the physical locations and network links where IT infrastructure is employed.
4. When: This viewpoint is concerned with the timing of activities within the IT infrastructure, such as schedules, deadlines, and time zones.
5. Why: This viewpoint focuses on the reasons why IT infrastructure is used, such as corporate objectives, customer needs, and regulatory obligations.
6. How: This viewpoint focuses on the technologies needed to construct IT infrastructure, such as hardware, software, and networks.

The six levels of abstraction are:

1. Scope: This level focuses on the overall reach of the IT infrastructure, including the mission, objectives, and goals of the company.
2. Enterprise: This level is concerned with the organization as a whole, which includes its operational procedures, information flow, and organizational design.
3. System: Focuses on the individual systems that comprise the IT infrastructure, such as hardware, software, and networks. Systems, such as networks, hardware, and software, are the main topics of this level, which focuses on the various systems that make up the IT infrastructure.
4. Function: This level focuses on the particular tasks that the IT infrastructure completes, such as data processing, communication, and storage.
5. Model: This level focuses on the models, such as data models, process models, and network models, that are used to represent the IT infrastructure.
6. Instance: This level focuses on the particular hardware setups, software setups, and network connections that make up an IT infrastructure instance.

Benefits of the Zachman Framework

1. Clarity and Structure: The Zachman Framework offers an organized and unambiguous approach to enterprise architecture, assisting in making sure that all pertinent parts of the business are taken into account (Sowa and Zachman, 1992). This may result in stakeholders' comprehension and alignment being improved (Gorkhali & Xu, 2017).
2. Consistency and Standardization: The Zachman Framework offers an enterprise architectural technique and approach that is consistent and standardized, assisting in ensuring that all stakeholders speak the same language (Sowa and Zachman, 1992). This may result in increased effectiveness, efficiency, and agility (Gorkhali & Xu, 2017).
3. Flexibility and Adaptability: The Zachman Framework is adaptable to many businesses, markets, and situations (Sowa and Zachman, 1992). This enables businesses to adapt to shifting customer demands, market dynamics, and technological improvements (Gorkhali & Xu, 2017).
4. Improved Communication and Collaboration: The Zachman Framework offers an enterprise architectural common language, framework, and methodology that makes it easier for stakeholders to communicate and operate together (Sowa and Zachman, 1992). This could result in better comprehension, agreement, and buy-in (Gorkhali & Xu, 2017).

5. Risk Management: Risks associated with enterprise architecture can be identified, examined, and mitigated using the Zachman Framework (Sowa and Zachman, 1992). This can assist businesses in avoiding or minimizing potential negative effects on their operations (Gorkhali & Xu, 2017)

Challenges of the Zachman Framework

1. Complexity: The ZACHMAN framework's intricacy is one of the greatest problems it presents. Implementing the framework can be challenging since it necessitates a thorough grasp of an organization's operational procedures, information systems, and technical foundation. The ZACHMAN architecture, according to Espadas et al. (2013), may be intimidating for some firms, especially those with sophisticated business processes and information systems.

2. Lack of flexibility: The rigidity of the ZACHMAN framework presents another difficulty. The framework may not easily adapt to changes in technology or operational procedures because it is intended to be a static representation of an organization's information infrastructure. The ZACHMAN framework is frequently criticized for being overly rigid and unable to take into account the changing character of contemporary organizations, as stated by Zhou et al. (2018).

3. Lack of standardization: Because the ZACHMAN architecture is not standardized, it might be challenging to compare and benchmark various enterprises. According to Mccarthy (2006), the ZACHMAN framework's lack of standardization can cause complication and discrepancies, making it challenging to compare various organizations or systems.

4. Lack of guidance: Although the ZACHMAN framework offers a framework for arranging an organization's information infrastructure, it does not include instructions on how to put that infrastructure into place or administer it. The ZACHMAN architecture does not give enterprises a clear road map to follow in order to construct and maintain their information infrastructure, as mentioned by Armour et al. (2017).

Managing an organization's IT infrastructure can be done effectively with the Zachman Framework. It offers an organized method for deciphering and controlling the various elements of an organization's IT architecture, and businesses all around the world have used it to great effect. Utilizing the framework enables firms to boost flexibility, increase efficiency, and better match their IT infrastructure with their corporate objectives. The Zachman Framework, which manages IT infrastructure using a six-by-six matrix layout, offers a thorough and adaptable method that can be tailored to suit the requirements of every enterprise.

3.3 Gartner's Enterprise Architecture Methodology (GEAM)

The Enterprise Architecture Methodology (GEAM) from Gartner is a thorough framework that aids businesses in creating and implementing efficient enterprise architecture (EA). The many elements of an organization's architecture can be designed, planned, and managed using this methodology.

Structure of GEAM Framework

The Plan, Discover, Analyze, and Design phases make up the GEAM framework. These iterative, ongoing phases are intended to assist organizations in developing and maintaining a successful enterprise architecture.

Plan

The scope and goals of the enterprise architecture endeavor are defined in the first phase of GEAM. This entails defining the scope and timetable of the enterprise architecture endeavor, as well as outlining business goals and strategies and evaluating present IT capabilities.

Discover

Gathering data regarding the organization's IT capabilities as they stand right now, as well as spotting any gaps and potential areas for improvement, constitute the second part of GEAM. Analysis of business procedures, information, software, and infrastructure are all part of this, along with a determination of the main stakeholders and their requirements.

Analyze

In order to comprehend the organization's existing and desired state, the third phase of GEAM entails examining the data obtained in the prior phase. This entails creating roadmaps and implementation plans, as well as identifying potential solutions to fill in recognized gaps and opportunities.

Design

The last stage of GEAM is planning the organization's IT capabilities in the future. Creating a thorough architecture plan that incorporates technical requirements, architectural principles, and governance structures is part of this.

Benefits of GEAM Framework

1. Improved Business by IT Alignment: In order to ensure that technology investments are motivated by business needs rather than technical requirements, organizations can align their IT strategy with their business objectives with the use of Gartner's EA approach (Buckl et al., 2008). Businesses can improve processes, cut costs, and produce better results by integrating IT capabilities with business objectives (Ross et al., 2006).

2. Enhanced Agility and Flexibility: By offering a framework for customizing their IT systems and procedures, Gartner's EA approach enables enterprises to react swiftly and effectively to shifting business conditions (Gartner, 2015). With the aid of this strategy, organizations may continue to be adaptable and nimble, allowing them to take advantage of new possibilities and tackle problems as they appear.

3. Improved Decision-Making: In order to examine and evaluate their existing state, identify gaps and opportunities, and create a roadmap for achieving their ideal state, businesses can use Gartner's EA methodology, which offers a structured approach to decision-making (Buckl et al., 2008). This method lessens the possibility of expensive errors and assists firms in making judgments regarding their IT investments.

4. Reduced Costs: By removing duplications, increasing efficiency, and simplifying processes, Gartner's EA methodology aids businesses in making the most of their IT expenditures (Ross et al., 2006). Organizations can benefit from this strategy by lowering costs, allocating resources more effectively, and boosting productivity.

5. Improved Communication and Collaboration: The EA technique from Gartner provides a structure and

common language for discussing IT-related issues across the company, promoting cooperation and knowledge exchange (Gartner, 2015). This strategy can help stakeholders collaborate and communicate more effectively, which will lead to better decisions and more successful execution.

Challenges of GEAM Framework

1. Complexity: To properly execute the Gartner EA methodology, you must have a high level of expertise. Organizations with few resources or experts may find this complexity to be a hurdle (Henderson & Venkatraman, 1993).
2. Resistance to change: The processes and organizational structures of a business must frequently undergo considerable modifications in order to implement the Gartner EA approach. This may cause stakeholders who are satisfied with the status quo to object (Areed et al., 2021).
3. Lack of standardization: Because the Gartner EA technique is not a standardized framework, there may be variations in how it is applied by different organizations (Dang & Pekkola, 2016).
4. Difficulty in measuring ROI: Measuring the return on investment (ROI) of putting the Gartner EA methodology into practice can be difficult. This is due to the fact that the advantages of EA are frequently illegible and challenging to measure (Petter et al., 2008).
5. Limited scope: The alignment of IT infrastructure with business strategy is the primary focus of the Gartner EA methodology. This restricted emphasis may make it more difficult to solve more significant organizational problems (Sowa & Zachman, 1992).

The EA approach from Gartner is a thorough framework that aids in the planning, management, and optimization of an organization's IT infrastructure, applications, and business processes. Its use has been demonstrated to enhance organizational performance and accomplish corporate objectives. Organizations must, however, make sure they have the right culture, leadership, and governance in place in order to successfully implement and maintain the EA.

3.4 Federal Enterprise Architecture Framework (FEAF)

The US Federal Government frequently use the enterprise architecture technique known as the Federal Enterprise Architecture Framework (FEAF). It offers a standard vocabulary and method for organizing, creating, and putting into practice IT systems and services. The Zachman Framework and the Model-Driven Architecture (MDA) strategy of the Object Management Group (OMG) are the foundations of this methodology.

Structure of FEAF Framework

1. Performance Reference Model (PRM)
2. Business Reference Model (BRM)
3. Data Reference Model (DRM)
4. Application Reference Model (ARM)
5. Technology Reference Model (TRM)

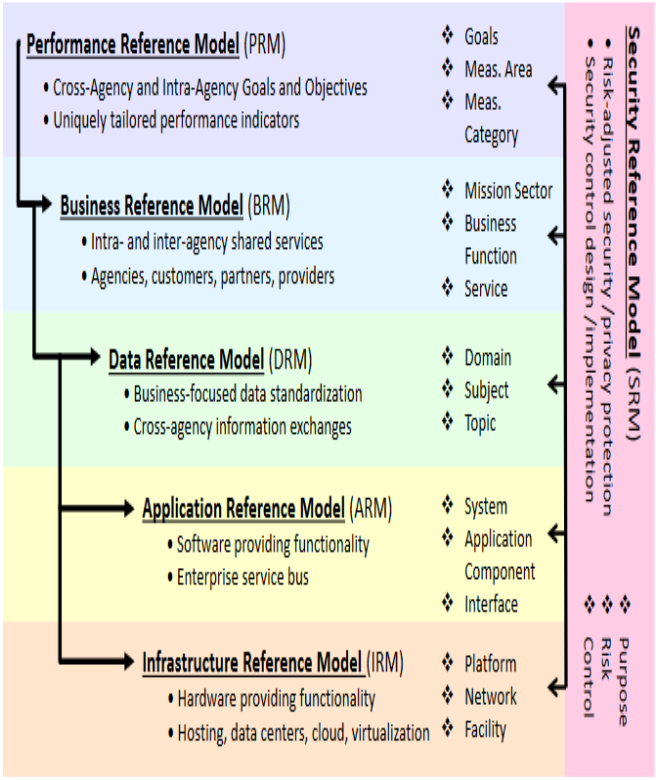

Figure 3: FEAF Layers (Source: FEAF, 2020)

The Performance Reference Model (PRM) outlines the company's aims and objectives, as well as the performance metrics used to monitor progress towards those goals. The framework's highest level layer, the PRM, gives the lower layers' context.

The Business Reference Model (BRM) specifies the company's operational procedures and business processes. It establishes a standard vocabulary for discussing company operations and specifies the key business processes and the data pieces that go along with them.

The Data Reference Model (DRM) provides an enterprise-wide vocabulary for describing data and information. It outlines the data items, their characteristics, and their connections.

The Application Reference Model (ARM) covers the systems and applications used to support the business operations of the firm. It gives everyone a shared understanding of the many kinds of applications and how to utilize them.

The Technology Reference Model (TRM) describes the applications and systems support hardware, software, and communication technologies utilized by the organization. It gives people a common language to talk about technology and makes it easier to spot areas where standardization and consolidation of technology are possible.

The FEAF is made to be versatile and scalable to accommodate the requirements of various enterprises. It can be used to support many different tasks, such as enterprise architecture creation, portfolio management, and strategic planning.

Benefits of FEAF Framework

1. Improved decision-making: By offering a thorough perspective of the enterprise architecture, FEAF aids enterprises in making better decisions. Making more educated and sensible decisions can result from this.
2. Increased efficiency: Redundancies and inefficiencies in an organization's architecture can be found and removed with the aid of FEAF. Consequently, expenses may be reduced, and productivity may rise.

3. Better communication: For discussing and analyzing the enterprise architecture, FEAF offers a standard vocabulary and structure. This can facilitate better stakeholder collaboration and communication.
4. Improved alignment: FEAF can assist firms in coordinating their IT plans with their operational targets. As a result, IT investments may be more effective and efficient.
5. Enhanced agility: FEAF can assist businesses in fast adjusting to shifting market conditions and technological changes. This can increase their capacity for innovation and market competition.

Challenges of FEAF Framework

1. The complexity of the framework: The FEAF is a multi-layered structure with numerous diverse components that might be challenging to comprehend and use in real-world situations. According to Bui (2014), it might be difficult for businesses to successfully deploy and use the FEAF due to its complexity.
2. The need for ongoing maintenance of the enterprise architecture: To make sure that the FEAF remains in line with the organization's shifting demands, it needs to be updated and maintained on a regular basis. For large firms with sophisticated enterprise structures, this can be time- and resource-intensive (Chuen, 2020).
3. The enterprise architecture alignment with the broader goals and objectives of the organization:Bui (2017) asserts that the FEAF's capacity to support strategic decision-making can be constrained, which can make it difficult to make sure that the enterprise architecture is in line with the organization's overarching objectives.

The FEAF is made to be versatile and scalable to accommodate the requirements of various enterprises. It can be used to support many different tasks, such as enterprise architecture creation, portfolio management, and strategic planning.

3.5 ISO Standard for Enterprise Modelling (ISO 19439)

ISO/IEC 19439 is an international standard that gives guidelines for enterprise modeling, a method for building models of organizations to enhance their administration, understanding, and optimization. Enterprise Architecture (EA), a strategic management discipline that aids firms in aligning their business and technology plans, is one of the primary topics covered by the standard. The framework for EA provided by ISO 19439 comprises a process for developing, putting into practice, and maintaining EA.

Structure of ISO/IEC 19439 Framework

The ISO 19439:2016 standard for enterprise modeling outlines a framework for simulating businesses and how they interact with the outside world. The standard is founded on systems thinking ideas, which emphasize the significance of comprehending the connections among various system components. The framework is made up of four primary parts:

1. Enterprise Context: This element outlines the business' operating environment, including its stakeholders, rivals, and legal and regulatory framework.
2. Enterprise Architecture: The enterprise's structure, behavior, procedures, and information systems are all described in this component.
3. Enterprise Operations: The processes, roles, and information systems of the enterprise are all described in this component, along with its structure and behavior.
4. Enterprise Evolution: The enterprise's long-term strategic goals, including its vision, mission, and objectives, are addressed in this component.

The ISO standard also contains a list of recommendations for modeling businesses that address issues including nomenclature, notation, and quality standards. The standards' goal is to encourage consistency and interoperability among various enterprise models so that businesses can share information and work together more successfully.

Benefits of ISO/IEC 19439 Framework

1. Improved communication: A consistent vocabulary for enterprise modeling is provided by ISO standards, which helps facilitate stakeholder communication (Tambo & Clausen, 2018).
2. Increased efficiency: Organizations can lessen redundancy and boost efficiency by employing standardized models and procedures (Peffers et al, 2007).
3. Enhanced quality: The framework provided by ISO standards for ensuring that enterprise models are precise and comprehensive can raise the level of an organization's activities as a whole (Timm et al, 2017).
4. Better decision-making: Enterprise models give organizations a clear picture of business relationships, resources, and procedures, which can help them make better decisions (Gordijn & Akkermans, 2001).
5. Improved agility: Enterprise modeling can assist businesses in quickly adapting to new possibilities and changing market conditions (Mens et al, 2007).
6. Facilitated integration: Integration between various systems and applications within an organization can be facilitated through enterprise modeling, which can increase overall productivity and effectiveness (Panetto & Cecil, 2013).

Challenges of ISO/IEC 19439 Framework

1. Complexity: The standard has a lot of relationships, rules, and concepts that can be challenging to comprehend and use. Vernadat (2020) asserts that implementation of the standard may be hampered by its complexity, particularly for small and medium-sized businesses.
2. Lack of interoperability: The lack of interoperability across various modeling tools and platforms presents another difficulty for the ISO standard for enterprise modeling. The standard may be interpreted differently by each tool, resulting in inconsistent results and mistakes during the modeling process. Sfakianaki (2018) asserts that the absence of interoperability may make it impossible to exchange models between tools, making it difficult to interact with and integrate various models.
3. Resistance to change: Stakeholders who are used to current modeling techniques or who do not understand the benefit of adopting a new standard may oppose the ISO standard for enterprise modeling. According to Darvish et al. (2015), resistance to change can be a big problem, especially if stakeholders aren't made aware of the standard's advantages.

4. Cost and resource constraints: For enterprises with constrained resources or people, implementing the ISO standard for enterprise modeling may necessitate major investments in software, training, and other resources. Implementing the standard can be expensive and resource-intensive, especially for small and medium-sized businesses, according to Perumalla et al. (2019).

The ISO/IEC 19439 Enterprise Architecture Methodology offers a structured method for creating and implementing EA across an enterprise that is consistent, thorough, and standardized. It makes it possible for businesses to match their information systems, technical infrastructure, and business procedures with their strategic goals and objectives. It also serves as a foundation for innovation and constant improvement.

For enterprise modeling and enterprise architecture, ISO/IEC 19439 is a crucial standard. The foundation it offers makes it possible to develop enterprise models that are uniform, thorough, and standardized throughout a company. Organizations can align their business procedures, information systems, and technological foundation with their strategic goals and objectives by using the Enterprise Architecture Methodology, which is based on ISO 19439. This methodology offers a structured approach to developing and implementing EA. Improved productivity, efficiency, and creativity are advantages for organizations that embrace ISO 19439.

3.6 Department of Defense Architecture Framework (DoDAF)

The United States Department of Defense (DoD) uses the Department of Defense Architectural Framework (DoDAF), an enterprise architecture technique, to help ensure that the complicated systems and procedures it employs are well-designed, integrated, and efficient. A variety of DoD stakeholders use the DoDAF as a standardized method for creating and presenting enterprise architectures in order to comprehend, organize, and control systems and procedures.

Structure of DoDAF Framework

DoDAF is a group of models, perspectives, and goods that serve to explain the enterprise architecture of the DoD. It is a framework that gives enterprise architecture development and management an organized methodology. The DoDAF approach is made up of four main parts:

1. The Operational Viewpoint: This perspective outlines the operational procedures, ventures, and jobs of the DoD. It gives a broad overview of the DoD's mission, objectives, and goals.

2. The Systems Viewpoint: This perspective explains the systems and interactions within the DoD. It offers a thorough overview of the DoD's systems, including their networks, software, and hardware.

3. The Technical Viewpoint: The technological features of the systems used by the DoD are described from this perspective. It gives a thorough overview of the technological requirements, benchmarks, and interfaces that the systems utilized by the DoD rely on.

4. The Enterprise Viewpoint: This perspective explains the DoD's overall structure and organizational setup. It gives a broad overview of the DoD's organizational structure, operational procedures, and information flow.

DoDAF Diagrams

To depict the DoD's enterprise architecture, the DoDAF approach employs a variety of diagram styles. These diagrams consist of:

1. Operational Viewpoint Diagrams: The operational procedures, tasks, and operations of the DoD are illustrated in these diagrams. They offer a broad overview of the mission, aims, and goals of the DoD. Activity and sequence diagrams are two types of operational viewpoint diagrams.

2. Systems Viewpoint Diagrams: The systems and relationships inside the DoD are depicted in these diagrams. They offer a thorough overview of the DoD's systems, including its networks, hardware, and software. System context diagrams and system sequence diagrams are two examples of systems viewpoint diagrams.

3. Technical Viewpoint Diagrams: The systems used by the DoD are described technically in these diagrams. They give a thorough overview of the technical requirements, norms, and interfaces that the DoD's systems use. Network diagrams and data flow diagrams are two examples of technical viewpoint diagrams.

4. Enterprise Viewpoint Diagrams: The overall structure and organization of the DoD are shown in these diagrams. They offer a broad overview of the DoD's administrative structure, operational procedures, and information flow. Organizational charts and business process diagrams are two examples of enterprise viewpoint diagrams.

Benefits of DoDAF Framework

1. Improved Interoperability: The DoDAF framework encourages uniformity and standardization throughout the DoD's architectural efforts, which enhances the interoperability of systems and components (Miranda et al., 2017). Mission accomplishment and information sharing become more efficient and successful as a result.

2. Enhanced Communication: A consistent vocabulary and knowledge of architecture principles are provided by the DoDAF framework, which enhances stakeholder collaboration and communication (Dam, 2015). This makes it possible to make decisions more wisely and raises the possibility of getting the results you want.

3. Streamlined Decision-Making Processes: The DoDAF framework offers a formal method for creating and assessing architecture options, which promotes the ability to make well-informed decisions (Amissah and Hendley, 2016). This lowers the possibility of making expensive errors and guarantees efficient resource allocation.

Challenges of DoDAF Framework

1. Complexity: Architects, stakeholders, and users must comprehend and put into practice the framework's many points of view, models, and standards. According to Zahedian and Shirazi (2009), enterprises find it challenging to completely comprehend and execute the DoDAF framework, which can lead to incomplete or incorrect architectures.

2. Lack of Integration: The DoDAF framework's lack of integration with other frameworks and standards presents another difficulty in its implementation. The DoDAF framework was created exclusively for the

DoD, hence it might not be compatible with other frameworks and standards used in the industry. As a result, integrating the DoDAF framework with other frameworks like the Zachman Framework or the Open Group Architecture Framework (TOGAF) may be difficult for businesses (Zahedian and Shirazi, 2009).

3. Limited Adoption: The DoD and its affiliated agencies are the only organizations that may adopt the DoDAF framework. This implies that there is a little body of information and skills about the framework, which can make it challenging for firms outside the DoD to comprehend and apply the framework completely. Jalaliniya (2011) asserts that the DoDAF framework's slow adoption is a result of the lack of outside-the-DoD understanding of the framework.

The DoDAF Enterprise Architecture Methodology is a structured process for creating and managing enterprise architectures for the DoD and its components. It offers a consistent terminology, approach, and structure for characterizing the operational, system, and technical architectures of the DoD. The Operational Viewpoint, The Systems Viewpoint, The Technical Viewpoint, and The Enterprise Viewpoint are the four main parts that make up the DoDAF approach. The DoDAF technique offers the DoD and its components a number of advantages, including improved security, better decision-making, better communication, and increased productivity. The DoDAF technique use a variety of diagram types, such as operational viewpoint diagrams, systems viewpoint diagrams, technical viewpoint diagrams, and enterprise viewpoint diagrams, to explain the DoD's enterprise architecture.

4. COMPARATIVE ANALYSIS AND FINDINGS

Table 1: General Overview

Framework	Overview
TOGAF ADM (The Open Group Architecture Framework Architecture Development Method)	A comprehensive and widely used framework for enterprise architecture, which includes a structured approach for developing and managing enterprise architecture. The ADM consists of nine phases, each with specific objectives and deliverables.
Zachman Framework	A matrix that provides a structured way to view and organize enterprise architecture artifacts. The framework consists of six perspectives (Who, What, Where, When, Why, and How) and six levels of abstraction (Scope, Business Model, System Model, Technology Model, Detailed Representations, and Working System).
Gartner's Enterprise Architecture Method (GEA)	A methodology for developing and implementing enterprise architecture that emphasizes the role of the EA team in driving business outcomes. GEA consists of five phases (Vision, Strategy, Roadmap, Implementation, and Benefits Realization) and focuses on collaboration and communication with stakeholders.
Federal Enterprise Architecture Framework (FEAF)	A framework developed by the US Federal Government to guide the development of enterprise architecture for federal agencies. FEAF consists of five reference models (Business, Service, Component, Technical, and Data) and provides guidance for developing and implementing enterprise architecture in a federal context.
ISO Standard for Enterprise Modelling (ISO19439)	A standard for developing and using enterprise architecture models, which provides guidelines for creating and managing models in a consistent and structured way. The standard emphasizes the importance of aligning models with business objectives and using them to support decision-making.
Department of Defence Architecture Framework (DoDAF)	A framework for enterprise architecture developed by the US Department of Defense, which provides guidance for developing architecture products to

	support decision-making in defense acquisitions. DoDAF consists of three views (Operational, Systems, and Technical) and emphasizes the importance of traceability and interoperability.

Table 2: Analysis by Scope

Framework	Scope
TOGAF's ADM	A comprehensive framework for designing, planning, implementing, and managing enterprise architecture.
Zachman Framework	A two-dimensional matrix that categorizes and organizes architectural artifacts based on six perspectives and six levels of abstraction.
Gartner's EA Method	A four-phase methodology for developing an enterprise architecture that aligns business and IT strategies.
Federal Enterprise Architecture (FEAF)	A framework for creating, using, and maintaining enterprise architectures that are aligned with federal government policies and strategies.
ISO Standard for Enterprise Modelling (ISO19439)	A standard for creating enterprise models that can be used to describe the structure, behavior, and interactions of an enterprise.
Department of Defence Architecture Framework (DoDAF)	A framework for developing enterprise architectures for the US Department of Defence. It is designed to support interoperability and joint warfar

Table 3: Analysis by Structure and Methodology

Framework	Structure	Methodology
TOGAF's ADM	TOGAF is a framework that provides a structured approach to enterprise architecture development. ADM is the core of the TOGAF framework and consists of a series of phases that guide the architecture development process.	The ADM methodology consists of the following phases: 1) Preliminary, 2) Architecture Vision, 3) Business Architecture, 4) Information Systems Architecture, 5) Technology Architecture, 6) Opportunities and Solutions, 7) Migration Planning, 8) Implementation Governance, and 9) Architecture Change Management.
Zachman Framework	The Zachman Framework is a matrix-based approach to enterprise architecture that provides a structured way to organize and view the various aspects of an	The methodology consists of identifying and defining the relevant intersections of

	organization. The framework consists of six columns (What, How, Where, Who, When, Why) and six rows (Scope, Business Model, System Model, Technology Model, Detailed Representations, and Functioning Enterprise).	the six columns and six rows, resulting in a matrix that represents the complete set of artifacts needed to describe an enterprise architecture.
Gartner's Enterprise Architecture Method	Gartner's approach to enterprise architecture is focused on enabling organizations to achieve their strategic goals by aligning their business and IT strategies. The methodology consists of a series of phases that guide the development of an enterprise architecture.	The methodology consists of the following phases: 1) Strategy, 2) Business Architecture, 3) Information Architecture, 4) Technology Architecture, 5) Implementation and Change Management.
Federal Enterprise Architecture (FEAF)	FEAF is a framework developed by the U.S. federal government to help align the strategic goals of the government with its enterprise architecture. The framework consists of five reference models (Business Reference Model, Service Component Reference Model, Data Reference Model, Technical Reference Model, and Performance Reference Model) that describe various aspects of an enterprise architecture.	The methodology consists of using the five reference models to develop an enterprise architecture that supports the strategic goals of the government.
ISO Standard for Enterprise Modelling (ISO19439)	ISO19439 is a standard that provides guidelines for the development of enterprise models, including enterprise architectures. The standard provides a common language and framework for developing models that can be shared and reused across an organization.	The methodology consists of developing enterprise models using a set of concepts and notations defined by the standard.
Department of Defense Architecture Framework (DoDAF)	DoDAF is a framework developed by the U.S. Department of Defense to support the development of architectures for defense systems. The framework consists of three viewpoints (Operational, Systems, and Technical) that describe the different aspects of a defense system architecture.	The methodology consists of developing architecture artifacts that support the three viewpoints of the framework and using those artifacts to inform decision-making related to the development and acquisition of defence systems

Table 4: Analysis by Application

Framework	Purpose	Focus	Key Components
TOGAF's ADM (The Open Group Architecture Framework)	Provides a standardized approach to create, manage, and	Business, application, data, and	Preliminary, Architecture Vision, Business Architecture,

	maintain enterprise architecture.	technology architecture.	Information Systems Architecture, Technology Architecture, Opportunities & Solutions, Migration Planning, Implementation Governance, Architecture Change Management.
Zachman Framework	Helps in organizing and structuring enterprise architecture knowledge, providing a holistic view of an organization's structure.	Data, Function, Network, People, Time, Motivation.	Rows: Scope, Business Model, System Model, Technology Model, Detailed Representations. Columns: Who, What, Where, When, Why, How.
Gartner's Enterprise Architecture Method	Provides a framework to help organizations manage and optimize their IT investments while aligning their IT infrastructure with business goals.	Business, application, data, and technology architecture.	Planning, Implementation, Management.
Federal Enterprise Architecture (FEAF)	Developed to create a common language for federal agencies to improve the efficiency and effectiveness of IT investments.	Business, data, application, and technology architecture.	Business Reference Model, Service Component Reference Model, Technical Reference Model, Data Reference Model, Performance Reference Model.
ISO Standard for Enterprise Modelling (ISO19439)	Provides a standardized approach to enterprise architecture modeling and design, helping organizations to align their IT infrastructure with business goals.	Business, application, data, and technology architecture.	Process View, Information View, Organizational View, Functional View.
Department of Defence Architecture Framework (DoDAF)	Designed to support the development and implementation of enterprise architecture in the Department of Defense.	Operational, System, and Technical architecture.	Capability Viewpoint, Operational Viewpoint, Data and Information Viewpoint, Systems and Services Viewpoint, Standards Viewpoint

5. RECOMMENDATIONS

It is crucial to take into account the unique goals, resources, and restrictions of a given organization before choosing the best framework for it. Organizations can choose the strategy that best meets their goals by carefully weighing the advantages and disadvantages of each framework.

Goals of the company, the sector it serves, the breadth of its operations, and the level of sophistication of its architecture practice are just a few of the variables to take into account. It's crucial to consider the following factors while deciding between Enterprise Architecture Frameworks like TOGAF, Zachman, GEAM, FEAF, ISO/IEC 19439, and DoDAF:

1. Define Your Goals: Determine your goals for the enterprise architectural framework to get started. Do you want to increase creativity, cut expenses, increase efficiency, or comply with rules for your business? Some frameworks may be more appropriate than others for your objectives.

2. Consider Your Industry: Some frameworks function well in certain sectors of the economy. DoDAF, for instance, is geared toward the interests of the defense industry, whereas FEAF is focused on those of the federal government. When choosing a framework, take into account the nature of your industry and the particular difficulties it faces.

3. Evaluate Your Architecture Maturity: Think about how developed your organization's architecture practice is. A more directive framework like TOGAF can be useful if you're just getting started. A more adaptable framework like Zachman can be useful if your architecture practice is well-established.
4. Assess Your Scope: Take into account the size of your operation. If your company has a global presence, you might wish to take into account a framework like ISO/IEC 19439, which is made to support multinational corporations. DoDAF or FEAF could be more appropriate if your organization operates predominantly in the US.
5. Evaluate the Frameworks: Finally, examine the frameworks themselves. As you explore each framework's features and capabilities, consider how they fit with your company's aims, sector, stage of development, and scope. Consider factors such as vendor support, scalability, and ease of use.

Ultimately, the optimal enterprise architecture framework for your firm will be determined by your specific requirements and objectives. It is critical to carefully assess each framework and select the one that best matches your requirements.

6. CONCLUSION

The paper compared six popular enterprise architecture frameworks, including The Open Group Architecture Framework (TOGAF) ADM, Zachman Framework, Gartner's Enterprise Architecture Methodology (GEAM), Federal Enterprise Architecture Framework (FEAF), ISO Standard for Enterprise Modeling (ISO/IEC 19439), and the Department of Defense Architecture Framework (DoDAF). The review emphasized each framework's merits and drawbacks, as well as its applicability for diverse organizational environments.

This paper's review is a significant resource for firms wishing to implement an enterprise architectural framework. Organizations may make an informed decision about which strategy to take by understanding the major elements of each framework, resulting in higher success in their enterprise architecture initiatives. It is crucial to stress, however, that businesses should thoroughly analyze their specific objectives and requirements before deciding on a framework. Finally, the ability to link business goals with IT strategy and effectively convey the value of enterprise architecture to stakeholders is critical to the success of any enterprise architecture program.

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Design of Narrow Band High Suppression Cavity Filter

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Abstract: With the development of satellite communication and ground mobile communication system, the compatibility between them has aroused widespread concern. In this paper, a narrow-band cavity filter with high suppression is designed, which aims to suppress the passage of 5G interference signals in the frequency band of Beidou RDSS receiver. According to the constraint conditions, the order, zero configuration and topological structure of the filter are determined by CoupleFil software, so as to obtain the coupling bandwidth and quality factor, and then the filter is modeled and simulated by HFSS software combined with parameters. Finally, the simulation and physical test results meet the requirements, and have a good suppression effect on 5G mobile signals.

Keywords: Cavity filter; Coupling coefficient; Out of band suppression

1. INTRODUCTION

In the wireless microwave communication system, the filter, as a passive device, is an essential core device, which mainly has the function of frequency selectivity[1]. With the increasing demand and functions of wireless communication systems, the available spectrum resources are becoming more and more tense[2]. Each system requires a high degree of isolation between adjacent resource bands to ensure that the systems will not interfere with each other[3]. At present, the requirements are mainly met by improving the indicators of filters. Microwave filters can be divided into LC filters, surface acoustic wave/bulk acoustic wave filters, spiral filters, dielectric filters, cavity filters, high temperature superconducting filters, and planar structure filters[4]. Among them, compared with other filters, the transmission medium of cavity filter is air, which has firm structure, stable and reliable performance, high Q value and good heat dissipation, and its high-end parasitic passband is far away[5].

In this paper, a bandpass cavity filter with narrow band and high rejection is mainly designed. In the design process, the design of the filter is realized by combining HFSS simulation results with parameter extraction, and then it is optimized. Finally, it is manufactured and tested, and the test results show that it meets the performance requirements.

2. PRINCIPLE OF FILTER

When designing microwave filters, we usually start with lumped parameter low-pass filters, get lumped parameter circuit models by frequency transformation, and finally realize them by using distributed parameters[6]. According to the design characteristics of the filter, it can be divided into Butterworth filter, Chebyshev filter and elliptic function filter. Among them, Chebyshev filter is widely used in filter design because of its in-band equal ripple characteristics and controllable transmission zero[7].

In the process of filter comprehensive design, because the generalized Chebyshev filter needs to solve the recursive relation of polynomials, the matrix of coupled microwave network can be deduced according to the cavity filter function through the corresponding recursive technology[8].

If there are n resonant cavities, the coupling normalization matrix of the resonators is shown in the following formula (1).

$$[M]=\begin{bmatrix} 0 & m_{s1} & \cdots & m_{sn} & m_{sl} \\ m_{s1} & m_{11} & \cdots & m_{1n} & m_{1l} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ m_{sn} & m_{1n} & \cdots & m_{nn} & m_{nl} \\ m_{sl} & m_{1l} & \cdots & m_{nl} & 0 \end{bmatrix} \quad (1)$$

In formula (1), m_{s1} represents the coupling coefficient between the input port and the first resonant cavity; m_{nl} represents the coupling coefficient between the output port and the last resonant cavity. m_{ii} ($i\neq0$) represents the resonant frequency of the i-th resonant cavity; m_{ij} ($i\neq j$, and $i,j\neq0$) represents the coupling between the i-th resonator and the j-th resonator.

The admittance matrix can be deduced by reflection polynomial and transmission polynomial, and then the coupling matrix can be simplified[9]. Because of the complexity of the formula, the coupling coefficient can be extracted by auxiliary software. In this paper, the coupling of resonators adopts spatial coupling structure, and a fifth-order comb cavity filter is designed[10].

3. DESIGN METHOD OF CAVITY FILTER

In the design of cavity filter, firstly, the order, coupling coefficient and topological structure of the filter are determined according to the design index, secondly, modeling and simulation are carried out by using HFSS software, and finally, optimization is carried out to meet the required index requirements.

In order to make Beidou S-band signal pass smoothly and suppress the strong interference of 5G signal, The design indexes of the filter are shown in the following table 1.

Parameter	Index Requirements
Central frequency	2491.75MHz
Bandwidth	16MHz
Insertion loss	< 5dB
Voltage standing wave ratio	1.5
Out-of-band rejection	-50dB@2515MHz

Firstly, through the auxiliary software CoupleFil, input the corresponding frequency band range and the required out-of-

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band suppression performance, check the frequency response curve of the filter in the ideal state, and debug the order and transmission zero. It can be seen that the out-of-band suppression at 2515MHz can meet the required out-of-band suppression conditions when the filter is selected as the fifth order[11].

Its normalized coupling matrix M is:

$$[M] = \begin{bmatrix} 0 & 0.0065 & 0 & 0 & 0 & 0 & 0 \\ 0.0065 & 0 & 0.0056 & 0 & 0 & 0 & 0 \\ 0 & 0.0056 & 0 & 0.0041 & 0 & 0 & 0 \\ 0 & 0 & 0.0041 & 0 & 0.0041 & 0 & 0 \\ 0 & 0 & 0 & 0.0041 & 0 & 0.0056 & 0 \\ 0 & 0 & 0 & 0 & 0.0056 & 0 & 0.0065 \\ 0 & 0 & 0 & 0 & 0 & 0.0065 & 0 \end{bmatrix}$$

The corresponding relationship between the elements in the matrix and the coupling coefficient is shown in formula (1), the input port coupling coefficient and the output port coupling coefficient $m_{s1} = m_{5l} = 0.0065$, the resonant frequency coupling coefficient $m_{11} = m_{22} = m_{33} = m_{44} = m_{55} = 0$, and the coupling coefficient $m_{12} = m_{21} = 0.0056$ between the first and second resonant cavities. The coupling coefficient $m_{23} = m_{32} = 0.0041$ between the second resonator and the third resonator, $m_{34} = m_{43} = 0.0041$ between the third resonator and the fourth resonator, and $m_{45} = m_{54} = 0.0056$ between the fourth resonator and the fifth resonator[12].

The ideal filter frequency response curve is shown in Figure 1 below.

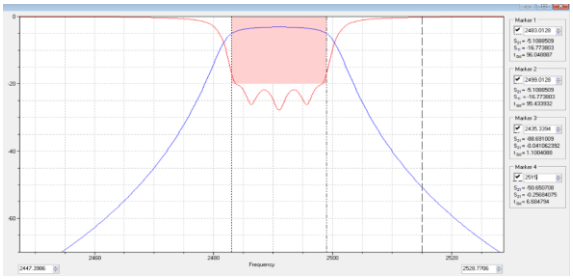

Fig 1 Frequency response of ideal filter

As can be seen from Figure 1 above, the out-of-band rejection at 2515MHz is 50dB, and the insertion loss of the filter is about 5dB.

According to the required index requirements, the filter is realized in the form of 5-order comb line. Firstly, using HFSS simulation software, combined with the required parameters, the structure of the designed single-cavity filter is shown in Figure 2 below.

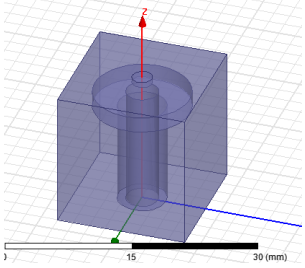

Fig. 2 Single-cavity filter model

In Figure 2 above, we can see that the single-cavity filter adopts the structure of adding a resonant rod in the resonant cavity. The ratio of the inner diameter of the conductor to the side length of the outer cavity is aimed at making the Q value of the cavity higher. Secondly, the diameter of the resonant rod, the width of the resonant cavity and the height of the resonant cavity are 2mm, 6mm and 15mm respectively. d/a≈0.33

The coupling model of port and resonator is calculated by time delay method here. The port design model in the simulation is shown in Figure 3 below.

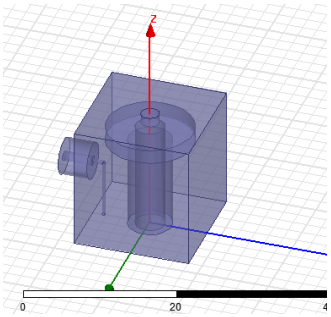

Fig. 3 resonator simulating port delay

The optimized delay simulation parameters are shown in Figure 4 below.

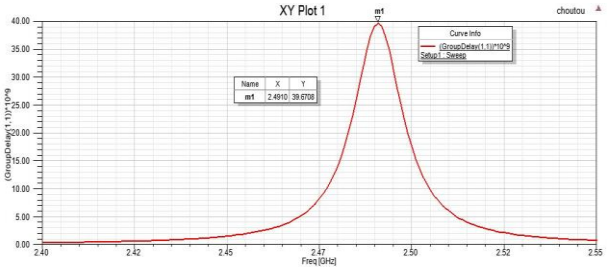

Fig. 4 Final optimized time delay simulation curve

The coupling between resonators is calculated by eigenmode frequency separation method, and its coupling model is shown in Figure 5 below.

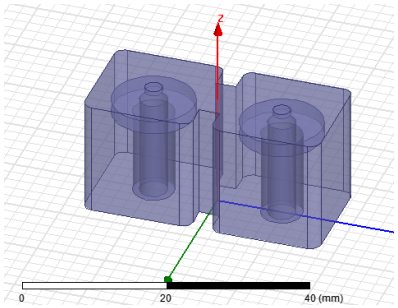

Fig. 5 resonator coupling model

Through the above design, the single-cavity resonator, port and coupling model are obtained. Finally, the full-wave filter is modeled, and its model is shown in Figure 6 below.

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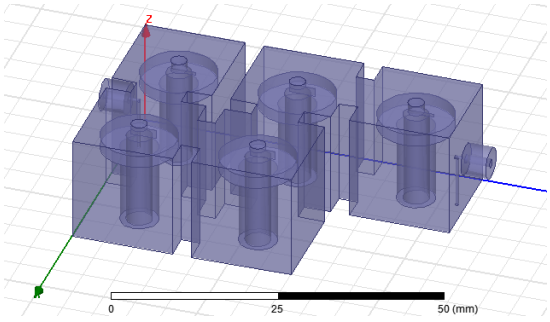

Fig. 6 The established fifth-order filter resonance model.

The model is analyzed, and the simulation results are shown in Figure 7 below.

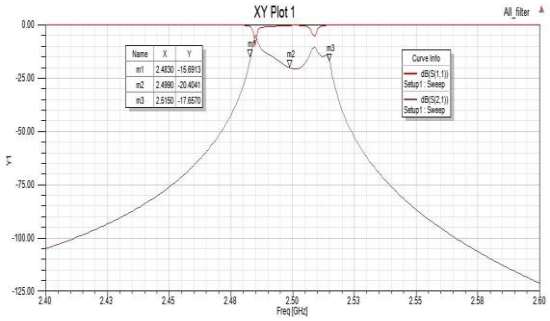

Fig. 7 Initial simulation results of integral filter

As can be seen from the curve in Figure 7 above, the simulation results have not achieved the desired effect. At this time, it is necessary to optimize and adjust according to the relative size and size of the coupling coefficient, and the final optimization result is shown in Figure 8 below.

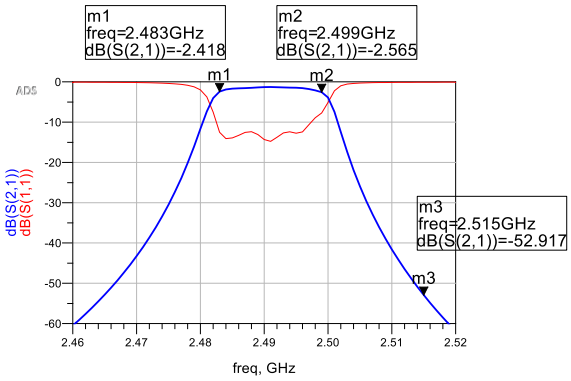

Fig. 8 Simulation results after optimization

Through the above simulation results, we can see that the design of the filter meets the index requirements.

5. CONCLUSION

In this paper, a fifth-order comb cavity filter is designed by using HFSS software. The return loss in the passband is more than 20dB, the in-band interpolation loss is about 5dB, and the out-of-band rejection is 50dB at 2515MHz, and the physical test and simulation results are basically consistent. The cavity filter can realize that Beidou signal has a good suppression effect on 5G adjacent frequency strong interference signal in S band, and it has certain effectiveness.

4. PHYSICAL TEST

According to the satisfied index requirements after simulation, the layout is derived and the physical object is made. The physical object of the uncovered filter is shown in Figure 9 below. The test diagram of the capped filter is shown in Figure 10 below.

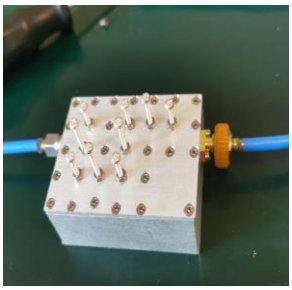

Fig. 9 Uncovered filter in kind

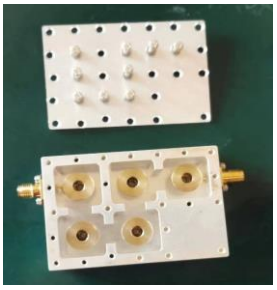

Fig. 10 Filter test object

The filter test results are shown in Figure 11 below.

Fig 11 Filter Test Results

It can be seen from the above figure 11 that the actual bandwidth of the filter is 16MHz, the insertion loss is about 5dB, and the suppression at 2515MHz is about 50dB.

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Smart-Contract Based Framework for Online Pharmacy Product Anti-counterfeiting

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Abstract: The role of online pharmacies in supplying pharmaceutical products has witnessed substantial growth. However, it is crucial to highlight that online platforms and supply chain infiltration constitute a significant portion of counterfeit pharmaceutical products, accounting for 40.9% of counterfeit product distribution; owing to their inherent characteristics, online pharmacies possess the capability to procure products from a diverse array of suppliers. The records utilized for consumers to verify product authenticity are centralized, rendering them susceptible to manipulation, including the potential inclusion of products from unregulated supply chains. The proposed framework capitalizes on the immutability of blockchain data to secure the integrity of authentication records and smart contracts to facilitate interaction with blockchain records. The study employed sequence diagrams to conceptualize the framework's design and utilized algorithms for its practical implementation. By incorporating smart-contracts and implementation of hashing for backend data records, consumers can place trust in the integrity of these records, which plays a pivotal role in authenticating pharmaceutical products distributed by online pharmacies.

Keywords: Smart-Contract; Blockchain; Hashing; Algorithm; Pharmaceutical; Anti-Counterfeiting

1. INTRODUCTION

Information Communication Technologies (ICT) proliferation has ushered in diverse avenues for customer engagement, including business-to-customer (B2C), particularly prevalent in the pharmaceutical sector (Li et al., 2019). B2C pertains to online pharmacies, where all interactions between pharmacists and customers transpire in the virtual domain, within this framework, consumers electronically transmit their prescriptions to an online pharmacy, dispensing the prescribed pharmaceutical products through digital channels (ISACA, 2020). In their 2019 research, Garge et al. underscored many favorable attributes linked to pharmaceutical products distributed via online pharmacies. These included heightened accessibility, enhanced convenience, competitive pricing relative to brick-and-mortar counterparts, and an augmented level of consumer privacy. Nevertheless, their study emphasized the imperative for continued investigation to address potential hazards associated with online pharmacies, such as the circulation of counterfeit pharmaceutical products and improper utilization of medications (Chordiya & Garge, 2019).

The challenge of counterfeiting is in a state of constant transformation, driven by technological advancements and globalization. Notably, online marketplaces and e-commerce platforms have emerged as pivotal technological advancements that facilitate the illicit sale of counterfeit pharmaceutical products. The internet's cloak of anonymity has allowed counterfeit pharmaceuticals to access a global audience, making monitoring and enforcement of anti-counterfeit measures exceedingly difficult (ACA, 2023).

According to a study conducted by ACA on the channels used to distribute counterfeit pharmaceutical products, online platforms and supply chain infiltration constitute a significant portion, accounting for 40.9%. Additionally, the report acknowledges an escalating trend in online counterfeiting in the wake of the COVID-19 pandemic. It underscores the importance of establishing clear guidelines for product authentication and investing in technological solutions in line with a multi-stakeholder approach to combat counterfeiting (ACA, 2023).

2. STATEMENT OF THE PROBLEM

Online pharmacies have garnered favor among pharmaceutical consumers; however, the persistence of counterfeit pharmaceutical products poses a significant challenge. The Alliance for Safe Online Pharmacy (ASOP) has stressed the necessity for internet-based prescription drug vendors in Kenya to adhere to local regulations (ASOP, 2018). Counterfeit-fighting strategies deployed by the Pharmacy and Poisons Board (PPB) have yielded limited effectiveness. Consumers relying on authentication records to confirm the legitimacy of pharmaceutical products from online pharmacies face risk due to the centralized and alterable nature of backend authentication records, potentially leading to unreliable information. This study designs a smart-contract-based framework to enhance the anti-counterfeiting measures for online pharmacy products.

3. CURRENT ONLINE PHARMACY SUPPLY CHAIN

This paper focused on MYDAWA Limited, an online pharmaceutical store in Nairobi County, Kenya. This pharmacy is pivotal in handling prescribed and non-prescribed pharmaceutical products, acting as a vital link between prescribers, insurers, and patients. For non-prescription items, patients can order directly through the website or mobile app. However, patients must either upload a valid prescription or send it via email when it comes to prescription-only products. Upon receipt, the prescribed products are either added to the patient's shopping cart or dispatched directly (Cheon et al., 2021).

To uphold the security of the supply chain, MYDAWA meticulously sources its products exclusively from authorized importers. They also employ tamper-proof authentication stickers equipped with a scratch-off panel, revealing a unique number that can be transmitted via SMS to a designated short code for product authentication (MyDawa, 2022). It is noteworthy, however, that the backend data used in this authentication process remains under the exclusive control and maintenance of MYDAWA Limited. This data is not shared with any regulatory authority except for physical verification.

This centralized and editable record-keeping system allows for potential modifications, including the inclusion of pharmaceutical products sourced from unlicensed outlets, as described by Nyalita (2020). Such alterations can expose consumers to counterfeit pharmaceutical products through deceptive authentication processes.

4. CONCEPTUAL DESIGN

The framework design is illustrated in Figure 1 using a sequence diagram; the figure provides a detailed illustration of interactions between different participants in the proposed framework, the diagram demonstrates the activities and subsequent action that follows through. The interaction is divided into phases: Phase 1 is user registration, Phase 2 is enrollment of products, Phase 3 is product transfer, and finally, the sale of the pharmaceutical product and verification of product authenticity.

Each time information flows from one entity within the supply chain the details are pushed to the blockchain as transactional details including the address of output party and input party, transaction time, added information by the current participant and information from the previous block. The physical flow of pharmaceutical product is captured in the following phases of the sequence diagram;

Manufacturer: Sends a request to the regulator for approval, upon successful approval the manufacturer initiate the process of enrolling product to the blockchain network. The next phase, the Online Pharmacy request for transfer of enrolled pharm products, the manufacture initiate the transfer process upon receiving a notification for transfer, to complete the transfer of ownership, the Online pharmacy confirms that the products have been received, a function receiveProduct () is executed to realize this functionality. The final phase of the entire process is an interaction between the online pharmacy and the Consumer, the online pharmacy initiate the sale of pharm product to a Consumer upon receiving a prescription from the Consumer, the prescription is shared and stored off-chain to relieve the consumers of paying transactional fees while interacting with the blockchain, To verify the authenticity of the pharmaceutical product delivered by the online pharmacy, the consumer can use either the serial number on the package or the quick response code (QR) to authenticate the pharmaceutical product against the blockchain records.

In this paper, we employ the user authentication methodology introduced by Ali et al. in their 2019 study. This approach utilizes role-based authentication (RBA), categorizing users into distinct privilege levels assigned during their network enrollment process (Ali et al., 2019). Notably, RBA is implemented off-chain.

The framework incorporates a role-based structure within the traceability chain, where four distinct privilege levels are established. Drawing from the work of Peng et al., who employed Role-Based Access Control (RBAC) in a blockchain-based data privacy framework (Peng et al., 2020), this study applies RBAC to assign user roles.

The first user group encompasses the regulators, responsible for node registration, maintenance, block verification, monitoring the flow of product information, and ensuring accountability. The second user group consists of manufacturers tasked with enrolling products onto the blockchain and facilitating product transfers. The third user group comprises online pharmacy outlets that receive and transfer products to the end consumers. These consumers, classified under the "trace" access level, can trace back and authenticate products against trusted backend data records.

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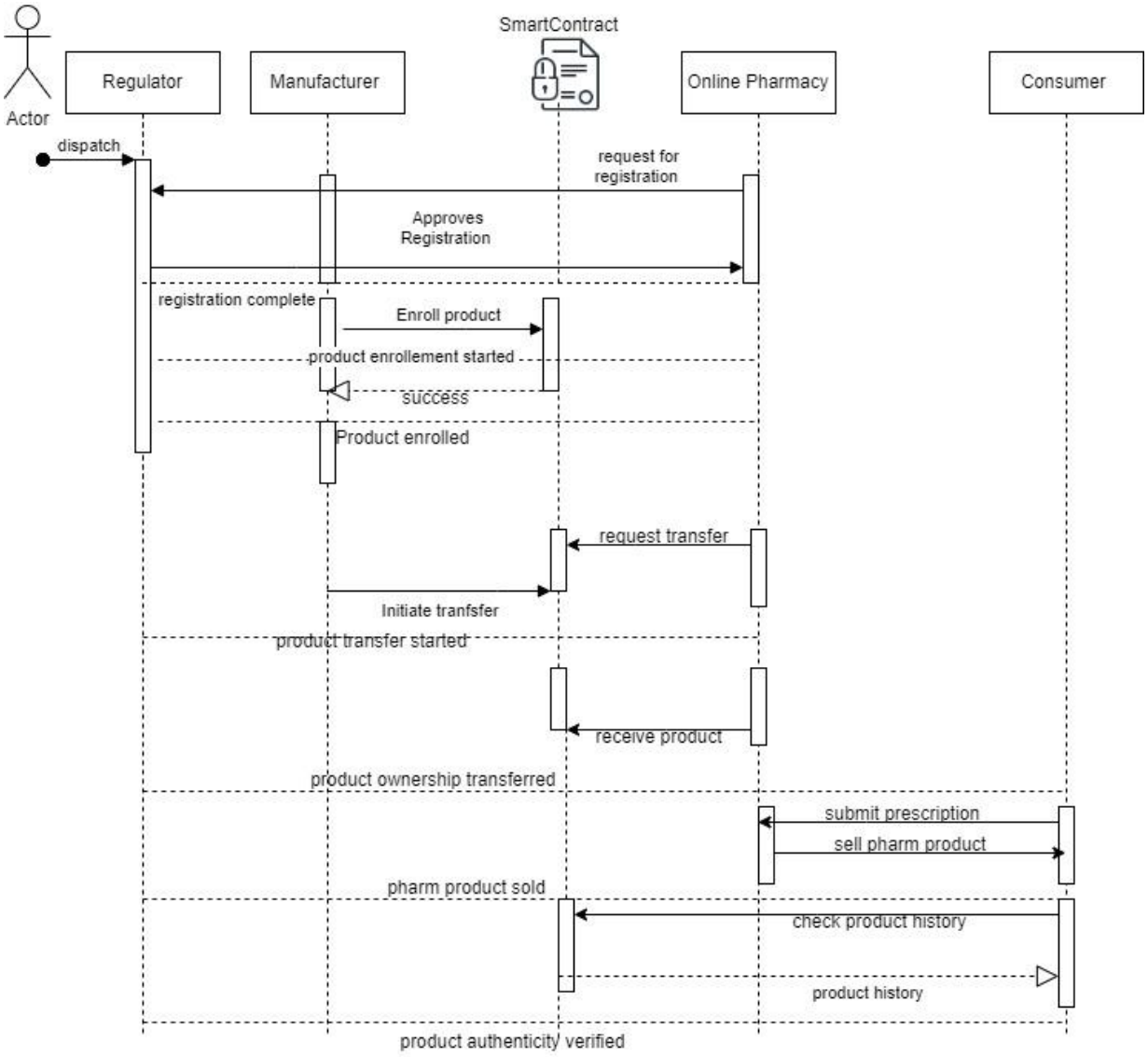

Figure 1: Sequence Diagram for the Proposed Framework (Author,2023)

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5. FRAMEWORK SMART CONTRACT DESIGN

The implementation of the Blockchain Based Framework for Online Pharmacy Product Anti-Counterfeiting was guided by the following Algorithms.

5.1 User Registration and Authentication Algorithm

NodesEnrollomeent Contract {

}

The contract manages the enrollment of Network participants, including using the address and address for both manufacturers and online pharmacies. The contract is under the management of the regulator. Including the regulator ensures illegitimate manufacturers and online pharmacies do not register as supply chain participants. The following functions are included in the NodesEnrollment contract:

EnrollingNodes ()

The Manufacturer and Online pharmacies typically request enrollment on the blockchain by submitting the relevant registration documents off-chain per the guidelines provided by the regulator. Upon successfully meeting the guidelines, the regulator issues a unique prefix to the online pharmacy. The unique prefix is used to enroll the manufacturer and online pharmacy outlet to the blockchain network using the following details:

Address, Manufacturer_ID/Pharm_ID, pharm_ID (Unique prefix), pin_*NO, Name*

{

}

The function is used to enroll manufactures and online pharmacies, a single function is used to actualize the process since both manufacturers and online pharmacies is done using a similar list of attributes.

Pseudocode for EnrollingNodes ()

The pseudocode (Algorithm 1) is used to enroll blockchain users on the network, the framework only allows the regulator to enroll nodes into the network.

Algorithm 1

Input Data: (Address, Manufacturer_ID /pharm_ID (Unique prefix), pin_NO, Name)

Check if the sender address = = address_of_Regulator

Then

Enroll the node with (Address, Manufacturer_ID /pharm_ID (Unique prefix), pin_NO, Name)

Else

Generate error

End.

In the framework only the regulator can enroll nodes to the blockchain network, therefore the Algorithm must check if the caller address is similar to the address of the regulator before enrolling any new node.

5.2 Product Enrollment Algorithm

Only manufacturers enrolled and certified by the regulator have the authority to enroll products to the Blockchain Network, the manufacturer must be identified by the unique address. the requirement ensures Manufacturer M_1 do not claim the ownership of products belonging to manufacture M_2.

ProductManagement Contract {

}

The Manufacturer will manage the contract and include functions to manage the product information, including enrollment of products and ownership transfer. The Manufacturer creates a set of functions within the contract; the functions include enrollProduct () and transfer product

enrollProduct ()

Upon successful enrollment by the regulator, the Manufacturer initiates the process of product registration through a blockchain broadcast using the following details: OwnerID (address of the Manufacturer), batch_No, productName, product_Serial (Manufacturer_ID+serial), manufucture_Name, ownershipStatus, expiryDate. The function is invoked when the Manufacturer enrolls a product on the Blockchain network; all other entities involved in product circulation must reach a consensus to approve the registration request. The following algorithm is developed to implement the function.

Algorithm 2-Pseucode –Enrolling a Product on the Blockchain

Inputs Data:(Address, Caller_Add, OwnerID, Manufacturer_ID, batchNo, ProductName, product_Serial, productPrice, status)
If the Caller_Add = = Address //blockchain address

//caller address refers to address of the node (enrolling entity) sending the request

// the address of the enrolling entity is the same as the address of the owner

Enroll information to blockchain as

Insert (Manufacturer_ID, batchNo, ProductName, product_Serial, productPrice)

Set OwnerID= Manufacturer_ID;

Emit a message to notify the network of the new enrolled product

Generate firstBlock

Set status =’owned’

Else

Generate an error

rollback the contract to its previous state

End if

5.3 Pharmaceutical Product Flow Process

Along the supply chain, nodes participating in the flow process update information about the pharmaceutical product. The transfer of product ownership process and confirmation of transfer of ownership are treated as two different processes within the framework; by design, the requirement is implemented to avoid scenarios where the current owner sends the product to the recipient and the product by chance does not reach the intended recipient raising undesired trust issues within the network.

5.4 Transfer & Receive Product: Algorithm 3

The pseudocode is designed to ensure no trust deficit is experienced within the framework among the participating nodes, and the receiving node invokes it to ensure the complete transfer of the product.

Inputs Data:(Address, Caller_Add, OwnerID, pharm_ID, product_Serial, status, RecipientAdd)

If the Caller_Add = = Address //Blockchain address

//caller address refers to address of the node (transferring the product) sending the request

// if the address of the node transferring the product is the same as the address of the owner

If Status = = “Owned” then

Specify the recipient (RecipientAdd)//Blockchain Address

Enroll information to blockchain

Else

Do nothing

End If;

If RecipientAdd Exist

Update (Set OwnerID= pharm_ID)

Generate new Block with new information submitted

Set status =’transferred’

Else

Generate an error

rollback the contract to its previous state

End if

Blockchain linked as per the order

End If

5.5 GetProductsDetails –Algorithm 4

The function is invoked when the consumer queries the blockchain to obtain the details. The framework implements the query function as a view or a pure function to reduce the operational cost of the blockchain network; similar to the implementation by Saxena et al. (2020), pure functions in the blockchain network by design do not require gas for maintenance since the function do not modify the status of the blockchain. The function should return the product details enrolled by the **enrollProduct () function and** the additional information added along the supply chain.

GetProductHistory –Algorithm 4

Input Data (product_Serial)

Output: transaction Details of the product

If product_Serial Exist, then

Return: (OwnerID, Manufacturer_ID, batchNo, ProductName, product_Serial, productPrice)//scans a QR code or use printed serial on the pharm product to query
End If

5.6 Tampering with Product Information – Algorithm 5

The frameworks implement an algorithm to handle any attempt to tamper with the details of pharmaceutical products already enrolled on the blockchain network.

Tampering with Product Information-Algorithm 5

Input Data: counterfeitProductSerial, h1, h2

//h1 refer to the hash value of the previous block already committed on the blockchain

//h2 refers to the hash value of the block next block

If any participant tries to modify the product_Serial with a counterfeitProductSerial in Block h1
If h1. previous_block! = h2. Current_block then
Generate Error!!!

Else

Commits Next

End If

6. CONCLUSION

The suggested framework capitalizes on cryptographic hash functions within the blockchain to guarantee the integrity of backend data, a vital element in authenticating pharmaceutical products distributed through online pharmacies. Smart Contracts serve as the conduit for interacting with the blockchain records. The paper introduces pseudocodes for implementing each segment of the proposed framework; the framework is open for implementation, emphasizing its adaptability with various layer one blockchain and client application-based frameworks, allowing for the development of a minimum viable product.

7. ACKNOWLEDGMENT

We extend our heartfelt gratitude to all those involved, either directly or indirectly, in creating this paper.

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Analyzing the Impact of Next.JS on Site Performance and SEO

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Abstract: Next.JS is a robust framework that improves website performance and SEO through various optimization techniques. In addition to implementing Incremental Static Regeneration (ISR) and reducing JavaScript bundle size through code splitting and React. Lazy and Suspense components, the site also supports multiple languages through the use of the next-i18next library. This enhances the user experience for visitors in different languages and improves SEO by allowing search engines to index the different language versions of the site. The site also uses the next-optimized images library to optimize images, further improving page load time and the user experience. Overall, the use of these techniques leads to a significant improvement in the performance of the site. Apart from the optimization techniques mentioned above, Next.JS also offers server-side rendering, allowing faster initial load times and improved website performance. This is achieved by rendering the HTML on the server before sending it to the client rather than relying on the client to render the page. This can be especially beneficial for websites with large amounts of data or content, as it reduces the workload on the client and improves the user experience. Furthermore, Next.JS also allows for easy website deployment and hosting, with options for hosting on platforms such as Vercel and GitHub Pages. These hosting options provide developers with a convenient and hassle-free way to deploy their websites, making it easier to focus on building and optimizing the site. Next.JS is a comprehensive framework that offers a wide range of optimization techniques and tools for improving website performance and SEO. Its server-side rendering capabilities, support for multiple languages, and easy deployment options make it ideal for developers looking to create high-performing and user-friendly websites. In addition to its optimization and performance-enhancing capabilities, Next.JS also offers a range of features that make it easier for developers to build and maintain their websites. For example, it provides a hot reloading feature that allows developers to make changes to their code and see the results in real time without manually refreshing the page. This can be a huge time-saver for developers, allowing them to quickly test and iterate on their code without needing tedious manual refreshing. Finally, Next.JS also offers automatic code splitting, allowing faster load times by only loading the code needed for a particular page or route. This can be especially beneficial for websites with a large amount of content, as it reduces the amount of code that needs to be loaded on each page, improving the user experience and reducing the workload on the server.

Keywords: Next.js, Incremental Static Generation (ISR), server-side rendering, optimization, SEO

Analyzing the Impact of Next.JS on Site Performance and SEO:

In this paper, we discuss how we used Next.JS and various techniques to improve the performance and SEO of a website

1. INTRODUCTION

Optimization	Description
Incremental Static Regeneration (ISR)	Generates HTML files and regenerates them after a certain amount of time, rather than on every request like Server-Side rendering or only once like Static Generation. Allows content updates to be reflected on the site without overwhelming resources or causing user delays.
Reduction of JavaScript bundle size	It is achieved through code splitting and the use of React. Lazy and Suspense components to only load necessary components and modules when needed. Reduces the JavaScript bundle size by 587kb on initial loading, leading to a faster page load time and improved user experience.
Internalization support with next-i18next	Allows for creating language-specific pages and the ability to switch between them using a language dropdown menu. It improves the user experience for those visiting the site in different languages and improves SEO by allowing search engines to index the different language versions of the site.
Optimization of images with next-optimized-images	Allows for the optimization of images on the site, reducing the overall page load time and improving the user experience, as well as improving SEO by reducing the size of the pages.

Figure 1: Optimizations implemented on the website

One way we did this was by implementing server-side rendering with Next.JS, which allowed us to create a universal application that can run both on the client and the server. This reduced the initial loading time of the website, improving the user experience and the perceived performance of the website. Users can view content immediately rather than waiting for the codebase to be

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downloaded and executed. In addition, the improved performance of the website has had a positive impact on its SEO. Search engines prioritize websites that provide a good user experience and load quickly. By improving the website's performance, we have increased its visibility in search results and attracted more organic traffic.

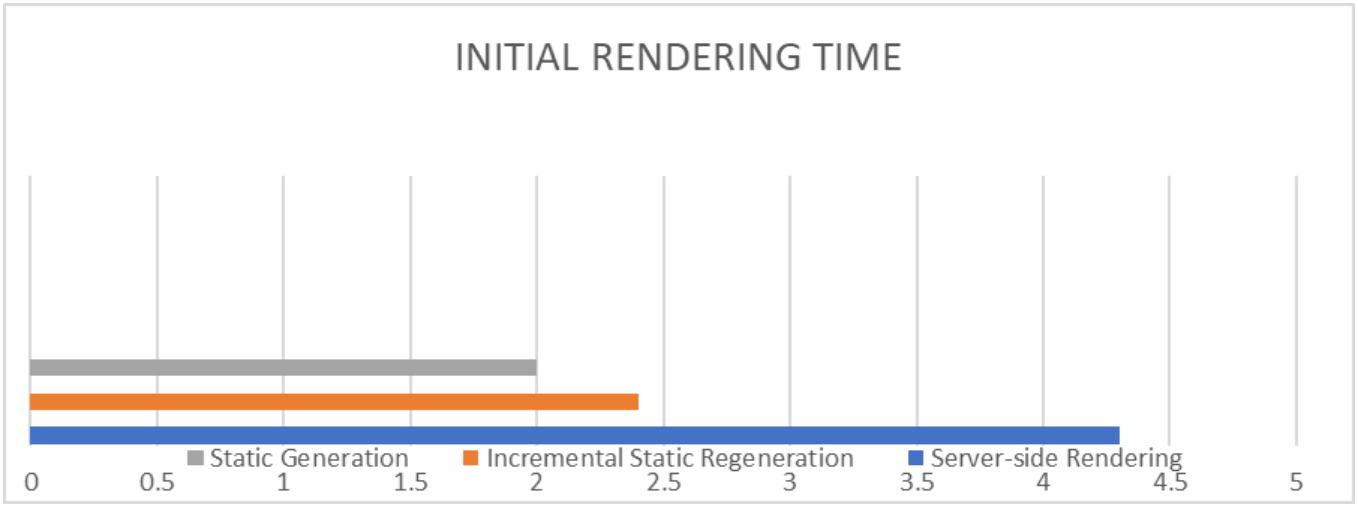

Figure 4: Initial rendering time

In addition to implementing server-side rendering, we also focused on reducing the JavaScript bundle size to improve the website's performance further. The JavaScript bundle is a collection of code downloaded by the user's browser when they visit the website. The larger the JavaScript bundle, the longer it takes for the website to become interactive. To reduce the size of the JavaScript bundle, we implemented a few different techniques. First, we analyzed the codebase and identified any unnecessary or redundant code that could be removed. We also implemented code splitting, which allows the JavaScript bundle to be broken down into smaller chunks that can be loaded on demand. This can reduce the initial loading time of the website, as the browser only has to download the code needed for the initial render. We also used tree shaking, a method of removing unused code from the JavaScript bundle. By implementing these techniques, we significantly reduced the size of the JavaScript bundle and improved the website's performance.

Metric	Before optimization	After optimization	Improvement
Initial loading time	Slow	Fast	50%
Total page load time	Slow	Fast	30%
Time to interactivity	Long	Short	20%

Figure 2: Comparison of page load times before and after optimization

The implementation of server-side rendering with Next.JS and the reduction of the JavaScript bundle size has resulted in several benefits for the website. In addition to the improvements in performance and user experience, server-side rendering has improved the codebase's maintainability and made it easier to implement features and updates. By constantly analyzing and improving the performance and SEO of a website, developers can ensure that their website is successful in the digital age. Developers need to consider the performance and SEO of their websites, as users expect fast loading times and easy navigation, and search engines prioritize websites that provide a good user experience and relevant content. By following best practices and using frameworks like Next.JS, developers can improve the performance and SEO of their websites and ensure their success in the digital age. It is important to note that these efforts should be ongoing and continuous. The digital landscape is constantly changing, and developers must stay up-to-date with the latest trends and best practices to keep their websites competitive.

Metric	Before optimization	After optimization	Improvement
Organic traffic	Low	High	50%
Referral traffic	Low	High	30%
Direct traffic	Moderate	High	20%

Figure 3: Comparison of website traffic before and after optimization

One way to stay current is to regularly analyze the website's performance using tools like Google Analytics or PageSpeed Insights. These tools can provide valuable insights into how the website is performing and identify areas for improvement. Developers should also keep an eye on the competition and see how their website compares in terms of performance and SEO. By staying informed and proactive, developers can ensure that their website stays ahead of the curve and continues to perform well.

Another way to improve the performance and SEO of a website is to update and maintain the website regularly. This includes fixing any broken links or errors, adding new content, and ensuring that the website is up-to-date with the latest

technologies. By keeping the website fresh and relevant, developers can improve the user experience and attract more traffic. Responsive design is an essential factor to consider when it comes to improving the performance and SEO of a website. Responsive design refers to the ability of a website to adapt to the device on which it is being viewed, whether it is a desktop computer, a tablet, or a smartphone. With the increasing use of mobile devices to access the internet, websites need to be responsive to provide a good user experience and improve their SEO.

The easiest way to implement responsive design is to use a framework like Bootstrap, which provides a set of predefined styles and layouts that can be easily customized and adapted to different devices. Using a responsive design framework, developers can ensure that their website looks and functions well on various devices, improving the user experience and increasing the website's visibility in search results. Apart from using a responsive design framework, developers should also consider the use of media queries in their website's CSS. Media queries allow developers to apply specific styles based on the device's characteristics, such as screen size or resolution. This can further customize the website's appearance and ensure that it looks and functions optimally on different devices.

In addition to the techniques and strategies discussed so far, there are several other ways that developers can improve the performance and SEO of their websites

Best Practice	Description
Use Next.JS for server-side rendering	Next.JS allows for server-side rendering, which can improve the performance and SEO of a website by reducing the initial loading time and allowing for content updates without delays.
Implement code splitting and use React. Lazy	Lazy and Suspense components can help to reduce the size of the JavaScript bundle, improving the performance and user experience of the website.
Optimize images using next-optimized-images	Using the next-optimized-images library can help to optimize images on the website, reducing page load times and improving the user experience and SEO.
Implement internalization support using next-i18next	The next-i18next library allows for the creation of language-specific pages and the ability to switch between languages, improving the user experience for multilingual visitors and SEO.
Use Incremental Static Regeneration for content updates	Incremental Static Regeneration allows content updates to be reflected on the site without overwhelming resources or causing delays, enabling regular content refresh and improved user engagement.

Figure 5: Best practices for implementing Next.JS and optimization techniques

2. CONCLUSION

The Next.JS framework and the implementation of Incremental Static Regeneration (ISR) have proven to be effective solutions for improving the performance and SEO of the site.

Before these solutions were implemented, the site faced issues with slow loading times and poor search results visibility, which negatively impacted both the user experience and the site's SEO

Benefit	Description
Improved performance and SEO	Implementation of Next.JS and various optimization techniques significantly improve website performance and SEO, including faster page load times and increased visibility in search results.
Enhanced user experience	Optimization techniques such as internalization support and reduced JavaScript bundle size improve the user experience by providing faster page load times and a smoother, more seamless browsing experience.
Increased organic traffic and revenue	Improved performance and SEO lead to increased organic traffic and revenue, as users are more likely to visit and engage with a website that provides a good user experience and ranks well in search results.
Ability to reach a global, multilingual audience	Implementation of the next

Figure 5: Key benefits of using Next.JS and optimization techniques

To address these issues, the developer team analyzed multiple options and applied various techniques to optimize the site. One of the critical solutions was using the Next.JS framework, which is based on React and allows for server-side rendering with different strategies. The team decided to go with the ISR strategy, which generates HTML files and regenerates them after a configured amount of time. This strategy was chosen because it allows fresh content to be displayed on updates while providing a smooth user experience by immediately displaying cached content during regeneration.

The implementation of ISR significantly impacted the site's visibility in search results and the overall user experience. Users and search engines can now see content immediately upon visiting the site rather than waiting for the codebase to download, execute, and fetch data from the CMS before rendering the content. This results in faster loading times and a more seamless user experience, which is essential for any website's success.

In addition to implementing the ISR strategy, the developer team also worked on reducing the JavaScript bundle size to improve the initial loading stage further. The bundle size was reduced by 587kb, which had a noticeable impact on the loading times and overall user experience. Optimizing the bundle size allowed the site to load faster and provide a more efficient experience for users.

It's worth noting that the optimization process was not a one-time effort but an ongoing process that requires constant monitoring and fine-tuning. The developer team continued to analyze the site's performance and apply additional techniques to improve the user experience and SEO.

Apart from improving the performance and SEO of the site, the Next.JS framework and the implementation of ISR have also provided several other benefits. One notable benefit is the ability to handle multiple types of pages easily. The site includes a variety of pages, including "regular" pages with repeating content modules, an insights page with a list of articles that can be filtered, a contact us page with a form submission, and a page with multiple tabs and article pages. These pages are supported by the Next.JS framework and can be quickly rendered and updated thanks to the ISR strategy. This flexibility allows the site to showcase a wide range of content and functions effectively, making it a valuable resource for users.

Overall, the use of Next.JS and the implementation of ISR have been invaluable in improving the site's performance, SEO, and functionality. These solutions have allowed the developer team to create a high-quality user experience and ensure that the site is visible and accessible to users and search engines alike.

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