Service Oriented Architecture Support in Various Architecture Frameworks: A Brief Review

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Abstract— **Service Oriented Architecture (SOA) is a promising approach used to reduce the time and cost of business solutions in enterprises, and it provides enterprises with agility to respond dynamically to its changing requirements. Therefore, there is a need for great efforts to move agencies and enterprises into systems, such as C4I systems and those that are supported by SOAs. For this reason, numerous Enterprise Architecture Frameworks (EAFs) have been developed by the architects to enhance the information system development process, System of Systems (SOS) architecture modeling, and in such, to seek for the one that can harness the state-of-the-art elements of SOAs. The main objective of this paper is to explore SOA support in various known Architecture Frameworks (AFs) of the Department of Defense (DoD), such as the United States Department of Defense Architecture Framework (DoDAF), British Ministry of Defense Architecture Framework (MoDAF), Department of National Defense and the Canadian Forces Architectural Framework (DNDAF), and NATO Architecture Framework (NAF). Further, this paper describes a comparison among different AFs based on SOA. This analysis will help architects, designers and developers to select the best architecture framework for building SOA-based C4I solutions.**

Keywords: Architecture Framework (AF), Department of Defense (DoD), DoDAF, interoperability, Service Oriented Architecture (SOA).

I. Introduction

Command, Control, Communications, Computers and Intelligence (C4I) is a System of Systems (SoS) that utilizes systematic methods to interoperate with other systems as a part of a complex structure to deliver additional operational capabilities [6]. C4I is widely using within military DoD applications, in which various heterogeneity systems operate with each other; in such, interoperability between them is an essential task to support highly volatile situations and changing mission requirements, as well as to control critical circumstances and assist commanders in making the right decision at the right time in warfare.

Nowadays, in addition to its use in defense departments, C4I is widely used in civil segments where domain awareness and command and control are needed to accomplish specific tasks [7].

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Therefore, the implementation of C4I systems effectively evolves in several Architecture Frameworks. Architecture is a tool to convert vision into reality; it organizes enterprise structure, behavior and properties. Consequently, it aligns business and IT, improves communication, facilitates the sharing of information, reduces IT complexity, and helps in decision making [21], [22]. AFs should adequately leverage the benefits of emerging technologies currently being used, such as SOA [24].

SOA is a new technology that facilitates the capability of matching additional needs required by any system that operates under C4I [2]. Moreover, it offers many other features like scalability, agility, and reusability in business environment. The use of SOA features in C4I can be configured flexibly with the economic degree of time and configuration cost in such a situation when requirements change rapidly in a systematic process [1], [19]. In such, harvesting the advantages of SOA technology occurs gradually, over time.

Nowadays, architects focus their attention on SOA features within the Enterprise Architecture Frameworks (EAFs). This paper investigates the adoption of SOA in EAFs, especially in military departments such as DoDAF, MoDAF, DNDAF and NAF. Accordingly, this paper is organized, as follows: Section II contains the literature review; Section III provides the definition and features of SOA; Section IV details four popular EAFs used in DoD; Section V offers a comparison between, and discussion of, the selected AFs; and Sections VI and VII are comprised of the conclusion and suggestions for future studies, respectively.

II. LITRETURE REVIEW

Since the appearance of SOA technology, attempts to integrate SOA artifacts with current AFs are a never-ending process. In the military domain, various approaches take place, specifically within the addressed system: the C4I system.

Wang and Luo [9] imported the entire scope of SOA-related issues into the C4ISRAF framework, and after integrating them, presented the Service Oriented C4ISR Architecture Framework (SOC4ISRAF). In such, and additional assessment labeled as the services view was added to the previous valuations of C4ISRAF. The service elements were then combined with the architecture, after analyzing the date elements of C4ISRAF based on the NAF Meta-Model (NMM). Then, the service view was integrated with the architecture after ensuring the view scope. As a result, Wang et al [11] expanded his work by formalizing a description of products supporting the service view and the interrelation among them.

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Many studies have been conducted to compare different AFs based on SOA goals, one of which was that of Alghamdi and Ahmad [4]. In such, the authors compared some selected defense AFs using a multi-criteria method; specifically, they used interoperability and scalability as attributes to measure the performance of the AF. They found that the Unified Profile for DoDAF/MoDAF (UPDM) is more preferable than DoDAF, MoDAF and NAF, correspondingly. Another study by Alghamdi [5] evaluated selected defense AFs using the Analytic Hierarchy Process (AHP) and concluded that DoDAF is preferable over MoDAF and NAF.

Alwadain et al. [21] emphasized the necessity of addressing the stakeholders' concerns to correctly formulate and position the services when integrating with EAFs. Śliwa and Amanowicz [25] identified nine fundamental challenges faced when implementing SOA in highly dynamic, heterogeneous and unpredictable NEC environments, such as the military context. In addition, the authors suggested different solutions that should be considered as SOA success factors to facilitate increased mission effectiveness and to guide SOA best practices. In such, they ensured that SOA will help significantly in facilitating the implementation of net-centric capabilities. Sanders et al. [23] illustrated that SOA is not a complete system view and should be combined with EAFs in a supplementary manner. Alwadain et al. [22] investigated the way in which EAFs embrace the SOA paradigm, selected five widely-used EAFs, specified the positions where SOA can be found in each one, compared these positions, and concluded that the SOA is not well-integrated into existing EAFs. Accordingly, many challenges were raised which require additional support and efforts for future application.

III. WHAT IS SOA

A. SOA Definition

Distinctive definitions for SOA were given by some popular groups such as IBM, OMG and OASIS [19], [24]. In simplest terms, we can say that SOA is an architectural paradigm that consists of needs and capabilities, where capabilities can be distributed between different stakeholders. The word 'service' is used to bring needs and capabilities together [2]. SOA introduced business processes as a collection of services in which each service may interact with one or more other services to accomplish a specific task, each service is accessed through its interface [1], and all services can be kept in a service registry [26]. In general, service participants are either people or organizations, where entities with needs are referred to as a service consumer while entities offering capabilities are referred to as a service provider [2]. SOA focuses on the business process chain and these processes are introduced in the architecture as a set of autonomous and reusable services, with a high level of collaboration. Integration between these services can be done in an orchestrated manner [10]. Any platform that embodies SOA principles and helps integrate, identify and configure distributed services is called a SOA platform [19]. Organizations need to integrate the SOA with its architecture framework in order to have a complete system [19], [23].

B. SOA Goals and Benefits

The main goal of SOA is to manage scalability or the growth of large, complex systems [1]; provide interoperability between heterogeneous platforms and systems to construct loosely coupling domains [6], [26]; offer cost and time reduction through the use of effective reusability opportunity (i.e. reuse of legacy assets); and provide flexibility and agility for the enterprise [1], [19], [26]. Accordingly, the impacts of SOA are: greater efficiency in developing composite applications because of modularity; reusability of the services in different applications, due to the loose coupling between them; ability to reflect on the enterprise budget; easy maintainability of the services that can be modified without affecting other parts of the system and for as long as the service interface remains unchanged; and the provision of incremental evolution, where services can be developed and gradually deployed in planned stages [1].

C. SOA Principles

SOA, in order to achieve its presumed goals, design and implementation of services should adhere to some specifications. The most important are: it should contain loose coupling (to minimize the dependencies among them); it should have a well-defined interface (to define service capabilities and provide an invoking format); it should have a service contract (communication agreement); it should be autonomous (service independent and self-contained); there should be composability (several services can be assembled to do a specific task); it should be location transparent (the physical location is unknown to the consumer); it should be based on open standards (to limit the role of proprietary); there should be discoverability (descriptive, so that they can be found using any discovery mechanism); it should be stateless (to minimize retaining information for a specific action, which makes service more reliable); and there should be adequate quality of service (QoS) (consider and provide some availability, accessibility, integrity, security and reliability capabilities when using the Internet) [1], [26].

D. SOA in DoD

Defense communities recognize that the impacts of SOA can provide a massive increase in capabilities' evolution during warfare time. These capabilities can be well-used to augment the operational effectiveness to the highest extent. SOA accelerated the DoD's efforts to transform to Network-Centric Operations (NCO) by ensuring the right information from reliable sources is received by the soldiers, when needed. Therefore, the DoD's vision is to start an NCE to increase and leverage the SOA's significant benefits, and share services among users (i.e., soldier, analyst, developer, etc.). The DoD's process of warfare consists of numerous missions, pieces of information and functional capabilities, as shown in Figure 1. The DoD's NCE improved the process of sharing by using services and allowing the mission, information and functional capabilities owners and producers to publish these services over the NCE. In such, these services are the building blocks of the system [25], [27]. The design of SOA in a military scenario begins with identifying business processes, actors, information needs and the flow between them, and then the services are created [25].

With SOA, the DoD is more adaptive to accommodate the soldiers' continuously changing mission needs in a superior manner, aid in interoperability and joint operations, permit agility, grant high quality of information sharing, and manage the battlefield when dramatically expanded [27]. Additionally, military information resources are available as services, which can be directly discovered and used. Reusing or developing new, value-added services is done in a modular and flexible fashion that is adapted to a changing operational context. Tactical domain ability provides a common operational picture (COP) in different levels of command to support situational awareness and to help commanders make reliable decisions in a critical and short amount of time. Finally, seamless information is exchanged under different policies and loosely coupled environments [25].

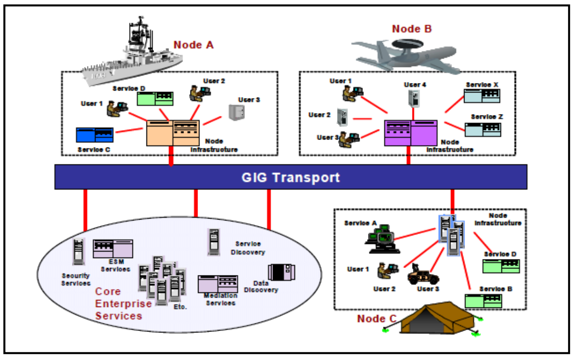

Figure 1: SOA in defense [28].

As mentioned in [23], SOA is best teamed with an AF in a complementary way. On the other hand, the importance of tailoring the SOA to cover all military environments in order to truly harvest the advantages of SOA, thus creating more advanced usability for the DoD, should be considered [25].

IV. MILITARY AFs SUPPORTING SOA

In this section, four selected AFs, which supported the SOA at different levels, have been described. The selection of these AFs depends on some criteria, which are: (1) use in DoD, (2) popularity, and (3) support SOA.

A. DoDAF

DoDAF is an architecture framework for the United States Department of Defense. It provides guidance for describing architectures for large systems with complex integration and interoperability challenges (e.g., war-fighting operations, business operations and processes). It provides a general form to describe, develop and present architecture, as well as the way in which to integrate it with other architecture in the organization [14]. DoDAF v2.0 is based on a data-centric approach. The primary goal of such an approach is collecting, analyzing, maintaining and reusing data needed for effective decision-making during warfare [13]. DoDAF is a foundational and consistent architecture approach, in which many frameworks derived are based on it, such as the NATO Architecture Framework (NAF) and Ministry of Defense Architecture Framework for the United Kingdom (MoDAF) [14].

DoDAF v2.0 consists of eight viewpoints, which are: All Viewpoint (AV), Capability Viewpoint (CV), Data and Information Viewpoint (DIV), Operational Viewpoint (OV), Project Viewpoint (PV), Services Viewpoint (SvcV), Standards Viewpoint (StdV) and Systems Viewpoint (SV). DoDAF supports SOA development through the service viewpoint and Service Models Descriptions. SvcV includes the definition, description, development and execution of services, and provides guidance based on service requirements. In addition, it depicts services and their interconnections supporting DoD war-fighting and business functions. Operational and capability requirements are presented as service resources through the Service Models to support the operational activities and facilitate information exchanging [13].

In the DoDAF Defense Meta-Model (DM2), the following service elements are found: a service (for both business and software), service description, a service port and a service performer (consumer and provider). Additionally, there are: service function, service contract (includes Service Level Agreement (SLA)), service policy, QoS and service channel found in the DoDAF documentation. Mainly, SOA elements appear in the Service Viewpoint but may appear in All Viewpoints and Capability Viewpoint in order to map services to capabilities [22].

B. MoDAF

MoDAF is an architecture framework for the Ministry of Defense in the United Kingdom based on the DoDAF v1.0. Its intent is to support planning and the change of management activities through capturing and presenting information rigorously. It provides coherent viewpoints of different perspectives to support different stakeholder interests. These viewpoints present a graphical and textual visualization for a specific business area and show a complete picture (vision) of the enterprise when viewed as a whole. MoDAF is widely used in defense acquisition domains to facilitate the delivery of military capabilities that will effectively support the missions [16].

Within MoDAF v1.2, the seven viewpoints are: All Viewpoints (AVs), Strategic Viewpoints (StVs), Operational Viewpoints (OVs), Service Oriented Viewpoints (SOVs), Systems Viewpoints (SVs), Acquisition Viewpoints (AcVs) and Technical Viewpoints (TVs). SOVs describe services specifications to support SOA [18].

The Service Oriented Viewpoint consists of seven Service Oriented Views (SOVs) that specify the desirable services in the deployment of SOA. These views describe the specifications, capabilities delivered and services orchestrated together, while focusing on the requirement that the service should fulfill rather than the implementation details. SOA elements in MoDAF models are: service, service interface, SLA, service policy, service function, service attribute and service consumer [17]. MoDAF has a meta-model called the MoDAF Meta-Model (M3) [16].

The predecessor versions of MoDAF were introduced to describe information technology services that appear in the system views. Therefore, the current version requires continuous efforts to allow the service-oriented viewpoint to

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support business services besides the information services. The MoDAF v1.2, with SOA version support, is different from the predecessor in the following views: OV-2, OV-5, OV-6c and SV5. Ov-2 is the Operational Node Connectivity Description that shows the information flow and interdependencies through the operational nodes. Unfortunately, this property is lost in the SOA version because services are implemented independently. OV-5 is the Operational Activity Model that describes capabilities and operations conducted during missions. Following responsibilities is a problem faced when altering the SOA version, otherwise decision making activities will enhance. OV-6c is the Operational Event-Trace Description that utilizes the services' orchestration to clearly trace the services. SV-5 is the Function to Operational Activity/Service Function Traceability Matrix, which depicts the mapping between functions in SV-4 and operational activities or service functions. Confusion between entities, operational activities service and functions is the main problem, leading to unclear analysis [12].

C. DNDAF

DNDAF is an AF used across the Department of National Defense and Canadian Forces (DND/CF) organizations. In (DND/CF) organizations, various architectural products are created, developed and preserved. The main objective of DNDAF is to support this creation through providing some rules and directions that help DND/CF organizations to standardize their products for future comparison or integration.

DNDAF V1.7 is constructed of eight views; each one, in turn, is composed of a list of interrelated sub-views. The views are: Common View (CV), Strategic View (StratV), Capability View (CapV), Operational View (OV), System View (SV), Technical View (TV), Information View (IV) and Security View (SecV).

From the above, we can notice that there is no discrete view for SOA. DNDAF embraced SOA through describing all Zachman framework elements in the DNDAF sub-view, implicitly. For example, the product OV-5a: Function Model describes the operational solutions to implement the objectives. These objectives are decomposed into a set of sub-functions; each is a stand-alone function and metaphorically, we can call it 'services'. Service descriptions are provided through the OV-5a product implicitly. The DND/CF Architecture Data Model (DADM) is used for organizing information in a logical model instead of meta-model. The consistent structure for DADM will potentially increase the interoperability and reusability aspects within the architecture. In addition, DND/CF Reference Models beside Standard Code Values (SCV) provide a set of common terms used to standardize the developing of the architecture, and thus, permit the interoperability. Efficient usage of both methods can strongly empower decision-making and activate the reusability principle [20].

D. NAF

The North Atlantic Treaty Organization (NATO) Architecture Framework (NAF) provides guidance, rules, and product descriptions for developing and describing NATO architecture and presenting architecture information. It consists of different views (i.e., diagrams, lists and text) of NATO enterprise processes, which depict capability, operation, business, system or services. These views are essential for the design, structure and behavior of the operation, mission and business or system. NAF provides tools that help implement NATO capability in a complex multinational environment. NNEC federate systems, sensors and effectors are used to effectively improve military missions. NATO missions are comprised of war-fighting missions and business processes.

NAF v.3 consists of seven views, which are: NATO All View (NAV), NATO Capability View (NCV), NATO Program View (NPV), NATO Operational View (NOV), NATO Systems View (NSV), NATO Service-Oriented View (NSOV) and NATO Technical View (NTV). The NSOV is divided into five additional sub-views, which are: the Service Taxonomy sub-view (NSOV-1), which organizes services in a hierarchy depending on NNEC C4ISR goals and then presents them in the NNEC Service Framework; the Service Definitions sub-view (NSOV-2), which identifies a service and specifies its properties, interface and policies; the Services to Operational Activities Mapping sub-view (NSOV-3), which links between operational activities and supporting services; the Service Orchestration sub-view (NSOV-4), which combines two or more services to provide higher operational processes; and the Service Behaviour sub-view (NSOV-5), which determines service function. One sub-view that is used for implementing SOA appears in NSV and is the Service Provision sub-view (NSV-12), which relates the service to a resource in the operational domain [15]. The advanced version of NAF, NAF v3.1, extends and changes some of the SOA sub-views to be similar to MoDAF v1.2 SOVs, with one more sub-view concern about service composition [8]. The NAF Meta-Model (NMM) expands MoDAF Meta-Model (M3) [15]. In NMM, SOA elements can be: service, service interface, service needline, service policy, service attribute, service level and service behavior [9].

There are many challenges still facing the implementation of SOA in the tactical network of NATO NEC, such as a lack in service discovery and service registry, dynamic security, and network constraints (i.e., bandwidth). Great effort is needed to fully deploy SOA with its full advantages [3].

V. COMPARISON

In section IV, we have reviewed four AFs that are widely used in DoD to fulfill the military missions and provide the best decisions for achieving an entity's desirable goals during battlefield. Table I presents a comparison among the aforementioned architecture frameworks, based on criteria such as SOA appearance, number of SOA subsections, meta-model, service products, reusability and security.

The enormous growth of military environments influences the complexity, reusability and security issues involved in such frameworks. From the review, NAF strongly supports this complexity more than other architectures due to its main goal to cover different nations. MoDAF and NAF are using SOA paradigms that provide a better approach to reuse capabilities during missions. Moreover, the comparison leads to different tactics in

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Table I: A comparison between defense AFs.

AFs / Evaluation Criteria	DoDAFv2.0	MoDAFv1.2	DNDAFv1.7	NAFv3.0
SOA appearance	Explicitly presented as Service Viewpoint (SvcV)	Explicitly presented as Service Oriented Viewpoint (SOVs)	Implicitly presented in the architecture	Explicitly presented as NATO Service-Oriented View (NSOV)
Number of SOA subsections	13 models	7 views	______________	5 subviews
Meta –model	DM2	M3	Data-Model (DADM)	NMM
Service products	SvcV-1, SvcV-2, SvcV-3a, SvcV-3b, SvcV-4, SvcV-5, SvcV-6, SvcV-7, SvcV-8, SvcV-9, SvcV-10a, SvcV-10b, SvcV-10c	SOV-1, SOV-2, SOV-3, SOV-4a, SOV-4b, SOV-4c, SOV-5	______________	NSOV-1, NSOV-2, NSOV-3, NSOV-4, NSOV-5
Reusability	Data-centric approach	SOA paradigms	Data-centric approach	SOA paradigms
Security	Implicitly presented as attributes in each product.	Implicitly presented similar to DoDAF	Explicitly Security View (SecV)	End-to-end security (different level)

handling security issues among architectures. Additional efforts are needed in this regard to have a reliable information flow for effective decision-making. Evidently, DoDAF is the baseline for most of today's defense architectures, as MoDAF, DNDAF and NAF develop their architectures to meet their individual requirements. All DoDs tend to enhance information-sharing mechanisms among heterogynous domains when dramatically expanded. SOA technology offers success in supporting defense architectures to reach DoDs objectives and provides more features to reduce complexity while supporting scalability and reusability.

Although the AFs did show similarity in their content, a clear variation is obvious in embracing SOA. They all presented the concept of SOA, while some did so in an explicit way by creating a distinct, service-oriented view (viewpoint), such as evident in DoDAF and MoDAF. Other AFs presented the SOA concept more implicitly by identifying some SOA elements through architecture views, such as evident in DNDAF. In this paper, we tried to specify and locate the SOA elements in each of the architectures.

Furthermore, it was discovered that the service-oriented view influences some other views, such as the operational view and strategic view. However, obviously, SOA elements have been included in all frameworks, with different levels and sometimes with different terminology.

In such, this variation may affect the SOA performance among the architectures. In addition, different terms used for SOA elements in these architectures may lead to some level of ambiguity. For example, DoDAF uses the term 'service port' to denote the service interface, while the term 'service interface' is used in MoDAF and NAF. Therefore, the need emerges to standardize or unify some of the commonly-used terminology to facilitate their handling and usages.

Some of the previous AFs have meta-model paradigms, such as DoDAF (DM2), MoDAF (3M) and NAF (NMM), while DNDAF uses DADM, which had the same concept. The meta-model shows the relation between SOA elements, themselves, as well as with other elements, and plays a great role in implementing SOA practically.

We conclude our discussion by emphasizing that the SOA is a useful and effective concept that is applicable in military environments. However, the integration of SOA with defense architectures still has limitations in interoperability, reusability and security. More effort and time will bring the SOA technology into practical context with its significance and impressive advantages.

VI. CONCLUSION

Exploitation of SOA artifacts in developing military architectural frameworks is desired for superior information sharing. In such, military organizations harness their potential possibilities to stimulate SOA technology through incorporating the SOA elements in their architectures. Thus, this paper investigated the applicability of SOA in four of the most popular military architectural frameworks, which are: DoDAF, MoDAF, DNDAF and NAF. It addressed the integration of SOA within the original architecture and explored the SOA elements in each framework with a brief explanation about

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its overall effects on the entire architecture of each. A comparison based on SOA-related issues was conducted. The comparison analysis proves the presence of SOA in various degrees and different manners, and tries to position SOA elements in these architectures. Some architecture has shortcomings in SOA features, such as interoperability, reusability and security. These shortcomings may strongly affect the operational missions and should be solved in order to have strong, consistent architecture with full SOA advantages.

VII. FUTURE WORK

Future work can overcome some of the SOA limitations found in this research. One of these limitations is the lack of consistent service elements terminology. This paper claims to have a controlled vocabulary system, which is the formal standardization list for service terms confirmed by competent communities in DoDs. Such a system will unify the terms between the heterogeneous agents to clear any ambiguity, increase interoperability among DoDs, and reduce the cost of ontology systems required for interoperability purposes.

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