Information Technology and Computer Application Engineering

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Table of contents

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Information Technology and Computer Application Engineering – Liu, Sung & Yao (Eds)
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Preface

The 2013 International Conference on Information Technology and Computer Application Engineering (ITCAE 2013) will be held in Hong Kong, during August 27–28, 2013. The aim is to provide a platform for researchers, engineers, academics as well as industrial professionals from all over the world to present their research results and development activities in Computer Application Engineering and Information Science.

For this conference, we received more than 400 submissions via email and the electronic submission system, which were reviewed by international experts, and some 189 papers have been selected for presentation, representing 9 national and international organizations. I believe that ITCAE 2013 will be the most comprehensive conference focused on Computer Application Engineering and Information Science. The conference will promote the development of Computer Application Engineering and Information Science, strengthening international academic cooperation and communications, and the exchange of research ideas.

We would like to thank the conference chairs, organization staff, the authors and the members of the International Technological Committees for their hard work. Thanks are also given to Alistair Bright.

We hope that ITCAE 2013 will be successful and enjoyable for all participants. We look forward to seeing all of you next year at ITCAE 2014.

June, 2013

Wen-Pei Sung
National Chin-Yi University of Technology

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Information Technology and Computer Application Engineering – Liu, Sung & Yao (Eds)

A new hybrid architecture framework for system of systems engineering in the net centric environment

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ABSTRACT: As the emergence of the Net Centric Warfare (NCW), the military information system has been evolved from platform-centric to be net-centric, which brings great challenges for System of Systems (SoS) engineering in the net centric environment. A major task of system engineering is to build system architecture. Although classical system engineering deals very well with architecting problems for a single system, it has no good solutions for SoS architecting problems. In this paper, existing architecture frameworks is evaluated, and a novel architecture framework model for SoS engineering is presented, which combines both advantages of enterprise architecture and system architecture, and enables SoS architecting with the kind of capability based development process.

1 INTRODUCTION

As the military information system moves through the brave new world of Net Centric Warfare (NCW) [1] or Net Enabled Operations (NCO) and the evolution of the U.S. Department of Defense (DoD) Global Information Grid to help implement that vision, the importance of engineering system of system (SoS) in the net centric environment becomes more urgent [2]. The field of system engineering has emerged to address the challenges inherent in these systems, or systems-of-systems. This has necessitated an evolution of the architecting approach, intensified focus on system properties (such as changeability, flexibility, agility, etc.), and recognition of the inseparability of technological system and the enterprise developing and operating such systems.

Architecture frameworks are methods used in system engineering. They provide a structured and systematic approach to designing systems. To date, there are many existing architecture frameworks [3–8] which can be divided into two categories as Enterprise Architecture based Frameworks (EAF) and System Architecture based Frameworks (SAF). These classical architecture frameworks work well with the straightforward requirement and the defined specification for single system design in the stove-piped environment. However, they have no good solutions for SoS design in the net centric environment when optimality and efficiency is not as important as run-time interoperability with services that were not envisioned at design time, and flexibility, compose-ability, and extensibility are now much more important.

The aim of this paper is therefore to develop a new architecture framework to resolve weaknesses in previous frameworks in order to support SoS architecting problems. For this purpose, an overview and evaluation of existing architecture frameworks is given in section 2. Building from here, a novel hybrid architecture framework is presented and analyzed in more details in section 3. The paper concludes with a summary of the proposed method and an outlook of further research in section 4.

2 ARCHITECTURE FRAMEWORKS OVERVIEW

The term "architecture" refers to any kind of socio-technical system, and stands for the fundamental organization of its components and their relationships to each other and the environment as well as the design rules for developing and structuring the system [9]. In order to support architecture descriptions, many architecture frameworks have been developed, which provides directions for developing various architectures and organizing detailed architecture models and architectures that manage tasks inside an enterprise as well as communication to develop the complicated structures of an enterprise [10].

To date, there exists many architecture frameworks, which can be divided into EAF (e.g. Zachman framework [3], FEAF [4], TOGAF [5], etc) and SAF (e.g. C^4ISRAF [6], DoDAF [7], MoDAF [8], etc). The EAF selects a higher level of an enterprise as one scope and uses it as a framework to develop architecture, while the SAF is based on the specific detailed structure of the enterprise, and it selects a sub-enterprise for one scope and applies it to the framework for systematic architecture development.

2.1 *Zachman Architecture Framework (ZAF)*

The ZAF was proposed by John A. Zachman in 1987. It is described in a matrix with (30 cells) which provides on the vertical axis five perspectives (i.e. planner, owner, designer, builder, and sub-contractor) and on the horizontal axis six classifications of the various stakeholders (i.e. Planner, Owner, Designer, Builder and Subcontractor). The ZAF provides clarity to a complicated enterprise, making it possible to identify models for some projects, and is an important factor in alignment. The ZAF is the de-facto framework to provide a model that describes an enterprise well, but this framework is too idealistic. Furthermore, it is difficult to apply because there is no definition of specific products or templates. An additional disadvantage is that there is no process for application of the architecture, so it is difficult to develop architectures.

2.2 *Federal Enterprise Architecture Framework (FEAF)*

The FEAF introduced in 1998 by the Chief Information Office consortium provides an enduring standard for developing and documenting architecture descriptions of high-priority areas. It divides a given architecture into business, data, applications and technology architecture descriptions, which are the four levels the FEAF consists of. In Version 1.0 the FEAF includes the first three columns of the Zachman Framework, so that the FEAF is graphically represented as a 3×5 matrix with architecture types (data, application, and technology) on one axis of the matrix and perspectives (planner, owner, designer, builder and subcontractor) on the other. The FEAF defines and clearly explains architecture descriptions for each level to allow better understanding of enterprise architecture concepts. However, even though the framework deals with high-level concepts, it has no template or product for development.

2.3 *The Open Group Architecture Framework (TOGAF)*

The TOGAF is an industry standard architecture framework that may be used freely by any organization wishing to develop enterprise architecture descriptions for the use within that organization. It is a detailed framework using a set of supporting tools [11]. It enables designing, evaluating, and building the right architecture for any organization. The key to TOGAF is the TOGAF Architecture Development Method (ADM) – a reliable, proven approach for developing enterprise architecture descriptions that meets the needs of the specific business. Even though TOGAF ADM describes the different inputs and outputs for each phase of the architecture development cycle, there are no specification documents that describe the output.

2.4 *C^4ISR Architecture Framework (C^4ISRAF)*

The Command, Control, Communication, Computer, Intelligence, Surveillance, and Reconnaissance Architecture Framework (C^4ISRAF) was developed by the Architecture Working Group (AWG) of the United States Department of Defense in 1997. It provides 27 concrete templates to facilitate target information system development by using operational view (OV), system view (SV) and technical view (TV). Besides it contains four main types of guidance for architecture development: (1) guidelines, (2) a high level process for using the framework, (3) a discussion of architecture data and tools, and (4) a detailed description of the products. However, it does not provide conceptual perspectives and views as in the ZAF, and there are no specific descriptions about who is responsible or needed in each step of the procedure model to develop architecture descriptions.

2.5 *Department of Defense Architecture Framework (DoDAF)*

The DoDAF is developed specifically for the US DoD to support its war-fighting operations, business operations and processes. It grew from and replaced the previous architecture framework, C4ISRAF. The DoDAF includes guidelines on determining architecture content based on intended use; focus on using architectures in support of DoD's Programming, Budgeting, and Execution process; Joint Capabilities Integration and Development System; and the Defense Acquisition System; and increasing emphasis on the architecture data elements. Architecture development techniques have been provided in DoDAF to specify processes for scope definition, data requirements definition, data collection, architecture objectives analysis and documentation. However, a role model for the development process is also missing in the DoDAF.

2.6 *Ministry of Defense Architecture Framework (MoDAF)*

The MoDAF was evolved from U.S. DoDAF with the purpose of facilitating architecture information exchange with U.S. forces. Therefore, the MODAF is consistent with DoDAF in most views, such as OV, SV and TV, and augments it with two new views, i.e. strategy view (StV) and acquisition view (AcV) for analyzing and optimizing ministry capabilities and providing support to associated acquisition plans. Although the MODAF divides architecture users into three kinds and provides guides of architecture development for each kind of users, it also does not provide conceptual perspectives as in the ZAF, and there are no specific descriptions of user role in the architecture development process.

A comprehensive comparison of existing architecture frameworks is shown in Table 1, where "Product/Template" denotes specification document of the

Table 1. Comparison of Current Architecture Frameworks.

	EAF			SAF		
	ZAF	FEAF	TOGAF	C^4ISAF	DoDAF	MoDAF
Products/Template	⊙	⊙	○	●	●	●
Architecture role	●	●	○	○	○	⊙
Meta model	○	○	○	⊙	●	⊙
Supporting technique	○	○	⊙	●	●	●
Development process	○	⊙	●	●	●	●

*Legend: ● Fully accomplished; ⊙ Partly accomplished; ○ Not accomplished

architecture, "Architecture role" denotes participating roles for the development and management of the architecture descriptions, "Meta model" denotes how the architecture data normally collected, organized, and maintained, "Supporting technique" denotes the modeling technique for architecting, and "Development process" denotes how the architecture (product or template) is constructed [12].

It can be observed from Table 1 that EAFs usually have strengths in describing architecture roles due to its conceptual perspectives and views. But they have weaknesses in providing specific products and development process, so they are very difficult to apply in reality. In contrast, SAFs have considered no or partly architecture roles, but generally have specification document, supporting technique (e.g. UML), and elaborate development process. Furthermore, it should be mentioned that roles and the procedure are related to each other. If there is no procedure model provided by a method, the definition of roles for the development process would not make any sense.

3 HYBRID ARCHITECTURE FRAMEWORK (HAF)

3.1 *The overall architecture*

In the following, a new hybrid architecture framework (HAF) resolving the weaknesses mentioned above, is proposed by combing both advantages of EAF and SAF and by introducing a new set of architecture products and its associated development process. The overall HAF is shown in Figure 1 and a description of the framework is given in the subsequent paragraphs.

3.1.1 *Architecture views*

The architecture is split up into four views: the Capability View (CV), the Operational View (OV), the System/Service View (SV) and the Technical View (TV).

The Capability View (CV) captures the enterprise goals associated with the overall vision for executing a specified course of action, or the ability to achieve a desired effect under specific standards and conditions through combinations of means and ways to perform a set of tasks. It provides a strategic context for the capabilities described in an architectural description,

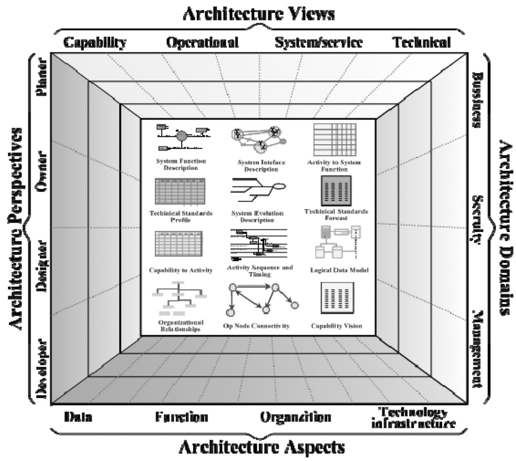

Figure 1. The Overall HAF Model.

and an accompanying high-level scope, more general than the scenario-based scope defined in an operational concept diagram. The models are high-level and describe capabilities using terminology, which is easily understood by decision makers and used for communicating a strategic vision regarding capability evolution.

The Operational View (OV) helps to give an understanding of the operational environment (the operational scenarios, processes and organization) for which systems will developed to support the operational (command and control) processes. Understanding of the operational processes is a prerequisite for the design and development of flexible solutions in the sense of information and communication systems. The OV describes the operational processes, their relationships, process threads that will be triggered by operational events and the description of the process by operational services.

The System/Service View (SV) captures system, service, and interconnection functionality providing for, or supporting, operational activities. It describes which applications and communication systems will be present, how they will interact and where the operational services will be implemented. Identified applications can be existing legacy applications, can be part of a newly installed package or can be newly built within or outside a program. It also describes the architecture of the individual systems by means of components that deliver services to support operational services for specific operational processes. Over time, the emphasis on service oriented environment and cloud computing may transform system view into service view.

The Technical View (TV) defines the infrastructure (middleware, hardware, network, transmissions media, protocols etc.) required to run systems. The other views mainly trigger the development and change, not only by the functionality but also by the characteristics of those views. Characteristics include performance requirements, volume figures, frequencies, actuality of information, method of use of functionality and resources, etc. The development and implementation of the technical infrastructure take these characteristics as a major input.

Although they are separate architecture views, the four have strong relationships and for the different aspects of business, security and management, they together form the HAF.

3.1.2 *Architecture perspectives*

The architecture consists of four perspectives: planner, owner, designer, and developer. A perspective is simply a point of view of the EA, and is mapped to a particular set of work products. Perspectives have a specific role in representing the enterprise or examining an organizational entity in the enterprise.

The Planner's Perspective identifies a skeleton of the organization and its function and category, and defines the function, size, and relativity to other systems so that the information system can be finally implemented. The planner is usually the information system project manager.

The Owner's Perspective creates a blueprint for an end-state information system and defines organizational function, the entities included in the process, and the relationship among those. The owner brings forward requirements for the information system.

The Designer's Perspective is a detailed specification for information system at a high level, based on an organization's function model.

The developer's Perspective is redefined at a high level, during which process the developer is constrained by developing tools, IT, and resources. Especially, the technology model specifies the concrete architecture from overall to atomic system scope and a specific part of sub-domains, for example, a programming language, I/O device, etc.

3.1.3 *Architecture aspects*

The architecture is composed of four aspects: data, function, organization, and technology infrastructure, an aspect means a specific view for observing a related special feature. As a general concept of information technology, applications consist of data and functions. In this case, the sub-hierarchy of an application is the shared data and common functions in the overall enterprise architecture.

The Data Aspect describes the set of data needed to perform enterprise data flow and the relationships in the EA database.

The Function Aspect describes enterprise functions, processes, and activities that act on enterprise information to support enterprise operations.

The Organization Aspect consists of the organizational structure of the enterprise, the major operations performed by organizations, the types of workers, the organization breakdown structure, and the distribution of the organizations to locations.

The Technology Infrastructure Aspect consists of the hardware, software, network, telecommunications, and general services that constitute the operational environment in which business applications operate.

3.1.4 *Architecture domains*

The architecture covers three main domains: Business, Security and Management.

The Business Architecture is the most important one that describes the core functionality of a business. This functionality deals with the vision, mission and goals of the organization. The Business Architecture is therefore the primary architecture and the others are supporting architectures for other aspects.

The Security Architecture describes the security that must be taken into account for the formulated business functionality. The architecture of the other domains follows the same structure and also covers the same four views, i.e. CV, OV, SV and TV. For example, the Security at the SV level describes the security with respect to the Systems (e.g. information systems and communication systems) in the Business Architecture.

The Management Architecture describes the management domain that is needed for the control and changes of the implemented business functionality, as well as the implemented security. It also encompasses the management of the system operations, the control, administration and management of the objects which will be taken into operation and which are liable to change. This domain also covers the administration and maintenance of the results of the business process modeling activities.

3.2 *Architecture products*

3.2.1 *Product list*

The architecture has a total of 33 products [7], which are divided into 5 categories according to architecture views, as shown in Table 2. The first column indicated the view applicable to each product. The second column provides an alphanumeric identifier and the formal name of the product. The fourth column captures the general nature of the product's content.

As shown in Table 2, most of architecture products are obtained from DoDAF. The framework also defines 2 products in the All View (AV) to describe the overview and summary information and the definition of architecture data. Additionally, in order to describe high level concepts of system/service from the Technology infrastructure aspects on the perspective of a planer, a Technical Reference Model (TV-1) used to define the interface within or without systems/services, is introduced. Furthermore, it should be noted that the sequence of products in the table does not imply a sequence for developing the products.

3.2.2 *Product Mapping*

A mapping of architecture products listed in the above paragraph on the perspectives and aspects of the framework is given in Figure 2. It can be seen that in the framework, Rows 1 and 2 (on the perspective of Planer and Owner) contain the products for the operation,

Table 2. The HAF Products List.

Views	Products	Descriptions
All View	AV-1:Overview and Summary Information	Describes a Project's Visions, Goals, Plans, Activities, Events, Conditions, Effects, and produced objects.
	AV-2:Integrated Dictionary	An architectural data repository with definitions of all terms used.
Capability View	CV-1:Vision	The overall vision for endeavors, which provides a strategic context for the capabilities described.
	CV-2:Capability Taxonomy	A hierarchy of capabilities which specifies all the capabilities throughout Architectural Descriptions.
	CV-3:Capability Phasing	The planned achievement of capability at different points in time or during specific periods of time.
	CV-4:Capability Dependencies	The dependencies between planned capabilities and the definition of logical groupings of capabilities.
	CV-5a:Capability to Systems/Services Mapping	A mapping between the capabilities and the systems/ services that these capabilities required.
	CV-5b:Capability to Operational Activities Mapping	A mapping between the capabilities required and the operational activities that those capabilities support.
Operational View	OV-1:High Level Operational Concept Graphic	The high-level graphical/textual description of the operational concept.
	OV-2:Operational Node Connectivity Description	A description of the operational nodes with needlines between those nodes that indicate exchange information.
	OV-3:Operational Information Exchange Matrix	A description of the information flows exchanged between operational activities.
	OV-4:Organizational Relationships Chart	The organizational context, role or other relationships among organizations.
	OV-5:Operational Activity Model	The context of capabilities and activities and their relationships among activities, inputs, and outputs
	OV-6a:Operational Rules Model	It identifies business rules that constrain operations.
	OV-6b:State Transition Description	It identifies business process responses to events.
	OV-6c:Event-Trace Description	It traces actions in a scenario or sequence of events.
	OV-7:Logical Data Model	The documentation of the data requirements and structural business process (activity) rules.
System/ Service View	SV-1:Systems/Services Interface Description	Identification of systems nodes, systems, system items, services, and service items and their interconnections
	SV-2:Systems/Services Communications Description	Systems nodes, systems, and services and their related communications laydowns.
	SV-3:Systems/Services -Systems/ervices Matrix	Relationships among systems and services; can be designed to show relationships of interest.
	SV-4:Systems/Services Functionality Description	Functions performed by systems/services and the /services data flows among system functions
	SV-5:Operational Activity to Systems/Services Traceability Matrix	Mapping of system, system functions, or service back to operational activities.
	SV-6:Systems/Services Data Exchange Matrix	Provides details of system or service data elements being exchanged and the attributes of that exchange.
	SV-7:Systems/Services Performance Parameters Matrix	Performance characteristics of Systems and Services View elements for the appropriate time frame(s).
	SV-8:Systems/Services Evolution Description	Planned incremental steps toward migrating a suite of systems or services to a more efficient suite.
	SV-9:Systems/Services Technology Forecast	Emerging technologies and software/hardware products that are expected to be available.
	SV-10a:Systems/Services Rules Model	Identification of constraints that are imposed on systems/services functionality
	SV-10b:Systems/Services State Transition Description	Identification of responses of a system/service to events
	SV-10c:Systems/Services Event-Trace Description	Identification of system/service-specific refinements of critical sequences of events in the Operational View.
	SV-11:Physical Data Model	The physical implementation format of the Logical Data Model entities.
Technique View	TV-1:Technical Reference Model	The model that defines the interface with systems/services in the System/Service View.
	TV-2:Technical Standards Profile	Listing of standards that apply to Systems and Services View elements in a given architecture.
	TV-3:Technical Standards Forecast	Description of emerging standards and potential impact on current Systems and Services View elements.

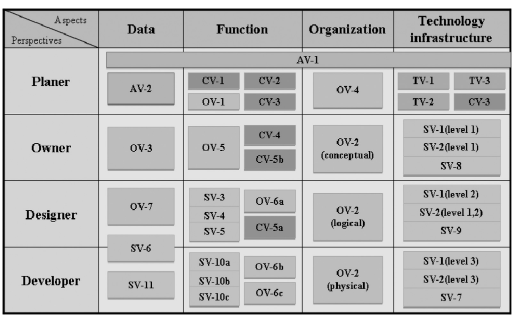

Figure 2. Mapping of architecture products on the perspectives and aspects of the framework.

and Rows 3 and 4 (on the perspective of Designer and Development) contain the products for the system.

Moreover, as the architecture development goes from plan to develop or implementation, the phases or level of associated products will be refined. For example, OV-1 on the perspective of Owner gives conceptual relationships among operational nodes, while on the perspective of Designer, it should describe information exchange (i.e. needlines) of nodes logically in more details.

3.2.3 *Relationship among products*

All products in HAF have a mutual relationship among themselves from the enterprise point of view. Figure 3 shows the relationship among products according to

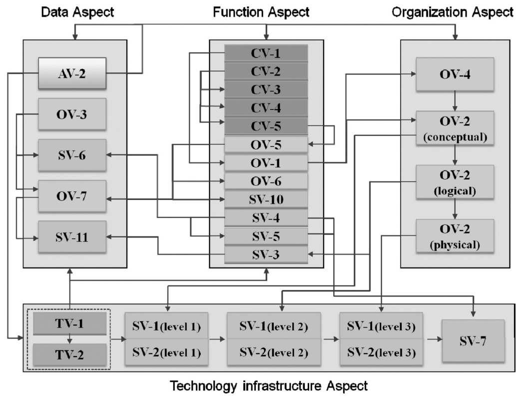

Figure 3. Relationship among Products on the Aspects of HAF.

each aspect. In each aspect, a sub-component function is inherited using a top-down methodology in stages.

In the aspect of Data, integrated dictionary (AV-1) defines all products and affects the Data, Function, and Technology infrastructure aspects. It must therefore be defined and updated until the product is fully completed. In the aspect of Function, the activity model (OV-5) is related with the operation rule model (OV-6a), operational state diagram (OV-6b), event trace diagram (OV-6c), system/service rule model (SV-10a), system/service state diagram (SV-10b), and system/service event trace (SV-10c), which describe sequence and timing. Moreover, the high level operational concept (OV-1) connects the operation node (OV-2) in the aspect of Organization, which in turn connects with the system node/interface (SV-1) in the aspect of Technology infrastructure at the corresponding level.

3.3 *Architecture development process*

With respect to a software development lifecycle [13], we propose a 5-step development process for the HAF as shown in Figure 4. The first step is to get organized, which consists of scoping the project, setting up the development team, and defining a target vision. The arrows represent initial relationships, and for implementing the target architecture at least one or two iteration of steps 2 through 5 should be performed. However, this is only the iteration at a high level. Iteration also occurs within steps. Steps 2 through 5 each have their own loops. Within step 3, for example, you may go back and forth between two aspects or loop through all the aspects more than once.

Furthermore, a capability based analysis process for architecture development is also proposed for the architecture development with steps, especially for step 2 and 3, as shown in Figure 5. The main idea is in that architecture development starts from or is based on capability vision, which is used to determine operational concepts and associated activities or tasks. In contrast to activity based method (ABM) that subjects to support specified tasks or requirements, the

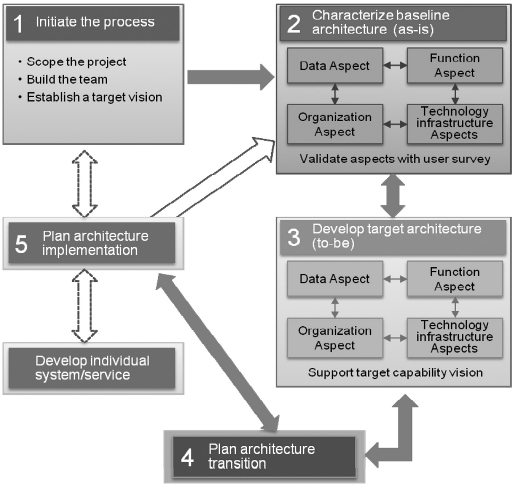

Figure 4. Development Process for HAF.

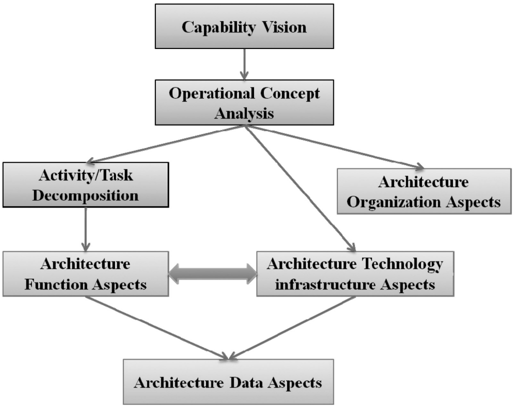

Figure 5. Capability based Analysis Process for Architecture Development.

capability based method (CBM) [14] is very suitable for building system of systems with various tasks or requirements, because its focus on capability design and implementation.

4 CONCLUSIONS

The implications behind Net Centric Warfare (NCW) or Net Enabled Operations (NCO) bring great challenges for architecting system of system (SoS) in the net centric environment. This has necessitated an evolution of the architecting approach considering SoS properties (such as changeability, flexibility, agility, etc.). In this paper, a new architecture framework for SoS engineering is proposed, which combines advantages existing frameworks by defining various views, perspectives, aspects and domains of the architecture. Furthermore, a capability based method (CBM) for SoS architecture development is introduced in order to support SoS engineering in the net centric environment. Further researches will be done to validate the effectives of the proposed framework and its associated development process.

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