Architecting a Network-Centric M&S Application

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**The Process of Architecting**

- **Architecting** is the process of creating and specifying an architecture for a network-centric M&S application based on the Conceptual Model and the M&S Requirements Specification Document (RSD).

- The process of Architecting takes the Conceptual Model and M&S RSD as input and produces a network-centric M&S Architecture Specification as the output work product.

- Architecting Quality Assurance (QA) integrates the assessments of
  - quality of the Architecture Specification work product,
  - quality of the architecting process,
  - quality of the people employed in architecting, and
  - project characteristics related to the life cycle stage for architecting.
The Process of Architecting

The output, Architecture Specification, is created using a standard description framework such as DoD Architecture Framework (DoDAF).
Is “Architect” a Verb?

- Both the Oxford English Dictionary and Merriam-Webster’s Third International dictionary list “architect” as a verb.

- Architect → (noun) a professional who creates an architecture

- Architect → (verb) act of creating an architecture

- Can you say “an Architecture”? YES!

- Can you say “Architectures”? YES!

- Merriam-Webster’s 11th Collegiate Dictionary →

  Main Entry: architecture
  Pronunciation: 'är-kept-cher
  Function: noun
  Date: 1555

1: the art or science of building; specifically: the art or practice of designing and building structures and especially habitable ones
2 a: formation or construction resulting from or as if from a conscious act (the architecture of the garden)
   b: a unifying or coherent form or structure (the novel lacks architecture)
3: architectural product or work
4: a method or style of building
5: the manner in which the components of a computer or computer system are organized and integrated
Example Architectures
The Architecting process deals with the creation of an architecture for a network-centric M&S application to satisfy the requirements stated in the RSD.

The Architecting process can be conducted by

- **Selection** of a known architecture,
- **Composition** of an architecture from a set of known architectures, or
- **Creation** of a new architecture.

“The **structure** of components, their **relationships**, and the **principles** and **guidelines** governing their design and evolution over time.”


“An architecture is the **fundamental organization** of a system embodied in its components, their **relationships** to each other, and to the environment, and the **principles** guiding its design and evolution.”

[IEEE STD 1471-2000]
Terminology

- Cloud Computing
- Cyberinfrastructure engineering
- Distributed system/software engineering
- E-system (e.g., e-business, e-government) engineering
- Internet-based system/software engineering
- Network-centric system/software engineering
- Online system/software engineering
- Web engineering
- Web-based system/software engineering

All of the terms above imply a system the components of which interoperate with each other over a network (e.g., Internet, virtual private network, wireless network) and the user uses the system over that network.
A network-centric M&S architecture refers to the
• fundamental organization of M&S components that interoperate with each other over a network,
• relationships among the M&S components, and
• the principles and guidelines governing the design and evolution of those M&S components.

We use the term “network” to refer to one or a combination of many types of communications networks such as
• Global System for Mobile communication (GSM),
• Internet,
• local area network (LAN),
• mobile ad-hoc network (MANET),
• virtual private network (VPN), or
• wireless network.
A design is an instantiation from an architecture similar to how an object is an instantiation from a class.

Example:

Client 1
Client 2
Client 3
Client N
Relational DBMS
SQL Server
HTTP Server
Application Server
Server Computer
Network

Instantiation

Design based on the .Net platform

Instantiation

Design based on the Java EE platform
Major Network-Centric System/Software Architectures that can be used for a Network-Centric M&S application:

1. Client-Server Architecture (CSA)
2. Distributed Objects Architecture (DOA)
3. Service-Oriented Architecture (SOA)

DoD / IEEE / NATO Standard Network-Centric (i.e., Distributed) M&S Architecture:

- High Level Architecture (HLA)

DoD Standard Description of Network-Centric Architectures

- DoD Architecture Framework (DoDAF)
Client-Server Architecture (CSA)

Two industry software standards for CSA:

- **Java EE-based Client-Server Architecture**
  

- **Microsoft .NET-based Client-Server Architecture**
  
  Microsoft (2013), “[Microsoft platform .NET Framework](https://docs.microsoft.com/en-us/dotnet),” Microsoft Corporation, Redmond, WA.
A Client-Server Architecture with Example Components

Network

Client 1

Client 2

Client 3

Client N

IBM WebSphere Application Server

App Server

HTTP Server

SQL Server

IBM HTTP Server

JDBC Driver

Relational DBMS

IBM DB2 Database

Server Computer
Example IBM Development and Deployment Environment

IBM Rational Application Developer for WebSphere Software

Client (Web Browser)

IBM HTTP Server

IBM WebSphere Application Server

IBM DB2 Database

JDBC

Data Base

Send

Receive

Publish HTML, Servlets, JSPs, EJBs, Java

Export

JDBC
Thin and Thick Clients

Thin-Client Model

- In a thin-client model, all of the application processing and data management is carried out on the server. The client is simply responsible for running the presentation software.
- A thin-client computer accesses applications and data from a server.

Thick-Client Model

- In this model, the server is only responsible for data management. The software on the client implements the application logic and the interactions with the system user.
- A thick-client computer includes an operating system and installed applications and can run either as a standalone or in a server environment.
Thin and Thick Clients

- **Thin-Client Model**
  - A major disadvantage is that it places a heavy processing load on both the server and the network

- **Thick-Client Model**
  - More processing is delegated to the client as the application processing is locally executed
  - Most suitable for new client-server systems where the capabilities of the client system are known in advance
  - More complex than a thin client model especially for management. New versions of the application have to be installed on all clients
Java EE-based Client-Server Architecture

1. **Data Source Layer** (Relational DBMS such as DB2, Oracle, SQL Server)
2. **Data Mapping Layer** (JDBC, Entity EJBs)
3. **Business Logic Layer / Domain Logic Layer / EJB Container Layer** (EJBs)
4. **Web Container Layer** (Servlets, JSP, JSF)
5. **Client Presentation Layer** (JavaScript, XML, AJAX, XHTML, CSS, XSLT, DOM)
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
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<tr>
<td>AJAX</td>
<td>Asynchronous JavaScript and XML</td>
</tr>
<tr>
<td>CSS</td>
<td>Cascading Style Sheets</td>
</tr>
<tr>
<td>DOM</td>
<td>Document Object Model</td>
</tr>
<tr>
<td>EJB</td>
<td>Enterprise Java Bean</td>
</tr>
<tr>
<td>HTML</td>
<td>HyperText Markup Language</td>
</tr>
<tr>
<td>HTTP</td>
<td>HyperText Transfer Protocol</td>
</tr>
<tr>
<td>Java EE</td>
<td>Java Platform, Enterprise Edition</td>
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<tr>
<td>JSF</td>
<td>Java Server Face</td>
</tr>
<tr>
<td>JSP</td>
<td>Java Server Page</td>
</tr>
<tr>
<td>RDBMS</td>
<td>Relational Data Base Management System</td>
</tr>
<tr>
<td>SQL</td>
<td>Structured Query Language</td>
</tr>
<tr>
<td>XHTML</td>
<td>Extensible HTML</td>
</tr>
<tr>
<td>XML</td>
<td>Extensible Markup Language</td>
</tr>
<tr>
<td>XSLT</td>
<td>Extensible Stylesheet Language Transformation</td>
</tr>
</tbody>
</table>
A Web-based Client-Server Visual Simulation Architecture

Web-based Queuing System Simulation System (WebQS3)

WebQS3 Simulator

Play the WebQS3 Simulator Video

Microsoft .NET-based Client-Server Architecture

Data Source Layer (Relational DBMS such as DB2, Oracle, SQL Server)

Data Mapping Layer (ActiveX Data Objects - ADO.NET)

Business Logic Layer / Domain Logic Layer (Managed Components, .NET Framework Class Library)

Web Container Layer (IIS, Active Server Pages - ASP.NET)

Client Presentation Layer (JavaScript, XML, AJAX, XHTML, CSS, XSLT, DOM, Web Forms, Windows Forms)
1. **Common Object Request Broker Architecture (CORBA)**

   - Interface Definition Language (IDL)
   - Object Request Broker (ORB)

2. **Microsoft’s Distributed Component Object Model (DCOM)**
An Example Composition of CSA and DOA

DOA (CORBA)

Client-Server Architecture

BEST = Battlespace Environment and Signatures Toolkit
A simulation integrated development environment (IDE)
Service-Oriented Architecture

- Provider independence.
- Public advertising of service availability.
- Potentially, run-time service binding.
- Opportunistic construction of new services through composition.
- Pay for use of services.
- Smaller, more compact applications.
- Reactive and adaptive applications.
Service-Oriented Architecture (SOA)

Web Services-based SOA

• **XML:** eXtensible Markup Language
• **TCP/IP:** Transmission Control Protocol / Internet Protocol
• **HTTP:** HyperText Transfer Protocol
• **SOAP:** Simple Object Access Protocol, an XML-based messaging protocol used to encode the information in web service request and response messages before sending them over a network.
• **WSDL:** Web Services Description Language, an XML-formatted language used to describe a Web service's capabilities.
• **UDDI:** Universal Description, Discovery and Integration, a web-based distributed directory that enables listing of web services and discovering each other, similar to a traditional phone book's yellow and white pages.
Service-Oriented Architecture

Layer Number
4

Services Management

Security

Orchestration
Composition of Services
BPEL
Delivery of Services

Grid Computing Services
Information Services
Policy-based Services
Other Services

Application Services
COI-Specific Services
Data Services
Enterprise Services

Service Requestor
Routing
Conversion
Transformation
UDDI

Service Provider

Enterprise Service Bus (ESB)

Web Services

HTTP
HTTPS
SMTP

Protocols
IPv6
TCP/IP
Others

Communications
Mobile Ad Hoc Networking
Multicast Networking

Transport

Wireless Networks
Wireless Sensor Networks
Wireline Networks

Sensor Nodes

Communication Nodes

Intended Uses of the system to be developed

Universe of Discourse
Service-Oriented Architecture (SOA)
A simulation application running on a client or server computer sends an RVG service request as an XML file over the network to the RVG web service provider software running on a server computer.

Random Variate Generation (RVG) Web Service for Stochastic Simulations

Simulation 1

Internet

HTTP Server

SOAP Request

RVG Web Service

Entity EJBs

Database (DB2)

Simulation 2

Simulation N

SOAP Response

RVG Service in XML

IBM WebSphere Application Server

RVG Web Service Provider Server Computer (http://sunfish.cs.vt.edu/)

High Level Architecture (HLA)

- HLA is a general purpose architecture that facilitates interoperability among network-centric M&S applications and enables reuse of M&S applications and their components.
- HLA-compliant M&S applications running on different hardware platforms can interoperate with each other over a network.
- Interoperability among the network-centric M&S applications is enabled by a RunTime Infrastructure (RTI).
- HLA is an IEEE Standard, a DoD Standard, and a NATO Standard.

HLA is composed of three major components:

- **HLA Rules**
  - A set of ten basic rules that together describe the general principles defining the HLA.

- **HLA Interface Specification**
  - A description of the functional interface between simulations (federates) and the HLA runtime infrastructure (RTI).

- **HLA Object Model Template (OMT)**
  - A specification of the common format and structure for documenting HLA object models.
The U.S. Department of Defense (DoD) Architecture Framework (DoDAF):

- "Provides a foundational framework for developing and representing architecture descriptions that ensure a common denominator for understanding, comparing, and integrating architectures across organizational, Joint, and multinational boundaries.
- It establishes data element definitions, rules, and relationships and a baseline set of products for consistent development of systems, integrated, or federated architectures.
- These architecture descriptions may include Families of Systems (FoSs), Systems of Systems (SoSs), and net-centric capabilities for interoperating and interacting in the Network-Centric Environment."
DoDAF Version 2.0

Architecture Viewpoints in DoDAF V2.0

- **Capability Viewpoint**: Articulate the capability requirement, delivery timing, and deployed capability.

- **Operational Viewpoint**: Articulate operational scenarios, processes, activities & requirements.

- **Services Viewpoint**: Articulate the performers, activities, services, and their exchanges providing for, or supporting, DoD functions.

- **Systems Viewpoint**: Articulate the legacy systems or independent systems, their composition, interconnectivity, and context providing for, or supporting, DoD functions.

- **Project Viewpoint**: Describes the relationships between operational and capability requirements and the various projects being implemented; Details dependencies between capability management and the Defense Acquisition System process.

- **Standards Viewpoint**: Articulate applicable Operational, Business, Technical, and Industry policy, standards, guidance, constraints, and forecasts.

- **Data and Information Viewpoint**: Articulate the data relationships and alignment structures in the architecture content.

- **All Viewpoint**: Overarching aspects of architecture context that relate to all views.
<table>
<thead>
<tr>
<th>Models</th>
<th>Descriptions</th>
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</thead>
<tbody>
<tr>
<td>AV-1: Overview and Summary Information</td>
<td>Describes a Project's Visions, Goals, Objectives, Plans, Activities, Events, Conditions, Measures, Effects (Outcomes), and produced objects.</td>
</tr>
<tr>
<td>AV-2: Integrated Dictionary</td>
<td>An architectural data repository with definitions of all terms used throughout the architectural data and presentations.</td>
</tr>
<tr>
<td>CV-1: Vision</td>
<td>The overall vision for transformational endeavors, which provides a strategic context for the capabilities described and a high-level scope.</td>
</tr>
<tr>
<td>CV-2: Capability Taxonomy</td>
<td>A hierarchy of capabilities which specifies all the capabilities that are referenced throughout one or more Architectural Descriptions.</td>
</tr>
<tr>
<td>CV-3: Capability Phasing</td>
<td>The planned achievement of capability at different points in time or during specific periods of time. The CV-3 shows the capability phasing in terms of the activities, conditions, desired effects, rules complied with, resource consumption and production, and measures, without regard to the performer and location solutions.</td>
</tr>
<tr>
<td>CV-4: Capability Dependencies</td>
<td>The dependencies between planned capabilities and the definition of logical groupings of capabilities.</td>
</tr>
<tr>
<td>CV-5: Capability to Organizational Development Mapping</td>
<td>The fulfillment of capability requirements shows the planned capability deployment and interconnection for a particular capability phase. The CV-5 shows the planned solution for the phase in terms of performers and locations and their associated concepts.</td>
</tr>
<tr>
<td>CV-6: Capability to Operational Activities Mapping</td>
<td>A mapping between the capabilities required and the operational activities that those capabilities support.</td>
</tr>
<tr>
<td>CV-7: Capability to Services Mapping</td>
<td>A mapping between the capabilities and the services that these capabilities enable.</td>
</tr>
</tbody>
</table>
## DoDAF V2.0 Models

<p>| DIV-1: Conceptual Data Model | The required high level data concepts and their relationships. |
| DIV-2: Logical Data Model | The documentation of the data requirements and structural business process (activity) rules. In DoDAF V1.5, this was the OV-7. |
| DIV-3: Physical Data Model | The physical implementation format of the Logical Data Model entities, e.g., message formats, file structures, physical schema. In DoDAF V1.5, this was the SV-11. |
| OV-1: High Level Operational Concept Graphic | The high-level graphical/textual description of the operational concept. |
| OV-2: Operational Resource Flow Description | A description of the resource flows exchanged between operational activities. |
| OV-3: Operational Resource Flow Matrix | A description of the resources exchanged and the relevant attributes of the exchanges. |
| OV-4: Organizational Relationships Chart | The organizational context, role or other relationships among organizations. |</p>
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<tr>
<td>OV-5a: Operational Activity Decomposition Tree</td>
<td>The capabilities and activities (operational activities) organized in an hierarchal structure.</td>
</tr>
<tr>
<td>OV-5b: Operational Activity Model</td>
<td>The context of capabilities and activities (operational activities) and their relationships among activities, inputs, and outputs; Additional data can show cost, performers or other pertinent information.</td>
</tr>
<tr>
<td>OV-6a: Operational Rules Model</td>
<td>One of three models used to describe activity (operational activity). It identifies business rules that constrain operations.</td>
</tr>
<tr>
<td>OV-6b: State Transition Description</td>
<td>One of three models used to describe operational activity (activity). It identifies business process (activity) responses to events (usually, very short activities).</td>
</tr>
<tr>
<td>OV-6c: Event-Trace Description</td>
<td>One of three models used to describe operational activity (activity). It traces actions in a scenario or sequence of events.</td>
</tr>
<tr>
<td>PV-1: Project Portfolio Relationships</td>
<td>Describes the dependency relationships between the organizations and projects and the organizational structures needed to manage a portfolio of projects.</td>
</tr>
<tr>
<td>PV-2: Project Timelines</td>
<td>A timeline perspective on programs or projects, with the key milestones and interdependencies.</td>
</tr>
<tr>
<td>PV-3: Project to Capability Mapping</td>
<td>A mapping of programs and projects to capabilities to show how the specific projects and program elements help to achieve a capability.</td>
</tr>
<tr>
<td>SvcV-1 Services Context Description</td>
<td>The identification of services, service items, and their interconnections.</td>
</tr>
<tr>
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</tr>
<tr>
<td>SvcV-2 Services Resource Flow Description</td>
<td>A description of resource flows exchanged between services.</td>
</tr>
<tr>
<td>SvcV-3a Systems-Services Matrix</td>
<td>The relationships among or between systems and services in a given Architectural Description.</td>
</tr>
<tr>
<td>SvcV-3b Services-Services Matrix</td>
<td>The relationships among services in a given Architectural Description. It can be designed to show relationships of interest, (e.g., service-type interfaces, planned vs. existing interfaces).</td>
</tr>
<tr>
<td>SvcV-4 Services Functionality Description</td>
<td>The functions performed by services and the service data flows among service functions (activities)</td>
</tr>
<tr>
<td>SvcV-5 Operational Activity to Services Traceability Matrix</td>
<td>A mapping of services (activities) back to operational activities (activities).</td>
</tr>
<tr>
<td>SvcV-6 Services Resource Flow Matrix</td>
<td>It provides details of service resource flow elements being exchanged between services and the attributes of that exchange.</td>
</tr>
<tr>
<td>SvcV-7 Services Measures Matrix</td>
<td>The measures (metrics) of Services Model elements for the appropriate time frame(s).</td>
</tr>
<tr>
<td>SvcV-8 Services Evolution Description</td>
<td>The planned incremental steps toward migrating a suite of services to a more efficient suite or toward evolving current services to a future implementation.</td>
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<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>SvcV-9 Services Technology &amp; Skills Forecast</td>
<td>The emerging technologies, software/hardware products, and skills that are expected to be available in a given set of time frames and that will affect future service development.</td>
</tr>
<tr>
<td>SvcV-10a Services Rules Model</td>
<td>One of three models used to describe service functionality. It identifies constraints that are imposed on systems functionality due to some aspect of system design or implementation.</td>
</tr>
<tr>
<td>SvcV-10b Services State Transition Description</td>
<td>One of three models used to describe service functionality. It identifies responses of services to events.</td>
</tr>
<tr>
<td>SvcV-10c Services Event-Trace Description</td>
<td>One of three models used to describe service functionality. It identifies service-specific refinements of critical sequences of events described in the Operational Viewpoint.</td>
</tr>
<tr>
<td>StdV-1 Standards Profile</td>
<td>The listing of standards that apply to solution elements.</td>
</tr>
<tr>
<td>StdV-2 Standards Forecast</td>
<td>The description of emerging standards and potential impact on current solution elements, within a set of time frames.</td>
</tr>
<tr>
<td>SV-1 Systems Interface Description</td>
<td>The identification of systems, system items, and their interconnections.</td>
</tr>
<tr>
<td>SV-2 Systems Resource Flow Description</td>
<td>A description of resource flows exchanged between systems.</td>
</tr>
<tr>
<td>SV-3 Systems-Systems Matrix</td>
<td>The relationships among systems in a given Architectural Description. It can be designed to show relationships of interest, (e.g., system-type interfaces, planned vs. existing interfaces).</td>
</tr>
<tr>
<td>SV-4 Systems Functionality Description</td>
<td>The functions (activities) performed by systems and the system data flows among system functions (activities).</td>
</tr>
<tr>
<td>Model Description</td>
<td>Description</td>
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</tr>
<tr>
<td>SV-5a Operational Activity to Systems Function Traceability Matrix</td>
<td>A mapping of system functions (activities) back to operational activities (activities).</td>
</tr>
<tr>
<td>SV-5b Operational Activity to Systems Traceability Matrix</td>
<td>A mapping of systems back to capabilities or operational activities (activities).</td>
</tr>
<tr>
<td>SV-6 Systems Resource Flow Matrix</td>
<td>Provides details of system resource flow elements being exchanged between systems and the attributes of that exchange.</td>
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<td>The measures (metrics) of Systems Model elements for the appropriate timeframe(s).</td>
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