

"Web services is the integration technology preferred by organizations implementing service-oriented architectures. I would recommend that anybody involved in application development obtain a working knowledge of these technologies, and I'm pleased to recommend Erl's book as a great place to begin."  
—Tom Glover, Senior Program Manager, Web Services Standards, IBM Software Group, and  
Chairman of the Web Services Interoperability Organization (WS-I)



# Service-Oriented Architecture

A Field Guide to Integrating XML and Web Services

Thomas Erl



# Contents

## Preface

xix

### Chapter 1

#### Introduction

1

1.1 Why this guide is important .....	2
1.1.1 The hammer and XML .....	2
1.1.2 XML and Web services .....	3
1.1.3 Web services and Service-Oriented Architecture .....	3
1.1.4 Service-Oriented Architecture and the hammer.....	3
1.1.5 The hammer and you.....	4
1.2 The XML & Web Services Integration Framework (XWIF).....	4
1.3 How this guide is organized .....	5
1.3.1 Part I: The technical landscape.....	6
1.3.2 Part II: Integrating technology .....	7
1.3.3 Part III: Integrating applications .....	9
1.3.4 Part IV: Integrating the enterprise .....	12
1.3.5 The extended enterprise .....	13
1.4 <a href="http://www.serviceoriented.ws">www.serviceoriented.ws</a> .....	13
1.5 Contact the author.....	13

---

**Part I****The technical landscape**

15

**Chapter 2****Introduction to XML technologies**

17

2.1 Extensible Markup Language (XML).....	18
2.1.1 Concepts.....	20
2.1.2 Schemas.....	21
2.1.3 Programming models.....	22
2.1.4 Syntax.....	23
2.2 Document Type Definitions (DTD) .....	24
2.2.1 Concepts.....	25
2.2.2 Syntax.....	25
2.3 XML Schema Definition Language (XSD).....	28
2.3.1 Concepts.....	28
2.3.2 Syntax.....	28
2.4 Extensible Stylesheet Language Transformations (XSLT) .....	33
2.4.1 Concepts.....	34
2.4.2 Syntax.....	35
2.5 XML Query Language (XQuery) .....	38
2.5.1 Concepts.....	38
2.5.2 Syntax.....	41
2.6 XML Path Language (XPath) .....	43
2.6.1 Concepts.....	43
2.6.2 Syntax.....	44

**Chapter 3****Introduction to Web services technologies**

47

3.1 Web services and the service-oriented architecture (SOA) .....	48
3.1.1 Understanding services .....	48
3.1.2 XML Web services .....	49
3.1.3 Service-oriented architecture (SOA).....	50
3.1.4 Web service roles .....	53
3.1.5 Web service interaction.....	56

3.1.6	Service models .....	60
3.1.7	Web service description structure.....	63
3.1.8	Introduction to first-generation Web services.....	65
3.2	Web Services Definition Language (WSDL) .....	66
3.2.1	Abstract interface definition.....	67
3.2.2	Concrete (implementation) definition .....	69
3.2.3	Supplementary constructs .....	70
3.3	Simple Object Access Protocol (SOAP).....	71
3.3.1	SOAP messaging framework.....	73
3.3.2	SOAP message structure .....	76
3.4	Universal Description, Discovery, and Integration (UDDI) .....	80

**Chapter 4**

Introduction to second-generation (WS-*) Web services technologies		89
4.1	Second-generation Web services and the service-oriented enterprise (SOE) .....	90
4.1.1	Problems solved by second-generation specifications .....	92
4.1.2	The second-generation landscape.....	94
4.2	WS-Coordination and WS-Transaction .....	96
4.2.1	Concepts.....	96
4.2.2	Syntax .....	99
4.3	Business Process Execution Language for Web Services (BPEL4WS) .....	100
4.3.1	Recent business process specifications .....	100
4.3.2	Concepts.....	100
4.3.3	Syntax .....	106
4.4	WS-Security and the Web services security specifications.....	109
4.4.1	General security concepts .....	110
4.4.2	Specifications .....	111
4.4.3	XML Key Management (XKMS) .....	112
4.4.4	Extensible Access Control Markup Language (XACML) and Extensible Rights Markup Language (XrML) .....	112
4.4.5	Security Assertion Markup Language (SAML) and .NET Passport.....	112
4.4.6	XML-Encryption and XML-Digital Signatures.....	113

4.4.7	Secure Sockets Layer (SSL) .....	113
4.4.8	The WS-Security framework .....	115
4.4.9	Concepts and syntax .....	117
4.5	WS-ReliableMessaging .....	118
4.5.1	WS-Addressing .....	119
4.5.2	Concepts .....	119
4.5.3	Acknowledgements .....	121
4.5.4	Syntax .....	123
4.6	WS-Policy .....	125
4.6.1	Concepts .....	126
4.6.2	Syntax .....	126
4.7	WS-Attachments .....	127

---

**Part II**

<b>Integrating technology</b>	131
-------------------------------	-----

**Chapter 5**

<b>Integrating XML into applications</b>	133	
5.1	Strategies for integrating XML data representation .....	135
5.1.1	Positioning XML data representation in your architecture .....	135
5.1.2	Think "tree" (a new way of representing data) .....	138
5.1.3	Easy now... (don't rush the XML document model) .....	139
5.1.4	Design with foresight .....	140
5.1.5	Focus on extensibility and reusability .....	142
5.1.6	Lose weight while modeling! (keeping your documents trim) .....	142
5.1.7	Naming element-types: performance vs. legibility .....	143
5.1.8	Applying XML consistently .....	144
5.1.9	Choosing the right API (DOM vs. SAX vs. Data Binding) .....	145
5.1.10	Securing XML documents .....	147
5.1.11	Pick the right tools .....	148
5.1.12	Don't try this at home (fringe optimization strategies) .....	150
5.2	Strategies for integrating XML data validation .....	151
5.2.1	XSD schemas or DTDs? .....	151
5.2.2	Positioning DTDs in your architecture .....	155
5.2.3	Positioning XSD schemas in your architecture .....	156

5.2.4	Understand the syntactical limitations of XSD schemas .....	158
5.2.5	Understand the performance limitations of XSD schemas .....	160
5.2.6	Other fish in the sea (more schema definition languages).....	160
5.2.7	Supplementing XSD schema validation.....	162
5.2.8	Integrating XML validation into a distributed architecture .....	163
5.2.9	Avoiding over-validation.....	165
5.2.10	Consider targeted validation .....	166
5.2.11	Building modular and extensible XSD schemas .....	167
5.2.12	Understand the integration limitations of your database.....	169
5.3	Strategies for integrating XML schema administration.....	170
5.3.1	XML schemas and the silent disparity pattern .....	170
5.3.2	A step-by-step XWIF process .....	171
5.4	Strategies for integrating XML transformation.....	174
5.4.1	Positioning XSLT in your architecture.....	174
5.4.2	Pre-transform for static caching .....	177
5.4.3	Create dynamic XSLT style sheets .....	178
5.4.4	Simplify aesthetic transformation with CSS .....	178
5.4.5	Understand the scalability limitations of XSLT .....	178
5.4.6	Strategic redundancy .....	179
5.5	Strategies for integrating XML data querying.....	179
5.5.1	Positioning XQuery in your architecture.....	180
5.5.2	Multi-data source abstraction .....	180
5.5.3	Establishing a data policy management layer.....	182
5.5.4	Unifying documents and data .....	183

**Chapter 6**

<b>Integrating Web services into applications</b>	187	
6.1	Service models.....	188
6.1.1	Utility services .....	189
6.1.2	Business services .....	191
6.1.3	Controller services .....	191
6.2	Modeling service-oriented component classes and Web service interfaces .....	194
6.2.1	Designing service-oriented component classes (a step-by-step XWIF process) .....	195
6.2.2	Designing Web service interfaces (a step-by-step XWIF process) .....	206

<b>6.3 Strategies for integrating service-oriented encapsulation .....</b>	<b>214</b>
6.3.1 Define criteria for consistent logic encapsulation and interface granularity .....	215
6.3.2 Establish a standard naming convention .....	215
6.3.3 Parameter-driven vs. operation-oriented interfaces.....	215
6.3.4 Designing for diverse granularity .....	216
6.3.5 Utilize generic services consistently .....	217
6.3.6 Establish separate standards for internal and external services .....	218
6.3.7 Considering third-party Web services .....	219
<b>6.4 Strategies for integrating service assemblies .....</b>	<b>220</b>
6.4.1 Everything in moderation, including service assemblies.....	221
6.4.2 Modeling service assemblies .....	221
6.4.3 Compound service assemblies .....	224
<b>6.5 Strategies for enhancing service functionality.....</b>	<b>225</b>
6.5.1 Outputting user-interface information.....	225
6.5.2 Caching more than textual data .....	226
6.5.3 Streamlining the service design with usage patterns.....	227
<b>6.6 Strategies for integrating SOAP messaging.....</b>	<b>228</b>
6.6.1 SOAP message performance management .....	228
6.6.2 SOAP message compression techniques .....	228
6.6.3 Security issues with SOAP messaging .....	230
6.6.4 SOAP data types .....	231
6.6.5 Easing into SOAP .....	232

**Chapter 7**

<b>Integrating XML and databases .....</b>	<b>235</b>
<b>7.1 Comparing XML and relational databases .....</b>	<b>236</b>
7.1.1 Data storage and security .....	237
7.1.2 Data representation .....	237
7.1.3 Data integrity and validation.....	238
7.1.4 Data querying and indexing .....	238
7.1.5 Additional features .....	238
<b>7.2 Integration architectures for XML and relational databases .....</b>	<b>239</b>
7.2.1 Storing XML documents as database records .....	242
7.2.2 Storing XML document constructs as database records .....	244

7.2.3	Using XML to represent a view of database queries .....	246
7.2.4	Using XML to represent a view of a relational data model.....	247
7.2.5	Using XML to represent relational data within an in-memory database (IMDB).....	248
7.3	Strategies for integrating XML with relational databases .....	249
7.3.1	Target only the data you need .....	250
7.3.2	Avoiding relationships by creating specialized data views.....	251
7.3.3	Create XML-friendly database models.....	251
7.3.4	Extending the schema model with annotations.....	252
7.3.5	Non-XML data models in XML schemas.....	253
7.3.6	Developing a caching strategy.....	253
7.3.7	Querying the XSD schema .....	254
7.3.8	Control XML output with XSLT.....	254
7.3.9	Integrate XML with query limitations in mind .....	255
7.3.10	Is a text file a legitimate repository? .....	256
7.3.11	Loose coupling and developer skill sets .....	256
7.4	Techniques for mapping XML to relational data.....	257
7.4.1	Mapping XML documents to relational data.....	257
7.4.2	The Bear Sightings application .....	258
7.4.3	Intrinsic one-to-one and one-to-many relationships with XML .....	258
7.4.4	Mapping XML to relational data with DTDs.....	260
7.4.5	Mapping XML to relational data with XSD schemas .....	267
7.5	Database extensions.....	273
7.5.1	Proprietary extensions to SQL .....	273
7.5.2	Proprietary versions of XML specifications .....	274
7.5.3	Proprietary XML-to-database mapping .....	274
7.5.4	XML output format .....	274
7.5.5	Stored procedures .....	275
7.5.6	Importing and exporting XML documents .....	275
7.5.7	Encapsulating proprietary database extensions within Web services .....	276
7.6	Native XML databases .....	276
7.6.1	Storage of document-centric data .....	276
7.6.2	Integrated XML schema models .....	277
7.6.3	Queries and data retrieval.....	277
7.6.4	Native XML databases for intermediary storage.....	278

---

**Part III****Integrating applications**

281

**Chapter 8****The mechanics of application integration**

283

<b>8.1 Understanding application integration .....</b>	<b>284</b>
8.1.1 Types of integration projects .....	284
8.1.2 Typical integration requirements .....	284
8.1.3 Progress versus impact .....	285
8.1.4 Types of integration solutions .....	286
<b>8.2 Integration levels .....</b>	<b>288</b>
8.2.1 Data-level integration .....	289
8.2.2 Application-level integration .....	290
8.2.3 Process-level integration .....	291
8.2.4 Service-oriented integration .....	292
<b>8.3 A guide to middleware .....</b>	<b>293</b>
8.3.1 "EAI" versus "middleware" .....	293
8.3.2 Shredding the Oreo .....	293
8.3.3 Common middleware services and products .....	294
8.3.4 A checklist for buying middleware .....	296
<b>8.4 Choosing an integration path .....</b>	<b>300</b>
8.4.1 Two paths, one destination .....	301
8.4.2 Moving to EAI .....	301
8.4.3 Common myths .....	301
8.4.4 The impact of an upgrade .....	302
8.4.5 Weighing your options .....	303

**Chapter 9****Service-oriented architectures for legacy integration**

305

<b>9.1 Service models for application integration .....</b>	<b>306</b>
9.1.1 Proxy services .....	307
9.1.2 Wrapper services .....	309
9.1.3 Coordination services (for atomic transactions) .....	310

9.2	Fundamental integration components .....	312
9.2.1	Adapters.....	312
9.2.2	Intermediaries .....	314
9.2.3	Interceptors .....	316
9.3	Web services and one-way integration architectures.....	316
9.3.1	Batch export and import.....	317
9.3.2	Direct data access .....	321
9.4	Web services and point-to-point architectures .....	326
9.4.1	Tightly coupled integration between homogenous legacy applications.....	326
9.4.2	Tightly coupled integration between heterogeneous applications .....	327
9.4.3	Integration between homogenous component-based applications .....	334
9.4.4	Integration between heterogeneous component-based applications .....	338
9.5	Web services and centralized database architectures.....	342
9.5.1	Traditional architecture .....	342
9.5.2	Using a Web service as a data access controller .....	343
9.6	Service-oriented analysis for legacy architectures.....	346

**Chapter 10**

	Service-oriented architectures for enterprise integration .....	355
10.1	Service models for enterprise integration architectures .....	356
10.1.1	Process services .....	356
10.1.2	Coordination services (for business activities) .....	358
10.2	Fundamental enterprise integration architecture components .....	360
10.2.1	Broker .....	362
10.2.2	Orchestration .....	365
10.3	Web services and enterprise integration architectures .....	370
10.4	Hub and spoke .....	371
10.4.1	Traditional architecture .....	372
10.4.2	Adding integration layers with Web services .....	374
10.5	Messaging bus .....	374
10.5.1	Traditional architecture .....	374
10.5.2	Messaging bus solutions that utilize Web services .....	376
10.6	Enterprise Service Bus (ESB) .....	377

**Chapter 11**

<b>Service-oriented integration strategies</b>	<b>381</b>
<b>11.1 Strategies for streamlining integration endpoint interfaces .....</b>	<b>383</b>
11.1.1 Make interfaces more generic.....	383
11.1.2 Consolidate legacy interfaces .....	384
11.1.3 Consolidate proxy interfaces.....	385
11.1.4 Supplement legacy logic with external logic .....	387
11.1.5 Add support for multiple data output formats .....	389
11.1.6 Provide alternative interfaces for different SOAP clients .....	389
<b>11.2 Strategies for optimizing integration endpoint services .....</b>	<b>391</b>
11.2.1 Minimize the use of service intermediaries .....	391
11.2.2 Consider using service interceptors .....	391
11.2.3 Data processing delegation .....	393
11.2.4 Caching the provider WSDL definition .....	394
<b>11.3 Strategies for integrating legacy architectures .....</b>	<b>396</b>
11.3.1 Create a transition architecture by adding partial integration layers.....	396
11.3.2 Data caching with an IMDB.....	396
11.3.3 Utilizing a queue to counter scalability demands .....	397
11.3.4 Adding a mini-hub .....	399
11.3.5 Abstract legacy adapter technology .....	400
11.3.6 Leveraging legacy integration architectures .....	400
11.3.7 Appending Web services to legacy integration architectures .....	402
<b>11.4 Strategies for enterprise solution integration.....</b>	<b>403</b>
11.4.1 Pragmatic service-oriented integration .....	404
11.4.2 Integrating disparate EAI products.....	405
11.4.3 Respect your elders (building EAI around your legacy environments) .....	406
11.4.4 Build a private service registry .....	408
<b>11.5 Strategies for integrating Web services security .....</b>	<b>408</b>
11.5.1 Learn about the Web services security specifications .....	409
11.5.2 Build services with a standardized service-oriented security (SOS) model .....	409
11.5.3 Create a security services layer.....	409
11.5.4 Beware remote third-party services .....	411
11.5.5 Prepare for the performance impact .....	411
11.5.6 Define an appropriate system for single sign-on.....	412

11.5.7	Don't over-describe your services.....	412
11.5.8	Fortify or retreat integrated legacy systems.....	413
11.5.9	Take advantage of granular security.....	414
11.5.10	Web services and port 80 .....	415
11.5.11	SOAP attachments and viruses .....	415
11.5.12	Consider the development of security policies.....	416
11.5.13	Don't wait to think about administration .....	416

---

**Part IV****Integrating the enterprise**

419

**Chapter 12****Thirty best practices for integrating XML**

421

12.1	Best practices for planning XML migration projects .....	422
12.1.1	Understand what you are getting yourself into.....	422
12.1.2	Assess the technical impact.....	424
12.1.3	Invest in an XML impact analysis.....	426
12.1.4	Assess the organizational impact .....	427
12.1.5	Targeting legacy data .....	428
12.2	Best practices for knowledge management within XML projects .....	431
12.2.1	Always relate XML to data .....	431
12.2.2	Determine the extent of education required by your organization .....	432
12.2.3	Customize a training plan .....	432
12.2.4	Incorporate mentoring into development projects.....	435
12.3	Best practices for standardizing XML applications.....	436
12.3.1	Incorporate standards .....	436
12.3.2	Standardize, but don't over-standardize .....	437
12.3.3	Define a schema management strategy .....	438
12.3.4	Use XML to standardize data access logic .....	440
12.3.5	Evaluate tools prior to integration .....	441
12.4	Best practices for designing XML applications.....	441
12.4.1	Develop a system for knowledge distribution.....	441
12.4.2	Remember what the "X" stands for .....	443

12.4.3	Design with service-oriented principles (even if not using Web services).....	443
12.4.4	Strive for a balanced integration strategy .....	444
12.4.5	Understand the roles of supplementary XML technologies .....	445
12.4.6	Adapt to new technology developments .....	446

**Chapter 13**

<b>Thirty best practices for integrating Web services</b>	449
---	-----

<b>13.1 Best practices for planning service-oriented projects</b> .....	450
13.1.1 Know when to use Web services .....	450
13.1.2 Know how to use Web services .....	451
13.1.3 Know when to avoid Web services .....	451
13.1.4 Moving forward with a transition architecture.....	452
13.1.5 Leverage the legacy.....	452
13.1.6 Sorry, no refunds (Web services and your bottom line).....	453
13.1.7 Align ROIs with migration strategies .....	454
13.1.8 Build toward a future state .....	455
<b>13.2 Best practices for standardizing Web services</b> .....	456
13.2.1 Incorporate standards .....	456
13.2.2 Label the infrastructure .....	457
13.2.3 Design against an interface (not vice versa) .....	458
13.2.4 Service interface designer .....	460
13.2.5 Categorize your services .....	460
<b>13.3 Best practices for designing service-oriented environments</b> .....	461
13.3.1 Use SOAs to streamline business models.....	461
13.3.2 Research the state of second-generation specifications .....	461
13.3.3 Strategically position second-generation specifications.....	462
13.3.4 Understand the limitations of your platform .....	462
13.3.5 Use abstraction to protect legacy endpoints from change .....	463
13.3.6 Build around a security model.....	464
<b>13.4 Best practices for managing service-oriented development projects</b> .....	467
13.4.1 Organizing development resources .....	467
13.4.2 Don't underestimate training for developers .....	468
<b>13.5 Best practices for implementing Web services</b> .....	469
13.5.1 Use a private service registry.....	469

13.5.2 Prepare for administration.....	471
13.5.3 Monitor and respond to changes in the service hosting environments .....	472
13.5.4 Test for the unknown .....	473
 <b>Chapter 14</b>	
Building the service-oriented enterprise (SOE) .....	475
14.1 SOA modeling basics.....	476
14.1.1 Activities.....	478
14.1.2 Services .....	479
14.1.3 Processes .....	479
14.2 SOE building blocks .....	481
14.2.1 SOE business modeling building blocks .....	482
14.2.2 SOE technology architecture building blocks.....	489
14.2.3 Service-oriented security model.....	498
14.3 SOE migration strategy .....	500
14.3.1 Overview of the Layered Scope Model (LSM) .....	500
14.3.2 Intrinsic Layer.....	503
14.3.3 Internal layer .....	505
14.3.4 A2A layer .....	508
14.3.5 EAI layer .....	511
14.3.6 Enterprise layer.....	514
14.3.7 The extended enterprise .....	515
14.3.8 Customizing the LSM .....	515
14.3.9 Alternatives to the LSM.....	517
 <b>About the Author</b>	519
 <b>About the Photographs</b>	521
 <b>Index</b>	523