Web Services & SOA: Principles and Technology

Second Edition

Michael P. Papazoglou

European Research Institute in Service Science, Tilburg University, The Netherlands



Prefa	асе	xxvii
_	word to second edition	xxxvii
Fore	word to first edition	xli
	nowledgements	×liii
Con	nprehensive case study	1
A.1	Overview of case study	1
A.2	Background: Automotive supply chain	1
A.3	Case study objectives	2
	A.3.1 The current situation	4
	A.3.2 The desired SOA solution	4
	A.3.2.1 Processing steps in the SOA solution	4
A. 4	SOA work plan stages	6
	A.4.1 Modelling the Service Oriented Architecture	6
	A.4.2 Specifying design patterns in the XML Schema	6
	A.4.3 Describing services in WSDL	6
	A.4.4 Service orchestration in BPEL	7
A.5	Solution	7
Part I	Basics	9
Chapte	er 1: Web service and SOA fundamentals	11
1.1	Introduction	12
	1.1.1 What are Web services?	14
	1.1.2 Typical Web service scenarios	14
1.2	The concept of software as service (SaaS)	15
1.3	Web services versus Web based applications	17
1.4	A more complete definition of Web services	17
1.5	Characteristics of Web services	19
	1.5.1 Types of Web service	19
	1.5.1.1 Simple or informational services	19
	1.5.1.2 Complex services (business processes)	21
	1.5.2 Functional and non-functional properties	22

x Contents

	1.5.3	State properties	23			
		Loose coupling	23			
		Service granularity	25			
1.5.6 Service synchronicity						
1.5.7 Well-definedness						
		Service usage context	26			
1.6		e interface and implementation	27			
		rvice Oriented Architecture	29			
	1.7.1		30			
		1.7.1.1 Web service provider	31			
		1.7.1.2 Web service requester	31			
		1.7.1.3 Web service registry	31			
	1.7.2	SOA operations	31			
		1.7.2.1 The publish operation	32			
		1.7.2.2 The find operation	32			
		1.7.2.3 The bind operation	33			
	1.7.3	SOA entry points	34			
	1.7.4	Layers in an SOA	35			
		1.7.4.1 Business domain	37			
		1.7.4.2 Business processes	37			
		1.7.4.3 Business services	38			
		1.7.4.4 Utility services	38			
		1.7.4.5 Infrastructure services	38			
		1.7.4.6 Component services	39			
		1.7.4.7 IT assets – operational systems	39			
1.8	The We	eb service technology stack	40			
	1.8.1	Enabling technology standards	41			
	1.8.2	Core service standards	41			
	1.8.3	Service composition and collaboration standards	42			
1.9	Quality	y of service (QoS)	42			
	1.9.1	QoS requirements for Web services	43			
	1.9.2	Service level agreements (SLAs)	44			
1.10	Web se	ervice interoperability	46			
1.11	Web se	ervices versus components	47			
1.12	RESTfu	l services	49			
1.13	Impact	t and shortcomings of Web services	51			
1.14	Summa	ary	53			
	Review	questions	54			
	Exercis	es	54			

Α.	4 4	
CO	ntents	ΧÌ

Part II	Enabling infrastructure	57		
Chapter 2: Distributed computing infrastructure				
2.1	Distributed computing and Internet protocols	60		
	2.1.1 Internet protocols	61		
	2.1.1.1 The Open Systems Interconnection			
	reference model	61		
	2.1.1.2 The TCP/IP network protocol	63		
2.2		66		
2.3		67		
2.4	Inter-process communication	69		
	2.4.1 Messaging	69		
	2.4.2 Message destinations and sockets	70		
	2.4.3 Forms of message communication	71		
2.5	J	72		
	2.5.1 Remote procedure calls (RPC)	72		
0.6	2.5.2 Remote method invocation	74		
2.6	Asynchronous forms of middleware	75		
	2.6.1 Store and forward messaging	75		
	2.6.2 Publish/subscribe messaging	77		
2.7	2.6.3 Event driven processing mechanisms	79		
2.7 2.8	1 - 7 - 1 - 3	80		
2.0	Message oriented middleware	81		
	2.8.1 Integration brokers 2.8.2 The Java Message Service (JMS)	83		
2.0	2.8.2 The Java Message Service (JMS) Transaction oriented middleware	85		
	Enterprise application and e-Business integration	86		
2.10	2.10.1 Enterprise application integration	87		
	2.10.2 e-Business integration	87		
2 11	Summary of learning objectives	88		
	Review questions	90 91		
	Exercises	91		
		91		
Chapte	r 3: Brief overview of XML	93		
3.1	XML document structure	94		
	3.1.1 XML declaration	95		
	3.1.2 XML elements	95		
	3.1.3 XML attributes	96		

3.2 XML namespaces				
3.3	Defining structure in XML documents	100		
	3.3.1 The XML Schema Definition Language	100		
	3.3.2 The XML schema document	101		
	3.3.3 Schema type definitions and declarations	103		
	3.3.3.1 Element declarations	105		
	3.3.3.2 Attribute declarations	105		
	3.3.4 Simple types	106		
	3.3.5 Complex types	106		
3.4		107		
	3.4.1 Deriving complex types	107		
	3.4.1.1 Complex type extensions	107		
	3.4.1.2 Complex type restrictions	108		
	3.4.1.3 Polymorphism	109		
	3.4.2 Importing and including schemas	111		
	3.4.2.1 Including schemas	111		
	3.4.2.2 Importing schemas	112		
3.5	——————————————————————————————————————	116		
	3.5.1 The XML Path Language	116		
	3.5.2 Using XSLT to transform documents	119		
3.6	5 5	120		
	Review questions	120		
	Exercises	121		
Part I	II Core functionality and standards	123		
Chapte	er 4: SOAP: Simple Object Access Protocol	125		
4.1	Inter-application communication and wire protocols	126		
	4.1.1 SOAP as a wire representation	127		
4.2	·	127		
4.3	Structure of a SOAP message	131		
	4.3.1 SOAP envelope	131		
	4.3.2 SOAP header	134		
	4.3.2.1 SOAP intermediaries	136		
	4.3.3 SOAP body	139		
4.4	SOAP communication model	139		
•••	4.4.1 RPC style Web services	139		
	4.4.2 Document (message) style Web services	142		
4.5	Error handling in SOAP	144		

	Conten	ts xiii
4.6	Advantages and disadvantages of SOAP	145
4.7	Summary of learning objectives	147
	Review questions	147
	Exercises	148
Chapt	er 5: Describing Web services	149
5.1	Why is a service description needed?	150
5.2	WSDL: Web Services Description Language	151
	5.2.1 The service interface and implementation	151
	5.2.2 WSDL definition element	154
	5.2.3 WSDL abstract service description	156
	5.2.3.1 The types element	157
	5.2.3.2 The message element	158
	5.2.3.3 The operation and portType elements5.2.3.4 Example of an abstract service	160
	definition in WSDL	161
	5.2.4 WSDL concrete service description – implementation	162
	5.2.4.1 The binding element	163
	5.2.4.2 The service and port elements	166
	5.2.4.3 Example of a concrete service	
	definition in WSDL	168
	5.2.5 Message exchange patterns	170
	5.2.5.1 One-way	172
	5.2.5.2 Request/response	172
	5.2.5.3 Notification	173
	5.2.5.4 Solicit/response	173
5.3	Non-functional service descriptions	174
5.4	WSDL 1.1 versus WSDL 2.0	174
5.5	Summary of learning objectives	175
	Review questions	175
	Exercises	176
Chapt	er 6: Registering and discovering services	177
6.1	The role of service registries	178
6.2	Service discovery	179
6.3	Universal Description, Discovery and Integration (UDDI)	180
	6.3.1 The UDDI data structures	182
	6.3.1.1 Service provider information	185

			Representing business service information	188
		6.3.1.3	Representing technical service	100
		621 /	information	190
		0.5.1.4	Best practices for storing technical service information	105
		6215	The publisher assertion structure	195 196
	6.3.2		g WSDL to UDDI	190
	0.3.2		Publishing service interfaces and	197
		0.3.2.1	service bindings	197
		6322	Publishing service implementations	200
			Summary of the WSDL to UDDI	200
		0.3.2.3	mapping model	203
	6.3.3	The UDI	• • •	204
	0.5.5		Publishing API	205
			Inquiry API	206
	6.3.4		g the UDDI model	207
		_	Retrieving information about businesses	207
			Retrieving technical service information	209
	6.3.5		registry usage model and	
			nent variants	210
6.4	Summ	ary of lea	rning objectives	212
	Reviev	v questio	ns	213
	Exerci	ses		213
Part I\	/ Eve	nt noti	fication and Service	
Orient	ed Arc	hitectu	res	215
Chapte	er 7: S	ervice a	ddressing and notification	217
7.1	Refere	ncing and	l addressing Web services	218
		WS-Addr		218
		7.1.1.1	Endpoint references	219
		7.1.1.2	Message addressing properties	220
7.2	Web Se	ervices No	otification	223
	7.2.1	Peer-to-	peer notification	224
	7.2.2	WS-Base	Notification interfaces	227
		7.2.2.1	The notification consumer interface	227
		7.2.2.2	The notification producer interface	229
		7.2.2.3	The subscription manager interface	229

				Contents	ΧV
		7.2.3	Filter expressions		230
		7.2.4	Notification topics		231
			7.2.4.1 Topic trees and spaces		231
			7.2.4.2 The WS-Topics specification		232
		7.2.5	Brokered notification		234
	7.3	Summ	ary of learning objectives		236
			v questions		237
		Exerci	ses		237
Cł	napte	r 8: S	ervice Oriented Architectures	2	41
	8.1	What i	s software architecture?		242
		8.1.1	System quality attributes		243
		8.1.2	Common architectural concerns		244
	8.2	SOA re	visited		245
	8.3	Service	e roles in an SOA		248
	8.4		le messaging		250
			Definition and scope of reliable messaging		251
		8.4.2	WS-ReliableMessaging	,	251
			8.4.2.1 Structure of WS-ReliableMessaging		253
	8.5		terprise Service Bus		255
		8.5.1			256
			The event driven nature of SOA		259
			Key capabilities of an ESB		261
		8.5.4	3 3	;	264
			8.5.4.1 Integration at the presentation tier	;	264
			8.5.4.2 Application connectivity	;	266
		8.5.5	Modules of an ESB	;	267
			8.5.5.1 Integration brokers		269
			8.5.5.2 Application servers		270
			8.5.5.3 ESB wrappers	;	272
			8.5.5.4 Business Process Management	i	273
		_	8.5.5.5 ESB transport level choices	i	273
		8.5.6	5		274
		8.5.7		;	276
	8.6		tended SOA		279
	8.7		ary of learning objectives		282
			questions		282
		Exercis	es		283

Part V	Serv	ice composition and transactions	287			
		ervice composition and	289			
busine	business processes					
9.1	Busine	ess processes and their management	290			
	9.1.1	Characteristics of business processes	291			
9.2	Workflo	OWS	293			
9.3	Busine	ss process management	297			
9.4	Cross-e	enterprise business processes	301			
9.5	Service	e composition model	302			
	9.5.1	Process flow modelling	303			
	9.5.2	Composing Web services	306			
9.6	Service	e orchestration and choreography	309			
	9.6.1	Service orchestration	310			
	9.6.2	Service choreography	311			
9.7	WS-BPI	EL: the Business Process				
	Executi	ion Language	313			
	9.7.1	The structure of a BPEL process	314			
	9.7.2	Abstract and executable BPEL processes	317			
		9.7.2.1 Abstract BPEL processes	317			
		9.7.2.2 Executable BPEL processes	317			
		9.7.2.3 Differences between abstract and				
		executable processes	318			
	9.7.3	Message flow in BPEL	319			
	9.7.4	Control flow in BPEL	322			
		9.7.4.1 Sequencing activities	323			
		9.7.4.2 Parallelising activities	323			
		9.7.4.3 Branching activities	324			
		9.7.4.4 Scoping activities	325			
	9.7.5	Data flow in BPEL	325			
	9.7.6	Service composition in BPEL	326			
		9.7.6.1 Synchronous operations	327			
		9.7.6.2 Asynchronous operations	328			
		9.7.6.3 Binding options	331			
	9.7.7	Service correlation in BPEL	331			
	9.7.8	Fault handling and compensation in BPEL	334			
		Event handling in BPEL	335			
	9.7.10	A comprehensive example in BPEL	336			
		9.7.10.1 Process orchestration	336			
		9 7 10 2 Data flow	337			

			Contents	xvii
	g	0.7.10.3 Process steps and control flow		339
		0.7.10.4 Declaring message correlations		342
9.8		rice choreography		346
		Choreography description		346
		Veb Services Choreography Description		
	Ĺ	anguage (WS-CDL)		347
9.9	Summary	of learning objectives		350
	Review o	juestions		350
	Exercises	5		351
Chapte	er 10: Se	ervice transactions		353
10.1	What is	a transaction?		354
	10.1.1	Properties of transactions		356
	10.1.2	Concurrency control mechanisms		357
		10.1.2.1 Transaction serialisability		357
		10.1.2.2 Two-phase locking		357
		10.1.2.3 Transaction isolation		358
10.2	Distribu	ted transactions	•	359
	10.2.1	Distributed transaction architectures		360
	10.2.2	Two-phase commit protocol		364
		10.2.2.1 Phase I: preparation		364
		10.2.2.2 Phase II: commitment/abortion		365
10.3		transactions		366
	10.3.1	The closed nested transaction model		368
		10.3.1.1 The two-phase commit protocol for	or	
		nested transactions		369
		10.3.1.2 Concurrency control		372
	10.3.2	The open nested transaction model		373
		10.3.2.1 Transactional workflows		376
		10.3.2.2 Recovery mechanisms		377
10.4		vice transactions		379
	10.4.1	Characteristics of Web service transactions		380
	10.4.2	Operational characteristics of Web service		
		transactions		381
		10.4.2.1 Atomic actions		382
		10.4.2.2 Long duration transactions		384
	10.4.3	Consensus groups and interposition		386
	10.4.4	States of Web service transactions		388
10.5	Web ser	vice coordination		389
	10.5.1	The WS-Coordination model		390

i

	10.5.2	rypical message exchange between	
		two applications	393
	10.5.3	Coordination context	394
	10.5.4	Activation service	395
	10.5.5	Registration service	397
10.6	Web ser	rvice transaction types	400
	10.6.1	Atomic transaction	400
		10.6.1.1 Completion protocol	402
		10.6.1.2 Durable Two-Phase Commit (2PC) protocol	402
		10.6.1.3 Volatile Two-Phase Commit (2PC) protocol	403
	10.6.2	Business activity	405
		10.6.2.1 Business activity characteristics	406
		10.6.2.2 Business agreement with participant	
		completion protocol	407
		10.6.2.3 Business agreement with coordinator	
		completion protocol	408
10.7		ry of learning objectives	409
		questions	410
	Exercise	es	411
Part VI	SOA s	security and policies	413
Chapter	[,] 11: Se	ecuring SOA and Web services	415
11.1	SOA and	d Web service security considerations	416
		Security threats for Web services	417
		Security countermeasures	420
11.2		k level security mechanisms	420
	11.2.1	•	420
		11.2.1.1 Firewall architectures	421
	11.2.2	Intrusion detection systems and	
		vulnerability assessment	425
	11.2.3	Securing network communications	426
		11.2.3.1 Symmetric encryption	427
		11.2.3.2 Asymmetric encryption	428
		11.2.3.3 Digital certificates and signatures	430
11.3	Applicat	tion level security mechanisms	433
	11.3.1	Authentication	433
		11.3.1.1 Protection domains	434
		11.3.1.2 Web resource protection	434
	11.3.2	Authorisation	435
	11 3 3	Integrity and confidentiality	437

			Conte	nts	xix
	11.3.4	Non-repu	diation		437
	11.3.5	Auditing			438
	11.3.6	Application	on level security protocols		438
		11.3.6.1	Secure sockets layer (SSL)		438
		11.3.6.2	Internet Protocol Security (IPSec)		440
		11.3.6.3	Kerberos		440
	11.3.7	Security in	nfrastructures		441
		11.3.7.1	Public-key infrastructure		442
		11.3.7.2	Directory services		444
11.4	Security	topologies	i		444
11.5	XML secu	urity standa	ards		447
	11.5.1	XML Signa	ture		447
	11.5.2	XML Encry	ption		450
	11.5.3	XML Key N	Management Specification (XKMS)		452
		11.5.3.1	XML Key Information Service		
			Specification (X-KISS)		455
		11.5.3.2	XML Key Registration Service		
			Specification (X-KRSS)		455
	11.5.4	Security A	ssertions Markup Language (SAML)	•	456
	11.5.5	XML Acces	s Control Markup Language (XACML)		461
11.6	Securing	SOA and V	Veb services		466
	11.6.1	Web servi	ce application level security challenges		466
		11.6.1.1	SSL shortcomings		467
		11.6.1.2	Message level security shortcomings		467
	11.6.2		ce security roadmap		469
	11.6.3	Web servi	ce security model		471
	11.6.4	WS-Securi	•		473
			Use case for WS-Security		474
		11.6.4.2	Integrating WS-Security in		
			SOA applications		477
		11.6.4.3	Key WS-Security features		478
	11.6.5		security policies		486
	11.6.6		secure sessions		488
	11.6.7	Managing			489
	11.6.8		federated identities		493
			Overview of WS-Federation		494
			Federation services		495
			Federated trust scenarios		497
11.7	-	of key poi	nts		499
	Review q	•			499
	Exercises	;			500

Chapter	12: Se	rvice pol	licies	501
12.1	What are	policies a	and why are they needed?	502
	12.1.1	Character	istics of service policies	502
	12.1.2	Character	istics of a policy language	504
12.2	Types of	policy		505
	12.2.1	Versionin	g policies	505
	12.2.2	QoS polic	ies	505
	12.2.3	Security p	policies	506
12.3			oort standards	506
12.4		y framewo		507
	12.4.1		of WS-Policy	509
			Policy expressions	512
	12.4.2	Policy op		518
			Equivalence property	518
			Associative property	518
			Commutative property	520
			Distributive property	520
			Idempotent rule	522
	12.4.3		g and comparing policies	523
			Merging policies	523
			Intersecting policies	525
	12.4.4	-	cachments	528
			WSDL policy attachments	529
			External policy attachments	532
12.5			ng objectives	533
		questions		533
	Exercise	S		534
Part VII	Servi	ice sema	ntics and business protocols	535
Chapter	13: Se	mantics	and Web services	537
13.1	The sem	antic inter	operability problem	538
13.2	The role	of metada	nta	540
	13.2.1	Organisat	ion of metadata	540
	13.2.2	Types of	metadata	541
			and ontologies	541
13.3	Service I	metadata		542
13.4	Resource	e Descripti	on Framework	543
	13.4.1	The RDF of	data model	544

	(Contents xxi
	13.4.2 RDF syntax	546
	13.4.3 RDF Schema	553
13 5	Richer schema languages	558
	WS-MetadataExchange	559
13.7		564
15.7	Review questions	564
	Exercises	565
Chapter	14: Business protocols and standards	568
14.1	The supply chain business ecosystem	569
	Semantic problems at the business process level	572
14.3	•	573
	14.3.1 Electronic Data Interchange	576
	14.3.2 Horizontal business standards: Electronic	
	Business XML	578
	14.3.2.1 The ebXML reference architecture	579
	14.3.2.2 ebXML functional phases	584
	14.3.2.3 ebXML and Web services	586
	14.3.3 Vertical business standards: RosettaNet	587
	14.3.3.1 The RosettaNet business architect	ure 587
	14.3.3.2 The RosettaNet Implementation	
	Framework	590
	14.3.3.3 RosettaNet and Web services	590
14.4	Vertical industry standards	591
	14.4.1 XML standards for the aviation industry	592
	14.4.2 XML standards for the automotive industry	593
	14.4.3 XML standards for the travel industry	593
	14.4.4 XML standards for the insurance industry	594
14.5		594
	Review questions	595
	Exercises	595
Part VII	I SOA modelling, design and developmen	t 597
Chapter	15: SOA based application modelling	599
15.1	The art of modelling	600
15.2	Business process modelling methodologies	602
	15.2.1 The UN/CEFACT modelling methodology	603
	15.2.1.1 The UMM meta-model	604

		15.2.1.2 The UMM worksheets	•	606
15.3	Busines	process reference models		608
		The Supply chain operations refere	ence model	608
		15.3.1.1 The SCOR primary		
		management processes		609
		15.3.1.2 SCOR levels of process	detail	611
		15.3.1.3 SCOR metrics		614
15.4	Busines	Process Modeling Notation		615
	15.4.1	BPMN constructs		616
	15.4.2	Notation	1	618
	15.4.3	BPMN examples of use	1	618
15.5	Summar	y of learning objectives		622
	Review	questions	(623
	Exercise	5	1	623
Chapter	16: S0	A development lifecycle	6	26
16.1	Unravell	ing the nature of SOA based applica	ations	627
16.2		e for SOA based application develo		629
16.3		OA development pitfalls		630
16.4	Software	development lifecycle	(631
	16.4.1	Software development models	•	632
		16.4.1.1 Waterfall model	(632
		16.4.1.2 Spiral model	(632
		16.4.1.3 Iterative methodologies	s (632
	16.4.2	Object oriented and component		
		based development	(633
		16.4.2.1 Object oriented develop	oment (633
		16.4.2.2 Component based devel	lopment	634
	16.4.3	Process modelling methodologies	(535
16.5	Element	of SOA based applications	(635
	16.5.1	Data-centric versus process-centric	2	
		SOA applications	(537
	16.5.2	SOA operational control and visibi	lity (637
	16.5.3	SOA maturity and governance		538
16.6	Best pra	ctices for developing SOA based ap	plications (539
16.7	Reference	e model for SOA development	(541
	16.7.1	Layers in the SOA reference model		541
		16.7.1.1 Navigating the reference	e model 6	542

			Contents	xxiii
		16.7.1.2	The logical view of the	
			SOA reference model	643
		16.7.1.3	The physical view of the	
			SOA reference model	644
	16.7.2	QoS consid	derations in the SOA reference model	646
16.8	Guiding	principles of	of SOA application development	647
	16.8.1	Service co	upling	647
	16.8.2	Service co	hesion	649
	16.8.3	Service gra	anularity	651
16.9	Overviev	v of SOA de	velopment lifecycle	654
16.10	The SOA	planning p	hase	657
16.11	The SOA	analysis ph	nase	658
	16.11.1	As-is proc	ess model analysis	660
	16.11.2	Atomic ser	vice and business process identification	661
	16.11.3	Business p	rocess scoping	663
	16.11.4	SOA gap a	nalysis	664
	16.11.5	Process re	alisation analysis	664
16.12			ecification) phase	668
	16.12.1	-	e design considerations	669
			Designing for service granularity	670
		16.12.1.2	Designing for loose coupling and	
			high cohesion	670
			Designing for service reusability	671
			Designing for service composability	671
	16.12.2		atomic services	671
		16.12.2.1	Structural and behavioural	
			service specification	672
			Specifying the service interaction style	674
	16.12.3		business processes	676
		16.12.3.1	Specifying the business	
			process structure	677
			Specifying roles and responsibilities	679
	16.12.4		service policies and QoS	
		•	nts in an SOA	682
			Business level SOA QoS requirements	682
			Resource level SOA QoS requirements	684
			SOA security considerations	685
	TI 00:		Specifying SOA policies	687
16.13	The SUA	construction	on pnase	689

		16.13.1	Leveraging legacy applications	689
		16.13.2	! The SOA programming and implementation model	692
		16.13.3	Service construction	693
			16.13.3.1 Constructing an SOA service:	
			the provider perspective	694
			16.13.3.2 Constructing an SOA service:	
			the client perspective	696
	16.14	The SOA	A testing phase	697
	16.15		A provisioning phase	699
			Service certification	699
			Service metering and rating	699
			deployment phase	700
			A execution phase	702
			management and monitoring phase	702
	16.19	SOA gov		703
			SOA versus IT governance	703
			SOA governance types	704
	16.20		y of learning objectives	707
			questions	708
		Exercise	S	709
Pa	rt IX	Servi	ce management	711
Ch	apter	17: S0	A and Web service management	713
	17.1	Managin	ng distributed systems	714
		17.1.1	~	714
		17.1.2	Distributed management for Web services	717
	17.2	Enterpris	se management frameworks	720
	17.3	Concent	ual management architecture	722
	17.5	concepti		
	17.5	17.3.1	Management capabilities and functions	723
		17.3.1	Management capabilities and functions distributed management frameworks	723 726
		17.3.1 Standard	•	
		17.3.1 Standard	d distributed management frameworks	726
		17.3.1 Standard 17.4.1	d distributed management frameworks Simple Network Management Protocol	726
	17.4	17.3.1 Standard 17.4.1 17.4.2	d distributed management frameworks Simple Network Management Protocol The Common Information Model/Web-based Enterprise Management rice management	726 726
	17.4	17.3.1 Standard 17.4.1 17.4.2 Web serv 17.5.1	d distributed management frameworks Simple Network Management Protocol The Common Information Model/Web-based Enterprise Management rice management Features of Web service management	726 726 727
	17.4	17.3.1 Standard 17.4.1 17.4.2 Web serv	d distributed management frameworks Simple Network Management Protocol The Common Information Model/Web-based Enterprise Management vice management Features of Web service management Functional characteristics of	726 726 727 728 728
	17.4	17.3.1 Standard 17.4.1 17.4.2 Web serv 17.5.1	d distributed management frameworks Simple Network Management Protocol The Common Information Model/Web-based Enterprise Management rice management Features of Web service management	726 726 727 728

		Conte	nts xx	V
	17.5.4 17.5.5	Connecting service management and	73	-
4- 4		application channels	73	
17.6		Services Distributed Management initiative	73	
		Management Using Web Services (MUWS)	74	
177	17.6.2	· ,	74	
17.7		y of learning objectives questions	74:	
	Exercise	•	74: 74:	_
	Exercise	:5	744	4
Part X	Emerg	ing trends	747	7
Chapter	18: Cl	oud Computing	749	9
18.1	What is	Cloud Computing?	750	0
	18.1.1	Essential characteristics of Cloud Computing	75	1
	18.1.2	Cloud service delivery models	75	3
		18.1.2.1 Infrastructure as a Service (IaaS)	75	4
		18.1.2.2 Platform provider as a Service (PaaS)	· 75	
		18.1.2.3 Software as a Service (SaaS)	75	
	18.1.3	, ,	75	7
		18.1.3.1 Public cloud	758	
		18.1.3.2 Private cloud	758	
		18.1.3.3 Hybrid cloud	75	
18.2		ets the Cloud	760	
		Comparing SOA with Cloud Computing	7.6	
	18.2.2	SOA deployment: Cloud Computing versus the ESB	76	
18.3			76	
	18.3.1	, , , , , , , , , , , , , , , , , , ,	76	
		18.3.1.1 Network virtualisation	76	
		18.3.1.2 Server virtualisation	76:	
		18.3.1.3 Server clustering	76:	
		18.3.1.4 Storage virtualisation	76:	
		18.3.1.5 Application virtualisation	76:	
	18.3.2	System virtualisation and management	764 765	
18.4	Multi-tenancy			
	18.4.1	Approaches to multi-tenancy	76	
18.5		cture model for Cloud Computing	76	
	18.5.1	Operational roles in cloud architecture	76	
	18.5.2	Functional parts in the cloud architecture	769	9

xxvi Contents

	18.5.3	Cloud AP	LS	//(
18.6	Cloud se	ecurity		77:
	18.6.1	Cloud sec	urity risks	772
	18.6.2	Cloud app	olication security	773
		18.6.2.1	IaaS level application security	774
		18.6.2.2	PaaS level application security	776
		18.6.2.3	SaaS level application security	777
18.7	Cloud se	ervice lifecy	ycle	778
18.8	Cloud st	andards		779
	18.8.1	Interoper	ability standard initiatives	779
	18.8.2	Security s	tandard initiatives	780
	18.8.3	API stand	lard initiatives	780
18.9	Benefits	and risks	of Cloud Computing	780
	18.9.1	Potential	benefits of Cloud Computing	781
	18.9.2	Potential	risks of Cloud Computing	782
18.10	Summar	y of learnir	ng objectives	783
	Review	questions		784
Refere	nces			785
Index				797