
Contents

Preface	xv
1 Network-as-a-Service and network cloudification in the next generation Internet	1
<i>Qiang Duan</i>	
Abstract	1
1.1 Introduction	1
1.2 The service-oriented architecture	2
1.3 Evolution of the NaaS concept in networking technologies	4
1.4 Virtualization in networking	6
1.4.1 Network virtualization	6
1.4.2 Network function virtualization	8
1.5 Service-oriented networking	9
1.5.1 General architecture for service-oriented networking	9
1.5.2 Resource description and discovery in NaaS	11
1.5.3 Network service composition in NaaS	12
1.6 Software-defined network control and management for NaaS	14
1.7 Network cloudification and network-cloud unification	16
1.7.1 Network cloudification	16
1.7.2 Unification of networking and cloud computing	18
1.8 Conclusion	20
References	21
2 Methods and Infrastructure of Network-as-a-Service	25
<i>Wu Chou and Li Li</i>	
Abstract	25
Keywords	25
2.1 Introduction	25
2.2 REST API for SDN	28
2.3 Hypertext-driven navigation principle of REST API	29
2.4 Flexible REST API design framework	30
2.5 Flexible REST client design framework	37
2.6 Hypertext-driven client-resource interaction patterns	40
2.6.1 Tree pattern	40
2.6.2 Backtracking pattern	40

2.6.3	Redirection pattern	41
2.6.4	Search pattern	41
2.6.5	Generator pattern	42
2.6.6	Factory pattern	43
2.7	Efficient cache mechanisms	44
2.7.1	Issues of caching for REST service clients	44
2.7.2	Differential and layered cache at clients	45
2.7.3	Cache replacement	47
2.8	Summary	47
	References	48
3	Flexible and dynamic Network-as-a-Service for next generation Internet	51
	<i>Amina Boubendir, Emmanuel Bertin, Gladys Diaz and Noémie Simoni</i>	
	Abstract	51
3.1	Introduction	52
3.1.1	Convergence of needs	52
3.1.2	Convergence of solutions	53
3.1.3	Convergence views	54
3.2	Technologies enabling Network-as-a-Service	55
3.2.1	Network functions virtualization	55
3.2.2	Software-defined networks (SDN)	56
3.2.3	Cloud computing and service and component-based models	57
3.2.4	Challenges to undertake for achieving NaaS	62
3.3	Schemes of transformation: the way toward NaaS	64
3.3.1	Modeling VNFs as service components	64
3.3.2	Properties of a VNF “as-a-Service” component	66
3.3.3	Dynamic APIs	69
3.4	Flexible and dynamic NaaS	70
3.4.1	Introduction: the convergence of NaaS actors	70
3.4.2	Flexibility of NaaS: flexibility in service offerings through exposition	73
3.4.3	Dynamic NaaS: orchestration	75
3.5	Conclusions	85
	References	86
4	Virtual deployment of virtual networks in Network as a Service	87
	<i>Gladys Diaz, Amina Boubendir and Noémie Simoni</i>	
	Abstract	87
4.1	Introduction	88
4.1.1	SDN: changes and benefits	88
4.1.2	NFV: changes and benefits	89
4.1.3	NaaS: the future	89

4.2	The process of deployment in virtualized environments	91
4.2.1	Deployment process in Cloud computing	91
4.2.2	Deployment process in Telco Cloud	92
4.2.3	Deployment process in cloud networking	93
4.3	Virtual deployment of virtual networks	94
4.3.1	Definition of the “virtual deployment of virtual networks”	95
4.3.2	Network life-cycle in NaaS	97
4.3.3	Virtual network deployment process	100
4.4	Personalized virtual network	102
4.4.1	NaaS components	102
4.4.2	Design elements	103
4.5	Implementation study	105
4.5.1	Strategies of network equipment vendors	105
4.5.2	Existing tools and products	106
4.5.3	Today’s shortcomings	107
4.6	Conclusion	111
	References	112
5	Network service discovery, selection, and brokerage	117
	<i>Guanhong Tao and Zibin Zheng</i>	
5.1	Introduction	117
5.2	Network virtualization for next generation Internet	119
5.3	Service-oriented architecture in network virtualization	121
5.4	Network service discovery and selection	125
5.4.1	Performance prediction for network service discovery and selection	125
5.4.2	Resource allocation for network service provisioning	127
5.5	Network service brokerage	128
5.6	Information update for network service discovery and selection	129
5.7	Conclusions	131
	References	131
6	Service selection and recommendation in integrated network environment	135
	<i>Lingyan Zhang, Mingzhe Yang, Yan Guo, and Shangguang Wang</i>	
6.1	Introduction	135
6.2	Integrated network	136
6.3	Service selection	136
6.3.1	Selection problem definition	136
6.3.2	Problem induction	138
6.3.3	Service selection algorithm	140
6.3.4	Service selection summary	143
6.4	Service recommendation	143
6.4.1	Recommendation scenarios	144

6.4.2	Recommendation problem definition	145
6.4.3	Recommendation systems and techniques	146
6.4.4	Service recommendation summary	151
6.5	Evaluation index	152
6.5.1	User preference	152
6.5.2	Accuracy	152
6.5.3	Coverage	153
6.5.4	Confidence and trust	154
6.5.5	Robustness and privacy	154
6.6	Conclusion	154
	References	154
7	Cloud networking evolution	159
	<i>Gladys Diaz and Noëmien Simoni</i>	
7.1	Introduction	159
7.1.1	The new landscape: changes	159
7.1.2	The new landscape: needs	160
7.1.3	The new landscape: a ranking of evolution	161
7.2	Virtualization of network equipment	162
7.2.1	Virtualization of links	162
7.2.2	Virtualization of nodes	163
7.2.3	Virtualization of the network	164
7.3	QoS-based network offers	164
7.3.1	QoS-aware model	165
7.3.2	VN-CoS for cloud networking	167
7.4	Network Cloudification	171
7.5	Network <i>Softwarization</i>	172
7.6	Network <i>ITification</i> : the convergence of service	175
7.6.1	Why the SOA?	175
7.6.2	QoS-based SCC components	176
7.6.3	The properties ‘as a Service’	178
7.7	NaaS: towards an on-demand customization	179
7.7.1	Customizable virtual networks	180
7.7.2	The customized session	181
7.8	Use case: provisioning of on-demand cloud services	183
7.9	Conclusion	185
	Glossary	186
	References	187
8	Mobile Cloud Networking: future communication architecture for mobile cloud	191
	<i>Zhongliang Zhao and Torsten Braun</i>	
	Abstract	191
8.1	Introduction	192

8.2	The MCN project	193
8.2.1	Objectives and scope	193
8.2.2	Project architecture	195
8.2.3	Project services	197
8.3	Radio Access Network as a Service	198
8.3.1	Architecture reference model	198
8.3.2	RANaaS life cycle	199
8.3.3	RANaaS performance analysis	199
8.3.4	Conclusions	208
8.4	Information-Centric Networking as a Service	208
8.4.1	ICNaaS architecture design	209
8.4.2	ICNaaS performance evaluation	210
8.5	Mobility Prediction as a Service	212
8.5.1	Architecture reference model	213
8.5.2	MOBaaS cloudification architecture	215
8.5.3	Sequence diagram of service management	217
8.5.4	Mobility prediction algorithm	219
8.5.5	Evaluation	221
8.6	Related works	224
8.7	Conclusion	224
	References	225
9	Composition of network and cloud service in next generation Internet	227
	<i>Jun Huang, Qiang Duan, and Ching-Hsien Hsu</i>	
	Abstract	227
9.1	Introduction	227
9.2	Modeling composite network–cloud service provisioning	229
9.2.1	A framework for network–cloud service composition	229
9.2.2	Model and formulation for composite network–cloud service provisioning	231
9.3	An algorithm for QoS-aware composition of network and cloud services	233
9.3.1	Algorithm description	233
9.3.2	Algorithm analysis	234
9.4	Experimental results for performance evaluation	236
9.5	Conclusion	240
	References	241
10	NaaS-enabled service composition in SDN environment	243
	<i>Yongyi Ran, Jian Yang, Enzhong Yang, and Shuangwu Chen</i>	
10.1	Introduction	243
10.2	Overview of service composition in SDN	245
10.2.1	SDN and cloud in substrate layer	245

10.2.2	NaaS in slice layer	246
10.2.3	Service request graph in abstract layer	248
10.2.4	Service composition	248
10.3	NaaS-enabled framework for service composition	249
10.3.1	Framework of service and resource management	249
10.3.2	Design of multipath	252
10.3.3	Multicast in SDN	253
10.3.4	Multi-domain connectivity	255
10.4	Use cases	255
10.4.1	Use case 1: DASH-based streaming service	256
10.4.2	Use case 2: dynamic switching for multi-tree multicast	257
10.5	Conclusion	260
	Acknowledgment	261
	References	261
11	Network-as-a-Service in software-defined networking for end-to-end quality of service provisioning	265
	<i>Qiang Duan</i>	
	Abstract	265
11.1	Introduction	265
11.2	End-to-end service provisioning in SDN—challenges and solutions	268
11.2.1	Challenges to end-to-end service provisioning in SDN	268
11.2.2	Network-as-a-Service in SDN—a promising solution	270
11.3	NaaS-based service delivery in SDN	271
11.4	Modeling and performance analysis for NaaS-based QoS provisioning in SDN	274
11.4.1	Modeling and analysis	274
11.4.2	Numerical examples	277
11.5	Modeling and performance analysis for composite network-compute services	278
11.5.1	Modeling and analysis	278
11.5.2	Numerical examples	282
11.6	Conclusion	284
	References	284
12	Flow management and orchestration for virtualized network functions in software-defined networks	287
	<i>Po-Han Huang and Charles H.-P. Wen</i>	
	Abstract	287
	Keywords	287
12.1	Introduction	288
12.2	Service chains, virtualized network functions and software-defined networks	290

12.3	Control plane: orchestration mechanisms for service chains of VNFs	293
12.3.1	Single-flow service chain	293
12.3.2	Multiple-flow service chain	296
12.4	Data plane: flow management algorithms for service chains	298
12.4.1	Latency-aware algorithms	298
12.4.2	Throughput-aware algorithms	299
12.5	Case study: Network-Aware CHains Orchestration Selection (NACHOS)	300
12.5.1	System architecture	300
12.5.2	Details of NACHOS	301
12.5.3	Simulation results	303
12.6	Service placement: more on flow management	305
12.6.1	VM placement for flow management	305
12.6.2	Maximization of resource utilization	307
12.6.3	Recent placement algorithms	308
12.7	Conclusion	310
	References	310
13	On-demand network virtualization and provisioning services in SDN-driven cloud platforms	313
	<i>Maha Shamseddine, Ali Chehab, Ayman Kayssi and Wassim Itani</i>	
	Abstract	313
	Keywords	313
13.1	Introduction	313
13.2	Network virtualization: basic concepts and architecture	315
13.3	Software-defined networking architecture	319
13.4	NaaS models in software-defined networks	321
13.5	NCaaS: network configuration as a service	323
13.5.1	NaaS providers offers	323
13.5.2	Tenants preferences and constraints	325
13.5.3	NCaaS partitioning algorithm	326
13.5.4	Topology generation	329
13.5.5	Partitions connection algorithm	329
13.5.6	NCaaS implementation	331
13.6	Conclusion and future extensions	335
	References	336
14	GPU-based acceleration of SDN controllers	339
	<i>Xuan Qi, Burak Kantarci and Chen Liu</i>	
14.1	Introduction	339
14.1.1	What is SDN?	339
14.1.2	SDN, benefits, and challenges	340
14.1.3	Summary	341

14.2	Existing SDN controller solutions	341
14.2.1	OpenFlow	341
14.2.2	Existing SDN controller implementations	343
14.3	Existing SDN controller solutions	345
14.3.1	GPU acceleration	345
14.3.2	GPU accelerated SDN controller	347
14.4	Case study	351
14.4.1	Experimental setup	351
14.4.2	Throughput and latency	351
14.5	Open issues and challenges	352
14.6	Conclusion	353
	Acknowledgment	354
	References	354
15	Virtualisation and management of application service networks	357
	<i>Indika Kumara, Jun Han, Alan Colman and Malinda Kapuruge</i>	
	Abstract	357
15.1	Introduction	357
15.2	Service networks and their virtualisation	359
15.2.1	Service networks	359
15.2.2	Multi-tenancy in service networks	360
15.2.3	Motivating scenarios	361
15.2.4	General requirements for an approach to virtualised service networks	363
15.3	SDSN: an approach to realising and managing virtualised service networks	363
15.3.1	Managed service networks	363
15.3.2	Virtual service networks	365
15.3.3	Service network management interfaces and managers	368
15.4	Management of virtualised service networks	368
15.4.1	Configuration management	368
15.4.2	Regulation management	369
15.4.3	Evolution management	372
15.4.4	Management policy: specification and enactment	372
15.4.5	Management policy: examples	373
15.5	Prototype implementation	375
15.6	Evaluation	376
15.6.1	Service network virtualisation	377
15.6.2	Service network management	377
15.7	Related work	378
15.7.1	Support for service networks and their virtualisation	380
15.7.2	Relating to SDN	380
15.8	Conclusion	381
	Acknowledgment	382
	References	382