Contents

Αd	Acknowledgment							
Αŀ	ostrac	:t		v				
Κι	Kurzfassung							
Lis	List of Abbreviations							
1	Intr	oductio	n	1				
	1.1		ation for Network Slicing-based (Private) 5G and Beyond					
	1.2		nunication Networks	1 7				
2	Related Work Regarding Private 5G Networks, 5G Network Slicing, and Automated Network Planning							
	2.1		t Developments Concerning Private 5G Networks	11				
		2.1.1	General Overviews and Surveys	12				
		2.1.2	Empirical Results and Analyses	12				
		2.1.3	Summary	14				
	2.2	Relate	ed Work in Network Slicing for the Radio Access Network .	15				
		2.2.1	RAN Slicing without Machine Learning	16				
		2.2.2	Machine Learning-based RAN Slicing	17				
		2.2.3	Summary	19				
	2.3	2.3 Related Work in Automated Network Planning \dots		22				
		2.3.1	Traditional Automated Network Planning	22				
		2.3.2	Automated Network Planning based on Machine Learning	23				
		2.3.3	Summary	24				
3			nt and Evaluation of Dynamic Radio Network Slicing based	27				
	on Experimental and Simulative Approaches							
	3.1		Evaluation of Network Slicing using 4G Concepts	27				
		3.1.1	Architecture of the Developed 4G-based End-to-End Net-	0.0				
		0.1.0	work Slicing System	28				
		3.1.2	Testing Environment and Evaluation Scenario of the De-	0.1				
		0.1.0	veloped 4G-based End-to-End Network Slicing System	31				
		3.1.3	Evaluation Results of the Developed 4G-based End-to-End	0.4				
			Network Slicing System	34				



	3.2		Summary, Conclusion, and Next Steps	37					
		Netwo 3.2.1	rk Slicing Scheduler	38					
			Scheduler	38					
		3.2.2	Laboratory Setup Based on SDR and SDN	40					
		3.2.3	Empirical Evaluation of the Developed RAN Slicing Scheduler	41					
		3.2.4	Summary, Conclusion, and Next Steps	47					
	3.3		and Simulative Evaluation of a Machine Learning-based uler for Reliable 5G Network Slicing	48					
		3.3.1	Motivation for Developing a 5G Network Slicing Scheduler Based on Machine Learning	48					
		3.3.2	Design of the Developed 5G Resource Grid Simulation (5G-RGS) for Scheduler Prototyping	52					
		3.3.3	Technical Design and Implementation of the Slice-Aware Machine Learning-based Ultra-Reliable Scheduling (SAMUS)						
			Prototype	54					
		3.3.4	Evaluation of the SAMUS Prototype based on Realistic Scenarios and Data Sets	56					
		3.3.5	Summary, Conclusion, and Next Steps	65					
4	Development and Evaluation of Automated Network Planning for								
4	Dev	eiopme	nt and Evaluation of Automated Network Planning for						
4				67					
4		work Sli	nt and Evaluation of Automated Network Planning for icing-based Communication Networks ts of Demand-Based Planning and Configuration of Private	67					
4	Netv	work Sli Benefi	icing-based Communication Networks	67					
4	Netv	work Sli Benefi	icing-based Communication Networks ts of Demand-Based Planning and Configuration of Private						
4	Netv	work Sli Benefi 5G Ne	icing-based Communication Networks ts of Demand-Based Planning and Configuration of Private etworks						
4	Netv	work Sli Benefi 5G Ne	icing-based Communication Networks ts of Demand-Based Planning and Configuration of Private etworks	68					
4	Netv	work Sli Benefi 5G Ne 4.1.1	icing-based Communication Networks ts of Demand-Based Planning and Configuration of Private etworks	68 68					
4	Netv	Work Sli Benefi 5G Ne 4.1.1	icing-based Communication Networks ts of Demand-Based Planning and Configuration of Private etworks	68 68					
4	Netv	Work Sli Benefi 5G Ne 4.1.1	icing-based Communication Networks Its of Demand-Based Planning and Configuration of Private Stworks	68 68 69					
4	Netv	work Sli Benefi 5G Ne 4.1.1 4.1.2 4.1.3	icing-based Communication Networks ts of Demand-Based Planning and Configuration of Private betworks Motivation and Basic Architecture of Automatic Demand- Based Network Planning and Configuration Description of the Developed Experiment Showcase Video Theoretical Underpinnings and Outcomes of the Simulative Validation Vision for Combined Private 5G Network and Event Operation	68 68 69 75					
4	Netv 4.1	Work Sli Benefi 5G Ne 4.1.1 4.1.2 4.1.3 4.1.4 4.1.5	icing-based Communication Networks Its of Demand-Based Planning and Configuration of Private Stworks Motivation and Basic Architecture of Automatic Demand- Based Network Planning and Configuration Description of the Developed Experiment Showcase Video Theoretical Underpinnings and Outcomes of the Simulative Validation Vision for Combined Private 5G Network and Event Operation Summary, Conclusion, and Next Steps	68 69 75 79					
4	Netv	Work Sli Benefi 5G Ne 4.1.1 4.1.2 4.1.3 4.1.4 4.1.5 Rapid	icing-based Communication Networks ts of Demand-Based Planning and Configuration of Private stworks Motivation and Basic Architecture of Automatic Demand- Based Network Planning and Configuration Description of the Developed Experiment Showcase Video Theoretical Underpinnings and Outcomes of the Simulative Validation Vision for Combined Private 5G Network and Event Operation Summary, Conclusion, and Next Steps and Automated Network Planning of Private 5G Networks	68 69 75 79					
4	Netv 4.1	Benefi 5G Ne 4.1.1 4.1.2 4.1.3 4.1.4 4.1.5 Rapid Based	icing-based Communication Networks ts of Demand-Based Planning and Configuration of Private stworks Motivation and Basic Architecture of Automatic Demand- Based Network Planning and Configuration Description of the Developed Experiment Showcase Video Theoretical Underpinnings and Outcomes of the Simulative Validation Vision for Combined Private 5G Network and Event Operation Summary, Conclusion, and Next Steps and Automated Network Planning of Private 5G Networks on Unsupervised Machine Learning	68 68 69 75 79 81					
4	Netv 4.1	Work Sli Benefi 5G Ne 4.1.1 4.1.2 4.1.3 4.1.4 4.1.5 Rapid	icing-based Communication Networks ts of Demand-Based Planning and Configuration of Private stworks Motivation and Basic Architecture of Automatic Demand- Based Network Planning and Configuration Description of the Developed Experiment Showcase Video Theoretical Underpinnings and Outcomes of the Simulative Validation Vision for Combined Private 5G Network and Event Operation Summary, Conclusion, and Next Steps and Automated Network Planning of Private 5G Networks on Unsupervised Machine Learning Description of the Developed Method for Rapid Automated	68 68 69 75 79 81					
4	Netv 4.1	Work Sli Benefi 5G Ne 4.1.1 4.1.2 4.1.3 4.1.4 4.1.5 Rapid Based 4.2.1	icing-based Communication Networks Its of Demand-Based Planning and Configuration of Private Stworks Motivation and Basic Architecture of Automatic Demand-Based Network Planning and Configuration Description of the Developed Experiment Showcase Video Theoretical Underpinnings and Outcomes of the Simulative Validation Vision for Combined Private 5G Network and Event Operation Summary, Conclusion, and Next Steps and Automated Network Planning of Private 5G Networks on Unsupervised Machine Learning Description of the Developed Method for Rapid Automated Network Planning	68 69 75 79 81					
4	Netv 4.1	Benefi 5G Ne 4.1.1 4.1.2 4.1.3 4.1.4 4.1.5 Rapid Based	icing-based Communication Networks Its of Demand-Based Planning and Configuration of Private Stworks Motivation and Basic Architecture of Automatic Demand-Based Network Planning and Configuration Description of the Developed Experiment Showcase Video Theoretical Underpinnings and Outcomes of the Simulative Validation Vision for Combined Private 5G Network and Event Operation Summary, Conclusion, and Next Steps and Automated Network Planning of Private 5G Networks on Unsupervised Machine Learning Description of the Developed Method for Rapid Automated Network Planning Detailed Description of Clustering Analysis for Automated	68 69 75 79 81					
4	Netv 4.1	Work Sli Benefi 5G Ne 4.1.1 4.1.2 4.1.3 4.1.4 4.1.5 Rapid Based 4.2.1	icing-based Communication Networks Its of Demand-Based Planning and Configuration of Private Stworks Motivation and Basic Architecture of Automatic Demand-Based Network Planning and Configuration Description of the Developed Experiment Showcase Video Theoretical Underpinnings and Outcomes of the Simulative Validation Vision for Combined Private 5G Network and Event Operation Summary, Conclusion, and Next Steps and Automated Network Planning of Private 5G Networks on Unsupervised Machine Learning Description of the Developed Method for Rapid Automated Network Planning Detailed Description of Clustering Analysis for Automated Network Planning	68 68 69 75 79 81 82					
4	Netv 4.1	Work Sli Benefi 5G Ne 4.1.1 4.1.2 4.1.3 4.1.4 4.1.5 Rapid Based 4.2.1 4.2.2	icing-based Communication Networks Its of Demand-Based Planning and Configuration of Private Stworks Motivation and Basic Architecture of Automatic Demand-Based Network Planning and Configuration Description of the Developed Experiment Showcase Video Theoretical Underpinnings and Outcomes of the Simulative Validation Vision for Combined Private 5G Network and Event Operation Summary, Conclusion, and Next Steps and Automated Network Planning of Private 5G Networks on Unsupervised Machine Learning Description of the Developed Method for Rapid Automated Network Planning Detailed Description of Clustering Analysis for Automated Network Planning Importance of Clustering or Unsupervised Learning for	68 68 69 75 79 81 82					
4	Netv 4.1	Work Sli Benefi 5G Ne 4.1.1 4.1.2 4.1.3 4.1.4 4.1.5 Rapid Based 4.2.1 4.2.2	icing-based Communication Networks Its of Demand-Based Planning and Configuration of Private Stworks Motivation and Basic Architecture of Automatic Demand-Based Network Planning and Configuration Description of the Developed Experiment Showcase Video Theoretical Underpinnings and Outcomes of the Simulative Validation Vision for Combined Private 5G Network and Event Operation Summary, Conclusion, and Next Steps and Automated Network Planning of Private 5G Networks on Unsupervised Machine Learning Description of the Developed Method for Rapid Automated Network Planning Detailed Description of Clustering Analysis for Automated Network Planning	68 68 69 75 79 81 82 82					

	4.3	Automated Coverage and Capacity Planning for Network Slicing-				
		based Private 5G Networks	102			
		4.3.1 Why Novel Concepts in Capacity Planning are Needed for				
		Future Mobile Communication Networks	103			
		4.3.2 Data Predictability in the Context of Capacity Planning.	105			
		4.3.3 Overall Architecture of the Developed Coverage and Ca-				
		pacity Planning Framework	107			
		4.3.4 Evaluation of the Impact of Data Uncertainty in ML-based				
		Network Slicing on Network Planning	112			
		4.3.5 Summary, Conclusion, and Next Steps	117			
	4.4	Performance Comparison of the Developed Network Planning				
		Method with the Optimal Solution (Exhaustive Search)	118			
		4.4.1 Summary and Conclusion	122			
5	Con	clusion and Future Work	125			
	5.1	Closing Summary	125			
	5.2	Derived Potentials and Future Work	128			
Bibliography						
Sc	Scientific Activity Report					