Module by Module - Self Study Note Guide

Nokia Bell Labs End-to-End 5G Certification Program

Nokia Bell Labs End-to-End 5G Foundation Course

Instructions

Research has shown that learning is most effective when understood from one's own personal perspective. As such, we have created this learning guide for you to use as a personal reference and study guide.

For each module, the guide starts with the objectives, potential exam topics, course topics, and then concludes with key takeaways. For each topic, space is provided for you to take notes, capture observations and insights, or simply create a study guide for reference in preparation for your certification exam.

Table of Contents....

Unit 1 - The 5G Imperative – 5G Drivers and Technology Essentials

Key Objectives

Here are our learning objectives for this module.

- Be able to distinguish the three primary limits driving the need for an end-to-end approach to 5G: consumer value creation, the deficiencies of our current networks, and constantly rising total ownership and operating costs.
- Learn how to begin bypassing these limits and explore the business trends and technology evolution that will create unique opportunities associated with the fourth industrial revolution.
- Use this knowledge to appraise the importance of new automated solutions, for industry in particular.

Potential Exam Topics – The 5G Imperative – 5G Drivers and Technology and The Industry Journey to End-to-End 5G

- Know example industries that are most digitized today.
- Know reasons why 5G could be better than 4G for certain applications (Delivery, Drone Control, Truck Platooning, etc)
- What are the limitations to some of today's networks that prevent them from delivering ultra low latency (1 to 10 ms) and other potential key capacity requirements of the future 5G networks.
- Know the key elements of the new 5G end-to-end architecture.
- Know the maximum capabilities of 5G networks.
- Be able to describe Network Slicing.
- What tools are available to increase automated services in a 5G network.
- Know different methods to increase capacity in the wireless interface.
- Know different technology enablers that allow for industrial and commercial applications of the future. Think of some of the examples from the course.

Notes Section

Topic Names	Your Notes
The future is end-to-end	Instructions. Type your notes in these boxes. Box will expand to accommodate your text.
Value Creation Limits: Consumer value creation	
Reaching Limits	
The quest for new value	

Digital opportunities of various industries	
Factories	
Worksites	
Cities	
Logistics and Transport	
Health	
Past and Present Value Creation. Exploring history of modern productivity.	
What can be done to reinvigorate today's slowing growth in productivity?	
Future transportation, Healthcare and Automation Examples	
Limit: Current networks	
The limitations of current networks	
Future network requirements	
Lower latency	
Data throughput, consumption, and storage demands	
Connectivity density	
New network architecture	
Business drivers of the network requirements	
The future network: the 100yr, 100x shift	

How do we get there?	
Future is end-to-end	
Five key end-to-end enablers of the 5G solution	
5G networking, distributed cloud, network slicing, security, and industrial automation.	
5G networking: Access	
5G networking: Core	
5G networking: Transport	
End-to-end distributed Cloud	
The Essence of network slices in 5G	
End-to-end security	
Limit: Total cost of ownership	
Evolution toward 5G network slicing	
Simplicity through automation	
Additional Notes	

Key Take Aways:

Let's recap the most important points covered in this module.

- You should remember that the end-to-end 5G network has five key components: Networking, Cloud, Slicing, Security, and Industrial Automation.
- And in order for these components to work together efficiently to facilitate end-to-end 5G, there are four critical performance requirements that must be delivered: extreme throughput, ultra-low latency, improved reliability and massive connectivity.
- Only when all of these come together, and we add in extensive analytics and automation, can a real-time dynamic service be delivered

Unit 1 (Continued) - The 5G Imperative - The Industry Journey to End-to-End 5G

Key Objectives

Here are our learning objectives for this module.

- After this module you will be able to identify some of the main industries who are expected to capitalize on end-to-end 5G today, and in the future.
- Secondly, you will also be able to explore these industries further, exploring how new value creation will be enabled via end-to-end 5G performance capabilities of extreme throughput, ultra low latency, improved reliability and massive connectivity.
- This module should give you a good basis from which to further explore how 5G levels of throughput, latency, reliability and connectivity can enable new value creation for these industries.
- Lastly, we will introduce you to an industry example which you should use to complete the exercises throughout the course.

Notes Section

Topic Names	Your Notes
The Industry Journey	Instructions. Type your notes in here. Box will expand to accommodate your text. Note: Select and Delete this comment.
Industry's journey to end-to-end 5G	
Many ways in which industry will benefit from 5G	
Port of Hamburg case example	
Additional Notes	

Foundations of 5G Networking: Access

Key Objectives

Here are our learning objectives for this module.

- Be able to describe how access is evolving in the 5G era to serve and facilitate emerging business applications.
- Be able to evaluate 5G access against the continuing evolution of fiber, cable, copper and Wi-Fi technologies.
- Be able to describe the fundamental technological and architectural build of access and its impact on end-to-end 5G.

Potential Exam Topics : Foundation of 5G Networking : Access

- Know 4G Limitations as they compare to 5G.
- Know what technologies drive 5G's increased throughput capacity, low latency, high reliability.
- What elements drive Access capacity growth.
- Be able to recognize some of the features that will be specified in 3GPP Release 16 and 17.
- Know frequency spectrums introduced in 5G and preferred ranges for different applications.
- Know what is the purpose/benefits of millimeter waves in 5G.
- Know benefits of massive MIMO and beamforming.
- Know benefits of multi-connectivity.
- Know radio factors that drive ultra- low latency for 5G access.
- Know performance attributes of mMTC.
- What are key benefits of Cloud RAN.

Notes Section

Topics	Your Notes
5G Networking: Access	Instructions. Type your notes in here. Box will expand to accommodate your text. Note: Select and Delete this comment.
5G Networking: Access	
Access requirements	
4G limitations and 5G's role in driving industry 4.0	
5G access specifications	
Extreme broadband	
Industry 4.0	

IoT & advanced sensors
High throughput
Ultra reliability Low latency
Massive connectivity
5G networking: access
Evolution of access: 5G provides equivalent, untethered capabilities
How access has evolved
Fixed - Copper/Fiber
Fixed - Cable
Wireless
3GPP evolution: realizing the full promise of 5G
Key technology enablers
The six technology enablers of 5G
Various access networks for 5G
5G access and multi-connectivity
Wireless spectrum
5G NR spectrum frequency ranges
mMIMO and Beamforming
Low Latency enablers

Ultra-low latency in 5G access	
Radio latency in 5G access	
Massive Connectivity enablers	
5G access: enabling massive connectivity for mMTC	
Access architecture	
Grid densification	
Cloud radio access network (Centralized/Cloud RAN)	
RAN evolution to Centralized/Cloud RAN	
RAN evolution to Centralized/Cloud RAN	
Additional Notes:	

Key Take Aways:

Let's sum up the most important points about this module.

- 5G New Radio brings several capacity-improving features, like spectral efficiency, new centimeter and millimeter frequency bands, massive MIMO and beamforming, and scalable TTI delivering lower radio latency.
- Introducing multi-connectivity improves reliability and capacity for end-to-end 5G. 5G New Radio also includes specific features that enable massive connectivity, and can be used to provide Fixed Wireless Access, thanks to its high throughput capabilities.
- Even though 5G New Radio allows us to make the most of 5G's benefits, 5G Access is not only 5G New Radio: 4G access and Wi-Fi can also be part of the 5G System. Finally, in a Cloud RAN architecture, some radio processing elements will move to the Edge Cloud, driving scalability and cost efficiency.

5G Networking: Transport

Key Objectives

Here are our learning objectives for this module.

- Explain how the transportation network will meet the important performance requirements of 5G.
- Map the key transport technology enablers in the end-to-end 5G network.
- Describe a 5G transport network's overall architecture.
- Understand how a flexible, scalable transport network amplifies 5G's business potential.

Potential Exam Topics : Foundation of 5G Networking : Transport

- Know where to find Fronthaul, Midhaul, Backhaul in an X-Haul access network diagram.
- Describe Self-Midhauling.
- Know what functionality is applied to find alternative path in case of failure in a Transport Network.
- Know Probabilistic Constellation Shaping in Optical Transport.
- Know solutions to reduce latency in a network.
- Know what technologies implement Transport Slices.
- Know 5G Transport challenges.
- Know the different components of a 5G Transport network .
- Know the different components of the 5G Flexible RAN architecture.

Notes Section

Topic Names	Your Notes
Transport requirements	Instructions. Type your notes in here. Box will expand to accommodate your text. Note: Select and Delete this comment.
Performance requirements	
5G transport challenges and transformation drivers	
Key technology enablers	
5G transport and routing network	
How do these technology enablers drive us forward?	
Driver 1: Modular and scalable transport X-haul	
Why do we need a flexible access backhaul?	

X-Haul, Cloud RAN and edge cloud	
Transport flexibility	
Fronthaul	
X-haul transport technologies - mid- and backhaul	
Cloud RAN flavors	
Transport capacity and performance	
Optical transport	
IP routing elements	
IP equipment requirements	
IP routing technology	
Driver 3: Software-defined networking (SDN)	
Delivering real-time traffic management	
Driver 4: Transport slices	
Transport slice orchestration	
Transport architecture	
End-to-end architecture for transport network	
Flexibility of end-to-end orchestration	
Additional Notes	

Key Take Aways:

Here are the key points to remember from this module.

- First off, transport networks that support end-to-end 5G are composed of three interworking elements: optical transport, IP routing, and orchestration.
- Looking to our first transformation driver, Cloud RAN is becoming increasingly modular and scalable. Additionally, modular backhaul, also referred to as X-haul, can be split into fronthaul, midhaul, and backhaul. For fronthaul and midhaul connectivity, Time Sensitive Network Ethernet, microwave , passive optical networks or even radio self-backhauling can be used.
- For the second transformation driver, transport capacity and performance are improved by optical technology enablers, which include Reconfigurable Optical Add Drop Multiplexers, Probabilistic Constellation Shaping, and Space Division Multiplexing . State-of-the-art IP routers with efficient routing silicon and programmable network processors add to capacity and performance.
- Thirdly, software-defined networking is required to support the dynamic and elastic traffic patterns of 5G. With SDN, traffic steering can be conducted in real-time, which leads to improved transport capacity and utilization.
- For our final driver, transport slice orchestration is also enabled by software-defined networking. Transport orchestration creates, assures and optimizes SLA-based transport slices.
- Finally, regarding transport architecture, the future transport fabric will be elastic and programmable with these various technology enablers. With transport technologies rapidly evolving, we are just around the corner from the era of 5G.

5G Networking: Core

Key Objectives

- Evaluate the limitations of core today, and understand how the core needs to adapt for the evolution of 5G networks.
- Analyze the technology concepts that enable the core to be both universal and adaptive, and examine the main functions it will deliver as part of an end-to-end 5G network.
- Know how the universal adaptive core is evolving to address 5G enterprise, industrial and convergence needs.

Potential Exam Topics : Foundation of 5G Networking : Core

- Know about the 5G Core functions in the programmable user plane.
- Know about the 5G Core function used to establish and manage user sessions.
- Know about the 5G Core architecture that is used to deploy and utilized services.
- Know current limitations of 4G in terms of low latency, high reliability, capacity.
- Know how current limitations of 4G can be overcome with aspects of 5G.
- Know why 5G Core universal and has capacity for adaptation.
- Know 5 Key 5G features.
- Know details about : NSSF, AMF, SMF, NRF, UDR, UDM, AUSF.
- Know which deployment option is used by initially deployed 5G non-standalone network

Notes Section

Topic Names	Your Notes
Section 1: Core requirements	Instructions. Type your notes in here. Box will expand to accommodate your text. Note: Select and Delete this comment.
5G networking: Core	
Addressing 5G requirements with 5G core	
Limitations of 4G EPC	
How will the core architecture evolve?	
Current end-to-end architecture is complex	

Section 2: Key technology enablers	
Key features for 5G core	
Control plane and user plane separation	
Service based architecture	
Stateless: decoupling of compute & storage	
5G core enables network slicing	
Multi-access, wireline-wireless convergence	
Section 3: Core architecture	
5G networking: Core	
User plane functions and connected elements	
NG RAN- New Generation Radio Access Network	
UPF - The User Plane Function	
DN - The Data Network	
Control plane functions	
AMF - The Access and Mobility Management Function	
SMF - The Session Management Function	
NRF - The Network Repository Function	
NSSF - The Network Slice Selection Function	
AUSF - The Authentication Server Function	

UDM - The Unified Data Management function	
NEF - The Network Exposure Function	
UDR - The Unified Data Repository	
UDSF - The Unstructured Data Storage Function	
Full 5G core	
Section 4: Core evolution	

Key Take Aways:

Let's sum up the key points to remember about this module.

- Evolution to 5G Core will greatly reduce complexity of previous core configurations.
- 5G Core is becoming the common-or universal-core for all access technologies across public and private networks.
- It is adaptive thanks to its service-based architecture and Control and User Plane separation, allowing for the roll-out and support of more efficient network slices.
- The flexibility of network functions across the 5G Core, such as Access & Mobility Management and Network Slice Selection Function, allows for multi-access and access convergence, as well as network slicing.
- Other important core systems and virtualized functions in the 5G Core include the Session Management Function, the Unified Data Management, the Authentication Server Function, the Network Repository Function, and the Network Exposure Function.
- The Unified Data Management and the State-Efficient aspects of network functions enable scalability and extreme resilience.
- There are currently multiple options for deploying 5G Core in a network.
- In the long term, many 5G networks will migrate towards Standalone 5G New Radios connected to a 5G Core.
- For industry players, evolution to the 5G core delivers higher reliability and continuity through convergence, and the ability to deploy a private core in dedicated networks for localized security and industrial services.

Foundation of Distributed Cloud

Key Objectives

Here are our learning objectives for this module.

- Describe how a distributed cloud is a vital piece in the delivery of low-latency services and applications in end-to-end 5G.
- Understand the benefit that distributed clouds bring to dense 5G RAN deployments, local low-latency services and network slicing.
- Map how levels of clouds fit as part of a distributed-cloud environment, and understand how this applies to industry players needing to enable low-latency, on-site services.
- Understanding of the 5G distributed cloud deployment options to be considered in your planning.
- Consider the implications needed to enable service delivery, in relation to hardware and software technology decisions and investments.

Potential Exam Topics : Foundation of Distributed Cloud

- Know about Cloud and Transport Orchestration, NFVO, SDN.
- Know what 5G Functions must be in Edge Cloud for low latency.
- Know benefits of Edge Cloud.
- Know what function(s) reduce helps reduce Edge Cloud management costs.
- Know what Resource elasticity in the Cloud enables.
- Know about different types of cloud types such as those provided by a web scale provider, or other method.
- Know what components provide could automation.
- Know what's in a VNF.
- Know what services Cloud Orchestration offers.

Notes Section

Topic Names	Your Notes
Section 1: Cloud requirements	Instructions. Type your notes in here. Box will expand to accommodate your text. Note: Select and Delete this comment.
Foundation of distributed cloud	
5G Cloud Solutions	
5G Cloud Solutions:	
5G distributed cloud architecture	
5G distributed cloud and latency impacts	

5G distributed cloud architecture
5G edge cloud for low latency applications enablement
Cloud orchestration principle
Section 2: Key technology architecture and enablers
Foundation of distributed cloud
The relationship between IT cloud and 5G distributed cloud
IT cloud
5G distributed cloud
Network functions
Multiple cloud instances
2-layer orchestration
Resource orchestration elaboration
Cloud orchestration
Resources and cloud orchestration standard
Distributed cloud security
Cloud security
The relationship between IT cloud and 5G distributed cloud

Section 3: Realizing the benefits of distributed cloud	
Foundation of distributed cloud	
Benefits of Cloud	

Key Take Aways:

- The distributed cloud is often comprised of edge, regional or metro, and central clouds. These distributed clouds enable both low latency and higher performance to meet the service demands of end-to-end 5G.
- Orchestration is the linking element that delivers performance across the complexity of distributed clouds.
- The distributed cloud infrastructure supports virtual machines and containers that deliver virtual network functions.
- Additional elements of the cloud infrastructure include a cloud software platform, resource orchestration and SDN.
- Cloud orchestration enables end-to-end network services - like slicing - in the cloud.
- The top benefits of the end-to-end distributed cloud include improved service and application performance as well as flexible and reusable resource pools for slicing, dynamic scaling and network recovery.

Foundation of Network Slicing

Key Objectives

Here are our learning objectives for this module.

- Gain understanding of the origin and technical concepts of network slicing. This leads to becoming familiar with end-to-end Quality of Service and service level agreements for 5G, and how network slicing delivers these concepts.
- Identify the technical and economic gains that can be had from network slicing, as well as be able to determine why network slicing requirements form a fundamental end-to-end 5G network driver.

Potential Exam Topics : Foundation of Network Slicing

- Know about basic principles of Network Slicing.
- Know about requirements, architecture, automation, performance, benefits.
- Know what could be different characteristics of a slice service request in various scenarios.
- Know what a vertical Network Slice is.
- Know about eMBB, mMTC and URLLC services.

Notes Section

Topic Names	Your Notes
Section 1: Essential requirements and principles	Instructions. Type your notes in here. Box will expand to accommodate your text. Note: Select and Delete this comment.
Essential requirements and principles	
The basic principle of network slicing	
Historical evolution of network slicing	
End-to-end 5G slicing requirements and solutions	
Network slicing performance	
2.9 New value creation through network slicing	
Transportation	
Manufacturing	
Healthcare	

Sports	
Power Industry	
Public Safety	
Mining	
Section 2: Slicing architecture and enablers	
The need for holistic resource management	
4G EPC enables basic slicing	
5G core facilitates extensive slicing	
5G efficient network slicing	
Traffic flow based on Quality of Service	
End-to-end slicing management with orchestration	
The benefits of slicing automation	
Additional Notes	

Key Takeaways

- Network slicing innovation extracts optimal value from 5G by providing efficient end-to-end network slicing functionality, which makes specific service level agreements and differentiated Quality of Service possible.
- The bedrock of network slicing is its end-to-end network slice management, which comprises access, transport, and core domains. Slice management incorporates virtualization, analytics, and cloud technologies as well.
- Network slicing is a transformative technology that enables the ability to provide network performance requirements needed to support a vast amount of use cases, many of which are not even in existence or known today!
- The ability to increase the number slices is highly dependent on intelligent slicing orchestration, and automation is essential for exploiting the full cost savings and new value potential from network slicing.

Foundation of Security

Key Objectives

Here are our learning objectives for this module.

- By the end of this module you will be able to talk about the security challenges that 5G will bring and the corresponding measures that need to be put in place.
- You will be able to give examples of potential attack vectors and the main 3GPP 5G security features. This will help you develop an understanding of how to protect the cloud, network function virtualization and network slicing in 5G.
- Finally, you will understand why a holistic and efficient end-to-end security solution must be implemented and automated using artificial intelligence and machine learning.

Potential Exam Topics : Foundation of Security

- Know about the most challenging security threats faced by 5G operators.
- Know about Proactive cybersecurity with automated security orchestration
- Know which standards organization define what : example NPV Security, EAP Protocol
- Know about AUSF, SOAR, EAP, NFV.
- Know benefits of an organization having a private 5G network vs a tenant Network Slice.
- Know 3 types of attacks on SDN.
- Know how to ensure robust slicing isolation.

Notes Section

Topic Names	Your Notes
1) 5G security requirements	Instructions. Type your notes in here. Box will expand to accommodate your text. Note: Select and Delete this comment.
Foundation of security	
5G potential attack vectors	
Requirements on future-proof 5G security	
End-to-end security approach	
2) 5G security standards and enablers	
5G security standards and enablers	

Elements of a 5G architecture	
New access-agnostic authentication framework	
3GPP 5G security standardization	
Enhanced subscription privacy	
User plane integrity protection on the radio interface	
Security for service-based interfaces	
Interconnection vulnerability in LTE	
Interconnection security in 5G	
Cloud security	
Security assurance	
3) End-to-end security: a holistic approach	
Security orchestration, automation and response	
Additional Notes	

Key Take Aways:

Let's recap the most important points covered in this module.

- End-to-end 5G will drive more expansive use cases, which in turn leads to a greater risk of more sophisticated attacks.
- These attacks can come from user devices or direct access to the gNB, malicious virtual functions, networks like the internet, or from threat actors working on the inside of the network.
- 5G security needs a layered and holistic approach, using both edge-based perimeter security and automated AI and machine learning security orchestration for efficiency.
- Several standards bodies have protocols and assurance approaches that address many 5G security concerns, while good practice implementation is closing the gap for edge-based perimeter security.
- An adaptive security architecture that leverages the attributes of SOAR will help prevent, detect, respond and predict attacks in the end-to-end 5G network.

Foundation of Industrial Automation

Key Objectives

- Be able to describe how the interplay of operational, information and communication technologies is driving new value creation in industrial automation.
- Articulate the role of 5G in meeting the automation needs of Industry 4.0.
- Map 5G-enabled horizontal applications to industrial business needs and technology performance requirements.
- Describe how these horizontal applications apply to very specific use cases in public safety, railway transportation, and manufacturing.

Potential Exam Topics : Industrial Automation

- Know about Industry 4.0. What does it describe.
- What is the sweet spot for Industry 4.0
- Know the role of 5G in Industrial Automation and how it supports requirements.
- Know about the 5G Technology Enablers and applications that can help Industrial Automation.

Notes Section

Topic Names	Your Notes
Use Cases	Instructions. Type your notes in here. Box will expand to accommodate your text. Note: Select and Delete this comment.
Industries benefiting today and tomorrow	
Enhancing public safety, railways and manufacturing:	
The 5G network and public safety applications	
End-to-end 5G for railway transport	
End-to-end 5G for manufacturing	
The 5G network and manufacturing applications	

Key Takeaways

- There are three main parallel and interweaving technological developments driving industrial automation in the age of Industry 4.0.
- Operational technology generates massive amounts of data for information technology to collect and process through sophisticated cloud computing platforms and techniques like analytics, machine learning and AI. This helps produce unique and previously unattainable insights into various parts of manufacturing performance. With end-to-end 5G, communication technology will provide the fundamental network infrastructure and performance needed to enable industry automation.
- In addition to performance aspects, we also learned that employing end-to-end 5G networks requires various business and strategy-related considerations, such as the decision to employ either private or public 5G solutions.
- In this particular case, industry's opting of either private or public 5G is driven by geographic coverage, security, regulatory and business agility requirements.
- Specifically, end-to-end 5G would enable applications demanding massive connectivity and inter-operability; consistently high levels of throughput; consistently ultra-low levels of latency reaching down to 5 milliseconds or less; and such extreme levels of reliability as to be practically failsafe.
- Finally, we saw that there is clear value of 5G use cases for public safety, transportation and manufacturing, which serve as an example for similar applications across the whole range of industries.

Industry Acronyms

The following Industry relevant acronyms may be referenced during the course and on the certification exam. You should become familiar with these terms as the acronym may be used on the certification exam.

Acronym	Meaning
3GPP	3rd Generation Partnership Project
4IR	Fourth Industrial Revolution
5G	5th generation wireless technology
5GC	5G Core
5GNR	5G New Radio
5GTTH	5G to the home
A2P	Application-to-person
ADM	Add-drop multiplexer
ADSL	Asymmetric digital subscriber line
AF	Application function
AGV	Automated guided vehicles
AI	Artificial intelligence
AKA	Authentication and key agreement
AMF	Access and mobility management function
API	Application programming interface
AR	Augmented reality
ASIC	Application-specific integrated circuit
AuC	Authentication center
AUSF	Authentication server function
BBU	Baseband unit
BGP	Border gateway protocol
BPaaS	Business Processes as as Service
BTS	Base transceiver station
CCAP	Converged cable access platform
CNF	Cloud-native network function
CPE	Customer premise equipment
CPRI	Common public radio interface
CPU	Central processing unit
CSP	Communication service provider
CU	Centralized unit
CUPS	Control and user plane separation
CWDM	Coarse wavelength division multiplexing
DC	Data center
DÉCOR	Dedicated core network
DL	Downlink
DN	Data network
DoS	Denial of service
DSCP	Differentiated service code point
DSL	Digital subscriber line

DSP	Digital Service Provider
DU	Distributed unit
DWDM	Dense wavelength division multiplexing
E2E	End-to-End
EAP	Extensible authentication protocol
ECMP	Equal-cost multi-path
eCPRI	Enhanced CPRI
eLTE	Evolved long-term evolution
eMBB	Enhanced mobile broadband
eMTC	Enhanced machine-type communication
EPC	Evolved packet core
ETSI	European Telecommunications Standards Institute
eVPN	Ethernet virtual private network
FPGA	Field programmable gate array
FR	Frequency range
FTTH	Fiber to the home
FWA	Fixed wireless access
GDP	Gross domestic product
GPU	Graphics processing unit
GSM A	GSM Association
GW	Gateway
HLR	Home location register
HPLMN	Home public land mobile network
HSS	Home subscriber server
HW	Hardware
ICP	Internet content provider
IETF	Internet Engineering Task Force
IKE	Internet key exchange
IMSI	International mobile subscriber identity
IMT	International Mobile Telecommunications
IPSec	Internet protocol security
IPX	Internetwork packet exchange
IS to IS	Intermediate system to intermediate system
IT	Information technology
ITU	International Telecommunications Union
ITU-T	ITU-telecommunication
LAN	Local area network
lIoT	Industrial Internet of Things
loT	Internet of Things
LTE	Long-term evolution
LTE-M	Long-term evolution machine-type communication
MAA	Massive antenna array
MANO	Management and network orchestration
MBB	Mobile broadband
MEC	Multi-access edge computing

MiTM	Man in the middle
ML	Machine learning
Ml MO	Multiple-input multiple-output
MME	Mobility management entity
mMIMO	Massive multiple-input multiple-output
mMTC	Massive machine-type communication
MNO	Mobile network operator
MOCN	Mobile operator core network
MTC	Machine-type communication
MU-MI MO	Multiple-user multiple-input multiple-output
MVNO	Mobile virtual network operator
NB-loT	Narrowband Internet of Things
NEF	Network exposure function
NESAS	Network element security assurance scheme
NF	Network function
NFV	Network function virtualization
NFV MANO	Network Function Virtualization Management and Orchestration
NFV-0	Network function virtualization orchestration
NFV-I	Network function virtualization infrastructure
NG RAN	New generation radio access network
NLRI	Network layer reachability information
NR	New radio
NRF	Network repository function
NS	Network service
NSA	Non-standalone
NSSF	Network slice selection function
NVP	Network visibility poisoning
NWDAF	Network data analytics function
Oauth	Open authentication
OPEX	Operating expense
OS	Operating system
OSPF	Open shortest path first
OTP	One-time password
PCE	Path computation engine
PCF	Policy control function
PCS	Probabilistic constellation shaping
PLMN	Public land mobile network
PNF	Physical network function
PON	Passive optical network
PSTN	Public switched telephone network
QoS	Quality of Service
RAM	Random access memory
RAN	Radio access network
RF	Radio frequency
ROADM	Reconfigurable optical add-drop multiplexer

Rt	Realtime
RU	Radio unit
SaaS	Software as a service
SBA	Service-based architecture
SCAS	Security assurance specification
SDN	Software-defined network
SECAM	Security assurance methods
SEPP	Secure edge protection proxy
SIDF	Subscription identifier de-concealing function
SLA	Service level agreement
SMF	Session management function
SMSF	Short message service function
S-NSSAI	Single network slice selection assistance information
SOAR	Security orchestration automation and response
SR	Segment routing
SR-TE	Segment routing-traffic engineering
SUCI	Subscription concealed identity
SUPI	Subscription permanent identifier
SW	Software
TCO	Total cost of ownership
TEU	Twenty-foot equivalent unit
TLS	Transport layer security
TOO	Total cost of ownership
TSN	Time sensitive network
TTI	Transmission time interval
UDM	Unified data management
UDR	Unified data repository
UDSF	Unstructured data storage function
UE	User equipment
UL	Uplink
UPF	User plane function
URLLC	Ultra-reliable low latency communication
V2X	Vehicle-to-everything
vDAA	Virtualized Distributed Access Architecture
VDSL	Very high speed digital subscriber line
VIM	Virtualized infrastructure manager
VM	Virtual machine
VNF	Virtualized network function
VNF-M	Virtualized network function manager
VOD	Video on demand
VoIP	Voice over internet protocol
VPLMN	Visited public land mobile network
VR	Virtual reality
vRAN	Virtual radio access network
WAN	Wide area network

WDM	Wavelength division multiplexing
Wi-fi	Wireless fidelity
WLAN	Wireless LAN
WTTA	Wireless to the antenna
WWC	Wireline-wireless convergence
xDSL	Digital subscriber line (collective summary)

Exam Table

The following table identifies the proportion of questions from each domain that will appear on the examination. These percentages are used to determine the number of questions related to each domain and task that should appear on the multiple-choice format examination.

Topic Area	Percentage of Items on Test
The 5G Imperative	12%
Foundation of 5G Networking - Access	13%
Foundation of 5G Networking - - Transport	13%
Foundation of 5G Networking - Core	13%
Foundation of Distributed Cloud	13%
Foundation of Network Slicing	12%
Foundation of Security	12%
Foundation of Industrial Automation	12%
Total	100%

Document Control

Type	Version	Date
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Update – add exam topics, acronyms, exam percentage table	1.3	07.10.2020