

Module by Module - Self Study Note Guide

Nokia Bell Labs End-to-End 5G Certification Program Nokia Bell Labs End-to-End 5G Networking 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 2 Module 2 - Access: Fixed & Fixed Wireless Access.....	2
Unit 2 Module 3 - Access: Massive Scale RAN and New Radio	3
Unit 2 Module 4 - Access: Solutions and Deployment Options	4
Unit 2 Module 5 - Access: Orchestration and Automation	5
Unit 3 Module 2 - Core: Functions and Features	6
Unit 3 Module 3 - Core: Solutions and Deployment Options.....	7
Unit 3 Module 4 - Core: Orchestration and Automation	8
Unit 4 Module 2 - Transport: Architecture and Technologies.....	9
Unit 4 Module 3 - Transport: Solutions and Deployment Options	10
Unit 4 Module 4 - Transport: Orchestration and Automation	11
Unit 5 Module 1 – Deployment: E2E 5G Network and Deployment.....	12
Unit 5 Module 2 – Deployment: Digital Automation Services and Slicing.....	12
Industry Acronyms.....	13
Exam Table	17

Unit 2 Module 2 – Access: Fixed & Fixed Wireless Access

Key Objectives

Here are our learning objectives for this module.

- Review the core concepts of fixed and wireless access networks
- Evaluate the role of fixed access for enterprises and consumers
- Consider how fixed wireless access provides a range of fiber-like options to a 5G Network.

Potential Exam Topics: Access: Fixed & Fixed Wireless Access

- General understanding of FTTH and how it fits into a 5G Network
- Understanding of how Fixed Wireless Access fits into a 5G Network
- How fixed wireless access can be used as a cost effective solution in a 5G network
- Knowledge of the standardization bodies.

Notes Section

Topic Names	Your Notes
Fixed & Fixed Wireless Access	Instructions. Type your notes in here. Box will expand to accommodate your text. Note: Select and Delete this comment.
Fixed & Fixed Wireless Access Principles	
Fixed Access	
Fixed Wireless Access	
Additional Notes	

Key Take Aways:

Here are the key points to remember from this module.

- Fiber-based Passive Optical Networks access has evolved from home access to a range of access uses, including wireless backhaul
- Fiber access is a key element for a range of 5G access solutions
- 5G Fixed Wireless Access provides access options for many consumer and enterprise connectivity needs
- 5G Fixed Wireless Access, also known as FWA, can also be a replacement of Fiber to the Home, using 5G Wireless for the last mile.

Unit 2 Module 3 - Access: Massive Scale RAN and New Radio

Key Objectives

- Articulate how the important evolutions in 5G New Radio technologies help support a wide range of use cases
- Describe how the contributions from key 5G standards bodies are driving 5G radio access network evolution and service enablement
- Evaluate the new and evolving network architectures for 5G radio access.

Potential Exam Topics: Access: Massive Scale RAN and New Radio

- Understand the interfaces related to RAN
- Understand the protocols related to RAN
- Know the names of the standardization bodies related to RAN and what they have been responsible for defining in a network
- Know the frequency bands related to RAN, what each band is primarily used for, and the advantage of higher frequency spectrum.
- Benefits of the following concepts in a 5G Network:
 - mMIMO
 - Beamforming
 - Dynamic Spectrum Sharing
 - Bandwidth Parts (BWP)

Notes Section

Topic Names	Your Notes
Massive Scale RAN and New Radio	Instructions. Type your notes in here. Box will expand to accommodate your text. Note: Select and Delete this comment.
5G Radio Network Differentiators	
Standards	
Network Architecture	
Additional Notes	

Key Take Aways:

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

- 5G offers a number of radio network resources and features—including Massive MIMO, 3D Beamforming, Scheduling Enhancements, and Flow-based QoS –to support a wide variety of services.

- 3GPP, ETSI NFV, and O-RAN are standardizing different aspects of the 5G RAN, providing a roadmap for 5G access evolution
- 5G allows for a range of RAN architectures such as Cloud RAN, which provides more flexibility on how access network functions are deployed.

Unit 2 Module 4 - Access: Solutions and Deployment Options

Key Objectives

Here are our learning objectives for this module.

- Describe the 5G radio access solutions available to meet differing deployment requirements
- Evaluate the different Radio Access Network deployment options for 5G in both public and non-public networks
- Articulate the requirements for different 5G RAN deployment scenarios.

Potential Exam Topics: Access: Solutions and Deployment Options

- Know the difference between standalone and non-standalone deployment
- Know the deployment options as defined by 3GPP
- Know the benefits of higher frequency spectrum over lower frequency spectrum
- Difference between the Spectrum Aggregation Methods for 5G
- Identify use cases for UPF deployment.

Notes Section

Topic Names	Your Notes
Access Solutions and Deployment Options	Instructions. Type your notes in here. Box will expand to accommodate your text. Note: Select and Delete this comment.
Radio Solutions	
System Deployment Solutions	
Deployment Scenarios	
Additional Information	

Key Take Aways:

- 5G provides a variety of radio solutions—from macro cell, small cell and integrated backhaul—to meet different coverage and capacity requirements.
- 5G flexibility allows for RAN to be deployed using 4G core or 5G core and as either a public, private or hybrid network.
- Understanding the use case requirements is crucial to evaluating and determining the best 5G deployment solution.

Unit 2 Module 5 - Access: Orchestration and Automation

Key Objectives

Here are our learning objectives for this module.

- Illustrate the concepts of orchestration, slicing and automation and their impact on 5G access
- Articulate how end-to-end network slices are applied in the 5G radio access network
- Explain how intelligence and programmability drive access enhancements including self-organizing networks and zero-touch automation.

Potential Exam Topics: Access: Orchestration and Automation

- Know the responsibilities of each protocol layer in the gNB
- Know the advantages of Access orchestration
- Understand SON and how it functions.

Notes Section

Topic Names	Your Notes
Access Orchestration and Automation	Instructions. Type your notes in here. Box will expand to accommodate your text. Note: Select and Delete this comment.
Orchestration, Slicing and Automation Principles	
Access Orchestration and Slicing	
Access Automation and Intelligence	
Additional Notes	

Key Take Aways:

- End to end network orchestration allows new 5G services to be deployed faster and managed more effectively
- The radio access network coordinates with the 5G core to map data flows to the necessary flow-based QoS
- The RAN Intelligent Controller (RIC) enhances Self Organizing Networks to support AI applications and automatically optimize the RAN.

Unit 3 Module 2 – Core: Functions and Features

Key Objectives

- Articulate the importance of the Service Based Architecture and the Service Communication Proxy in the 5G Core
- Depict the basic procedures of the Control Plane, and the role of specific network functions in those procedures
- Explain how the new features outlined in the current and upcoming 3GPP standard releases will impact the evolution of 5G Core.

Potential Exam Topics: Core: Functions and Features

- Be able to explain the information that is exchanged during Session Establishment
- Be able to explain the information that is exchanged during Registration Acceptance
- Be able to explain the information that is exchanged during Policy Association/Modification
- Understand the functionality of the Session Management Function
- Understand the functionality of the User Plane Function
- Know the elements of the 5G Core Auxiliary functions

Notes Section

Topic Names	Your Notes
Core Functions and Features	Instructions. Type your notes in here. Box will expand to accommodate your text. Note: Select and Delete this comment.
Service Based Architecture	
Simplified message flows	
Core feature evolution towards 3GPP releases	
Additional Topics	

Key Takeaways:

- The 5G Core Service based architecture enables more flexible deployments, greater interoperability and is cloud-ready, opening the way for Service Mesh.
- Message flows in the 5G Core follow control plane procedure that are dependent on a series of network functions
- The new core functionality and features tied to 3GPP releases 15, 16, and 17 will enable E2E 5G networking to better meet the needs of industry communications.

Unit 3 Module 3 - Core: Solutions and Deployment Options

Key Objectives

- Articulate how the 5G core supports legacy technologies and is a platform for future service deployments
- Plan how to leverage the 5G Core as a Universal access core to cover the expanded range of access networking options
- Identify the key elements of a flexible 5G Core that enable Cloud Native deployment
- Understand how the 5G core enables APIs, which can deliver services that can be developed faster and cheaper
- Leverage decision-making criteria for choosing the right 5G Core deployment option.

Potential Exam Topics: Core: Solutions and Deployment Options

- Be able to identify the valid access methods to 5G technology
- Know the 3GPP Release 15 deployment option features
- Which features are supported by stand alone deployments

Notes Section

Topic Names	Your Notes
Core Solutions and Deployment Options	Instructions. Type your notes in here. Box will expand to accommodate your text. Note: Select and Delete this comment.
EPC/5GC interworking	
Fixed and non 3GPP access	
Cloud Native deployment	
Open API Data and service Exposure	
Deployment options	
Additional Topics	

Key Takeaways:

- Initial 5G networks using EPC core (Option 3x) use existing LTE voice/SMS solutions (VoLTE, VoWiFi, SRVCC, CSFB)
- For 5G Option 2, IMS voice is the only solution to provide voice services (EPS Fallback, VoNR)
- Combined EPC/5GC functions are required for Voice handover between LTE/5G and when slicing is deployed in both technologies.
- Home Routing versus Local Break Out as well as deployments options and services offered to users have to be considered in setting a roaming agreement.

- As new 3GPP releases come, better interworking is achieved.
- The 5G Core is very adaptable, and will also be able to interwork with 2G, 3G, and 4G networks.
- There are several elements of the 5G core that enable universal connectivity access.
- The key enablers for 5G core Cloud Native deployment are:
- 3GPP technology enablers: Control and User Plane Separation, decomposed functions, SCP and Service Mesh,
- IT technology enablers: Containers, Micro Services and Infrastructure Agnostic.
- Open APIs are crucial for Network Optimization Automation, an enabler for advanced customer services.
- The 5G Core can support the slicing needs of a variety of enterprise services deployment options, including public and private networks as well as shared RAN models.

Unit 3 Module 4 - Core: Orchestration and Automation

Key Objectives

- Articulate the importance of Core Orchestration to 5G Networking and end to end 5G slicing
- Explain how key 5G core functions enables slicing through orchestration
- Describe how the intelligence in the 5G core enables automation.

Potential Exam Topics: Core: Orchestration and Automation

- Understand the principals behind closed loop automatic fault mitigation.
- Understand the principals of the core domain orchestrator.
- Understand the principals behind NFV orchestration.
- Know the main benefits of core network slicing.
- Know the functions of Network Service Orchestration Management

Notes Section

Topic Names	Your Notes
Core Orchestration and Automation	Instructions. Type your notes in here. Box will expand to accommodate your text. Note: Select and Delete this comment.
Core Orchestration and Slicing	
Core Automation and Intelligence	
Additional Notes	

Key Takeaways:

- 5G core orchestration is crucial to meet the 5G service requirements such as speed, latency, reliability and agility, especially when delivering end to end slicing

- Various features enables large scale automation of dynamic services and slices, including NFV and Containers Orchestration, NWDAF, Service Mesh with Service Communication Proxies, and ETSI ZSM. The whole enables full automation for a Zero Touch Network

Unit 4 Module 2 – Transport: Architecture and Technologies

Key Objectives

- Articulate the standards-driven architecture options for 5G transport
- Explain the concepts of fronthaul, midhaul and backhaul, and their role in 5G transport networks
- Convey the value proposition for cloud-enabled midhaul and backhaul to meet evolving 5G requirements.

Potential Exam Topics: Transport: Architecture and Technologies

- Know what eCPRI is and its benefit.
- Know the transport network segments and which network functions they are responsible for.
- Know the benefits of CPRI and eCPRI
- Understand the features of Time Sensitive Networking

Notes Section

Topic Names	Your Notes
Transport Architecture and Technologies	Instructions. Type your notes in here. Box will expand to accommodate your text. Note: Select and Delete this comment.
5G Transport architectures	
Fronthaul Transport	
Mid and Backhaul Transport	
Additional Topics	

Key Takeaways:

- The 5G transport architecture is underpinned by a combination of cloud optimized IP routing and ultra-scale flexible optics
- New 5G requirements are driving radio partitioning, separating fronthaul, midhaul and backhaul, formalized by 3GPP and O-RAN standards
- The value proposition for midhaul and backhaul in 5G transport is supported by new technologies including Time Sensitive Networking (TSN) and cloud-enabled automation.

Unit 4 Module 3 – Transport: Solutions and Deployment Options

Key Objectives

- Articulate the fronthaul, midhaul and backhaul approaches enabling any-to-any connectivity architecture
- Describe how highly accurate synchronization over transport meets the most important requirements of 5G
- Explain how the elements of a Time Sensitive Network are superior to ethernet in transport networks, and why it’s needed for 5G Fronthaul.
- Identify the enabling technologies driving midhaul and backhaul transportation deployments in complex 5G networks.

Potential Exam Topics: Transport: Solutions and Deployment Options

- Understand the benefit of Time Sensitive Networking
- Know the fronthaul solutions
- Know which technologies carry fronthaul traffic
- Know the difference between Time Sensitive and Classical Ethernet Networking

Notes Section

Topic Names	Your Notes
Transport Solutions and Deployment Options	Instructions. Type your notes in here. Box will expand to accommodate your text. Note: Select and Delete this comment.
5G Transport Solutions	
Fronthaul Solutions	
Mid and Backhaul Solutions	
Additional Topics	

Key Takeaways:

- The requirements of 5G networks require a new approach to fronthaul focused on higher bandwidth and a reduced latency
- Time Sensitive Network technology is a new packet solution that ensure the lower latency and time synchronization for 5G connectivity
- The new Precision Time Protocol is a step beyond SynchE, allowing for the high time synchronization accuracy in E2E 5G connections
- New IP and Optics solutions have been introduced in Midhaul and Backhaul, increasing capacity and ensuring the security of the 5G connections.

Unit 4 Module 4 – Transport: Orchestration and Automation

Key Objectives

- Explain the principles and essential elements of software defined networking in 5G transport
- Articulate the impact of the Software Defined Networking Controller and its key features
- Identify the importance of orchestration and automation in delivering transport slicing in 5G networks.

Potential Exam Topics: Transport: Orchestration and Automation

- Know the purpose and benefits of SDN
- Understand the importance of SDN
- Understand how traffic engineering is managed in a SDN
- Know the definition of a Transport Slice
- Understand the benefits of Transport Slicing

Notes Section

Topic Names	Your Notes
Transport Orchestration and Automation	Instructions. Type your notes in here. Box will expand to accommodate your text. Note: Select and Delete this comment.
Software Defined Networking Principles	
Software Defined Network Controller	
Transport slicing	
Additional Topics	

Key Takeaways:

- Software Defined Networking (SDN) in the transport network is crucial to introduce a 5G network
- Leveraging SDN in 5G networks reduces operational costs and improves the networking experience for important 5G networking use cases
- Traffic deployment, network assurance, net supervision and northbound API management are the key blocks in the SDN controller allowing software centralization of the network
- Transport slicing helps deliver 5G networking SLAs by addressing latency, packet loss, and jitter concerns.

Unit 5 Module 1 – Deployment: E2E 5G Network and Deployment

Key Objectives

- Illustrate how the elements of access, core and transport work together in an overall end-to-end 5G networking architecture.
- Articulate how the network lifecycle planning for end-to-end 5G is evolving to incorporate automation and analytics-driven tools.

Potential Exam Topics: Deployment: E2E 5G Network and Deployment

- Know the phases of the network lifecycle
- Know the parts of the value packages

Notes Section

Topic Names	Your Notes
Network lifecycle and automation	Instructions. Type your notes in here. Box will expand to accommodate your text. Note: Select and Delete this comment.
End to end network overview	
Network Lifecycle planning concept	
On the road to Network Deployment	
Additional Topics	

Key Takeaways:

- An End-to-end 5G network architecture includes Access, transport, Core and management and orchestration layers.
- Network slices, which deliver services with optimum user experience, leverage the service orchestration and management framework.
- The 4 steps of a 5G network lifecycle include design, deploy, operate and monetize.
- Network lifecycle planning and execution can be complex, especially for public networks, which also need backward compatibility with previous generation networks.

Unit 5 Module 2 – Deployment: Digital Automation Services and Slicing

Key Objectives

- Map the major steps to deploy and operate a 5G networking service,

- Articulate how to leverage an automated approach for 5G network deployment and digital services,
- Explain how closed loop automation will help drive digital services and slicing workflow,
- Prove how digitalization can shorten the 5G network deployment phase,
- Apply the 3GPP standards guidance for 5G network slicing.

Potential Exam Topics: Deployment: Digital Automation Services and Slicing

- Know which network phase concentrator location is done in
- Know the building blocks of digital operations
- Know the goal of RF Design
- Know the demand algorithm

Notes Section

Topic Names	Your Notes
Digital Automation Services and Slicing	Instructions. Type your notes in here. Box will expand to accommodate your text. Note: Select and Delete this comment.
E2E networking details of Railway case study	
Additional Topics	

Key Takeaways:

- Leveraging automation is crucial to address the major 5G networking planning and deployment challenges Service Providers face,
- Digital automation tools and resources are essential for the planning, design, deployment, and operation of new 5G services, including end-to-end slicing,
- Closed-loop network and service automation is a critical enabler for dynamic 5G service creation and delivery, to ultimately reach Zero Touch network,
- 3GPP helps the standardization of Network Slicing management by decomposing the Slicing management into 3 main layers: CSMF, NSMF and, NSSMF.

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
5G NR	5G New Radio
5GTTTH	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
IIoT	Industrial Internet of Things
IoT	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
MI 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-IoT	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

Exam Breakdown

Number of Questions: 60 Questions

Exam Time Limit: 90 Minutes

Topic	Percentage of Items on Exam
Access: Fixed & Fixed Wireless Access	7%
Access: Massive Scale RAN and New Radio	10%
Access: Solutions and Deployment Options	10%
Access: Orchestration and Automation	7%
Core: Functions and Features	12%
Core: Solutions and Deployment Options	13%
Core: Orchestration and Automation	8%
Transport: Architecture and Technologies	8%
Transport: Solutions and Deployment Options	8%
Transport: Orchestration and Automation	8%
Deployment - E2E 5G Network and Deployment	3%
Deployment - Digital Automation Services and Slicing	5%

Document Control

Type	Version	Date
Initial Creation – draft	1.1	07.17.2020