Course Type	Course Code	Name of Course	L	T	P	Credit
DE	OCSD601	Advanced Computer Networks	3	0	0	3

Course Objective

This is an advanced course on Computer Networks covering four main contemporary topics namely how high-performance networks are designed covering algorithms and implementations, data center networking, information centric networking and network softwarization: software defined networking, network virtualization and programmable networks. This course assumes a basic knowledge of computer networks and working proficiency with Unix/Linux Operating Systems. It has practical component with programming assignments giving hands on to the students

Learning Outcomes

This course will be providing a detailed understanding of the Advanced networks routing, DCN and software-based networks.

Unit No.	Topics To be covered	No of Lecture Video	Video Time (Minutes)	Learning Outcome
1	High Performance Switching and Routing: Introduction, performance considerations, IP address lookup. Routing and Routing Table Internet Service Provider Networks Router Components Router Design Goals. Route Prefixes Route Lookup Performance Trie-based Data Structures for Route Lookup	4	132	Understand high-performance router architectures, key hardware components, and design goals within ISP networks. Evaluate packet forwarding performance considerations and computational bottlenecks during wire-speed IP lookups. Analyze routing table organization, Classless Inter-Domain Routing (CIDR), and route prefix matching mechanics. Design and implement trie-based data structures (such as binary, Patricia, and multi-bit tries) for fast route lookup. Balance memory footprint, update overhead, and search latency to achieve efficient Longest Prefix Matching (LPM).
2	Algorithms for IP address lookup and optimization, hardware implementation of address lookup. Data Structures for Route Lookup: Binary Trie Optimizations to Binary Trie Multi-Bit Trie. Multi-Bit Trie Level Compressed Trie Hardware Route Lookup	4	130	Master core algorithms and optimization strategies for high-speed IP address lookup and packet forwarding. Design and analyze trie data structures, including optimized Binary Tries, Multi-Bit Tries, and Level-Compressed Tries (LC-Tries). Evaluate stride selection and memory trade-offs to maximize search throughput and reduce routing table size. Understand hardware-based route lookup architectures, including TCAMs, pipelining, and parallel memory engines. Apply algorithmic compression and hardware acceleration techniques to achieve scalable, wire-speed Longest Prefix Matching (LPM).
3	Packet Classification: Need for packet classification and methods for packet classification. Packet Classification Quality of Service Requirements Trie based Data Structure for Packet Classification. Quality of Service (QoS) Need for QoS Methods for Providing QoS Integrated Service Model	7	215	Explain the necessity of multi-field packet classification and evaluate core classification algorithms in modern networks. Analyze Quality of Service (QoS) principles, service requirements, and the Integrated Services (IntServ) model for traffic differentiation. Apply trie-based data structures (such as Grid-of-Tries and Hierarchical Tries) to optimize multi-dimensional rule matching. Assess QoS provisioning methods and performance trade-offs required to guarantee network throughput and latency at wire speed.
4	Differentiated Service, Quality of Service, Traffic Polishing, Traffic Shaping Differentiated Service in Networks Per Hop Behavior Code Points. Traffic Policing Traffic Scheduling Traffic Shaping. Packet Switching Types of Switch Fabric Single Path and Mult.ipath Switches.	7	188	Evaluate Quality of Service (QoS) and Differentiated Services (DiffServ) frameworks, including Per-Hop Behaviors (PHB) and DSCP markings. Apply traffic policing and traffic shaping mechanisms to enforce bandwidth constraints and control bursty network traffic. Analyze traffic scheduling algorithms to manage buffer queues, prevent congestion, and prioritize packet delivery.
5	Network Softwarization – Introduction Network Softwarization Evolution of Internet Design Principles. Network Architecture and Design Principles Network Stack Internet Impasse Internet Ossification.	5	129	Understand the core principles of Network Softwarization and the evolution of traditional Internet design architectures. Analyze the structural limitations of the network stack that led to "Internet Impasse" and "Internet Ossification."

	Network Architecture and Design Principles Internet Impasse Internet Ossification Network Softwarization.			Evaluate how software abstractions decouple network control from hardware to resolve architectural ossification. Assess how Network Softwarization enables rapid innovation, flexibility, and dynamic management in modern network infrastructure.
6	Software Defined Networking (SDN) - Deep Dive (Northbound and Southbound interface) , Working with Mininet + Lab Exercises with Mininet SDN History Active Networking ForCES Software-Defined Networking Programmable Networking. Control Plane Abstractions SDN NBI SBI. SDN Layering CP FP MP ONOS ODL. OpenFlow OpenVswitch OVS. SDN Summary Challenges and Research directions.	9	193	Trace the historical evolution of programmable networks and analyze multi-layer SDN architectures separating Control, Data, and Management planes. Examine Northbound (NBI) and Southbound (SBI) interfaces, OpenFlow protocol mechanics, and Open vSwitch (OVS) packet handling. Gain hands-on experience using Mininet to emulate custom network topologies and evaluate enterprise SDN controllers like ONOS and OpenDaylight. Critically analyze current SDN deployment challenges, scalability constraints, and emerging research directions in softwarized networking.
7	Network Function Virtualization (NFV) - Architecture and Concepts NFV Middleboxes Virtualized Network Functions CoTS. NFV MANO VNF NFVI OSS BSS Terminology. NFV MANO VNF NFVI OSS BSS Use cases. NFV MANO NFV Challenges Resiliency Reliability Interoperability Portability. NFV DPDK UIO Pipelined model Run-to-completion model. NFV SDN Future Research Challenges.	7	236	Understand NFV architectural frameworks (VNF, NFVI, MANO, OSS/BSS) and the transition from proprietary hardware middleboxes to software-based virtualization on COTS hardware. Analyze data plane acceleration mechanisms using DPDK and UIO, evaluating performance under pipelined and run-to-completion execution models. Evaluate key operational deployment challenges—including resiliency, reliability, interoperability, and portability—alongside future SDN and NFV research directions.
8	Programmable Networks - Introduction to P4, SmartNICS and P4 switches. + Lab Exercise with Mininet and BMV2 switches. SDN DSL SMT MMT RMT, PHV RMT Parse Graphs	4	162	Understand the principles of data plane programmability, the P4 domain-specific language, and switch architectures (RMT, SMT, MMT, SmartNICs). Analyze P4 packet processing pipeline abstractions, including parse graphs, Packet Header Vectors (PHVs), and Reconfigurable Match-Action Tables. Gain hands-on experience developing custom P4 data plane programs and emulating programmable switches using Mininet and BMv2 targets.
9	Data Center Networking (DCN) – Introduction DCN Micro and Macro Data Centers Tail Latency, DCN NaDa PDU HVAC, Load balancing Multipath routing ToR EoR MoR, Three Tier topology Bisection Bandwidth K-ary FatTree Clos F16 Three Tier topology Bisection Bandwidth K-ary FatTree Clos F17	5	163	Analyze micro/macro data center physical architectures (ToR, EoR, MoR, PDU/HVAC) alongside multi-tier, Fat-Tree, and Clos (F16/F17) topologies. Quantify critical network performance metrics, including bisection bandwidth and tail latency, across high-density switch fabrics. Apply multipath routing and dynamic load balancing techniques to optimize traffic distribution and throughput in scalable data center fabrics.
10	DCN - Deep Dive (Network topologies, Container Network Interfaces) DCTCP RoCE RDMA QUIC, Network Telemetry Monitoring INT, Serverless Lambda GCF. Azure Functions. NPU sNIC DPU INT SDN 3.0	6	236	Analyze ultra-low-latency transport protocols (DCTCP, RoCE, RDMA, QUIC) and Container Network Interfaces (CNI) tailored for high-performance cloud workloads. Evaluate real-time network observability via In-band Network Telemetry (INT) alongside hardware offloading technologies including SmartNICs, NPUs, and DPUs. Examine the integration of serverless computing paradigms (Lambda, GCF, Azure Functions) with emerging next-generation SDN 3.0 data center architectures.
11	Content Distribution on the Internet, Architectures for Information Centric Networking HPPT3 QUIC HOLB TCP TLS, PUE DCiE GCE ERF CUE, Point-to-Point communication semantics of IP network Content Distribution Content Delivery Networks Caching Peer-to-Peer Networks Notion of Security in TCP/IP, Information Centric Networking Overview Design Goals for ICN Fundamental Concept Revisit for ICN	7	213	Analyze modern web protocols (HTTP/3, QUIC, TLS) and data center energy metrics (PUE, DCiE) designed to eliminate Head-of-Line Blocking and optimize transport efficiency. Evaluate internet content delivery mechanisms—including CDNs, edge caching, and P2P networks—transitioning from traditional point-to-point IP semantics to content-driven distribution. Examine the architectural design principles, fundamental concepts, and security paradigms of Information-Centric Networking (ICN) compared to legacy TCP/IP frameworks.

12	Content Naming, Routing and Caching, Security in Named Data Networking NDN overview Naming in NDN, Routing in NDN Caching Technique in NDN Security in NDN	2	65	Analyze Named Data Networking (NDN) principles, evaluating hierarchical content naming schemes and stateful data-centric forwarding mechanisms over location-based IP address routing. Evaluate in-network caching strategies and dynamic routing protocols designed to minimize retrieval latency and optimize content delivery across NDN architectures. Understand NDN's intrinsic security model, focusing on data-centric security, cryptographic signatures per packet, and built-in protection against network-level attacks.
Total No of video lectures & Video time		**67**	**2062**	

Text books

1 High-Performance Switches and Routers, H. Jonathan Chao, Bin Liu, 2007, John Wiley & Sons, Inc. ISBN-10: 0-470-05367-4

2 Information-Centric Networks: A New Paradigm for the Internet (Focus Series in Networks and Telecommunications), Gabriel M. de Brito, Pedro B. Velloso, Igor M. Moraes, Wiley-ISTE; 1st edition, 2013, ISBN: 9781848214491

Reference books:

3 Information-Centric Networking (ICN): Content Centric Networking (CCNx) and Named Data Networking (NDN) Terminology, B. Wissingh, C. Wood, A. Afanasyev, L. Zhang, D. Oran and C. Tschudin, RFC 8793, June 2020

4 Software-Defined Networks: A Systems Approach, Peterson, Cascone, O'Connor, Vachuska, and Davie, Online Free Reference Book available at https://sdn.systemsapproach.org/index.html

5 Cloud Networking: Understanding Cloud-based Data Centre Networks, Gary Lee (Author), Morgan Kaufmann (Publisher), 2014,ISBN-139780128007280

Link of NPTEL Course:

https://nptel.ac.in/courses/106106243