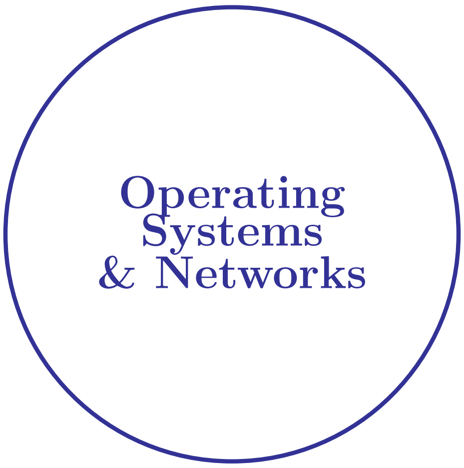
Operating Systems & Networks

Computer Science Discipline Map

Student Project - Multilevel Map of Computer Science



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1 Area Overview

Operating Systems & Networks represents a fundamental pillar of computer science that bridges hardware and software, enabling distributed computing and system-level programming. This area encompasses two deeply interconnected domains:

1.1 Operating Systems

The software layer that manages computer hardware resources and provides services for application programs. Operating systems handle:

- Process management and scheduling
- Memory management and virtual memory
- File system organization and access
- Device drivers and hardware abstraction
- Security and access control mechanisms

1.2 Computer Networks

The interconnection of computing devices that enables communication and resource sharing across distributed systems. This includes:

- Network protocols and architectures
- Data transmission and routing algorithms
- Network security and cryptography
- Performance optimization and quality of service
- Wireless and mobile networking technologies

1.3 Key Characteristics

- **Systems-oriented**: Focus on building and managing complex computing systems
- **Performance-critical**: Emphasis on efficiency, scalability, and reliability
- **Hardware-aware**: Deep understanding of underlying hardware architectures
- **Security-conscious**: Protection of resources and data integrity

2 Main Activities

2.1 Theory

2.1.1 Operating Systems Theory

- Process synchronization and concurrency theory
- Deadlock detection and prevention algorithms
- Memory management algorithms (paging, segmentation)
- File system design principles and optimization
- Real-time systems and scheduling theory

2.1.2 Networks Theory

- Graph theory applications in network topology design
- Queueing theory for network performance analysis
- Information theory for efficient data transmission
- Game theory in network resource allocation
- Cryptographic protocols and security theory

2.2 Experiment

2.2.1 Operating Systems Experiments

- Performance benchmarking of different OS architectures
- Concurrency testing and race condition detection
- Memory management efficiency studies
- File system performance analysis under various workloads
- Real-time system response time measurements

2.2.2 Networks Experiments

- Network protocol testing and validation
- Bandwidth and latency measurements across topologies
- Network security vulnerability assessments
- Load balancing effectiveness studies
- Wireless network performance in various environments

2.3 Design

2.3.1 Operating Systems Design

- Kernel architecture design (monolithic, microkernel, hybrid)
- Device driver development and hardware abstraction
- File system implementation and optimization
- Process scheduler design for specific requirements
- Virtual memory management systems

2.3.2 Networks Design

- Network protocol design and implementation
- Network topology optimization for specific use cases
- Security protocol development and deployment
- Quality of Service (QoS) mechanisms implementation
- Software-defined networking (SDN) architectures

3 Relations to Other Areas

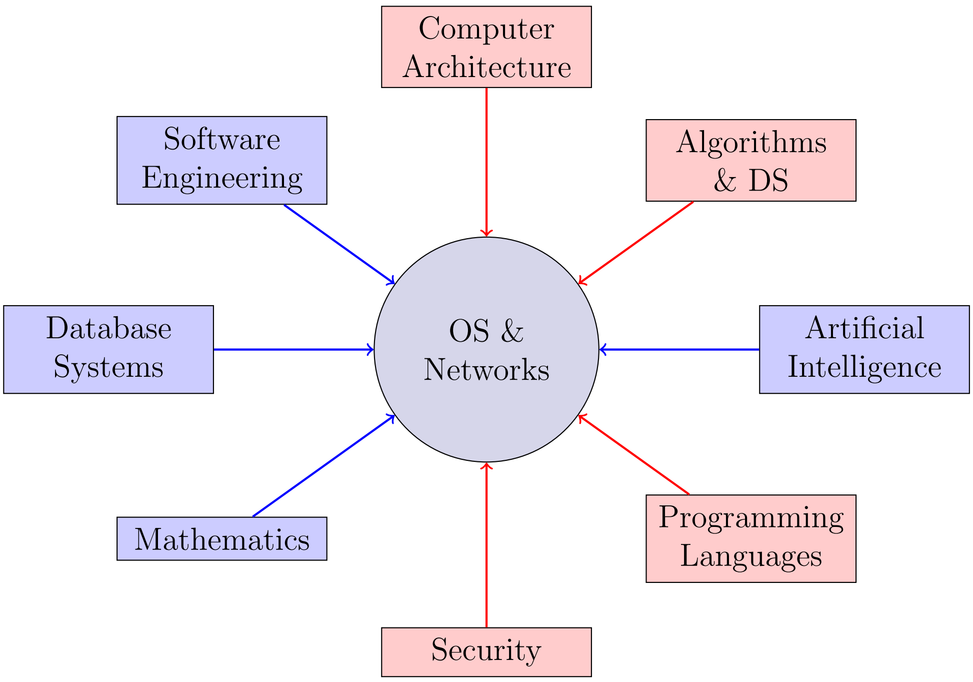

Figure 1: Relationships between Operating Systems & Networks and other CS areas

3.1 Strong Dependencies

- **Computer Architecture**: Hardware understanding essential for OS kernel design
- **Algorithms & Data Structures**: Core to efficient system implementations
- **Programming Languages**: System programming languages (C, Rust, Assembly)
- **Security**: Cryptography, access control, and secure communications

3.2 Influences From

- **Mathematics**: Probability theory, discrete mathematics, linear algebra
- **Software Engineering**: Large-scale system design methodologies
- **Database Systems**: Storage management and transaction processing
- **Artificial Intelligence**: Intelligent resource allocation and optimization

3.3 Influences To

- **Distributed Systems**: Foundation for distributed computing platforms
- **Cloud Computing**: Virtualization and containerization technologies
- **Internet of Things (IoT)**: Embedded systems and edge computing
- **High-Performance Computing**: Parallel and cluster computing systems

4 Important Problems & Open Challenges

4.1 Classic Problems (Solved)

Problem	Intuition	Solution
Producer-Consumer	Coordinating processes that produce and consume data at different rates	Semaphores, monitors, message passing
Dining Philosophers	Avoiding deadlock when multiple processes need multiple shared resources	Resource ordering, timeout mechanisms
Byzantine Generals	Achieving consensus in distributed systems with faulty nodes	Byzantine fault-tolerant algorithms

4.2 Current Open Problems

4.2.1 Operating Systems Challenges

1. **Energy-Efficient Computing**
   - *Challenge*: Balancing performance with power consumption
   - *Research*: Dynamic voltage scaling, heterogeneous architectures
2. **Real-Time Systems Guarantees**
   - *Challenge*: Hard real-time guarantees in multicore systems
   - *Research*: Multicore scheduling, execution time analysis
3. **Operating System Security**
   - *Challenge*: Protection against sophisticated attacks
   - *Research*: Hardware-software co-design, trusted execution

4.2.2 Computer Networks Challenges

1. **Network Function Virtualization (NFV)**
   - *Challenge*: Efficient placement and chaining of virtual functions
   - *Research*: AI-driven optimization, edge computing integration
2. **5G/6G Network Slicing**
   - *Challenge*: Dynamic resource allocation for diverse services
   - *Research*: ML for network slicing, ultra-low latency
3. **IoT Security**
   - *Challenge*: Securing billions of resource-constrained devices
   - *Research*: Lightweight cryptography, blockchain for IoT
4. **Quantum Networks**
   - *Challenge*: Building quantum communication infrastructure
   - *Research*: Quantum key distribution, quantum internet protocols

5 Important People

5.1 Operating Systems Pioneers

- **Dennis Ritchie** (1941-2011)
  Creator of C and co-creator of UNIX
- **Ken Thompson** (1943-)
  Co-creator of UNIX and B language
- **Linus Torvalds** (1969-)
  Creator of Linux kernel and Git
- **Andrew Tanenbaum** (1944-)
  Creator of MINIX, OS textbook au-

thor

- **Butler Lampson** (1943-)
  Personal computing and distributed systems

5.2 Computer Networks Pioneers

- **Vint Cerf** (1943-)
  Co-inventor of TCP/IP, "Father of Internet"
- **Bob Kahn** (1938-)
  Co-inventor of TCP/IP protocol suite
- **Tim Berners-Lee** (1955-)
  Inventor of the World Wide Web
- **Leonard Kleinrock** (1934-)
  Pioneer of packet switching theory
- **Paul Baran** (1926-2011)
  Developed packet switching concepts

5.3 Contemporary Leaders

- **Barbara Liskov** (1939-)
  Distributed systems, programming languages
- **Leslie Lamport** (1941-)
  Distributed algorithms, formal methods
- **Jennifer Rexford** (1969-)
  Software-defined networking
- **Hari Balakrishnan** (1973-)
  Mobile and wireless networking
- **Ion Stoica** (1965-)
  Cloud computing, distributed systems

6 Important Venues

6.1 Top-Tier Conferences

6.1.1 Operating Systems

- **SOSP** - ACM Symposium on Operating Systems Principles
- **OSDI** - USENIX Symposium on Operating Systems Design and Implementation
- **EuroSys** - European Conference on Computer Systems
- **ASPLOS** - Architectural Support for Programming Languages and OS
- **FAST** - USENIX Conference on File and Storage Technologies

6.1.2 Computer Networks

- **SIGCOMM** - ACM Special Interest Group on Data Communication
- **NSDI** - USENIX Symposium on Networked Systems Design
- **INFOCOM** - IEEE International Conference on Computer Communications
- **IMC** - Internet Measurement Conference
- **CoNEXT** - International Conference on Emerging Networking

6.1.3 Security

- **IEEE S&P** - IEEE Symposium on Security and Privacy
- **USENIX Security** - USENIX Security Symposium
- **CCS** - ACM Conference on Computer and Communications Security
- **NDSS** - Network and Distributed System Security Symposium

6.2 Premier Journals

- **ACM TOCS** - Transactions on Computer Systems
- **IEEE/ACM ToN** - Transactions on Networking
- **ACM TOS** - Transactions on Storage
- **Computer Networks** (Elsevier)
- **IEEE TPDS** - Transactions on Parallel and Distributed Systems

7 Local Dimension - UVT

7.1 Department Structure

Course	Course Coordinator	Seminar Coordinator
Operating Systems	Ciprian Pungilă	Darius Galiș
Computer Networks	Panica Silviu	Grumeza Theodor
Intro to Cybersecurity	Cristian Cira	Coroban Laurențiu
Network Administration	Horia Popa Andreescu	Horia Popa Andreescu

Table 2: UVT Faculty Structure for OS & Networks

7.2 Special Initiatives

UVT Cybersecurity Team

- **Mentor**: Cristian Cira
- **Focus**: CTF competitions, security research
- **Connection**: Strong relationship with network security

7.3 Local Research Focus

Core Areas of Emphasis:

- Practical system administration and network management
- Cybersecurity with network security focus

- System-level programming and OS internals
- Applied network protocols and security implementations
- Integration of theory and practice

7.4 Student Opportunities

- **Laboratory Experience**: Hands-on OS and network configuration
- **Cybersecurity Team**: CTF competitions and security research
- **Research Projects**: Network security and system administration
- **Industry Collaboration**: Practical coursework applications
- **Skill Development**: System administration, network design, security

8 Global Dimension

8.1 Major Research Centers

8.1.1 United States

- **MIT CSAIL** - Distributed systems, network protocols, OS research
- **Stanford Systems Group** - Database systems, distributed computing
- **UC Berkeley RISELab** - Big data systems, cloud computing
- **CMU PDL** - Storage systems, distributed systems

8.1.2 Europe

- **ETH Zurich** - Operating systems, distributed systems, security
- **Cambridge** - Security, distributed systems, network protocols
- **INRIA France** - Distributed systems, network protocols
- **MPI Germany** - Distributed systems, network measurement

8.2 Industry Leaders

8.2.1 Operating Systems

- **Microsoft** - Windows, Azure
- **Apple** - macOS, iOS
- **Google** - Android, Chrome OS
- **Red Hat** - Linux distributions
- **VMware** - Virtualization

8.2.2 Networking

- **Cisco** - Network infrastructure
- **Juniper** - High-performance networking
- **Cloudflare** - CDN and security
- **Akamai** - Content delivery
- **Amazon AWS** - Cloud networking

8.3 Global Trends

- **Cloud Computing Revolution** - Infrastructure transformation
- **Edge Computing Growth** - Distributed processing paradigm
- **5G and Beyond** - Next-generation mobile networking
- **Cybersecurity Evolution** - Advanced threat landscape
- **Green Computing** - Energy-efficient system design
- **Quantum Computing** - Post-quantum cryptography preparation

9 Future Directions

9.1 Emerging Technologies

1. **Quantum Operating Systems** - Managing quantum computing resources
2. **Neuromorphic Computing** - Brain-inspired architectures
3. **Edge-Native Systems** - Operating systems for edge computing
4. **Autonomous Networks** - AI-driven network optimization
5. **Post-Quantum Cryptography** - Quantum-resistant security

9.2 Research Opportunities

- Integration of AI/ML into system management
- Sustainable and energy-efficient computing solutions
- Privacy-preserving distributed systems architectures
- Blockchain integration with traditional computing systems
- Real-time analytics and comprehensive telemetry systems

10 Conclusion

Operating Systems & Networks represents a dynamic and continuously evolving field that sits at the very heart of modern computing infrastructure. From the foundational principles established by computing pioneers like Dennis Ritchie and Vint Cerf to the cutting-edge research in quantum networks and AI-driven systems, this area continues to fundamentally shape how we interact with and derive benefit from computing technology.

The local dimension at UVT provides students with strong foundations in both theoretical understanding and practical skills, preparing them for immediate industry impact. The global dimension offers exciting opportunities for research and innovation, with emerging technologies like quantum computing, edge systems, and autonomous networks opening new frontiers for exploration.

As we progress toward an increasingly connected and distributed world, the importance of robust, secure, and efficient operating systems and networks will only continue to grow. This comprehensive map serves as a guide to understanding both the breadth and depth of the Operating Systems & Networks area within computer science, highlighting its historical significance and promising future directions.

The integration of theoretical knowledge with practical application, as demonstrated in the UVT curriculum structure, represents the ideal approach to preparing the next generation of systems engineers and network architects who will build the computing infrastructure of tomorrow.