

**BIRLA INSTITUTE OF TECHNOLOGY & SCIENCE, PILANI, K. K. BIRLA GOA  
CAMPUS  
SECOND SEMESTER 2019-2020  
COURSE HANDOUT (PART II)**

**Date: 12/12/2019**

In addition to Part I (General Handout for all courses appended to the timetable) this portion gives further specific details regarding the course.

**Course No. :** CS F446  
**Course Title :** Data Storage Technologies and Networks  
**Instructor-in-charge :** Dr. Biju K Raveendran ([biyu@goa.bits-pilani.ac.in](mailto:biyu@goa.bits-pilani.ac.in))

**1.1. Objective**

- A. To educate students about various memory management strategies.
- B. To introduce various data storage technologies like hard disk, JBOD, RAID, NAS, SAN, IPSAN, etc.
- C. To measure the performance of the storage technologies and their utilities
- D. To introduce the issues of partitioning, replication, distribution, virtualization, backup and recovery in storage.

**1.2. Scope and Description of the Course**

The course starts with reviewing the basics of memory management strategies followed in conventional operating systems. The course uses Linux as a case study to review these concepts. This course also reviews the basics of Mass storage technologies like Hard disks and Flash memories and the file systems used for these technologies. The course also covers various other storage technologies like JBOD, RAID, NAS, SAN, IPSAN etc. It also covers various interconnection networks like IDE, ATA, SATA, SCSI, and iSCSI with the help of Fibre channel and copper bus as medium. The primary focus of the course is to understand the importance of data storage so that processing, storage (centralized / distributed), access (virtualized / physical), backup, recovery, partitioning and replication are taken care of efficiently according to the requirements.. This course also looks at measuring the performance of these storage technologies and optimizes them based on energy consumption, size and access time. This course aims at covering the up to date technologies used in storage systems with the help of research articles.

**2. Text and Reference Books:**

**2.1. Text Book:**

- T1.** Storage Networks: The complete Reference. Robert Spalding, McGraw-Hill/Osborne, 2003.
- T2.** Information Storage and Managements Storing, Managing and Protecting Digital Information. EMC Education Services, Wiley Publishing Inc., 2008.

**T3.** Storage Networking-Real World Skills for the CompTIA Storage+ Certification and Beyond by Nigel Poulton, Publishers: SYBEX a Wiley brand, 2014

## **2.2. Reference Material**

**R1.** Computer Systems – A Programmer’s Perspective. Randall Bryant and David O’Hallaron. Pearson Education. 2003.

**R2.** The Design and Implementation of the 4.4 BSD Operating System. McKusick, Bostic, Karels, and Quateman. 1996.

**R3.** Introduction to Storage Area Networks, IBM, 2006.

**R4.** Storage Area Network Essentials, A complete guide to understanding and Implementing SANs, Richard Barker and Paul Massiglia, John Wiley & Sons, 2002.

**R5.** Operating System Concepts, Abraham Silberschatz, Peter Baer Galvin & Greg Gagne, 8<sup>th</sup> edition, John Wesley & Sons, 2008.

**R6.** The Design of the Unix Operating System, Maurice J. Bach, PHI, 1993.

**R7.** Computer Organization & Design, Patterson, David A & J L Hennenssy, Harcourt Asia, 4<sup>th</sup> Ed., 2009.

**R8.** Storage Networks Explained, Ulf Tropprn, Rainer Erkens and Wolfgang Muller, John Wiley & Sons, 2004.

**AR.** Additional references as assigned and made available by the instructor ( Papers, Articles, Standards and Blue books).

## **3.1 Lecture Modules & Learning Objectives**

<b>Module</b>	<b>Title</b>	<b>Learning Objectives</b>
1	Memory Management	Review of basics of Memory Management – We revise Paging, Segmentation, demand paging, etc with the help of Linux operating system
2	Hard disks, Disk Scheduling and File Systems	Hard disks – Internal structure and access mechanisms. Disk scheduling – FCFS, SCAN, LOOK, C-SCAN, C-LOOK etc. File Systems – File systems for disks and flashes. UFS, ext3, ext4, JFFS etc.
3	RAID, NAS, SAN, IPSAN	RAID – various RAID levels, performance, storage requirements, optimizations. NAS, SAC, IPSAN – basic architecture of each of these technologies, merits and demerits of these technologies.
4	IDE, SATA, SCSI, iSCSI, Fibre	Fibre channel protocols, various interconnections, their merits and demerits.
5	Partitioning, replication, distribution, virtualization, backup and recovery	Performance measurement of storage devices. Various techniques to improve availability, access time, space, backup and recovery
6	Advance concepts in Storage	Advancements in the area of Storage systems

### 3.2. Lecture Plan

Lecture No.s	Topic	Reading / Reference
1 to 10	Paging, Segmentation, Virtual Memory using Linux & Intel Architecture	R5
11	Introduction to Storage Systems. Storage requirements and usage.	T1. Ch. 1 T2. Ch. 1
<b>Start your planning: Implementation of a cluster [symmetric or asymmetric] with minimum 4 nodes. This will be an evaluative assignment later.</b>		
12	Basic Storage Requirement – Motivation to go for high end storage solutions.	T1. Ch. 1 T2. Ch. 1
13	Components of Storage System and Data Explosion	T2. Ch. 2
14	Memory hierarchy – Principles and Types of Storage, Properties, location, unit of transfer & access methods	R1. Ch. 6 R7. Ch.
15	I/O devices, I/O techniques, I/O performance parameters	R1. Ch. R8. Ch. 3
16 – 20	Secondary Storage Devices: Hard Disks – types, Geometry, internal assembly, Zoning, Addressing. Low Level Performance – Access times, Latency and throughput measurement Disk scheduling algorithms. Case study: Linux disk scheduling algorithms	T2. Ch. 2 T3. Chs. 2, 3 R1. Ch. 6 R5. Ch. R8. Chs. 2,3,9 AR
<b>Assignment #1: Implementation of a new Disk Scheduling algorithm in Disksim. Download, Install and Learn Disksim and IOMeter well in advance.</b>		
21 – 23	RAID – RAID 0, RAID 1, RAID 2, RAID 3, RAID 4, RAID 5, RAID PQ, RAID 0/1 and RAID 1/0. Various advancements in RAID, Design and Performance Issues. Remote Mirroring, LUN.	T2. Ch. 3 T3. Ch. 4 R5. Ch. R8. Ch. 2
<b>Paper Presentation #1 on Advancement in RAID technology. International Journal papers only [IEEE, ACM and Elsevier preferred]</b>		
24 – 27	System Level Design – Locality improvement – Buffering & Caching [ RAM & CACHE] for high performance storage systems, Virtual Memory System, Operating System Support	T1. Ch. 8 T2. Ch. 4 R5 R7
28 – 30	I/O and File Systems – File System Operations. Case Study: UFS and LFS	T1. Ch. 8 R2. Chs. 6,7 R6. Ch. R8. Ch. 4
31 – 33	File Systems – Networked File System, Google File System	T1. Ch. 8 R2. Chs. 6,7 R8. Ch. 4
34 – 37	Storage Interfaces: Bus – Bus Structures, Bus Design, timing. Bus standard – PCI, IDE/ATA, SATA, SCSI, iSCSI	T1. Ch. 7 T2. Chs. 5,8 R8. Ch. 3
39 – 40	Direct Attached Storage Network Attached Storage (NAS) – Architecture NAS Design – Devices/Components, Interfaces & protocols, NFS	T1. Chs. 9, 10, 11 T2. Chs. 5,7

	File Access over NAS, NAS Performance - Access rates and Bandwidth. Scalability. Availability. Reliability	T3. Ch. 7 R2. Ch. 9 R8. Ch. 4 AR
<b>41 – 42</b>	Storage Area Networks (SAN) – Architecture, SAN – Devices/Components, Interfaces & protocols, Storage Area Networks – Design and Implementation Issues. Performance Measurements, SAN File Systems and Applications on SAN	T1. Chs. 13, 14, 15, 16, 17 T2. Ch. 6 T3. Chs. 5, 6 R3 & R4 R8. Ch. 3 AR
<b>43</b>	SAN and NAS solutions. Integration issues.	T1. Ch. 22
<b>Additio nal Reading</b>	Performance Issues – Reliability and Availability: Redundancy – Multipathing; Fault recovery. Performance Issues – Availability: Replication, and Synchronization. Storage Clusters / Grids.	T1. Ch. 22 T3. Chs. 8, 11 R8. Ch. 6 AR
<b>Additio nal Reading</b>	Performance Issues - Availability and throughput. Caching levels, techniques and strategies. Case Study - Storage for Large Transaction Processing Case Study - Storage for a Web Search Engine. Storage Virtualization Conclusion – Course Summary. Open Issues and Current Directions in Storage.	AR T1. Ch. 18 T2. Ch. 10 T3. Chs. 9,10,12 R8. Ch. 5 Class Notes

#### 4.1 Evaluation Scheme:

<b>S. No.</b>	<b>Evaluation Component</b>	<b>Duration (Mints)</b>	<b>Weight age (%)</b>	<b>Date &amp; Time</b>	<b>Nature of Component</b>
1.	Mid Semester Test	90	25%		Closed Book
3.	Attendance	--	10%	-----	-----
4.	Project / Assignments / Quizzes	--	30%	-----	Open Book
6.	Comprehensive Examination	180	35%		Closed Book

#### 5.a. Assignments / Online(s):

- Students shall implement all the assignments / attend all online(s).
- Assignments / online(s) will be evaluated individually through a viva-voce / demonstration.
- Assignments are to be completed in time with no postponements.

### **5.b. Malpractice Regulations:**

1. Any student or team of students found involved in mal practices in working out assignments will be awarded negative marks equal to the weightage of that assignment and will be blacklisted.
2. Any student or team of students found repeatedly – more than once across all courses – involved in mal-practices will be reported to the Disciplinary Committee for further action. This will be in addition to the sanction mentioned above.
3. A mal-practice - in this context - will include but not be limited to:
  - Submitting some other student's / team's solution(s) as one's own;
  - Copying some other student's / team's data or code or other forms of a solution;
  - Seeing some other student's / team's data or code or other forms of a solution;
  - Permitting some other student / team to see or to copy or to submit one's own solution;
  - OR other equivalent forms of plagiarism wherein the student or team does not work out the solution and/or uses some other solution or part thereof (such as downloading it from the web).
4. The degree of mal-practice (the size of the solution involved or the number of students involved) will not be considered as mitigating evidence. Failure on the part of instructor(s) to detect mal-practice at or before the time of evaluation may not prevent sanctions later on.

6. **Chamber Consultation Hour:** To be announced in the class.

7. **Notice:** Notice concerning this course will be displayed on photon.

8. **Makeup Policy:**

- Permission of the Instructor-in-Charge is required to take make-up
- Make-up applications must be given to the Instructor-in-charge personally.
- A make-up test shall be granted only in genuine cases wherein the Instructor's judgment - the student would be physically unable to appear for the test.
- In case of an unanticipated illness preventing a student from appearing for a test, the student must present a Medical Certificate from BITS medical centre.
- Requests for make-up for the comprehensive examination – under any circumstances – can only be made to In-charge, Instruction Division.

**Instructor-in-charge (CS F446)**  
**(Dr. Biju K Raveendran)**