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BCA Honours | Semester VI | BCA6EJ303(3)

Storage Technologies

Module 4 Comprehensive Notes

Module 4: Backup, Archival Technologies, and Storage Security

Enterprise data management requires business continuity planning, automated backup and recovery systems, deduplication, and multi-layered security controls.

4.1 Backup Paradigms and Deduplication

- **Backup Granularities:** Full Backup (complete copy), Incremental Backup (copies data modified since the previous backup), Differential Backup (copies data modified since the last Full backup).
- **Data Deduplication:** Identifies and eliminates redundant data chunks, storing only unique blocks:
  - *Source-Based Deduplication:* Client software deduplicates data before network transmission, conserving network bandwidth.
  - *Target-Based Deduplication:* Raw data is sent to the backup appliance, which deduplicates blocks inline or post-process.

4.2 Storage Security Architecture

Storage security is enforced across three operational domains: **Management Interface** (securing array administrative consoles via SSH/HTTPS and multi-factor authentication), **Data-in-Transit** (encrypting network packets via IPSec or FC-SP), and **Data-at-Rest** (encrypting physical drives via Self-Encrypting Drives SED and hardware security modules HSM).

Advanced Theoretical Foundations & Industrial Systems Synthesis

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1. Architectural Trade-offs and Computational Complexity

Software architects and systems engineers designing scalable computational pipelines centered on Storage Technologies must methodically navigate core trade-offs:

- **Time Complexity Optimization versus Spatial Footprint:** In high-throughput algorithmic pipelines handling Module 4 Core Concepts and Methods, pre-computing intermediate lookup tables, spatial indices, and hashing structures achieves near-instantaneous $O(1)$ query latency, but inflates the physical memory footprint. Conversely, in-place algorithms minimize RAM utilization at the cost of higher CPU cycle counts. Modern architectures dynamically calibrate memory allocations using memory-mapped files and cache-aware structures.
- **Concurrency Scalability versus Thread Contention:** While multi-core hardware allows horizontal execution, concurrent modifications to shared state structures create severe lock contention, thread synchronization bottlenecks, and cache line invalidation storms. High-performance frameworks deploy lock-free algorithms, optimistic concurrency control, and atomic compare-and-swap (CAS) primitives.

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- **Algorithmic Determinism versus Heuristic Scalability:** Exact mathematical algorithms frequently encounter NP-hard combinatorial barriers as problem dimensions scale. Contemporary systems bridge this gap by deploying bounded approximation algorithms and meta-heuristics that produce near-optimal solutions within guaranteed execution time windows.

2. Empirical Comparative Framework

A structured comparative assessment clarifies operational distinctions across conventional paradigms and modern production implementations in Storage Technologies:

Evaluation Dimension	Conventional Traditional Approach	Contemporary Integrated Paradigm	Strategic Impact Metric
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System Telemetry & Auditing	Passive log file aggregation with retrospective forensic analysis.	Distributed tracing, structured metrics collection, and real-time observability telemetry.	Proactive bottleneck resolution and sub-second mean time to detection (MTTD).

3. Production Implementation Patterns and Resilience Engineering

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- **Defensive Memory Management:** High-throughput applications implement strict resource pools, bounded buffer queues, and proactive leak detection to ensure predictable garbage collection pause times and prevent memory exhaustion.

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