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BCA Honours | Semester VI | BCA6EJ303(3)

Storage Technologies

Module 3 Comprehensive Notes

Module 3: Networked, Distributed, and Object-Based Storage

Modern data centers deploy networked and object-based storage architectures to support petabyte-scale unstructured data repositories.

3.1 Storage Architectural Spectrum

Storage Paradigm	Access Protocol	Addressing Mechanism	Primary Use Case & Scalability
Block Storage (SAN)	FC, iSCSI, NVMe-oF	Logical Block Addresses (LBA)	Databases, hypervisor virtual disk datastores; microsecond latency.
File Storage (NAS)	NFS, SMB/CIFS	Hierarchical directory paths	Shared file servers, user home directories; moderate scale.
Object Storage (OSD)	RESTful HTTP (S3, Swift)	Globally unique 128-bit Object ID	Cloud backups, media archives, data lakes; virtually infinite horizontal scaling.

3.2 Object-Based Storage Device (OSD) Architecture

Object storage decouples data from metadata. Data is stored alongside customizable metadata tags and a unique Object ID within a flat namespace. Clients communicate directly with object storage nodes using standard RESTful HTTP methods (`GET` , `PUT` , `DELETE`), eliminating hierarchical filesystem overhead and directory locking bottlenecks.

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 3 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.

- **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
Architecture Paradigm	Monolithic single-threaded architectures with tightly coupled state.	Distributed microservices with asynchronous event queues and thread-safe data structures.	Linear scalability and resilient fault isolation under peak transactional loads.
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Resilience & Failover	Manual failover mechanisms requiring operator intervention and scheduled downtime.	Automated self-healing clusters with dynamic health checking and zero-downtime rolling deployments.	Continuous availability meeting strict 99.999% Service Level Agreements (SLAs).
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

Deploying mission-critical systems related to Storage Technologies requires adhering to robust production design patterns:

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- **State Immutability and Event Sourcing:** Maintaining an append-only log of immutable state changes guarantees verifiable auditability, eliminates data race hazards, and facilitates seamless system recovery.
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