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BCA Honours | Semester VI | BCA6EJ304(2)

Internet of Things

Module 2 Comprehensive Notes

Module 2: Wireless Networking Standards and Constrained Protocols

IoT devices frequently operate on limited battery budgets and low-power microcontrollers, necessitating energy-efficient wireless networking standards.

2.1 Low-Power Wireless Standards

Standard	Radio Frequency Band	Data Transmission Rate	Typical Operational Range	Network Topology
Bluetooth Low Energy (BLE)	2.4 GHz ISM band	1 to 2 Mbps	10 to 50 meters	Star / Mesh topology (GATT profiles, beacons).
Zigbee (IEEE 802.15.4)	2.4 GHz / 868/915 MHz	250 kbps	10 to 100 meters	Self-healing Mesh; ideal for smart home automation.
LoRaWAN	Sub-GHz ISM (868/915 MHz)	0.3 to 50 kbps	2 to 15 km	Star-of-Stars; long-range telemetry with multi-year battery life.
NB-IoT (Narrowband IoT)	Licensed cellular spectrum	Up to 200 kbps	Up to 10 km (high penetration)	Cellular star topology; connects directly to telecom base stations.

2.2 6LoWPAN and RPL in Constrained Networks

- **6LoWPAN (IPv6 over Low-Power WPAN):** Adapts 128-bit IPv6 packets into 127-byte IEEE 802.15.4 payload frames via stateless header compression, link-layer fragmentation, and mesh routing.
- **RPL (Routing Protocol for Low-Power and Lossy Networks):** Distance-vector routing protocol that constructs a Directed Acyclic Graph (DAG) oriented toward root gateways, optimizing power consumption.

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1. Architectural Trade-offs and Computational Complexity

Software architects and systems engineers designing scalable computational pipelines centered on Internet of Things must methodically navigate core trade-offs:

- **Time Complexity Optimization versus Spatial Footprint:** In high-throughput algorithmic pipelines handling Module 2 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 Internet of Things:

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.
Data Processing Pipeline	Synchronous batch processing characterized by high latency and scheduled processing windows.	Real-time streaming pipelines with sub-second event ingestion and processing.	Zero-latency decision intelligence and immediate anomaly response.
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 Internet of Things 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.

- **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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