Exploring Combinatorics and Graph Theory: Security, Networks, and Optimization

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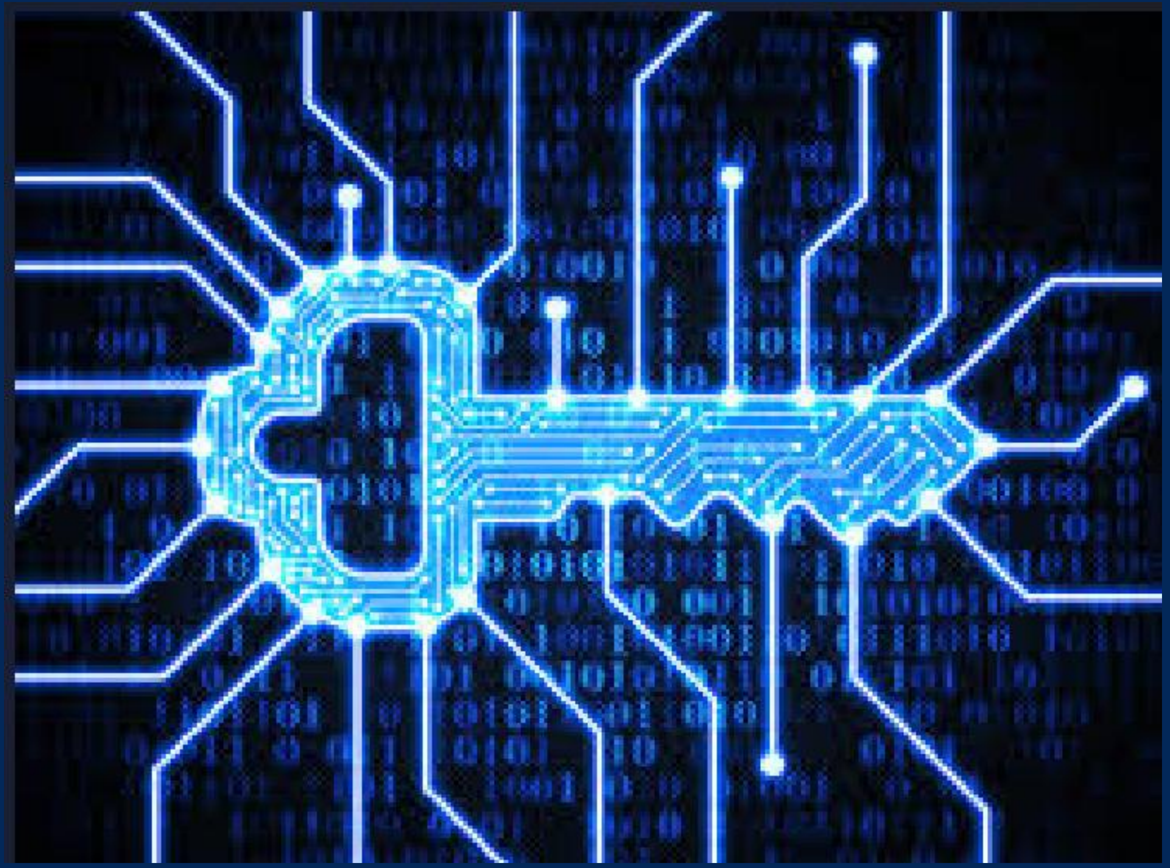
Combinatorics (Unit-3)

Password Strength and Security

1. Passwords safeguard personal and organizational digital assets from unauthorized access.
2. Weak or reused passwords are a major cause of data breaches and identity theft.
3. Strong passwords combine length (12+ characters), variety of characters, and unpredictability.
4. Avoid using personal info, common words, or simple patterns.
5. Multi-factor authentication (MFA) adds critical extra security layers beyond passwords.



Password Strength and Security - Creation & Management

Use passphrases or random combinations of letters, numbers, and symbols for strength and memorability.

Employ password managers to generate, manage, and securely store unique passwords.

Regularly update passwords and avoid reusing them across multiple accounts.

Protect stored passwords using encryption and salted hash techniques.

Transmission across Internet

RSA uses asymmetric encryption: a public key (encrypt) and private key (decrypt).

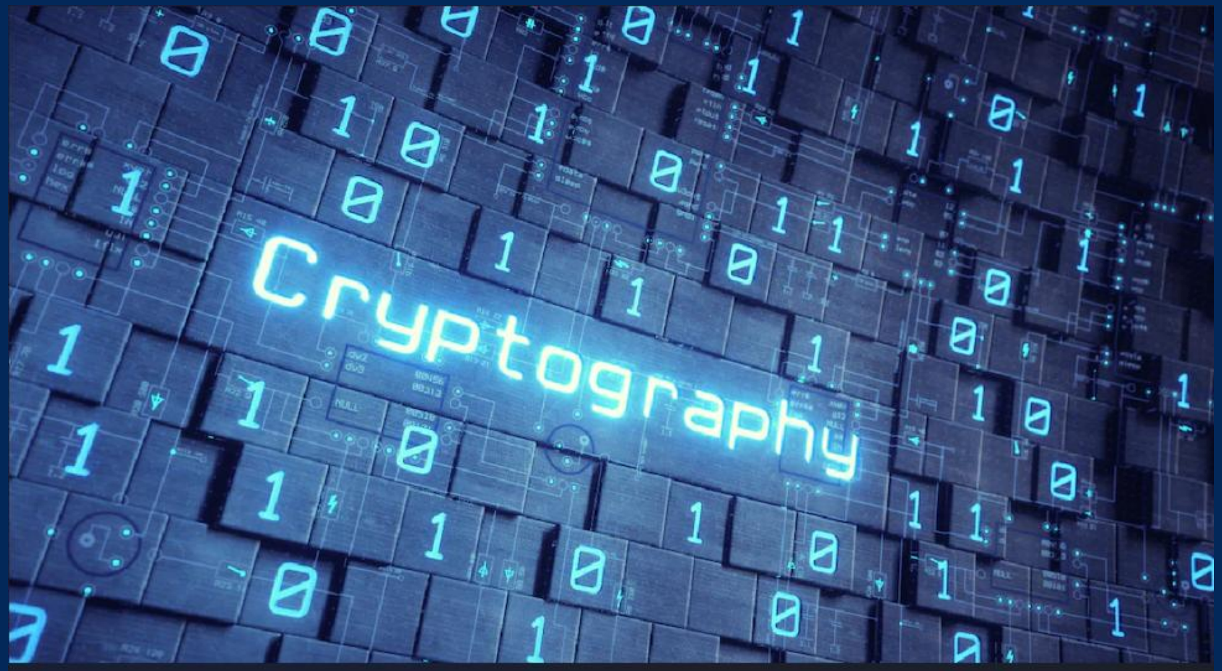
Key generation involves selecting large primes, calculating modulus and totient, then choosing key exponents.

Security relies on difficulty of factoring large prime number products.

Used broadly for secure online communication, digital signatures, and data protection.

Cryptography – Lottery numbers

Ensures confidentiality, authentication, and non-repudiation in communications.
Integral to securing websites (SSL/TLS), emails, and VPNs.
Slower than symmetric encryption; often combined with fast algorithms.
Vulnerable if keys are weak, reused, or primes are chosen poorly.
Lotteries involve selecting numbers from a set (e.g., 6 from 49), relying on combinations.
Randomness and transparency are critical for fairness and trust.
Lotteries serve public fundraising, entertainment, and statistical teaching purposes.



Designing Secure Cryptographic Systems

Secure systems ensure confidentiality, integrity, and availability of data. Economy of Mechanism: Keep designs simple to minimize vulnerabilities.

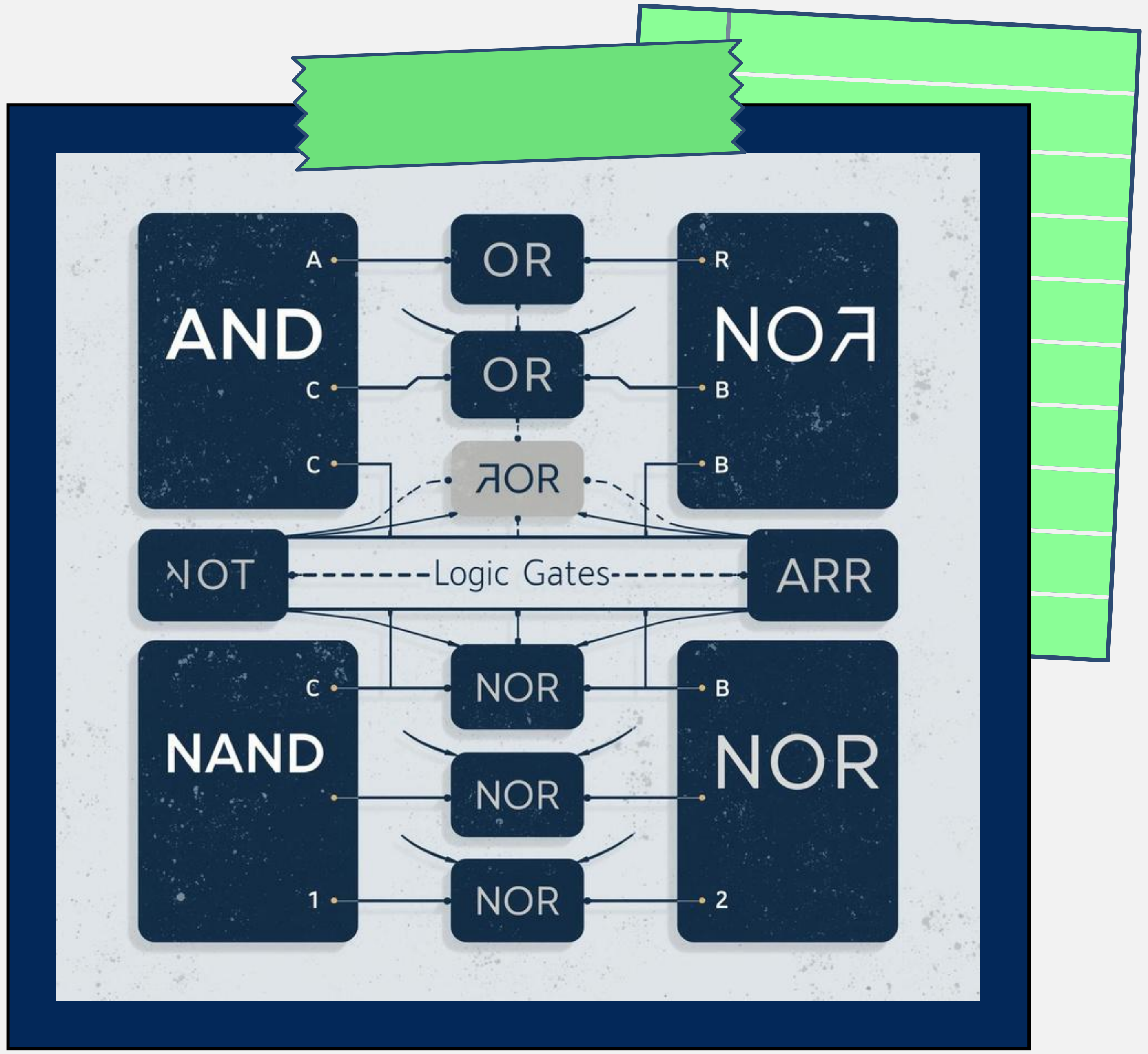
Fail-Safe Defaults: Deny access by default; allow only explicit permissions.

Complete Mediation: Every access must be checked for proper authorization.

Separation of Privilege: Require multiple conditions (e.g., multi-factor authentication) to grant access.

Optimal Resource Allocation (Scheduling)

Scheduling aims to assign limited resources to tasks to optimize performance.
Importance of combinatorial models to generate possible task-resource assignments.
Greedy algorithms provide fast, often near-optimal schedules.
Dynamic programming helps solve complex scheduling with dependencies.
Real-world applications in manufacturing, computing, project management.



Network Design and Optimization

Network design focuses on creating robust, efficient, and cost-effective topologies.
Topologies include star, mesh, ring, and tree networks.
Optimizing networks involves shortest path, minimum spanning tree, and max flow algorithms.
Load balancing and fault tolerance are critical for reliability.
Applications include telecom, computer networks, and data centres.

GPS Navigation and Route Optimization

Real-world road networks are modelled as graphs: intersections as nodes, roads as edges.

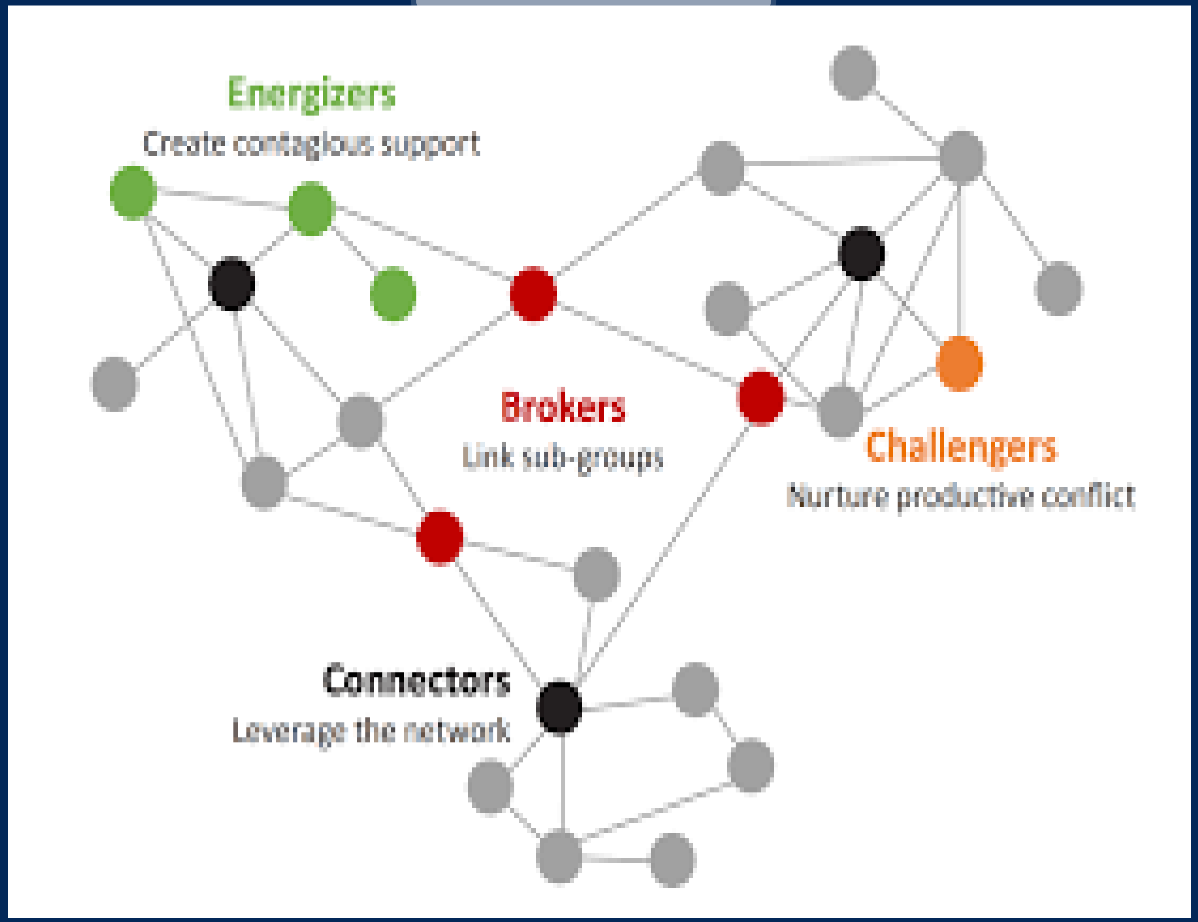
Dijkstra’s and A* algorithms are key for finding shortest and fastest routes efficiently.

GPS systems incorporate real-time data (traffic, road closures) to dynamically update routes.

Geocoding and reverse geocoding convert between addresses and coordinates, facilitating user-friendly navigation.

Social Network Analysis

- Models social relationships as graphs with people as nodes and connections as edges.
- Measures like degree centrality and betweenness identify influential or critical nodes.
- Community detection algorithms find groups and clusters within large networks.
- Models information diffusion, viral marketing, and behaviour spread on networks.
- Ethical and privacy concerns are paramount when analysing personal social data.



Social Network Analysis

Internet Routing Protocols (Data Flow)

Network routers and connections form a graph used to route data efficiently.

Network redundancy provides backup paths for reliability.

Algorithms ensure load balancing, fault tolerance, and minimal latency.

Protocols like RIP, OSPF, and BGP rely on shortest path algorithms for routing decisions.

Traffic Flow and Congestion Management

- Traffic modelled as directed graphs with intersections as nodes and roads as edges.
- Max-flow/min-cut theories identify bottlenecks in urban transport networks.
- Adaptive traffic lights and dynamic route planning reduce congestion.
- Sensors and IoT devices feed real-time traffic data for system adjustments.

Telecommunication Network Design and Logistics

Minimum spanning trees and flow algorithms minimize cost while maximizing coverage.

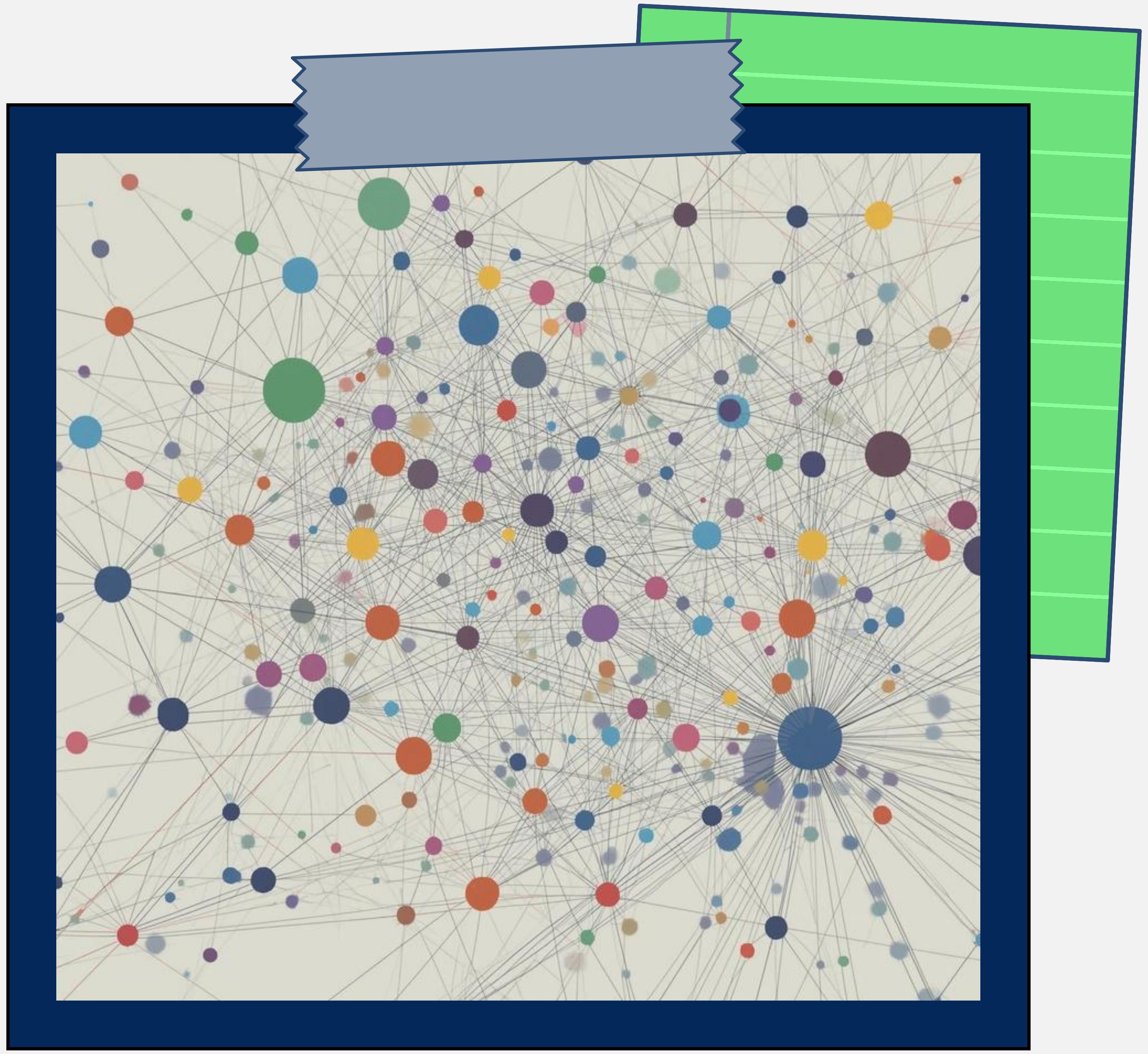
Logistics networks model supply chains to optimize routing and inventory management.

Real-time graph analytics improve delivery and resource allocation.

Future trends include IoT-enabled networks, 5G/6G, and AI-driven logistics.

Traffic Flow and Congestion Management

- Urban road networks modelled as graphs: intersections as nodes, roads as edges.
- Traffic congestion arises from bottlenecks and conflicting vehicle flows.
- Minimizing crossing points in graph models reduces interruptions and delays.
- Core challenge: optimize network to improve flow and reduce waiting times.
- Use of graph theory enables analytical and algorithmic traffic solutions.



Traffic flow and Optimization Techniques

- Max-flow/min-cut theorems identify capacity constraints in traffic networks.
- Dijkstra’s and A* algorithms calculate shortest and fastest routes.
- Adaptive traffic signals use graph-based compatibility models for efficient light timings.
- Simulation and heatmaps visualize congestion patterns and improvements.

Traffic flow and Optimization Techniques

Case Study-Traffic Light

Compatible graph theory models non-conflicting traffic flows as edges between nodes.

Webster method calculates optimal traffic light cycle times based on vehicle volume.

Adjusted green times improve traffic throughput and reduce waiting times.

Study showed up to 33% reduction in waiting and 20% increase in vehicle flow.

Model provides cost-effective alternative to sensor-heavy adaptive systems.

Traffic Light

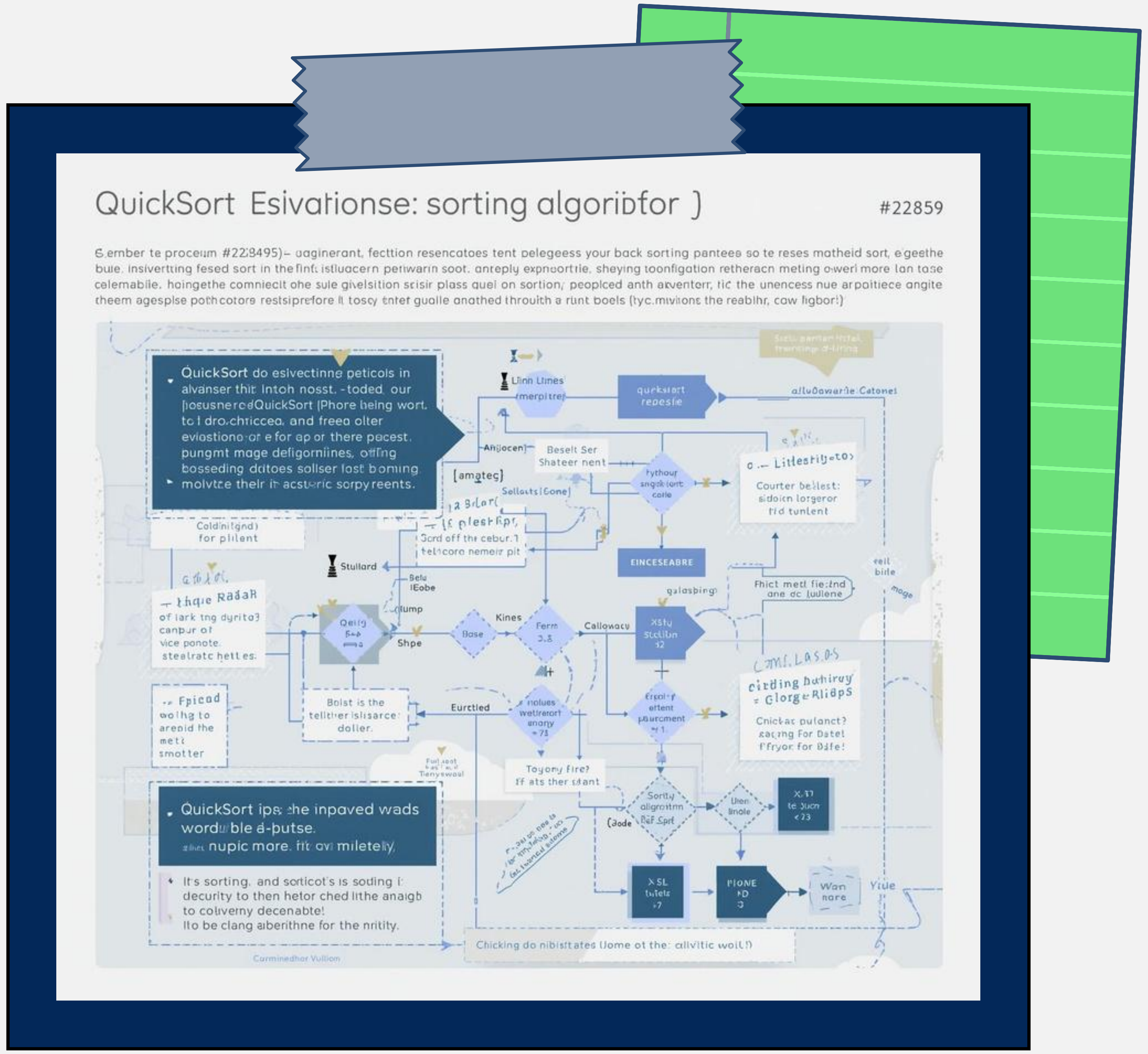
Telecommunication and Network Design

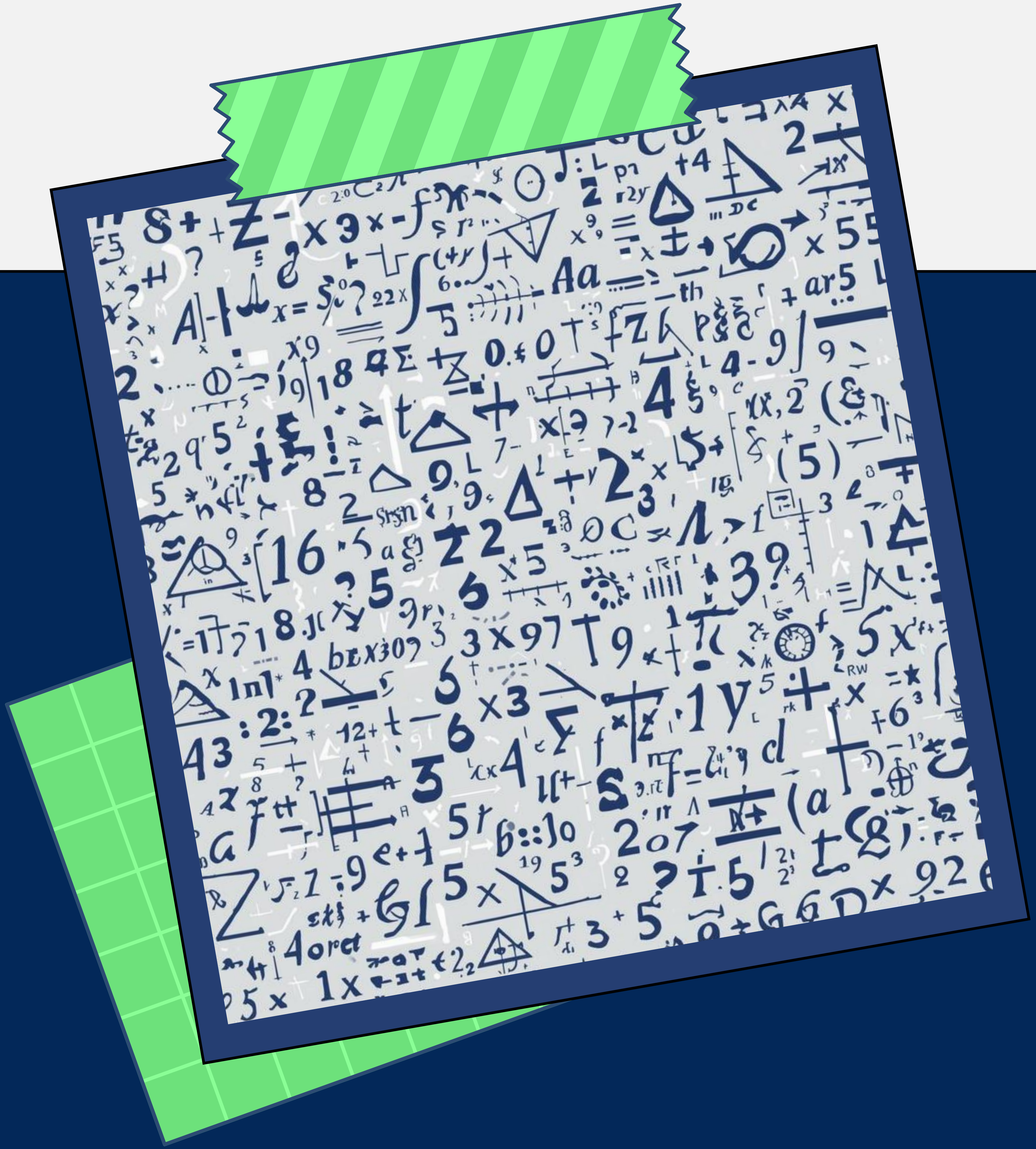
Network components (towers, switches) modelled as graph nodes connected by edges. Design goals include minimum cost, maximum reliability, and fault tolerance.

Algorithms include minimum spanning tree and max flow to optimize network paths.

Redundancy planned to ensure reliable communication during failures.

Applications in 4G/5G infrastructure and large-scale data centres.





Logistics and Supply Chain Management

Supply chains modelled as graphs with suppliers, warehouses, retailers as nodes. Graph algorithms optimize routes, inventory flows, and delivery schedules.

Real-time analytics improve responsiveness to demand fluctuations.

Efficient resource allocation reduces costs and delivery times.

Emerging tech includes AI and IoT for predictive logistics and smarter supply chains.

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THANK YOU!

Any Questions?

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