

Computer Networking

Examples: Patterns, Strengths, and Pitfalls



- **Goal:** build practical mental models beyond memorizing acronyms



- **Patterns:** reusable structures for moving data



- **Strengths:** what a design does well



- **Pitfalls:** common failure modes and trade-offs

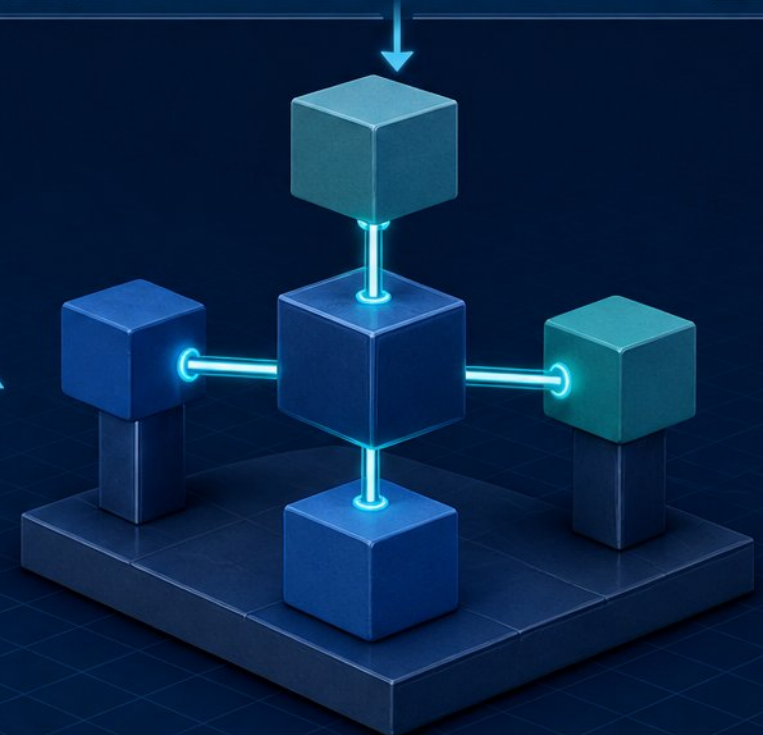
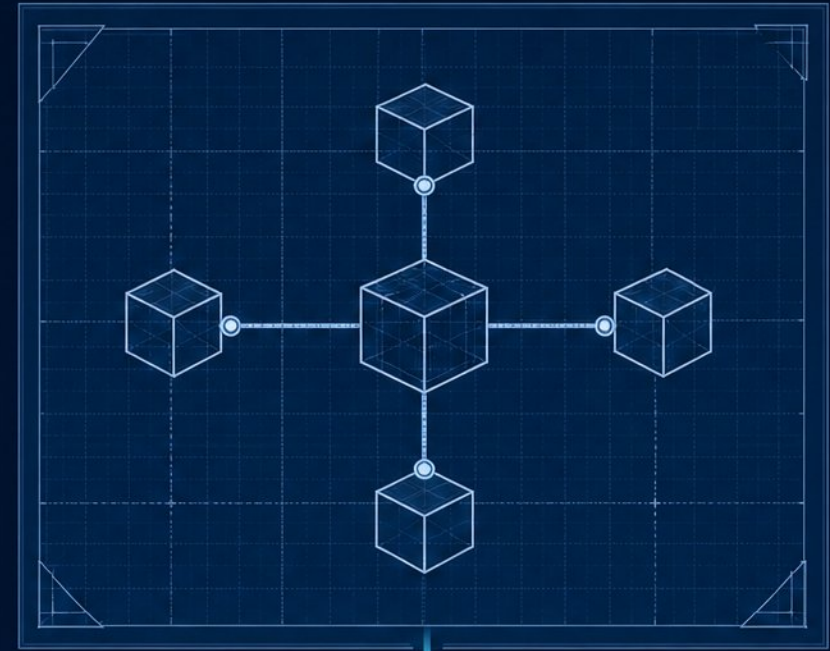


- **Roadmap:** building blocks, topologies, applications, troubleshooting, security



What Counts as a Networking Pattern

- Reusable structure for moving data between systems
- Not merely a single device or protocol
- Router is equipment, OSPF is a protocol
- Hub-and-spoke is a pattern combining both
- Categories: layout, communication, reliability
- Know traffic flow, failure mode, and scale limits



The Underlying Design Logic

- Balancing performance, reliability, cost, and manageability
- Small networks tolerate almost any layout
- Full mesh offers maximum redundancy but scales poorly
- 150 full-mesh switches need 11,175 links
- Hierarchical design creates repeatable, manageable blocks



Building Blocks: Devices, Protocols, and Links



ROUTER

Moves packets
between networks



SWITCH

Forwards frames
within a LAN



ACCESS POINT

Bridges Wi-Fi
devices



FIREWALL

Enforces traffic
rules

- - Routers move packets between networks; switches forward frames within a LAN
- - Access points bridge Wi-Fi devices; firewalls enforce traffic rules
- - Ethernet handles local delivery; IP handles global addressing and routing
- - TCP/UDP manage reliability and speed; DNS and DHCP handle naming and addressing
- - Patterns emerge from how these building blocks are combined and configured

LAN, WAN, and Cloud: Where Patterns Live



- **LAN:** privately owned, typically one building or campus; Ethernet dominates.



- **WAN:** connects separate LANs via leased lines, VPN, MPLS, or SD-WAN.



- **Cloud:** virtual routers, firewalls, and networks provisioned on demand.

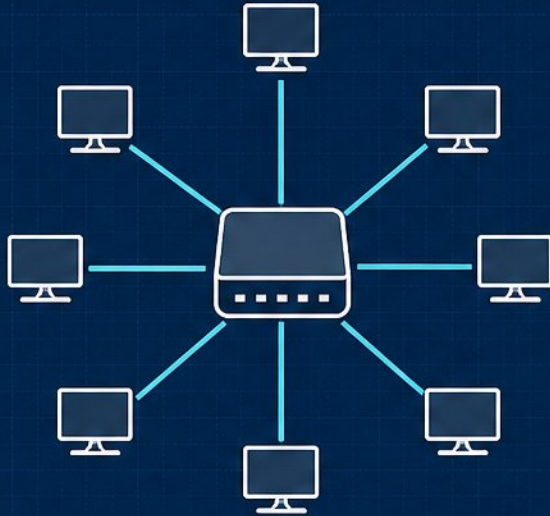


- Same logical patterns appear in all three, with different trade-offs.

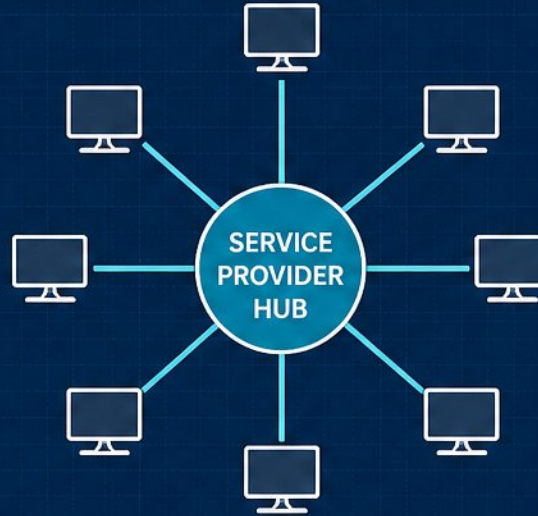


Star, Hub-and-Spoke, and Ring Patterns

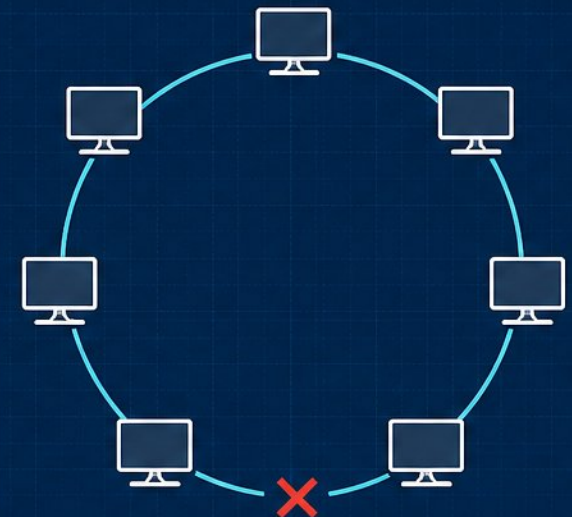
STAR PATTERN



HUB-AND-SPOKE PATTERN



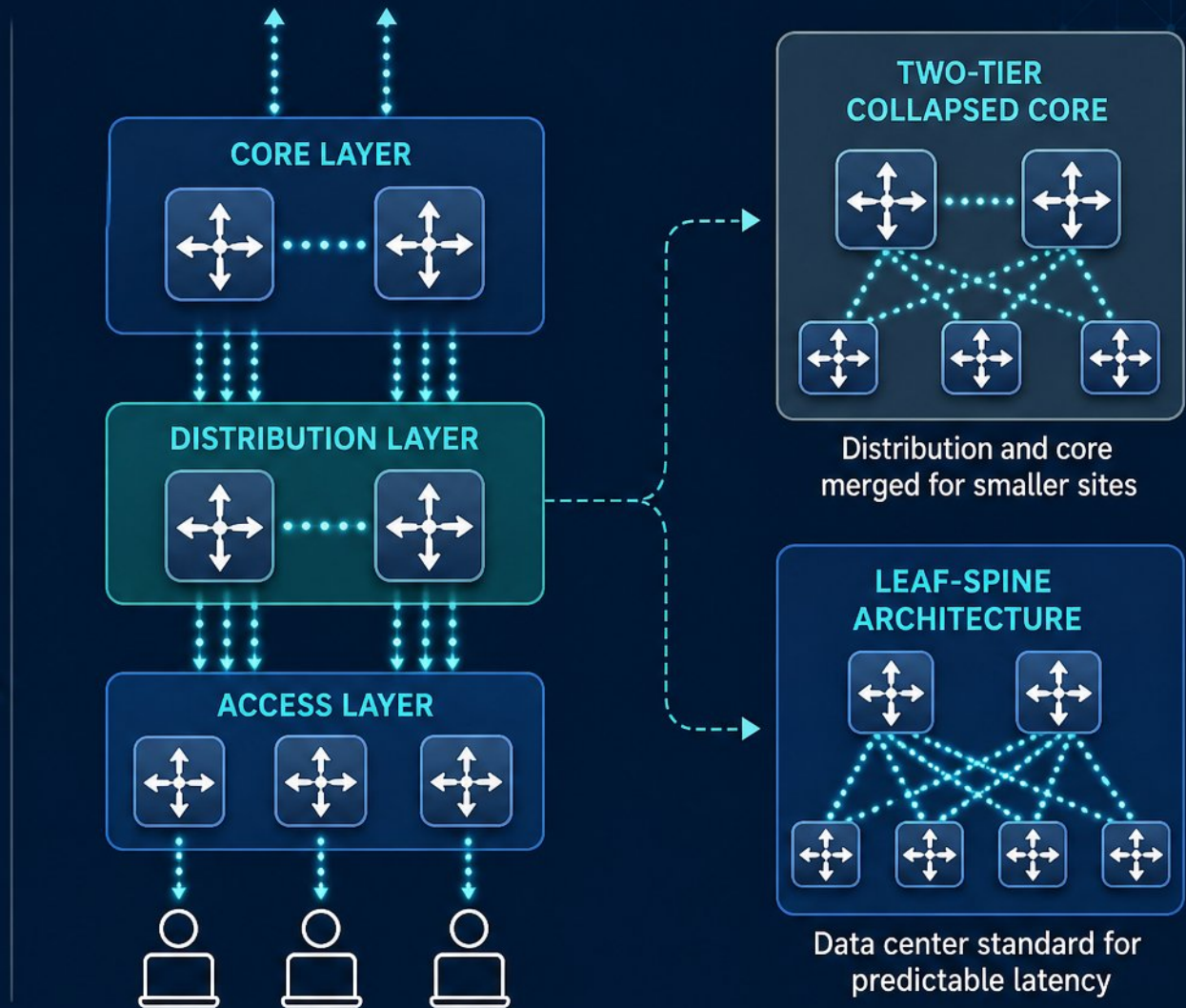
RING PATTERN (WITH BREAK)



- **Star/hub-and-spoke:** all devices connect to a central switch or router
- **Strength:** easy expansion, simple troubleshooting, isolated cable failures
- **Pitfall:** central hub is a single point of failure
- **Ring:** each device connects to two others in a loop
- Single break can disrupt ring unless dual-ring redundancy is used

Hierarchical and Leaf-Spine Designs

- Three-tier model: access, distribution, and core layers
- Access connects users; distribution aggregates and applies policy
- Core forwards traffic at high speed
- Two-tier collapsed core merges distribution and core for smaller sites
- Leaf-spine is the data center standard for predictable latency

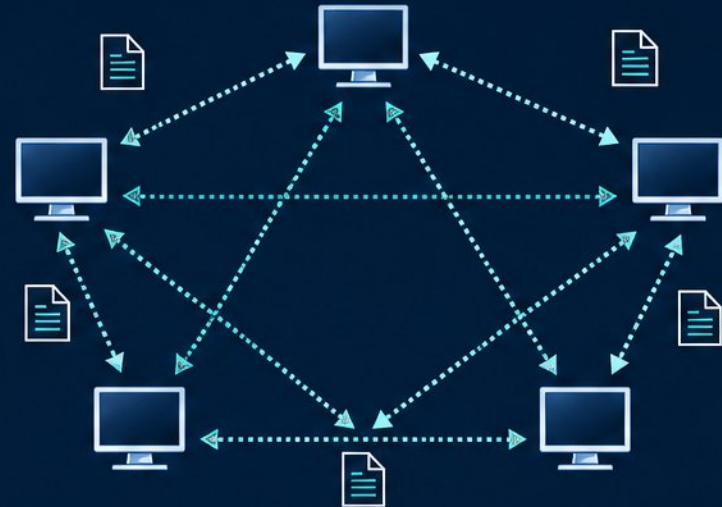


Client-Server, Peer-to-Peer, and Hybrid Patterns

CLIENT-SERVER PATTERN

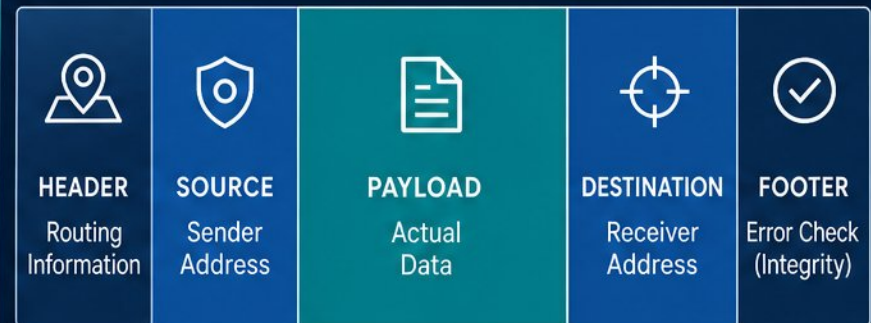


PEER-TO-PEER PATTERN



- **Client-server:** central control, easier security, but higher cost and single point of failure.
- **Peer-to-peer:** every device shares; cheap and resilient, but harder to secure and manage.
- **Hybrid:** central control for critical functions, distributed sharing for performance.
- **Rule:** client-server fits authoritative data; peer-to-peer fits large-scale sharing.

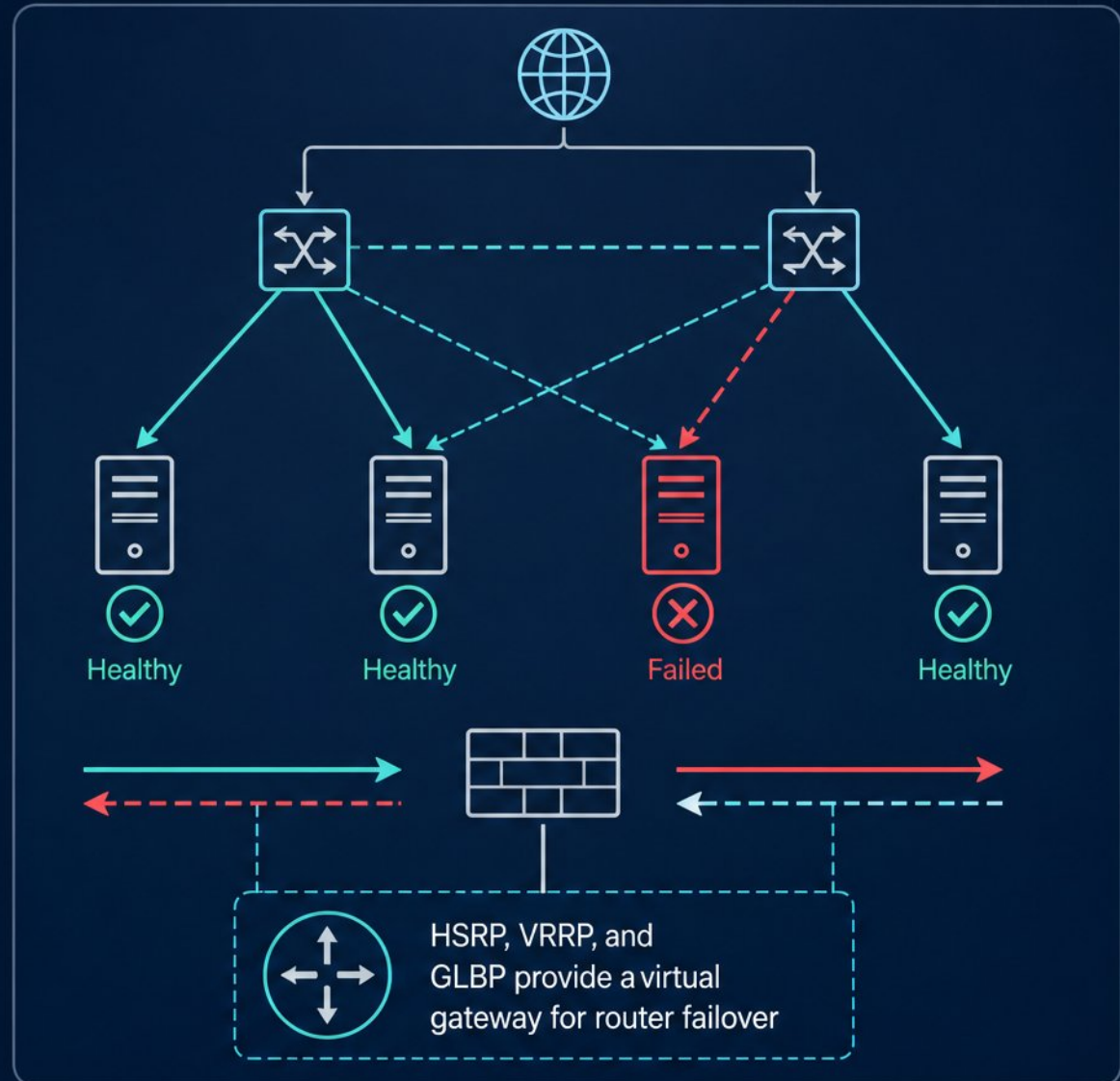
ANATOMY OF A DATA PACKET



ENTRY EXIT

Load Balancing, Redundancy, and Failover

- Load balancing spreads traffic across servers to improve capacity and availability
- Dual-homing and paired switches eliminate single points of failure
- Misconfigured health checks can route to failed servers
- Asymmetric traffic breaks stateful firewalls; missing shared state loses sessions
- HSRP, VRRP, and GLBP provide a virtual gateway for router failover



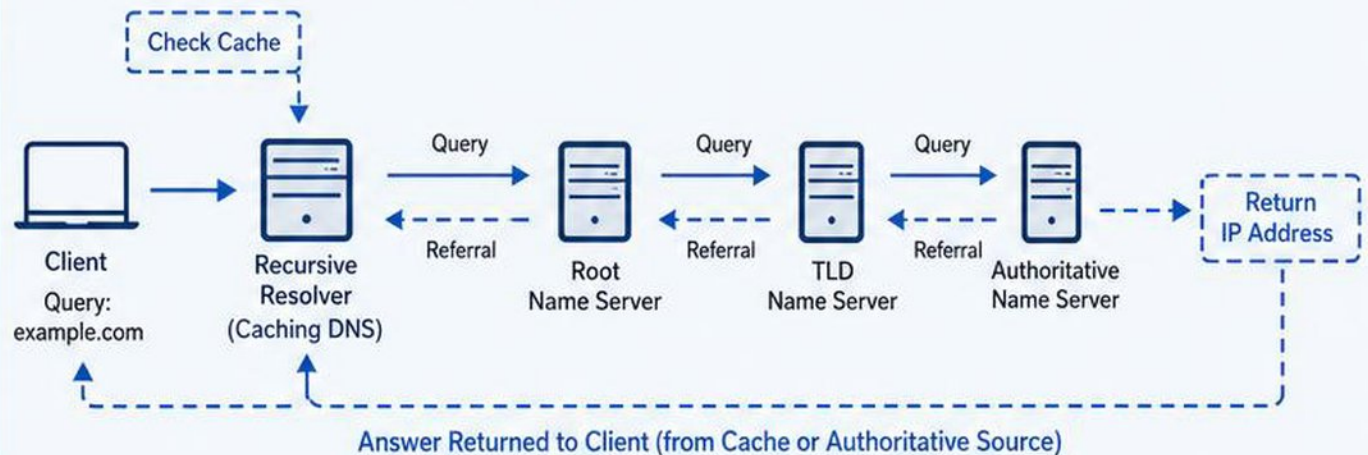
DNS and DHCP: Naming and Addressing in Action

- DHCP automates IP, gateway, and DNS assignment to reduce manual setup
- DNS resolves names to IPs through recursive and caching lookups
- Both scale network management and simplify changes
- Pitfalls include exhausted scopes, rogue DHCP, wrong records, long TTLs
- Symptoms like 169.254.x.y suggest DHCP failure; IP working but names failing suggests DNS

DHCP: Address Assignment (Lease Process)



DNS: Recursive Resolution with Caching



Anatomy of a Data Packet



Troubleshooting with Pattern Thinking

- Structured workflow: symptom, isolate layer, verify, fix root cause
- Key commands: ping, traceroute/tracert, nslookup/dig, ipconfig/ip
- DHCP failure often shows APIPA 169.254.x.y addresses
- IP works but names fail: likely DNS resolution issue
- Traceroute break: routing problem or down link

ping

```
Pinging...  
Reply from...  
Reply from...  
Request timed out.  
Reply from...
```

traceroute

```
1 ...  
2 ...  
3 ...  
4 ...  
* * *  
Request timed out.
```

nslookup

```
Server:  
***  
Address:  
***  
Name:  
***  
*** not found
```

Security Patterns and Their Trade-Offs



- Segmentation and VLANs isolate device groups, limiting threat lateral movement



- A DMZ isolates public-facing services between two layers of protection



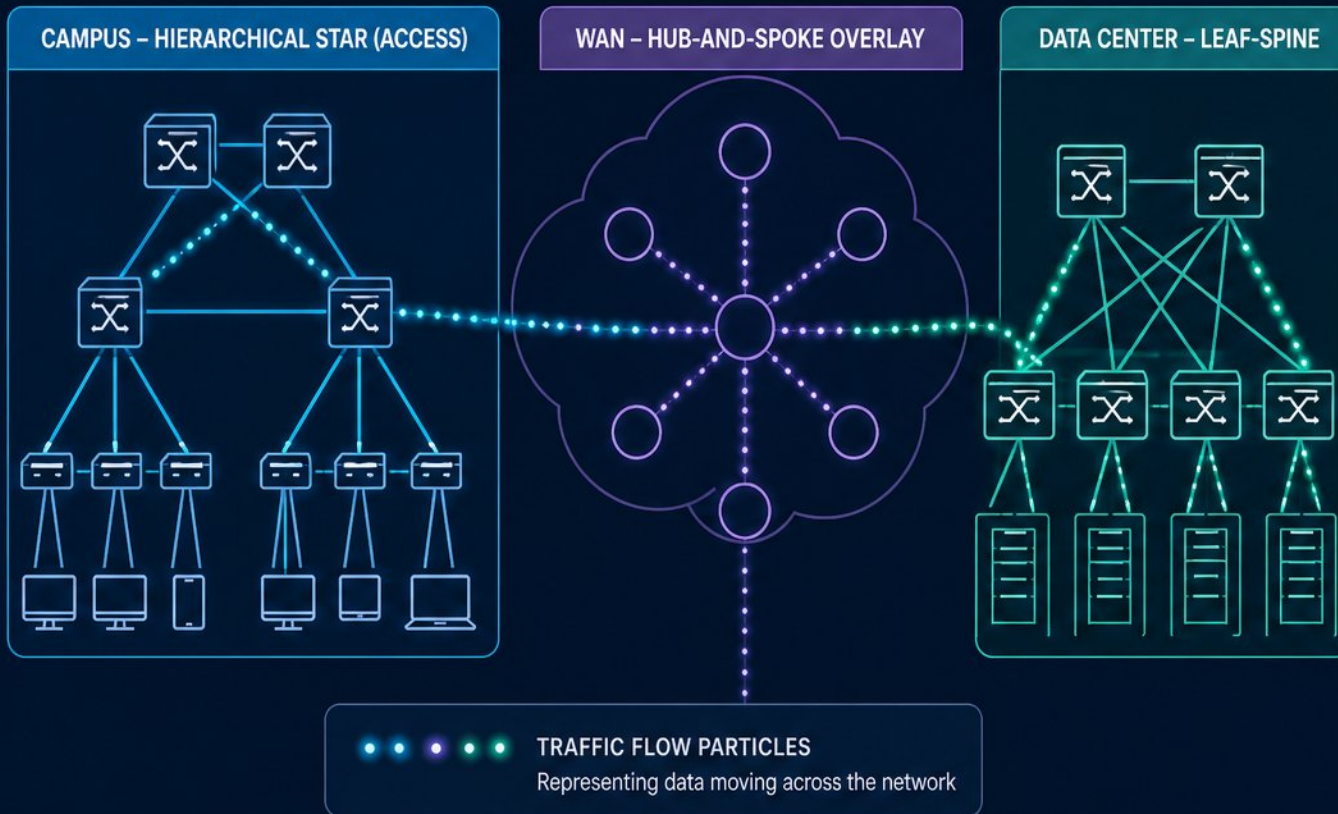
- Least-privilege access and encryption add latency, complexity, and operational overhead



- Pitfalls: broad firewall rules, misconfigured encryption, shadow IT, poorly tuned detection



Putting the Patterns Together



Real networks are hybrids: campus, WAN, and data center patterns coexist



Choose by traffic flow, availability needs, budget, and operational maturity



Avoid core user ports, single access uplinks, legacy bus designs



Strong mental models explain design choices, strain points, and troubleshooting

Summary and Practical Next Steps



- Recognize topology patterns to predict strengths and failure modes



- Every design has trade-offs; choose the best fit



- Document your home or office network for pattern fluency



- Test with ping, traceroute, and DNS queries



- Explore VLAN segmentation, SD-WAN, and BGP routing next



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