

Control-Plane Architectures Cross-Chapter Comparison Sidebar

1,435 words · ~7 min read

*Cross-chapter shared reference for [vca-rf-301](#) Ch 5 (Cellular protocols, LTE + 5G NR) + [vca-net-301](#) Ch 8 (Wireless / 802.11 deep-dive, where the 5G companion framing lives) + cross-link back to [vca-net-201](#) SDN / control-plane chapter for the OpenFlow primary. Anchors: Kurose & Ross, *Computer Networking: A Top-Down Approach*, 9th ed., Pearson, 2021, §7.4 (5G Core), §7.5.4 (Mobile-IP), §5 (SDN). *

Purpose: explicit three-way comparison of three contemporary control-plane architectures students encounter at advanced register. **5G Core (3GPP)**, **SDN (OpenFlow)**, and **Mobile-IP**, against a common set of three architectural axes (control-plane decomposition, routing model, state-management strategy). **Pedagogical thesis:** *the control-plane decisions that distinguish these architectures are not implementation accidents; they are different answers to the same recurring question, where does the per-flow state live, who owns it, and what fails when the owner fails?* When a student walks into a 5G-AKA capture trace, an OpenFlow controller log, or a Mobile-IP foreign-agent registration sequence, the architectural axes below are what makes each readable as a coherent design rather than a flat set of message names.

Print and pin during [rf-301](#) Ch 5 (cellular module, 5G Core and 5G-AKA appear), [net-301](#) Ch 8 (wireless / cellular companion module), and [net-201](#)'s SDN chapter (the OpenFlow primary).

At a glance

Property	Value
Architectures compared	5G Core (3GPP Rel-15+), SDN (OpenFlow data-plane abstraction), Mobile-IP (IETF MIPv4 / MIPv6)
Comparison axes	3 (control-plane decomposition / routing model / state-management strategy)
Primary anchor	Kurose & Ross 9e, §7.4 (5G Core), §7.5.4 (Mobile-IP), §5 (SDN chapter)
Track readers	rf-301 Ch 5 (signal-side / RAN-attach lens) + net-301 Ch 8 (control-plane / NF-decomposition lens) + net-201 SDN chapter (controller-and-data-plane primary)
Voice family	Petzold-style Architecture Comparison Sidebar (parallels the OFDM/CDMA/TDMA/FHSS/DSSS, Snort/Suricata/Zeek, and ARM/x86/MIPS/RV32I-Lite roster pattern)

Three architectures. One-paragraph each

5G Core (3GPP). The 5G Core (5GC) is a service-based architecture in which the control-plane functions are split across roughly a half-dozen named **Network Functions**, AMF (Access and Mobility Management), SMF (Session Management), UDM (Unified Data Management), AUSF (Authentication Server), NRF (Network Repository Function), NSSF (Network Slice Selection Function), each speaking HTTP/2 + JSON over a service-bus. The user-plane is a separate function entirely (UPF), tunneled to/from the radio side via GTP-U. The control/user-plane separation is named **CUPS** (Control / User Plane Separation) and is the explicit architectural break with 4G EPC's monolithic-ish gateways. 9e §7.4 anchor.

SDN (OpenFlow data-plane abstraction). SDN logically centralises the control-plane behind a controller (single controller in the simplest deployments; cluster-of-controllers in production) and exposes a thin southbound API (OpenFlow most prominently; gRPC and P4Runtime in newer deployments) that the controller uses to push **match-action flow rules** into the forwarding ASIC of every switch. The data-plane is reduced to a stateless table-lookup engine; the control intelligence (routing decisions, ACL evaluation, forwarding-policy synthesis) lives controller-side. Northbound, the controller exposes an application API for network-management apps. 9e §5 anchor (SDN chapter).

Mobile-IP. Mobile-IP is a 1990s-era IETF design for transparent host mobility on the routed Internet. Two named agents own per-mobile-node state: the **Home Agent** (HA, on the mobile node's home network) and the **Foreign Agent** (FA, on the visited network). When a mobile node attaches to a foreign network, it registers a **Care-of-Address** with its home agent; subsequent traffic to the mobile node is intercepted by the home agent and tunneled to the foreign agent, which delivers the packet locally, the well-known **triangle-routing** pattern. Mobile-IPv6 collapses the foreign-agent role into a route-optimisation extension on the mobile node itself. 9e §7.5.4 anchor.

Three comparison axes

Axis 1: Control-plane decomposition

Architecture	Decomposition style	Locus of intelligence
5G Core	Microservice-like NF separation (AMF / SMF / UDM / AUSF / NRF. Distinct services on a service bus)	Distributed across NFs; cross-NF orchestration via the service-based interface (SBI)
SDN	Logically-centralised controller (single controller view; cluster realisation)	Controller-side; switches are stateless until pushed
Mobile-IP	Distributed agent pair (Home Agent + Foreign Agent per mobile node)	Distributed across HAs and FAs; per-MN state held at both endpoints of the tunnel

Reading the axis. The three architectures answer the "where does control live" question with three distinct philosophies. 5G Core says: split the control plane into named functional roles, each owning one slice of the lifecycle (mobility / session / authentication / data). SDN says: collapse the control plane into one logical authority and let the data plane be stupid. Mobile-IP says: keep the control plane distributed across the parties that actually have a stake in the mobility event (home and foreign networks). Each of those decisions has consequences the other two axes surface.

Axis 2: Routing model

Architecture	Data-plane model	Path topology
5G Core	GTP-U user-plane tunneling through the UPF; per-PDU-session tunnel	Radio ↔ UPF ↔ Internet (linear; UPF is the user-plane anchor)
SDN	Match-action flow tables populated by the controller; data-plane is stateless until rules push	Whatever the controller computes (arbitrary; ASIC-table-bounded)
Mobile-IP	Tunnel from HA to FA (or HA-to-MN in MIPv6 route-optimisation); home-network interception	Triangle-routing (sender → HA → FA → MN); flattened in MIPv6 RO

Reading the axis. GTP-U gives 5G a stateful per-session tunnel anchored at a known network function. At scale, this means the UPF is the high-throughput data-plane node, and CUPS lets operators independently scale UPFs from control-plane NFs. Match-action gives SDN data-plane statelessness, but at the cost of all topology decisions being controller-resolved. Mobile-IP's triangle-routing was the design's original criticism (it adds latency and bandwidth cost on the home-network leg); MIPv6 route-optimisation directly addresses it. Three answers; three different cost models.

Axis 3: State-management strategy

Architecture	State location	Failure-domain implications
5G Core	Per-NF state (UDM holds subscriber profile; AMF holds mobility context; SMF holds session context)	NF-bounded failure; service-bus mediates cross-NF dependencies; control-plane redundancy is per-NF
SDN	Controller-centralised state (or cluster-replicated)	Controller-bounded failure; switches forward stale flows during controller outage (until rules expire); cluster coordination is the hard problem
Mobile-IP	Distributed per-MN state at HA + FA	Per-mobile-node failure; HA outage strands mobility for that home-network's mobile nodes; FA outage strands one visited network's local traffic

Reading the axis. The state-management answer is what determines the deployment story. 5G Core's per-NF state means an operator can scale subscriber-database (UDM) independently of mobility-management (AMF), and a UDM outage does not necessarily break the AMF, depending on cached state. SDN's controller-centralised state means

controller availability is the hard architectural problem; production SDN deployments invest heavily in controller clustering and consensus protocols. Mobile-IP's distributed state means the failure domain follows the network ownership. A clean per-network failure isolation, at the cost of per-MN-pair coordination overhead.

Cross-track pedagogy notes

rf-301 Ch 5. Signal-side / RAN-attach lens. The RF track reads these architectures from the radio outward: the 5G Core's NF roster is what the UE-side attach-procedure trace decodes against (which NF is acknowledging which step?); the GTP-U tunneling is observable as a fingerprint on the user-plane interface; 5G-AKA's SUCI computation is a side-channel opportunity. SDN and Mobile-IP appear as comparison framings. *why did 3GPP not just use OpenFlow for the control plane? why did 3GPP not just use Mobile-IP for mobility?*, those questions only become readable once a student has the three architectures side by side.

net-301 Ch 8. Protocol-side / control-plane decomposition lens. The NET-track register reads these architectures from the control plane down: the 5G Core's microservice-like NF decomposition is a study in functional-decomposition rationale at carrier scale (compare to a monolithic 4G EPC); SDN's logical centralisation is a study in centralisation tradeoffs (latency cost of controller round-trips vs. policy-coherence gain); Mobile-IP is a 1990s baseline that surfaces what later architectures kept and what they discarded. The 5G-Core-vs-SDN comparison is particularly central for students heading toward NFV / O-RAN work.

net-201 SDN chapter. Primary OpenFlow home. The OpenFlow primary lives in net-201's SDN chapter. CT-B is the cross-chapter pickup pointer: at the net-201 SDN-chapter landing, a one-sentence cross-link reads. *for the contemporary cellular-control-plane comparison and the legacy mobile-control-plane comparison, see CT-B.*

Anchor citations

- **Primary.** Kurose & Ross, *Computer Networking: A Top-Down Approach*, 9th ed., Pearson, 2021. §7.4 (5G Core architecture and NF roster); §7.5.4 (Mobile-IP and triangle routing); §5 (SDN, OpenFlow, match-action data plane).
- **Secondary.** 3GPP TS 23.501 (5G system architecture; NF roster authoritative). ONF OpenFlow specification (data-plane abstraction authoritative). RFC 5944 / RFC 6275 (Mobile-IPv4 / MIPv6 normative).

- **Cross-references.** OpenAirInterface community docs for 5G Core hands-on (rf-301 Lab 5 substrate). ONOS / OpenDaylight documentation for production SDN-controller patterns.

Cross-references

Picks up at	Chapter / module	Purpose
<code>vca-rf-301.html</code>	Ch 5 (Cellular protocols, LTE + 5G NR via OAI)	RF-track-register weave; sidebar slot anchor in the Foundational Anchor Weaves section
<code>vca-net-301.html</code>	Ch 8 (Wireless / 802.11 deep-dive)	NET-track-register weave; cellular companion to the 802.11 wireless module
<code>vca-net-201.html</code>	SDN / control-plane chapter	OpenFlow primary; one-sentence pickup pointer to CT-B for the contemporary-cellular and legacy-mobility comparisons

Companion handouts: `cross-chapter-rf-301-architecture-sidebars.md` (*RF-301 sidebar roster*), `cross-chapter-net-301-architecture-sidebars.md` (*NET-301 sidebar roster*).