SDN (Software Defined Networking)—Network programmability using network controllers gets away from a distributed configuration model where each switch or router has its tiny piece of the overall config and moves toward a centralized model.

Data Plane—forwarding user data (the goal). Includes encapsulation, filtering, and forwarding decisions at L2 and L3.

Control Plane—Control of and Overhead for the Data Plane—Routing and MAC tables, STP, routing protocols, ARP/NDP (IPv4/v6). Traditionally distributed across the devices and things like routing protocols are used to coordinate.

Management Plane—supports network engineers—telnet, SSH

Network Controllers—(SDN Controllers) —This is software running on a server to centralize the control plane. In practice, this varies from centralized monitoring to actual centralized control. Centralized control can even directly and exclusively insert forwarding table entries (MAC and routing) into the distributed devices. Routing protocols can be eliminated because the central controller knows all.

SouthBound Interface (SBI)—The channel between the controller (top of a diagram) and the controlled devices (southbound on a diagram). Note: "interface" is a software term in this chapter, not the physical port like it is in the rest of the CCNA. Examples:

- OpenFlow
- OpFlex (Cisco, used with ACI)
- CLI (Telnet/SSH) and SNMP (Cisco, used with APIC-EM)

API (Application Programming Interface)—A standardized set of messages that any application can use to get involved. Shows the concept that the SBI is more than a contolling protocol, it's an extensible framework for custom software to control the devices.

NorthBound Interface (NBI)—Any API that allows software access to the controller's data and functions, allowing network programmability via applications that are even further above the controller.

REST (REpresentational State Transfer)—an API that layers the NBI onto HTTP messages so that the software using the controller's API doesn't have to be on the save device.

In other words, this all mirrors the way MIDI allowed centralized control of musical keyboard synthesizers on a single computer in the 1980s.

EXAMPLES

Open SDN / OpenFlow

Open SDN—From the Open Networking Foundation (ONF). Represents their vision of SDN.

Open SDN Defines:

- OpenFlow—The SBI for Open SDN
- n IP-based communications protocol for the SBI
- What a switch is (abstraction)—based on widely used chipsets. Includes traditional L2, L3 switching plus added flexibility beyond those clichés
- Network control belongs to the controller and software using any NBI supported by the implementation

Example Controllers

- OpenDaylight (ODL)—One example controller that works within the Open SDN model, including OpenFlow. ODL is an open source project from which multiple commercial products have been forked. Supports multiple SBIs.
- Cisco Open SDN Controller (OSC)—Cisco's commercial version of ODL. Contains a subset of ODL features. Some Cisco Nexus switches and Cisco ASR routers support OpenFlow.

ACI

ACI (Application Centric Infrastructure)—Cisco's Approach. The network adapts in real-time as data center automation spawns and retires virtual machines to cope with load. Fixed configuration on physical switchports is abandoned as the applications drive the network structure and capacity. Network admins don't connect to individual devices to configure CLI commands. Major aspects of the ACI:

- Endpoints—virtual machines or real servers
- Endpoint Groups—similar needs
- Policies—which endpoint groups can communicate with whom and with what QoS settings
- Partially centralized control plane

CCNA-type settings, such as which interfaces are in which VLAN or EtherChannel, are entirely derived from application needs, not configured directly.

APIC (Application Policy Infrastructure Controller)—a centralized "controller that creates application policies for the data center infrastructre."

Network Programmability—Applications and custom scripts can define enpoint groups and policies by connecting to the APIC. Network engineers no longer configure individual devices.

APIC-EM

APIC-EM (APIC Enterprise Module)—Unlike the above, this uses traditional switches and routers. It is *not* the same as the APIC mentioned above. It only adds programmability to a traditional enterprise networking infrastructure.

- APIC-EM uses an APIC-EM controller (not APIC)
- A collection of Cisco applications can run on the controller
- NorthBound API—It uses a RESTful northbound API—no further explanation offered
- Backward Compatible—No change (yet) to the control or data planes of the network devices. The central controller doesn't insert forwarding table entries (routing or MAC tables). Instead, it changes the configuration of the devices.
- SouthBound Interface—uses traditional telnet, SSH, and SNMP. Bidirectional—controller learns too.

Examples Recap / Comparison

	Open SDN	ACI	APIC-EM
Changes Device Control Plane	•	•	
Centralized Dashboard / Control Panel	•	•	•
Centralized Control Plane	Mostly	Partially	
SouthBound Interfaces	OpenFlow	OpFlex	Telnet, SSH, SNMP
Controller Examples	OpenDaylight, Cisco OSC	APIC	APIC-EM
Open Source / Cisco Proprietary	Open	Cisco	Cisco