**Layer 3 (IPv4 or IPv6)**

- IPv6 Unicast service (6VPE, IPv6 Unicast service)
- CCC & TCC (Private Wire Service)
- PWE (Private Wire, or PWE3, PWE, L2 Circuit)
- IP/GRE, IP-in-IP
- BGP/MPLS VPN
- Ethernet VPN
- EVPN
- VPLS
- MPLS

**IPSEC**

- Security Association (SA) is typically established via IKE (Internet Key Exchange)
- Layer 3 routing can be processed with ESP (Encapsulating Security Payload), or with AH (Authentication Header)

**Key Advantages**

- Flexibility in terms of security options
- Slightly better performance than SSL/TLS

**Key Limitations**

- No security. Doesn’t work across web proxies.

**GRE & IP/IPv4**

- Private IPv4 and IPv6 Unicast, IPv6 Multicast
- For UniCircuit Service
- For Multicast IPv4
- BGP or LDP (most vendors)

**Novel**

- Can be coupled to GRE (GRE over IPv6)

**Tunnels**

- MPLS (point-to-point)
- MPLS (point-to-multipoint)

**Security**

- Security is implemented by the Service Provider, which keeps separate per-VPN forwarding routing instances, called VPs that are transparent to the end customer.

**Ethernet VPN**

- Layer 2 Ethernet, Frame Relay, ATM, PPP, or HDLC

**CCC & TCC**

- Layer 2: Ethernet, Frame Relay, ATM, PPP, or HDLC
- Point-to-point: The tunnel is coupled to service, and each service (or cross-connect) has a different tunnel.

**Tunneling**

- VPLS is a full mesh between PE points, a partial mesh, or a hub-and-spoke topology
- One key point is that the tunnels for L2 VPLS can transport traffic from many different VPs of different types (endpoints, push, pop, swap, too).

**VPLS & MPLS**

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**Service Layer**

- MPLS IP VPN
- BGP/MPLS and VPLS
- Layer 3 (IPv4 or IPv6), Junos OS
- Supports Unicast and Multicast Layer 2 traffic, raw Ethernet frames, as well as VLAN-tagged ones

**Control Plane (tunnel signaling)**

- Control Plane (tunnel signaling): If forwarding plane is MPLS, then tunnel signaling can be either static or dynamically performed by LDP, RSVP, or BGP. If forwarding plane is GRE, then there is no tunnel signaling for Unicast services, while for Multicast services, if forwarding plane is GRE, it’s performed by PIM.

**Scalability**

- Flexibility, maturity, redundancy, interoperability: It’s the VPN solution.

**SDN**

- The service interfaces at each endpoint (PE1 and PE2) for CCC must be the same type (same as both Ethernet or both ATM). The service interfaces for TCC can be different types, but Junos OS can support changing the Layer 2 encapsulation through Layer 3 routing (hence the nickname L2.5 VPN).

**Layer 3 Engineering**

- Layer 2: Ethernet, Frame Relay, ATM, PPP, or HDLC
- Layer 3 (IPv4 or IPv6), Junos OS
- Supports Unicast and Multicast Layer 2 traffic, raw Ethernet frames, as well as VLAN-tagged ones

**VPLS**

- Layer 2 Ethernet, Frame Relay, ATM, PPP, or HDLC
- MPLS (point-to-point): Tunnel signaling can be performed by RSVP only.

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**GRE**

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