IPv4 over IPv6
for the Transition to IPv6

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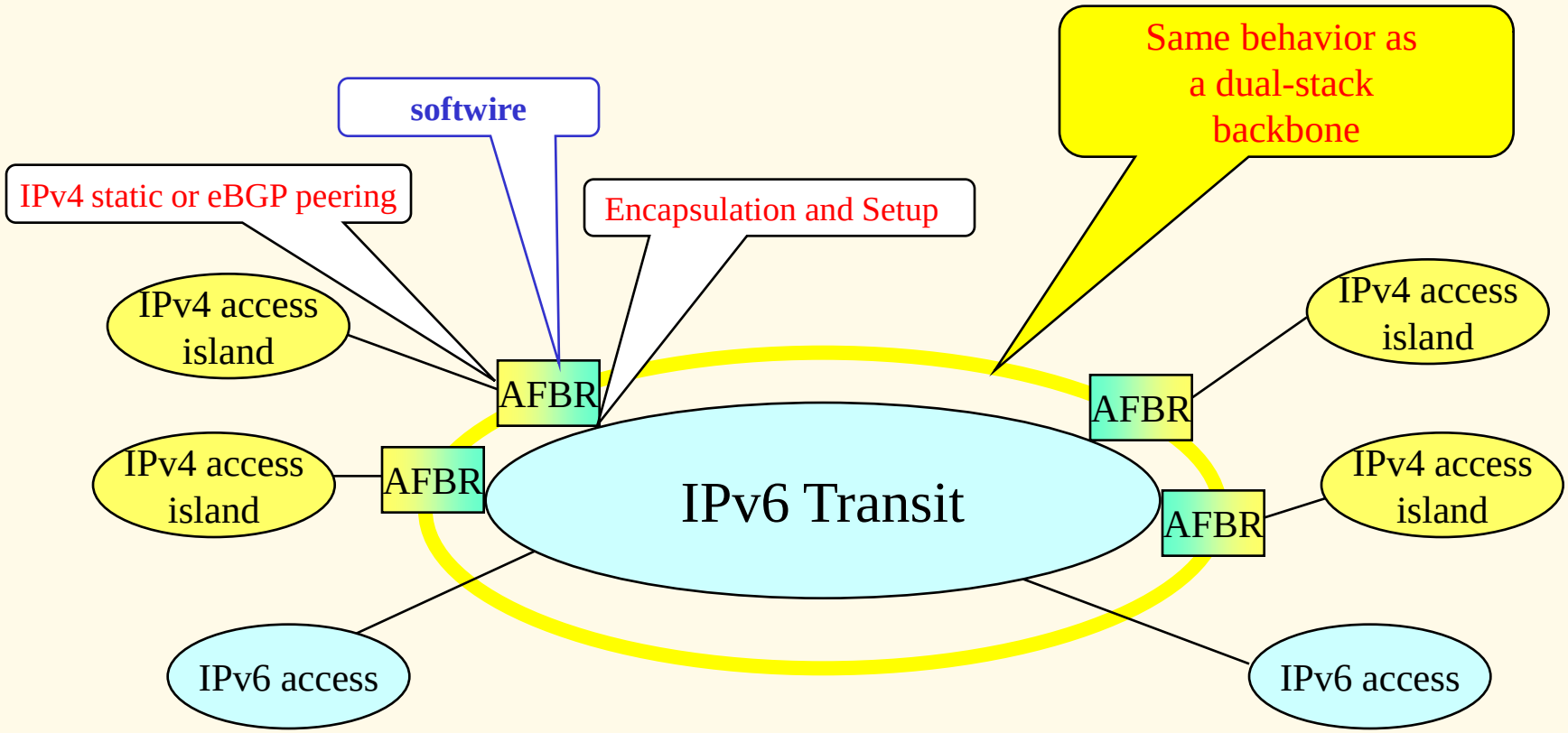
Mesh Problem

- **Description**
  - Core network problem
  - ISP initiated
  - complex routing topology
- **Applicability**
  - ISPs (or large enterprise networks acting as ISP for their internal resources) establish connectivity to 'islands' of networks of one address family type across a transit core of a differing address family type.

4over6 Framework for Mesh Problem

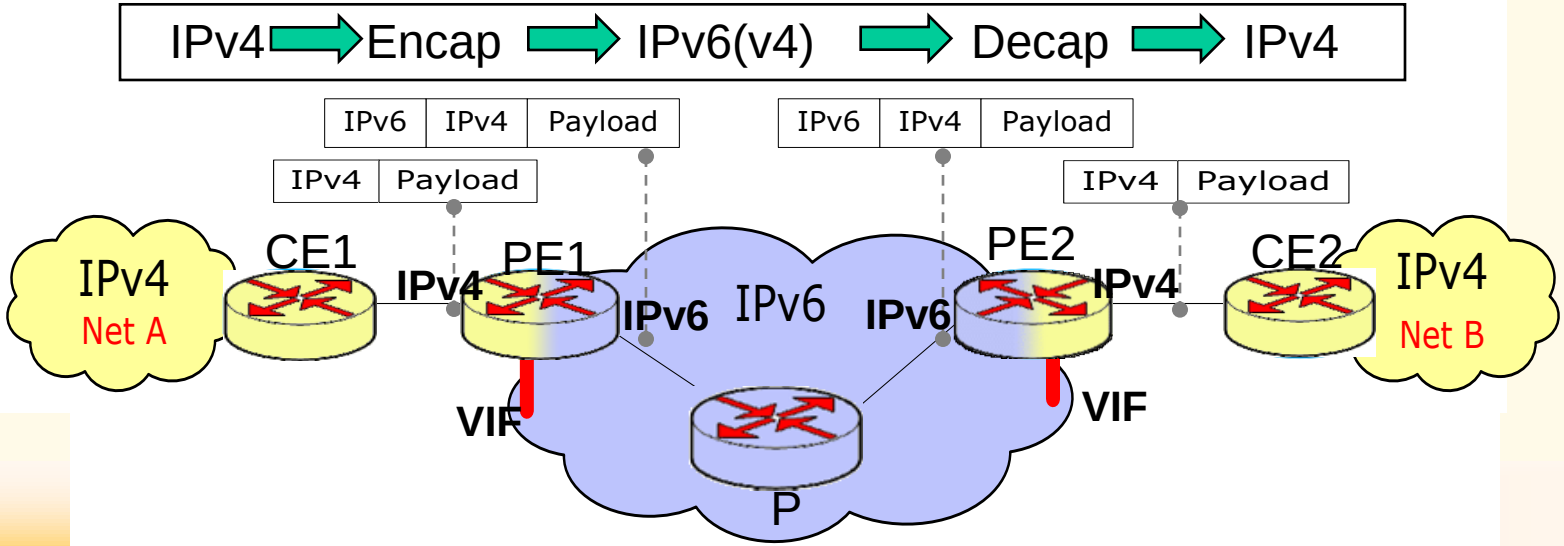


Framework Functionalities

- Mesh problem statement
  - Core (consisting of P routers) provides transit in one address family
  - Access networks are in another address family
  - Therefore, PE routers are dual-stack and provide Functionalities of softwires
- Proposed solution for mesh problem
  - Data plane of PE routers
    - Encapsulation (GRE, IP-IP, IP over UDP over IP, etc.)
  - Control plane of PE routers
    - End point discovery

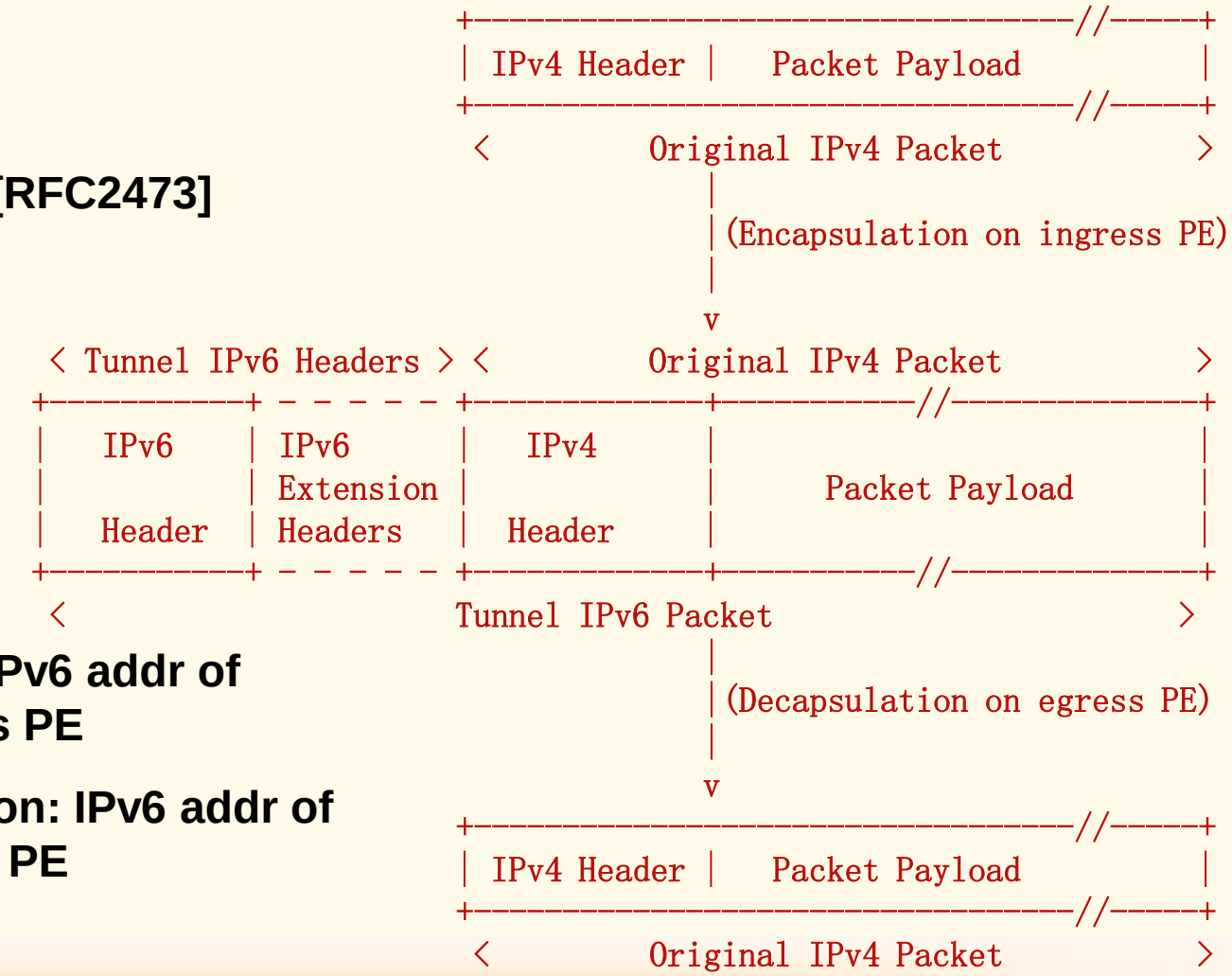
Packet Forwarding

- 4over6 packet forwarding
  - Encapsulation on ingress PE
  - Transmission of encapsulated packet in IPv6 Core via P routers
  - Decapsulation on egress PE back to IPv4 edge
- Reuse existing encapsulation technologies
  - GRE [2784], IP over IP [2473], IP over UDP over IP[RFC 3142]
  - Emerging technologies
- 4over6 VIF
  - 4over6 virtual interface on PE with both IPv4/v6 addresses



Example of IPv4 over IPv6 Encapsulation and Decapsulation

By reusing [RFC2473]



IPv6 source: IPv6 addr of VIF on ingress PE

IPv6 destination: IPv6 addr of VIF on egress PE

Encapsulation table

- **Encapsulation table**
  - Contains the mapping from dest IPv4 network addr to IPv6 addr on egress PE
  - Routing info about egress PE and dst networks
  - Use for encapsulation on ingress PE(AFBR)
  - Currently no automatic scheme for endpoint discovery
- **How to construct Enc Tab?**
  - Transmit Network Reachability info from egress PE to ingress PE
- **Why use BGP?**
  - Have similar extensions with BGP-MP
  - Setup a peering relationship between PEs

BGP-MP 4over6 Protocol Definition

- **BGP-MP Objective**
  - **Peering between AFBR (PE)**
  - **Encapsulation table**
    - **From IPv4 edge network addresses with prefix**
    - **To IPv6 address on egress PE**
- **BGP-MP 4over6 extension**
  - **OPEN message indicates the capability of BGP entity by AFI and SAFI**
  - **BGP UPDATE Message includes routing info (Next Hop, NLRI) with AFI and SAFI**

Address Family Identifier

Number	Description	Reference
0	Reserved	
1	IP (IP version 4)	
2	IP6 (IP version 6)	
3	NSAP	
4	HDLC (8-bit multidrop)	
5	BBN 1822	
6	802 (includes all 802 media plus Ethernet "canonical format")	
7	E.163	
8	E.164 (SMDS, Frame Relay, ATM)	
9	F.69 (Telex)	
10	X.121 (X.25, Frame Relay)	
11	IPX	
12	Appletalk	
13	Decnet IV	
14	Banyan Vines	
15	E.164 with NSAP format subaddress	[UNI-3.1] [Malis]
16	DNS (Domain Name System)	
17	Distinguished Name	[Lynn]
18	AS Number	[Lynn]
19	XTP on IP version 4	[Saul]
20	XTP on IP version 6	[Saul]
21	XTP native mode XTP	[Saul]
22	Fibre Channel World-Wide Port Name	[Bakke]
23	Fibre Channel World-Wide Node Name	[Bakke]
24	GWID	[Hegde]
65535	Reserved	

Use: IP=1 for IPv4 edge networks

SAFI

Value	Description	Reference
0	Reserved	
1	Network Layer Reachability Information used for unicast forwarding	[RFC2858]
2	Network Layer Reachability Information used for mulitcast forwarding	[RFC2858]
3	Network Layer Reachability Information used for both unicast and multicast forwarding	[RFC2858]
4	Network Layer Reachability Information (NLRI) with MPLS Labels	[RFC3107]
5-63	Unassigned	
64	Tunnel SAFI	[Nalawade]
65	Virtual Private LAN Service (VPLS)	[Kompella]
66	BGP MDT SAFI	[Nalawade]
67-127	Unassigned	
128	MPLS-labeled VPN address	
129-255	Private Use	

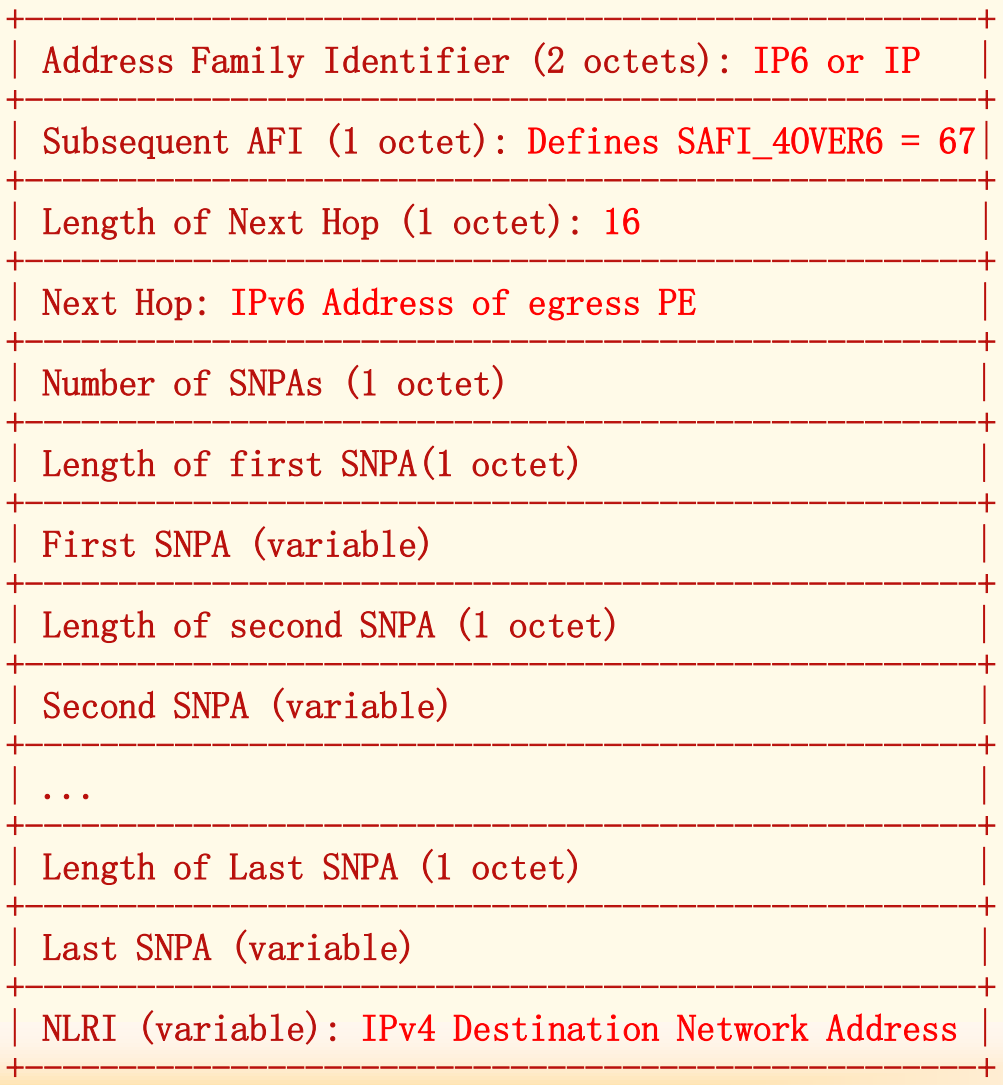
Define: SAFI_4over6 = 67 (FCFS for 64-128)

Indicate 4over6 capability

BGP-MP 4over6 Protocol Definition

UPDATE Message

IPv4 over IPv6



AFI_IP=1

SAFI_4OVER6 = 67

Length of IPv6

IPv6 VIF on egress PE

Dst IPv4 network addr
With prefix length

AFBR Protocol Behavior

- **Behavior overview**
  - **On 4over6 PE routers**
  - **Routing between PE <-> CE**
    - Make PE learn edge routing info of local edge network
    - RIP, OSPF, I-BGP, E-BGP, static, etc.
  - **Routing between PE <-> PE**
    - I-BGP peering with each other
    - Use BGP-MP 4over6 extension

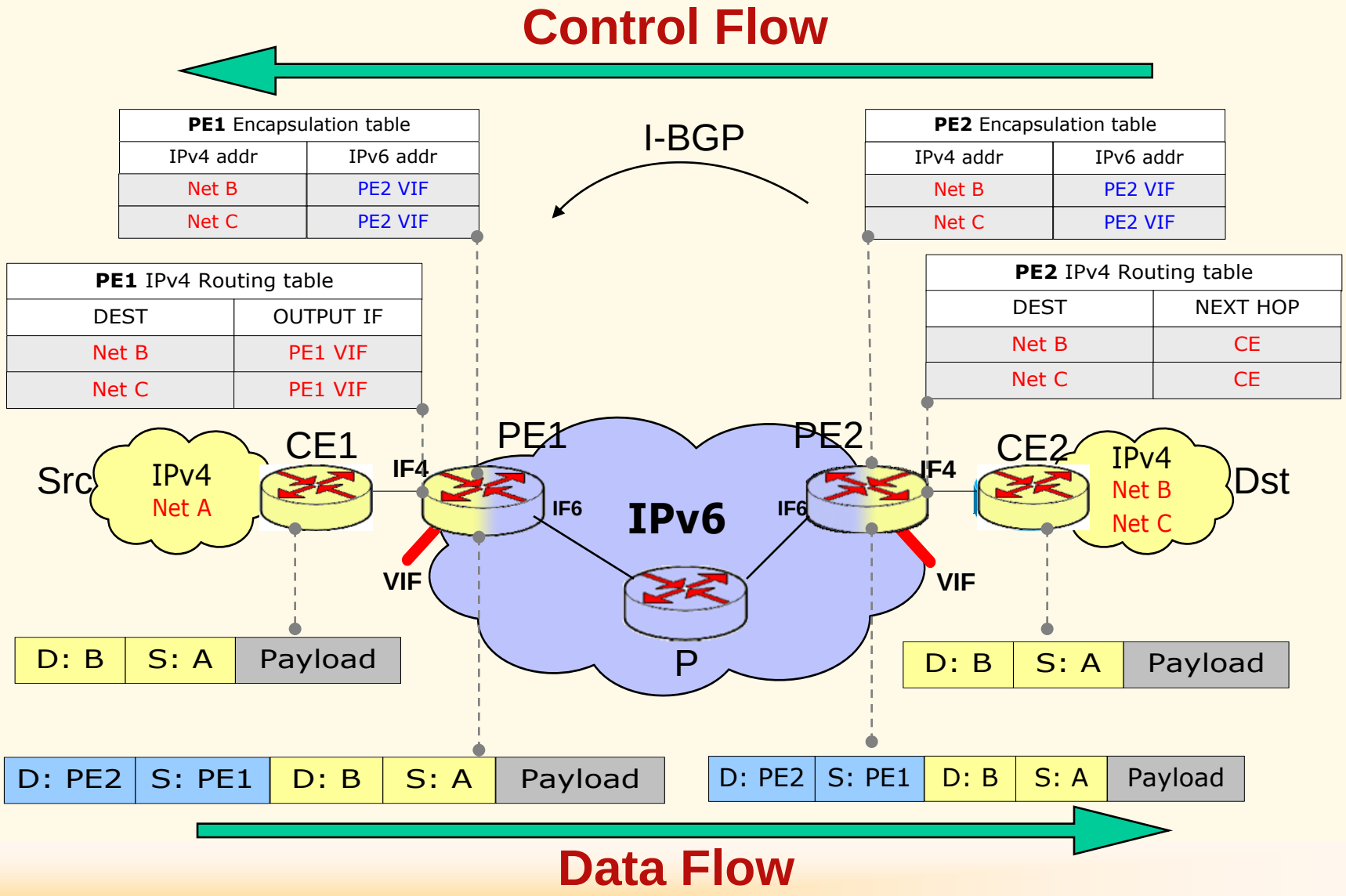
Protocol Behavior of BGP-MP 4over6 Extension

- For routing info received from CE (static)
  - Construct the encapsulation table
    - IPv4 Network addr with prefix
      - Should be the original edge destination
    - Corresponding IPv6 addr
      - should be the address of PE's 4over6 VIF
  - 4over6 I-BGP entity sends to its peers on core network
    - Taking AFI as edge IPv4 AFI
    - Taking SAFI as SAFI_4OVER6 = 67
    - Destination (in IPv4 edge AF)
      - Should be the original edge destination with prefix
    - Nexthop (in IPv6 core AF)
      - should be the address of its 4over6 VIF

Protocol Behavior of BGP-MP 4over6 Extension

- **For routing info received from other PE**
  - **Confirm the routing type**
    - Edge AFI (IPv4) and SAFI_4OVER6
    - Destination is in edge AF format (IPv4)
    - Next hop is in core AF format (IPv6)
  - **Construct the encapsulation table**
    - IPv4 network addr/prefix is NLRI in UPDATE message
    - Mapped IPv6 addr is NEXTHOP in UPDATE message
  - **Set IPv4 routing table**
    - Keep the original destination in Edge AF (IPv4)
    - Take OUTPUT IF as 4over6 VIF

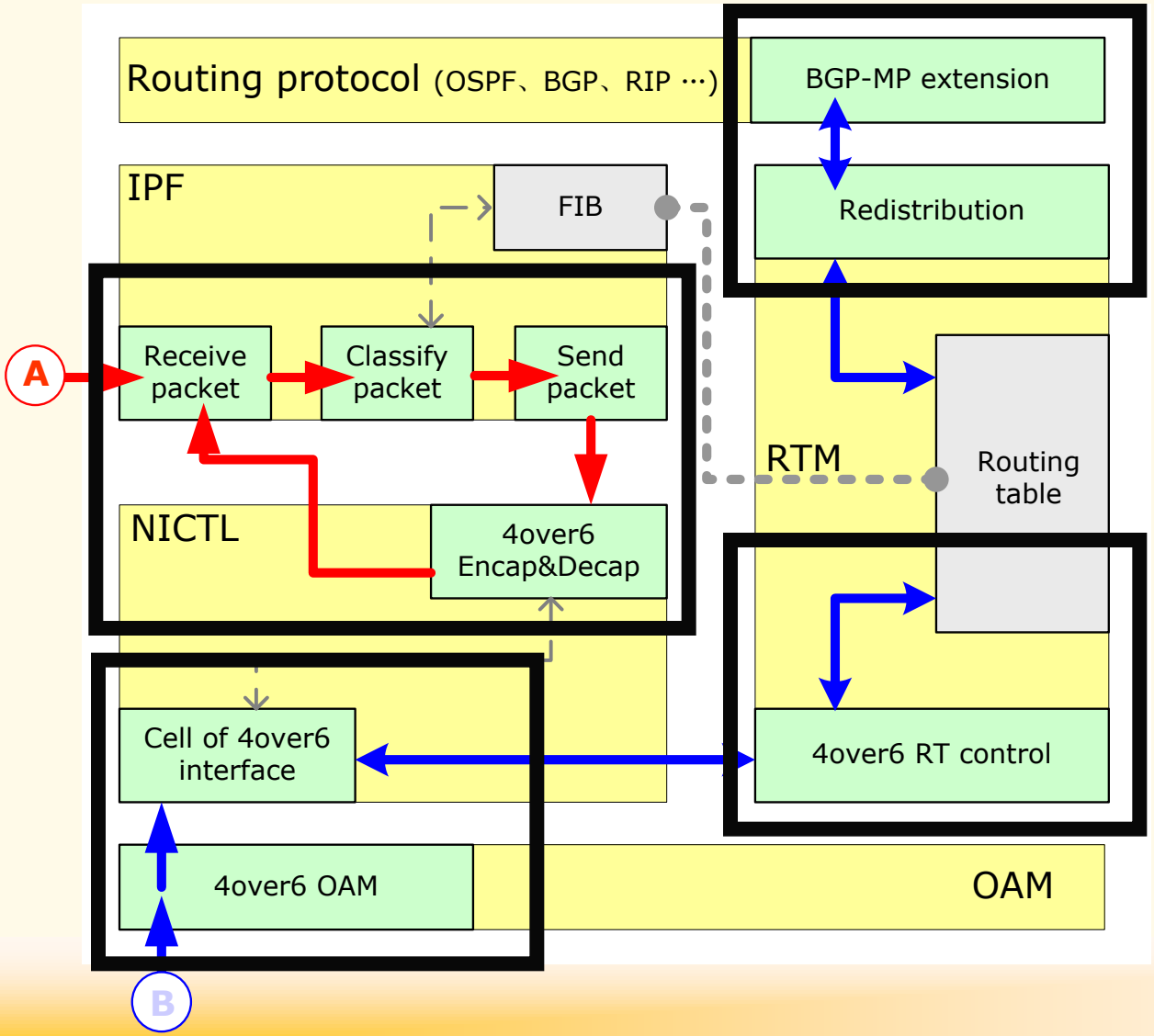
Example of 4over6



4over6 capability

- MP-BGP 4over6 extension
  - In MP_REACH_NLRI
  - Next hop: IPv6 address of Egress PE
  - NLRI: dest IPv4 prefixes
- <AFI, SAFI> for MP-BGP 4over6 capability
- Need a new SAFI
  - IANA has assigned SAFI=67 as the BGP 4over6 SAFI
  - <AFI, SAFI>: <IP=1, BGP 4over6 SAFI=67>

Implementation Framework



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1) 4over6 OAM
2) 4over6 RT control
3) BGP-MP Ext
4) 4over6 VIF

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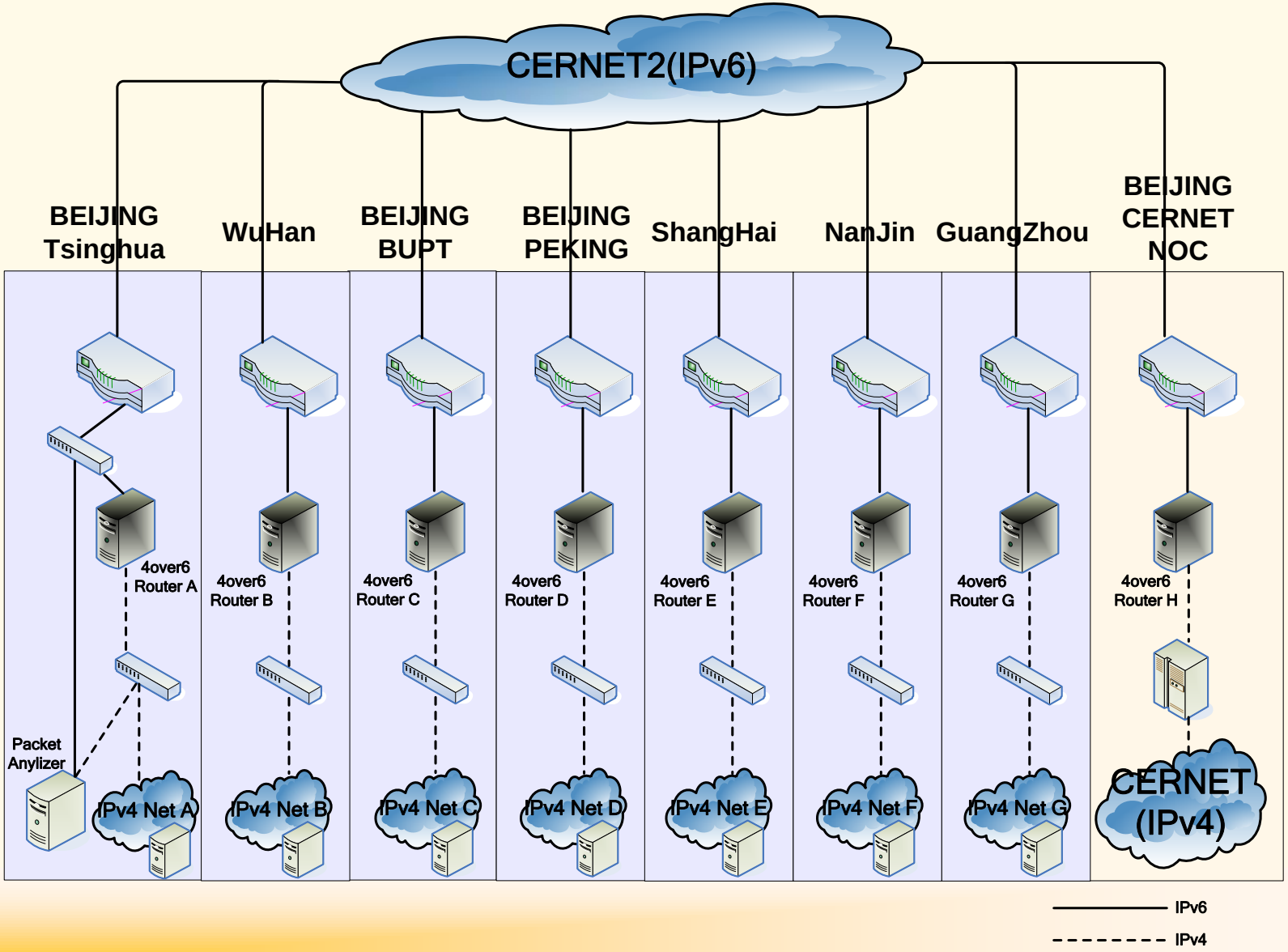
Control level

Data level

CERNET2 Deployment



Extension to IPv6 over IPv4

- Address format
  - 4over6 proposal uses IPv4/IPv6 address in an equal position rather than coding one addr to another
- Encapsulation table for 4over6
  - IPv4 dst network -> IPv6 on egress PE
- Encapsulation table for 6over4
  - IPv6 dst network -> IPv4 on egress PE
- Encapsulation techniques
  - GRE[2784], IPv6 over IPv4 [2893], etc.

Extension to IPv6 over IPv4 (AFI)

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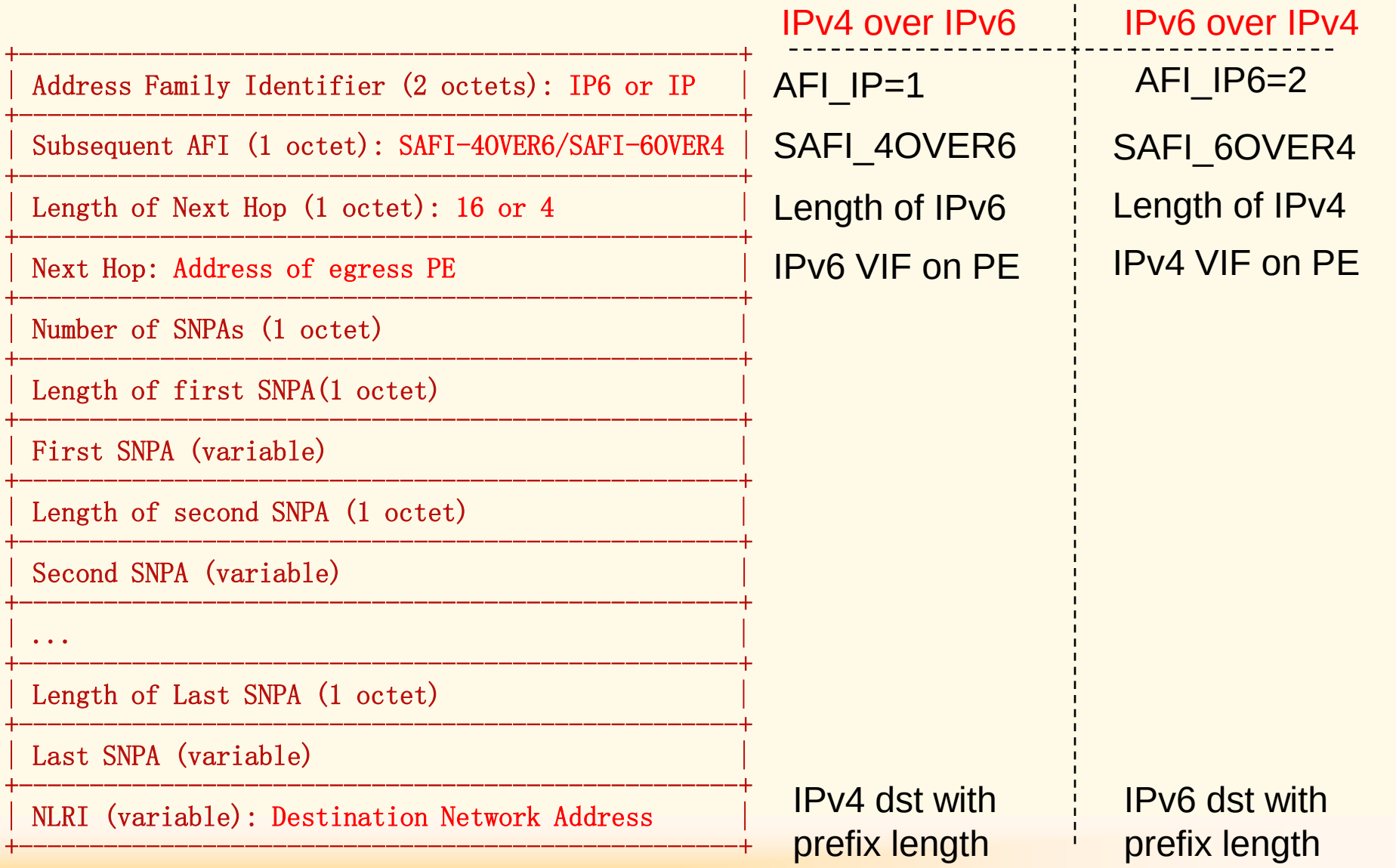
24	GWID	[Hegde]
65535	Reserved	

Use: IP=1 for IPv4 edge networks
IP6=2 for IPv6 edge networks

Extension to IPv6 over IPv4 Protocol Definition



Current Status in IETF Work

- Problem statement
  - In RFC-editor queue
- Mesh framework
  - draft-ietf-softwire-mesh-framework-00.txt
- Solutions
  - Unicast
  - Multicast

Publications on IPv4 over Ipv6

- **IEEE Internet Computing, May and Sept., 2006**

Conclusion

- 4over6 proposal for Mesh Problem
  - IPv4 over IPv6 backbones
  - IPv6 backbones act as dual-stack core
- Packet encapsulation is reused
  - Encapsulation and Decapsulation
- BGP-MP 4over6 extension is defined
  - New SAFI: SAFI_4OVER6 = 67
  - Protocol behavior is defined
- Advantage
  - Only PE router needs to be extended to maintain routing info of access networks
  - Core networks and custom networks are not aware of 4over6
  - Simple extension and configuration
  - Easy to extend to IPv6 over IPv4

Q and A

Thanks