Traffic Tunneling
&
Overlay Networks

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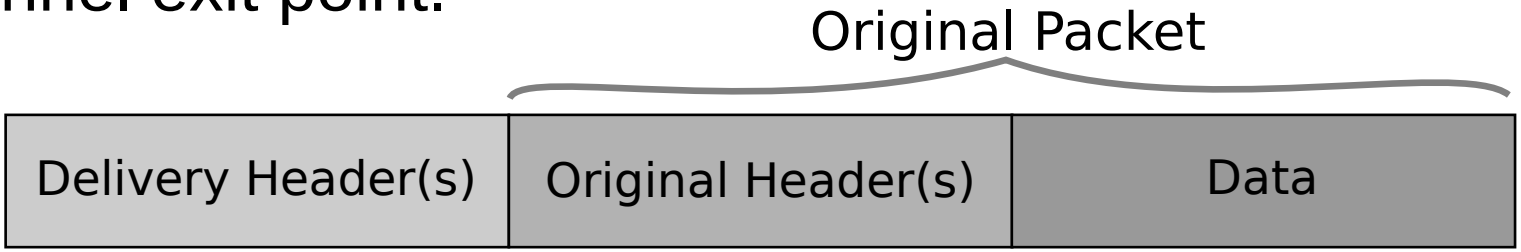
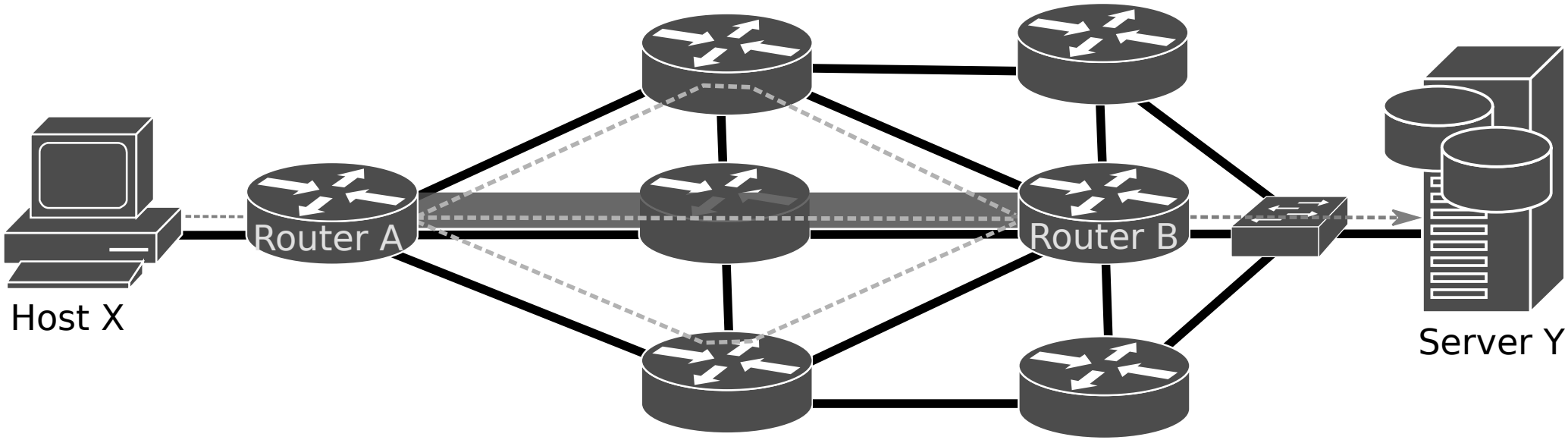
Traffic Tunnel Concept

- Main purposes
  - Guarantee that a packet that reaches a network node will reach a specific secondary network node independently of the intermediary nodes routing processes,
  - Guarantee the delivery of a packet to a remote node when the intermediary nodes do not support the original packet network protocol, and,
  - Define a virtual channel that adds additional data transport features in order to provide differentiated QoS, security requirements and/or optimized routing.
- Achieved by adding, at the tunnel entry point, one or more protocol headers to the original packets to handle their delivery to the tunnel exit point.



Tunnel End-Points



Delivery protocol(s)	Original protocol(s)	Data
Source: A address Destination: B address	Source: X address Destination: Y address	

Virtual Tunnel Interface (VTI)

- Logical construction that creates a virtual network interface that can be handled as any other network interface within a network equipment.
- A tunnel does not require to have any network addresses other the ones already bound to the end-point router.
- However, most implementations impose that a network address must be bound to a tunnel interface in order to enable IP processing on the interface.
  - The tunnel interface may have a explicitly bound network address or reuse an address of another interface already configured on the router.

```
#interface Tunnel 1
 #ip address 10.1.1.1 255.255.255.252
 #ipv6 address 2001:A:A::1/64
 #ip unnumbered FastEthernet0/0
 #ipv6 unnumbered FastEthernet0/0
 #ip ospf cost 10
 #ipv6 ospf 1 area 0
 #tunnel mode ipip
 #tunnel source FastEthernet0/0
 #tunnel destination 200.2.2.2
```

VTI Requirements

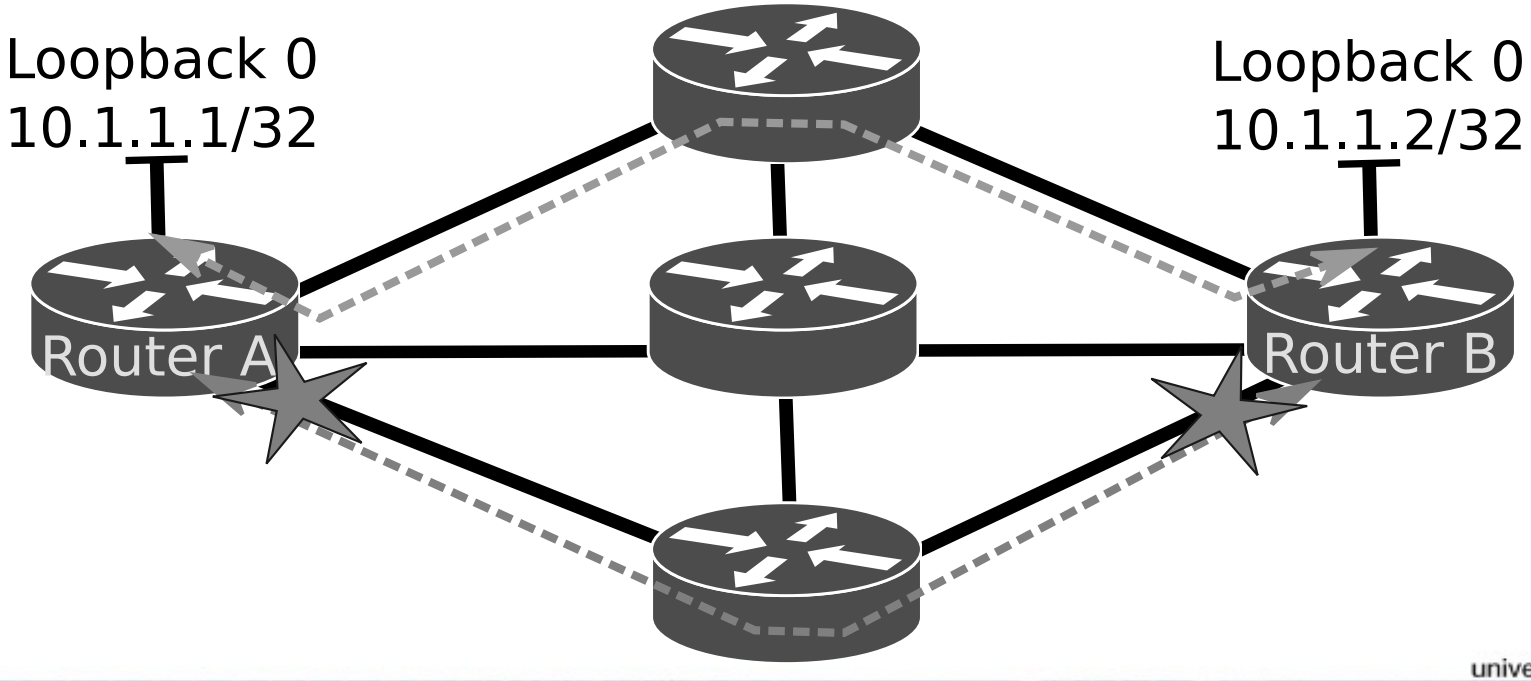
- A numeric identifier,
- A bounded IP address, this will enable IP processing,
  - Add the tunnel interface to the routing table and allow routing via the interface,

```
1  #interface Tunnel 1
2   #ip address 10.1.1.1 255.255.255.252
3   #ipv6 address 2001:A:A::1/64
4   #ip unnumbered FastEthernet0/0
5   #ipv6 unnumbered FastEthernet0/0
6   #ip ospf cost 10
7   #ipv6 ospf 1 area 0
8   #tunnel mode ipip
9   #tunnel source FastEthernet0/0
10  #tunnel destination 200.2.2.2
```

- A defined mode or type of tunnel,
  - Availability of tunnel models depends on the Router model, operating software and licenses.
- Tunnel source,
  - Defined as the name of the local interface or IPv4/IPv6 address depending on the type of the tunnel.
- Tunnel destination,
  - Defined as a domain name or IPv4/IPv6 address depending on the type of the tunnel.
  - This definition is not mandatory for all types of tunnels because in some cases the tunnel end-point is determined dynamically.
- May optionally have additional configurations for routing, security and QoS purposes.

Loopback Interfaces as End-Points

- Loopback interface is another logical construction that creates a virtual network interface completely independent from the remaining physical and logical router network interfaces.
- The main propose of a loopback interface is to provide a network address to serve as router identifier in remote network configurations and distribute algorithms.
- The main advantage of using loopback interfaces as tunnel end-points, is the creation of a tunnel not bounded to any individual network card/link that may fail.

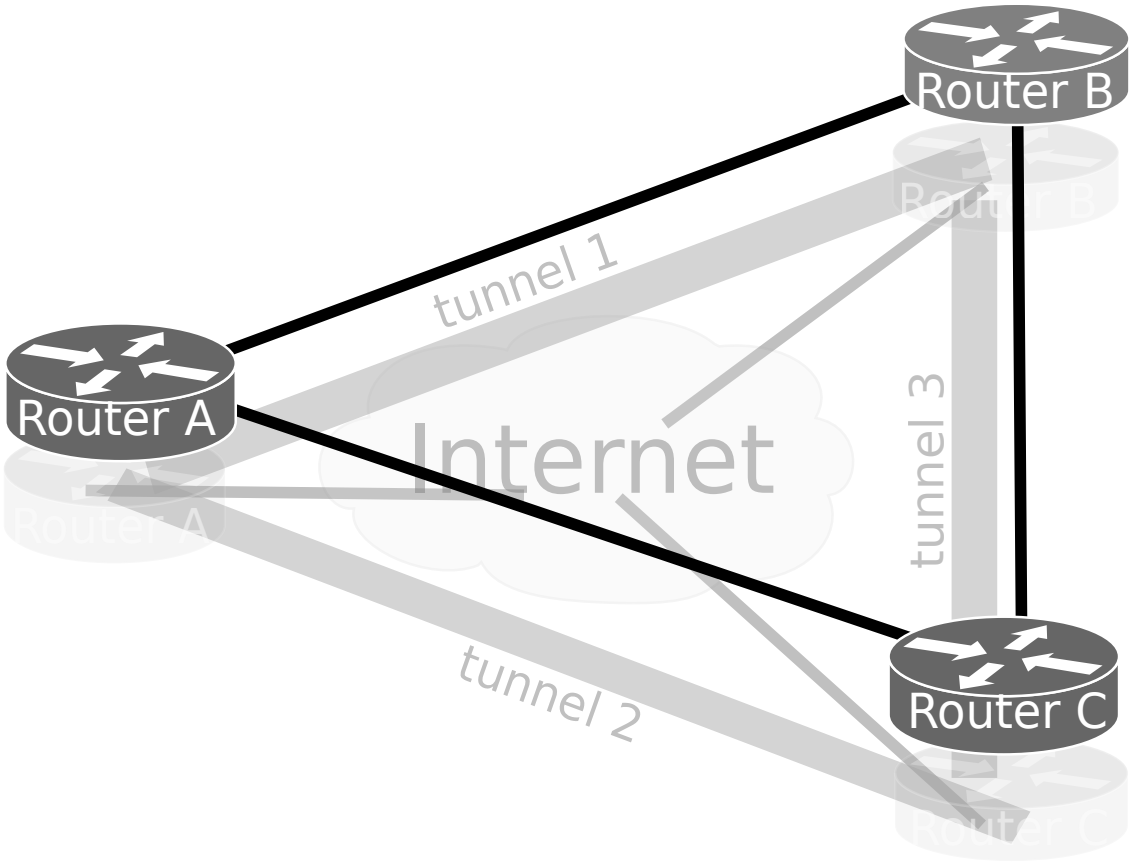


IP Tunnel Types

- IPv4-IPv4
  - Original IPv4 packets are delivered using IPV4 as network protocol.
- GRE IPv4
  - Original packets protocol (any network protocol) is defined by GRE header and delivered using IPv4 as network protocol.
- IPv6-IPv6
  - Original IPv6 packets are delivered using IPv6 as network protocol.
- GRE IPv6
  - Original packets protocol (any network protocol) is defined by a GRE header and delivered using IPv6 as network protocol.
- IPv6-IPv4
  - Original IPv6 packets are delivered using IPv4 as network protocol.
- IPv4-IPv6
  - Original IPv4 packets are delivered using IPv6 as network protocol.

Overlay Network

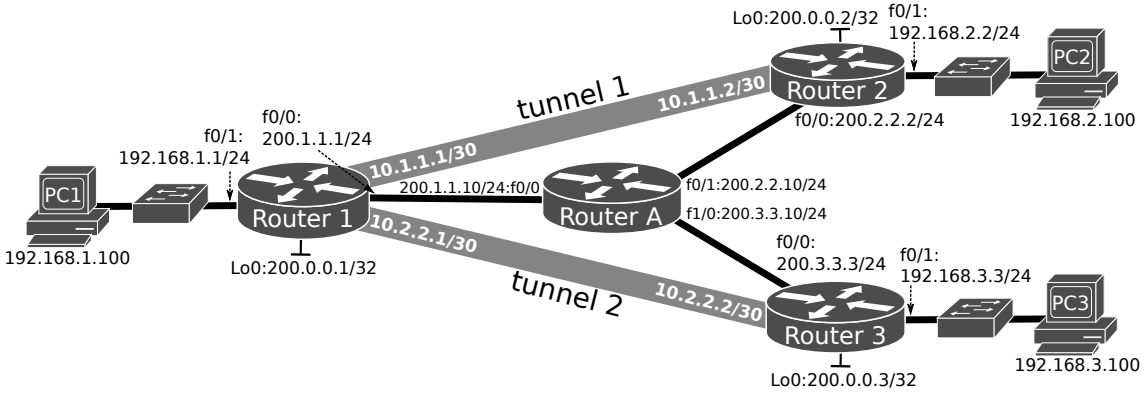
- An overlay network can be defined as a virtual network defined over another network.
  - For a specific purpose like private transport/routing policies, QoS, security.
- The underlying network can be physical or also virtual.
  - May result in multiple layers of overlay networks.
- When any level of privacy protocol is present on an overlay network is designated by Virtual Private Network (VPN).



Routing Through/Between Tunnels

- Static Routes

```
#ip route 192.168.2.0 255.255.255.0 Tunnel1
#ip route 192.168.2.0 255.255.255.0 10.1.1.2
#ipv6 route 2001:A:1::/64 Tunnel1
#ipv6 route 2001:A:1::/64 2001:0:0::2
#ip route 192.168.2.100 255.255.255.255 10.1.1.2
#ipv6 route 2001:A:1::100/128 2001:0:0::2
```



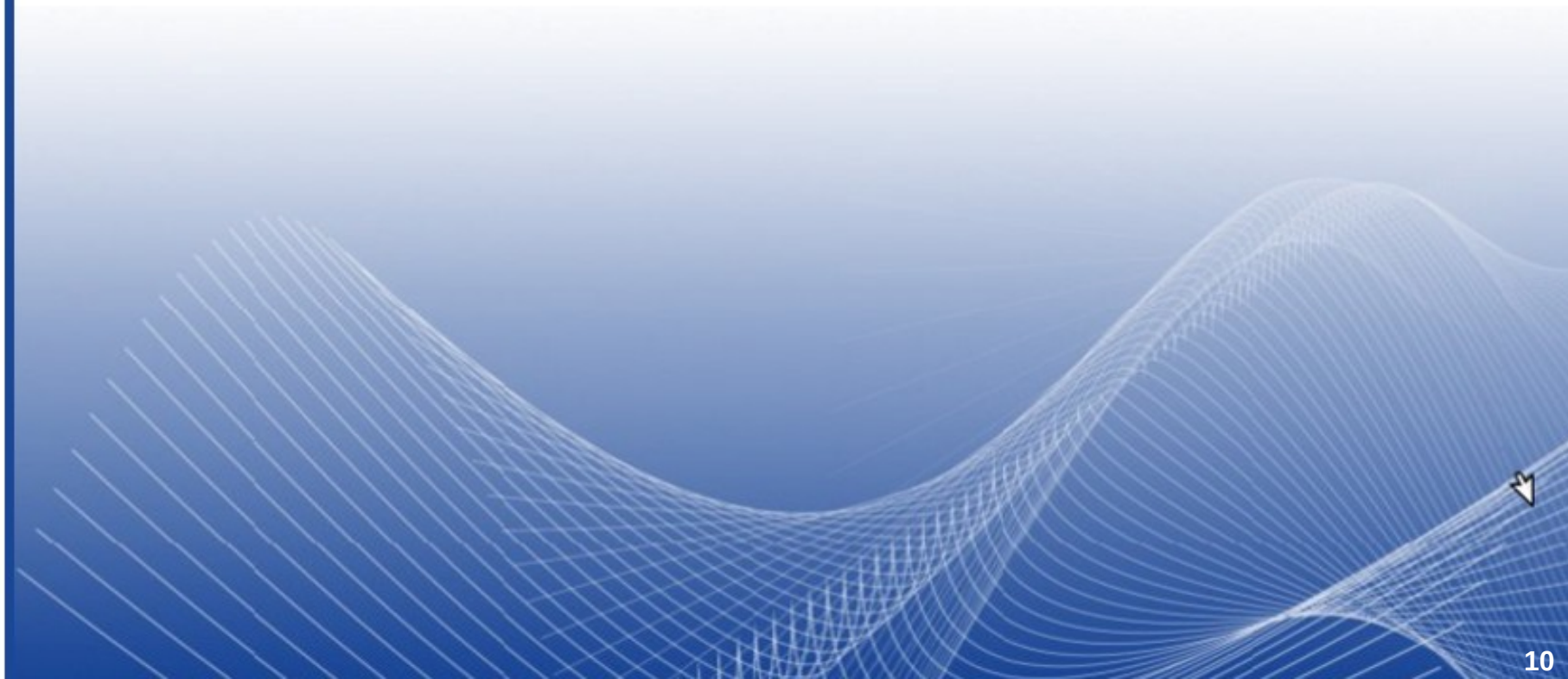
- Route-maps

```
#access-list 100 permit ip host 192.168.1.100 192.168.2.0 255.255.255.0
#route-map routeT1
 #match ip address 100
 #set ip next-hop 10.1.1.2
#interface FastEthernet0/1
 #ip policy route-map routeT1
```

- Dynamic Routing
  - Multiple (distinct) routing processes.
    - One per overlay network, and
    - One for the underlying network.

```
#router ospf 1
 #network 200.1.1.0 0.0.0.255 area 0
 #network 200.0.0.1 0.0.0.0 area 0
!
#router ospf 2
 #network 10.0.0.0 0.255.255.255 area 0
 #network 192.168.0.0 0.0.255.255 area 1
```

IPv4/IPv6 Transition Mechanisms



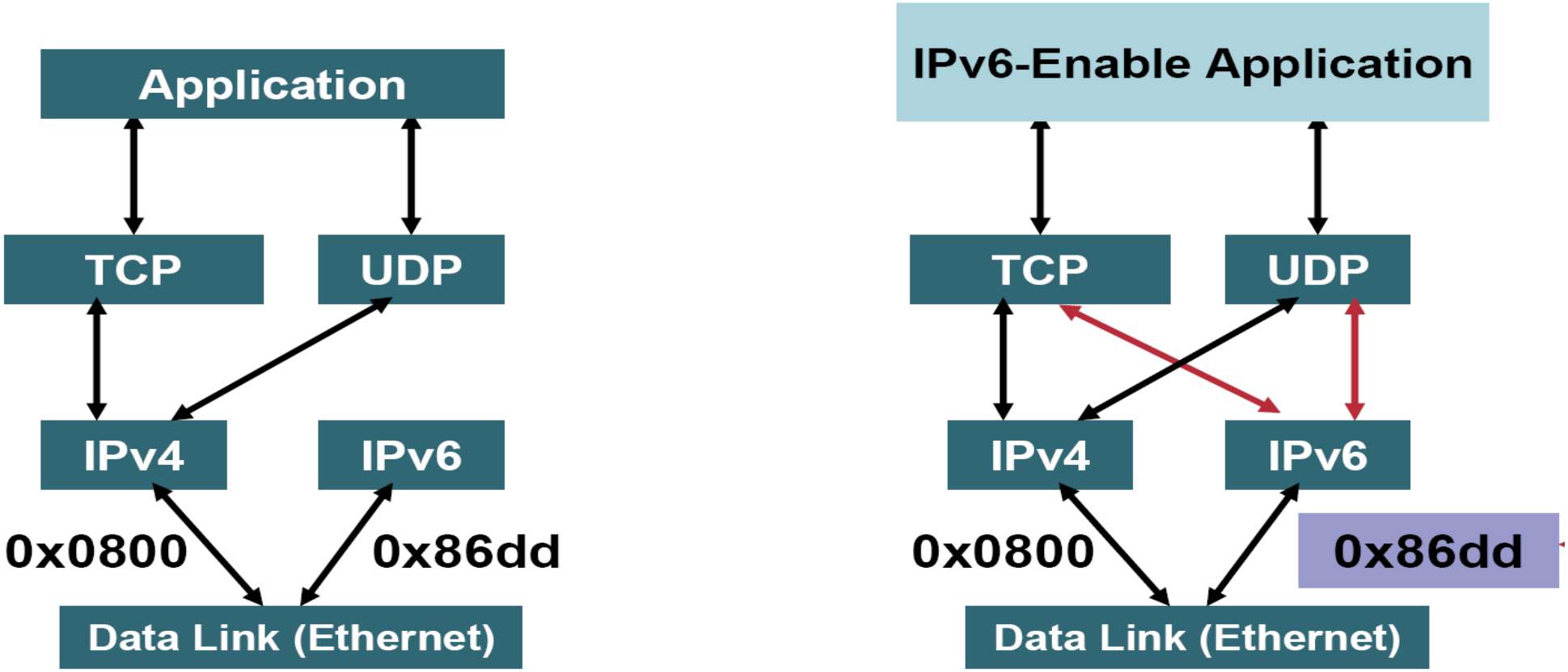
IPv6 Deployment Techniques (1)

- Deploying IPv6 using dual-stack backbones
  - IPv4 and IPv6 applications coexist in a dual IP layer routing backbone
  - All routers in the network need to be upgraded to be dual-stack
- IPv6 over IPv4 tunnels
  - Manually configured
    - With and without Generic Routing Encapsulation (GRE)
  - Semiautomatic tunnel mechanisms
  - Fully automatic tunnel mechanisms (IPv4-compatible and 6to4)

IPv6 Deployment Techniques (2)

- Translation Mechanisms
  - Network Address Translation-Protocol Translation (NAT-PT)
  - TCP-UDP Relay
  - Bump-in-the-Stack (BIS)
  - SOCKS-Based Gateway
  - ...
- Deploying IPv6 over dedicated data links
  - Using the same Layer 2 infrastructure as for IPv4
  - Using separate Frame Relay or ATM PVCs, separate optical links, or Wave Division Multiplexing (WDM)
- Deploying IPv6 over MPLS backbones

Dual Stack



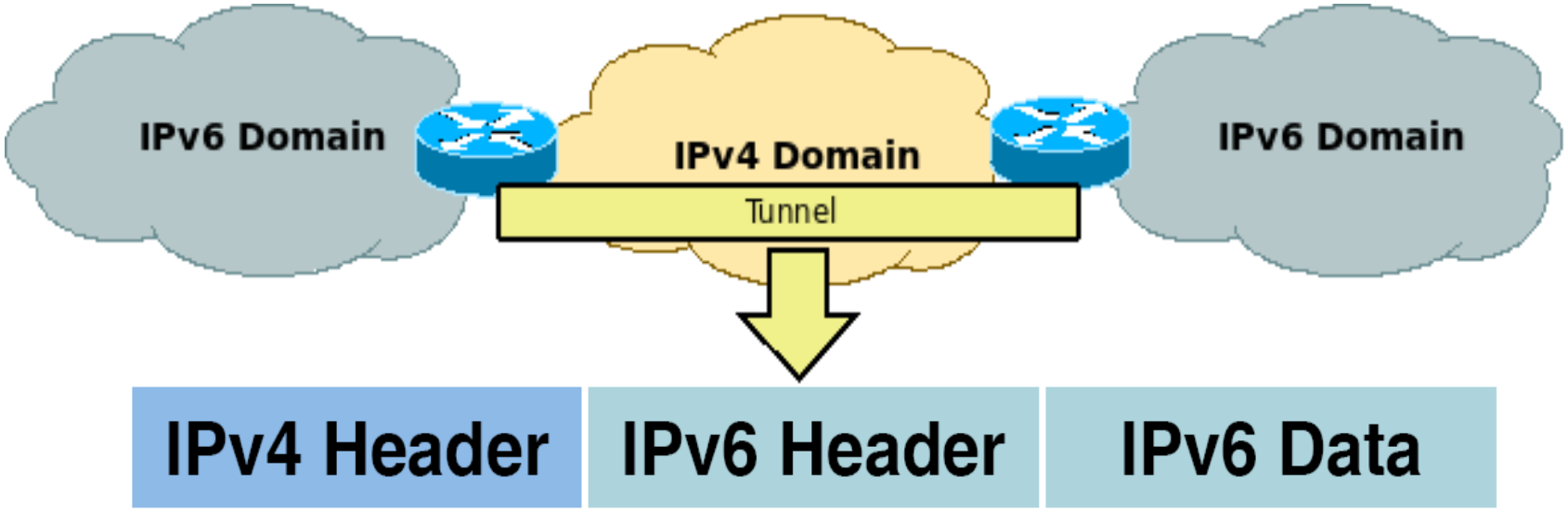
- Applications may talk to both
- Choice of the IP version is based on DNS responses and application preferences

Overlay Tunneling

- Manual
  - IPv6 Manually Configured IPv6 over IPv4
  - IPv6 over IPv4 GRE Tunnel
- Semi-automatic mechanisms
  - Tunnel Broker
  - Teredo
  - Dual Stack Transition Mechanism (DSTM)
- Automatic mechanisms
  - Automatic IPv4 Compatible Tunnel (deprecated)
  - 6to4 Tunnel
  - ISATAP Tunnels

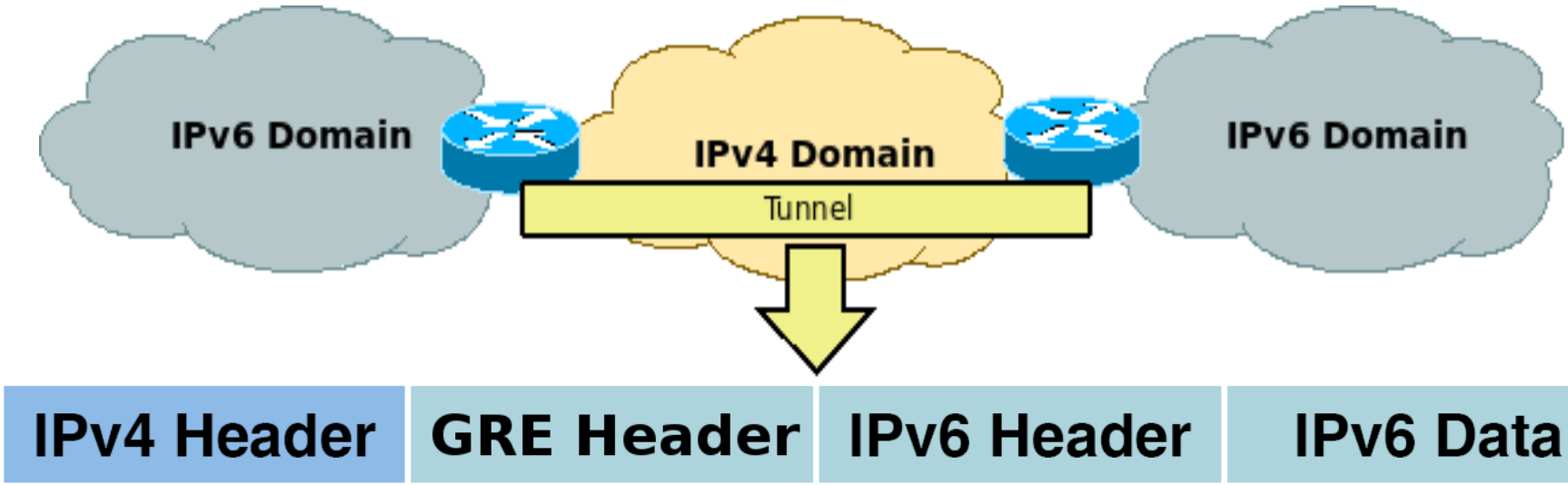
IPv6 Manually Configured

- Permanent link between two IPv6 domains over an IPv4 backbone
- Primary use is for stable connections that require regular secure communication between
  - Two edge routers, end system and an edge router, or for connection to remote IPv6 networks
- Tunnel between two points
- Complex management



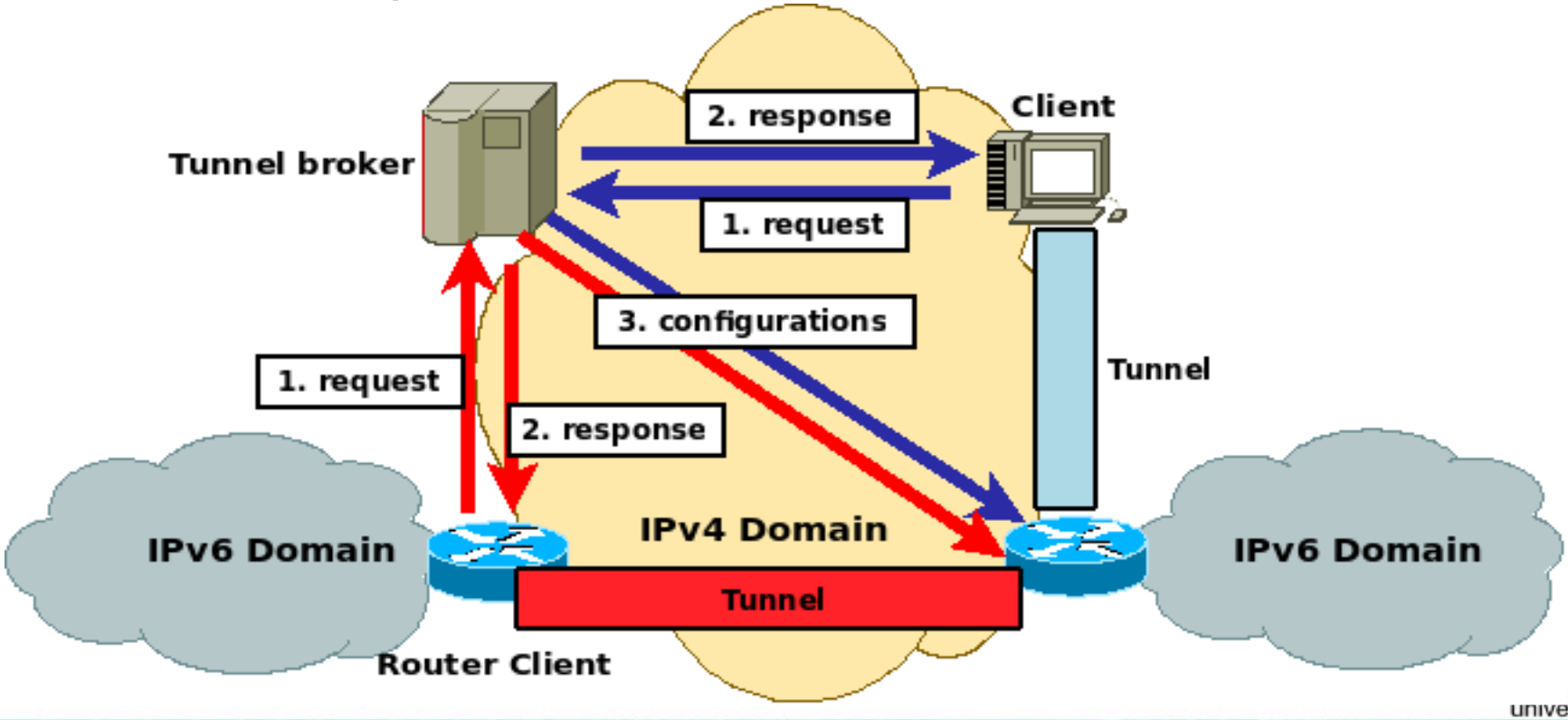
IPv6 over IPv4 GRE Tunnel

- Uses the standard GRE tunneling technique
  - GRE – Generic Route Encapsulation
- Also must be manually configured
- Primary use is for stable connections that require regular stable communications
- IPv4 over IPv6 also possible



Tunnel Broker

- A tunnel broker service allows IPv6 applications on dual-stack systems access to an IPv6 backbone
- Automatically manages tunnel requests and configuration
- Potential security implications
  - Broker is a single point of failure
- Most common implementation: Teredo.

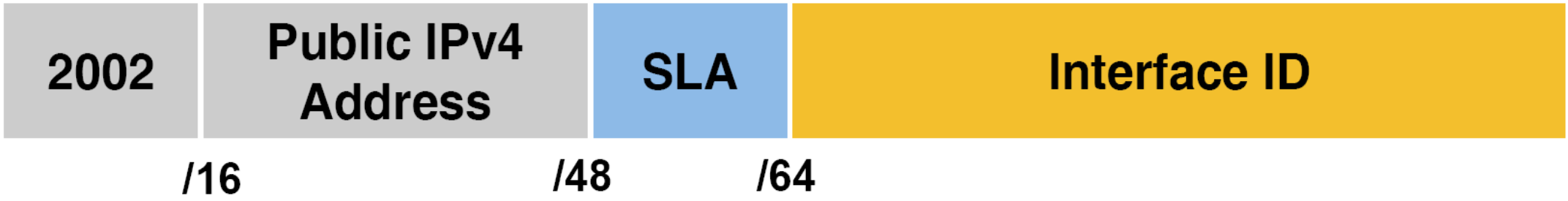


Automatic IPv4 Compatible Tunnel

- IPv4 tunnel end-point address is embedded within the destination IPv6 address
- An automatic IPv4-compatible tunnel can be configured between edge routers or between an edge router and an end system.
- Systems must be dual-stack
- Communication only with other IPv4-compatible sites
- This tunneling technique is currently deprecated

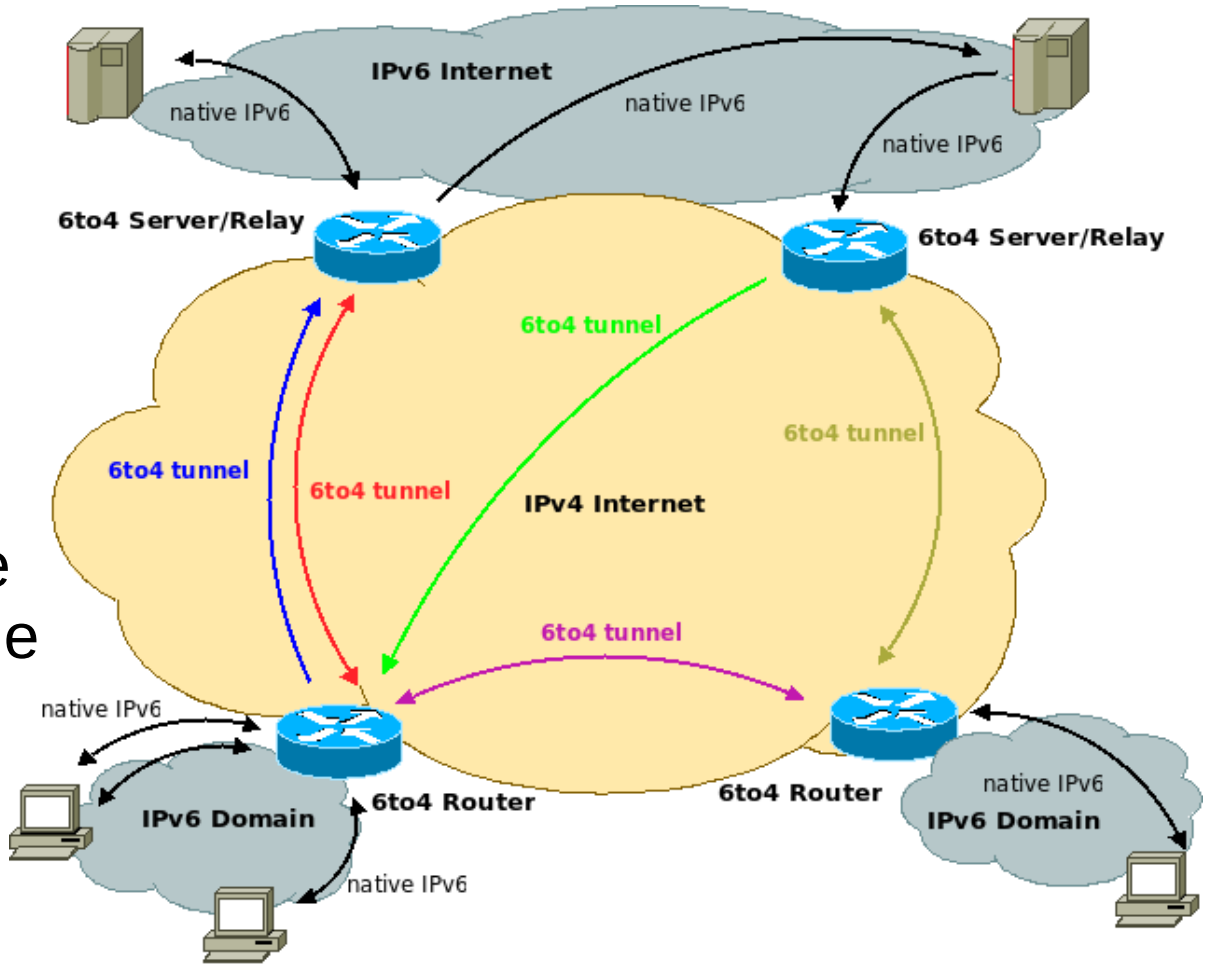
Automatic 6to4 Tunnels

- IPv4 tunnel end-point address is embedded within the destination IPv6 address
  - Automatic 6to4 tunnel allows isolated IPv6 domains to connect over an IPv4 network
  - Unlike the manually configured tunnels are not point-to-point, they are multipoint tunnels
  - 6to4 host/router needs to have a globally addressable IPv4 address
  - Cannot be located behind a NAT box
  - Unless the NAT box supports protocol 41 packets forwarding
  - Address format is:



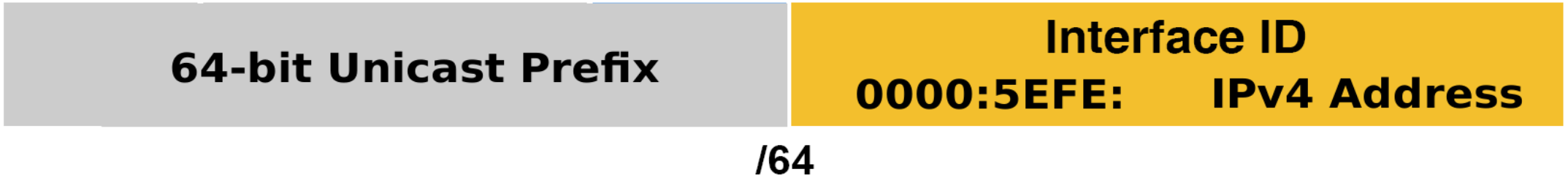
6to4 Relay Routers

- 6to4 router
  - Connects 6to4 hosts from a IPv6 domain and
    - Other 6to4 routers
    - The IPv6 Internet through a 6to4 relay router
- 6to4 relay router
  - Connects 6to4 routers on the IPv4 Internet and hosts on the IPv6 Internet.



ISATAP Tunnels

- Intra-site Automatic Tunnel Address Protocol
- Point-to-multipoint tunnels that can be used to connect systems within a site
- Used to tunnel IPv4 within as administrative domain to create a virtual IPv6 network over a IPv4 network
- Scalable approach for incremental deployment
- Encode IPv4 Address in IPv6 Address within the interface ID



Translation Mechanisms (1)

- Stateless IP/ICMP Translator (SIIT) Model
  - General mechanism that translates IPv4 headers into IPv6 headers or vice versa
- NAT-PT and NAPT-PT
  - NAT-PT translates an IPv4 packet into a semantically equivalent IPv6 datagram or vice versa
    - Translates only between IPv4 and IPv6 addresses
  - NATPT-PT perform network addresses plus port translation plus packet translation
  - DNS Application Level Gateway (DNS-ALG) performs a translation between the IPv4 and IPv6 DNS records (A and AAAA records)
  - IETF is currently deprecating NAT-PT
- Bump-In-the-Stack (BIS)
  - Translation at OS protocol stack in each host
  - Is a translation interface between IPv4 applications and the underlying IPv6 network
  - Three extra layers (name resolver extension, address mapper, and translator) are added to the IPv4 protocol stack
  - The BIS mechanism may be useful during initial stages of IPv4 transition to IPv6 when IPv4 applications remain unmodified within IPv6 domains

Translation Mechanisms (2)

- Bump-In-The-API (BIA)
  - Very similar to BIS
  - Instead of translating between IPv4 and IPv6 headers, BIA inserts an API translator between the socket API and the TCP/IP modules of the host stack
- SOCKS-Based IPv6/IPv4 Gateway
  - Based on SOCKSv5 permits communication between IPv4-only and IPv6-only hosts
  - When a client wants to connect to an application server
    - Sets up a connection to a well known, preconfigured proxy server using a special proxy protocol
    - Informs the proxy about the IP address and the port number of the application server it wants to communicate with
    - The proxy server is now responsible to set up a connection to the application server
    - After establishing the connection, the proxy relays packet between the client and application server hiding the actual connection

Translation Mechanisms (3)

- Transport Relay Translator (TRT)
  - Enables IPv6-only hosts to exchange traffic with IPv4-only hosts
  - No modification on hosts is required
  - IPv6 host uses a DNS-ALG to resolve its DNS queries
    - Will receive an IPv6 address specially constructed from the IPv4 address
    - Consists of a special network prefix associated with the transport relay and a host ID (the lower 64 bits) that embeds the IPv4 address of the remote host