DYNAMIC MULTIPOINT VPN HUB AND SPOKE INTRODUCTION

NOVEMBER 2004

INTRODUCTION

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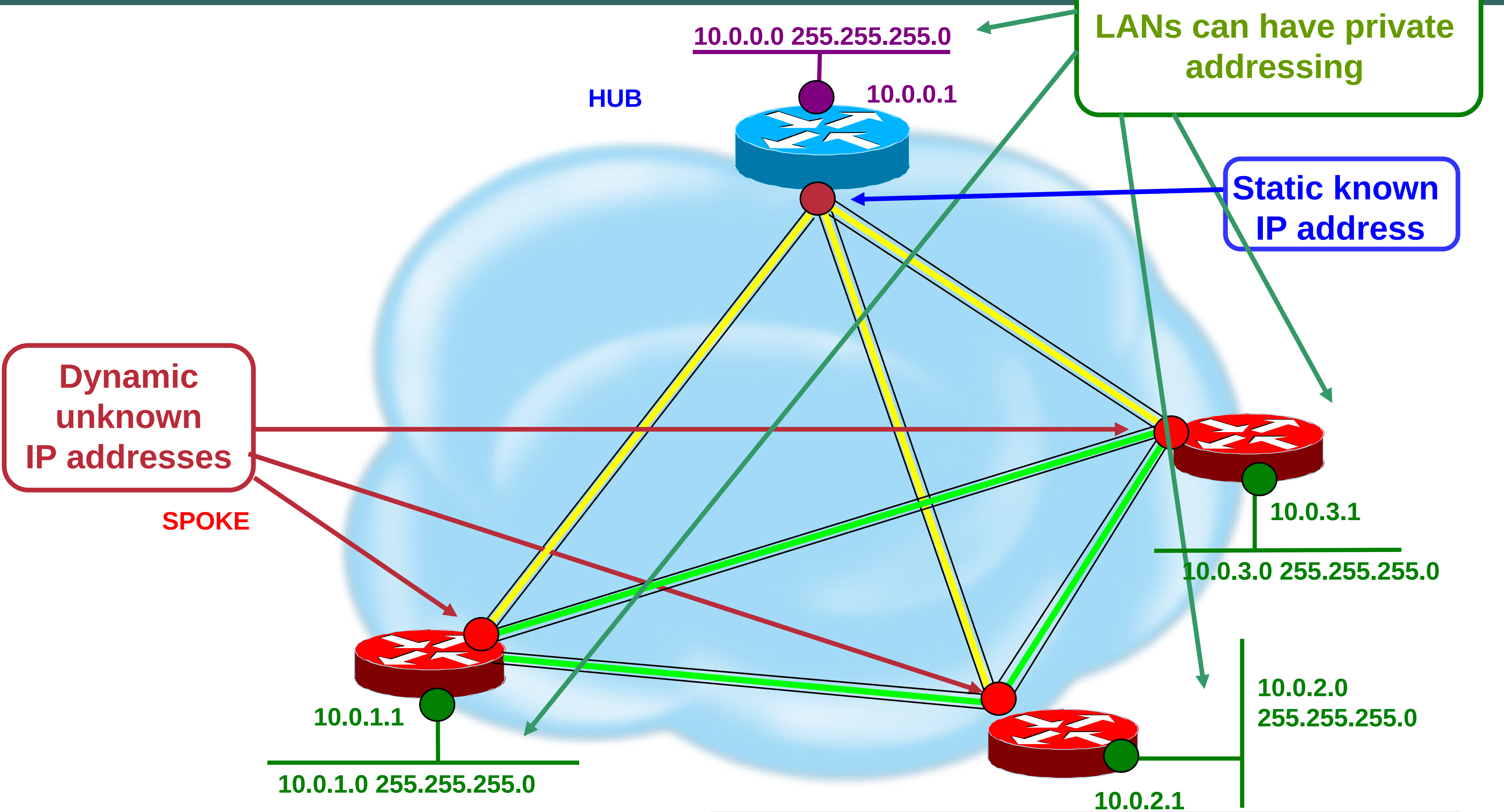
What is Dynamic Multipoint VPN ?

- Dynamic Multipoint VPN (DMVPN) is a combination of GRE, NHRP, and IPsec
- NHRP allows the peers to have dynamic addresses (ie: Dial and DSL) with GRE / IPsec tunnels
- Backbone is a hub and spoke topology
- Allows direct spoke to spoke tunneling by auto leveling to a partial mesh

Site-to-Site, DMVPN: mGRE/IPsec/NHRP Integration, Only HUB address Is Known



🟨 = Static spoke-to-hub IPsec tunnels

🟩 = Dynamic&Temporary Spoke-to-spoke IPsec tunnels

Terminology Pause

- DMVPN is a partial dynamic mesh

  Spoke: all the devices that contact a central router called “hub”

  Node: any hub or a spoke

This Presentation

- This presentation concentrate on hub and spoke to explain how DMVPN works

DMVPN

GRE Tunnels

- A GRE tunnel is a simple non-negotiated tunnel; GRE only needs tunnel endpoints
- GRE encapsulate frames or packets into an other IP packet + IP header
- GRE has only 4 to 8 bytes of overhead
- GRE tunnels exist in two main flavors:

    Point-to-point (GRE)

    Point-to-multipoint (mGRE)

GRE multipoint and DMVPN

- A GRE interface definition includes

An IP address

A tunnel source

A tunnel destination

An optional tunnel key

```
interface Tunnel 0
     ip address 10.0.0.1 255.0.0.0
     tunnel source Dialer1
     tunnel destination 172.16.0.2
     tunnel key 1
```

- An mGRE interface definition includes

An IP address

A tunnel source

A tunnel key

```
interface Tunnel 0
     ip address 10.0.0.1 255.0.0.0
     tunnel source Dialer1
     tunnel mode gre multipoint
     tunnel key 1
```

- mGRE interfaces do not have a tunnel destination

Terminology Pause

- The **tunnel address** is the ip address defined on the tunnel interface
- The Non-Broadcast Multiple Access (NBMA) address is the ip address used as tunnel source (or destination)
- Example… on router A, one configures

```
interface Ethernet0/0
   ip address 172.16.0.1 255.255.255.0
interface Tunnel0
   ip address 10.0.0.1 255.0.0.0
   tunnel source Ethernet0/0
   […]
```

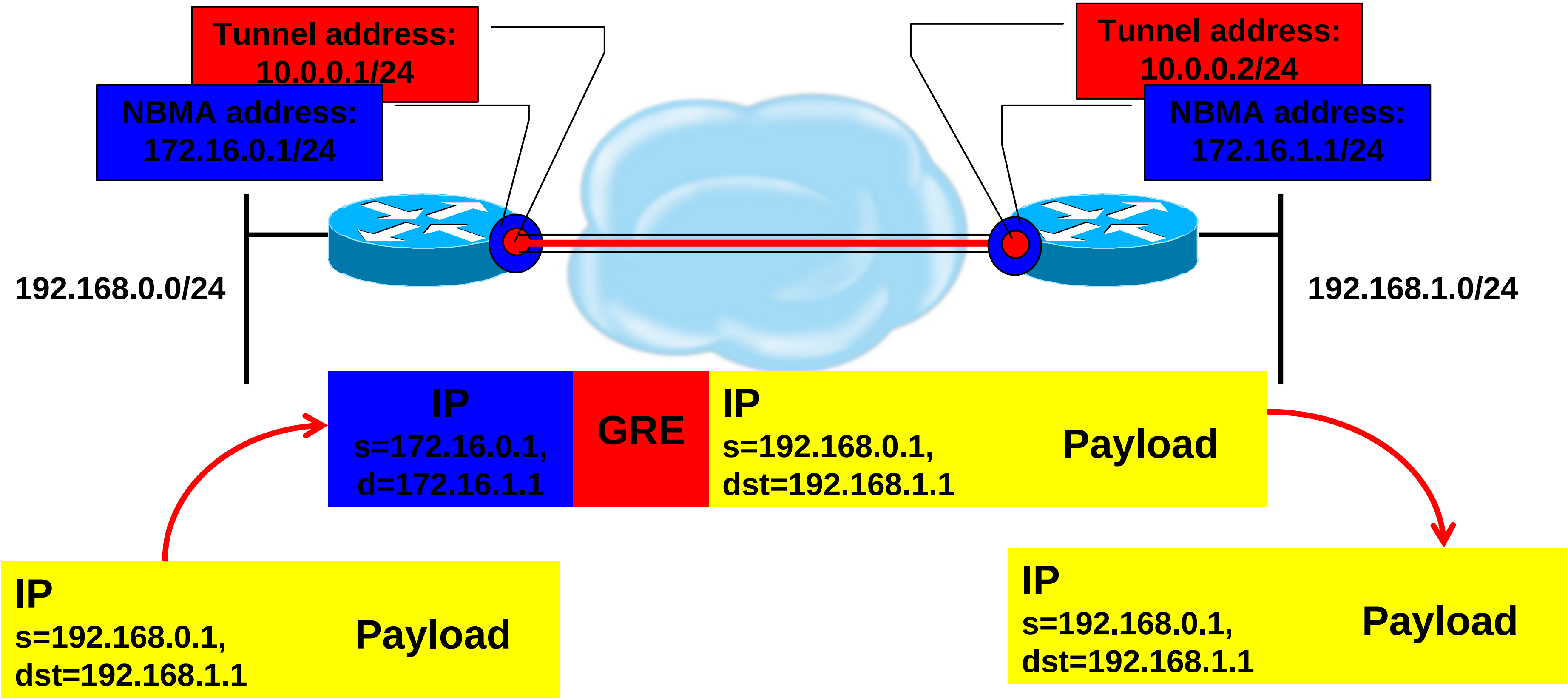
10.0.0.1 is router A's tunnel address

172.16.0.1 is router A's NBMA address

mGRE Tunnels

- **Single tunnel interface (mp)**
  - **Non-Broadcast Multi-Access (NBMA) Network**
  - **Multiple (dynamic) tunnel destinations**
  - **Multicast/broadcast support**
- **Next Hop Resolution Protocol (NHRP)**
  - **VPN IP to NBMA IP address mapping**

GRE Encapsulation



DMVPN GRE Interfaces

- In DMVPN, the hub must have a point to mGRE
- Spokes can have a point to point GRE interface or an mGRE interface
- This presentation will use mGRE everywhere for consistency
- Note that point-to-point GRE interfaces prevent spoke to spoke direct tunneling

mGRE Talking to a Peer

- Because mGRE tunnels do not have a tunnel destination defined, they can not be used alone
- NHRP tells mGRE where to send the packets to
- NHRP is defined in RFC 2332

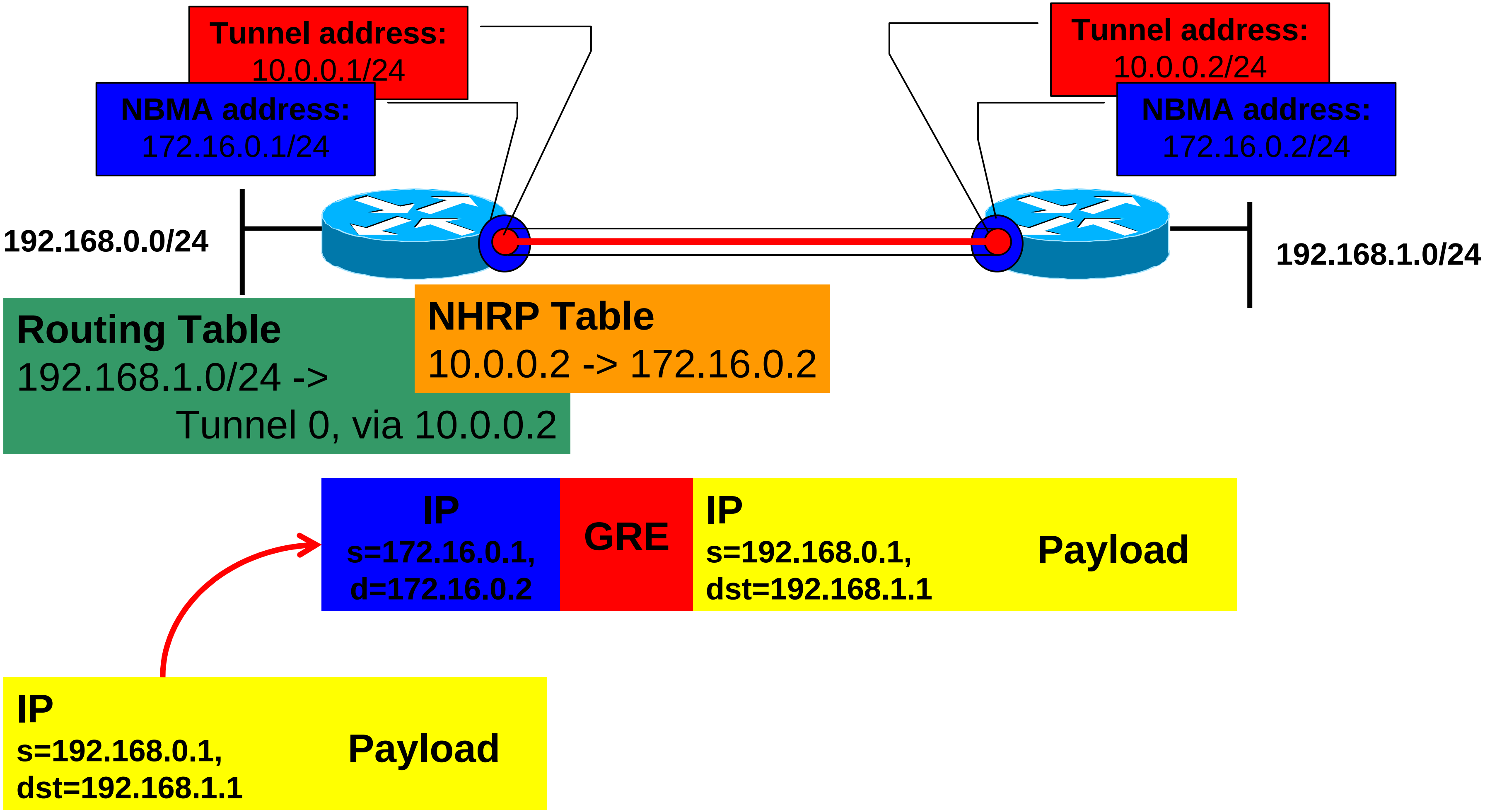
What is NHRP?

- NHRP is a layer two resolution protocol and cache like ARP or Reverse ARP (Frame Relay)
- It is used in DMVPN to map a tunnel IP address to an NBMA address
- Like ARP, NHRP can have static and dynamic entries
- NHRP has worked fully dynamically since Release 12.2(13)T

How mGRE Uses NHRP

- When a packet is routed, it is passed to the mGRE interface along with a next-hop
- The next-hop is the tunnel address of a remote peer
- mGRE looks up the NHRP cache for the next-hop address and retrieves the NBMA address of the remote peer
- mGRE encapsulates the packet into a GRE/IP payload
- The new packet destination is the NMBA address
- Multicast packets are only sent to specific remote peers identified in the NHRP configuration

mGRE/NHRP Path



Tunnel address:
10.0.0.1/24

NBMA address:
172.16.0.1/24

Tunnel address:
10.0.0.2/24

NBMA address:
172.16.0.2/24

192.168.0.0/24

192.168.1.0/24

Routing Table
192.168.1.0/24 ->
Tunnel 0, via 10.0.0.2

NHRP Table
10.0.0.2 -> 172.16.0.2

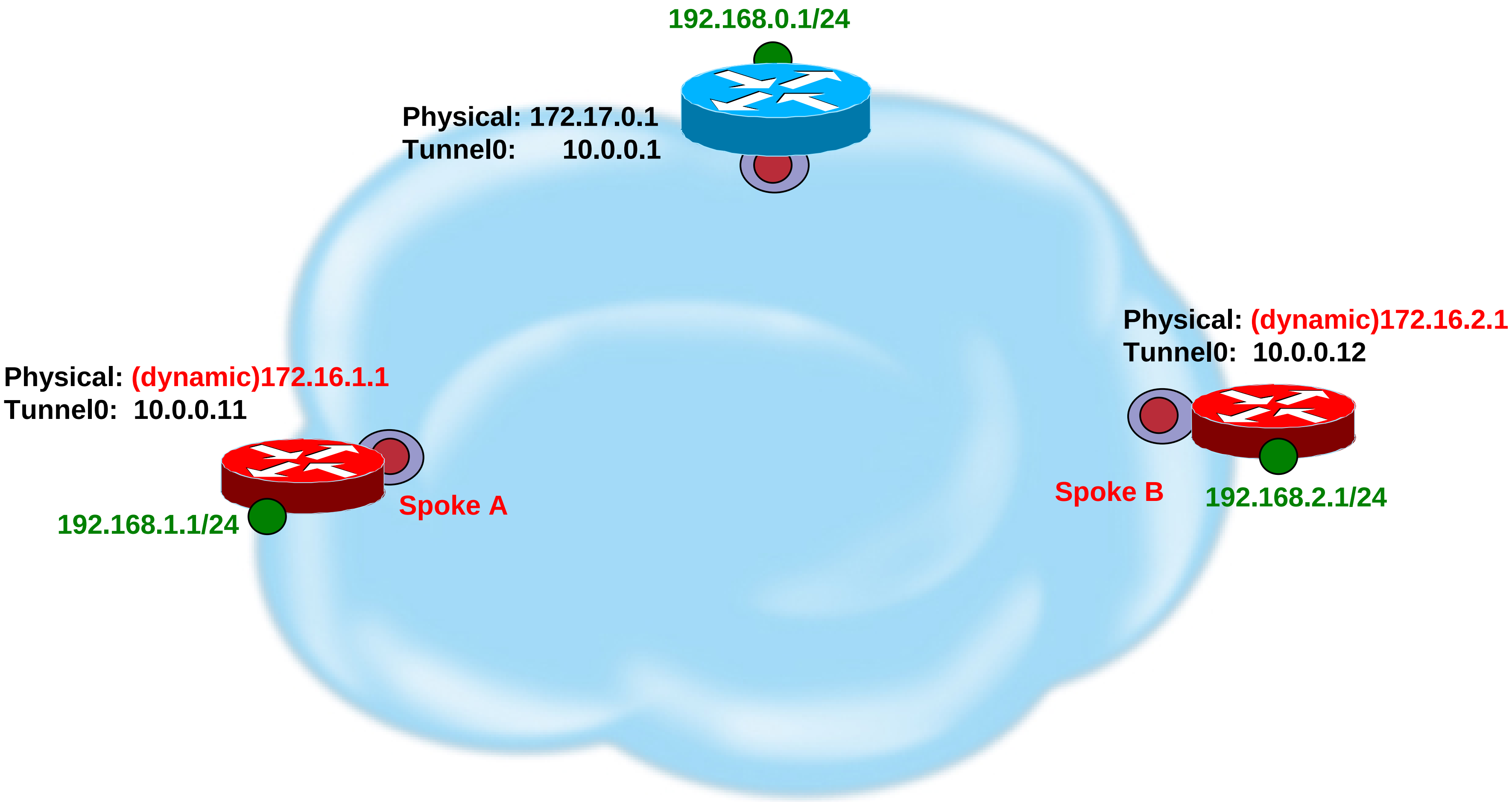
IP
s=172.16.0.1,
d=172.16.0.2
	GRE	IP
		s=192.168.0.1,
		dst=192.168.1.1
			Payload

IP
s=192.168.0.1,
dst=192.168.1.1
	Payload

How NHRP Works

- mGRE uses NHRP, but how does NHRP work?
- This presentation will introduce a network topology and illustrate the associated NHRP commands

NHRP Registration
Dynamically Addressed Spokes



Basic NHRP Configuration

- In order to configure an mGRE interface to use NHRP, the following command is necessary:

```
ip nhrp network-id <id>
```

- Where <id> is a unique number (same on hub and all spokes)
- <id> has nothing to do with tunnel key
- The network ID defines an NHRP domain

  Several domains can co-exist on the same router

Populating the NHRP Cache

- Three ways to populate the NHRP cache:

  Manually add static entries

  Hub learns via registration requests

  Spokes learn via resolution requests

- We will now study “static” and “registration”
- “Resolution” is for spoke to spoke

Initial NHRP Caches

- Initially, the hub has an empty cache
- The spoke has one static entry mapping the hub's tunnel address to the hub's NBMA address:

```
ip nhrp map 10.0.0.1 172.17.0.1
```

- Multicast traffic must be sent to the hub

```
ip nhrp map multicast 172.17.0.1
```

The Spokes Must Register To The Hub

- In order for the spokes to register themselves to the hub, the hub must be declared as a Next Hop Server (NHS):

```
ip nhrp nhs 10.0.0.1
ip nhrp holdtime 3600 (optional)
ip nhrp registration no-unique (optional)
```

- Spokes control the cache on the hub

Registration Process

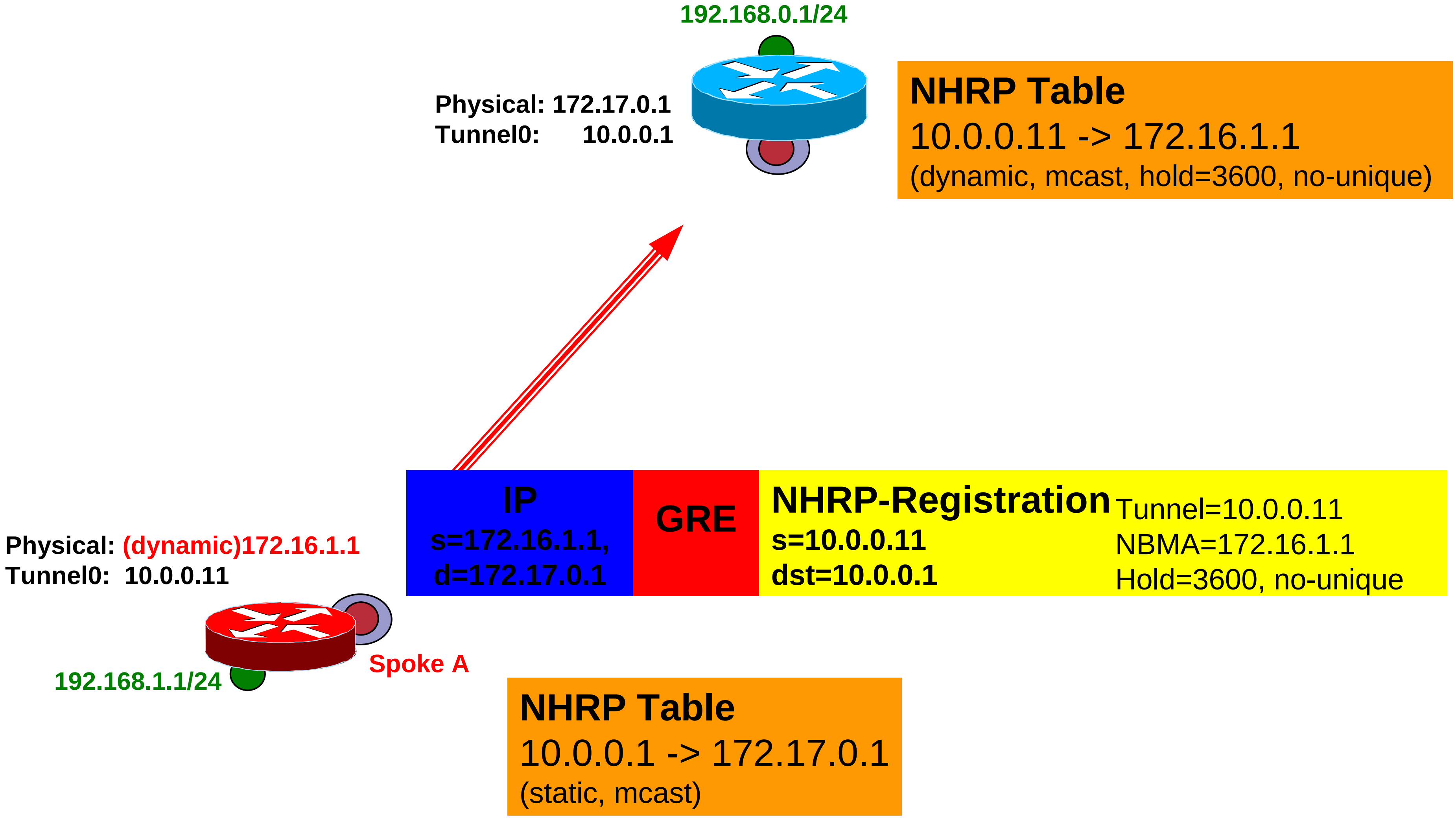
- The spokes send Registration-requests to the hub
- The request contains the spoke’s Tunnel and NBMA addresses as well as the hold time and some flags
- The hub creates an entry in its NHRP cache
- The entry will be valid for the duration of the hold time defined in the registration
- The NHS returns a registration reply (acknowledgement)

Multicast Packets from the Hub

- The hub must also send multicast traffic to all the spokes that registered to it
- This must be done dynamically (possible since Release 12.2(13)T)
- This is not the default

```
ip nhrp map multicast dynamic
```

NHRP Registration Request



192.168.0.1/24

Physical: 172.17.0.1
Tunnel0: 10.0.0.1

NHRP Table
10.0.0.11 -> 172.16.1.1
(dynamic, mcast, hold=3600, no-unique)

IP
s=172.16.1.1,
d=172.17.0.1

GRE

NHRP-Registration
s=10.0.0.11
dst=10.0.0.1

Tunnel=10.0.0.11
NBMA=172.16.1.1
Hold=3600, no-unique

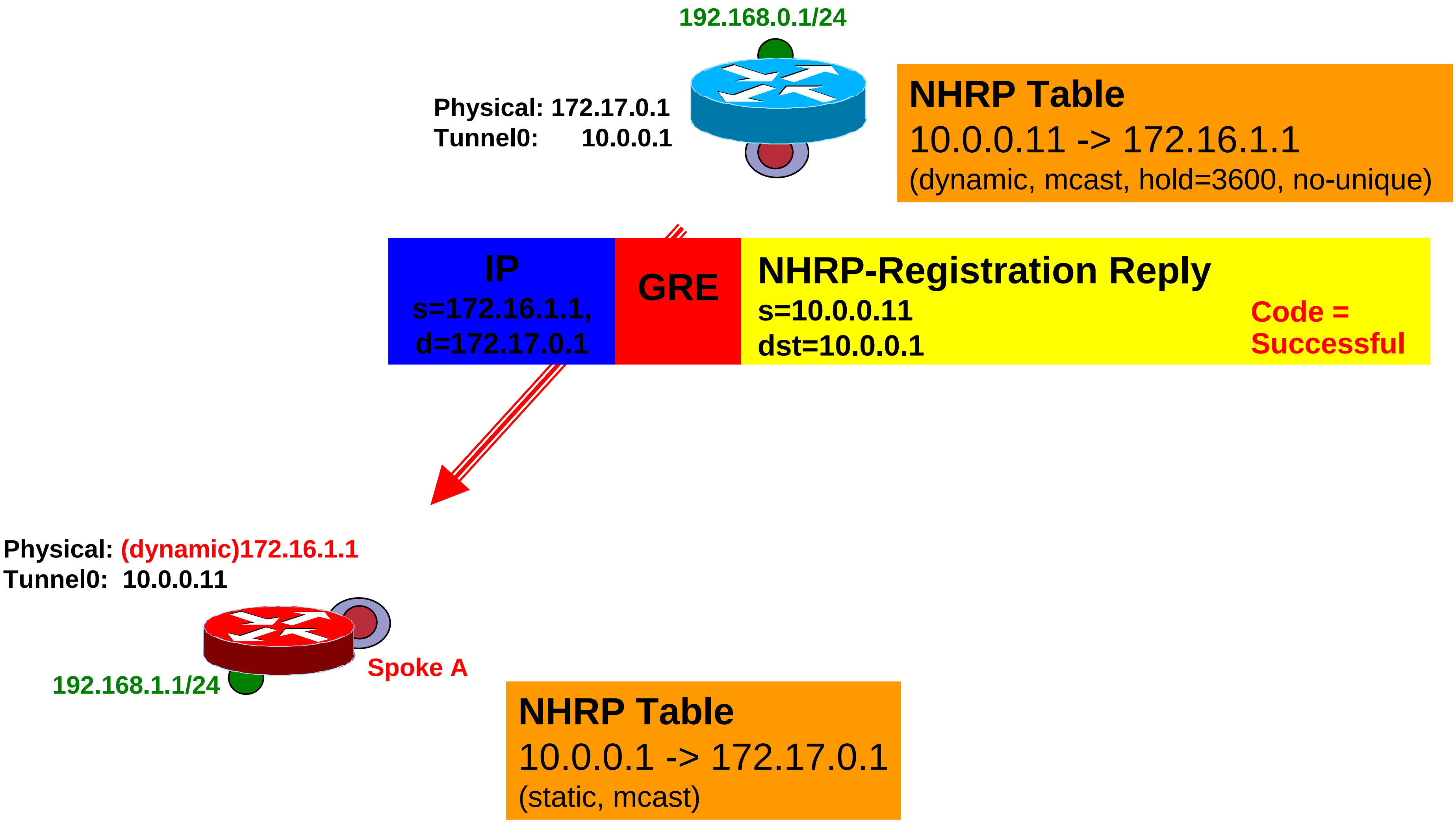
Physical: (dynamic)172.16.1.1
Tunnel0: 10.0.0.11

192.168.1.1/24

Spoke A

NHRP Table
10.0.0.1 -> 172.17.0.1
(static, mcast)

NHRP Registration Reply



192.168.0.1/24

Physical: 172.17.0.1
Tunnel0: 10.0.0.1

NHRP Table
10.0.0.11 -> 172.16.1.1
(dynamic, mcast, hold=3600, no-unique)

IP	GRE	NHRP-Registration Reply	

s=172.16.1.1,
d=172.17.0.1
		s=10.0.0.11
		dst=10.0.0.1
			Code =
			Successful

Physical: (dynamic)172.16.1.1
Tunnel0: 10.0.0.11

192.168.1.1/24

Spoke A

NHRP Table
10.0.0.1 -> 172.17.0.1
(static, mcast)

NHRP Functionality

- **Address mapping/resolution**

  Static NHRP mapping

  Next Hop Client (NHC) registration with Next Hop Server (NHS)

- **Packet Forwarding**

  Resolution of VPN to NBMA mapping

Routing:	**IP destination ➔ Tunnel IP next-hop**
NHRP:	**Tunnel IP next-hop ➔ NBMA address**

Routing Protocol

- The spoke needs to advertise its private network to the hub
- Can use BGP, EIGRP, OSPF, RIP or ODR; however, this presentation will focus on EIGRP
- Must consider several caveats

Spoke Hellos

- **Spoke has all it needs to send hellos immediately:**
  - **Tunnel is defined**
  - **Static NHRP entry to hub is present**
  - **NHRP entry is marked for multicast**
- **So the spoke never waits…**

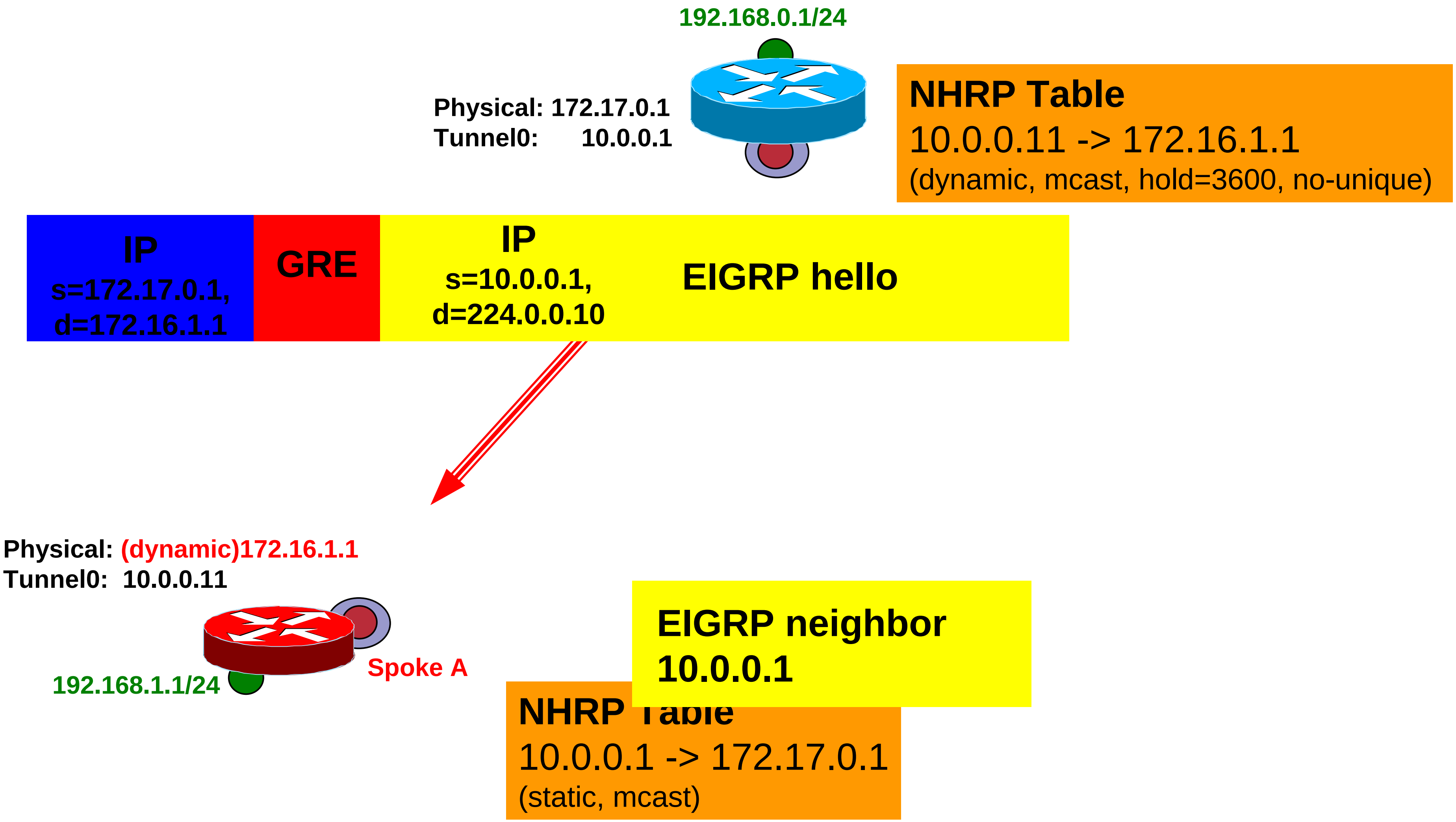
Hub hello's

- **With its basic tunnel definition, the hub cannot send anything (including hellos) to anyone**
- **It must wait NHRP for registrations to arrive**
- **As soon as the spokes have registered, the NHRP is marked "Multicast" due to**

```
   ip nhrp map multicast dynamic
```

- **The hub sends hellos to all the registered spokes simultaneously**

Hub sending EIGRP hello



192.168.0.1/24

Physical: 172.17.0.1
Tunnel0: 10.0.0.1

NHRP Table
10.0.0.11 -> 172.16.1.1
(dynamic, mcast, hold=3600, no-unique)

IP
s=172.17.0.1,
d=172.16.1.1
	GRE	IP
		s=10.0.0.1,
		d=224.0.0.10
			EIGRP hello

Physical: (dynamic)172.16.1.1
Tunnel0: 10.0.0.11

Spoke A

192.168.1.1/24

EIGRP neighbor
10.0.0.1

NHRP Table
10.0.0.1 -> 172.17.0.1
(static, mcast)

GRE and EIGRP

- The default bandwidth of a GRE tunnel is 9Kbps
- This has no influence on the traffic but…
- EIGRP will take ½ the interface bandwidth maximum (4.5 Kbps) – this is too low

```
bandwidth 1000
```

Spoke EIGRP configuration

- Nothing special on the spoke
- EIGRP stub should be considered

Hub EIGRP Configuration

- There are many options…
- If you want a spoke to see other spokes:

```
no ip split-horizon eigrp 1
```

- Summarization is to be considered
- Setting the bandwidth is crucial in the hub to spoke direction
- Best-practice: Set the bandwidth the same on all nodes

IPsec Protection

- GRE/NHRP can build a fully functional overlay network
- GRE is insecure; ideally, it must be protected
- The good old crypto map configuration is rather cumbersome; DMVPN introduced tunnel protection
- Still need to define an IPsec security level

The IPsec Security Policy

- A transform set must be defined:

```
crypto ipsec transform-set ts esp-sha-hmac esp-3des
  mode transport
```

- An IPsec profile replaces the crypto map

```
crypto ipsec profile prof
  set transform-set ts
```

- The IPsec profile is like a crypto map without “set peer” and “match address”

Protecting the tunnel

- The profile must be applied on the tunnel

```
tunnel protection ipsec profile prof
```

- Internally Cisco IOS® Software will treat this as a dynamic crypto map and it derives the `local-address, set peer` and `match address` parameters from the tunnel parameters and the NHRP cache
- This must be configured on the hub and spoke tunnels

Relation Between GRE, NHRP and IPsec

- **For each NHRP cache unique NBMA address, Cisco IOS Software will create an internal crypto map that protects**
  - GRE traffic
  - From tunnel source (NBMA) address
  - To NHRP entry NBMA address
- **The SAs will be negotiated as soon as the cache entry is created (static and resolved)**

Relationship (cont’d.)

- **NHRP registration will be triggered**

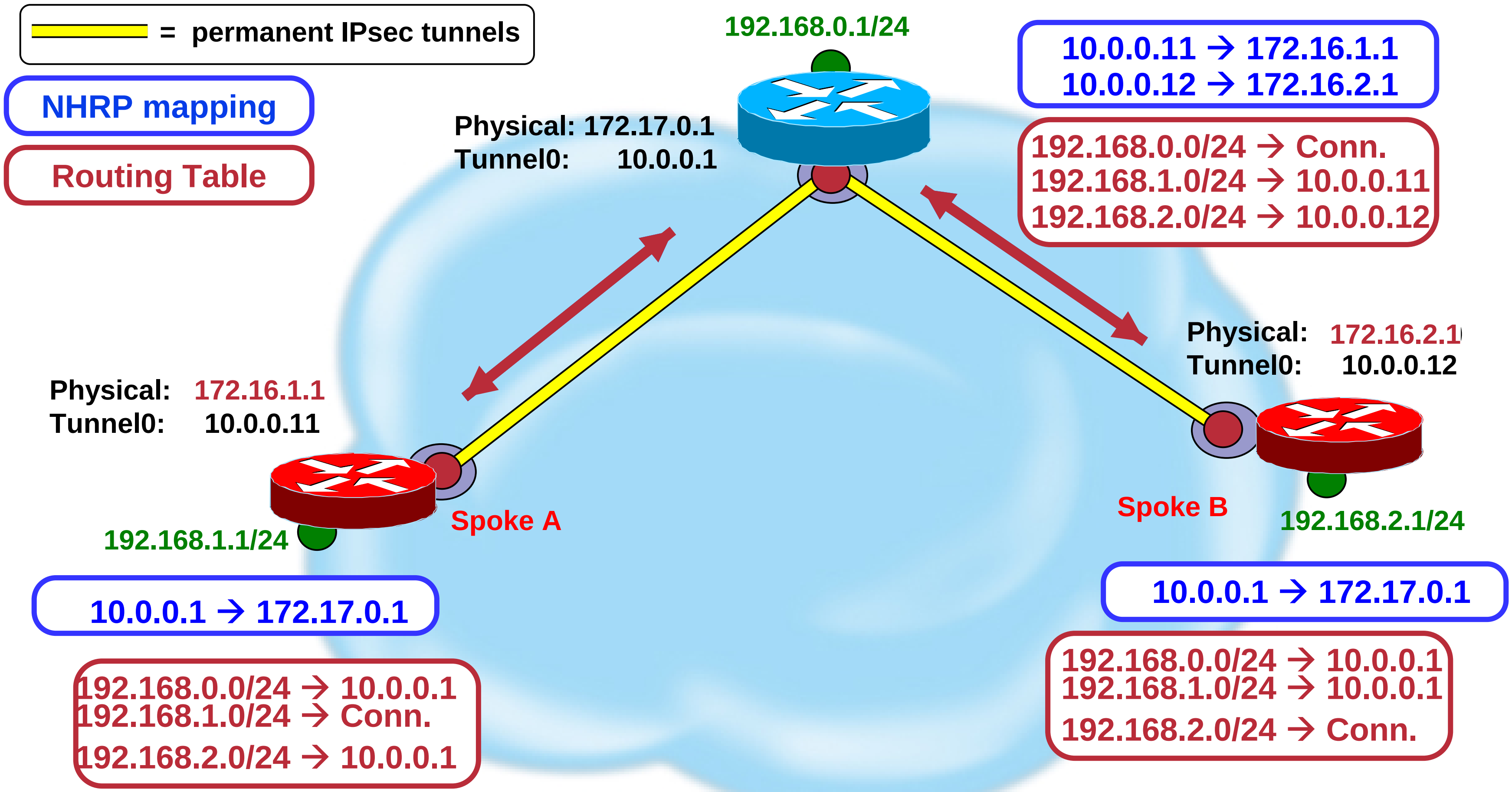
  When the Tunnel interface comes up/up

  When the tunnel source address changes

  When IPsec finishes negotiating the phase 2 related to the tunnel protection

  When the registration timer expires

NHRP Registration
Dynamically Addressed Spokes



= permanent IPsec tunnels

NHRP mapping

Routing Table

192.168.0.1/24

Physical: 172.17.0.1
Tunnel0: 10.0.0.1

10.0.0.11 → 172.16.1.1
10.0.0.12 → 172.16.2.1

192.168.0.0/24 → Conn.
192.168.1.0/24 → 10.0.0.11
192.168.2.0/24 → 10.0.0.12

Physical: 172.16.1.1
Tunnel0: 10.0.0.11

Spoke A

192.168.1.1/24

10.0.0.1 → 172.17.0.1

192.168.0.0/24 → 10.0.0.1
192.168.1.0/24 → Conn.
192.168.2.0/24 → 10.0.0.1

Physical: 172.16.2.1
Tunnel0: 10.0.0.12

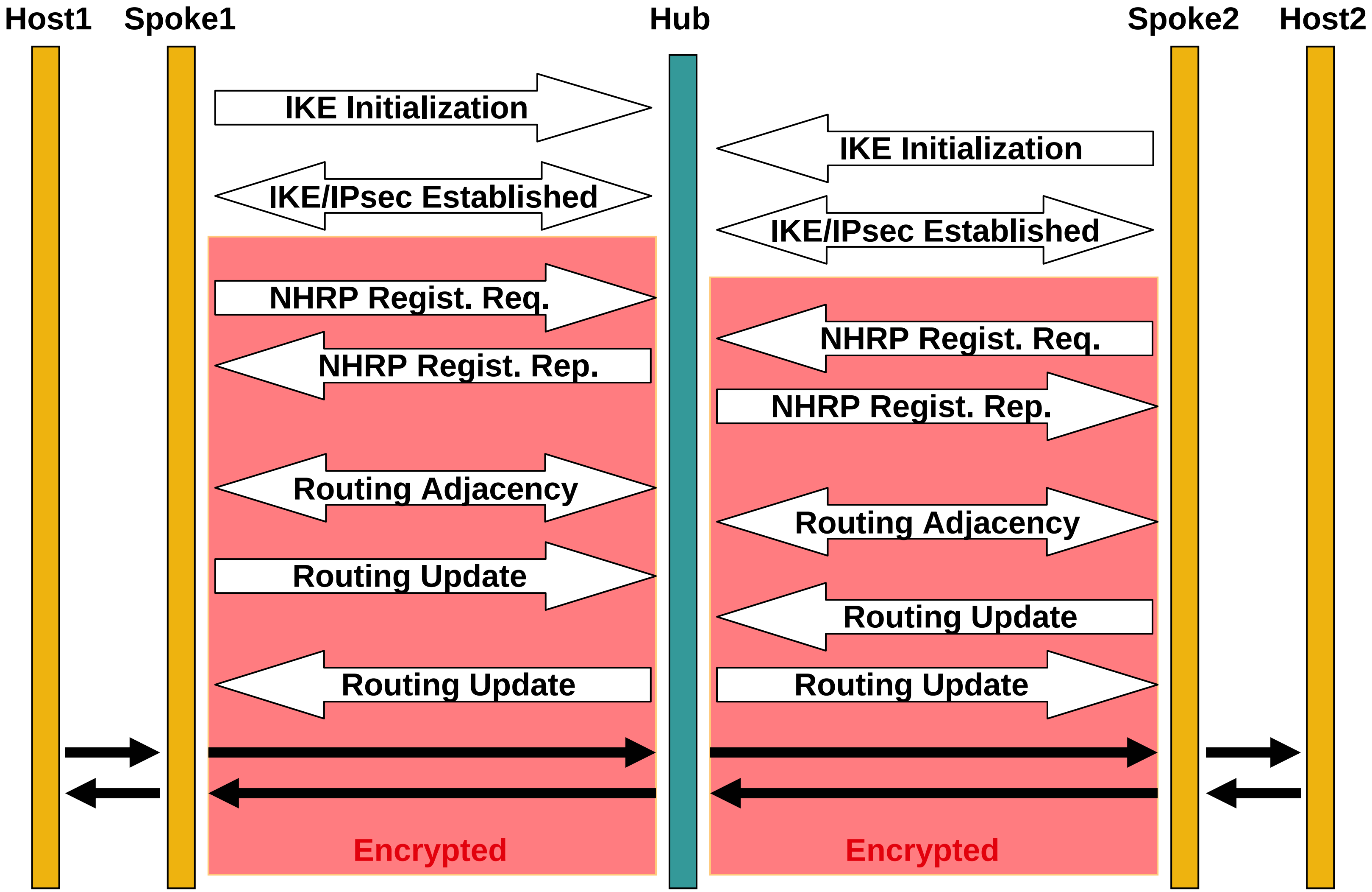
Spoke B

192.168.2.1/24

10.0.0.1 → 172.17.0.1

192.168.0.0/24 → 10.0.0.1
192.168.1.0/24 → 10.0.0.1
192.168.2.0/24 → Conn.

Building Hub-and-Spoke tunnels NHRP Registration


Host1
Spoke1
Hub
Spoke2
Host2
IKE Initialization
IKE Initialization
IKE/IPsec Established
IKE/IPsec Established
NHRP Regist. Req.
NHRP Regist. Req.
NHRP Regist. Rep.
NHRP Regist. Rep.
Routing Adjacency
Routing Adjacency
Routing Update
Routing Update
Routing Update
Routing Update
Encrypted
Encrypted