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Case Study Scenario

Due to the volume of information shared, the Air Guitar Company (AGC) requires a Frame Relay link between the central site (R1) and a branch site (R2). For fault tolerance, the Frame Relay link will be backed up with ISDN. The AGC also has a small SOHO site, which is represented by R3, which periodically connects through an asynchronous dial-up connection to download corporate e-mail and verify the status of orders.

To secure mission critical data traffic, IPSec VPN will be used between Frame Relay links, and PPP CHAP will be used between ISDN and PSTN connections. QoS will also be configured between the Frame Relay links.

Generic Tasks

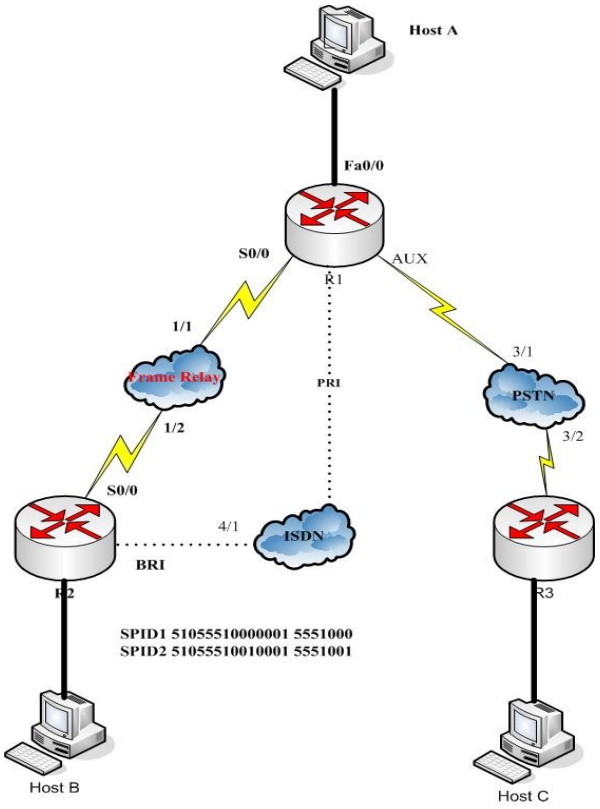
- The WAN provider supplying the Frame Relay, ISDN, and PSTN circuits has assigned the AGC the 10.1.1.0/24 subnet.
- Use the private network address 192.168.x.0/24 for each router LAN, where the "x" refers to the router number.
- AAA authentication must be configured on all routers
- Configure appropriate router security

Detailed Tasks

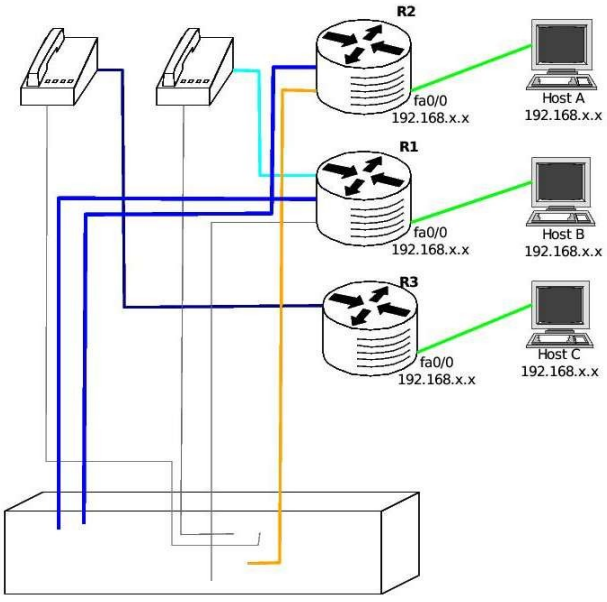
- AGC wishes to use sub-interfaces on the Frame Relay link
- Upon receipt of a BECN all relevant routers will throttle down to the contracted service rate of CIR = 16000, BC = 64000,and BE = 64000
- AGC wishes to use an ISDN DDR link in the eventuality of failure of the Frame Relay link.
- The two sites will use the EIGRP routing protocol
- AGC requires IPSec to encrypt traffic between the R1 and R2 LANs when traversing the Frame Relay link. Use pre-share keys with esp-des SA.
- Use CALLBACK on the R1 router when R3 initiates a connection. Use static routing on this link
- AGC wishes to test QoS over the Frame Relay link. To test the link, they require that Telnet traffic should be guaranteed 16Kbps of the Frame Relay bandwidth.

Chapter 1 – The Topology

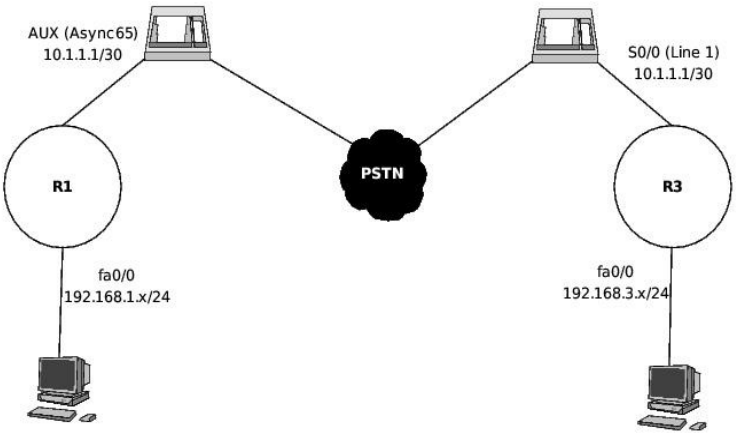
Below is the topology of the network given to me.



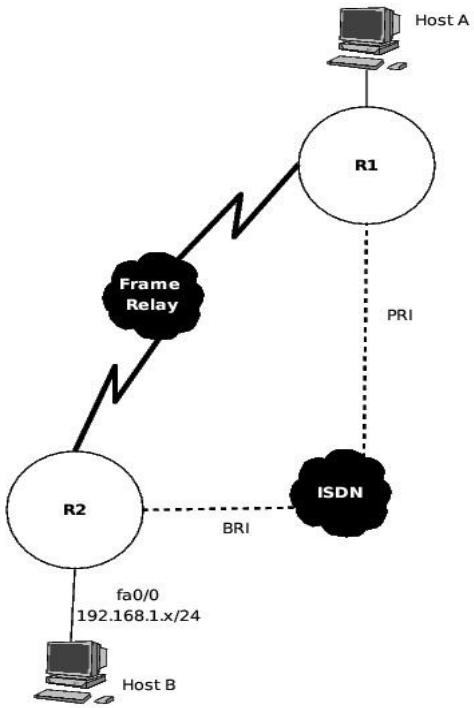
Below is the physical topology used in the lab.



Below is the topology used for the PSTN part of the network



Finally, below is the topology used for Frame Relay and Backup ISDN.



Chapter 2 – Generic Tasks

2.1 – Subnetting – 10.1.1.0/24

Although AGC was given a /24 (255.255.255.0) subnet, I chose to further reduce it to /30 (255.255.255.252) between the routers, increasing efficiency and allowing for future expansion.

	Network Adr	*Start IP*	*End IP*	*Broadcast Adr*
Frame Relay: Serial 0	10.1.1.0	10.1.1.1	10.1.1.2	10.1.1.3
ISDN: BRI / PRI	10.1.1.4	10.1.1.5	10.1.1.6	10.1.1.7
PSTN AUX/Serial	10.1.1.8	10.1.1.9	10.1.1.10	10.1.1.11
Fast Ethernet 0	192.168.0.0	192.168.1.0	192.168.3.254	192.168.0.255

Router R1

```
interface Async65
 ip address 10.1.1.9 255.255.255.252
 ...
!

interface Serial0/0.18 point-to-point
 ip address 10.1.1.1 255.255.255.252
 ...
!

interface Serial1/0:23
 ip address 10.1.1.5 255.255.255.252
 ...
!
```

Router R2

```
interface Serial0/0.16 point-to-point
 ip address 10.1.1.2 255.255.255.252
 ...
!

interface BRI0/0
 ip address 10.1.1.6 255.255.255.252
 ...
!
```

Router R3

```
interface Serial0/0
 physical-layer async
 async mode dedicated
 ip address 10.1.1.2 255.255.255.0
 no shutdown
!
```

2.2 – Use the private network address 192.168.x.0/24 for each router LAN, where the "x" refers to the router number.

IP Addressing Scheme

	Router R1	*Router R2*	*Router R3*
Frame Relay: Serial 0	10.1.1.1 /30	10.1.1.2 /30	
ISDN: BRI / PRI	10.1.1.5 /30	10.1.1.6 /30	
PSTN AUX/Serial	10.1.1.9 /30		10.1.1.10 /30
Fast Ethernet 0	192.168.1.0 /24	192.168.2.0 /24	192.168.3.0 /24

The networks were given an IP address ("x") depending on the router's numbers respectively. For example, Router R2 would have the network 192.168.2.0/24

Router R1

```
interface FastEthernet0/0
 ip address 192.168.1.1 255.255.255.0
 no shutdown
!
```

Router R2

```
interface FastEthernet0/0
 ip address 192.168.2.1 255.255.255.0
 no shutdown
!
```

Router R3

```
interface FastEthernet0/0
 ip address 192.168.3.1 255.255.255.0
 no shutdown
!
```

AAA authentication

It's possible to include multiple usernames and passwords for users wishing to connect to the router remotely. The passwords are stored locally in the router's database.

Router R1

```
username R2 password 0 cisco
username R3 password 0 cisco
username R1 password 0 cisco

! aaa configuration
aaa new-model
aaa authentication login default local-case enable
enable password cisco
isdn switch-type primary-ni
```

Router R2

```
username R1 password 0 cisco
username R2 password 0 cisco
username R3 password 0 cisco

aaa new-model
aaa authentication password-prompt "password:"
aaa authentication username-prompt "username:"
aaa authentication login default local-case enable
enable password cisco
```

Configure appropriate router security

Use encryption in the configuration file (globally), and assign a password of 'cisco'.

```
service password-encryption
enable password cisco
```

Set up both the auxiliary and virtual terminal ports to include authentication with a username and password. For telnet, the usernames are configured through AAA authentication above.

```
line aux 0
 password cisco
 login
exit

line vty 0 4
 password cisco
 login
exit
```

Other possible security measures one could take include,

Multiple Privilege Levels

```
(config)# privilege exec level 2 ping
(config)# enable secret level 2 Patriot
```

Changing Command Privilege

```
(config)#
privilege exec level 15 connect
privilege exec level 15 telnet
privilege exec level 15 rlogin
privilege exec level 15 show ip access-lists
privilege exec level 15 show access-lists
privilege exec level 15 show logging
privilege exec level 1 show ip
```

Creating Local Users

Note that the user details are stored in local database, which can be easily obtained and cracked with physical access to the router.

```
username xushi password asdf123
no username deadman
```

Banner Messages

Don't use the word 'welcome', and make sure to have the legal department to review the content, validity, and legality of the message.

```
banner motd Warning, unauthorised access prohibeted. Use of this system is for
administrators only. Privacy should not be expected when using this system. #
```

5.1.2 – Restricting Services

The following is a list of all services and servers that should be disabled on a router when not being used. Some of these services include application layer protocols that allow user/host processes to connect to the router, while other services are automatic processes intended to support legacy configurations that are detrimental to security.

Small servers

Globally disable both TCP and UDP small servers.

```
no service tcp-small-servers
no service udp-small-servers
```

BootP server

Globally disable the BootP service

```
no ip bootp server
```

Finger

Globally disable the finger service

```
no ip finger
no service finger
```

Http server

Globally disable the http server

```
no ip http server
```

CDP server

Globally disable the CDP service.

```
no cdp run
```

Auto loading service

Globally disable the BOOTP on the router and disable auto loading of configuration files from a network server respectively

```
no boot network
no service config
```

IP source routing

Globally disable the response to packets with the IP header source routing options set

```
no ip source-route
```

Proxy ARP

Disable the proxy ARP on an interface

```
interface ethernet0/0
        no ip proxy-arp
!
```

Directed broadcast

Disable ICMP echo requests to directed broadcast addresses on an interface

```
interface ethernet0/0
        no ip directed-broadcast
!
```

IP classless routing

Globally disable the IP classless routing service.

```
no ip classless
```

Chapter 3 – Detailed Tasks

Sub-interfaces

AGC wishes to use sub-interfaces on the Frame Relay link. This is achieved using the following configuration on Routers R1 and R2,

Router R1

```
! DLCI 18 Frame Relay
interface Serial0/0.18 point-to-point
 ip address 10.1.1.1 255.255.255.252
 frame-relay class BECN
 frame-relay interface-dlci 18
 crypto map MYMAP
!

! ISDN
interface Serial1/0:23
 ip address 10.1.1.5 255.255.255.252
 encapsulation ppp
 dialer idle-timeout 60
 dialer watch-disable 15
 dialer map ip 10.1.1.6 name R2 broadcast 5551234
 dialer map ip 10.1.1.6 name R2 broadcast 5551235
 dialer map ip 192.168.2.0 name R2 broadcast 5551234
 dialer map ip 192.168.2.0 name R2 broadcast 5551235
 dialer load-threshold 1 outbound
 dialer watch-group 2
 dialer-group 1
 isdn switch-type primary-ni
 ppp authentication chap
 ppp multilink
!
```

Router R2

```
! DLCI 16 Frame Relay
interface Serial0/0.16 point-to-point
 ip address 10.1.1.2 255.255.255.252
 frame-relay class BECN
 frame-relay interface-dlci 16
 crypto map MYMAP
!
```

Bandwidth Throttling

Upon receipt of a BECN all relevant routers will throttle down to the contracted service rate of CIR = 16000, BC = 64000,and BE = 64000

Firstly, we need to create an access list and define a class map that will establish the match criteria for identifying data belonging in a policy class. This is shown in section 'X', page 'Y'

Next, a map-class defining Frame Relay traffic shaping parameters.

```
! class map for frame relay
map-class frame-relay BECN
 frame-relay cir 32000
 frame-relay bc 64000
 frame-relay be 64000
 frame-relay adaptive-shaping becn
 service-policy output TELNET-QOS
!
```

The **frame-relay adaptive-shaping becn** command uses BECN notices from the Frame Relay switch as the congestion backward notification mechanism. From these notices, traffic shaping will adapt.

The **frame-relay cir 32000** sets the committed information rate to 32kbps.
The **frame-relay bc 64000** sets the committed burst to 64bps.
The **frame-relay bc 64000** sets the excess burst to 64bps.
The **service-policy output** command attaches the BECN policy class to the frame-relay map-class.

Finally, the map-class needs to be applied to the serial interface.

```
interface Serial0/0
 encapsulation frame-relay
 no fair-queue
 frame-relay traffic-shaping
 frame-relay lmi-type ansi
 no shutdown
!

interface Serial0/0.18 point-to-point
 ip address 10.1.1.1 255.255.255.252
 frame-relay class BECN
 frame-relay interface-dlci 18
 crypto map MYMAP
!
```

ISDN Backup

AGC wishes to use an ISDN DDR link in the eventuality of failure of the Frame Relay link.
The two sites will use the EIGRP routing protocol.

Router R1

The following on both R1 and R2 will configure ISDN BRI and PRI respectively, including CHAP authentication over PPP

```
isdn switch-type primary-ni
interface Serial1/0:23
 ip address 10.1.1.5 255.255.255.252
 encapsulation ppp
 dialer idle-timeout 60
 dialer watch-disable 15
 dialer map ip 10.1.1.6 name R2 broadcast 5551234
 dialer map ip 10.1.1.6 name R2 broadcast 5551235
 dialer map ip 192.168.2.0 name R2 broadcast 5551234
 dialer map ip 192.168.2.0 name R2 broadcast 5551235
```

```
 dialer load-threshold 1 outbound
 dialer watch-group 2
 dialer-group 1
 isdn switch-type primary-ni
 ppp authentication chap
 ppp multilink
!
username R3 password 0 cisco
username R2 password 0 cisco
username R1 password 0 cisco
```

Router R2

```
interface BRI0/0
 ip address 10.1.1.6 255.255.255.252
 encapsulation ppp
 dialer idle-timeout 60
 dialer watch-disable 15
 dialer map ip 10.1.1.5 name R1 broadcast 5555000
 dialer map ip 192.168.1.0 name R1 broadcast 5555000
 dialer load-threshold 1 either
 dialer watch-group 2
 dialer-group 1
 isdn switch-type basic-ni
 isdn spid1 51055512340001 5551234
 isdn spid2 51055512350001 5551235
 ppp authentication chap
 ppp multilink
 no shutdown
!
username R1 password 0 cisco
username R2 password 0 cisco
username R3 password 0 cisco
```

EIGRP

EIGRP uses a static default route

bandwidth	delay	reliability	loading	mtu
10000	100	255	1	500

Both the 10.0.0.0 and 192.168.0.0 networks are advertised with auto summarisation disabled. The use of the "**passive-interface"** prevents the exchange of hello packets between the two routers through the Async65 interface (ISDN), which stops not only routing updates from being advertised or received. This is necessary so that the ISDN line does not stay active.

Router R1

```
router eigrp 64512
 redistribute static metric 10000 100 255 1 1500
 passive-interface Async65
 network 10.0.0.0
 network 192.168.1.0
 no auto-summary
!
```

Router R2

```
router eigrp 64512
 network 10.0.0.0
 network 192.168.2.0
 no auto-summary
!
```

IPSec

AGC requires IPSec to encrypt traffic between the R1 and R2 LANs when traversing the Frame Relay link using pre-share keys with esp-des SA.

Router R1

To configure a policy with a priority of 100 using pre-share keys as the method of authentication, the following is needed,

```
!crypto policy map
crypto isakmp policy 100
 authentication pre-share
 crypto isakmp key cisco1234 address 10.1.1.2
```

An Access List is needed to specify which traffic is to be encrypted. In this case, all traffic between the two routers.

```
access-list 120 permit ip 192.168.1.0 0.0.0.255 192.168.2.0 0.0.0.255
```

Next is configuring an IPSec transform set, called MYSET, specifying that ESP with DES will be used.

```
crypto ipsec transform-set MYSET esp-des
```

Next, configuring an IPSec crypto map using a pap name of MYMAP, and a sequence number of 110. This crypto map is to use **ipsec-isakmp**

```
crypto map MYMAP 110 ipsec-isakmp
 set peer 10.1.1.2
 set transform-set MYSET
 match address 120
!
```

Router R2

Similarely, the policy with priority = 100 using pre-share keys,

```
crypto isakmp policy 100
 authentication pre-share
 crypto isakmp key cisco1234 address 10.1.1.1
```

The Access List,

```
access-list 120 permit ip 192.168.2.0 0.0.0.255 192.168.1.0 0.0.0.255
```

The IPSec transform set

```
crypto ipsec transform-set MYSET esp-des
```

The IPSec crypto map

```
crypto map MYMAP 110 ipsec-isakmp
 set peer 10.1.1.1
 set transform-set MYSET
 match address 120
!
```

PSTN Callback & Static Routing

Use CALLBACK on the R1 router when R3 initiates a connection. Use static routing on this link

Router R1

The Modem configuration - Asynchronous port #65

```
! configure the async port for the modem
interface Async65
 ip address 10.1.1.9 255.255.255.252
 encapsulation ppp
 dialer in-band
 dialer callback-secure
 dialer idle-timeout 300
 dialer wait-for-carrier-time 60
 dialer map ip 10.1.1.10 name R3 class dialback modem-script hayes56k broadcast 5556002
 dialer hold-queue 50
 dialer-group 1
 async mode dedicated
 ppp callback accept
 ppp authentication chap
!
username R3 password 0 cisco
username R1 password 0 cisco
```

The line configuration – AUX

```
line aux 0
 password cisco
 login
 modem InOut
 modem autoconfigure type hayes_optima
 transport input all
 stopbits 1
 speed 115200
 flowcontrol hardware
!
```

The Static Route

```
! add a default route (static)
ip route 192.168.3.0 255.255.255.0 10.1.1.10
```

Router R2

The modem's chatscript

```
chat-script hayes56k ABORT ERROR "" "AT Z" OK "ATDT \T" TIMEOUT 30 CONNECT \c
```

The Modem configuration – Serial 0/0

```
! set up ppp encapsulation, the dialer, and then the ppp callback on s0/0
interface Serial0/0
 encapsulation ppp
 dialer in-band
```

```
 dialer idle-timeout 300
 dialer wait-for-carrier-time 60
 dialer map ip 10.1.1.1 name R1 modem-script hayes56k broadcast 5556001
 dialer hold-queue 50
 dialer-group 1
 ppp callback request
 ppp authentication chap
 no shut
!
username R1 password 0 cisco
username R3 password 0 cisco
```

The line configuration – line 1

```
! line 1 for s0/0
line 1
 password cisco
 login
 modem InOut
 transport input all
 stopbits 1
 speed 115200
 flowcontrol hardware
!
```

The Static Route

```
! static route and dialer list filter
ip route 0.0.0.0 0.0.0.0 10.1.1.1
```

QoS over Frame Relay

AGC wishes to test QoS over the Frame Relay link. To test the link, they require that Telnet traffic should be guaranteed 16Kbps of the Frame Relay bandwidth. A class map and policy map for class-based weighted fair queuing needs to be defined to establish the match criteria for identifying data belonging in a policy class.

To begin, we need an access list to permit telnet traffic between the routers.

```
access-list 101 permit tcp any any eq telnet
```

Next, a class-map is need to match the condition with the access list.

```
! class map
class-map match-all TELNET
  match access-group 101
!
```

Next, a policy-map with a traffic policy for the class to allocate a 16k bandwidth

```
! policy to set bandwidth to 16k
policy-map TELNET-QOS
  class TELNET
  bandwidth 16
!
```

Chapter 4 – Output

PSTN Communication, Authentication, & Dialback

Router 1

```
R1#debug ppp authentication
PPP authentication debugging is on
R1#debg ug dialer
Dial on demand events debugging is on
R1#
01:43:51: %LINK-3-UPDOWN: Interface Async65, changed state to up
R1#
01:43:51: As65 DDR: Dialer statechange to up
01:43:51: As65 DDR: Dialer received incoming call from <unknown>
01:43:51: As65 PPP: Using dialer call direction
01:43:51: As65 PPP: Treating connection as a callin
```

Above we can see that R1 received an incoming call from R3. And below we can see the CHAP challenge being successful. Afterwards, the line is dropped, and PPP Callback is started to call R3 at 5556002 (highlighted)

```
01:43:53: As65 CHAP: O CHALLENGE id 7 len 23 from "R1"
01:43:54: As65 CHAP: I CHALLENGE id 10 len 23 from "R3"
01:43:54: As65 CHAP: Waiting for peer to authenticate first
01:43:54: As65 CHAP: I RESPONSE id 7 len 23 from "R3"
01:43:54: As65 CHAP: O SUCCESS id 7 len 4
01:43:54: As65 CHAP: Processing saved Challenge, id 10
01:43:54: As65 CHAP: O RESPONSE id 10 len 23 from "R1"
R1#
01:44:03: As65 CHAP: O RESPONSE id 10 len 23 from "R1"
01:44:04: As65 CHAP: I CHALLENGE id 11 len 23 from "R3"
01:44:04: As65 CHAP: O RESPONSE id 11 len 23 from "R1"
01:44:04: As65 CHAP: I SUCCESS id 11 len 4
01:44:04: As65 DDR: PPP callback: Callback server starting to R3 5556002
01:44:05: %LINEPROTO-5-UPDOWN: Line protocol on Interface Async65, changed state to up
R1#
01:44:05: As65 DDR: disconnecting call
R1#
01:44:07: %LINK-5-CHANGED: Interface Async65, changed state to reset
01:44:08: %LINEPROTO-5-UPDOWN: Line protocol on Interface Async65, changed state to down
R1#
01:44:08: DDR: Dialer Watch: watch-group = 2
01:44:08: DDR:      network 192.168.2.0/255.255.255.0 UP,
01:44:08: DDR:      primary UP
01:44:12: %LINK-3-UPDOWN: Interface Async65, changed state to down
```

Below we see the actual callback dial up, and highlighted is the chap authentication success.

```
01:44:22: As65 DDR: re-enable timeout
01:44:22: DDR: callback triggered by dialer_timers
01:44:22: As65 DDR: beginning callback to R3 5556002
01:44:22: As65 DDR: Attempting to dial 5556002
01:44:22: CHAT65: Attempting async line dialer script
01:44:22: CHAT65: no matching chat script found for 5556002
01:44:22: CHAT65: Dialing using Modem script: d0efault-d0ials0cript & System script: none
```

```
01:44:22: CHAT65: process started
01:44:22: CHAT65: Asserting DTR
01:44:22: CHAT65: Chat script d0efault-d0ials0cript started
R1#
01:44:47: CHAT65: Chat script d0efault-d0ials0cript finished, status = Success
01:44:49: %LINK-3-UPDOWN: Interface Async65, changed state to up
R1#
01:44:49: As65 DDR: Dialer statechange to up
01:44:49: DDR: Freeing callback to R3 5556002
01:44:49: As65 DDR: Dialer call has been placed
01:44:49: As65 PPP: Using dialer call direction
01:44:49: As65 PPP: Treating connection as a callout
01:44:49: As65 CHAP: O CHALLENGE id 8 len 23 from "R1"
01:44:50: As65 CHAP: I CHALLENGE id 12 len 23 from "R3"
01:44:50: As65 CHAP: O RESPONSE id 12 len 23 from "R1"
01:44:50: As65 CHAP: I SUCCESS id 12 len 4
01:44:50: As65 CHAP: I RESPONSE id 8 len 23 from "R3"
01:44:50: As65 CHAP: O SUCCESS id 8 len 4
R1#
01:44:52: As65 DDR: dialer protocol up
```

Below, we see the routes.

```
R1#sh ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     172.16.0.0/32 is subnetted, 1 subnets
C       172.16.1.1 is directly connected, Loopback0
     10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
C       10.1.1.10/32 is directly connected, Async65
C       10.1.1.8/30 is directly connected, Async65
C       10.1.1.0/30 is directly connected, Serial0/0.18
C       10.1.1.4/30 is directly connected, Serial1/0:23
C    192.168.1.0/24 is directly connected, FastEthernet0/0
D    192.168.2.0/24 [90/20514560] via 10.1.1.2, 00:28:58, Serial0/0.18
S    192.168.3.0/24 [1/0] via 10.1.1.10
```

Router 3

Now, if we look at the other side of the dialler, we can see the dial attempt to R1, and the successful CHAP authentication highlighted on the next page.

```
debug ppp auth
R3#debug ppp authentication
PPP authentication debugging is on
R3#debug dialer
Dial on demand events debugging is on
R3#
02:31:00: Se0/0 DDR: Dialing cause ip (s=192.168.3.2, d=192.168.1.2)
02:31:00: Se0/0 DDR: Attempting to dial 5556001
02:31:00: CHAT1: Attempting async line dialer script
02:31:00: CHAT1: Dialing using Modem script: hayes56k & System script: none
02:31:00: CHAT1: process started
02:31:00: CHAT1: Asserting DTR
```

```
02:31:00: CHAT1: Chat script hayes56k started
R3#
02:31:23: CHAT1: Chat script hayes56k finished, status = Success
02:31:23: Se0/0 PPP: Using dialer call direction
02:31:23: Se0/0 PPP: Treating connection as a callout
02:31:23: %LINK-3-UPDOWN: Interface Serial0/0, changed state to up
R3#
02:31:23: Se0/0 DDR: Dialer statechange to up
02:31:23: Se0/0 DDR: Dialer call has been placed
02:31:23: Se0/0 CHAP: O CHALLENGE id 10 len 23 from "R3"
02:31:23: Se0/0 CHAP: I CHALLENGE id 7 len 23 from "R1"
02:31:23: Se0/0 CHAP: O RESPONSE id 7 len 23 from "R3"
02:31:23: Se0/0 CHAP: I SUCCESS id 7 len 4
R3#
```

Afterwards, Callback is negotiated, and the line is disconnected.

```
02:31:33: Se0/0 CHAP: O CHALLENGE id 11 len 23 from "R3"
02:31:33: Se0/0 CHAP: I RESPONSE id 10 len 23 from "R1"
02:31:33: Se0/0 CHAP: Response ignored, expected id 11, got id 10
02:31:33: Se0/0 CHAP: I RESPONSE id 11 len 23 from "R1"
02:31:33: Se0/0 CHAP: O SUCCESS id 11 len 4
02:31:33: Se0/0 DDR: Callback negotiated - Disconnecting
02:31:33: DDR: Callback client for R1 5556001 created
R3#
02:31:34: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/0, changed state to up
R3#
02:31:34: Se0/0 DDR: disconnecting call
R3#
02:31:36: %LINK-5-CHANGED: Interface Serial0/0, changed state to reset
02:31:37: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/0, changed state to down
R3#
02:31:41: %LINK-3-UPDOWN: Interface Serial0/0, changed state to down
R3#
02:31:51: Se0/0 DDR: re-enable timeout
R3#
```

Finally, the incoming call is authenticated.

```
02:32:19: Se0/0 PPP: Using dialer call direction
02:32:19: Se0/0 PPP: Treating connection as a callin
02:32:19: %LINK-3-UPDOWN: Interface Serial0/0, changed state to up
R3#
02:32:19: Se0/0 DDR: Dialer statechange to up
02:32:19: Se0/0 DDR: Dialer received incoming call from <unknown>
02:32:19: Se0/0 CHAP: O CHALLENGE id 12 len 23 from "R3"
02:32:19: Se0/0 CHAP: I CHALLENGE id 8 len 23 from "R1"
02:32:19: Se0/0 CHAP: Waiting for peer to authenticate first
02:32:19: Se0/0 CHAP: I RESPONSE id 12 len 23 from "R1"
02:32:19: Se0/0 CHAP: O SUCCESS id 12 len 4
02:32:19: Se0/0 CHAP: Processing saved Challenge, id 8
02:32:19: Se0/0 CHAP: O RESPONSE id 8 len 23 from "R3"
02:32:19: Se0/0 CHAP: I SUCCESS id 8 len 4
02:32:19: Se0/0 DDR: Callback received from R1 5556001
02:32:19: DDR: Freeing callback to R1 5556001
R3#
02:32:21: Se0/0 DDR: dialer protocol up
02:32:22: Se0/0 DDR: Call connected, 50 packets unqueued, 50 transmitted, 0 discarded
```

Finally, here is the output of the routes learnt by R3.

```
R3#sh ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
```

```
      E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
      i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
      ia - IS-IS inter area, * - candidate default, U - per-user static route
      o - ODR, P - periodic downloaded static route

Gateway of last resort is 10.1.1.1 to network 0.0.0.0

    10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C       10.1.1.0/24 is directly connected, Serial0/0
C       10.1.1.1/32 is directly connected, Serial0/0
    12.0.0.0/32 is subnetted, 1 subnets
C       12.12.12.12 is directly connected, Loopback1
C    192.168.3.0/24 is directly connected, FastEthernet0/0
S*   0.0.0.0/0 [1/0] via 10.1.1.1
R3#
```

Frame Relay & BRI Backup

Router R1

Below shows the routes learnt through Frame Relay.

```
sh ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

    172.16.0.0/32 is subnetted, 1 subnets
C       172.16.1.1 is directly connected, Loopback0
    10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
C       10.1.1.10/32 is directly connected, Async65
C       10.1.1.8/30 is directly connected, Async65
C       10.1.1.0/30 is directly connected, Serial0/0.18
C       10.1.1.4/30 is directly connected, Serial1/0:23
C    192.168.1.0/24 is directly connected, FastEthernet0/0
D    192.168.2.0/24 [90/20514560] via 10.1.1.2, 00:30:55, Serial0/0.18
S    192.168.3.0/24 [1/0] via 10.1.1.10
```

When the Frame Relay link is down, the EIGRP routes are gone. After the holding timeout expires, BRI Backup goes up. When showing the routes again, the list is empty (apart from the directly connected routes) until EIGRP negotiates and learns its new routes.

```
R1#
01:47:39: %LINK-3-UPDOWN: Interface Serial0/0, changed state to down
01:47:39: %DUAL-5-NBRCHANGE: IP-EIGRP 64512: Neighbor 10.1.1.2 (Serial0/0.18) is down: interface
down
R1#
01:47:39: DDR: Dialer Watch: watch-group = 2
01:47:39: DDR:      network 192.168.2.0/255.255.255.0 DOWN,
01:47:39: DDR:      primary DOWN
01:47:39: DDR: Dialer Watch: Dial Reason: Primary of group 2 DOWN
01:47:39: DDR: Dialer Watch: watch-group = 2,
```

```
01:47:39: DDR: Dialer Watch: watch-group = 2
01:47:39: DDR:      network 192.168.2.0/255.255.255.0 DOWN,
01:47:39: DDR:      primary DOWN
01:47:39: DDR: Dialer Watch: Dial Reason: Primary of group 2 DOWN
01:47:39: DDR: Dialer Watch: watch-group = 2,
R1#
01:47:40: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial0/0, changed state to down
R1#


R1#sh ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     172.16.0.0/32 is subnetted, 1 subnets
C       172.16.1.1 is directly connected, Loopback0
     10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
C       10.1.1.10/32 is directly connected, Async65
C       10.1.1.8/30 is directly connected, Async65
C       10.1.1.4/30 is directly connected, Serial1/0:23
C    192.168.1.0/24 is directly connected, FastEthernet0/0
S    192.168.3.0/24 [1/0] via 10.1.1.10
```

As shown below, the routes are now identified again, but learnt through the ISDN interface (BRI0/0)

```
01:48:73014444096: %LINK-3-UPDOWN: Interface Serial1/0:22, changed state to up
01:48:75196051196: Se1/0:22 PPP: Using dialer call direction
01:48:75196051196: Se1/0:22 PPP: Treating connection as a callin
01:48:17: Se1/0:22 CHAP: O CHALLENGE id 6 len 23 from "R1"
01:48:17: Se1/0:22 CHAP: I CHALLENGE id 6 len 23 from "R2"
01:48:17: Se1/0:22 CHAP: Waiting for peer to authenticate first
01:48:17: Se1/0:22 CHAP: I RESPONSE id 6 len 23 from "R2"
01:48:17: Se1/0:22 CHAP: O SUCCESS id 6 len 4
01:48:17: Se1/0:22 CHAP: Processing saved Challenge, id 6
01:48:17: Se1/0:22 CHAP: O RESPONSE id 6 len 23 from "R1"
01:48:17: Se1/0:22 CHAP: I SUCCESS id 6 len 4
01:48:17: %LINK-3-UPDOWN: Interface Virtual-Access1, changed state to up
01:48:17: Vi1 DDR: Dialer statechange to up
01:48:17: Vi1 PPP: Using dialer call direction
01:48:17: Vi1 PPP: Treating connection as a callin
01:48:17: Vi1 DDR: dialer protocol up
01:48:18: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial1/0:22, changed state to up
01:48:18: %LINEPROTO-5-UPDOWN: Line protocol on Interface Virtual-Access1, changed state to up
01:48:18: %DUAL-5-NBRCHANGE: IP-EIGRP 64512: Neighbor 10.1.1.6 (Serial1/0:23) is up: new
adjacency
R1#
01:48:23: %ISDN-6-CONNECT: Interface Serial1/0:22 is now connected to 5551234 R2


R1#sh ijp    p route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route
```

```
Gateway of last resort is not set

     172.16.0.0/32 is subnetted, 1 subnets
C       172.16.1.1 is directly connected, Loopback0
     10.0.0.0/8 is variably subnetted, 5 subnets, 2 masks
C       10.1.1.10/32 is directly connected, Async65
C       10.1.1.8/30 is directly connected, Async65
D       10.1.1.0/30 [90/41024000] via 10.1.1.6, 00:00:15, Serial1/0:23
C       10.1.1.6/32 is directly connected, Serial1/0:23
C       10.1.1.4/30 is directly connected, Serial1/0:23
C    192.168.1.0/24 is directly connected, FastEthernet0/0
D    192.168.2.0/24 [90/40514560] via 10.1.1.6, 00:00:16, Serial1/0:23
S    192.168.3.0/24 [1/0] via 10.1.1.10
```

After the Frame Relay is up again, ISDN disconnects, and Frame Relay takes preference once more.

```
01:50:21: %DUAL-5-NBRCHANGE: IP-EIGRP 64512: Neighbor 10.1.1.2 (Serial0/0.18) is up: new
adjacency
R1#
01:50:21: Se1/0:23 DDR: Attempting to dial 5551234
01:50:21: Serial1/0:23: wait for isdn carrier timeout, call id=0x84D3
01:50:21: Se1/0:23 DDR: Attempting to dial 5551235
01:50:21: DDR: Dialer Watch: watch-group = 2
01:50:21: DDR:      network 192.168.2.0/255.255.255.0 UP,
01:50:21: DDR:      primary DOWN
01:50:21: DDR: Dialer Watch: Dial Reason: Secondary of group 2 AVAILABLE
01:50:21: DDR: Dialer Watch: watch-group = 2,
01:50:21: Serial1/0:23: wait for isdn carrier timeout, call id=0x84D4
01:50:22: DDR: Dialer Watch: watch-group = 2
01:50:22: DDR:      network 192.168.2.0/255.255.255.0 UP,
01:50:22: DDR:      primary DOWN
R1#
01:50:22: DDR: Dialer Watch: Dial Reason: Secondary of group 2 AVAILABLE
01:50:22: DDR: Dialer Watch: watch-group = 2,
R1#


R1#sh ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     172.16.0.0/32 is subnetted, 1 subnets
C       172.16.1.1 is directly connected, Loopback0
     10.0.0.0/8 is variably subnetted, 5 subnets, 2 masks
C       10.1.1.10/32 is directly connected, Async65
C       10.1.1.8/30 is directly connected, Async65
C       10.1.1.0/30 is directly connected, Serial0/0.18
C       10.1.1.6/32 is directly connected, Serial1/0:23
C       10.1.1.4/30 is directly connected, Serial1/0:23
C    192.168.1.0/24 is directly connected, FastEthernet0/0
D    192.168.2.0/24 [90/20514560] via 10.1.1.2, 00:00:21, Serial0/0.18
S    192.168.3.0/24 [1/0] via 10.1.1.10
```

Router R2

Below shows the routes learnt through Frame Relay.

```
R2#sh ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
D       10.1.1.10/32 [90/25332736] via 10.1.1.1, 00:01:58, Serial0/0.16
D       10.1.1.8/30 [90/25332736] via 10.1.1.1, 00:02:24, Serial0/0.16
C       10.1.1.0/30 is directly connected, Serial0/0.16
C       10.1.1.4/30 is directly connected, BRI0/0
D    192.168.1.0/24 [90/20514560] via 10.1.1.1, 00:30:34, Serial0/0.16
C    192.168.2.0/24 is directly connected, FastEthernet0/0
D EX 192.168.3.0/24 [170/20537600] via 10.1.1.1, 00:02:24, Serial0/0.16
```

When the Frame Relay link is down, the EIGRP routes are gone. After the holding timeout expires, BRI Backup goes up. When showing the routes again, the list is empty (apart from the directly connected routes) until EIGRP negotiates and learns its new routes.

```
02:37:36: %DUAL-5-NBRCHANGE: IP-EIGRP 64512: Neighbor 10.1.1.1 (Serial0/0.16) is down: holding
time expired


R2#
02:37:38: %ISDN-6-LAYER2UP: Layer 2 for Interface BR0/0, TEI 64 changed to up
R2#sh ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/30 is subnetted, 2 subnets
C       10.1.1.0 is directly connected, Serial0/0.16
C       10.1.1.4 is directly connected, BRI0/0
C    192.168.2.0/24 is directly connected, FastEthernet0/0
R2#
02:37:49: %ISDN-6-LAYER2UP: Layer 2 for Interface BR0/0, TEI 65 changed to up
```

As shown below, the routes are now identified again, but learnt through the ISDN interface (BRI0/0)

```
02:38:06: %LINK-3-UPDOWN: Interface BRI0/0:1, changed state to up
02:38:06: %LINK-3-UPDOWN: Interface Virtual-Access1, changed state to up
02:38:07: %LINEPROTO-5-UPDOWN: Line protocol on Interface BRI0/0:1, changed state to up
02:38:07: %LINEPROTO-5-UPDOWN: Line protocol on Interface Virtual-Access1, changed state to up
02:38:09: %DUAL-5-NBRCHANGE: IP-EIGRP 64512: Neighbor 10.1.1.5 (BRI0/0) is up: new adjacency
02:38:12: %ISDN-6-CONNECT: Interface BRI0/0:1 is now connected to 5555000 R1
R2#
```

```
R2#sh ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 5 subnets, 2 masks
D       10.1.1.10/32 [90/43072000] via 10.1.1.5, 00:00:09, BRI0/0
D       10.1.1.8/30 [90/43072000] via 10.1.1.5, 00:00:09, BRI0/0
C       10.1.1.0/30 is directly connected, Serial0/0.16
C       10.1.1.4/30 is directly connected, BRI0/0
C       10.1.1.5/32 is directly connected, BRI0/0
D    192.168.1.0/24 [90/40514560] via 10.1.1.5, 00:00:09, BRI0/0
C    192.168.2.0/24 is directly connected, FastEthernet0/0
D EX 192.168.3.0/24 [170/40537600] via 10.1.1.5, 00:00:10, BRI0/0
R2#

02:38:158913789952: %LINK-3-UPDOWN: Interface BRI0/0:2, changed state to up
02:38:40: %LINEPROTO-5-UPDOWN: Line protocol on Interface BRI0/0:2, changed state to up
02:38:43: %ISDN-6-CONNECT: Interface BRI0/0:2 is now connected to 5555000 R1
```

Throttling Down

When the routers receive a BECN, they will throttle down their rates as shown,

Router R1

```
R1#sh frame-relay pvc 18
PVC Statistics for interface Serial0/0 (Frame Relay DTE)
DLCI = 18, DLCI USAGE = LOCAL, PVC STATUS = ACTIVE, INTERFACE = Serial0/0.18
  input pkts 2648          output pkts 2635         in bytes 259875
  out bytes 261916         dropped pkts 0           in pkts dropped 0
  out pkts dropped 0               out bytes dropped 0
  in FECN pkts 0           in BECN pkts 0           out FECN pkts 0
  out BECN pkts 0          in DE pkts 0             out DE pkts 0
  out bcast pkts 493       out bcast bytes 42577
  Shaping adapts to BECN
  pvc create time 01:32:05, last time pvc status changed 00:20:29
  cir 32000     bc 64000     be 64000     byte limit 8500   interval 125
  mincir 16000     byte increment 500   Adaptive Shaping BECN
  pkts 2635      bytes 261916    pkts delayed 0         bytes delayed 0
  shaping inactive
  traffic shaping drops 0
  service policy TELNET-QOS
 Serial0/0.18: DLCI 18 -

  Service-policy output: TELNET-QOS

    Class-map: TELNET (match-all)
      0 packets, 0 bytes
      5 minute offered rate 0 bps, drop rate 0 bps
      Match: access-group 101
      Queueing
        Output Queue: Conversation 25
        Bandwidth 16 (kbps) Max Threshold 64 (packets)
        (pkts matched/bytes matched) 0/0
```

```
    (depth/total drops/no-buffer drops) 0/0/0

  Class-map: class-default (match-any)
    2635 packets, 261916 bytes
    5 minute offered rate 0 bps, drop rate 0 bps
    Match: any
 Output queue size 0/max total 600/drops 0
```

Router 2

```
R2#sh frame-relay pb b vc 16
PVC Statistics for interface Serial0/0 (Frame Relay DTE)
DLCI = 16, DLCI USAGE = LOCAL, PVC STATUS = ACTIVE, INTERFACE = Serial0/0.16

 input pkts 2871          output pkts 2988         in bytes 283534
 out bytes 202627         dropped pkts 0           in pkts dropped 0
 out pkts dropped 0               out bytes dropped 0
 in FECN pkts 0           in BECN pkts 0           out FECN pkts 0
 out BECN pkts 0          in DE pkts 0             out DE pkts 0
 out bcast pkts 564       out bcast bytes 47121
 Shaping adapts to BECN
 pvc create time 02:28:52, last time pvc status changed 00:23:31
 cir 32000     bc 64000     be 64000     byte limit 8500   interval 125
 mincir 16000     byte increment 500   Adaptive Shaping BECN
 pkts 2982      bytes 290243    pkts delayed 0         bytes delayed 0
 shaping inactive
 traffic shaping drops 0
 service policy TELNET-QOS
Serial0/0.16: DLCI 16 -

 Service-policy output: TELNET-QOS

  Class-map: TELNET (match-all)
    108 packets, 4860 bytes
    5 minute offered rate 0 bps, drop rate 0 bps
    Match: access-group 101
    Queueing
      Output Queue: Conversation 25
      Bandwidth 16 (kbps) Max Threshold 64 (packets)
      (pkts matched/bytes matched) 0/0
      (depth/total drops/no-buffer drops) 0/0/0

  Class-map: class-default (match-any)
    2874 packets, 285383 bytes
    5 minute offered rate 1000 bps, drop rate 0 bps
    Match: any
 Output queue size 0/max total 600/drops 0
```

IPSec crypto

Below is the output showing the encryption of traffic between R1 and R2 LANs.

Router R1

```
R1#sh crypto ipsec sa

interface: Serial0/0.18
   Crypto map tag: MYMAP, local addr. 10.1.1.1

  local  ident (addr/mask/prot/port): (192.168.1.0/255.255.255.0/0/0)
  remote ident (addr/mask/prot/port): (192.168.2.0/255.255.255.0/0/0)
```

```
current_peer: 10.1.1.2
  PERMIT, flags={origin_is_acl,}
 #pkts encaps: 2008, #pkts encrypt: 2008, #pkts digest 0
 #pkts decaps: 2009, #pkts decrypt: 2009, #pkts verify 0
 #pkts compressed: 0, #pkts decompressed: 0
 #pkts not compressed: 0, #pkts compr. failed: 0, #pkts decompress failed: 0
 #send errors 0, #recv errors 0

  local crypto endpt.: 10.1.1.1, remote crypto endpt.: 10.1.1.2
  path mtu 1500, ip mtu 1500
  current outbound spi: FBD4AEC4

  inbound esp sas:
   spi: 0xB7DB039B(3084583835)
     transform: esp-des ,
     in use settings ={Tunnel, }
     slot: 0, conn id: 2000, flow_id: 1, crypto map: MYMAP
     sa timing: remaining key lifetime (k/sec): (4607803/1294)
     IV size: 8 bytes
     replay detection support: N

  inbound ah sas:

  inbound pcp sas:

  outbound esp sas:
   spi: 0xFBD4AEC4(4225019588)
     transform: esp-des ,
     in use settings ={Tunnel, }
     slot: 0, conn id: 2001, flow_id: 2, crypto map: MYMAP
     sa timing: remaining key lifetime (k/sec): (4607803/1293)
     IV size: 8 bytes
     replay detection support: N

  outbound ah sas:

  outbound pcp sas:
```

Router R2

```
R2#sh crypto ipsec sa

interface: Serial0/0.16
    Crypto map tag: MYMAP, local addr. 10.1.1.2

   local  ident (addr/mask/prot/port): (192.168.2.0/255.255.255.0/0/0)
   remote ident (addr/mask/prot/port): (192.168.1.0/255.255.255.0/0/0)
   current_peer: 10.1.1.1
     PERMIT, flags={origin_is_acl,}
    #pkts encaps: 2248, #pkts encrypt: 2248, #pkts digest 0
    #pkts decaps: 2215, #pkts decrypt: 2215, #pkts verify 0
    #pkts compressed: 0, #pkts decompressed: 0
    #pkts not compressed: 0, #pkts compr. failed: 0, #pkts decompress failed: 0
    #send errors 2, #recv errors 0

     local crypto endpt.: 10.1.1.2, remote crypto endpt.: 10.1.1.1
     path mtu 1500, ip mtu 1500
     current outbound spi: B7DB039B

     inbound esp sas:
      spi: 0xFBD4AEC4(4225019588)
        transform: esp-des ,
        in use settings ={Tunnel, }
        slot: 0, conn id: 2000, flow_id: 1, crypto map: MYMAP
        sa timing: remaining key lifetime (k/sec): (4607783/1074)
```

```
    IV size: 8 bytes
    replay detection support: N

  inbound ah sas:

  inbound pcp sas:

  outbound esp sas:
   spi: 0xB7DB039B(3084583835)
    transform: esp-des ,
    in use settings ={Tunnel, }
    slot: 0, conn id: 2001, flow_id: 2, crypto map: MYMAP
    sa timing: remaining key lifetime (k/sec): (4607780/1073)
    IV size: 8 bytes
    replay detection support: N

  outbound ah sas:

  outbound pcp sas:
```

QoS Over Frame Relay

The Policy Map's output,

Router R1

```
R1#sh policy-map m   ?
  WORD       policy-map name
  interface  Show Qos Policy Interface
  |          Output modifiers
  <cr>

R1#sh policy-map
  Policy Map TELNET-QOS
    Class TELNET
      Bandwidth 16 (kbps) Max Threshold 64 (packets)
```

Router R2

```
R2#sh policy-map
  Policy Map TELNET-QOS
    Class TELNET
      Bandwidth 16 (kbps) Max Threshold 64 (packets)
```

Appendix I – Router Configuration

Router 1

```
R1#sh run
Building configuration...

Current configuration : 3218 bytes
!
version 12.2
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname R1
!
aaa new-model
aaa authentication login default local-case enable
enable password cisco
!
username R2 password 0 cisco
username R3 password 0 cisco
username R1 password 0 cisco
memory-size iomem 10
ip subnet-zero
!
!
!
frame-relay switching
!
crypto isakmp policy 100
 authentication pre-share
crypto isakmp key cisco1234 address 10.1.1.2
!
!
crypto ipsec transform-set MYSET esp-des
!
crypto map MYMAP 110 ipsec-isakmp
 set peer 10.1.1.2
 set transform-set MYSET
 match address 120
!
isdn switch-type primary-ni
call rsvp-sync
!
!
!
```

```
!
!
!
controller T1 1/0
 framing esf
 linecode b8zs
 pri-group timeslots 1-24
!
!
class-map match-all TELNET
  match access-group 101
!
!
policy-map TELNET-QOS
  class TELNET
   bandwidth 16
!
!
!
interface Loopback0
 ip address 172.16.1.1 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.1 255.255.255.0
 duplex auto
 speed auto
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
 no fair-queue
 frame-relay traffic-shaping
 frame-relay lmi-type ansi
!
interface Serial0/0.18 point-to-point
 ip address 10.1.1.1 255.255.255.252
 frame-relay class BECN
 frame-relay interface-dlci 18
 crypto map MYMAP
!
interface Serial0/1
 no ip address
 shutdown
!
interface Serial1/0:23
 ip address 10.1.1.5 255.255.255.252
 encapsulation ppp
 dialer idle-timeout 60
 dialer watch-disable 15
 dialer map ip 10.1.1.6 name R2 broadcast 5551234
```

```
 dialer map ip 10.1.1.6 name R2 broadcast 5551235
 dialer map ip 192.168.2.0 name R2 broadcast 5551234
 dialer map ip 192.168.2.0 name R2 broadcast 5551235
 dialer load-threshold 1 outbound
 dialer watch-group 2
 dialer-group 1
 isdn switch-type primary-ni
 ppp authentication chap
 ppp multilink
!
interface Async65
 ip address 10.1.1.9 255.255.255.252
 encapsulation ppp
 dialer in-band
 dialer callback-secure
 dialer idle-timeout 300
 dialer wait-for-carrier-time 60
 dialer map ip 10.1.1.10 name R3 class dialback modem-script hayes56k broadcast 5556002
 dialer hold-queue 50
 dialer-group 1
 async mode dedicated
 ppp callback accept
 ppp authentication chap
!
router eigrp 64512
 redistribute static metric 10000 100 255 1 1500
 passive-interface Async65
 network 10.0.0.0
 network 192.168.1.0
 no auto-summary
!
ip classless
ip route 192.168.3.0 255.255.255.0 10.1.1.10
ip http server
!
!
map-class frame-relay BECN
 frame-relay cir 32000
 frame-relay bc 64000
 frame-relay be 64000
 frame-relay adaptive-shaping becn
 service-policy output TELNET-QOS
!
map-class dialer dialback
 dialer callback-server username
access-list 101 permit tcp any any eq telnet
access-list 120 permit ip 192.168.1.0 0.0.0.255 192.168.2.0 0.0.0.255
access-list 150 deny   eigrp any any
access-list 150 permit ip any any
dialer watch-list 2 ip 192.168.2.0 255.255.255.0
```

```
dialer-list 1 protocol ip list 150
!
!
dial-peer cor custom
!
!
!
!
!
line con 0
 exec-timeout 0 0
 password cisco
 logging synchronous
line aux 0
 password cisco
 modem InOut
 modem autoconfigure type hayes_optima
 transport input all
 stopbits 1
 speed 115200
 flowcontrol hardware
line vty 0 4
 password cisco
!
end
```

Router 2

```
sh run
Building configuration...

Current configuration : 2553 bytes
!
version 12.2
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname R2
!
aaa new-model
aaa authentication password-prompt "Please enter your password:"
aaa authentication username-prompt "Please enter your username:"
aaa authentication login default local-case enable
enable password cisco
!
username R1 password 0 cisco
username R2 password 0 cisco
username R3 password 0 cisco
memory-size iomem 10
ip subnet-zero
!
!
!
!
crypto isakmp policy 100
 authentication pre-share
crypto isakmp key cisco1234 address 10.1.1.1
!
!
crypto ipsec transform-set MYSET esp-des
!
crypto map MYMAP 110 ipsec-isakmp
 set peer 10.1.1.1
 set transform-set MYSET
 match address 120
!
isdn switch-type basic-ni
call rsvp-sync
!
!
!
!
!
!
```

```
!
class-map match-all TELNET
  match access-group 101
!
!
policy-map TELNET-QOS
  class TELNET
   bandwidth 16
!
!
!
interface FastEthernet0/0
 ip address 192.168.2.1 255.255.255.0
 duplex auto
 speed auto
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
 no fair-queue
 frame-relay traffic-shaping
 frame-relay lmi-type ansi
!
interface Serial0/0.16 point-to-point
 ip address 10.1.1.2 255.255.255.252
 frame-relay class BECN
 frame-relay interface-dlci 16
 crypto map MYMAP
!
interface BRI0/0
 ip address 10.1.1.6 255.255.255.252
 encapsulation ppp
 dialer idle-timeout 60
 dialer watch-disable 15
 dialer map ip 10.1.1.5 name R1 broadcast 5555000
 dialer map ip 192.168.1.0 name R1 broadcast 5555000
 dialer load-threshold 1 either
 dialer watch-group 2
 dialer-group 1
 isdn switch-type basic-ni
 isdn spid1 51055512340001 5551234
 isdn spid2 51055512350001 5551235
 ppp authentication chap
 ppp multilink
!
interface FastEthernet0/1
 no ip address
 shutdown
 duplex auto
 speed auto
```

```
!
interface Serial0/1
 no ip address
 shutdown
!
router eigrp 64512
 network 10.0.0.0
 network 192.168.2.0
 no auto-summary
!
ip classless
ip http server
!
!
map-class frame-relay BECN
 frame-relay cir 32000
 frame-relay bc 64000
 frame-relay be 64000
 frame-relay adaptive-shaping becn
 service-policy output TELNET-QOS
access-list 101 permit tcp any any eq telnet
access-list 120 permit ip 192.168.2.0 0.0.0.255 192.168.1.0 0.0.0.255
access-list 150 deny   eigrp any any
access-list 150 permit ip any any
dialer watch-list 2 ip 192.168.1.0 255.255.255.0
dialer-list 1 protocol ip list 150
!
!
dial-peer cor custom
!
!
!
!
!
line con 0
 exec-timeout 0 0
 password cisco
 logging synchronous
line aux 0
 password cisco
line vty 0 4
 password cisco
!
end
```

Router 3

```
sh run
Building configuration...

Current configuration : 1345 bytes
!
version 12.2
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname R3
!
enable password cisco
!
username R1 password 0 cisco
username R3 password 0 cisco
memory-size iomem 10
ip subnet-zero
!
!
!
!
chat-script hayes56k ABORT ERROR "" "AT Z" OK "ATDT \T" TIMEOUT 30 CONNECT \c
call rsvp-sync
!
!
!
!
!
!
!
!
interface Loopback1
 ip address 12.12.12.12 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.3.1 255.255.255.0
 duplex auto
 speed auto
!
interface BRI0/0
 no ip address
 encapsulation hdlc
 shutdown
!
interface Serial0/0
 physical-layer async
```

```
 ip address 10.1.1.10 255.255.255.252
 encapsulation ppp
 dialer in-band
 dialer idle-timeout 300
 dialer wait-for-carrier-time 60
 dialer map ip 10.1.1.1 name R1 modem-script hayes56k broadcast 5556001
 dialer hold-queue 50
 dialer-group 1
 async mode dedicated
 ppp callback request
 ppp authentication chap
!
interface Serial0/1
 no ip address
 shutdown
!
ip classless
ip route 0.0.0.0 0.0.0.0 10.1.1.1
ip http server
!
dialer-list 1 protocol ip permit
!
!
dial-peer cor custom
!
!
!
!
!
line con 0
 exec-timeout 0 0
 logging synchronous
line 1
 password cisco
 login
 modem InOut
 transport input all
 stopbits 1
 speed 115200
 flowcontrol hardware
line aux 0
 password cisco
 login
line vty 0 4
 password cisco
 login
!
end
```

Appendix II – Configuration Order

Below are the configurations in the order they were inputed.

Router R1

```
en
conf t

hostname R1

! aaa configuration, and the chatscript
aaa new-model
aaa authentication login default local-case enable
enable password cisco
isdn switch-type primary-ni

frame-relay switching

! the lines configuration
line con 0
 exec-timeout 0 0
 logging sync
 password cisco
exit

line aux 0
 password cisco
 login
 modem InOut
 modem autoconfigure type hayes_optima
 transport input all
 stopbits 1
 speed 115200
 flowcontrol hardware
exit

line vty 0 4
 password cisco
 login
exit


!crypto policy map
crypto isakmp policy 100
 authentication pre-share
```

```
crypto isakmp key cisco1234 address 10.1.1.2
crypto ipsec transform-set MYSET esp-des
crypto map MYMAP 110 ipsec-isakmp
 set peer 10.1.1.2
 set transform-set MYSET
 match address 120
exit

!frame relay configuration
controller T1 1/0
 framing esf
 linecode b8zs
 pri-group timeslots 1-24
exit

! class map
class-map match-all TELNET
  match access-group 101
exit

! policy to set bandwidth to 16k
policy-map TELNET-QOS
  class TELNET
   bandwidth 16
exit

!loopback
interface Loopback0
 ip address 172.16.1.1 255.255.255.255
exit

!fast ethernet
interface FastEthernet0/0
 ip address 192.168.1.1 255.255.255.0
 no shutdown
exit

! configure the async port for the modem
interface Async65
 ip address 10.1.1.9 255.255.255.252
 encapsulation ppp
 dialer in-band
 dialer callback-secure
 dialer idle-timeout 300
 dialer wait-for-carrier-time 60
 dialer map ip 10.1.1.10 name R3 class dialback modem-script hayes56k broadcast 5556002
 dialer hold-queue 50
 dialer-group 1
 async mode dedicated
 ppp callback accept
```

```
 ppp authentication chap
exit
username R2 password 0 cisco
username R3 password 0 cisco
username R1 password 0 cisco

!then configure the serial port, as well as the subinterfaces
interface Serial0/0
 encapsulation frame-relay
 no fair-queue
 frame-relay traffic-shaping
 frame-relay lmi-type ansi
 no shutdown
exit

interface Serial0/0.18 point-to-point
 ip address 10.1.1.1 255.255.255.252
 frame-relay class BECN
 frame-relay interface-dlci 18
 crypto map MYMAP
exit

interface Serial1/0:23
 ip address 10.1.1.5 255.255.255.252
 encapsulation ppp
 dialer idle-timeout 60
 dialer watch-disable 15
 dialer map ip 10.1.1.6 name R2 broadcast 5551234
 dialer map ip 10.1.1.6 name R2 broadcast 5551235
 dialer map ip 192.168.2.0 name R2 broadcast 5551234
 dialer map ip 192.168.2.0 name R2 broadcast 5551235
 dialer load-threshold 1 outbound
 dialer watch-group 2
 dialer-group 1
 isdn switch-type primary-ni
 ppp authentication chap
 ppp multilink
exit



!add dynamic routes (eigrp)
router eigrp 64512
 redistribute static metric 10000 100 255 1 1500
 passive-interface Async65
 network 10.0.0.0
 network 192.168.1.0
 no auto-summary
exit
```

```
! add a default route (static)
ip route 192.168.3.0 255.255.255.0 10.1.1.10

! class map for frame relay
map-class frame-relay BECN
 frame-relay cir 32000
 frame-relay bc 64000
 frame-relay be 64000
 frame-relay adaptive-shaping becn
 service-policy output TELNET-QOS
exit

map-class dialer dialback
 dialer callback-server username
exit

! access lists
access-list 101 permit tcp any any eq telnet
access-list 120 permit ip 192.168.1.0 0.0.0.255 192.168.2.0 0.0.0.255
access-list 150 deny   eigrp any any
access-list 150 permit ip any any
dialer watch-list 2 ip 192.168.2.0 255.255.255.0
dialer-list 1 protocol ip list 150


exit
```

Router R2

```
en
conf t

hostname R2

aaa new-model
aaa authentication password-prompt "Please enter your password:"
aaa authentication username-prompt "Please enter your username:"
aaa authentication login default local-case enable
enable password cisco



line con 0
 exec-timeout 0 0
 logging sync
 password cisco
exit

line aux 0
 password cisco
 login
exit

line vty 0 4
 password cisco
 login
exit


crypto isakmp policy 100
 authentication pre-share
crypto isakmp key cisco1234 address 10.1.1.1
crypto ipsec transform-set MYSET esp-des
crypto map MYMAP 110 ipsec-isakmp
 set peer 10.1.1.1
 set transform-set MYSET
 match address 120
exit

isdn switch-type basic-ni

class-map match-all TELNET
  match access-group 101
exit
```

```
policy-map TELNET-QOS
  class TELNET
   bandwidth 16
exit


interface FastEthernet0/0
 ip address 192.168.2.1 255.255.255.0
 no shutdown
exit


interface Serial0/0
 encapsulation frame-relay
 no fair-queue
 frame-relay traffic-shaping
 frame-relay lmi-type ansi
 no shutdown
exit


interface Serial0/0.16 point-to-point
 ip address 10.1.1.2 255.255.255.252
 frame-relay class BECN
 frame-relay interface-dlci 16
 crypto map MYMAP
exit


interface BRI0/0
 ip address 10.1.1.6 255.255.255.252
 encapsulation ppp
 dialer idle-timeout 60
 dialer watch-disable 15
 dialer map ip 10.1.1.5 name R1 broadcast 5555000
 dialer map ip 192.168.1.0 name R1 broadcast 5555000
 dialer load-threshold 1 either
 dialer watch-group 2
 dialer-group 1
 isdn switch-type basic-ni
 isdn spid1 51055512340001 5551234
 isdn spid2 51055512350001 5551235
 ppp authentication chap
 ppp multilink
 no shutdown
exit
username R1 password 0 cisco
username R2 password 0 cisco
username R3 password 0 cisco
```

```
router eigrp 64512
 network 10.0.0.0
 network 192.168.2.0
 no auto-summary
exit


map-class frame-relay BECN
 frame-relay cir 32000
 frame-relay bc 64000
 frame-relay be 64000
 frame-relay adaptive-shaping becn
 service-policy output TELNET-QOS
exit

access-list 101 permit tcp any any eq telnet
access-list 120 permit ip 192.168.2.0 0.0.0.255 192.168.1.0 0.0.0.255
access-list 150 deny   eigrp any any
access-list 150 permit ip any any
dialer watch-list 2 ip 192.168.1.0 255.255.255.0
dialer-list 1 protocol ip list 150


exit
```

Router R3

```
en

conf t


hostname R3
enable password cisco
chat-script hayes56k ABORT ERROR "" "AT Z" OK "ATDT \T" TIMEOUT 30 CONNECT \c



! console configuration, then aux, then vty.
line con 0
  exec-timeout 0 0
  logging syn
exit

line aux 0
  password cisco
  login
exit

line vty 0 4
  password cisco
  login
exit




! ip address, async mode dedicated, and physical layer async on s0/0
interface Serial0/0
 physical-layer async
 async mode dedicated
 ip address 10.1.1.10 255.255.255.252
 no shutdown
exit

! line 1 for s0/0
line 1
 password cisco
 login
 modem InOut
 transport input all
 stopbits 1
```

```
 speed 115200
 flowcontrol hardware
exit

! set up ppp encapsulation, the dialer, and then the ppp callback on s0/0
interface Serial0/0
 encapsulation ppp
 dialer in-band
 dialer idle-timeout 300
 dialer wait-for-carrier-time 60
 dialer map ip 10.1.1.1 name R1 modem-script hayes56k broadcast 5556001
 dialer hold-queue 50
 dialer-group 1
 ppp callback request
 ppp authentication chap
 no shut
exit
username R1 password 0 cisco
username R3 password 0 cisco


! loopback and fa0/0
interface Loopback1
 ip address 12.12.12.12 255.255.255.255
exit

interface FastEthernet0/0
 ip address 192.168.3.1 255.255.255.0
 no shutdown
exit


! static route and dialer list filter
ip route 0.0.0.0 0.0.0.0 10.1.1.1
dialer-list 1 protocol ip permit

exit
```