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CCNP Enterprise Advanced Routing

ENARSI 300-410

RAYMOND LACOSTE

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Appendix E Study Planner

About the Authors

Raymond Lacoste has dedicated his career to developing the skills of those interested in IT. In 2001, he began to mentor hundreds of IT professionals pursuing their Cisco certification dreams. This role led to teaching Cisco courses full time. Raymond is currently master instructor for Cisco Enterprise Routing and Switching, AWS, and ITIL at StormWind Studios. Raymond treats all technologies as an escape room, working to uncover every mystery in the protocols he works with. Along this journey, Raymond has passed more than 110 exams, and his office wall includes certificates from Microsoft, Cisco, ISC2, ITIL, AWS, and CompTIA. If you were visualizing Raymond's office, you'd probably expect the usual network equipment, certifications, and awards. Those certainly take up space, but they aren't his pride and joy. Most impressive, at least to Raymond, is his gemstone and mineral collection; once he starts talking about it, he just can't stop. Who doesn't get excited by a wondrous barite specimen in a pyrite matrix? Raymond presently resides with his wife and two children in eastern Canada, where they experience many adventures together.

Brad Edgeworth, CCIE No. 31574 (R&S and SP), is a systems architect at Cisco Systems. He is a distinguished speaker at Cisco Live, where he has presented on various topics. Before joining Cisco, Brad worked as a network architect and consultant for various Fortune 500 companies. Brad's expertise is based on enterprise and service provider environments, with an emphasis on architectural and operational simplicity and consistency. Brad holds a bachelor of arts degree in computer systems management from St. Edward's University in Austin, Texas. Brad can be found on Twitter as @BradEdgeworth.

About the Technical Reviewers

Hector Mendoza, Jr., No. 10687 (R&S, SP, and Security) has spent the past 14 years at Cisco Systems and is currently a solutions integration architect supporting large SP customers. Prior to this proactive role in CX, he spent nearly a decade providing reactive support in High Touch Technical Services in the Security Group, where he provided escalation support for some of the largest customers for Cisco. A four-time Cisco Live speaker and an Alpha reviewer of Cisco Security courseware, he is a huge advocate of continuing education and knowledge sharing. Hector has a passion for technology, enjoys solving complex problems, and loves working with customers. In his spare time, he tech reviews his esteemed colleagues' Cisco Press books.

Russ Long was introduced to computers and networking at a very young age, when he tried to save the world from digital monsters and aliens, an endeavor that keeps him busy to this day. Russ started his career in enterprise-level IT work splicing fiber-optic networks in the Pacific Northwest. His career has taken a long and winding path from there: from systems administrator, to IT consultant and computer shop owner, to IT instructor. Roughly the last decade of his career has focused solely on instruction and consulting in IT environments. Some of his favorite topics include Cisco routing and switching, real-world security, storage solutions, and virtualization.

Dedications

Raymond Lacoste:

This book is dedicated to my wife, Melanie, who has dedicated her life to making me a better person, which is the hardest job in the world. Thank you, Melanie, for being the most amazing wife and mother in the world.

Brad Edgeworth:

This book is dedicated to my daughter, Teagan. I know that you want to write a book with wizards and princesses, but I don't know how to do that. However, these are your words in a book:

> I can speak in Spanish, English, French, Chinese, and Parseltongue!
>
> —*Teagan Edgeworth*

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To my wife and children for allowing me to avoid many family adventures while this book was being developed and supporting me though the entire process. Love you guys!

To Russ Long, a long-time friend and a man whom I can trust. Thank you for finding my mistakes before the readers do. You have always been there to make me look my best. (*The R&R Show* for life!)

To Hector Mendoza, Jr.: I don't know you personally, but you found those little things that make a huge difference to the readers, and for that I thank you!

To Brett Bartow, thanks for trusting us to put this book together and put our knowledge on paper.

To MJB, thank you for keeping me on task and making sure nothing slipped through the cracks.

Finally, thank you to the entire team at Cisco Press, as well as their families and friends, who work extremely hard to produce high-quality training material.

Brad Edgeworth:
To Raymond and Brett, thanks for letting me write this book. I am privileged to be able to share my knowledge with others, and I'm grateful. To the rest of the Cisco Press team, thanks for taking my block of stone and turning it into a work of art.

To the technical editors: Hector and Russ, thank you for finding our mistakes before everyone else found them. If any slipped by, I completely blame the both of you.

Many people within Cisco have shared their knowledge with me and taken a chance on me with various projects over the years. For that I'm forever indebted. Special gratitude goes to Craig Smith, Aaron Foss, Ramiro Garza Rios, Vinit Jain, Richard Furr, David Prall, Dustin Schuemann, Tyson Scott, Denise Fishbourne, Tyler Creek, and Mohammad Ali.

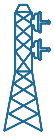
Icons Used in This Book


ASA Firewall

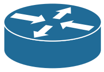

LAN Segment


Serial


Switched Circuit


Radio Tower


Routing Domain


Router

Command Syntax Conventions

The conventions used to present command syntax in this book are the same conventions used in the IOS Command Reference. The Command Reference describes these conventions as follows:

- **Boldface** indicates commands and keywords that are entered literally as shown. In actual configuration examples and output (not general command syntax), boldface indicates commands that are manually input by the user (such as a **show** command).
- *Italic* indicates arguments for which you supply actual values.
- Vertical bars (|) separate alternative, mutually exclusive elements.
- Square brackets ([ ]) indicate an optional element.
- Braces ({ }) indicate a required choice.
- Braces within brackets ([{ }]) indicate a required choice within an optional element.

Introduction

Congratulations! If you are reading this Introduction, then you have probably decided to obtain your Cisco CCNP Enterprise certification. Obtaining a Cisco certification will ensure that you have a solid understanding of common industry protocols along with Cisco's device architecture and configuration. Cisco has a high market share of routers and switches, with a global footprint.

Professional certifications have been an important part of the computing industry for many years and will continue to become more important. Many reasons exist for these certifications, but the most popularly cited reason is credibility. All other considerations held equal, a certified employee/consultant/job candidate is considered more valuable than one who is not certified.

Cisco provides three primary certifications:

Cisco Certified Network Associate (CCNA), Cisco Certified Network Professional (CCNP), and Cisco Certified Internetwork Expert (CCIE).

Cisco announced changes to all three certifications to take effect in February 2020. The announcement included many changes, but these are the most notable:

- The exams will include additional topics, such as programming.
- The CCNA certification is not a prerequisite for obtaining the CCNP certification. CCNA specializations will not be offered anymore.
- The exams will test a candidate's ability to configure and troubleshoot network devices in addition to answering multiple-choice questions.
- The CCNP is obtained by taking and passing a Core exam and a Concentration exam, like the Implementing Cisco Enterprise Advanced Routing and Services (ENARSI).

CCNP Enterprise candidates need to take and pass the CCNP and CCIE Enterprise Core ENCOR 350-401 examination. Then they need to take and pass one of the following Concentration exams to obtain their CCNP Enterprise:

- 300-410 ENARSI to obtain Implementing Cisco Enterprise Advanced Routing and Services (ENARSI)
- 300-415 ENSDWI to obtain Implementing Cisco SD-WAN Solutions (SDWAN300)
- 300-420 ENSLD to obtain Designing Cisco Enterprise Networks (ENSLD)
- 300-425 ENWLSD to obtain Designing Cisco Enterprise Wireless Networks (ENWLSD)
- 300-430 ENWLSI to obtain Implementing Cisco Enterprise Wireless Networks (ENWLSI)
- 300-435 ENAUTO to obtain Implementing Automation for Cisco Enterprise Solutions (ENAUI)

Goals and Methods

The most important and somewhat obvious goal of this book is to help you pass the CCNP Implementing Cisco Enterprise Advanced Routing and Services (ENARSI) 300-410 exam. In fact, if the primary objective of this book were different, then the book's title would be misleading; however, the methods used in this book to help you pass the exam are designed to also make you much more knowledgeable about how to do your job.

One key methodology used in this book is to help you discover the exam topics that you need to review in more depth, to help you fully understand and remember those details, and to help you prove to yourself that you have retained your knowledge of those topics. This book does not try to help you pass by memorization but helps you truly learn and understand the topics. The ENARSI 300-410 exam covers foundation topics in the CCNP certification, and the knowledge contained within is vitally important for a truly skilled routing/switching engineer or specialist. This book would do you a disservice if it didn't attempt to help you learn the material. To that end, the book will help you pass the exam by using the following methods:

- Helping you discover which test topics you have not mastered
- Providing explanations and information to fill in your knowledge gaps
- Supplying exercises and scenarios that enhance your ability to recall and deduce the answers to test questions
- Providing practice exercises on the topics and the testing process via test questions on the companion website

Who Should Read This Book?

This book is not designed to be a general networking topics book, although it can be used for that purpose. This book is intended to tremendously increase your chances of passing the ENARSI 300-410 exam. Although other objectives can be achieved from using this book, the book is written with one goal in mind: to help you pass the exam.

So why should you want to pass the ENARSI 300-410 exam? Because it's one of the milestones toward getting the CCNP Enterprise certification, which is no small feat. What would getting the CCNP Enterprise certification mean to you? A raise, a promotion, recognition? How about enhancing your resume? Demonstrating that you are serious about continuing the learning process and that you're not content to rest on your laurels? Pleasing your reseller-employer, who needs more certified employees for a higher discount from Cisco? You might have one of these reasons for getting the CCNP Enterprise certification or one of many others.

Strategies for Exam Preparation

The strategy you use for taking the ENARSI 300-410 exam might be slightly different from strategies used by other readers, depending on the skills, knowledge, and experience you already have obtained. For instance, if you have attended the CCNP Implementing Cisco Enterprise Advanced Routing and Services (ENARSI) 300-410 course, you might take a different approach than someone who learned routing through on-the-job training.

Regardless of the strategy you use or the background you have, this book is designed to help you get to the point where you can pass the exam with the least amount of time required. For instance, there is no need for you to practice or read about IP addressing and subnetting if you fully understand it already. However, many people like to make sure that they truly know a topic and thus read over material that they already know. Several book features will help you gain the confidence you need to be convinced that you know some material already and to also help you know what topics you need to study more.

How This Book Is Organized

Although this book could be read cover-to-cover, it is designed to be flexible and allow you to easily move between chapters and sections of chapters to cover just the material that you need more work with. If you intend to read the entire book, the order in the book is an excellent sequence to use.

The chapters cover the following topics:

- **Chapter 1, "IPv4/IPv6 Addressing and Routing Review":** This chapter provides a review of IPv4 and IPv6 addressing, DHCP, and routing, as well as details about how to troubleshoot these topics.
- **Chapter 2, "EIGRP":** This chapter explains the underlying mechanics of the EIGRP routing protocol, the path metric calculations, and how to configure EIGRP.
- **Chapter 3, "Advanced EIGRP":** This chapter explains the a variety of advanced concepts, such as failure detection, network summarization, router filtering, and techniques to optimize WAN sites.
- **Chapter 4, "Troubleshooting EIGRP for IPv4":** This chapter focuses on how to troubleshoot EIGRP neighbor adjacency issues as well as EIGRP route issues.
- **Chapter 5, "EIGRPv6":** This chapter explains how EIGRP advertises IPv6 networks and guides you through configuring, verifying, and troubleshooting EIGRPv6.
- **Chapter 6, "OSPF":** This chapter explains the core concepts of OSPF, the exchange of routes, OSPF network types, failure detection, and OSPF authentication.
- **Chapter 7, "Advanced OSPF":** This chapter expands on Chapter 6 by explaining the OSPF database and how it builds the topology. It also explains OSPF path selection, router summarization, and techniques to optimize an OSPF environment.
- **Chapter 8, "Troubleshooting OSPFv2":** This chapter explores how to troubleshooting OSPFv2 neighbor adjacency issues as well as route issues.

- **Chapter 9, "OSPFv3":** This chapter explains how the OSPF protocol has changed to accommodate support of the IPv6 protocol.
- **Chapter 10, "Troubleshooting OSPFv3":** This chapter explains how you can troubleshooting issues that may arise with OSPFv3.
- **Chapter 11, "BGP":** This chapter explains the core concepts of BGP, its path attributes, and configuration for IPv4 and IPv6 network prefixes.
- **Chapter 12, "Advanced BGP":** This chapter expands on Chapter 11 by explaining BGP communities and configuration techniques for routers with lots of BGP peerings.
- **Chapter 13, "BGP Path Selection":** This chapter explains the BGP path selection process, how BGP identifies the best BGP path, and methods for load balancing across equal paths.
- **Chapter 14, "Troubleshooting BGP":** This chapter explores how you can identify and troubleshoot issues relating to BGP neighbor adjacencies, BGP routes, and BGP path selection. It also covers MP-BGP (BGP for IPv6).
- **Chapter 15, "Route Maps and Conditional Forwarding":** This chapter explains route maps, concepts for selecting a network prefix, and how packets can be conditionally forwarded out different interfaces for certain network traffic.
- **Chapter 16, "Route Redistribution":** This chapter explains the rules of redistribution, configuration for route redistribution, and behaviors of redistribution based on the source or destination routing protocol.
- **Chapter 17, "Troubleshooting Redistribution":** This chapter focuses on how to troubleshoot issues related to redistribution, including configuration issues, suboptimal routing issues, and routing loop issues.
- **Chapter 18, "VRF, MPLS, and MPLS Layer 3 VPNs":** This chapter explores how to configure and verify VRF and introduces you to MPLS operations and MPLS Layer 3 VPNs.
- **Chapter 19, "DMVPN Tunnels":** This chapter covers GRE tunnels, NHRP, DMVPN, and techniques to optimize a DMVPN deployment.
- **Chapter 20, "Securing DMVPN Tunnels":** This chapter explains the importance of securing network traffic on the WAN and techniques for deploying IPsec tunnel protection for DMVPN tunnels.
- **Chapter 21, "Troubleshooting ACLs and Prefix Lists":** This chapter shows how to troubleshoot issues related to IPv4 and IPv6 access control lists and prefix lists.
- **Chapter 22, "Infrastructure Security":** This chapter covers how to troubleshoot AAA issues, uRPF issues, and CoPP issues. In addition, it introduces various IPv6 First-Hop Security features.
- **Chapter 23, "Device Management and Management Tools Troubleshooting":** This chapter explores how to troubleshoot issues that you might experience with local or

remote access, remote transfers, syslog, SNMP, IP SLA, Object Tracking, NetFlow, and Flexible NetFlow. In addition, it introduces the troubleshooting options available with Cisco DNA Center Assurance.

- The last chapter, **Chapter 24**, **“Final Preparation,”** provides tips and strategies for studying for the ENARSI 300-410 exam.

Certification Exam Topics and This Book

The questions for each certification exam are a closely guarded secret. However, we do know which topics you must know to *successfully* complete the ENARSI 300-410 exam. Cisco publishes them as an exam blueprint. Table I-1 lists the exam topics from the blueprint along with references to the book chapters that cover each topic. These are the same topics you should be proficient in when working with enterprise technologies in the real world.

Table I-1 Enterprise Core Topics and Chapter References

Implementing Cisco Enterprise Advanced Routing (ENARSI) (300-410) Exam Topic	Chapter(s) in Which Topic Is Covered
1.0 Layer 3 Technologies	
1.1 Troubleshoot administrative distance (all routing protocols)	1
1.2 Troubleshoot route map for any routing protocol (attributes, tagging, filtering)	17
1.3 Troubleshoot loop prevention mechanisms (filtering, tagging, split horizon, route poisoning)	17
1.4 Troubleshoot redistribution between any routing protocols or routing sources	16, 17
1.5 Troubleshoot manual and auto-summarization with any routing protocol	3, 4, 5, 7, 8, 9, 10, 12
1.6 Configure and verify policy-based routing	15
1.7 Configure and verify VRF-Lite	18
1.8 Describe Bidirectional Forwarding Detection	23
1.9 Troubleshoot EIGRP (classic and named mode)	4, 5
1.9.a Address families (IPv4, IPv6)	2, 3, 4, 5
1.9.b Neighbor relationship and authentication	2, 4, 5
1.9.c Loop-free path selections (RD, FD, FC, successor, feasible successor, stuck in active)	3, 4
1.9.d Stubs	4
1.9.e Load balancing (equal and unequal cost)	2
1.9.f Metrics	2
1.10 Troubleshoot OSPF (v2/v3)	6, 7, 8, 9, 10
1.10.a Address families (IPv4, IPv6)	8, 10
1.10.b Neighbor relationship and authentication	6, 8, 10

Implementing Cisco Enterprise Advanced Routing (ENARSI) (300-410) Exam Topic	Chapter(s) in Which Topic Is Covered
1.10.c Network types, area types, and router types	8, 10
1.10.c (i) Point-to-point, multipoint, broadcast, nonbroadcast	6, 8, 10
1.10.c (ii) Area type: backbone, normal, transit, stub, NSSA, totally stub	7, 8, 10
1.10.c (iii) Internal router, backbone router, ABR, ASBR	6, 8, 10
1.10.c (iv) Virtual link	7, 8
1.10.d Path preference	7
1.11 Troubleshoot BGP (Internal and External)	11, 12, 13, 14
1.11.a Address families (IPv4, IPv6)	10, 14
1.11.b Neighbor relationship and authentication (next-hop, mulithop, 4-byte AS, private AS, route refresh, synchronization, operation, peer group, states and timers)	10, 14
1.11.c Path preference (attributes and best-path)	13, 14
1.11.d Route reflector (excluding multiple route reflectors, confederations, dynamic peer)	10
1.11.e Policies (inbound/outbound filtering, path manipulation)	11, 14
2.0 VPN Technologies	
2.1 Describe MPLS operations (LSR, LDP, label switching, LSP)	18
2.2 Describe MPLS Layer 3 VPN	18
2.3 Configure and verify DMVPN (single hub)	19, 20
2.3.a GRE/mGRE	19
2.3.b NHRP	19
2.3.c IPsec	20
2.3.d Dynamic neighbor	19
2.3.e Spoke-to-spoke	19
3.0 Infrastructure Security	
3.1 Troubleshoot device security using IOS AAA (TACACS+, RADIUS, local database)	22
3.2 Troubleshoot router security features	
3.2.a IPv4 access control lists (standard, extended, time-based)	21
3.2.b IPv6 traffic filter	21
3.2.c Unicast reverse path forwarding (uRPF)	22
3.3 Troubleshoot control plane policing (CoPP) (Telnet, SSH, HTTP(S), SNMP, EIGRP, OSPF, BGP)	22
3.4 Describe IPv6 First Hop Security features (RA Guard, DHCP Guard, binding table, ND inspection/snooping, Source Guard)	22
4.0 Infrastructure Services	
4.1 Troubleshoot device management	23
4.1.a Console and VTY	23

Implementing Cisco Enterprise Advanced Routing (ENARSI) (300-410) Exam Topic	Chapter(s) in Which Topic Is Covered
4.1.b Telnet, HTTP, HTTPS, SSH, SCP	23
4.1.c (T)FTP	23
4.2 Troubleshoot SNMP (v2c, v3)	23
4.3 Troubleshoot network problems using logging (local, syslog, debugs, conditional debugs, timestamps)	23
4.4 Troubleshoot IPv4 and IPv6 DHCP (DHCP client, IOS DHCP server, DHCP relay, DHCP options)	1
4.5 Troubleshoot network performance issues using IP SLA (jitter, tracking objects, delay, connectivity)	23
4.6 Troubleshoot NetFlow (v5, v9, flexible NetFlow)	23
4.7 Troubleshoot network problems using Cisco DNA Center assurance (connectivity, monitoring, device health, network health)	23

Each version of the exam can have topics that emphasize different functions or features, and some topics can be rather broad and generalized. The goal of this book is to provide the most comprehensive coverage to ensure that you are well prepared for the exam. Although some chapters might not address specific exam topics, they provide a foundation that is necessary for a clear understanding of important topics.

It is also important to understand that this book is a “static” reference, whereas the exam topics are dynamic. Cisco can and does change the topics covered on certification exams often.

This exam guide should not be your only reference when preparing for the certification exam. You can find a wealth of information at Cisco.com that covers each topic in great detail. If you think that you need more detailed information on a specific topic, read the Cisco documentation that focuses on that topic.

Learning in a Lab Environment

This book is an excellent self-study resource for learning the technologies. However, reading is not enough, and any network engineer can tell you that you must implement a technology to fully understand it. We encourage the reader to re-create the topologies and technologies and follow the examples in this book.

A variety of resources are available for practicing the concepts in this book. Look online for the following:

- Cisco VIRL (Virtual Internet Routing Lab) provides a scalable, extensible network design and simulation environment. For more information about VIRL, see http://virl.cisco.com.
- Cisco dCloud provides a huge catalog of demos, training, and sandboxes for every Cisco architecture. It offers customizable environments and is free. For more information, see http://dcloud.cisco.com.
- Cisco Devnet provides many resources on programming and programmability, along with free labs. For more information, see http://developer.cisco.com.

CHAPTER 2

EIGRP

This chapter covers the following topics:

- **EIGRP Fundamentals:** This section explains how EIGRP establishes a neighborship with other routers and how routes are exchanged with other routers.
- **EIGRP Configuration Modes:** This section defines the two methods of configuring EIGRP with a baseline configuration.
- **Path Metric Calculation:** This section explains how EIGRP calculates the path metric to identify the best and alternate loop-free paths.

Enhanced Interior Gateway Routing Protocol (*EIGRP*) is an enhanced distance vector routing protocol commonly found in enterprise networks. EIGRP is a derivative of Interior Gateway Routing Protocol (IGRP) but includes support for variable-length subnet masking (VLSM) and metrics capable of supporting higher-speed interfaces. Initially, EIGRP was a Cisco proprietary protocol, but it was released to the Internet Engineering Task Force (IETF) through RFC 7868, which was ratified in May 2016.

This chapter explains the underlying mechanics of the EIGRP routing protocol and the path metric calculations, and it demonstrates how to configure EIGRP on a router. This is the first of several chapters in the book that discuss EIGRP:

- **Chapter 2, "EIGRP":** This chapter describes the fundamental concepts of EIGRP.
- **Chapter 3, "Advanced EIGRP":** This chapter describes EIGRP's failure detection mechanisms and techniques to optimize the operations of the routing protocol. It also includes topics such as route filtering and traffic manipulation.
- **Chapter 4, "Troubleshooting EIGRP for IPv4":** This chapter reviews common problems with the routing protocols and the methodology to troubleshoot EIGRP from an IPv4 perspective.
- **Chapter 5, "EIGRPv6":** This chapter demonstrates how IPv4 EIGRP concepts carry over to IPv6 and the methods to troubleshoot common problems.

"Do I Know This Already?" Quiz

The "Do I Know This Already?" quiz allows you to assess whether you should read this entire chapter thoroughly or jump to the "Exam Preparation Tasks" section. If you are in doubt about your answers to these questions or your own assessment of your knowledge of the topics, read the entire chapter. Table 2-1 lists the major headings in this chapter and their corresponding "Do I Know This Already?" quiz questions. You can find the answers in Appendix A, "Answers to the 'Do I Know This Already?' Quiz Questions."

Table 2-1 "Do I Know This Already?" Foundation Topics Section-to-Question Mapping

Foundation Topics Section	Questions
EIGRP Fundamentals	1–6
EIGRP Configuration Modes	7–9
Path Metric Calculation	10

CAUTION The goal of self-assessment is to gauge your mastery of the topics in this chapter. If you do not know the answer to a question or are only partially sure of the answer, you should mark that question as wrong for purposes of self-assessment. Giving yourself credit for an answer that you correctly guess skews your self-assessment results and might provide you with a false sense of security.

1. EIGRP uses protocol number ____ for inter-router communication.
   a. 87
   b. 88
   c. 89
   d. 90
2. How many packet types does EIGRP use for inter-router communication?
   a. Three
   b. Four
   c. Five
   d. Six
   e. Seven
3. Which of the following is not required to match to form an EIGRP adjacency?
   a. Metric K values
   b. Primary subnet
   c. Hello and hold timers
   d. Authentication parameters
4. What is an EIGRP successor?
   a. The next-hop router for the path with the lowest path metric for a destination prefix
   b. The path with the lowest metric for a destination prefix
   c. The router selected to maintain the EIGRP adjacencies for a broadcast network
   d. A route that satisfies the feasibility condition where the reported distance is less than the feasible distance

5. What attributes does the EIGRP topology table contain? (Choose all that apply.)
   a. Destination network prefix
   b. Hop Count
   c. Total path delay
   d. Maximum path bandwidth
   e. List of EIGRP neighbors
6. What destination addresses does EIGRP use when feasible? (Choose two.)
   a. IP address 224.0.0.9
   b. IP address 224.0.0.10
   c. IP address 224.0.0.8
   d. MAC address 01:00:5E:00:00:0A
   e. MAC address 0C:15:C0:00:00:01
7. The EIGRP process is initialized by which of the following technique? (Choose two.)
   a. Using the interface command **ip eigrp** *as-number* **ipv4 unicast**
   b. Using the global configuration command **router eigrp** *as-number*
   c. Using the global configuration command **router eigrp** *process-name*
   d. Using the interface command **router eigrp** *as-number*
8. True or false: The EIGRP router ID (RID) must be configured for EIGRP to be able to establish neighborship.
   a. True
   b. False
9. True or false: When using MD5 authentication between EIGRP routers, the key-chain sequence number can be different, as long as the password is the same.
   a. True
   b. False
10. Which value can be modified on a router to manipulate the path taken by EIGRP but does not have impacts on other routing protocols, like OSPF?
    a. Interface bandwidth
    b. Interface MTU
    c. Interface delay
    d. Interface priority

Foundation Topics

EIGRP Fundamentals

EIGRP overcomes the deficiencies of other distance vector routing protocols, such as Routing Information Protocol (RIP), with features such as unequal-cost load balancing, support for networks 255 hops away, and rapid convergence features. EIGRP uses a *diffusing update algorithm* (*DUAL*) to identify network paths and provides for fast convergence using precalculated loop-free backup paths. Most distance vector routing protocols use hop count as the metric for routing decisions. Using hop count for path selection does not take into account link speed and total delay. EIGRP adds logic to the route-selection algorithm that uses factors besides hop count.

Autonomous Systems

A router can run multiple EIGRP processes. Each process operates under the context of an autonomous system, which represents a common routing domain. Routers within the same domain use the same metric calculation formula and exchange routes only with members of the same autonomous system. Do not confuse an EIGRP autonomous system with a Border Gateway Protocol (BGP) autonomous system.

In Figure 2-1, EIGRP autonomous system (AS) 100 consists of R1, R2, R3, R4, and EIGRP AS 200 consists of R3, R5, and R6. Each EIGRP process correlates to a specific autonomous system and maintains an independent EIGRP topology table. R1 does not have knowledge of routes from AS 200 because it is different from its own autonomous system, AS 100. R3 is able to participate in both autonomous systems and, by default, does not transfer routes learned from one autonomous system into a different autonomous system.

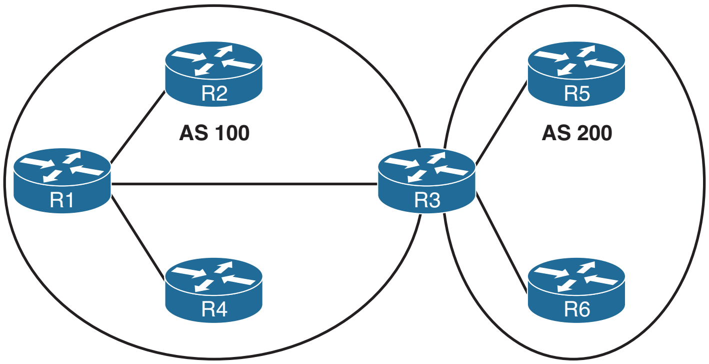


Figure 2-1 *EIGRP Autonomous Systems*

EIGRP uses *protocol-dependent modules* (*PDMs*) to support multiple network protocols, such as IPv4, IPv6, AppleTalk, and IPX. EIGRP is written so that the PDM is responsible for the functions to handle the route selection criteria for each communication protocol. In theory, new PDMs can be written as new communication protocols are created. Current implementations of EIGRP support only IPv4 and IPv6.

EIGRP Terminology

This section explains some of the core concepts of EIGRP, along with the path selection process. Figure 2-2 is used as a reference topology for R1 calculating the best path and alternative loop-free paths to the 10.4.4.0/24 network. The values in parentheses represent the link's calculated metric for a segment based on bandwidth and delay.

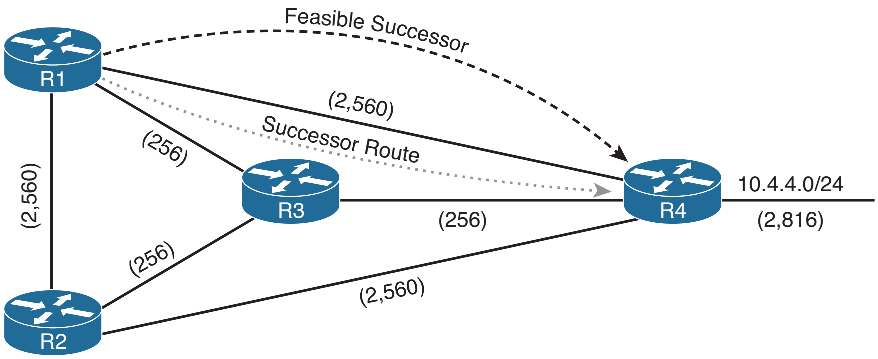


Figure 2-2 *EIGRP Reference Topology*

Table 2-2 defines important terms related to EIGRP and correlates them to Figure 2-2.

Key Topic

Table 2-2 EIGRP Terminology

Term	Definition
Successor route	The route with the lowest path metric to reach a destination. The successor route for R1 to reach 10.4.4.0/24 on R4 is R1→R3→R4.
Successor	The first next-hop router for the successor route. The successor for 10.4.4.0/24 is R3.
Feasible distance (FD)	The metric value for the lowest-metric path to reach a destination. The feasible distance is calculated locally using the formula shown in the "Path Metric Calculation" section, later in this chapter. The FD calculated by R1 for the 10.4.4.0/24 network is 3328 (that is, 256 + 256 + 2816).
Reported distance (RD)	Distance reported by a router to reach a prefix. The reported distance value is the feasible distance for the advertising router. R3 advertises the 10.4.4.0/24 prefix with an RD of 3072. R4 advertises the 10.4.4.0/24 to R1 and R2 with an RD of 2816.
Feasibility condition	For a route to be considered a backup route, the RD received for that route must be less than the FD calculated locally. This logic guarantees a loop-free path.
Feasible successor	A route with that satisfies the feasibility condition is maintained as a backup route. The feasibility condition ensures that the backup route is loop free. The route R1→R4 is the feasible successor because the RD of 2816 is lower than the FD of 3328 for the R1→R3→R4 path.

Key Topic

Topology Table

EIGRP contains a topology table, which makes it different from a true distance vector routing protocol. EIGRP's topology table is a vital component of DUAL and contains information to identify loop-free backup routes. The topology table contains all the network prefixes advertised within an EIGRP autonomous system. Each entry in the table contains the following:

- Network prefix
- EIGRP neighbors that have advertised that prefix
- Metrics from each neighbor (reported distance and hop count)
- Values used for calculating the metric (load, reliability, total delay, and minimum bandwidth)

The command **show ip eigrp topology** [**all-links**] provides the topology table. By default, only the successor and feasible successor routes are displayed, but the optional **all-links** keyword shows the paths that did not pass the feasibility condition.

Figure 2-3 shows the topology table for R1 from Figure 2-2. This section focuses on the 10.4.4.0/24 network when explaining the topology table.

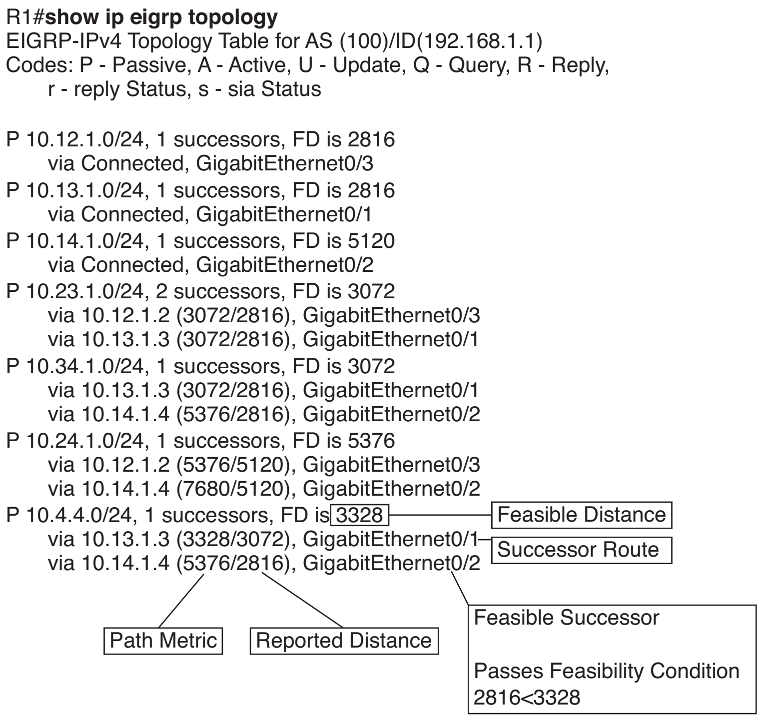


Figure 2-3 *EIGRP Topology Output*

Examine the network 10.4.4.0/24 and notice that R1 calculates an FD of 3328 for the successor route. The successor (upstream router) advertises the successor route with an RD of 3072. The second path entry has a metric of 5376 and has an RD of 2816. Because 2816 is less than 3072, the second entry passes the feasibility condition and classifies the second entry as the feasible successor for the prefix.

The 10.4.4.0/24 route is passive (P), which means the topology is stable. During a topology change, routes go into an active (A) state when computing a new path.

EIGRP Neighbors

EIGRP does not rely on periodic advertisement of all the network prefixes in an autonomous system, which is done with routing protocols such as Routing Information Protocol (RIP), Open Shortest Path First (OSPF), and Intermediate System-to-Intermediate System (IS-IS). EIGRP neighbors exchange the entire routing table when forming an adjacency, and they advertise incremental updates only as topology changes occur within a network. The neighbor adjacency table is vital for tracking neighbor status and the updates sent to each neighbor.

Inter-Router Communication

EIGRP uses five different packet types to communicate with other routers, as shown in Table 2-3. EIGRP uses its own IP protocol number (88) and uses multicast packets where possible; it uses unicast packets when necessary. Communication between routers is done with multicast using the group address 224.0.0.10 or the MAC address 01:00:5e:00:00:0a when possible.

Key Topic

Table 2-3 EIGRP Packet Types

Packet Type	Packet Name	Function
1	Hello	Used for discovery of EIGRP neighbors and for detecting when a neighbor is no longer available
2	Request	Used to get specific information from one or more neighbors
3	Update	Used to transmit routing and reachability information with other EIGRP neighbors
4	Query	Sent out to search for another path during convergence
5	Reply	Sent in response to a query packet

NOTE EIGRP uses multicast packets to reduce bandwidth consumed on a link (one packet to reach multiple devices). While broadcast packets are used in the same general way, all nodes on a network segment process broadcast packets, whereas with multicast, only nodes listening for the particular multicast group process the multicast packets.

EIGRP uses *Reliable Transport Protocol* (*RTP*) to ensure that packets are delivered in order and to ensure that routers receive specific packets. A sequence number is included in each EIGRP packet. The sequence value zero does not require a response from the receiving EIGRP router; all other values require an ACK packet that includes the original sequence number.

Ensuring that packets are received makes the transport method reliable. All update, query, and reply packets are deemed reliable, and hello and ACK packets do not require acknowledgment and could be unreliable.

If the originating router does not receive an ACK packet from the neighbor before the retransmit timeout expires, it notifies the non-acknowledging router to stop processing its multicast packets. The originating router sends all traffic by unicast until the neighbor is fully synchronized. Upon complete synchronization, the originating router notifies the destination router to start processing multicast packets again. All unicast packets require acknowledgment. EIGRP retries up to 16 times for each packet that requires confirmation, and it resets the neighbor relationship when the neighbor reaches the retry limit of 16.

NOTE In the context of EIGRP, do not confuse RTP with the Real-Time Transport Protocol (RTP), which is used for carrying audio or video over an IP network. EIGRP's RTP allows for confirmation of packets while supporting multicast. Other protocols that require reliable connection-oriented communication, such as TCP, cannot use multicast addressing.

Key Topic

Forming EIGRP Neighbors

Unlike other distance vector routing protocols, EIGRP requires a neighbor relationship to form before routes are processed and added to the Routing Information Base (RIB). Upon hearing an EIGRP hello packet, a router attempts to become the neighbor of the other router. The following parameters must match for the two routers to become neighbors:

- Metric formula K values
- Primary subnet matches
- Autonomous system number (ASN) matches
- Authentication parameters

Figure 2-4 shows the process EIGRP uses for forming neighbor adjacencies.

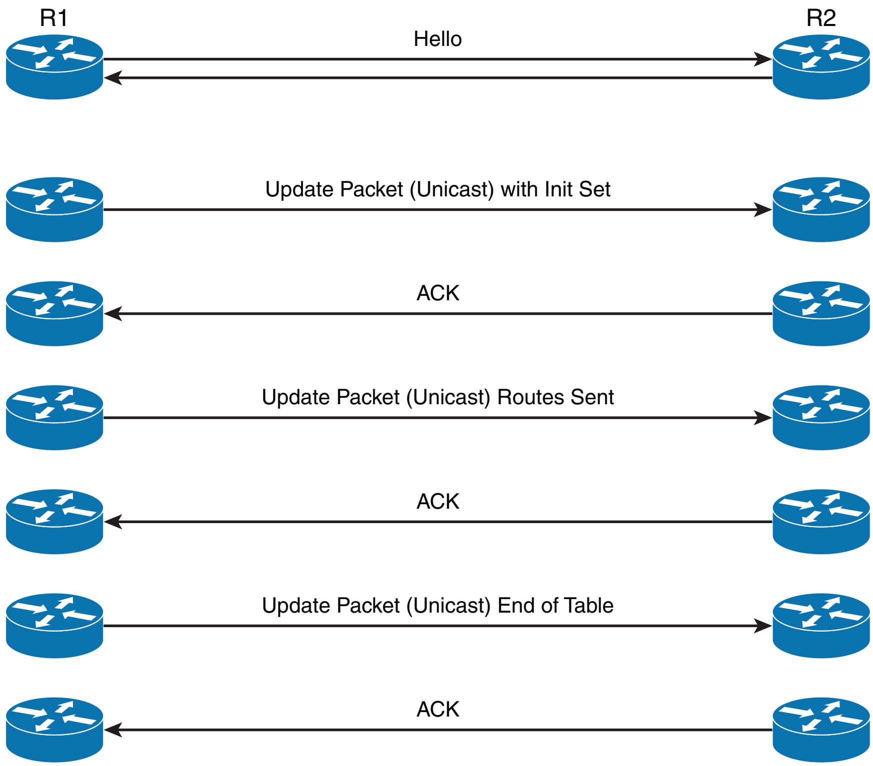


Figure 2-4 *EIGRP Neighbor Adjacency Process from R1's Perspective*

EIGRP Configuration Modes

This section describes the two methods of EIGRP configuration: classic mode and named mode.

Classic Configuration Mode

With classic EIGRP configuration mode, most of the configuration takes place in the EIGRP process, but some settings are configured under the interface configuration submode. This can add complexity for deployment and troubleshooting as users must scroll back and forth between the EIGRP process and individual network interfaces. Some of the settings set individually are hello advertisement interval, split-horizon, authentication, and summary route advertisements.

Key Topic

Classic configuration requires the initialization of the routing process with the global configuration command **router eigrp** *as-number* to identify the ASN and initialize the EIGRP process. The second step is to identify the network interfaces with the command **network** *ip-address* [*mask*]. The network statement is explained in the following sections.

Key Topic

EIGRP Named Mode

EIGRP named mode configuration was released to overcome some of the difficulties network engineers have with classic EIGRP autonomous system configuration, including scattered configurations and unclear scope of commands.

EIGRP named configuration provides the following benefits:

- All the EIGRP configuration occurs in one location.
- It supports current EIGRP features and future developments.
- It supports multiple address families (including Virtual Routing and Forwarding [VRF] instances). EIGRP named configuration is also known as *multi-address family configuration mode*.
- Commands are clear in terms of the scope of their configuration.

EIGRP named mode provides a hierarchical configuration and stores settings in three subsections:

- **Address Family:** This submode contains settings that are relevant to the global EIGRP AS operations, such as selection of network interfaces, EIGRP K values, logging settings, and stub settings.
- **Interface:** This submode contains settings that are relevant to the interface, such as hello advertisement interval, split-horizon, authentication, and summary route advertisements. In actuality, there are two methods of the EIGRP interface section's configuration. Commands can be assigned to a specific interface or to a *default* interface, in which case those settings are placed on all EIGRP-enabled interfaces. If there is a conflict between the default interface and a specific interface, the specific interface takes priority over the default interface.
- **Topology:** This submode contains settings regarding the EIGRP topology database and how routes are presented to the router's RIB. This section also contains route redistribution and administrative distance settings.

EIGRP named configuration makes it possible to run multiple instances under the same EIGRP process. The process for enabling EIGRP interfaces on a specific instance is as follows:

Step 1. Initialize the EIGRP process by using the command **router eigrp** *process-name*. (If a number is used for *process-name*, the *number* does not correlate to the autonomous system number.)

Step 2. Initialize the EIGRP instance for the appropriate address family with the command **address-family {IPv4 | IPv6} {unicast | vrf** *vrf-name*} *autonomous-system as-number*.

Step 3. Enable EIGRP on interfaces by using the command **network** *network mask*.

EIGRP Network Statement

Both configuration modes use a network statement to identify the interfaces that EIGRP will use. The network statement uses a wildcard mask, which allows the configuration to be as specific or ambiguous as necessary.

NOTE The two styles of EIGRP configuration are independent. Using the configuration options from classic EIGRP autonomous system configuration does not modify settings on a router running EIGRP named configuration.

The syntax for the network statement, which exists under the EIGRP process, is **network** *ip-address* [*mask*]. The optional *mask* can be omitted to enable interfaces that fall within the classful boundaries for that network statement.

A common misconception is that the **network** statement adds the networks to the EIGRP topology table. In reality, the **network** statement identifies the interface to enable EIGRP on, and it adds the interface's connected network to the EIGRP topology table. EIGRP then advertises the topology table to other routers in the EIGRP autonomous system.

EIGRP does not add an interface's secondary connected network to the topology table. For secondary connected networks to be installed in the EIGRP routing table, they must be redistributed into the EIGRP process. Chapter 16, "Route Redistribution," provides additional coverage of route redistribution.

To help illustrate the concept of the wildcard mask, Table 2-4 provides a set of IP addresses and interfaces for a router. The following examples provide configurations to match specific scenarios.

Table 2-4 Table of Sample Interface and IP Addresses

Router Interface	IP Address
Gigabit Ethernet 0/0	10.0.0.10/24
Gigabit Ethernet 0/1	10.0.10.10/24
Gigabit Ethernet 0/2	192.0.0.10/24
Gigabit Ethernet 0/3	192.10.0.10/24

The configuration in Example 2-1 enables EIGRP only on interfaces that explicitly match the IP addresses in Table 2-4.

Example 2-1 *EIGRP Configuration with Explicit IP Addresses*

```
Router eigrp 1
    network 10.0.0.10 0.0.0.0
    network 10.0.10.10 0.0.0.0
    network 192.0.0.10 0.0.0.0
    network 192.10.0.10 0.0.0.0
```

Example 2-2 shows the EIGRP configuration using **network** statements that match the subnets used in Table 2-4. Setting the last octet of the IP address to 0 and changing the wildcard mask to 255 causes the network statements to match all IP addresses within the /24 network range.

Example 2-2 *EIGRP Configuration with Explicit Subnet*

```
Router eigrp  1
    network 10.0.0.0 0.0.0.255
    network 10.0.10.0 0.0.0.255
    network 192.0.0.0 0.0.0.255
    network 192.10.0.0 0.0.0.255
```

The following snippet shows the EIGRP configuration using **network** statements for interfaces that are within the 10.0.0.0/8 or 192.0.0.0/8 network ranges:

```
router eigrp  1
     network 10.0.0.0 0.255.255.255
     network 192.0.0.0 0.255.255.255
```

The following snippet shows the configuration to enable all interfaces with EIGRP:

```
router eigrp  1
     network 0.0.0.0 255.255.255.255
```

NOTE A key topic with wildcard network statements is that large ranges simplify configuration; however, they may possibly enable EIGRP on unintended interfaces.

Sample Topology and Configuration

Figure 2-5 shows a sample topology for demonstrating EIGRP configuration in classic mode for R1 and named mode for R2.

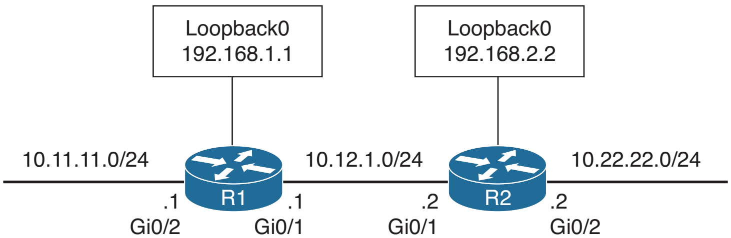


Figure 2-5 *EIGRP Sample Topology*

R1 and R2 enable EIGRP on all of their interfaces. R1 configures EIGRP using multiple specific network interface addresses, and R2 enables EIGRP on all network interfaces with one command. Example 2-3 provides the configuration that is applied to R1 and R2.

Example 2-3 *Sample EIGRP Configuration*

```
R1 (Classic Configuration)
interface Loopback0
 ip address 192.168.1.1 255.255.255.255
!
interface GigabitEthernet0/1
    ip address 10.12.1.1 255.255.255.0
!
interface GigabitEthernet0/2
    ip address 10.11.11.1 255.255.255.0
!
router eigrp 100
 network 10.11.11.1 0.0.0.0
 network 10.12.1.1 0.0.0.0
 network 192.168.1.1 0.0.0.0
```

```
R2 (Named Mode Configuration)
interface Loopback0
 ip address 192.168.2.2 255.255.255.255
!
interface GigabitEthernet0/1
    ip address 10.12.1.2 255.255.255.0
!
interface GigabitEthernet0/2
    ip address 10.22.22.2 255.255.255.0
!
router eigrp EIGRP-NAMED
 address-family ipv4 unicast autonomous-system 100
  network 0.0.0.0 255.255.255.255
```

As mentioned earlier, EIGRP named mode has three configuration submodes. The configuration from Example 2-3 uses only the EIGRP address-family submode section, which uses the **network** statement. The EIGRP topology base submode is created automatically with the command **topology base** and exited with the command **exit-af-topology**. Settings for the topology submode are listed between those two commands.

Example 2-4 demonstrates the slight difference in how the configuration is stored on the router between EIGRP classic and named mode configurations.

Example 2-4 *Named Mode Configuration Structure*

```
R1# show run | section router eigrp
router eigrp 100
 network 10.11.11.1 0.0.0.0
 network 10.12.1.1 0.0.0.0
 network 192.168.1.1 0.0.0.0
```

```
R2# show run | section router eigrp
router eigrp EIGRP-NAMED
 !
 address-family ipv4 unicast autonomous-system 100
  !
  topology base
  exit-af-topology
  network 0.0.0.0
 exit-address-family
```

NOTE The EIGRP interface submode configurations contain the command **af-interface** *interface-id* or **af-interface default** with any specific commands listed immediately. The EIGRP interface submode configuration is exited with the command **exit-af-interface**. This is demonstrated later in this chapter.

Confirming Interfaces

Upon configuring EIGRP, it is a good practice to verify that only the intended interfaces are running EIGRP. The command **show ip eigrp interfaces** [{*interface-id* [**detail**] | **detail**}] shows active EIGRP interfaces. Appending the optional **detail** keyword provides additional information, such as authentication, EIGRP timers, split horizon, and various packet counts.

Example 2-5 demonstrates R1's non-detailed EIGRP interface and R2's detailed information for the Gi0/1 interface.

Example 2-5 *Verification of EIGRP Interfaces*

```
R1# show ip eigrp interfaces
EIGRP-IPv4 Interfaces for AS(100)
                 Xmit Queue   PeerQ        Mean   Pacing Time  Multicast   Pending
Interface Peers  Un/Reliable  Un/Reliable  SRTT   Un/Reliable  Flow Timer  Routes
Gi0/2        0       0/0          0/0         0       0/0            0          0
Gi0/1        1       0/0          0/0        10       0/0           50          0
Lo0          0       0/0          0/0         0       0/0            0          0
```

```
R2# show ip eigrp interfaces gi0/1 detail
```

```
EIGRP-IPv4 VR(EIGRP-NAMED) Address-Family Interfaces for AS(100)
                 Xmit Queue   PeerQ        Mean   Pacing Time  Multicast  Pending
Interface Peers  Un/Reliable  Un/Reliable  SRTT   Un/Reliable  Flow Timer Routes
Gi0/1        1        0/0       0/0        1583       0/0       7912          0
  Hello-interval is 5, Hold-time is 15
  Split-horizon is enabled
  Next xmit serial <none>
  Packetized sent/expedited: 2/0
  Hello's sent/expedited: 186/2
  Un/reliable mcasts: 0/2  Un/reliable ucasts: 2/2
  Mcast exceptions: 0  CR packets: 0  ACKs suppressed: 0
  Retransmissions sent: 1  Out-of-sequence rcvd: 0
  Topology-ids on interface - 0
  Authentication mode is not set
  Topologies advertised on this interface:  base
  Topologies not advertised on this interface:
```

Table 2-5 provides a brief explanation to the key fields shown with the EIGRP interfaces.

Table 2-5 EIGRP Interface Fields

Field	Description
Interface	Interfaces running EIGRP.
Peers	Number of peers detected on that interface.
Xmt Queue Un/Reliable	Number of unreliable/reliable packets remaining in the transmit queue. The value zero is an indication of a stable network.
Mean SRTT	Average time for a packet to be sent to a neighbor and a reply from that neighbor to be received, in milliseconds.
Multicast Flow Timer	Maximum time (seconds) that the router sent multicast packets.
Pending Routes	Number of routes in the transmit queue that need to be sent.

Verifying EIGRP Neighbor Adjacencies

Each EIGRP process maintains a table of neighbors to ensure that they are alive and processing updates properly. Without keeping track of a neighbor state, an autonomous system could contain incorrect data and could potentially route traffic improperly. EIGRP must form a neighbor relationship before a router advertises update packets containing network prefixes.

The command **show ip eigrp neighbors** [*interface-id*] displays the EIGRP neighbors for a router. Example 2-6 shows the EIGRP neighbor information using this command.

Example 2-6 *EIGRP Neighbor Confirmation*

```
R1# show ip eigrp neighbors
EIGRP-IPv4 Neighbors for AS(100)
H   Address                 Interface              Hold Uptime   SRTT   RTO  Q  Seq
                                                   (sec)         (ms)       Cnt Num
0   10.12.1.2               Gi0/1                    13 00:18:31   10    100  0  3
```

Table 2-6 provides a brief explanation of the key fields shown in Example 2-6.

Table 2-6 EIGRP Neighbor Columns

Field	Description
Address	IP address of the EIGRP neighbor
Interface	Interface the neighbor was detected on
Holdtime	Time left to receive a packet from this neighbor to ensure that it is still alive
SRTT	Time for a packet to be sent to a neighbor and a reply to be received from that neighbor, in milliseconds
RTO	Timeout for retransmission (waiting for ACK)
Q Cnt	Number of packets (update/query/reply) in queue for sending
Seq Num	Sequence number that was last received from this router

Displaying Installed EIGRP Routes

You can see EIGRP routes that are installed into the RIB by using the command **show ip route eigrp.** EIGRP routes originating within the autonomous system have an administrative distance (AD) of 90 and are indicated in the routing table with a D. Routes that originate from outside the autonomous system are external EIGRP routes. External EIGRP routes have an AD of 170 and are indicated in the routing table with D EX. Placing external EIGRP routes into the RIB with a higher AD acts as a loop-prevention mechanism.

Example 2-7 displays the EIGRP routes from the sample topology in Figure 2-5. The metric for the selected route is the second number in brackets.

Example 2-7 *EIGRP Routes for R1 and R2*

```
R1# show ip route eigrp
Codes: L - local, C - connected, S - static, 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
       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, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override, p - overrides from PfR
```

```
Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 5 subnets, 2 masks
D        10.22.22.0/24 [90/3072] via 10.12.1.2, 00:19:25, GigabitEthernet0/1
      192.168.2.0/32 is subnetted, 1 subnets
D        192.168.2.2 [90/2848] via 10.12.1.2, 00:19:25, GigabitEthernet0/1
```

```
R2# show ip route eigrp
! Output omitted for brevity
Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 5 subnets, 2 masks
D        10.11.11.0/24 [90/15360] via 10.12.1.1, 00:20:34, GigabitEthernet0/1
      192.168.1.0/32 is subnetted, 1 subnets
D        192.168.1.1 [90/2570240] via 10.12.1.1, 00:20:34, GigabitEthernet0/1
```

NOTE The metrics for R2's routes are different from the metrics from R1's routes. This is because R1's classic EIGRP mode uses classic metrics, and R2's named mode uses wide metrics by default. This topic is explained in depth in the "Path Metric Calculation" section, later in this chapter.

Router ID

The router ID (RID) is a 32-bit number that uniquely identifies an EIGRP router and is used as a loop-prevention mechanism. The RID can be set dynamically, which is the default, or manually.

The algorithm for dynamically choosing the EIGRP RID uses the highest IPv4 address of any *up* loopback interfaces. If there are not any *up* loopback interfaces, the highest IPv4 address of any active *up* physical interfaces becomes the RID when the EIGRP process initializes.

IPv4 addresses are commonly used for the RID because they are 32 bits and are maintained in dotted-decimal format. You use the command **eigrp router-id** *router-id* to set the RID, as demonstrated in Example 2-8, for both classic and named mode configurations.

Example 2-8 *Static Configuration of EIGRP Router ID*

```
R1(config)# router eigrp 100
R1(config-router)# eigrp router-id 192.168.1.1
```

```
R2(config)# router eigrp EIGRP-NAMED
R2(config-router)# address-family ipv4 unicast autonomous-system 100
R2(config-router-af)# eigrp router-id 192.168.2.2
```

Key Topic

Passive Interfaces

Some network topologies must advertise a network segment into EIGRP but need to prevent neighbors from forming adjacencies with other routers on that segment. This might be the case, for example, when advertising access layer networks in a campus topology. In such a scenario, you need to put the EIGRP interface in a passive state. Passive EIGRP interfaces do not send out or process EIGRP hellos, which prevents EIGRP from forming adjacencies on that interface.

To configure an EIGRP interface as passive, you use the command **passive-interface** *interface-id* under the EIGRP process for classic configuration. Another option is to configure all interfaces as passive by default with the command **passive-interface default** and then use the command **no passive-interface** *interface-id* to allow an interface to process EIGRP packets, preempting the global passive interface default configuration.

Example 2-9 demonstrates making R1's Gi0/2 interface passive and also the alternative option of making all interfaces passive but setting Gi0/1 as non-passive.

Example 2-9 *Passive EIGRP Interfaces for Classic Configuration*

```
R1# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)# router eigrp 100
R1(config-router)# passive-interface gi0/2
```

```
R1(config)# router eigrp 100
R1(config-router)# passive-interface default
04:22:52.031: %DUAL-5-NBRCHANGE: EIGRP-IPv4 100: Neighbor 10.12.1.2 (GigabitEther-
net0/1) is down: interface passive
R1(config-router)# no passive-interface gi0/1
*May 10 04:22:56.179: %DUAL-5-NBRCHANGE: EIGRP-IPv4 100: Neighbor 10.12.1.2 (Giga-
bitEthernet0/1) is up: new adjacency
```

For a named mode configuration, you place the **passive-interface** state on **af-interface default** for all EIGRP interfaces or on a specific interface with the **af-interface** *interface-id* section. Example 2-10 shows how to set the Gi0/2 interface as passive while allowing the Gi0/1 interface to be active using both configuration strategies.

Example 2-10 *Passive EIGRP Interfaces for Named Mode Configuration*

```
R2# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)# router eigrp EIGRP-NAMED
R2(config-router)# address-family ipv4 unicast autonomous-system 100
R2(config-router-af)# af-interface gi0/2
R2(config-router-af-interface)# passive-interface
R2(config-router-af-interface)# exit-af-interface
```

```
R2(config)# router eigrp EIGRP-NAMED
R2(config-router)# address-family ipv4 unicast autonomous-system 100
R2(config-router-af)# af-interface default
R2(config-router-af-interface)# passive-interface
04:28:30.366: %DUAL-5-NBRCHANGE: EIGRP-IPv4 100: Neighbor 10.12.1.1
(GigabitEthernet0/1) is down: interface passiveex
R2(config-router-af-interface)# exit-af-interface
R2(config-router-af)# af-interface gi0/1
R2(config-router-af-interface)# no passive-interface
R2(config-router-af-interface)# exit-af-interface
*May 10 04:28:40.219: %DUAL-5-NBRCHANGE: EIGRP-IPv4 100: Neighbor 10.12.1.1
(GigabitEthernet0/1) is up: new adjacency
```

Example 2-11 shows what the named mode configuration looks like with some settings (i.e. **passive-interface** or **no passive-interface**) placed under the **af-interface default** or the **af-interface** *interface-id* setting.

Example 2-11 *Viewing the EIGRP Interface Settings with Named Mode*

```
R2# show run | section router eigrp
router eigrp EIGRP-NAMED
 !
 address-family ipv4 unicast autonomous-system 100
  !
  af-interface default
   passive-interface
  exit-af-interface
  !
  af-interface GigabitEthernet0/1
   no passive-interface
  exit-af-interface
  !
  topology base
  exit-af-topology
  network 0.0.0.0
 exit-address-family
```

A passive interface does not appear in the output of the command **show ip eigrp interfaces** even though it was enabled. Connected networks for passive interfaces are still added to the EIGRP topology table so that they are advertised to neighbors.

Example 2-12 shows that the Gi0/2 interface on R1 no longer appears; compare this to Example 2-5, where it does exist.

Example 2-12 *Passive Interfaces do not Appear*

```
R1# show ip eigrp interfaces
EIGRP-IPv4 Interfaces for AS(100)
                 Xmit Queue   PeerQ        Mean   Pacing Time  Multicast  Pending
Interface Peers  Un/Reliable  Un/Reliable  SRTT   Un/Reliable  Flow Timer Routes
Gi0/1       1       0/0       0/0            9       0/0          50          0
```

To accelerate troubleshooting of passive interfaces, and other settings, the command **show ip protocols** provides a lot of valuable information about all the routing protocols. With EIGRP, it displays the EIGRP process identifier, the ASN, K values that are used for path calculation, RID, neighbors, AD settings, and all the passive interfaces.

Example 2-13 provides sample output for both classic and named mode instances on R1 and R2.

Example 2-13 *IP Protocols Output*

```
R1# show ip protocols
! Output omitted for brevity
Routing Protocol is "eigrp 100"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Default networks flagged in outgoing updates
  Default networks accepted from incoming updates
  EIGRP-IPv4 Protocol for AS(100)
    Metric weight K1=1, K2=0, K3=1, K4=0, K5=0
    Soft SIA disabled
    NSF-aware route hold timer is 240
    Router-ID: 192.168.1.1
    Topology : 0 (base)
      Active Timer: 3 min
      Distance: internal 90 external 170
      Maximum path: 4
      Maximum hopcount 100
      Maximum metric variance 1

  Automatic Summarization: disabled
  Maximum path: 4
  Routing for Networks:
    10.11.11.1/32
    10.12.1.1/32
    192.168.1.1/32
  Passive Interface(s):
    GigabitEthernet0/2
    Loopback0
```

```
  Routing Information Sources:
    Gateway         Distance      Last Update
    10.12.1.2             90      00:21:35
  Distance: internal 90 external 170
```

```
R2# show ip protocols
! Output omitted for brevity
Routing Protocol is "eigrp 100"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Default networks flagged in outgoing updates
  Default networks accepted from incoming updates
  EIGRP-IPv4 VR(EIGRP-NAMED) Address-Family Protocol for AS(100)
    Metric weight K1=1, K2=0, K3=1, K4=0, K5=0 K6=0
    Metric rib-scale 128
    Metric version 64bit
    Soft SIA disabled
    NSF-aware route hold timer is 240
    Router-ID: 192.168.2.2
    Topology : 0 (base)
      Active Timer: 3 min
      Distance: internal 90 external 170
      Maximum path: 4
      Maximum hopcount 100
      Maximum metric variance 1
      Total Prefix Count: 5
      Total Redist Count: 0

  Automatic Summarization: disabled
  Maximum path: 4
  Routing for Networks:
    0.0.0.0
  Passive Interface(s):
    GigabitEthernet0/2
    Loopback0
  Routing Information Sources:
    Gateway         Distance      Last Update
    10.12.1.1             90      00:24:26
  Distance: internal 90 external 170
```

Key Topic

Authentication

Authentication is a mechanism for ensuring that only authorized routers are eligible to become EIGRP neighbors. It is possible for someone to add a router to a network and introduce invalid routes accidentally or maliciously. Authentication prevents such scenarios from happening. A precomputed password hash is included with all EIGRP packets, and the receiving router decrypts the hash. If the passwords do not match for a packet, the router discards the packet.

EIGRP encrypts the password by using a Message Digest 5 (MD5) authentication, using the keychain function. The hash consists of the key number and a password. EIGRP authentication encrypts just the password rather than the entire EIGRP packet.

NOTE Keychain functionality allows a password to be valid for a specific time, so passwords can change at preconfigured times. Restricting the key sequence to a specific time is beyond the scope of this book. For more information, see Cisco.com.

To configure EIGRP authentication, you need to create a keychain and then enable EIGRP authentication on the interface. The following sections explain the steps.

Keychain Configuration

Keychain creation is accomplished with the following steps:

Step 1. Create the keychain by using the command **key chain** *key-chain-name*.

Step 2. Identify the key sequence by using the command **key** *key-number*, where *key-number* can be anything from 0 to 2147483647.

Step 3. Specify the preshared password by using the command **key-string** *password*.

NOTE Be careful not to use a space after the password because that will be used for computing the hash.

Enabling Authentication on the Interface

When using classic configuration, authentication must be enabled on the interface under the interface configuration submode. The following commands are used in the interface configuration submode:

ip authentication key-chain eigrp *as-number key-chain-name*

ip authentication mode eigrp *as-number* **md5**

The named mode configuration places the configurations under the EIGRP interface submode, under the **af-interface default** or the **af-interface** *interface-id*. Named mode configuration supports MD5 or *Hashed Message Authentication Code-Secure Hash*

2

Algorithm-256 (*HMAC-SHA-256*) authentication. MD5 authentication involves the following commands:

authentication key-chain eigrp *key-chain-name*

authentication mode md5

The HMAC-SHA-256 authentication involves the command **authentication mode hmac-sha-256** *password*.

Example 2-14 demonstrates MD5 configuration on R1 with classic EIGRP configuration and on R2 with named mode configuration. Remember that the hash is computed using the key sequence number and key string, which must match on the two nodes.

Example 2-14 *EIGRP Authentication Configuration*

```
R1(config)# key chain EIGRPKEY
R1(config-keychain)# key 2
R1(config-keychain-key)# key-string CISCO
R1(config)# interface gi0/1
R1(config-if)# ip authentication mode eigrp 100 md5
R1(config-if)# ip authentication key-chain eigrp 100 EIGRPKEY
```

```
R2(config)# key chain EIGRPKEY
R2(config-keychain)# key 2
R2(config-keychain-key)# key-string CISCO
R2(config-keychain-key)# router eigrp EIGRP-NAMED
R2(config-router)# address-family ipv4 unicast autonomous-system 100
R2(config-router-af)# af-interface default
R2(config-router-af-interface)# authentication mode md5
R2(config-router-af-interface)# authentication key-chain EIGRPKEY
```

The command **show key chain** provides verification of the keychain. Example 2-15 shows that each key sequence provides the lifetime and password.

Example 2-15 *Verification of Keychain Settings*

```
R1# show key chain
Key-chain EIGRPKEY:
    key 2 -- text "CISCO"
        accept lifetime (always valid) - (always valid) [valid now]
        send lifetime (always valid) - (always valid) [valid now]
```

The EIGRP interface detail view provides verification of EIGRP authentication on a specific interface. Example 2-16 provides detailed EIGRP interface output.

Example 2-16 *Verification of EIGRP Authentication*

```
R1# show ip eigrp interface detail
EIGRP-IPv4 Interfaces for AS(100)
                            Xmit Queue   PeerQ        Mean   Pacing Time   Multicast
    Pending
Interface         Peers  Un/Reliable  Un/Reliable  SRTT   Un/Reliable   Flow Timer   Routes
Gi0/1               0        0/0         0/0           0       0/0            50
0
  Hello-interval is 5, Hold-time is 15
  Split-horizon is enabled
  Next xmit serial <none>
  Packetized sent/expedited: 10/1
  Hello's sent/expedited: 673/12
  Un/reliable mcasts: 0/9  Un/reliable ucasts: 6/19
  Mcast exceptions: 0  CR packets: 0  ACKs suppressed: 0
  Retransmissions sent: 16  Out-of-sequence rcvd: 1
  Topology-ids on interface - 0
  Authentication mode is md5,  key-chain is "EIGRPKEY"
```

Key Topic

Path Metric Calculation

Metric calculation is a critical component for any routing protocol. EIGRP uses multiple factors to calculate the metric for a path. Metric calculation uses *bandwidth* and *delay* by default but can include interface load and reliability, too. The formula shown in Figure 2-6 illustrates the EIGRP classic metric formula.

$$\text{Metric} = \left[\left(K_1 * \text{BW} + \frac{K_2 * \text{BW}}{256 - \text{Load}} + K_3 * \text{Delay}\right) * \frac{K_5}{K_4 + \text{Reliability}}\right]$$

Figure 2-6 *EIGRP Classic Metric Formula*

EIGRP uses K values to define which factors the formula uses and the impact associated with a factor when calculating the metric. A common misconception is that the K values directly apply to bandwidth, load, delay, or reliability; this is not accurate. For example, K_1 and K_2 both reference bandwidth (BW).

BW represents the slowest link in the path, scaled to a 10 Gbps link (10^7). Link speed is collected from the configured interface bandwidth on an interface. Delay is the total measure of delay in the path, measured in tens of microseconds (μs).

The EIGRP formula is based on the IGRP metric formula, except the output is multiplied by 256 to change the metric from 24 bits to 32 bits. Taking these definitions into consideration, the formula for EIGRP is shown in Figure 2-7.

$$\text{Metric} = 256^* \left[\left(K_1 * \frac{10^7}{\text{Min. Bandwidth}} + \frac{K_2 * \frac{10^7}{\text{Min. Bandwidth}}}{256 - \text{Load}} + \frac{K_3 * \text{Total Delay}}{10}\right) * \frac{K_5}{K_4 + \text{Reliability}}\right]$$

Figure 2-7 *EIGRP Classic Metric Formula with Definitions*

By default, K_1 and K_3 have a value of 1, and K_2, K_4, and K_5 are set to 0. Figure 2-8 places default K values into the formula and shows a streamlined version of the formula.

$$\text{Metric} = 256 * \left[\left(1 * \frac{10^7}{\text{Min. Bandwidth}} + \frac{\dfrac{10^7}{0 * \text{Min. Bandwidth}}}{256 - \text{Load}} + \frac{1 * \text{Total Delay}}{10}\right) * \frac{0}{0 + \text{Reliability}}\right]$$

Equals

$$\text{Metric} = 256 * \left(\frac{10^7}{\text{Min. Bandwidth}} + \frac{\text{Total Delay}}{10}\right)$$

Figure 2-8 *EIGRP Classic Metric Formula with Default K Values*

Key Topic

The EIGRP update packet includes path attributes associated with each prefix. The EIGRP path attributes can include hop count, cumulative delay, minimum bandwidth link speed, and RD. The attributes are updated each hop along the way, allowing each router to independently identify the shortest path.

Figure 2-9 shows the information in the EIGRP update packets for the 10.1.1.0/24 prefix propagating through the autonomous system. Notice that the hop count increments, minimum bandwidth decreases, total delay increases, and the RD changes with each EIGRP update.

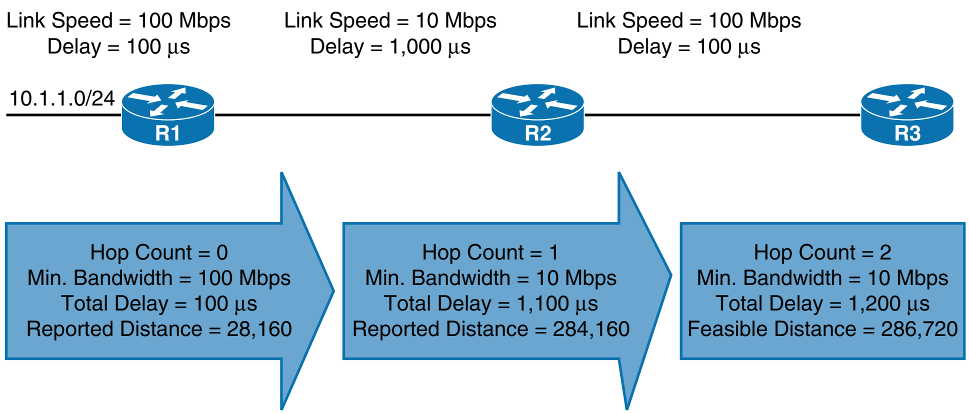


Figure 2-9 *EIGRP Attribute Propagation*

Table 2-7 shows some of the common network types, link speeds, delay, and EIGRP metric, using the streamlined formula from Figure 2-7.

Table 2-7 Default EIGRP Interface Metrics for Classic Metrics

Interface Type	Link Speed (Kbps)	Delay	Metric
Serial	64	20,000 µs	40,512,000
T1	1544	20,000 µs	2,170,031
Ethernet	10,000	1000 µs	281,600
FastEthernet	100,000	100 µs	28,160
GigabitEthernet	1,000,000	10 µs	2816
TenGigabitEthernet	10,000,000	10 µs	512

Using the topology from Figure 2-2, the metrics from R1 and R2 for the 10.4.4.0/24 network are calculated using the formula in Figure 2-10. The link speed for both routers is 1 Gbps, and the total delay is 30 µs (10 µs for the 10.4.4.0/24 link, 10 µs for the 10.34.1.0/24 link, and 10 µs for the 10.13.1.0/24 link).

$$\text{Metric} = 256 * \left(\frac{10^7}{1{,}000{,}000} + \frac{30}{10}\right) = 3{,}328$$

Figure 2-10 *EIGRP Classic Metric Formula with Default K Values*

If you are unsure of the EIGRP metrics, you can query the parameters for the formula directly from EIGRP's topology table by using the command **show ip eigrp topology** *network/prefix-length*.

Example 2-17 shows R1's topology table output for the 10.4.4.0/24 network. Notice that the output includes the successor route, any feasible successor paths, and the EIGRP state for the prefix. Each path contains the EIGRP attributes minimum bandwidth, total delay, interface reliability, load, and hop count.

Example 2-17 *EIGRP Topology for a Specific Prefix*

```
R1# show ip eigrp topology 10.4.4.0/24
! Output omitted for brevity
EIGRP-IPv4 Topology Entry for AS(100)/ID(10.14.1.1) for 10.4.4.0/24
  State is Passive, Query origin flag is 1, 1 Successor(s), FD is 3328
  Descriptor Blocks:
  10.13.1.3 (GigabitEthernet0/1), from 10.13.1.3, Send flag is 0x0
      Composite metric is (3328/3072), route is Internal
      Vector metric:
        Minimum bandwidth is 1000000 Kbit
        Total delay is 30 microseconds
        Reliability is 252/255
        Load is 1/255
        Minimum MTU is 1500
        Hop count is 2
        Originating router is 10.34.1.4
  10.14.1.4 (GigabitEthernet0/2), from 10.14.1.4, Send flag is 0x0
      Composite metric is (5376/2816), route is Internal
```

```
    Vector metric:
      Minimum bandwidth is 1000000 Kbit
      Total delay is 110 microseconds
      Reliability is 255/255
      Load is 1/255
      Minimum MTU is 1500
      Hop count is 1
      Originating router is 10.34.1.4
```

Wide Metrics

The original EIGRP specifications measured delay in 10-microsecond (μs) units and bandwidth in kilobytes per second, which did not scale well with higher-speed interfaces. In Table 2-7, notice that the delay is the same for the GigabitEthernet and TenGigabitEthernet interfaces.

Example 2-18 provides some metric calculations for common LAN interface speeds. Notice that there is not a differentiation between an 11 Gbps interface and a 20 Gbps interface. The composite metric stays at 256, despite the different bandwidth rates.

Example 2-18 *Metric Calculation for Common LAN Interface Speeds*

```
GigabitEthernet:
Scaled Bandwidth = 10,000,000 / 1,000,000
Scaled Delay = 10 / 10
Composite Metric = 10 + 1 * 256 = 2816
```

```
10 GigabitEthernet:
Scaled Bandwidth = 10,000,000 / 10,000,000
Scaled Delay = 10 / 10
Composite Metric = 1 + 1 * 256 = 512
```

```
11 GigabitEthernet:
Scaled Bandwidth = 10,000,000 / 11,000,000
Scaled Delay = 10 / 10
Composite Metric = 0 + 1 * 256 = 256
```

```
20 GigabitEthernet:
Scaled Bandwidth = 10,000,000 / 20,000,000
Scaled Delay = 10 / 10
Composite Metric = 0 + 1 * 256 = 256
```

EIGRP includes support for a second set of metrics, known as *wide metrics*, that addresses the issue of scalability with higher-capacity interfaces. The original formula referenced in Figure 2-6 is known as *EIGRP classic metrics*.

Figure 2-11 shows the explicit EIGRP wide metrics formula. Notice that an additional K value (K_6) is included that adds an extended attribute to measure jitter, energy, or other future attributes.

Key Topic

2

$$\text{Wide Metric} = \left[\left(K_1 * BW + \frac{K_2 * BW}{256 - \text{Load}} + K_3 * \text{Latency} + K_6 * \text{Extended}\right) * \frac{K_5}{K_4 + \text{Reliability}}\right]$$

Figure 2-11 *EIGRP Wide Metrics Formula*

Just as EIGRP scaled by 256 to accommodate IGRP, EIGRP wide metrics scale by 65,535 to accommodate higher-speed links. This provides support for interface speeds up to 655 terabits per second ($65{,}535 \times 10^7$) without any scalability issues. Latency is the total interface delay measured in picoseconds (10^{-12}) instead of in microseconds (10^{-6}). Figure 2-12 shows an updated formula that takes into account the conversions in latency and scalability.

$$\text{Wide Metric} = 65{,}535 * \left[\left(\frac{K_1 * 10^7}{\text{Min. Bandwidth}} + \frac{\frac{K_2 * 10^7}{\text{Min. Bandwidth}}}{256 - \text{Load}} + \frac{K_3 * \text{Latency}}{10^{\wedge 6}} + K_6 * \text{Extended}\right) * \frac{K_5}{K_4 + \text{Reliability}}\right]$$

Figure 2-12 *EIGRP Wide Metrics Formula with Definitions*

The interface delay varies from router to router, depending on the following logic:

- If the interface's delay was specifically set, the value is converted to picoseconds. Interface delay is always configured in tens of microseconds and is multiplied by 10^7 for picosecond conversion.
- If the interface's bandwidth was specifically set, the interface delay is configured using the classic default delay, converted to picoseconds. The configured bandwidth is not considered when determining the interface delay. If delay was configured, this step is ignored.
- If the interface supports speeds of 1 Gbps or less and does not contain bandwidth or delay configuration, the delay is the classic default delay, converted to picoseconds.
- If the interface supports speeds over 1 Gbps and does not contain bandwidth or delay configuration, the interface delay is calculated by 10^{13}/interface bandwidth.

The EIGRP classic metrics exist only with EIGRP classic configuration, while EIGRP wide metrics exist only in EIGRP named mode. The metric style used by a router is identified with the command **show ip protocols**; if a K_6 metric is present, the router is using wide-style metrics.

Example 2-19 verifies the operational mode of EIGRP on R1 and R2. R1 does not have a K_6 metric and is using EIGRP classic metrics. R2 has a K_6 metric and is using EIGRP wide metrics.

Example 2-19 *Verification of EIGRP Metric Style*

```
R1# show ip protocols | include AS|K
  EIGRP-IPv4 Protocol for AS(100)
    Metric weight K1=1, K2=0, K3=1, K4=0, K5=0
```

```
R2# show ip protocols | include AS|K
  EIGRP-IPv4 VR(EIGRP-NAMED) Address-Family Protocol for AS(100)
    Metric weight K1=1, K2=0, K3=1, K4=0, K5=0 K6=0
```

Metric Backward Compatibility

EIGRP wide metrics were designed with backward compatibility in mind. EIGRP wide metrics set K_1 and K_3 to a value of 1 and set K_2, K_4, K_5, and K_6 to 0, which allows backward compatibility because the K value metrics match with classic metrics. As long as K_1 through K_5 are the same and K_6 is not set, the two metric styles allow adjacency between routers.

EIGRP is able to detect when peering with a router is using classic metrics, and it *unscales* the metric to the formula in Figure 2-13.

$$\text{Unscaled Bandwidth} = \left(\frac{\text{EIGRP Bandwidth} * \text{EIGRP Classic Scale}}{\text{Scaled Bandwidth}}\right)$$

Figure 2-13 *Formula for Calculating Unscaled EIGRP Metrics*

This conversion results in loss of clarity if routes pass through a mixture of classic metric and wide metric devices. An end result of this intended behavior is that paths learned from wide metric peers always look better than paths learned from classic peers. Using a mixture of classic metric and wide metric devices could lead to suboptimal routing, so it is best to keep all devices operating with the same metric style.

Interface Delay Settings

If you do not remember the delay values from Table 2-7, the values can be dynamically queried with the command **show interface** *interface-id*. The output displays the EIGRP interface delay, in microseconds, after the DLY field. Example 2-20 provides sample output of the command on R1 and R2. Both interfaces have a delay of 10.

Example 2-20 *Verification of EIGRP Interface Delay*

```
R1# show interfaces gigabitEthernet 0/1 | i DLY
  MTU 1500 bytes, BW 1000000 Kbit/sec, DLY 10 usec,
```

```
R2# show interfaces gigabitEthernet 0/1 | i DLY
  MTU 1500 bytes, BW 1000000 Kbit/sec, DLY 10 usec,
```

EIGRP delay is set on an interface-by-interface basis, allowing for manipulation of traffic patterns flowing through a specific interface on a router. Delay is configured with the interface parameter command **delay** *tens-of-microseconds* under the interface.

Example 2-21 demonstrates the modification of the delay on R1 to 100, increasing the delay to 1000 μs on the link between R1 and R2. To ensure consistent routing, modify the delay on R2's Gi0/1 interface as well. Afterward, you can verify the change.

Example 2-21 *Interface Delay Configuration*

```
R1# configure terminal
R1(config)# interface gi0/1
R1(config-if)# delay 100
R1(config-if)# do show interface Gigabit0/1 | i DLY
  MTU 1500 bytes, BW 1000000 Kbit/sec, DLY 1000 usec,
```

NOTE Bandwidth modification with the interface parameter command **bandwidth** *bandwidth* has a similar effect on the metric calculation formula but can impact other routing protocols, such as OSPF, at the same time. Modifying the interface delay only impacts EIGRP.

Key Topic

Custom K Values

If the default metric calculations are insufficient, you can change them to modify the path metric formula. K values for the path metric formula are set with the command **metric weights** *TOS* K_1 K_2 K_3 K_4 K_5 [K_6] under the EIGRP process. The TOS value always has a value of 0, and the K_6 value is used for named mode configurations.

To ensure consistent routing logic in an EIGRP autonomous system, the K values must match between EIGRP neighbors to form an adjacency and exchange routes. The K values are included as part of the EIGRP hello packet. The K values are displayed with the **show ip protocols** command, as demonstrated with the sample topology in Example 2-13. Notice that both routers are using the default K values, with R1 using classic metrics and R2 using wide metrics.

Load Balancing

EIGRP allows multiple successor routes (with the same metric) to be installed into the RIB. Installing multiple paths into the RIB for the same prefix is called *equal-cost multipathing* (*ECMP*) routing. At the time of this writing, the default maximum ECMP is four routes. You change the default ECMP setting with the command **maximum-paths** *maximum-paths* under the EIGRP process in classic mode and under the topology base submode in named mode.

Example 2-22 shows the configuration for changing the maximum paths on R1 and R2 so that classic and named mode configurations are visible.

Example 2-22 *Changing the EIGRP Maximum Paths*

```
R1# show run | section router eigrp
router eigrp 100
 maximum-paths 6
 network 0.0.0.0
```

```
R2# show run | section router eigrp
router eigrp EIGRP-NAMED
 !
 address-family ipv4 unicast autonomous-system 100
  !
  topology base
   maximum-paths 6
  exit-af-topology
  network 0.0.0.0
  eigrp router-id 192.168.2.2
 exit-address-family
```

Key Topic

EIGRP supports unequal-cost load balancing, which allows installation of both successor routes and feasible successors into the EIGRP RIB. To use unequal-cost load balancing with EIGRP, change EIGRP's *variance multiplier*. The EIGRP *variance value* is the feasible distance (FD) for a route multiplied by the EIGRP variance multiplier. Any feasible successor's FD with a metric below the EIGRP variance value is installed into the RIB. EIGRP installs multiple routes where the FD for the routes is less than the EIGRP multiplier value up to the maximum number of ECMP routes, as discussed earlier.

Dividing the feasible successor metric by the successor route metric provides the variance multiplier. The variance multiplier is a whole number, and any remainders should always round up.

Using the topology shown in Figure 2-2 and output from the EIGRP topology table in Figure 2-3, the minimum EIGRP variance multiplier can be calculated so that the direct path from R1 to R4 can be installed into the RIB. The FD for the successor route is 3328, and the FD for the feasible successor is 5376. The formula provides a value of about 1.6 and is always rounded up to the nearest whole number to provide an EIGRP variance multiplier of 2. Figure 2-14 shows the calculation.

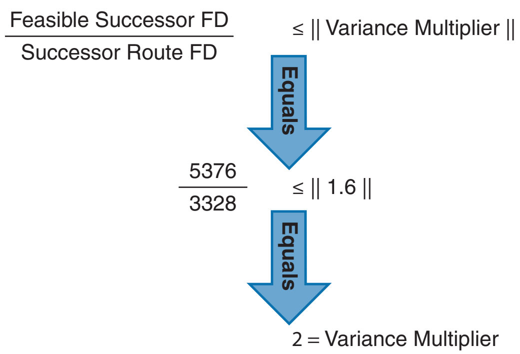


Figure 2-14 *EIGRP Variance Multiplier Formula*

The command **variance** *multiplier* configures the variance multiplier under the EIGRP process for classic configuration and under the topology base submode in named mode. Example 2-23 provides a sample configuration for both configuration modes.

Example 2-23 *EIGRP Variance Configuration*

```
R1 (Classic Configuration)
router eigrp 100
 variance 2
 network 0.0.0.0
```

```
R1 (Named Mode Configuration)
router eigrp EIGRP-NAMED
 !
 address-family ipv4 unicast autonomous-system 100
  !
  topology base
   variance 2
  exit-af-topology
  network 0.0.0.0
  exit-address-family
```

Example 2-24 provides a brief verification that both paths were installed into the RIB. Notice that the metrics for the paths are different. One path metric is 3328, and the other path metric is 5376. To see the traffic load-balancing ratios, you use the command **show ip route** *network*, as demonstrated in the second output. The load-balancing traffic share is highlighted.

Example 2-24 *Verification of Unequal-Cost Load Balancing*

```
R1# show ip route eigrp | begin Gateway
Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 10 subnets, 2 masks
D        10.4.4.0/24 [90/5376] via 10.14.1.4, 00:00:03, GigabitEthernet0/2
                     [90/3328] via 10.13.1.3, 00:00:03, GigabitEthernet0/1
```

```
R1# show ip route 10.4.4.0
Routing entry for 10.4.4.0/24
  Known via "eigrp 100", distance 90, metric 3328, type internal
  Redistributing via eigrp 100
  Last update from 10.13.1.3 on GigabitEthernet0/1, 00:00:35 ago
  Routing Descriptor Blocks:
  * 10.14.1.4, from 10.14.1.4, 00:00:35 ago, via GigabitEthernet0/2
      Route metric is 5376, traffic share count is 149
      Total delay is 110 microseconds, minimum bandwidth is 1000000 Kbit
      Reliability 255/255, minimum MTU 1500 bytes
      Loading 1/255, Hops 1
```

```
    10.13.1.3, from 10.13.1.3, 00:00:35 ago, via GigabitEthernet0/1
      Route metric is 3328, traffic share count is 240
      Total delay is 30 microseconds, minimum bandwidth is 1000000 Kbit
      Reliability 254/255, minimum MTU 1500 bytes
      Loading 1/255, Hops 2
```

References in This Chapter

Edgeworth, Brad, Foss, Aaron, and Garza Rios, Ramiro. *IP Routing on Cisco IOS, IOS XE, and IOS XR*. Cisco Press: 2014.

RFC 7838, *Cisco's Enhanced Interior Gateway Routing Protocol (EIGRP)*, D. Savage, J. Ng, S. Moore, D. Slice, P. Paluch, R. White. http://tools.ietf.org/html/rfc7868, May 2016.

Cisco. *Cisco IOS Software Configuration Guides*. http://www.cisco.com.

Exam Preparation Tasks

As mentioned in the section "How to Use This Book" in the Introduction, you have a couple choices for exam preparation: the exercises here, Chapter 24, "Final Preparation," and the exam simulation questions in the Pearson Test Prep software.

Review All Key Topics

Review the most important topics in this chapter, noted with the Key Topic icon in the outer margin of the page. Table 2-8 lists these key topics and the page number on which each is found.

Table 2-8 Key Topics

Key Topic Element	Description	Page Number
Paragraph	EIGRP terminology	74
Paragraph	Topology table	75
Table 2-3	EIGRP packet types	76
Paragraph	Forming EIGRP neighbors	77
Paragraph	Classic configuration mode	78
Paragraph	EIGRP named mode	79
Paragraph	Passive interfaces	87
Paragraph	Authentication	91
Paragraph	Path metric calculation	93
Paragraph	EIGRP attribute propagation	94
Figure 2-11	EIGRP wide metrics formula	97
Paragraph	Custom K values	99
Paragraph	Unequal-cost load balancing	100

Complete Tables and Lists from Memory

There are no memory tables in this chapter.

Define Key Terms

Define the following key terms from this chapter and check your answers in the glossary:

autonomous system (AS), successor route, successor, feasible distance, reported distance, feasibility condition, feasible successor, topology table, EIGRP classic configuration, EIGRP named mode configuration, passive interface, K values, wide metrics, variance value

Use the Command Reference to Check Your Memory

This section includes the most important configuration and verification commands covered in this chapter. It might not be necessary to memorize the complete syntax of every command, but you should be able to remember the basic keywords that are needed.

To test your memory of the commands, cover the right side of Table 2-9 with a piece of paper, read the description on the left side, and then see how much of the command you can remember.

The ENARSI 300-410 exam focuses on practical, hands-on skills that are used by a networking professional. Therefore, you should be able to identify the commands needed to configure, verify, and troubleshoot the topics covered in this chapter.

Table 2-9 Command Reference

Task	Command Syntax
Initialize EIGRP in classic configuration	**router eigrp** *as-number* **network** *network mask*
Initialize EIGRP in named mode configuration	**router eigrp** *process-name* *address-family* **{ipv4| ipv6} {unicast | vrf** *vrf-name}* **autonomous-system** *as-number* **network** *network mask*
Define the EIGRP router ID	**eigrp router-id** *router-id*
Configure an EIGRP-enabled interface to prevent neighbor adjacencies	Classic: (EIGRP Process) **passive-interface** *interface-id* Named Mode: **af-interface {default |** *interface-id***}** **passive-interface**
Configure a keychain for EIGRP MD5 authentication	**key chain** *key-chain-name* **key** *key-number* **key-string** *password*

Task	Command Syntax
Configure MD5 authentication for an EIGRP interface	Classic: (EIGRP Process) **ip authentication key-chain eigrp** *as-number key-chain-name* **ip authentication mode eigrp** *as-number* **md5** Named Mode: **af-interface {default** | *interface-id***}** **authentication key-chain eigrp** *key-chain-name* **authentication mode md5**
Configure SHA authentication for EIGRP named mode interfaces	Named Mode: **af-interface {default** | *interface-id***}** **authentication mode hmac-sha-256** *password*
Modify the interface delay for an interface	**delay** *tens-of-microseconds*
Modify the EIGRP K values	**metric weights** *TOS* K_1 K_2 K_3 K_4 K_5 [K_6]
Modify the default number of EIGRP maximum paths that can be installed into the RIB	**maximum-paths** *maximum-paths*
Modify the EIGRP variance multiplier for unequal-cost load balancing	**variance** *multiplier*
Display the EIGRP-enabled interfaces	**show ip eigrp interface** [{*interface-id* [**detail**] | **detail**}]
Display the EIGRP topology table	**show ip eigrp topology** [**all-links**]
Display the configured EIGRP keychains and passwords	**show key chain**
Display the IP routing protocol information configured on the router	**show ip protocols**

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