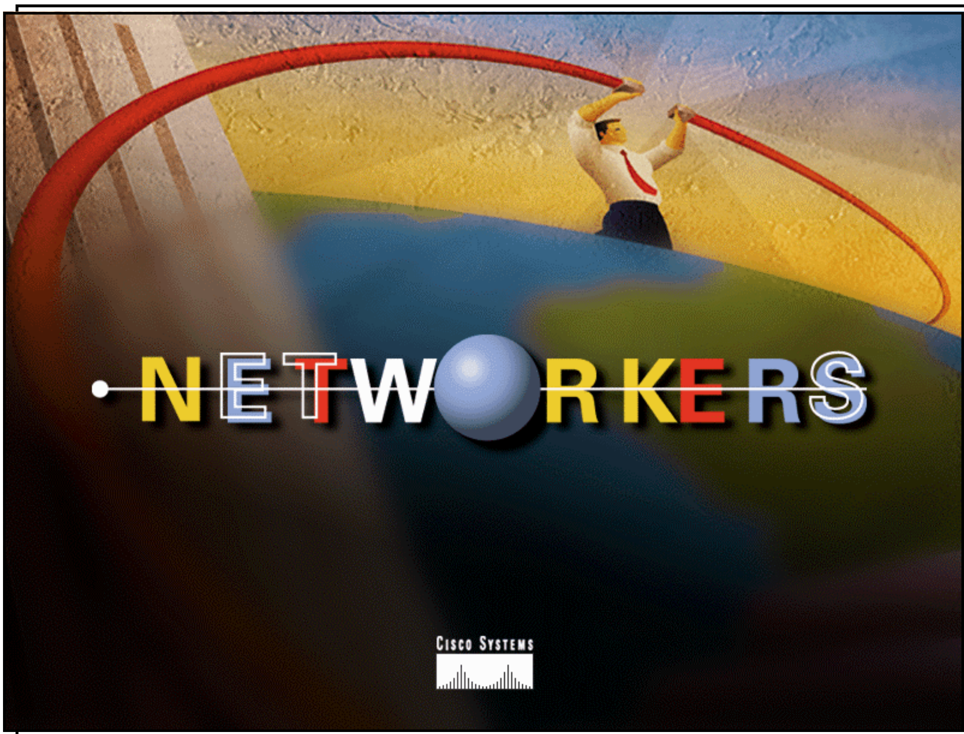
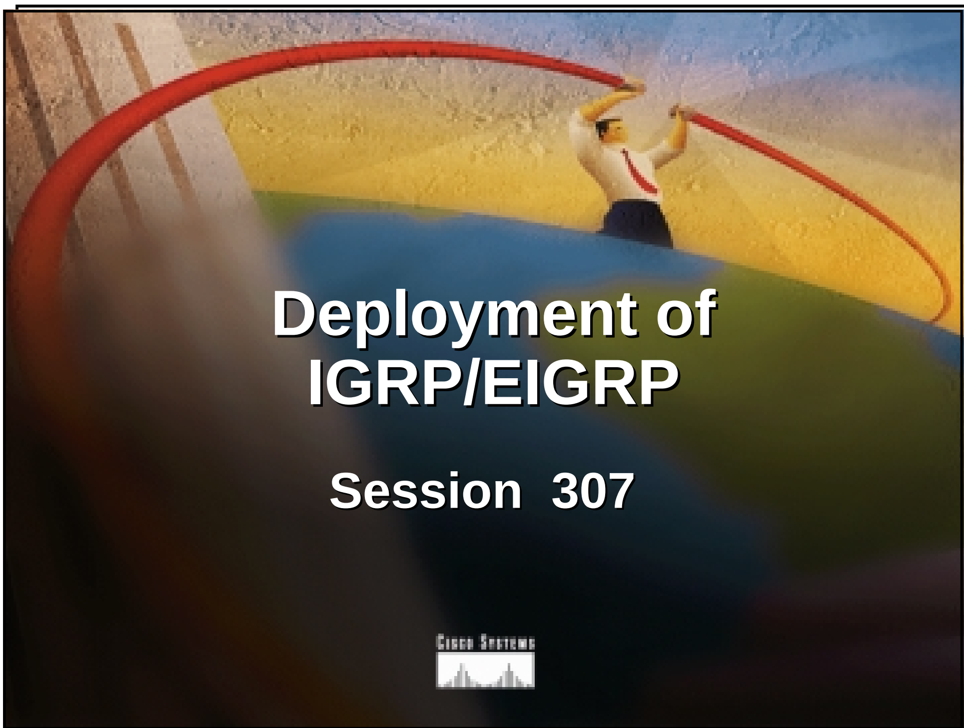

NETWORKERS
Cisco Systems


Deployment of
IGRP/EIGRP
Session 307
Cisco Systems

Agenda

- Fundamentals of EIGRP
- Dual
- Summarization and Load Balancing
- EIGRP/IGRP Interaction
- Query Process
- Deployment Guidelines with EIGRP
- Summary

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IGRP: Interior Gateway Routing Protocol

- Cisco proprietary
- Distance vector
- Broadcast based
- Utilizes link bandwidth and delay

  15 hops is no longer the limit
- 90 seconds updates (RIP is 30 sec.)
- Load balance over unequal cost paths

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IGRP Metrics Calculation

- Metric = [K1 x BW + (K2 x BW) / (256 - Load) + K3 x Delay] x [K5 / (Reliability + K4)]

  By Default: K1 = 1, K2 = 0, K3 = 1, K4 = K5 = 0

- Delay is sum of all the delays of the link along the paths

  Delay = Delay/10

- Bandwidth is the lowest bandwidth of the link along the paths

  Bandwidth = 10000000/Bandwidth

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Problems with RIP and IGRP

- Slow convergence
- Not 100% loop free
- Don’t support VLSM and discontiguous network
- Periodic full routing updates
- RIP has hop count limitation

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Advantages of EIGRP

- Advanced distance vector
- 100% loop free
- Fast convergence
- Easy configuration
- Less network design constraints than OSPF
- Incremental update
- Supports VLSM and discontiguous network
- Classless routing
- Compatible with existing IGRP network
- Protocol independent (support IPX® and AppleTalk)

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Advantages of EIGRP

- Uses multicast instead of broadcast
- Utilize link bandwidth and delay
  - EIGRP Metric = IGRP Metric x 256 (32 bit Vs. 24 bit)
- Unequal cost paths load balancing
- More flexible than OSPF
  - Full support of distribute list
  - Manual summarization can be done in any interface at any router within network

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EIGRP Packets

- Hello: Establish neighbor relationships
- Update: Send routing updates
- Query: Ask neighbors about routing information
- Reply: Response to query about routing information
- Ack: Acknowledgement of a reliable packet

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EIGRP Neighbor Relationship

- Two routers become neighbors when they see each other's hello packet
  - Hello address = 224.0.0.10
- Hellos sent once every five seconds on the following links:
  - Broadcast Media: Ethernet, Token Ring, fddi, etc.
  - Point-to-point serial links: PPP, HDLC, point-to-point Frame Relay/ATM subinterfaces
  - Multipoint circuits with bandwidth greater than T1: ISDN PRI, SMDS, Frame Relay

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EIGRP Neighbor Relationship

- Hellos sent once every 60 seconds on the following links:
  - Multipoint circuits with bandwidth less than T1: ISDN BRI, Frame Relay, SMDS, etc.
- Neighbor declared dead when no EIGRP packets are received within hold interval
  - Not only Hello can reset the hold timer
- Hold time by default is three times the hello time

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EIGRP Neighbor Relationship

- EIGRP will form neighbors even though hello time and hold time don’t match
- EIGRP sources hello packets from primary address of the interface
- EIGRP will not form neighbor if K-values are mismatched
- EIGRP will not form neighbor if AS numbers are mismatched
- Passive interface (IGRP vs. EIGRP)

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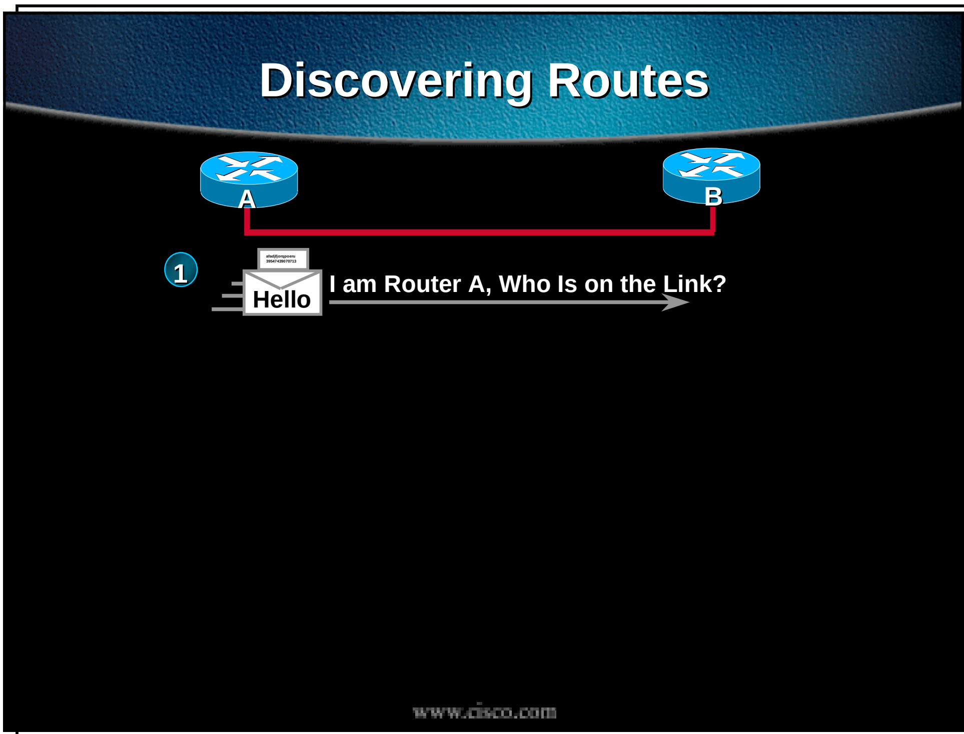
Discovering Routes
A
B
1
Hello
I am Router A, Who Is on the Link?
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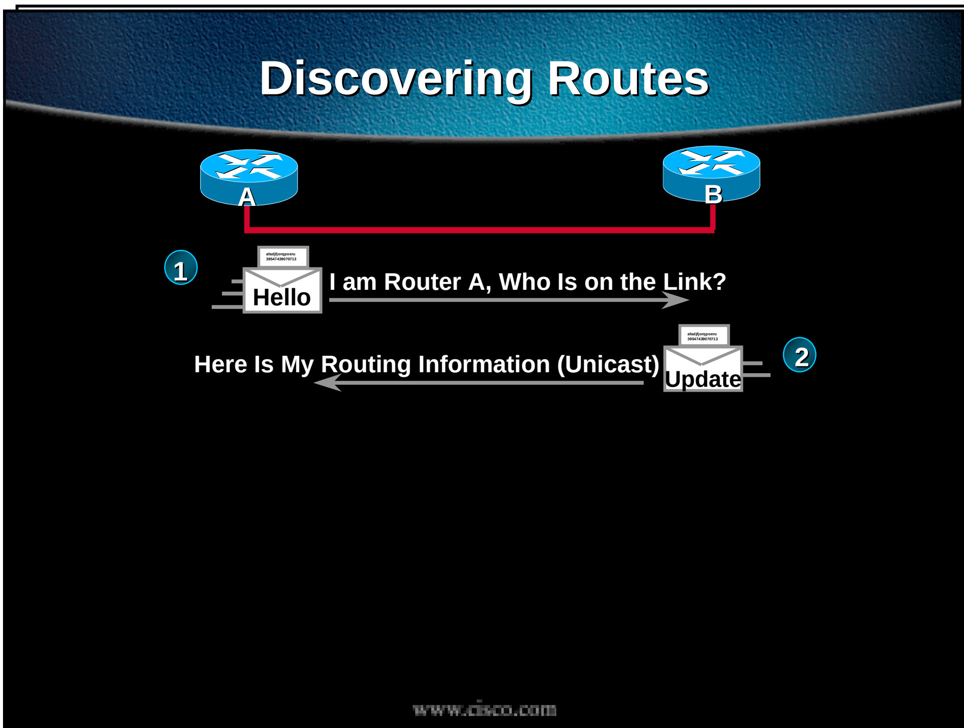
Discovering Routes
A
B
1
Hello
I am Router A, Who Is on the Link?
Here Is My Routing Information (Unicast)
Update
2
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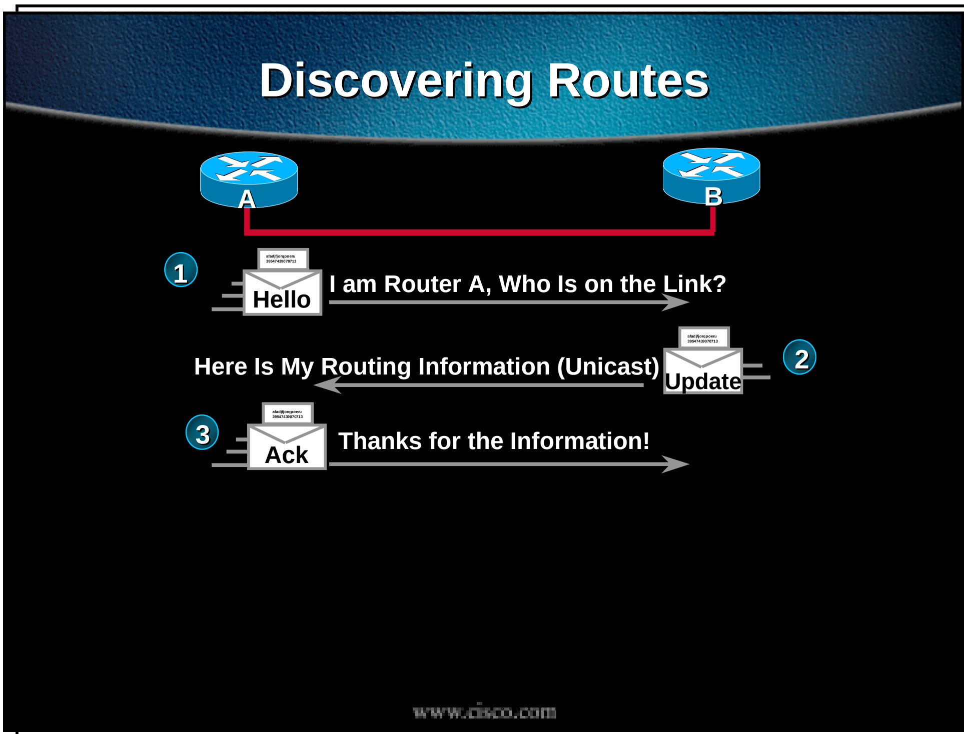
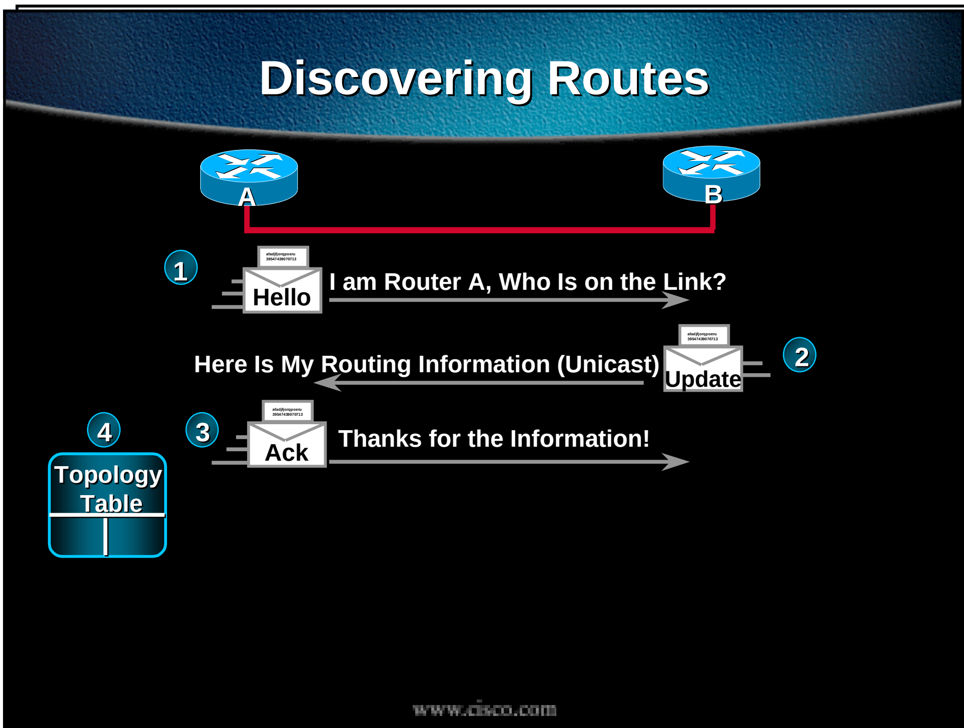
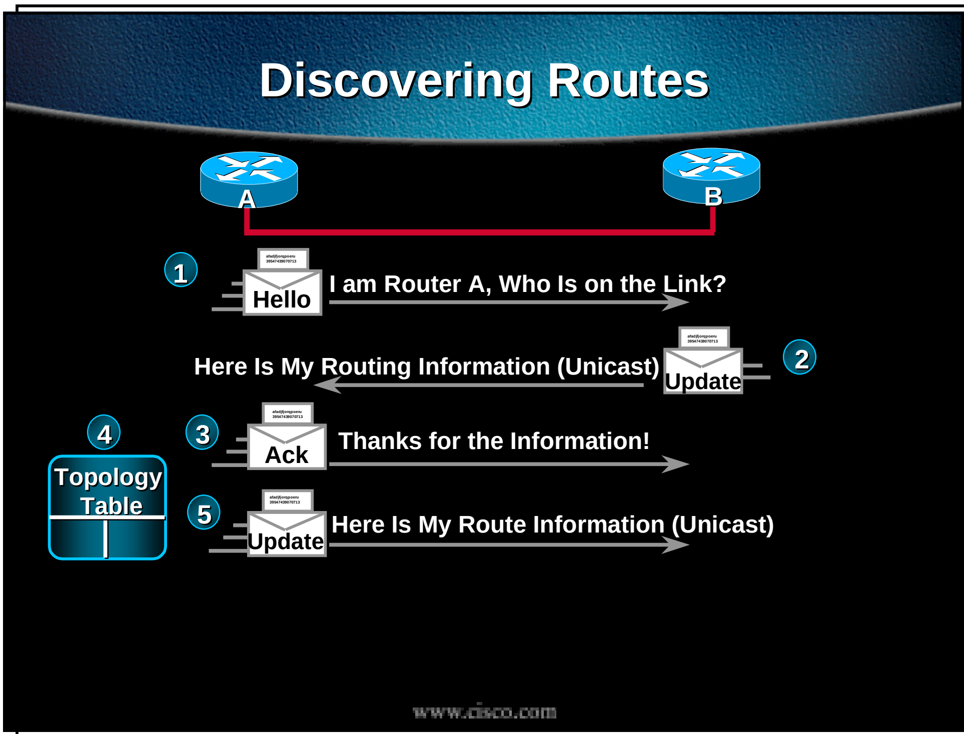

Discovering Routes
A
B
1
Hello
I am Router A, Who Is on the Link?
Here Is My Routing Information (Unicast)
Update
2
3
Ack
Thanks for the Information!
www.cisco.com


Discovering Routes
A
B
1
Hello
I am Router A, Who Is on the Link?
Here Is My Routing Information (Unicast)
Update
2
4
Topology Table
3
Ack
Thanks for the Information!
www.cisco.com


Discovering Routes
A
B
1
Hello
I am Router A, Who Is on the Link?
Here Is My Routing Information (Unicast)
Update
2
4
Topology Table
3
Ack
Thanks for the Information!
5
Update
Here Is My Route Information (Unicast)
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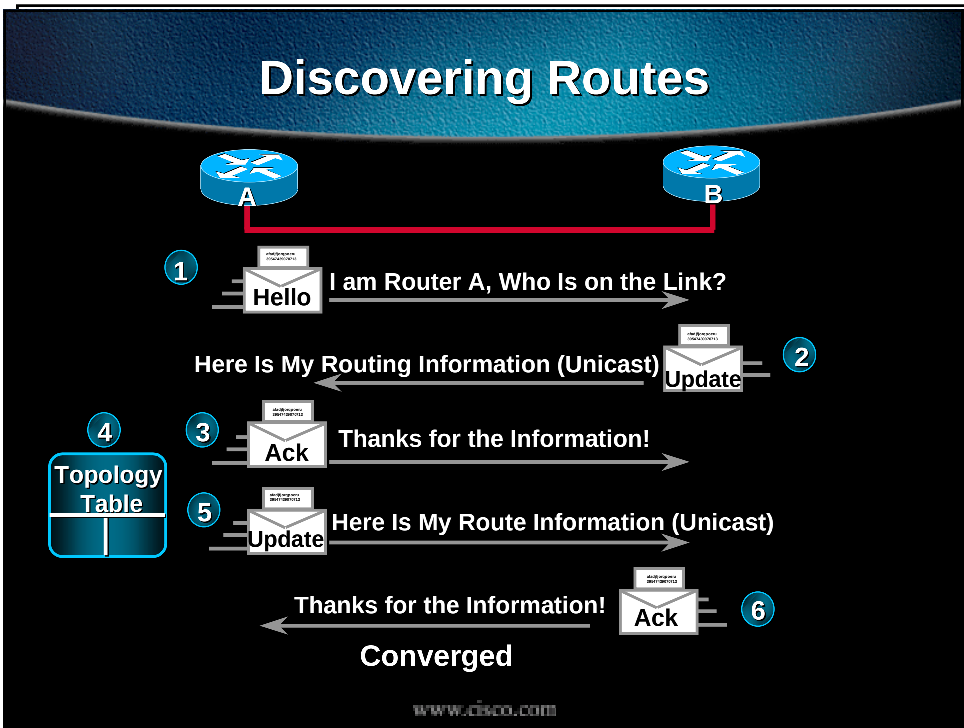
Discovering Routes
A
B
1
Hello
I am Router A, Who Is on the Link?
Here Is My Routing Information (Unicast)
Update
2
4
Topology Table
3
Ack
Thanks for the Information!
5
Update
Here Is My Route Information (Unicast)
Thanks for the Information!
Ack
6
Converged
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Agenda

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EIGRP Dual

- Diffusing update algorithm
- Finite-state-machine
  - Track all routes advertised by neighbors
  - Select loop-free path using a successor and remember any feasible successors
  - If successor lost
    - Use feasible successor
  - If no feasible successor
    - Query neighbors and recompute new successor

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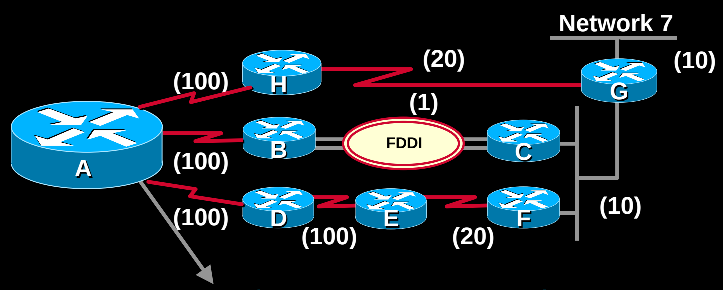
EIGRP Feasible Distance (FD)

- Feasible distance is the minimum distance (metric) along a path to a destination network

Feasible Distance Example



Topology Table

Destination	Feasible Distance (FD)	Neighbor
7	100+20+10=130	H
7	100+1+10+10=121	B
7	100+100+20+10+10=240	D

EIGRP Reported Distance (RD)

- Reported distance is the distance (metric) towards a destination as advertised by an upstream neighbor

  Reported distance is the distance reported in the queries, the replies and the updates

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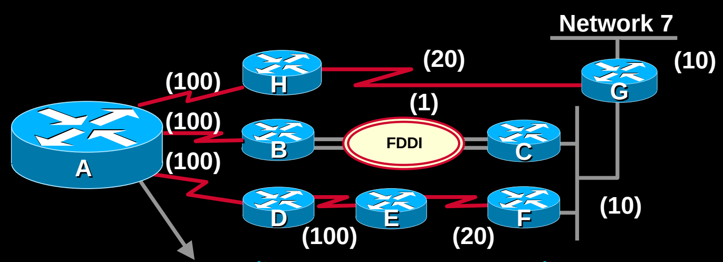
Reported Distance Example



Topology Table

Destination	Reported Distance (RD)	Neighbor
7	20+10=30	H
7	1+10+10=21	B
7	100+20+10+10=140	D

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EIGRP Feasibility Condition (FC)

- A neighbor meets the feasibility condition (FC) if the reported distance by the neighbor is smaller than the feasible distance (FD) of this router

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EIGRP Successor

- A successor is a neighbor that has met the feasibility condition and has the least cost path towards the destination
- It is the next hop for forwarding packets
- Multiple successors are possible (load balancing)

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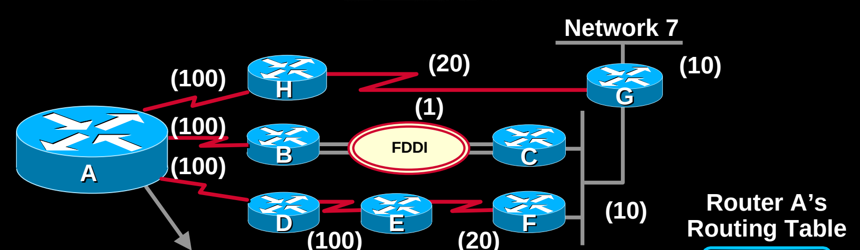
EIGRP Feasible Successor (FS)

- A feasible successor is a neighbor whose reported distance (RD) is less than the feasible distance (FD)

Successor Example



Router A's Routing Table

7	121	B

Topology Table

Destination	FD	RD	Neighbor
7	130	30	H
7	121	21	B
7	240	140	D

- B is current successor (FD = 121)
- H is the feasible successor (30 < 121)

Passive, Active, and Stuck in Active (SIA)

- Passive routes are routes that have successor information

  Passive route = good

- Active routes are routes that have lost their successors and no feasible successors are available. The router is actively looking for alternative paths

  Active route = bad

- Stuck in Active means the neighbor still has not replied to the original query within three minutes

  Stuck in active = ugly

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Dual Algorithm

- Local computation

  When a route is no longer available via the current successor, the router checks its topology table

  Router can switch from successor to feasible successor without involving other routers in the computation

  Router stays passive

  Updates are sent

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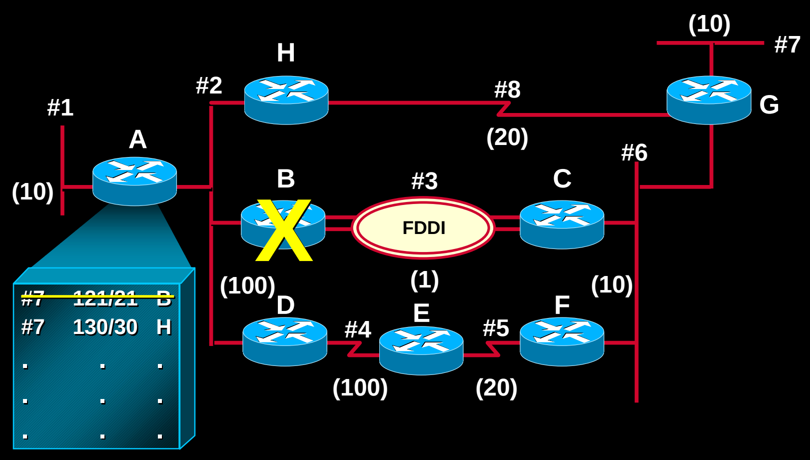
Dual: Local Computation



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Dual Algorithm

- Diffused Computation

  When a route is no longer available via its current successor and no feasible successor is available, queries are sent out to neighbors asking about the lost route

  The route is said to be in active state

  Neighbors reply to the query if they have information about the lost route. If not, queries are sent out to all of their neighbors.

  The router sending out the query waits for all of the replies from its neighbors and will make routing decision based on the replies

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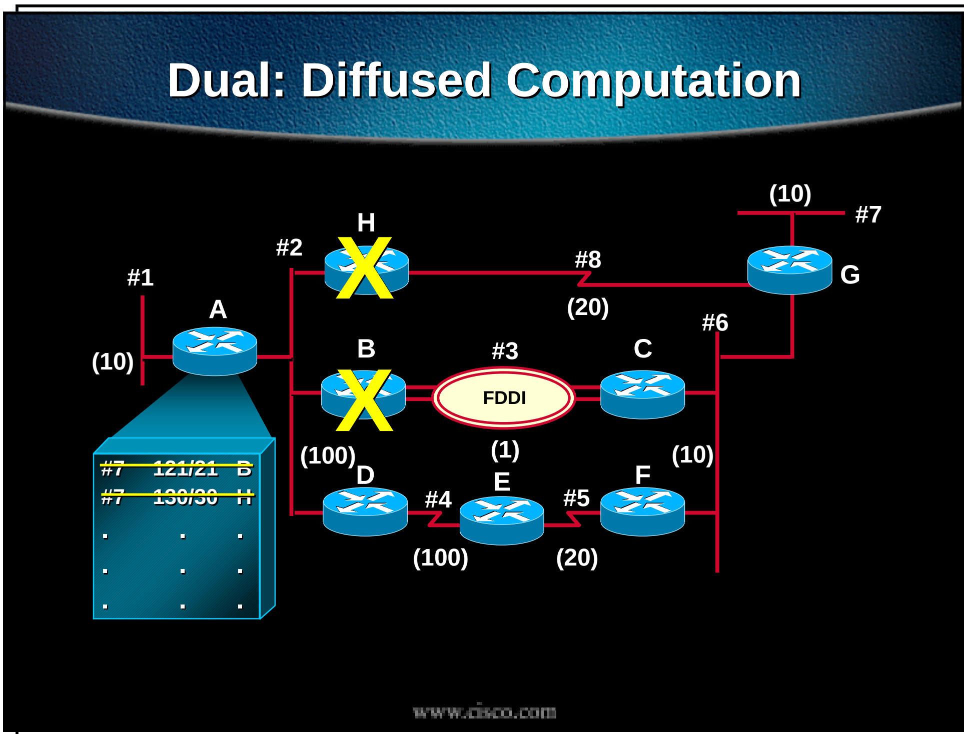
Dual: Diffused Computation
H
#2
#8
(10)
#7
G
#1
A
(20)
#6
(10)
B
#3
C
FDDI
#7 121/21 B
#7 130/30 H
(100)
D
(1)
E
(10)
F
#4
#5
(100)
(20)
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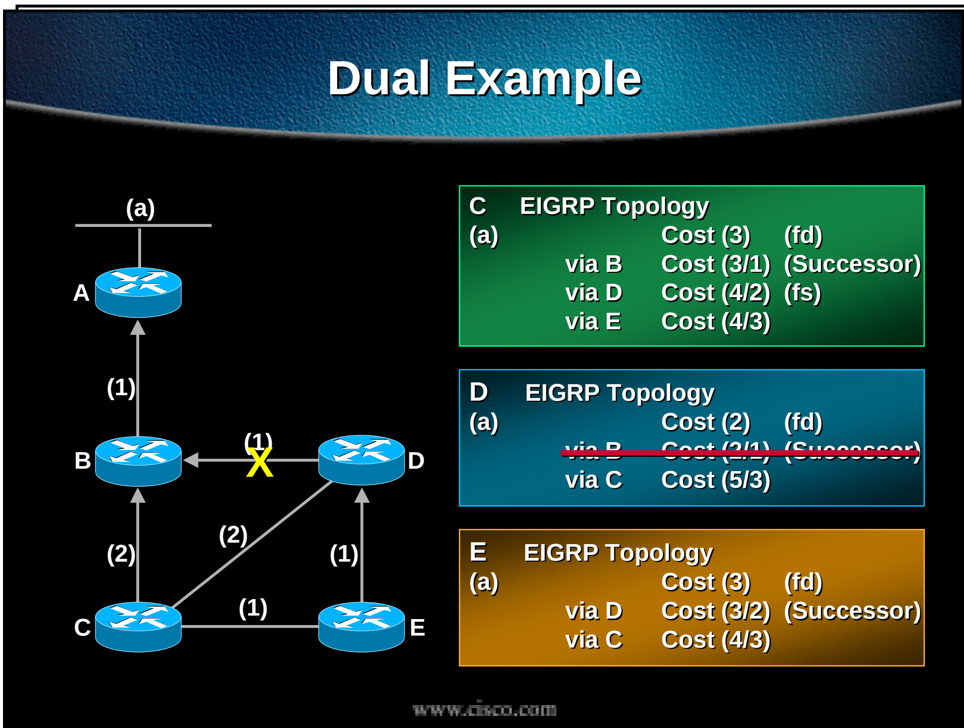
Dual Example
(a)
A
(1)
B
(1)
D
(2)
(2)
(1)
C
(1)
E
C EIGRP Topology
(a) Cost (3) (fd)
via B Cost (3/1) (Successor)
via D Cost (4/2) (fs)
via E Cost (4/3)
D EIGRP Topology
(a) Cost (2) (fd)
via B Cost (2/1) (Successor)
via C Cost (5/3)
E EIGRP Topology
(a) Cost (3) (fd)
via D Cost (3/2) (Successor)
via C Cost (4/3)
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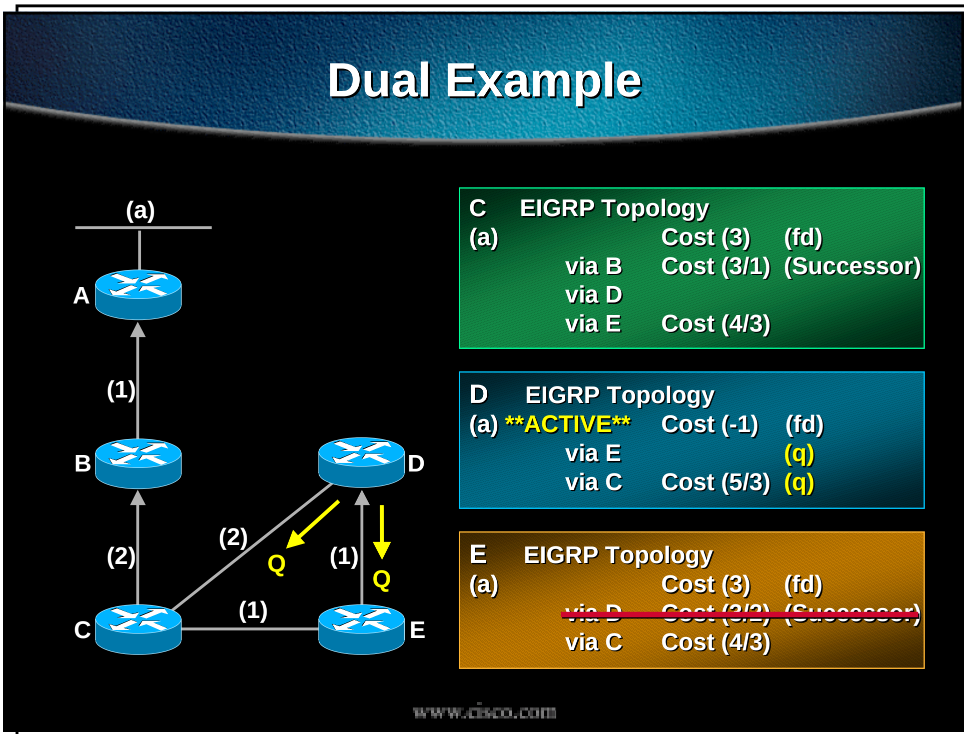
Dual Example
(a)
A
(1)
B
D
(2)
(2)
Q
(1)
Q
C
(1)
E
C EIGRP Topology
(a) Cost (3) (fd)
via B Cost (3/1) (Successor)
via D
via E Cost (4/3)
D EIGRP Topology
(a) **ACTIVE** Cost (-1) (fd)
via E (q)
via C Cost (5/3) (q)
E EIGRP Topology
(a) Cost (3) (fd)
~~via D Cost (3/2) (Successor)~~
via C Cost (4/3)
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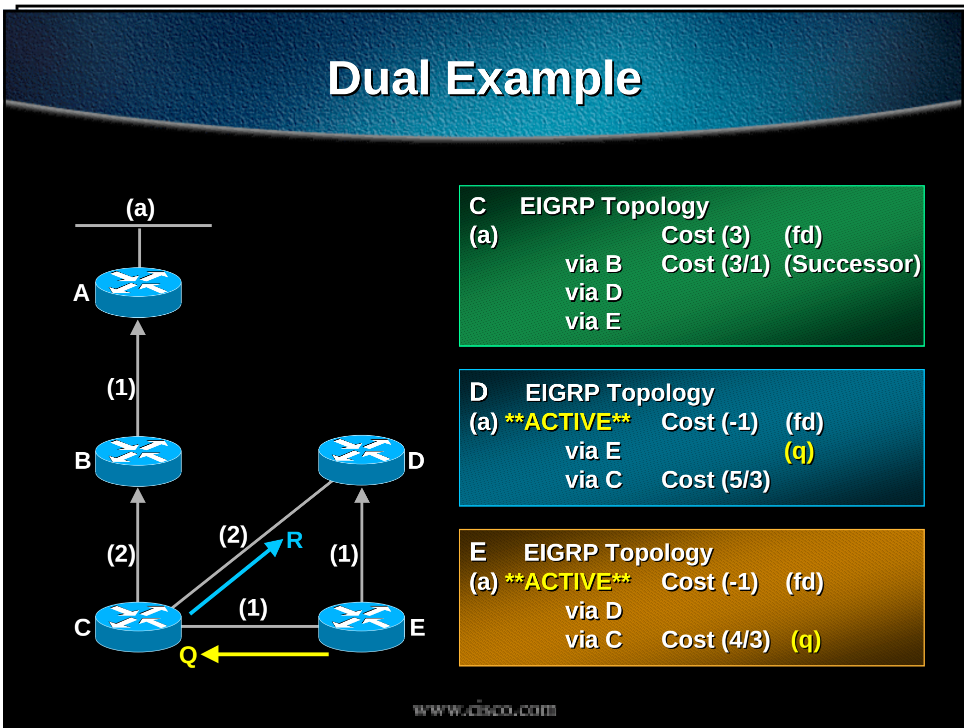
Dual Example
(a)
A
(1)
B
D
(2)
R
(2)
(1)
C
(1)
E
Q
C EIGRP Topology
(a) Cost (3) (fd)
via B Cost (3/1) (Successor)
via D
via E
D EIGRP Topology
(a) **ACTIVE** Cost (-1) (fd)
via E (q)
via C Cost (5/3)
E EIGRP Topology
(a) **ACTIVE** Cost (-1) (fd)
via D
via C Cost (4/3) (q)
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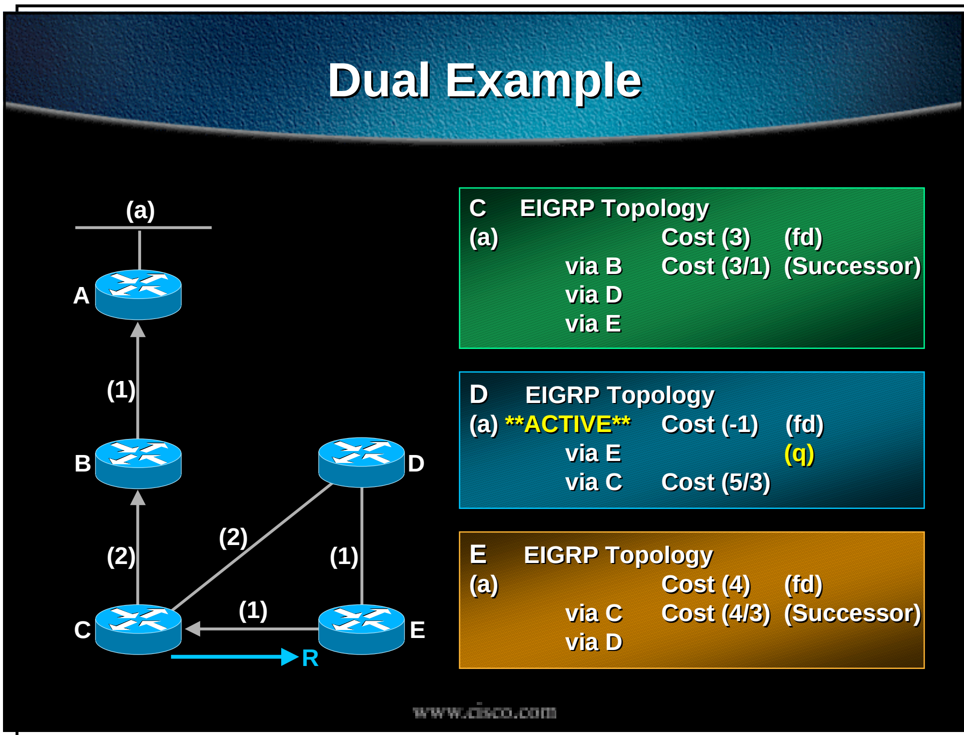
Dual Example
(a)
A
(1)
B
D
(2)
(2)
(1)
(1)
C
E
R
C EIGRP Topology
(a) Cost (3) (fd)
via B Cost (3/1) (Successor)
via D
via E
D EIGRP Topology
(a) **ACTIVE** Cost (-1) (fd)
via E (q)
via C Cost (5/3)
E EIGRP Topology
(a) Cost (4) (fd)
via C Cost (4/3) (Successor)
via D
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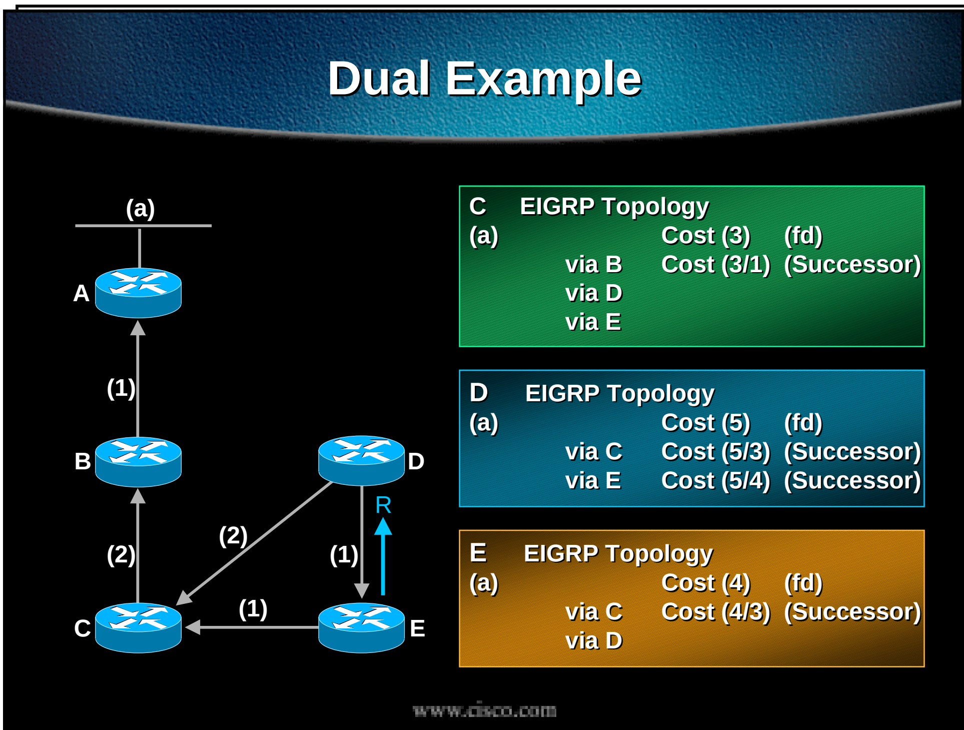
Dual Example
(a)
A
(1)
B
D
R
(2)
(2)
(1)
(1)
C
E
C EIGRP Topology
(a) Cost (3) (fd)
via B Cost (3/1) (Successor)
via D
via E
D EIGRP Topology
(a) Cost (5) (fd)
via C Cost (5/3) (Successor)
via E Cost (5/4) (Successor)
E EIGRP Topology
(a) Cost (4) (fd)
via C Cost (4/3) (Successor)
via D
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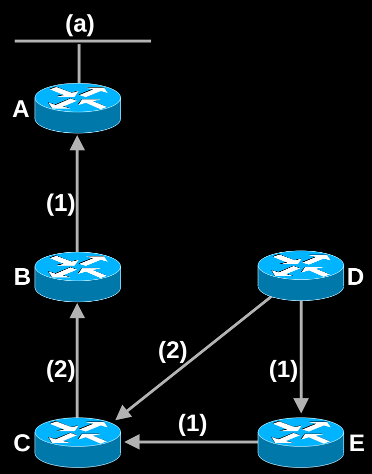
Dual Example



C EIGRP Topology

(a)		Cost (3)	(fd)
	via B	Cost (3/1)	(Successor)
	via D		
	via E		

D EIGRP Topology

(a)		Cost (5)	(fd)
	via C	Cost (5/3)	(Successor)
	via E	Cost (5/4)	(Successor)

E EIGRP Topology

(a)		Cost (4)	(fd)
	via C	Cost (4/3)	(Successor)
	via D		

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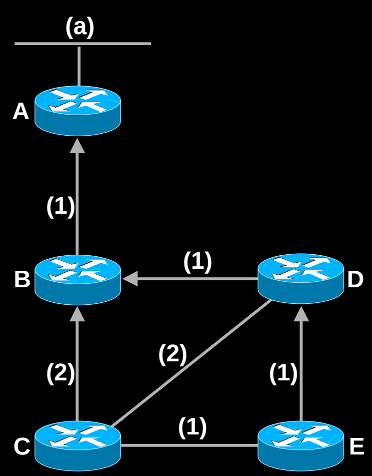
Dual Example (Start)



C EIGRP Topology

(a)		Cost (3)	(fd)
	via B	Cost (3/1)	(Successor)
	via D	Cost (4/2)	(fs)
	via E	Cost (4/3)	

D EIGRP Topology

(a)		Cost (2)	(fd)
	via B	Cost (2/1)	(Successor)
	via C	Cost (5/3)	

E EIGRP Topology

(a)		Cost (3)	(fd)
	via D	Cost (3/2)	(Successor)
	via C	Cost (4/3)	

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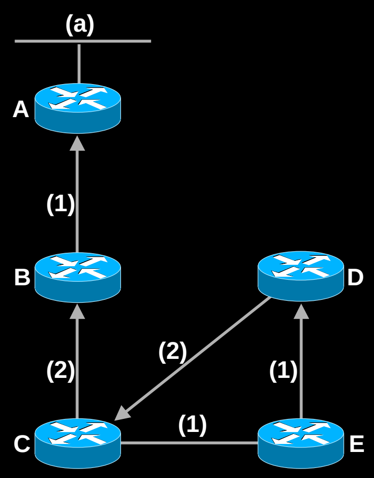
Dual Example (End)



C EIGRP Topology

(a)		Cost (3)	(fd)
	via B	Cost (3/1)	(Successor)
	via D		
	via E		

D EIGRP Topology

(a)		Cost (5)	(fd)
	via C	Cost (5/3)	(Successor)
	via E	Cost (5/4)	(Successor)

E EIGRP Topology

(a)		Cost (4)	(fd)
	via C	Cost (4/3)	(Successor)
	via D		

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EIGRP Reliable Transport Protocol

- EIGRP **reliable packets** are packets that requires explicit acknowledgement:

  Update

  Query

  Reply

- EIGRP **unreliable packets** are packets that do not require explicit acknowledgement:

  Hello

  Ack

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EIGRP Reliable Transport Protocol

- The router keeps a neighbor list and a retransmission list for every neighbor
- Each reliable packet (Update, Query, Reply) will be retransmitted when packet is not acked
- EIGRP transport has window size of one (stop and wait mechanism)

  Every single reliable packet needs to be acknowledged before the next sequenced packet can be sent

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EIGRP Reliable Transport Protocol

- With reliable multicast traffic, one must wait to transmit the next reliable multicast packets, until all peers have acknowledged the previous multicast
- If one or more peers are slow in acknowledging, all other peers suffer from this
- Solution: The nonacknowledged multicast packet will be retransmitted as a unicast to the slow neighbor

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EIGRP Reliable Transport Protocol

- Per neighbor, retransmission limit is 16
- Neighbor relationship is reset when retry limit (limit = 16) for reliable packets is reached

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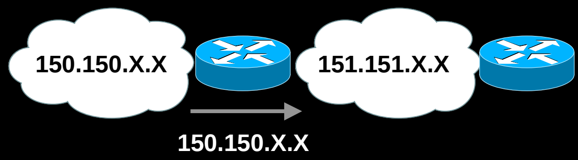
EIGRP Summarization

- Purpose: Smaller routing tables, smaller updates, query boundary
- Auto summarization:

  On major network boundaries, networks are summarized to the major networks

  Auto summarization is turned on by default



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EIGRP Summarization

- Manual summarization

  Configurable on per interface basis in any router within network

  When summarization is configured on an interface, the router immediate creates a route pointing to null zero with administrative distance of five

  - Loop prevention mechanism

  When the last specific route of the summary goes away, the summary is deleted

  The minimum metric of the specific routes is used as the metric of the summary route

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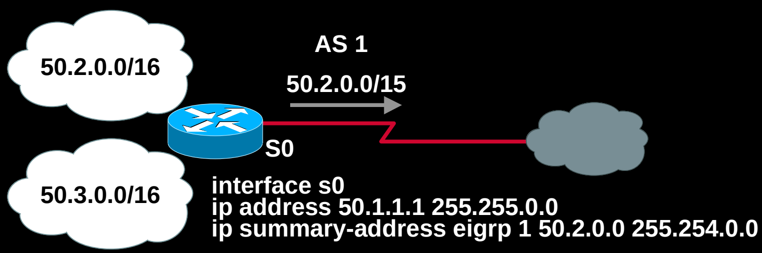
EIGRP Summarization

- Manual summarization command:

  ip summary-address eigrp <as number> <address> <mask>



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EIGRP Load Balancing

- Routes with equal metric to the minimum metric, will be installed in the routing table (Equal Cost Load Balancing)
- There can be up to six entries in the routing table for the same destination (default = 4)

  ip maximum-paths <1-6>

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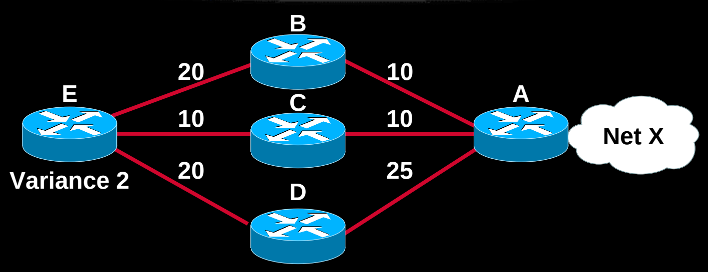
EIGRP Unequal Cost-Load Balancing

- EIGRP offers unequal cost load balancing feature with the command:

  Variance <multiplier>

- Variance command will allow the router to include routes with a metric smaller than multiplier times the minimum metric route for that destination, where multiplier is the number specified by the variance command

Variance Example



- Router E will choose router C to get to net X FD=20
- With variance of 2, router E will also choose router B to get to net X
- Router D will not be used to get to net X

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EIGRP and IGRP Interaction

- Administrative distance vs. routing metrics

  Administrative distance is used to compare with routes coming from two different routing protocols

  - Connected = 0
  - Static route = 1
  - EIGRP summary route = 5
  - EBGP = 20
  - Internal EIGRP = 90
  - IGRP = 100
  - OSPF = 110
  - RIP = 120
  - External EIGRP = 170
  - IBGP = 200

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EIGRP and IGRP Interaction

- Metric is used to compare routes coming from the same routing protocol
  - RIP = Hop count
  - EIGRP/IGRP = Bandwidth and delay
  - OSPF = Link cost

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EIGRP and IGRP Interaction

- External vs. internal EIGRP
  - External EIGRP:
    - Any routes being redistributed into an EIGRP process from another routing protocol or EIGRP process is considered as external EIGRP routes
    - Administrative distance = 170
  - Internal EIGRP:
    - Any routes that originated from its own EIGRP process is considered as internal EIGRP routes
    - Administrative distance = 90

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EIGRP and IGRP Interaction

- To make EIGRP compatible with existing IGRP network with minimum interruption, EIGRP and IGRP with the same process number will be automatically redistributed into each other

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EIGRP and IGRP Interaction

- Rules for IGRP/EIGRP interaction to avoid routing loops:
  - Internal EIGRP routes preferred over IGRP routes
    - Administrative distance considered (90 vs. 100)
  - External EIGRP routes preferred over IGRP routes on same AS number and same scaled route metric
    - Administrative distance not considered

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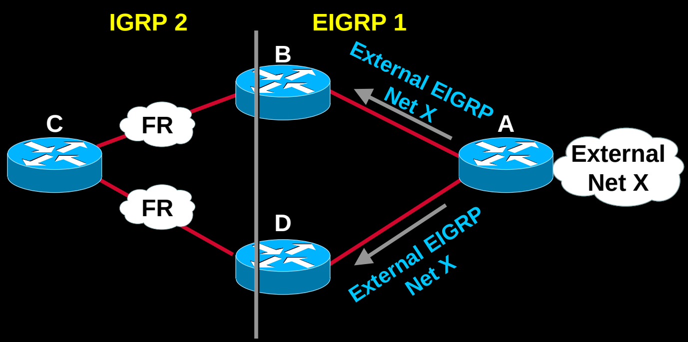
EIGRP/IGRP Example



- Network X is external EIGRP route
- Router A forwards external EIGRP routes to router B and D

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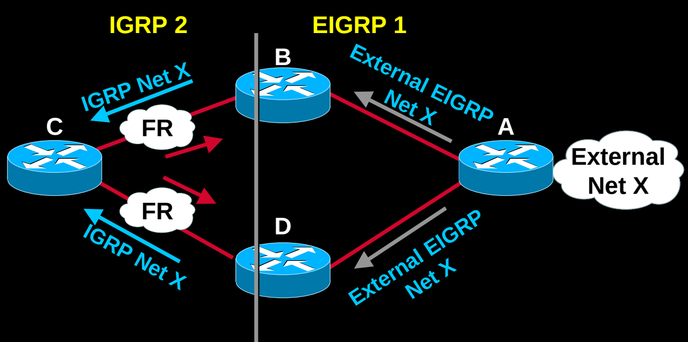
EIGRP/IGRP Example (Different AS)



- Router B and D sends IGRP route to router C
- Router C sends IGRP network X route back to Router B and D
- Router B and D will choose IGRP route because of lower administrative distance
  - Result: Router B and D will take the wrong route to Net X

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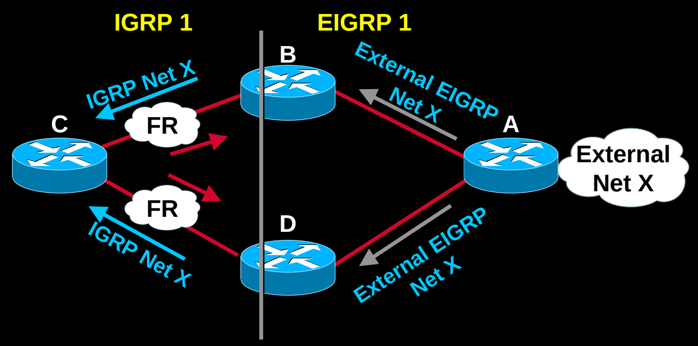
EIGRP/IGRP Example (Same AS)



- Router B and D will not take administrative distance as decision process if EIGRP and IGRP has the same AS
- Router B and D still favors external EIGRP routes from router A

Result: Router B and D will take correct route to Net X

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Agenda

- Fundamentals of EIGRP
- Dual
- Summarization and Load Balancing
- EIGRP/IGRP Interaction
- Query Process
- Deployment Guidelines with EIGRP
- Summary

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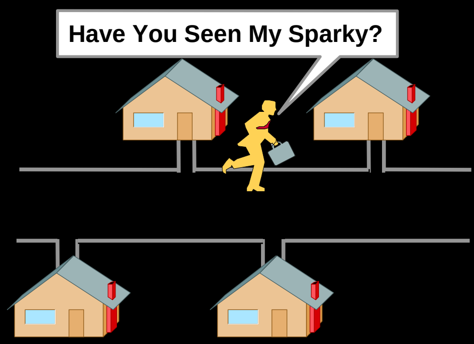
EIGRP Query Process

- EIGRP is Advanced Distant Vector. It relies on its neighbor to provide routing information
- If a route is lost and no feasible successor is available, EIGRP needs to converge fast, its only mechanism for fast convergence is to actively query for the lost route to its neighbors



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EIGRP Query Process

- Queries are sent out when a route is lost and no feasible successor is available
- The lost route is now in active state
- Queries are sent out to all of its neighbors on all interfaces except the interface to the successor
- If the neighbor does not have the lost route information, queries are sent out to their neighbors

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EIGRP Query Process

- The router will have to get ALL of the replies from the neighbors before the router calculates the successor information
- If any neighbor fails to reply the query in three minutes, this route is **stuck** in **active** and the router reset the neighbor that fails to reply
- Solution is to limit query range to be covered later in presentation

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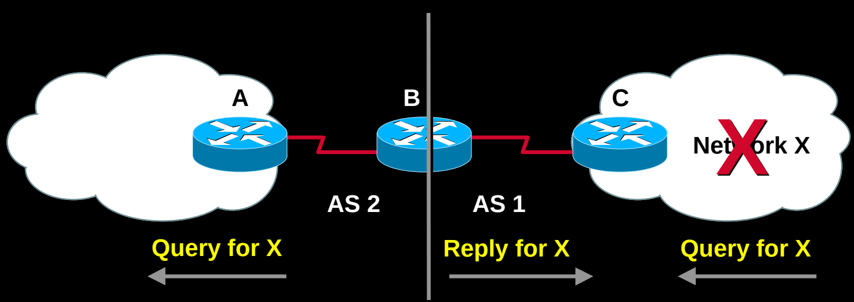
EIGRP Query Range

- Autonomous system boundaries

  Contrary to popular belief, queries are not bounded by AS boundaries. Queries from AS 1 will be propagated to AS 2



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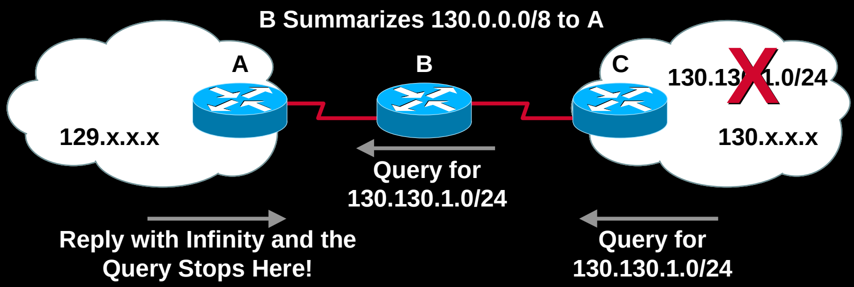
EIGRP Query Range

- Summarization point

  Auto or manual summarization is the best way to bound queries

  Requires a good address allocation scheme



EIGRP Bandwidth Utilization

- EIGRP by default will use up to 50% of the link bandwidth for EIGRP packets
- This parameter is manually configurable by using the command:

  ip bandwidth-percent eigrp <AS-number> <nnn>

- Use for greater EIGRP load control

Bandwidth over WAN Interfaces

- **Bandwidth utilization over point-to-point subinterface Frame Relay**

  Treats bandwidth as T1 by default

  Best practice is to manually configure bandwidth as the CIR of the PVC

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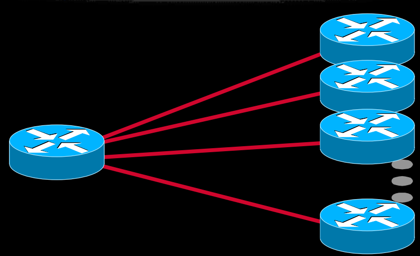
Bandwidth over WAN Interfaces



- **Bandwidth over multipoint Frame Relay, ATM, SMDS, and ISDN PRI:**

  EIGRP uses the bandwidth on the main interface divided by the number of neighbors on that interface to get the bandwidth information per neighbor

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Bandwidth over WAN Interfaces

- Each PVC might have different CIR, this might create EIGRP packet pacing problem
  - Multipoint interfaces:
    - Convert to point-to-point
    - Bandwidth configured = (lowest CIR x number of PVC)
  - ISDN PRI:
    - Use Dialer Profile (treat as point-to-point link)

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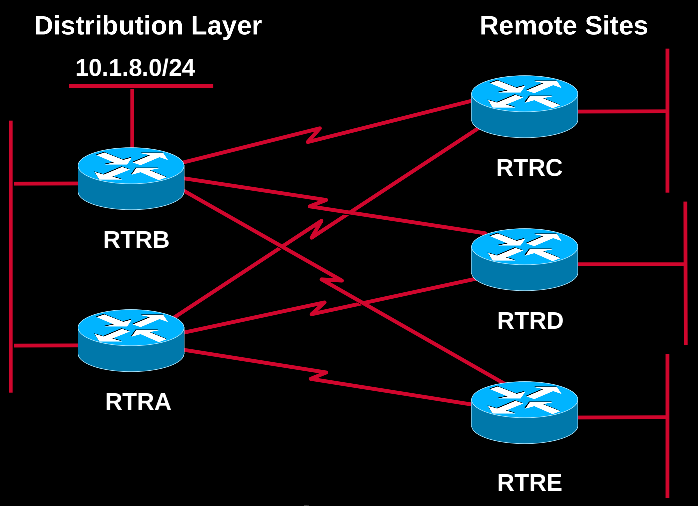
Factors That Influence EIGRP Scalability

- Keep in mind that EIGRP is not plug and play for large networks
- Limit EIGRP query range!
- Quantity of routing information exchanged between peers

Limiting Updates/Queries—Example



Limiting Size/Scope of Updates/Queries

- Evaluate routing requirements
  - What routes are needed where?
- Once needs are determined
  - Use summary address
  - Use distribute lists

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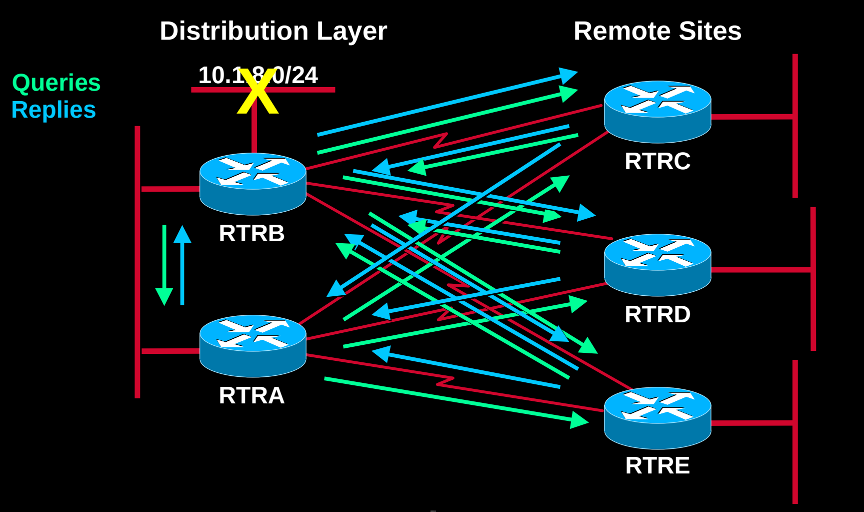
Limiting Updates/Queries—Example



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Limiting Updates/Queries—Summary

- Remote routers fully involved in convergence

  Most remotes are never intended to be transit

  Convergence complicated through lack of information hiding

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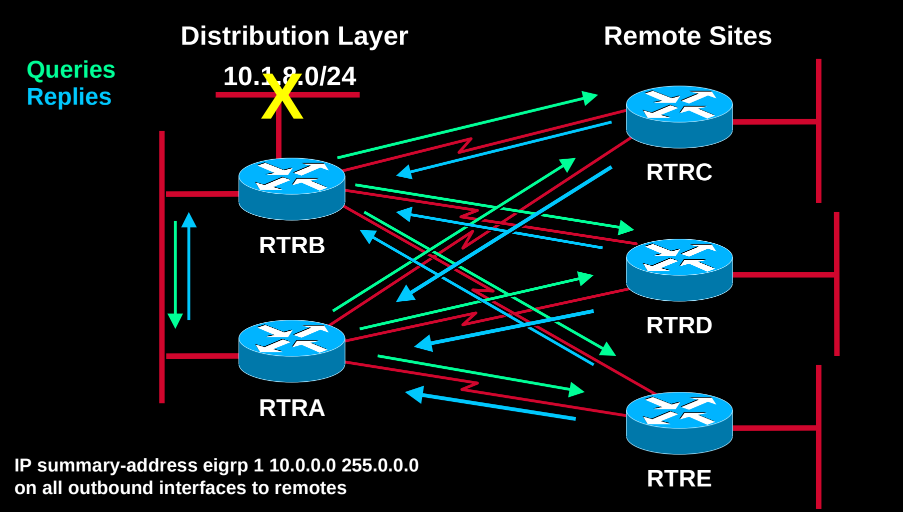
Limiting Updates/Queries—Better



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Limiting Updates/Queries—Summary

- Convergence simplified by adding the summary-address statements
- Remote routers just reply when queried

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Hierarchy/Addressing

- Permits maximum information hiding
- Advertise major net or default route to regions or remotes
- Provides adequate redundancy

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EIGRP Scalability

- EIGRP is a very scalable routing protocol if proper design methods are used:
  - Good allocation of address space
    - Each region should have an unique address space so route summarization is possible
  - Have a tiered network design model (Core, Distribution, Access)

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EIGRP Scalability

- Proper network resources
  - Sufficient memory on the router
  - Sufficient bandwidth on WAN interfaces
- Proper configuration of the “bandwidth” statement over WAN interfaces, especially over Frame Relay
- Avoid blind mutual redistribution between two routing protocols or two EIGRP processes

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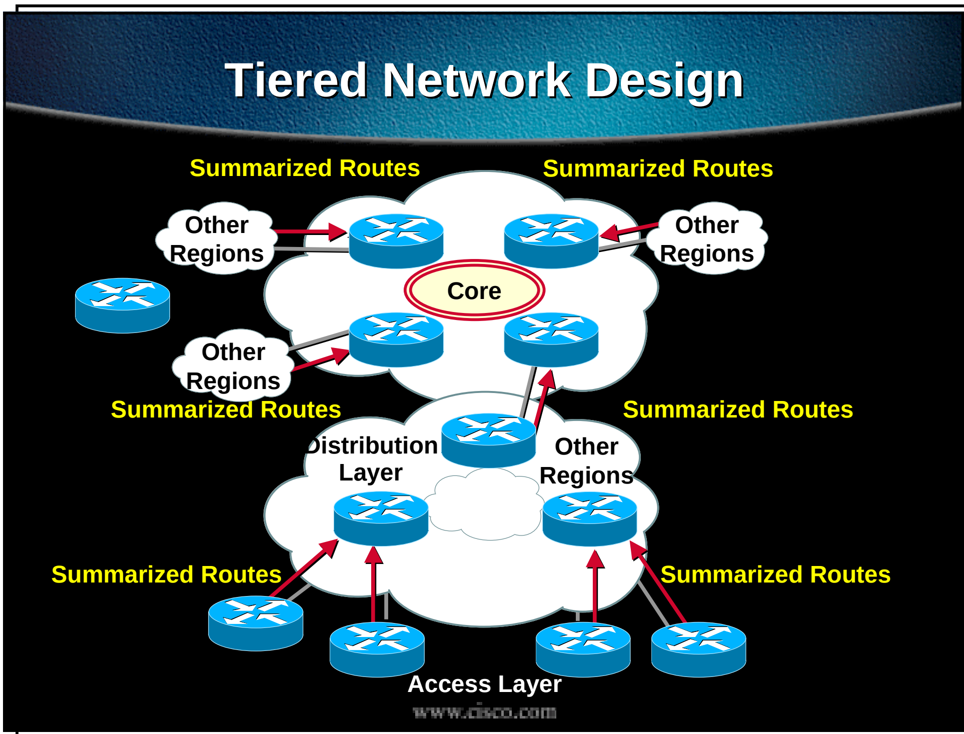
Tiered Network Design
Summarized Routes
Summarized Routes
Other Regions
Other Regions
Core
Other Regions
Summarized Routes
Summarized Routes
Distribution Layer
Other Regions
Summarized Routes
Summarized Routes
Access Layer
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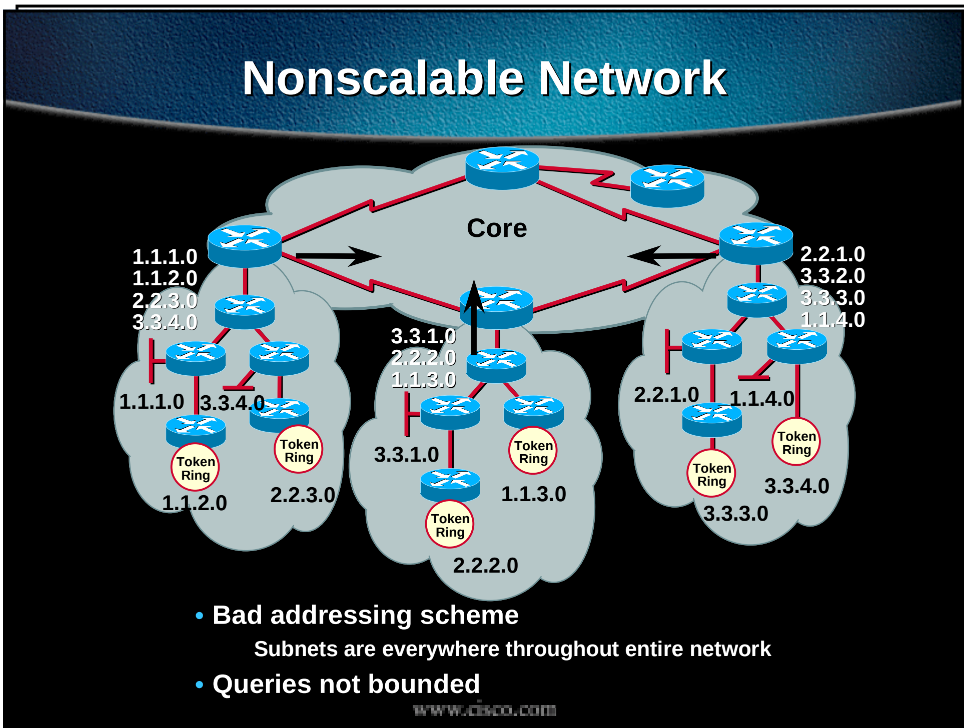
Nonscalable Network
Core
1.1.1.0
1.1.2.0
2.2.3.0
3.3.4.0
1.1.1.0
3.3.4.0
Token Ring
Token Ring
1.1.2.0
2.2.3.0
3.3.1.0
2.2.2.0
1.1.3.0
3.3.1.0
Token Ring
Token Ring
1.1.3.0
2.2.2.0
2.2.1.0
3.3.2.0
3.3.3.0
1.1.4.0
2.2.1.0
1.1.4.0
Token Ring
Token Ring
3.3.4.0
3.3.3.0
• Bad addressing scheme
Subnets are everywhere throughout entire network
• Queries not bounded
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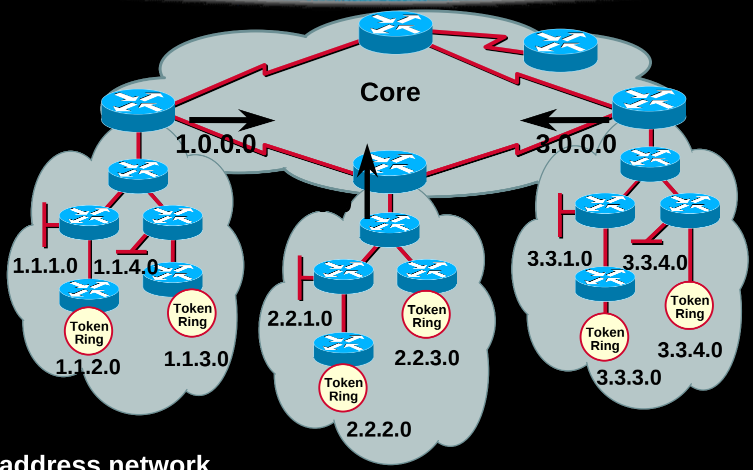
Scalable Network



- Readdress network
  - Each region has its own block of address
- Queries bounded by using “ip summary-address eigrp” command

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Summary

- Query range
  - Best way to limit query is through route summarization
- EIGRP is not plug and play for large networks
  - It’s a very scalable protocol with little design requirement
- Optimizing EIGRP network
  - Limiting query range
    - Route summarization
    - Tiered network design
  - Sufficient network resources

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