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CISCO

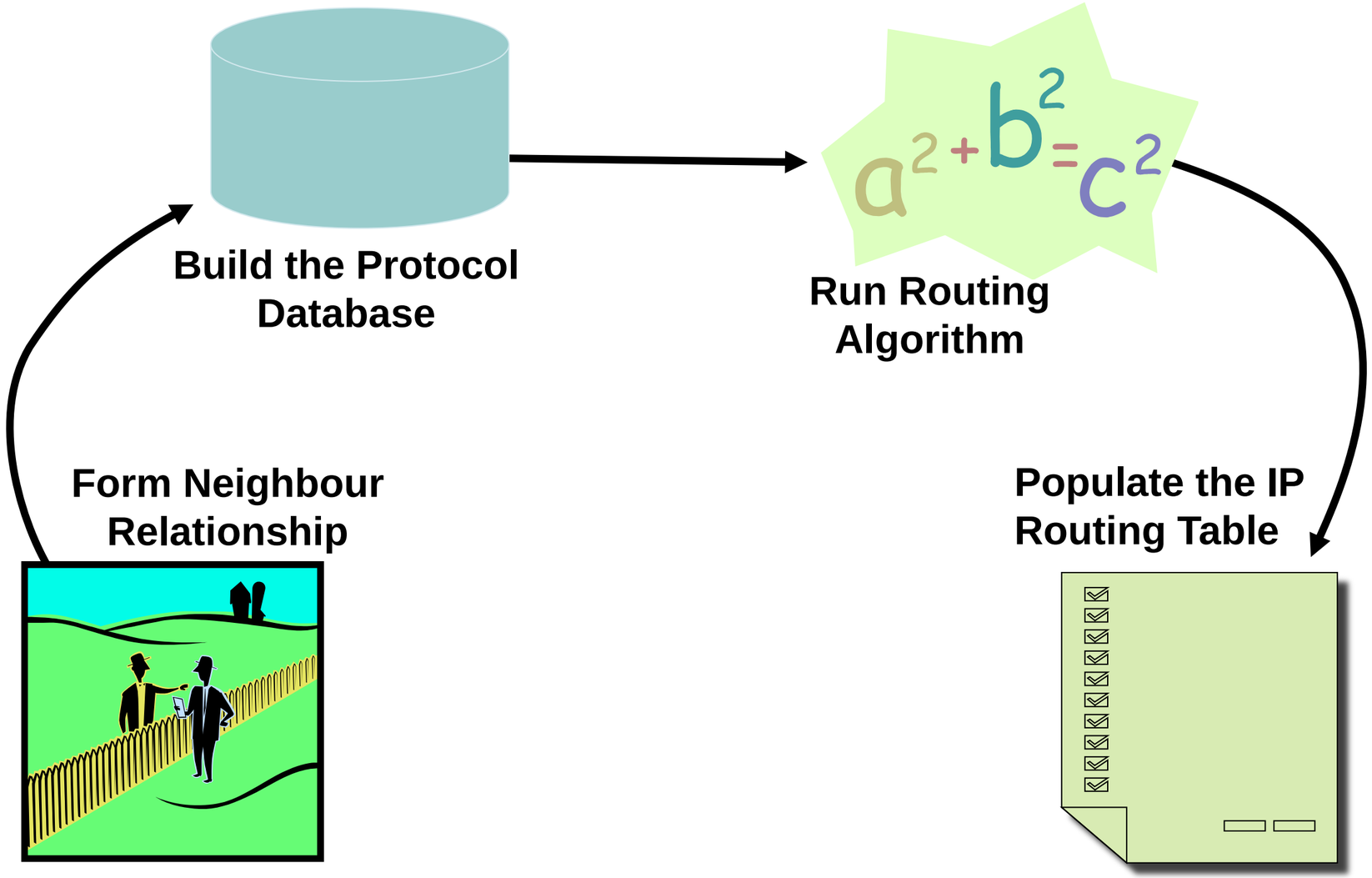
Troubleshooting Routing Protocols - BGP / OSPF / EIGRP

BRKRST-2619

Agenda

- View from 50,000 meters
- Generic Lifecycle approach to troubleshoot the following protocols:
  - EIGRP
  - OSPF
  - BGP

View From 50,000 Metres



Lifecycle View of the EIGRP Routing Process

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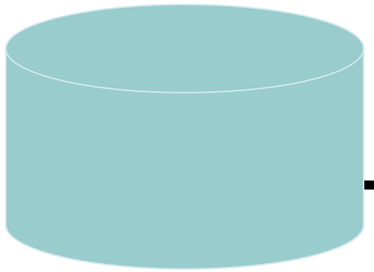
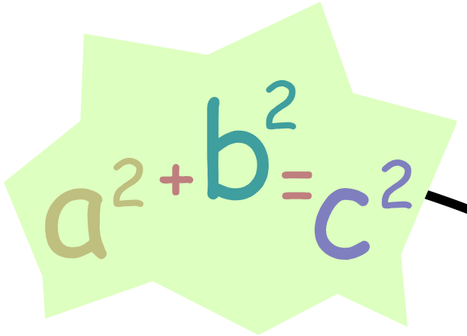
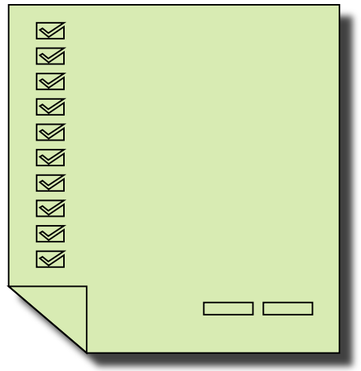


Build the EIGRP Topology Database

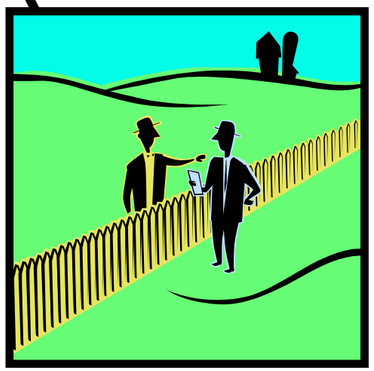


Run EIGRP Dual Routing Algorithm

Populate the IP Routing Table



Form EIGRP Neighbour Relationship



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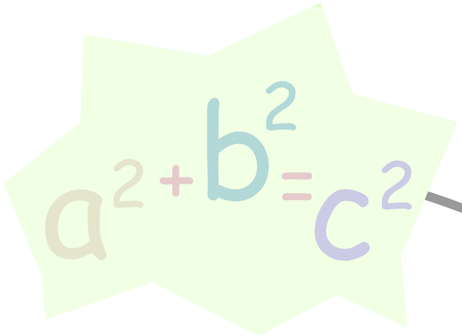

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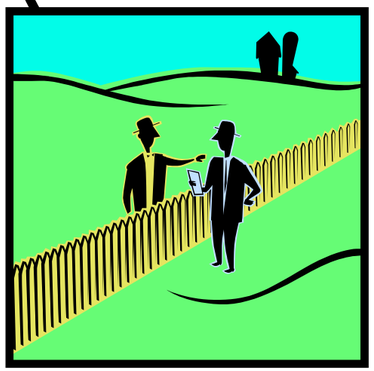

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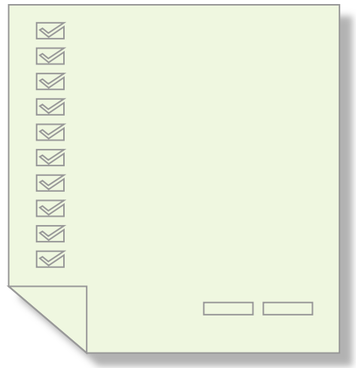
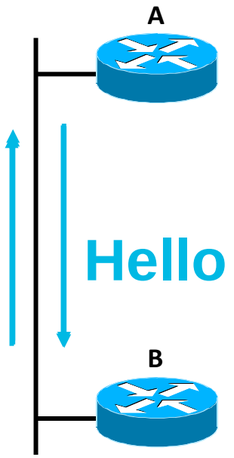


EIGRP Neighbour Process

- Hello process used for neighbour discovery and maintenance

Hello Types
K-value
AS number
IP subnet
Primary/secondary IP address

should match



- Multicast hellos (by default)
  - 224.0.0.10 (0100.5e00.000a)
- Hello Interval
  - 60 seconds for low-speed NBMA
  - 5 seconds for all other interfaces

EIGRP Neighbour Process

```
RTRA#show ip eigrp neighbors
IP-EIGRP neighbors for process 1
H   Address     Interface Hold Uptime  SRTT   RTO  Q    Seq
                          (sec)       (ms)       Cnt  Num
2   20.1.1.2    Et0       12   6d16h   20     200  0    233
1   10.1.4.3    Et1       13   2w2d    87     522  0    452
0   10.1.4.2    Et1       10   2w2d    85     510  0    3
```

Seconds remaining before declaring neighbour down

How long since the last time neighbour was discovered

How long it takes for this neighbour to respond to reliable packets

How long we'll wait before retransmitting if no acknowledgement

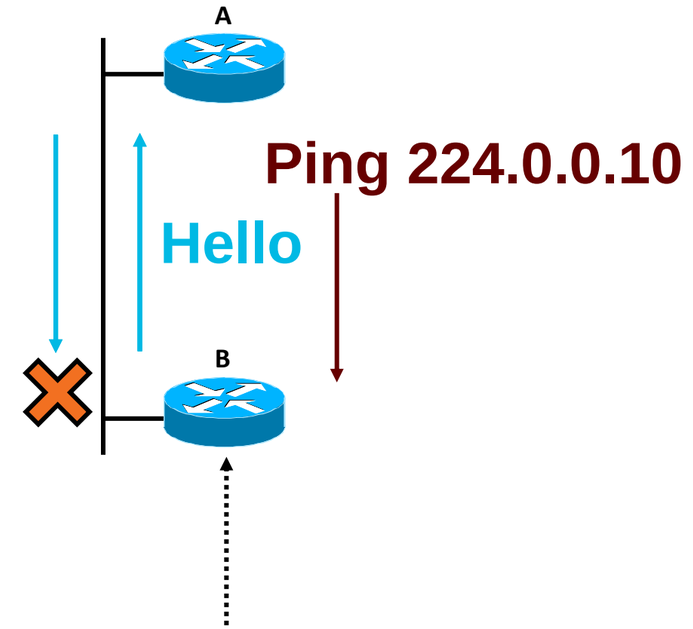
* Normal to have 5000 during the startup

Number of EIGRP packets unacknowledged by neighbour

EIGRP Neighbour Problems

Hold Time Expired

- The hold time expires when an EIGRP packet is not received during hold time
  - Typically caused by congestion or physical errors
- Ping the multicast Address (224.0.0.10) from the Other Router
- Other checks:
  - Access-lists
  - Debug EIGRP packet hello
  - Ping neighbour with small & large packets
  - Interface errors
  - Configure neighbour statements



EIGRP Neighbour Problems

Manual Changes

- Some manual configuration changes can also reset EIGRP neighbours, depending on the IOS version:
  - Summary changes (manual and auto)
  - Route filter changes
- This is normal behaviour for older code
  - CSCdy20284 removed many of these neighbour resets
    - Implemented in 12.2S, 12.3T, and 12.4
- Dynamic peer resynchronisation uses graceful restart to resynchronise neighbour relationships, rather than restarting them
  - **clear ip eigrp neighbor <address> soft**
  - Available in 12.3(12.06)T

EIGRP Neighbour Log Messages

eigrp log-neighbor-changes must be enabled
Enabled by default since 12.1.3

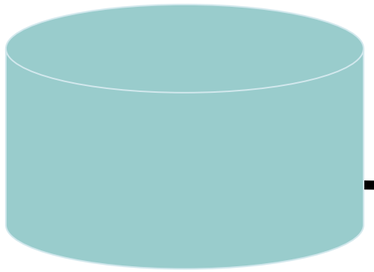
Example logs

Neighbor 20.1.1.2 (Ethernet0) is down: peer restarted
Neighbor 20.1.1.2 (Ethernet0) is down: holding time expired
Neighbor 20.1.1.2 (Ethernet0) is down: retry limit exceeded
Neighbor 20.1.1.2 (Ethernet0) is down: route filter changed (old)
Neighbor 20.1.1.2 (Ethernet0) is down: K-value mismatch
Neighbor 20.1.1.2 (Ethernet0) is down: manually cleared
Neighbor 20.1.1.2 (Ethernet0) is down: Interface Goodbye received

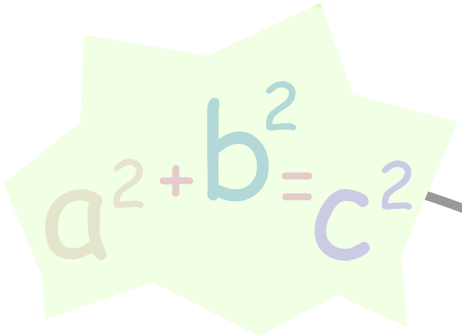
Neighbor 20.1.1.2 (Ethernet0) is resync: route configuration changed
Neighbor 20.1.1.2 (Ethernet0) is resync: manually cleared
Neighbor 20.1.1.2 (Ethernet0) is resync: peer graceful-restart

There are others, but not seen very often…

Lifecycle View of the EIGRP Routing Process

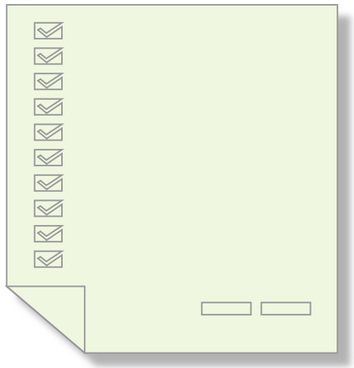


Build the EIGRP Topology Database

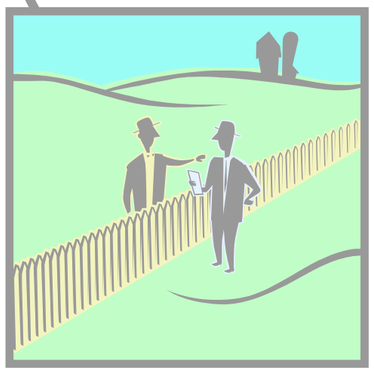


Run EIGRP Dual Routing Algorithm

Populate the IP Routing Table

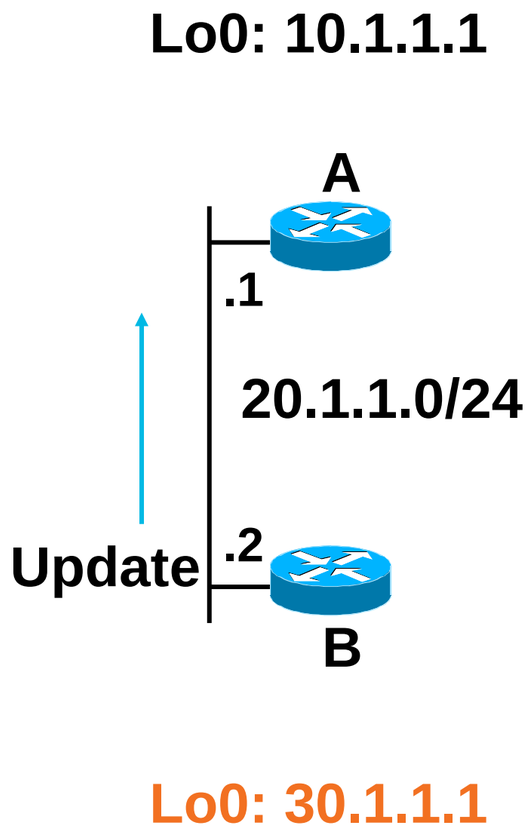


Form EIGRP Neighbor Relationship



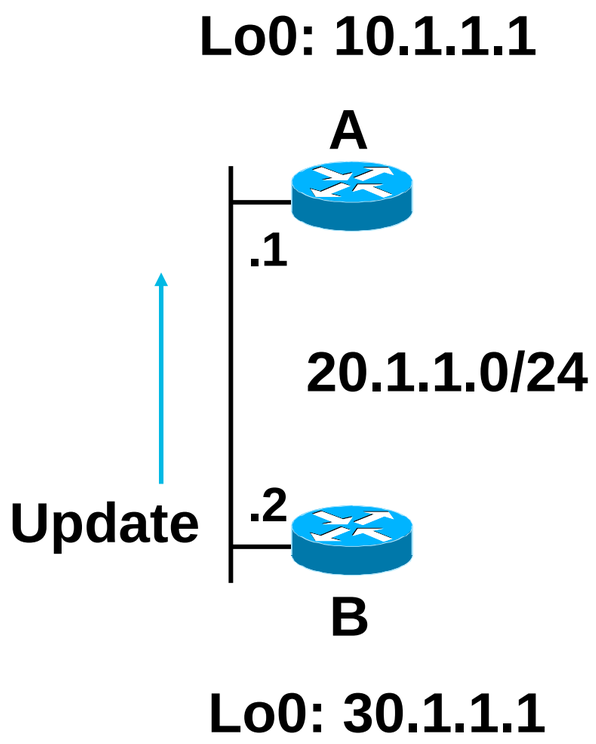
EIGRP Topology Exchange

```
RouterA#debug ip eigrp
IP-EIGRP Route Events debugging is on

RouterA#debug ip eigrp 10 30.1.1.0 255.255.255.0
IP-EIGRP AS Target Events debugging is on

02:13:13.765: IP-EIGRP(Default-IP-Routing-Table:10):
   Processing incoming UPDATE packet

02:13:13.765: IP-EIGRP(Default-IP-Routing-Table:10): Int
   30.1.1.0/24 M 409600 - 256000 153600 SM 128256 - 256
   128000
```



EIGRP Topology Exchange

```
RouterA#show ip eigrp events
Event information for AS 10:
...
...
10   13:20:43.289 Rcv update met/succmet:
                  409600 128256
11   13:20:43.289 Rcv update dest/nh:
                  30.1.1.0/24          20.1.1.2
...
```



EIGRP Event Log

- Always running (unless manually disabled)
- Separate event log is kept for each AS
- Default 500 lines (size is user configurable):
- eigrp event-log-size ## (where ### are number of lines)

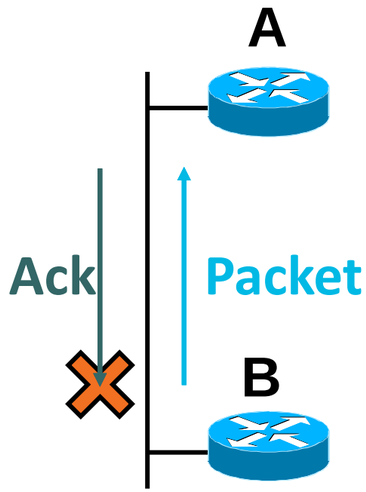
  If number of lines set to 0, disables log
- Most recent events at top of log. So Read bottom to top!
- Clearing the event log by typing:

  clear ip eigrp event

EIGRP Topology Exchange

Retry Limit Exceeded

- Reliable packets are re-sent after Retransmit Time Out (RTO)
  - Typically 6 x Smooth Round Trip Time (SRTT)
  - Minimum 200 ms
  - Maximum 5000 ms (5 seconds)
  - 16 retransmits takes between 50 and 80 seconds
- If a reliable packet is not acknowledged before 16 retransmissions and the Hold Timer duration has passed, re-initialise the neighbour



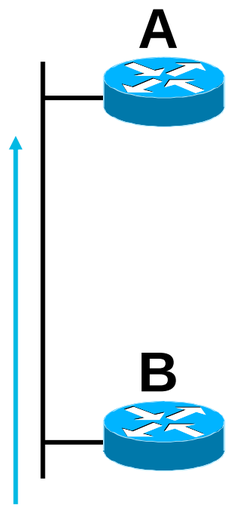
Neighbour 10.1.102.2 (Ethernet0) is down: retry limit exceeded

```
RtrB#show ip eigrp neighbors
IP-EIGRP neighbors for process 1
H Address      Interface Hold Uptime    SRTT RTO  Q    Seq
                         (sec)          (ms)      Cnt Num

1 10.1.102.2   Et0         14  00:00:15    0  5000  4    0
```

EIGRP Topology Exchange

Retry Limit Exceeded - Troubleshoot and Causes

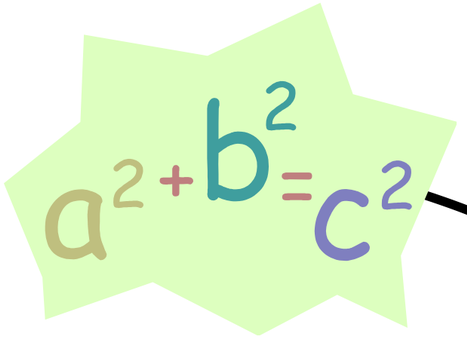
- Ping the neighbour's unicast address
  - Vary the packet size
  - Try large numbers of packets
- This Ping Can Be Issued from Either Neighbour; the Results Should Be the Same
- Common causes
  - Mismatched MTU – **CSCsc72090**
  - Unidirectional link
  - Dirty link




```
RtB# ping
Protocol[ip]:
Target IP address: 10.1.1.1
Repeat count [5]: 100
Datagram Size: 1500
Timeout in seconds[2]:
Extended commands[n]: y
```

Lifecycle View of the EIGRP Routing Process

Build the EIGRP Topology Database



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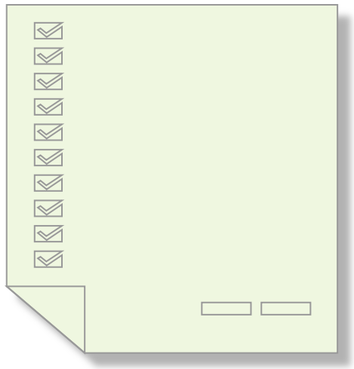

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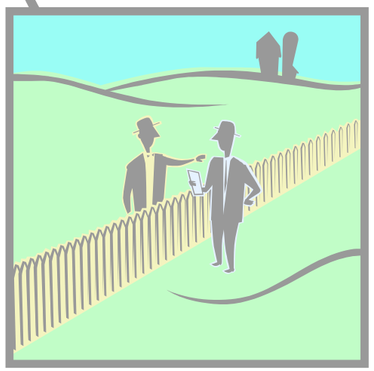


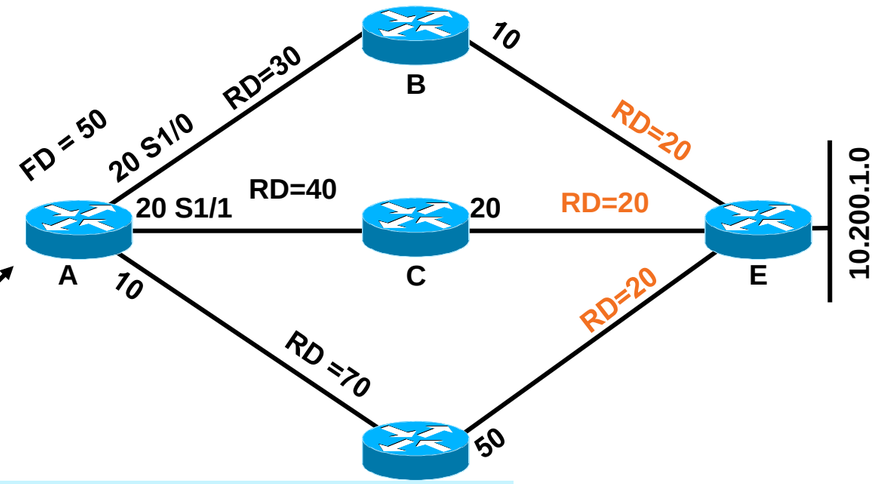
EIGRP DUAL Routing Algorithm Concepts

- Feasible Distance (FD) is the minimum distance (metric) along a path to a destination network.
- Reported distance is the distance (metric) towards a destination as advertised by an upstream neighbour.
- A neighbour meets the feasibility condition (FC) if the reported distance by the neighbour is smaller than the feasible distance (FD) of this router.

DUAL FD, RD, FS and Successor

A-B-E = 20+30 = 50
A-C-E = 20+40 = 60
A-D-E = 20+70 = 90

FD = 50




```
RtrA#show ip eigrp topology
IP-EIGRP Topology Table for AS(1)/ID(10.1.6.1)
..snip…..
P 10.200.1.0/24, 1 successors, FD is 50
         via 10.1.1.2 (50   /   30), Serial1/0
         via 10.1.2.2 (60   /   40), Serial1/1
```

Feasible Distance

Successor

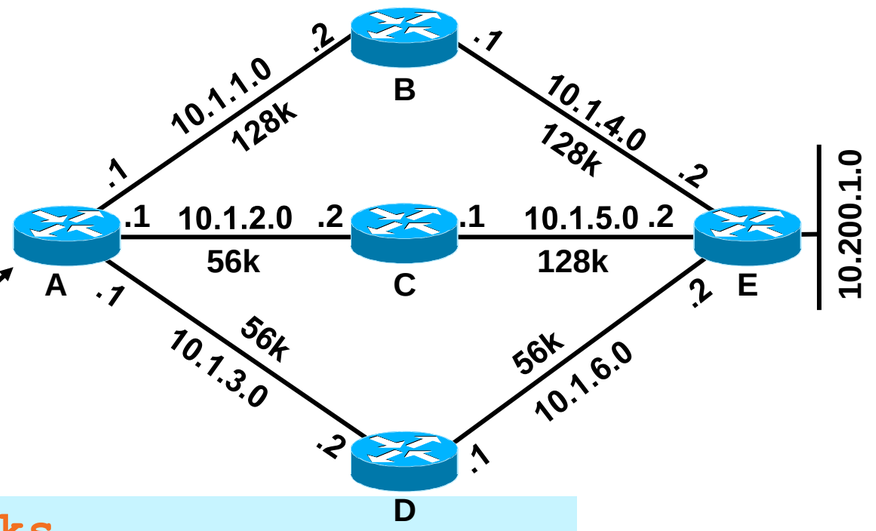
Feasible Successor

Computed Distance

Reported Distance

Show IP EIGRP Topology All-Links

Show ip eigrp topology all-links displays a list of All neighbours who are providing EIGRP with an alternative path to each destination




```
RtrA#show  ip eigrp topology all-links
IP-EIGRP Topology Table for AS(1)/ID(10.1.6.1)
…..snip…..
P 10.200.1.0/24, 1 successors, FD is 21026560
         via 10.1.1.2 (21026560/20514560), Serial1/0
         via 10.1.2.2 (46740736/20514560), Serial1/1
         via 10.1.3.2 (46740736/46228736), Serial1/2
```

Successor

Feasible Successor

Possible Successor

Reported Distance

Show IP EIGRP Topology Summary

Total number of routes in the local topology table

Number of queries this router is waiting on replies for

Internal data structures used to manage the topology table

```
RtrA#sh ip eigrp topology sum
IP-EIGRP Topology Table for AS(200)/ID(40.80.0.17)
Head serial 1, next serial 1526
589 routes, 0 pending replies, 0 dummies
IP-EIGRP(0) enabled on 12 interfaces, neighbors present on 4 interfaces
Quiescent interfaces:  Po3 Po6 Po2 Gi8/5
```

Interfaces with no outstanding packets to be sent or acknowledged

EIGRP DUAL Routing Algorithm

- Finite-State-Machine
  - Track all routes advertised by neighbours
    - Select loop-free path using a Successor and remember any Feasible Successors
  - If Successor lost
    - Use Feasible Successor
  - If no Feasible Successor exists
    - Query Neighbours and Recompute new Successor

EIGRP DUAL Routing Algorithm

Active Process

- Normal (stable) state of a route is passive
- Going active is the normal process for resolving network topology changes
  - Route becomes active if it is lost (or metric increases) and there aren't any feasible successors
  - Going active means sending Queries to neighbours looking for an alternative path
  - SIA timer is 180 seconds

EIGRP DUAL Routing Algorithm

Stuck in Active

%DUAL-3-SIA: Route 10.64.5.0 255.255.255.192 stuck-in-active state in IP-EIGRP 100. Cleaning up

- Two (probably) unrelated causes of the problem stuck and active
  - Need to troubleshoot both parts
    - Cause of active often easier to find
    - Cause of stuck more important to find

EIGRP DUAL Routing Algorithm

Troubleshooting the Stuck Part of SIAs

- Show ip eigrp topology active

  Useful only while the problem is occurring

  If problem isn't occurring at the time, it is difficult to find the source of routes getting stuck

```
rtrA#show ip eigrp topology active
IP-EIGRP Topology Table for AS(1)/ID(20.1.1.1)
A 20.1.1.0/24, 1 successors, FD is Inaccessible
    1 replies, active 00:01:17, query-origin: Local origin
       via Connected (Infinity/Infinity), Ethernet1/0
      Remaining replies:
         via 10.1.1.2, r, Ethernet0/0
```

rtrA is waiting on reply from 10.1.1.2

Alternate position for the reply flag

EIGRP DUAL Routing Algorithm

Likely Causes for Stuck-in-Active

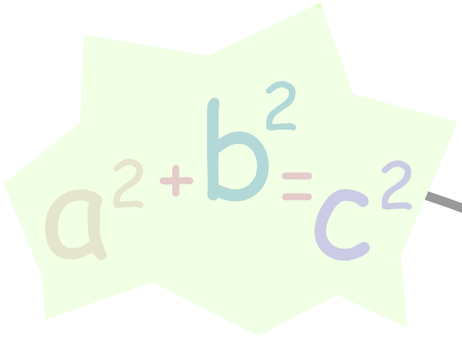
- Bad or congested links
- Query range is too long (Reduce Scope or Summarise)
- Excessive redundancy
- Overloaded router (high CPU)
- Router memory shortage
- Dead-lock queries (rare)
- Software defects (seldom)

Minimising SIA Routes

- Decrease query scope (involve fewer routers in the query process)
  - Summarisation (manual or auto)
  - Distribute-lists
  - Define remote routers as stubs
- Run a Cisco IOS which includes the fix for CSCdp33034

Lifecycle View of the EIGRP Routing Process

Build the EIGRP Topology Database



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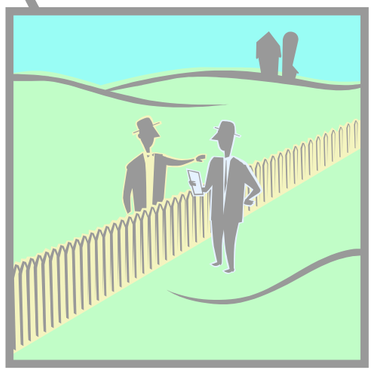

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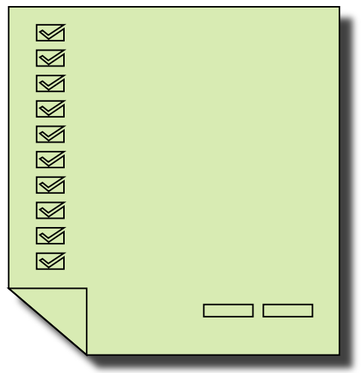
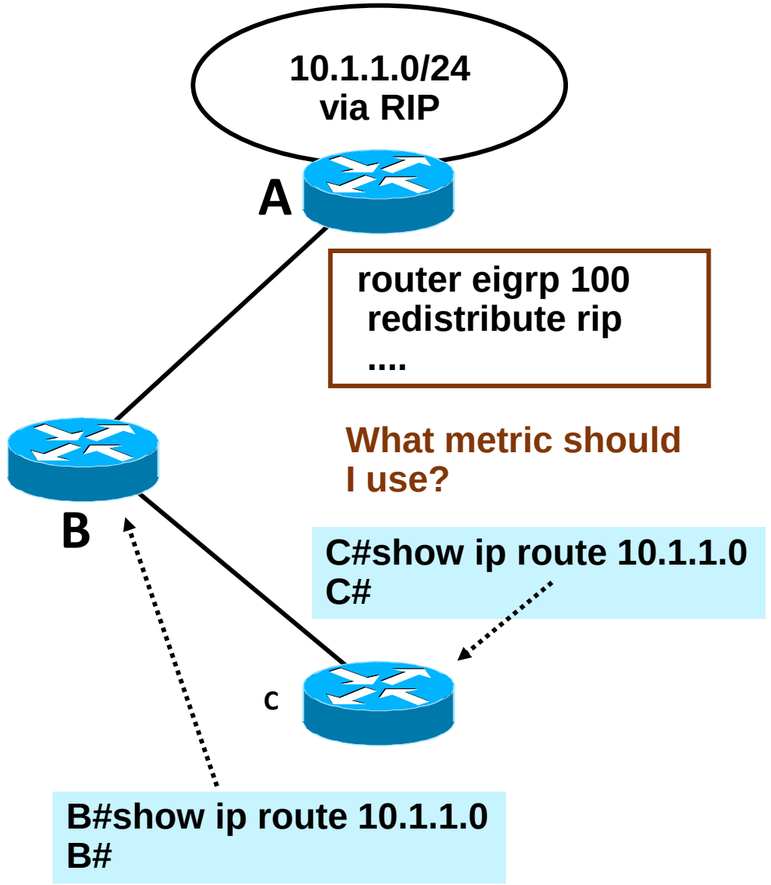


EIGRP Routing Table

Problem with External Routes

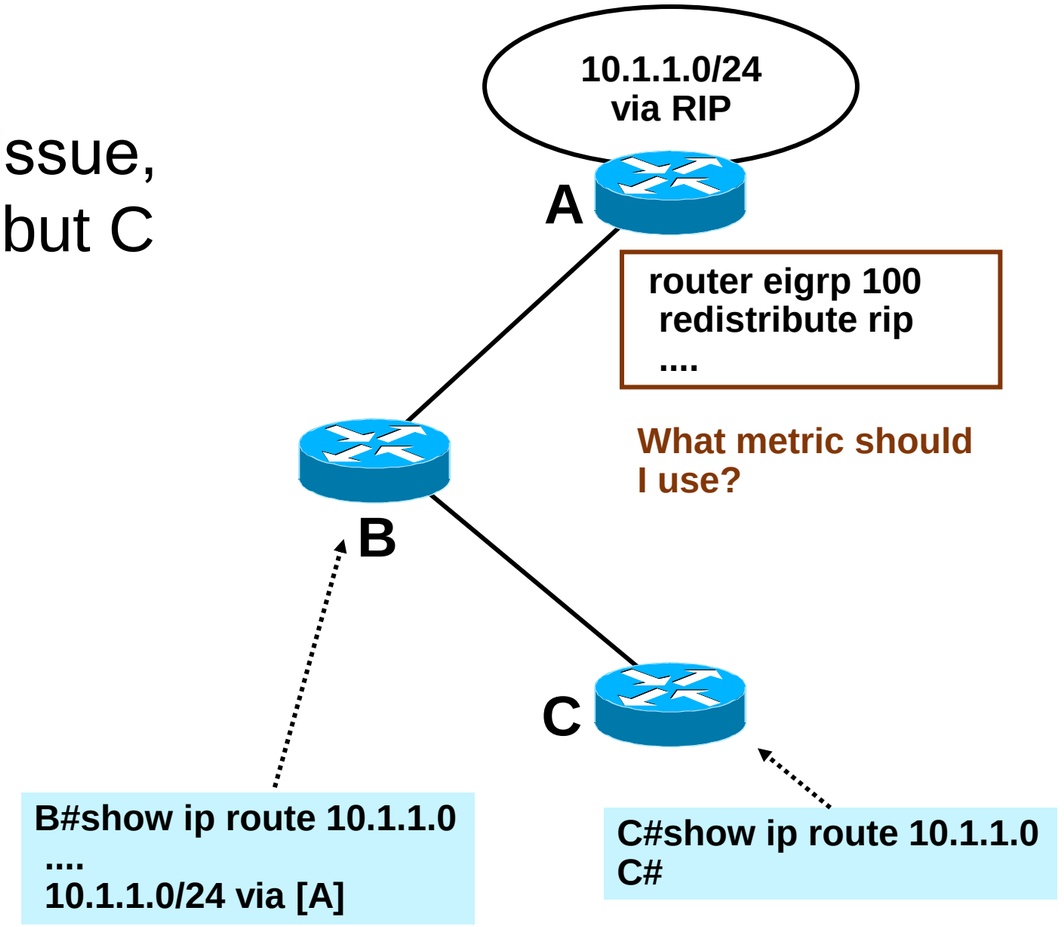
- The most common external problem is EIGRP not installing external routes
- The first thing to check is to see if A has a default metric configured, or a metric tied to the redistribution statement
  - default-metric
  - redistribute .... <metric>



EIGRP Routing Table

Problem with External Routes

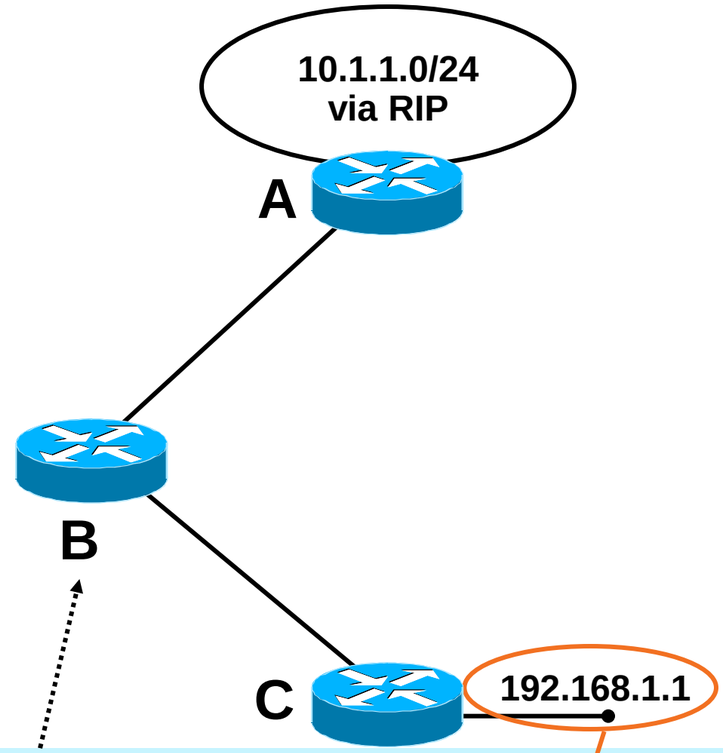
- We've resolved the metric issue, and B picked the route up, but C didn't—why?



EIGRP Routing Table

Problem with External Routes

- We've resolved the metric issue, and B picked the route up, but C didn't—why?
- Looking at B's topology table, we can see the originating router ID field in the external route is set to 192.168.1.1
- But, that's Router C's loopback address!




```
B#show ip eigrp topology 10.1.1.0
IP-EIGRP (AS 1) topology entry for
10.10.1.0/24
....
External data:
  Originating router is 192.168.1.1
```

EIGRP Routing Table

Problem with External Routes

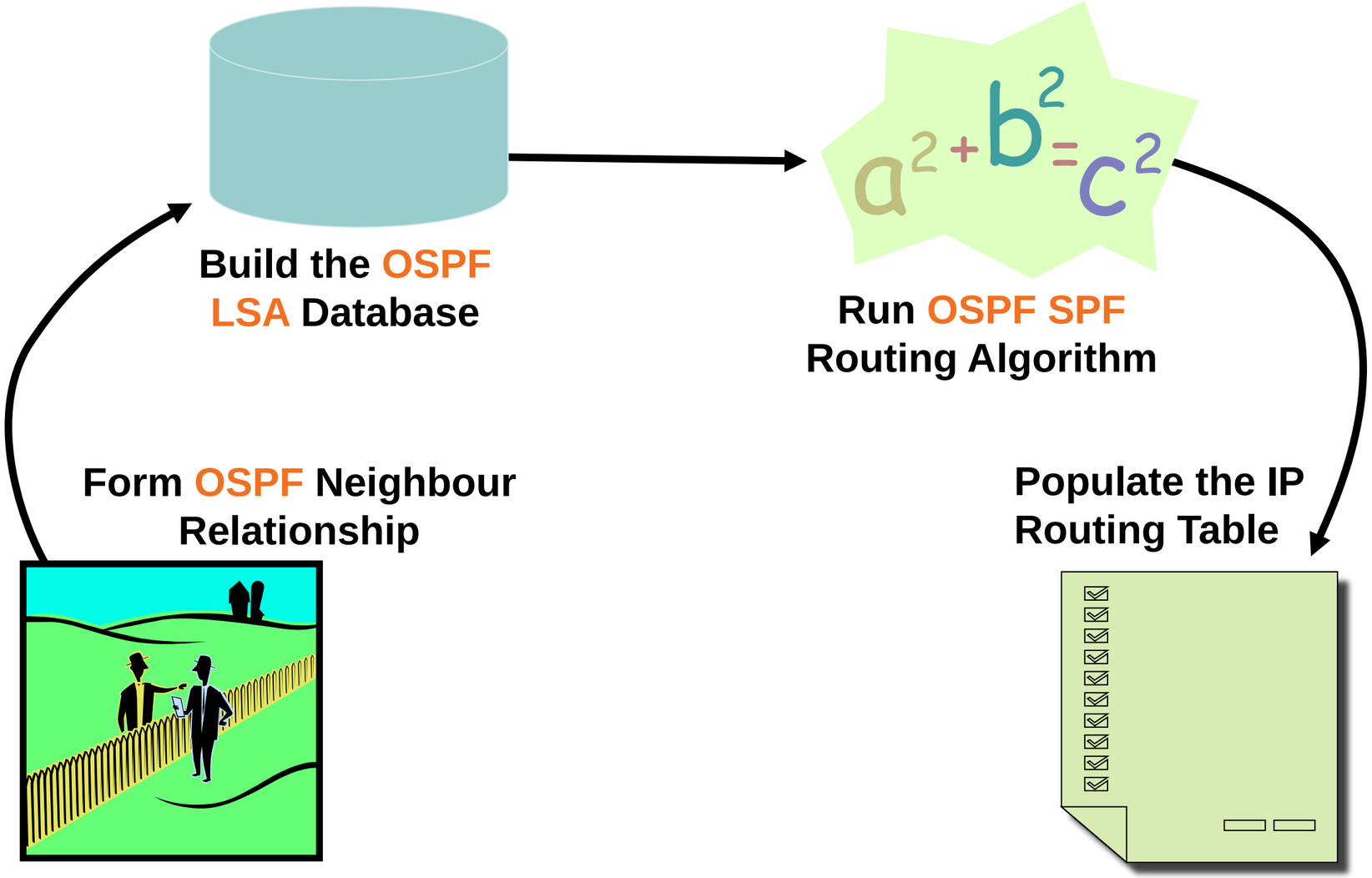
- In newer versions of Cisco IOS Software, a router's router ID is listed in the output of show ip eigrp topology:

```
router-1# show ip eigrp topology
IP-EIGRP Topology Table for AS(7)/ID(192.168.1.1)
....
```

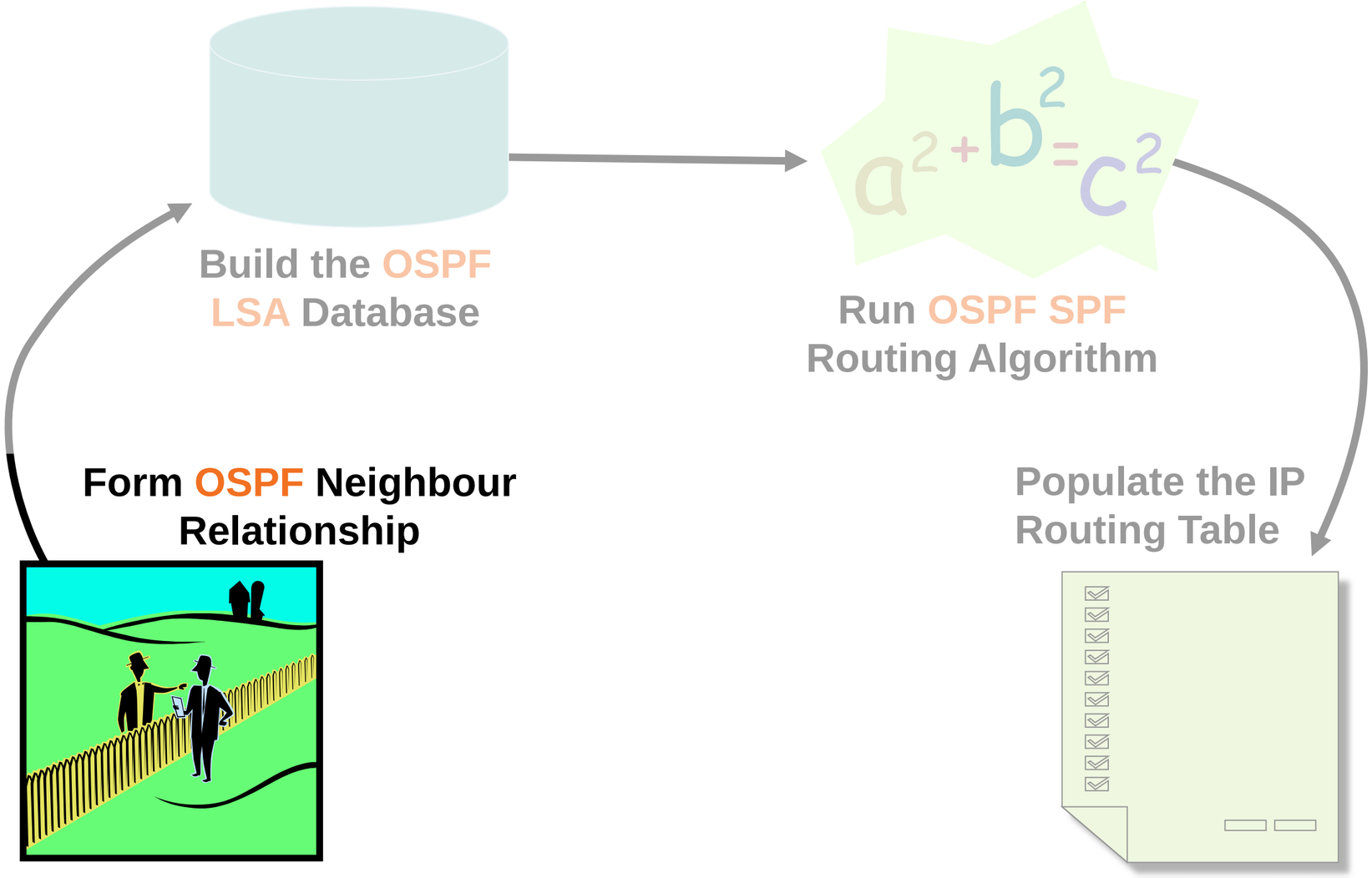
- If your event log is big enough, or things are slow enough, you might see the problem indicated in your event log:

```
1     02:30:18.591 Ignored route, metric: 192.168.1.0 2297856
2     02:30:18.591 Ignored route, neighbor info: 10.1.1.0/24 Serial0/3
3     02:30:18.591 Ignored route, dup router: 192.168.1.1
```

Lifecycle View of the OSPF Routing Process

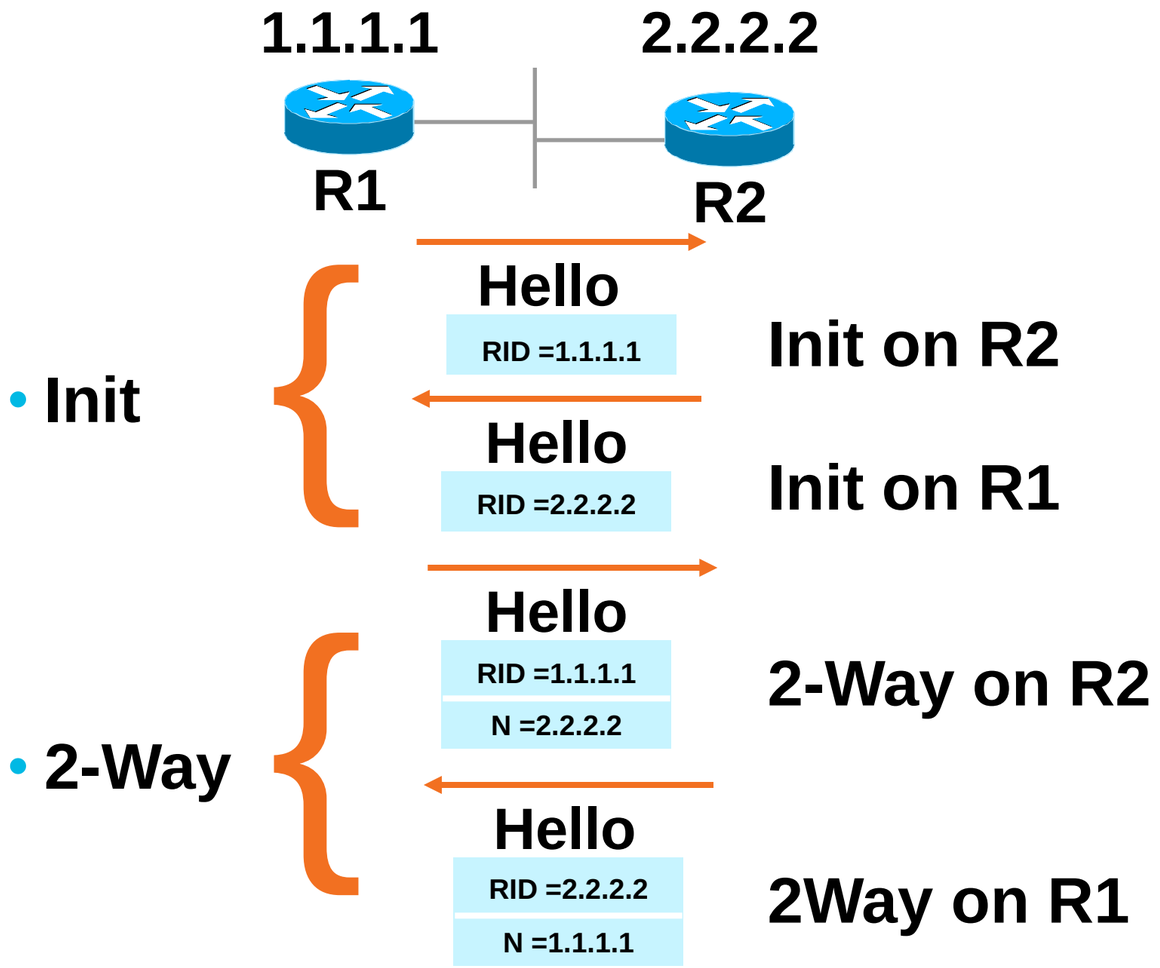


Lifecycle View of the OSPF Routing Process



OSPF Neighbour Adjacency Process

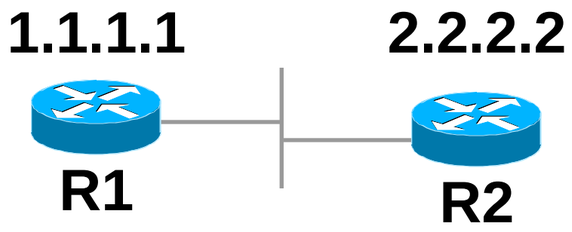
Init, 2-Way



- Init
- 2-Way

OSPF Neighbour Adjacency Process

Init, 2-Way



R1#debug ip ospf adj

OSPF adjacency events debugging is on

20:23:45.539: OSPF: Rcv DBD from 2.2.2.2 on Ethernet0/0 seq 0x2571 opt 0x52 flag 0x7 len 32 mtu 1500 state INIT

20:23:45.539: OSPF: 2 Way Communication to 2.2.2.2 on Ethernet0/0, state 2WAY

20:23:45.539: OSPF: Neighbor change Event on interface Ethernet0/0

20:23:45.539: OSPF: DR/BDR election on Ethernet0/0

R1#debug ip ospf events

OSPF events debugging is on

13:51:14.146: OSPF: Rcv hello from 2.2.2.2 area 0 from Ethernet0/0 10.10.100.2

13:51:14.146: OSPF: Send immediate hello to nbr 2.2.2.2, src address 10.10.100.2, on Ethernet0/0

OSPF Neighbour Adjacency

Stuck in Init

Possible Reasons for Stuck in Init

- Hello packet blocked in one direction with access-list
- One side multicast capabilities is broken (Layer 2)
- OSPF authentication configured on one side only
- Dialer map or frame-relay map is missing the keyword ‘broadcast’
- Link-Local Signalling capability not compatible between neighbours when IOS is upgraded

Troubleshooting Steps

- Debug ip ospf adj
- Debug ip ospf events
- Debug ip packet 101 detail – access-list local-int 224.0.0.5
- Ping 224.0.0.5 from both sides

OSPF Neighbour Adjacency

Stuck in 2-WAY

Possible Reasons for Stuck in 2-WAY

- This is normal in broadcast network types
- This is to reduce the amount of flooding on the wire
- Problem can happen if all the router are configured with priority equal to “0”

OSPF Neighbour Adjacency

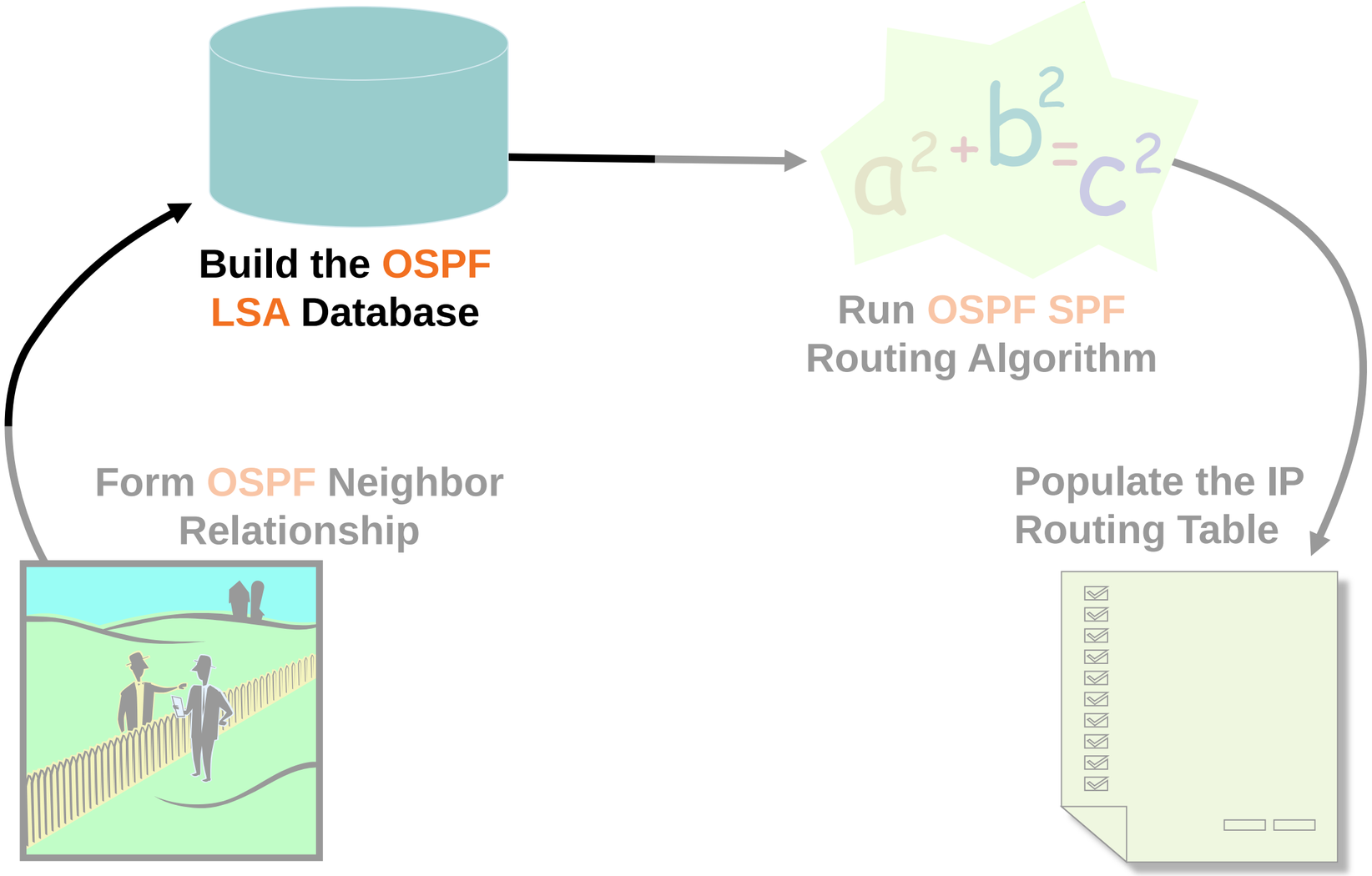
Common Issues

- Mismatched Subnet Mask
- Mismatched Hello/Dead Interval
- Mismatched Authentication Key
- Mismatched Area Id
- Mismatched Transit/Stub/NSSA Option
- OSPF Graceful Shutdown; Router or Interface mode
  shutdown / ip ospf shutdown
- OSPF TTL Security Check
  ttl-security all-interfaces [hops hop-count]
  ip ospf ttl-security [hops hop-count | disable]

Interface Scoped Debugging

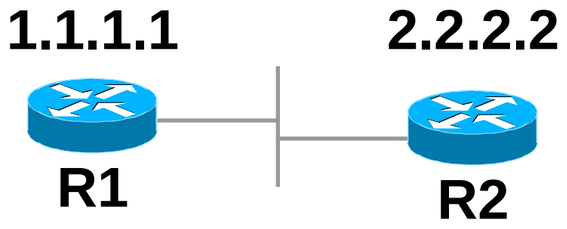
- Enhancement in limiting the OSPF debug output to just a selection of interfaces
- Example below will generate debug output for only two interfaces specified below
  - debug condition interface Ethernet 0/0
  - debug condition interface Ethernet 1/0
  - debug ip ospf hello
  - debug ip ospf adjacency
  - Available in: 12.4(4)T 12.2(30)S 12.0(32)S

Lifecycle View of the OSPF Routing Process



OSPF LSA Database

EXSTART /EXCHANGE



- **EXSTART**

DBD

MTU = 1500
Flag = 0x7
Seq = 0x2499

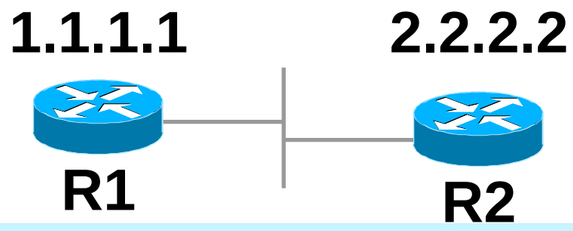
- **EXCHANGE**

DBD

MTU = 1500
Flag = 0x3
Seq = 0x837

OSPF LSA Database

EXSTART



R1#debug ip ospf adj

23:42:08.259: OSPF: Send DBD to 2.2.2.2 on Ethernet0/0 seq u opt 0x52 flag 0x7 len 32

23:42:08.339: OSPF: Rcv DBD from 2.2.2.2 on Ethernet0/0 seq 0x836 opt 0x52 flag 0x7 len 32 mtu 1500 state EXSTART

23:42:08.339: OSPF: NBR Negotiation Done. We are the SLAVE

R2#debug ip ospf adj

23:42:08.423: OSPF: Send DBD to 1.1.1.1 on Ethernet0/0 seq 0x836 opt 0x52 flag 0x7 len 32

23:42:08.423: OSPF: First DBD and we are not SLAVE

23:42:08.511: OSPF: Rcv DBD from 1.1.1.1 on Ethernet0/0 seq 0x836 opt 0x52 flag 0x2 len 52 mtu 1500 state EXSTART

23:42:08.511: OSPF: NBR Negotiation Done. We are the MASTER

OSPF LSA Database

The Flag Field

OSPF: Send DBD to 1.1.1.1 on Ethernet0/0 seq 0x836 opt 0x52 flag 0x7 len 32

Flag 0x7--> 111 means I(Initial) = 1, M = 1(More), MS = 1(Master)
Flag 0x6 --> 110 not possible
Flag 0x5 --> 101 not possible
Flag 0x4 --> 100 not possible
Flag 0x3 --> 011 means master has more data to send
Flag 0x2 --> 010 means slave has more data to send
Flag 0x1 --> 001 means master has no more data left to send
Flag 0x0 --> 000 means slave has no more data left to send

0	0	0	0	0	I	M	MS

OSPF Neighbour Adjacency

The Options Field

Normal area: OSPF: Send DBD to 141.108.97.1 on Serial0 seq 0xBC4 opt 0x2 flag 0x3 len 492

E bit is 1, Allow externals, option: 0x2(HEX) = 00000010(Bin)

Stub area: OSPF: Send DBD to 141.108.97.1 on Serial0 seq 0x1866 opt 0x0 flag 0x3 len 372

E bit is 0, no external allowed, options: 0x0 = 00000000

NSSA: OSPF: Send DBD to 141.108.97.1 on Serial0 seq 0x118 opt 0x8 flag 0x3 len 372

N/P bit is on, options: 0x8 = 00001000

DC: OSPF: Send DBD to 141.108.97.1 on Serial0 seq 0x1A1E opt 0x20 flag 0x3 len 392

DC bit is negotiated, options: 0x20 = 00100000

*	O	DC	EA	N/P	MC	E	*

OSPF LSA Database

Stuck in EXSTART or EXCHANGE - Common Causes

- MTU mismatch— Stuck in EXCHANGE

  Note: If IOS is < 12.0.3 neighbour will show stuck in EXCHANGE

- Neighbour RID is same as ours— Stuck in EXSTART

  Note: If IOS is > 12.0.7, it displays msg: %OSPF-3-DUP_RTRID and OSPF neighbour list will be empty – Highest RTRID should be master in election

- Unicast is broken—Stuck in EXCHANGE

  a. Wrong VC/DLCI mapping in frame/ATM environment in highly redundant network

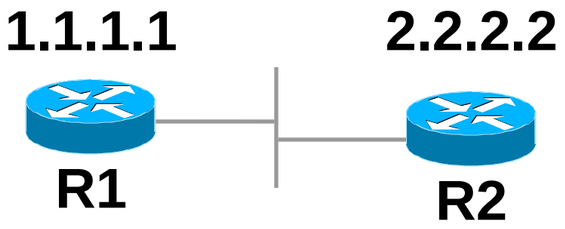
  b. MTU problem, can't ping across with more than certain length packet

  c. Access-list blocking unicast; after 2-way OSPF send unicast packet except for p2p links

- Between PRI and BRI/Dialer and network type is p2p - Stuck in EXCHANGE

OSPF LSA Database

Loading and Full



- **LOADING**

LS Type
Link State ID
Advertising Router

- **FULL**

 # LSA's
LSA's
LSA ..

OSPF LSA Database

Stuck in LOADING

- **LS request is being made and neighbour ius sending bad packet or memory corrupt**
  a. Do show ip ospf bad-checksum to see bad LSA (hidden command)
  b. Show log will show OSPF-4-BADLSATYPE message
- **LS request is being made and neighbour is ignoring the request**
- **OSPF should detect if the neighbour MTU is smaller than ours**

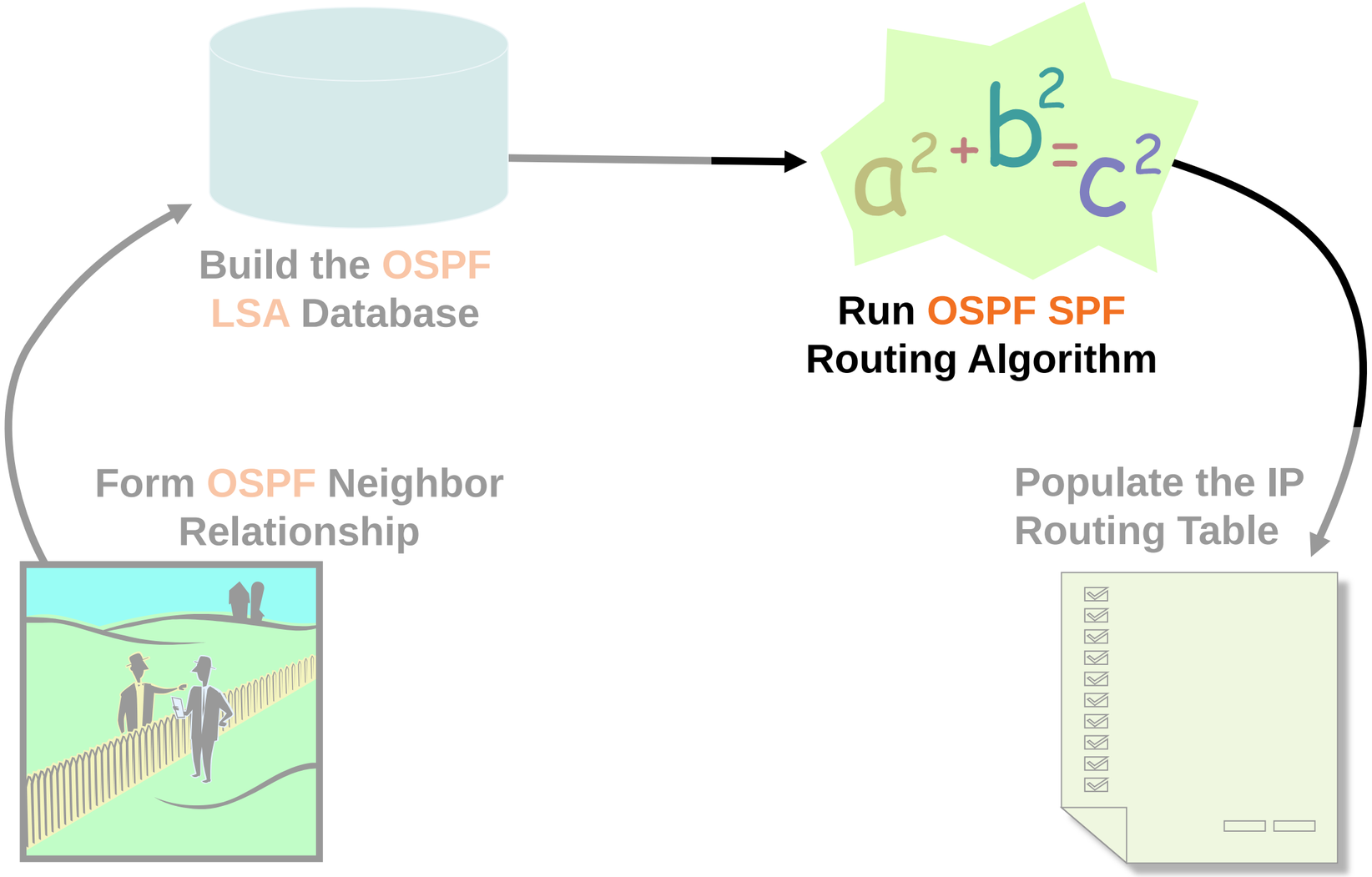
  CSCee23634 - Fixed in 12.3(15) 12.4(2) 12.0(31)S1 12.2(18)SXF 12.2(28)SB 12.2(29)S 12.4(2)T
- **OSPF packet size honours IP MTU**

  CSCse01519 - Available in 12.4(13), 12.2(33)SXH, 12.2(33)SRB
- **debug ip ospf flood**

  Further enhancement to allow an access-list filter and a “detail” option (for verbose output)

  Available in: 12.4(4)T 12.2(30)S 12.0(32)S

Lifecycle View of the OSPF Routing Process

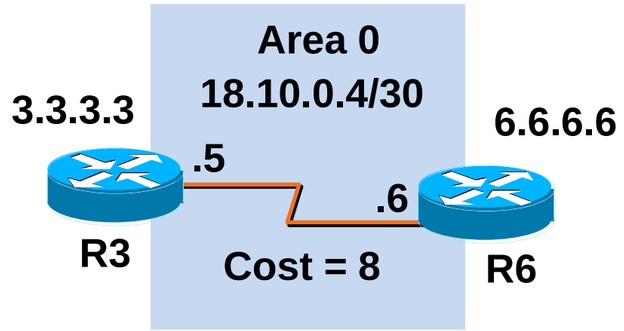


OSPF LSA Database - LSA Type Review

Type	LSA
1	Router
2	Network
3	Summary Network
4	Summary ASBR
5	External
6	~~Group Membership~~
7	NSSA
8	~~External Attributes~~
9–11	~~Opaque~~

Router LSA of R3 for Area 0

```
R3#show ip ospf database router 3.3.3.3

                Router Link States (Area 0)
LS age  =  0
Options  = (No TOS-capability, DC)
LS type  =  Router Links              This is a Type 1 LSA
Link State ID  =  3.3.3.3
Advertising Router   =  3.3.3.3
It is an area border router bit B  =  1

# links  =  2
Link ID  =  6.6.6.6                   Router id of the neighbor
Link Data  =  18.10.0.5               IP interface address of the router
   Type  =  1                         This is a point-to-point link
   # TOS metrics  =  0
   metric  =  8

   Link ID  =  18.10.0.4              IP subnet address
   Link Data  =  255.255.255.252      Subnet mask
   Type  =  3                         This is a stub link
   # TOS metrics  =  0
   metric  =  8
```



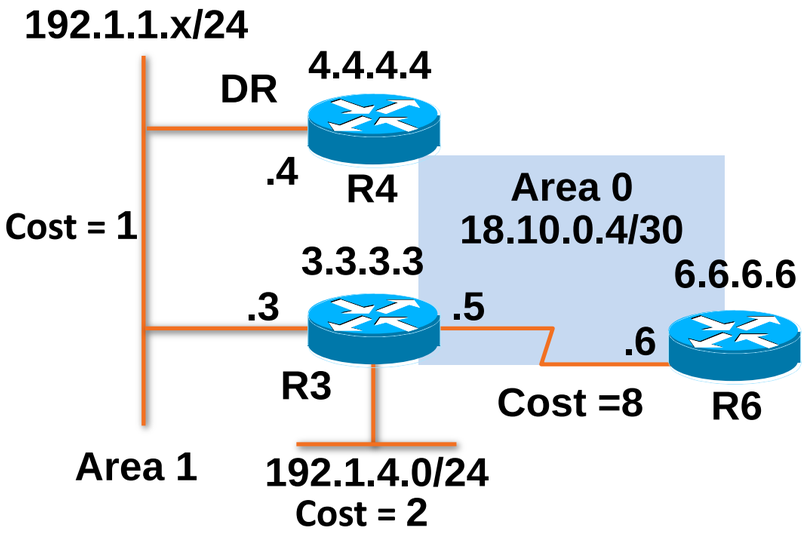
Router LSA of R3 for Area 1

Router Link States (Area 1)

LS age = 253
Options = (No TOS-capability, DC)
LS type = Router Links — This is a Type 1 LSA
Link State ID = 3.3.3.3
Advertising Router = 3.3.3.3 — Router ID of R3
It is an area border router bit B = 1

links = 2
- Link ID = 192.1.1.4 — IP address of the DR
- Link Data = 192.1.1.3 — Interface address of this router
- Type = 2 — This is a transit network
- # TOS metrics = 0

- metric = 1 — Cost to reach the interface
- Link ID = 192.1.4.0 — IP network number
- Link Data = 255.255.255.0 — Subnet mask of the interface
- Type = 3 — Stub network
- # TOS metrics = 0
- metric = 2

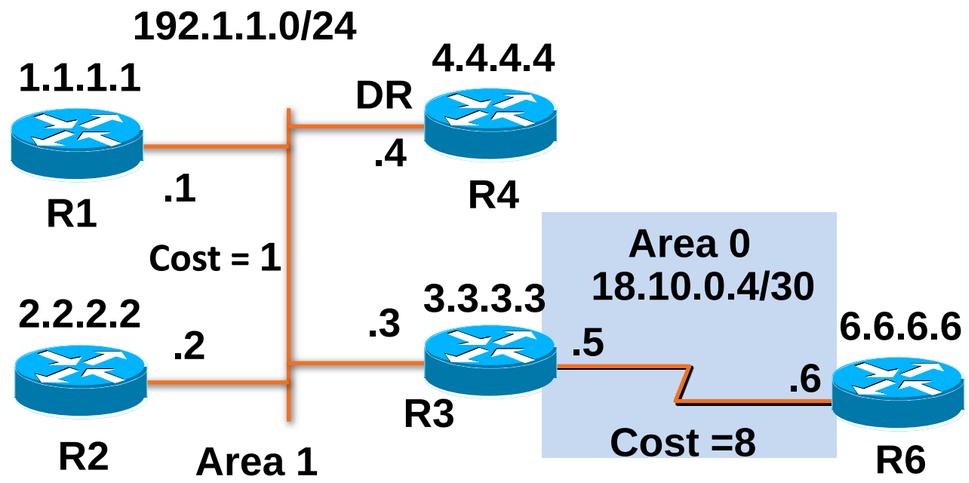


Link Details

Type	Description	Link ID	Link Data
1	Point-to-Point Numbered	Neighbors' RID	Interface IP Address
1	Point-to-Point Unnumbered	Neighbors' RID	MIB-II Ifindex Value
2	Transit	IP Address of the DR	Interface IP Address
3	Stub	IP Network Number	Subnet Mask
4	Virtual Link	Neighbors' RID	Interface IP Address

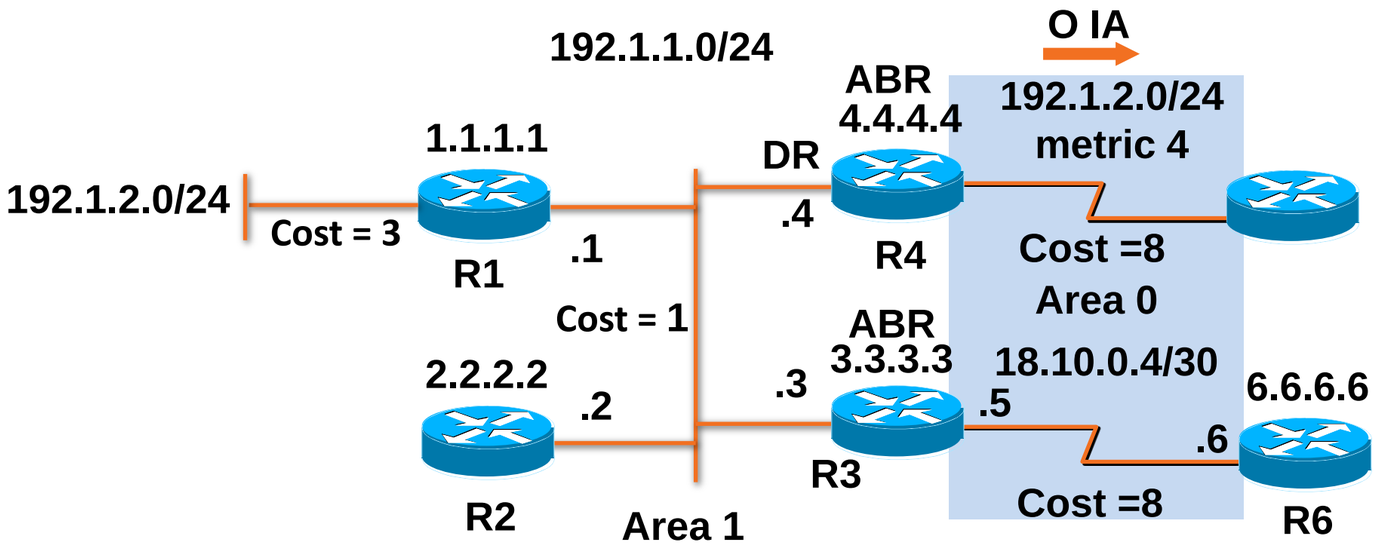
Network LSA for 192.1.1.0

```
R3#show ip ospf database network 192.1.1.4
                Network Link States (Area 1)
LS age  =  0
Options  =  (No TOS-capability, DC)
LS type  =  Network Links            Type 2 LSA
Link State ID  =  192.1.1.4          IP interface address of DR
Advertising Router   =  4.4.4.4      RID of DR
Network Mask  =  255.255.255.0
   Attached Router  =  4.4.4.4
   Attached Router  =  3.3.3.3       RID of attached routers FULL with DR
   Attached Router  =  2.2.2.2
   Attached Router  =  1.1.1.1
```



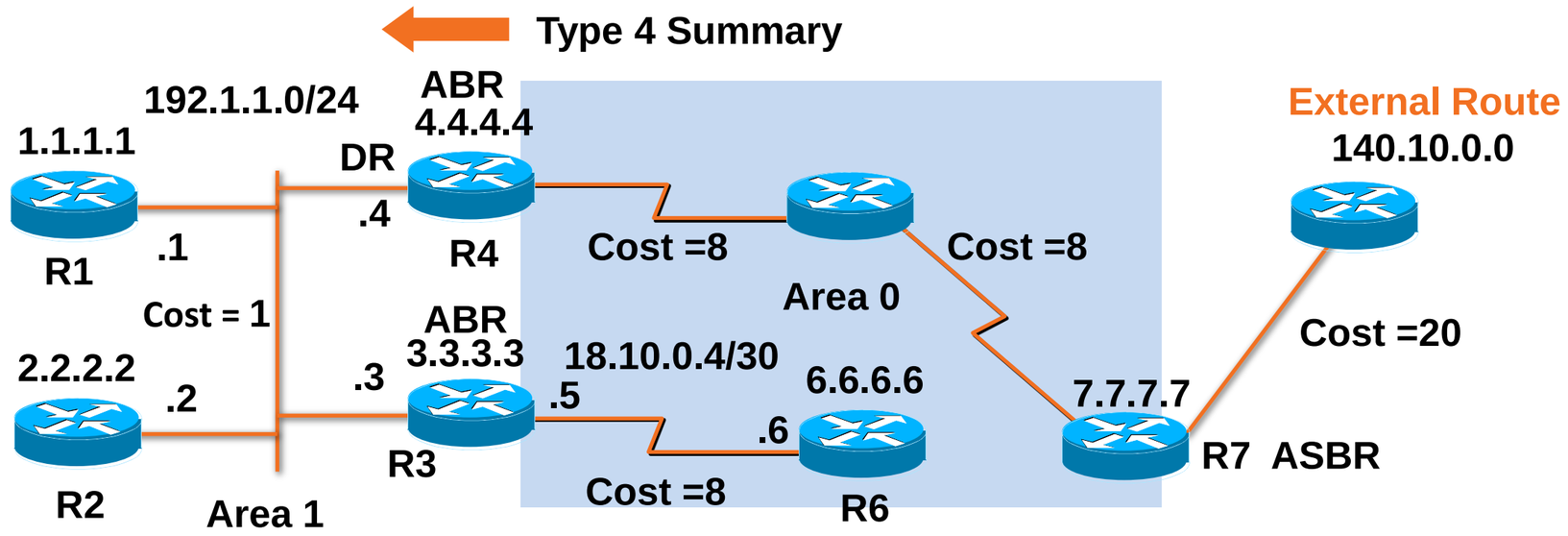
Type 3 Details

```
R4#show ip ospf database summary 192.1.2.0
            Summary Net Link States (Area 0)
LS age  =  0
Options  = (No TOS-capability, DC, Upward)
LS type  = Network Links                Type 3 LSA
Link State ID  =  192.1.2.0             Summary IP network number
Advertising Router   =  4.4.4.4         RID of ABR
Network Mask  =  255.255.255.0
metric = 4
```



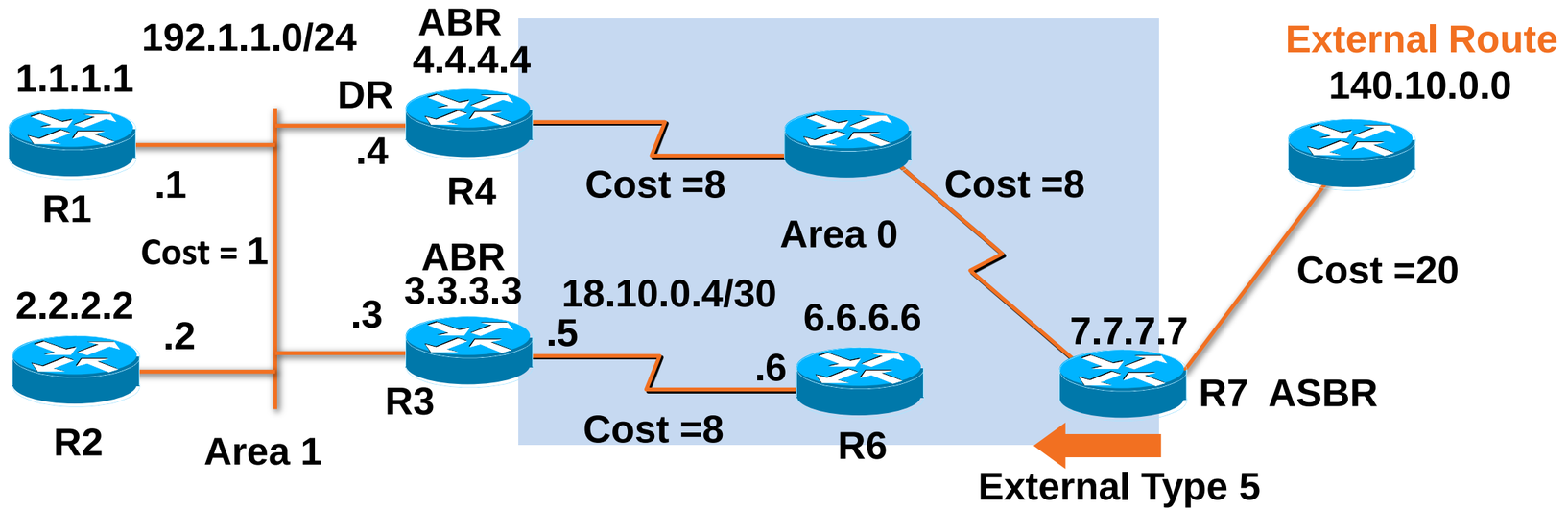
Type 4 Details

```
R4#show ip ospf database asbr-summary 7.7.7.7
            Summary ASB Link States (Area 1)
LS age  =  0
Options  =  (No TOS-capability, DC, Upward )
LS type  =  Summary Links(ASBR)
Link State ID  =  7.7.7.7            RID of ASBR
Advertising Router   =  4.4.4.4     RID of ABR
Network Mask  =  0.0.0.0
metric = 16
```



Type 5 Details

```
R4#show ip ospf database external 140.10.0.0
Routing Bit Set on this LSA
LS age  =  0
Options  =  (No TOS-capability, DC)
LS type  =  AS External Link        Type 5
Link State ID  =  140.10.0.0        IP network number
Advertising Router   =  7.7.7.7    Router ID of R7
Network Mask = 255.255.0.0
Metric Type: 2                      Bit E  = 1 -> O E2 (Default)
metric  =  20                       Metric is 20 in all redistributed E2 routes
Forwarding address   =  0.0.0.0    Traffic should be forwarded to the ASBR
```

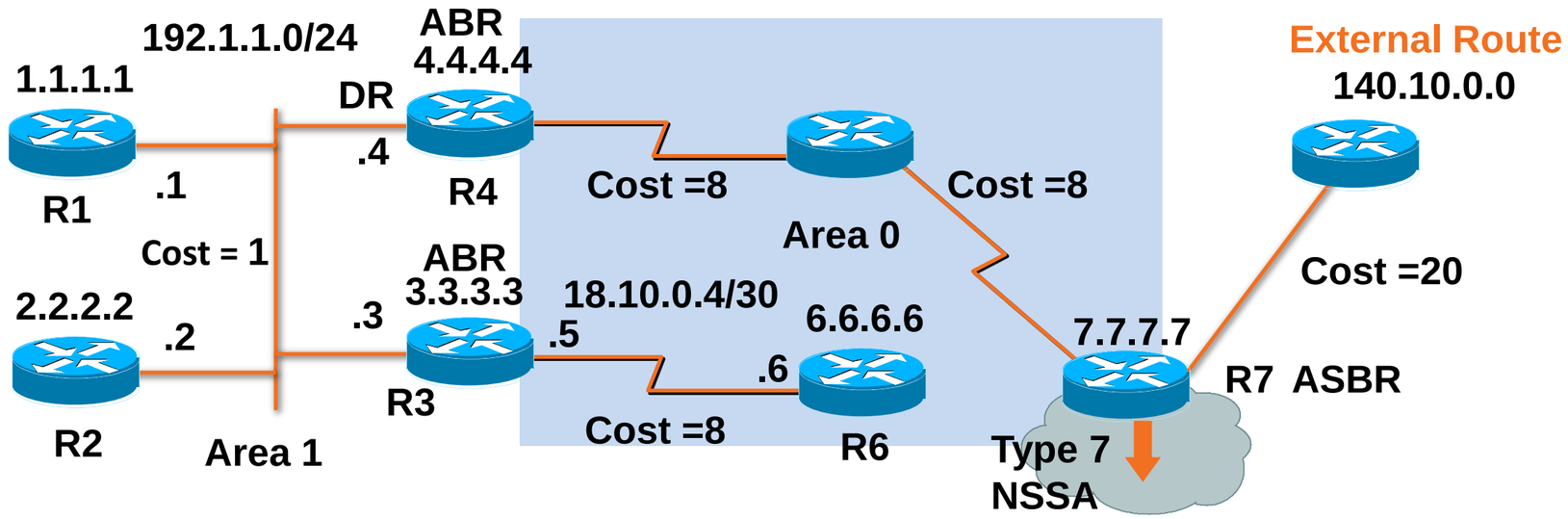


Forwarding Address (Type 5)

- When will it set to non-zero?
  - OSPF is enabled on the ASBR’s next hop interface &&
  - The ASBR's next hop interface is non-passive to OSPF &&
  - The ASBR's next hop interface network-type is NOT p2p or p2mp &&
  - The ASBR's next hop interface address falls into OSPF network range

Type 7 Details

```
R7#show ip ospf database nssa-external 140.10.0.0
LS age  =  0
Options  =  (No TOS-capability, No Type 7/5 translation, DC)
LS type  =  AS External Link        Type 7 LSA
Link State ID  =  140.10.0.0        IP network number
Advertising Router   =  7.7.7.7    Router ID of R7(NSSA ASBR)
Network Mask = 255.255.0.0
                          P = 0 -> This router is an NSSA ASBR+ ABR
                          P = 1 -> This router is an NSSA ASBR
metric  =  20
Forwarding address   =  0.0.0.0    Traffic should be forwarded to the ASBR
```



OSPF SPF Algorithm

SPF Running Constantly

```
R3#show ip ospf statistics <details>
  Area 0: SPF algorithm executed 42 times
  Area 1: SPF algorithm executed 38 times

  SPF calculation time
Delta T    Intra  D-Intra      Summ        D-Summ            Ext      D-Ext        Total        Reason
00:22:00    0        0           0           0               0        0            0          R, N, SN,
00:21:44    0        0           4           0               0        0            4          R, SN, X
00:21:34    0        0           4           0               0        0            4          R, SN, X
00:21:24    0        0           0           4               0        0            4          R, SN, X
00:20:44    0        0           4           0               0        0            4          R, SN, X
00:20:34    0        0           0           0               0        0            0          X
00:00:17    4        0           0           0               0        0            4          R, N, SN, SA
. . .
R=Router LSA; N=NetworkLSA; SN=Summary Network LSA; SA=Summary ASBR LSA; X=External LSA
```

OSPF SPF Algorithm

SPF Running Constantly - Debugging Commands

```
R3#debug ip ospf monitor
OSPF: Schedule SPF in area 1
      Change in LS ID 1.1.1.1, LSA type R,
OSPF: schedule SPF: spf_time 0ms wait_interval 861421816s
OSPF: Begin SPF at 0x33585480ms, process time 752ms
      spf_time 0ms, wait_interval 861421816s
OSPF: End SPF at 0x33585488ms, Total elapsed time 8ms
        Intra: 4ms, Inter: 0ms, External: 0ms
```

```
R2#debug ip ospf spf ?
  external   OSPF spf external-route
  inter      OSPF spf inter-route
  intra      OSPF spf inter-route
  statistic  OSPF spf statistics
  <cr>
R2#
```

```
R2#debug ip ospf spf external ?
  <1-99>       Access list
  <1300-1999>  Access list (expanded range)
  <cr>
R2#
```

OSPF SPF Algorithm

SPF Running Constantly

```
R3#show ip ospf database

       OSPF Router with ID (3.3.3.3) (Process ID 1)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum  Link count
3.3.3.3         3.3.3.3         106         0x80000009  0xC3F1    3

                Summary Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
18.10.0.0       7.7.7.7         3   (DNA)   0x80000008 0x3DC2
18.10.0.0       8.8.8.8         1396        0x80000004 0x27D8

                Router Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum  Link count
1.1.1.1         1.1.1.1         2           0x80000016 0xE6CD    2
. . .
```

OSPF Traffic Statistics

show/clear ip ospf [process-id] traffic [interface]

- Output consists of:
  - Global summary section
  - Per-process sections
    - OSPF queues
    - Interface details
    - Per-process summary

```
router2#show ip ospf traffic

OSPF statistics:
 Rcvd: 29 total, 0 checksum errors
    7 Hello, 8 database desc, 2 link state req
    8 link state updates, 4 link state acks

 Sent: 29 total
    8 Hello, 6 database desc, 2 link state req
    8 link state updates, 5 link state acks
```

- Available in: 12.4(6)T 12.0(28)S 12.2(30)S
- OSPFv3 support in 12.2(31)SB

OSPF Traffic Statistics

Per Process Summary

Per process filter:
show ip ospf <process_id> traffic

```
Summary traffic statistics for process ID 1:

OSPF packets received/sent

 Type      Packets        Bytes
 RX Invalid    0             0
 RX Hello      8             384
 RX DB des     8             496
 RX LS req     2             72
 RX LS upd     8             740
 RX LS ack     4             236
 RX Total      30            1928

 TX Failed     0             0
 TX Hello      10            792
 TX DB des     6             624
 TX LS req     2             112
 TX LS upd     8             708
 TX LS ack     5             460
 TX Total      31            2696

OSPF header errors
 Length 0, Checksum 0, Version 0, Bad Source 0,
 No Virtual Link 0, Area Mismatch 0, No Sham Link 0,
 Self Originated 0, Duplicate ID 0, Hello 0,
 MTU Mismatch 0, Nbr Ignored 0, LLS 0,
 Authentication 0, TTL Check Fail 0,

OSPF LSA errors
 Type 0, Length 0, Data 0, Checksum 0,
```

OSPF Traffic Statistics

Queues

```
                    InputQ      UpdateQ     OutputQ
Limit               0           200         0
Drops               0           8881        0
Max delay [msec]    1076        21188       28
Max size            3961        200         6
  Invalid           0           0           0
  Hello             3961        0           0
  DB des            0           0           0
  LS req            0           0           0
  LS upd            0           200         0
  LS ack            0           0           6
Current size        0           0           0
  Invalid           0           0           0
  Hello             0           0           0
  DB des            0           0           0
  LS req            0           0           0
  LS upd            0           0           0
  LS ack            0           0           0
```

OSPF Traffic Statistics

Interface Details

Per interface filter:

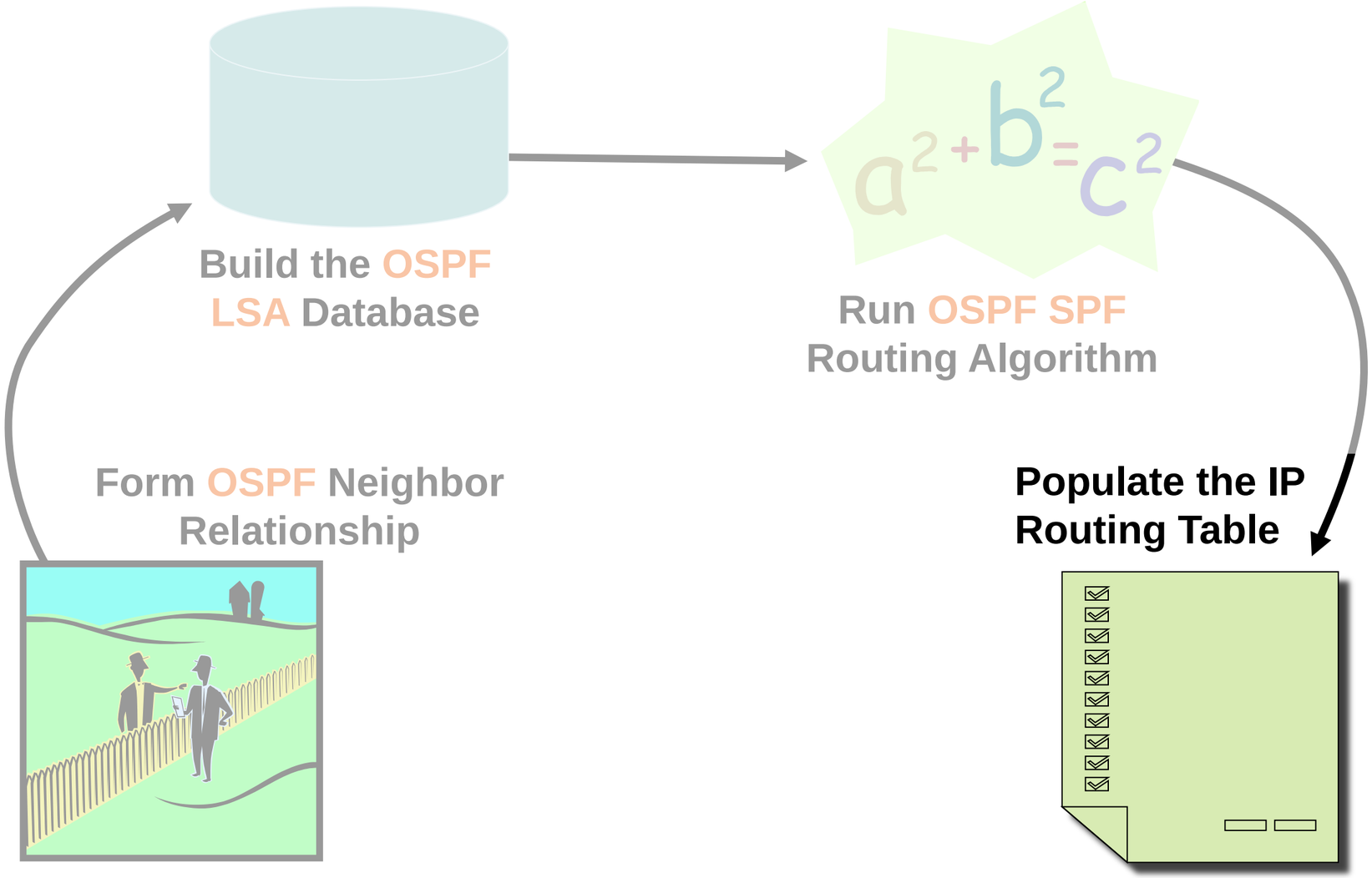
Show/clear ip ospf traffic <if_name>

Available in: 12.4(6)T 12.0(28)S

```
OSPF header errors
  Length 0, Checksum 0, Version 0, Bad Source 0,
  No Virtual Link 0, Area Mismatch 0, No Sham Link 0,
  Self Originated 0, Duplicate ID 0, Hello 0,
  MTU Mismatch 0, Nbr Ignored 0, LLS 0,
  Authentication 0, TTL Check Fail 0,

OSPF LSA errors
  Type 0, Length 0, Data 0, Checksum 0,
```

```
Interface Serial2/0

OSPF packets received/sent
  Type          Packets          Bytes
  RX Invalid    0                0
  RX Hello      8                384
  RX DB des     8                496
  RX LS req     2                72
  RX LS upd     8                740
  RX LS ack     4                236
  RX Total      30               1928
  TX Failed     0                0
  TX Hello      10               792
  TX Total      31               2696
```

Lifecycle View of the OSPF Routing Process



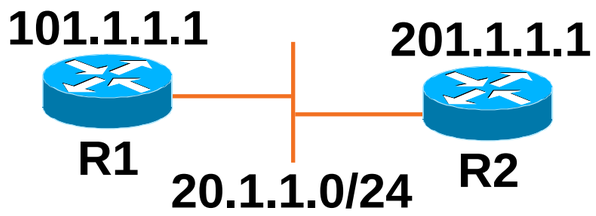
OSPF Routing Table

Prefix in Database but not in the Routing Table

```
R1#sh ip ospf nei
Neighbor ID     Pri   State           Dead Time   Address         Interface
201.1.1.1         0   FULL/  -        00:00:30    20.1.1.2        Ethernet0/0
R1#
```

```
R2#sh ip ospf nei
Neighbor ID     Pri   State           Dead Time   Address         Interface
101.1.1.1         1   FULL/BDR        00:00:30    20.1.1.1        Ethernet0/0
R2#
```

```
R1#sh ip route ospf
R1#
```



OSPF Routing Table

Prefix in Database but not in the Routing Table

R1#sh ip ospf data router 201.1.1.1

OSPF Router with ID (101.1.1.1) (Process ID 1)

Adv Router is not-reachable

LS age: 1254

Options: (No TOS-capability, DC)

LS Type: Router Links

Link State ID: 201.1.1.1

Advertising Router: 201.1.1.1

Link connected to: a Transit Network

(Link ID) Designated Router address: 20.1.1.2

(Link Data) Router Interface address: 20.1.1.2

Number of TOS metrics: 0

TOS 0 Metrics: 10

R1#sh ip ospf data router 101.1.1.1

OSPF Router with ID (201.1.1.1) (Process ID 1)

Adv Router is not-reachable

LS age: 1670

Options: (No TOS-capability, DC)

LS Type: Router Links

Link State ID: 101.1.1.1

Advertising Router: 101.1.1.1

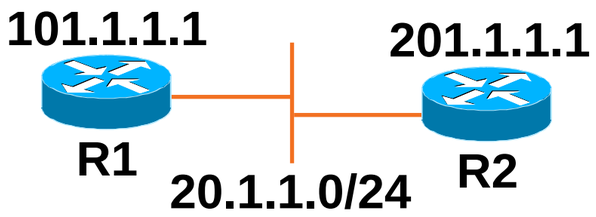
Link connected to: a Stub Network

(Link ID) Network/subnet number: 20.1.1.0

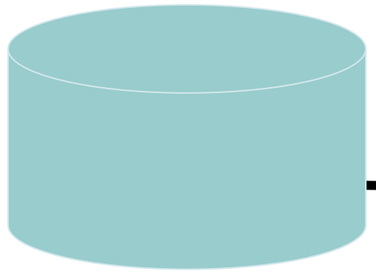
(Link Data) Network Mask: 255.255.255.0

Number of TOS metrics: 0

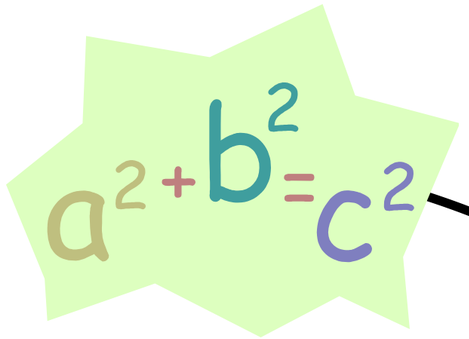
TOS 0 Metrics: 10



Lifecycle View of the BGP Routing Process

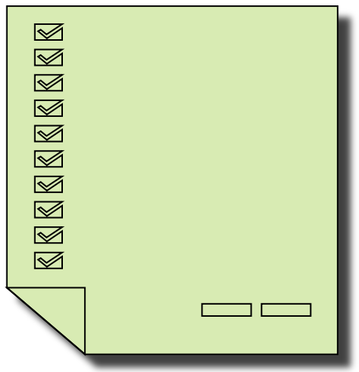


Build the BGP Database

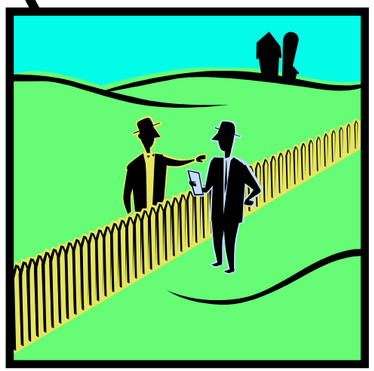


Run BGP Best Path Selection Algorithm

Populate the IP Routing Table

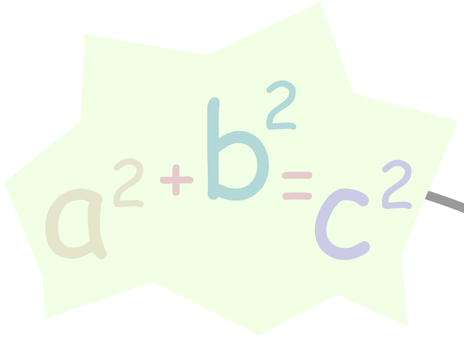


Form BGP Peers



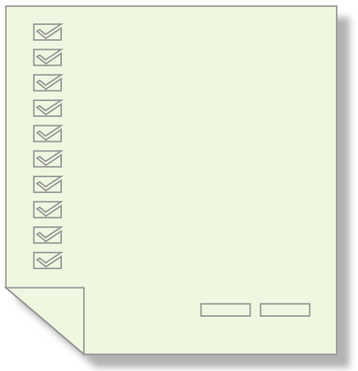
Lifecycle View of the BGP Routing Process

Build the BGP Database

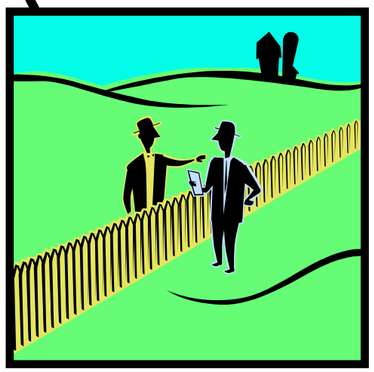


Run BGP Best Path Selection Algorithm

Populate the IP Routing Table



Form BGP Peers



BGP Peers - Peering Finite State Machine

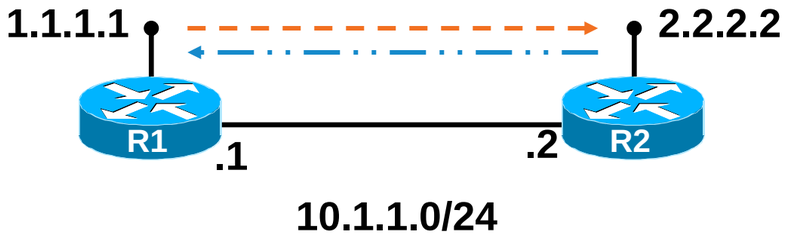
```
R1#debug ip bgp (shows the state transitions)
BGP: 2.2.2.2 went from Idle to Active

BGP: 2.2.2.2 active open failed - TCP session must be opened passively

BGP: 2.2.2.2 passive open to 192.168.1.1
BGP: 2.2.2.2 open active, local address 1.1.1.1
BGP: 2.2.2.2 read request no-op
BGP: 2.2.2.2 went from Active to OpenSent
BGP: 2.2.2.2 sending OPEN, version 4, my as: 100, holdtime 180 se
BGP: 2.2.2.2 rcv OPEN, version 4, holdtime 180 seconds
BGP: 2.2.2.2 rcv OPEN w/ OPTION parameter len: 16
BGP: 2.2.2.2 rcvd OPEN w/ optional parameter type 2 (Capability) len 6
BGP: 2.2.2.2 OPEN has CAPABILITY code: 1, length 4
BGP: 2.2.2.2 OPEN has ROUTE-REFRESH capability(new) for all address-families
BGP: 2.2.2.2 rcvd OPEN w/ remote AS 200
BGP: 2.2.2.2 went from OpenSent to OpenConfirm
BGP: 2.2.2.2 went from OpenConfirm to Established
%BGP-5-ADJCHANGE: neighbor 2.2.2.2 Up
R1#
```

Lifecycle of BGP Peers

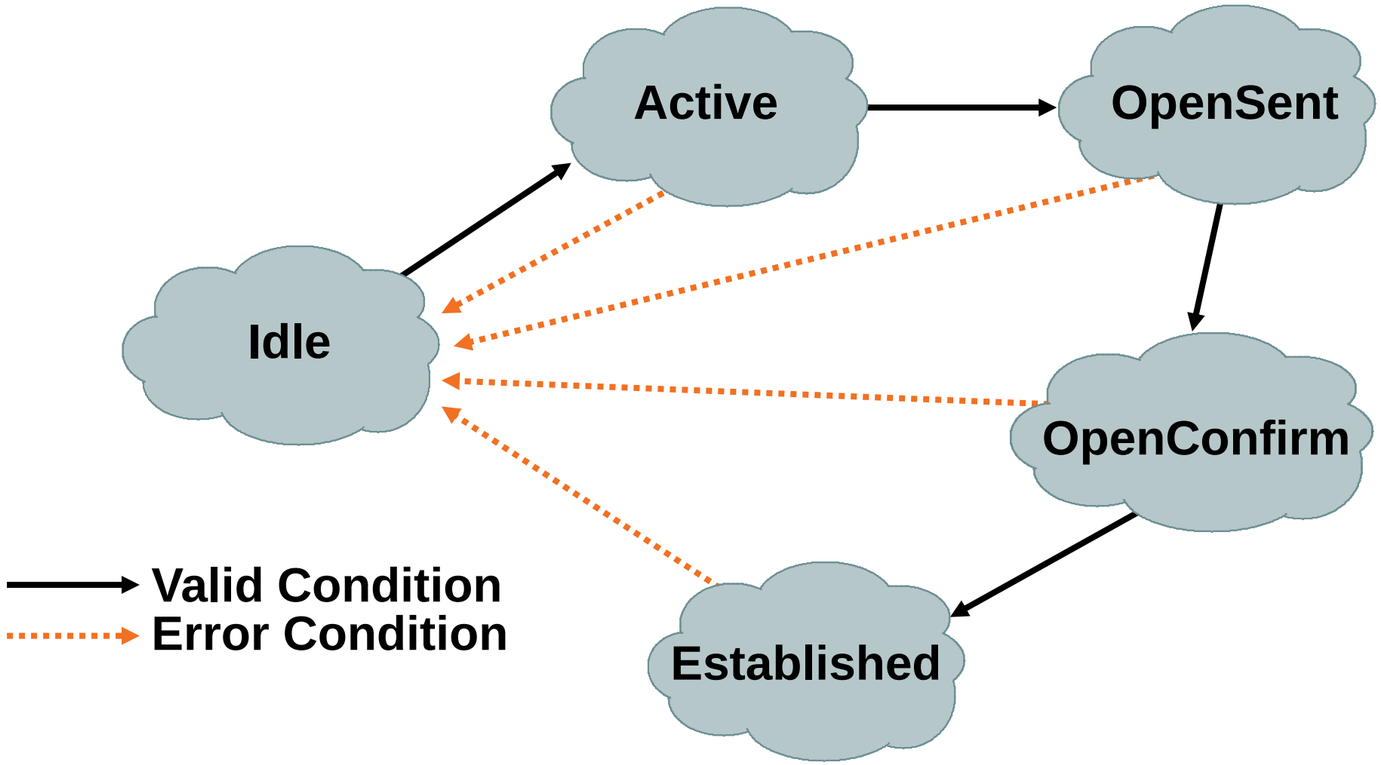
- BGP uses TCP port 179 and attempts to open a TCP session to every peer
- Peers exchange OPEN messages which contain basic info:
  - Router ID
  - AS #
  - Capabilities
  - Hold Time
- FSM (Finite State Machine) is used to negotiate to Established state
- Initial exchange of entire table
- Incremental updates after initial exchange
- Keepalive messages exchanged when there no updates

BGP Peers – The TCP Connection

- R1 to R2 TCP connection
  - –neighbor 2.2.2.2 remote-as 100
  - –neighbor 2.2.2.2 update-source loopback 0
- R2 to R1 TCP connection
  - –neighbor 1.1.1.1 remote-as 100
  - –neighbor 1.1.1.1 update-source loopback 0
- neighbor x.x.x.x transport connection-mode <active|passive>
- neighbor x.x.x.x transport path-mtu-discovery disable
- neighbor N.N.N.N ttl-security hops <hops away>



BGP Peers - Peering Finite State Machine



- If everything is okay, proceed to the next state
- If not, reset back to Idle state

BGP Peers

Show ip bgp neighbours
AFI independent BGP info

```
R1#show ip bgp neighbors 2.2.2.2
BGP neighbor is 2.2.2.2,  remote AS 200, external link
  BGP version 4, remote router ID 2.2.2.2
  BGP state = Established, up for 00:02:07
  Last read 00:00:06, last write 00:00:13, hold time is 180, keepalive
  interval is 60 seconds
  Neighbor capabilities:
    Route refresh: advertised and received(new)
    Address family IPv4 Unicast: advertised and received
  Message statistics:
    InQ depth is 0
    OutQ depth is 0
                         Sent       Rcvd
    Opens:                  6          6
    Notifications:          0          0
    Updates:                4          0
    Keepalives:           175        177
    Route Refresh:          0          0
    Total:                185        183
  Default minimum time between advertisement runs is 30 seconds
```

Keepalive & Holdtime

- Holdtime is negotiated via OPEN messages In seconds

  Lowest holdtime requested by the two peers wins

  0 seconds means infinite holdtime

  3 seconds is the lowest non-zero setting

  180 seconds by default

```
R1(config-router)# neighbor x.x.x.x timers X Y Z

      X (0-65535) is keepalive
      Y (0-65535) is holdtime
      Z (0-65535) minimum acceptable holdtime
```

BGP Peers

Show ip bgp neighbors
AFI specific BGP info

```
R1#show ip bgp neighbors
<snip>
For address family: IPv4 Unicast
  BGP table version 2, neighbor version 2/0
  Output queue size : 0
  Index 1, Offset 0, Mask 0x2
  1 update-group member
                                Sent       Rcvd
  Prefix activity:              ----       ----
    Prefixes Current:              1          0
    Prefixes Total:                1          0
    Implicit Withdraw:             0          0
    Explicit Withdraw:             0          0
    Used as bestpath:            n/a          0
    Used as multipath:           n/a          0

                                  Outbound    Inbound
  Local Policy Denied Prefixes:   --------    -------
    Total:                               0          0
  Number of NLRIs in the update sent: max 1, min 1
```

BGP Peers

Show ip bgp neighbors (cont) BGP specific TCP info

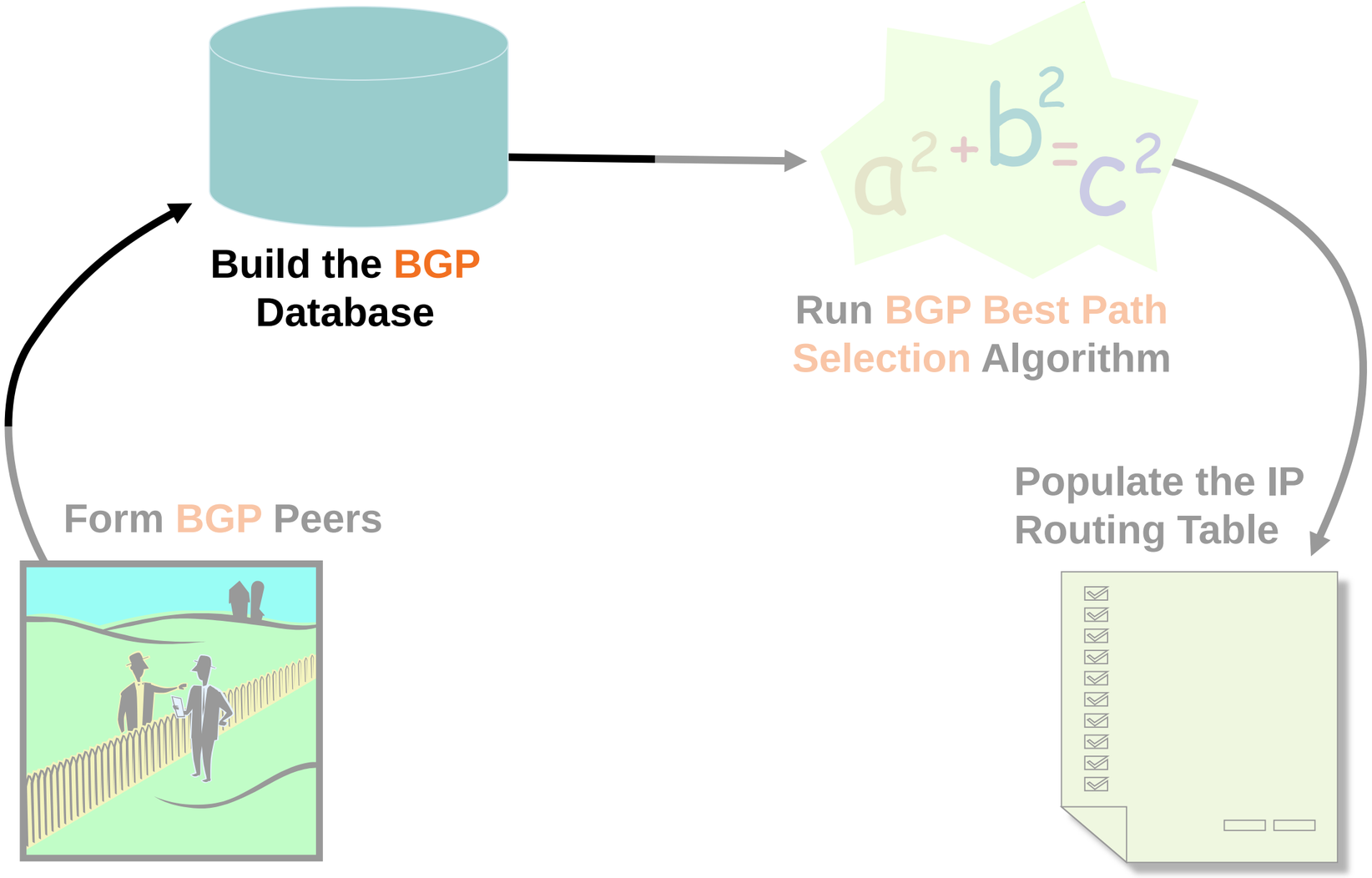
```
 <snip>
Connections established 6; dropped 5
Last reset 00:02:09, due to User reset
External BGP neighbor may be up to 255 hops away.
Connection state is ESTAB, I/O status: 1, unread input bytes: 0
Local host: 1.1.1.1, Local port: 12348
Foreign host: 2.2.2.2, Foreign port: 179
```

BGP Peers

Show ip bgp neighbors (cont) Generic TCP info

```
Enqueued packets for retransmit: 0, input: 0  mis-ordered: 0 (0 bytes)

Event Timers (current time is 0x5817B38):
Timer          Starts    Wakeups            Next
Retrans             5          0             0x0
TimeWait            0          0             0x0
AckHold             4          3             0x0
SendWnd             0          0             0x0
KeepAlive           0          0             0x0
GiveUp              0          0             0x0
PmtuAger            0          0             0x0
DeadWait            0          0             0x0

iss: 3541899715  snduna: 3541899871  sndnxt: 3541899871     sndwnd:  16229
irs: 2288128196  rcvnxt: 2288128318  rcvwnd:      16263  delrcvwnd:    121

SRTT: 146 ms, RTTO: 1283 ms, RTV: 1137 ms, KRTT: 0 ms
minRTT: 0 ms, maxRTT: 300 ms, ACK hold: 200 ms
Flags: higher precedence, retransmission timeout, nagle, path mtu capable

Datagrams (max data segment is 1460 bytes):
Rcvd: 7 (out of order: 0), with data: 4, total data bytes: 121
Sent: 10 (retransmit: 0), with data: 5, total data bytes: 155
```

Lifecycle View of the BGP Routing Process



BGP Database Table

BGP Peers exchange UPDATE packets to advertise and withdraw prefixes.

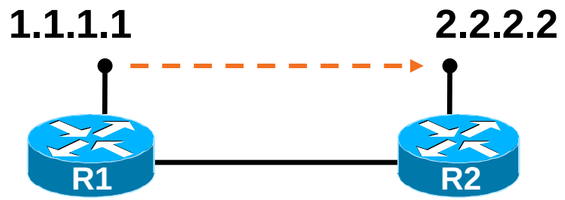
- All the locally known routes
- If Multiple paths, only the bestpath is advertised

What Information is populated in the BGP Database Table?

- Locally generated prefixes via the network command in BGP
- Prefixes learnt from BGP Peers via BGP UPDATE packets that have passed through neighbour distribute/filter-lists

BGP Database Table

```
R1#
router bgp 2
 no synchronization
 bgp log-neighbor-changes
 network 100.1.1.0 mask 255.255.255.0
 network 101.1.1.0 mask 255.255.255.0
 neighbor 2.2.2.2 remote-as 2
 neighbor 2.2.2.2 update-source Loopback0
```

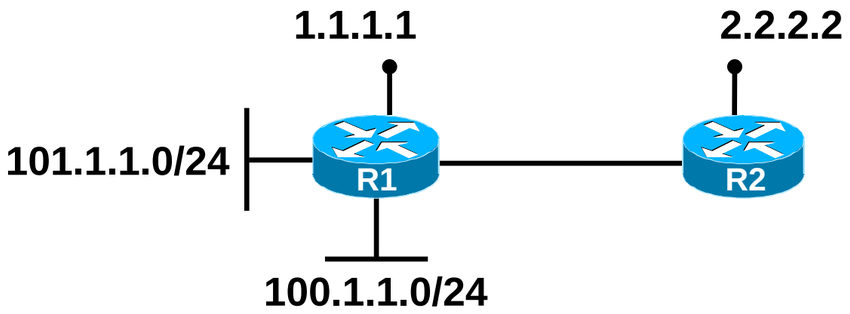



```
R2#
router bgp 2
 no synchronization
 bgp log-neighbor-changes
 network 200.1.1.0 mask 255.255.255.0
 network 201.1.1.0 mask 255.255.255.0
 neighbor 1.1.1.1 remote-as 2
 neighbor 1.1.1.1 update-source Loopback0
 neighbor 1.1.1.1 prefix-list From_R1 in
 neighbor 1.1.1.1 prefix-list To_R1 out
 no auto-summary

ip prefix-list To_R1 seq 5 deny 201.1.1.0/24
ip prefix-list To_R1 seq 7 permit 0.0.0.0/0 ge 1

ip prefix-list From_R1 seq 5 deny 101.1.1.0/24
ip prefix-list From_R1 seq 7 permit 0.0.0.0/0 ge 1
```

BGP Database Table

- All routes advertised by a neighbour can be seen with show ip bgp neighbor x.x.x.x received-routes
- soft-reconfiguration inbound must be configured

```
R2#sh ip bgp neighbors 1.1.1.1 received-routes
BGP table version is 6, local router ID is 2.2.2.2
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop            Metric LocPrf Weight Path
*>i100.1.1.0/24     1.1.1.1                  0    100      0 i
* i101.1.1.0/24     1.1.1.1                  0    100      0 i
```



BGP Database Table

- With soft-reconfiguration inbound configured, filtered prefixes can also be seen with show ip bgp <prefix>
- The prefix is marked as received-only and not advertised to any peer, due to being filtered with the prefix-list inbound

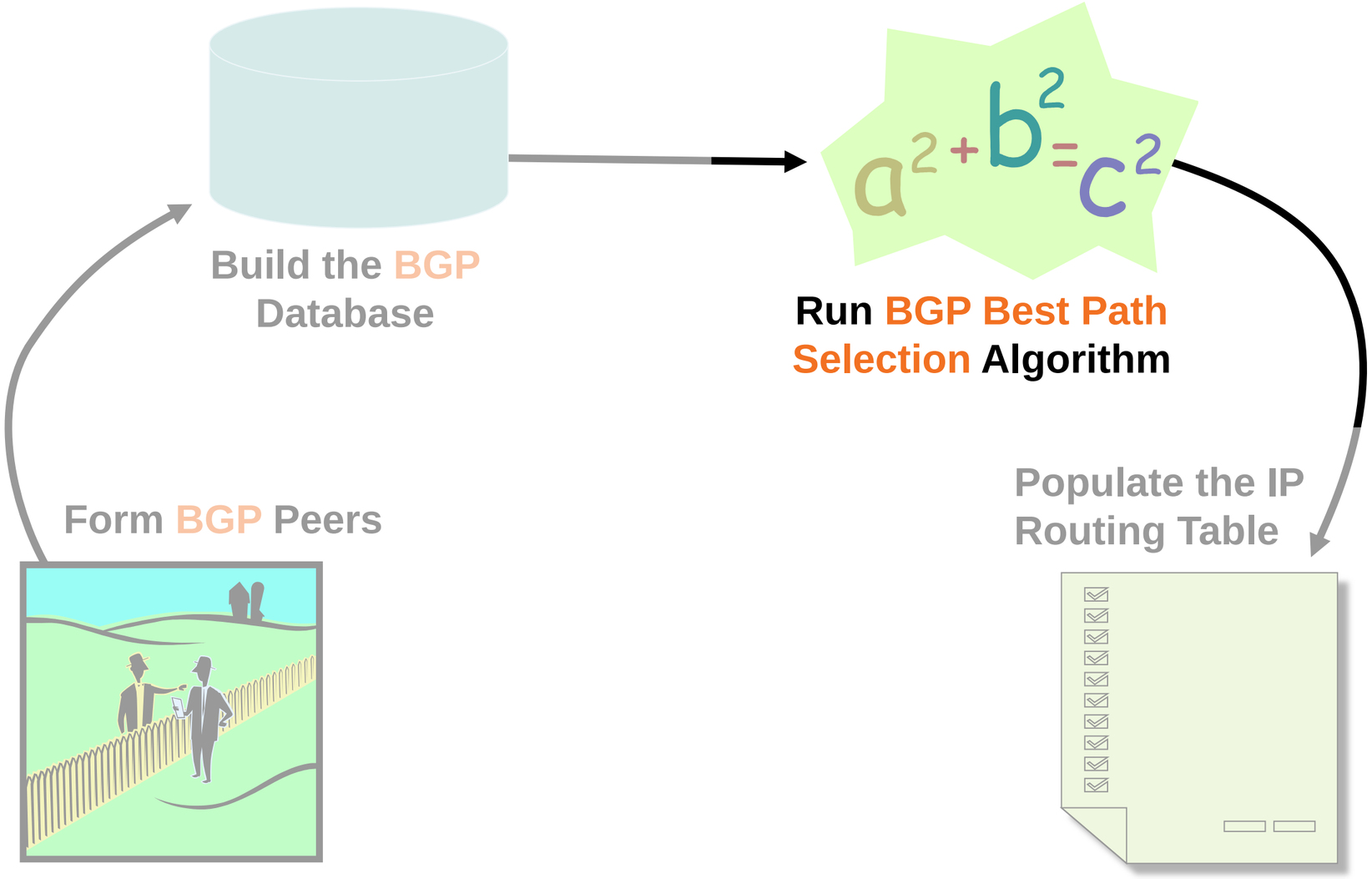
```
R2#sh ip bgp 101.1.1.1
BGP routing table entry for 101.1.1.0/24, version 3
Paths: (1 available, no best path)
  Not advertised to any peer
  Local, (received-only)
    1.1.1.1 (metric 409600) from 1.1.1.1 (1.1.1.1)
      Origin IGP, metric 0, localpref 100, valid, internal
R2#sh ip bgp
<snip>
   Network          Next Hop            Metric LocPrf Weight Path
*>i100.1.1.0/24     1.1.1.1                  0    100      0 i
*> 200.1.1.0        0.0.0.0                  0         32768 i
*> 201.1.1.0        0.0.0.0                  0         32768 i
```

BGP Database Table

- How do we verify what prefixes we have advertised and/or received from our BGP peer

```
R2#debug ip bgp update
BGP updates debugging is on

13:49:45.878: BGP(0): 1.1.1.1 rcvd UPDATE w/ attr: nexthop 1.1.1.1, origin i, localpref 100, metric 0
13:49:45.878: BGP(0): 1.1.1.1 rcvd 101.1.1.0/24 -- DENIED due to: distribute/prefix-list;
13:49:45.878: BGP(0): 1.1.1.1 rcvd 100.1.1.0/24
13:49:46.146: BGP(0): Revise route installing 1 of 1 routes for 100.1.1.0/24 -> 1.1.1.1(main) to main IP table
13:49:46.146: BGP(0): nettable_walker 200.1.1.0/24 route sourced locally
13:49:46.146: BGP(0): nettable_walker 201.1.1.0/24 route sourced locally len is 4
13:49:46.146: BGP(0): 1.1.1.1 send UPDATE (format) 200.1.1.0/24, next 2.2.2.2, metric 0, path
R2#
```

Lifecycle View of the BGP Routing Process



BGP Best Path Algorithm – BGP Router

- BGP Router Process decides the best path for all routes from the BGP Database

  Uses a 13 Step program to do this,

  http://www.cisco.com/en/US/partner/tech/tk365/technologies_tech_note09186a0080094431.shtml

- Keep the RIB up to date

  Add/Delete routes to reflect bestpath changes

  Modify current RIB entry in place when possible

- Lots of things must happen when bestpaths change

  RIB must be notified

  Peers must be informed

  Must have a way to track who has been informed of which bestpath changes

BGP Path Selection Algorithm Simplified

1. Next-hop has to be accessible (in the routing table)
2. Route must be synchronised (better turn synchronisation off)
3. Largest weight (Admin Preference, local to the router)
4. Largest local preference (Admin Preference. Spread within AS)
5. Router originated (Metric= “0 ASes” - Better if we originated it)
6. Shortest as-path (Metric in AS’s)
7. Lowest origin (igp < egp < incomplete)
8. Lowest MED (metric information from the next AS)
9. External over internal (Metric better if we are the border router)
10. Closest next-hop (IGP metric - the next-hop must be close)
11. Lowest router-id of Originator (tie-breaker)
12. Shortest Cluster-list (tie-breaker)
13. Lowest IP address of Neighbour (tie-breaker)

BGP Best Path Algorithm

How to Identify constant bestpath changes

- Prefix Table Version

  Each prefix has a 32 bit number that is its table version

  A prefix's table version is bumped up for every bestpath change

```
R1#show ip bgp 10.0.0.0
BGP routing table entry for 10.0.0.0/8, version 31
Paths: (1 available, best #1, table Default-IP-Routing-Table)
Flag: 0x820
  Not advertised to any peer
  200
    2.2.2.2 from 2.2.2.2 (2.2.2.2)
      Origin IGP, metric 0, localpref 100, valid, external,
  best
R1#
```

BGP Best Path Algorithm

How to Identify constant bestpath changes

- RIB and Peer Table versions
  - We have a table version for the RIB
  - Also have a table version for each peer
  - Used to keep track of which bestpath changes have been propagated to whom

```
R2#show ip bgp summ
   BGP router identifier 2.2.2.2, local AS number 200
   BGP table version is 13, main routing table version 13
   3 network entries using 351 bytes of memory
   3 path entries using 156 bytes of memory

   Neighbor        V    AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
   1.1.1.1         4   100    4386    4388       13    0    0 01:20:24        1
   R2#
```

BGP Best Path Algorithm – BGP Scanner

- The Scanner performs the following Housekeeping Tasks
  - Validate nexthop reachability
  - Validate bestpath selection
  - Route redistribution and network statements
  - Conditional advertisement
  - Route dampening
  - BGP Database cleanup
- Full Scanner Run happens every 60 Seconds
  - bgp scan-time X (Lowering Value not recommended)
- CPU spike is normal when scanner runs
  - Is a low priority process
  - Scanner spike shouldn’t adversely effect other processes

BGP Best Path Algorithm – BGP Scanner

- "debug ip bgp events" will show you when scanner ran for each address-family

```
BGP: Performing BGP general scanning
BGP(0): scanning IPv4 Unicast routing tables
BGP(IPv4 Unicast): Performing BGP Nexthop scanning for general scan
BGP(0): Future scanner version: 7, current scanner version: 6
BGP(1): scanning IPv6 Unicast routing tables
BGP(IPv6 Unicast): Performing BGP Nexthop scanning for general scan
BGP(1): Future scanner version: 13, current scanner version: 12
BGP(2): scanning VPNv4 Unicast routing tables
```

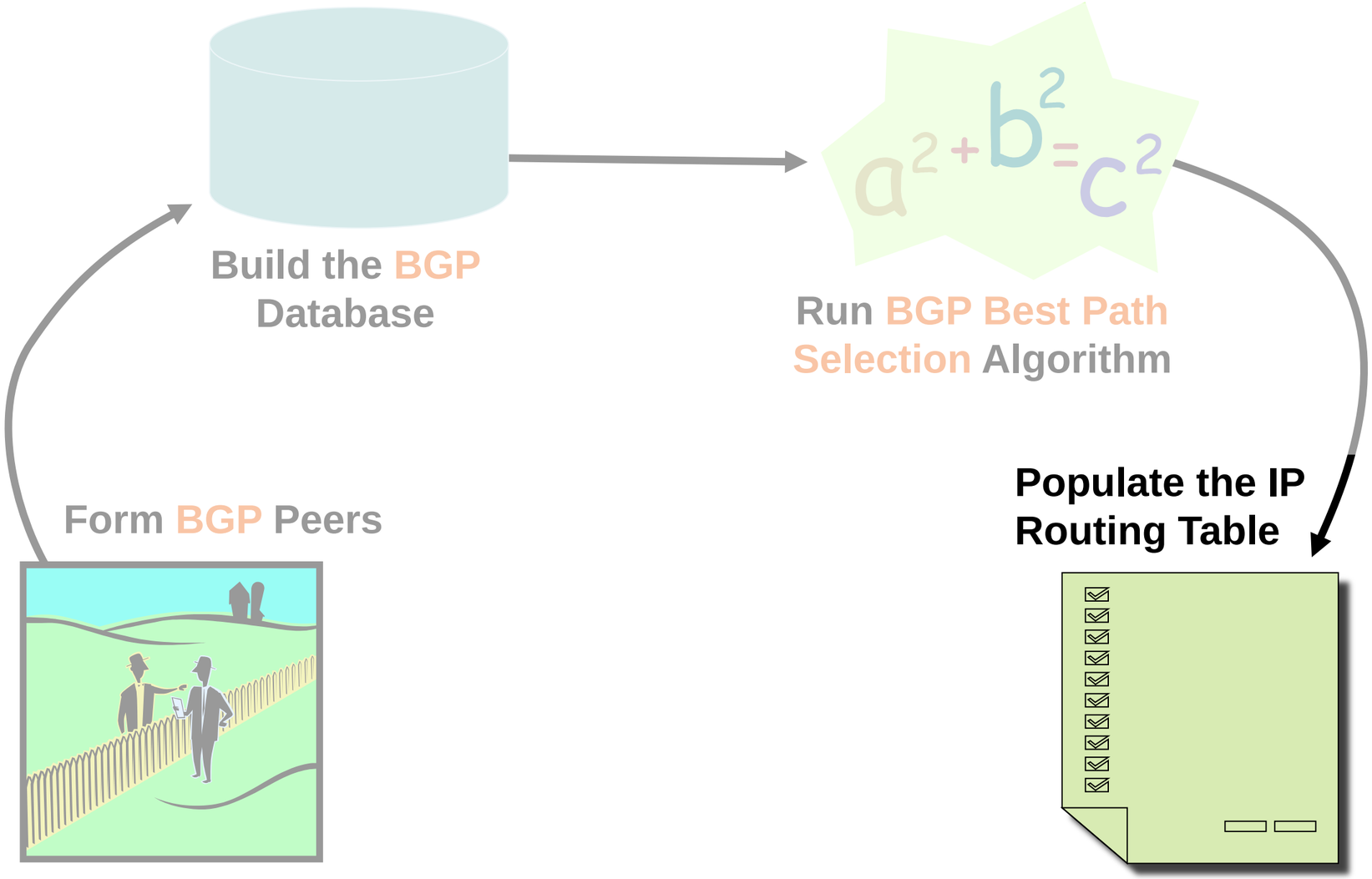
- Improvements have been made to reduce CPU Impact

  Route Redistribution and Network Statements are now event driven

  Next-Hop AddressTracking available by default in 12.0(29)S/12.3(14)T/12.4(1) helps in validating nexthop reachability and recalculating bestpaths for only those BGP nexthops that have changed.

  show ip bgp attr nexthop
  show ip bgp attr next-hop ribfilter

Lifecycle View of the BGP Routing Process



The BGP Routing Table

- The Best path selected from the BGP path decision Algorithm is placed in the Routing Table (RIB)

```
R2#show ip bgp nei 1.1.1.1 routes
<..snip..>
   Network          Next Hop            Metric LocPrf Weight Path
*>i100.1.1.0/24     1.1.1.1                  0    100      0 i
Total number of prefixes 1
```

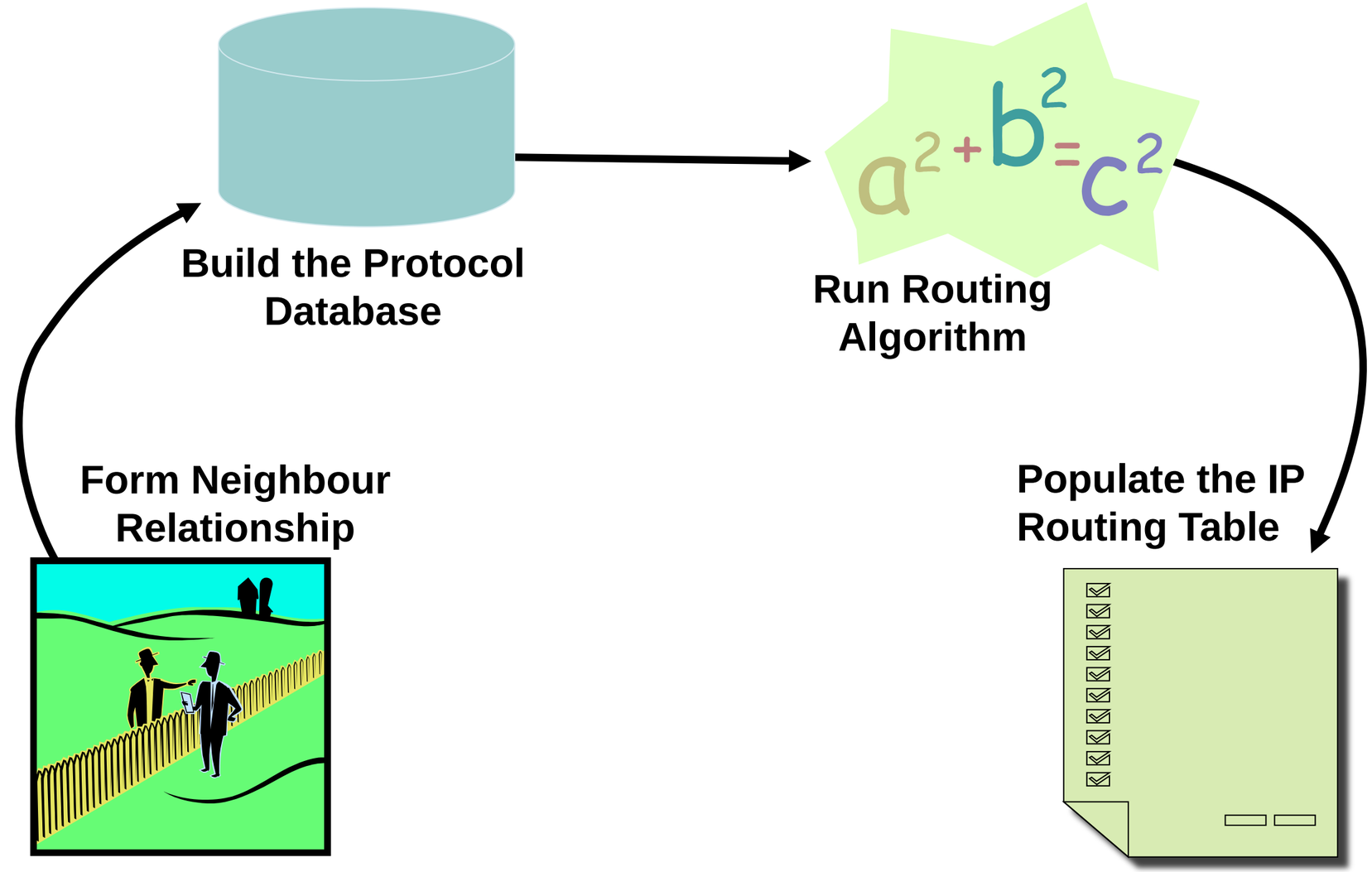
```
R2#show ip bgp nei 1.1.1.1 advertised-routes
<..snip..>
   Network          Next Hop            Metric LocPrf Weight Path
*> 200.1.1.0        0.0.0.0                  0         32768 i
Total number of prefixes 1
```

The BGP Routing Table

Why is the prefix not in the Routing Table ?

```
R2#show ip bgp 101.1.1.0
BGP routing table entry for 101.1.1.0/24, version 7
Paths: (1 available, best #1, RIB-failure(17))
  Not advertised to any peer
  Local
    1.1.1.1 (metric 11) from 1.1.1.1 (101.1.1.1)
      Origin IGP, metric 0, localpref 100, valid, internal, best

R2#sh ip bgp rib-failure
Network            Next Hop                        RIB-failure   RIB-NH Matches
101.1.1.0/24       1.1.1.1                 Higher admin distance              n/a
R2#
```

Summary



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