Link State Routing with OSPF

Foreword

OSPF is an **interior gateway protocol (IGP)** designed for **IP networks**, that is founded on the principles of link state routing. The link state behavior provides many alternative advantages for medium and even large enterprise networks. Its application as an IGP is introduced along with information relevant to the understanding of OSPF convergence and implementation, for supporting OSPF in enterprise networks.

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Objectives

Upon completion of this section, trainees will be able to:

- Explain the OSPF convergence process.

- Describe the different network types supported by OSPF.

- Successfully configure single area OSPF networks.

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Link State Protocol

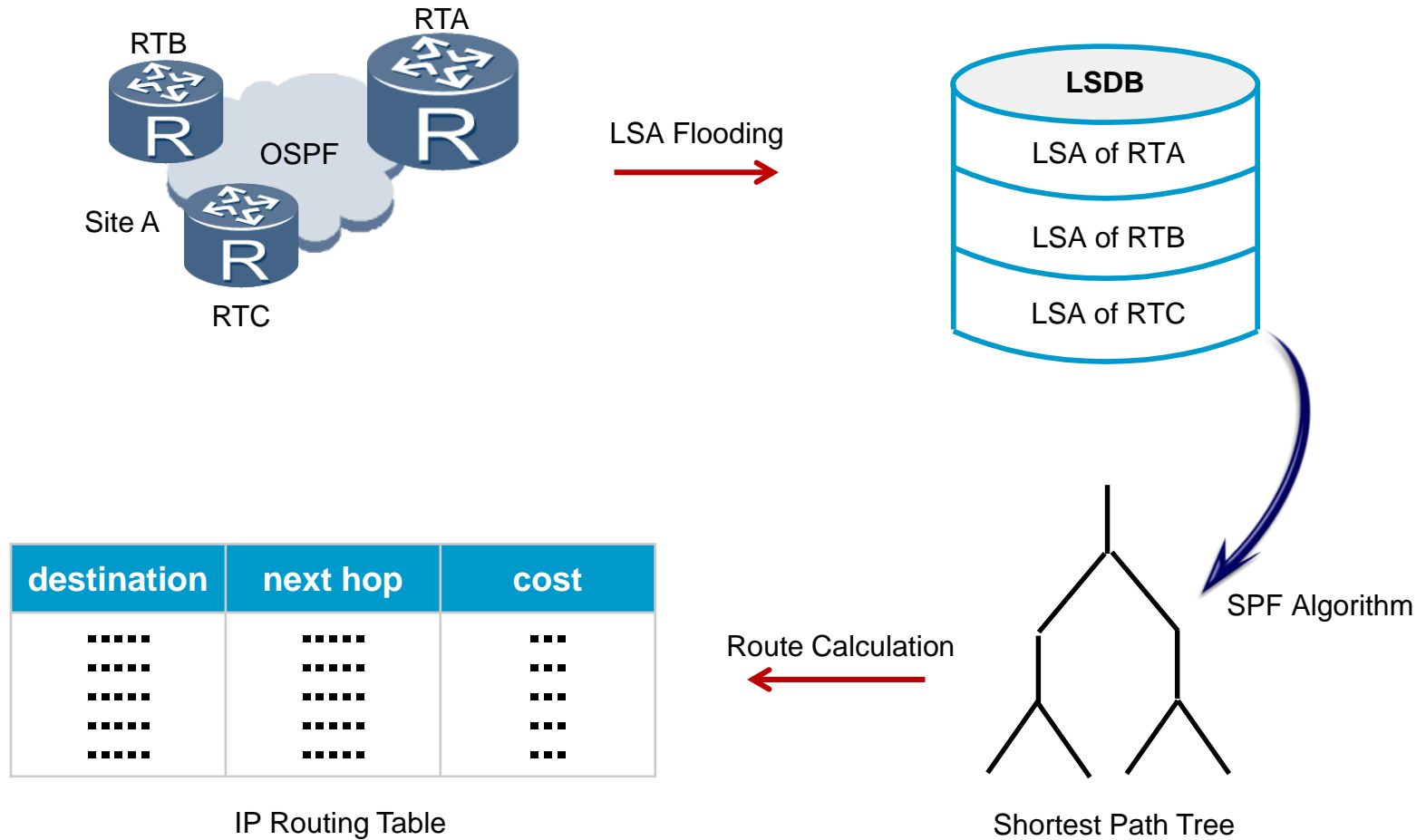Il funzionamento dei protocolli "link-state" può essere suddiviso in tre sezioni:

*   Network Discovery

    ricerca dei router vicini e analisi delle informazioni in possesso;

*   Topology Database Exchange

    I router collaborano tra loro per scambiare informazioni sulla topologia. Popolazione del LSDB.

*   Route Computation

    Ogni router in modo indipendente, analizza le informazioni topologiche e sceglie la migliore rotta verso una destinazione secondo la SUA prospettiva.

Open Shortest Path First（OSPF）

RTB

RTA

Site B

OSPF

RIP

Site A

RTC

OSPF over MPLS

OSPF

Site C
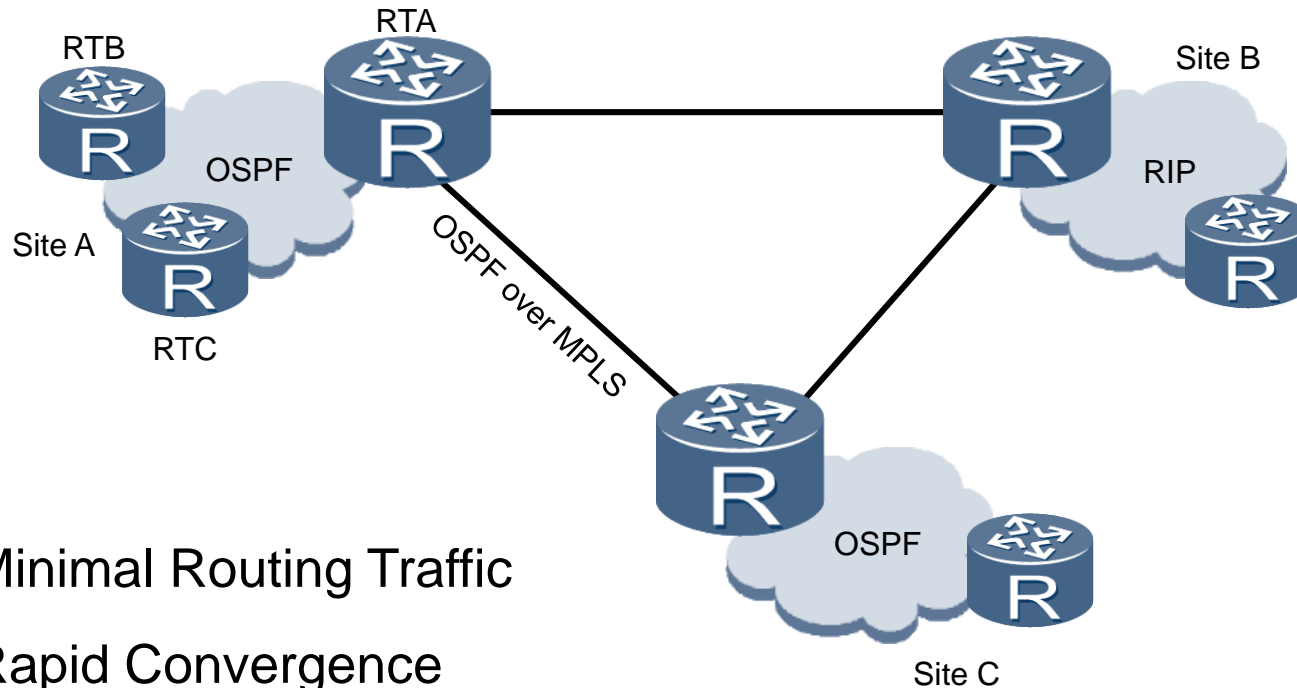
- Minimal Routing Traffic

- Rapid Convergence

- Scalable

- Accurate Route Metrics

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OSPF Convergence Behavior

RTB

RTA

OSPF

Site A

RTC

LSA Flooding

LSDB

LSA of RTA

LSA of RTB

LSA of RTC

SPF Algorithm

destination	next hop	cost
.....	.....	...
.....	.....	...
.....	.....	...
.....	.....	...
.....	.....	...

Route Calculation
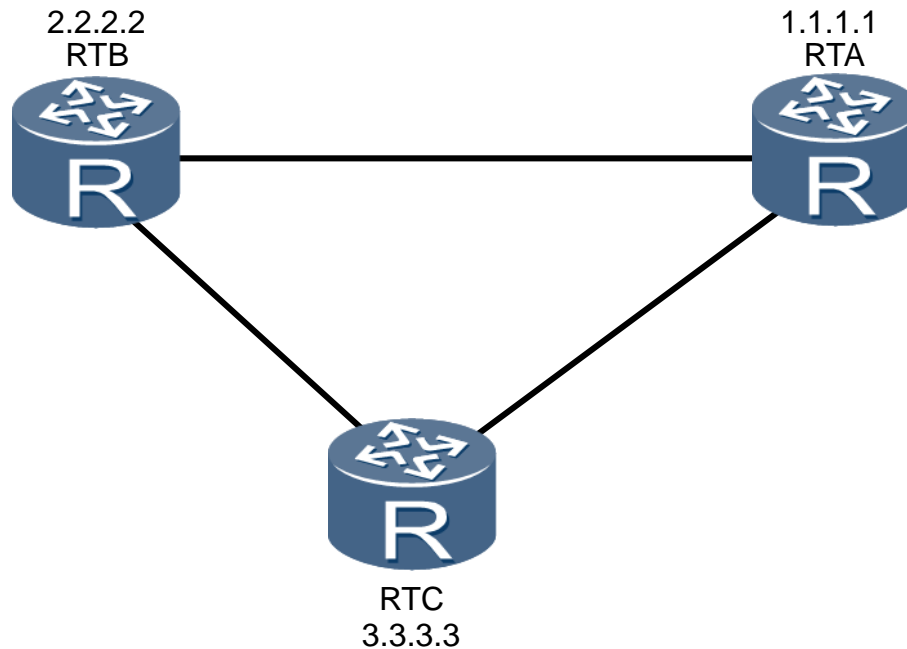
IP Routing Table

Shortest Path Tree

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OSPF LSAs Type
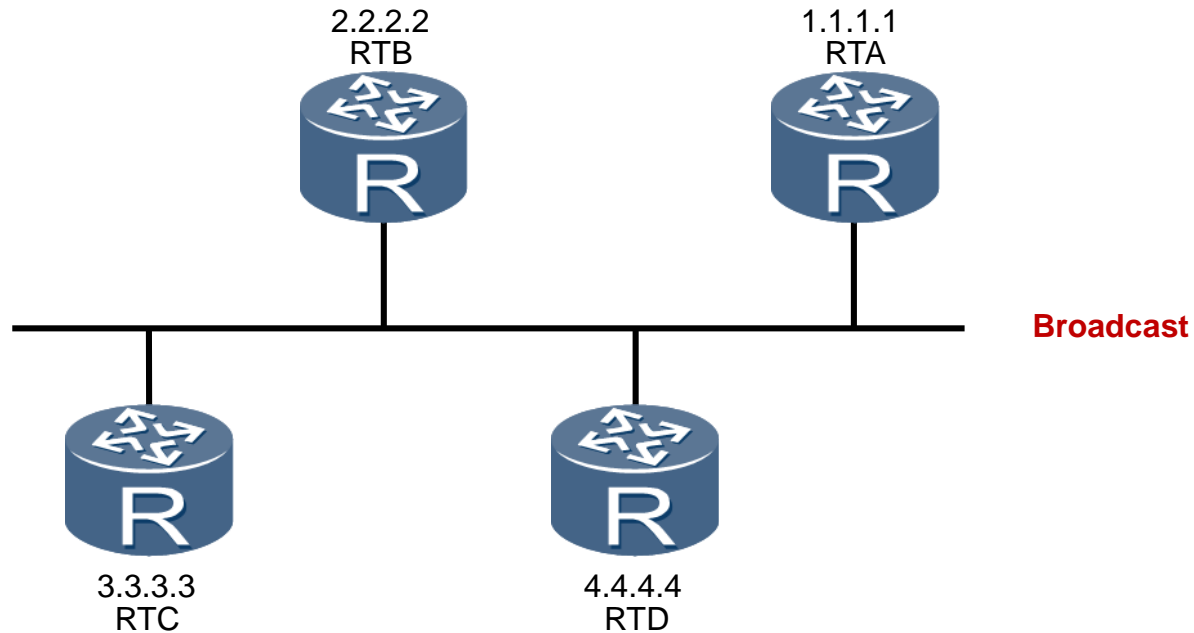
Tipologie di LSA:

- Router (tipo 1);

- Network (tipo 2);

- Net Summary (tipo 3);

- ASBR Summary (tipo 4);

- AS External (tipo 5);

- Group Membership (tipo 6);

- NSSA External (tipo 7);

- LInk LSAs (tipo 8);

- Intra-Area Prefix LSAs (tipo 9);

- Opaque (tipo 10,11),

Router ID

- A router ID is a 32-bit value used to identify each router running the OSPF protocol.

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OSPF Supported Network Types

● Ethernet based networks adopt the broadcast network type by default.

OSPF Supported Network Types

Interface Type	Uses DR/BDR?	Default Hello Interval	Dynamic Discovery of Neighbors?	More Than Two Routers Allowed in the Subnet?
Broadcast	Yes	10	Yes	Yes
Point-to-point[1]	No	10	Yes	No
Loopback	No	—	—	No
Nonbroadcast[2] (NBMA)	Yes	30	No	Yes
Point-to-multipoint	No	30	Yes	Yes
Point-to-multipoint nonbroadcast	No	30	No	Yes

[1] Default on Frame Relay point-to-point subinterfaces.

[2] Default on Frame Relay physical and multipoint subinterfaces.
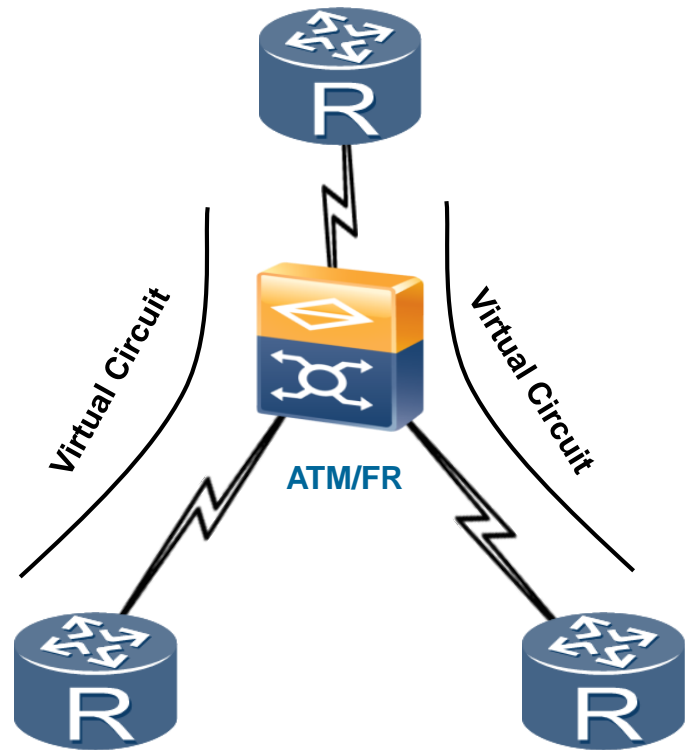
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OSPF Supported Network Types

2.2.2.2
RTB

1.1.1.1
RTA

Broadcast

2.2.2.2
RTB

1.1.1.1
RTA
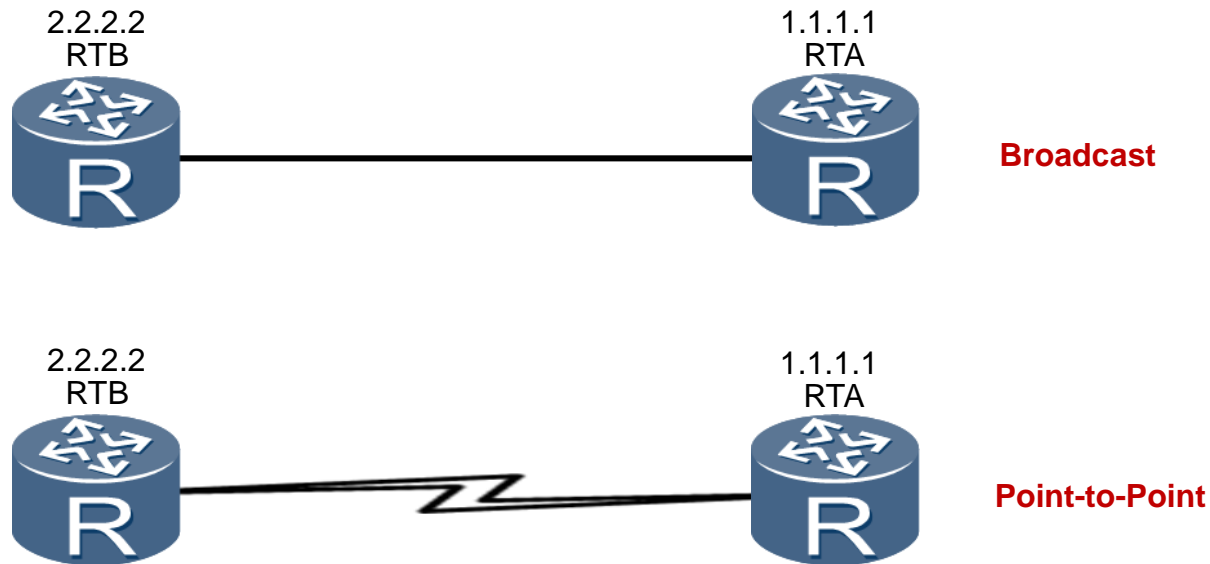
Point-to-Point

● Serial technologies such as PPP and HDLC will default to the Point-to-Point network type.

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OSPF Supported Network Types

DR
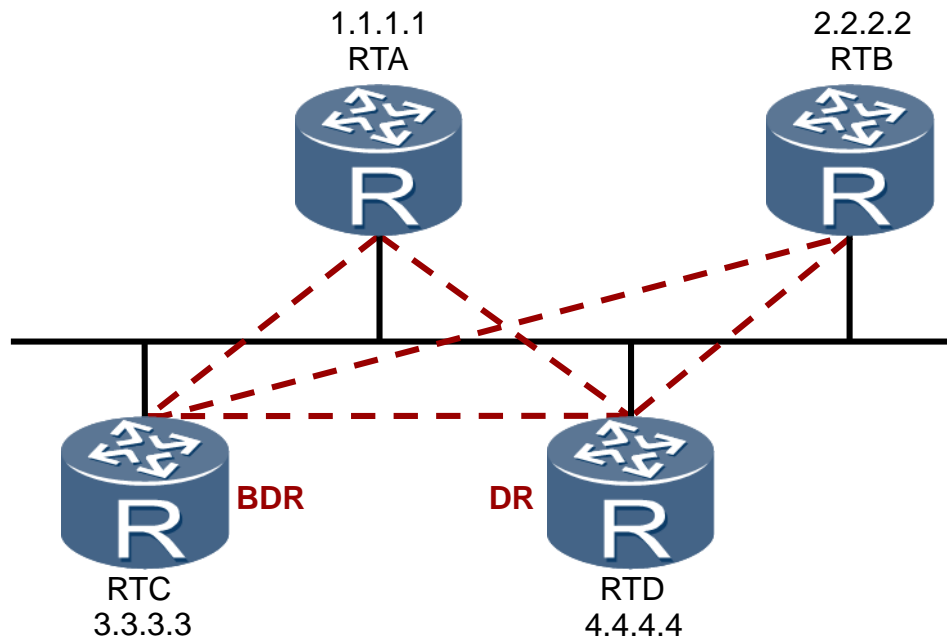
ATM/FR

Virtual Circuit

Virtual Circuit

Non-Broadcast Multi-Access (NBMA)

ATM/FR

Virtual Circuit

Virtual Circuit
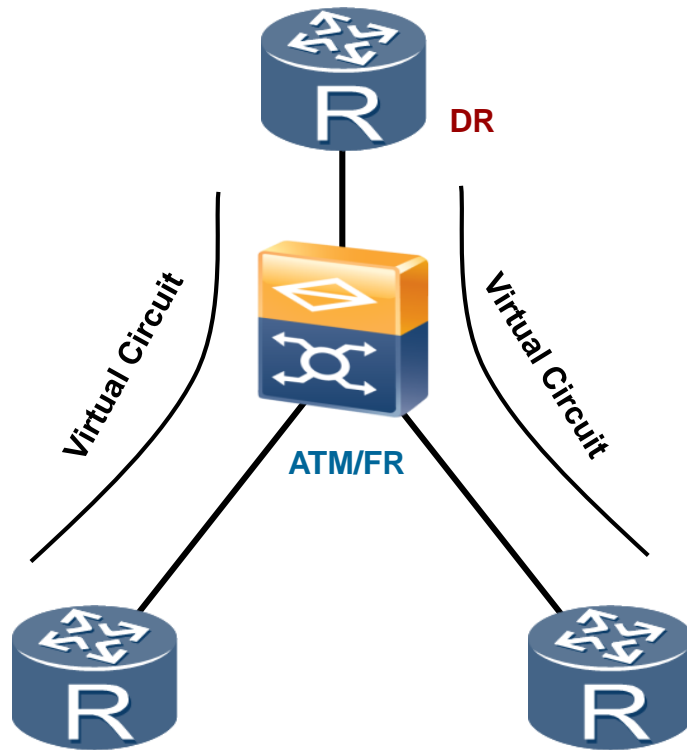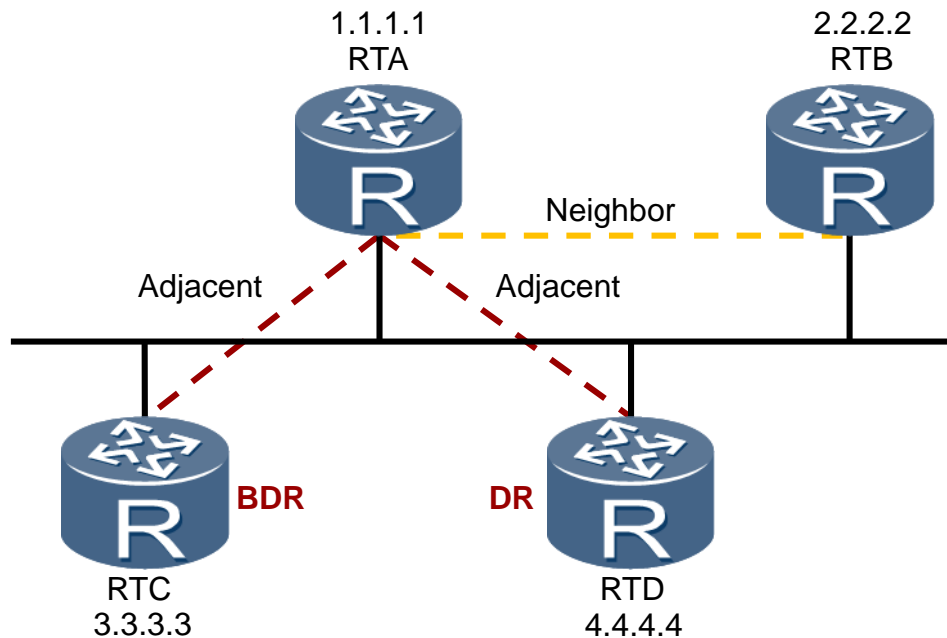
Point to Multi-Point

● ATM & Frame Relay default to Non-Broadcast Multi-Access.

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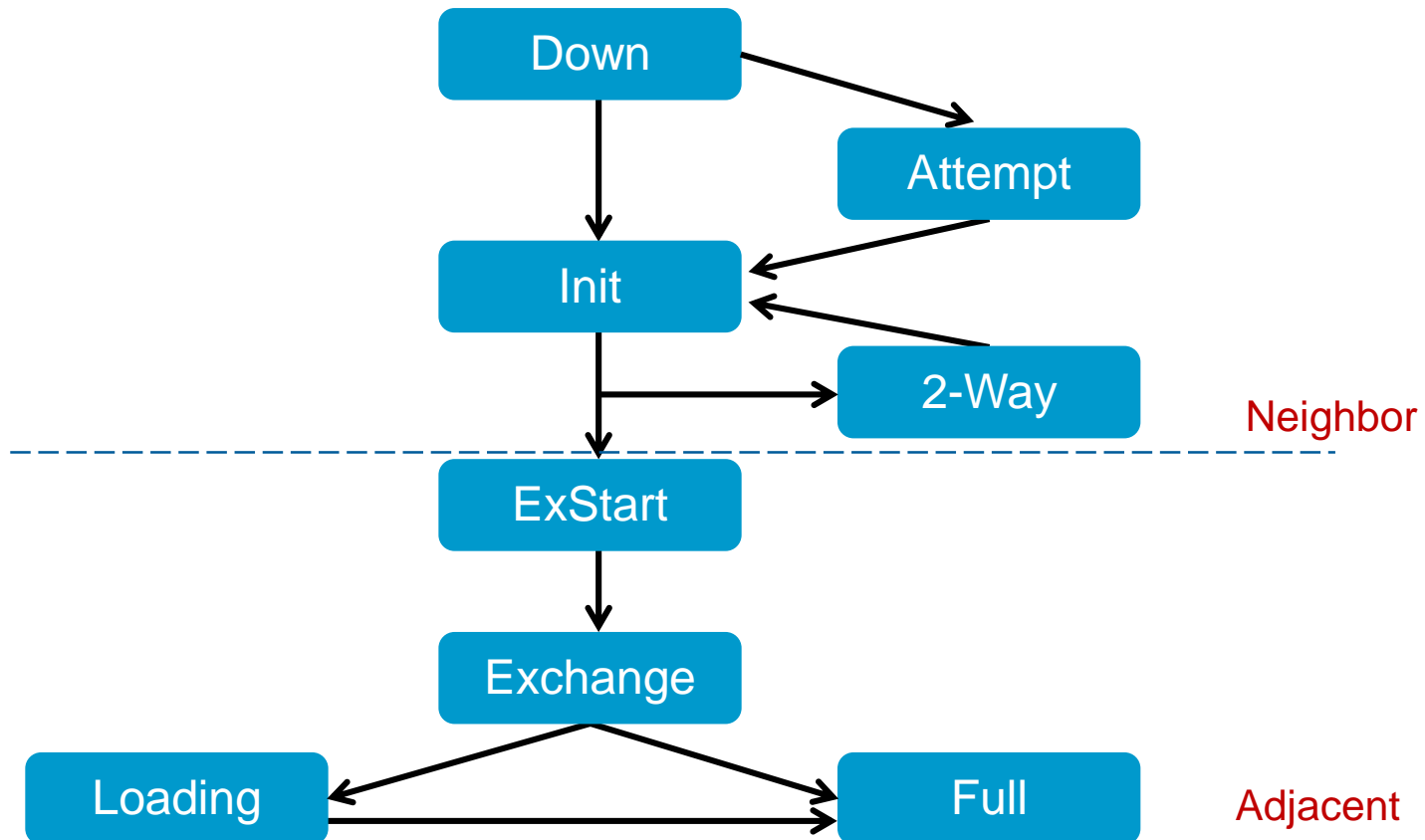# Designated Router & Backup Designated Router

- Designated Routers limit the number of adjacencies necessary in broadcast (Ethernet) networks.
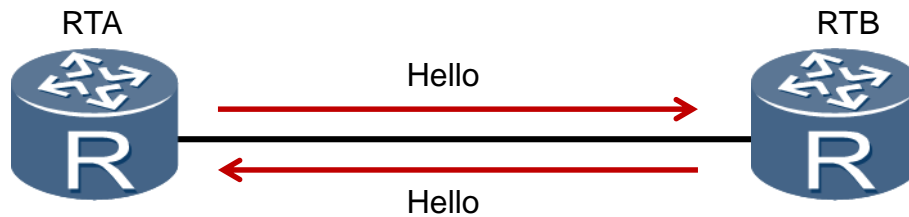
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Neighbor States

- Defines form of relationship between neighbors.

- Two neighbor states are possible, neighbor and adjacent.

Link State Establishment

● State changes allow for neighbor relationships to be achieved.

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Neighbor Discovery

RTA   RTB

Hello →

← Hello

Hello Interval	Options	Router Priority
Router Dead Interval		
Designated Router		
Backup Designated Router		
Neighbor		

● The Hello protocol is responsible for neighbor discovery and maintenance for two way communication between neighbors.

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Designated Router Election

RTA Priority=0

RTB (Priority=1)

Broadcast

DR (Priority=255)

Broadcast

RTC

RTD

DR (Priority=255)

```
[RTD]interface GigabitEthernet0/0/0
[RTD-GigabitEthernet0/0/0]ospf network-type p2p
```
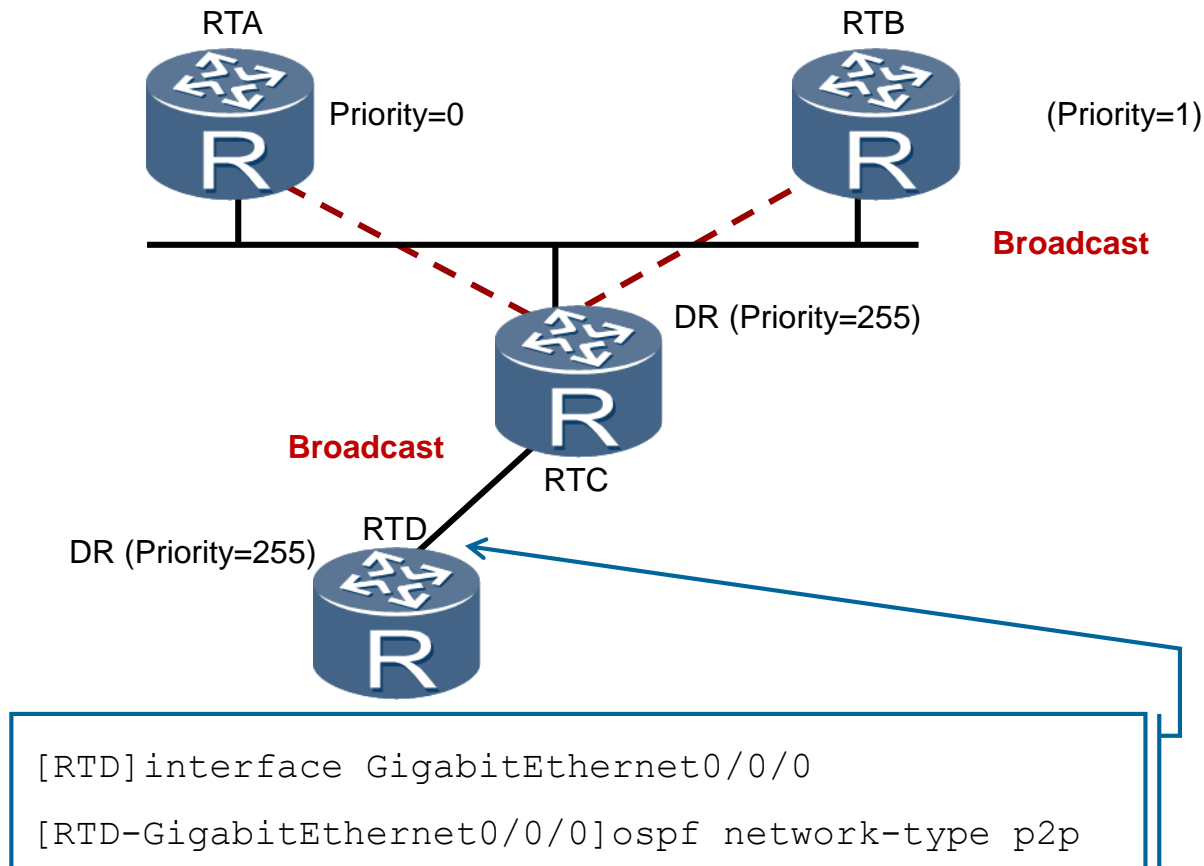
● A Designated Router is elected based on the priority value.

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Backup Designated Router Election
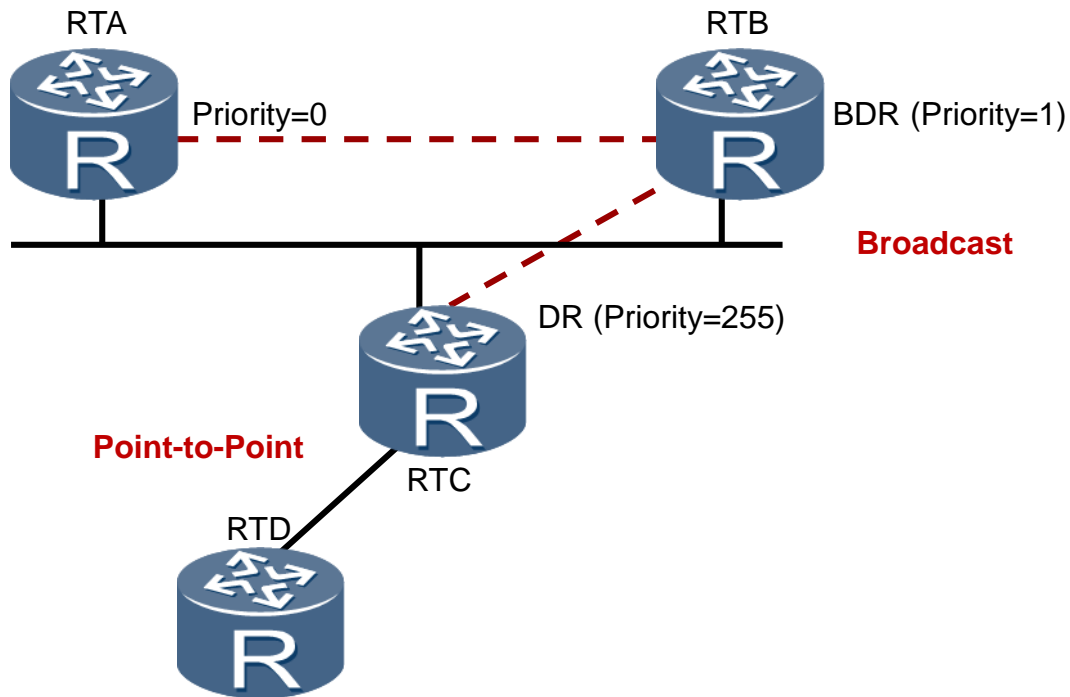
- The Backup Designated Router (BDR) forms adjacencies with all other routers and will become the DR if the existing DR fails.

Designated Router Election - Casi
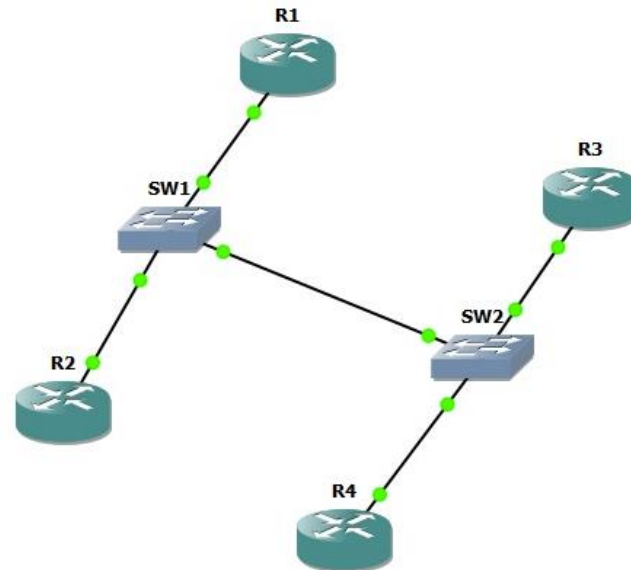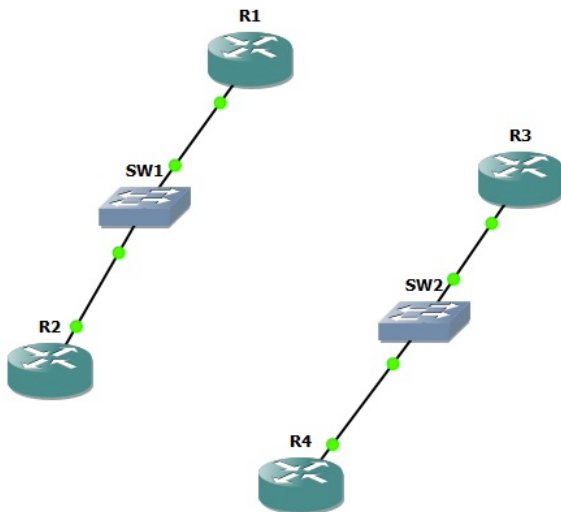
- Un solo router nella topologia:

  - elegge se stesso come DR dopo 40 secondi (dead interval);

- Viene acceso un ulteriore router nella stessa topologia (dopo 40s):

  - il Nuovo router viene nominato BDR;

- DR e BDR sono già eletti, viene acceso un terzo router:

  - Il nuovo router accetta le elezioni e inizia subito le procedure di scambio dati (non preemptive).

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Designated Router Election - Casi

● Tre router accesi contemporaneamente:

  ● Attendono il wait time (40s) ed iniziano le elezioni:

  ● Elezione del BDR;

  ● Elezione del DR;

  ● A parità di priorità vince il router-id più alto.

Designated Router Election - Casi

- Unione di due segmenti di rete con DR già presente

    - Viene fatta una nuova elezione;

    - Il processo è, in questo caso, preemptive!

Database Synchronization

RTA (Router ID: 1.1.1.1)   RTB (Router ID: 2.2.2.2)

DD, (Master)(Sequence=X)

DD, (Master)(Sequence=Y)

DD, (Slave)(Sequence=Y)

DD, (Master)(Sequence=Y+1)

DD, (Master)(Sequence=Y+1)
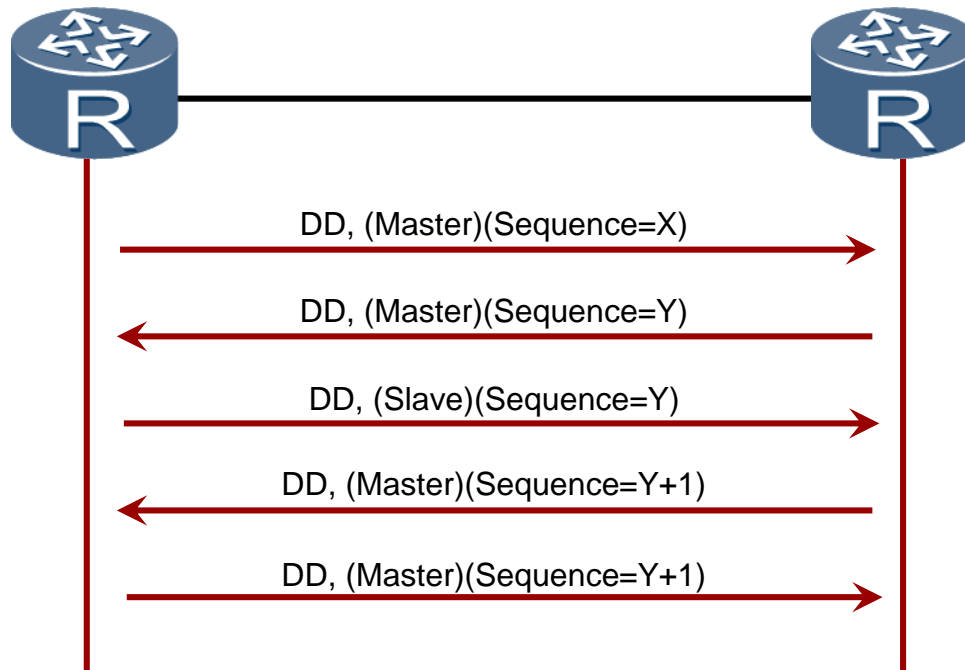
● Neighboring routers form a master/slave relationship.

● Database Description packets contain LSA header information.

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Establishing Full Adjacency

RTA (Router ID: 1.1.1.1)   RTB (Router ID: 2.2.2.2)

Loading

Link State Request →

← Link State Update

Link State Request →

← Link State Update
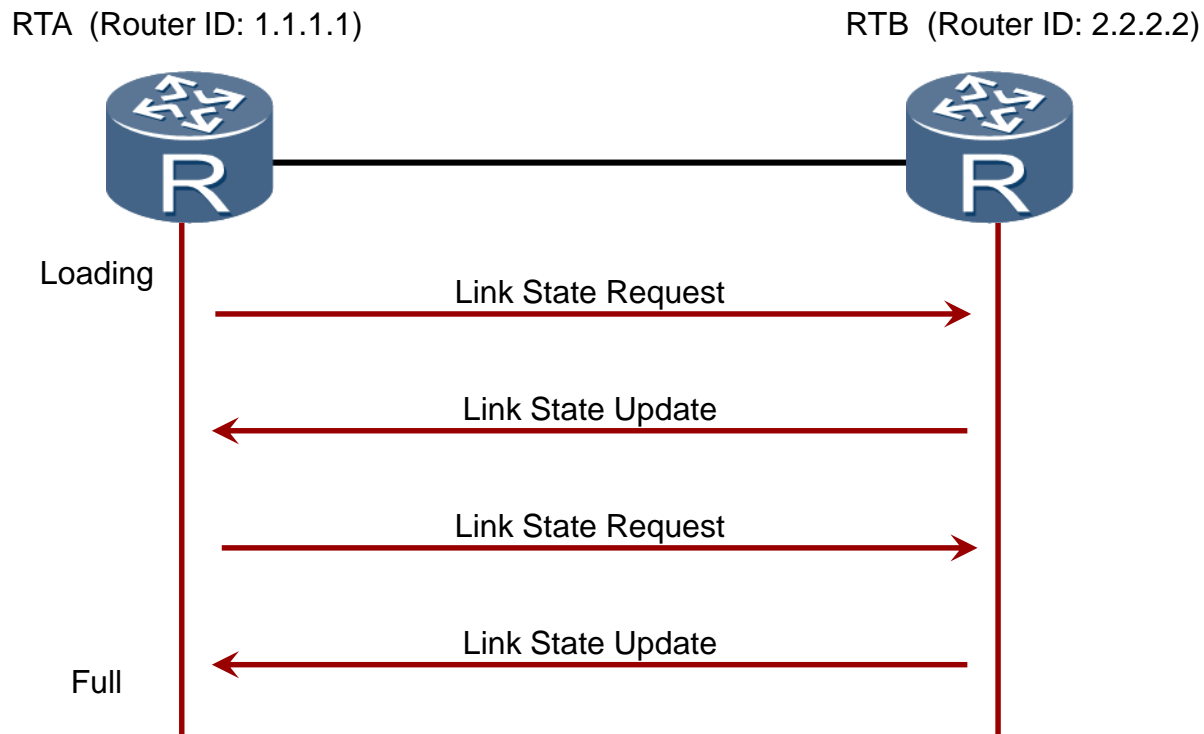
Full

- Missing or newer instances of LSA are requested using LSR.

- The entire requested LSA is sent as an update.

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Establishing Full Adjacency - Procedure

R1
RID: 1.1.1.1

R2
RID: 2.2.2.2

1 - Il link viene attivato - interfacce UP/UP

INIT

2 - HELLO, Seen [null], My RouterID: 1.1.1.1 →

INIT

3 - HELLO, Seen [1.1.1.1], My RouterID: 2.2.2.2 ←

2-WAY

4 - HELLO, Seen[1.1.1.1, 2.2.2.2] My RouterID: 1.1.1.1 →

2-WAY

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Establishing Full Adjacency - Procedure

RTA (Router ID: 1.1.1.1)   RTB (Router ID: 2.2.2.2)

ExStart   Database Description ⟶

                   ⟵ Database Description   **Exchange**

Loading   ⟵ LSU con molti LSA   **Loading**

                   LSU con molti LSA
                   ⟵

FULL   **FULL**

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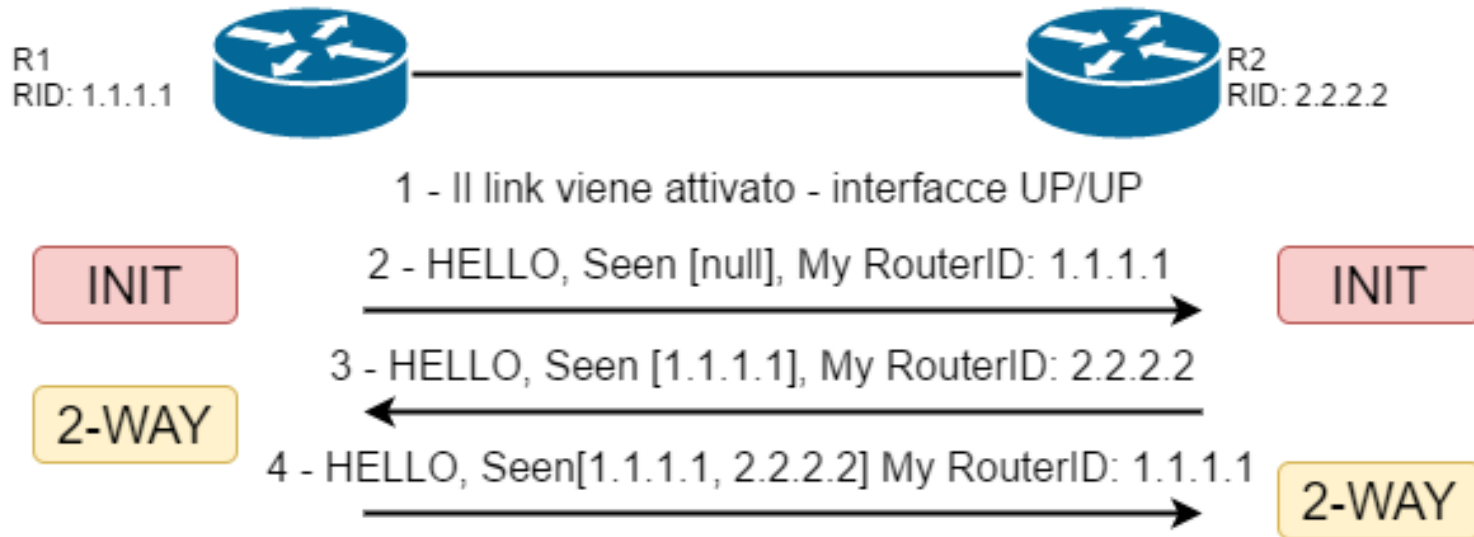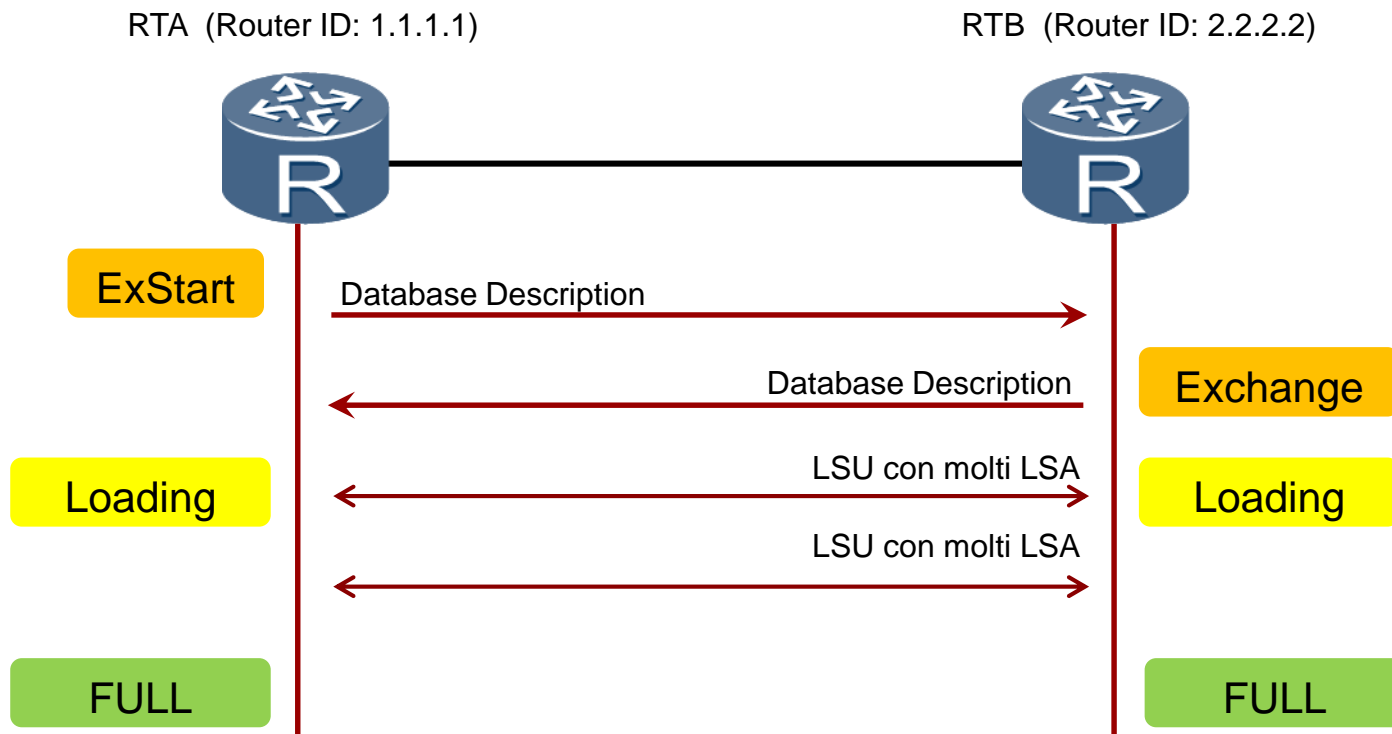
Establishing Full Adjacency - Procedure

ospf_neighbor.pcapng

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OSPF Metric

RTA (Router ID: 1.1.1.1)   RTB (Router ID: 2.2.2.2)

G0/0/0

```
[RTA]interface GigabitEthernet 0/0/0
[RTA-GigabitEthernet0/0/0]ospf cost 20
```

```
[RTB]ospf
[RTB-ospf-1]bandwidth-reference 10000
```
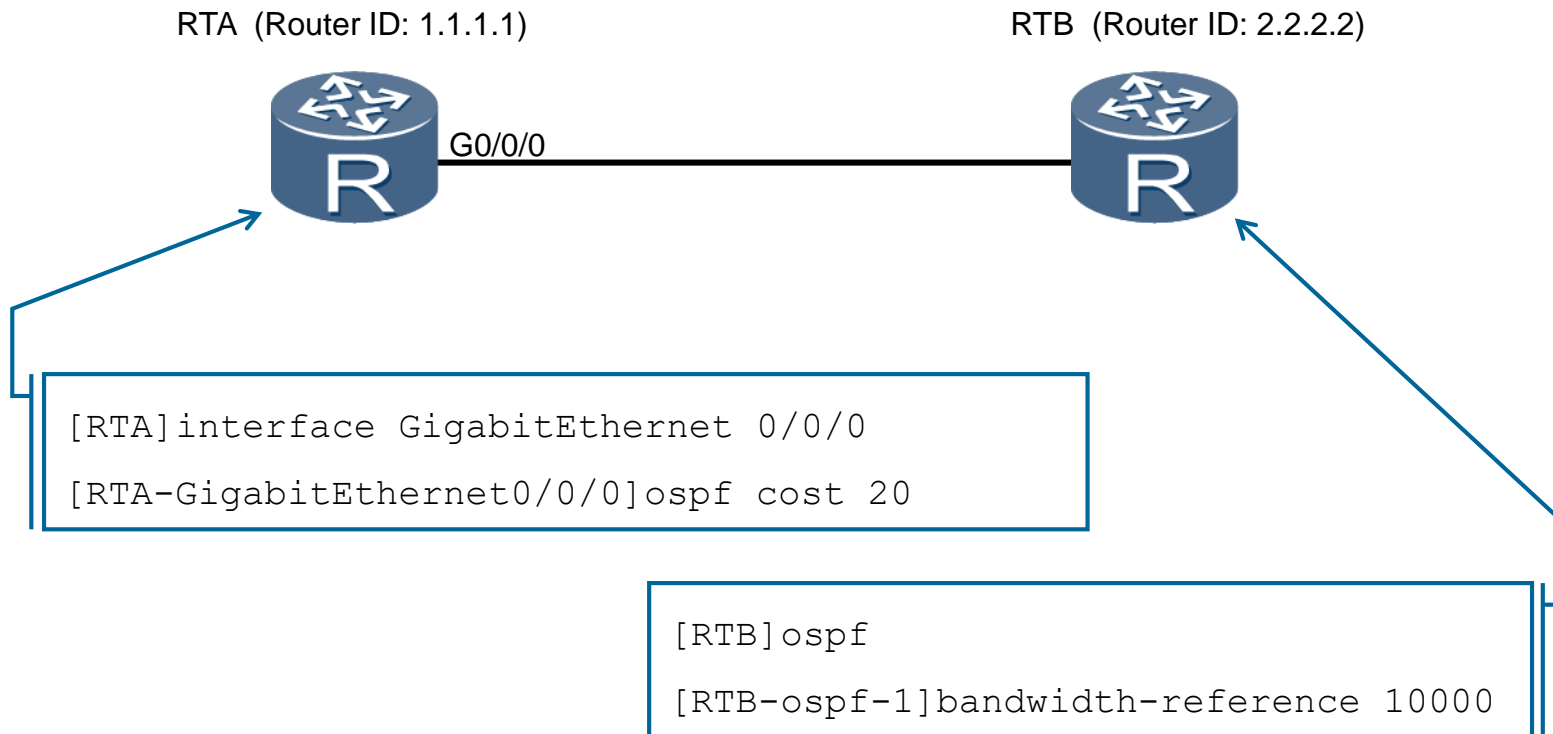
- The cost metric is based on the formula 10^8/bandwidth.

- The bandwidth reference command improves metric accuracy.

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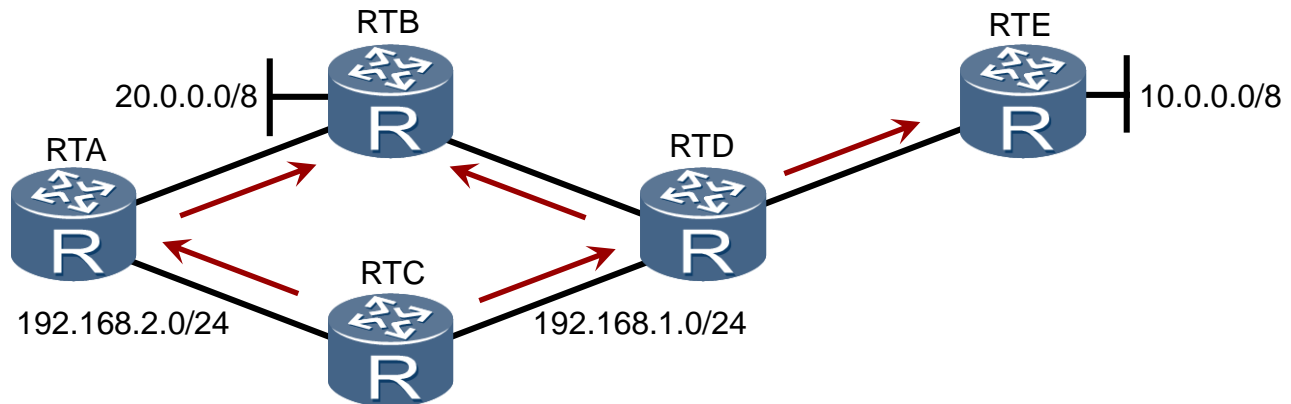
Shortest Path Tree
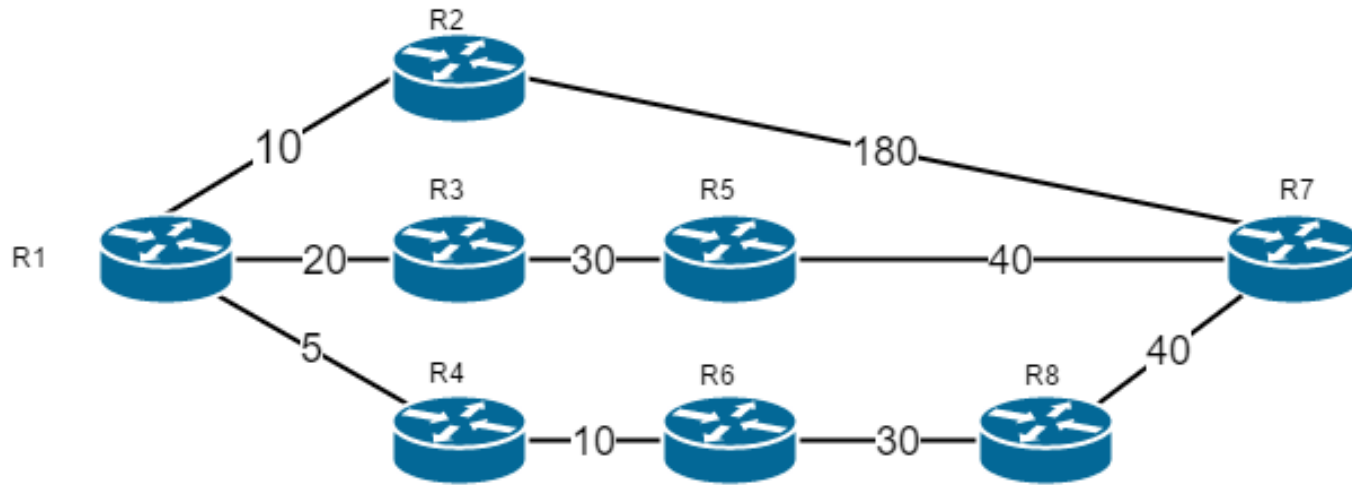


```
[RTC]display ip routing-table

……

Destination/Mask Proto Pre Cost   Flags NextHop        Interface
  10.0.0.0/8       OSPF  10   20     D    192.168.1.4    G0/0/0
  20.0.0.0/8       OSPF  10   20     D    192.168.1.4    G0/0/0
                   OSPF  10   20     D    192.168.2.1    G0/0/1
```
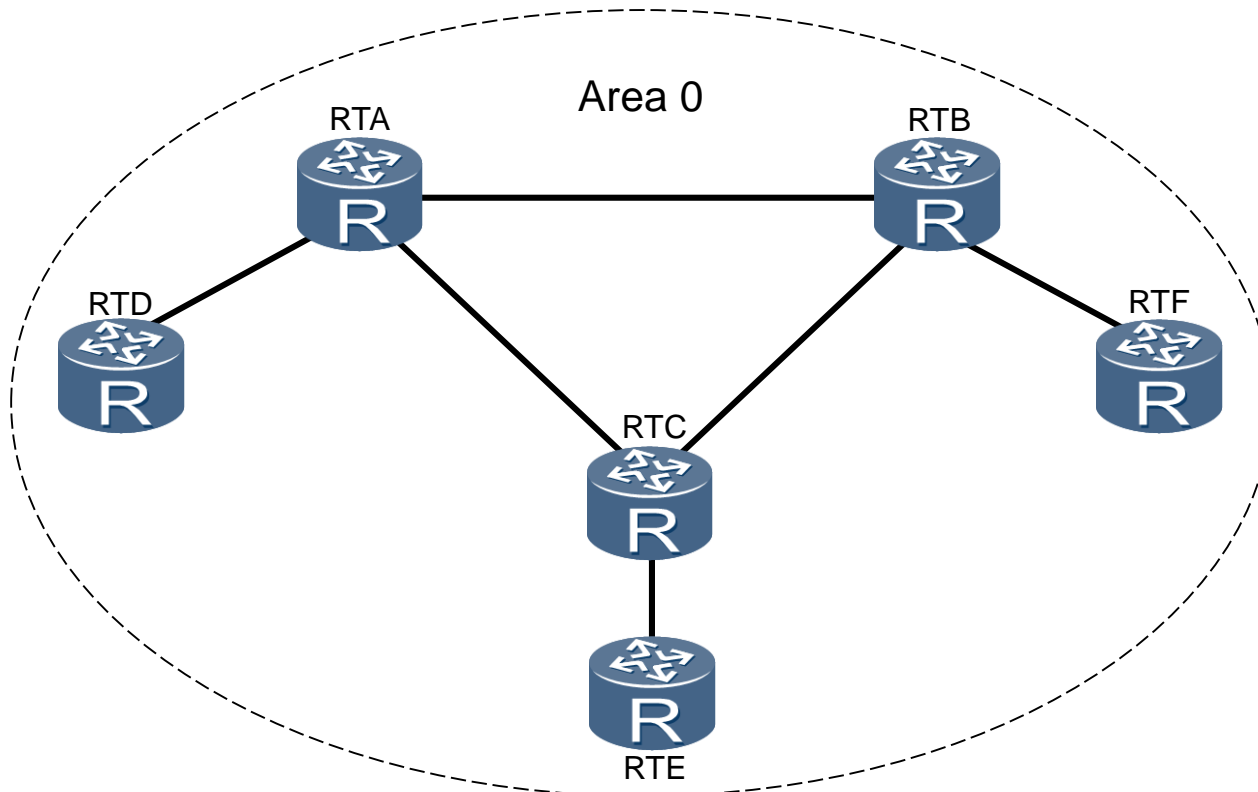
● Each router calculates the shortest path to all other networks.

Shortest Path Tree

Path : R1 -> R7	Costo
Via R2	190
Via R3	90
Via R4	85

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OSPF Areas – Single Area

- A single link state database for the administrative domain.

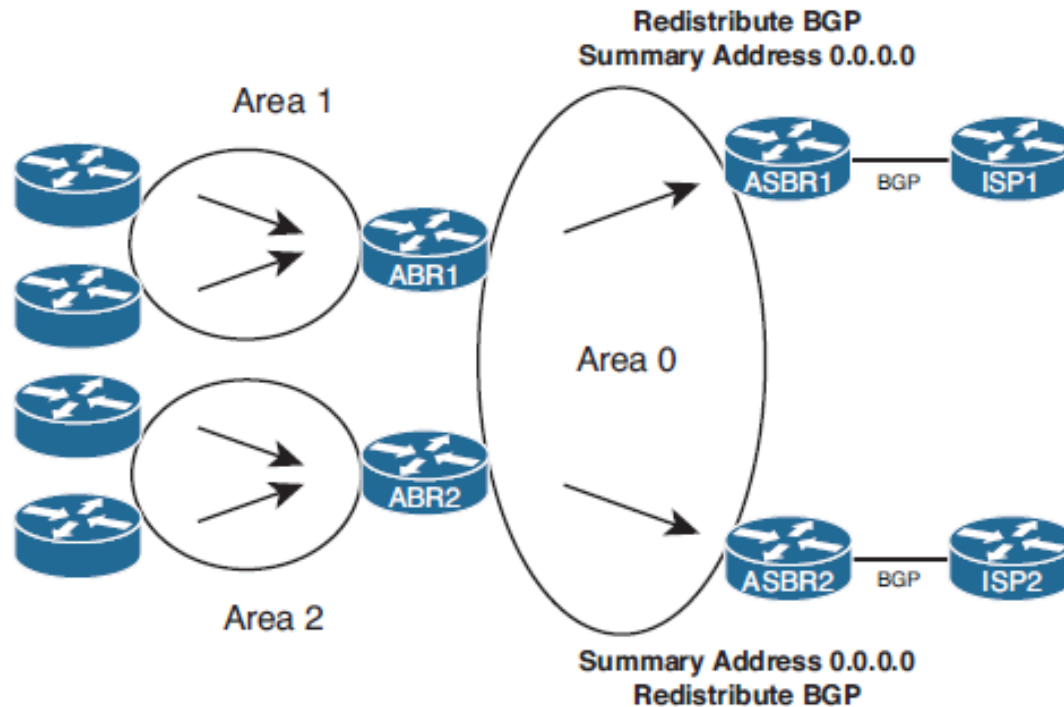- Any area number can be assigned but area 0 is recommended.

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OSPF Areas – Multi Area
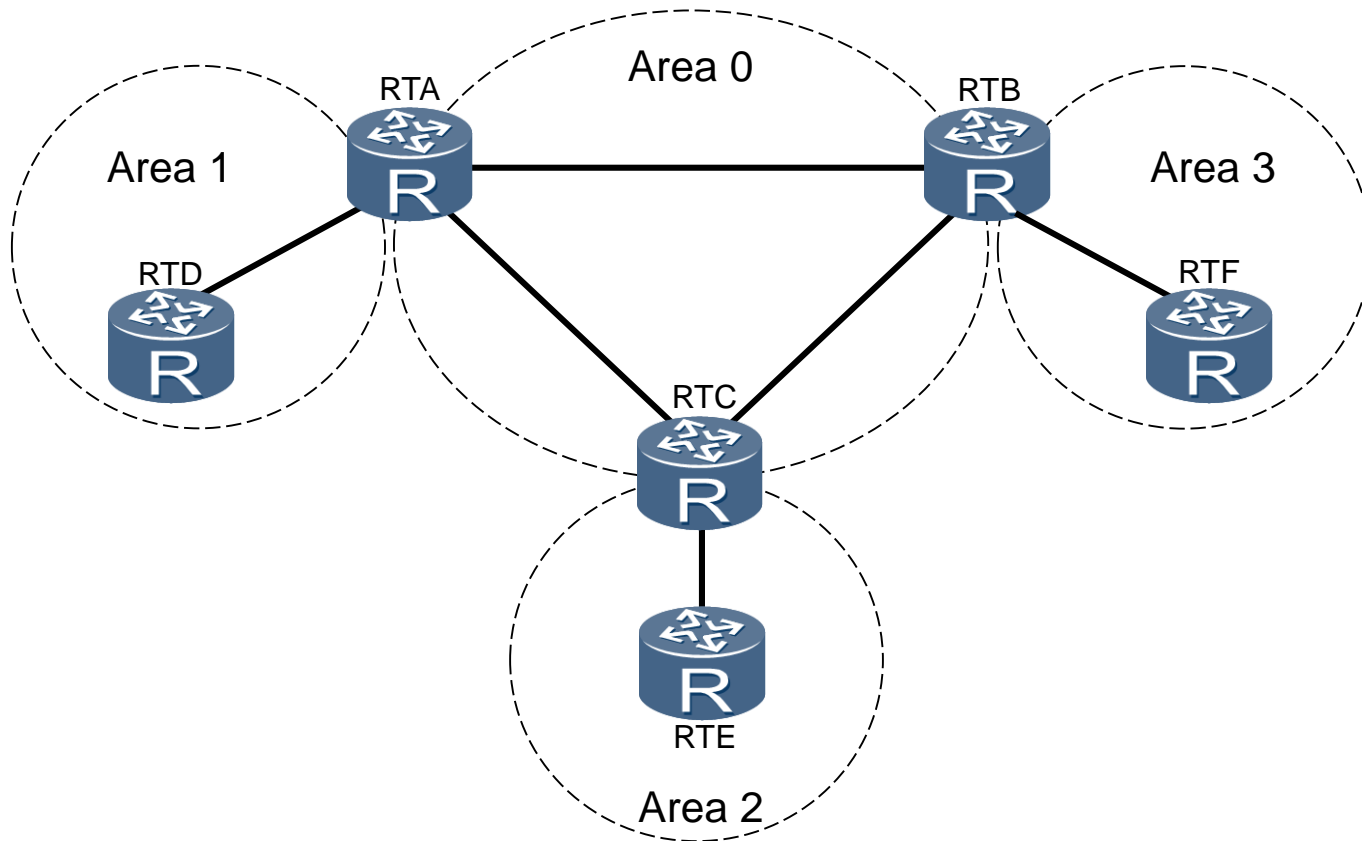
- Areas build separate LS databases, minimize impact of change.

OSPF Areas – Altre tipologie di aree

● Questi concetti sono tipicamente collegati al processo di "route summarization" e di distribuzione delle "default routes";

OSPF Areas – Stubby Areas
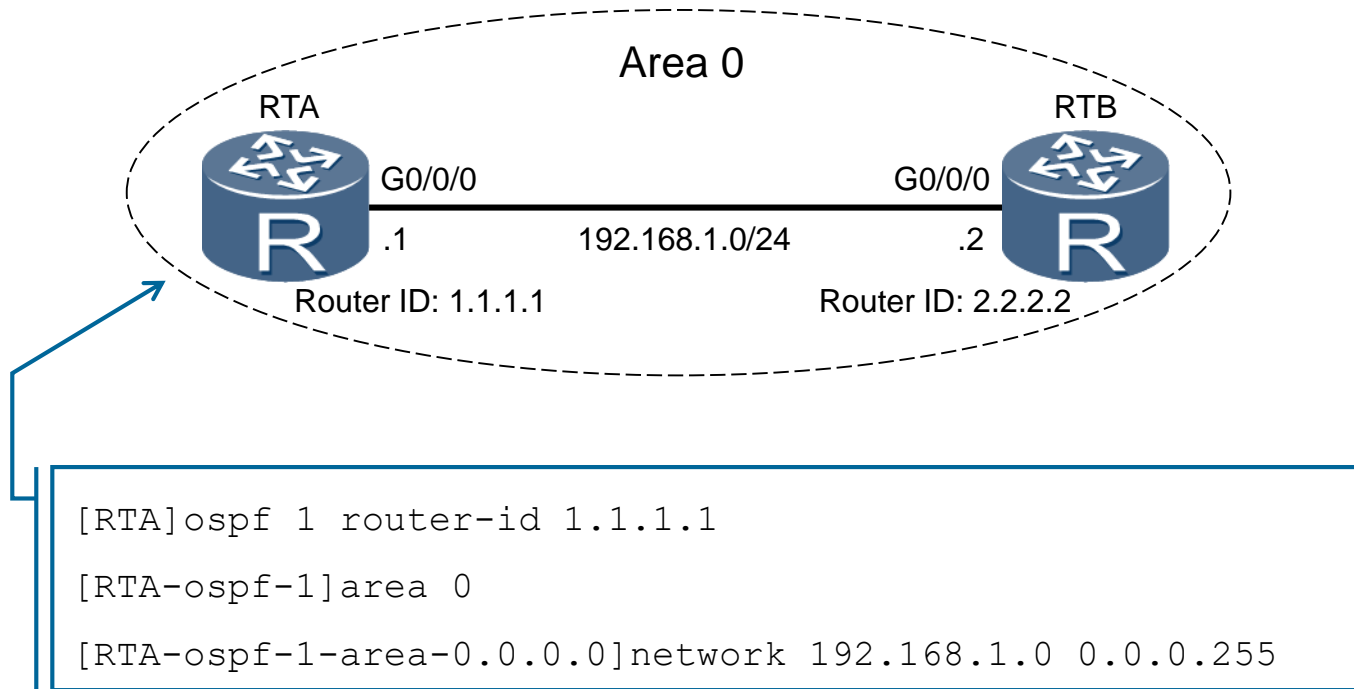
● Sono aree che si collegano ad una Area 0 attraverso un ABR;

● Il traffico viene tipicamente gestito con delle default routes;

● Non vengono propagate alter rotte all'interno della stubby area;

● Richiede una configurazione specifica sui router che

   appartengono all'are.

● Tipologie di stubby areas;

  ● Stub;

  ● Totally Stubby;

  ● not-so-stubby (NSSA);

  ● totally NSSA;

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WildCard Mask

● Uno dei metodi per confrontare un gruppo i bit in una stringa usando diverse regole di matching:

- ● Subnet mask – i bit a valore 1 indicano che deve esserci un match (192.168.2.0 255.255.255.0);

- ● Wildcard Mask – i bit a valore 0 indicano che deve esserci un match, i bit a valore "1" (1=ignore) sono ignorati: (10.0.3.4 255.255.0.0)

● Calcolo della wildcard mask:

255-subnet per ogni byte.

OSPF Network Advertisement

Area 0

RTA   RTB

G0/0/0   G0/0/0

.1   192.168.1.0/24   .2

Router ID: 1.1.1.1   Router ID: 2.2.2.2

```
[RTA]ospf 1 router-id 1.1.1.1

[RTA-ospf-1]area 0

[RTA-ospf-1-area-0.0.0.0]network 192.168.1.0 0.0.0.255
```

- The network command defines the network to be advertised.

- Route advertisements are forwarded based on areas.

OSPF Network Advertisement

Attenzione:

- The network command specifies the interface that runs OSPF and the area to which the interface belongs;

- On a loopback interface, by default, OSPF advertises its IP address in the form of a 32-bit host route, independent of the mask length of the IP address on the interface.

- To advertise the network segment route of a loopback interface, you need to run the ospf network-type command to set the network type to broadcast or NBMA.

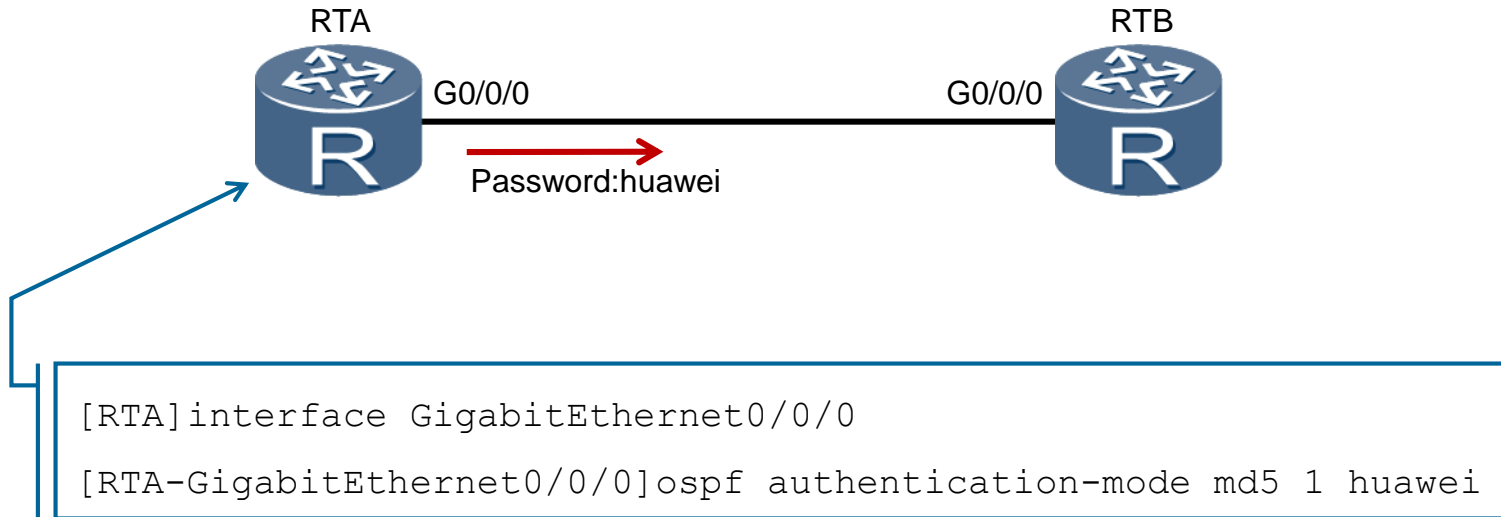- La configurazione consigliata prevede di utilizzare una wildcard-mask pari a 0;

Configuration Validation

```
[RTA]display ospf peer


        OSPF Process 1 with Router ID 1.1.1.1
                  Neighbors


Area 0.0.0.0 interface 192.168.1.1(GigabitEthernet0/0/0)'s neighbors
Router ID: 2.2.2.2              Address: 192.168.1.2
   State: Full  Mode:Nbr is  Master  Priority: 1
   DR: 192.168.1.2  BDR: 192.168.1.1  MTU: 0
   Dead timer due in 40  sec
   Retrans timer interval: 5
   Neighbor is up for 00:00:31
   Authentication Sequence: [ 0 ]
```

OSPF Authentication

RTA

G0/0/0

Password:huawei

RTB

G0/0/0

```
[RTA]interface GigabitEthernet0/0/0
[RTA-GigabitEthernet0/0/0]ospf authentication-mode md5 1 huawei
```

● OSPF supports two forms of authentication, simple password or cryptographic authentication.

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Configuration Validation

```
<RTA>terminal debugging
<RTA>debugging ospf packet
Aug 19 2013 08:10:06.850.2+00:00 RTA RM/6/RMDEBUG:  Source Address:
192.168.1.1
Aug 19 2013 08:10:06.850.3+00:00 RTA RM/6/RMDEBUG:  Destination
Address: 224.0.0.5
……
Aug 19 2013 08:10:06.850.6+00:00 RTA RM/6/RMDEBUG:  Area: 0.0.0.0,
Chksum: 0
Aug 19 2013 08:10:06.850.7+00:00 RTA RM/6/RMDEBUG:  AuType: 02
Aug 19 2013 08:10:06.850.8+00:00 RTA RM/6/RMDEBUG:  Key(ascii): * *
* * * * *
```
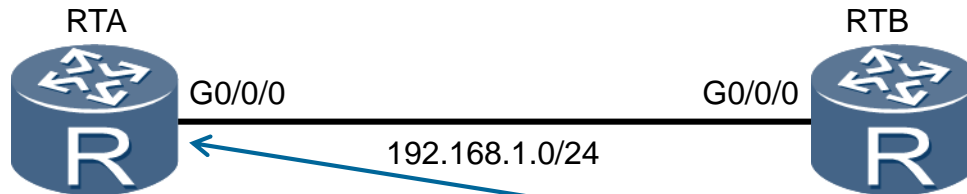
OSPF Silent Interface

RTA   RTB

G0/0/0   G0/0/0

192.168.1.0/24

```
[RTA]ospf

[RTA-ospf-1]silent-interface GigabitEthernet0/0/0
```

- The *silent-interface* command prevents an interface from forming neighbor relationships with peers.

Configuration Validation

```
[RTA]display ospf 1 interface GigabitEthernet0/0/0


        OSPF Process 1 with Router ID 1.1.1.1
                    Interfaces


 Interface: 192.168.1.1 (GigabitEthernet0/0/0)
 Cost: 1          State: DR          Type: Broadcast      MTU: 1500
 Priority: 1
 Designated Router: 192.168.1.1
 Backup Designated Router: 0.0.0.0
 Timers: Hello 10 , Dead 40 , Poll  120 , Retransmit 5 , Transmit
Delay 1
 Silent interface, No hellos
```

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```
[R1]dis ospf 1 brief

        OSPF Process 1 with Router ID 192.168.1.1
              OSPF Protocol Information

RouterID: 192.168.1.1        Border Router:
Multi-VPN-Instance is not enabled
Global DS-TE Mode: Non-Standard IETF Mode
Graceful-restart capability: disabled
Helper support capability  : not configured
Applications Supported: MPLS Traffic-Engineering
Spf-schedule-interval: max 10000ms, start 500ms, hold 1000ms
Default ASE parameters: Metric: 1 Tag: 1 Type: 2
Route Preference: 10
ASE Route Preference: 150
SPF Computation Count: 23
RFC 1583 Compatible
Retransmission limitation is disabled
Area Count: 1    Nssa Area Count: 0
ExChange/Loading Neighbors: 0
Process total up interface count: 1
Process valid up interface count: 1

Area: 0.0.0.0             (MPLS TE not enabled)
Authtype: None   Area flag: Normal
SPF scheduled Count: 23
ExChange/Loading Neighbors: 0
Router ID conflict state: Normal
Area interface up count: 1

Interface: 192.168.1.1 (GigabitEthernet0/0/0)
Cost: 1        State: BDR        Type: Broadcast     MTU: 1500
Priority: 1
Designated Router: 192.168.1.2
Backup Designated Router: 192.168.1.1
Timers: Hello 10 , Dead 40 , Poll  120 , Retransmit 5 , Transmit Delay 1
```
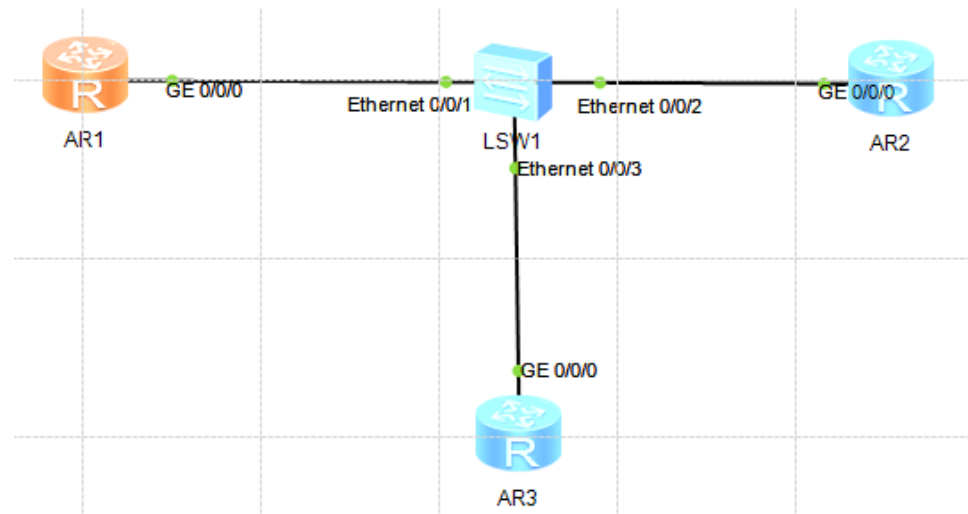
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```
[R1]dis ospf 1 peer

        OSPF Process 1 with Router ID 192.168.1.1
            Neighbors

Area 0.0.0.0 interface 192.168.1.1(GigabitEthernet0/0/0)'s neighbors
Router ID: 192.168.1.2      Address: 192.168.1.2
  State: Full  Mode:Nbr is  Master  Priority: 1
  DR: 192.168.1.2  BDR: 192.168.1.1  MTU: 0
  Dead timer due in 32  sec
  Retrans timer interval: 5
  Neighbor is up for 00:15:15
  Authentication Sequence: [ 0 ]

Router ID: 3.3.3.3          Address: 192.168.1.3
  State: Full  Mode:Nbr is  Slave  Priority: 1
  DR: 192.168.1.2  BDR: 192.168.1.1  MTU: 0
  Dead timer due in 37  sec
  Retrans timer interval: 5
  Neighbor is up for 00:15:15
  Authentication Sequence: [ 0 ]
```
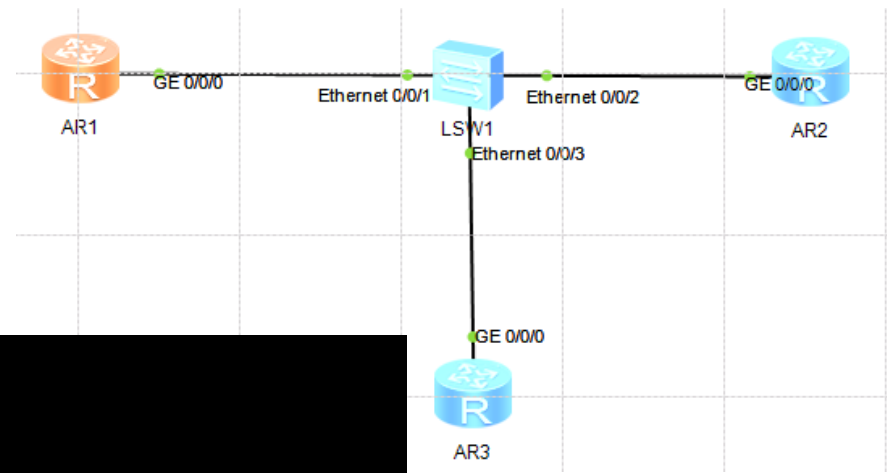
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```
[R1]dis ospf 1 interface gig 0/0/0

        OSPF Process 1 with Router ID 192.168.1.1
                Interfaces


 Interface: 192.168.1.1 (GigabitEthernet0/0/0)
 Cost: 1          State: BDR          Type: Broadcast      MTU: 1500
 Priority: 1
 Designated Router: 192.168.1.2
 Backup Designated Router: 192.168.1.1
 Timers: Hello 10 , Dead 40 , Poll  120 , Retransmit 5 , Transmit Delay 1
```

```
[R1]dis ospf 1 lsdb

        OSPF Process 1 with Router ID 192.168.1.1
                Link State Database

                     Area: 0.0.0.0
 Type       LinkState ID     AdvRouter          Age   Len   Sequence    Metric
 Router     192.168.1.2      192.168.1.2        1064  36    8000001A      1
 Router     192.168.1.1      192.168.1.1        1062  36    80000019      1
 Router     3.3.3.3          3.3.3.3            1064  36    80000019      1
 Network    192.168.1.2      192.168.1.2        1064  36    80000011      0
```

Note!

- LoopBack interface

  For a loopback interface, by default, OSPF advertises its IP address in 32-bit host route, regardless of the mask length of the IP address on the interface. To advertise the segment route of the loopback interface, configure the network type as NBMA or broadcast in the interface view.

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Summary

- What is the purpose of the dead interval in the OSPF header?

- In a broadcast network, what is the multicast address that is used by the Designated Router (DR) and Backup Designated Router (BDR) for listening for link state update information?

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Thank you

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