

OSPF

OSPF - Open Shortest Path First

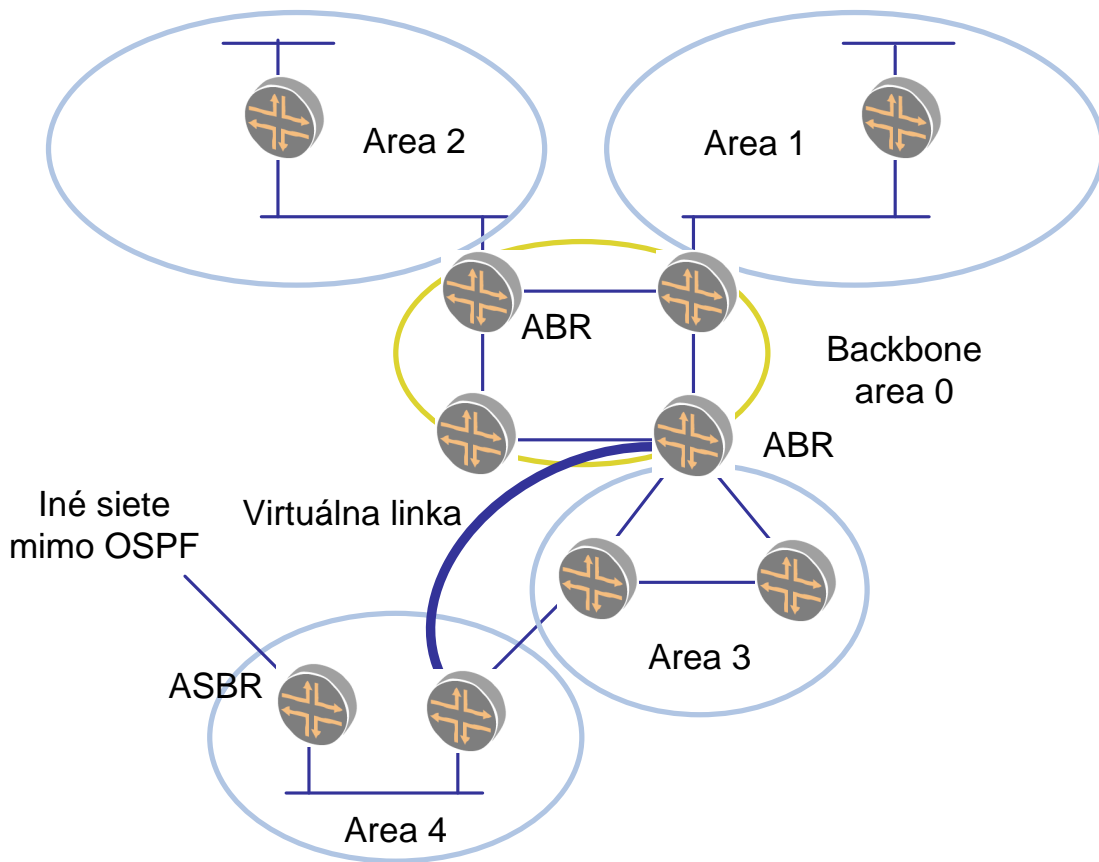
- Link State protokol
- Na výpočet cesty používa SPF algoritmus
- Default ohodnotenie je $10^8 / \text{bandwidth (bps)}$; [1 pre $\geq 100\text{Mbps}$]
- OSPF pakety sú vkladane priamo do IP paketu, port 89
- Všetky smerovače komunikujú prostredníctvom multicastovej adresy 224.0.0.5
- V prípade broadcastovej siete, všetky DR, BDR musia akceptovať riadiace pakety s cieľovou adresou 224.0.0.6
- Hello pakety verifikujú a udržujú spojenia medzi susedmi, v prípade liniek typu bod-bod alebo virtuálnych liniek, sú tieto posielané ako unicast
- Každý smerovač má osobitnú DB pre každú oblasť (area)
- Všetky smerovače v jednej oblasti majú identickú DB
- SPF výpočty sú nezávislé pre rôzne domény
- Šírenie LSA paketov je limitované hranicami oblasti

Terminológia OSPF

- Link-state database (topologická databáza)
 - databáza stavu liniek, všetky smerovače ju majú rovnakú, topologická databáza celej oblasti siete
- LSA - Link State Advertisement
 - Dátová štruktúra, ktorú generujú jednotlivé smerovače
 - Popisuje objekt siete a jeho prepojenie s okolitými objektmi
 - LSA má obmedzenú životnosť na 60 min, obnova každých 30 min
- OSPF oblasť
 - Administrátorom definovaná časť/oblasť siete a smerovačov, ktoré majú rovnakú oblastnú identifikáciu, 4B číslom
- DR - Designated Router
 - DR je smerovač, ktorý je pripojený do broadcast-ovej alebo NBMA (Non Broadcast Multi Access) domény a je zvolený, ako zástupca všetkých smerovačov v tejto sieti. Minimalizuje počet spojení v danej sieti
- ABR - Area Border Router
 - ABR je smerovač, ktorý je súčasťou viacerých oblastí
- ASBR - Autonomous System Boundary Router
 - ASBR je smerovač, ktorý má aspoň jedno sieťové rozhranie mimo OSPF domény a propaguje do siete externé smerovacie záznamy

Hierarchický dizajn

- Per oblasť (Area)
topologická DB
 - Neviditeľná mimo doménu
 - Umožňuje redukovať množstvo riadiacej prevádzky
- Chrbticová oblasť
 - Integruje iné oblasti
 - Iné oblasti musia byť vždy pripojené do chrbticovej oblasti
- Virtuálne linky



OSPF správy

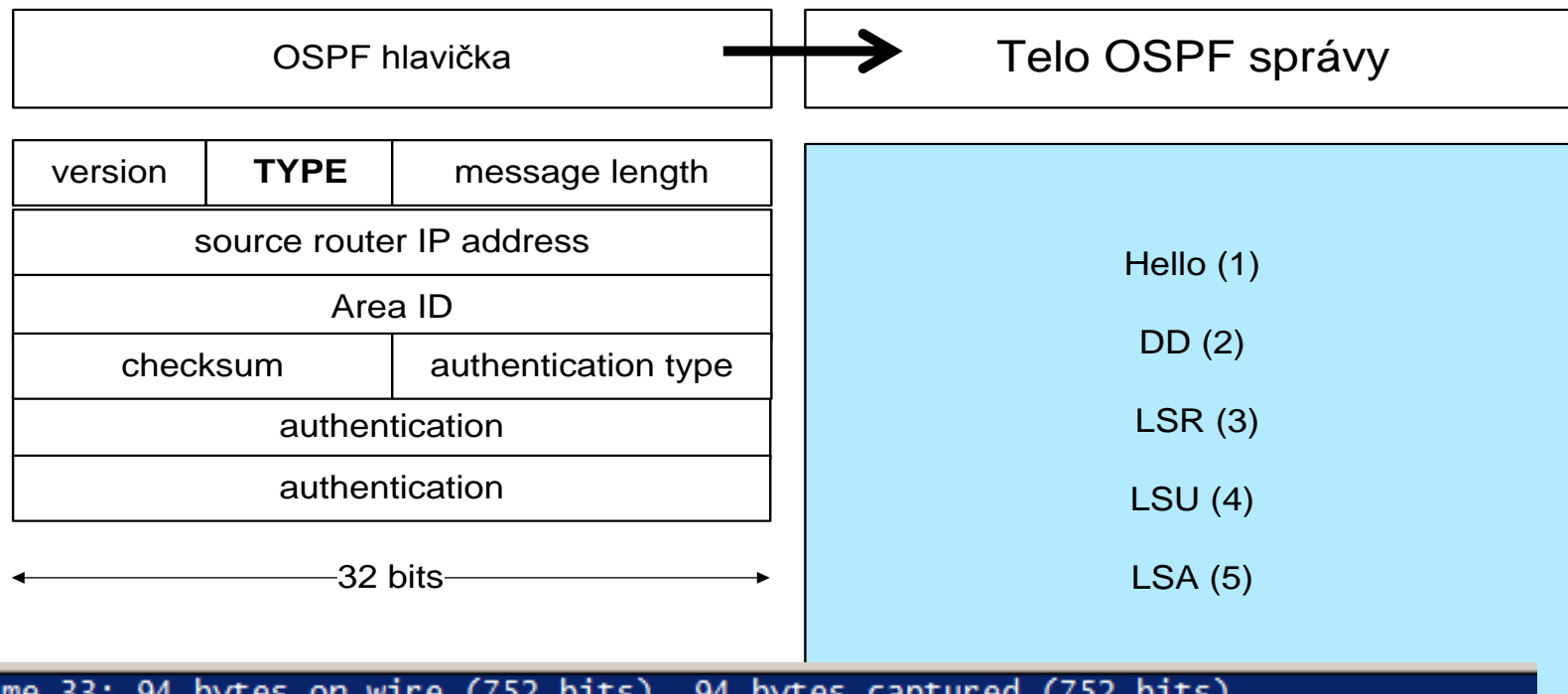
5 typov OSPF správ:

- Hello messages, OSPF Message **Type 1**
 - Udržujú spojenie so susedmi, detekujú nedostupnosť suseda
- DB Description, OSPF Message **Type 2**
 - Topologická informácia, synchronizácia štruktúry topologických databáz pri vytváraní spojenia, výmena iba LSA hlavičiek
- Link Status Request (LSR), OSPF Message **Type 3**
 - Požiadavka zaslaná smerovačom inému, aby poslal aktuálne dáta z databázy
- Link Status Update (LSU), OSPF Message **Type 4**
 - Odpoveď na LSR, posiela dáta o spojeniach a sieťach v LSA štruktúre
- Link Status Acknowledgement, OSPF Message **Type 5**
 - Indikácia, že LSU bola prijatá

Nadviazanie spojenia

No.	Time	Source	Destination	Protocol	Length	Info
30	79.092000	10.1.3.15	224.0.0.5	OSPF	90	Hello Packet
31	79.132000	10.1.3.14	224.0.0.5	OSPF	94	Hello Packet
32	79.185000	10.1.3.15	224.0.0.5	OSPF	78	DB Description
33	79.185000	10.1.3.15	224.0.0.5	OSPF	94	Hello Packet
34	79.203000	10.1.3.14	224.0.0.5	OSPF	78	DB Description
35	79.232000	10.1.3.14	224.0.0.5	OSPF	118	DB Description
36	79.262000	10.1.3.15	224.0.0.5	OSPF	78	DB Description
37	79.292000	10.1.3.14	224.0.0.5	OSPF	78	DB Description
38	79.322000	10.1.3.15	224.0.0.5	OSPF	82	LS Request
39	79.352000	10.1.3.14	224.0.0.5	OSPF	150	LS Update
40	79.522000	10.1.3.15	224.0.0.5	OSPF	134	LS Update
41	79.782000	10.1.3.14	224.0.0.5	OSPF	134	LS Update
43	80.455000	10.1.3.14	224.0.0.5	OSPF	94	Hello Packet
45	81.893000	10.1.3.15	224.0.0.5	OSPF	98	LS Acknowledge
46	82.030000	10.1.3.14	224.0.0.5	OSPF	78	LS Acknowledge
47	84.049000	10.1.3.15	224.0.0.5	OSPF	90	LS Update
48	84.513000	10.1.3.14	224.0.0.5	OSPF	134	LS Update
52	86.558000	10.1.3.14	224.0.0.5	OSPF	78	LS Acknowledge
53	87.026000	10.1.3.15	224.0.0.5	OSPF	78	LS Acknowledge
55	89.008000	10.1.3.15	224.0.0.5	OSPF	94	Hello Packet
56	90.436000	10.1.3.14	224.0.0.5	OSPF	94	Hello Packet
59	99.024000	10.1.3.15	224.0.0.5	OSPF	94	Hello Packet
60	100.458000	10.1.3.14	224.0.0.5	OSPF	94	Hello Packet

Formát OSPF paketu



```
Frame 33: 94 bytes on wire (752 bits), 94 bytes captured (752 bits) on interface 0
Ethernet II, Src: c2:01:0e:88:00:01 (c2:01:0e:88:00:01), Dst: IPv4mcast_00:00:05 (01:00:00:00:00:05)
Internet Protocol Version 4, Src: 10.1.3.15 (10.1.3.15), Dst: 224.0.0.5 (224.0.0.5)
Open Shortest Path First
  OSPF Header
    OSPF Version: 2
    Message Type: Hello Packet (1)
    Packet Length: 48
    Source OSPF Router: 10.1.255.5 (10.1.255.5)
    Area ID: 0.0.0.0 (Backbone)
    Packet Checksum: 0xda8d [correct]
    Auth Type: Null
    Auth Data (none)
  OSPF Hello Packet
```

LSU

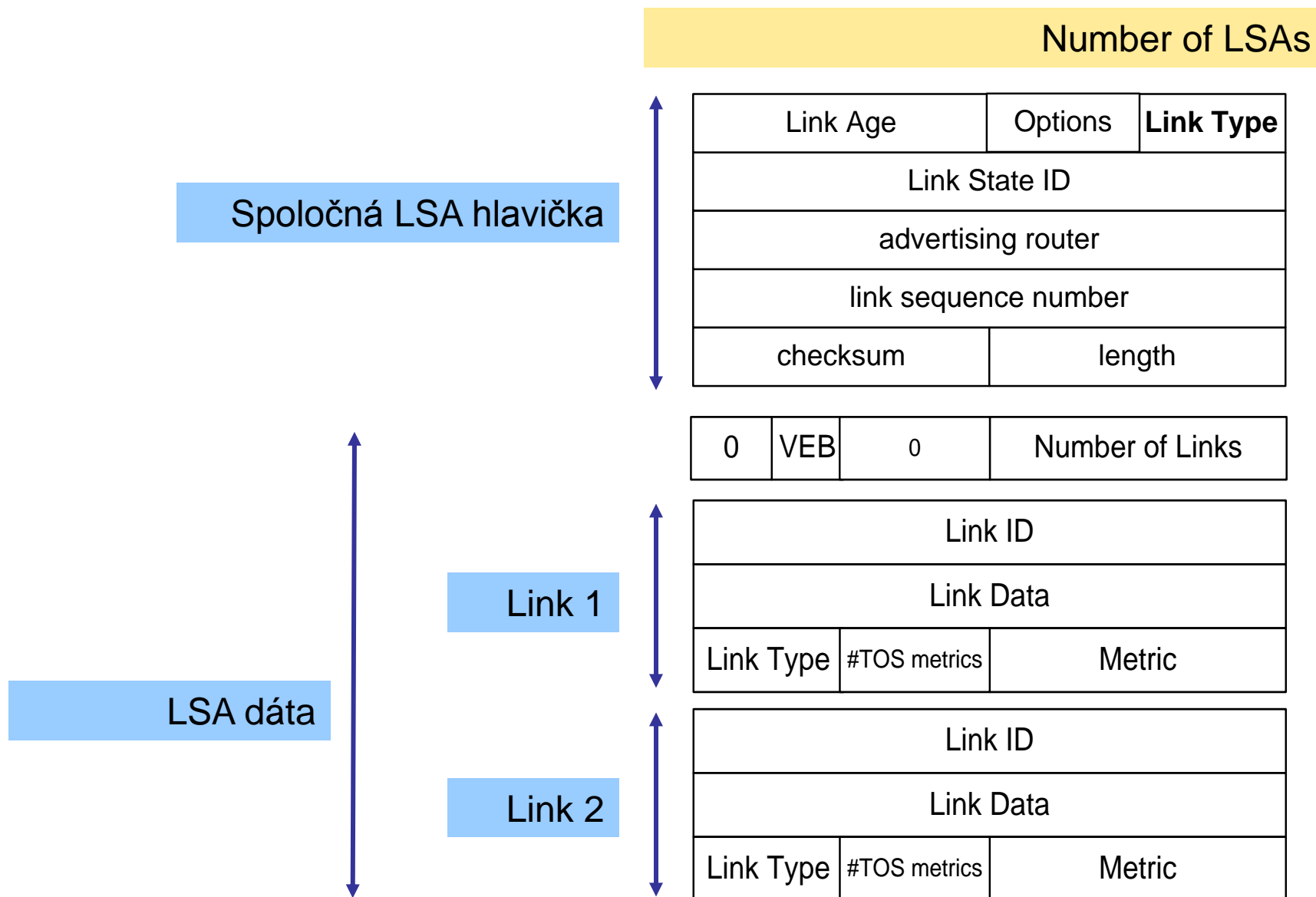
Typy Link State Advertisement (LSA) správ

LSU správa môže obsahovať viacero LSA štruktúr. LSA typ popisuje objekt siete a jeho vzťah (prepojenie) s okolitými objektmi:

- LSA Type 1 : Router LSA
- LSA Type 2 : Network LSA
- LSA Type 3 : Summary LSA
- LSA Type 4 : Summary LSA ASBR
- LSA Type 5 : AS External LSA
- LSA Type 6: Group Membership LSA
- LSA Type 7: NSSA LSA
- LSA Type 8: External Attributes LSA
- LSA Type 9, 10, 11: Opaque LSA

LSU

Formát LSA (LS Advertisement) LSU štruktúry



LSU

Open Shortest Path First

OSPF Header

LS Update Packet

Number of LSAs: 2

LS Type: Router-LSA

LS Age: 79 seconds

Do Not Age: False

Options: 0x22 (DC, E)

Link-State Advertisement Type: Router-LSA (1)

Link State ID: 10.1.255.4

Advertising Router: 10.1.255.4 (10.1.255.4)

LS Sequence Number: 0x80000001

LS Checksum: 0x3a8c

Length: 60

Flags: 0x01 (B)

Number of Links: 3

+ Type: Stub ID: 10.1.255.4 Data: 255.255.255.255 Metric: 1

+ Type: Stub ID: 10.1.3.0 Data: 255.255.255.0 Metric: 1

+ Type: Stub ID: 10.1.2.0 Data: 255.255.255.0 Metric: 1

LS Type: Summary-LSA (IP network)

LS Age: 74 seconds

Do Not Age: False

Options: 0x22 (DC, E)

Link-State Advertisement Type: Summary-LSA (IP network) (3)

Link State ID: 10.1.11.0

Advertising Router: 10.1.255.4 (10.1.255.4)

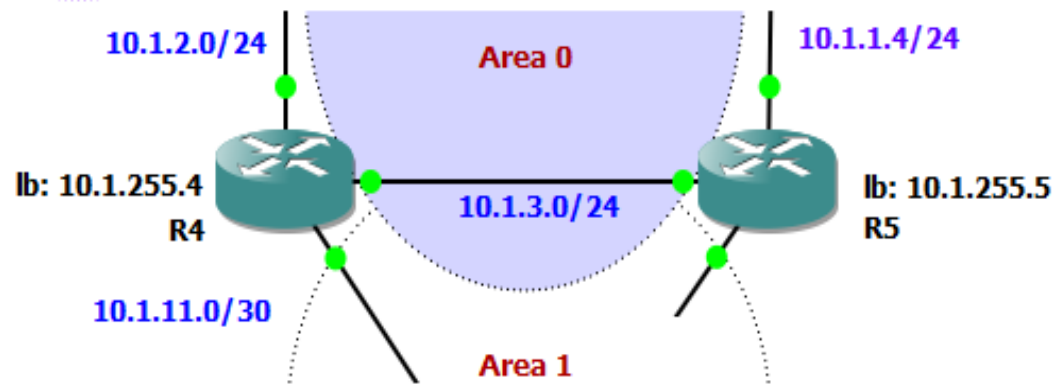
LS Sequence Number: 0x80000001

LS Checksum: 0xfe1b

Length: 28

Netmask: 255.255.255.252

Metric: 1



Router LSA (Type 1)

- Popisuje status a ohodnotenie sieťových rozhraní smerovača
 - Šíri sa iba v rámci oblasti
 - Smerovač indikuje, či sa jedná o ABR, ASBR alebo virtuálnu linku príznakmi VEB
B: ABR, E: ASBR, V: Virtuálna linka

Link Type	Link ID	Link Data
Point-to-Point Type 1	Neighbor's router ID	Local router's iface IP
Transit Type 2	DR's iface IP	Local router's iface IP
Stub Type 3	Network number	Subnet mask
Virtual Link Type 4	Neighbor's router ID	Local router's iface IP

0	VEB	0	Number of Links
---	-----	---	-----------------

Link ID		
Link Data		
Link Type	#TOS metrics	Metric

Link ID		
Link Data		
Link Type	#TOS metrics	Metric

Link-State Advertisement Type: Router-LSA (1)

Link State ID: 10.1.255.5

Advertising Router: 10.1.255.5 (10.1.255.5)

LS Sequence Number: 0x80000001

LS Checksum: 0xc1c4

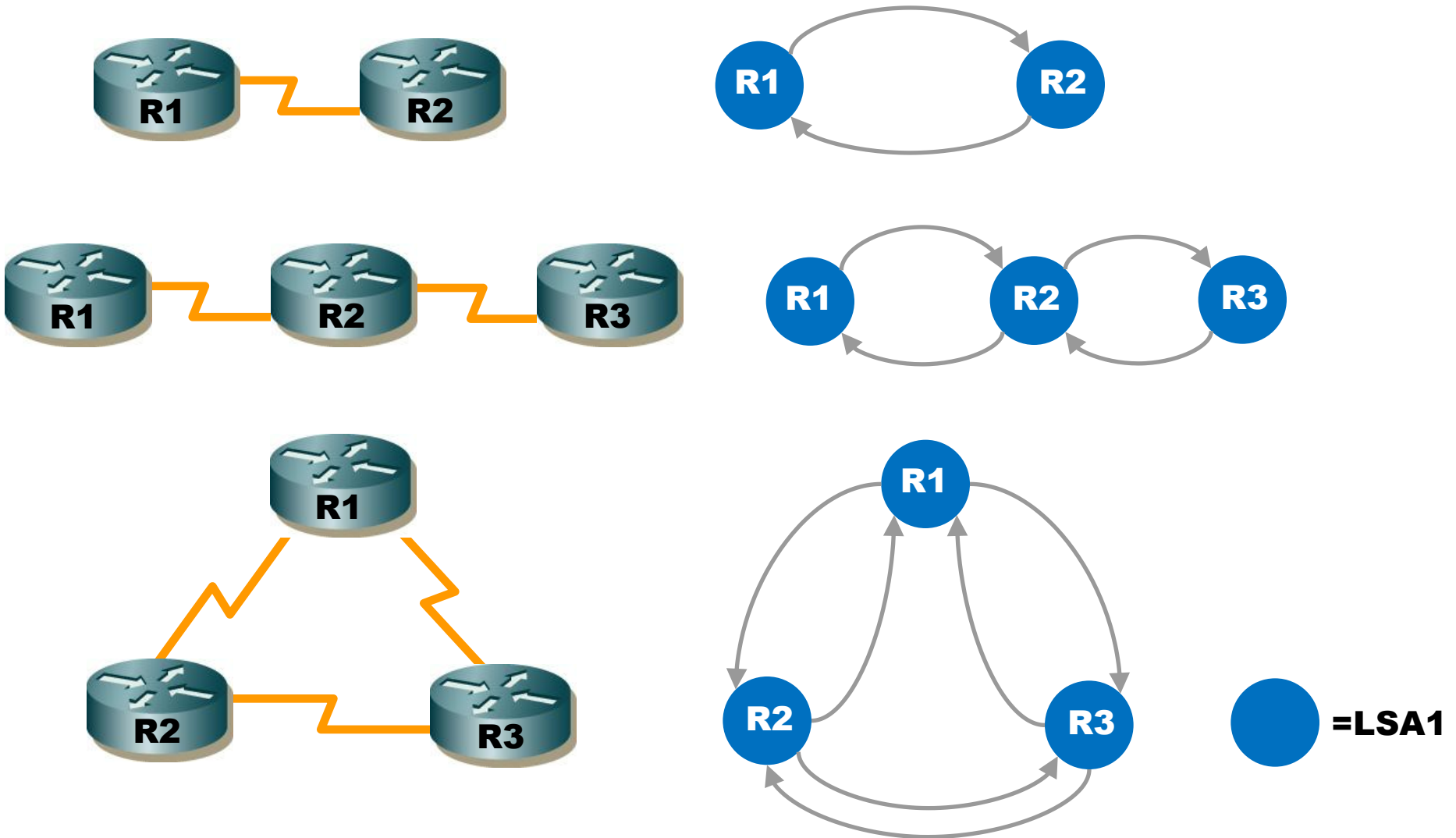
Length: 72

⊕ Flags: 0x01 (B)

Number of Links: 4

⊕ Type: Stub	ID: 10.1.255.5	Data: 255.255.255.255	Metric: 1
⊕ Type: Stub	ID: 10.1.4.0	Data: 255.255.255.0	Metric: 1
⊕ Type: PTP	ID: 10.1.255.4	Data: 10.1.3.15	Metric: 1
⊕ Type: Stub	ID: 10.1.3.0	Data: 255.255.255.0	Metric: 1

Význam LSA Type 1 (Router-LSA)



Network LSA (Type 2)

- Generovaný len pre každú broadcast alebo NBMA (non broadcast multiple access) sieť (nie pre P2P prepojenia)
 - Popisuje všetky smerovače pripojené k tejto sieti
 - Iba DR generuje tento typ LSA
 - Šíri sa iba v rámci oblasti
 - Skladá sa zo spoločnej LSA hlavičky, masky siete a zoznamu pripojených smerovačov

LS Type: Network-LSA

LS Age: 1 seconds

Do Not Age: False

Options: 0x22 (DC, E)

Link-State Advertisement Type: Network-LSA (2)

Link State ID: 10.1.1.13

Advertising Router: 10.1.255.3 (10.1.255.3)

LS Sequence Number: 0x80000001

LS Checksum: 0xd611

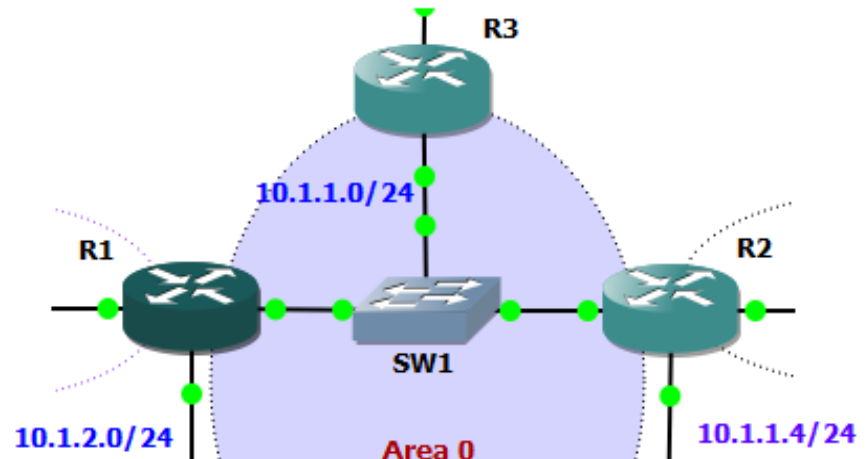
Length: 36

Netmask: 255.255.255.0

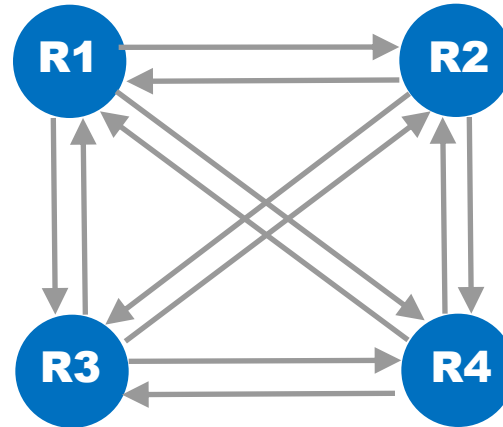
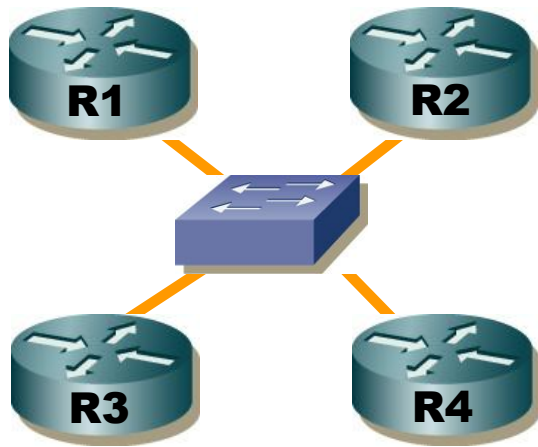
Attached Router: 10.1.255.3

Attached Router: 10.1.255.1

Attached Router: 10.1.255.2

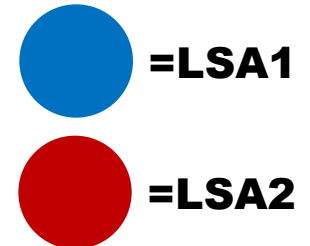
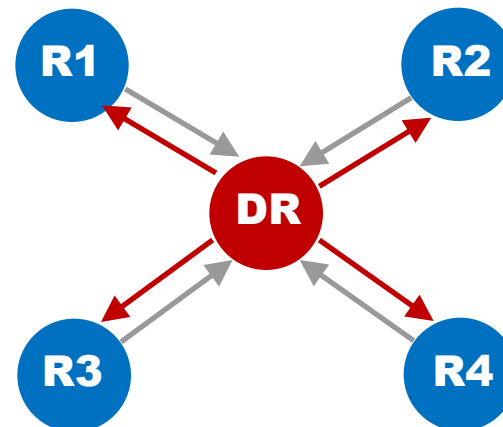


Význam LSA Type 2 (Network-LSA)

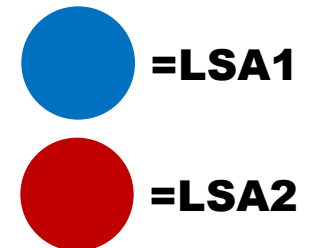
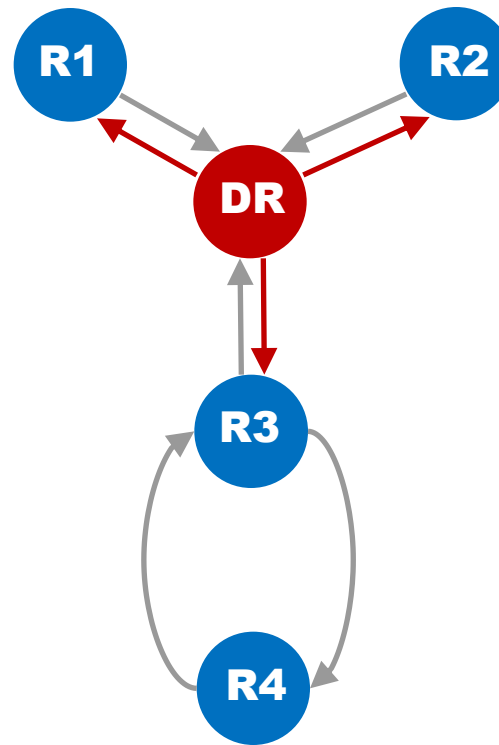
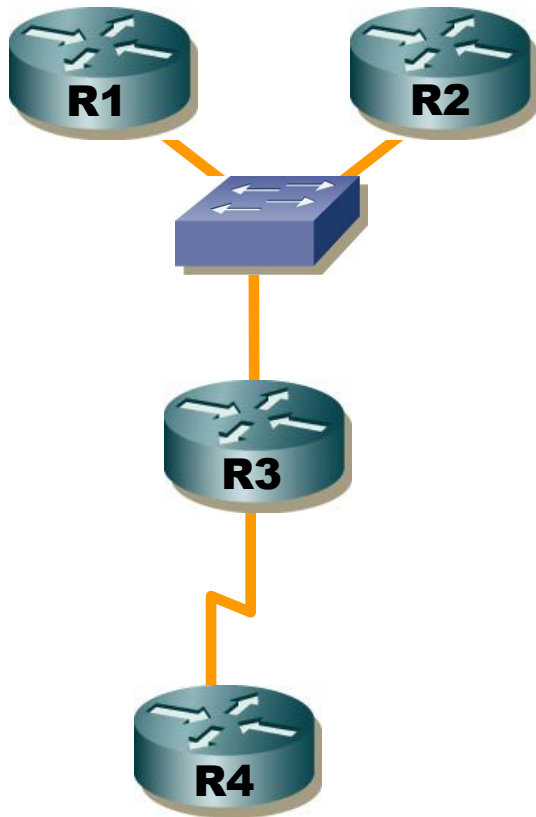


Pamäťovo a výpočtovo náročné riešenie

Princíp OSPF typu siete Point-to-Multipoint



Modelovanie oblasti pomocou LSA-1 a LSA-2



Summary LSA (Type 3)

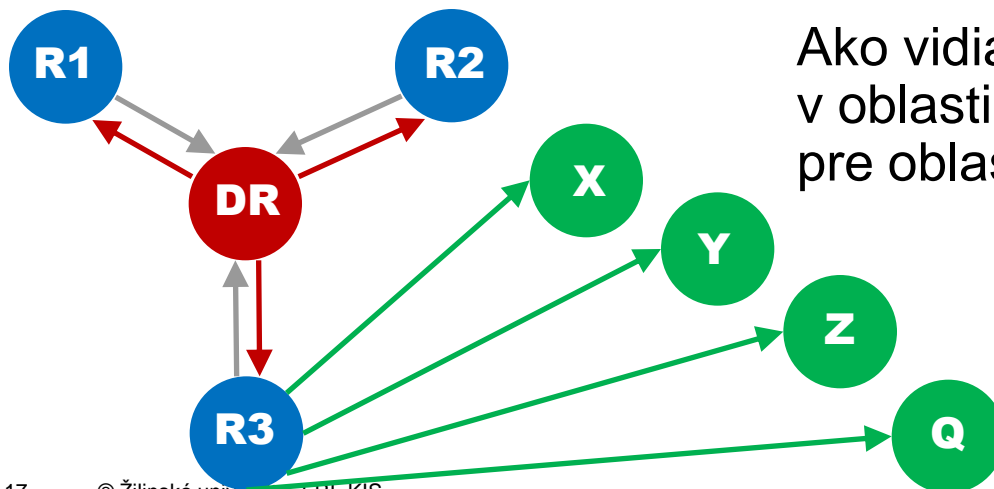
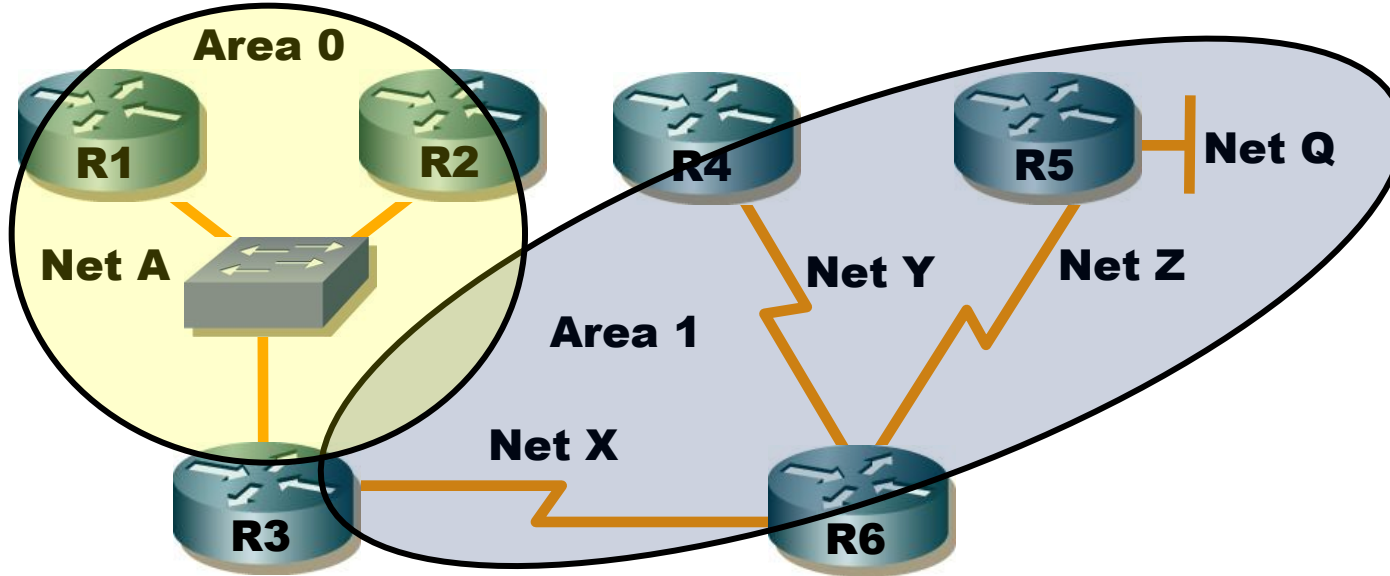
- LSA Type 3 popisuje siete mimo oblasť ale stále v rámci toho istého OSPF autonómneho systému, t.j. prichádzajúce z iných domén
 - Generuje iba ABR smerovač
 - Šíri sa iba v rámci oblasti
 - Skladá sa zo spoločnej LSA hlavičky, masky siete, ohodnotenia (metriky)
 - LSA T3, ktoré sú v nie chrbtových oblastiach nie sú nazad oznamované do chrbtovej oblasti

```

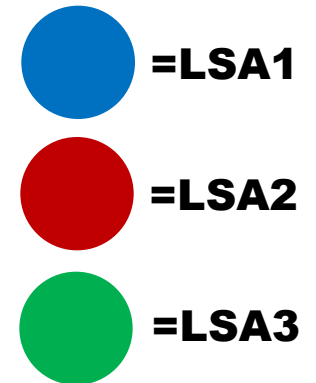
- Open Shortest Path First
  + OSPF Header
  - LS Update Packet
    Number of LSAs: 18
    + LS Type: Router-LSA
    + LS Type: Router-LSA
    + LS Type: Summary-LSA (IP network)
    + LS Type: Summary-LSA (IP network)
    + LS Type: Summary-LSA (IP network)
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    + LS Type: Summary-LSA (IP network)
    + LS Type: Summary-LSA (IP network)
    + LS Type: Summary-LSA (IP network)
    - LS Type: Summary-LSA (IP network)
      LS Age: 674 seconds
      Do Not Age: False
      + options: 0x20 (DC)
        Link-State Advertisement Type: Summary-LSA (IP network) (3)
        Link State ID: 10.1.255.2
        Advertising Router: 10.1.255.1 (10.1.255.1)
        LS Sequence Number: 0x80000002
        LS Checksum: 0xae74
        Length: 28
        Netmask: 255.255.255.255
        Metric: 2
      + LS Type: Summary-LSA (IP network)
      + LS Type: Summary-LSA (IP network)
      + LS Type: Summary-LSA (IP network)
      + LS Type: Summary-LSA (IP network)
      + LS Type: Summary-LSA (IP network)

```

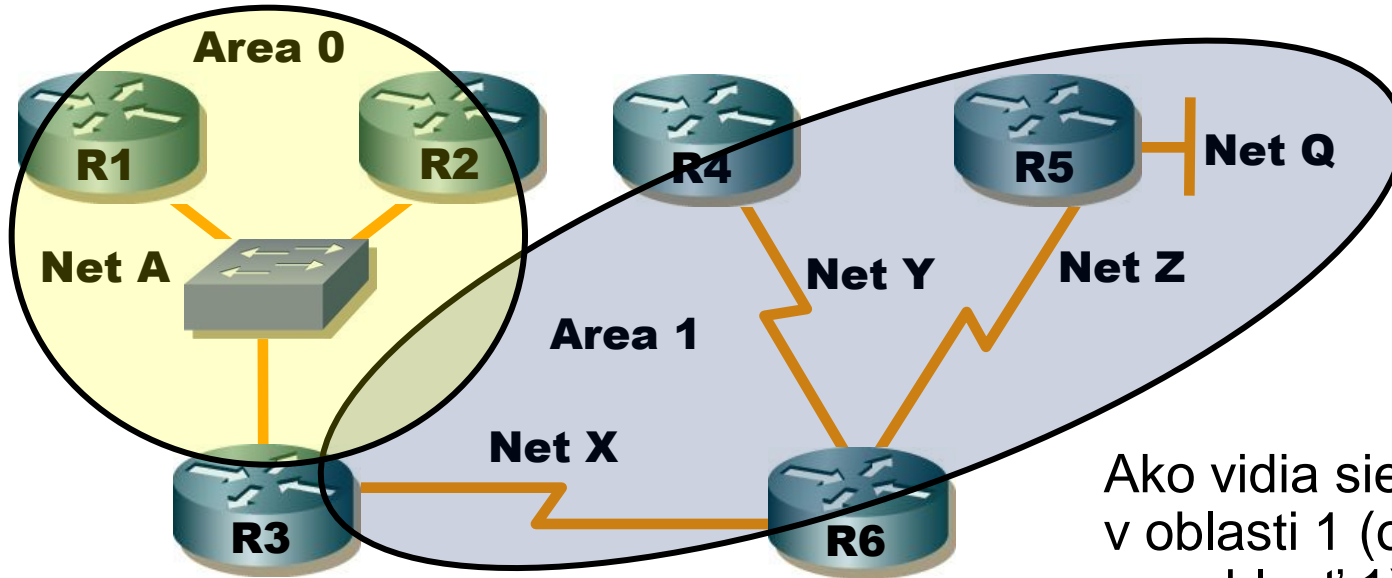

Význam LSA Type 3 (Network-Summary-LSA)



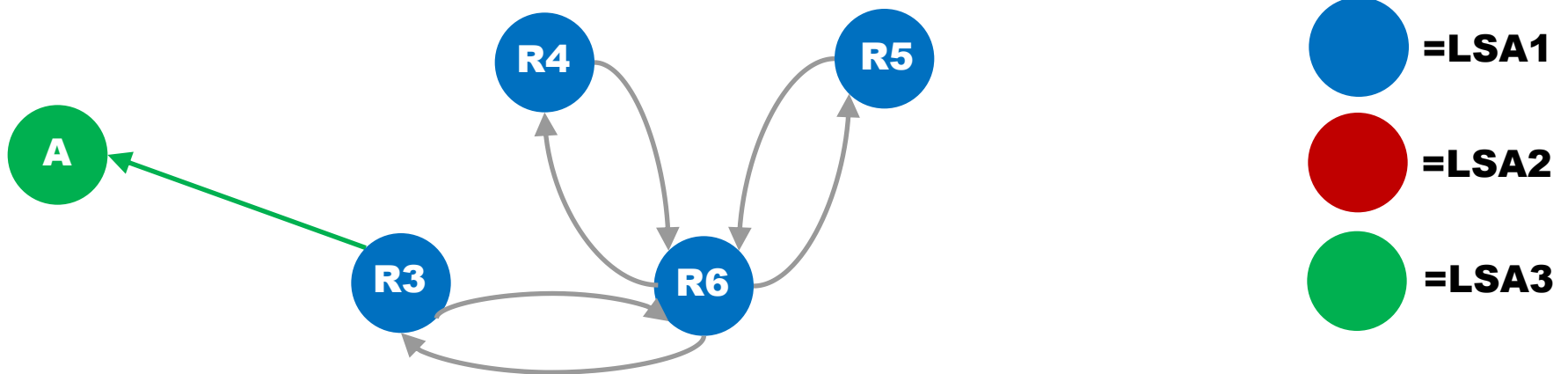
Ako vidia sieť smerovače v oblasti 0 (obsah LSDB pre oblasť 0)



Význam LSA Type 3 (Network-Summary-LSA)

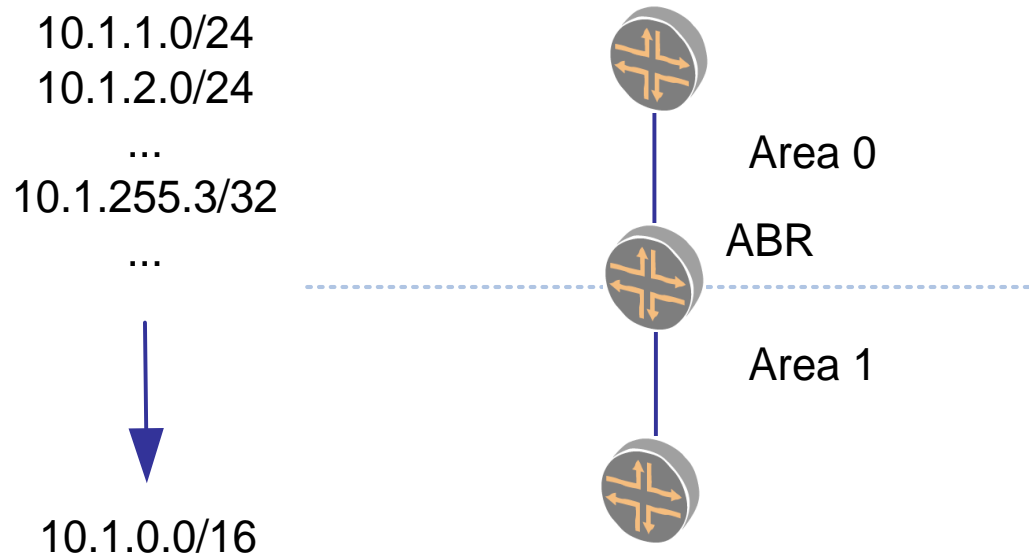


Ako vidia sieť smerovače v oblasti 1 (obsah LSDB pre oblasť 1)



Inter-Area sumarizácia

- Redukcia množstva smerovacích záznamov prichádzajúcich z oblasti 0
- Optimalizácia veľkosti non-backbone databázy a SPF kalkulácií
 - area 0 range 10.1.0.0/16 cost 100



External LSA (Type 5/7)

- Definuje prefixy, ktoré sú mimo OSPF autonómny systém
- Skladá sa zo spoločnej LSA hlavičky plus
 - Masku siete, E bit, Ohodnotenie, Forwarding Address
- Dva typy externých LSA:
 - E1: berie do úvahy celkové ohodnotenie cesty
 - E2: berie do úvahy iba ohodnotenie ku sieťovému rozhraniu ASBR, ktorý je už súčasťou iného AS, nezohľadňuje cestu od aktuálneho smerovača po ASBR
- Ak je externý smerovací záznam a ASBR z inej oblasti, potom nie je k dispozícii informácia ako dosiahnuť ASBR smerovač v inej oblasti → next-hop problém.
 - Riešenie: Summary ASBR Type 4, ktorý je generovaný najbližším ABR – ten zároveň poskytuje next hop informáciu na seba.

LS Type: Router-LSA

LS Age: 111 seconds

Do Not Age: False

Options: 0x22 (DC, E)

Link-State Advertisement Type: Router-LSA (1)

Link State ID: 10.1.255.5

Advertising Router: 10.1.255.5 (10.1.255.5)

LS Sequence Number: 0x80000005

LS Checksum: 0x7d3f

Length: 48

Flags: 0x01 (B)

Number of Links: 2

⊕ Type: PTP ID: 10.1.255.10

Data: 10.1.12.1 Metric: 1

Next hop

⊕ Type: Stub ID: 10.1.12.0

Data: 255.255.255.252 Metric: 1

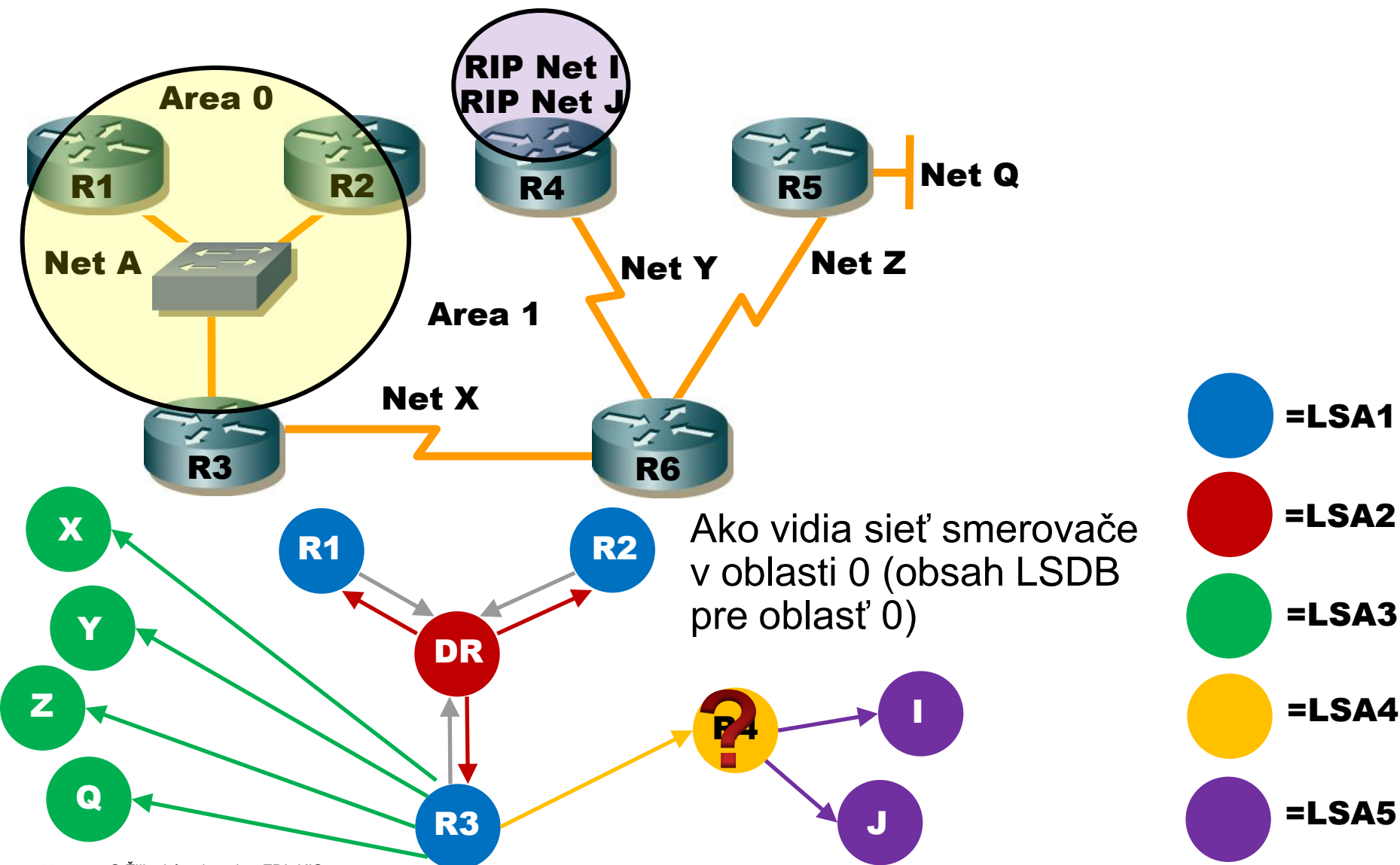
ABR Router for Next hop

Summary LSA ASBR (Type 4)

- Type 4 popisuje next-hop ku ASBR smerovaču v inej oblasti, kde vznikli externé smerovacie záznamy (Type 5)
 - ABR poskytuje informáciu smerovačom v iných oblastiach, ako LSA T5 siete dosiahnuť

```
▣ LS Type: Summary-LSA (ASBR)
  LS Age: 341 seconds
  Do Not Age: False
  ⊕ Options: 0x22 (DC, E)
  Link-State Advertisement Type: Summary-LSA (ASBR) (4)
  Link State ID: 10.1.255.3
  Advertising Router: 10.1.255.5 (10.1.255.5)
  LS Sequence Number: 0x80000002
  LS Checksum: 0x60ba
  Length: 28
  Netmask: 0.0.0.0
  Metric: 2
▣ LS Type: AS-External-LSA (ASBR)
  LS Age: 350 seconds
  Do Not Age: False
  ⊕ Options: 0x20 (DC)
  Link-State Advertisement Type: AS-External-LSA (ASBR) (5)
  Link State ID: 192.168.111.0
  Advertising Router: 10.1.255.3 (10.1.255.3)
  LS Sequence Number: 0x80000002
  LS Checksum: 0xf5c2
  Length: 36
  Netmask: 255.255.255.0
  External Type: Type 2 (metric is larger than any other link state path)
  Metric: 20
  Forwarding Address: 0.0.0.0
  External Route Tag: 0
```

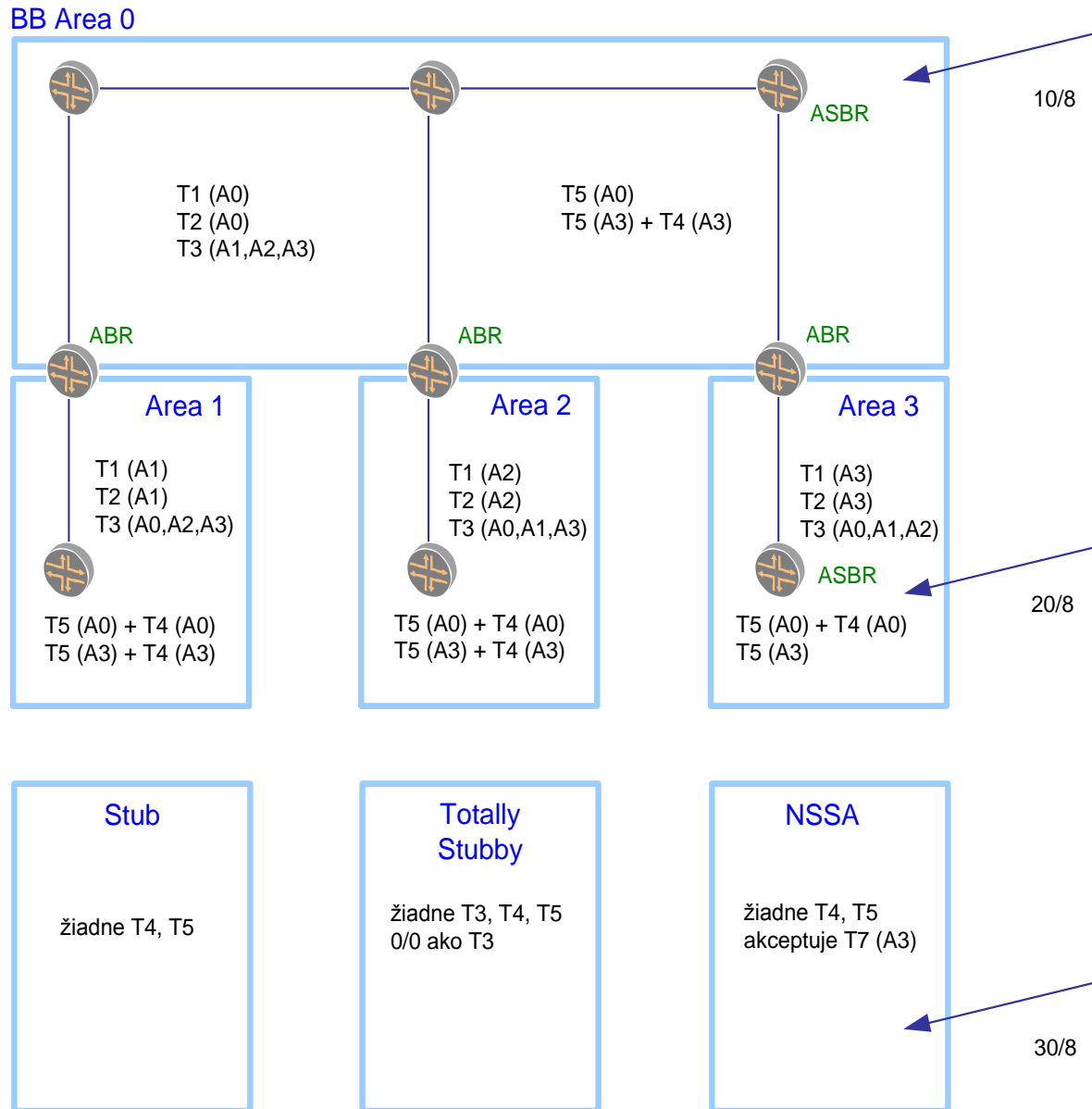
Význam LSA Type 4 (ASBR-Summary-LSA)



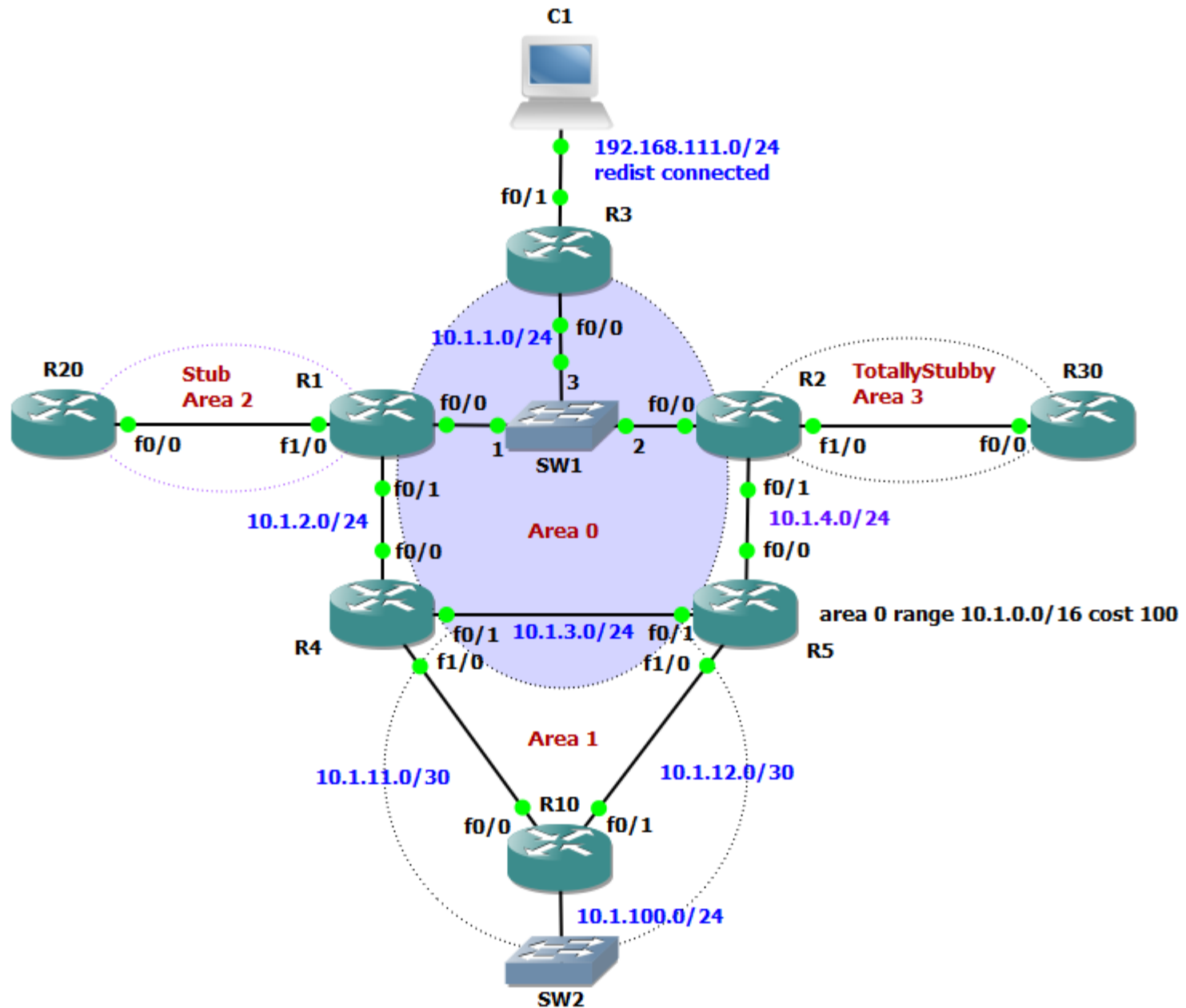
OSPF typy oblastí

- Štandardná oblasť
 - Sumárne LSA z iných oblastí sú redistribuované
 - Externé LSA taktiež
- Stub oblasť
 - Sumárne LSA z iných oblastí sú redistribuované
 - Externé LSA nie, ABR generuje 0.0.0.0/0 ako T3
- Totally Stubby oblasť (Stub & no-summary)
 - ABR generuje iba 0.0.0.0/0
- NSSA Not-so-Stubby oblasť
 - Podobne ako totally stubby ale
 - Umožňuje importovať externé záznamy
 - Type-7 LSA pre externé smerovacie záznamy
 - NSSA ABR prekladá T7 na T5

Prehľad LSA a typov domén



Interpretácia OSPF databázy



Interpretácia OSPF databázy

- Každý OSPF smerovač v oblasti má identickú databázu!
 - show ip ospf database
- LSA T1 – počet smerovačov v oblasti

```
R3#sh ip ospf database ?
adv-router      Advertising Router link states
asbr-summary    ASBR summary link states
database-summary Summary of database
external        External link states
network         Network link states
nssa-external   NSSA External link states
opaque-area     Opaque Area link states
opaque-as       Opaque AS link states
opaque-link     Opaque Link-Local link states
router          Router link states
self-originate  Self-originated link states
summary         Network summary link states
|
<cr>
```

```
R3#sh ip ospf database

          OSPF Router with ID (10.1.255.3) (Process ID 1)

          Router Link States (Area 0)

Link ID      ADV Router    Age          Seq#          Checksum Link count
10.1.255.1   10.1.255.1    952          0x80000005   0x00F47F  4
10.1.255.2   10.1.255.2    1734         0x80000005   0x00C5A4  4
10.1.255.3   10.1.255.3    1762         0x80000004   0x002B95  2
10.1.255.4   10.1.255.4    954          0x80000001   0x00B79D  5
10.1.255.5   10.1.255.5    953          0x80000005   0x00E265  5
```

Interpretácia OSPF databázy

- Informácia o jednotlivých spojeniach, ktoré konkrétny smerovač pozná
 - LSA T1
 - LSA T2

```
R3#sh ip ospf database network

      OSPF Router with ID (10.1.255.3) (Process
          Net Link States (Area 0)

Routing Bit Set on this LSA
LS age: 901
Options: (No TOS-capability, DC)
LS Type: Network Links
Link State ID: 10.1.1.13 (address of Designated Router)
Advertising Router: 10.1.255.3
LS Seq Number: 80000005
Checksum: 0xCE15
Length: 36
Network Mask: /24
    Attached Router: 10.1.255.3
    Attached Router: 10.1.255.1
    Attached Router: 10.1.255.2
```

```
R3#sh ip ospf database router 10.1.255.2

      OSPF Router with ID (10.1.255.3) (Process ID 1)
          Router Link States (Area 0)

Routing Bit Set on this LSA
LS age: 272
Options: (No TOS-capability, DC)
LS Type: Router Links
Link State ID: 10.1.255.2
Advertising Router: 10.1.255.2
LS Seq Number: 80000006
Checksum: 0xC3A5
Length: 72
Area Border Router
Number of Links: 4

Link connected to: a Stub Network
(Link ID) Network/subnet number: 10.1.255.2
(Link Data) Network Mask: 255.255.255.255
Number of TOS metrics: 0
    TOS 0 Metrics: 1

Link connected to: another Router (point-to-point)
(Link ID) Neighboring Router ID: 10.1.255.5
(Link Data) Router Interface address: 10.1.4.12
Number of TOS metrics: 0
    TOS 0 Metrics: 1

Link connected to: a Stub Network
(Link ID) Network/subnet number: 10.1.4.0
(Link Data) Network Mask: 255.255.255.0
Number of TOS metrics: 0
    TOS 0 Metrics: 1

Link connected to: a Transit Network
(Link ID) Designated Router address: 10.1.1.13
(Link Data) Router Interface address: 10.1.1.12
Number of TOS metrics: 0
    TOS 0 Metrics: 1
```

Interpretácia OSPF databázy

- Informácia o LSA T3 sieťach v oblasti 0, ktoré existujú za ABR smerovačom v oblasti 2
- Informácia o LSA T5 sieťach v oblasti 0

```
R3#sh ip ospf dat external
```

```
OSPF Router with ID (10.1.255.3) (Process ID
```

```
Type-5 AS External Link States
```

```
LS age: 1747
Options: (No TOS-capability, DC)
LS Type: AS External Link
Link State ID: 192.168.111.0 (External Network Number )
Advertising Router: 10.1.255.3
LS Seq Number: 80000004
Checksum: 0xF1C4
Length: 36
Network Mask: /24
Metric Type: 2 (Larger than any link state path)
TOS: 0
Metric: 20
Forward Address: 0.0.0.0
External Route Tag: 0
```

```
R3#sh ip ospf database sum adv-router 10.1.255.1
```

```
OSPF Router with ID (10.1.255.3) (Process ID 1)
```

```
Summary Net Link States (Area 0)
```

```
Routing Bit Set on this LSA
```

```
LS age: 1400
```

```
Options: (No TOS-capability, DC, Upward)
```

```
LS Type: Summary Links(Network)
```

```
Link State ID: 10.1.21.0 (summary Network Number)
```

```
Advertising Router: 10.1.255.1
```

```
LS Seq Number: 80000004
```

```
Checksum: 0x9C73
```

```
Length: 28
```

```
Network Mask: /30
```

```
TOS: 0 Metric: 1
```

```
Routing Bit Set on this LSA
```

```
LS age: 1357
```

```
Options: (No TOS-capability, DC, Upward)
```

```
LS Type: Summary Links(Network)
```

```
Link State ID: 10.1.255.20 (summary Network Number)
```

```
Advertising Router: 10.1.255.1
```

```
LS Seq Number: 80000004
```

```
Checksum: 0xD735
```

```
Length: 28
```

```
Network Mask: /32
```

```
TOS: 0 Metric: 2
```

Ďakujem za pozornosť

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