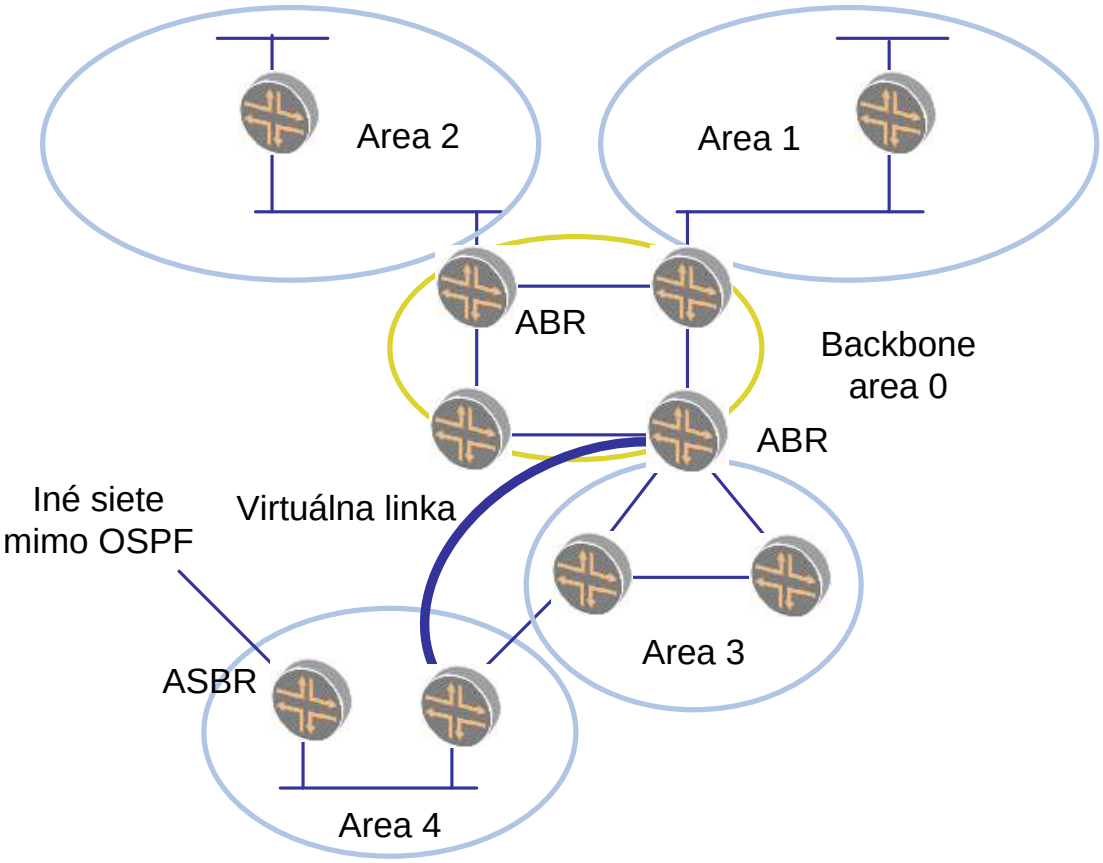
OSPF

OSPF - Open Shortest Path First

- Link State protokol
- Na výpočet cesty používa SPF algoritmus
- Default ohodnotenie je 10^8 / bandwidth (bps); [1 pre >= 100Mbps]
- OSPF pakety sú vkladané 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

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

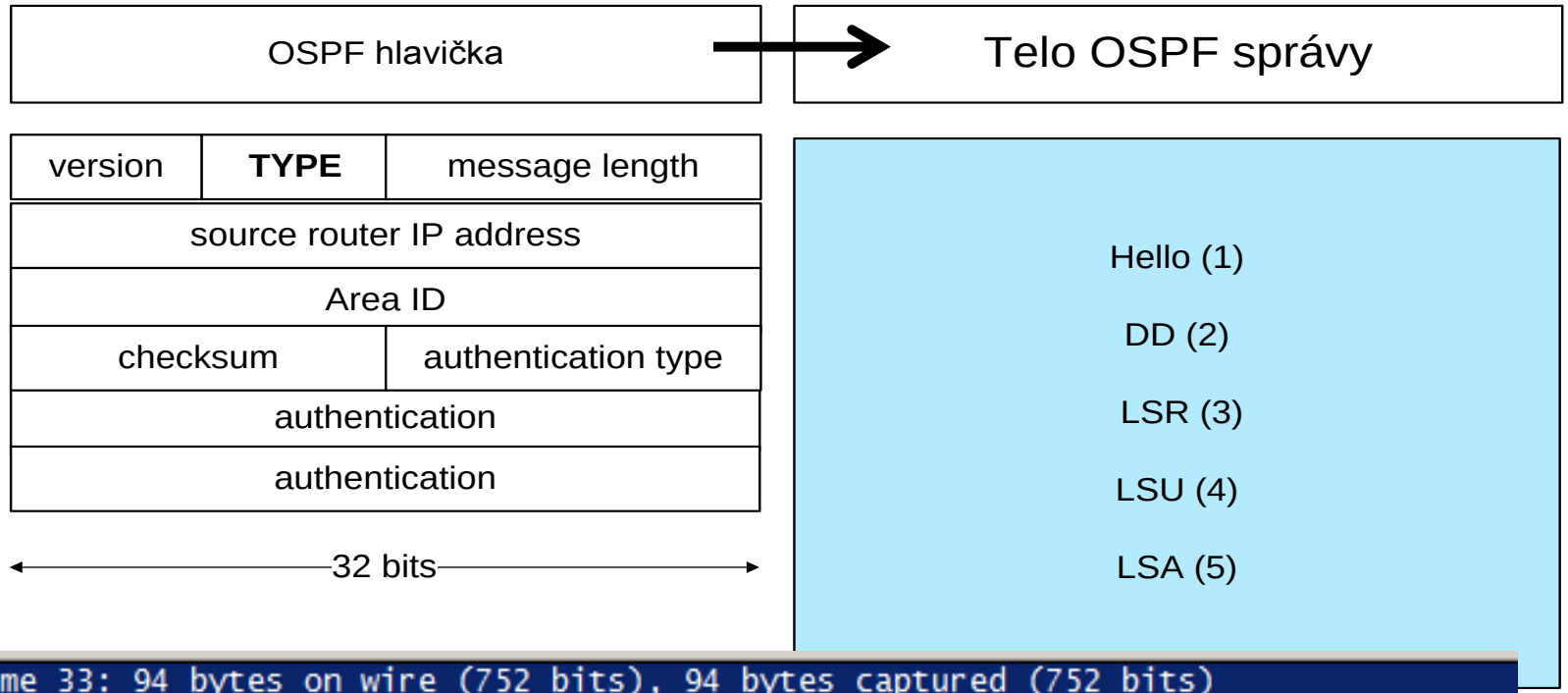
OSPF FSM

- DOWN
- ATTEMPT "Hello" unicast has been sent (usually on NBMA networks)
- INIT - A hello message has been received but in that hello, our router-id is not included
- 2-WAY - A hello message has been received and in that hello, our router-id is included
- ExSTART - The "Master & Slave" role is decided for each router. The router with the highest router-id will select the sequence number for the DBD (database descriptors) exchange
- Exchange - DBDs with the defined sequence number are sent
- LOADING Detailed information is requested to the neighbor, based on the summary information previously exchanged via DBD, of the LSAs that the router doesn't have specific information.
- FULL

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



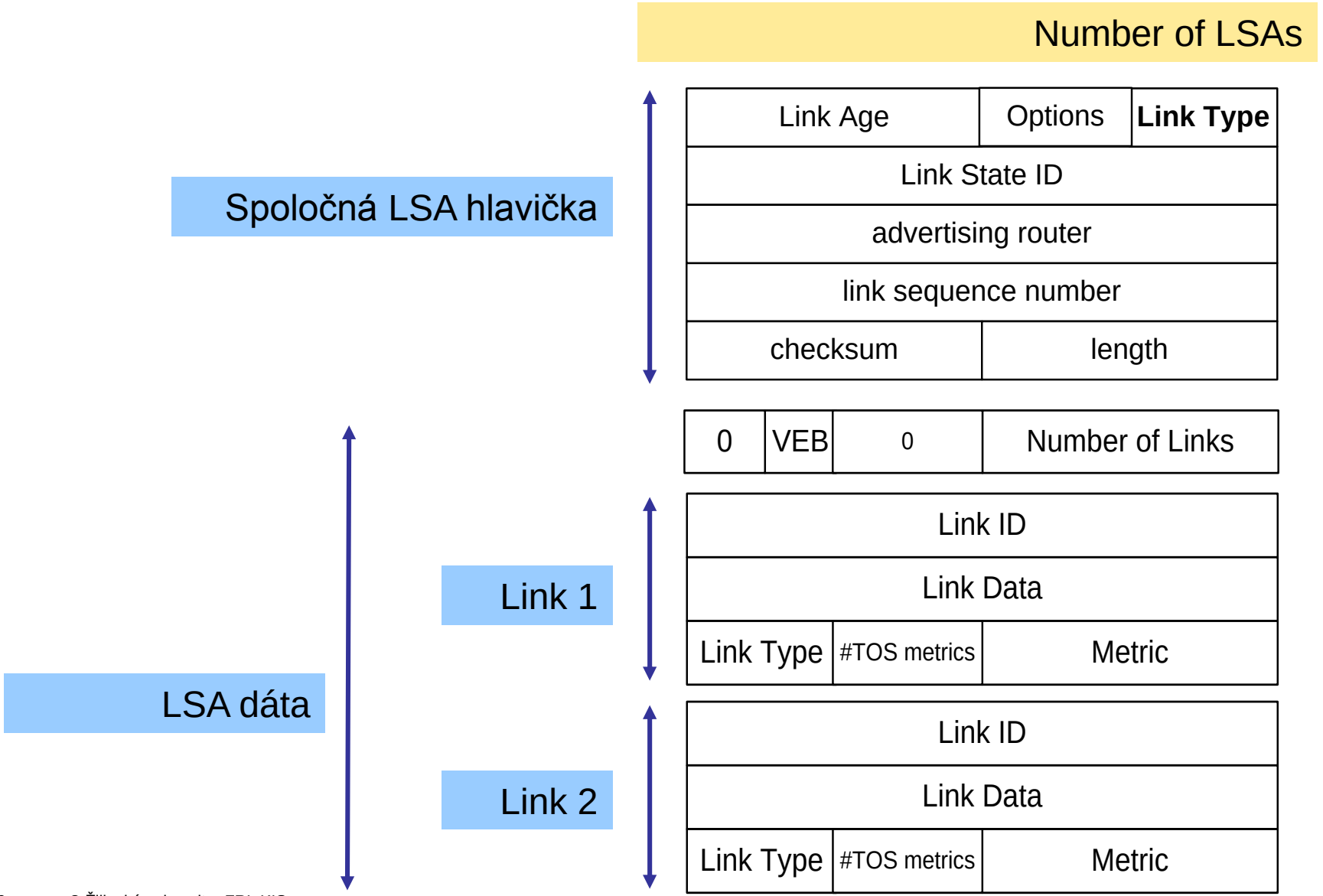

```
⊞ Frame 33: 94 bytes on wire (752 bits), 94 bytes captured (752 bits)
⊞ Ethernet II, Src: c2:01:0e:88:00:01 (c2:01:0e:88:00:01), Dst: IPv4mcast_00:00:05 (0
⊞ Internet Protocol Version 4, Src: 10.1.3.15 (10.1.3.15), Dst: 224.0.0.5 (224.0.0.5)
⊟ Open Shortest Path First
  ⊟ OSPF Header
      OSPF Version: 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

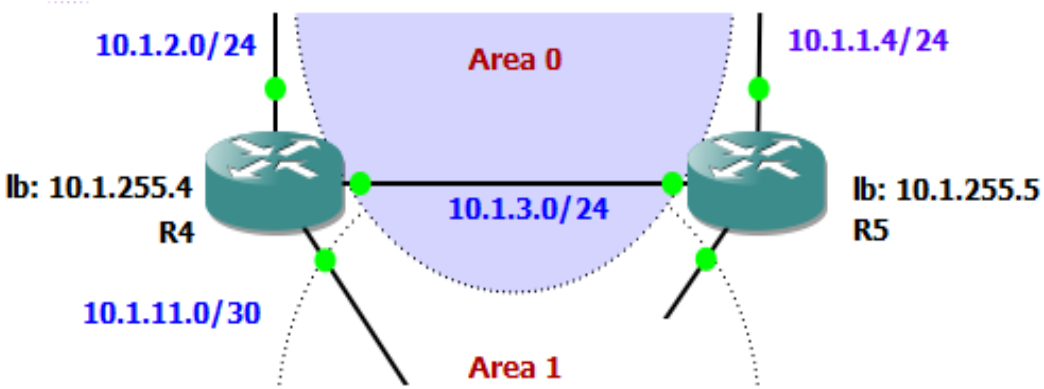
LSU správa môže obsahovať viacero LSA štruktúr. LSA typ popisuje objekt siete a jeho vzťah (prepojenie) s okolitými objektmi:

- 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

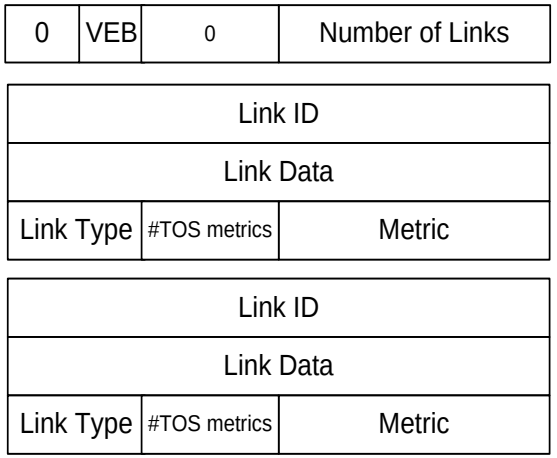



```
⊟ Open Shortest Path First
  ⊞ OSPF Header
  ⊟ LS Update Packet
      Number of LSAs: 2
    ⊟ LS Type: Router-LSA
        LS Age: 79 seconds
        Do Not Age: False
      ⊞ Options: 0x22 (DC, E)
        Link-State Advertisement Type: Router-LSA (1)
        Link State ID: 10.1.255.4
        Advertising 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)

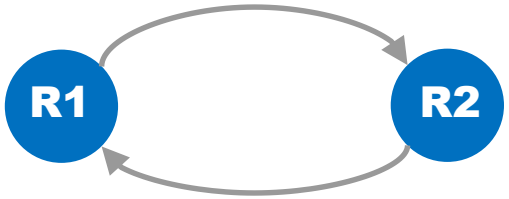
- Popisuje status a ohodnotenie sieťových rozhraní smerovača
  - Šíri sa iba v rámci oblasti
  - Smerovač indikuje, či sa jedná o ABR, ASBR alebo virtuálnu linku príznakmi VEB B: ABR, E: ASBR, V: Virtuálna linka

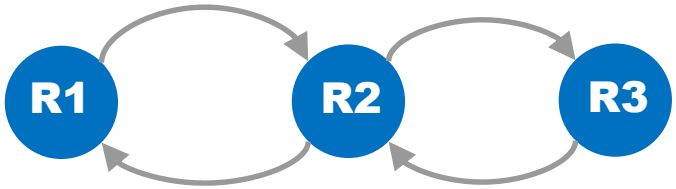
Link Type	Link ID	Link Data
Point-to-Point Type 1	Neighbor's router ID	Local router's iface IP
Transit Type 2	DR's iface IP	Local router's iface IP
Stub Type 3	Network number	Subnet mask
Virtual Link Type 4	Neighbor's router ID	Local router's iface IP

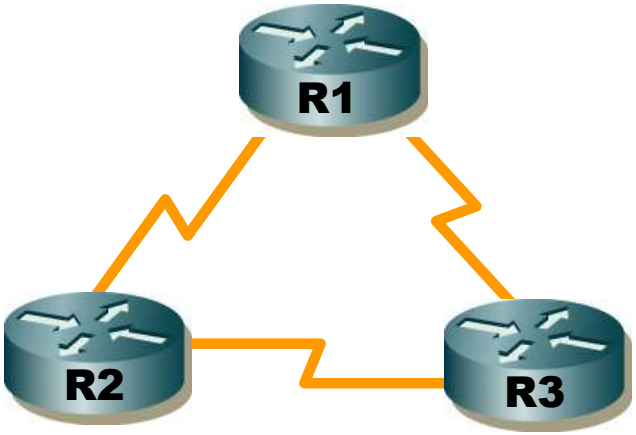


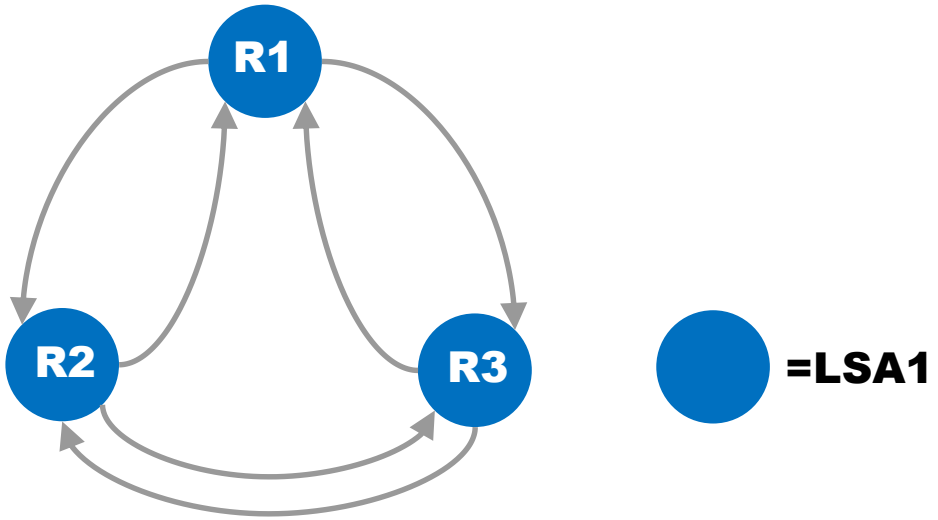

```
    Link-State Advertisement Type: Router-LSA (1)
    Link State ID: 10.1.255.5
    Advertising Router: 10.1.255.5 (10.1.255.5)
    LS Sequence Number: 0x80000001
    LS Checksum: 0xc1c4
    Length: 72
  ⊞ Flags: 0x01 (B)
    Number of Links: 4
  ⊞ Type: Stub     ID: 10.1.255.5      Data: 255.255.255.255 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)





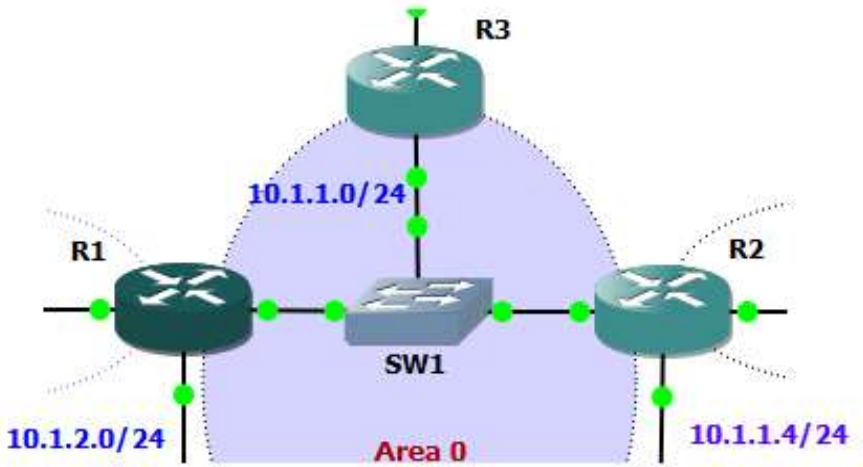




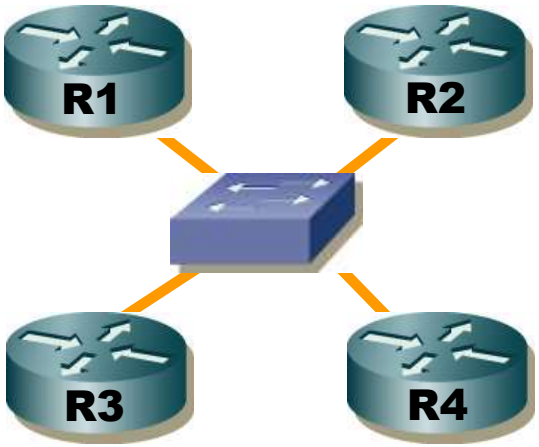
Network LSA (Type 2)

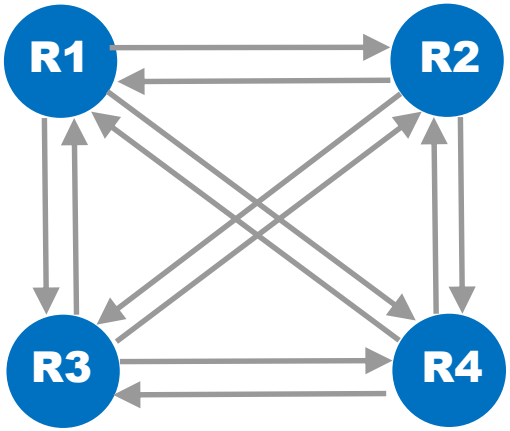
- Generovaný len pre každú broadcast alebo NBMA (non broadcast multiple access) sieť (nie pre P2P prepojenia)
  - Popisuje všetky smerovače pripojené k tejto sieti
  - Iba DR generuje tento typ LSA
  - Šíri sa iba v rámci oblasti
  - Skladá sa zo spoločnej LSA hlavičky, masky siete a zoznamu pripojených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



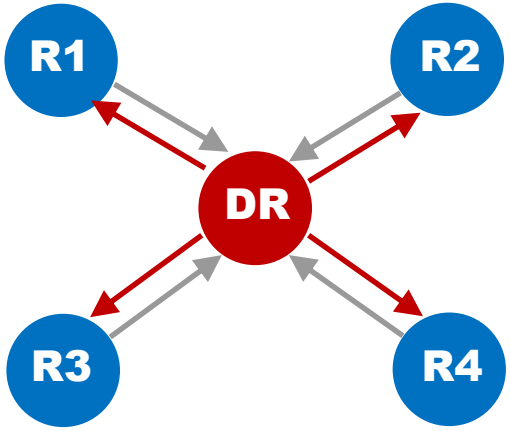
Význam LSA Type 2 (Network-LSA)

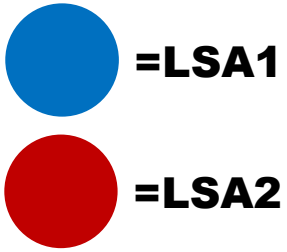




Pamäťovo a výpočtovo náročné riešenie

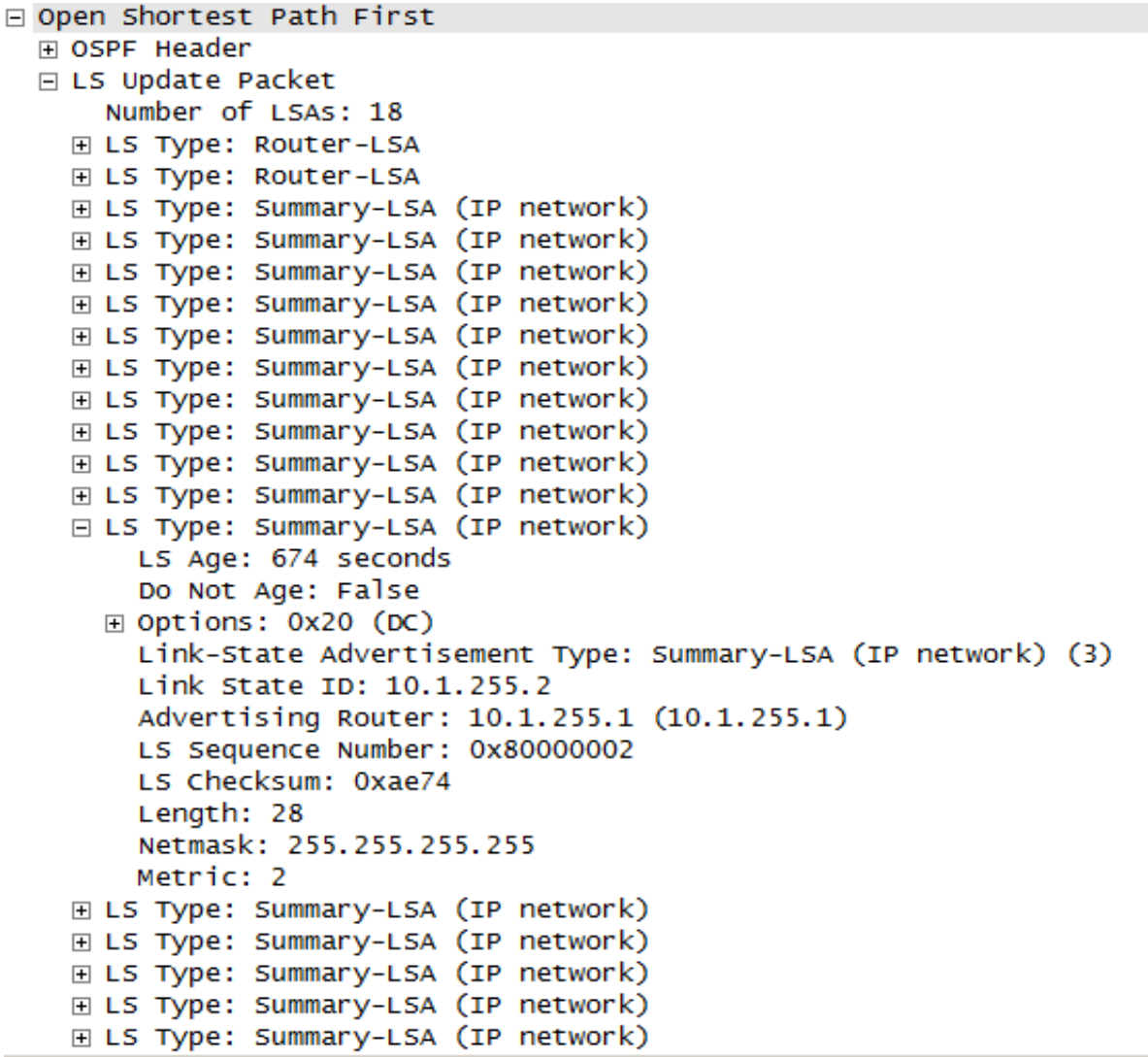
Princíp OSPF typu siete Point-to-Multipoint



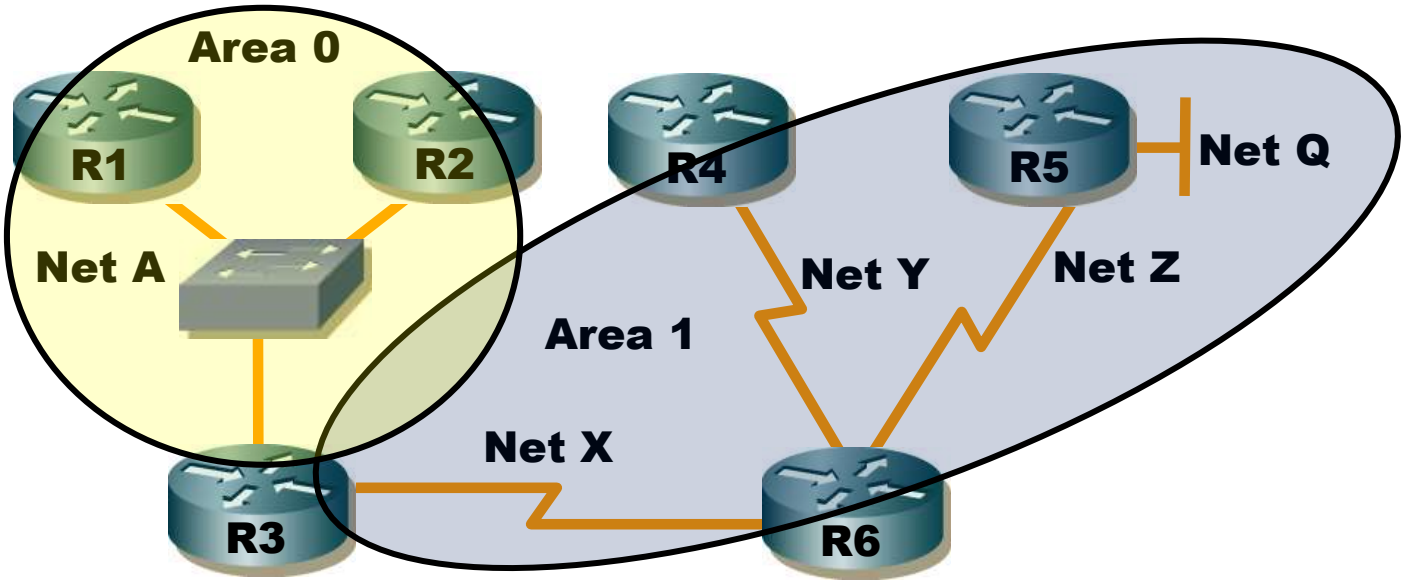


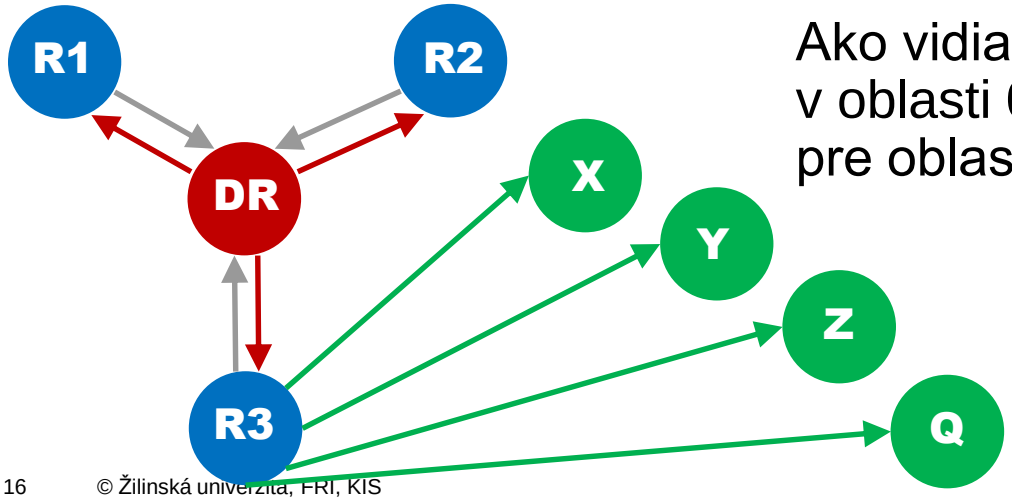
Summary LSA (Type 3)

- LSA Type 3 popisuje siete mimo oblasť ale stále v rámci toho istého OSPF autonomného 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



Význam LSA Type 3 (Network-Summary-LSA)





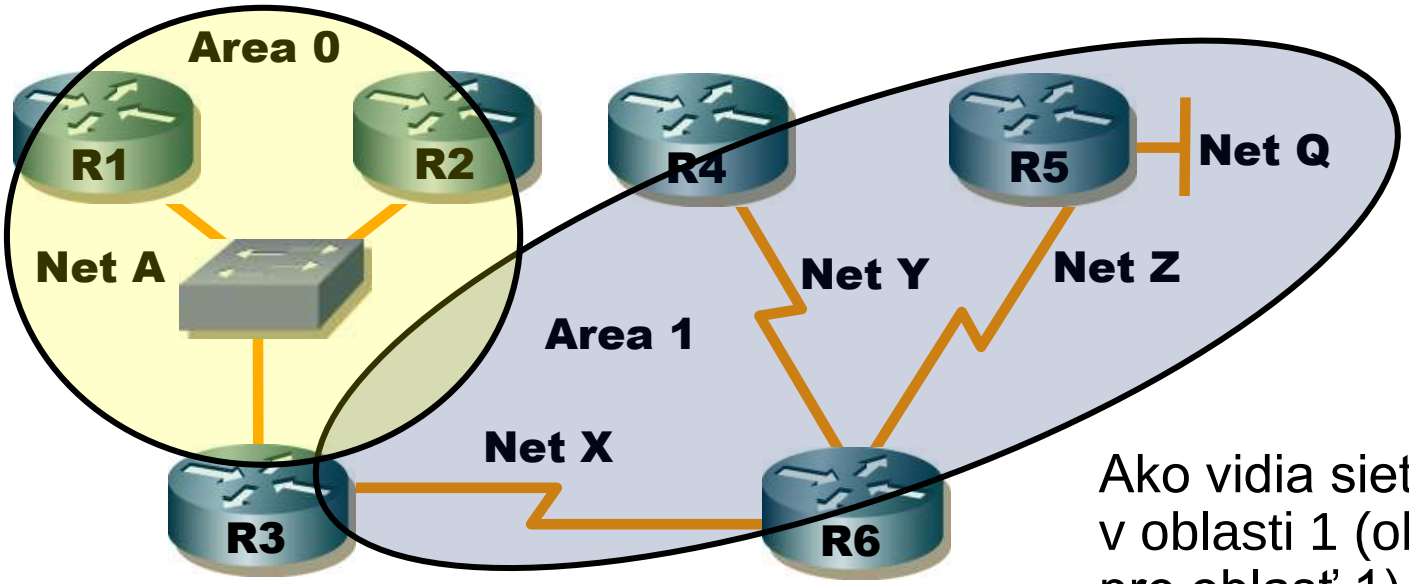
Ako vidia sieť smerovače v oblasti 0 (obsah LSDB pre oblasť 0)

=LSA1

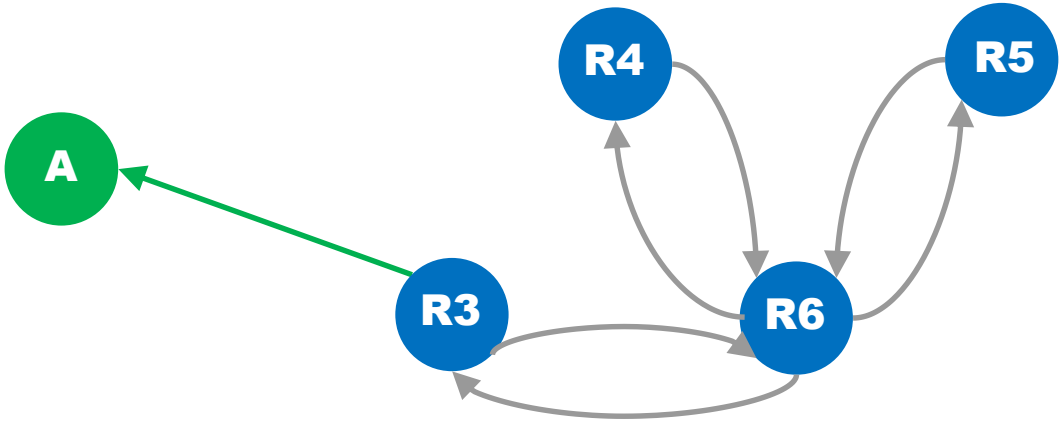
=LSA2

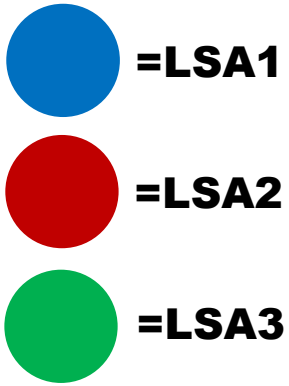
=LSA3

Význam LSA Type 3 (Network-Summary-LSA)



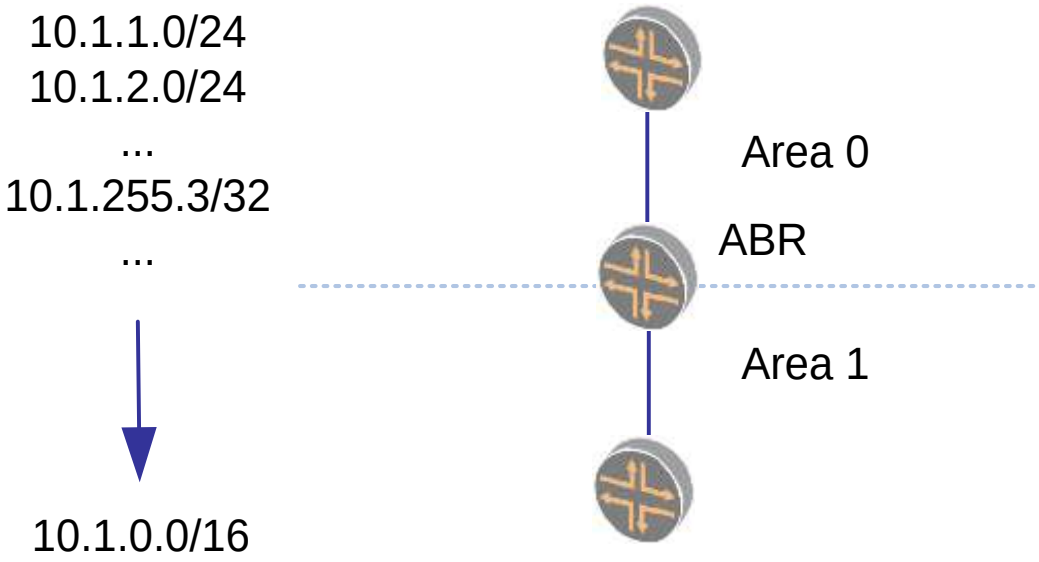
Ako vidia sieť smerovače v oblasti 1 (obsah LSDB pre oblasť 1)





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)

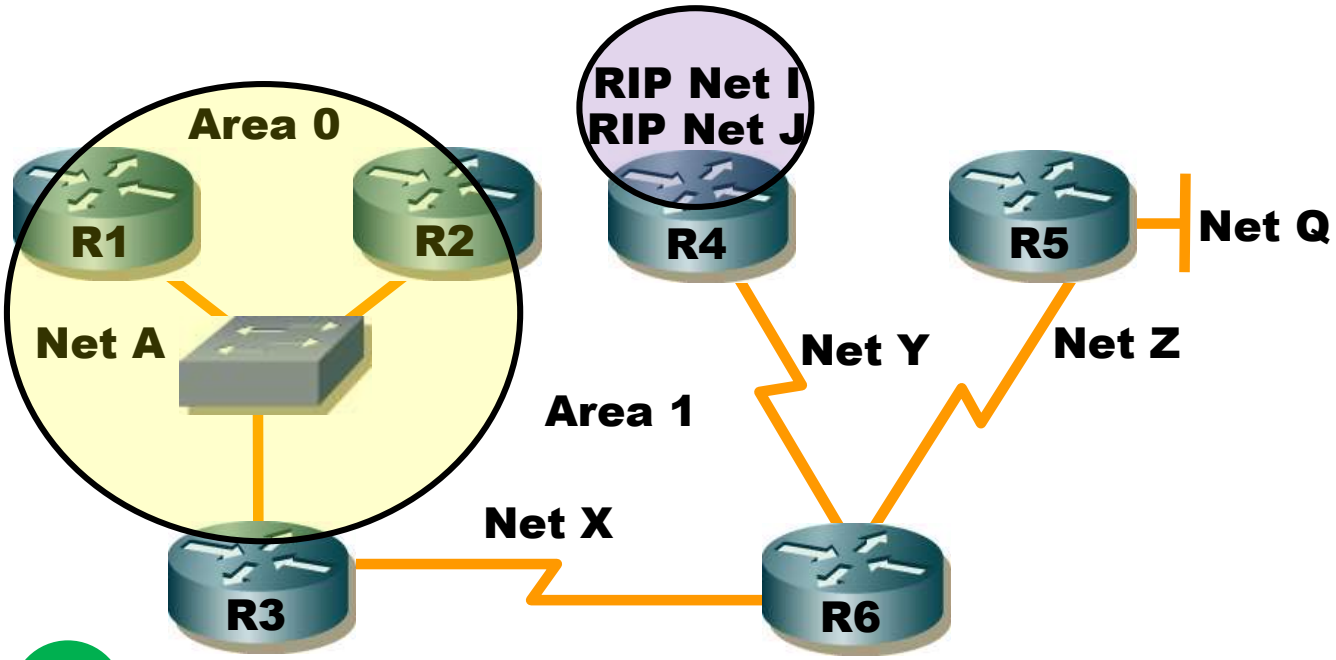
- Definuje prefixy, ktoré sú mimo OSPF autonómny systém
- Skladá sa zo spoločnej LSA hlavičky plus
  - Maska siete, E bit, Ohodnotenie, Forwarding Address
- Dva typy externých LSA:
  - E1: berie do úvahy celkové ohodnotenie cesty
  - E2: berie do úvahy iba ohodnotenie ku sieťovému rozhraniu ASBR, ktorý 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.

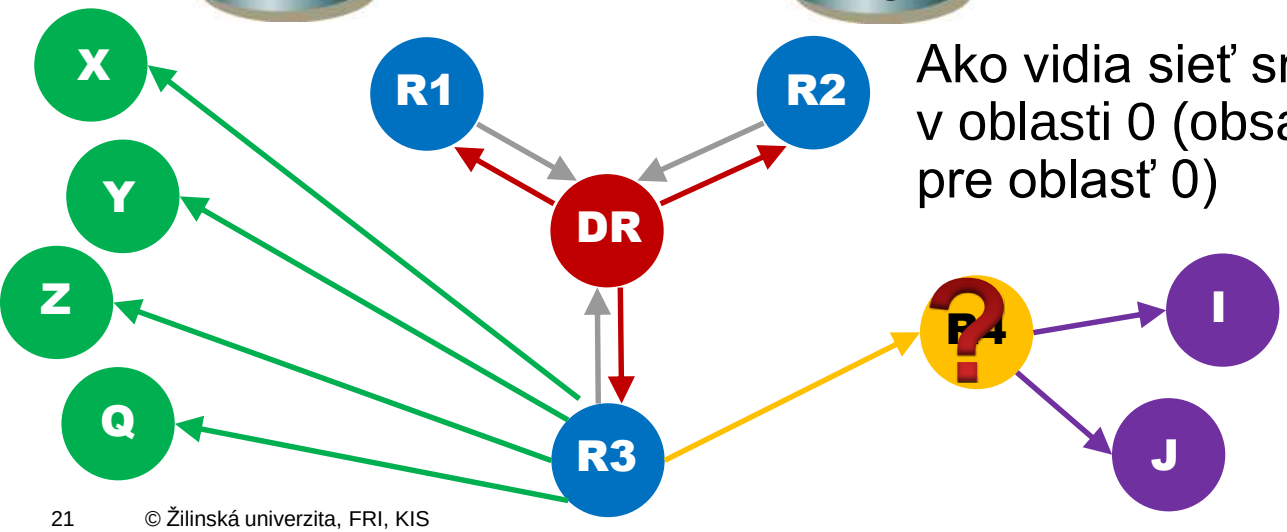
Summary LSA ASBR (Type 4)

- 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)





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

=LSA1

=LSA2

=LSA3

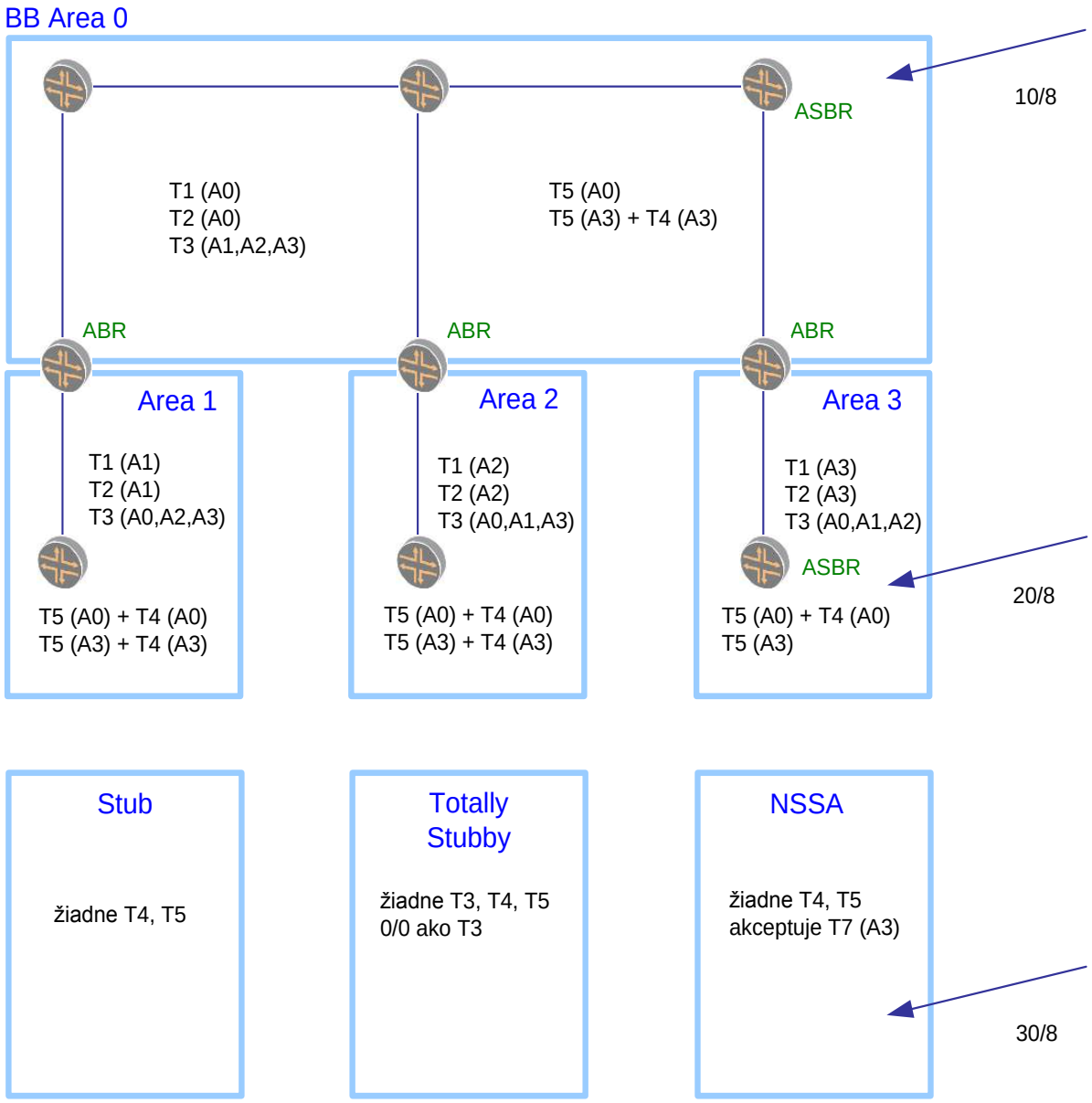
=LSA4

=LSA5

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

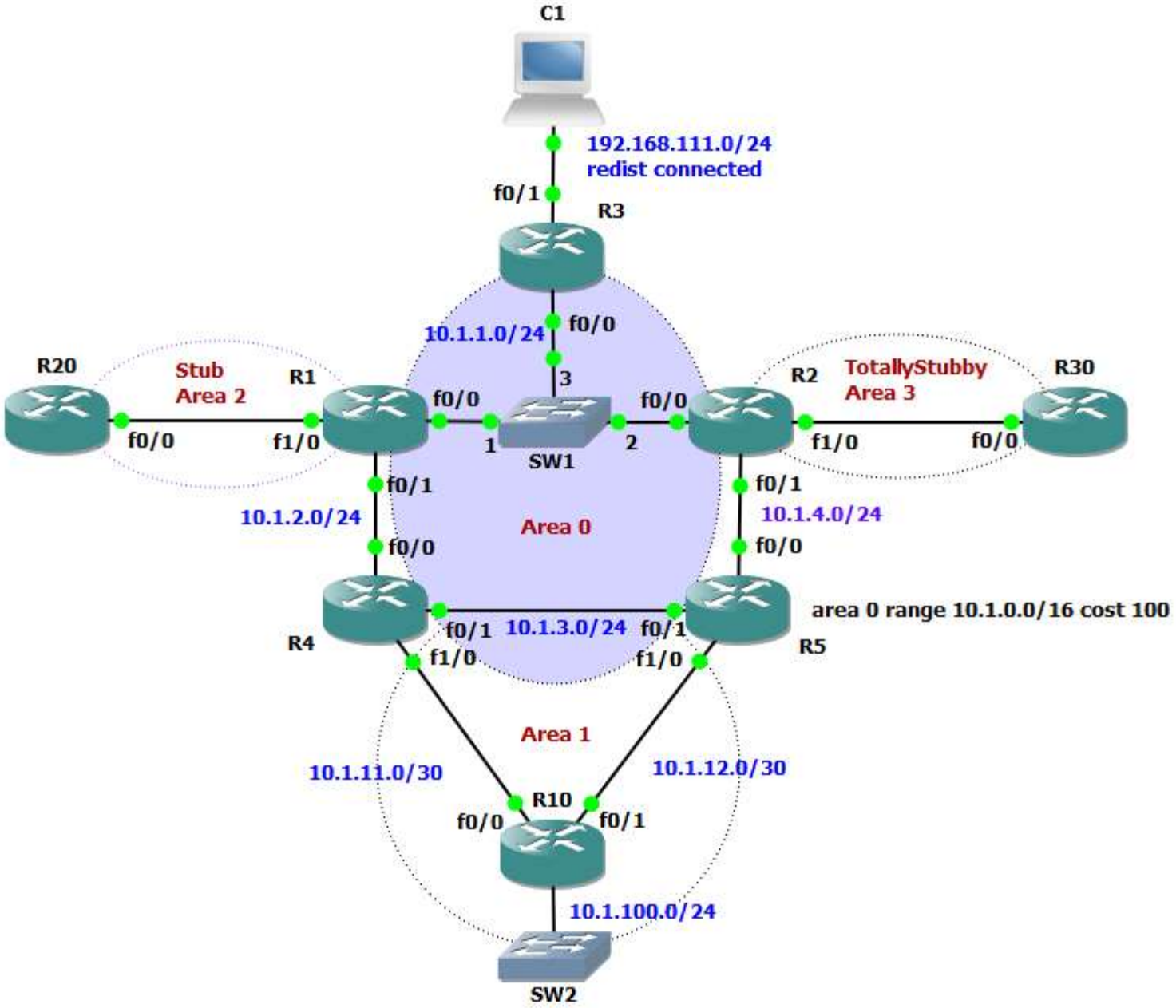
Prehľad LSA a typov domén



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

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
  |                   Output modifiers
  <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 Rout
  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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