

# Raport: Transmisja Danych - OSPF

Igor Kowalik, Wiktor Szymonek

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## 1. Podstawowa konfiguracja urządzenia

Oto tabela przedstawiająca schemat adresowania zgodnie z wytycznymi zadania.

Router	Interfejs	Adres IP	Maska	Prefiks
<b>R1</b>	loopback	192.168.0.1	255.255.255.255	/32
	e0/0	192.168.11.1	255.255.255.252	/30
<b>R2</b>	loopback	192.168.0.2	255.255.255.255	/32
	e0/0	192.168.11.2	255.255.255.252	/30
	e0/1	192.168.10.1	255.255.255.252	/30
	e0/2	192.168.10.5	255.255.255.252	/30
<b>R3</b>	loopback	192.168.0.3	255.255.255.255	/32
	e0/0	192.168.10.9	255.255.255.252	/30
	e0/2	192.168.10.6	255.255.255.252	/30
	e0/3	192.168.10.13	255.255.255.252	/30
<b>R4</b>	loopback	192.168.0.4	255.255.255.255	/32
	e0/1	192.168.10.2	255.255.255.252	/30
	e0/2	192.168.10.17	255.255.255.252	/30
	e0/3	192.168.10.14	255.255.255.252	/30
<b>R5</b>	loopback	192.168.0.5	255.255.255.255	/32
	e0/0	192.168.10.10	255.255.255.252	/30
	e0/2	192.168.10.18	255.255.255.252	/30

## Analiza tablic routingu

Celem tej części jest weryfikacja poprawności działania routingu w sieci oraz zrozumienie, w jaki sposób routery podejmują decyzje o przesyłaniu pakietów. Poniżej przedstawiono zrzuty polecenia show ip route dla poszczególnych routerów wraz z analizą kluczowych wpisów.

Routery:

```
R1#show ip route
```

```
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
```

```
D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
```

```
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
```

```
E1 - OSPF external type 1, E2 - OSPF external type 2
```

```
i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
```

```
ia - IS-IS inter area, * - candidate default, U - per-user static route
```

```
o - ODR, P - periodic downloaded static route
```

Gateway of last resort is not set

```
192.168.11.0/30 is subnetted, 1 subnets
C      192.168.11.0 is directly connected, Ethernet0/0
192.168.0.0/32 is subnetted, 1 subnets
C      192.168.0.1 is directly connected, Loopback0
R1#
```

R2#show ip route

Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP  
D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area  
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2  
E1 - OSPF external type 1, E2 - OSPF external type 2  
i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2  
ia - IS-IS inter area, \* - candidate default, U - per-user static route  
o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

```
192.168.10.0/30 is subnetted, 2 subnets
C      192.168.10.0 is directly connected, Ethernet0/1
C      192.168.10.4 is directly connected, Ethernet0/2
192.168.11.0/30 is subnetted, 1 subnets
C      192.168.11.0 is directly connected, Ethernet0/0
192.168.0.0/32 is subnetted, 1 subnets
C      192.168.0.2 is directly connected, Loopback0
R2#
```

R3#show ip route

Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP  
D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area  
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2  
E1 - OSPF external type 1, E2 - OSPF external type 2  
i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2  
ia - IS-IS inter area, \* - candidate default, U - per-user static route  
o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

```
192.168.10.0/30 is subnetted, 3 subnets
C      192.168.10.4 is directly connected, Ethernet0/2
C      192.168.10.8 is directly connected, Ethernet0/0
C      192.168.10.12 is directly connected, Ethernet0/3
192.168.0.0/32 is subnetted, 1 subnets
C      192.168.0.3 is directly connected, Loopback0
R3#
```

R4#show ip route

Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP  
D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area

```
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2
i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
ia - IS-IS inter area, * - candidate default, U - per-user static route
o - ODR, P - periodic downloaded static route
```

Gateway of last resort is not set

```
192.168.10.0/30 is subnetted, 3 subnets
C      192.168.10.0 is directly connected, Ethernet0/1
C      192.168.10.12 is directly connected, Ethernet0/3
C      192.168.10.16 is directly connected, Ethernet0/2
192.168.0.0/32 is subnetted, 1 subnets
C      192.168.0.4 is directly connected, Loopback0
R4#
```

R5#show ip route

```
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
        D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
        N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
        E1 - OSPF external type 1, E2 - OSPF external type 2
        i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
        ia - IS-IS inter area, * - candidate default, U - per-user static route
        o - ODR, P - periodic downloaded static route
```

Gateway of last resort is not set

```
192.168.10.0/30 is subnetted, 2 subnets
C      192.168.10.8 is directly connected, Ethernet0/0
C      192.168.10.16 is directly connected, Ethernet0/2
192.168.0.0/32 is subnetted, 1 subnets
C      192.168.0.5 is directly connected, Loopback0
R5#
```

Wpisy oznaczone literą C informują o sieciach podłączonych bezpośrednio do interfejsów routera. Router wie o nich automatycznie po przypisaniu adresu IP i podniesieniu interfejsu (stan up/up). Na tym etapie routery nie widzą jeszcze sieci odległych (np. R1 nie widzi pętli loopback routera R5), ponieważ nie skonfigurowaliśmy jeszcze protokołu routingu dynamicznego OSPF

## 2. Konfiguracja OSPF

```
R1(config-router)#do show ip ospf
Routing Process "ospf 1" with ID 192.168.0.1
Start time: 00:09:28.308, Time elapsed: 00:02:24.668
Supports only single TOS(TOS0) routes
Supports opaque LSA
Supports Link-local Signaling (LLS)
Supports area transit capability
Router is not originating router-LSAs with maximum metric
Initial SPF schedule delay 5000 msecs
```

```

Minimum hold time between two consecutive SPF's 10000 msec
Maximum wait time between two consecutive SPF's 10000 msec
Incremental-SPF disabled
Minimum LSA interval 5 secs
Minimum LSA arrival 1000 msec
LSA group pacing timer 240 secs
Interface flood pacing timer 33 msec
Retransmission pacing timer 66 msec
Number of external LSA 0. Checksum Sum 0x000000
Number of opaque AS LSA 0. Checksum Sum 0x000000
Number of DCbitless external and opaque AS LSA 0
Number of DoNotAge external and opaque AS LSA 0
Number of areas in this router is 1. 1 normal 0 stub 0 nssa
Number of areas transit capable is 0
External flood list length 0
  Area BACKBONE(0)
    Number of interfaces in this area is 2 (1 loopback)
    Area has no authentication
    SPF algorithm last executed 00:00:03.944 ago
    SPF algorithm executed 6 times
    Area ranges are
    Number of LSA 10. Checksum Sum 0x03410C
    Number of opaque link LSA 0. Checksum Sum 0x000000
    Number of DCbitless LSA 0
    Number of indication LSA 0
    Number of DoNotAge LSA 0
    Flood list length 0

```

Wynik polecenia potwierdza poprawność uruchomienia procesu routingu.

- Router przyjął identyfikator 192.168.0.1 (zgodnie z adresem Loopback).
- Interfejsy zostały poprawnie przypisane do obszaru zerowego (szkieletowego).
- Obecność 10 rekordów LSA świadczy o tym, że router otrzymał informacje o wszystkich łączach i pętlach zwrotnych od pozostałych 4 routerów w sieci.

```
R1(config-router)#do show ip route
```

```

Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

```

```
Gateway of last resort is not set
```

```

    192.168.10.0/30 is subnetted, 5 subnets
0       192.168.10.0 [110/20] via 192.168.11.2, 00:00:08, Ethernet0/0
0       192.168.10.4 [110/20] via 192.168.11.2, 00:00:08, Ethernet0/0
0       192.168.10.8 [110/30] via 192.168.11.2, 00:00:08, Ethernet0/0
0       192.168.10.12 [110/30] via 192.168.11.2, 00:00:08, Ethernet0/0

```

```

0       192.168.10.16 [110/30] via 192.168.11.2, 00:00:08, Ethernet0/0
192.168.11.0/30 is subnetted, 1 subnets
C       192.168.11.0 is directly connected, Ethernet0/0
192.168.0.0/32 is subnetted, 5 subnets
C       192.168.0.1 is directly connected, Loopback0
0       192.168.0.2 [110/11] via 192.168.11.2, 00:00:09, Ethernet0/0
0       192.168.0.3 [110/21] via 192.168.11.2, 00:00:09, Ethernet0/0
0       192.168.0.4 [110/21] via 192.168.11.2, 00:00:09, Ethernet0/0
0       192.168.0.5 [110/31] via 192.168.11.2, 00:00:11, Ethernet0/0
R1(config-router)#

```

Tabela routingu wykazuje pełną zbieżność sieci:

- (O) R1 nauczył się tras do wszystkich odległych podsieci (192.168.10.x) oraz interfejsów Loopback innych routerów (192.168.0.2 – 192.168.0.5).
- Wartość metryki 110 to domyślny dystans administracyjny OSPF. Druga wartość (np. 31) to koszt ścieżki, obliczony na podstawie przepustowości łączy (referencyjne 100 Mbps).
- Wszystkie trasy prowadzą przez adres 192.168.11.2 (R2), co jest zgodne z fizycznym połączeniem R1 do reszty topologii.

### 3. Baza danych OSPF

```
R5#show ip ospf database
```

```
OSPF Router with ID (192.168.0.5) (Process ID 1)
```

```
Router Link States (Area 0)
```

Link ID	ADV Router	Age	Seq#	Checksum	Link count
192.168.0.1	192.168.0.1	554	0x80000003	0x001ECD	2
192.168.0.2	192.168.0.2	95	0x80000007	0x008B48	6
192.168.0.3	192.168.0.3	56	0x80000008	0x008E1B	6
192.168.0.4	192.168.0.4	30	0x80000008	0x00128B	6
192.168.0.5	192.168.0.5	13	0x80000007	0x00BAEB	5

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

Link ID	ADV Router	Age	Seq#	Checksum
192.168.10.14	192.168.0.4	516	0x80000001	0x00C9AA
192.168.11.2	192.168.0.2	553	0x80000001	0x001372

```
R5#show ip ospf database router
```

```
OSPF Router with ID (192.168.0.5) (Process ID 1)
```

```
Router Link States (Area 0)
```

```

LS age: 560
Options: (No TOS-capability, DC)
LS Type: Router Links

```

Link State ID: 192.168.0.1  
Advertising Router: 192.168.0.1  
LS Seq Number: 80000003  
Checksum: 0x1ECD  
Length: 48  
Number of Links: 2

Link connected to: a Stub Network  
(Link ID) Network/subnet number: 192.168.0.1  
(Link Data) Network Mask: 255.255.255.255  
Number of TOS metrics: 0  
TOS 0 Metrics: 1

Link connected to: a Transit Network  
(Link ID) Designated Router address: 192.168.11.2  
(Link Data) Router Interface address: 192.168.11.1  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

LS age: 104  
Options: (No TOS-capability, DC)  
LS Type: Router Links  
Link State ID: 192.168.0.2  
Advertising Router: 192.168.0.2  
LS Seq Number: 80000007  
Checksum: 0x8B48  
Length: 96  
Number of Links: 6

Link connected to: a Stub Network  
(Link ID) Network/subnet number: 192.168.0.2  
(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: 192.168.0.3  
(Link Data) Router Interface address: 192.168.10.5  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

Link connected to: a Stub Network  
(Link ID) Network/subnet number: 192.168.10.4  
(Link Data) Network Mask: 255.255.255.252  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

Link connected to: another Router (point-to-point)  
(Link ID) Neighboring Router ID: 192.168.0.4

(Link Data) Router Interface address: 192.168.10.1  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

Link connected to: a Stub Network  
(Link ID) Network/subnet number: 192.168.10.0  
(Link Data) Network Mask: 255.255.255.252  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

Link connected to: a Transit Network  
(Link ID) Designated Router address: 192.168.11.2  
(Link Data) Router Interface address: 192.168.11.2  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

LS age: 75  
Options: (No TOS-capability, DC)  
LS Type: Router Links  
Link State ID: 192.168.0.3  
Advertising Router: 192.168.0.3  
LS Seq Number: 80000008  
Checksum: 0x8E1B  
Length: 96  
Number of Links: 6

Link connected to: a Stub Network  
(Link ID) Network/subnet number: 192.168.0.3  
(Link Data) Network Mask: 255.255.255.255  
Number of TOS metrics: 0  
TOS 0 Metrics: 1

Link connected to: a Transit Network  
(Link ID) Designated Router address: 192.168.10.14  
(Link Data) Router Interface address: 192.168.10.13  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

Link connected to: another Router (point-to-point)  
(Link ID) Neighboring Router ID: 192.168.0.5  
(Link Data) Router Interface address: 192.168.10.9  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

Link connected to: a Stub Network  
(Link ID) Network/subnet number: 192.168.10.8  
(Link Data) Network Mask: 255.255.255.252  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

Link connected to: another Router (point-to-point)  
(Link ID) Neighboring Router ID: 192.168.0.2  
(Link Data) Router Interface address: 192.168.10.6  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

Link connected to: a Stub Network  
(Link ID) Network/subnet number: 192.168.10.4  
(Link Data) Network Mask: 255.255.255.252  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

LS age: 57  
Options: (No TOS-capability, DC)  
LS Type: Router Links  
Link State ID: 192.168.0.4  
Advertising Router: 192.168.0.4  
LS Seq Number: 80000008  
Checksum: 0x128B  
Length: 96  
Number of Links: 6

Link connected to: a Stub Network  
(Link ID) Network/subnet number: 192.168.0.4  
(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: 192.168.0.5  
(Link Data) Router Interface address: 192.168.10.17  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

Link connected to: a Stub Network  
(Link ID) Network/subnet number: 192.168.10.16  
(Link Data) Network Mask: 255.255.255.252  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

Link connected to: a Transit Network  
(Link ID) Designated Router address: 192.168.10.14  
(Link Data) Router Interface address: 192.168.10.14  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

Link connected to: another Router (point-to-point)  
(Link ID) Neighboring Router ID: 192.168.0.2



(Link Data) Router Interface address: 192.168.10.2  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

Link connected to: a Stub Network  
(Link ID) Network/subnet number: 192.168.10.0  
(Link Data) Network Mask: 255.255.255.252  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

LS age: 45  
Options: (No TOS-capability, DC)  
LS Type: Router Links  
Link State ID: 192.168.0.5  
Advertising Router: 192.168.0.5  
LS Seq Number: 80000007  
Checksum: 0xBAEB  
Length: 84  
Number of Links: 5

Link connected to: a Stub Network  
(Link ID) Network/subnet number: 192.168.0.5  
(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: 192.168.0.4  
(Link Data) Router Interface address: 192.168.10.18  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

Link connected to: a Stub Network  
(Link ID) Network/subnet number: 192.168.10.16  
(Link Data) Network Mask: 255.255.255.252  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

Link connected to: another Router (point-to-point)  
(Link ID) Neighboring Router ID: 192.168.0.3  
(Link Data) Router Interface address: 192.168.10.10  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

Link connected to: a Stub Network  
(Link ID) Network/subnet number: 192.168.10.8  
(Link Data) Network Mask: 255.255.255.252  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

```
R5#show ip ospf database network
```

```
OSPF Router with ID (192.168.0.5) (Process ID 1)
```

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

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

```
LS age: 564
```

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

```
LS Type: Network Links
```

```
Link State ID: 192.168.10.14 (address of Designated Router)
```

```
Advertising Router: 192.168.0.4
```

```
LS Seq Number: 80000001
```

```
Checksum: 0xC9AA
```

```
Length: 32
```

```
Network Mask: /30
```

```
Attached Router: 192.168.0.4
```

```
Attached Router: 192.168.0.3
```

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

```
LS age: 601
```

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

```
LS Type: Network Links
```

```
Link State ID: 192.168.11.2 (address of Designated Router)
```

```
Advertising Router: 192.168.0.2
```

```
LS Seq Number: 80000001
```

```
Checksum: 0x1372
```

```
Length: 32
```

```
Network Mask: /30
```

```
Attached Router: 192.168.0.2
```

```
Attached Router: 192.168.0.1
```

```
R5#
```

#### A. Dlaczego w bazie danych OSPF jest dokładnie 5 Router LSA i 2 Network LSA?

- 5 Router LSA: W bazie znajduje się 5 wpisów tego typu, ponieważ w obszarze 0 aktywnie uczestniczy 5 routerów. W protokole OSPF każdy router generuje jeden LSA Typu 1, aby opisać samego siebie i swoje bezpośrednie połączenia.
- 2 Network LSA: LSA Typu 2 są generowane wyłącznie przez router wyznaczony dla łączy typu wielodostępowego. Po zmianie konfiguracji większości połączeń na typ point-to-point (które nie generują Network LSA), w sieci pozostały tylko dwa segmenty typu Broadcast, R-R2 oraz R3-R4. Dlatego w bazie widnieją dokładnie 2 wpisy Network LSA, reprezentujące te dwa segmenty.

#### B. Treść wiadomości typu Router LSA rozgłaszanej przez router R3

Analizując sekcję Link State ID: 192.168.0.3 z wydruku `show ip ospf database router`, router R3 ogłasza 6 połączeń (Number of Links: 6), co jest zgodne z topologią:

- Stub Network: 192.168.0.3 – interfejs Loopback.
- Transit Network: Link do DR 192.168.10.14 (połączenie z R4 typu Broadcast).

- Point-to-Point: Sąsiad 192.168.0.5 (połączenie z R5).
- Stub Network: 192.168.10.8/30 (podsieć połączenia z R5).
- Point-to-Point: Sąsiad 192.168.0.2 (połączenie z R2).
- Stub Network: 192.168.10.4/30 (podsieć połączenia z R2).

### C. Zawartość wszystkich Network LSA

Komenda `show ip ospf database network` wyświetla dwa wpisy, które potwierdzają strukturę segmentów Broadcast w topologii:

- Link ID 192.168.10.14: Reprezentuje segment łączący R3 i R4.
  - Attached Router: 192.168.0.4 (R4)
  - Attached Router: 192.168.0.3 (R3)
- Link ID 192.168.11.2: Reprezentuje segment łączący R1 i R2.
  - Attached Router: 192.168.0.2 (R2)
  - Attached Router: 192.168.0.1 (R1)

### D. Które routery zostały wybrane jako urządzenia DR i dlaczego?

Wybór DR (Designated Router) w OSPF zależy od priorytetu interfejsu (domyślnie 1), a w przypadku remisu decyduje najwyższy identyfikator routera (Router ID).

- Segment R1-R2: DR to R2 (adres interfejsu 192.168.11.2).
  - Router ID R2 (192.168.0.2) jest wyższe niż Router ID R1 (192.168.0.1).
- Segment R3-R4: DR to R4 (adres interfejsu 192.168.10.14).
  - Router ID R4 (192.168.0.4) jest wyższe niż Router ID R3 (192.168.0.3).

### E. W jaki sposób router R5 może wykryć topologię sieci na podstawie informacji z LSA?

Router R5 gromadzi wszystkie otrzymane LSA w swojej bazie danych stanu łącza (LSDB).

- Router LSA (Typ 1) dostarczają informacji o węzłach sieci (routerach) i ich krawędziach (do kogo są podłączeni).
- Network LSA (Typ 2) dostarczają informacji o wspólnych segmentach sieci i routerach do nich podłączonych. Składając te dane, R5 buduje kompletny graf skierowany całej sieci. Następnie uruchamia na tym grafie algorytm Dijkstry (SPF - Shortest Path First), umieszczając siebie w korzeniu drzewa, aby obliczyć najkrótsze i bezpętlowe ścieżki do każdej dostępnej podsieci.

## 4. Wieloobszarowy OSPF

```
R1#show ip ospf database
```

```
OSPF Router with ID (192.168.0.1) (Process ID 1)
```

```
Router Link States (Area 1)
```

Link ID	ADV Router	Age	Seq#	Checksum	Link count
192.168.0.1	192.168.0.1	43	0x80000003	0x001ECD	2
192.168.0.2	192.168.0.2	44	0x80000002	0x008FD4	1

Net Link States (Area 1)

Link ID	ADV Router	Age	Seq#	Checksum
192.168.11.2	192.168.0.2	44	0x80000001	0x001372

Summary Net Link States (Area 1)

Link ID	ADV Router	Age	Seq#	Checksum
192.168.0.2	192.168.0.2	84	0x80000001	0x00B5AF
192.168.0.3	192.168.0.2	84	0x80000001	0x00104A
192.168.0.4	192.168.0.2	84	0x80000001	0x000653
192.168.0.5	192.168.0.2	84	0x80000001	0x0060ED
192.168.10.0	192.168.0.2	84	0x80000001	0x00A3B3
192.168.10.4	192.168.0.2	84	0x80000001	0x007BD7
192.168.10.8	192.168.0.2	84	0x80000001	0x00B78D
192.168.10.12	192.168.0.2	87	0x80000001	0x008FB1
192.168.10.16	192.168.0.2	88	0x80000001	0x0067D5

R1#show ip ospf database summary

OSPF Router with ID (192.168.0.1) (Process ID 1)

Summary Net Link States (Area 1)

Routing Bit Set on this LSA

LS age: 92

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

LS Type: Summary Links(Network)

Link State ID: 192.168.0.2 (summary Network Number)

Advertising Router: 192.168.0.2

LS Seq Number: 80000001

Checksum: 0xB5AF

Length: 28

Network Mask: /32

TOS: 0 Metric: 1

Routing Bit Set on this LSA

LS age: 92

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

LS Type: Summary Links(Network)

Link State ID: 192.168.0.3 (summary Network Number)

Advertising Router: 192.168.0.2

LS Seq Number: 80000001

Checksum: 0x104A

Length: 28

Network Mask: /32

TOS: 0 Metric: 11

Routing Bit Set on this LSA

LS age: 96  
Options: (No TOS-capability, DC, Upward)  
LS Type: Summary Links(Network)  
Link State ID: 192.168.0.4 (summary Network Number)  
Advertising Router: 192.168.0.2  
LS Seq Number: 80000001  
Checksum: 0x653  
Length: 28  
Network Mask: /32  
TOS: 0 Metric: 11

Routing Bit Set on this LSA  
LS age: 98  
Options: (No TOS-capability, DC, Upward)  
LS Type: Summary Links(Network)  
Link State ID: 192.168.0.5 (summary Network Number)  
Advertising Router: 192.168.0.2  
LS Seq Number: 80000001  
Checksum: 0x60ED  
Length: 28  
Network Mask: /32  
TOS: 0 Metric: 21

Routing Bit Set on this LSA  
LS age: 100  
Options: (No TOS-capability, DC, Upward)  
LS Type: Summary Links(Network)  
Link State ID: 192.168.10.0 (summary Network Number)  
Advertising Router: 192.168.0.2  
LS Seq Number: 80000001  
Checksum: 0xA3B3  
Length: 28  
Network Mask: /30  
TOS: 0 Metric: 10

Routing Bit Set on this LSA  
LS age: 101  
Options: (No TOS-capability, DC, Upward)  
LS Type: Summary Links(Network)  
Link State ID: 192.168.10.4 (summary Network Number)  
Advertising Router: 192.168.0.2  
LS Seq Number: 80000001  
Checksum: 0x7BD7  
Length: 28  
Network Mask: /30  
TOS: 0 Metric: 10

Routing Bit Set on this LSA  
LS age: 102  
Options: (No TOS-capability, DC, Upward)

```
LS Type: Summary Links(Network)
Link State ID: 192.168.10.8 (summary Network Number)
Advertising Router: 192.168.0.2
LS Seq Number: 80000001
Checksum: 0xB78D
Length: 28
Network Mask: /30
    TOS: 0  Metric: 20
```

```
Routing Bit Set on this LSA
LS age: 104
Options: (No TOS-capability, DC, Upward)
LS Type: Summary Links(Network)
Link State ID: 192.168.10.12 (summary Network Number)
Advertising Router: 192.168.0.2
LS Seq Number: 80000001
Checksum: 0x8FB1
Length: 28
Network Mask: /30
    TOS: 0  Metric: 20
```

```
Routing Bit Set on this LSA
LS age: 104
Options: (No TOS-capability, DC, Upward)
LS Type: Summary Links(Network)
Link State ID: 192.168.10.16 (summary Network Number)
Advertising Router: 192.168.0.2
LS Seq Number: 80000001
Checksum: 0x67D5
Length: 28
Network Mask: /30
    TOS: 0  Metric: 20
```

R1#

R5#show ip ospf database network

OSPF Router with ID (192.168.0.5) (Process ID 1)

Net Link States (Area 0)

```
Routing Bit Set on this LSA
LS age: 564
Options: (No TOS-capability, DC)
LS Type: Network Links
Link State ID: 192.168.10.14 (address of Designated Router)
Advertising Router: 192.168.0.4
LS Seq Number: 80000001
Checksum: 0xC9AA
Length: 32
```

```

Network Mask: /30
    Attached Router: 192.168.0.4
    Attached Router: 192.168.0.3

Routing Bit Set on this LSA
LS age: 601
Options: (No TOS-capability, DC)
LS Type: Network Links
Link State ID: 192.168.11.2 (address of Designated Router)
Advertising Router: 192.168.0.2
LS Seq Number: 80000001
Checksum: 0x1372
Length: 32
Network Mask: /30
    Attached Router: 192.168.0.2
    Attached Router: 192.168.0.1

```

```
R5#show ip ospf database
```

```
    OSPF Router with ID (192.168.0.5) (Process ID 1)
```

```
        Router Link States (Area 0)
```

Link ID	ADV Router	Age	Seq#	Checksum	Link count
192.168.0.1	192.168.0.1	1060	0x80000003	0x001ECD	2
192.168.0.2	192.168.0.2	111	0x80000009	0x006175	5
192.168.0.3	192.168.0.3	562	0x80000008	0x008E1B	6
192.168.0.4	192.168.0.4	536	0x80000008	0x00128B	6
192.168.0.5	192.168.0.5	519	0x80000007	0x00BAEB	5

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

Link ID	ADV Router	Age	Seq#	Checksum
192.168.10.14	192.168.0.4	1021	0x80000001	0x00C9AA

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

Link ID	ADV Router	Age	Seq#	Checksum
192.168.0.1	192.168.0.2	69	0x80000001	0x002438
192.168.11.0	192.168.0.2	109	0x80000001	0x0098BD

```
R5#show ip ospf database summary
```

```
    OSPF Router with ID (192.168.0.5) (Process ID 1)
```

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

```

Routing Bit Set on this LSA
LS age: 74
Options: (No TOS-capability, DC, Upward)

```

```

LS Type: Summary Links(Network)
Link State ID: 192.168.0.1 (summary Network Number)
Advertising Router: 192.168.0.2
LS Seq Number: 80000001
Checksum: 0x2438
Length: 28
Network Mask: /32
      TOS: 0  Metric: 11

Routing Bit Set on this LSA
LS age: 115
Options: (No TOS-capability, DC, Upward)
LS Type: Summary Links(Network)
Link State ID: 192.168.11.0 (summary Network Number)
Advertising Router: 192.168.0.2
LS Seq Number: 80000001
Checksum: 0x98BD
Length: 28
Network Mask: /30
      TOS: 0  Metric: 10

```

### Analiza show ip ospf database

**Router 1:** W sekcji Router Link States (Area 1) widoczne są tylko dwa routery: 192.168.0.1 (R1) oraz 192.168.0.2 (R2). R1 znajduje się w obszarze typu “stub” (Area 1) i nie posiada pełnej wiedzy o topologii sieci szkieletowej (Area 0). Widzi jedynie routery znajdujące się w tym samym obszarze co on.

**Router 5:** W sekcji Router Link States (Area 0) widoczne są routery tworzące szkielet sieci: R2, R3, R4, R5. R5 posiada pełną mapę topologiczną tylko dla swojego obszaru (Area 0). Nie widzi szczegółów połączeń wewnątrz Area 1.

### Analiza show ip ospf database summary

Summary LSA (Typ 3) to informacje generowane przez router brzegowy obszaru (ABR - w tym przypadku R2). Służą do ogłaszania dostępności sieci z jednego obszaru do drugiego, bez przekazywania szczegółów topologii (czyli “jak” routery są połączone). Zawierają jedynie informację: “Sieć X jest osiągalna przeze mnie z kosztem Y”.

**Router 1** Widzimy listę Summary LSA dla wszystkich sieci z Area 0 (np. 192.168.10.x, loopbacki R3, R4, R5). Advertising Router: 192.168.0.2 (R2) – R2 jest bramą do reszty sieci.

**Router 5** Widzimy listę Summary LSA dla sieci z Area 1 (czyli Loopback R1 192.168.0.1 oraz łącze 192.168.11.0). Advertising Router: 192.168.0.2 (R2) – R2 informuje szkielet o istnieniu sieci w Area 1.

Bazy danych różnią się, ponieważ każdy router utrzymuje szczegółową mapę tylko własnego obszaru, a o innych obszarach wie jedynie tyle, ile przekaże mu router ABR (R2) w formie podsumowań (Summary LSA).

```
R1#show ip route
```

Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP



D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area  
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2  
E1 - OSPF external type 1, E2 - OSPF external type 2  
i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2  
ia - IS-IS inter area, \* - candidate default, U - per-user static route  
o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

192.168.10.0/30 is subnetted, 5 subnets

O IA 192.168.10.0 [110/20] via 192.168.11.2, 00:03:16, Ethernet0/0  
O IA 192.168.10.4 [110/20] via 192.168.11.2, 00:03:16, Ethernet0/0  
O IA 192.168.10.8 [110/30] via 192.168.11.2, 00:03:16, Ethernet0/0  
O IA 192.168.10.12 [110/30] via 192.168.11.2, 00:03:16, Ethernet0/0  
O IA 192.168.10.16 [110/30] via 192.168.11.2, 00:03:16, Ethernet0/0

192.168.11.0/30 is subnetted, 1 subnets

C 192.168.11.0 is directly connected, Ethernet0/0

192.168.0.0/32 is subnetted, 5 subnets

C 192.168.0.1 is directly connected, Loopback0  
O IA 192.168.0.2 [110/11] via 192.168.11.2, 00:03:17, Ethernet0/0  
O IA 192.168.0.3 [110/21] via 192.168.11.2, 00:03:17, Ethernet0/0  
O IA 192.168.0.4 [110/21] via 192.168.11.2, 00:03:17, Ethernet0/0  
O IA 192.168.0.5 [110/31] via 192.168.11.2, 00:03:19, Ethernet0/0

R2#show ip route

Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP

D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area

N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2

E1 - OSPF external type 1, E2 - OSPF external type 2

i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2

ia - IS-IS inter area, \* - candidate default, U - per-user static route

o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

192.168.10.0/30 is subnetted, 5 subnets

C 192.168.10.0 is directly connected, Ethernet0/1

C 192.168.10.4 is directly connected, Ethernet0/2

O 192.168.10.8 [110/20] via 192.168.10.6, 00:03:57, Ethernet0/2

O 192.168.10.12 [110/20] via 192.168.10.6, 00:03:57, Ethernet0/2  
[110/20] via 192.168.10.2, 00:03:57, Ethernet0/1

O 192.168.10.16 [110/20] via 192.168.10.2, 00:03:57, Ethernet0/1

192.168.11.0/30 is subnetted, 1 subnets

C 192.168.11.0 is directly connected, Ethernet0/0

192.168.0.0/32 is subnetted, 5 subnets

O 192.168.0.1 [110/11] via 192.168.11.1, 00:03:19, Ethernet0/0

C 192.168.0.2 is directly connected, Loopback0

O 192.168.0.3 [110/11] via 192.168.10.6, 00:03:59, Ethernet0/2

O 192.168.0.4 [110/11] via 192.168.10.2, 00:04:00, Ethernet0/1

O 192.168.0.5 [110/21] via 192.168.10.6, 00:04:01, Ethernet0/2

[110/21] via 192.168.10.2, 00:04:01, Ethernet0/1

R3#show ip route

Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP

D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area

N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2

E1 - OSPF external type 1, E2 - OSPF external type 2

i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2

ia - IS-IS inter area, \* - candidate default, U - per-user static route

o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

192.168.10.0/30 is subnetted, 5 subnets

O 192.168.10.0 [110/20] via 192.168.10.14, 00:03:55, Ethernet0/3

[110/20] via 192.168.10.5, 00:03:55, Ethernet0/2

C 192.168.10.4 is directly connected, Ethernet0/2

C 192.168.10.8 is directly connected, Ethernet0/0

C 192.168.10.12 is directly connected, Ethernet0/3

O 192.168.10.16 [110/20] via 192.168.10.14, 00:03:55, Ethernet0/3

[110/20] via 192.168.10.10, 00:03:55, Ethernet0/0

192.168.11.0/30 is subnetted, 1 subnets

O IA 192.168.11.0 [110/20] via 192.168.10.5, 00:03:57, Ethernet0/2

192.168.0.0/32 is subnetted, 5 subnets

O IA 192.168.0.1 [110/21] via 192.168.10.5, 00:03:24, Ethernet0/2

O 192.168.0.2 [110/11] via 192.168.10.5, 00:03:57, Ethernet0/2

```

C      192.168.0.3 is directly connected, Loopback0
O      192.168.0.4 [110/11] via 192.168.10.14, 00:03:58, Ethernet0/3
O      192.168.0.5 [110/11] via 192.168.10.10, 00:03:58, Ethernet0/0

R4#show ip route

Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

192.168.10.0/30 is subnetted, 5 subnets
C      192.168.10.0 is directly connected, Ethernet0/1
O      192.168.10.4 [110/20] via 192.168.10.13, 00:04:00, Ethernet0/3
           [110/20] via 192.168.10.1, 00:04:00, Ethernet0/1
O      192.168.10.8 [110/20] via 192.168.10.18, 00:04:00, Ethernet0/2
           [110/20] via 192.168.10.13, 00:04:00, Ethernet0/3
C      192.168.10.12 is directly connected, Ethernet0/3
C      192.168.10.16 is directly connected, Ethernet0/2

192.168.11.0/30 is subnetted, 1 subnets
O IA   192.168.11.0 [110/20] via 192.168.10.1, 00:04:02, Ethernet0/1

192.168.0.0/32 is subnetted, 5 subnets

```

```

O IA    192.168.0.1 [110/21] via 192.168.10.1, 00:03:29, Ethernet0/1
O       192.168.0.2 [110/11] via 192.168.10.1, 00:04:02, Ethernet0/1
O       192.168.0.3 [110/11] via 192.168.10.13, 00:04:03, Ethernet0/3
C       192.168.0.4 is directly connected, Loopback0
O       192.168.0.5 [110/11] via 192.168.10.18, 00:04:03, Ethernet0/2

```

R5#show ip route

Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP

D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area

N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2

E1 - OSPF external type 1, E2 - OSPF external type 2

i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2

ia - IS-IS inter area, \* - candidate default, U - per-user static route

o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

192.168.10.0/30 is subnetted, 5 subnets

```

O       192.168.10.0 [110/20] via 192.168.10.17, 00:04:05, Ethernet0/2
O       192.168.10.4 [110/20] via 192.168.10.9, 00:04:05, Ethernet0/0
C       192.168.10.8 is directly connected, Ethernet0/0
O       192.168.10.12 [110/20] via 192.168.10.17, 00:04:05, Ethernet0/2
          [110/20] via 192.168.10.9, 00:04:05, Ethernet0/0
C       192.168.10.16 is directly connected, Ethernet0/2

```

192.168.11.0/30 is subnetted, 1 subnets

```

O IA    192.168.11.0 [110/30] via 192.168.10.17, 00:04:06, Ethernet0/2

```

```

[110/30] via 192.168.10.9, 00:04:06, Ethernet0/0

192.168.0.0/32 is subnetted, 5 subnets
O IA    192.168.0.1 [110/31] via 192.168.10.17, 00:03:34, Ethernet0/2
[110/31] via 192.168.10.9, 00:03:34, Ethernet0/0
O       192.168.0.2 [110/21] via 192.168.10.17, 00:04:07, Ethernet0/2
[110/21] via 192.168.10.9, 00:04:07, Ethernet0/0
O       192.168.0.3 [110/11] via 192.168.10.9, 00:04:08, Ethernet0/0
O       192.168.0.4 [110/11] via 192.168.10.17, 00:04:08, Ethernet0/2
C       192.168.0.5 is directly connected, Loopback0

```

### Analiza show ip route

Komendy potwierdzają poprawną segmentację sieci na obszary. Kluczowym dowodem jest znacznik IA (Inter-Area).

- Na R1 (Area 1): Wszystkie trasy do sieci szkieletowych (np. 192.168.10.0, 192.168.0.5) są oznaczone jako O IA. O IA 192.168.0.5 [110/31] via 192.168.11.2 Oznacza to, że R1 wie, iż te sieci znajdują się w innym obszarze i musi wysyłać pakiety do ABR (R2).
- Na R5 (Area 0): Trasy do sieci z Area 1 (Loopback R1 192.168.0.1 oraz łącze R1-R2 192.168.11.0) są oznaczone jako O IA. O IA 192.168.0.1 [110/31] via ...
- Na R2 (ABR): Jako router graniczny, R2 posiada interfejsy w obu obszarach. Dlatego w jego tablicy routingu nie ma tras oznaczonych IA. Traktuje on sieci z obu obszarów jako lokalne (Intra-Area) lub bezpośrednio podłączone (Connected).

## 5. Koszty łącza OSPF

```

R4#ping 192.168.11.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.11.1, timeout is 2 seconds:
!!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 40/131/356 ms
R4#

```

Polecenie ping wykorzystuje protokół ICMP do sprawdzenia osiągalności węzła docelowego.

- Sekwencja znaków !!!!! oznacza, że na 5 wysłanych zapytań otrzymano 5 odpowiedzi.
- Success rate 100% potwierdza pełną łączność w warstwie 3 (IP) pomiędzy routerem R4 a R1. Sieć jest zbieżna i działa poprawnie.

```
R4#traceroute 192.168.11.1
```

```
Type escape sequence to abort.  
Tracing the route to 192.168.11.1
```

```
 1 192.168.10.1 28 msec 12 msec 20 msec  
 2 192.168.11.1 48 msec 68 msec 52 msec  
R4#
```

Polecenie `traceroute` obrazuje rzeczywistą ścieżkę pakietów w sieci. Z powyższego wydruku wynika, że ruch odbywa się następująco:

- Krok 1: 192.168.10.1 – pakiet trafia do routera R2.
- Krok 2: 192.168.11.1 – pakiet dociera do celu (router R1).

Pakiety są przekazywane najkrótszą drogą fizyczną (R4 → R2 → R1). Router OSPF wybrał tę trasę, ponieważ przy domyślnych ustawieniach wszystkie łącza Ethernet mają ten sam koszt, więc trasa bezpośrednia ma najniższy sumaryczny koszt

```
R1#show ip route  
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP  
        D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area  
        N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2  
        E1 - OSPF external type 1, E2 - OSPF external type 2  
        i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2  
        ia - IS-IS inter area, * - candidate default, U - per-user static route  
        o - ODR, P - periodic downloaded static route
```

```
Gateway of last resort is not set
```

```
    192.168.10.0/30 is subnetted, 5 subnets  
O IA   192.168.10.0 [110/20] via 192.168.11.2, 00:08:35, Ethernet0/0  
O IA   192.168.10.4 [110/20] via 192.168.11.2, 00:08:35, Ethernet0/0  
O IA   192.168.10.8 [110/30] via 192.168.11.2, 00:08:35, Ethernet0/0  
O IA   192.168.10.12 [110/30] via 192.168.11.2, 00:08:35, Ethernet0/0  
O IA   192.168.10.16 [110/30] via 192.168.11.2, 00:08:35, Ethernet0/0  
    192.168.11.0/30 is subnetted, 1 subnets  
C       192.168.11.0 is directly connected, Ethernet0/0  
    192.168.0.0/32 is subnetted, 5 subnets  
C       192.168.0.1 is directly connected, Loopback0  
O IA   192.168.0.2 [110/11] via 192.168.11.2, 00:08:37, Ethernet0/0  
O IA   192.168.0.3 [110/21] via 192.168.11.2, 00:08:37, Ethernet0/0  
O IA   192.168.0.4 [110/21] via 192.168.11.2, 00:08:37, Ethernet0/0  
O IA   192.168.0.5 [110/31] via 192.168.11.2, 00:08:38, Ethernet0/0  
R1#
```

## Tablica routingu R1

W powyższym wydruku dla trasy do routera R4 (Loopback 192.168.0.4) widzimy wpis [110/21].

- 110 – to Dystans Administracyjny (Administrative Distance) dla OSPF.
- 21 – to całkowity koszt (metryka) ścieżki.

OSPF obliczył ten koszt sumując wagi wszystkich łączy po drodze: łącze R1-R2 (koszt 10) + łącze R2-R4

(koszt 10) + Loopback R4 (koszt 1) = 21.

```
R2#show interface Ethernet0/1 | include BW
    MTU 1500 bytes, BW 10000 Kbit/sec, DLY 1000 usec,
R2#show ip ospf interface Ethernet0/1 | include Cost
    Process ID 1, Router ID 192.168.0.2, Network Type POINT_TO_POINT, Cost: 10
R2#
```

## Przepustowość do kosztu (R2)

Zastosowanie poleceń na routerze R2 daje następujące wyniki:

- BW 10000 Kbit/sec
- Cost: 10

Protokół OSPF automatycznie oblicza koszt łącza na podstawie jego przepustowości, korzystając z domyślnego pasma referencyjnego wynoszącego 100 Mbps. Wzór wygląda następująco:

$$Koszt = \frac{\text{Reference Bandwidth}}{\text{Interface Bandwidth}} = \frac{100 \text{ Mbps}}{10 \text{ Mbps}} = 10$$

Wynik ten potwierdza, że dla standardowego łącza Ethernet (10 Mbps) OSPF przypisuje koszt równy 10.

```
R2(config-if)#do show ip ospf interface Ethernet0/1 | include Cost
    Process ID 1, Router ID 192.168.0.2, Network Type POINT_TO_POINT, Cost: 100
R2(config-if)#
```

Powyższy wynik potwierdza, że dla interfejsu Ethernet0/1 (łącze R2-R4) parametr Cost został skutecznie zmieniony z domyślnej wartości 10 na 100. Oznacza to, że dla protokołu OSPF to łącze stało się “droższe” (mniej preferowane).

```
R4#ping 192.168.11.1
```

```
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.11.1, timeout is 2 seconds:
!!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 56/65/76 ms
```

Mimo drastycznej zmiany kosztów jednego z łączy, sieć zachowała pełną spójność. Wynik !!!!! (100%) świadczy o tym, że protokół OSPF poprawnie przeliczył tablicę routingu i znalazł alternatywną, działającą ścieżkę do celu.

```
R4#traceroute 192.168.11.1
```

```
Type escape sequence to abort.
Tracing the route to 192.168.11.1

 1 192.168.10.13 56 msec 12 msec 28 msec
 2 192.168.10.5 48 msec 48 msec 48 msec
 3 192.168.11.1 60 msec 56 msec 76 msec
```

Wynik traceroute pokazuje zmianę w ścieżce pakietów. Zamiast bezpośredniego połączenia do R2, pakiety wędrują teraz drogą okrężną: R4 (start) -> R3 (192.168.10.13) -> R2 (192.168.10.5) ->



R1 (cel). OSPF wybrał trasę, która fizycznie jest dłuższa (więcej skoków), ale posiada niższy łączny koszt:

- Stara trasa bezpośrednia (R4-R2): Koszt  $100 + 10$  (R2-R1) = 110.
- Nowa trasa przez R3: Koszt  $10$  (R4-R3) +  $10$  (R3-R2) +  $10$  (R2-R1) = 30.

Ponieważ  $30 < 110$ , protokół wybrał drogę przez router R3.

## 6. Redystrybucja tras

```
R1(config-router)#do show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route
```

Gateway of last resort is not set

```
R      192.168.10.0/24 [120/2] via 192.168.11.2, 00:00:06, Ethernet0/0
      192.168.11.0/30 is subnetted, 1 subnets
C      192.168.11.0 is directly connected, Ethernet0/0
      192.168.0.0/24 is variably subnetted, 2 subnets, 2 masks
R      192.168.0.0/24 [120/2] via 192.168.11.2, 00:00:06, Ethernet0/0
C      192.168.0.1/32 is directly connected, Loopback0
R1(config-router)#
```

```
R5#show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route
```

Gateway of last resort is not set

```
      192.168.10.0/30 is subnetted, 5 subnets
O      192.168.10.0 [110/110] via 192.168.10.17, 00:01:00, Ethernet0/2
O      192.168.10.4 [110/20] via 192.168.10.9, 00:01:00, Ethernet0/0
C      192.168.10.8 is directly connected, Ethernet0/0
O      192.168.10.12 [110/20] via 192.168.10.17, 00:01:00, Ethernet0/2
      [110/20] via 192.168.10.9, 00:01:00, Ethernet0/0
C      192.168.10.16 is directly connected, Ethernet0/2
      192.168.11.0/30 is subnetted, 1 subnets
O E2   192.168.11.0 [110/100] via 192.168.10.9, 00:00:43, Ethernet0/0
      192.168.0.0/24 is variably subnetted, 5 subnets, 2 masks
O E2   192.168.0.0/24 [110/100] via 192.168.10.9, 00:00:42, Ethernet0/0
```

```

O    192.168.0.2/32 [110/21] via 192.168.10.9, 00:01:01, Ethernet0/0
O    192.168.0.3/32 [110/11] via 192.168.10.9, 00:01:01, Ethernet0/0
O    192.168.0.4/32 [110/11] via 192.168.10.17, 00:01:08, Ethernet0/2
C    192.168.0.5/32 is directly connected, Loopback0

```

## Weryfikacja redystrybucji tras

W tablicy routingu R1 pojawiły się trasy oznaczone literą R. R 192.168.10.0/24 [120/2] via 192.168.11.2.

- Router R1 uczy się o sieciach z domeny OSPF za pośrednictwem protokołu RIP.
- Metryka [120/2] - 120 to Dystans Administracyjny dla RIP, 2 to liczba skoków. Wartość ta wynika z konfiguracji na R2, który sztywno ustawił metrykę wejściową dla tras OSPF wchodzących do RIP.

## Analiza znacznika E2 przy Routerze R5

W tablicy routingu R5 pojawiły się trasy oznaczone np. tak O E2 192.168.11.0 [110/100] via 192.168.10.9

O E2 (OSPF External Type 2): Oznacza trasę zewnętrzną, która została redystrybuowana do OSPF z innego protokołu (w tym przypadku z RIP przez router R2). W przeciwieństwie do tras E1, w trasach E2 koszt jest stały w całej domenie OSPF i nie jest powiększany o koszt wewnętrznych łączy przesyłowych.

Wartość 100 wynika z konfiguracji routera ASBR (R2), gdzie ustawiono `default-metric 100`. Router R5 widzi ten koszt jako 100, niezależnie od tego, jak daleko znajduje się od routera R2.

```
R5#show ip ospf database
```

```
OSPF Router with ID (192.168.0.5) (Process ID 1)
```

```
Router Link States (Area 0)
```

Link ID	ADV Router	Age	Seq#	Checksum	Link count
192.168.0.1	192.168.0.1	2018	0x80000003	0x001ECD	2
192.168.0.2	192.168.0.2	76	0x8000000C	0x00B865	5
192.168.0.3	192.168.0.3	1520	0x80000008	0x008E1B	6
192.168.0.4	192.168.0.4	383	0x80000009	0x00E205	6
192.168.0.5	192.168.0.5	1477	0x80000007	0x00BAEB	5

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

Link ID	ADV Router	Age	Seq#	Checksum
192.168.10.14	192.168.0.4	33	0x80000002	0x00C7AB

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

Link ID	ADV Router	Age	Seq#	Checksum	Tag
192.168.0.0	192.168.0.2	54	0x80000001	0x00413A	0
192.168.11.0	192.168.0.2	54	0x80000001	0x00B5BD	0

```
R5#show ip ospf database external
```

OSPF Router with ID (192.168.0.5) (Process ID 1)

Type-5 AS External Link States

Routing Bit Set on this LSA

LS age: 60

Options: (No TOS-capability, DC)

LS Type: AS External Link

Link State ID: 192.168.0.0 (External Network Number )

Advertising Router: 192.168.0.2

LS Seq Number: 80000001

Checksum: 0x413A

Length: 36

Network Mask: /24

Metric Type: 2 (Larger than any link state path)

TOS: 0

Metric: 100

Forward Address: 0.0.0.0

External Route Tag: 0

Routing Bit Set on this LSA

LS age: 60

Options: (No TOS-capability, DC)

LS Type: AS External Link

Link State ID: 192.168.11.0 (External Network Number )

Advertising Router: 192.168.0.2

LS Seq Number: 80000001

Checksum: 0xB5BD

Length: 36

Network Mask: /30

Metric Type: 2 (Larger than any link state path)

TOS: 0

Metric: 100

Forward Address: 0.0.0.0

External Route Tag: 0

**Analiza show ip ospf database external**

- W bazie widoczne są sieci z domeny RIP, np. 192.168.11.0 (połączenie R1-R2) oraz 192.168.0.0 (obejmująca loopback R1).
- Pole Metric: 100 potwierdza, że trasa zewnętrzna ma nadany stały koszt 100, co jest zgodne z poleceniem default-metric 100 wydanym na routerze redystrybuującym (R2).

R5#show ip ospf database router

OSPF Router with ID (192.168.0.5) (Process ID 1)

Router Link States (Area 0)

Adv Router is not-reachable

LS age: 2035  
Options: (No TOS-capability, DC)  
LS Type: Router Links  
Link State ID: 192.168.0.1  
Advertising Router: 192.168.0.1  
LS Seq Number: 80000003  
Checksum: 0x1ECD  
Length: 48  
Number of Links: 2

Link connected to: a Stub Network  
(Link ID) Network/subnet number: 192.168.0.1  
(Link Data) Network Mask: 255.255.255.255  
Number of TOS metrics: 0  
TOS 0 Metrics: 1

Link connected to: a Transit Network  
(Link ID) Designated Router address: 192.168.11.2  
(Link Data) Router Interface address: 192.168.11.1  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

Routing Bit Set on this LSA  
LS age: 96  
Options: (No TOS-capability, DC)  
LS Type: Router Links  
Link State ID: 192.168.0.2  
Advertising Router: 192.168.0.2  
LS Seq Number: 8000000C  
Checksum: 0xB865  
Length: 84  
AS Boundary Router  
Number of Links: 5

Link connected to: a Stub Network  
(Link ID) Network/subnet number: 192.168.0.2  
(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: 192.168.0.3  
(Link Data) Router Interface address: 192.168.10.5  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

Link connected to: a Stub Network  
(Link ID) Network/subnet number: 192.168.10.4  
(Link Data) Network Mask: 255.255.255.252

Number of TOS metrics: 0  
TOS 0 Metrics: 10

Link connected to: another Router (point-to-point)  
(Link ID) Neighboring Router ID: 192.168.0.4  
(Link Data) Router Interface address: 192.168.10.1  
Number of TOS metrics: 0  
TOS 0 Metrics: 100

Link connected to: a Stub Network  
(Link ID) Network/subnet number: 192.168.10.0  
(Link Data) Network Mask: 255.255.255.252  
Number of TOS metrics: 0  
TOS 0 Metrics: 100

LS age: 1549  
Options: (No TOS-capability, DC)  
LS Type: Router Links  
Link State ID: 192.168.0.3  
Advertising Router: 192.168.0.3  
LS Seq Number: 80000008  
Checksum: 0x8E1B  
Length: 96  
Number of Links: 6

Link connected to: a Stub Network  
(Link ID) Network/subnet number: 192.168.0.3  
(Link Data) Network Mask: 255.255.255.255  
Number of TOS metrics: 0  
TOS 0 Metrics: 1

Link connected to: a Transit Network  
(Link ID) Designated Router address: 192.168.10.14  
(Link Data) Router Interface address: 192.168.10.13  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

Link connected to: another Router (point-to-point)  
(Link ID) Neighboring Router ID: 192.168.0.5  
(Link Data) Router Interface address: 192.168.10.9  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

Link connected to: a Stub Network  
(Link ID) Network/subnet number: 192.168.10.8  
(Link Data) Network Mask: 255.255.255.252  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

Link connected to: another Router (point-to-point)  
(Link ID) Neighboring Router ID: 192.168.0.2  
(Link Data) Router Interface address: 192.168.10.6  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

Link connected to: a Stub Network  
(Link ID) Network/subnet number: 192.168.10.4  
(Link Data) Network Mask: 255.255.255.252  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

LS age: 416  
Options: (No TOS-capability, DC)  
LS Type: Router Links  
Link State ID: 192.168.0.4  
Advertising Router: 192.168.0.4  
LS Seq Number: 80000009  
Checksum: 0xE205  
Length: 96  
Number of Links: 6

Link connected to: a Stub Network  
(Link ID) Network/subnet number: 192.168.0.4  
(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: 192.168.0.5  
(Link Data) Router Interface address: 192.168.10.17  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

Link connected to: a Stub Network  
(Link ID) Network/subnet number: 192.168.10.16  
(Link Data) Network Mask: 255.255.255.252  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

Link connected to: a Transit Network  
(Link ID) Designated Router address: 192.168.10.14  
(Link Data) Router Interface address: 192.168.10.14  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

Link connected to: another Router (point-to-point)  
(Link ID) Neighboring Router ID: 192.168.0.2  
(Link Data) Router Interface address: 192.168.10.2

Number of TOS metrics: 0  
TOS 0 Metrics: 100

Link connected to: a Stub Network  
(Link ID) Network/subnet number: 192.168.10.0  
(Link Data) Network Mask: 255.255.255.252  
Number of TOS metrics: 0  
TOS 0 Metrics: 100

LS age: 1515  
Options: (No TOS-capability, DC)  
LS Type: Router Links  
Link State ID: 192.168.0.5  
Advertising Router: 192.168.0.5  
LS Seq Number: 80000007  
Checksum: 0xBAEB  
Length: 84  
Number of Links: 5

Link connected to: a Stub Network  
(Link ID) Network/subnet number: 192.168.0.5  
(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: 192.168.0.4  
(Link Data) Router Interface address: 192.168.10.18  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

Link connected to: a Stub Network  
(Link ID) Network/subnet number: 192.168.10.16  
(Link Data) Network Mask: 255.255.255.252  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

Link connected to: another Router (point-to-point)  
(Link ID) Neighboring Router ID: 192.168.0.3  
(Link Data) Router Interface address: 192.168.10.10  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

Link connected to: a Stub Network  
(Link ID) Network/subnet number: 192.168.10.8  
(Link Data) Network Mask: 255.255.255.252  
Number of TOS metrics: 0  
TOS 0 Metrics: 10

### Analiza show ip ospf database router

Aby znaleźć router pełniący funkcję bramy do sieci zewnętrznej (ASBR), analizujemy LSA routera R2:

```
Link State ID: 192.168.0.2
Advertising Router: 192.168.0.2
LS Seq Number: 8000000C
Checksum: 0xB865
Length: 84
AS Boundary Router
```

Identyfikator routera ASBR to 192.168.0.2 (Router R2).

## 7. Podsumowanie

Ostatecznie:

- Wieloobszarowy OSPF działa stabilnie, a wymiana LSA między strefami przebiega bezbłędnie.
- Manipulacja kosztem łącza skutecznie pozwala sterować wyborem ścieżki przez router.
- Redystrybucja tras połączyła protokoły OSPF i RIP, zapewniając komunikację w całej topologii.

Sieć jest w pełni sprawna, co potwierdziły testy łączności.