ELEKTROTEHNIČKI FAKULTET UNIVERZITETA U BEOGRADU

ANALIZA PRIMENE TEHNOLOGIJA ZA POSTIZANJE VISOKE RASPOLOŽIVOSTI U MREŽAMA

–Master rad–

Kandidat:

Vladimir Damjanović2012/3026

Mentor:

doc. dr ZoranČiča

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SADRŽAJ

1. UVOD

HA (*High Availability*), je sposobnost sistema da obavlja svoju funkciju kontinulano (bez prekida), na duži vremenski period. U mrežama to znači sposobnost mreže da se oporavi od različitih otkaza, nebitno da li su oni unutar same mreže ili van nje. U praksi mreža može da otkaže, ili može doći do prekida servisa zbog neizbežnih netehničkih faktora. Da bi poboljšali raspoloživost sistema treba poboljšati otpornost na otkaze samog sistema, ubrzati vreme oporavka od otkaza, kao i smanjiti uticaj otkaza na servise. Različite vrste poslova imaju različite zahteve po pitanju dostupnosti njihovih servisa. Mreža servis provajdera treba da ima veoma visoku dostupnost, kao mreža kroz koju prolaze servisi svih njenih korisnika i koja nudi servise istim. Novi korisnici koji su zavisni u većoj meri od svojih servisa sada traže i SLA (*Service Level Agreement*), čime je značaj visoke rapoloživosti još veći.

Ono što mi želimo da predložimo je HArešenje za topologiju mreže koju koristimo za praktični deo rada (koja predstavlja servis provajder mrežu), koje će garantovati visoku raspoloživost svih servisa u slučaju različitih varijanti otkaza u mreži. Prikazaćemo konfiguraciju predloženih tehnologija za različite delove mreže, i uporediti ponašanje mreže sa primenom tih tehnologija, u odnosu na mrežu u kojoj ih ne primenjujemo, analizirati i na kraju doneti zaključke o valjanosti predloženog rešenja.

U prvom delu rada, “pregled HA tehnologija” opisane su tehnologije od značaja, za ovu tezu. Naglasak je dat na HA tehnologije sa osvrtom na FRR (*Fast ReRoute*), BFD (*BiForwarding Detection*) i VRRP (*Virtual Router Redundancy Protocol*). Opisane su BFD, E-VRRP (*Enchanced – VRRP*), MPLS TE *Hot-Standby*(*MultiProtocol Label Switching Traffic Engineering Hot-Standby*), IP FRR (*Internet Protocol Fast ReRoute*), TE FRR (*Traffic Engineering Fast ReRoute*), VPN FRR (*Virtual Private Network Fast ReRoute*), OSPF BFD (*Open Shortest Path First BiForwarding Detection*). U sekciji “Konfiguracija mreže” je prikazan softver koji se koristio za rad, Huawei eNSP (*enterprise Network Simulation Platform*), prikazana je oprema koja je korišćena za postavljanje naše IP/MPLS (I*nterenet Protocol / Multi Protocol Label Switching*)mreže i prikazani su postupno koraci u konfigurisanju te mreže. U sekciji “Testiranje i analiza tehnologija” je objašnjena procedura testiranja koja je rađena sa i bez različitih HA tehnologija i prikazani su rezultati testiranja. I na kraju su analizirana testiranja i prikazani zaključci. Na početku rada postoji sadržaj, a na kraju je navedena i literatura koja je korišćena pri pisanju ovog rada.

2. PREGLED HIGH AVAILABILITY (HA) TEHNOLOGIJA

2.1. Osnovni koncepti HA

HA sugeriše da mreža ili proizvod imaju visoku raspoloživosti da mrežni servisi mogu normalno da se koriste kada uređaj ili deo mreže otkaže. HA posmatramo sa više aspekta:

- Sistemska i hardverska pouzdanost (u smislu redundantih ključnih hardverskih komponenti itd...)
- Softverska pouzdanost (u smislu pouzdanosti aplikacija i slično)
- Pouzdanost IP mreže

Mi ćemo se fokusirati na analiziranje pouzdanosti IP mreže.

2.2. Kako merimo HA?

Indikatori za pouzdanost su MTTR (*Mean Time to Repair*), MTBF (*Mean Time Between Failures*)i *availability* (raspoloživost). Uopšteno govoreći, pouzdanost proizvoda ili sistema se procenjuje najčešće na osnovu dva indikatora:

- *Mean Time to Repair* (MTTR)
- *Mean Time Between Failures* (MTBF)

2.2.1. MTTR

MTTR ukazuje na sposobnost sistema da se vrati u normalno stanje. MTTR je prosečno vreme koje će komponenti ili uređaju trebati da se povrati od otkaza. MTTR je u suštini atribut koji nam govori koja je tolerancija na otkaz. MTTR se obično koristi prilikom definisanja ugovora o održavanju.

Formula koja se koristi da se izračuna MTTR je [2]:

MTTR = Vreme detekcije otkaza + vreme zamene dela + vreme podzianja sistema + vreme oporavka linka + vreme oporavka ruta + vreme povratka prosleđivanja (*Forwarding*)

Da bi se sistem vratio u operativno stanje nakon što dođe do otkaza, potrebno je da se nekoliko različitih procesa odigra u cilju vraćanja u operativno stanje. Potrebno je da se detektuje da je došlo do otkaza (vreme se može razlikovati od tipa otkaza i tehnike detekcije otkaza). Zatim vreme zamene dela koji je otkazao (u slučaju da govorimo o fizičkom oštećenju). Nakon zamene dela tipično je potrebno startovati uređaj ponovo i to traje neko vreme (vreme podizanja sistema). Nakon što se sistem podigne, potrebno je da dođe do detekcija interfejsa, linkova, zatim da se razmene rute (formira *routing table*), kao i da se iznova kreira *forwarding* tabela.

Što je manji MTTR veća je raspoloživost.

2.2.2. MTBF

MTBF ukazuje na verovatnoću otkaza. To je indeks pouzdanosti. MTBF je pretpostavljeno vreme između otkaza tokom rada, obično se izražava u satima.

2.2.3. Availability (raspoloživost)

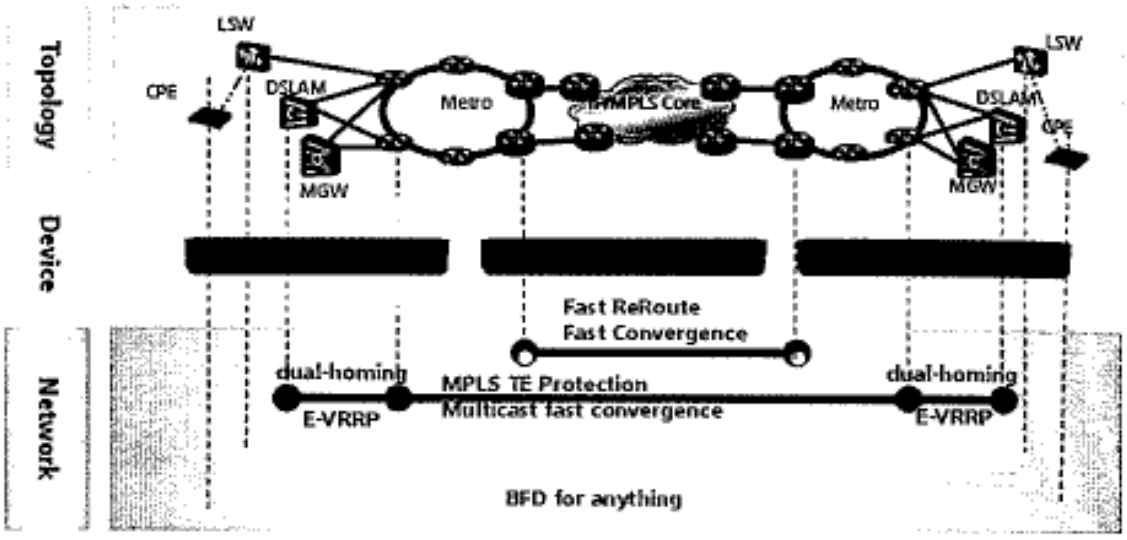
Raspoloživost ukazuje na korisnost sistema. Formula za izračunavanje raspoloživosti je sledeća [2]:

$$Availability = \frac{MTBF}{MTBF + MTTR}$$

Raspoloživost se može popraviti povećavanjem MTBF-a i/ili smanjenjem MTTR-a. U telekomunikacionoj industriji, 99,999% raspoloživost znači da imamo prekid servisa manje od 5 min, na period od godinu dana. U praksi u mrežama, mrežni otkazi i prekidi servisa su neizbežni. Zbog toga, je bitno da obezbedimo tehnologije koje će omogućiti uređajima da se povrate od otkaza veoma brzo. Takve tehnologije povećavaju raspoloživost uređaja i smanjuju MTTR.

2.3. Pouzdanost IP mreže

HA tehnike na mrežnom nivou su tehnike koje se koriste za zaštitu servisa od prekida kada link ili ceo element u mreži otkaže.



Slika 2.3.1 Logički prikaz servis provajder mreže

Kao što vidimo na slici 2.3.1[2] IGP*(Interior Gateway Protocol)* brza konvergencija, FRR (*Faste ReRoute*) i MPLS TE zaštita se primenjuju u jezgru (*core*) delu mreže. *Dual – homing* konekcije i E-VRRP se koriste u pristupnom (*access*) delu. BFD *(Bidirectional Forwarding Detection)* je primenjen na celoj mreži kao tehnologija za detekciju otkaza. Nešto više o ovim tehnologijama u nastavku.

2.4. Brza Detekcija

2.4.1. BFD

BFD je uniformni mehanizam detekcije za celu mrežu. Detektuje otkaze brzo i monitoriše prosleđivanje saobraćaja i konektivnost linkova ili IP ruta u mreži. Uopšteno, u mreži se pad linka detektuje na neki od sledećih načina [3]:

- Hardverski detekcioni signali, kao na primer oni koje pružaju SDH (*Synchronous Digital Hierarchy*) alarm funkcije, se koriste da detektuju brzo otkaz linka.
- Ako hardverska detekcija nije dostupna, postoji *Hello* mehanizam protokola rutiranja koji detektuje otkaze.

Kod ovakvih metoda postoje sledeći problemi:

- Hardver se koristi samo od strane određenog broja medijuma za detektovanje otkaza.
- Protokolu rutiranja *Hello* mehanizma je potrebno preko 1 sec da detektuje otkaz. Ako se podaci prosleđuju brzinom koja se meri u gigabitima, velika količina podataka će biti odbačena.
- U malim *layer 3* mrežama, ako nema protokola rutiranja, nemamo ni *Hell*o mehanizam da detektuje problem. U tim slučajevima problem između međusobno povezanih sistema je teško uočiti.

BFD je razvijen da reši ove probleme. On omogućava sledeće funkcije:

- Detektuje problem brzo duž putanje između suseda koji prosleđuju podatke, sa malim opterećenjem i velikom brzinom.
- Koristi jedinstveni mehanizam da prati bilo koju vrstu medijuma i protokola u realnom vremenu. Vreme detekcije i cena variraju.

2.4.2. BFD Mehanizam Detekcije

BFD mehanizam detekcije se zasniva na tome da dva sistema uspostave BFD sesiju i periodično šalju BFD kontrolne pakete duž putanje između njih. Ako jedna strana ne primi BFD kontrolni paket predefinisani broj puta u zadatom periodu, sistem smatra da se desio otkaz na putanji.

BFD kontrolni paketi su enkapsulirani u UDP (*User Datagram Protocol*)paketima. U inicijalnoj fazi BFD sesije, obe strane pregovaraju oko parametara, kao što su diskriminatori, očekivani minimalni vremenski intervali slanja i primanja BFD kontrolnih paketa, i status lokalne BFD sesije, koji se nose u BFD kontrolnom paketu. Nakon što pregovaranje bude uspešno, BFD kontrolni paketi se šalju putanjom između dve strane u vremenskim intervalima koji su dogovoreni.

Da bi dostigli zahteve brze detekcije, BFD protokol specificira da je jedinica za intervale slanja u milisekundama. Zbog ograničenja uređaja, intervali slanja i primanja za BFD kod većine proizvođača mogu da dostignu samo nivo milisekundi. Uređaje koje koristimo u simulaciji imaju minimalni period detekcije od 30 milisekundi.

BFD omogućava dva moda detekcije [3]:

- Asinhroni mod: U ovom modu dve strane periodično šalju BFD kontrolne pakete. Ako sistem ne primi BFD kontrolni paket u zadatom period, sistem javlja da je BFD sesija pala (*Down*).
- *Demand mode*: Ako veliki broj BFD sesija postoji u sistemu, periodično slanje utiče na performanse sistema. Da bi sprečili ovaj problem, može se koristiti *demand mode*. U *demand mode*-u pošto su BFD sesije uspostavljene, sistem ne šalje periodično BFD kontrolne pakete. Sistem detektuje konektivnost putem drugih mehanizama (kao što su *Hello* mehanizmi protokola rutiranja i hardverski mehanizmi detekcije) da bi se smanjila cena BFD sesije.

Postoji još jedna funkcija oba moda. To je *echo* funkcija. Kada je *echo* funkcija uključena, BFD kontrolni paket se šalje korišćenjem jedne od sledećih metoda. Lokalni sistem šalje BFD kontrolne pakete, a udaljeni sistem ga šalje nazad kroz kanal za prosleđivanje. Ako nekoliko *echo* paketa nisu primljena u kontinuitetu, proglašava se da je sesija *Down*. *Echo* funkcija može da radi sa asinhronim modom ili *demand mod*e - om.

BFD sesija ima četiri stanja. *Down, Init, Up* i *AdminDown*:

- *Down*: ukazuje da je sesija *Down* ili da je tek kreirana
- *Init*: ukazuje da lokalna strana može da komunicira sa drugim krajem, i lokalni kraj očekuje da promeni stanje u *Up*
- *Up*: ukazuje da je sesija ostvarena uspešno
- *AdminDown*: ukazuje da je sesija u *AdminDown* stanju

Stanje sesije se šalje u *State* polju u BFD kontrolnom paketu. Lokalni uređaj menja stanje sesije na osnovu primljene informacije o statusu sesije.

Kada BFD sesija treba da se uspostavi ili da bude obrisana, BFD radi *three-way handshake* da bi oba sistema bila svesna promene statusa.

Uspostavljanje BFD sesije (slika 2.4.2) funkcioniše u sledećim koracima [2]:

(1) Ruter A i Ruter B uključuju BFD. Početno stanje BFD state machine je *Down*. Ruter A i Ruter B šalju BFD kontrolne pakete sa *State* poljem kao *Down*. Ako je BFD sesija konfigurisana statički, vrednosti diskriminatora u paketima su statički konfigurisane. Ako su BFD sesije konfigurisane dinamički, vrednost diskriminatora su podešene na 0.

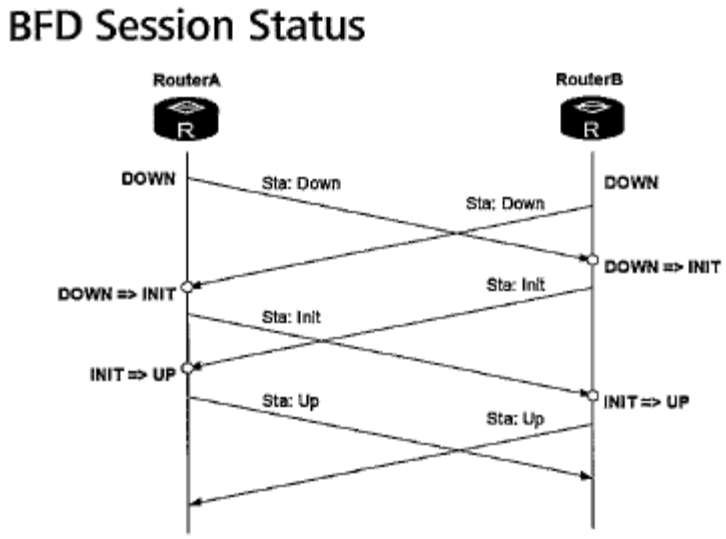
(2) Pošto se BFD paketi prime sa *State* poljem *Down*, Ruter B menja status sesije u *Init*, i šalje BFD paket sa Statusnim poljem kao *Init*.

(3) Pošto se lokalni BFD status sesije od Rutera B promenio u *Init*, Ruter B ne procesira više pakete koji stižu sa *State* poljem *Down*.

(4) Promena *State* polja u BFD sesiji na Ruteru A je isto kao i na Ruteru B

(5) Pošto se primi BFD paket sa *State*poljem kao Init, Ruter B menja stanje u *Up*

(6) Kod Rutera A se isto događa promena statusa sesije kao i kod Rutera B, u *Up*.



Slika 2.4.2 Uspostavljanje BFD sesije

BFD se može koristiti u različitim varijantama. Mi ćemo ga koristiti u nekim od sledećih:

- BFD for *default-ip*: *Single-hop* BFD sesija brzo detektuje otkaze na direktnim linkovima u mreži. Ako je link interfejsa *Layer 3* fizički interfejs ili *Layer 2* interfejs koji nema IP adresu, konfigurišemo statički BFD za detekciju linka.
- BFD za OSPF: Kod OSPF-a ruter periodično šalje *Hello* pakete ka susedu, radi detekcije ako ima nekih izmena ili problema. Detekcija problema traje duže od 1 sec. Kako se tehnologija razvija, *voice*, video ili neki VOD servisi se koriste u velikoj meri. Ovi servisi su osetljivi na gubitak paketa i kašnjenja. U ovim slučajevima ovako duga detekcija problema će dovesti do gubitka velike količine podataka i pada servisa. Da bi smo dostigli HA standarde u mreži sa ovim servisima, koristimo BFD za OSPF. Kada se BFD za OSPF konfiguriše, na samom interfejsu ili na celom OSPF procesu, promena stanja linka se može brzo detektovati u vremenu reda milisekundi. Ovo značajno ubrzava konvergenciju OSPF-a kada se promeni stanje linka.
- BFD za LDP (*Label Discovery Protocol*) Tunel: Dinamički BFD se može konfigurisati da se uspostavi dinamička BFD sesija da prati primarni i *backup* LDP LSP(*Link State Path*) u LDP tunelu. Ako BFD detektuje otkaz, BFD komunicira sa LDP *upper-layer* aplikacijom da odradi *switchover* zaštitu.
- BFD za TE: omogućava aplikaciji kao što su VPN FRR da brzo prebaci saobraćaj ako primarni tunel padne, i tako spreči prekid servisa
- BFD za VRRP: BFD može brzo da detektuje otkaz linka ili IP ruta. BFD za VRRP omogućava brzi prelaz između *master*/*backup* VRRP-a da bude dovršen za manje od 1 sec, i time spreči gubitak podataka. BFD sesija se formira između *master* i *backup* uređaja u VRRP grupi. BFD detektuje problem u komunikaciji u VRRP grupi, i komunicira da VRRP odradi *master*/*backup* prelaz, i time smanji vreme prekida servisa.

2.5. FRR Tehnologije

FRR je MPLS i IP tehnologija koja nam za rezultat daje otporniju mrežu. Ona omogućava brz oporavak saobraćaja za kritične servise nakon što link ili ruter otkažu. Može da omogući

oporavak saobraćaja za reda 50 ms. U nastavku ćemo izložiti neke varijante FRR-a i njihove osnovne koncepte i načine funkcionisanja.

2.5.1. IP FRR

Vreme konvergencije protokola rutiranja u IP mreži traje dugo. Uobičajno reda sekunde. Čak i kada imamo implementiranu brzu konvergenciju, i dalje je to reda sekundi. Takva konvergencija (koja traje reda sekundi) ne zadovoljava zahteve servisa kao što su *voice*, video itd. Zbog ovoga koristimo IP FRR tehniku za zaštitu na interfejs nivou.

Konvergencija koja se obavlja na *forwarding* nivou je značajno brža od one na IP (*routing*) nivou. Princip FRR tehnologije je da koristi *bypass* putanju (unapred određenu) koju ima u *forwardingplane*-u za brzo prebacivanje. Kada se pad linka desi, sa IP FRR brzo prebacivanje saobraćaja na drugi link može da se odigra za oko 50 ms.

2.5.2. LDP FRR

IP FRR nemože efikasno da štiti saobraćaj u MPLS mreži. Za takvu vrstu zaštite koristimo LDP FRR, za protekciju na nivou interfejsa. U poređenju sa brzom konvergencijom u IGP-u, LDP FRR proračunava sekundarni interfejs unapred. Zbog toga kalkulacija rute i ponovno uspostavljanje LSP-a posle otkaza traje kraće, odnosno prelaz se ubrzava.

Kada LDP radi u *DownstreamUnsolicited* (DU) *labeldistribution* modu, uređena *label* kontrola i *liberallabelretention*, LSR čuva sve poruke mapiranja labela. Samo poruka mapiranja labele poslata od strane sledećeg hopa koja odgovara FEC (*Forwarding Equivalence Class*), može da generiše *label* tabelu za prosleđivanje.

U ovakvoj varijanti, kada se generiše tabela za prosleđivanje, kreira se i *bypass* LSP. Paket se normalno prosleđuje kroz primarni LSP. Kada odlazni interfejs od primarnog LSP-a je *Down*, paketi se prosleđuju na *bypass* LSP. Na ovaj način obezbđujemo kontinuitet u saobraćaju u kratkom vremenskom roku pre konvergencije mreže.

2.5.3. MPLS TE FRR

MPLS TE FRR se često koristi kao rešenje problema sa otkazima. Ideja je da se napravi *end-to-end* TE tunel između PE(*Provider Edge*) uređaja i *bypass* LSP-aza zaštitu primarnog LSP-a. Kada ruter detektuje da je primarni LSP nedostupan zbog pada nekog noda ili linka, saobraćaj se prebacuje na *bypass* LSP.

U smislu koncepta, MPLS TE FRR može da omogući brzo prebacivanje kada link ili element između dva PE uređaja koji služe kao krajnje tačke TE tunela.

Ali, MPLS TE FRR se nemože nositi sa otkazom samog PE uređaja koji služi kao startna ili početna tačka TE tunela. Kada PE uređaj otkaže, saobraćaj će se nastaviti konvergencijom ruta i LSP konvergencijom. Vreme konvergencije biće srazmerno broju ruta u MPLS VPN mreži i broju hopova u mreži. Tipično konvergencija može da traje reda 5 sec, što je duže od 1 sec za *end-to-end* konvergenciju saobraćaja kada *node* padne.

FRR je tehnika da se primeni delimična protekcija u MPLS TE. FRR brži prelaz može da dostigne 50 ms. To umanjuje gubitak podataka kada mreža otkaže.

FRR je samo privremena zaštita. Pošto zaštićeni link ili *node* se povrati ili novi LSP uspostavi, saobraćaj se vraća nazad na originalni LSP ili novo uspostavljeni LSP.

Pošto se FRR funkcija konfiguriše a neki LSP, saobraćaj se prebacuje na *standby* link kada određeni link ili element na LSP-u otkaže. U međuvremenu *ingress* LSP pokušava da uspostavi novi LSP.

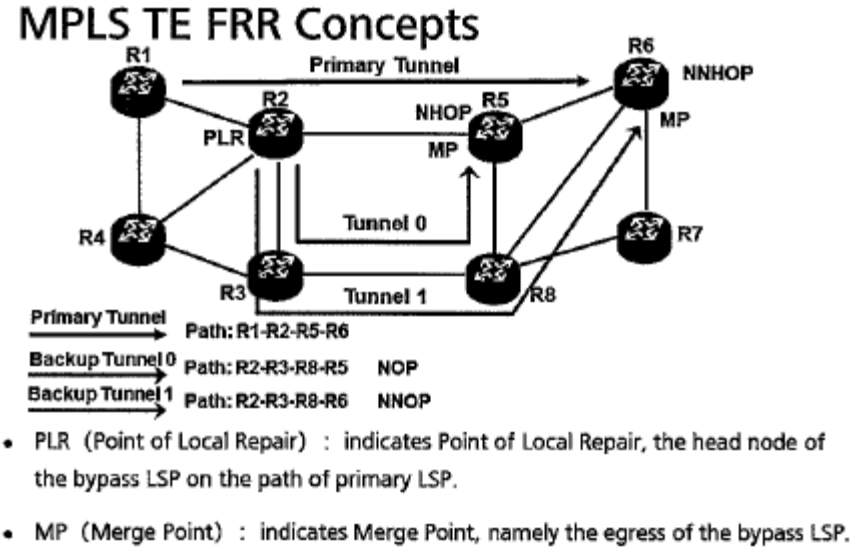
Na osnovu objekta koji štitimo možemo imati

- Protekciju linka
- Protekciju noda (elementa)

Tipovi protekcije koji su podržani su:

- Jedan na jedan *backup*
- *Facility backup*

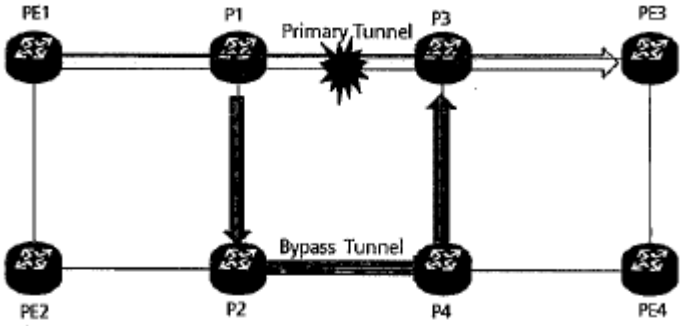
Osnovni koncepti (slika 2.5.3) [2] su sledeći. Imamo primarni LSP, odnosno LSP koji ćemo da štitimo. Imamo *bypass* LSP, odnosno LSP koji štiti primarni. Zatim imamo PLR(*Point of Local Repair*), koji pokazuje na *Point of Local Repair*, odnosno početak odakle radimo *bypass* LSP na putanji primarnog LSP. I imamo MP, odnosno *Merge Point*, koji je *egress* od *bypass* LSP-a. Treba da bude na putanji primarnog LSP-a.



Slika 2.5.3 MPLS TE FRR koncepti

2.5.4. TE FRR

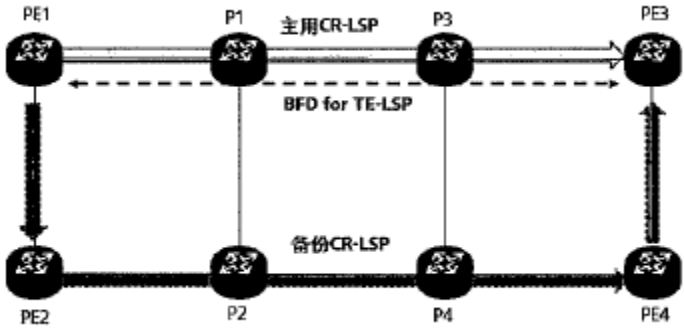
Kada direktan link padne i primarni LSP prolazi kroz taj link (kao što vidimo na slici 2-4, obeleženo sa *Primary Tunnel*). Onda se koristi *bypass* LSP (koristi se za sve TE tunele koji su prolazili kroz taj link), na slici 2.5.4[2] označen kao *Bypass Tunnel*.



Slika 2.5.4 TE FRR koncepti

2.5.5. MPLS TE Hot-Standby

MPLS TE *Hot-Standby*, je konfiguracija CR-LSP (*Constraint-based Routing – Link State Path*)*backup*-a. Odnosno ovo je protekcija sa kraja na kraj jednog tunela (slika 2.5.5) [2]. Ova *backup* putanja se uspostavlja čim se uspostavi i primarna putanja. Ako primarni CR_LSP otkaže, saobraćaj se brzo prebaci na *backup* CR-LSP, i time osigurava nesmetani prenos podataka. Ako i primarni i *backup* tunel padnu, bira se *best-effort* putanja.



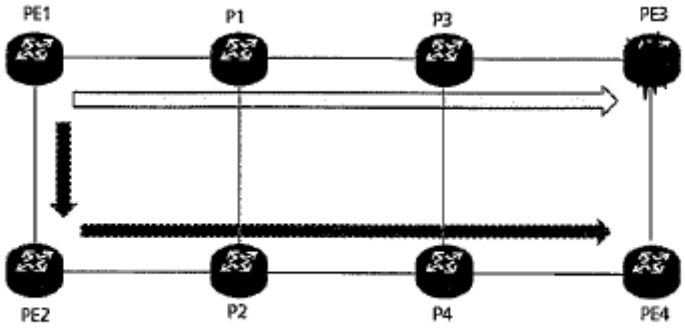
Slika 2.5.5 MPLS TE *Hot-Standby* koncepti

2.5.6. VPN FRR

Zasnovan na VPN *fast route switching* tehnologiji, VPN FRR pripremi *switchover* unos za prosleđivanje koji je usmeren prema primarnom, *backup* i *remote* PE-u. Sa VPN FRR tehnologijom kada PE *node*otkaže, konvergencija *end-to-end* servisa traje manje od 1 sec.

Na PE uređaju, koji je konfigurisan sa VPN FRR (na slici 2-6 to je PE1) [2], odgovarajuće VPNv4 (*Virtual Private Network version 4*)rute su izabrane da *match police*-u. Za ove rute, uz one koje su poslate od *next-hop*-ova (uključujući *forwardingprefix, inner tag* i selektovane *outer* LSP tunele), informacija inferiornom *next hop*-u su takođe ubačene u *forwarding* unosima.

Kada preferirani *next-hopnode* padne (PE3 na slici 2.5.6), što detektujemo putem BFD ili MPLS OAM(*Operation Administration and Maintenence*), PE detektuje da spoljni tunel koji se vezuje sa PE putem preferiranog noda nije dostupan. PE označava da *outer* LSP nije dostupan, i to se označava i u *forwarding* tabeli. Kada se u *forwarding* delu dobije informacija o statusu LSP tunela, on na osnovu toga daje odgovarajuću informaciju, odnosno daje rute za inferiorni *next-hop*(odnosno prema PE2, ka PE4, kao što se vidi na slici 2.5.6).

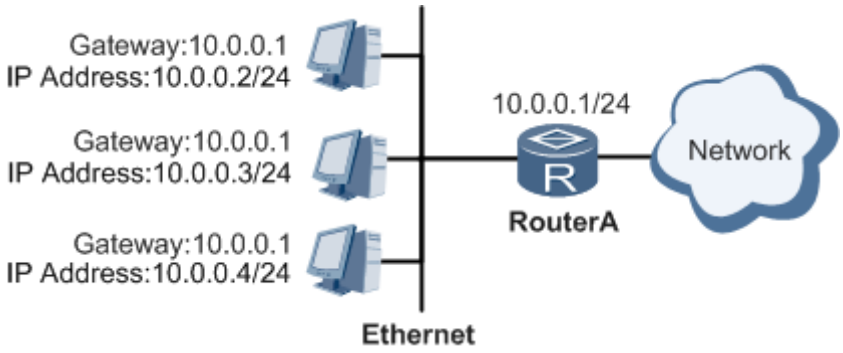


Slika 2.5.6 VPN FRR Koncept

2.6. VRRP

VRRP je *fault-tolerant* protokol na ruterima. Ovi ruteri obezbeđuju jedinstvenu *default-gateway* adresu za hostove. Ako VRRP-*enabled* ruter padne, drugi VRRP-*enabled* ruter će preuzeti saobraćaj, i na taj način osigurati kontinuitet i pouzdanost za mrežnu komunikaciju.

Host-ovi u LAN-u su obično povezani na spoljnu mrežu preko *default-gateway*-a (na slici 2.6.1, ruter A) [3]. Kada korisnik šalje pakete za neku adresu koja je van njegove mreže, ti paketi će ići na *default-gateway*, a odatle će dalje da idu ka spoljnoj mreži.

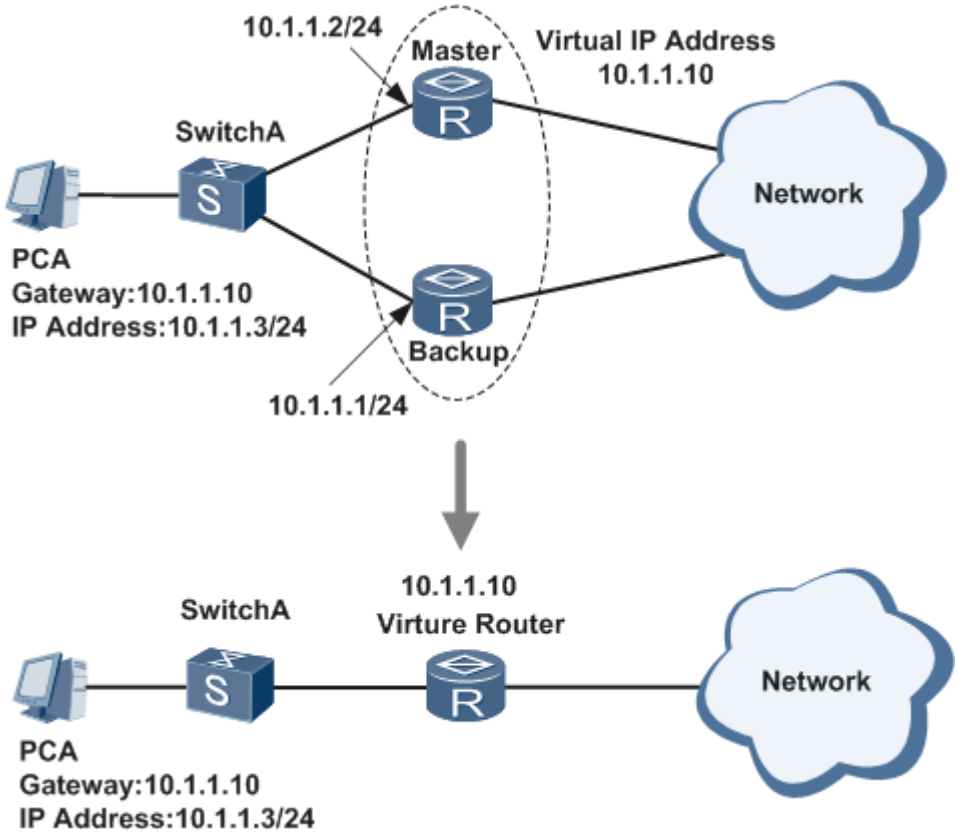


Slika 2.6.1 Prikaz dela mreže bez VRRP-a

Ako ruter A padne (slika 2.6.1), korisnici koji su konektovani nemogu da komuniciraju sa spoljnom mrežom. Taj problem će postojati čak i ako dodamo još jedan ruter u LAN, jer uglavnom možemo samo jedan *default-gateway* da konfigurišemo na *host*-u. Varijanta u kojoj možemo da obezbedimo konektivnost sa spoljnom mrežom čak i ako bi jedan ruter pao je putem VRRP tehnologije.

VRRP tehnologija je *fault-tolerant* protokol definisan u RFC 3768. VRRP dozvoljava logičkim uređajima da rade nezavisno od fizičkih uređaja, i implementira izbor rute prema više *gateway*-a.

VRRP je na primeru sa slike 2.6.2 [3] uključen na dva rutera. Jedan je *master*, a drugi je *backup*. Ova dva rutera formiraju virtuelni ruter i ovaj virtuelni ruter ima virtuelnu IP adresu i virtuelnu MAC (*Media Access Control*)adresu. *Host*-ovi prate stanje virtuelnog rutera, a ne fizičkih *master* i *backup* rutera. Samo *master* ruter prosleđuje pakete, a ako *master* ruter padne, *backup* ruter će biti novi *master* i preuzeće saobraćaj.



Slika 2.6.2 VRRP koncepti

2.6.1. VRRP Fast Switchover (E – VRRP)

Osnovna ideja je ubrzati *switchover* kada VRRP *master* padne. BFD može da pruži takvu informaciju brzo. Može se koristiti u sledećim situacijama [1]:

- Kada se problem desi na interfejsu gde je VRRP backup grupa kreirana
- *Master* i *backup* ruter nisu direktno konektovani
- *Master* i *backup* ruter su direktno konektovani, ali postoji neki uređaj za transmisiju između njih.

BFD prati vezu komunikacije između *master* i *backup* rutera. I ako se javi problem u komunikaciji, *backup* ruter smatra da je *master* nedostupan i proglašava se *master*-om.

Ono što je potrebno da bi ovo napravili je sledeće[1]:

- BFD sesija koja prati interfejs na *backup* ruteru mora biti konektovana na *master* ruter
- Kada je *master* ruter nedostupan, prioritet *backup* interfejsa se mora povećati, i *backup* ruter se unapređuje u *master* ruter

3. KONFIGURACIJA MREŽE

3.1. Instalacija softvera potrebnog za simulaciju

Za pravljenje naše topologije i sredine za testiranje, koristili smo Huawei softverski paket eNSP, verzija 1.2.00.350. Ruteri koji su korišćeni u simulaciji su simulirani AR1220-S ruteri, sa verzijom softvera V100R002C00.

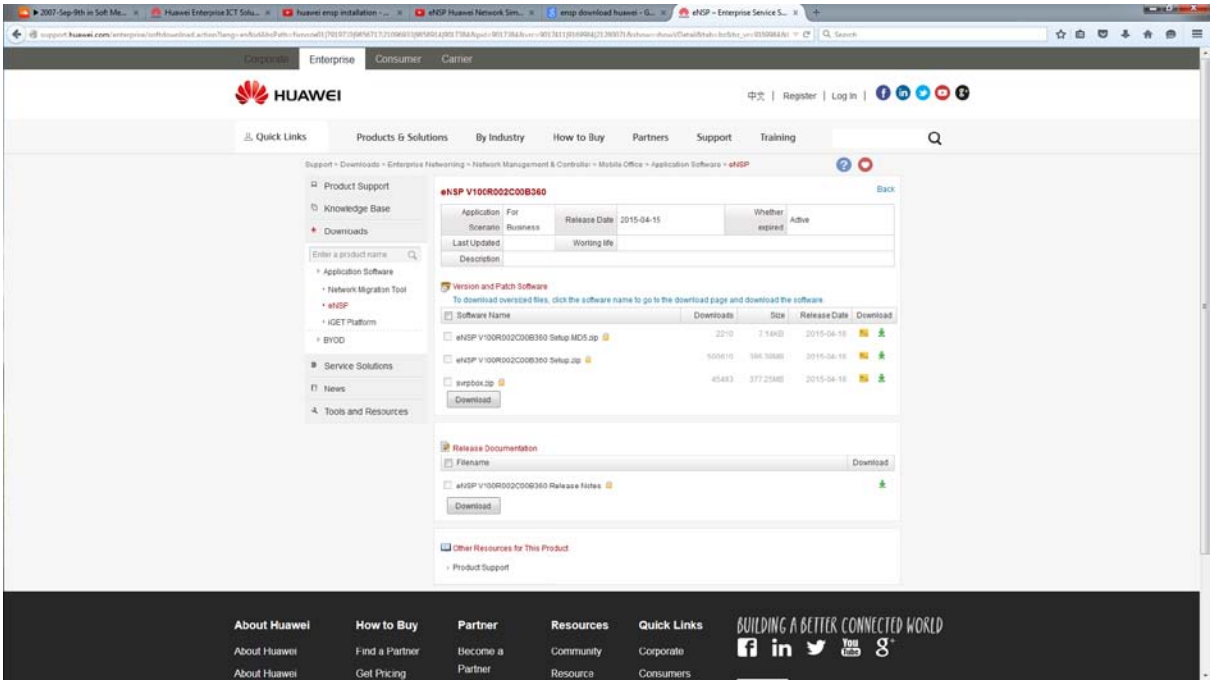
Instalaciju eNSP-a se može pronaći na http://e.huawei.com/en/ gde se dalje ide na *support* deo, gde se može naći sama aplikacija.

U vreme skidanja link gde se može naći download je bio na

http://support.huawei.com/enterprise/softdownload.action?lang=en&idAbsPath=fixnode01|7919710|9856717|21096933|9858914|9017384&pid=9017384&vrc=9017411|9169984|21280071&show=showVDetail&tab=bz&bz_vr=9169984&bz_vrc=21280071&nbz_vr=9169984

a prikaz strane se može videti na slici 3.1.1.

Potrebno je registrovati se na sajtu da bi mogli da skinete ovaj softver.

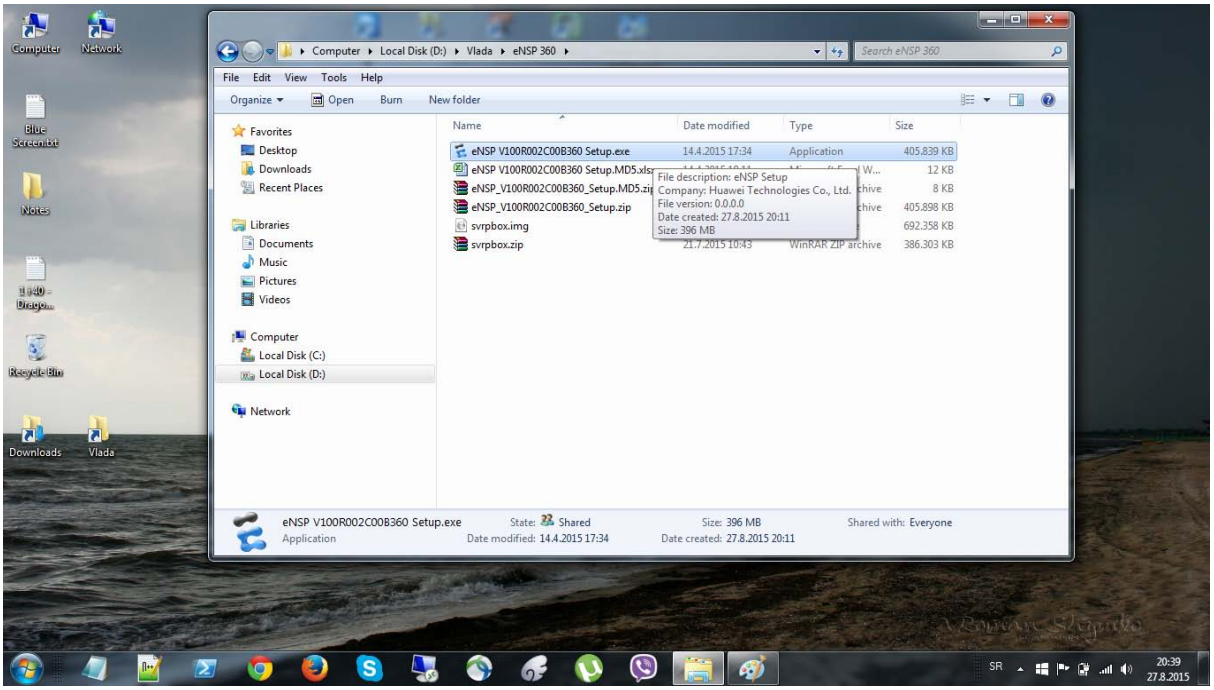


Slika 3.1.1 Izgled strane sa koje se skida eNSP

Nakon što se skine eNSP instalacija sa sajta, njegova instalacija je prilično jednostavna. Svodi se na pritiskanje nastavka instalacije na svakom koraku, i potrebno je instalirati sve programe

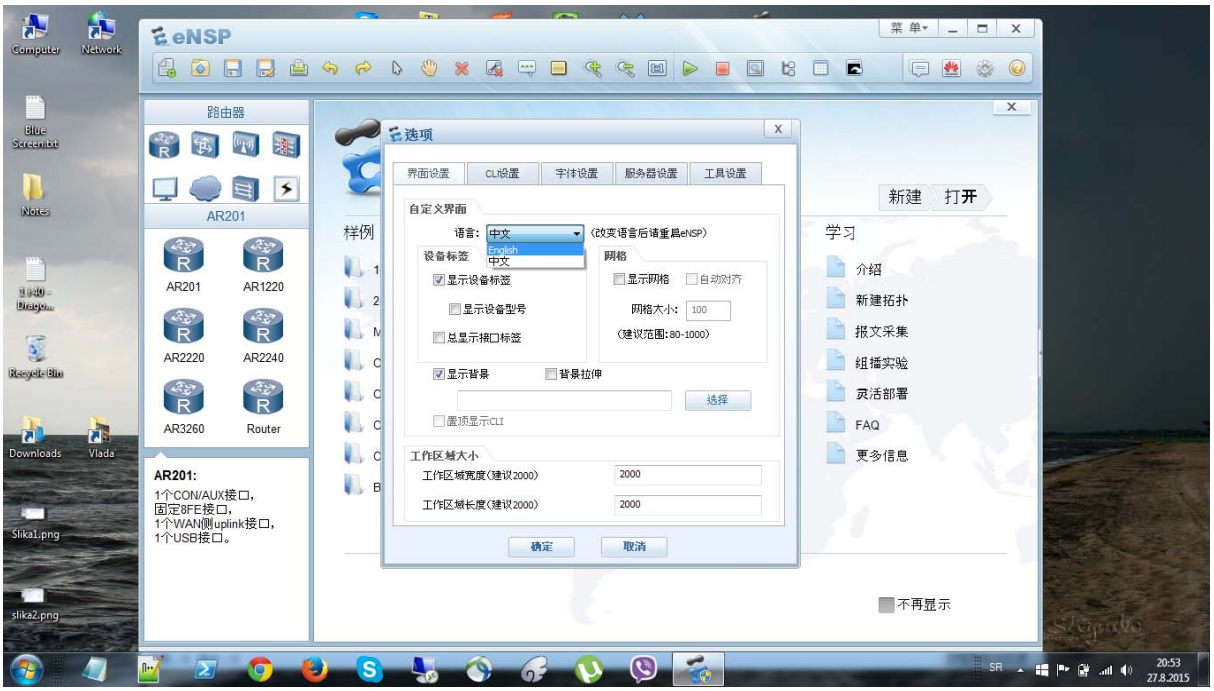
usput koji se ponude kao što su, Oracle VM Virtual Box (potreban za virtualizaciju rutera), Wireshark (da bi mogli da se analiziraju paketi). Tipična jednostavna instalacija Windows softvera.

Ispod je dato nekoliko sličica (slike 3.1.2 do 3.1.4) iz procesa instalacije i prvog startovanja aplikacije. Naznačeno je kako da promenite na engleski (slika 3.1.4), pošto nakon instalacije GUI(*Graphical User Interface*) će biti na kineskom jeziku. U gornjem desnom uglu postoji ikonica '?' gde postoji pregledno urađen*help*, gde se lako može videti kako da koristite program i pravite topologiju (koristite rutere ispod kojih piše *Router*).



Slika 3.1.2 Prikaz fajla koji startovati za instaliranje eNSP-a

Slika 3.1.3 Prikaz eNSP-a pri prvom startovanju

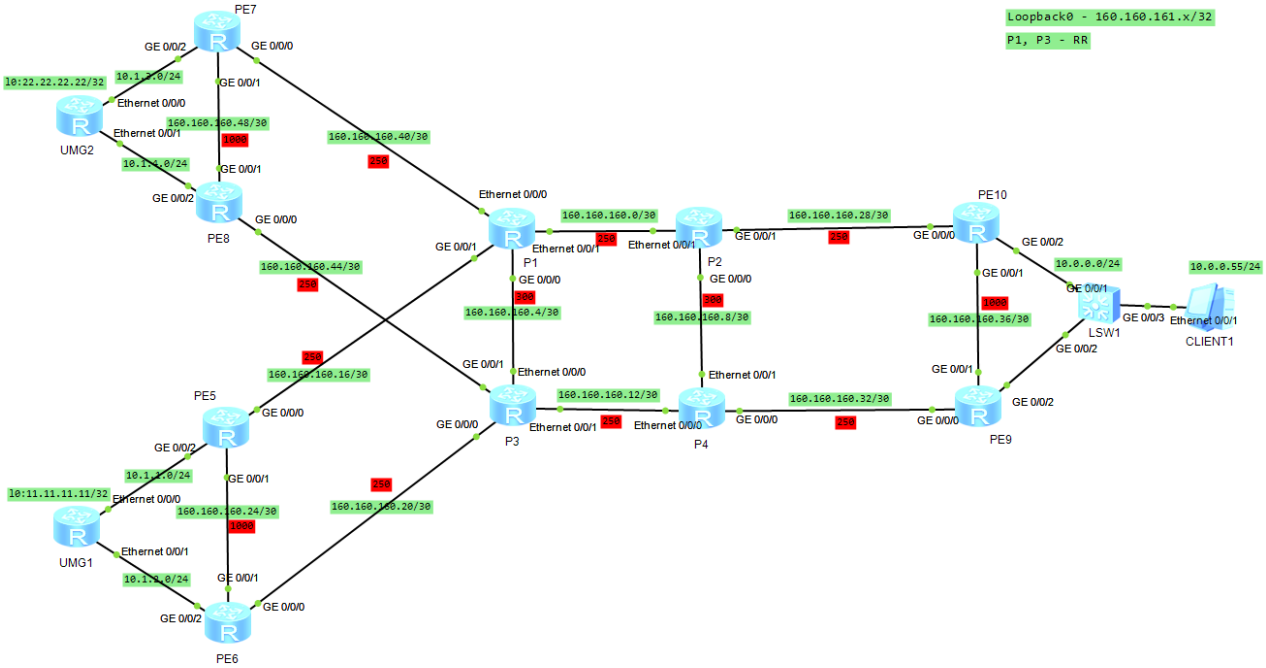


Slika 3.1.4 Prikaz gde promeniti jezik na engleski

Nakon instalacije eNSP-a, napravićemo topologiju, koja izgleda kao na slici 3-5.

Na slici 3.1.5 možemo videti topologiju mreže. UMG1, UMG2, LSW1, CLIENT1 predstavljaju korisničku opremu, dok ostatak predstavlja mrežu provajdera. P1 – P4 su zamišljeni kao *Core* ruteri, dok su PE5 – PE10 *Provider Edge*, PE, ruteri. Topologija je osmišljena tako da postoji redundansa sa topološkog aspekta. PE5 i PE6 su par, i slično a PE7 i PE8, kao i PE9 i PE10.

U nastavku ćemo izložiti konfiguraciju mreže u koracima i dati odgovarajuća objašnjenja za svaki korak u konfiguraciji.



Slika 3.1.5 Prikaz mreže koju konfigurišemo i na kojoj vršimo testiranja

.

3.2. Konfiguarcija IP adresa na interfejsima

Na slici 3.1.5 možemo videti raspodelu *subnet*-a za svaki od segmenata mreže. Za provajder deo mreže za *loopback* adrese su birane adrese iz 160.160.161.0/24 segmenta. A za adrese interfejsa na linkovima su dodeljivane adrese iz segmenta 160.160.160.0/24. Ka korisničkim delovima mreže korišćeni su subneti iz privatnog adresnog opsega.

Konfiguracija P1:

```
interface Ethernet0/0/0
 description TO_PE7_Gi0/0/0
 ip address 160.160.160.41 255.255.255.252
 undo shutdown
#
interface Ethernet0/0/1
 description TO_P2_Eth0/0/1
 ip address 160.160.160.1 255.255.255.252
 undo shutdown
#
interface GigabitEthernet0/0/0
 description TO_P3_Eth0/0/0
 ip address 160.160.160.5 255.255.255.252
 undo shutdown
#
interface GigabitEthernet0/0/1
 description TO_PE5_Gi0/0/0
 ip address 160.160.160.17 255.255.255.252
```

```
 undo shutdown
#
interface LoopBack0
 ip address 160.160.161.1 255.255.255.255
```

Konfiguracija P2:

```
interface Ethernet0/0/1
 description TO_P1_Eth0/0/1
 ip address 160.160.160.2 255.255.255.252
 undo shutdown
#
interface GigabitEthernet0/0/0
 description TO_P4_Eth0/0/1
 ip address 160.160.160.9 255.255.255.252
 undo shutdown
#
interface GigabitEthernet0/0/1
 description TO_PE10_Gi0/0/0
 ip address 160.160.160.29 255.255.255.252
 undo shutdown
#
interface LoopBack0
 ip address 160.160.161.2 255.255.255.255
```

Konfiguracija P3:

```
interface Ethernet0/0/0
 description TO_P1_Gi0/0/0
 ip address 160.160.160.6 255.255.255.252
 undo shutdown
#
interface Ethernet0/0/1
 description TO_P4_Eth0/0/0
 ip address 160.160.160.13 255.255.255.252
 undo shutdown
#
interface GigabitEthernet0/0/0
 description TO_PE6_Gi0/0/0
 ip address 160.160.160.21 255.255.255.252
 undo shutdown
#
interface GigabitEthernet0/0/1
 description TO_PE8_Gi0/0/0
 ip address 160.160.160.45 255.255.255.252
 undo shutdown
#
interface LoopBack0
 ip address 160.160.161.3 255.255.255.255
```

Konfiguracija P4:

```
interface Ethernet0/0/0
 description TO_P3_Eth0/0/1
 ip address 160.160.160.14 255.255.255.252
 undo shutdown
#
interface Ethernet0/0/1
 description TO_P2_Gi0/0/0
```

```
 ip address 160.160.160.10 255.255.255.252
 undo shutdown
#
interface GigabitEthernet0/0/0
 description TO_PE9_Gi0/0/0
 ip address 160.160.160.33 255.255.255.252
 undo shutdown
#
interface LoopBack0
 ip address 160.160.161.4 255.255.255.255
```

KonfiguracijaPE5:

```
interface GigabitEthernet0/0/0
 description TO_P1_Gi0/0/1
 ip address 160.160.160.18 255.255.255.252
 undo shutdown
#
interface GigabitEthernet0/0/1
 description TO_PE6_Gi0/0/1
 ip address 160.160.160.25 255.255.255.252
 undo shutdown
#
interface GigabitEthernet0/0/1.1
 vlan-type dot1q 10
 ip binding vpn-instance media
 ip address 160.160.165.1 255.255.255.252
 undo shutdown
#
interface GigabitEthernet0/0/2
 description TO_UMG1
 ip binding vpn-instance media
 ip address 10.1.1.1 255.255.255.252
 undo shutdown
#
interface LoopBack0
 ip address 160.160.161.5 255.255.255.255
```

KonfiguracijaPE6:

```
interface GigabitEthernet0/0/0
 description TO_P3_Gi0/0/0
 ip address 160.160.160.22 255.255.255.252
 undo shutdown
#
interface GigabitEthernet0/0/1
 description TO_PE5_Gi0/0/1
 ip address 160.160.160.26 255.255.255.252
 undo shutdown
#
interface GigabitEthernet0/0/1.1
 vlan-type dot1q 10
 ip binding vpn-instance media
 ip address 160.160.165.2 255.255.255.252
 undo shutdown
#
interface GigabitEthernet0/0/2
 description TO_UMG1
```

```
 ip binding vpn-instance media
 ip address 10.1.2.1 255.255.255.252
 undo shutdown
#
interface LoopBack0
 ip address 160.160.161.6 255.255.255.255
```

KonfiguracijaPE7:

```
interface GigabitEthernet0/0/0
 description TO_P1_Eth0/0/0
 ip address 160.160.160.42 255.255.255.252
 undo shutdown
#
interface GigabitEthernet0/0/1
 description TO_PE8_Gi0/0/1
 ip address 160.160.160.49 255.255.255.252
 undo shutdown
#
interface GigabitEthernet0/0/1.1
 vlan-type dot1q 10
 ip address 160.160.165.5 255.255.255.252
 undo shutdown
#
interface GigabitEthernet0/0/2
 description TO_UMG2
 ip binding vpn-instance media
 ip address 10.1.3.1 255.255.255.252
 undo shutdown
#
interface LoopBack0
 ip address 160.160.161.7 255.255.255.255
```

KonfiguracijaPE8:

```
interface GigabitEthernet0/0/0
 description TO_P3_Gi0/0/1
 ip address 160.160.160.46 255.255.255.252
 undo shutdown
#
interface GigabitEthernet0/0/1
 description TO_PE7_Gi0/0/1
 ip address 160.160.160.50 255.255.255.252
 undo shutdown
#
interface GigabitEthernet0/0/1.1
 vlan-type dot1q 10
 ip address 160.160.165.6 255.255.255.252
 undo shutdown
#
interface GigabitEthernet0/0/2
 description TO_UMG2
 ip binding vpn-instance media
 ip address 10.1.4.1 255.255.255.252
 undo shutdown
#
interface LoopBack0
 ip address 160.160.161.8 255.255.255.255
```

KonfiguracijaPE9:

```
interface GigabitEthernet0/0/0
 description TO_P4_Gi0/0/0
 ip address 160.160.160.34 255.255.255.252
 undo shutdown
#
interface GigabitEthernet0/0/1
 description TO_PE10_Gi0/0/1
 ip address 160.160.160.37 255.255.255.252
 undo shutdown
#
interface GigabitEthernet0/0/2
 description VRRP_Testing
 ip address 10.0.0.1 255.255.255.0
 undo shutdown
#
interface LoopBack0
 ip address 160.160.161.9 255.255.255.255
```

KonfiguracijaPE10:

```
interface GigabitEthernet0/0/0
 description TO_P2_Gi0/0/1
 ip address 160.160.160.30 255.255.255.252
 undo shutdown
#
interface GigabitEthernet0/0/1
 description TO_PE9_Gi0/0/1
 ip address 160.160.160.38 255.255.255.252
 undo shutdown
#
interface GigabitEthernet0/0/2
 description VRRP_Testing
 ip address 10.0.0.2 255.255.255.0
 undo shutdown
#
interface LoopBack0
 ip address 160.160.161.10 255.255.255.255
```

KonfiguracijaUMG1:

```
interface Ethernet0/0/0
 description TO_PE5
 ip address 10.1.1.2 255.255.255.252
 undo shutdown
#
interface Ethernet0/0/1
 description TO_PE6
 ip address 10.1.2.2 255.255.255.252
 undo shutdown
#
interface LoopBack1
 ip address 11.11.11.11 255.255.255.255
```

KonfiguracijaUMG2:

```
interface Ethernet0/0/0
 description TO_PE7
 ip address 10.1.3.2 255.255.255.252
 undo shutdown
#
interface Ethernet0/0/1
 description TO_PE8
 ip address 10.1.4.2 255.255.255.252
 undo shutdown
#
interface LoopBack1
 ip address 22.22.22.22 255.255.255.255
```

Verifikacija:

Korišćenjem komande **display ip interface description** možemo videti statuse interfejsa, njihove ip adrese kao i opis koji stoji uz interfejs.

```
<P1>display ip interface description
Codes:
      Ana(Analogmodem),       Asy(Async),             Cell(Cellular),
      Dia(Dialer),            Eth(Ethernet)           GE(GigabitEthernet),
      H(Hssi),                Ima(Ima-group),         Loop(LoopBack),
      MTun(MTunnel),          S(Serial),              Tun(Tunnel),
      VE(Virtual-Ethernet),   VT(Virtual-Template)

      d(dampened),            D(down),                *D(administratively down),
      !D(FIB overload down),  ^D(standby),            l(loopback),
      s(spoofing),            U(up)
--------------------------------------------------------------------------------
Number of interfaces whose physical status is Up: 8
Number of interfaces whose physical status is Down: 6
Number of interfaces whose protocol status is Up: 8
Number of interfaces whose protocol status is Down: 6

Interface                      IP Address/Mask    Phy  Prot Description
Eth0/0/0                       160.160.160.41/30  U    U    TO_PE7_Gi0/0/0
Eth0/0/1                       160.160.160.1/30   U    U    TO_P2_Eth0/0/1
GE0/0/0                        160.160.160.5/30   U    U    TO_P3_Eth0/0/0
GE0/0/1                        160.160.160.17/30  U    U    TO_PE5_Gi0/0/0
GE0/0/2                        unassigned         D    D
GE0/0/3                        unassigned         D    D
Loop0                          160.160.161.1/32   U    U(s)
NULL0                          unassigned         U    U(s)
S0/0/0                         unassigned         D    D
S0/0/1                         unassigned         D    D
S0/0/2                         unassigned         D    D
S0/0/3                         unassigned         D    D
```

Korišćenjem **ping** komande možemo potvrditi konektivnost direktno povezanih linkova. Dat je primer provere konektivnosti na P1 uređaju i priložen je*output*.

```
<P1>ping 160.160.160.2
  PING 160.160.160.2: 56  data bytes, press CTRL_C to break
```

```
  Reply from 160.160.160.2: bytes=56 Sequence=1 ttl=255 time=30 ms
  Reply from 160.160.160.2: bytes=56 Sequence=2 ttl=255 time=50 ms
  Reply from 160.160.160.2: bytes=56 Sequence=3 ttl=255 time=50 ms
  Reply from 160.160.160.2: bytes=56 Sequence=4 ttl=255 time=50 ms
  Reply from 160.160.160.2: bytes=56 Sequence=5 ttl=255 time=20 ms

--- 160.160.160.2 ping statistics ---
  5 packet(s) transmitted
  5 packet(s) received
  0.00% packet loss
  round-trip min/avg/max = 20/40/50 ms
```

Ovako se može verifikovati konektivnost sa svim direktno povezanim linkovima.

3.3. Konfiguracija OSPF-a

Konfiguracija OSPF protokola je urađena na sledeći način. Prvo svi P (*Provider*)i PE (provajder ruteri) su u istom *Area 0.0.0.0*. Nije veliki broj uređaja i nema potrebe segmentirati. Takođe, ručno je konfigurisan OSPF *cost* linkova. Zarad bolje preglednost i jednostavnosti toka saobraćaja, podelili smo mrežu na 2 *layer*-a. Jedan koji čine P1, P2, PE5, PE7, PE9 i drugi koji čine P3, P4, PE6, PE8, PE10. U zavisnosti od toga na koji PE ruter je poslat saobraćaj od korisnika on će se dalje rutirati kroz taj *layer* do izlazne tačke. To je postignuto sa većim OSPF *cost* na interfejsima između *layer*-a. Između rutera u istom *layer*-u konfigurisan je *cost* 250, između P rutera u različitim *layer*-ima *cost* je 300, dok je između PE rutera u različitim *layer*-ima *cost* 1000. Na ovaj na ako ima potrebe da se saobraćaj kreće između *layer*-a on će preferirati da to uradi kod P rutera ako je moguće.U nastavku je priložena konfiguracija OSPF protokola na ruterima.

Konfiguracija P1:

```
router id 160.160.161.1
ospf 1
 area 0.0.0.0
  network 160.160.161.1 0.0.0.0
  network 160.160.160.0 0.0.0.3 description TO_P2
  network 160.160.160.4 0.0.0.3 description TO_P3
  network 160.160.160.16 0.0.0.3 description TO_PE5
  network 160.160.160.40 0.0.0.3 description TO_PE7
#
interface Ethernet0/0/0
 ospf cost 250
#
interface Ethernet0/0/1
 ospf cost 250
#
interface GigabitEthernet0/0/0
 ospf cost 300
#
interface GigabitEthernet0/0/1
 ospf cost 250
```

Konfiguracija P2:

```
router id 160.160.161.2
ospf 1
 area 0.0.0.0
  network 160.160.161.2 0.0.0.0
  network 160.160.160.0 0.0.0.3 description TO_P1
```

```
  network 160.160.160.8 0.0.0.3 description TO_P4
  network 160.160.160.28 0.0.0.3 description TO_PE10
#
interface Ethernet0/0/1
 ospf cost 250
#
interface GigabitEthernet0/0/0
 ospf cost 300
#
interface GigabitEthernet0/0/1
 ospf cost 250
```

Konfiguracija P3:

```
router id 160.160.161.3
ospf 1
 area 0.0.0.0
  network 160.160.161.3 0.0.0.0
  network 160.160.160.4 0.0.0.3 description TO_P1
  network 160.160.160.12 0.0.0.3 description TO_P4
  network 160.160.160.20 0.0.0.3 description TO_PE6
  network 160.160.160.44 0.0.0.3 description TO_PE8
#
interface Ethernet0/0/0
 ospf cost 300
#
interface Ethernet0/0/1
 ospf cost 250
#
interface GigabitEthernet0/0/0
 ospf cost 250
#
interface GigabitEthernet0/0/1
 ospf cost 250
```

Konfiguracija P4:

```
router id 160.160.161.4
ospf 1
 area 0.0.0.0
  network 160.160.161.4 0.0.0.0
  network 160.160.160.8 0.0.0.3 description TO_P2
  network 160.160.160.12 0.0.0.3 description TO_P3
  network 160.160.160.32 0.0.0.3 description TO_PE9
#
interface Ethernet0/0/0
 ospf cost 250
#
interface Ethernet0/0/1
 ospf cost 300
#
interface GigabitEthernet0/0/0
 ospf cost 250
```

Konfiguracija PE5:

```
router id 160.160.161.5
ospf 1
 area 0.0.0.0
```

```
  network 160.160.160.16 0.0.0.3 description TO_P1
  network 160.160.160.24 0.0.0.3 description TO_PE6
  network 160.160.161.5 0.0.0.0
#
interface GigabitEthernet0/0/0
 ospf cost 250
#
interface GigabitEthernet0/0/1
 ospf cost 1000
```

Konfiguracija PE6:

```
router id 160.160.161.6
ospf 1
 area 0.0.0.0
  network 160.160.160.20 0.0.0.3 description TO_P3
  network 160.160.160.24 0.0.0.3 description TO_PE5
  network 160.160.161.6 0.0.0.0
#
interface GigabitEthernet0/0/0
 ospf cost 250
#
interface GigabitEthernet0/0/1
 ospf cost 1000
```

Konfiguracija PE7:

```
router id 160.160.161.7
ospf 1
 area 0.0.0.0
  network 160.160.160.40 0.0.0.3 description TO_P1
  network 160.160.160.48 0.0.0.3 description TO_PE8
  network 160.160.161.7 0.0.0.0
  mpls-te enable
#
interface GigabitEthernet0/0/0
 ospf cost 250
#
interface GigabitEthernet0/0/1
 ospf cost 1000
```

Konfiguracija PE8:

```
router id 160.160.161.8
ospf 1
 area 0.0.0.0
  network 160.160.160.44 0.0.0.3 description TO_P2
  network 160.160.160.48 0.0.0.3 description TO_PE7
  network 160.160.161.8 0.0.0.0
#
interface GigabitEthernet0/0/0
 ospf cost 250
#
interface GigabitEthernet0/0/1
 ospf cost 1000
```

Konfiguracija PE9:

```
router id 160.160.161.9
```

```
ospf 1
 area 0.0.0.0
  network 160.160.160.32 0.0.0.3 description TO_P4
  network 160.160.160.36 0.0.0.3 description TO_PE10
  network 160.160.161.9 0.0.0.0
#
interface GigabitEthernet0/0/0
 ospf cost 250
#
interface GigabitEthernet0/0/1
 ospf cost 1000
```

Konfiguracija PE10:

```
router id 160.160.161.10
ospf 1
 area 0.0.0.0
  network 160.160.160.28 0.0.0.3 description TO_P2
  network 160.160.160.36 0.0.0.3 description TO_PE9
  network 160.160.161.10 0.0.0.0
#
interface GigabitEthernet0/0/0
 ospf cost 250
#
interface GigabitEthernet0/0/1
 ospf cost 1000
```

Verifikacija

Koristimo komandu **display ospf peer brief** da vidimo status OSPF *neighbor*-a. *Output* komande na P1 se može videti ispod:

```
<P1>display ospf peer brief

       OSPF Process 1 with Router ID 160.160.161.1
              Peer Statistic Information
 --------------------------------------------------------------------------
 Area Id          Interface                       Neighbor id      State
 0.0.0.0          Ethernet0/0/0                   160.160.161.7    Full
 0.0.0.0          Ethernet0/0/1                   160.160.161.2    Full
 0.0.0.0          GigabitEthernet0/0/0            160.160.161.3    Full
 0.0.0.0          GigabitEthernet0/0/1            160.160.161.5    Full
 --------------------------------------------------------------------------
```

Možemo uneti komandu **display ip routing-table protocol ospf** da bi videli informacije o OSPF rutama:

```
<P1>display ip routing-table protocol ospf
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Public routing table : OSPF
         Destinations : 15       Routes : 17

OSPF routing table status : <Active>
         Destinations : 15       Routes : 17

Destination/Mask    Proto   Pre  Cost      Flags NextHop         Interface
```

```
  160.160.160.8/30  OSPF    10   550         D   160.160.160.2   Ethernet0/0/1
 160.160.160.12/30  OSPF    10   550         D   160.160.160.6
GigabitEthernet0/0/0
 160.160.160.20/30  OSPF    10   550         D   160.160.160.6
GigabitEthernet0/0/0
 160.160.160.24/30  OSPF    10   1250        D   160.160.160.18
GigabitEthernet0/0/1
 160.160.160.28/30  OSPF    10   500         D   160.160.160.2   Ethernet0/0/1
 160.160.160.32/30  OSPF    10   800         D   160.160.160.2   Ethernet0/0/1
                    OSPF    10   800         D   160.160.160.6
GigabitEthernet0/0/0
 160.160.160.44/30  OSPF    10   550         D   160.160.160.6
GigabitEthernet0/0/0
 160.160.160.48/30  OSPF    10   1250        D   160.160.160.42  Ethernet0/0/0
  160.160.161.2/32  OSPF    10   250         D   160.160.160.2   Ethernet0/0/1
  160.160.161.3/32  OSPF    10   300         D   160.160.160.6
GigabitEthernet0/0/0
  160.160.161.4/32  OSPF    10   550         D   160.160.160.2   Ethernet0/0/1
                    OSPF    10   550         D   160.160.160.6
GigabitEthernet0/0/0
  160.160.161.5/32  OSPF    10   250         D   160.160.160.18
GigabitEthernet0/0/1
  160.160.161.6/32  OSPF    10   550         D   160.160.160.6
GigabitEthernet0/0/0
  160.160.161.7/32  OSPF    10   250         D   160.160.160.42  Ethernet0/0/0
  160.160.161.8/32  OSPF    10   550         D   160.160.160.6
GigabitEthernet0/0/0

OSPF routing table status : <Inactive>
         Destinations : 0        Routes : 0
```

Sa **ping** komandom možemo verifikovati konektivnost između različitih delova mreže. Dole je primer provere kontektivnosti između *loopback* adresa rutera PE6 i PE7.

```
<PE6>ping 160.160.161.7
  PING 160.160.161.7: 56  data bytes, press CTRL_C to break
    Reply from 160.160.161.7: bytes=56 Sequence=1 ttl=253 time=100 ms
    Reply from 160.160.161.7: bytes=56 Sequence=2 ttl=253 time=80 ms
    Reply from 160.160.161.7: bytes=56 Sequence=3 ttl=253 time=60 ms
    Reply from 160.160.161.7: bytes=56 Sequence=4 ttl=253 time=60 ms
    Reply from 160.160.161.7: bytes=56 Sequence=5 ttl=253 time=60 ms

  --- 160.160.161.7 ping statistics ---
    5 packet(s) transmitted
    5 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 60/72/100 ms
```

3.4. Uključivanje MPLS/MPLS TE/RSVP TE/CSPF-a

Zbog kasnije konfiguracije MP-BGP-a(*Multi Protocol – Border Gateway Protocol*) i MPLS TE, na svim linkovima ćemo uključiti MPLS LDP, a po potrebi (tamo gde prolaze tuneli) i MPLS TE. A za potrebe konfigurisanja MPLS TE-a uključeni su i RSVP(*Resource Reservation Protocol*) koji nam je potreban da bi 'statički' definisali MPLS putanje, kao i CSPF(*Constrained Shortest Path First*) koji nam između ostalog treba i zbog izbora odgovarajuće MPLS TE putanje. Naglasiću da je pri konfiguraciji potrebno uneti komandu **opaque-capability enable**, koja omogućava

komunikaciju i sa nestandardnim LSA tipovima, koji su potrebni za MPLS-TE. U nastavku je priložena konfiguracija na ruterima.

Konfiguracija P1:

```
mpls lsr-id 160.160.161.1
mpls
 mpls te
 mpls rsvp-te
 mpls te cspf
mpls ldp
#
interface Ethernet0/0/0
 mpls
 mpls te
 mpls te bandwidth max-reservable-bandwidth 100000
 mpls te bandwidth bc0 100000
 mpls rsvp-te
 mpls ldp
#
interface Ethernet0/0/1
 mpls
 mpls ldp
#
interface GigabitEthernet0/0/0
 mpls
 mpls te
 mpls te bandwidth max-reservable-bandwidth 100000
 mpls te bandwidth bc0 100000
 mpls rsvp-te
 mpls ldp
#
interface GigabitEthernet0/0/1
 mpls
 mpls te
 mpls te bandwidth max-reservable-bandwidth 100000
 mpls te bandwidth bc0 100000
 mpls rsvp-te
 mpls ldp
#
ospf 1
 opaque-capability enable
 area 0.0.0.0
  mpls-te enable
```

Konfiguracija P2:

```
mpls lsr-id 160.160.161.2
mpls
 mpls te
 mpls rsvp-te
 mpls te cspf
mpls ldp
#
interface Ethernet0/0/1
 mpls
 mpls ldp
#
interface GigabitEthernet0/0/0
```

```
 mpls
 mpls ldp
#
interface GigabitEthernet0/0/1
 mpls
 mpls ldp
#
ospf 1
 opaque-capability enable
 area 0.0.0.0
  mpls-te enable
```

Konfiguracija P3:

```
mpls lsr-id 160.160.161.3
mpls
 mpls te
 mpls rsvp-te
 mpls te cspf
mpls ldp
#
interface Ethernet0/0/0
 mpls
 mpls te
 mpls te bandwidth max-reservable-bandwidth 100000
 mpls te bandwidth bc0 100000
 mpls rsvp-te
 mpls ldp
#
interface Ethernet0/0/1
 mpls
 mpls ldp
#
interface GigabitEthernet0/0/0
 mpls
 mpls te
 mpls te bandwidth max-reservable-bandwidth 100000
 mpls te bandwidth bc0 100000
 mpls rsvp-te
 mpls ldp
#
interface GigabitEthernet0/0/1
 mpls
 mpls te
 mpls te bandwidth max-reservable-bandwidth 100000
 mpls te bandwidth bc0 100000
 mpls rsvp-te
 mpls ldp
#
ospf 1
 opaque-capability enable
 area 0.0.0.0
 mpls-te enable
```

Konfiguracija P4:

```
mpls lsr-id 160.160.161.4
mpls
 mpls te
 mpls rsvp-te
 mpls te cspf
mpls ldp
#
interface Ethernet0/0/0
 mpls
 mpls ldp
#
interface Ethernet0/0/1
 mpls
 mpls ldp
#
interface GigabitEthernet0/0/0
 mpls
 mpls ldp
#
ospf 1
 opaque-capability enable
 area 0.0.0.0
  mpls-te enable
```

Konfiguracija PE5:

```
mpls lsr-id 160.160.161.5
mpls
 mpls te
 mpls rsvp-te
 mpls te cspf
mpls ldp
#
interface GigabitEthernet0/0/0
 mpls
 mpls te
 mpls te bandwidth max-reservable-bandwidth 100000
 mpls te bandwidth bc0 100000
 mpls rsvp-te
 mpls rsvp-te bfd enable
 mpls ldp
#
interface GigabitEthernet0/0/1
 mpls
 mpls te
 mpls te bandwidth max-reservable-bandwidth 100000
 mpls te bandwidth bc0 100000
 mpls rsvp-te
 mpls ldp
#
ospf 1
 opaque-capability enable
 area 0.0.0.0
 mpls-te enable
```

Konfiguracija PE6:

```
mpls lsr-id 160.160.161.6
mpls
 mpls te
 mpls rsvp-te
 mpls te cspf
mpls ldp
#
interface GigabitEthernet0/0/0
 mpls
 mpls te
 mpls te bandwidth max-reservable-bandwidth 100000
 mpls te bandwidth bc0 100000
 mpls rsvp-te
 mpls rsvp-te bfd enable
 mpls ldp
#
interface GigabitEthernet0/0/1
 mpls
 mpls te
 mpls te bandwidth max-reservable-bandwidth 100000
 mpls te bandwidth bc0 100000
 mpls rsvp-te
 mpls ldp
#
ospf 1
 opaque-capability enable
 area 0.0.0.0
  mpls-te enable
```

Konfiguracija PE7:

```
mpls lsr-id 160.160.161.7
mpls
 mpls te
 mpls rsvp-te
 mpls te cspf
mpls ldp
#
interface GigabitEthernet0/0/0
 mpls
 mpls te
 mpls te bandwidth max-reservable-bandwidth 100000
 mpls te bandwidth bc0 100000
 mpls rsvp-te
 mpls rsvp-te bfd enable
 mpls ldp
#
interface GigabitEthernet0/0/1
 mpls
 mpls te
 mpls te bandwidth max-reservable-bandwidth 100000
 mpls te bandwidth bc0 100000
 mpls rsvp-te
 mpls ldp
#
```

```
ospf 1
 opaque-capability enable
 area 0.0.0.0
  mpls-te enable
```

Konfiguracija PE8:

```
mpls lsr-id 160.160.161.8
mpls
 mpls te
 mpls rsvp-te
 mpls te cspf
mpls ldp
#
interface GigabitEthernet0/0/0
 mpls
 mpls te
 mpls te bandwidth max-reservable-bandwidth 100000
 mpls te bandwidth bc0 100000
 mpls rsvp-te
 mpls rsvp-te bfd enable
 mpls ldp
#
interface GigabitEthernet0/0/1
 mpls
 mpls te
 mpls te bandwidth max-reservable-bandwidth 100000
 mpls te bandwidth bc0 100000
 mpls rsvp-te
 mpls ldp
#
ospf 1
 opaque-capability enable
 area 0.0.0.0
  mpls-te enable
```

Konfiguracija PE9:

```
mpls lsr-id 160.160.161.9
mpls
 mpls te
 mpls rsvp-te
 mpls te cspf
mpls ldp
#
interface GigabitEthernet0/0/0
 mpls
 mpls ldp
#
interface GigabitEthernet0/0/1
 mpls
 mpls ldp
```

Konfiguracija PE10:

```
mpls lsr-id 160.160.161.10
```

```
 mpls
  mpls te
  mpls rsvp-te
  mpls te cspf
 mpls ldp
 #
 interface GigabitEthernet0/0/0
  mpls
  mpls ldp
 #
 interface GigabitEthernet0/0/1
  mpls
  mpls ldp
```

Verifikacija:

Ako unesemo komandu **display mpls ldp peer**videćemo status LDP *neighbor*-a. Možemo videti kako to izgleda na P1 ruteru:

```
<P1>display mpls ldp peer

 LDP Peer Information in Public network
 A '*' before a peer means the peer is being deleted.
 ------------------------------------------------------------------------------
 PeerID                 TransportAddress   DiscoverySource
 ------------------------------------------------------------------------------
 160.160.161.2:0        160.160.161.2      Ethernet0/0/1
 160.160.161.3:0        160.160.161.3      GigabitEthernet0/0/0
 160.160.161.5:0        160.160.161.5      GigabitEthernet0/0/1
 160.160.161.7:0        160.160.161.7      Ethernet0/0/0
 ------------------------------------------------------------------------------
 TOTAL: 4 Peer(s) Found.
```

Ako unesemo komandu **display mpls ldp lsp**možemo da vidimo LDP LSP tabelu. Dat je prikaz iste na P1 ruteru:

```
<P1>display mpls ldp lsp

 LDP LSP Information
 -------------------------------------------------------------------------------
 DestAddress/Mask   In/OutLabel    UpstreamPeer    NextHop         OutInterface
 -------------------------------------------------------------------------------
 160.160.161.1/32   3/NULL         160.160.161.2   127.0.0.1       InLoop0
 160.160.161.1/32   3/NULL         160.160.161.3   127.0.0.1       InLoop0
 160.160.161.1/32   3/NULL         160.160.161.5   127.0.0.1       InLoop0
 160.160.161.1/32   3/NULL         160.160.161.7   127.0.0.1       InLoop0
*160.160.161.1/32   Liberal/1028                   DS/160.160.161.3
*160.160.161.1/32   Liberal/1029                   DS/160.160.161.2
*160.160.161.1/32   Liberal/1024                   DS/160.160.161.5
*160.160.161.1/32   Liberal/1026                   DS/160.160.161.7
 160.160.161.2/32   NULL/3         -               160.160.160.2   Eth0/0/1
 160.160.161.2/32   1025/3         160.160.161.2   160.160.160.2   Eth0/0/1
 160.160.161.2/32   1025/3         160.160.161.3   160.160.160.2   Eth0/0/1
 160.160.161.2/32   1025/3         160.160.161.5   160.160.160.2   Eth0/0/1
 160.160.161.2/32   1025/3         160.160.161.7   160.160.160.2   Eth0/0/1
```

```
*160.160.161.2/32   Liberal/1024                 DS/160.160.161.3
*160.160.161.2/32   Liberal/1025                 DS/160.160.161.5
*160.160.161.2/32   Liberal/1027                 DS/160.160.161.7
 160.160.161.3/32   NULL/3         -             160.160.160.6   GE0/0/0
 160.160.161.3/32   1029/3         160.160.161.2 160.160.160.6   GE0/0/0
 160.160.161.3/32   1029/3         160.160.161.3 160.160.160.6   GE0/0/0
 160.160.161.3/32   1029/3         160.160.161.5 160.160.160.6   GE0/0/0
 160.160.161.3/32   1029/3         160.160.161.7 160.160.160.6   GE0/0/0
*160.160.161.3/32   Liberal/1030                 DS/160.160.161.2
*160.160.161.3/32   Liberal/1026                 DS/160.160.161.5
*160.160.161.3/32   Liberal/1028                 DS/160.160.161.7
 160.160.161.4/32   NULL/1027      -             160.160.160.2   Eth0/0/1
                    NULL/1025      -             160.160.160.6   GE0/0/0
 160.160.161.4/32   1026/1027      160.160.161.2 160.160.160.2   Eth0/0/1
                    1026/1025      160.160.161.2 160.160.160.6   GE0/0/0
 160.160.161.4/32   1026/1027      160.160.161.3 160.160.160.2   Eth0/0/1
                    1026/1025      160.160.161.3 160.160.160.6   GE0/0/0
 160.160.161.4/32   1026/1027      160.160.161.5 160.160.160.2   Eth0/0/1
                    1026/1025      160.160.161.5 160.160.160.6   GE0/0/0
 160.160.161.4/32   1026/1027      160.160.161.7 160.160.160.2   Eth0/0/1
                    1026/1025      160.160.161.7 160.160.160.6   GE0/0/0
*160.160.161.4/32   Liberal/1027                 DS/160.160.161.5
*160.160.161.4/32   Liberal/1029                 DS/160.160.161.7
 160.160.161.5/32   NULL/3         -             160.160.160.18  GE0/0/1
 160.160.161.5/32   1031/3         160.160.161.5 160.160.160.18  GE0/0/1
 160.160.161.5/32   1031/3         160.160.161.7 160.160.160.18  GE0/0/1
 160.160.161.5/32   1031/3         160.160.161.2 160.160.160.18  GE0/0/1
 160.160.161.5/32   1031/3         160.160.161.3 160.160.160.18  GE0/0/1
*160.160.161.5/32   Liberal/1460                 DS/160.160.161.3
*160.160.161.5/32   Liberal/1092                 DS/160.160.161.2
*160.160.161.5/32   Liberal/1280                 DS/160.160.161.7
 160.160.161.6/32   NULL/1036      -             160.160.160.6   GE0/0/0
 160.160.161.6/32   1486/1036      160.160.161.5 160.160.160.6   GE0/0/0
 160.160.161.6/32   1486/1036      160.160.161.7 160.160.160.6   GE0/0/0
 160.160.161.6/32   1486/1036      160.160.161.2 160.160.160.6   GE0/0/0
 160.160.161.6/32   1486/1036      160.160.161.3 160.160.160.6   GE0/0/0
*160.160.161.6/32   Liberal/1093                 DS/160.160.161.2
*160.160.161.6/32   Liberal/1031                 DS/160.160.161.5
*160.160.161.6/32   Liberal/1285                 DS/160.160.161.7
 160.160.161.7/32   NULL/3         -             160.160.160.42  Eth0/0/0
 160.160.161.7/32   1034/3         160.160.161.7 160.160.160.42  Eth0/0/0
 160.160.161.7/32   1034/3         160.160.161.2 160.160.160.42  Eth0/0/0
 160.160.161.7/32   1034/3         160.160.161.3 160.160.160.42  Eth0/0/0
 160.160.161.7/32   1034/3         160.160.161.5 160.160.160.42  Eth0/0/0
*160.160.161.7/32   Liberal/1094                 DS/160.160.161.2
*160.160.161.7/32   Liberal/1471                 DS/160.160.161.3
*160.160.161.7/32   Liberal/1309                 DS/160.160.161.5
 160.160.161.8/32   NULL/1042      -             160.160.160.6   GE0/0/0
 160.160.161.8/32   1567/1042      160.160.161.2 160.160.160.6   GE0/0/0
 160.160.161.8/32   1567/1042      160.160.161.3 160.160.160.6   GE0/0/0
 160.160.161.8/32   1567/1042      160.160.161.5 160.160.160.6   GE0/0/0
 160.160.161.8/32   1567/1042      160.160.161.7 160.160.160.6   GE0/0/0
*160.160.161.8/32   Liberal/1037                 DS/160.160.161.7
*160.160.161.8/32   Liberal/1325                 DS/160.160.161.5
*160.160.161.8/32   Liberal/1097                 DS/160.160.161.2
 ------------------------------------------------------------------------------
 TOTAL: 44 Normal LSP(s) Found.
 TOTAL: 24 Liberal LSP(s) Found.
 TOTAL: 0 Frr LSP(s) Found.
```

```
 A '*' before an LSP means the LSP is not established
 A '*' before a Label means the USCB or DSCB is stale
 A '*' before a UpstreamPeer means the session is stale
 A '*' before a DS means the session is stale
 A '*' before a NextHop means the LSP is FRR LSP
```

Možemo kucati **display mpls interface** da vidimo informacije o interfejsima na kojima je MPLS uključen. Dat je prikaz sa P1 rutera:

```
<P1>display mpls interface
Interface             Status    TE Attr   LSP Count  CRLSP Count Effective MTU
Eth0/0/0              Up        En        2          9           1500
Eth0/0/1              Up        Dis       4          0           1500
GE0/0/0               Up        En        8          4           1500
GE0/0/1               Up        En        2          9           1500
```

Možemo kucati **display mpls rsvp-te** komandu da vidimo konfiguraciju vezano za MPLS RSVP-TE. Prikazan je *output* za P1 ruter kao primer:

```
<P1>display mpls rsvp-te
 LSR ID: 160.160.161.1
 RSVP-TE Function Capability: Enable
 Resv Confirmation Request: DISABLE
 RSVP Hello Extension: DISABLE
 Hello interval: 3 sec         Max Hello misses: 3
 Path and Resv message refresh interval: 30 sec
 Path and Resv message refresh retries count: 3
 Blockade Multiplier: 4
 Bfd Enabled: DISABLE                  Bfd Min-Tx: 1000
 Bfd Min-Rx: 1000                      Bfd Detect-Multi: 3
```

Sa komandom **display ospf brief** možemo verifikovati da je MPLS-TE uključen za OSPF proces.

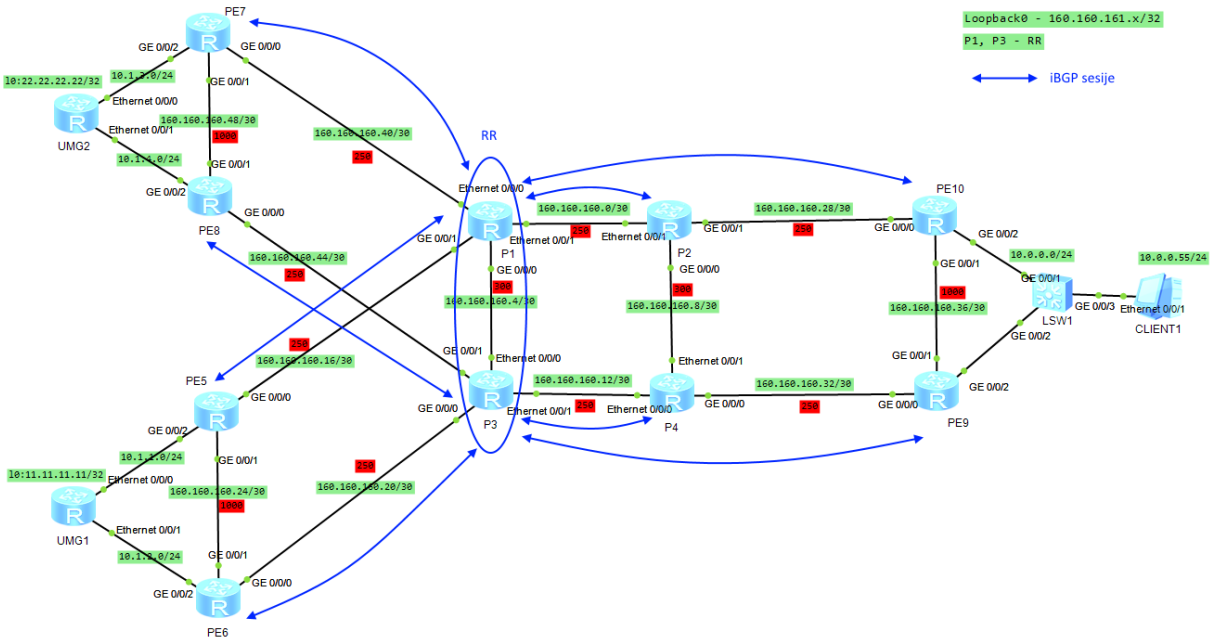
```
<P1>display ospf brief

       OSPF Process 1 with Router ID 160.160.161.1
             OSPF Protocol Information

 RouterID: 160.160.161.1    Border Router:
 Multi-VPN-Instance is not enabled
 Opaque Capable
 Global DS-TE Mode: Non-Standard IETF Mode
 Spf-schedule-interval: max 10000ms, start 500ms, hold 1000ms
 Default ASE parameters: Metric: 1 Tag: 1 Type: 2
 Route Preference: 10
 ASE Route Preference: 150
 SPF Computation Count: 27
 RFC 1583 Compatible
 Retransmission limitation is disabled
 bfd enabled
 BFD Timers: Tx-Interval 100 , Rx-Interval 100 , Multiplier 3
 Area Count: 1   Nssa Area Count: 0
 ExChange/Loading Neighbors: 0
```

```
Area: 0.0.0.0          (MPLS TE enabled)
Authtype: None   Area flag: Normal
SPF scheduled Count: 27
ExChange/Loading Neighbors: 0
Router ID conflict state: Normal

Interface: 160.160.160.41 (Ethernet0/0/0)
Cost: 250     State: BDR       Type: Broadcast    MTU: 1500
Priority: 1
Designated Router: 160.160.160.42
Backup Designated Router: 160.160.160.41
Timers: Hello 10 , Dead 40 , Poll  120 , Retransmit 5 , Transmit Delay 1
MPLS Traffic-Engineering Link

Interface: 160.160.160.1 (Ethernet0/0/1)
Cost: 250     State: Down      Type: Broadcast    MTU: 1500
Priority: 1
Designated Router: 0.0.0.0
Backup Designated Router: 0.0.0.0
Timers: Hello 10 , Dead 40 , Poll  120 , Retransmit 5 , Transmit Delay 1

Interface: 160.160.160.5 (GigabitEthernet0/0/0)
Cost: 300     State: BDR       Type: Broadcast    MTU: 1500
Priority: 1
Designated Router: 160.160.160.6
Backup Designated Router: 160.160.160.5
Timers: Hello 10 , Dead 40 , Poll  120 , Retransmit 5 , Transmit Delay 1
MPLS Traffic-Engineering Link

Interface: 160.160.160.17 (GigabitEthernet0/0/1)
Cost: 250     State: BDR       Type: Broadcast    MTU: 1500
Priority: 1
Designated Router: 160.160.160.18
Backup Designated Router: 160.160.160.17
Timers: Hello 10 , Dead 40 , Poll  120 , Retransmit 5 , Transmit Delay 1
MPLS Traffic-Engineering Link

Interface: 160.160.161.1 (LoopBack0)
Cost: 0       State: P-2-P     Type: P2P       MTU: 1500
Timers: Hello 10 , Dead 40 , Poll  120 , Retransmit 5 , Transmit Delay 1

Interface: 160.160.161.1 (Tunnel0/0/0)
Cost: 1562    State: P-2-P     Type: P2P       MTU: 1500
Unnumbered
Timers: Hello 10 , Dead 40 , Poll  120 , Retransmit 5 , Transmit Delay 1
Silent interface, No hellos

Interface: 160.160.161.1 (Tunnel0/0/1)
Cost: 1562    State: P-2-P     Type: P2P       MTU: 1500
Unnumbered
Timers: Hello 10 , Dead 40 , Poll  120 , Retransmit 5 , Transmit Delay 1
Silent interface, No hellos
```

3.5. Konfiguracija MP – BGP-a i RR-a

Ovde smo se odlučili za konfiguraciju RR *(Route Reflectora)*. P1 i P3 su RR za celu mrežu. RR-ove koristimo da bi smanjili broj iBGP(*interior Border Gateway Protocol*) sesija u našoj BGP

mreži (slika 3.5.1). Na P1 i P3 se kreira grupa RR, i članovi te grupe su svi ostali ruteri, dok su P1 i P3 reflektori u istoj. U nastavku je priložena konfiguracija.



Slika 3.5.1 Obeleženi *Route Reflectori* i obeležene iBGP sesije

Konfiguracija P1:

```
bgp 15000
 router-id 160.160.161.1
 peer 160.160.161.3 as-number 15000
 peer 160.160.161.3 description P3
 peer 160.160.161.3 connect-interface LoopBack0
 group RR internal
 peer RR connect-interface LoopBack0
 peer 160.160.161.2 as-number 15000
 peer 160.160.161.2 group RR
 peer 160.160.161.2 description P2
 peer 160.160.161.4 as-number 15000
 peer 160.160.161.4 group RR
 peer 160.160.161.4 description P4
 peer 160.160.161.5 as-number 15000
 peer 160.160.161.5 group RR
 peer 160.160.161.5 description PE5
 peer 160.160.161.6 as-number 15000
 peer 160.160.161.6 group RR
 peer 160.160.161.6 description PE6
 peer 160.160.161.7 as-number 15000
 peer 160.160.161.7 group RR
 peer 160.160.161.7 description PE7
 peer 160.160.161.8 as-number 15000
```

```
 peer 160.160.161.8 group RR
 peer 160.160.161.8 description PE8
 peer 160.160.161.9 as-number 15000
 peer 160.160.161.9 group RR
 peer 160.160.161.9 description PE9
 peer 160.160.161.10 as-number 15000
 peer 160.160.161.10 group RR
 peer 160.160.161.10 description PE10
 #
 ipv4-family unicast
  undo synchronization
  import-route direct
  undo peer RR enable
  undo peer 160.160.161.2 enable
  undo peer 160.160.161.3 enable
  undo peer 160.160.161.4 enable
  undo peer 160.160.161.5 enable
  undo peer 160.160.161.6 enable
  undo peer 160.160.161.7 enable
  undo peer 160.160.161.8 enable
  undo peer 160.160.161.9 enable
  undo peer 160.160.161.10 enable
 #
 ipv4-family vpnv4
  reflector cluster-id 111
  undo policy vpn-target
  peer 160.160.161.3 enable
  peer 160.160.161.3 advertise-community
  peer RR enable
  peer RR reflect-client
  peer RR advertise-community
  peer 160.160.161.2 enable
  peer 160.160.161.2 group RR
  peer 160.160.161.4 enable
  peer 160.160.161.4 group RR
  peer 160.160.161.5 enable
  peer 160.160.161.5 group RR
  peer 160.160.161.6 enable
  peer 160.160.161.6 group RR
  peer 160.160.161.7 enable
  peer 160.160.161.7 group RR
  peer 160.160.161.8 enable
  peer 160.160.161.8 group RR
  peer 160.160.161.9 enable
  peer 160.160.161.9 group RR
  peer 160.160.161.10 enable
  peer 160.160.161.10 group RR
```

Konfiguracija P2:

```
bgp 15000
 router-id 160.160.161.2
 peer 160.160.161.1 as-number 15000
 peer 160.160.161.1 description P1
 peer 160.160.161.1 connect-interface LoopBack0
 peer 160.160.161.3 as-number 15000
 peer 160.160.161.3 description P3
 peer 160.160.161.3 connect-interface LoopBack0
 #
```

```
 ipv4-family unicast
  undo synchronization
  undo peer 160.160.161.1 enable
  undo peer 160.160.161.3 enable
 #
 ipv4-family vpnv4
  policy vpn-target
  peer 160.160.161.1 enable
  peer 160.160.161.1 advertise-community
  peer 160.160.161.3 enable
  peer 160.160.161.3 advertise-community
```

Konfiguracija P3:

```
bgp 15000
 router-id 160.160.161.3
 peer 160.160.161.1 as-number 15000
 peer 160.160.161.1 description P1
 peer 160.160.161.1 connect-interface LoopBack0
 group RR internal
 peer RR connect-interface LoopBack0
 peer 160.160.161.2 as-number 15000
 peer 160.160.161.2 group RR
 peer 160.160.161.2 description P2
 peer 160.160.161.4 as-number 15000
 peer 160.160.161.4 group RR
 peer 160.160.161.4 description P4
 peer 160.160.161.5 as-number 15000
 peer 160.160.161.5 group RR
 peer 160.160.161.5 description PE5
 peer 160.160.161.6 as-number 15000
 peer 160.160.161.6 group RR
 peer 160.160.161.6 description PE6
 peer 160.160.161.7 as-number 15000
 peer 160.160.161.7 group RR
 peer 160.160.161.7 description PE7
 peer 160.160.161.8 as-number 15000
 peer 160.160.161.8 group RR
 peer 160.160.161.8 description PE8
 peer 160.160.161.9 as-number 15000
 peer 160.160.161.9 group RR
 peer 160.160.161.9 description PE9
 peer 160.160.161.10 as-number 15000
 peer 160.160.161.10 group RR
 peer 160.160.161.10 description PE10
 #
 ipv4-family unicast
  undo synchronization
  import-route direct
  undo peer RR enable
  undo peer 160.160.161.1 enable
  undo peer 160.160.161.2 enable
  undo peer 160.160.161.4 enable
  undo peer 160.160.161.5 enable
  undo peer 160.160.161.6 enable
  undo peer 160.160.161.7 enable
  undo peer 160.160.161.8 enable
  undo peer 160.160.161.9 enable
  undo peer 160.160.161.10 enable
```

```
 #
 ipv4-family vpnv4
  reflector cluster-id 111
  undo policy vpn-target
  peer 160.160.161.1 enable
  peer 160.160.161.1 advertise-community
  peer RR enable
  peer RR reflect-client
  peer RR advertise-community
  peer 160.160.161.2 enable
  peer 160.160.161.2 group RR
  peer 160.160.161.4 enable
  peer 160.160.161.4 group RR
  peer 160.160.161.5 enable
  peer 160.160.161.5 group RR
  peer 160.160.161.6 enable
  peer 160.160.161.6 group RR
  peer 160.160.161.7 enable
  peer 160.160.161.7 group RR
  peer 160.160.161.8 enable
  peer 160.160.161.8 group RR
  peer 160.160.161.9 enable
  peer 160.160.161.9 group RR
  peer 160.160.161.10 enable
  peer 160.160.161.10 group RR
```

Konfiguracija P4:

```
bgp 15000
 router-id 160.160.161.4
 peer 160.160.161.1 as-number 15000
 peer 160.160.161.1 description P1
 peer 160.160.161.1 connect-interface LoopBack0
 peer 160.160.161.3 as-number 15000
 peer 160.160.161.3 description P3
 peer 160.160.161.3 connect-interface LoopBack0
 #
 ipv4-family unicast
  undo synchronization
  undo peer 160.160.161.1 enable
  undo peer 160.160.161.3 enable
 #
 ipv4-family vpnv4
  policy vpn-target
  peer 160.160.161.1 enable
  peer 160.160.161.1 advertise-community
  peer 160.160.161.3 enable
  peer 160.160.161.3 advertise-community
```

Konfiguracija PE5:

```
bgp 15000
 router-id 160.160.161.5
 peer 160.160.161.1 as-number 15000
 peer 160.160.161.1 description P1
 peer 160.160.161.1 connect-interface LoopBack0
 peer 160.160.161.3 as-number 15000
 peer 160.160.161.3 description P3
 peer 160.160.161.3 connect-interface LoopBack0
```

```
 #
 ipv4-family unicast
  undo synchronization
  import-route static
  bestroute nexthop-resolved tunnel
  undo peer 160.160.161.1 enable
  undo peer 160.160.161.3 enable
 #
 ipv4-family vpnv4
  policy vpn-target
  peer 160.160.161.1 enable
  peer 160.160.161.1 advertise-community
  peer 160.160.161.3 enable
  peer 160.160.161.3 advertise-community
```

Konfiguracija PE6:

```
bgp 15000
 router-id 160.160.161.6
 peer 160.160.161.1 as-number 15000
 peer 160.160.161.1 description P1
 peer 160.160.161.1 connect-interface LoopBack0
 peer 160.160.161.3 as-number 15000
 peer 160.160.161.3 description P3
 peer 160.160.161.3 connect-interface LoopBack0
 #
 ipv4-family unicast
  undo synchronization
  import-route static
  bestroute nexthop-resolved tunnel
  undo peer 160.160.161.1 enable
  undo peer 160.160.161.3 enable
 #
 ipv4-family vpnv4
  policy vpn-target
  peer 160.160.161.1 enable
  peer 160.160.161.1 advertise-community
  peer 160.160.161.3 enable
  peer 160.160.161.3 advertise-community
```

Konfiguracija PE7:

```
bgp 15000
 router-id 160.160.161.7
 peer 160.160.161.1 as-number 15000
 peer 160.160.161.1 description P1
 peer 160.160.161.1 connect-interface LoopBack0
 peer 160.160.161.3 as-number 15000
 peer 160.160.161.3 description P3
 peer 160.160.161.3 connect-interface LoopBack0
 #
 ipv4-family unicast
  undo synchronization
  undo peer 160.160.161.1 enable
  undo peer 160.160.161.3 enable
 #
 ipv4-family vpnv4
  policy vpn-target
  peer 160.160.161.1 enable
```

```
  peer 160.160.161.1 advertise-community
  peer 160.160.161.3 enable
  peer 160.160.161.3 advertise-community
```

Konfiguracija PE8:

```
bgp 15000
 router-id 160.160.161.8
 peer 160.160.161.1 as-number 15000
 peer 160.160.161.1 description P1
 peer 160.160.161.1 connect-interface LoopBack0
 peer 160.160.161.3 as-number 15000
 peer 160.160.161.3 description P3
 peer 160.160.161.3 connect-interface LoopBack0
 #
 ipv4-family unicast
  undo synchronization
  undo peer 160.160.161.1 enable
  undo peer 160.160.161.3 enable
 #
 ipv4-family vpnv4
  policy vpn-target
  peer 160.160.161.1 enable
  peer 160.160.161.1 advertise-community
  peer 160.160.161.3 enable
  peer 160.160.161.3 advertise-community
```

Konfiguracija PE9:

```
bgp 15000
 router-id 160.160.161.9
 peer 160.160.161.1 as-number 15000
 peer 160.160.161.1 description P1
 peer 160.160.161.1 connect-interface LoopBack0
 peer 160.160.161.3 as-number 15000
 peer 160.160.161.3 description P3
 peer 160.160.161.3 connect-interface LoopBack0
 #
 ipv4-family unicast
  undo synchronization
  undo peer 160.160.161.1 enable
  undo peer 160.160.161.3 enable
 #
 ipv4-family vpnv4
  policy vpn-target
  peer 160.160.161.1 enable
  peer 160.160.161.1 advertise-community
  peer 160.160.161.3 enable
  peer 160.160.161.3 advertise-community
```

Konfiguracija PE10:

```
bgp 15000
 router-id 160.160.161.10
 peer 160.160.161.1 as-number 15000
 peer 160.160.161.1 description P1
 peer 160.160.161.1 connect-interface LoopBack0
 peer 160.160.161.3 as-number 15000
 peer 160.160.161.3 description P3
```

```
 peer 160.160.161.3 connect-interface LoopBack0
 #
 ipv4-family unicast
  undo synchronization
  undo peer 160.160.161.1 enable
  undo peer 160.160.161.3 enable
 #
 ipv4-family vpnv4
  policy vpn-target
  peer 160.160.161.1 enable
  peer 160.160.161.1 advertise-community
  peer 160.160.161.3 enable
  peer 160.160.161.3 advertise-community
```

Verifikacija:

Sa komandom **display bgp vpnv4 all peer**, možemo da proverimo sve BGP vpnv4 *peer*-ove. Dati su prikazi za P1 (*Route Reflector*) i PE5.

```
<P1>display bgp vpnv4 all peer

 BGP local router ID : 160.160.161.1
 Local AS number : 15000
 Total number of peers : 9            Peers in established state : 9

  Peer            V          AS  MsgRcvd  MsgSent  OutQ  Up/Down       State
Pref
Rcv

  160.160.161.2   4       15000       18       20     0 00:16:02 Established
  0
  160.160.161.3   4       15000       20       20     0 00:16:11 Established
  0
  160.160.161.4   4       15000       17       18     0 00:15:39 Established
  0
  160.160.161.5   4       15000       19       20     0 00:16:09 Established
  1
  160.160.161.6   4       15000       19       20     0 00:16:03 Established
  1
  160.160.161.7   4       15000       18       20     0 00:16:03 Established
  0
  160.160.161.8   4       15000       17       18     0 00:15:39 Established
  0
  160.160.161.9   4       15000       17       19     0 00:15:25 Established
  0
  160.160.161.10  4       15000       17       19     0 00:15:36 Established
  0

<PE5>display bgp vpnv4 all peer

 BGP local router ID : 160.160.161.5
 Local AS number : 15000
 Total number of peers : 2            Peers in established state : 2

  Peer            V          AS  MsgRcvd  MsgSent  OutQ  Up/Down       State
Pref
Rcv

  160.160.161.1   4       15000       19       19     0 00:16:40 Established
```

```
0
160.160.161.3   4       15000       20       19     0 00:16:40 Established
1
```

3.6. Konfiguracija L3VPN-a

U konfiguraciji koju prezentujemo, kreirali smo posebnu VPN instancu (VRF, *Virtual Route Forwarding*)pod imenom *media* za korisnike prema UMG1 i UMG2 ruterima. Radi jednostavnosti, nismo konfigurisali dinamički protokol između PE rutera i UMG rutera, već smo samo definisali statičke rute koje će nam biti potrebne za testiranje. U nastavku se može videti konfiguracija.

Konfiguracija PE5:

```
ip vpn-instance media
 ipv4-family
  route-distinguisher 15000:100
  ip frr route-policy ip-frr-umg1
  vpn frr route-policy vpn-frr-pe7
  tnl-policy pe5
  vpn-target 15000:100 export-extcommunity
  vpn-target 15000:100 import-extcommunity
#
bgp 15000
 ipv4-family vpn-instance media
  import-route static
#
ip route-static vpn-instance media 11.11.11.11 255.255.255.255 10.1.1.2
ip route-static vpn-instance media 11.11.11.11 255.255.255.255
160.160.165.2 preference 100
```

Konfiguracija PE6:

```
ip vpn-instance media
 ipv4-family
  route-distinguisher 15000:100
  vpn frr route-policy vpn-frr-pe7
  tnl-policy pe6
  vpn-target 15000:100 export-extcommunity
  vpn-target 15000:100 import-extcommunity
#
bgp 15000
ipv4-family vpn-instance media
        import-route static
#
ip route-static vpn-instance media 11.11.11.11 255.255.255.255 10.1.2.2
ip route-static vpn-instance media 11.11.11.11 255.255.255.255
160.160.165.1 preference 100
```

Konfiguracija PE7:

```
ip vpn-instance media
 ipv4-family
  route-distinguisher 15000:100
  ip frr route-policy ip-frr-umg2
  vpn frr route-policy vpn-frr-pe5
  tnl-policy pe7
  vpn-target 15000:100 export-extcommunity
```

```
  vpn-target 15000:100 import-extcommunity
#
bgp 15000
 ipv4-family vpn-instance media
   import-route static
#
ip route-static vpn-instance media 22.22.22.22 255.255.255.255 10.1.3.2
ip route-static vpn-instance media 22.22.22.22 255.255.255.255
160.160.165.6 preference 100
```

Konfiguracija PE8:

```
ip vpn-instance media
 ipv4-family
  route-distinguisher 15000:100
  vpn frr route-policy vpn-frr-pe6
  tnl-policy pe8
  vpn-target 15000:100 export-extcommunity
  vpn-target 15000:100 import-extcommunity
#
bgp 15000
 ipv4-family vpn-instance media
   import-route static
#
ip route-static vpn-instance media 22.22.22.22 255.255.255.255 10.1.4.2
ip route-static vpn-instance media 22.22.22.22 255.255.255.255
160.160.165.5 preference 100
```

Konfiguracija PE9:

```
ip vpn-instance media
 ipv4-family
  route-distinguisher 15000:100
  vpn-target 15000:100 export-extcommunity
  vpn-target 15000:100 import-extcommunity
#
bgp 15000
 ipv4-family vpn-instance media
 import-route direct
```

Konfiguracija PE10:

```
ip vpn-instance media
 ipv4-family
  route-distinguisher 15000:100
  vpn-target 15000:100 export-extcommunity
  vpn-target 15000:100 import-extcommunity
#
bgp 15000
 ipv4-family vpn-instance media
 import-route direct
```

Konfiguracija CLIENT11:

```
ip route-static 0.0.0.0 0.0.0.0 10.0.0.10
```

Konfiguracija UMG1:

```
ip route-static 0.0.0.0 0.0.0.0 10.1.2.1 preference 30
```

```
ip route-static 0.0.0.0 0.0.0.0 10.1.1.1 preference 20
```

Konfiguracija UMG2:

```
ip route-static 0.0.0.0 0.0.0.0 10.1.3.1 preference 20
ip route-static 0.0.0.0 0.0.0.0 10.1.4.1 preference 30
```

Verifikacija:

Možemo sa **display ip routing-table** videti tabelu rutiranja i videti da imamo rute koje potiču i sa UMG1 i sa UMG2:

```
<UMG1>dis ip routing-table
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Routing Tables: Public
         Destinations : 9        Routes : 9

Destination/Mask    Proto   Pre  Cost      Flags NextHop         Interface

        0.0.0.0/0   Static  20   0           RD   10.1.1.1     Ethernet0/0/0
       10.1.1.0/30  Direct  0    0            D   10.1.1.2     Ethernet0/0/0
       10.1.1.2/32  Direct  0    0            D   127.0.0.1    Ethernet0/0/0
       10.1.2.0/30  Direct  0    0            D   10.1.2.2     Ethernet0/0/1
       10.1.2.2/32  Direct  0    0            D   127.0.0.1    Ethernet0/0/1
    11.11.11.11/32  Direct  0    0            D   127.0.0.1       LoopBack1
    22.22.22.22/32  Static  20   0           RD   10.1.1.1     Ethernet0/0/0
      127.0.0.0/8   Direct  0    0            D   127.0.0.1     InLoopBack0
      127.0.0.1/32  Direct  0    0            D   127.0.0.1      InLoopBack0
```

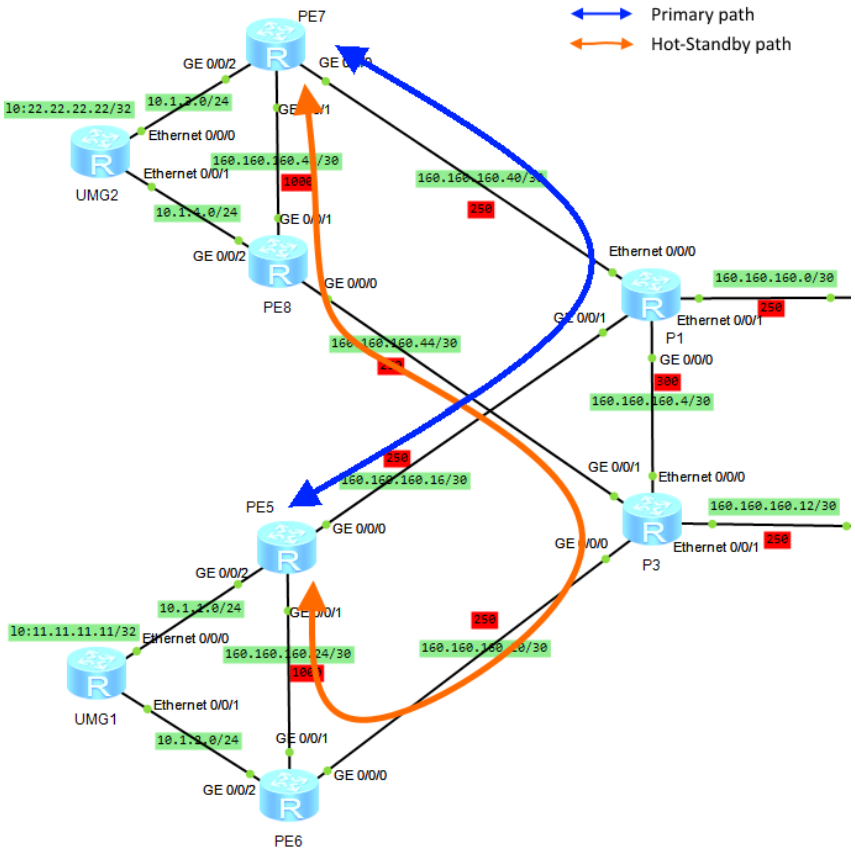
Možemo takođe proveriti konektivnost između *loopback* adresa sa **ping** komandom.

```
<UMG1>ping -a 11.11.11.11 22.22.22.22
  PING 22.22.22.22: 56  data bytes, press CTRL_C to break
    Reply from 22.22.22.22: bytes=56 Sequence=1 ttl=253 time=110 ms
    Reply from 22.22.22.22: bytes=56 Sequence=2 ttl=253 time=110 ms
    Reply from 22.22.22.22: bytes=56 Sequence=3 ttl=253 time=80 ms
    Reply from 22.22.22.22: bytes=56 Sequence=4 ttl=253 time=110 ms
    Reply from 22.22.22.22: bytes=56 Sequence=5 ttl=253 time=90 ms

  --- 22.22.22.22 ping statistics ---
    5 packet(s) transmitted
    5 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 80/100/110 ms
```

3.7. Konfiguracija tunela i *hot-standby*

Zarad našeg testiranja i analize, konfigurisani su tuneli između dve lokacije našeg korisnika (lokacije kod PE5/PE6 i lokacije kod PE7/PE8 rutera). To su PE5 – PE7, PE5 – PE8, PE6 – PE7, PE6 – PE8, kao i odgovarajuće zaštite a svaki od njih koje idu nezavisnom putanjom od primarne. U slučaju otkaza nekog dela putanje, saobraćaj će se prebaciti na *hot-standby* putanju, i neće doći do obaranja tunela i prekida saobraćaja. Za svaki tunel je konfigurisan BFD zbog brze detekcije

pada tunela. Na slici 3.7.1 možete videti prikaz *Primary* i *Hot-Standby* putanje od PE5 ka PE7 ruteru. U nastavku je priložena konfiguracija relevantna za konfigurisanje ovih tunela i *hot-standby* zaštite:



Slika 3.7.1 Prikazane PE5 – PE7 primarna i *Hot-Standby* putanja

Konfiguracija PE5:

```
bfd
 mpls-passive
#
//pe5 – pe7 hot-standby putanja: pe5 – pe6 – p3 – pe8 – pe7
explicit-path to_pe7_backup
 next hop 160.160.160.26
 next hop 160.160.160.21
 next hop 160.160.160.46
 next hop 160.160.160.49
 next hop 160.160.161.7
#
//pe5 – pe7 primarna putanja: pe5 – p1 – pe7
explicit-path to_pe7_main
 next hop 160.160.160.17
 next hop 160.160.160.42
 next hop 160.160.161.7
#
//pe5 – pe8 hot-standby putanja: pe5 – pe6 – p3 – pe8
explicit-path to_pe8_backup
 next hop 160.160.160.26
```

```
 next hop 160.160.160.21
 next hop 160.160.160.46
 next hop 160.160.161.8
#
//pe5 – pe8 primarna putanja: pe5 – p1 – pe7 – pe8
explicit-path to_pe8_main
 next hop 160.160.160.17
 next hop 160.160.160.42
 next hop 160.160.160.50
 next hop 160.160.161.8
#
interface Tunnel0/0/0
 description TO_PE7
 ip address unnumbered interface LoopBack0
 tunnel-protocol mpls te
 destination 160.160.161.7
mpls te tunnel-id 100
mpls te bfd enable
mpls te bfd min-tx-interval 100 min-rx-interval 100
 mpls te record-route label
 mpls te bandwidth ct0 10000
 mpls te path explicit-path to_pe7_main
 mpls te path explicit-path to_pe7_backup secondary
 mpls te fast-reroute
 mpls te backup hot-standby mode revertive wtr 30
 mpls te reserved-for-binding
 mpls te commit
#
interface Tunnel0/0/1
 description TO_PE8
 ip address unnumbered interface LoopBack0
 tunnel-protocol mpls te
 destination 160.160.161.8
mpls te tunnel-id 101
mpls te bfd enable
mpls te bfd min-tx-interval 100 min-rx-interval 100
 mpls te record-route label
 mpls te bandwidth ct0 10000
 mpls te path explicit-path to_pe8_main
 mpls te path explicit-path to_pe8_backup secondary
 mpls te fast-reroute
 mpls te backup hot-standby mode revertive wtr 30
 mpls te reserved-for-binding
 mpls te commit
#
tunnel-policy pe5
 tunnel binding destination 160.160.161.7 te Tunnel0/0/0
 tunnel binding destination 160.160.161.8 te Tunnel0/0/1
#
ip vpn-instance media
 ipv4-family
  tnl-policy pe5
```

Konfiguracija PE6:

```
bfd
 mpls-passive
```

```
#
//pe6 – pe7 hot-standby putanja: pe6 – pe5 – p1 – pe7
explicit-path to_pe7_backup
 next hop 160.160.160.25
 next hop 160.160.160.17
 next hop 160.160.160.42
 next hop 160.160.161.7
#
//pe6 – pe7 primarna putanja: pe6 – p3 – pe8 – pe7
explicit-path to_pe7_main
 next hop 160.160.160.21
 next hop 160.160.160.46
 next hop 160.160.160.49
 next hop 160.160.161.7
#
//pe6 – pe8 hot-standby putanja: pe6 – pe5 – p1 – pe7 – pe8
explicit-path to_pe8_backup
 next hop 160.160.160.25
 next hop 160.160.160.17
 next hop 160.160.160.42
 next hop 160.160.160.50
 next hop 160.160.161.8
#
//pe6 – pe8 primarna putanja: pe6 – p3 – pe8
explicit-path to_pe8_main
 next hop 160.160.160.21
 next hop 160.160.160.46
 next hop 160.160.161.8
#
interface Tunnel0/0/0
 description to_pe7
 ip address unnumbered interface LoopBack0
 tunnel-protocol mpls te
 destination 160.160.161.7
mpls te tunnel-id 102
mpls te bfd enable
mpls te bfd min-tx-interval 100 min-rx-interval 100
 mpls te record-route label
 mpls te bandwidth ct0 10000
 mpls te path explicit-path to_pe7_main
 mpls te path explicit-path to_pe7_backup secondary
 mpls te fast-reroute
 mpls te backup hot-standby mode revertive wtr 30
 mpls te reserved-for-binding
 mpls te commit
#
interface Tunnel0/0/1
 description to_pe8
 ip address unnumbered interface LoopBack0
 tunnel-protocol mpls te
 destination 160.160.161.8
mpls te tunnel-id 103
mpls te bfd enable
mpls te bfd min-tx-interval 100 min-rx-interval 100
 mpls te record-route label
 mpls te bandwidth ct0 10000
 mpls te path explicit-path to_pe8_main
 mpls te path explicit-path to_pe8_backup secondary
 mpls te fast-reroute
```

```
 mpls te backup hot-standby mode revertive wtr 30
 mpls te reserved-for-binding
 mpls te commit
#
tunnel-policy pe6
 tunnel binding destination 160.160.161.7 te Tunnel0/0/0
 tunnel binding destination 160.160.161.8 te Tunnel0/0/1
#
ip vpn-instance media
 ipv4-family
   tnl-policy pe6
```

Konfiguracija PE7:

```
bfd
 mpls-passive
#
//pe7 – pe5 hot-standby putanja: pe7 – pe8 – p3 – pe6 – pe5
explicit-path to_pe5_backup
 next hop 160.160.160.50
 next hop 160.160.160.45
 next hop 160.160.160.22
 next hop 160.160.160.25
 next hop 160.160.161.5
#
//pe7 – pe5 primarna putanja: pe7 – p1 – pe5
explicit-path to_pe5_main
 next hop 160.160.160.41
 next hop 160.160.160.18
 next hop 160.160.161.5
#
//pe7 – pe6 hot-standby putanja: pe7 – pe8 – p3 – pe6
explicit-path to_pe6_backup
 next hop 160.160.160.50
 next hop 160.160.160.45
 next hop 160.160.160.22
 next hop 160.160.161.6
#
//pe7 – pe6 primarna putanja: pe7 – p1 – pe5 – pe6
explicit-path to_pe6_main
 next hop 160.160.160.41
 next hop 160.160.160.18
 next hop 160.160.160.26
 next hop 160.160.161.6
#
interface Tunnel0/0/0
 description to_pe5
 ip address unnumbered interface LoopBack0
 tunnel-protocol mpls te
 destination 160.160.161.5
mpls te tunnel-id 104
mpls te bfd enable
mpls te bfd min-tx-interval 100 min-rx-interval 100
 mpls te record-route label
 mpls te bandwidth ct0 10000
 mpls te path explicit-path to_pe5_main
 mpls te path explicit-path to_pe5_backup secondary
 mpls te fast-reroute
 mpls te backup hot-standby mode revertive wtr 30
```

```
 mpls te reserved-for-binding
 mpls te commit
#
interface Tunnel0/0/1
 description to_pe6
 ip address unnumbered interface LoopBack0
 tunnel-protocol mpls te
 destination 160.160.161.6
mpls te tunnel-id 105
mpls te bfd enable
mpls te bfd min-tx-interval 100 min-rx-interval 100
 mpls te record-route label
 mpls te bandwidth ct0 10000
 mpls te path explicit-path to_pe6_main
 mpls te path explicit-path to_pe6_backup secondary
 mpls te fast-reroute
 mpls te backup hot-standby mode revertive wtr 30
 mpls te reserved-for-binding
 mpls te commit
#
tunnel-policy pe7
 tunnel binding destination 160.160.161.5 te Tunnel0/0/0
 tunnel binding destination 160.160.161.6 te Tunnel0/0/1
#
ip vpn-instance media
 ipv4-family
   tnl-policy pe7
```

Konfiguracija PE8:

```
bfd
 mpls-passive
#
//pe8 – pe5 hot-standby putanja: pe8 – pe7 – p1 – pe5
explicit-path to_pe5_backup
 next hop 160.160.160.49
 next hop 160.160.160.41
 next hop 160.160.160.18
 next hop 160.160.161.5
#
//pe8 – pe5 primarna putanja: pe8 – p3 – pe6 – pe5
explicit-path to_pe5_main
 next hop 160.160.160.45
 next hop 160.160.160.22
 next hop 160.160.160.25
 next hop 160.160.161.5
#
//pe8 – pe6 hot-standby putanja: pe8 – pe7 – p1 – pe5 – pe6
explicit-path to_pe6_backup
 next hop 160.160.160.49
 next hop 160.160.160.41
 next hop 160.160.160.18
 next hop 160.160.160.26
 next hop 160.160.161.6
#
//pe8 – pe6 primarna putanja: pe8 – p3 – pe6
explicit-path to_pe6_main
 next hop 160.160.160.45
 next hop 160.160.160.22
```

```
 next hop 160.160.161.6
#
interface Tunnel0/0/0
 description to_pe5
 ip address unnumbered interface LoopBack0
 tunnel-protocol mpls te
 destination 160.160.161.5
mpls te tunnel-id 106
mpls te bfd enable
mpls te bfd min-tx-interval 100 min-rx-interval 100
 mpls te record-route label
 mpls te bandwidth ct0 10000
 mpls te path explicit-path to_pe5_main
 mpls te path explicit-path to_pe5_backup secondary
 mpls te fast-reroute
 mpls te backup hot-standby mode revertive wtr 30
 mpls te reserved-for-binding
 mpls te commit
#
interface Tunnel0/0/1
 description to_pe6
 ip address unnumbered interface LoopBack0
 tunnel-protocol mpls te
 destination 160.160.161.6
 mpls te tunnel-id 107
mpls te bfd enable
mpls te bfd min-tx-interval 100 min-rx-interval 100
 mpls te record-route label
 mpls te bandwidth ct0 10000
 mpls te path explicit-path to_pe6_main
 mpls te path explicit-path to_pe6_backup secondary
 mpls te fast-reroute
 mpls te backup hot-standby mode revertive wtr 30
 mpls te reserved-for-binding
 mpls te commit
#
tunnel-policy pe8
 tunnel binding destination 160.160.161.5 te Tunnel0/0/0
 tunnel binding destination 160.160.161.6 te Tunnel0/0/1
#
ip vpn-instance media
 ipv4-family
   tnl-policy pe8
```

Verifikacija:

Koristimo **display explicit-path** komandu da proverimo informacije vezano za *explicith path.* Prikazujemo *output* na PE5.

```
<PE5>display explicit-path
Path Name : to_pe7_backup  Path Status : Enabled
 1      160.160.160.26    Strict      Include
 2      160.160.160.21    Strict      Include
 3      160.160.160.46    Strict      Include
 4      160.160.160.49    Strict      Include
 5      160.160.161.7     Strict      Include
```

```
Path Name : to_pe7_main  Path Status : Enabled
 1      160.160.160.17    Strict      Include
 2      160.160.160.42    Strict      Include
 3      160.160.161.7     Strict      Include

Path Name : to_pe8_backup  Path Status : Enabled
 1      160.160.160.26    Strict      Include
 2      160.160.160.21    Strict      Include
 3      160.160.160.46    Strict      Include
 4      160.160.161.8     Strict      Include

Path Name : to_pe8_main  Path Status : Enabled
 1      160.160.160.17    Strict      Include
 2      160.160.160.42    Strict      Include
 3      160.160.160.50    Strict      Include
 4      160.160.161.8     Strict      Include
```

Koristimo **display mpls te tunnel-interface tunnel 0/0/0** da bi videli osnovne informacije o tunelu. Prikazujemo *output* za *Tunnel* 0/0/0 na PE5 ruteru.

```
<PE5>display mpls te tunnel-interface Tunnel 0/0/0
    ------------------------------------------------------------------
                              Tunnel0/0/0
    ------------------------------------------------------------------
    Tunnel State Desc   :  UP
    Active LSP          :  Primary LSP
    Session ID          :  100
    Ingress LSR ID      :  160.160.161.5    Egress LSR ID:  160.160.161.7
    Admin State         :  UP               Oper State   :  UP
    Primary LSP State      : UP
      Main LSP State       : READY              LSP ID  : 3
    Hot-Standby LSP State  : UP
      Main LSP State       : READY              LSP ID  : 32770
```

Sa **ping lsp te tunnel 0/0/0 hot-standby** komandom možemo da proverimo konektivnost *hot-standby* CR-LSP-a. Prikaz je dat za *Tunnel* 0/0/0 na ruteru PE5.

```
<PE5>ping lsp te Tunnel 0/0/0 hot-standby
  LSP PING FEC: TE TUNNEL IPV4 SESSION QUERY Tunnel0/0/0 : 100  data bytes,
press
 CTRL_C to break
    Reply from 160.160.161.7: bytes=100 Sequence=1 time=110 ms
    Reply from 160.160.161.7: bytes=100 Sequence=2 time=70 ms
    Reply from 160.160.161.7: bytes=100 Sequence=3 time=50 ms
    Reply from 160.160.161.7: bytes=100 Sequence=4 time=90 ms
    Reply from 160.160.161.7: bytes=100 Sequence=5 time=100 ms

  --- FEC: TE TUNNEL IPV4 SESSION QUERY Tunnel0/0/0 ping statistics ---
    5 packet(s) transmitted
    5 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 50/84/110 ms
```

A da proverimo putanju koju koristi, tunel možemo koristiti **tracert lsp te Tunnel 0/0/0 hot-standby**. Na primer isto za T*unnel* 0/0/0 na PE5 ruteru.

```
<PE5>tracert lsp te Tunnel 0/0/0 hot-standby
  LSP Trace Route FEC: TE TUNNEL IPV4 SESSION QUERY Tunnel0/0/0 , press CTRL_C
to
 break.
  TTL   Replier            Time    Type      Downstream
  0                                Ingress   160.160.160.26/[1032 ]
  1     160.160.160.26     30 ms   Transit   160.160.160.21/[1035 ]
  2     160.160.160.21     70 ms   Transit   160.160.160.46/[1032 ]
  3     160.160.160.46     80 ms   Transit   160.160.160.49/[3 ]
  4     160.160.161.7      80 ms   Egress
```

Koristimo komandu **display bfd session dynamic** da proverimo status BFD-a. Prikazujemo *output* na PE5 ruter:

```
<PE5>display bfd session dynamic
------------------------------------------------------------------------------
Local Remote     PeerIpAddr      State     Type        InterfaceName
------------------------------------------------------------------------------
8194  8197       160.160.161.7   Up        D_TE_LSP    Tunnel0/0/0
8195  8197       160.160.161.8   Up        D_TE_LSP    Tunnel0/0/1
------------------------------------------------------------------------------
     Total UP/DOWN Session Number : 2/0
```

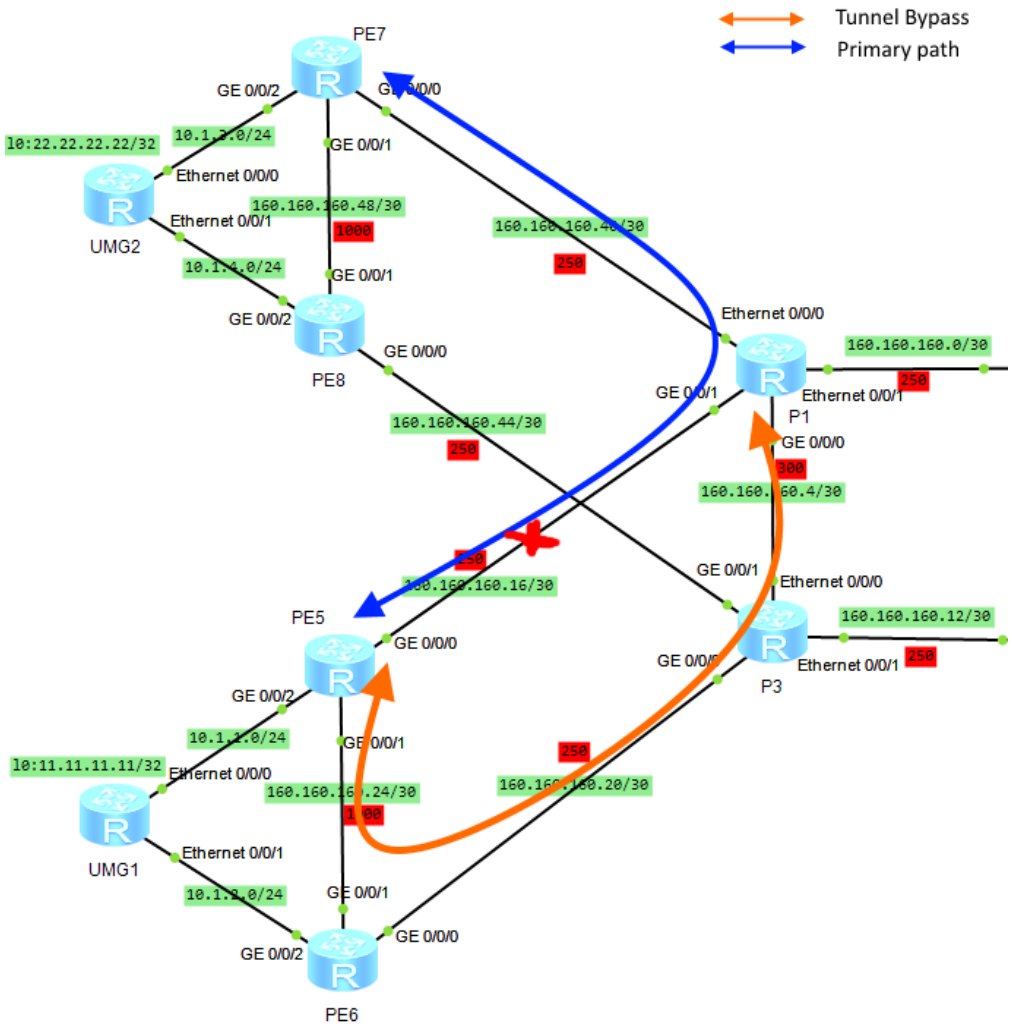
3.8. Konfiguracija TE FRR-a

Slično *hot-standby* rešenju i TE FRR smo konfigurisali na segmentu koji je potreban da bi se zaštitila konektivnost između dve lokacije korisnika (ka UMG1 i UMG2 ruterima). U tom cilju konfigurisane su TE FRR zaštite za sledeće linkove: PE5 – P1, PE6 – P3, P1 – PE7 i P3 – PE8. Ova vrsta zaštite štiti sve tunele za dotični link za koji je konfigurisana. Na slici 3.8.1 se može videti *Primary* i *Bypass* putanja u slučaju otkaza linka između PE5 i P1 rutera.

Konfiguracija P1:

```
//bypass za p1 – pe5 link: p1 – p3 – pe6 – pe5
explicit-path to_pe5_bypass
 next hop 160.160.160.6
 next hop 160.160.160.22
 next hop 160.160.160.25
 next hop 160.160.161.5
#
//bypass za p1 – pe7 link: p1 – p3 – pe8 – pe7
explicit-path to_pe7_bypass
 next hop 160.160.160.6
 next hop 160.160.160.46
 next hop 160.160.160.49
 next hop 160.160.161.7
#
interface Tunnel0/0/0
 description to_pe7_bypass
 ip address unnumbered interface LoopBack0
 tunnel-protocol mpls te
destination 160.160.161.7
 mpls te tunnel-id 110
 mpls te record-route
```

```
 mpls te bandwidth ct0 8000
 mpls te path explicit-path to_pe7_bypass
 mpls te bypass-tunnel
```



Slika 3.8.1 Prikazana PE5 – PE7 primarna i *bypass* TE FRR putanja

```
mpls te protected-interface Ethernet0/0/0
 mpls te fast-reroute
 mpls te commit
#
interface Tunnel0/0/1
 description to_pe5
 ip address unnumbered interface LoopBack0
 tunnel-protocol mpls te
 destination 160.160.161.5
 mpls te tunnel-id 112
 mpls te record-route
 mpls te bandwidth ct0 8000
 mpls te path explicit-path to_pe5_bypass
 mpls te bypass-tunnel
```

```
 mpls te protected-interface GigabitEthernet0/0/1
 mpls te fast-reroute
 mpls te commit
#
interface Ethernet0/0/0
 mpls rsvp-te bfd enable
 mpls rsvp-te bfd min-tx-interval 100 min-rx-interval 100
#
interface GigabitEthernet0/0/1
 mpls rsvp-te bfd enable
 mpls rsvp-te bfd min-tx-interval 100 min-rx-interval 100
```

Konfiguracija P3:

```
//bypass za p3 – pe6 link: p3 – p1 – pe5 – pe6
explicit-path to_pe6_bypass
 next hop 160.160.160.5
 next hop 160.160.160.18
 next hop 160.160.160.26
 next hop 160.160.161.6
#
//bypass za p3 – pe8 link: p3 – p1 – pe7 – pe8
explicit-path to_pe8_bypass
 next hop 160.160.160.5
 next hop 160.160.160.42
 next hop 160.160.160.50
 next hop 160.160.161.8
#
interface Tunnel0/0/0
 description to_pe8_bypass
 ip address unnumbered interface LoopBack0
 tunnel-protocol mpls te
 destination 160.160.161.8
 mpls te tunnel-id 111
 mpls te record-route
 mpls te bandwidth ct0 8000
 mpls te path explicit-path to_pe8_bypass
 mpls te bypass-tunnel
 mpls te protected-interface GigabitEthernet0/0/1
 mpls te fast-reroute
 mpls te commit
#
interface Tunnel0/0/1
 description to_pe5_bypass
 ip address unnumbered interface LoopBack0
 tunnel-protocol mpls te
 destination 160.160.161.6
 mpls te tunnel-id 113
 mpls te record-route
 mpls te bandwidth ct0 8000
 mpls te path explicit-path to_pe6_bypass
 mpls te bypass-tunnel
 mpls te protected-interface GigabitEthernet0/0/0
 mpls te fast-reroute
 mpls te commit
#
interface GigabitEthernet0/0/0
 mpls rsvp-te bfd enable
```

```
 mpls rsvp-te bfd min-tx-interval 100 min-rx-interval 100
#
interface GigabitEthernet0/0/1
 mpls rsvp-te bfd enable
 mpls rsvp-te bfd min-tx-interval 100 min-rx-interval 100
```

Konfiguracija PE5:

```
interface GigabitEthernet0/0/0
 mpls rsvp-te bfd enable
```

Konfiguracija PE6:

```
interface GigabitEthernet0/0/0
 mpls rsvp-te bfd enable
```

Konfiguracija PE7:

```
interface GigabitEthernet0/0/0
 mpls rsvp-te bfd enable
```

Konfiguracija PE8:

```
interface GigabitEthernet0/0/0
 mpls rsvp-te bfd enable
```

Verifikacija:

Koristimo **display bfd session dynamic** da vidimo status BFD sesija koje imamo konfigurisane

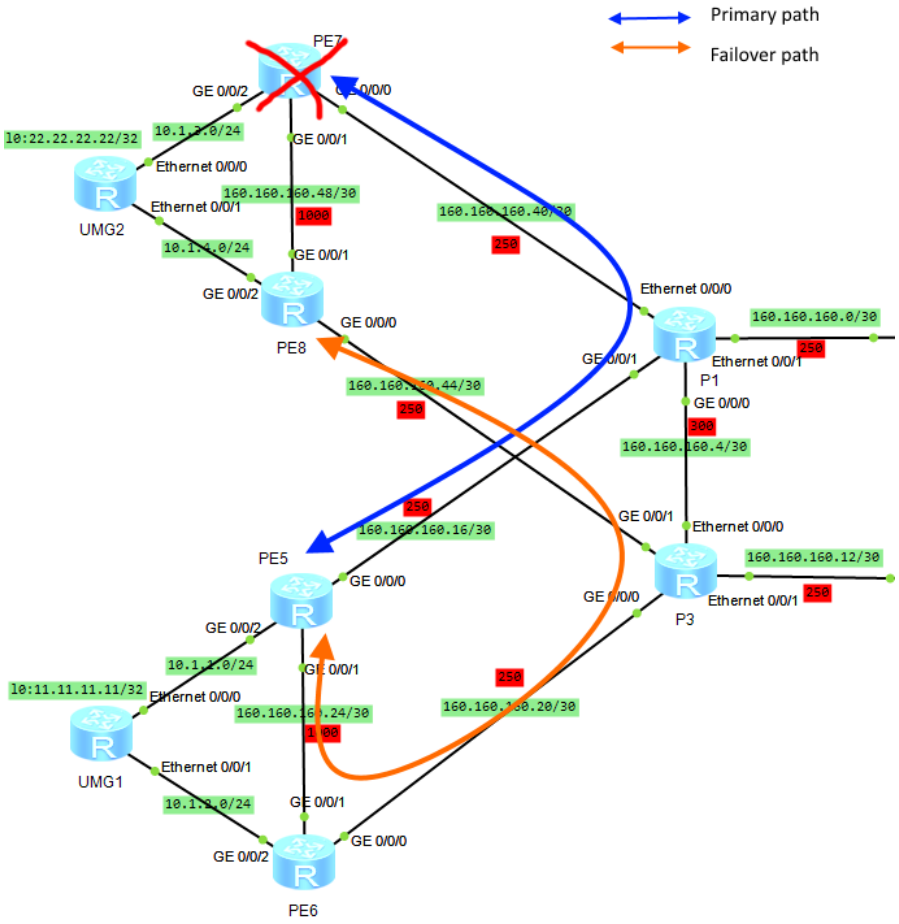
```
[P1]display bfd session dynamic
--------------------------------------------------------------------------------
Local Remote     PeerIpAddr      State     Type        InterfaceName
--------------------------------------------------------------------------------
8193  8192       160.160.160.18  Up        D_IP_IF     GigabitEthernet0/0/1
8196  8213       160.160.160.42  Up        D_IP_IF     Ethernet0/0/0
--------------------------------------------------------------------------------
     Total UP/DOWN Session Number : 2/0
```

Da verifikujemo da je tunel korektno konfigurisan koristimo **tracert lsp te Tunnel 0/0/0**.

```
[P1]tracert lsp te Tunnel 0/0/0
  LSP Trace Route FEC: TE TUNNEL IPV4 SESSION QUERY Tunnel0/0/0 , press CTRL_C
to
 break.
  TTL   Replier            Time    Type      Downstream
  0                                Ingress   160.160.160.6/[1031 ]
  1     160.160.160.6      70 ms   Transit   160.160.160.46/[1025 ]
  2     160.160.160.46     30 ms   Transit   160.160.160.49/[3 ]
  3     160.160.161.7      30 ms   Egress
```

3.9. Konfiguracija VPN FRR-a

Ovu zaštitu koristimo da bi se zaštitili od otkaza PE rutera. Konfigurisali smo je za varijante otkaza PE5, PE6, PE7 ili PE8 rutera. Na slici 3.9.1 se može videti šta se dešava u slučaju otkaza PE7 rutera (iscrtane su *Primary* i *Failover* putanja).



Slika 3.9.1 Prikazana *primary* i *failover* putanja od PE5 u slučaju otkaza PE7

Konfiguracija PE5:

```
ip ip-prefix vpnpe7 index 10 permit 160.160.161.7 32
#
route-policy vpn-frr-pe7 permit node 10
 if-match ip next-hop ip-prefix vpnpe7
 apply backup-nexthop 160.160.161.8
#
ip vpn-instance media
 ipv4-family
  vpn frr route-policy vpn-frr-pe7
```

Konfiguracija PE6:

```
route-policy vpn-frr-pe7 permit node 10
 if-match ip next-hop ip-prefix vpnpe7
 apply backup-nexthop 160.160.161.8
#
```

```
ip ip-prefix vpnpe7 index 10 permit 160.160.161.7 32
#
ip vpn-instance media
 ipv4-family
  vpn frr route-policy vpn-frr-pe7
```

Konfiguracija PE7:

```
route-policy vpn-frr-pe5 permit node 10
 if-match ip next-hop ip-prefix pe5
 apply backup-nexthop 160.160.161.6
#
ip ip-prefix pe5 index 10 permit 160.160.161.5 32
#
ip vpn-instance media
 ipv4-family
vpn frr route-policy vpn-frr-pe5
```

Konfiguracija PE8:

```
route-policy vpn-frr-pe6 permit node 10
 if-match ip next-hop ip-prefix pe6
 apply backup-nexthop 160.160.161.5
#
ip ip-prefix pe6 index 10 permit 160.160.161.6 32
#
ip vpn-instance media
 ipv4-family
vpn frr route-policy vpn-frr-pe6
```

Verifikacija:

Kucamo **display route-policy vpn-frr –pe7** komandu na PE5

```
<PE5>dis route-policy vpn-frr-pe7
Route-policy : vpn-frr-pe7
  permit : 10 (matched counts: 0)
    Match clauses :
      if-match ip next-hop ip-prefix vpnpe7
    Apply clauses :
      apply backup-nexthop 160.160.161.8
```

Kada ugasimo PE7 i videćemo da neće biti prekida saobraćaja, i kada ponovo startujemo PE7, nakon što se uspostave sve sesije, saobraćaj se vraća na primarnu putanju, a da smo imali poklapanje sa vpn-frr polisom i da je bila primenjena možemo verifikovati sa **display route-policy vpn-frr-pe7**, i videćemo povećani broj *counter*-a.

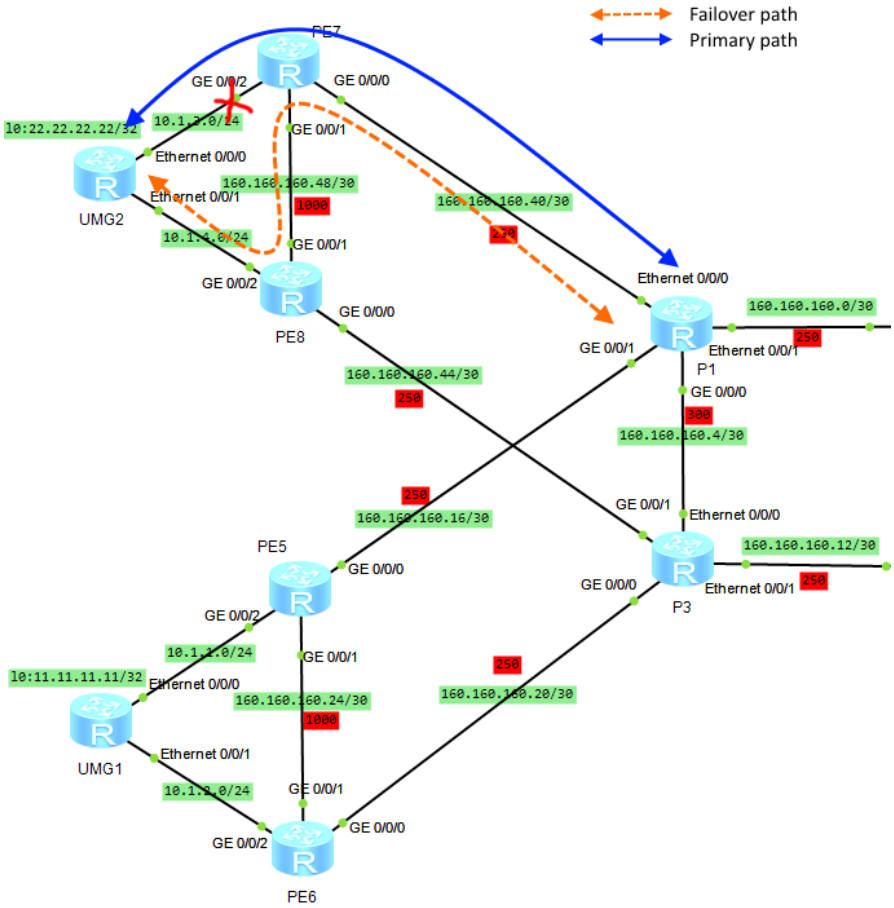
```
<PE5>dis route-policy vpn-frr-pe7
Route-policy : vpn-frr-pe7
  permit : 10 (matched counts: 3)
    Match clauses :
      if-match ip next-hop ip-prefix vpnpe7
    Apply clauses :
      apply backup-nexthop 160.160.161.8
```

Dok u *ping*-u neće biti više od jednog *timeout*-a u trenutku pada PE7

```
<UMG1>ping -c 500 -a 11.11.11.11 22.22.22.22
  PING 22.22.22.22: 56  data bytes, press CTRL_C to break
    Reply from 22.22.22.22: bytes=56 Sequence=13 ttl=253 time=90 ms
    Reply from 22.22.22.22: bytes=56 Sequence=14 ttl=253 time=90 ms
    Reply from 22.22.22.22: bytes=56 Sequence=15 ttl=253 time=110 ms
    Reply from 22.22.22.22: bytes=56 Sequence=16 ttl=253 time=90 ms
    Reply from 22.22.22.22: bytes=56 Sequence=17 ttl=253 time=70 ms
    Reply from 22.22.22.22: bytes=56 Sequence=18 ttl=253 time=110 ms
    Request time out
    Reply from 22.22.22.22: bytes=56 Sequence=20 ttl=252 time=160 ms
    Reply from 22.22.22.22: bytes=56 Sequence=21 ttl=252 time=130 ms
    Reply from 22.22.22.22: bytes=56 Sequence=22 ttl=252 time=140 ms
    Reply from 22.22.22.22: bytes=56 Sequence=23 ttl=252 time=130 ms
    Reply from 22.22.22.22: bytes=56 Sequence=24 ttl=252 time=140 ms
```

3.10.Konfiguracija IP FRR-a

U slučaju otkaza linka prema korisničkoj mreži (na slici 3.10.1 vidimo otkaz linka od PE7 ka korisničkom UMG2 ruteru), konfigurišemo IP FRR, koji omogućava da se saobraćaj brzo prebaci na alternativnu putanju preko redundantnog PE rutera.



Slika 3.10.1 IP FRR u slučaju otkaza linka UMG2 – PE7

Konfiguracija PE5:

```
route-policy ip-frr-umg1 permit node 10
 if-match ip next-hop ip-prefix UMG1
 apply backup-nexthop 160.160.165.2
 apply backup-interface GigabitEthernet0/0/1.1
#
ip ip-prefix UMG1 index 30 permit 10.1.1.0 30 greater-equal 30 less-equal
32
#
bfd umg1 bind peer-ip 10.1.1.2 vpn-instance media interface
GigabitEthernet0/0/2
 discriminator local 55
 discriminator remote 66
 min-tx-interval 100
 min-rx-interval 100
 commit
```

Konfiguracija UMG1:

```
bfd umg1 bind peer-ip 10.1.1.1 interface Ethernet0/0/0
 discriminator local 66
 discriminator remote 55
 min-tx-interval 100
 min-rx-interval 100
 commit
```

Konfiguracija PE7:

```
route-policy ip-frr-umg2 permit node 10
 if-match ip next-hop ip-prefix umg2
 apply backup-nexthop 160.160.165.6
 apply backup-interface GigabitEthernet0/0/1.1
#
ip ip-prefix umg2 index 20 permit 10.1.3.0 30 greater-equal 30 less-equal
32
#
bfd umg2 bind peer-ip 10.1.3.2 vpn-instance media interface
GigabitEthernet0/0/2
 discriminator local 88
 discriminator remote 77
 min-tx-interval 100
 min-rx-interval 100
 commit
```

Konfiguracija UMG2:

```
bfd umg2 bind peer-ip 10.1.3.1 interface Ethernet0/0/0
 discriminator local 77
 discriminator remote 88
 min-tx-interval 100
 min-rx-interval 100
 commit
```

Verifikacija:

Uradićemo proveru na PE5 ruteru. Ako uradimo **display route-policy ip-frr-umg1** videćemo broj *counter*-a trenutni:

```
[PE5]dis route-policy ip-frr-umg1
Route-policy : ip-frr-umg1
  permit : 10 (matched counts: 0)
    Match clauses :
      if-match ip next-hop ip-prefix UMG1
    Apply clauses :
      apply backup-nexthop 160.160.165.2
      apply backup-interface GigabitEthernet0/0/1.1
```

Nakon što napravimo prekid linka, pa onda ispravimo prekid, broj *counter*-a će se povećati, kao što se može videti:

```
[PE5]dis route-policy ip-frr-umg1
Route-policy : ip-frr-umg1
  permit : 10 (matched counts: 1)
    Match clauses :
      if-match ip next-hop ip-prefix UMG1
    Apply clauses :
      apply backup-nexthop 160.160.165.2
      apply backup-interface GigabitEthernet0/0/1.1
```

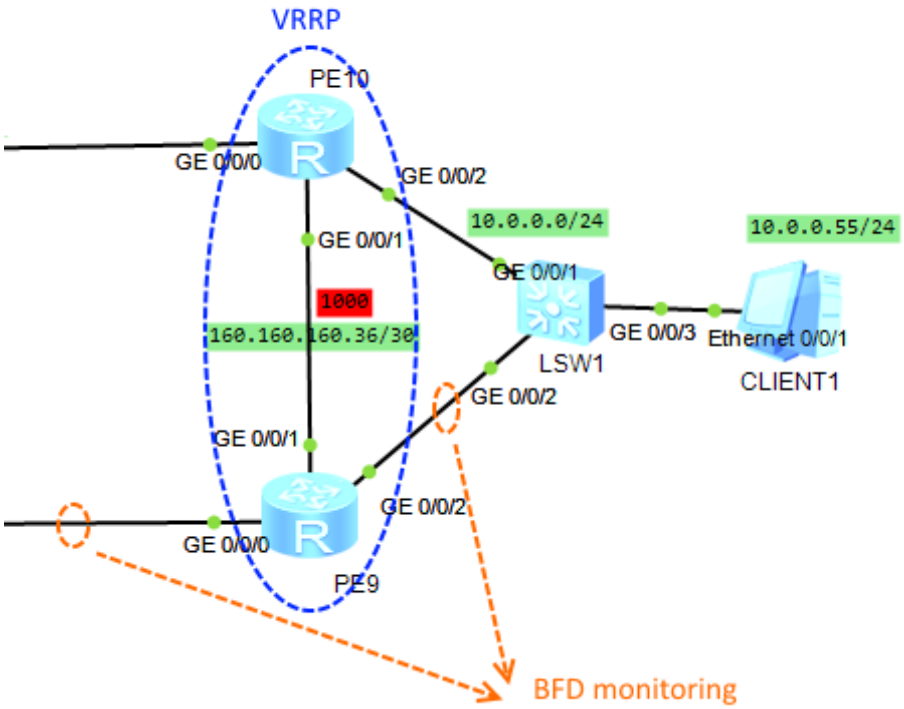
A kako se saobraćaj ponašao u tom periodu možemo videti sa ping komandom

```
<UMG1>ping -c 500 -a 11.11.11.11 22.22.22.22
  PING 22.22.22.22: 56  data bytes, press CTRL_C to break

    Reply from 22.22.22.22: bytes=56 Sequence=62 ttl=253 time=90 ms
    Reply from 22.22.22.22: bytes=56 Sequence=63 ttl=253 time=130 ms
    Reply from 22.22.22.22: bytes=56 Sequence=64 ttl=253 time=90 ms
    Reply from 22.22.22.22: bytes=56 Sequence=65 ttl=253 time=110 ms
    Reply from 22.22.22.22: bytes=56 Sequence=66 ttl=253 time=110 ms
    Reply from 22.22.22.22: bytes=56 Sequence=67 ttl=253 time=70 ms
    Reply from 22.22.22.22: bytes=56 Sequence=68 ttl=253 time=70 ms
    Reply from 22.22.22.22: bytes=56 Sequence=69 ttl=253 time=110 ms
Reply from 22.22.22.22: bytes=56 Sequence=70 ttl=253 time=90 ms
Aug 19 2015 20:34:52-08:00 UMG1 %%01BFD/4/STACHG_TODWN(l)[0]:BFD session changed
to Down. (SlotNumber=0, Discriminator=66, Diagnostic=DetectDown,
Applications=Non
e, ProcessPST=False, BindInterfaceName=Ethernet0/0/0, InterfacePhysicalState=Up,
InterfaceProtocolState=Up)
Aug 19 2015 20:34:52-08:00 UMG1 %%01PHY/1/PHY(l)[1]:    Ethernet0/0/0: change
sta
tus to down
Aug 19 2015 20:34:52-08:00 UMG1 %%01IFNET/4/LINK_STATE(l)[2]:The line protocol
IP
 on the interface Ethernet0/0/0 has entered the DOWN state.
Aug 19 2015 20:34:52-08:00 UMG1 %%01RM/4/IPV4_DEFT_RT_CHG(l)[3]:IPV4 default
Rout
e is changed.
(ChangeType=Delete,InstanceId=0,Protocol=Static,ExitIf=Unknown,Next
hop=10.1.1.1,Neighbour=0.0.0.0,Preference=20,Label=NULL,Metric=0)
    Reply from 22.22.22.22: bytes=56 Sequence=71 ttl=252 time=170 ms
    Reply from 22.22.22.22: bytes=56 Sequence=72 ttl=252 time=160 ms
    Reply from 22.22.22.22: bytes=56 Sequence=73 ttl=252 time=90 ms
    Reply from 22.22.22.22: bytes=56 Sequence=74 ttl=252 time=130 ms
    Reply from 22.22.22.22: bytes=56 Sequence=75 ttl=252 time=80 ms
    Reply from 22.22.22.22: bytes=56 Sequence=76 ttl=252 time=90 ms
    Reply from 22.22.22.22: bytes=56 Sequence=77 ttl=252 time=120 ms
    Reply from 22.22.22.22: bytes=56 Sequence=78 ttl=252 time=90 ms
```

```
    Reply from 22.22.22.22: bytes=56 Sequence=79 ttl=252 time=110 ms
    Reply from 22.22.22.22: bytes=56 Sequence=80 ttl=252 time=130 ms
    Reply from 22.22.22.22: bytes=56 Sequence=81 ttl=252 time=110 ms
    Reply from 22.22.22.22: bytes=56 Sequence=82 ttl=252 time=130 ms
    Reply from 22.22.22.22: bytes=56 Sequence=83 ttl=252 time=90 ms
    Reply from 22.22.22.22: bytes=56 Sequence=84 ttl=252 time=140 ms
    Reply from 22.22.22.22: bytes=56 Sequence=85 ttl=252 time=140 ms
    Reply from 22.22.22.22: bytes=56 Sequence=86 ttl=252 time=100 ms
    Reply from 22.22.22.22: bytes=56 Sequence=87 ttl=252 time=120 ms
    Reply from 22.22.22.22: bytes=56 Sequence=88 ttl=252 time=90 ms
    Reply from 22.22.22.22: bytes=56 Sequence=89 ttl=252 time=90 ms
    Reply from 22.22.22.22: bytes=56 Sequence=90 ttl=252 time=110 ms
    Reply from 22.22.22.22: bytes=56 Sequence=91 ttl=252 time=120 ms
Aug 19 2015 20:35:05-08:00 UMG1 %%01PHY/1/PHY(l)[4]:    Ethernet0/0/0: change
sta
tus to up
Aug 19 2015 20:35:05-08:00 UMG1 %%01IFNET/4/LINK_STATE(l)[5]:The line protocol
IP
 on the interface Ethernet0/0/0 has entered the UP state.
    Reply from 22.22.22.22: bytes=56 Sequence=92 ttl=253 time=170 ms
Aug 19 2015 20:35:05-08:00 UMG1 %%01RM/4/IPV4_DEFT_RT_CHG(l)[6]:IPV4 default
Rout
e is changed.
(ChangeType=Delete,InstanceId=0,Protocol=Static,ExitIf=Ethernet0/0/
1,Nexthop=10.1.2.1,Neighbour=0.0.0.0,Preference=30,Label=NULL,Metric=0)
    Reply from 22.22.22.22: bytes=56 Sequence=93 ttl=253 time=110 ms
    Reply from 22.22.22.22: bytes=56 Sequence=94 ttl=253 time=90 ms
    Reply from 22.22.22.22: bytes=56 Sequence=95 ttl=253 time=70 ms
Aug 19 2015 20:35:07-08:00 UMG1 %%01BFD/4/STACHG_TOUP(l)[7]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=66, FormerStatus=Down, Applications=None,
Bind
InterfaceName=Ethernet0/0/0, ProcessPST=False)
    Reply from 22.22.22.22: bytes=56 Sequence=96 ttl=253 time=110 ms
    Reply from 22.22.22.22: bytes=56 Sequence=97 ttl=253 time=90 ms
    Reply from 22.22.22.22: bytes=56 Sequence=98 ttl=253 time=90 ms
    Reply from 22.22.22.22: bytes=56 Sequence=99 ttl=253 time=90 ms
    Reply from 22.22.22.22: bytes=56 Sequence=100 ttl=253 time=70 ms
    Reply from 22.22.22.22: bytes=56 Sequence=101 ttl=253 time=120 ms
    Reply from 22.22.22.22: bytes=56 Sequence=102 ttl=253 time=100 ms
    Reply from 22.22.22.22: bytes=56 Sequence=103 ttl=253 time=100 ms
    Reply from 22.22.22.22: bytes=56 Sequence=104 ttl=253 time=80 ms
    Reply from 22.22.22.22: bytes=56 Sequence=105 ttl=253 time=60 ms
    Reply from 22.22.22.22: bytes=56 Sequence=106 ttl=253 time=100 ms
```

3.11.Konfiguracija VRRP-a

Konfigurisali smo VRRP na PE9 i PE10 ruterima (slika 3.11.1), gde je PE9 konfigurisan da bude kao *master*. Zarad brže detekcije pada linka, i brže prebacivanje PE10 u *master*-a, konfigurisan je i BFD na odgovarajućim linkovima koji je okidač za promenu u VRRP prioritetu rutera. Prati se stanje linka, putem BFD-a, prema korisničkoj mreži kao i prema *uplink*-u. Konfiguracija se može videti u nastavku.



Slika 3.11.1 Prikaz VRRP-a i gde primenjujemo BFD za E-VRRP rešenje

Konfiguracija PE9:

```
bfd vrrp bind peer-ip 10.0.0.2 vpn-instance media interface
GigabitEthernet0/0/2 source-ip 10.0.0.1
 discriminator local 2
 discriminator remote 1
 min-tx-interval 100
 min-rx-interval 100
 commit
#
bfd vrrp_gi0/0/0 bind peer-ip 160.160.160.33 interface
GigabitEthernet0/0/0 sourc
e-ip 160.160.160.34
 discriminator local 11
 discriminator remote 22
 min-tx-interval 100
 min-rx-interval 100
 commit
#
interface GigabitEthernet0/0/2
 description VRRP_Testing
 ip bind vpn-instance media
 ip address 10.0.0.1 255.255.255.0
 vrrp vrid 1 virtual-ip 10.0.0.10
 vrrp vrid 1 priority 120
 vrrp vrid 1 preempt-mode timer delay 3
 vrrp vrid 1 track bfd-session 2
```

```
 vrrp vrid 1 track bfd-session 11 reduced 30
```

Konfiguracija PE10:

```
bfd vrrp bind peer-ip 10.0.0.1 vpn-instance media interface
GigabitEthernet0/0/2 source-ip 10.0.0.2
 discriminator local 1
 discriminator remote 2
 min-tx-interval 100
 min-rx-interval 100
 commit
#
interface GigabitEthernet0/0/2
 description VRRP_Testing
 ip bind vpn-instance media
 ip address 10.0.0.2 255.255.255.0
 vrrp vrid 1 virtual-ip 10.0.0.10
 vrrp vrid 1 preempt-mode timer delay 3
 vrrp vrid 1 track bfd-session 1 increased 30
```

Konfiguracija PE4:

```
bfd vrrp_gi0/0/0 bind peer-ip 160.160.160.34 interface
GigabitEthernet0/0/0 sourc
e-ip 160.160.160.33
 discriminator local 22
 discriminator remote 11
 min-tx-interval 100
 min-rx-interval 100
 commit
```

Verifikacija:

Koristimo komandu **display bfd session all**, da bi videli bfd sesije koje se koriste za VRRP:

```
<PE9>display bfd  session all
--------------------------------------------------------------------------------
Local Remote     PeerIpAddr      State     Type        InterfaceName
--------------------------------------------------------------------------------
2     1          10.0.0.2        Up        S_IP_IF     GigabitEthernet0/0/2
11    22         160.160.160.33  Up        S_IP_IF     GigabitEthernet0/0/0
--------------------------------------------------------------------------------
     Total UP/DOWN Session Number : 2/0
```

Da vidimo detalje konfiguracije VRRP-a koristimo **display vrrp 1 verbose**

```
<PE9>display vrrp 1 verbose
  GigabitEthernet0/0/2 | Virtual Router 1
    State : Master
    Virtual IP : 10.0.0.10
    Master IP : 1.0.0.10
    PriorityRun : 120
    PriorityConfig : 120
    MasterPriority : 120
    Preempt : YES   Delay Time : 3 s   Remain : --
    TimerRun : 1 s
    TimerConfig : 1 s
    Auth type : NONE
    Virtual MAC : 0000-5e00-0101
```

```
Check TTL : YES
Config type : normal-vrrp
Backup-forward : disabled
Track BFD : 2  Priority reduced : 10
BFD-session state : UP
Track BFD : 11  Priority reduced : 30
BFD-session state : UP
Create time : 2015-08-23 13:03:46 UTC-05:13
Last change time : 2015-08-23 13:12:30 UTC-05:13
```

3.12.Konfiguracija OSPF BFD-a

OSPF BFD ćemo konfigurisati na svim OSPF linkovima. Ova tehnologija treba da doprinese bržem detektovanju otkaza OSPF *neighbor*-a. Konfiguracija je relativno jednostavna.

Konfiguracija P1:

```
ospf 1
 bfd all-interfaces enable
 bfd all-interfaces min-tx-interval 100 min-rx-interval 100
```

Konfiguracija P2:

```
ospf 1
 bfd all-interfaces enable
 bfd all-interfaces min-tx-interval 100 min-rx-interval 100
```

Konfiguracija P3:

```
ospf 1
 bfd all-interfaces enable
 bfd all-interfaces min-tx-interval 100 min-rx-interval 100
```

Konfiguracija P4:

```
ospf 1
 bfd all-interfaces enable
 bfd all-interfaces min-tx-interval 100 min-rx-interval 100
```

Konfiguracija PE5:

```
ospf 1
 bfd all-interfaces enable
 bfd all-interfaces min-tx-interval 100 min-rx-interval 100
```

Konfiguracija PE6:

```
ospf 1
 bfd all-interfaces enable
 bfd all-interfaces min-tx-interval 100 min-rx-interval 100
```

Konfiguracija PE7:

```
ospf 1
 bfd all-interfaces enable
 bfd all-interfaces min-tx-interval 100 min-rx-interval 100
```

Konfiguracija PE8:

```
ospf 1
 bfd all-interfaces enable
 bfd all-interfaces min-tx-interval 100 min-rx-interval 100
```

Konfiguracija PE9:

```
ospf 1
 bfd all-interfaces enable
 bfd all-interfaces min-tx-interval 100 min-rx-interval 100
```

Konfiguracija PE10:

```
ospf 1
 bfd all-interfaces enable
 bfd all-interfaces min-tx-interval 100 min-rx-interval 100
```

Verifikacija:

Korišćenjem komande **display bfd session all**, možemo videti BFD sesije na ruteru. Prikaz je dat za P1:

```
<P1>display bfd session all
--------------------------------------------------------------------------------
Local Remote     PeerIpAddr      State     Type        InterfaceName
--------------------------------------------------------------------------------
8192  8192       160.160.160.6   Up        D_IP_IF     GigabitEthernet0/0/0
8193  8193       160.160.160.42  Up        D_IP_IF     Ethernet0/0/0
8194  8193       160.160.160.18  Up        D_IP_IF     GigabitEthernet0/0/1
8195  8196       160.160.160.2   Up        D_IP_IF     Ethernet0/0/1
--------------------------------------------------------------------------------
     Total UP/DOWN Session Number : 4/0
```

Kucanjem komande **display ospf brief**, možemo videti da je BFD zaista i konfigurisan za OSPF proces na ovom ruteru. Prikaz je dat za P1:

```
<P1>display ospf brief

       OSPF Process 1 with Router ID 160.160.161.1
             OSPF Protocol Information

 RouterID: 160.160.161.1    Border Router:
 Multi-VPN-Instance is not enabled
 Opaque Capable
 Global DS-TE Mode: Non-Standard IETF Mode
 Spf-schedule-interval: max 10000ms, start 500ms, hold 1000ms
 Default ASE parameters: Metric: 1 Tag: 1 Type: 2
 Route Preference: 10
 ASE Route Preference: 150
 SPF Computation Count: 16
 RFC 1583 Compatible
 Retransmission limitation is disabled
 bfd enabled
 BFD Timers: Tx-Interval 100 , Rx-Interval 100 , Multiplier 3
 Area Count: 1   Nssa Area Count: 0
 ExChange/Loading Neighbors: 0
 ...
```

4. TESTIRANJE I ANALIZA TEHNOLOGIJA

4.1. Testiranje MPLS TE Hot-standby tehnologije

Ponašanje MPLS TE Hot-Standby ćemo demonstrirati na *Tunnel 0/0/0*PE5 rutera. Prvo ćemo testirati ponašanje mreže kada se ne koristi MPLS TE *Hot-Standby*, a zatim i njeno ponašanje sa impelementiranom tehnologijom u sistem.

Radićemo kontinualni ping sa UMG1 rutera, *source* adresa 11.11.11.11 prema adresi 22.22.22.22 (*loopback* adresa na UMG2 ruteru). Putanja kojom ide taj saobraćaj je preko PE5 rutera, kroz *Tunnel 0/0/0* ka PE7 ruteru i konačno do UMG2 rutera i finalne destinacije. A putanja se može videti i iz komand *output*-a prikazanih nastavku.

```
<UMG1>tracert -a 11.11.11.11 22.22.22.22

 traceroute to  22.22.22.22(22.22.22.22), max hops: 30 ,packet length: 40,press
CTRL_C to break

 1 10.1.1.1 40 ms  50 ms  50 ms

 2 10.1.3.1 80 ms  60 ms  80 ms

 3 10.1.3.2 120 ms  60 ms  110 ms
<PE5>display ip routing-table vpn-instance media 22.22.22.22
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Routing Table : media
Summary Count : 1
Destination/Mask    Proto   Pre  Cost      Flags NextHop         Interface

    22.22.22.22/32  IBGP    255  0          RD   160.160.161.7   Tunnel0/0/0
```

4.1.1. Test sa MPLS TE Hot-Standby zaštitom

Pošto radimo testiranje u već kompletno konfigurisanoj mreži kako je izloženo u trećem poglavlju ovog rada, biće potrebno isključiti funkcionalnost nekih tehnologija prilikom određenih testiranja zarad testiranja određenih ponašanja. Konkretno, za ovo testiranje, stavićemo *Tunnel 0/0/1* na PE5 ruteru u *Down state*. Da bi to uradili koristimo komandu **interface Tunnel 0/0/1**, pa zatim kucamo **shutdown**. Ovo radimo da bi prikazali kako dolazi do otkaza u nedostatku MPLS TE *Hot-Standby*.

Prvo ćemo demonstirati ponašanje *Tunnel 0/0/0* u slučaju kada nema konfigurisan *Hot-Standby*. Za to je potrebno ukloniti

```
mpls te backup hot-standby mode revertive wtr 30
```

a to ćemo uraditi kucanjem unutar *Tunnel 0/0/0* interfejsa komande **undo mpls te backup** i zatim **mpls te commit**, da bi nova konfiguracija tunela ušla u upotrebu. Iz sledećeg *output*-a se može videti da više nemamo *Hot-Standby* u funkciji.

```
[PE5-Tunnel0/0/0]display mpls te tunnel-interface Tunnel 0/0/0
    ------------------------------------------------------------------
                              Tunnel0/0/0
    ------------------------------------------------------------------
    Tunnel State Desc   :  UP
    Active LSP          :  Primary LSP
    Session ID          :  100
    Ingress LSR ID      :  160.160.161.5    Egress LSR ID:  160.160.161.7
    Admin State         :  UP               Oper State   :  UP
    Primary LSP State      : UP
      Main LSP State       : READY              LSP ID  : 5
```

Nakon što pustimo kontinualni ping komandom **ping –a 11.11.11.11 –c 1000 22.22.22.22**stavićemo u *Down state* interfejs *GigabitEthernet 0/0/1*, i nakon 10sec ga vratiti u *Up state*, i videti vreme trajanja otkaza.

```
<UMG1>ping -a 11.11.11.11 -c 1000 22.22.22.22
  PING 22.22.22.22: 56  data bytes, press CTRL_C to break
    Reply from 22.22.22.22: bytes=56 Sequence=1 ttl=253 time=100 ms
    Reply from 22.22.22.22: bytes=56 Sequence=2 ttl=253 time=110 ms
    ...
    Reply from 22.22.22.22: bytes=56 Sequence=21 ttl=253 time=90 ms
    Reply from 22.22.22.22: bytes=56 Sequence=22 ttl=253 time=90 ms
    Reply from 22.22.22.22: bytes=56 Sequence=23 ttl=253 time=110 ms
    Reply from 22.22.22.22: bytes=56 Sequence=24 ttl=253 time=90 ms
    Request time out
    Request time out
    Request time out
    ...
    Request time out
    Request time out
    Request time out
    Request time out
    Reply from 22.22.22.22: bytes=56 Sequence=74 ttl=251 time=170 ms
    Reply from 22.22.22.22: bytes=56 Sequence=75 ttl=251 time=90 ms
    Reply from 22.22.22.22: bytes=56 Sequence=76 ttl=251 time=90 ms
    ...
    Reply from 22.22.22.22: bytes=56 Sequence=109 ttl=251 time=180 ms
    Reply from 22.22.22.22: bytes=56 Sequence=110 ttl=251 time=110 ms
    Reply from 22.22.22.22: bytes=56 Sequence=111 ttl=251 time=190 ms
    Reply from 22.22.22.22: bytes=56 Sequence=112 ttl=251 time=130 ms
    Reply from 22.22.22.22: bytes=56 Sequence=113 ttl=251 time=120 ms

  --- 22.22.22.22 ping statistics ---
    113 packet(s) transmitted
    64 packet(s) received
    43.36% packet loss
    round-trip min/avg/max = 70/114/190 ms

[PE5-GigabitEthernet0/0/0]
[PE5-GigabitEthernet0/0/0]shut
[PE5-GigabitEthernet0/0/0]
```

```
Sep 22 2015 06:52:12-08:00 PE5 %%01PHY/1/PHY(l)[47]:    GigabitEthernet0/0/0:
cha
nge status to down
Sep 22 2015 06:52:12-08:00 PE5 %%01IFNET/4/LINK_STATE(l)[48]:The line protocol
IP
 on the interface GigabitEthernet0/0/0 has entered the DOWN state.
Sep 22 2015 06:52:12-08:00 PE5 %%01OSPF/3/NBR_CHG_DOWN(l)[49]:Neighbor
event:neig
hbor state changed to Down. (ProcessId=1, NeighborAddress=160.160.161.1,
Neighbor
Event=KillNbr, NeighborPreviousState=Full, NeighborCurrentState=Down)
Sep 22 2015 06:52:12-08:00 PE5 %%01OSPF/3/NBR_DOWN_REASON(l)[50]:Neighbor state
l
eaves full or changed to Down. (ProcessId=1, NeighborRouterId=160.160.161.1,
Neig
hborAreaId=0, NeighborInterface=GigabitEthernet0/0/0,NeighborDownImmediate
reason
=Neighbor Down Due to Kill Neighbor, NeighborDownPrimeReason=Physical Interface
S
tate Change, NeighborChangeTime=2015-09-22 06:52:12-08:00)
Sep 22 2015 06:52:12-08:00 PE5 %%01BFD/4/STACHG_TODWN(l)[51]:BFD session changed
to Down. (SlotNumber=0, Discriminator=8240, Diagnostic=DetectDown,
Applications=O
SPF | RSVP, ProcessPST=False, BindInterfaceName=GigabitEthernet0/0/0,
InterfacePh
ysicalState=Down, InterfaceProtocolState=Down)
Sep 22 2015 06:52:12-08:00 PE5 %%01IFNET/4/LINK_STATE(l)[52]:The line protocol
IP
 on the interface Tunnel0/0/0 has entered the DOWN state.
[PE5-GigabitEthernet0/0/0]
Sep 22 2015 06:52:15-08:00 PE5 DS/4/DATASYNC_CFGCHANGE:OID
1.3.6.1.4.1.2011.5.25.
191.3.1 configurations have been changed. The current change number is 8, the
cha
nge loop count is 0, and the maximum number of records is 4095.
[PE5-GigabitEthernet0/0/0]
Sep 22 2015 06:52:26-08:00 PE5 %%01LDP/4/HOLDTMREXP(l)[53]:Sessions were deleted
because the hello hold timer expired. (PeerId=160.160.161.1)
[PE5-GigabitEthernet0/0/0]
[PE5-GigabitEthernet0/0/0]
Sep 22 2015 06:52:30-08:00 PE5 %%01BFD/4/STACHG_TODWN(l)[54]:BFD session changed
to Down. (SlotNumber=0, Discriminator=8242, Diagnostic=(Receive AdminDown),
Appli
cations=LSPV, ProcessPST=False, BindInterfaceName=None,
InterfacePhysicalState=No
ne, InterfaceProtocolState=None)
[PE5-GigabitEthernet0/0/0]
Sep 22 2015 06:52:33-08:00 PE5 %%01BFD/4/STACHG_TOUP(l)[55]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=8243, FormerStatus=Down, Applications=LSPV,
Bi
ndInterfaceName=None, ProcessPST=False)
[PE5-GigabitEthernet0/0/0]
[PE5-GigabitEthernet0/0/0]display mpls te tunnel-interface Tunnel 0/0/0
    -------------------------------------------------------------------
                              Tunnel0/0/0
    -------------------------------------------------------------------
    Tunnel State Desc   :  DOWN
    Active LSP          :  -
```

```
    Session ID          :  100
    Ingress LSR ID      :  160.160.161.5    Egress LSR ID:  160.160.161.7
    Admin State         :  UP               Oper State   :  DOWN
    Primary LSP State      : DOWN
      Main LSP State       : SETTING UP

[PE5-GigabitEthernet0/0/0]undo shut
[PE5-GigabitEthernet0/0/0]undo shutdown
[PE5-GigabitEthernet0/0/0]
Sep 22 2015 06:53:18-08:00 PE5 %%01PHY/1/PHY(l)[56]:    GigabitEthernet0/0/0:
cha
nge status to up
Sep 22 2015 06:53:18-08:00 PE5 %%01IFNET/4/LINK_STATE(l)[57]:The line protocol
IP
 on the interface GigabitEthernet0/0/0 has entered the UP state.
[PE5-GigabitEthernet0/0/0]
Sep 22 2015 06:53:25-08:00 PE5 DS/4/DATASYNC_CFGCHANGE:OID
1.3.6.1.4.1.2011.5.25.
191.3.1 configurations have been changed. The current change number is 9, the
cha
nge loop count is 0, and the maximum number of records is 4095.
Sep 22 2015 06:53:26-08:00 PE5 %%01OSPF/4/NBR_CHANGE_E(l)[58]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.17,
Neigh
borEvent=HelloReceived, NeighborPreviousState=Down, NeighborCurrentState=Init)
Sep 22 2015 06:53:26-08:00 PE5 %%01OSPF/4/NBR_CHANGE_E(l)[59]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.17,
Neigh
borEvent=2WayReceived, NeighborPreviousState=Init, NeighborCurrentState=2Way)
[PE5-GigabitEthernet0/0/0]display mpls te tunnel-interface Tunnel 0/0/0
    -------------------------------------------------------------------
                              Tunnel0/0/0
    -------------------------------------------------------------------
    Tunnel State Desc   :  DOWN
    Active LSP          :  -
    Session ID          :  100
    Ingress LSR ID      :  160.160.161.5    Egress LSR ID:  160.160.161.7
    Admin State         :  UP               Oper State   :  DOWN
    Primary LSP State      : DOWN
      Main LSP State       : SETTING UP

[PE5-GigabitEthernet0/0/0]display mpls te tunnel-interface Tunnel 0/0/0
    -------------------------------------------------------------------
                              Tunnel0/0/0
    -------------------------------------------------------------------
    Tunnel State Desc   :  DOWN
    Active LSP          :  -
    Session ID          :  100
    Ingress LSR ID      :  160.160.161.5    Egress LSR ID:  160.160.161.7
    Admin State         :  UP               Oper State   :  DOWN
    Primary LSP State      : DOWN
      Main LSP State       : SETTING UP

[PE5-GigabitEthernet0/0/0]
Sep 22 2015 06:53:59-08:00 PE5 %%01OSPF/4/NBR_CHANGE_E(l)[60]:Neighbor changes
ev
```

```
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.17,
Neigh
borEvent=AdjOk?, NeighborPreviousState=2Way, NeighborCurrentState=ExStart)
Sep 22 2015 06:53:59-08:00 PE5 %%01OSPF/4/NBR_CHANGE_E(l)[61]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.17,
Neigh
borEvent=NegotiationDone, NeighborPreviousState=ExStart,
NeighborCurrentState=Exc
hange)
Sep 22 2015 06:54:00-08:00 PE5 %%01OSPF/4/NBR_CHANGE_E(l)[62]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.17,
Neigh
borEvent=ExchangeDone, NeighborPreviousState=Exchange,
NeighborCurrentState=Loadi
ng)
Sep 22 2015 06:54:00-08:00 PE5 %%01OSPF/4/NBR_CHANGE_E(l)[63]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.17,
Neigh
borEvent=LoadingDone, NeighborPreviousState=Loading, NeighborCurrentState=Full)
Sep 22 2015 06:54:00-08:00 PE5 %%01IFNET/4/LINK_STATE(l)[64]:The line protocol
IP
 on the interface Tunnel0/0/0 has entered the UP state.
Sep 22 2015 06:54:02-08:00 PE5 %%01BFD/4/STACHG_TOUP(l)[65]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=8244, FormerStatus=Init, Applications=OSPF |
R
SVP, BindInterfaceName=GigabitEthernet0/0/0, ProcessPST=False)
[PE5-GigabitEthernet0/0/0]display mpls te tunnel-interface Tunnel 0/0/0
    -------------------------------------------------------------------
                              Tunnel0/0/0
    -------------------------------------------------------------------
    Tunnel State Desc   :  UP
    Active LSP          :  Primary LSP
    Session ID          :  100
    Ingress LSR ID      :  160.160.161.5    Egress LSR ID:  160.160.161.7
    Admin State         :  UP               Oper State   :  UP
    Primary LSP State      : UP
      Main LSP State       : READY              LSP ID  : 8

[PE5-GigabitEthernet0/0/0]
Sep 22 2015 06:54:07-08:00 PE5 %%01BFD/4/STACHG_TOUP(l)[66]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=8245, FormerStatus=Init, Applications=LSPM |
T
E | L2VPN | TUNNEL_PS, BindInterfaceName=Tunnel0/0/0, ProcessPST=True)
[PE5-GigabitEthernet0/0/0]display mpls te tunnel-interface Tunnel 0/0/0
    -------------------------------------------------------------------
                              Tunnel0/0/0
    -------------------------------------------------------------------
    Tunnel State Desc   :  UP
    Active LSP          :  Primary LSP
    Session ID          :  100
    Ingress LSR ID      :  160.160.161.5    Egress LSR ID:  160.160.161.7
    Admin State         :  UP               Oper State   :  UP
    Primary LSP State      : UP
      Main LSP State       : READY              LSP ID  : 8
```

```
[PE5-GigabitEthernet0/0/0]
[PE5-GigabitEthernet0/0/0]
```

Otkaz na linku je krenuo nakon kucanja **shutdown** komande na interfejsu, u 6:52:12 kada je status fizičkog interfejsa promenjen u *Down*. Vidi se niz logova gde vidimo da i *Tunnel 0/0/0* u isto vreme kao posledica pada fizičkog interfejsa koji se nalazi na *Primary* LSP putanji ulazi u *Down state*. Kao rezultat počinjemo da dobijamo *request timeout*-e na UMG1. Link je vraćen u *Upstate* kucanjem **undo shutdown**komande u 6:53:18. Može se videti da istog momenta fizički link ide u *Up state*, ali je potrebno *Tunnel* još uvek *Down*. Odnosno potrebno je vreme da se uspostave iznova L2 i L3 procesi da bi se *Tunnel* vratio u *Up state*, i to se desilo u 6:54:02, kada smo počeli i da primamo opet *ping reply*.

4.1.2. Test bez MPLS TE Hot-Standby zaštite

Sledeće što smo radili je da smo ponovili ovaj test, samo u varijanti kada je *Hot-Standby* implementiran, što se može videti iz izloženog *output*-a.

```
<PE5>display mpls te tunnel-interface Tunnel 0/0/0
    ------------------------------------------------------------------
                              Tunnel0/0/0
    ------------------------------------------------------------------
    Tunnel State Desc   :  UP
    Active LSP          :  Primary LSP
    Session ID          :  100
    Ingress LSR ID      :  160.160.161.5    Egress LSR ID:  160.160.161.7
    Admin State         :  UP               Oper State   :  UP
    Primary LSP State      : UP
      Main LSP State       : READY              LSP ID  : 11
    Hot-Standby LSP State  : UP
      Main LSP State       : READY              LSP ID  : 32771
```

Nakon što pustimo kontinualni ping komandom **ping –a 11.11.11.11 –c 1000 22.22.22.22**stavićemo u *Down state* interfejs *GigabitEthernet 0/0/1*, i nakon 10sec ga vratiti u *Up state*, i videti vreme trajanja otkaza.

```
<UMG1>ping -a 11.11.11.11 -c 1000 22.22.22.22
  PING 22.22.22.22: 56  data bytes, press CTRL_C to break
    Reply from 22.22.22.22: bytes=56 Sequence=1 ttl=253 time=90 ms
    Reply from 22.22.22.22: bytes=56 Sequence=2 ttl=253 time=90 ms

    ...

    Reply from 22.22.22.22: bytes=56 Sequence=39 ttl=253 time=80 ms
    Reply from 22.22.22.22: bytes=56 Sequence=40 ttl=253 time=80 ms
    Request time out
    Reply from 22.22.22.22: bytes=56 Sequence=42 ttl=252 time=250 ms
    Reply from 22.22.22.22: bytes=56 Sequence=43 ttl=252 time=170 ms
    Reply from 22.22.22.22: bytes=56 Sequence=44 ttl=252 time=190 ms
    Reply from 22.22.22.22: bytes=56 Sequence=45 ttl=252 time=140 ms

    ...

    Reply from 22.22.22.22: bytes=56 Sequence=211 ttl=251 time=80 ms
```

```
    Reply from 22.22.22.22: bytes=56 Sequence=212 ttl=251 time=120 ms
    Reply from 22.22.22.22: bytes=56 Sequence=213 ttl=251 time=120 ms
Sep 22 2015 07:26:42-08:00 UMG1 %%01BFD/4/STACHG_TODWN(l)[0]:BFD session changed
to Down. (SlotNumber=0, Discriminator=66, Diagnostic=DetectDown,
Applications=Non
e, ProcessPST=False, BindInterfaceName=Ethernet0/0/0, InterfacePhysicalState=Up,
InterfaceProtocolState=Up)
    Reply from 22.22.22.22: bytes=56 Sequence=214 ttl=252 time=890 ms
Sep 22 2015 07:26:43-08:00 UMG1 %%01BFD/4/STACHG_TOUP(l)[1]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=66, FormerStatus=Init, Applications=None,
Bind
InterfaceName=Ethernet0/0/0, ProcessPST=False)
    Reply from 22.22.22.22: bytes=56 Sequence=215 ttl=252 time=110 ms
    Reply from 22.22.22.22: bytes=56 Sequence=216 ttl=252 time=130 ms
    Reply from 22.22.22.22: bytes=56 Sequence=217 ttl=252 time=130 ms

    ...

    Reply from 22.22.22.22: bytes=56 Sequence=328 ttl=253 time=90 ms
    Reply from 22.22.22.22: bytes=56 Sequence=329 ttl=253 time=80 ms

  --- 22.22.22.22 ping statistics ---
    329 packet(s) transmitted
    328 packet(s) received
    0.30% packet loss
    round-trip min/avg/max = 60/128/890 ms



[PE5-GigabitEthernet0/0/0]shutdown
[PE5-GigabitEthernet0/0/0]
Sep 22 2015 07:25:13-08:00 PE5 %%01PHY/1/PHY(l)[0]:    GigabitEthernet0/0/0:
chan
ge status to down
Sep 22 2015 07:25:13-08:00 PE5 %%01IFNET/4/LINK_STATE(l)[1]:The line protocol IP
on the interface GigabitEthernet0/0/0 has entered the DOWN state.
Sep 22 2015 07:25:13-08:00 PE5 %%01OSPF/3/NBR_CHG_DOWN(l)[2]:Neighbor
event:neigh
bor state changed to Down. (ProcessId=1, NeighborAddress=160.160.161.1,
NeighborE
vent=KillNbr, NeighborPreviousState=Full, NeighborCurrentState=Down)
Sep 22 2015 07:25:13-08:00 PE5 %%01OSPF/3/NBR_DOWN_REASON(l)[3]:Neighbor state
le
aves full or changed to Down. (ProcessId=1, NeighborRouterId=160.160.161.1,
Neigh
borAreaId=0, NeighborInterface=GigabitEthernet0/0/0,NeighborDownImmediate
reason=
Neighbor Down Due to Kill Neighbor, NeighborDownPrimeReason=Physical Interface
St
ate Change, NeighborChangeTime=2015-09-22 07:25:13-08:00)
Sep 22 2015 07:25:13-08:00 PE5 %%01BFD/4/STACHG_TODWN(l)[4]:BFD session changed
t
o Down. (SlotNumber=0, Discriminator=8253, Diagnostic=DetectDown,
Applications=OS
PF | RSVP, ProcessPST=False, BindInterfaceName=GigabitEthernet0/0/0,
InterfacePhy
sicalState=Down, InterfaceProtocolState=Down)
```

```
Sep 22 2015 07:25:13-08:00 PE5 %%01BFD/4/STACHG_TODWN(l)[5]:BFD session changed
t
o Down. (SlotNumber=0, Discriminator=8255, Diagnostic=DetectDown,
Applications=LS
PV, ProcessPST=False, BindInterfaceName=None, InterfacePhysicalState=None,
Interf
aceProtocolState=None)
[PE5-GigabitEthernet0/0/0]
[PE5-GigabitEthernet0/0/0]
[PE5-GigabitEthernet0/0/0]
[PE5-GigabitEthernet0/0/0]dis
Sep 22 2015 07:25:16-08:00 PE5 %%01BFD/4/STACHG_TOUP(l)[6]:BFD session changed
to
 Up. (SlotNumber=0, Discriminator=8258, FormerStatus=Init, Applications=LSPM |
TE
 | L2VPN | TUNNEL_PS, BindInterfaceName=Tunnel0/0/0, ProcessPST=True)
[PE5-GigabitEthernet0/0/0]display
Sep 22 2015 07:25:16-08:00 PE5 DS/4/DATASYNC_CFGCHANGE:OID
1.3.6.1.4.1.2011.5.25.
191.3.1 configurations have been changed. The current change number is 15, the
ch
ange loop count is 0, and the maximum number of records is 4095.
Sep 22 2015 07:25:16-08:00 PE5 %%01BFD/4/STACHG_TOUP(l)[7]:BFD session changed
to
 Up. (SlotNumber=0, Discriminator=8257, FormerStatus=Init, Applications=LSPM |
TE
 | L2VPN | TUNNEL_PS, BindInterfaceName=Tunnel0/0/1, ProcessPST=True)
Sep 22 2015 07:25:52-08:00 PE5 %%01OSPF/4/NBR_CHANGE_E(l)[13]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.17,
Neigh
borEvent=2WayReceived, NeighborPreviousState=Init, NeighborCurrentState=2Way)
[PE5-GigabitEthernet0/0/0]display mpls te tunnel-interface Tunnel 0/0/0
    -------------------------------------------------------------------
                              Tunnel0/0/0
    -------------------------------------------------------------------
    Tunnel State Desc   :  UP
    Active LSP          :  Hot-Standby LSP
    Session ID          :  100
    Ingress LSR ID      :  160.160.161.5    Egress LSR ID:  160.160.161.7
    Admin State         :  UP               Oper State   :  UP
    Primary LSP State      : DOWN
      Main LSP State       : SETTING UP
    Hot-Standby LSP State  : UP
      Main LSP State       : READY              LSP ID  : 32771


[PE5-GigabitEthernet0/0/0]
Sep 22 2015 07:26:21-08:00 PE5 %%01OSPF/4/NBR_CHANGE_E(l)[14]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.17,
Neigh
borEvent=AdjOk?, NeighborPreviousState=2Way, NeighborCurrentState=ExStart)
Sep 22 2015 07:26:21-08:00 PE5 %%01OSPF/4/NBR_CHANGE_E(l)[15]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.17,
Neigh
borEvent=NegotiationDone, NeighborPreviousState=ExStart,
NeighborCurrentState=Exc
```

```
hange)
Sep 22 2015 07:26:21-08:00 PE5 %%01OSPF/4/NBR_CHANGE_E(l)[16]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.17,
Neigh
borEvent=ExchangeDone, NeighborPreviousState=Exchange,
NeighborCurrentState=Loadi
ng)
Sep 22 2015 07:26:21-08:00 PE5 %%01OSPF/4/NBR_CHANGE_E(l)[17]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.17,
Neigh
borEvent=LoadingDone, NeighborPreviousState=Loading, NeighborCurrentState=Full)
Sep 22 2015 07:26:21-08:00 PE5 %%01BFD/4/STACHG_TODWN(l)[18]:BFD session changed
to Down. (SlotNumber=0, Discriminator=8257, Diagnostic=DetectDown,
Applications=L
SPM | TE | L2VPN | TUNNEL_PS, ProcessPST=True, BindInterfaceName=Tunnel0/0/1,
Int
erfacePhysicalState=Up, InterfaceProtocolState=Up)
Sep 22 2015 07:26:21-08:00 PE5 %%01BFD/4/STACHG_TODWN(l)[19]:BFD session changed
to Down. (SlotNumber=0, Discriminator=8258, Diagnostic=DetectDown,
Applications=L
SPM | TE | L2VPN | TUNNEL_PS, ProcessPST=True, BindInterfaceName=Tunnel0/0/0,
Int
erfacePhysicalState=Up, InterfaceProtocolState=Up)
Sep 22 2015 07:26:21-08:00 PE5 %%01BFD/4/STACHG_TOUP(l)[20]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=8258, FormerStatus=Init, Applications=LSPM |
T
E | L2VPN | TUNNEL_PS, BindInterfaceName=Tunnel0/0/0, ProcessPST=True)
Sep 22 2015 07:26:21-08:00 PE5 %%01BFD/4/STACHG_TOUP(l)[21]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=8257, FormerStatus=Init, Applications=LSPM |
T
E | L2VPN | TUNNEL_PS, BindInterfaceName=Tunnel0/0/1, ProcessPST=True)display
mpls te tunnel-interface Tunnel 0/0/0
Sep 22 2015 07:26:23-08:00 PE5 %%01BFD/4/STACHG_TOUP(l)[22]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=8260, FormerStatus=Init, Applications=OSPF |
R
SVP, BindInterfaceName=GigabitEthernet0/0/0, ProcessPST=False)

[PE5-GigabitEthernet0/0/0]display mpls te tunnel-interface Tunnel 0/0/0
    -------------------------------------------------------------------
                              Tunnel0/0/0
    -------------------------------------------------------------------
    Tunnel State Desc   :  GRACEFUL SWITCH
    Active LSP          :  Hot-Standby LSP
    Traffic Switch      :  Hot-Standby LSP -> Primary LSP
    Session ID          :  100
    Ingress LSR ID      :  160.160.161.5    Egress LSR ID:  160.160.161.7
    Admin State         :  UP               Oper State   :  UP
    Primary LSP State      : UP
      Main LSP State       : READY              LSP ID  : 12
    Hot-Standby LSP State  : UP
      Main LSP State       : READY              LSP ID  : 32771


[PE5-GigabitEthernet0/0/0]
```

```
Sep 22 2015 07:26:46-08:00 PE5 %%01BFD/4/STACHG_TODWN(l)[23]:BFD session changed
to Down. (SlotNumber=0, Discriminator=8258, Diagnostic=NeighborDown,
Applications
=LSPM | TE | L2VPN | TUNNEL_PS, ProcessPST=True, BindInterfaceName=Tunnel0/0/0,
I
nterfacePhysicalState=Up, InterfaceProtocolState=Up)
Sep 22 2015 07:26:46-08:00 PE5 %%01BFD/4/STACHG_TODWN(l)[24]:BFD session changed
to Down. (SlotNumber=0, Discriminator=55, Diagnostic=NeighborDown,
Applications=N
one, ProcessPST=False, BindInterfaceName=GigabitEthernet0/0/2,
InterfacePhysicalS
tate=Up, InterfaceProtocolState=Up)
Sep 22 2015 07:26:46-08:00 PE5 %%01BFD/4/STACHG_TODWN(l)[25]:BFD session changed
to Down. (SlotNumber=0, Discriminator=8259, Diagnostic=NeighborDown,
Applications
=LSPV, ProcessPST=False, BindInterfaceName=None, InterfacePhysicalState=None,
Int
erfaceProtocolState=None)
Sep 22 2015 07:26:46-08:00 PE5 %%01BFD/4/STACHG_TODWN(l)[26]:BFD session changed
to Down. (SlotNumber=0, Discriminator=8257, Diagnostic=NeighborDown,
Applications
=LSPM | TE | L2VPN | TUNNEL_PS, ProcessPST=True, BindInterfaceName=Tunnel0/0/1,
I
nterfacePhysicalState=Up, InterfaceProtocolState=Up)
Sep 22 2015 07:26:46-08:00 PE5 %%01BFD/4/STACHG_TODWN(l)[27]:BFD session changed
to Down. (SlotNumber=0, Discriminator=8224, Diagnostic=NeighborDown,
Applications
=LSPV, ProcessPST=False, BindInterfaceName=None, InterfacePhysicalState=None,
Int
erfaceProtocolState=None)
Sep 22 2015 07:26:46-08:00 PE5 %%01BFD/4/STACHG_TOUP(l)[28]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=55, FormerStatus=Down, Applications=None,
Bind
InterfaceName=GigabitEthernet0/0/2, ProcessPST=False)
Sep 22 2015 07:26:46-08:00 PE5 %%01BFD/4/STACHG_TOUP(l)[29]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=8224, FormerStatus=Down, Applications=LSPV,
Bi
ndInterfaceName=None, ProcessPST=False)
Sep 22 2015 07:26:46-08:00 PE5 %%01BFD/4/STACHG_TOUP(l)[30]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=8259, FormerStatus=Down, Applications=LSPV,
Bi
ndInterfaceName=None, ProcessPST=False)
Sep 22 2015 07:26:46-08:00 PE5 %%01BFD/4/STACHG_TODWN(l)[31]:BFD session changed
to Down. (SlotNumber=0, Discriminator=8219, Diagnostic=DetectDown,
Applications=O
SPF, ProcessPST=False, BindInterfaceName=GigabitEthernet0/0/1,
InterfacePhysicalS
tate=Up, InterfaceProtocolState=Up)
Sep 22 2015 07:26:46-08:00 PE5 %%01BFD/4/STACHG_TODWN(l)[32]:BFD session changed
to Down. (SlotNumber=0, Discriminator=8260, Diagnostic=DetectDown,
Applications=O
SPF | RSVP, ProcessPST=False, BindInterfaceName=GigabitEthernet0/0/0,
InterfacePh
ysicalState=Up, InterfaceProtocolState=Up)
Sep 22 2015 07:26:46-08:00 PE5 %%01OSPF/3/NBR_CHG_DOWN(l)[33]:Neighbor
event:neig
```

```
hbor state changed to Down. (ProcessId=1, NeighborAddress=160.160.161.6,
Neighbor
Event=KillNbr, NeighborPreviousState=Full, NeighborCurrentState=Down)
Sep 22 2015 07:26:46-08:00 PE5 %%01OSPF/3/NBR_DOWN_REASON(l)[34]:Neighbor state
l
eaves full or changed to Down. (ProcessId=1, NeighborRouterId=160.160.161.6,
Neig
hborAreaId=0, NeighborInterface=GigabitEthernet0/0/1,NeighborDownImmediate
reason
=Neighbor Down Due to Kill Neighbor, NeighborDownPrimeReason=BFD Session Down,
Ne
ighborChangeTime=2015-09-22 07:26:46-08:00)
Sep 22 2015 07:26:46-08:00 PE5 %%01OSPF/3/NBR_CHG_DOWN(l)[35]:Neighbor
event:neig
hbor state changed to Down. (ProcessId=1, NeighborAddress=160.160.161.1,
Neighbor
Event=KillNbr, NeighborPreviousState=Full, NeighborCurrentState=Down)
Sep 22 2015 07:26:46-08:00 PE5 %%01OSPF/3/NBR_DOWN_REASON(l)[36]:Neighbor state
l
eaves full or changed to Down. (ProcessId=1, NeighborRouterId=160.160.161.1,
Neig
hborAreaId=0, NeighborInterface=GigabitEthernet0/0/0,NeighborDownImmediate
reason
=Neighbor Down Due to Kill Neighbor, NeighborDownPrimeReason=BFD Session Down,
Ne
ighborChangeTime=2015-09-22 07:26:46-08:00)
Sep 22 2015 07:26:46-08:00 PE5 %%01BFD/4/STACHG_TOUP(l)[37]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=8219, FormerStatus=Down, Applications=OSPF,
Bi
ndInterfaceName=GigabitEthernet0/0/1, ProcessPST=False)
Sep 22 2015 07:26:46-08:00 PE5 %%01BFD/4/STACHG_TOUP(l)[38]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=8260, FormerStatus=Down, Applications=OSPF |
R
SVP, BindInterfaceName=GigabitEthernet0/0/0, ProcessPST=False)
[PE5-GigabitEthernet0/0/0]
Sep 22 2015 07:26:46-08:00 PE5 %%01BFD/4/STACHG_TODWN(l)[39]:BFD session changed
to Down. (SlotNumber=0, Discriminator=8224, Diagnostic=NeighborDown,
Applications
=LSPV, ProcessPST=False, BindInterfaceName=None, InterfacePhysicalState=None,
Int
erfaceProtocolState=None)
Sep 22 2015 07:26:46-08:00 PE5 %%01BFD/4/STACHG_TODWN(l)[40]:BFD session changed
to Down. (SlotNumber=0, Discriminator=8259, Diagnostic=NeighborDown,
Applications
=LSPV, ProcessPST=False, BindInterfaceName=None, InterfacePhysicalState=None,
Int
erfaceProtocolState=None)
[PE5-GigabitEthernet0/0/0]
[PE5-GigabitEthernet0/0/0]display mpls te tunnel-interface Tunnel 0/0/0
    -------------------------------------------------------------------
                              Tunnel0/0/0
    -------------------------------------------------------------------
    Tunnel State Desc   :  UP
    Active LSP          :  Hot-Standby LSP
    Session ID          :  100
    Ingress LSR ID      :  160.160.161.5    Egress LSR ID:  160.160.161.7
    Admin State         :  UP               Oper State   :  UP
```

```
    Primary LSP State      : DOWN
      Main LSP State       : SETTING UP
    Hot-Standby LSP State  : UP
      Main LSP State       : READY               LSP ID  : 32771

[PE5-GigabitEthernet0/0/0]
Sep 22 2015 07:26:49-08:00 PE5 %%01BFD/4/STACHG_TODWN(l)[41]:BFD session changed
to Down. (SlotNumber=0, Discriminator=8219, Diagnostic=(Receive AdminDown),
Appli
cations=OSPF, ProcessPST=False, BindInterfaceName=GigabitEthernet0/0/1,
Interface
PhysicalState=Up, InterfaceProtocolState=Up)
Sep 22 2015 07:26:49-08:00 PE5 %%01OSPF/4/NBR_CHANGE_E(l)[42]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.26,
Neigh
borEvent=HelloReceived, NeighborPreviousState=Down, NeighborCurrentState=Init)
Sep 22 2015 07:26:49-08:00 PE5 %%01OSPF/4/NBR_CHANGE_E(l)[43]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.26,
Neigh
borEvent=2WayReceived, NeighborPreviousState=Init, NeighborCurrentState=ExStart)
Sep 22 2015 07:26:49-08:00 PE5 %%01OSPF/4/NBR_CHANGE_E(l)[44]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.26,
Neigh
borEvent=NegotiationDone, NeighborPreviousState=ExStart,
NeighborCurrentState=Exc
hange)
Sep 22 2015 07:26:50-08:00 PE5 %%01BFD/4/STACHG_TODWN(l)[45]:BFD session changed
to Down. (SlotNumber=0, Discriminator=8260, Diagnostic=(Receive AdminDown),
Appli
cations=OSPF, ProcessPST=False, BindInterfaceName=GigabitEthernet0/0/0,
Interface
PhysicalState=Up, InterfaceProtocolState=Up)
Sep 22 2015 07:26:50-08:00 PE5 %%01OSPF/4/NBR_CHANGE_E(l)[46]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.26,
Neigh
borEvent=ExchangeDone, NeighborPreviousState=Exchange,
NeighborCurrentState=Loadi
ng)
[PE5-GigabitEthernet0/0/0]
Sep 22 2015 07:26:50-08:00 PE5 %%01OSPF/4/NBR_CHANGE_E(l)[47]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.26,
Neigh
borEvent=LoadingDone, NeighborPreviousState=Loading, NeighborCurrentState=Full)
[PE5-GigabitEthernet0/0/0]
[PE5-GigabitEthernet0/0/0]display mpls te tunnel-interface Tunnel 0/0/0
Sep 22 2015 07:26:51-08:00 PE5 %%01BFD/4/STACHG_TOUP(l)[48]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=8219, FormerStatus=Down, Applications=OSPF,
Bi
ndInterfaceName=GigabitEthernet0/0/1, ProcessPST=False)
Sep 22 2015 07:26:51-08:00 PE5 %%01BFD/4/STACHG_TOUP(l)[49]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=8224, FormerStatus=Down, Applications=LSPV,
Bi
```

```
ndInterfaceName=None, ProcessPST=False)
    ------------------------------------------------------------------
                              Tunnel0/0/0
    ------------------------------------------------------------------
    Tunnel State Desc   :  UP
    Active LSP          :  Hot-Standby LSP
    Session ID          :  100
    Ingress LSR ID      :  160.160.161.5    Egress LSR ID:  160.160.161.7
    Admin State         :  UP               Oper State   :  UP
    Primary LSP State      : DOWN
      Main LSP State       : SETTING UP
    Hot-Standby LSP State  : UP
      Main LSP State       : READY              LSP ID  : 32771

[PE5-GigabitEthernet0/0/0]
Sep 22 2015 07:26:51-08:00 PE5 %%01BFD/4/STACHG_TOUP(l)[50]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=8259, FormerStatus=Down, Applications=LSPV,
Bi
ndInterfaceName=None, ProcessPST=False)
[PE5-GigabitEthernet0/0/0]
Sep 22 2015 07:26:52-08:00 PE5 %%01OSPF/4/NBR_CHANGE_E(l)[51]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.17,
Neigh
borEvent=HelloReceived, NeighborPreviousState=Down, NeighborCurrentState=Init)
Sep 22 2015 07:26:52-08:00 PE5 %%01OSPF/4/NBR_CHANGE_E(l)[52]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.17,
Neigh
borEvent=2WayReceived, NeighborPreviousState=Init, NeighborCurrentState=ExStart)
[PE5-GigabitEthernet0/0/0]
Sep 22 2015 07:26:52-08:00 PE5 %%01OSPF/4/NBR_CHANGE_E(l)[53]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.17,
Neigh
borEvent=NegotiationDone, NeighborPreviousState=ExStart,
NeighborCurrentState=Exc
hange)
Sep 22 2015 07:26:53-08:00 PE5 %%01OSPF/4/NBR_CHANGE_E(l)[54]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.17,
Neigh
borEvent=ExchangeDone, NeighborPreviousState=Exchange,
NeighborCurrentState=Loadi
ng)
Sep 22 2015 07:26:53-08:00 PE5 %%01OSPF/4/NBR_CHANGE_E(l)[55]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.17,
Neigh
borEvent=LoadingDone, NeighborPreviousState=Loading, NeighborCurrentState=Full)
[PE5-GigabitEthernet0/0/0]display mpls te tunnel-interface Tunnel 0/0/0
    ------------------------------------------------------------------
                              Tunnel0/0/0
    ------------------------------------------------------------------
    Tunnel State Desc   :  GRACEFUL SWITCH
    Active LSP          :  Hot-Standby LSP
    Traffic Switch      :  Hot-Standby LSP -> Primary LSP
    Session ID          :  100
```

```
    Ingress LSR ID      :  160.160.161.5    Egress LSR ID:  160.160.161.7
    Admin State         :  UP               Oper State   :  UP
    Primary LSP State      : UP
      Main LSP State       : READY              LSP ID  : 13
    Hot-Standby LSP State  : UP
      Main LSP State       : READY              LSP ID  : 32771

[PE5-GigabitEthernet0/0/0]
Sep 22 2015 07:26:55-08:00 PE5 %%01BFD/4/STACHG_TOUP(l)[56]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=8261, FormerStatus=Down, Applications=OSPF |
R
SVP, BindInterfaceName=GigabitEthernet0/0/0, ProcessPST=False)
[PE5-GigabitEthernet0/0/0]
[PE5-GigabitEthernet0/0/0]
[PE5-GigabitEthernet0/0/0]
[PE5-GigabitEthernet0/0/0]
[PE5-GigabitEthernet0/0/0]
Sep 22 2015 07:27:12-08:00 PE5 %%01BFD/4/STACHG_TOUP(l)[57]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=8257, FormerStatus=Init, Applications=LSPM |
T
E | L2VPN | TUNNEL_PS, BindInterfaceName=Tunnel0/0/1, ProcessPST=True)
Sep 22 2015 07:27:12-08:00 PE5 %%01BFD/4/STACHG_TOUP(l)[58]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=8258, FormerStatus=Init, Applications=LSPM |
T
E | L2VPN | TUNNEL_PS, BindInterfaceName=Tunnel0/0/0, ProcessPST=True)
[PE5-GigabitEthernet0/0/0]
[PE5-GigabitEthernet0/0/0]
[PE5-GigabitEthernet0/0/0]
[PE5-GigabitEthernet0/0/0]display mpls te tunnel-interface Tunnel 0/0/0
    -------------------------------------------------------------------
                              Tunnel0/0/0
    -------------------------------------------------------------------
    Tunnel State Desc   :  GRACEFUL DELETE
    Active LSP          :  Primary LSP
    Traffic Switch      :  Hot-Standby LSP -> Primary LSP
    Session ID          :  100
    Ingress LSR ID      :  160.160.161.5    Egress LSR ID:  160.160.161.7
    Admin State         :  UP               Oper State   :  UP
    Primary LSP State      : UP
      Main LSP State       : READY              LSP ID  : 13
    Hot-Standby LSP State  : UP
      Main LSP State       : READY              LSP ID  : 32771

[PE5-GigabitEthernet0/0/0]
[PE5-GigabitEthernet0/0/0]
[PE5-GigabitEthernet0/0/0]
Sep 22 2015 07:27:33-08:00 PE5 %%01BFD/4/STACHG_TOUP(l)[59]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=8263, FormerStatus=Init, Applications=LSPM |
T
E | L2VPN | TUNNEL_PS, BindInterfaceName=Tunnel0/0/1, ProcessPST=True)
Sep 22 2015 07:27:34-08:00 PE5 %%01BFD/4/STACHG_TOUP(l)[60]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=8262, FormerStatus=Init, Applications=LSPM |
T
E | L2VPN | TUNNEL_PS, BindInterfaceName=Tunnel0/0/0, ProcessPST=True)
```

```
[PE5-GigabitEthernet0/0/0]
[PE5-GigabitEthernet0/0/0]display mpls te tunnel-interface Tunnel 0/0/0
Sep 22 2015 07:27:37-08:00 PE5 %%01BFD/4/STACHG_TODWN(l)[61]:BFD session changed
to Down. (SlotNumber=0, Discriminator=8259, Diagnostic=(Receive AdminDown),
Appli
cations=LSPV, ProcessPST=False, BindInterfaceName=None,
InterfacePhysicalState=No
ne, InterfaceProtocolState=None)
    -------------------------------------------------------------------
                              Tunnel0/0/0
    -------------------------------------------------------------------
    Tunnel State Desc   :  UP
    Active LSP          :  Primary LSP
    Session ID          :  100
    Ingress LSR ID      :  160.160.161.5    Egress LSR ID:  160.160.161.7
    Admin State         :  UP               Oper State   :  UP
    Primary LSP State      : UP
      Main LSP State       : READY              LSP ID  : 13
    Hot-Standby LSP State  : UP
      Main LSP State       : READY              LSP ID  : 32771

[PE5-GigabitEthernet0/0/0]
[PE5-GigabitEthernet0/0/0]
[PE5-GigabitEthernet0/0/0]
[PE5-GigabitEthernet0/0/0]
[PE5-GigabitEthernet0/0/0]
Sep 22 2015 07:27:40-08:00 PE5 %%01BFD/4/STACHG_TOUP(l)[62]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=8264, FormerStatus=Down, Applications=LSPV,
Bi
ndInterfaceName=None, ProcessPST=False)
[PE5-GigabitEthernet0/0/0]
[PE5-GigabitEthernet0/0/0]
[PE5-GigabitEthernet0/0/0]
```

Ono što možemo videti ovde je da u trenutku kada stavimo fizički interfejs *GigabitEthernet0/0/0* u *Down state*, se desi mali *glitch*, koji rezultira u jednom *request timeout*-u, i da potom imamo neometan ping. U tom momentu se desila promena sa *Primary* LSP na *Hot-Standby* LSP, što se može i videti iz priloženog *output*-a. Kada smo vratili interfejs u *Up state*, postepeno su se oporavljali procesi i može se videti kako je sam tunel menjao stanja dok na kraju nije prešao na *Primary* LSP.

Benefit ovakve vrste zaštite je vidljiv iz ovog testa. Možemo zaključiti da *Primary* LSP zaštita efikasno radi posao u slučaju otkaza jednog linka na *Primary* LSP putanju, i u tom slučaju prelazi na *Hot-Standby* LSP, uz minimalni *convergenece time* naspram potpunom otkazu u slučaju nedostatka zaštite MPLS TE tunela. U slučaju otkaza i dela putanje na *Hot-Standby* LSP-u došlo bi do otkaza servisa.

4.2. Testiranje TE FRR tehnologije

Ponašanje MPLS TE FRR ćemo testirati tako što ćemo pratiti ponašanje saobraćaja u slučaju otkaza interfejsa koji je zaštićen sa ovom tehnlogijom, kao i u slučaju kada je ne koristimo.

Konkretno pratićemo ping sa *source* adresom 11.11.11.11 prema adresi 22.22.22.22. Saobraćaj se takođe kreće preko PE5 kroz *Tunnel 0/0/0* do PE7 pa do konačnog odredišta (može se videti iz *output*-a prikazanog u 4.1 sekciji). Primarna putanja ovog tunela ide preko P1 rutera, i mi ćemo posmatrati šta se dešava u slučaju otkaza *Ethernet 0/0/0* interfejsa na P1 ruteru. Prikazujemo *output* iz kog se vidi putanja *Tunnel 0/0/0*.

```
<PE5>tracert lsp te Tunnel 0/0/0
  LSP Trace Route FEC: TE TUNNEL IPV4 SESSION QUERY Tunnel0/0/0 , press CTRL_C
to
 break.
  TTL   Replier            Time    Type      Downstream
  0                                Ingress   160.160.160.17/[1670 ]
  1     160.160.160.17     60 ms   Transit   160.160.160.42/[3 ]
  2     160.160.161.7      30 ms   Egress
<PE5>
```

4.2.1. Test bez TE FRR zaštite

Prvo ćemo videti ponašanje mreže u slučaju kada nemamo konfigurisanu zaštitu. Da bi to testirali, treba da sklonimo MPLS TE FRR protekciju sa *Tunnel 0/0/0* interfejsa na P1 ruteru

```
undo mpls te protected-interface Ethernet 0/0/0
mpls te commit
```

Zatim zarad ovog testiranja na PE5 ruteru stavićemo u *Down stateTunnel 0/0/1*, komandom **shutdown**.

Puštamo ping sa UMG1 ka UMG2, i pratimo ponašanje kada ugasimo *Ethernet 0/0/0* interfejs i kada ga ponovo vratimo u *Up state*. *Output* testa se može videti u nastavku, ovog puta sa nešto manje detalja sa logovima u toku konvergencije.

```
<UMG1>ping -a 11.11.11.11 -c 1000 22.22.22.22
  PING 22.22.22.22: 56  data bytes, press CTRL_C to break
    Reply from 22.22.22.22: bytes=56 Sequence=1 ttl=253 time=100 ms
    Reply from 22.22.22.22: bytes=56 Sequence=2 ttl=253 time=110 ms
    Reply from 22.22.22.22: bytes=56 Sequence=3 ttl=253 time=100 ms
...
Reply from 22.22.22.22: bytes=56 Sequence=4 ttl=253 time=110 ms
    Reply from 22.22.22.22: bytes=56 Sequence=5 ttl=253 time=110 ms
    Reply from 22.22.22.22: bytes=56 Sequence=6 ttl=253 time=100 ms

Request time out
    Request time out
    Request time out
    Request time out
     ...
    Request time out
    Request time out
    Request time out
    Request time out
    Request time out
    Request time out
    Reply from 22.22.22.22: bytes=56 Sequence=188 ttl=253 time=90 ms
    Reply from 22.22.22.22: bytes=56 Sequence=189 ttl=253 time=100 ms
...
Reply from 22.22.22.22: bytes=56 Sequence=190 ttl=253 time=90 ms
    Reply from 22.22.22.22: bytes=56 Sequence=191 ttl=253 time=110 ms
```

```
    Reply from 22.22.22.22: bytes=56 Sequence=192 ttl=253 time=90 ms

  --- 22.22.22.22 ping statistics ---
    192 packet(s) transmitted
    160 packet(s) received
    16.66% packet loss
    round-trip min/avg/max = 60/112/190 ms
[P1-Ethernet0/0/0]shut
[P1-Ethernet0/0/0]
Sep 22 2015 21:18:08-08:00 P1 %%01PHY/1/PHY(l)[0]:    Ethernet0/0/0: change
statu
s to down
Sep 22 2015 21:18:08-08:00 P1 %%01IFNET/4/LINK_STATE(l)[1]:The line protocol IP
o
n the interface Ethernet0/0/0 has entered the DOWN state.
Sep 22 2015 21:18:08-08:00 P1 %%01OSPF/3/NBR_CHG_DOWN(l)[2]:Neighbor
event:neighb
or state changed to Down. (ProcessId=1, NeighborAddress=160.160.161.7,
NeighborEv
ent=KillNbr, NeighborPreviousState=Full, NeighborCurrentState=Down)
Sep 22 2015 21:18:08-08:00 P1 %%01OSPF/3/NBR_DOWN_REASON(l)[3]:Neighbor state
lea
ves full or changed to Down. (ProcessId=1, NeighborRouterId=160.160.161.7,
Neighb
orAreaId=0, NeighborInterface=Ethernet0/0/0,NeighborDownImmediate
reason=Neighbor
 Down Due to Kill Neighbor, NeighborDownPrimeReason=Physical Interface State
Chan
ge, NeighborChangeTime=2015-09-22 21:18:08-08:00)
Sep 22 2015 21:18:08-08:00 P1 %%01BFD/4/STACHG_TODWN(l)[4]:BFD session changed
to
 Down. (SlotNumber=0, Discriminator=8280, Diagnostic=DetectDown,
Applications=OSP
F | RSVP, ProcessPST=False, BindInterfaceName=Ethernet0/0/0,
InterfacePhysicalSta
te=Down, InterfaceProtocolState=Down)
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]
Sep 22 2015 21:18:18-08:00 P1 DS/4/DATASYNC_CFGCHANGE:OID
1.3.6.1.4.1.2011.5.25.1
91.3.1 configurations have been changed. The current change number is 21, the
cha
nge loop count is 0, and the maximum number of records is 4095.
Sep 22 2015 21:18:19-08:00 P1 %%01LDP/4/HOLDTMREXP(l)[5]:Sessions were deleted
be
cause the hello hold timer expired. (PeerId=160.160.161.7)
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]undo shut
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]
Sep 22 2015 21:18:30-08:00 P1 %%01PHY/1/PHY(l)[6]:    Ethernet0/0/0: change
statu
```

```
s to up
Sep 22 2015 21:18:30-08:00 P1 %%01IFNET/4/LINK_STATE(l)[7]:The line protocol IP
o
n the interface Ethernet0/0/0 has entered the UP state.
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]
Sep 22 2015 21:18:30-08:00 P1 %%01OSPF/4/NBR_CHANGE_E(l)[8]:Neighbor changes
even
t: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.42,
Neighbo
rEvent=HelloReceived, NeighborPreviousState=Down, NeighborCurrentState=Init)
Sep 22 2015 21:18:38-08:00 P1 DS/4/DATASYNC_CFGCHANGE:OID
1.3.6.1.4.1.2011.5.25.1
91.3.1 configurations have been changed. The current change number is 22, the
cha
nge loop count is 0, and the maximum number of records is 4095.
Sep 22 2015 21:18:40-08:00 P1 %%01OSPF/4/NBR_CHANGE_E(l)[9]:Neighbor changes
even
t: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.42,
Neighbo
rEvent=2WayReceived, NeighborPreviousState=Init, NeighborCurrentState=2Way)
Sep 22 2015 21:19:14-08:00 P1 %%01OSPF/4/NBR_CHANGE_E(l)[10]:Neighbor changes
eve
nt: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.42,
Neighb
orEvent=AdjOk?, NeighborPreviousState=2Way, NeighborCurrentState=ExStart)
Sep 22 2015 21:19:19-08:00 P1 %%01OSPF/4/NBR_CHANGE_E(l)[11]:Neighbor changes
eve
nt: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.42,
Neighb
orEvent=NegotiationDone, NeighborPreviousState=ExStart,
NeighborCurrentState=Exch
ange)
Sep 22 2015 21:19:19-08:00 P1 %%01OSPF/4/NBR_CHANGE_E(l)[12]:Neighbor changes
eve
nt: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.42,
Neighb
orEvent=ExchangeDone, NeighborPreviousState=Exchange,
NeighborCurrentState=Loadin
g)
Sep 22 2015 21:19:19-08:00 P1 %%01OSPF/4/NBR_CHANGE_E(l)[13]:Neighbor changes
eve
nt: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.42,
Neighb
orEvent=LoadingDone, NeighborPreviousState=Loading, NeighborCurrentState=Full)
Sep 22 2015 21:19:22-08:00 P1 %%01BFD/4/STACHG_TOUP(l)[14]:BFD session changed
to
 Up. (SlotNumber=0, Discriminator=8281, FormerStatus=Init, Applications=OSPF |
RS
VP, BindInterfaceName=Ethernet0/0/0, ProcessPST=False)
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]
```

Možemo videti da smo imali otkaz koji je trajao od momenta kada je link pao, 21:18:08, zatim se link vratio u 21:18:30, da bi se uspostavila konektivnost u 21:19:22.

4.2.2. Test sa TE FRR zaštitom

Druga varijanta je da imamo TE FRR aktivan za *Ethernet 0/0/0* na P1 ruteru, i da vidimo kako se ponaša mreža u toj varijanti u slučaju otkaza istog linka. *Output* testiranja je prikazan u nastavku.

```
<UMG1>ping -a 11.11.11.11 -c 1000 22.22.22.22
  PING 22.22.22.22: 56  data bytes, press CTRL_C to break
    Reply from 22.22.22.22: bytes=56 Sequence=1 ttl=253 time=100 ms
    Reply from 22.22.22.22: bytes=56 Sequence=2 ttl=253 time=90 ms
...
    Reply from 22.22.22.22: bytes=56 Sequence=79 ttl=253 time=110 ms
    Reply from 22.22.22.22: bytes=56 Sequence=80 ttl=253 time=60 ms
    Reply from 22.22.22.22: bytes=56 Sequence=81 ttl=253 time=100 ms
    Request time out
    Reply from 22.22.22.22: bytes=56 Sequence=83 ttl=251 time=160 ms
    Reply from 22.22.22.22: bytes=56 Sequence=84 ttl=251 time=190 ms
    Reply from 22.22.22.22: bytes=56 Sequence=85 ttl=251 time=170 ms
...
    Reply from 22.22.22.22: bytes=56 Sequence=286 ttl=251 time=140 ms
    Reply from 22.22.22.22: bytes=56 Sequence=287 ttl=251 time=160 ms
    Reply from 22.22.22.22: bytes=56 Sequence=288 ttl=251 time=140 ms

  --- 22.22.22.22 ping statistics ---
    288 packet(s) transmitted
    287 packet(s) received
    0.34% packet loss
    round-trip min/avg/max = 60/123/250 ms

[P1-Ethernet0/0/0]shut
[P1-Ethernet0/0/0]
Sep 22 2015 20:59:50-08:00 P1 %%01PHY/1/PHY(l)[0]:    Ethernet0/0/0: change
statu
s to down
Sep 22 2015 20:59:50-08:00 P1 %%01IFNET/4/LINK_STATE(l)[1]:The line protocol IP
o
n the interface Ethernet0/0/0 has entered the DOWN state.
Sep 22 2015 20:59:50-08:00 P1 %%01OSPF/3/NBR_CHG_DOWN(l)[2]:Neighbor
event:neighb
or state changed to Down. (ProcessId=1, NeighborAddress=160.160.161.7,
NeighborEv
ent=KillNbr, NeighborPreviousState=Full, NeighborCurrentState=Down)
Sep 22 2015 20:59:50-08:00 P1 %%01OSPF/3/NBR_DOWN_REASON(l)[3]:Neighbor state
lea
ves full or changed to Down. (ProcessId=1, NeighborRouterId=160.160.161.7,
Neighb
orAreaId=0, NeighborInterface=Ethernet0/0/0,NeighborDownImmediate
reason=Neighbor
 Down Due to Kill Neighbor, NeighborDownPrimeReason=Physical Interface State
Chan
ge, NeighborChangeTime=2015-09-22 20:59:50-08:00)
Sep 22 2015 20:59:50-08:00 P1 %%01BFD/4/STACHG_TODWN(l)[4]:BFD session changed
to
 Down. (SlotNumber=0, Discriminator=8279, Diagnostic=DetectDown,
Applications=OSP
F | RSVP, ProcessPST=False, BindInterfaceName=Ethernet0/0/0,
InterfacePhysicalSta
```

```
te=Down, InterfaceProtocolState=Down)
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]display mpls te tunnel name Tunnel0/0/0 verbose


    No                      :  3
    Tunnel-Name             :  Tunnel0/0/0
    Tunnel Interface Name   :  -
    TunnelIndex             :  15          LSP Index         :  2052
    Session ID              :  100         LSP ID            :  59
    Lsr Role                :  Transit
    Ingress LSR ID          :  160.160.161.5
    Egress LSR ID           :  160.160.161.7
    In-Interface            :  GE0/0/1
    Out-Interface           :  Eth0/0/0
    Sign-Protocol           :  RSVP TE     Resv Style        :  SE
    IncludeAnyAff           :  0x0         ExcludeAnyAff     :  0x0
    IncludeAllAff           :  0x0
    ER-Hop Table Index      :  -           AR-Hop Table Index:  15
    C-Hop Table Index       :  -
    PrevTunnelIndexInSession:  -           NextTunnelIndexInSession:  -
    PSB Handle              :  10937
    Created Time            :  2015-09-22 20:45:02-08:00
    --------------------------------
              DS-TE Information
    --------------------------------
    Bandwidth Reserved Flag :  Unreserved
    CT0 Bandwidth(Kbit/sec) :  10000       CT1 Bandwidth(Kbit/sec):  0
    CT2 Bandwidth(Kbit/sec) :  0           CT3 Bandwidth(Kbit/sec):  0
    CT4 Bandwidth(Kbit/sec) :  0           CT5 Bandwidth(Kbit/sec):  0
    CT6 Bandwidth(Kbit/sec) :  0           CT7 Bandwidth(Kbit/sec):  0
    Setup-Priority          :  7           Hold-Priority     :  7
    --------------------------------
                FRR Information
    --------------------------------
    Primary LSP Info
    TE Attribute Flag       :  0x63        Protected Flag    :  0x1
    Bypass In Use           :  In Use
    Bypass Tunnel Id        :  225
    BypassTunnel            :  Tunnel Index[Tunnel0/0/0], InnerLabel[3]
    Bypass Lsp ID           :  85          FrrNextHop        :  160.160.160.49
    ReferAutoBypassHandle   :  -
    FrrPrevTunnelTableIndex :  8           FrrNextTunnelTableIndex:  -
    Bypass Attribute(Not configured)
    Setup Priority          :  -           Hold Priority     :  -
    HopLimit                :  -           Bandwidth         :  -
    IncludeAnyGroup         :  -           ExcludeAnyGroup   :  -
    IncludeAllGroup         :  -
    Bypass Unbound Bandwidth Info(Kbit/sec)
    CT0 Unbound Bandwidth   :  -           CT1 Unbound Bandwidth:  -
    CT2 Unbound Bandwidth   :  -           CT3 Unbound Bandwidth:  -
    CT4 Unbound Bandwidth   :  -           CT5 Unbound Bandwidth:  -
    CT6 Unbound Bandwidth   :  -           CT7 Unbound Bandwidth:  -
    --------------------------------
               BFD Information
    --------------------------------
```

```
    NextSessionTunnelIndex  :  -           PrevSessionTunnelIndex:  -
    NextLspId               :  -           PrevLspId         :  -


[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]
Sep 22 2015 20:59:58-08:00 P1 DS/4/DATASYNC_CFGCHANGE:OID
1.3.6.1.4.1.2011.5.25.1
91.3.1 configurations have been changed. The current change number is 19, the
cha
nge loop count is 0, and the maximum number of records is 4095.
Sep 22 2015 21:00:05-08:00 P1 %%01LDP/4/HOLDTMREXP(l)[5]:Sessions were deleted
be
cause the hello hold timer expired. (PeerId=160.160.161.7)
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]undo shut
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]
Sep 22 2015 21:00:30-08:00 P1 %%01PHY/1/PHY(l)[6]:    Ethernet0/0/0: change
statu
s to up
Sep 22 2015 21:00:30-08:00 P1 %%01IFNET/4/LINK_STATE(l)[7]:The line protocol IP
o
n the interface Ethernet0/0/0 has entered the UP state.
[P1-Ethernet0/0/0]
Sep 22 2015 21:00:38-08:00 P1 DS/4/DATASYNC_CFGCHANGE:OID
1.3.6.1.4.1.2011.5.25.1
91.3.1 configurations have been changed. The current change number is 20, the
cha
nge loop count is 0, and the maximum number of records is 4095.
Sep 22 2015 21:00:39-08:00 P1 %%01OSPF/4/NBR_CHANGE_E(l)[8]:Neighbor changes
even
t: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.42,
Neighbo
rEvent=HelloReceived, NeighborPreviousState=Down, NeighborCurrentState=Init)
Sep 22 2015 21:00:39-08:00 P1 %%01OSPF/4/NBR_CHANGE_E(l)[9]:Neighbor changes
even
t: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.42,
Neighbo
rEvent=2WayReceived, NeighborPreviousState=Init, NeighborCurrentState=2Way)
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]
Sep 22 2015 21:01:09-08:00 P1 %%01OSPF/4/NBR_CHANGE_E(l)[10]:Neighbor changes
eve
nt: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.42,
Neighb
orEvent=AdjOk?, NeighborPreviousState=2Way, NeighborCurrentState=ExStart)

[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]
Sep 22 2015 21:01:13-08:00 P1 %%01OSPF/4/NBR_CHANGE_E(l)[11]:Neighbor changes
eve
nt: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.42,
Neighb
orEvent=NegotiationDone, NeighborPreviousState=ExStart,
NeighborCurrentState=Exch
ange)
```

```
Sep 22 2015 21:01:14-08:00 P1 %%01OSPF/4/NBR_CHANGE_E(l)[12]:Neighbor changes
eve
nt: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.42,
Neighb
orEvent=ExchangeDone, NeighborPreviousState=Exchange,
NeighborCurrentState=Loadin
g)
Sep 22 2015 21:01:14-08:00 P1 %%01OSPF/4/NBR_CHANGE_E(l)[13]:Neighbor changes
eve
nt: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.42,
Neighb
orEvent=LoadingDone, NeighborPreviousState=Loading, NeighborCurrentState=Full)
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]
Sep 22 2015 21:01:16-08:00 P1 %%01BFD/4/STACHG_TOUP(l)[14]:BFD session changed
to
 Up. (SlotNumber=0, Discriminator=8280, FormerStatus=Init, Applications=OSPF |
RS
VP, BindInterfaceName=Ethernet0/0/0, ProcessPST=False)
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]display mpls te tunnel name Tunnel0/0/0 verbose


    No                     :  3
    Tunnel-Name            :  Tunnel0/0/0
    Tunnel Interface Name  :  -
    TunnelIndex            :  6           LSP Index         :  2062
    Session ID             :  100         LSP ID            :  60
    Lsr Role               :  Transit
    Ingress LSR ID         :  160.160.161.5
    Egress LSR ID          :  160.160.161.7
    In-Interface           :  GE0/0/1
    Out-Interface          :  Eth0/0/0
    Sign-Protocol          :  RSVP TE     Resv Style        :  SE
    IncludeAnyAff          :  0x0         ExcludeAnyAff     :  0x0
    IncludeAllAff          :  0x0
    ER-Hop Table Index     :  8           AR-Hop Table Index:  6
    C-Hop Table Index      :  -
    PrevTunnelIndexInSession:  -           NextTunnelIndexInSession:  -
    PSB Handle             :  11348
    Created Time           :  2015-09-22 21:01:14-08:00
    ------------------------------
              DS-TE Information
    ------------------------------
    Bandwidth Reserved Flag :  Reserved
    CT0 Bandwidth(Kbit/sec) :  10000       CT1 Bandwidth(Kbit/sec):  0
    CT2 Bandwidth(Kbit/sec) :  0           CT3 Bandwidth(Kbit/sec):  0
    CT4 Bandwidth(Kbit/sec) :  0           CT5 Bandwidth(Kbit/sec):  0
    CT6 Bandwidth(Kbit/sec) :  0           CT7 Bandwidth(Kbit/sec):  0
    Setup-Priority         :  7           Hold-Priority     :  7
    ------------------------------
                FRR Information
    ------------------------------
    Primary LSP Info
    TE Attribute Flag      :  0x63        Protected Flag    :  0x1
```

```
    Bypass In Use           :  Not Used
    Bypass Tunnel Id        :  310
    BypassTunnel            :  Tunnel Index[Tunnel0/0/0], InnerLabel[3]
    Bypass Lsp ID           :  85          FrrNextHop        :  160.160.160.49
    ReferAutoBypassHandle   :  -
    FrrPrevTunnelTableIndex :  7           FrrNextTunnelTableIndex:  -
    Bypass Attribute(Not configured)
    Setup Priority          :  -           Hold Priority     :  -
    HopLimit                :  -           Bandwidth         :  -
    IncludeAnyGroup         :  -           ExcludeAnyGroup   :  -
    IncludeAllGroup         :  -
    Bypass Unbound Bandwidth Info(Kbit/sec)
    CT0 Unbound Bandwidth   :  -           CT1 Unbound Bandwidth:  -
    CT2 Unbound Bandwidth   :  -           CT3 Unbound Bandwidth:  -
    CT4 Unbound Bandwidth   :  -           CT5 Unbound Bandwidth:  -
    CT6 Unbound Bandwidth   :  -           CT7 Unbound Bandwidth:  -
    ------------------------------
              BFD Information
    ------------------------------
    NextSessionTunnelIndex  :  -           PrevSessionTunnelIndex:  -
    NextLspId               :  -           PrevLspId         :  -


[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]
[P1-Ethernet0/0/0]
```

Ono što se desi je da imamo mali *glitch* u paketima veoma kratkog trajanja, a posle sve vreme kontinuirani ping. Iz logova na P1 ruteru, možemo videti da nakon stavljanja interfejsa u *Down state*,*Bypass* je *in use*, a nakon ponovnog uspostavljanja linka potrebno je vreme da prođe da se uspostave tabele usmeravanja nakon čega ponovo *bypass* prestaje da se koristi.

Možemo zaključiti da je ovo takođe efikasna zaštita, s tim što u ovom slučaju na ovaj *bypass* će koristiti sav saobraćaj koji je prolazio kroz taj interfejs, odnosno i više konfigurisanih tunela čiji LSP prolazi kroz taj interfejs.

4.3. Testiranje VPN FRR tehnologije

U ovom delu ćemo posmatrati ponašanje saobraćaja u slučaju otkaza PE7 rutera, i videti kako se saobraćaj sa *source* adresom 11.11.11.11 prema 22.22.22.22 ponaša u slučaju kada imamo implementiran VPN FRR, odnosno kada se ne koristi.

4.3.1. Test sa VPN FRR zaštitom

Prvo ćemo prikazati varijantu kada se koristi VPN FRR. Šaljemo ping sa UMG1 ka 22.22.22.22, i pratimo ponašanja kada ugasimo PE7, i zatim ga opet startujemo. U nastavku je prikazan *output* tog testa.

```
<UMG1>ping -a 11.11.11.11 -c 1000 22.22.22.22
  PING 22.22.22.22: 56  data bytes, press CTRL_C to break
    Reply from 22.22.22.22: bytes=56 Sequence=1 ttl=253 time=110 ms
```

```
    Reply from 22.22.22.22: bytes=56 Sequence=2 ttl=253 time=110 ms
...
    Reply from 22.22.22.22: bytes=56 Sequence=21 ttl=253 time=110 ms
    Reply from 22.22.22.22: bytes=56 Sequence=22 ttl=253 time=110 ms
    Request time out
    Request time out
    Reply from 22.22.22.22: bytes=56 Sequence=33 ttl=252 time=100 ms
    Reply from 22.22.22.22: bytes=56 Sequence=34 ttl=252 time=140 ms
...
    Reply from 22.22.22.22: bytes=56 Sequence=83 ttl=252 time=120 ms
    Reply from 22.22.22.22: bytes=56 Sequence=84 ttl=252 time=110 ms
    Reply from 22.22.22.22: bytes=56 Sequence=85 ttl=252 time=140 ms
    Reply from 22.22.22.22: bytes=56 Sequence=86 ttl=252 time=130 ms
    Request time out
    Request time out
    Request time out
    Request time out
    Request time out
    Request time out
    Request time out
    Request time out
    Request time out
    Request time out
    Request time out
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    Request time out
    Request time out
    Request time out
    Reply from 22.22.22.22: bytes=56 Sequence=127 ttl=253 time=110 ms
    Reply from 22.22.22.22: bytes=56 Sequence=128 ttl=253 time=160 ms
    Reply from 22.22.22.22: bytes=56 Sequence=129 ttl=253 time=110 ms
    Reply from 22.22.22.22: bytes=56 Sequence=130 ttl=253 time=120 ms
    Reply from 22.22.22.22: bytes=56 Sequence=131 ttl=253 time=60 ms
    Reply from 22.22.22.22: bytes=56 Sequence=132 ttl=253 time=100 ms
```

```
    Reply from 22.22.22.22: bytes=56 Sequence=133 ttl=253 time=110 ms

  --- 22.22.22.22 ping statistics ---
    144 packet(s) transmitted
    91 packet(s) received
    36.80% packet loss
    round-trip min/avg/max = 60/122/300 ms
############################
<PE7>
<PE7>
<PE7>
<PE7>
<PE7>
Sep 22 2015 22:05:57-08:00 PE7 %%01BFD/4/STACHG_TOUP(l)[0]:BFD session changed
to
 Up. (SlotNumber=0, Discriminator=8194, FormerStatus=Init, Applications=LSPM |
TE
 | L2VPN | TUNNEL_PS, BindInterfaceName=Tunnel0/0/1, ProcessPST=True)
Sep 22 2015 22:05:58-08:00 PE7 %%01BFD/4/STACHG_TOUP(l)[1]:BFD session changed
to
 Up. (SlotNumber=0, Discriminator=88, FormerStatus=Init, Applications=None,
BindI
nterfaceName=GigabitEthernet0/0/2, ProcessPST=False)
<PE7>
<PE7>
Sep 22 2015 22:06:16-08:00 PE7 %%01BGP/3/STATE_CHG_UPDOWN(l)[2]:The status of
the
 peer 160.160.161.1 changed from OPENCONFIRM to ESTABLISHED.
(InstanceName=Public
, StateChangeReason=Up)
Sep 22 2015 22:06:19-08:00 PE7 %%01BFD/4/STACHG_TOUP(l)[3]:BFD session changed
to
 Up. (SlotNumber=0, Discriminator=8198, FormerStatus=Down, Applications=LSPV,
Bin
dInterfaceName=None, ProcessPST=False)
Sep 22 2015 22:06:20-08:00 PE7 %%01BFD/4/STACHG_TOUP(l)[4]:BFD session changed
to
 Up. (SlotNumber=0, Discriminator=8199, FormerStatus=Init, Applications=LSPM |
TE
 | L2VPN | TUNNEL_PS, BindInterfaceName=Tunnel0/0/0, ProcessPST=True)
Sep 22 2015 22:06:20-08:00 PE7 %%01BFD/4/STACHG_TOUP(l)[5]:BFD session changed
to
 Up. (SlotNumber=0, Discriminator=8200, FormerStatus=Init, Applications=LSPM |
TE
 | L2VPN | TUNNEL_PS, BindInterfaceName=Tunnel0/0/1, ProcessPST=True)
Sep 22 2015 22:06:23-08:00 PE7 %%01BGP/3/STATE_CHG_UPDOWN(l)[6]:The status of
the
 peer 160.160.161.3 changed from OPENCONFIRM to ESTABLISHED.
(InstanceName=Public
, StateChangeReason=Up)
Sep 22 2015 22:06:27-08:00 PE7 %%01BFD/4/STACHG_TOUP(l)[7]:BFD session changed
to
 Up. (SlotNumber=0, Discriminator=8201, FormerStatus=Down, Applications=LSPV,
Bin
dInterfaceName=None, ProcessPST=False)
<PE7>
<PE7>
<PE7>
<PE7>
```

```
Sep 22 2015 22:06:33-08:00 PE7 %%01BFD/4/STACHG_TODWN(l)[8]:BFD session changed
t
o Down. (SlotNumber=0, Discriminator=8201, Diagnostic=NeighborDown,
Applications=
LSPV, ProcessPST=False, BindInterfaceName=None, InterfacePhysicalState=None,
Inte
rfaceProtocolState=None)
Sep 22 2015 22:06:33-08:00 PE7 %%01BFD/4/STACHG_TOUP(l)[9]:BFD session changed
to
 Up. (SlotNumber=0, Discriminator=8201, FormerStatus=Down, Applications=LSPV,
Bin
dInterfaceName=None, ProcessPST=False)
```

Ono što se desi ovde je sledeće. Nakon što je PE7 isključen, imamo mali *glitch* u saobraćaju, gde se desila konvergencija na drugu putanju, odnosno korišćen je *Tunnel 0/0/1* na PE5 ruteru. Nakon što se PE7 podigne, i njegova *loopback* adresa postane *reachable*, dođe do otkaza servisa opet, dok se ne uspostave svi tuneli, i imamo u tom periodu*outage*. U novijoj verziji softvera postoji komanda koja bi sprečila ovakvu vrstu *outage*-a, ali u verziji sa kojom radimo imamo, i treba voditi računa kada se ruter vraća ponovo u operativno stanje.

4.3.2. Test bez VPN FRR zaštite

Naredno testiranje, radimo za slučaj kada nemamo VPN zaštitu, odnosno uklonili smo vpn frr polisu saPE5 rutera prema PE7 za ovo testiranje.

```
[PE5]ip vpn-instance media
[PE5-vpn-instance-media] vpn frr
```

Zatim ćemo isto kao u prethodnom testiranju slati ping između 11.11.11.11 i 22.22.22.22, i ugasiti ruter PE7, i videti ponašanje u mreži. Priložen je *output* testa.

```
<UMG1>ping -a 11.11.11.11 -c 1000 22.22.22.22
  PING 22.22.22.22: 56  data bytes, press CTRL_C to break
    Reply from 22.22.22.22: bytes=56 Sequence=1 ttl=253 time=80 ms
    Reply from 22.22.22.22: bytes=56 Sequence=2 ttl=253 time=110 ms
...
    Reply from 22.22.22.22: bytes=56 Sequence=44 ttl=253 time=110 ms
    Reply from 22.22.22.22: bytes=56 Sequence=45 ttl=253 time=70 ms
    Reply from 22.22.22.22: bytes=56 Sequence=46 ttl=253 time=70 ms
    Reply from 22.22.22.22: bytes=56 Sequence=47 ttl=253 time=90 ms
    Reply from 22.22.22.22: bytes=56 Sequence=48 ttl=253 time=90 ms
    Reply from 22.22.22.22: bytes=56 Sequence=49 ttl=253 time=90 ms
    Request time out
    Request time out
    Request time out
    Request time out
    Request time out
    Request time out
    Request time out
    Request time out
    Request time out
    Request time out
    Request time out
    Request time out
    Request time out
    Request time out
```

```
    Request time out
    Request time out
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    Request time out
    Request time out
    Request time out
    Reply from 22.22.22.22: bytes=56 Sequence=98 ttl=253 time=90 ms
    Reply from 22.22.22.22: bytes=56 Sequence=99 ttl=253 time=110 ms
...
    Reply from 22.22.22.22: bytes=56 Sequence=112 ttl=253 time=90 ms
    Reply from 22.22.22.22: bytes=56 Sequence=113 ttl=253 time=100 ms
    Reply from 22.22.22.22: bytes=56 Sequence=114 ttl=253 time=80 ms

  --- 22.22.22.22 ping statistics ---
    114 packet(s) transmitted
    66 packet(s) received
    42.10% packet loss
    round-trip min/avg/max = 60/101/220 ms
######################
<PE7>
Sep 22 2015 22:37:25-08:00 PE7 %%01PHY/1/PHY(l)[0]:    GigabitEthernet0/0/0:
chan
ge status to up
Sep 22 2015 22:37:25-08:00 PE7 %%01IFNET/4/LINK_STATE(l)[1]:The line protocol IP
on the interface GigabitEthernet0/0/0 has entered the UP state.
Sep 22 2015 22:37:25-08:00 PE7 %%01PHY/1/PHY(l)[2]:    GigabitEthernet0/0/1:
chan
ge status to up
Sep 22 2015 22:37:25-08:00 PE7 %%01IFNET/4/LINK_STATE(l)[3]:The line protocol IP
on the interface GigabitEthernet0/0/1 has entered the UP state.
Sep 22 2015 22:37:25-08:00 PE7 %%01IFNET/4/LINK_STATE(l)[4]:The line protocol IP
```

```
on the interface GigabitEthernet0/0/1.1 has entered the UP state.
Sep 22 2015 22:37:25-08:00 PE7 %%01PHY/1/PHY(l)[5]:    GigabitEthernet0/0/2:
chan
ge status to up
Sep 22 2015 22:37:25-08:00 PE7 %%01IFNET/4/LINK_STATE(l)[6]:The line protocol IP
on the interface GigabitEthernet0/0/2 has entered the UP state.
Sep 22 2015 22:37:33-08:00 PE7 %%01OSPF/4/NBR_CHANGE_E(l)[7]:Neighbor changes
eve
nt: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.41,
Neighb
orEvent=HelloReceived, NeighborPreviousState=Down, NeighborCurrentState=Init)
Sep 22 2015 22:37:33-08:00 PE7 %%01OSPF/4/NBR_CHANGE_E(l)[8]:Neighbor changes
eve
nt: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.41,
Neighb
orEvent=2WayReceived, NeighborPreviousState=Init, NeighborCurrentState=2Way)
Sep 22 2015 22:37:34-08:00 PE7 %%01OSPF/4/NBR_CHANGE_E(l)[9]:Neighbor changes
eve
nt: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.50,
Neighb
orEvent=HelloReceived, NeighborPreviousState=Down, NeighborCurrentState=Init)
Sep 22 2015 22:37:34-08:00 PE7 %%01OSPF/4/NBR_CHANGE_E(l)[10]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.50,
Neigh
borEvent=2WayReceived, NeighborPreviousState=Init, NeighborCurrentState=2Way)
Sep 22 2015 22:38:04-08:00 PE7 %%01OSPF/4/NBR_CHANGE_E(l)[11]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.41,
Neigh
borEvent=AdjOk?, NeighborPreviousState=2Way, NeighborCurrentState=ExStart)
Sep 22 2015 22:38:04-08:00 PE7 %%01OSPF/4/NBR_CHANGE_E(l)[12]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.41,
Neigh
borEvent=NegotiationDone, NeighborPreviousState=ExStart,
NeighborCurrentState=Exc
hange)
Sep 22 2015 22:38:04-08:00 PE7 %%01OSPF/4/NBR_CHANGE_E(l)[13]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.41,
Neigh
borEvent=ExchangeDone, NeighborPreviousState=Exchange,
NeighborCurrentState=Loadi
ng)
Sep 22 2015 22:38:04-08:00 PE7 %%01OSPF/4/NBR_CHANGE_E(l)[14]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.41,
Neigh
borEvent=LoadingDone, NeighborPreviousState=Loading, NeighborCurrentState=Full)
Sep 22 2015 22:38:04-08:00 PE7 %%01OSPF/4/NBR_CHANGE_E(l)[15]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.50,
Neigh
borEvent=AdjOk?, NeighborPreviousState=2Way, NeighborCurrentState=ExStart)
Sep 22 2015 22:38:04-08:00 PE7 %%01IFNET/4/LINK_STATE(l)[16]:The line protocol
IP
 on the interface Tunnel0/0/0 has entered the UP state.
```

```
Sep 22 2015 22:38:04-08:00 PE7 %%01IFNET/4/LINK_STATE(l)[17]:The line protocol
IP
 on the interface Tunnel0/0/1 has entered the UP state.
Sep 22 2015 22:38:06-08:00 PE7 %%01BFD/4/STACHG_TOUP(l)[18]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=8192, FormerStatus=Down, Applications=OSPF |
R
SVP, BindInterfaceName=GigabitEthernet0/0/0, ProcessPST=False)
Sep 22 2015 22:38:07-08:00 PE7 %%01OSPF/4/NBR_CHANGE_E(l)[19]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.50,
Neigh
borEvent=NegotiationDone, NeighborPreviousState=ExStart,
NeighborCurrentState=Exc
hange)
Sep 22 2015 22:38:07-08:00 PE7 %%01OSPF/4/NBR_CHANGE_E(l)[20]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.50,
Neigh
borEvent=ExchangeDone, NeighborPreviousState=Exchange,
NeighborCurrentState=Loadi
ng)
Sep 22 2015 22:38:07-08:00 PE7 %%01OSPF/4/NBR_CHANGE_E(l)[21]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.50,
Neigh
borEvent=LoadingDone, NeighborPreviousState=Loading, NeighborCurrentState=Full)
<PE7>
<PE7>
Sep 22 2015 22:38:09-08:00 PE7 %%01BFD/4/STACHG_TOUP(l)[22]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=8195, FormerStatus=Down, Applications=OSPF,
Bi
ndInterfaceName=GigabitEthernet0/0/1, ProcessPST=False)
Sep 22 2015 22:38:10-08:00 PE7 %%01LDP/4/SSNHOLDTMREXP(l)[23]:Sessions were
delet
ed because the session hold timer expired and the notification of the expiry was
sent to the peer 160.160.161.8.
Sep 22 2015 22:38:10-08:00 PE7 %%01LDP/4/SSNHOLDTMREXP(l)[24]:Sessions were
delet
ed because the session hold timer expired and the notification of the expiry was
sent to the peer 160.160.161.1.
<PE7>
<PE7>
<PE7>
<PE7>
<PE7>
Sep 22 2015 22:38:26-08:00 PE7 %%01BFD/4/STACHG_TOUP(l)[25]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=8196, FormerStatus=Down, Applications=LSPV,
Bi
ndInterfaceName=None, ProcessPST=False)
<PE7>
<PE7>
Sep 22 2015 22:38:32-08:00 PE7 %%01BFD/4/STACHG_TOUP(l)[26]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=88, FormerStatus=Init, Applications=None,
Bind
InterfaceName=GigabitEthernet0/0/2, ProcessPST=False)
```

```
Sep 22 2015 22:38:32-08:00 PE7 %%01BFD/4/STACHG_TOUP(l)[27]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=8194, FormerStatus=Init, Applications=LSPM |
T
E | L2VPN | TUNNEL_PS, BindInterfaceName=Tunnel0/0/1, ProcessPST=True)
Sep 22 2015 22:38:33-08:00 PE7 %%01BFD/4/STACHG_TOUP(l)[28]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=8193, FormerStatus=Init, Applications=LSPM |
T
E | L2VPN | TUNNEL_PS, BindInterfaceName=Tunnel0/0/0, ProcessPST=True)
Sep 22 2015 22:38:33-08:00 PE7 %%01BFD/4/STACHG_TOUP(l)[29]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=8197, FormerStatus=Down, Applications=LSPV,
Bi
ndInterfaceName=None, ProcessPST=False)
<PE7>
<PE7>
<PE7>
<PE7>
Sep 22 2015 22:38:37-08:00 PE7 %%01BGP/3/STATE_CHG_UPDOWN(l)[30]:The status of
th
e peer 160.160.161.1 changed from OPENCONFIRM to ESTABLISHED.
(InstanceName=Publi
c, StateChangeReason=Up)
Sep 22 2015 22:38:44-08:00 PE7 %%01BFD/4/STACHG_TODWN(l)[31]:BFD session changed
to Down. (SlotNumber=0, Discriminator=8197, Diagnostic=(Receive AdminDown),
Appli
cations=LSPV, ProcessPST=False, BindInterfaceName=None,
InterfacePhysicalState=No
ne, InterfaceProtocolState=None)
Sep 22 2015 22:38:48-08:00 PE7 %%01BFD/4/STACHG_TOUP(l)[32]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=8198, FormerStatus=Down, Applications=LSPV,
Bi
ndInterfaceName=None, ProcessPST=False)
Sep 22 2015 22:38:55-08:00 PE7 %%01BGP/3/STATE_CHG_UPDOWN(l)[33]:The status of
th
e peer 160.160.161.3 changed from OPENCONFIRM to ESTABLISHED.
(InstanceName=Publi
c, StateChangeReason=Up)
<PE7>
<PE7>
```

Može se videti da je momenta kada je uređaj ugašen, došlo do otkaza, i da se saobraćaj nije ponovo uspostavio dok se PE7 nije startovao, i dok se svi procesi nisu ponovo uspostavili.

Možemo zaključiti da je primena VPN FRR značajno bolja opcija, i da pruža dobru zaštitu od otkaza rutera, sa naglaskom da treba voditi računa pri ponovnom startovanju rutera, i obezbediti alternativnu putanju dok se ruter ne podigne i procesi se ne uspostave.

4.4. Testiranje IP FRR tehnologije

U ovom delu ćemo testirati ponašanje sistema sa i bez primene IP FRR tehnologije. Slaćemo ping između adresa 11.11.11.11 i 22.22.22.22, i pratiti ponašanje saobraćaja. Posmatraćemo konfigurisan IP FRR na PE5 ruteru, odnosno stavljaćemo u *Downstate* interfejs *GigabitEthernet 0/0/2* na PE5 ruteru, za koji je konfigurisan IP FRR.

4.4.1. Test sa IP FRR zaštitom

Ne pravimo nikakve izmene i gledamo da li ima prekida u saobraćaju dok šaljemo ping sa UMG2 na UMG1, 11.11.11.11 adresu, pri stavljanju prethodno pomenutog interfejsa u *Downstate*. U nastavku je dat *output* testiranja.

```
<UMG2>ping -a 22.22.22.22 -c 1000 11.11.11.11
  PING 11.11.11.11: 56  data bytes, press CTRL_C to break
    Reply from 11.11.11.11: bytes=56 Sequence=1 ttl=253 time=70 ms
    Reply from 11.11.11.11: bytes=56 Sequence=2 ttl=253 time=110 ms
    ..
    Reply from 11.11.11.11: bytes=56 Sequence=126 ttl=253 time=80 ms
    Reply from 11.11.11.11: bytes=56 Sequence=127 ttl=253 time=90 ms
    Reply from 11.11.11.11: bytes=56 Sequence=128 ttl=253 time=90 ms
    Reply from 11.11.11.11: bytes=56 Sequence=129 ttl=253 time=110 ms
    Reply from 11.11.11.11: bytes=56 Sequence=130 ttl=253 time=110 ms
    Reply from 11.11.11.11: bytes=56 Sequence=131 ttl=253 time=120 ms
    Reply from 11.11.11.11: bytes=56 Sequence=132 ttl=253 time=60 ms
    Reply from 11.11.11.11: bytes=56 Sequence=133 ttl=253 time=70 ms
    Reply from 11.11.11.11: bytes=56 Sequence=134 ttl=253 time=90 ms
    Reply from 11.11.11.11: bytes=56 Sequence=135 ttl=253 time=170 ms

  --- 11.11.11.11 ping statistics ---
    135 packet(s) transmitted
    135 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 60/111/250 ms
<UMG1>
Sep 23 2015 06:22:25-08:00 UMG1 %%01PHY/1/PHY(l)[0]:    Ethernet0/0/0: change
sta
tus to down
Sep 23 2015 06:22:25-08:00 UMG1 %%01IFNET/4/LINK_STATE(l)[1]:The line protocol
IP
 on the interface Ethernet0/0/0 has entered the DOWN state.
Sep 23 2015 06:22:25-08:00 UMG1 %%01RM/4/IPV4_DEFT_RT_CHG(l)[2]:IPV4 default
Rout
e is changed.
(ChangeType=Delete,InstanceId=0,Protocol=Static,ExitIf=Unknown,Next
hop=10.1.1.1,Neighbour=0.0.0.0,Preference=20,Label=NULL,Metric=0)
Sep 23 2015 06:22:25-08:00 UMG1 %%01BFD/4/STACHG_TODWN(l)[3]:BFD session changed
to Down. (SlotNumber=0, Discriminator=66, Diagnostic=DetectDown,
Applications=Non
e, ProcessPST=False, BindInterfaceName=Ethernet0/0/0,
InterfacePhysicalState=Down
, InterfaceProtocolState=Down)
Sep 23 2015 06:22:44-08:00 UMG1 %%01PHY/1/PHY(l)[4]:    Ethernet0/0/0: change
sta
tus to up
Sep 23 2015 06:22:44-08:00 UMG1 %%01IFNET/4/LINK_STATE(l)[5]:The line protocol
IP
 on the interface Ethernet0/0/0 has entered the UP state.
Sep 23 2015 06:22:44-08:00 UMG1 %%01RM/4/IPV4_DEFT_RT_CHG(l)[6]:IPV4 default
Rout
e is changed.
(ChangeType=Delete,InstanceId=0,Protocol=Static,ExitIf=Ethernet0/0/
1,Nexthop=10.1.2.1,Neighbour=0.0.0.0,Preference=30,Label=NULL,Metric=0)
Sep 23 2015 06:22:45-08:00 UMG1 %%01BFD/4/STACHG_TOUP(l)[7]:BFD session changed
t
```

```
o Up. (SlotNumber=0, Discriminator=66, FormerStatus=Down, Applications=None,
Bind
InterfaceName=Ethernet0/0/0, ProcessPST=False)
[PE5-GigabitEthernet0/0/2]shut
[PE5-GigabitEthernet0/0/2]
Sep 23 2015 06:22:26-08:00 PE5 %%01PHY/1/PHY(l)[1]:    GigabitEthernet0/0/2:
chan
ge status to down
Sep 23 2015 06:22:26-08:00 PE5 %%01IFNET/4/LINK_STATE(l)[2]:The line protocol IP
on the interface GigabitEthernet0/0/2 has entered the DOWN state.
Sep 23 2015 06:22:26-08:00 PE5 %%01BFD/4/STACHG_TODWN(l)[3]:BFD session changed
t
o Down. (SlotNumber=0, Discriminator=55, Diagnostic=DetectDown,
Applications=None
, ProcessPST=False, BindInterfaceName=GigabitEthernet0/0/2,
InterfacePhysicalStat
e=Down, InterfaceProtocolState=Down)
Sep 23 2015 06:22:28-08:00 PE5 DS/4/DATASYNC_CFGCHANGE:OID
1.3.6.1.4.1.2011.5.25.
191.3.1 configurations have been changed. The current change number is 1, the
cha
nge loop count is 0, and the maximum number of records is 4095.
[PE5-GigabitEthernet0/0/2]undo shut
[PE5-GigabitEthernet0/0/2]
Sep 23 2015 06:22:46-08:00 PE5 %%01PHY/1/PHY(l)[4]:    GigabitEthernet0/0/2:
chan
ge status to up
Sep 23 2015 06:22:46-08:00 PE5 %%01IFNET/4/LINK_STATE(l)[5]:The line protocol IP
on the interface GigabitEthernet0/0/2 has entered the UP state.
Sep 23 2015 06:22:46-08:00 PE5 %%01BFD/4/STACHG_TOUP(l)[6]:BFD session changed
to
 Up. (SlotNumber=0, Discriminator=55, FormerStatus=Init, Applications=None,
BindI
nterfaceName=GigabitEthernet0/0/2, ProcessPST=False)
Sep 23 2015 06:22:48-08:00 PE5 DS/4/DATASYNC_CFGCHANGE:OID
1.3.6.1.4.1.2011.5.25.
191.3.1 configurations have been changed. The current change number is 2, the
cha
nge loop count is 0, and the maximum number of records is 4095.
[PE5-GigabitEthernet0/0/2]
[PE5-GigabitEthernet0/0/2]disp
[PE5-GigabitEthernet0/0/2]display bfd sess
[PE5-GigabitEthernet0/0/2]display bfd session all
--------------------------------------------------------------------------------
Local Remote     PeerIpAddr      State     Type        InterfaceName
--------------------------------------------------------------------------------
55    66         10.1.1.2        Up        S_IP_IF     GigabitEthernet0/0/2
8241  8205       160.160.160.17  Up        D_IP_IF     GigabitEthernet0/0/0
8250  8259       160.160.160.26  Up        D_IP_IF     GigabitEthernet0/0/1
8257  8259       160.160.161.7   Up        D_TE_LSP    Tunnel0/0/0
8258  8271       160.160.161.8   Up        D_TE_LSP    Tunnel0/0/1
8260  8269       160.160.161.8   Up        E_Dynamic         -
8261  8257       160.160.161.7   Up        E_Dynamic         -
--------------------------------------------------------------------------------
     Total UP/DOWN Session Number : 7/0
[PE5-GigabitEthernet0/0/2]
[PE5-GigabitEthernet0/0/2]
[PE5-GigabitEthernet0/0/2]dis
[PE5-GigabitEthernet0/0/2]display tun
```

```
[PE5-GigabitEthernet0/0/2]display tunnel-po
[PE5-GigabitEthernet0/0/2]disp cur conf ip vpn
[PE5-GigabitEthernet0/0/2]disp cur conf ip vpn
[PE5-GigabitEthernet0/0/2]disp cur conf vpn
[PE5-GigabitEthernet0/0/2]disp cur conf vpn-instance
#
ip vpn-instance media
 ipv4-family
  route-distinguisher 15000:100
  ip frr route-policy ip-frr-umg1
  vpn frr route-policy vpn-frr-pe7
  tnl-policy pe5
  vpn-target 15000:100 export-extcommunity
  vpn-target 15000:100 import-extcommunity
#
return
[PE5-GigabitEthernet0/0/2]disp ro
[PE5-GigabitEthernet0/0/2]disp route-po
[PE5-GigabitEthernet0/0/2]disp route-policy ip
[PE5-GigabitEthernet0/0/2]disp route-policy ip-frr-umg1
Route-policy : ip-frr-umg1
  permit : 10 (matched counts: 2)
    Match clauses :
      if-match ip next-hop ip-prefix UMG1
    Apply clauses :
      apply backup-nexthop 160.160.165.2
      apply backup-interface GigabitEthernet0/0/1.1
[PE5-GigabitEthernet0/0/2]
```

Ono što možemo videti iz ovog testiranja je da nijedan ICMP paket nije *dropped*, ni u trenutku otkaza ni u momentu kada se saobraćaj vratio na originalnu putanju nakon prestanka otkaza linka. Može se videti iz logova, kako je BFD detektovao pad linka i kako se vraća u *Up state*. I na kraju se vidi da je polisa za IP FRR ima povećani broj poklapanja, odnosno da se konvergencija saobraćaja zaista i desila.

U nastavku ćemo odraditi testiranje bez zaštite.

4.4.2. Test bez IP FRR zaštite

Test će biti rađen slično kao i prethodni, odnosno slaćemo ICMP pakete sa UMG2 ka UMG1 na adresu 11.11.11.11. i pratiti ponašanje, ovaj put bez IP FRR zaštite. Da bi se isključila IP FRR zaštita uklanjamo ip frr polisu iz dela konfiguracije za vpn instancu.

```
[PE5]ip vpn-instance media
[PE5-vpn-instance-media]dis this
#
ip vpn-instance media
 ipv4-family
  route-distinguisher 15000:100
  ip frr route-policy ip-frr-umg1
  vpn frr route-policy vpn-frr-pe7
  tnl-policy pe5
  vpn-target 15000:100 export-extcommunity
  vpn-target 15000:100 import-extcommunity
#
return
[PE5-vpn-instance-media]undo ip frr
```

U testu ćemo prvo staviti interfejs *GigabitEthernet0/0/2* u *Downstate*, pa ga vratiti u *Up state*, i videti kako se to odražava na saobraćaj koji generišemo. U nastavku je pokazan *output* testa.

```
<UMG2>ping -a 22.22.22.22 -c 1000 11.11.11.11
  PING 11.11.11.11: 56  data bytes, press CTRL_C to break
    Reply from 11.11.11.11: bytes=56 Sequence=1 ttl=253 time=110 ms
    Reply from 11.11.11.11: bytes=56 Sequence=2 ttl=253 time=110 ms
    Reply from 11.11.11.11: bytes=56 Sequence=3 ttl=253 time=90 ms
    ...
    Reply from 11.11.11.11: bytes=56 Sequence=14 ttl=253 time=90 ms
    Reply from 11.11.11.11: bytes=56 Sequence=15 ttl=253 time=110 ms
    Reply from 11.11.11.11: bytes=56 Sequence=16 ttl=253 time=150 ms
    Request time out
    Reply from 11.11.11.11: bytes=56 Sequence=18 ttl=252 time=160 ms
    Reply from 11.11.11.11: bytes=56 Sequence=19 ttl=252 time=120 ms
    Reply from 11.11.11.11: bytes=56 Sequence=20 ttl=252 time=120 ms
    Reply from 11.11.11.11: bytes=56 Sequence=21 ttl=252 time=120 ms
    ...
    Reply from 11.11.11.11: bytes=56 Sequence=68 ttl=253 time=110 ms
    Reply from 11.11.11.11: bytes=56 Sequence=69 ttl=253 time=130 ms
    Reply from 11.11.11.11: bytes=56 Sequence=70 ttl=253 time=90 ms
    Reply from 11.11.11.11: bytes=56 Sequence=71 ttl=253 time=110 ms

  --- 11.11.11.11 ping statistics ---
    71 packet(s) transmitted
    70 packet(s) received
    1.40% packet loss
    round-trip min/avg/max = 60/108/340 ms

<UMG1>
Sep 23 2015 06:50:22-08:00 UMG1 %%01BFD/4/STACHG_TODWN(l)[0]:BFD session changed
to Down. (SlotNumber=0, Discriminator=66, Diagnostic=DetectDown,
Applications=Non
e, ProcessPST=False, BindInterfaceName=Ethernet0/0/0, InterfacePhysicalState=Up,
InterfaceProtocolState=Up)
Sep 23 2015 06:50:22-08:00 UMG1 %%01PHY/1/PHY(l)[1]:    Ethernet0/0/0: change
sta
tus to down
Sep 23 2015 06:50:22-08:00 UMG1 %%01IFNET/4/LINK_STATE(l)[2]:The line protocol
IP
 on the interface Ethernet0/0/0 has entered the DOWN state.
Sep 23 2015 06:50:22-08:00 UMG1 %%01RM/4/IPV4_DEFT_RT_CHG(l)[3]:IPV4 default
Rout
e is changed.
(ChangeType=Delete,InstanceId=0,Protocol=Static,ExitIf=Unknown,Next
hop=10.1.1.1,Neighbour=0.0.0.0,Preference=20,Label=NULL,Metric=0)
Sep 23 2015 06:50:31-08:00 UMG1 %%01PHY/1/PHY(l)[4]:    Ethernet0/0/0: change
sta
tus to up
Sep 23 2015 06:50:31-08:00 UMG1 %%01IFNET/4/LINK_STATE(l)[5]:The line protocol
IP
 on the interface Ethernet0/0/0 has entered the UP state.
Sep 23 2015 06:50:32-08:00 UMG1 %%01RM/4/IPV4_DEFT_RT_CHG(l)[6]:IPV4 default
Rout
e is changed.
(ChangeType=Delete,InstanceId=0,Protocol=Static,ExitIf=Ethernet0/0/
1,Nexthop=10.1.2.1,Neighbour=0.0.0.0,Preference=30,Label=NULL,Metric=0)
Sep 23 2015 06:50:33-08:00 UMG1 %%01BFD/4/STACHG_TOUP(l)[7]:BFD session changed
t
```

```
o Up. (SlotNumber=0, Discriminator=66, FormerStatus=Init, Applications=None,
Bind
InterfaceName=Ethernet0/0/0, ProcessPST=False)
<UMG1>

[PE5-GigabitEthernet0/0/2]shut
[PE5-GigabitEthernet0/0/2]
Sep 23 2015 06:50:24-08:00 PE5 %%01PHY/1/PHY(l)[0]:    GigabitEthernet0/0/2:
chan
ge status to down
Sep 23 2015 06:50:24-08:00 PE5 %%01IFNET/4/LINK_STATE(l)[1]:The line protocol IP
on the interface GigabitEthernet0/0/2 has entered the DOWN state.
Sep 23 2015 06:50:24-08:00 PE5 %%01BFD/4/STACHG_TODWN(l)[2]:BFD session changed
t
o Down. (SlotNumber=0, Discriminator=55, Diagnostic=DetectDown,
Applications=None
, ProcessPST=False, BindInterfaceName=GigabitEthernet0/0/2,
InterfacePhysicalStat
e=Down, InterfaceProtocolState=Down)
[PE5-GigabitEthernet0/0/2]
Sep 23 2015 06:50:29-08:00 PE5 DS/4/DATASYNC_CFGCHANGE:OID
1.3.6.1.4.1.2011.5.25.
191.3.1 configurations have been changed. The current change number is 4, the
cha
nge loop count is 0, and the maximum number of records is 4095.
[PE5-GigabitEthernet0/0/2]
[PE5-GigabitEthernet0/0/2]undo shut
[PE5-GigabitEthernet0/0/2]
Sep 23 2015 06:50:33-08:00 PE5 %%01PHY/1/PHY(l)[3]:    GigabitEthernet0/0/2:
chan
ge status to up
Sep 23 2015 06:50:33-08:00 PE5 %%01IFNET/4/LINK_STATE(l)[4]:The line protocol IP
on the interface GigabitEthernet0/0/2 has entered the UP state.
[PE5-GigabitEthernet0/0/2]
[PE5-GigabitEthernet0/0/2]
[PE5-GigabitEthernet0/0/2]
Sep 23 2015 06:50:35-08:00 PE5 %%01BFD/4/STACHG_TOUP(l)[5]:BFD session changed
to
 Up. (SlotNumber=0, Discriminator=55, FormerStatus=Down, Applications=None,
BindI
nterfaceName=GigabitEthernet0/0/2, ProcessPST=False)
[PE5-GigabitEthernet0/0/2]
[PE5-GigabitEthernet0/0/2]
Sep 23 2015 06:50:39-08:00 PE5 DS/4/DATASYNC_CFGCHANGE:OID
1.3.6.1.4.1.2011.5.25.
191.3.1 configurations have been changed. The current change number is 5, the
cha
nge loop count is 0, and the maximum number of records is 4095.
[PE5-GigabitEthernet0/0/2]
[PE5-GigabitEthernet0/0/2]q
[PE5]dis
[PE5]display ro
[PE5]display route
[PE5]display route-policy ip
[PE5]display route-policy ip-frr-umg1
Route-policy : ip-frr-umg1
  permit : 10 (matched counts: 2)
    Match clauses :
      if-match ip next-hop ip-prefix UMG1
```

```
    Apply clauses :
      apply backup-nexthop 160.160.165.2
      apply backup-interface GigabitEthernet0/0/1.1
```

Može se videti da se u trenutku otkaza desio jedan *request timeout*, i posle smo imali kontinualni ping. Prikazana je i polisa, i vidi se da i dalje imamo isti broj poklapanja kao i pre testiranja (i dalje dva), odnosno da IP FRR nije korišćen. Vidi se da je konvergencija nešto sporija kada se ne primenjuje IP FRR tehnologija, što dovodi do kratkog prekida na linku.

4.5. Testiranje E-VRRP tehnologije

Ono što ćemo ovde testirati je primena E-VRRP tehnologije, odnosno VRRP u kombinaciji sa BFD-om zarad brže konvergencije. Hoćemo da ispitamo da li i koliko poboljšanje daje ova tehnologija. Testiranje ćemo vršiti tako što ćemo slati kontinualni ping od CLIENT1 prema UMG2 na adresu 22.22.22.22. Zatim ćemo obarati interfejs *GigabitEthernet0/0/2* na PE9 ruteru i posmatrati konvergenciju, pa ga zatim vratiti u operativno stanje i opet posmatrati konvergenciju.

4.5.1. Test sa E-VRRP

U ovoj varijanti kao što je prethodno opisano šaljemo ping sa CLIENT1 i pratimo ponašanje mreže pri simuliranom otkazu i zatim ponovnim vraćanjem u operativno stanje interfejsa *GigabitEthernet 0/0/2* na PE9 ruteru. Naglasićemo da je u početnoj postavci PE9 *Master*, a PE10 *Backup* VRRP ruter. *Output* testiranja se može videti u nastavku.

```
[CLIENT1]ping -c 1000 22.22.22.22
  PING 22.22.22.22: 56  data bytes, press CTRL_C to break
    Reply from 22.22.22.22: bytes=56 Sequence=1 ttl=252 time=170 ms
    Reply from 22.22.22.22: bytes=56 Sequence=2 ttl=252 time=130 ms
    Reply from 22.22.22.22: bytes=56 Sequence=3 ttl=252 time=180 ms
    Reply from 22.22.22.22: bytes=56 Sequence=4 ttl=252 time=140 ms
    ...
    Reply from 22.22.22.22: bytes=56 Sequence=319 ttl=252 time=180 ms
    Reply from 22.22.22.22: bytes=56 Sequence=320 ttl=252 time=170 ms
    Reply from 22.22.22.22: bytes=56 Sequence=321 ttl=252 time=120 ms
  --- 22.22.22.22 ping statistics ---
    323 packet(s) transmitted
    323 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 70/138/310 ms

<PE10>dis vrrp
  GigabitEthernet0/0/2 | Virtual Router 1
    State : Master
    Virtual IP : 10.0.0.10
    Master IP : 2.0.0.10
    PriorityRun : 130
    PriorityConfig : 100
    MasterPriority : 130
    Preempt : YES   Delay Time : 3 s
    TimerRun : 1 s
    TimerConfig : 1 s
    Auth type : NONE
    Virtual MAC : 0000-5e00-0101
    Check TTL : YES
```

```
    Config type : normal-vrrp
    Backup-forward : disabled
    Track BFD : 1  Priority increased : 30
    BFD-session state : DOWN
    Create time : 2015-09-23 23:02:39 UTC-05:13
    Last change time : 2015-09-23 23:34:45 UTC-05:13

<PE10>
<PE10>
<PE10>
<PE10>
<PE10>disp vrrp
  GigabitEthernet0/0/2 | Virtual Router 1
    State : Master
    Virtual IP : 10.0.0.10
    Master IP : 2.0.0.10
    PriorityRun : 130
    PriorityConfig : 100
    MasterPriority : 130
    Preempt : YES   Delay Time : 3 s
    TimerRun : 1 s
    TimerConfig : 1 s
    Auth type : NONE
    Virtual MAC : 0000-5e00-0101
    Check TTL : YES
    Config type : normal-vrrp
    Backup-forward : disabled
    Track BFD : 1  Priority increased : 30
    BFD-session state : DOWN
    Create time : 2015-09-23 23:02:39 UTC-05:13
    Last change time : 2015-09-23 23:34:45 UTC-05:13

<PE10>disp b
Sep 23 2015 23:36:22-05:13 PE10 %%01BFD/4/STACHG_TOUP(l)[0]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=16777216, FormerStatus=Init,
Applications=VRRP
, BindInterfaceName=GigabitEthernet0/0/2, ProcessPST=False)
<PE10>disp bfd sess all
--------------------------------------------------------------------------------
Local Remote     PeerIpAddr      State     Type        InterfaceName
--------------------------------------------------------------------------------
1     2          10.0.0.1        Up        S_IP_IF     GigabitEthernet0/0/2
--------------------------------------------------------------------------------
     Total UP/DOWN Session Number : 1/0
<PE10>disp vrrp
Sep 23 2015 23:36:26-05:13 PE10 VRRP/2/VRRPMASTERDOWN:OID
16777216.50331648.10066
3296.16777216.67108864.16777216.3674669056.83886080.419430400.2130706432.3355443
2
.503316480.16777216 The state of VRRP changed from master to other state.
(VrrpIf
Index=83886080, VrId=16777216, IfIndex=83886080, IPAddress=10.161.160.160,
NodeNa
me=PE10, IfName=GigabitEthernet0/0/2, CurrentState=Backup, ChangeReason=priority
calculation)
<PE10>disp vrrp
Sep 23 2015 23:36:26-05:13 PE10 %%01VRRP/4/STATEWARNINGEXTEND(l)[1]:Virtual
Route
```

```
r state MASTER changed to BACKUP, because of priority calculation.
(Interface=Gig
abitEthernet0/0/2, VrId=16777216, InetType=IPv4)
<PE10>disp vrrp
  GigabitEthernet0/0/2 | Virtual Router 1
    State : Backup
    Virtual IP : 10.0.0.10
    Master IP : 10.0.0.1
    PriorityRun : 100
    PriorityConfig : 100
    MasterPriority : 120
    Preempt : YES   Delay Time : 3 s
    TimerRun : 1 s
    TimerConfig : 1 s
    Auth type : NONE
    Virtual MAC : 0000-5e00-0101
    Check TTL : YES
    Config type : normal-vrrp
    Backup-forward : disabled
    Track BFD : 1  Priority increased : 30
    BFD-session state : UP
    Create time : 2015-09-23 23:02:39 UTC-05:13
    Last change time : 2015-09-23 23:36:26 UTC-05:13

[PE9]inter gig 0/0/2
[PE9-GigabitEthernet0/0/2]shut
[PE9-GigabitEthernet0/0/2]
Sep 23 2015 23:34:46-05:13 PE9 %%01IFPDT/4/IF_STATE(l)[0]:Interface
GigabitEthern
et0/0/2 has turned into DOWN state.
[PE9-GigabitEthernet0/0/2]
Sep 23 2015 23:34:46-05:13 PE9 %%01BFD/4/STACHG_TODWN(l)[1]:BFD session changed
t
o Down. (SlotNumber=0, Discriminator=33554432, Diagnostic=DetectDown,
Application
s=VRRP, ProcessPST=False, BindInterfaceName=GigabitEthernet0/0/2,
InterfacePhysic
alState=Up, InterfaceProtocolState=Up)
[PE9-GigabitEthernet0/0/2]
Sep 23 2015 23:34:46-05:13 PE9 %%01IFNET/4/LINK_STATE(l)[2]:The line protocol IP
on the interface GigabitEthernet0/0/2 has entered the DOWN state.
[PE9-GigabitEthernet0/0/2]
Sep 23 2015 23:34:46-05:13 PE9 %%01VRRP/4/STATEWARNINGEXTEND(l)[3]:Virtual
Router
 state MASTER changed to INITIALIZE, because of interface down.
(Interface=Gigabi
tEthernet0/0/2, VrId=16777216, InetType=IPv4)
[PE9-GigabitEthernet0/0/2]
Sep 23 2015 23:34:46-05:13 PE9 VRRP/2/VRRPMASTERDOWN:OID
16777216.50331648.100663
296.16777216.67108864.16777216.3674669056.83886080.419430400.2130706432.33554432
.
503316480.16777216 The state of VRRP changed from master to other state.
(VrrpIfI
ndex=83886080, VrId=16777216, IfIndex=83886080, IPAddress=9.161.160.160,
NodeName
=PE9, IfName=GigabitEthernet0/0/2, CurrentState=Initialize,
ChangeReason=interfac
e down)
```

```
[PE9-GigabitEthernet0/0/2]disp vrrp
  GigabitEthernet0/0/2 | Virtual Router 1
    State : Initialize
    Virtual IP : 10.0.0.10
    Master IP : 0.0.0.0
    PriorityRun : 110
    PriorityConfig : 120
    MasterPriority : 0
    Preempt : YES   Delay Time : 3 s
    TimerRun : 1 s
    TimerConfig : 1 s
    Auth type : NONE
    Virtual MAC : 0000-5e00-0101
    Check TTL : YES
    Config type : normal-vrrp
    Backup-forward : disabled
    Track BFD : 11  Priority reduced : 30
    BFD-session state : UP
    Track BFD : 2  Priority reduced : 10
    BFD-session state : DOWN
    Create time : 2015-09-23 23:04:43 UTC-05:13
    Last change time : 2015-09-23 23:34:46 UTC-05:13

[PE9-GigabitEthernet0/0/2]undo shut
[PE9-GigabitEthernet0/0/2]
Sep 23 2015 23:35:47-05:13 PE9 %%01IFPDT/4/IF_STATE(l)[4]:Interface
GigabitEthern
et0/0/2 has turned into UP state.
[PE9-GigabitEthernet0/0/2]
Sep 23 2015 23:35:47-05:13 PE9 %%01IFNET/4/LINK_STATE(l)[5]:The line protocol IP
on the interface GigabitEthernet0/0/2 has entered the UP state.
[PE9-GigabitEthernet0/0/2]
Sep 23 2015 23:35:51-05:13 PE9 VRRP/2/VRRPCHANGETOMASTER:OID
16777216.50331648.10
0663296.16777216.33554432.16777216.1140850688.0.16777216 The status of VRRP
chang
ed to master. (VrrpIfIndex=83886080, VrId=16777216, IfIndex=83886080,
IPAddress=9
.161.160.160, NodeName=PE9, IfName=GigabitEthernet0/0/2, ChangeReason=protocol
ti
mer expired(GigabitEthernet0/0/2 up))
[PE9-GigabitEthernet0/0/2]
Sep 23 2015 23:35:51-05:13 PE9 %%01VRRP/4/STATEWARNINGEXTEND(l)[6]:Virtual
Router
 state BACKUP changed to MASTER, because of protocol timer expired.
(Interface=Gi
gabitEthernet0/0/2, VrId=16777216, InetType=IPv4)
[PE9-GigabitEthernet0/0/2]disp vrrp
  GigabitEthernet0/0/2 | Virtual Router 1
    State : Master
    Virtual IP : 10.0.0.10
    Master IP : 1.0.0.10
    PriorityRun : 110
    PriorityConfig : 120
    MasterPriority : 110
    Preempt : YES   Delay Time : 3 s
    TimerRun : 1 s
    TimerConfig : 1 s
    Auth type : NONE
```

```
    Virtual MAC : 0000-5e00-0101
    Check TTL : YES
    Config type : normal-vrrp
    Backup-forward : disabled
    Track BFD : 11  Priority reduced : 30
    BFD-session state : UP
    Track BFD : 2  Priority reduced : 10
    BFD-session state : DOWN
    Create time : 2015-09-23 23:04:43 UTC-05:13
    Last change time : 2015-09-23 23:35:51 UTC-05:13

[PE9-GigabitEthernet0/0/2]
Sep 23 2015 23:36:21-05:13 PE9 VRRP/2/VRRPMASTERDOWN:OID
16777216.50331648.100663
296.16777216.67108864.16777216.3674669056.83886080.419430400.2130706432.33554432
.
503316480.16777216 The state of VRRP changed from master to other state.
(VrrpIfI
ndex=83886080, VrId=16777216, IfIndex=83886080, IPAddress=9.161.160.160,
NodeName
=PE9, IfName=GigabitEthernet0/0/2, CurrentState=Backup, ChangeReason=priority
cal
culation)
[PE9-GigabitEthernet0/0/2]
Sep 23 2015 23:36:21-05:13 PE9 %%01VRRP/4/STATEWARNINGEXTEND(l)[7]:Virtual
Router
 state MASTER changed to BACKUP, because of priority calculation.
(Interface=Giga
bitEthernet0/0/2, VrId=16777216, InetType=IPv4)
[PE9-GigabitEthernet0/0/2]
Sep 23 2015 23:36:24-05:13 PE9 %%01BFD/4/STACHG_TOUP(l)[8]:BFD session changed
to
 Up. (SlotNumber=0, Discriminator=33554432, FormerStatus=Down,
Applications=VRRP,
 BindInterfaceName=GigabitEthernet0/0/2, ProcessPST=False)
[PE9-GigabitEthernet0/0/2]
Sep 23 2015 23:36:27-05:13 PE9 VRRP/2/VRRPCHANGETOMASTER:OID
16777216.50331648.10
0663296.16777216.33554432.16777216.1140850688.0.16777216 The status of VRRP
chang
ed to master. (VrrpIfIndex=83886080, VrId=16777216, IfIndex=83886080,
IPAddress=9
.161.160.160, NodeName=PE9, IfName=GigabitEthernet0/0/2, ChangeReason=priority
ca
lculation)
[PE9-GigabitEthernet0/0/2]
Sep 23 2015 23:36:27-05:13 PE9 %%01VRRP/4/STATEWARNINGEXTEND(l)[9]:Virtual
Router
 state BACKUP changed to MASTER, because of priority calculation.
(Interface=Giga
bitEthernet0/0/2, VrId=16777216, InetType=IPv4)
```

Iz *output*-a testamože se jasno videti da nije bilo prekida usled konvergencije ni u jednom trenutku. U trenutku pada linka, PE10 je odmah preuzeo ulogu *Master*-a brzom detekcijom uz pomoć BFD sesije postavljene između PE9 i PE10. Zatim kada je vraćen interfejs u operativno stanje, oba su bila *Master* određeno vreme dok nije isteklo 30 sekundi, kada je i PE9 ponovo preuzeo ulogu *Mastera* dok je PE10 ponovo postao *Backup*, kao što je i konfigurisano.

4.5.2. Test bez E-VRRP

Sada ćemo ponoviti isto testiranje, samo što ćemo raditi test kada imamo klasičan VRRP konfigurisan. Da bi to postigli, uklonili smo VRRP konfiguraciju koja se odnosi na VRRP, odnosno:

```
[PE10-GigabitEthernet0/0/2]undo vrrp vrid 1 track bfd-session 1 increased 30
[PE9-GigabitEthernet0/0/2]undo vrrp vrid 1 track bfd-session 2
```

Nakon ovoga možemo da otpočnemo test, i *output* testa je dat u nastavku.

```
[CLIENT1]ping -c 1000 22.22.22.22
  PING 22.22.22.22: 56  data bytes, press CTRL_C to break
    Reply from 22.22.22.22: bytes=56 Sequence=1 ttl=252 time=150 ms
    Reply from 22.22.22.22: bytes=56 Sequence=2 ttl=252 time=140 ms
    ...
    Reply from 22.22.22.22: bytes=56 Sequence=29 ttl=252 time=160 ms
    Reply from 22.22.22.22: bytes=56 Sequence=30 ttl=252 time=210 ms
    Reply from 22.22.22.22: bytes=56 Sequence=31 ttl=252 time=130 ms
    Reply from 22.22.22.22: bytes=56 Sequence=32 ttl=252 time=150 ms
    Reply from 22.22.22.22: bytes=56 Sequence=33 ttl=252 time=160 ms
    Request time out
    Request time out
    Reply from 22.22.22.22: bytes=56 Sequence=36 ttl=252 time=140 ms
    Reply from 22.22.22.22: bytes=56 Sequence=37 ttl=252 time=120 ms
    Reply from 22.22.22.22: bytes=56 Sequence=38 ttl=252 time=110 ms
    Reply from 22.22.22.22: bytes=56 Sequence=39 ttl=252 time=130 ms
    ...
    Reply from 22.22.22.22: bytes=56 Sequence=230 ttl=252 time=140 ms
    Reply from 22.22.22.22: bytes=56 Sequence=231 ttl=252 time=140 ms
    Reply from 22.22.22.22: bytes=56 Sequence=232 ttl=252 time=120 ms
    Reply from 22.22.22.22: bytes=56 Sequence=233 ttl=252 time=140 ms
    Reply from 22.22.22.22: bytes=56 Sequence=234 ttl=252 time=120 ms
    Reply from 22.22.22.22: bytes=56 Sequence=235 ttl=252 time=90 ms
    Reply from 22.22.22.22: bytes=56 Sequence=236 ttl=252 time=90 ms

  --- 22.22.22.22 ping statistics ---
    236 packet(s) transmitted
    234 packet(s) received
    0.84% packet loss
    round-trip min/avg/max = 80/134/270 ms

[PE10]disp vrrp
  GigabitEthernet0/0/2 | Virtual Router 1
    State : Backup
    Virtual IP : 10.0.0.10
    Master IP : 10.0.0.1
    PriorityRun : 100
    PriorityConfig : 100
    MasterPriority : 120
    Preempt : YES   Delay Time : 3 s
    TimerRun : 1 s
    TimerConfig : 1 s
    Auth type : NONE
    Virtual MAC : 0000-5e00-0101
    Check TTL : YES
    Config type : normal-vrrp
    Backup-forward : disabled
```

```
    Create time : 2015-09-23 23:02:39 UTC-05:13
    Last change time : 2015-09-23 23:36:26 UTC-05:13

[PE10]
Sep 23 2015 23:44:43-05:13 PE10 %%01BFD/4/STACHG_TODWN(l)[0]:BFD session changed
to Down. (SlotNumber=0, Discriminator=16777216, Diagnostic=DetectDown,
Applicatio
ns=None, ProcessPST=False, BindInterfaceName=GigabitEthernet0/0/2,
InterfacePhysi
calState=Up, InterfaceProtocolState=Up)
[PE10]
Sep 23 2015 23:44:46-05:13 PE10 VRRP/2/VRRPCHANGETOMASTER:OID
16777216.50331648.1
00663296.16777216.33554432.16777216.1140850688.0.16777216 The status of VRRP
chan
ged to master. (VrrpIfIndex=83886080, VrId=16777216, IfIndex=83886080,
IPAddress=
10.161.160.160, NodeName=PE10, IfName=GigabitEthernet0/0/2,
ChangeReason=protocol
 timer expired)
[PE10]
Sep 23 2015 23:44:46-05:13 PE10 %%01VRRP/4/STATEWARNINGEXTEND(l)[1]:Virtual
Route
r state BACKUP changed to MASTER, because of protocol timer expired.
(Interface=G
igabitEthernet0/0/2, VrId=16777216, InetType=IPv4)
[PE10]disp vrrp
  GigabitEthernet0/0/2 | Virtual Router 1
    State : Master
    Virtual IP : 10.0.0.10
    Master IP : 2.0.0.10
    PriorityRun : 100
    PriorityConfig : 100
    MasterPriority : 100
    Preempt : YES   Delay Time : 3 s
    TimerRun : 1 s
    TimerConfig : 1 s
    Auth type : NONE
    Virtual MAC : 0000-5e00-0101
    Check TTL : YES
    Config type : normal-vrrp
    Backup-forward : disabled
    Create time : 2015-09-23 23:02:39 UTC-05:13
    Last change time : 2015-09-23 23:44:46 UTC-05:13

[PE10]disp vrrp
  GigabitEthernet0/0/2 | Virtual Router 1
    State : Master
    Virtual IP : 10.0.0.10
    Master IP : 2.0.0.10
    PriorityRun : 100
    PriorityConfig : 100
    MasterPriority : 100
    Preempt : YES   Delay Time : 3 s
    TimerRun : 1 s
    TimerConfig : 1 s
    Auth type : NONE
    Virtual MAC : 0000-5e00-0101
    Check TTL : YES
```

```
    Config type : normal-vrrp
    Backup-forward : disabled
    Create time : 2015-09-23 23:02:39 UTC-05:13
    Last change time : 2015-09-23 23:44:46 UTC-05:13

[PE10]
Sep 23 2015 23:46:03-05:13 PE10 VRRP/2/VRRPMASTERDOWN:OID
16777216.50331648.10066
3296.16777216.67108864.16777216.3674669056.83886080.419430400.2130706432.3355443
2
.503316480.16777216 The state of VRRP changed from master to other state.
(VrrpIf
Index=83886080, VrId=16777216, IfIndex=83886080, IPAddress=10.161.160.160,
NodeNa
me=PE10, IfName=GigabitEthernet0/0/2, CurrentState=Backup, ChangeReason=priority
calculation)
[PE10]
Sep 23 2015 23:46:03-05:13 PE10 %%01VRRP/4/STATEWARNINGEXTEND(l)[2]:Virtual
Route
r state MASTER changed to BACKUP, because of priority calculation.
(Interface=Gig
abitEthernet0/0/2, VrId=16777216, InetType=IPv4)
[PE10]
Sep 23 2015 23:46:12-05:13 PE10 %%01BFD/4/STACHG_TOUP(l)[3]:BFD session changed
t
o Up. (SlotNumber=0, Discriminator=16777216, FormerStatus=Init,
Applications=None
, BindInterfaceName=GigabitEthernet0/0/2, ProcessPST=False)
[PE10]disp vrrp
  GigabitEthernet0/0/2 | Virtual Router 1
    State : Backup
    Virtual IP : 10.0.0.10
    Master IP : 10.0.0.1
    PriorityRun : 100
    PriorityConfig : 100
    MasterPriority : 120
    Preempt : YES   Delay Time : 3 s
    TimerRun : 1 s
    TimerConfig : 1 s
    Auth type : NONE
    Virtual MAC : 0000-5e00-0101
    Check TTL : YES
    Config type : normal-vrrp
    Backup-forward : disabled
    Create time : 2015-09-23 23:02:39 UTC-05:13
    Last change time : 2015-09-23 23:46:03 UTC-05:13

[PE9-GigabitEthernet0/0/2]disp vrrp
  GigabitEthernet0/0/2 | Virtual Router 1
    State : Master
    Virtual IP : 10.0.0.10
    Master IP : 1.0.0.10
    PriorityRun : 120
    PriorityConfig : 120
    MasterPriority : 120
    Preempt : YES   Delay Time : 3 s
    TimerRun : 1 s
    TimerConfig : 1 s
    Auth type : NONE
```

```
    Virtual MAC : 0000-5e00-0101
    Check TTL : YES
    Config type : normal-vrrp
    Backup-forward : disabled
    Track BFD : 11  Priority reduced : 30
    BFD-session state : UP
    Create time : 2015-09-23 23:04:43 UTC-05:13
    Last change time : 2015-09-23 23:36:27 UTC-05:13

[PE9-GigabitEthernet0/0/2]shut
[PE9-GigabitEthernet0/0/2]
Sep 23 2015 23:44:44-05:13 PE9 %%01IFPDT/4/IF_STATE(l)[0]:Interface
GigabitEthern
et0/0/2 has turned into DOWN state.
[PE9-GigabitEthernet0/0/2]
Sep 23 2015 23:44:44-05:13 PE9 %%01BFD/4/STACHG_TODWN(l)[1]:BFD session changed
t
o Down. (SlotNumber=0, Discriminator=33554432, Diagnostic=DetectDown,
Application
s=None, ProcessPST=False, BindInterfaceName=GigabitEthernet0/0/2,
InterfacePhysic
alState=Up, InterfaceProtocolState=Up)
[PE9-GigabitEthernet0/0/2]
Sep 23 2015 23:44:44-05:13 PE9 %%01IFNET/4/LINK_STATE(l)[2]:The line protocol IP
on the interface GigabitEthernet0/0/2 has entered the DOWN state.
[PE9-GigabitEthernet0/0/2]
Sep 23 2015 23:44:44-05:13 PE9 %%01VRRP/4/STATEWARNINGEXTEND(l)[3]:Virtual
Router
 state MASTER changed to INITIALIZE, because of interface down.
(Interface=Gigabi
tEthernet0/0/2, VrId=16777216, InetType=IPv4)
[PE9-GigabitEthernet0/0/2]
Sep 23 2015 23:44:44-05:13 PE9 VRRP/2/VRRPMASTERDOWN:OID
16777216.50331648.100663
296.16777216.67108864.16777216.3674669056.83886080.419430400.2130706432.33554432
.
503316480.16777216 The state of VRRP changed from master to other state.
(VrrpIfI
ndex=83886080, VrId=16777216, IfIndex=83886080, IPAddress=9.161.160.160,
NodeName
=PE9, IfName=GigabitEthernet0/0/2, CurrentState=Initialize,
ChangeReason=interfac
e down)
[PE9-GigabitEthernet0/0/2]disp vrrp
  GigabitEthernet0/0/2 | Virtual Router 1
    State : Initialize
    Virtual IP : 10.0.0.10
    Master IP : 0.0.0.0
    PriorityRun : 120
    PriorityConfig : 120
    MasterPriority : 0
    Preempt : YES   Delay Time : 3 s
    TimerRun : 1 s
    TimerConfig : 1 s
    Auth type : NONE
    Virtual MAC : 0000-5e00-0101
    Check TTL : YES
    Config type : normal-vrrp
    Backup-forward : disabled
```

```
    Track BFD : 11  Priority reduced : 30
    BFD-session state : UP
    Create time : 2015-09-23 23:04:43 UTC-05:13
    Last change time : 2015-09-23 23:44:44 UTC-05:13

[PE9-GigabitEthernet0/0/2]undo shut
[PE9-GigabitEthernet0/0/2]
Sep 23 2015 23:45:33-05:13 PE9 %%01IFPDT/4/IF_STATE(l)[4]:Interface
GigabitEthern
et0/0/2 has turned into UP state.
[PE9-GigabitEthernet0/0/2]
Sep 23 2015 23:45:33-05:13 PE9 %%01IFNET/4/LINK_STATE(l)[5]:The line protocol IP
on the interface GigabitEthernet0/0/2 has entered the UP state.
[PE9-GigabitEthernet0/0/2]
Sep 23 2015 23:45:36-05:13 PE9 VRRP/2/VRRPCHANGETOMASTER:OID
16777216.50331648.10
0663296.16777216.33554432.16777216.1140850688.0.16777216 The status of VRRP
chang
ed to master. (VrrpIfIndex=83886080, VrId=16777216, IfIndex=83886080,
IPAddress=9
.161.160.160, NodeName=PE9, IfName=GigabitEthernet0/0/2, ChangeReason=protocol
ti
mer expired(GigabitEthernet0/0/2 up))
[PE9-GigabitEthernet0/0/2]
Sep 23 2015 23:45:36-05:13 PE9 %%01VRRP/4/STATEWARNINGEXTEND(l)[6]:Virtual
Router
 state BACKUP changed to MASTER, because of protocol timer expired.
(Interface=Gi
gabitEthernet0/0/2, VrId=16777216, InetType=IPv4)
[PE9-GigabitEthernet0/0/2]disp vrrp
  GigabitEthernet0/0/2 | Virtual Router 1
    State : Master
    Virtual IP : 10.0.0.10
    Master IP : 1.0.0.10
    PriorityRun : 120
    PriorityConfig : 120
    MasterPriority : 120
    Preempt : YES   Delay Time : 3 s
    TimerRun : 1 s
    TimerConfig : 1 s
    Auth type : NONE
    Virtual MAC : 0000-5e00-0101
    Check TTL : YES
    Config type : normal-vrrp
    Backup-forward : disabled
    Track BFD : 11  Priority reduced : 30
    BFD-session state : UP
    Create time : 2015-09-23 23:04:43 UTC-05:13
    Last change time : 2015-09-23 23:45:36 UTC-05:13

[PE9-GigabitEthernet0/0/2]
Sep 23 2015 23:46:13-05:13 PE9 %%01BFD/4/STACHG_TOUP(l)[7]:BFD session changed
to
 Up. (SlotNumber=0, Discriminator=33554432, FormerStatus=Down,
Applications=None,
 BindInterfaceName=GigabitEthernet0/0/2, ProcessPST=False)
[PE9-GigabitEthernet0/0/2]disp vrrp
  GigabitEthernet0/0/2 | Virtual Router 1
    State : Master
```

```
    Virtual IP : 10.0.0.10
    Master IP : 1.0.0.10
    PriorityRun : 120
    PriorityConfig : 120
    MasterPriority : 120
    Preempt : YES   Delay Time : 3 s
    TimerRun : 1 s
    TimerConfig : 1 s
    Auth type : NONE
    Virtual MAC : 0000-5e00-0101
    Check TTL : YES
    Config type : normal-vrrp
    Backup-forward : disabled
    Track BFD : 11  Priority reduced : 30
    BFD-session state : UP
    Create time : 2015-09-23 23:04:43 UTC-05:13
    Last change time : 2015-09-23 23:45:36 UTC-05:13
```

Način na koji se odvijala promena je slična prethodnom slučaju. Odnosno PE9 je preuzeo ulogu *Master*-a, nakon otkaza interfejsa, a nakon što smo vratili interfejs u operativno stanje bilo je potrebno 30 sekundi da PE10 ponovo preuzme ulogu *Master*-a. Razlika je u ovoj varijanti da je bilo potrebno duže vreme da se detektuje otkaz, i da se odigra konvergencija što je rezultiralo sa dva *request timeout*-a. Na osnovu ova dva testa se vidi benefit korišćenja E-VRRP tehnologije.

4.6. Testiranje OSPF sa BFD konvergencije

Ovde hoćemo da vidimo da li i koliko ubrzanje u konvergenciji imamo sa BFD tehnologijom primenjenom na OSPF process. Test ćemo raditi za OSPF sesiju između P2 i P10. Slaćemo ping sa P2 ka P10 i posmatrati šta se desi kada link između P2 i P10 rutera otkaže.

4.6.1. Test sa uključenim BFD-om za OSPF

Slaćemo kontinuirani ping sa P2 na 160.160.160.10 (*loopback* adresa P10). Na P10 ruteru pravimo prekid na interfejsu *GigabitEthernet 0/0/0*, i zatim ga vraćamo u operativno stanje. Za to vreme posmsatramo šta se dešava sa saobraćajem i kako konvergira mreža. *Output* testiranja je dat u nastavku.

```
<P2>ping -c 200 160.160.160.10
  PING 160.160.160.10: 56  data bytes, press CTRL_C to break
    Reply from 160.160.160.10: bytes=56 Sequence=1 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=2 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=3 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=4 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=5 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=6 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=7 ttl=255 time=10 ms
    Reply from 160.160.160.10: bytes=56 Sequence=8 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=9 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=10 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=11 ttl=255 time=1 ms
    Reply from 160.160.160.10: bytes=56 Sequence=12 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=13 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=14 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=15 ttl=255 time=50 ms
```

```
    Reply from 160.160.160.10: bytes=56 Sequence=16 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=17 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=18 ttl=255 time=140 ms
    Reply from 160.160.160.10: bytes=56 Sequence=19 ttl=255 time=60 ms
    Reply from 160.160.160.10: bytes=56 Sequence=20 ttl=255 time=240 ms
    Reply from 160.160.160.10: bytes=56 Sequence=21 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=22 ttl=255 time=150 ms
    Reply from 160.160.160.10: bytes=56 Sequence=23 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=24 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=25 ttl=255 time=20 ms
    Reply from 160.160.160.10: bytes=56 Sequence=26 ttl=255 time=40 ms
Sep 23 2015 21:59:59-08:00 P2 %%01BFD/4/STACHG_TODWN(l)[11]:BFD session changed
t
o Down. (SlotNumber=0, Discriminator=8202, Diagnostic=DetectDown,
Applications=OS
PF, ProcessPST=False, BindInterfaceName=GigabitEthernet0/0/1,
InterfacePhysicalSt
ate=Up, InterfaceProtocolState=Up)
Sep 23 2015 21:59:59-08:00 P2 %%01OSPF/3/NBR_CHG_DOWN(l)[12]:Neighbor
event:neigh
bor state changed to Down. (ProcessId=1, NeighborAddress=160.160.161.10,
Neighbor
Event=KillNbr, NeighborPreviousState=Full, NeighborCurrentState=Down)
Sep 23 2015 21:59:59-08:00 P2 %%01OSPF/3/NBR_DOWN_REASON(l)[13]:Neighbor state
le
aves full or changed to Down. (ProcessId=1, NeighborRouterId=160.160.161.10,
Neig
hborAreaId=0, NeighborInterface=GigabitEthernet0/0/1,NeighborDownImmediate
reason
=Neighbor Down Due to Kill Neighbor, NeighborDownPrimeReason=BFD Session Down,
Ne
ighborChangeTime=2015-09-23 21:59:59-08:00)
    Reply from 160.160.160.10: bytes=56 Sequence=27 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=28 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=29 ttl=255 time=30 ms
Sep 23 2015 22:00:00-08:00 P2 %%01PHY/1/PHY(l)[14]:    GigabitEthernet0/0/1:
chan
ge status to down
Sep 23 2015 22:00:00-08:00 P2 %%01IFNET/4/LINK_STATE(l)[15]:The line protocol IP
on the interface GigabitEthernet0/0/1 has entered the DOWN state.
    Reply from 160.160.160.10: bytes=56 Sequence=30 ttl=255 time=80 ms
    Reply from 160.160.160.10: bytes=56 Sequence=31 ttl=255 time=1 ms
    Reply from 160.160.160.10: bytes=56 Sequence=32 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=33 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=34 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=35 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=36 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=37 ttl=255 time=20 ms
    Reply from 160.160.160.10: bytes=56 Sequence=38 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=39 ttl=255 time=10 ms
    Reply from 160.160.160.10: bytes=56 Sequence=40 ttl=255 time=20 ms
    Reply from 160.160.160.10: bytes=56 Sequence=41 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=42 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=43 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=44 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=45 ttl=255 time=150 ms
    Reply from 160.160.160.10: bytes=56 Sequence=46 ttl=255 time=20 ms
Sep 23 2015 22:00:09-08:00 P2 %%01LDP/4/HOLDTMREXP(l)[16]:Sessions were deleted
b
```

```
ecause the hello hold timer expired. (PeerId=160.160.161.10)
    Reply from 160.160.160.10: bytes=56 Sequence=47 ttl=255 time=120 ms
    Reply from 160.160.160.10: bytes=56 Sequence=48 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=49 ttl=255 time=70 ms
    Reply from 160.160.160.10: bytes=56 Sequence=50 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=51 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=52 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=53 ttl=255 time=20 ms
    Reply from 160.160.160.10: bytes=56 Sequence=54 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=55 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=56 ttl=255 time=20 ms
    Reply from 160.160.160.10: bytes=56 Sequence=57 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=58 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=59 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=60 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=61 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=62 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=63 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=64 ttl=255 time=20 ms
    Reply from 160.160.160.10: bytes=56 Sequence=65 ttl=255 time=20 ms
    Reply from 160.160.160.10: bytes=56 Sequence=66 ttl=255 time=20 ms
    Reply from 160.160.160.10: bytes=56 Sequence=67 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=68 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=69 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=70 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=71 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=72 ttl=255 time=20 ms
    Reply from 160.160.160.10: bytes=56 Sequence=73 ttl=255 time=20 ms
    Reply from 160.160.160.10: bytes=56 Sequence=74 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=75 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=76 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=77 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=78 ttl=255 time=1 ms
    Reply from 160.160.160.10: bytes=56 Sequence=79 ttl=255 time=10 ms
    Reply from 160.160.160.10: bytes=56 Sequence=80 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=81 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=82 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=83 ttl=255 time=60 ms
    Reply from 160.160.160.10: bytes=56 Sequence=84 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=85 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=86 ttl=255 time=10 ms
    Reply from 160.160.160.10: bytes=56 Sequence=87 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=88 ttl=255 time=80 ms
    Reply from 160.160.160.10: bytes=56 Sequence=89 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=90 ttl=255 time=100 ms
    Reply from 160.160.160.10: bytes=56 Sequence=91 ttl=255 time=30 ms
Sep 23 2015 22:00:32-08:00 P2 %%01PHY/1/PHY(l)[17]:    GigabitEthernet0/0/1:
chan
ge status to up
Sep 23 2015 22:00:32-08:00 P2 %%01IFNET/4/LINK_STATE(l)[18]:The line protocol IP
on the interface GigabitEthernet0/0/1 has entered the UP state.
    Reply from 160.160.160.10: bytes=56 Sequence=92 ttl=255 time=70 ms
    Reply from 160.160.160.10: bytes=56 Sequence=93 ttl=255 time=40 ms
Sep 23 2015 22:00:33-08:00 P2 %%01OSPF/4/NBR_CHANGE_E(l)[19]:Neighbor changes
eve
nt: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.30,
Neighb
orEvent=HelloReceived, NeighborPreviousState=Down, NeighborCurrentState=Init)
    Reply from 160.160.160.10: bytes=56 Sequence=94 ttl=255 time=1 ms
```

```
    Reply from 160.160.160.10: bytes=56 Sequence=95 ttl=255 time=20 ms
    Reply from 160.160.160.10: bytes=56 Sequence=96 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=97 ttl=255 time=20 ms
    Reply from 160.160.160.10: bytes=56 Sequence=98 ttl=255 time=20 ms
    Reply from 160.160.160.10: bytes=56 Sequence=99 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=100 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=101 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=102 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=103 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=104 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=105 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=106 ttl=255 time=20 ms
    Reply from 160.160.160.10: bytes=56 Sequence=107 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=108 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=109 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=110 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=111 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=112 ttl=255 time=30 ms
Sep 23 2015 22:00:43-08:00 P2 %%01OSPF/4/NBR_CHANGE_E(l)[20]:Neighbor changes
eve
nt: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.30,
Neighb
orEvent=2WayReceived, NeighborPreviousState=Init, NeighborCurrentState=2Way)
    Reply from 160.160.160.10: bytes=56 Sequence=113 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=114 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=115 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=116 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=117 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=118 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=119 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=120 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=121 ttl=255 time=10 ms
    Reply from 160.160.160.10: bytes=56 Sequence=122 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=123 ttl=255 time=20 ms
    Reply from 160.160.160.10: bytes=56 Sequence=124 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=125 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=126 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=127 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=128 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=129 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=130 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=131 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=132 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=133 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=134 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=135 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=136 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=137 ttl=255 time=10 ms
    Reply from 160.160.160.10: bytes=56 Sequence=138 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=139 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=140 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=141 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=142 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=143 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=144 ttl=255 time=10 ms
    Reply from 160.160.160.10: bytes=56 Sequence=145 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=146 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=147 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=148 ttl=255 time=30 ms
```

```
    Reply from 160.160.160.10: bytes=56 Sequence=149 ttl=255 time=10 ms
    Reply from 160.160.160.10: bytes=56 Sequence=150 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=151 ttl=255 time=60 ms
    Reply from 160.160.160.10: bytes=56 Sequence=152 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=153 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=154 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=155 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=156 ttl=255 time=90 ms
    Reply from 160.160.160.10: bytes=56 Sequence=157 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=158 ttl=255 time=110 ms
    Reply from 160.160.160.10: bytes=56 Sequence=159 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=160 ttl=255 time=60 ms
    Reply from 160.160.160.10: bytes=56 Sequence=161 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=162 ttl=255 time=60 ms
    Reply from 160.160.160.10: bytes=56 Sequence=163 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=164 ttl=255 time=80 ms
    Reply from 160.160.160.10: bytes=56 Sequence=165 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=166 ttl=255 time=40 ms
Sep 23 2015 22:01:11-08:00 P2 %%01OSPF/4/NBR_CHANGE_E(l)[21]:Neighbor changes
eve
nt: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.30,
Neighb
orEvent=AdjOk?, NeighborPreviousState=2Way, NeighborCurrentState=ExStart)
    Reply from 160.160.160.10: bytes=56 Sequence=167 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=168 ttl=255 time=60 ms
    Reply from 160.160.160.10: bytes=56 Sequence=169 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=170 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=171 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=172 ttl=255 time=30 ms
Sep 23 2015 22:01:15-08:00 P2 %%01OSPF/4/NBR_CHANGE_E(l)[22]:Neighbor changes
eve
nt: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.30,
Neighb
orEvent=NegotiationDone, NeighborPreviousState=ExStart,
NeighborCurrentState=Exch
ange)
Sep 23 2015 22:01:15-08:00 P2 %%01OSPF/4/NBR_CHANGE_E(l)[23]:Neighbor changes
eve
nt: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.30,
Neighb
orEvent=ExchangeDone, NeighborPreviousState=Exchange,
NeighborCurrentState=Loadin
g)
Sep 23 2015 22:01:15-08:00 P2 %%01OSPF/4/NBR_CHANGE_E(l)[24]:Neighbor changes
eve
nt: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.30,
Neighb
orEvent=LoadingDone, NeighborPreviousState=Loading, NeighborCurrentState=Full)
    Reply from 160.160.160.10: bytes=56 Sequence=173 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=174 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=175 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=176 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=177 ttl=255 time=20 ms
    Reply from 160.160.160.10: bytes=56 Sequence=178 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=179 ttl=255 time=10 ms
Sep 23 2015 22:01:18-08:00 P2 %%01BFD/4/STACHG_TOUP(l)[25]:BFD session changed
to
 Up. (SlotNumber=0, Discriminator=8204, FormerStatus=Down, Applications=OSPF,
Bin
```

```
dInterfaceName=GigabitEthernet0/0/1, ProcessPST=False)
    Reply from 160.160.160.10: bytes=56 Sequence=180 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=181 ttl=255 time=60 ms
    Reply from 160.160.160.10: bytes=56 Sequence=182 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=183 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=184 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=185 ttl=255 time=10 ms
    Reply from 160.160.160.10: bytes=56 Sequence=186 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=187 ttl=255 time=60 ms
    Reply from 160.160.160.10: bytes=56 Sequence=188 ttl=255 time=20 ms
    Reply from 160.160.160.10: bytes=56 Sequence=189 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=190 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=191 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=192 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=193 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=194 ttl=255 time=10 ms
    Reply from 160.160.160.10: bytes=56 Sequence=195 ttl=255 time=50 ms
    Reply from 160.160.160.10: bytes=56 Sequence=196 ttl=255 time=40 ms
    Reply from 160.160.160.10: bytes=56 Sequence=197 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=198 ttl=255 time=30 ms
    Reply from 160.160.160.10: bytes=56 Sequence=199 ttl=255 time=80 ms
    Reply from 160.160.160.10: bytes=56 Sequence=200 ttl=255 time=30 ms

  --- 160.160.160.10 ping statistics ---
    200 packet(s) transmitted
    200 packet(s) received
    0.00% packet loss
    round-trip min/avg/max = 1/40/240 ms

[PE10-GigabitEthernet0/0/0]shut
[PE10-GigabitEthernet0/0/0]
Sep 24 2015 01:13:16-05:13 PE10 %%01IFPDT/4/IF_STATE(l)[0]:Interface
GigabitEther
net0/0/0 has turned into DOWN state.
[PE10-GigabitEthernet0/0/0]
Sep 24 2015 01:13:16-05:13 PE10 %%01BFD/4/STACHG_TODWN(l)[1]:BFD session changed
to Down. (SlotNumber=0, Discriminator=153092096, Diagnostic=DetectDown,
Applicati
ons=OSPF, ProcessPST=False, BindInterfaceName=GigabitEthernet0/0/0,
InterfacePhys
icalState=Up, InterfaceProtocolState=Up)
[PE10-GigabitEthernet0/0/0]
Sep 24 2015 01:13:16-05:13 PE10 %%01OSPF/3/NBR_CHG_DOWN(l)[2]:Neighbor
event:neig
hbor state changed to Down. (ProcessId=256, NeighborAddress=2.161.160.160,
Neighb
orEvent=KillNbr, NeighborPreviousState=Full, NeighborCurrentState=Down)
[PE10-GigabitEthernet0/0/0]
Sep 24 2015 01:13:16-05:13 PE10 %%01OSPF/3/NBR_DOWN_REASON(l)[3]:Neighbor state
l
eaves full or changed to Down. (ProcessId=256, NeighborRouterId=2.161.160.160,
Ne
ighborAreaId=0, NeighborInterface=GigabitEthernet0/0/0,NeighborDownImmediate
reas
on=Neighbor Down Due to Kill Neighbor, NeighborDownPrimeReason=BFD Session Down,
NeighborChangeTime=2015-09-24 01:13:16-05:13)
[PE10-GigabitEthernet0/0/0]
Sep 24 2015 01:13:16-05:13 PE10 %%01IFNET/4/LINK_STATE(l)[4]:The line protocol
IP
```

```
 on the interface GigabitEthernet0/0/0 has entered the DOWN state.
[PE10-GigabitEthernet0/0/0]
Sep 24 2015 01:13:28-05:13 PE10 %%01LDP/4/HOLDTMREXP(l)[5]:Sessions were deleted
because the hello hold timer expired. (PeerId=160.160.161.2)
[PE10-GigabitEthernet0/0/0]undo shut
[PE10-GigabitEthernet0/0/0]
[PE10-GigabitEthernet0/0/0]
[PE10-GigabitEthernet0/0/0]
Sep 24 2015 01:13:51-05:13 PE10 %%01IFPDT/4/IF_STATE(l)[6]:Interface
GigabitEther
net0/0/0 has turned into UP state.
[PE10-GigabitEthernet0/0/0]
Sep 24 2015 01:13:51-05:13 PE10 %%01IFNET/4/LINK_STATE(l)[7]:The line protocol
IP
 on the interface GigabitEthernet0/0/0 has entered the UP state.
[PE10-GigabitEthernet0/0/0]
[PE10-GigabitEthernet0/0/0]
[PE10-GigabitEthernet0/0/0]
Sep 24 2015 01:14:00-05:13 PE10 %%01OSPF/4/NBR_CHANGE_E(l)[8]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=256, NeighborAddress=29.160.160.160,
Nei
ghborEvent=HelloReceived, NeighborPreviousState=Down, NeighborCurrentState=Init)
[PE10-GigabitEthernet0/0/0]
Sep 24 2015 01:14:00-05:13 PE10 %%01OSPF/4/NBR_CHANGE_E(l)[9]:Neighbor changes
ev
ent: neighbor status changed. (ProcessId=256, NeighborAddress=29.160.160.160,
Nei
ghborEvent=2WayReceived, NeighborPreviousState=Init, NeighborCurrentState=2Way)
[PE10-GigabitEthernet0/0/0]
Sep 24 2015 01:14:32-05:13 PE10 %%01OSPF/4/NBR_CHANGE_E(l)[10]:Neighbor changes
e
vent: neighbor status changed. (ProcessId=256, NeighborAddress=29.160.160.160,
Ne
ighborEvent=AdjOk?, NeighborPreviousState=2Way, NeighborCurrentState=ExStart)
[PE10-GigabitEthernet0/0/0]
Sep 24 2015 01:14:32-05:13 PE10 %%01OSPF/4/NBR_CHANGE_E(l)[11]:Neighbor changes
e
vent: neighbor status changed. (ProcessId=256, NeighborAddress=29.160.160.160,
Ne
ighborEvent=NegotiationDone, NeighborPreviousState=ExStart,
NeighborCurrentState=
Exchange)
[PE10-GigabitEthernet0/0/0]
Sep 24 2015 01:14:32-05:13 PE10 %%01OSPF/4/NBR_CHANGE_E(l)[12]:Neighbor changes
e
vent: neighbor status changed. (ProcessId=256, NeighborAddress=29.160.160.160,
Ne
ighborEvent=ExchangeDone, NeighborPreviousState=Exchange,
NeighborCurrentState=Lo
ading)
[PE10-GigabitEthernet0/0/0]
Sep 24 2015 01:14:32-05:13 PE10 %%01OSPF/4/NBR_CHANGE_E(l)[13]:Neighbor changes
e
vent: neighbor status changed. (ProcessId=256, NeighborAddress=29.160.160.160,
Ne
ighborEvent=LoadingDone, NeighborPreviousState=Loading,
NeighborCurrentState=Full
)
```

```
[PE10-GigabitEthernet0/0/0]
```

Može se videti da gubitka paketa nije bilo, odnosno da je konvergencija obavljena veoma brzo. OSPF *peering* između dva rutera je raskinut i nakon vraćanja linka u operativno stanje ponovo uspostavljen.

4.6.2. Test bez BFD-a za OSPF

Da bi smo testirali ponašanje bez BFD-a potrebno je da uklonimo BFD za OSPF. Unete su sledeće komande sa tim ciljem

```
[PE10-ospf-1]undo bfd all-interfaces enable
[P2-ospf-1] undo bfd all-interfaces enable
```

Zatim isto kao i u prethodnom testu, šaljemo ping sa P2 prema 160.160.161.10, a pravimo prekid na interfejsu *GigabitEthernet0/0/0* P10 rutera, i pratimo ponašanje saobraćaja. Rezultati testiranja su prikazani u nastavku.

```
<P2>ping -c 100 160.160.161.10
  PING 160.160.161.10: 56  data bytes, press CTRL_C to break
    Reply from 160.160.161.10: bytes=56 Sequence=1 ttl=255 time=30 ms
    Reply from 160.160.161.10: bytes=56 Sequence=2 ttl=255 time=20 ms
    Reply from 160.160.161.10: bytes=56 Sequence=3 ttl=255 time=20 ms
    Reply from 160.160.161.10: bytes=56 Sequence=4 ttl=255 time=30 ms
    Reply from 160.160.161.10: bytes=56 Sequence=5 ttl=255 time=40 ms
    Reply from 160.160.161.10: bytes=56 Sequence=6 ttl=255 time=30 ms
    Reply from 160.160.161.10: bytes=56 Sequence=7 ttl=255 time=50 ms
    Reply from 160.160.161.10: bytes=56 Sequence=8 ttl=255 time=10 ms
    Reply from 160.160.161.10: bytes=56 Sequence=9 ttl=255 time=40 ms
    Reply from 160.160.161.10: bytes=56 Sequence=10 ttl=255 time=40 ms
    Reply from 160.160.161.10: bytes=56 Sequence=11 ttl=255 time=30 ms
    Reply from 160.160.161.10: bytes=56 Sequence=12 ttl=255 time=10 ms
    Reply from 160.160.161.10: bytes=56 Sequence=13 ttl=255 time=30 ms
    Reply from 160.160.161.10: bytes=56 Sequence=14 ttl=255 time=20 ms
    Reply from 160.160.161.10: bytes=56 Sequence=15 ttl=255 time=30 ms
    Reply from 160.160.161.10: bytes=56 Sequence=16 ttl=255 time=20 ms
    Reply from 160.160.161.10: bytes=56 Sequence=17 ttl=255 time=20 ms
    Reply from 160.160.161.10: bytes=56 Sequence=18 ttl=255 time=20 ms
    Reply from 160.160.161.10: bytes=56 Sequence=19 ttl=255 time=30 ms
    Reply from 160.160.161.10: bytes=56 Sequence=20 ttl=255 time=20 ms
    Reply from 160.160.161.10: bytes=56 Sequence=21 ttl=255 time=40 ms
    Reply from 160.160.161.10: bytes=56 Sequence=22 ttl=255 time=40 ms
    Reply from 160.160.161.10: bytes=56 Sequence=23 ttl=255 time=50 ms
    Reply from 160.160.161.10: bytes=56 Sequence=24 ttl=255 time=10 ms
    Reply from 160.160.161.10: bytes=56 Sequence=25 ttl=255 time=40 ms
    Reply from 160.160.161.10: bytes=56 Sequence=26 ttl=255 time=50 ms
    Reply from 160.160.161.10: bytes=56 Sequence=27 ttl=255 time=30 ms
Sep 23 2015 21:34:49-08:00 P2 %%01PHY/1/PHY(l)[2]:    GigabitEthernet0/0/1:
chang
e status to down
Sep 23 2015 21:34:49-08:00 P2 %%01IFNET/4/LINK_STATE(l)[3]:The line protocol IP
o
n the interface GigabitEthernet0/0/1 has entered the DOWN state.
Sep 23 2015 21:34:49-08:00 P2 %%01OSPF/3/NBR_CHG_DOWN(l)[4]:Neighbor
event:neighb
```

```
or state changed to Down. (ProcessId=1, NeighborAddress=160.160.161.10,
NeighborE
vent=KillNbr, NeighborPreviousState=Full, NeighborCurrentState=Down)
Sep 23 2015 21:34:49-08:00 P2 %%01OSPF/3/NBR_DOWN_REASON(l)[5]:Neighbor state
lea
ves full or changed to Down. (ProcessId=1, NeighborRouterId=160.160.161.10,
Neigh
borAreaId=0, NeighborInterface=GigabitEthernet0/0/1,NeighborDownImmediate
reason=
Neighbor Down Due to Kill Neighbor, NeighborDownPrimeReason=Physical Interface
St
ate Change, NeighborChangeTime=2015-09-23 21:34:49-08:00)
    Request time out
    Reply from 160.160.161.10: bytes=56 Sequence=29 ttl=253 time=60 ms
    Reply from 160.160.161.10: bytes=56 Sequence=30 ttl=253 time=60 ms
    Reply from 160.160.161.10: bytes=56 Sequence=31 ttl=253 time=80 ms
    Reply from 160.160.161.10: bytes=56 Sequence=32 ttl=253 time=60 ms
    Reply from 160.160.161.10: bytes=56 Sequence=33 ttl=253 time=80 ms
    Reply from 160.160.161.10: bytes=56 Sequence=34 ttl=253 time=90 ms
    Reply from 160.160.161.10: bytes=56 Sequence=35 ttl=253 time=100 ms
    Reply from 160.160.161.10: bytes=56 Sequence=36 ttl=253 time=100 ms
    Reply from 160.160.161.10: bytes=56 Sequence=37 ttl=253 time=70 ms
    Reply from 160.160.161.10: bytes=56 Sequence=38 ttl=253 time=60 ms
    Reply from 160.160.161.10: bytes=56 Sequence=39 ttl=253 time=40 ms
    Reply from 160.160.161.10: bytes=56 Sequence=40 ttl=253 time=80 ms
    Reply from 160.160.161.10: bytes=56 Sequence=41 ttl=253 time=60 ms
    Reply from 160.160.161.10: bytes=56 Sequence=42 ttl=253 time=160 ms
    Reply from 160.160.161.10: bytes=56 Sequence=43 ttl=253 time=60 ms
    Reply from 160.160.161.10: bytes=56 Sequence=44 ttl=253 time=80 ms
Sep 23 2015 21:34:58-08:00 P2 %%01PHY/1/PHY(l)[6]:    GigabitEthernet0/0/1:
chang
e status to up
Sep 23 2015 21:34:58-08:00 P2 %%01IFNET/4/LINK_STATE(l)[7]:The line protocol IP
o
n the interface GigabitEthernet0/0/1 has entered the UP state.
    Reply from 160.160.161.10: bytes=56 Sequence=45 ttl=253 time=30 ms
    Reply from 160.160.161.10: bytes=56 Sequence=46 ttl=253 time=120 ms
Sep 23 2015 21:35:00-08:00 P2 %%01OSPF/4/NBR_CHANGE_E(l)[8]:Neighbor changes
even
t: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.30,
Neighbo
rEvent=HelloReceived, NeighborPreviousState=Down, NeighborCurrentState=Init)
    Reply from 160.160.161.10: bytes=56 Sequence=47 ttl=253 time=60 ms
    Reply from 160.160.161.10: bytes=56 Sequence=48 ttl=253 time=160 ms
    Reply from 160.160.161.10: bytes=56 Sequence=49 ttl=253 time=110 ms
    Reply from 160.160.161.10: bytes=56 Sequence=50 ttl=253 time=80 ms
    Reply from 160.160.161.10: bytes=56 Sequence=51 ttl=253 time=100 ms
    Reply from 160.160.161.10: bytes=56 Sequence=52 ttl=253 time=60 ms
    Reply from 160.160.161.10: bytes=56 Sequence=53 ttl=253 time=80 ms
    Reply from 160.160.161.10: bytes=56 Sequence=54 ttl=253 time=80 ms
    Reply from 160.160.161.10: bytes=56 Sequence=55 ttl=253 time=70 ms
    Reply from 160.160.161.10: bytes=56 Sequence=56 ttl=253 time=50 ms
    Reply from 160.160.161.10: bytes=56 Sequence=57 ttl=253 time=80 ms
    Reply from 160.160.161.10: bytes=56 Sequence=58 ttl=253 time=80 ms
    Reply from 160.160.161.10: bytes=56 Sequence=59 ttl=253 time=80 ms
    Reply from 160.160.161.10: bytes=56 Sequence=60 ttl=253 time=50 ms
    Reply from 160.160.161.10: bytes=56 Sequence=61 ttl=253 time=90 ms
    Reply from 160.160.161.10: bytes=56 Sequence=62 ttl=253 time=80 ms
    Reply from 160.160.161.10: bytes=56 Sequence=63 ttl=253 time=70 ms
```

```
    Reply from 160.160.161.10: bytes=56 Sequence=64 ttl=253 time=80 ms
    Reply from 160.160.161.10: bytes=56 Sequence=65 ttl=253 time=100 ms
    Reply from 160.160.161.10: bytes=56 Sequence=66 ttl=253 time=50 ms
    Reply from 160.160.161.10: bytes=56 Sequence=67 ttl=253 time=50 ms
    Reply from 160.160.161.10: bytes=56 Sequence=68 ttl=253 time=80 ms
    Reply from 160.160.161.10: bytes=56 Sequence=69 ttl=253 time=90 ms
    Reply from 160.160.161.10: bytes=56 Sequence=70 ttl=253 time=80 ms
    Reply from 160.160.161.10: bytes=56 Sequence=71 ttl=253 time=60 ms
    Reply from 160.160.161.10: bytes=56 Sequence=72 ttl=253 time=60 ms
    Reply from 160.160.161.10: bytes=56 Sequence=73 ttl=253 time=70 ms
    Reply from 160.160.161.10: bytes=56 Sequence=74 ttl=253 time=60 ms
    Reply from 160.160.161.10: bytes=56 Sequence=75 ttl=253 time=100 ms
    Reply from 160.160.161.10: bytes=56 Sequence=76 ttl=253 time=70 ms
    Reply from 160.160.161.10: bytes=56 Sequence=77 ttl=253 time=80 ms
    Reply from 160.160.161.10: bytes=56 Sequence=78 ttl=253 time=70 ms
    Reply from 160.160.161.10: bytes=56 Sequence=79 ttl=253 time=310 ms
    Reply from 160.160.161.10: bytes=56 Sequence=80 ttl=253 time=60 ms
    Reply from 160.160.161.10: bytes=56 Sequence=81 ttl=253 time=50 ms
    Reply from 160.160.161.10: bytes=56 Sequence=82 ttl=253 time=90 ms
Sep 23 2015 21:35:19-08:00 P2 %%01OSPF/4/NBR_CHANGE_E(l)[9]:Neighbor changes
even
t: neighbor status changed. (ProcessId=1, NeighborAddress=160.160.160.30,
Neighbo
rEvent=2WayReceived, NeighborPreviousState=Init, NeighborCurrentState=2Way)
    Reply from 160.160.161.10: bytes=56 Sequence=83 ttl=253 time=80 ms
    Reply from 160.160.161.10: bytes=56 Sequence=84 ttl=253 time=60 ms
    Reply from 160.160.161.10: bytes=56 Sequence=85 ttl=253 time=70 ms
    Reply from 160.160.161.10: bytes=56 Sequence=86 ttl=253 time=60 ms
    Reply from 160.160.161.10: bytes=56 Sequence=87 ttl=253 time=110 ms
    Reply from 160.160.161.10: bytes=56 Sequence=88 ttl=253 time=60 ms
    Reply from 160.160.161.10: bytes=56 Sequence=89 ttl=253 time=120 ms
    Reply from 160.160.161.10: bytes=56 Sequence=90 ttl=253 time=40 ms
    Reply from 160.160.161.10: bytes=56 Sequence=91 ttl=253 time=80 ms
    Reply from 160.160.161.10: bytes=56 Sequence=92 ttl=253 time=50 ms
    Reply from 160.160.161.10: bytes=56 Sequence=93 ttl=253 time=60 ms
    Reply from 160.160.161.10: bytes=56 Sequence=94 ttl=253 time=60 ms
    Reply from 160.160.161.10: bytes=56 Sequence=95 ttl=253 time=50 ms
    Reply from 160.160.161.10: bytes=56 Sequence=96 ttl=253 time=60 ms
    Reply from 160.160.161.10: bytes=56 Sequence=97 ttl=253 time=60 ms
    Reply from 160.160.161.10: bytes=56 Sequence=98 ttl=253 time=60 ms
    Reply from 160.160.161.10: bytes=56 Sequence=99 ttl=253 time=60 ms
    Reply from 160.160.161.10: bytes=56 Sequence=100 ttl=253 time=60 ms

  --- 160.160.161.10 ping statistics ---
    100 packet(s) transmitted
    99 packet(s) received
    1.00% packet loss
    round-trip min/avg/max = 10/64/310 ms

[PE10-GigabitEthernet0/0/0]shut
[PE10-GigabitEthernet0/0/0]
Sep 24 2015 00:48:06-05:13 PE10 %%01IFPDT/4/IF_STATE(l)[7]:Interface
GigabitEther
net0/0/0 has turned into DOWN state.
[PE10-GigabitEthernet0/0/0]
Sep 24 2015 00:48:06-05:13 PE10 %%01IFNET/4/LINK_STATE(l)[8]:The line protocol
IP
 on the interface GigabitEthernet0/0/0 has entered the DOWN state.
[PE10-GigabitEthernet0/0/0]
```

```
Sep 24 2015 00:48:06-05:13 PE10 %%01OSPF/3/NBR_CHG_DOWN(l)[9]:Neighbor
event:neig
hbor state changed to Down. (ProcessId=256, NeighborAddress=2.161.160.160,
Neighb
orEvent=KillNbr, NeighborPreviousState=Full, NeighborCurrentState=Down)
[PE10-GigabitEthernet0/0/0]
Sep 24 2015 00:48:06-05:13 PE10 %%01OSPF/3/NBR_DOWN_REASON(l)[10]:Neighbor state
leaves full or changed to Down. (ProcessId=256, NeighborRouterId=2.161.160.160,
N
eighborAreaId=0, NeighborInterface=GigabitEthernet0/0/0,NeighborDownImmediate
rea
son=Neighbor Down Due to Kill Neighbor, NeighborDownPrimeReason=Physical
Interfac
e State Change, NeighborChangeTime=2015-09-24 00:48:06-05:13)
[PE10-GigabitEthernet0/0/0]
[PE10-GigabitEthernet0/0/0]
[PE10-GigabitEthernet0/0/0]undo shut
[PE10-GigabitEthernet0/0/0]
[PE10-GigabitEthernet0/0/0]
[PE10-GigabitEthernet0/0/0]
Sep 24 2015 00:48:17-05:13 PE10 %%01IFPDT/4/IF_STATE(l)[11]:Interface
GigabitEthe
rnet0/0/0 has turned into UP state.
[PE10-GigabitEthernet0/0/0]
Sep 24 2015 00:48:17-05:13 PE10 %%01IFNET/4/LINK_STATE(l)[12]:The line protocol
I
P on the interface GigabitEthernet0/0/0 has entered the UP state.
[PE10-GigabitEthernet0/0/0]
Sep 24 2015 00:48:19-05:13 PE10 %%01LDP/4/HOLDTMREXP(l)[13]:Sessions were
deleted
 because the hello hold timer expired. (PeerId=160.160.161.2)
[PE10-GigabitEthernet0/0/0]
Sep 24 2015 00:48:27-05:13 PE10 %%01OSPF/4/NBR_CHANGE_E(l)[14]:Neighbor changes
e
vent: neighbor status changed. (ProcessId=256, NeighborAddress=29.160.160.160,
Ne
ighborEvent=HelloReceived, NeighborPreviousState=Down,
NeighborCurrentState=Init)

[PE10-GigabitEthernet0/0/0]
Sep 24 2015 00:48:27-05:13 PE10 %%01OSPF/4/NBR_CHANGE_E(l)[15]:Neighbor changes
e
vent: neighbor status changed. (ProcessId=256, NeighborAddress=29.160.160.160,
Ne
ighborEvent=2WayReceived, NeighborPreviousState=Init, NeighborCurrentState=2Way)
[PE10-GigabitEthernet0/0/0]
[PE10-GigabitEthernet0/0/0]
[PE10-GigabitEthernet0/0/0]
[PE10-GigabitEthernet0/0/0]
[PE10-GigabitEthernet0/0/0]
[PE10-GigabitEthernet0/0/0]
Sep 24 2015 00:48:58-05:13 PE10 %%01OSPF/4/NBR_CHANGE_E(l)[16]:Neighbor changes
e
vent: neighbor status changed. (ProcessId=256, NeighborAddress=29.160.160.160,
Ne
ighborEvent=AdjOk?, NeighborPreviousState=2Way, NeighborCurrentState=ExStart)
[PE10-GigabitEthernet0/0/0]
Sep 24 2015 00:48:58-05:13 PE10 %%01OSPF/4/NBR_CHANGE_E(l)[17]:Neighbor changes
e
```

```
vent: neighbor status changed. (ProcessId=256, NeighborAddress=29.160.160.160,
Ne
ighborEvent=NegotiationDone, NeighborPreviousState=ExStart,
NeighborCurrentState=
Exchange)
[PE10-GigabitEthernet0/0/0]
Sep 24 2015 00:48:58-05:13 PE10 %%01OSPF/4/NBR_CHANGE_E(l)[18]:Neighbor changes
e
vent: neighbor status changed. (ProcessId=256, NeighborAddress=29.160.160.160,
Ne
ighborEvent=ExchangeDone, NeighborPreviousState=Exchange,
NeighborCurrentState=Lo
ading)
[PE10-GigabitEthernet0/0/0]
Sep 24 2015 00:48:58-05:13 PE10 %%01OSPF/4/NBR_CHANGE_E(l)[19]:Neighbor changes
e
vent: neighbor status changed. (ProcessId=256, NeighborAddress=29.160.160.160,
Ne
ighborEvent=LoadingDone, NeighborPreviousState=Loading,
NeighborCurrentState=Full
)
[PE10-GigabitEthernet0/0/0]
[PE10-GigabitEthernet0/0/0]
[PE10-GigabitEthernet0/0/0]dis ospf peer brief

       OSPF Process 1 with Router ID 160.160.161.10
              Peer Statistic Information
 --------------------------------------------------------------------------
 Area Id          Interface                       Neighbor id      State
 0.0.0.0          GigabitEthernet0/0/0            160.160.161.2    Full
 0.0.0.0          GigabitEthernet0/0/1            160.160.161.9    Full
 --------------------------------------------------------------------------
```

Možemo videti da smo imali jedan *request timeout* u trenutku kada je link pao. Nakon vraćanja linka u operativno stanje, OSPF *peering* se ponovo uspostavio.

4.7. Zaključci testiranja

U prethodnoj sekciji, testirali smo više tehnologija, i posmatrali njihov uticaj na ponašanje saobraćaja u našoj mreži.

Iz testiranja MPLS TE *Hot-Standby* tehnlogije možemo izvući zaključak da tehnologija predstavlja očigledno poboljšanje u smislu raspoloživosti mreže. U varijanti kada tunel nema zaštitu imamo totalni otkaz tunela, a sa primenom *Hot-Standby* tehnologije omogućavamo da ne dolazi do otkaza, ili da imamo minimalan prekid pri konvergenciji na *Hot-Standby* putanju.

Iz testiranja TE FRR tehnologije zaključujemo da dobijamo veliko poboljšanje primenom ove tehnologije. Test je pokazao da ona štiti sve tunele čiji LSP prolaze kroz interfejse zaštićene ovom tehnologijom, i na taj način se sprečava pad tih LSP-a. Sa druge strane bez primene te tehnologije, u slučaju da nema druge zaštite tunela imaćemo gubitak raspoloživosti usled prekida saobraćaja. U slučaju da koristimo i MPLS TE *Hot-Standby* u kombinaciji, imaćemo dvostruku zaštitu tunela. Sa jedne strane štitimo *Primary* LSP, a sa druge, u slučaju da ipak otkaže *Primary* LSP, imaćemo i *Hot-Standby* LSP, od svakih od dotičnih tunela, da preuzme saobraćaj.

Testiranje VPN FRR tehnologije nam omogućava zaštitu u slučaju otkaza kompletnog rutera. Test je pokazao da u slučaju da ne primenjujemo VPN FRR ćemo imati kompletan prekid saobraćaja u slučaju otkaza rutera. Sa druge strane u varijanti kada primenjujemo VPN FRR tehnologiju, u trenutku otkaza rutera nećemo imati prekid saobraćaja, ali se problem javlja u trenutku kada se ruter ponovo startuje, gde imamo prekid u periodu od kada se digne uređaj pa do pokretanja svih servisa na samom ruteru. Kada konfigurišemo MPLS TE *Hot-Standby* može da nam pomogne donekle, jer kada primenimo *Hot-Standby* prema primarnom i backup VPN FRR ruteru, saobraćaj će funkcionisati i u periodu ponovnog uspostavljanja rada primarnog rutera koji je prvobitno otkazao. Takođe, ovaj problem VPN FRR tehnologije je prevaziđen sa novijom verzijom softvera koji nismo imali u eNSP simulatoru.

Testiranje IP FRR tehnologije je pokazalo poboljšanja u konvergenciji i raspoloživosti u primeni na linkovima prema korisnicima. Pokazali smo da imamo nešto bržu konvergenciju saobraćaja u slučaju otkaza linka prema korisniku.

Testiranje E-VRRP tehnologije je takođe pokazalo poboljšanje u smislu raspoloživosti servisa u slučaju otkaza linka prema korisnicima. Takođe može da nas štiti i u slučaju otkaza *upstream l*inka, kao i otkaza rutera. Videli smo da u slučaju primene E-VRRP nema gubitka saobraćaja dok pri primeni klasične VRRP tehnike postoje gubici.

Testiranje OSPF BFD tehnologije je pokazala bržu konvergenciju saobraćaja na altrenativne putanje u slučaju otkaza linka između dva OSPF *peer*-a za slučaj kada primenjujemo OSPF BFD. Stoga preporučujemo da se koristi na linkovima između OSPF *peer*-ova. Naravno treba imati u vidu da BFD tehnologija se može primenjivati samo na putanjama koje ne izlaze na Interent, zbog mogućih čestih flapovanja usled kvaliteta veze.

5. ZAKLJUČAK

U ovom radu smo se bavili analizom tehnologija za visoko raspoložive mreže. Naglasak je dat na mehanizme brze detekcije, BFD *(BiForwarding Detection)*. Zatim na FRR *(Fast ReRouting)* tehnologije, kao i E-VRRP *(Enhanced - Virtual Route Redoundancy Protocol)* tehnologiju. Objašnjene su teoretske osnove ovih tehnologija i njihove prednosti u teoriji. Projektovana je i konfigurisana IP/MPLS mreža sa Huawei opremom korišćenjem programskog paketa eNSP, u kojoj smo praktično proverili prednosti ovih tehnologija u smislu visoke raspoloživosti i izveli zaključke testiranja.

Osnovni doprinosi rada su:

(a) Prikaz i metodologija projektovanja, kao i konfiguracija IP/MPLS visoko rapoložive mreže.

(b) Mogućnost primene, ovako visoko raspoložive mreže, za različite osetljive servise kao što su Voice, Video, VoD i slično.

(c) Mogućnost daljeg razvoja rada u smislu dalje optimizacije i poboljšanja raspoloživosti mreže, optimalnim kombinovanim korišćenjem ovih tehnologija.

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A. PRILOZI

A.1. Lista skraćenica

HA –*High Availability*

SLA –*Service Level Agreement*

FRR –*Fast ReRoute*

BFD –*BiForwarding Detection*

VRRP –*Virtual Router Redundancy Protocol*

E-VRRP –*Enchanced Virtual Router Redundancy Protocol*

MPLS – *Multi Protocol Label Switching*

MPLS TE – *Multi Protocol Label Switching Traffic Engineering*

IP – *Internet Protocol*

IP FRR – *Internet Protocol Fast ReRoute*

TE FRR – *Traffic Engineering Fast ReRoute*

VPN – *Virtual Private Network*

VPN FRR – *Virtual Private Network Fast ReRoute*

OSPF – *Open Shortest Path First*

OSPF BFD – *Open Shortest Path First BiForwarding Protection*

eNSP – *enterprise Network Simulation Platform*

IP/MPLS – *Internet Protocol / Multi Protocol Label Switching*

MTTR – *Mean Time to Repair*

MTBF – *Mean Time Between Failures*

IGP – *Interior Gateway Protocol*

SDH – *Synchronous Digital Hierarchy*

UDP – *User Datagram Protocol*

LDP – *Label Discovery Protocol*

DU – *Downstream Unsolicited*

FEC – *Forwarding Equivalence Class*

PE – *Provider Edge*

P – *Provider*

PLR – *Point of local Repair*

MP – *Merge Point*

CR – *Constraint-based Routing*

LSP – *Link State Path*

CR-LSP – *Constraint-based Routing – Link State Path*

OAM – *Operation Administration and Maintenence*

MAC – *Media Access Control*

GUI – *Graphical User Interface*

BGP – *Border Gateway Protocol*

MP-BGP – *Multi Protocol Border Gateway Protocol*

RSVP – *Resource Reservation Protocol*

CSPF – *Constrained Shortest Path First*

RR – *Route Reflector*

iBGP – *interior Border Gateway Protocol*

VRF – *Virtual Route Forwarding*

VoD – *Video on Demand*

A.2. Komande korišćene pri konfiguraciji i testiranju

KOMANDA	*VIEW*	OPIS
ip addressip-address { *mask* | *mask-length* } [*sub*]	[Huawei-Ethernet0/0/0]	Konfiguriše IP adresu
routeridrouter-id	[Huawei]	Konfiguriše*router* ID
ospf [*process-id* | *router-idrouter-id* | *vpn-instancevpn-instance-name*]	[Huawei]	Kreira OSPF proces
area*area-id*	[Huawei-ospf-1]	Prikazuje OSPF *area view*
network*addresswildcard-mask* [*descriptiontext*]	[Huawei-ospf-1-area-0.0.0.1]	Konfiguriše uređaj da reklamira mrežu za specifični *area*
mplslsr-id*lsr-id*	[Huawei]	Konfiguriše LSR ID

mpls	[Huawei]	Uključuje MPLS globalno
mpls te	[Huawei-mpls]	Uključuje MPLS TE globalno
mpls rsvp-te	[Huawei-mpls]	Uključuje MPLS RSVP-TE globalno
mpls te cspf	[Huawei-mpls]	Uključuje MPLS CSPF globalno
mpls	[Huawei-Ethernet0/0/0]	Uključuje MPLS na interfejsu
mpls te	[Huawei-Ethernet0/0/0]	Uključuje MPLS TE na interfejsu
mpls rsvp te	[Huawei-Ethernet0/0/0]	Uključuje MPLS RSVP TE na interfejsu
mpls te bandwidth max-reservable-bandwidth *bw-value*	[Huawei-Ethernet0/0/0]	Podešava *maximum reserved bandwidth*
mpls te bandwidth {bc0 *bc0-bw-value*}	[Huawei-Ethernet0/0/0]	Podešava *bandwidth* za BC0
mpls ldp [vpn-instance *vpn-instance-name*]	[Huawei]	Konfiguriše MPLS LDP globalno
mpls ldp	[Huawei-Ethernet0/0/0]	Konfiguriše MPLS LDP na interfejsu
ospf cost *cost*	[Huawei-Ethernet0/0/0]	Konfiguriše OSPF cost na interfejsu
opaque-capability enable	[Huawei-ospf-1]	Uključuje*opaque LSA capabilities*
mpls-te enable	[Huawei-ospf-1-area-0.0.0.1]	Uključuje MPLS TE datom OSPF area
explicith-path *path-name*	[Huawei]	Kreira explicith-path i ulazi u zadati *view*
mpls te metric	[Huawei-Ethernet0/0/0]	Konfiguriše TE *metric*
interface *Tunnel0/0/1*	[Huawei]	Kreira tunel interfejs
ip address unnumbered interface*interface-name*	[Huawei-Tunnel0/0/1]	Pozajmljuje IP adresu od drugog interfejsa

tunnelprotocol mpls te	[Huawei-Tunnel0/0/1]	Konfiguriše tunel protokol
destination *x.x.x.x*	[Huawei-Tunnel0/0/1]	Konfiguriše odredišnu adresu zza tunel
mpls te tunnel-id *1*	[Huawei-Tunnel0/0/1]	Konfiguriše *Tunnel ID*
mpls te signalprotocol rsvp-te	[Huawei-Tunnel0/0/1]	Konfiguriše *tunnelsignaling* protokol
mpls te path *explicitpath-name*	[Huawei-Tunnel0/0/1]	Koristi*explicitpath*
mpls te backup hot-standby	[Huawei-Tunnel0/0/1]	Uključuje*hot-standby*
mpls te reserved-for binding	[Huawei-Tunnel0/0/1]	Vezuje MPLS TE tunel za VPN
mpls te commit	[Huawei-Tunnel0/0/1]	Primenjuje konfiguraciju
bfd	[Huawei]	Uključuje BFD globalno
mpls te bfd enable	[Huawei-Tunnel0/0/1]	Uključuje dinamički BFD
mpls te bfd min-tx-interval *100* min-rx-interval *100* detect multiplier *5*	[Huawei-Tunnel0/0/1]	Konfiguriše BFD parametre
ip vpn-instance *vpn-instance-name*	[Huawei]	Kreira i konfiguriše VPN instancu
route-distinguisher	[Huawei-VPN-name]	Konfiguriše RD za VPN instancu
vpn-target vpn-target [*both*|*export-extcommunity*|*import-extcommunity*]	[Huawei-VPN-name]	Konfiguriše*route-target extended community attribute* for a VPN instance
ip binding vpn-instance *vpn-instance-name*	[Huawei-Ethernet0/0/0]	Konfiguriše*bindingrelationship*između interfejsa i VPN instance
peer *peer-address* as-number *number*	[Huawei]	Uspostavlja iBGP *neighbourrelationship* između PE rutera

ipv4-family vpnv4 peer *peer-address* enable	[Huawei-bgp]	Konfiguriše MP-BGP između PE rutera uVPNv4 *view*
ip route-static *x.x.x.x y.y.y.y*	[Huawei]	Konfiguriše statičku rutu
mpls te bandwidth bc0	[Huawei-Tunnel0/0/1]	Konfiguriše *bandwidth* od bc0
mpls te bypass-tunnel	[Huawei-Tunnel0/0/1]	Konfiguriše*bypass* tunel
mpls te protected-interface *GigabitEthernet0/0/1*	[Huawei-Tunnel0/0/1]	Precizira interfejs za*linkprotection*
mpls te fast-reroute	[Huawei-Tunnel0/0/1]	Uključuje TE FRR
mpls rsvp-te bfd enable	[Huawei-Ethernet0/0/0]	Konfiguriše BFD za RSVP
mpls rsvp-te bfd min-tx-interval *100*	[Huawei-Ethernet0/0/0]	Konfiguriše minimalni interval sa kojim se šalju BFD paketi
mpls rsvp-te bfd min-rx-interval *100*	[Huawei-Ethernet0/0/0]	Konfiguriše minimalni interval sa kojim se BFD paketi primaju
mpls rsvp-te bfd detect-multiplier *5*	[Huawei-Ethernet0/0/0]	Konfiguriše*localdetectionmultiplier*za BFD pakete
ip ip-prefix name index 10 permit *x.x.x.x*	[Huawei]	Konfiguriše IP-prefix
route-policy name permit node 10	[Huawei]	Kreira*route-policy*
if-match ip next-hop *ip-prefix-name*	[Huawei-route-policy]	Konfiguriše route-policy
apply backup-nexthop *x.x.x.x*	[Huawei-route-policy]	Konfiguriše*backup next hop*
vpn frr route-policy *vpn-frr*	[Huawei-vpn-instance-vpnname]	Konfiguriše route-policy za VPN FRR u VPN instance view
tunnel-policy name	[Huawei]	Konfiguriše tunnel-policy
tunnel binding destination	[Huawei-tunnel-policy-	Verzujetunel za navedeni interfejs

x.x.x.x te *Tunnel0/0/0*	p1]	
apply backup-interface *interface*	[Huawei-route-policy]	Konfiguriše backup outbound interfejs
ip frr route-policy *ip-frr*	[Huawei-vpn-instance-vpnname]	Konfiguriše route-policy za IP FRR u VPN instance view
bfd name bind peer-ip *x.x.x.x* interface*interface-name*	[Huawei]	Vezuje peer IP adresuza BFD sesiju
discriminator *local/remote*	[Huawei-bfd-bfdname]	Konfiguriše local i remote discriminators koji se koriste za BFD sesiju
mpls rsvp-te bfd min-tx-interval*100*	[Huawei-bfd-bfdname]	Konfigurišeminimalni interval sa kojima se šalju BFD control paketi
mpls rsvp-te bfd min-rx-interval*100*	[Huawei-bfd-bfdname]	Konfiguriše minimalni interval sa kojima se primaju BFD control paketi
mpls rsvp-te bfd detect-multiplier *5*	[Huawei-bfd-bfdname]	Konfiguriše local detection multiplier za BFD pakete
Next hop *ip address*	[Huawei-path-name]	Konfiguriše next hop
bgp { *as-number-plain* | *as-number-dot* }	[Huawei]	The bgp komanda uključuje BGP
router-id { *ipv4-address* | *vpn-instance auto-select* }	[Huawei-bgp]	Komanda zadaje router-id a ruter
peer { *group-name* | *ipv4-address* | *ipv6-address* } as-number { *as-number-plain* | *as-number-dot* }	[Huawei-bgp]	Komanda definiše AS number za peer ili peer group
peer { *group-name* | *ipv4-address* | *ipv6-address* } connect-interface interface-type interface-number [*ipv4-source-address* | *ipv6-source-address*]	[Huawei-bgp]	Definiše source interfejskroz koji se BGP paketi šalju, i source adresusa kojom se BGP konekcija uspostavlja

group *group-name* [external | internal]	[Huawei-bgp]	Kreira peer group
undo synchronization	[Huawei-bgp]	Isključuje sinhronizaciju BGP-a i IGP-a
import-route { direct | isis process-id | ospf process-id | rip process-id | unr | static } [med med | route-policy route-policy-name]	[Huawei-bgp]	Importuje rute iz drugih protokola
reflector cluster-id *cluster-id*	[Huawei-bgp]	podešava cluster ID za route reflectors
peer { *group-name* | *ipv4-address* | *ipv6-address* } advertise-community	[Huawei-bgp]	Konfiguriše rutere da reklamiraju community attribute ka peer-uili peer group-i
peer { group-name | ipv4-address | ipv6-address } enable	[Huawei-bgp]	Komanda uključuje za konkretan peer ili peer grupu da ramenjuje rute u address family view
peer { group-name | ipv4-address | ipv6-address } reflect-client	[Huawei-bgp]	Konfiguriše lokalni ruter kao route reflector i peer ili peer group kao klijent route reflector-a
peer { ipv4-address | ipv6-address } group group-name	[Huawei-bgp]	Dodajea peer u peer group
ipv4-family { unicast | multicast | vpnv4 [unicast] | vpn-target | vpn-instance *vpn-instance-name* | *mdt* | *mvpn* }	[Huawei-bgp]	Uključuje BGP IPv4 address family i prikazuje address family view

Tabela A.2.1 Komande i objašnjenja