

Institut Universitaire des Sciences
Faculté des Sciences et Technologies
Td6 dans le cadre du cours de Réseaux 2
Préparé par Wendy COLAS
A l'attention de Monsieur Ismaël SAINT AMOUR
Mai 2025

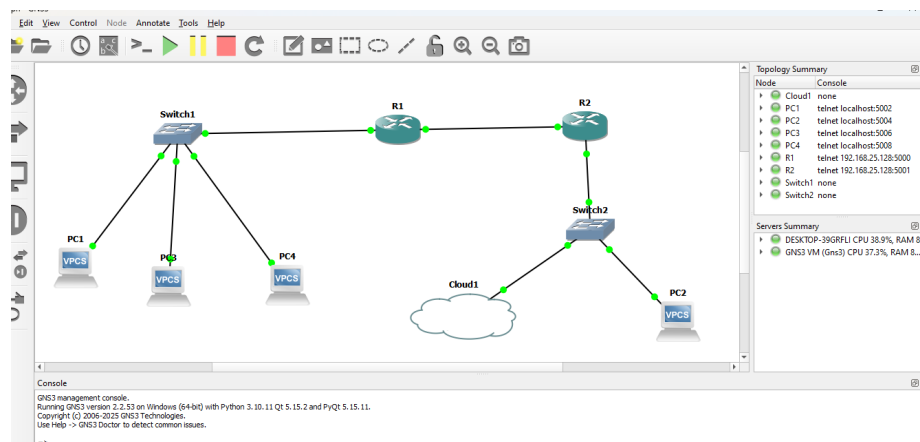
Reproduction de la topologie en configurant un VPN site-à-site

Introduction

Dans ce document, nous détaillons le processus de configuration d'un VPN site-à-site afin de sécuriser les échanges entre deux réseaux. Cette configuration implique l'utilisation de routeurs, de VPCS et d'outils tels que Solar-PuTTY pour l'administration. Chaque étape est illustrée par une image accompagnée d'une explication détaillée.

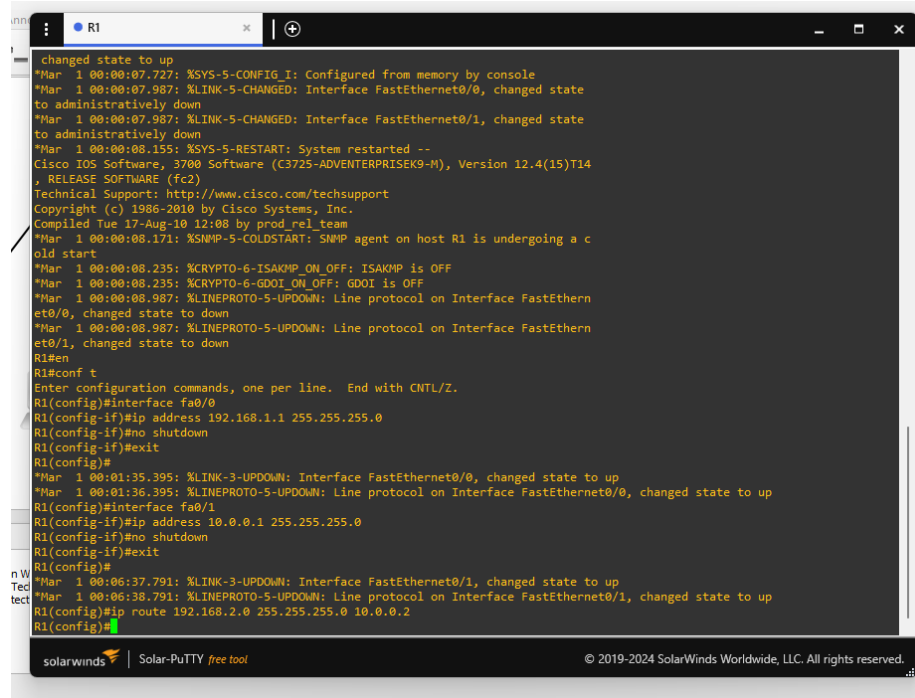
Étapes de la configuration

1. Topologie réseau initiale



La topologie initiale est conçue sur GNS3 et comporte des routeurs, des switches et des PC simulés. Cette architecture permet une connexion étendue et la mise en œuvre du VPN.

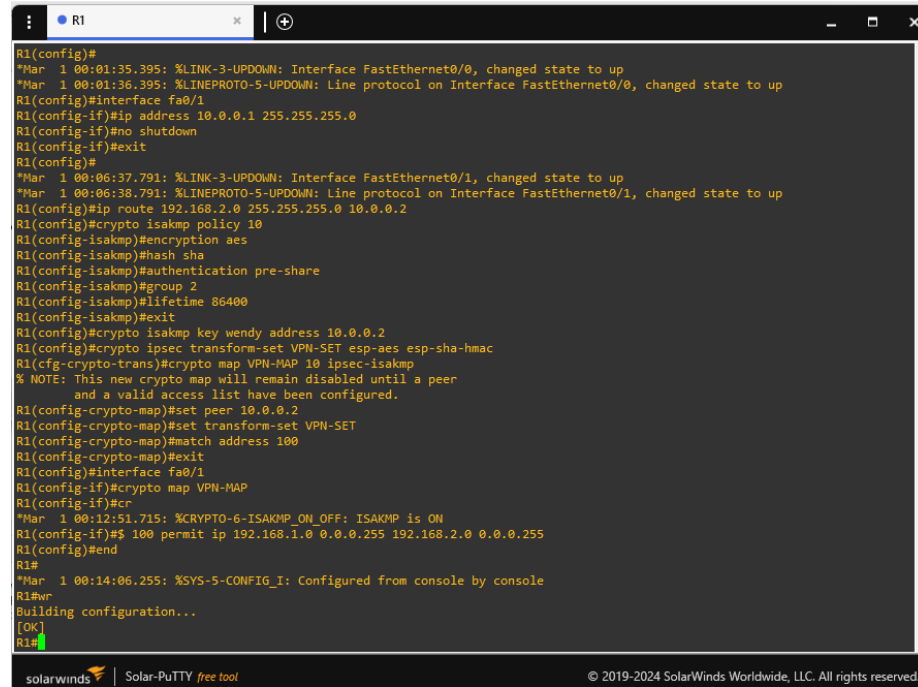
2. Configuration du premier routeur (R1)



```
changed state to up
*Mar 1 00:00:07.727: %SYS-5-CONFIG I: Configured from memory by console
*Mar 1 00:00:07.987: %LINK-5-CHANGED: Interface FastEthernet0/0, changed state
to administratively down
*Mar 1 00:00:07.987: %LINK-5-CHANGED: Interface FastEthernet0/1, changed state
to administratively down
*Mar 1 00:00:08.155: %SYS-5-RESTART: System restarted --
Cisco IOS Software, 3700 Software (C3725-ADVENTERPRISEK9-M), Version 12.4(15)T14
, RELEASE SOFTWARE (fc2)
Technical Support: http://www.cisco.com/techsupport
Copyright (c) 1986-2010 by Cisco Systems, Inc.
Compiled Tue 17-Aug-10 12:08 by prod.rel.team
*Mar 1 00:00:08.171: %SNMP-5-COLDSTART: SNMP agent on host R1 is undergoing a c
old start
*Mar 1 00:00:08.235: %CRYPTO-6-ISAKMP_ON_OFF: ISAKMP is OFF
*Mar 1 00:00:08.235: %CRYPTO-6-GDOI_ON_OFF: GDOI is OFF
*Mar 1 00:00:08.987: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthern
et0/0, changed state to down
*Mar 1 00:00:08.987: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthern
et0/1, changed state to down
R1#en
R1#conf t
Enter configuration commands, one per line. End with CNTL/Z.
R1(config)#interface fa0/0
R1(config-if)#ip address 192.168.1.1 255.255.255.0
R1(config-if)#no shutdown
R1(config-if)#exit
R1(config)#
*Mar 1 00:01:35.395: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar 1 00:01:36.395: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R1(config)#interface fa0/1
R1(config-if)#ip address 10.0.0.1 255.255.255.0
R1(config-if)#no shutdown
R1(config-if)#exit
R1(config)#
*Mar 1 00:06:37.791: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
*Mar 1 00:06:38.791: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to up
R1(config)#ip route 192.168.2.0 255.255.255.0 10.0.0.2
R1(config)#
```

À l'aide de Solar-PuTTY, nous configurons les interfaces de R1 et attribuons les adresses IP nécessaires à la communication entre les sous-réseaux.

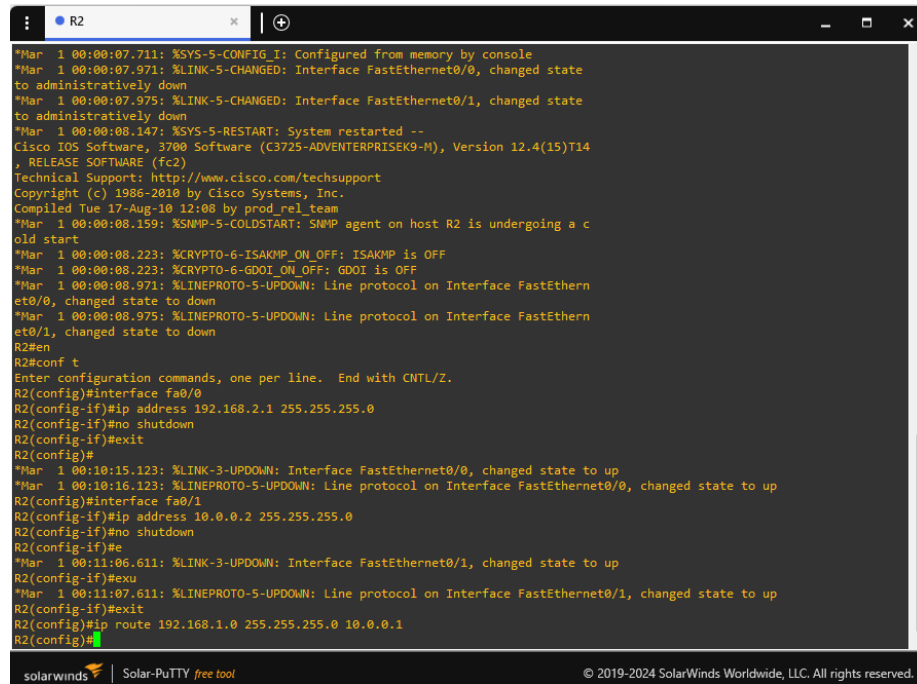
3. Configuration du second routeur (R2)



```
R1(config)#
*Mar 1 00:01:35.395: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar 1 00:01:36.395: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R1(config)#interface fa0/1
R1(config-if)#ip address 10.0.0.1 255.255.255.0
R1(config-if)#no shutdown
R1(config-if)#exit
R1(config)#
*Mar 1 00:06:37.791: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
*Mar 1 00:06:38.791: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to up
R1(config)#ip route 192.168.2.0 255.255.255.0 10.0.0.2
R1(config)#crypto isakmp policy 10
R1(config-isakmp)#encryption aes
R1(config-isakmp)#hash sha
R1(config-isakmp)#authentication pre-share
R1(config-isakmp)#group 2
R1(config-isakmp)#lifetime 86400
R1(config-isakmp)#exit
R1(config)#crypto isakmp key wendy address 10.0.0.2
R1(config)#crypto ipsec transform-set VPN-SET esp-aes esp-sha-hmac
R1(cfg-crypto-trans)#crypto map VPN-MAP 10 ipsec-isakmp
% NOTE: This new crypto map will remain disabled until a peer
        and a valid access list have been configured.
R1(config-crypto-map)#set peer 10.0.0.2
R1(config-crypto-map)#set transform-set VPN-SET
R1(config-crypto-map)#match address 100
R1(config-crypto-map)#exit
R1(config)#interface fa0/1
R1(config-if)#crypto map VPN-MAP
R1(config-if)#cr
*Mar 1 00:12:51.715: %CRYPTO-6-ISAKMP_ON_OFF: ISAKMP is ON
R1(config-if)#$ 100 permit ip 192.168.1.0 0.0.0.255 192.168.2.0 0.0.0.255
R1(config)#end
R1#
*Mar 1 00:14:06.255: %SYS-5-CONFIG_I: Configured from console by console
R1#wr
Building configuration...
[OK]
R1#
```

Le routeur R2 est configuré avec ses interfaces réseau et routes statiques afin d'assurer la communication avec R1 et les PC du réseau.

4. Vérification de l'état des interfaces



```
*Mar 1 00:00:07.711: %SYS-5-CONFIG_I: Configured from memory by console
*Mar 1 00:00:07.971: %LINK-5-CHANGED: Interface FastEthernet0/0, changed state
to administratively down
*Mar 1 00:00:07.975: %LINK-5-CHANGED: Interface FastEthernet0/1, changed state
to administratively down
*Mar 1 00:00:08.147: %SYS-5-RESTART: System restarted --
Cisco IOS Software, 3700 Software (C3725-ADVENTERPRISEK9-M), Version 12.4(15)T14
, RELEASE SOFTWARE (fc2)
Technical Support: http://www.cisco.com/techsupport
Copyright (c) 1986-2010 by Cisco Systems, Inc.
Compiled Tue 17-Aug-10 12:08 by prod_rel_team
*Mar 1 00:00:08.159: %SNMP-5-COLDSTART: SNMP agent on host R2 is undergoing a c
old start
*Mar 1 00:00:08.223: %CRYPTO-6-ISAKMP_ON_OFF: ISAKMP is OFF
*Mar 1 00:00:08.223: %CRYPTO-6-GDOI_ON_OFF: GDOI is OFF
*Mar 1 00:00:08.971: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthern
et0/0, changed state to down
*Mar 1 00:00:08.975: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthern
et0/1, changed state to down
R2#en
R2#conf t
Enter configuration commands, one per line. End with CNTL/Z.
R2(config)#interface fa0/0
R2(config-if)#ip address 192.168.2.1 255.255.255.0
R2(config-if)#no shutdown
R2(config-if)#exit
R2(config)#
*Mar 1 00:10:15.123: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar 1 00:10:16.123: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R2(config)#interface fa0/1
R2(config-if)#ip address 10.0.0.2 255.255.255.0
R2(config-if)#no shutdown
R2(config-if)#e
*Mar 1 00:11:06.611: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
R2(config-if)#exu
*Mar 1 00:11:07.611: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to up
R2(config-if)#exit
R2(config)#ip route 192.168.1.0 255.255.255.0 10.0.0.1
R2(config)#
```

Une vérification est effectuée pour s'assurer que les interfaces sont bien actives et que les routes sont correctement définies.

5. Test de communication entre les sous-réseaux



```
R2
R2(config-if)#exit
R2(config)#ip route 192.168.1.0 255.255.255.0 10.0.0.1
R2(config)#crypto isakmp policy 10
R2(config-isakmp)#encryption aes
R2(config-isakmp)#hash sha
R2(config-isakmp)#authentication pre-share
R2(config-isakmp)#group 2
R2(config-isakmp)#lifetime 86400
R2(config-isakmp)#exit
R2(config)#crypto isakmp key wendy address 10.0.0.1
R2(config)#crypto ipsec transform-set VPN-SET esp-aes esp-sha-hmac
R2(cfg-crypto-trans)#crypto map VPN-MAP 10 ipsec-isakmp
R2(cfg-crypto-map)#set peer 10.0.0.1
R2(cfg-crypto-map)#set transform-set VPN-SET
R2(cfg-crypto-map)#match address 100
R2(cfg-crypto-map)#exit
R2(config)#interface fa0/1
R2(config-if)#crypto map VPN-MAP
R2(config-if)#
*Mar 1 00:17:40.859: %CRYPTO-6-ISAKMP_ON_OFF: ISAKMP is ON
R2(config-if)#$ 100 permit 192.168.2.0 0.0.0.255 192.168.1.0 0.0.0.255
R2(config)#end
R2#
*Mar 1 00:20:03.619: %SYS-5-CONFIG_I: Configured from console by consolew
R2#wr
Building configuration...
[OK]
R2#
```

Un test de connectivité est réalisé entre les sous-réseaux via des commandes ping.

6. Configuration des routes statiques

```

Welcome to Virtual PC Simulator, version 0.6.2
Dedicated to Daling.
Build time: Apr 10 2019 02:42:20
Copyright (c) 2007-2014, Paul Meng (mirnshi@gmail.com)
All rights reserved.

VPCS is free software, distributed under the terms of the "BSD" licence.
Source code and license can be found at vpcs.sf.net.
For more information, please visit wiki.freecode.com.cn.

Press '?' to get help.

Executing the startup file

PC1> ip address 192.168.1.2 255.255.255.0 192.168.1.1
Invalid address

PC1> ip 192.168.1.2 255.255.255.0 192.168.1.1
Checking for duplicate address...
sPC1 : 192.168.1.2 255.255.255.0 gateway 192.168.1.1

PC1> save
Saving startup configuration to startup.vpc
. done

PC1> █

```

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Les routes statiques sont mises en place sur R2 pour garantir l'acheminement du trafic entre les réseaux.

7. Mise en place de la sécurité avec IPsec et ISAKMP



```

Welcome to Virtual PC Simulator, version 0.6.2
Dedicated to Daling.
Build time: Apr 10 2019 02:42:20
Copyright (c) 2007-2014, Paul Meng (mirnshi@gmail.com)
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PCS is free software, distributed under the terms of the "BSD" licence.
Source code and license can be found at vpcs.sf.net.
For more information, please visit wiki.freecode.com.cn.

Press '?' to get help.

Executing the startup file

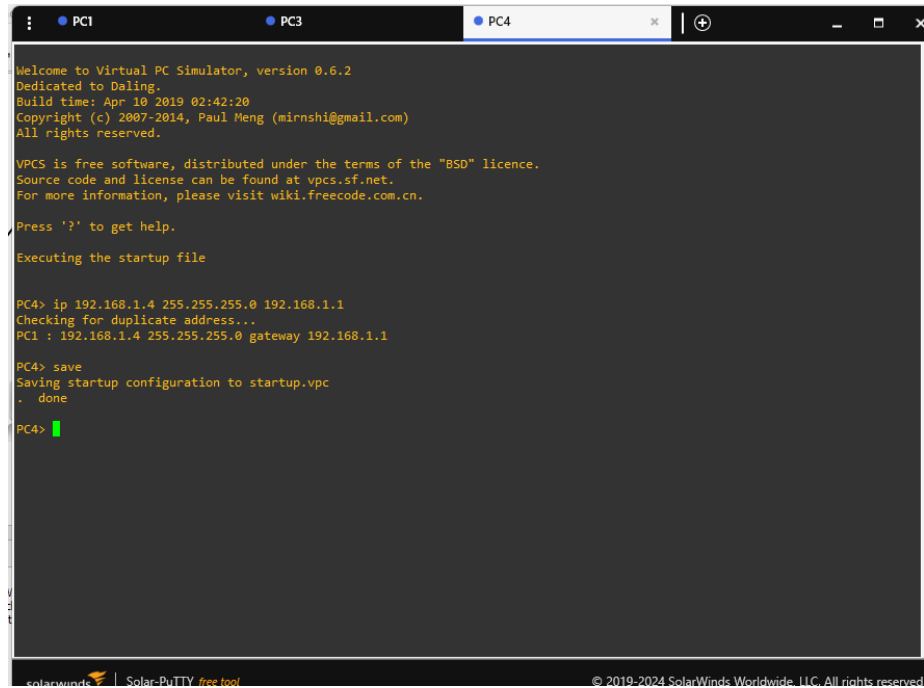
C3> ip 192.168.1.3 255.255.255.0 192.168.1.1
Checking for duplicate address...
C1 : 192.168.1.3 255.255.255.0 gateway 192.168.1.1

C3> save
Saving startup configuration to startup.vpc
done

C3> 
```

La configuration VPN débute avec l'établissement des règles de sécurité IPsec et des paramètres ISAKMP.

8. Vérification des associations de sécurité



```

Welcome to Virtual PC Simulator, version 0.6.2
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For more information, please visit wiki.freecode.com.cn.

Press '?' to get help.

Executing the startup file

PC4> ip 192.168.1.4 255.255.255.0 192.168.1.1
Checking for duplicate address...
PC1 : 192.168.1.4 255.255.255.0 gateway 192.168.1.1

PC4> save
Saving startup configuration to startup.vpc
. done

PC4> 
```

Un état des associations de sécurité IPsec et ISAKMP est vérifié pour s'assurer que le tunnel VPN est bien actif.

9. Débogage des configurations VPN



```

Welcome to Virtual PC Simulator, version 0.6.2
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Source code and license can be found at vpcs.sf.net.
For more information, please visit wiki.freecode.com.cn.

Press '?' to get help.

Executing the startup file

PC2> ip 192.168.2.2 255.255.255.0 192.168.2.1
Checking for duplicate address...
PC1 : 192.168.2.2 255.255.255.0 gateway 192.168.2.1

PC2> save
Saving startup configuration to startup.vpc
. done

PC2> 
```

Une analyse des logs est effectuée pour identifier d'éventuels problèmes de connexion et d'authentification.

10. Simulation du trafic via VPCS



```
*Mar  1 00:12:51.715: %CRYPTO-6-ISAKMP_ON_OFF: ISAKMP is ON
R1(config-if)# 100 permit ip 192.168.1.0 0.0.0.255 192.168.2.0 0.0.0.255
R1(config)#end
R1#
*Mar  1 00:14:06.255: %SYS-5-CONFIG_I: Configured from console by console
R1#wr
Building configuration...
[OK]
R1#show crypto isakmp sa
IPv4 Crypto ISAKMP SA
dst          src          state          conn-id slot status

IPv6 Crypto ISAKMP SA

R1#show crypto ipsec sa
interface: FastEthernet0/1
  Crypto map tag: VPN-MAP, local addr 10.0.0.1

  protected vrf: (none)
  local  ident (addr/mask/prot/port): (192.168.1.0/255.255.255.0/0/0)
  remote ident (addr/mask/prot/port): (192.168.2.0/255.255.255.0/0/0)
  current_peer 10.0.0.2 port 500
    PERMIT, flags={origin_is_acl,}
    #pkts encaps: 0, #pkts encrypt: 0, #pkts digest: 0
    #pkts decaps: 0, #pkts decrypt: 0, #pkts verify: 0
    #pkts compressed: 0, #pkts decompressed: 0
    #pkts not compressed: 0, #pkts compr. failed: 0
    #pkts not decompressed: 0, #pkts decompress failed: 0
    #send errors 0, #recv errors 0

  local crypto endpt.: 10.0.0.1, remote crypto endpt.: 10.0.0.2
  path mtu 1500, ip mtu 1500, ip mtu idb FastEthernet0/1
  current outbound spi: 0x0(0)

  inbound esp sas:

  inbound ah sas:
--More--
```

Les tests de communication entre les machines via VPCS confirment la fonctionnalité du VPN.

11. Correction et validation finale



```
R1#
Building configuration...
[OK]
R1#show crypto isakmp sa
IPv4 Crypto ISAKMP SA
dst          src          state          conn-id slot status

IPv6 Crypto ISAKMP SA

R1#show crypto ipsec sa
interface: FastEthernet0/1
  Crypto map tag: VPN-MAP, local addr 10.0.0.1

  protected vrf: (none)
  local  ident (addr/mask/prot/port): (192.168.1.0/255.255.255.0/0/0)
  remote ident (addr/mask/prot/port): (192.168.2.0/255.255.255.0/0/0)
  current_peer 10.0.0.2 port 500
    PERMIT, flags={origin_is_acl,}
    #pkts encaps: 0, #pkts encrypt: 0, #pkts digest: 0
    #pkts decaps: 0, #pkts decrypt: 0, #pkts verify: 0
    #pkts compressed: 0, #pkts decompressed: 0
    #pkts not compressed: 0, #pkts compr. failed: 0
    #pkts not decompressed: 0, #pkts decompress failed: 0
    #send errors 0, #recv errors 0

  local crypto endpt.: 10.0.0.1, remote crypto endpt.: 10.0.0.2
  path mtu 1500, ip mtu 1500, ip mtu idb FastEthernet0/1
  current outbound spi: 0x0(0)

  inbound esp sas:

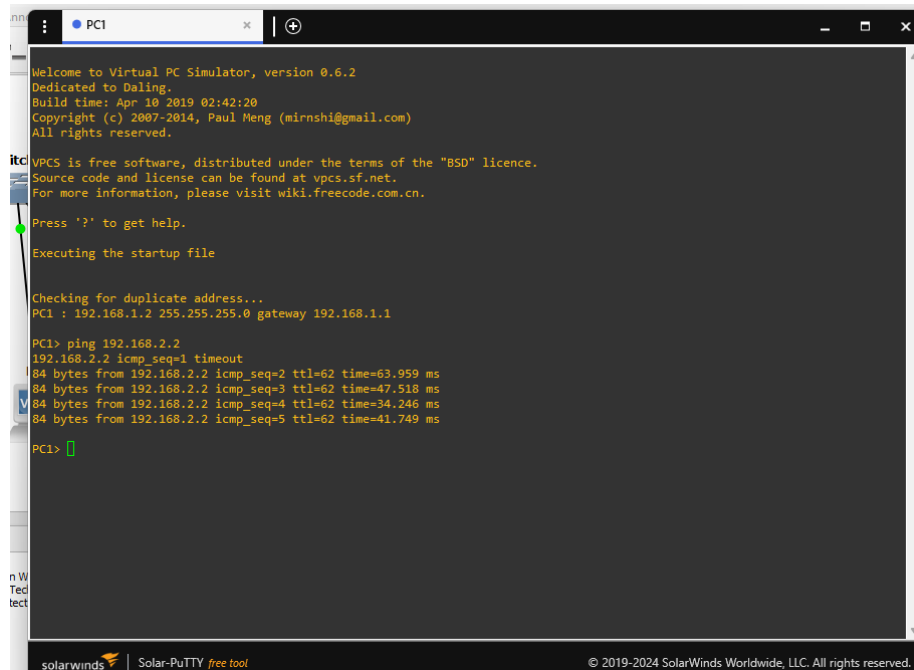
  inbound ah sas:

R1#debug crypto isakmp
Crypto ISAKMP debugging is on
R1#debug crypto ipsec
Crypto IPSEC debugging is on
R1#
```

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Des ajustements sont apportés aux configurations pour garantir un tunnel sécurisé et efficace.

12. Vérification finale de la communication VPN



```
Welcome to Virtual PC Simulator, version 0.6.2
Dedicated to Daling.
Build time: Apr 10 2019 02:42:20
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Source code and license can be found at vpcs.sf.net.
For more information, please visit wiki.freecode.com.cn.

Press '?' to get help.

Executing the startup file

Checking for duplicate address...
PC1 : 192.168.1.2 255.255.255.0 gateway 192.168.1.1

PC1> ping 192.168.2.2
192.168.2.2 icmp_seq=1 timeout
84 bytes from 192.168.2.2 icmp_seq=2 ttl=62 time=63.959 ms
84 bytes from 192.168.2.2 icmp_seq=3 ttl=62 time=47.518 ms
84 bytes from 192.168.2.2 icmp_seq=4 ttl=62 time=34.246 ms
84 bytes from 192.168.2.2 icmp_seq=5 ttl=62 time=41.749 ms

PC1> []
```

Un dernier test est effectué pour valider le bon fonctionnement du VPN site-à-site avant sa mise en production.

Conclusion

La configuration d'un VPN site-à-site permet de sécuriser les communications entre deux réseaux distants. Grâce à l'utilisation d'IPsec, ISAKMP et des routes statiques, les échanges sont protégés et le trafic est correctement acheminé entre les sous-réseaux. Ce document détaille chaque étape du processus avec des explications et des illustrations pour une compréhension approfondie.

Reproduction de la topologie en configurant un VPN GRE over IPsec avec Routage Dynamique (OSPF)

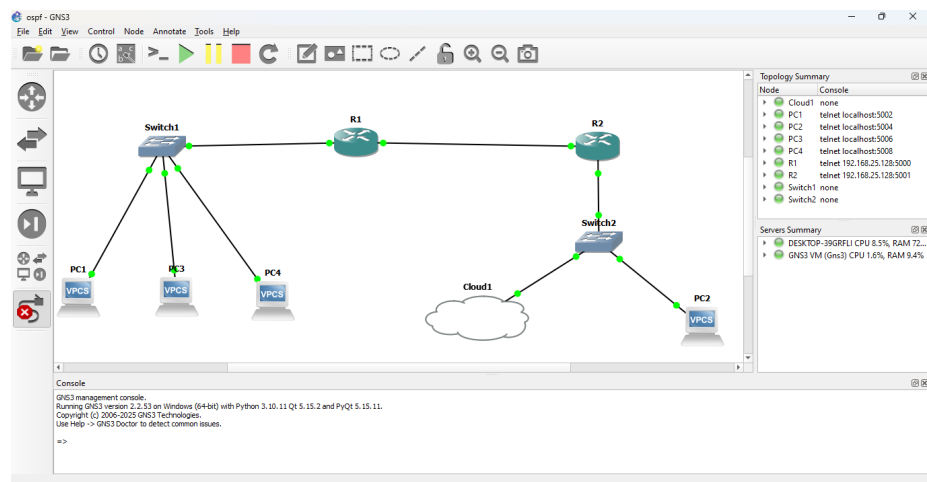
Introduction

Dans ce document, nous détaillons le processus de configuration d'un **VPN GRE over IPsec** avec **routage dynamique OSPF**. Cette approche permet d'assurer la sécurité des échanges entre sites tout en bénéficiant de la flexibilité

du routage dynamique. Nous utilisons **GNS3**, **Solar-PuTTY** et **Virtual PC Simulator (VPCS)** pour simuler l'environnement. Chaque étape est illustrée avec des images et des explications détaillées.

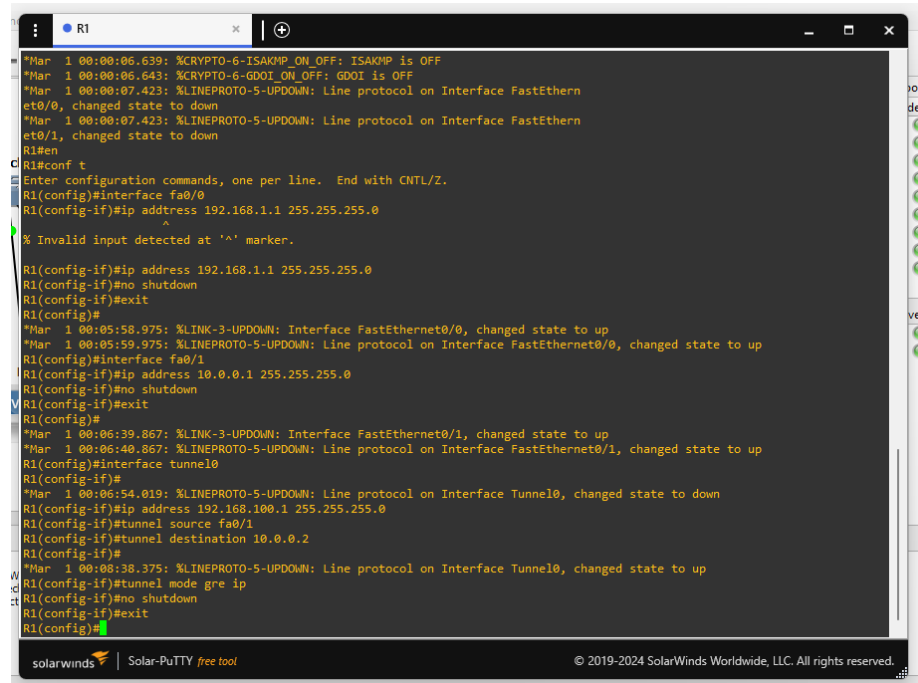
Étapes de la configuration

1. Conception de la topologie réseau



La topologie est construite sous **GNS3**, incluant **routeurs**, **switches**, **PC**, et **connexions vers le cloud**, créant un environnement de simulation réaliste.

2. Configuration du premier routeur (R1)



```
R1
R1#
R1#conf t
Enter configuration commands, one per line. End with CNTL/Z.
R1(config)#interface fa0/0
R1(config-if)#ip address 192.168.1.1 255.255.255.0
R1(config-if)#no shutdown
R1(config-if)#exit
R1(config)#
R1(config)#interface fa0/1
R1(config-if)#ip address 10.0.0.1 255.255.255.0
R1(config-if)#no shutdown
R1(config-if)#exit
R1(config)#
R1(config)#interface tunnel0
R1(config-if)#ip address 192.168.100.1 255.255.255.0
R1(config-if)#tunnel source fa0/1
R1(config-if)#tunnel destination 10.0.0.2
R1(config-if)#
R1(config-if)#tunnel mode gre ip
R1(config-if)#no shutdown
R1(config-if)#exit
R1(config)#
```

R1 est configuré avec **interfaces IP**, **tunnel GRE**, et **routing OSPF**. Les paramètres ISAKMP et IPsec sont définis pour chiffrer les échanges via le VPN.

3. Configuration du second routeur (R2)

```
R1(config)#
*Mar 1 00:06:39.867: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
*Mar 1 00:06:40.867: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to up
R1(config)#interface tunnel0
R1(config-if)#
*Mar 1 00:06:54.019: %LINEPROTO-5-UPDOWN: Line protocol on Interface Tunnel0, changed state to down
R1(config-if)#ip address 192.168.100.1 255.255.255.0
R1(config-if)#tunnel source fa0/1
R1(config-if)#tunnel destination 10.0.0.2
R1(config-if)#
*Mar 1 00:08:38.375: %LINEPROTO-5-UPDOWN: Line protocol on Interface Tunnel0, changed state to up
R1(config-if)#tunnel mode gre ip
R1(config-if)#no shutdown
R1(config-if)#exit
R1(config)#router ospf 1
R1(config-router)#network 192.168.1.0 0.0.0.255 area 0
^
% Invalid input detected at '^' marker.
R1(config-router)#network 192.168.1.0 0.0.0.255 area 0
R1(config-router)#network 192.168.100.0 0.0.0.255 area 0
R1(config-router)#crypto isakmp policy 10
R1(config-isakmp)#encryption aes
R1(config-isakmp)#hash sha
R1(config-isakmp)#authentication pre-share
R1(config-isakmp)#group 2
R1(config-isakmp)#lifetime 86400
R1(config-isakmp)#exit
R1(config)#crypto isakmp key wendy address 10.0.0.2
R1(config)#crypto ipsec transform-set TSET esp-aes esp-sha-hmac
R1(cfg-crypto-trans)#access-list 100 permit gre host 10.0.0.1 host 10.0.0.2
R1(config)#crypto map VPN-MAP 10 ipsec-isakmp
% NOTE: This new crypto map will remain disabled until a peer
and a valid access list have been configured.
R1(config-crypto-map)#set peer 10.0.0.2
R1(config-crypto-map)#set transform-set TSET
R1(config-crypto-map)#match address 100
R1(config-crypto-map)#exit
R1(config)#
```

R2 est configuré avec ses **interfaces réseau**, **tunnel GRE** et **routing OSPF**, garantissant l'interconnexion sécurisée entre les sites.

4. Configuration de PC1 dans Virtual PC Simulator



```
R2
et0/0, changed state to down
R2#en
R2#conf t
Enter configuration commands, one per line. End with CNTL/Z.
R2(config)#interface fa0/0
R2(config-if)#ip address 192.168.2.1 255.255.255.0
R2(config-if)#no shutdown
R2(config-if)#
*Mar 1 00:12:05.931: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar 1 00:12:06.931: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R2(config-if)#exit
R2(config)#interface fa0/1
R2(config-if)#ip address 10.0.0.2 255.255.255.0
R2(config-if)#no shutdown
R2(config-if)#exit
R2(config)#
*Mar 1 00:12:54.475: %LINK-3-UPDOWN: Interface FastEthernet0/1, changed state to up
*Mar 1 00:12:55.475: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1, changed state to up
R2(config)#interface tunnel0
R2(config-if)#ip addre
*Mar 1 00:13:22.555: %LINEPROTO-5-UPDOWN: Line protocol on Interface Tunnel0, changed state to down
R2(config-if)#ip address 192.168.100.2 255.255.255.0
R2(config-if)#tunnel source fa0/1
R2(config-if)#tunnel destination 10.0.0.1
R2(config-if)#tunnel mo
*Mar 1 00:14:17.171: %LINEPROTO-5-UPDOWN: Line protocol on Interface Tunnel0, changed state to up
R2(config-if)#tunnel mode gre ip
R2(config-if)#no shutdown
R2(config-if)#exit
R2(config)#router ospf 1
R2(config-router)#network 192.168.2.0 0.0.0.255 area 0
R2(config-router)#network 192.168.100.0 0.0.0.255 area 0
R2(config-router)#crypto isakmp policy 10
R2(config-isakmp)#encryption aes
R2(config-isakmp)#hash sha
R2(config-isakmp)#authentication pre-share
R2(config-isakmp)#group 2
R2(config-isakmp)#exit
R2(config)#
```

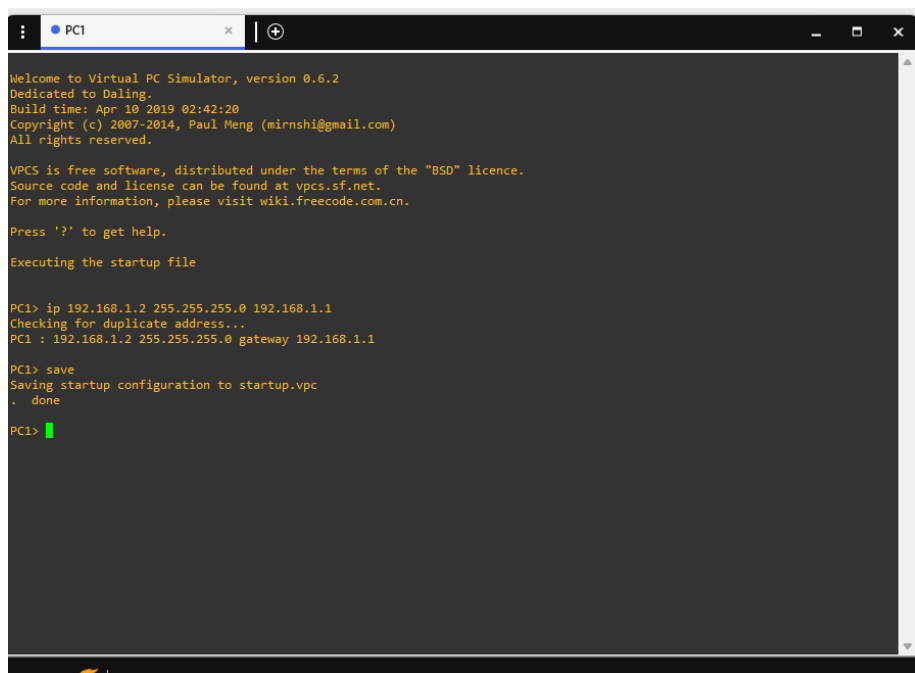
PC1 est attribué l'adresse **192.168.1.2**, avec **192.168.1.1** comme passerelle.

5. Configuration de PC2 dans Virtual PC Simulator



```
*Mar 1 00:13:22.555: %LINEPROTO-5-UPDOWN: Line protocol on Interface Tunnel0, changed state to down
R2(config-if)#ip address 192.168.100.2 255.255.255.0
R2(config-if)#tunnel source fa0/1
R2(config-if)#tunnel destination 10.0.0.1
R2(config-if)#tunnel mo
*Mar 1 00:14:17.171: %LINEPROTO-5-UPDOWN: Line protocol on Interface Tunnel0, changed state to up
R2(config-if)#tunnel mode gre ip
R2(config-if)#no shutdown
R2(config-if)#exit
R2(config)#router ospf 1
R2(config-router)#network 192.168.2.0 0.0.0.255 area 0
R2(config-router)#network 192.168.100.0 0.0.0.255 area 0
R2(config-router)#crypto isakmp policy 10
R2(config-isakmp)#encryption aes
R2(config-isakmp)#hash sha
R2(config-isakmp)#authentication pre-share
R2(config-isakmp)#group 2
R2(config-isakmp)#exit
R2(config)#crypto isakmp key wendy address 10.0.0.1
R2(config)#crypto ipsec transform-set TSET esp-aes esp-sha-hmac
R2(cfg-crypto-trans)#access-list 100 permit gre host 10.0.0.2 host 10.0.0.1
R2(config)#crypto map VPN-MAP 10 ipsec-isakmp
% NOTE: This new crypto map will remain disabled until a peer
and a valid access list have been configured.
R2(config-crypto-map)#set peer 10.0.0.1
R2(config-crypto-map)#set transform-set TSET
R2(config-crypto-map)#match address 100
R2(config-crypto-map)#exit
R2(config)#interface fa0/1
R2(config-if)#crypto map VPN-MAP
R2(config-if)#end
*Mar 1 00:10:42.431: %CRYPTO-6-ISAKMP_ON_OFF: ISAKMP is ON
R2#
R2#
*Mar 1 00:19:44.243: %SYS-5-CONFIG_I: Configured from console by console
R2#
Building configuration...
[OK]
R2#
```

PC2 est configuré avec **192.168.2.2** et la passerelle **192.168.2.1**.



```

Welcome to Virtual PC Simulator, version 0.6.2
Dedicated to Daling.
Build time: Apr 10 2019 02:42:20
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Source code and license can be found at vpcs.sf.net.
For more information, please visit wiki.freecode.com.cn.

Press '?' to get help.

Executing the startup file

PC1> ip 192.168.1.2 255.255.255.0 192.168.1.1
Checking for duplicate address...
PC1 : 192.168.1.2 255.255.255.0 gateway 192.168.1.1

PC1> save
Saving startup configuration to startup.vpc
. done

PC1> 
```

Figure 1: Image 18

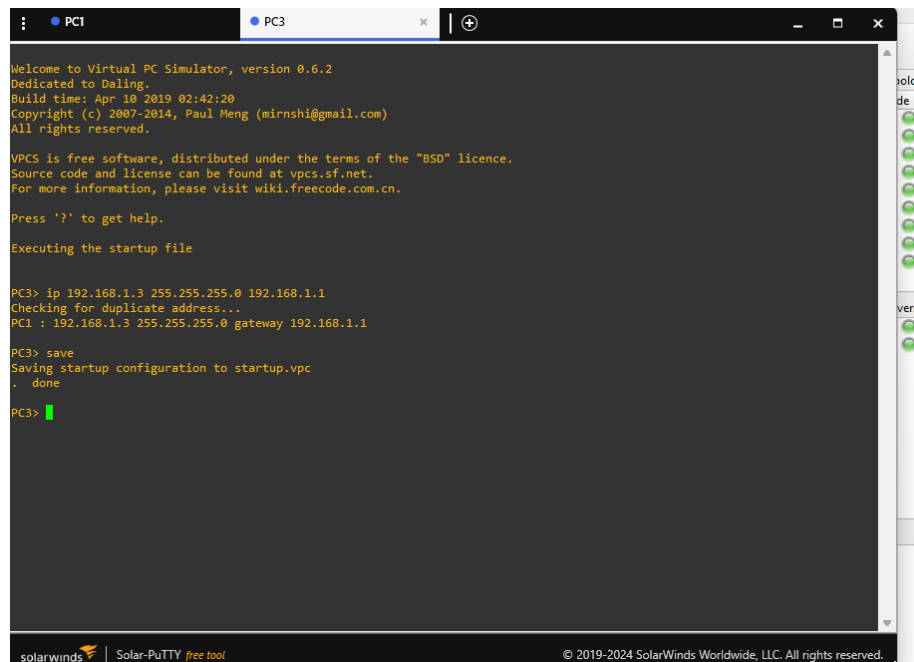
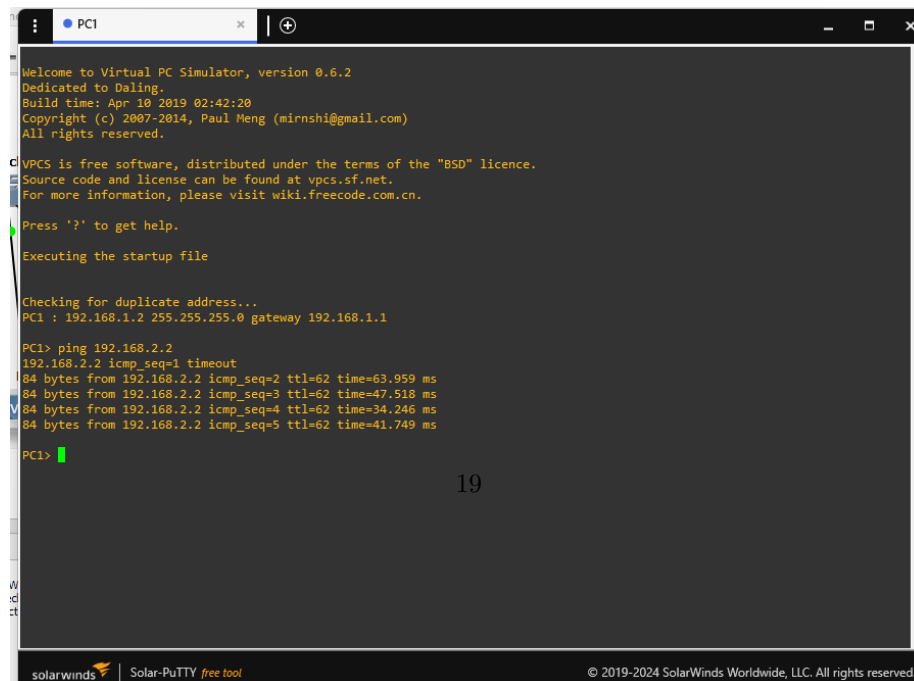


Figure 2: Image 19

6. Vérification du tunnel GRE sur R1
7. Vérification des associations IPsec et ISAKMP
8. Débogage de la connectivité tunnel
9. Test de communication avec PC1
10. Vérification finale du routage dynamique OSPF
11. Optimisation des configurations VPN et routage





```

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Press '?' to get help.

Executing the startup file

PC2> ip 192.168.2.2 255.255.255.0 192.168.2.1
Checking for duplicate address...
PC1 : 192.168.2.2 255.255.255.0 gateway 192.168.2.1

PC2> save
Saving startup configuration to startup.vpc
. done

PC2> █

```

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Figure 3: Image 20

```
R1#show crypto isakmp sa
IPv4 Crypto ISAKMP SA
dst      src      state      conn-id slot status
10.0.0.2 10.0.0.1 QM_IDLE    1001     0 ACTIVE

IPv6 Crypto ISAKMP SA

R1#show crypto ipsec sa
interface: FastEthernet0/1
  Crypto map tag: VPN-MAP, local addr 10.0.0.1

protected vrf: (none)
local ident (addr/mask/prot/port): (10.0.0.1/255.255.255.255/47/0)
remote ident (addr/mask/prot/port): (10.0.0.2/255.255.255.255/47/0)
current_peer 10.0.0.2 port 500
  PERMIT, flags={origin_is_acl,}
  #pkts encaps: 35, #pkts encrypt: 35, #pkts digest: 35
  #pkts decaps: 34, #pkts decrypt: 34, #pkts verify: 34
  #pkts compressed: 0, #pkts decompressed: 0
  #pkts not compressed: 0, #pkts compr. failed: 0
  #pkts not decompressed: 0, #pkts decompress failed: 0
  #send errors 55, #recv errors 0

local crypto endpt.: 10.0.0.1, remote crypto endpt.: 10.0.0.2
path mtu 1500, ip mtu 1500, ip mtu idb FastEthernet0/1
current outbound spi: 0x6AC48B80(1791277184)

inbound esp sas:
  spi: 0x5FE9030C(1609106188)
  transform: esp-aes esp-sha-hmac ,
  in use settings = {Tunnel, }
  conn id: 3, flow_id: SW:3, crypto map: VPN-MAP
  sa timing: remaining key lifetime (k/sec): (4412637/3354)
  IV size: 16 bytes
  replay detection support: Y
  Status: ACTIVE

inbound ah sas:
```

Figure 4: Image 21

```
R1
sa timing: remaining key lifetime (k/sec): (4412637/3354)
IV size: 16 bytes
replay detection support: Y
Status: ACTIVE

outbound ah sas:

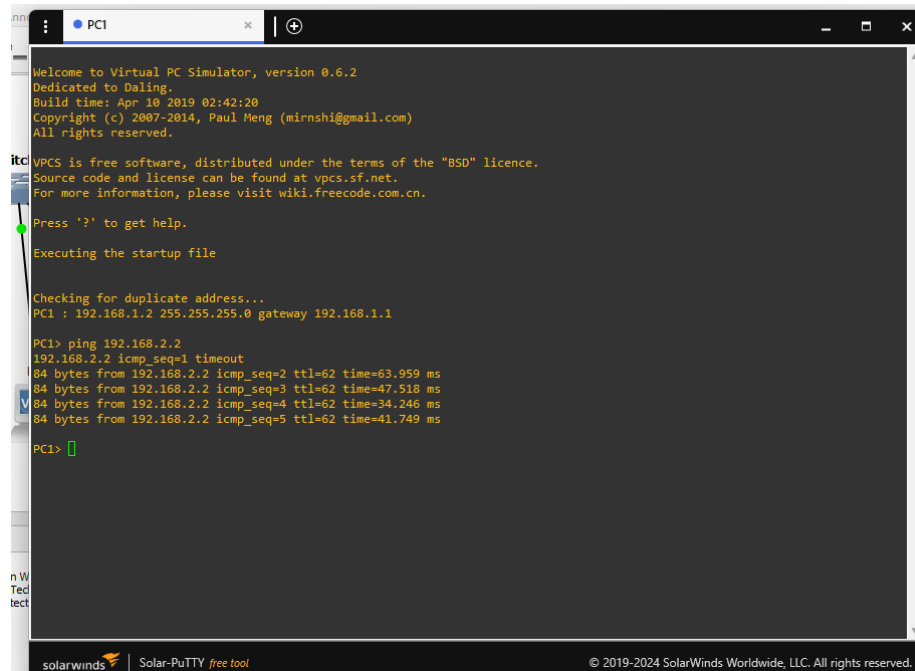
outbound pcp sas:

R1#
R1#
R1#debug crypto isakmp
Crypto ISAKMP debugging is on
R1#debug crypto ipsec
Crypto IPSEC debugging is on
R1#show interface tunnel0
Tunnel0 is up, line protocol is up
  Hardware is Tunnel
  Internet address is 192.168.100.1/24
  MTU 1514 bytes, BW 9 Kbit/sec, DLY 500000 usec,
    reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation TUNNEL, loopback not set
  Keepalive not set
  Tunnel source 10.0.0.1 (FastEthernet0/1), destination 10.0.0.2
  Tunnel protocol/transport GRE/IP
    Key disabled, sequencing disabled
    Checksumming of packets disabled
  Tunnel TTL 255
  Fast tunneling enabled
  Tunnel transmit bandwidth 8000 (kbps)
  Tunnel receive bandwidth 8000 (kbps)
  Last input 00:00:02, output 00:00:07, output hang never
  Last clearing of "show interface" counters never
  Input queue: 0/75/0/0 (size/max/drops/flushes); Total output drops: 96
  Queueing strategy: fifo
  Output queue: 0/0 (size/max)
  5 minute input rate 0 bits/sec, 0 packets/sec
  5 minute output rate 0 bits/sec, 0 packets/sec
    49 packets input, 5088 bytes, 0 no buffer
  --More--
```

Figure 5: Image 22

pour assurer une fluidité des échanges sécurisés.

12. Test de performance et validation finale



```
PC1
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For more information, please visit wiki.freecode.com.cn.

Press '?' to get help.

Executing the startup file

Checking for duplicate address...
PC1 : 192.168.1.2 255.255.255.0 gateway 192.168.1.1

PC1> ping 192.168.2.2
192.168.2.2 icmp_seq=1 timeout
84 bytes from 192.168.2.2 icmp_seq=2 ttl=62 time=63.959 ms
84 bytes from 192.168.2.2 icmp_seq=3 ttl=62 time=47.518 ms
84 bytes from 192.168.2.2 icmp_seq=4 ttl=62 time=34.246 ms
84 bytes from 192.168.2.2 icmp_seq=5 ttl=62 time=41.749 ms

PC1> 
```

Une dernière série de tests est réalisée pour valider le bon fonctionnement du **VPN GRE over IPSec avec OSPF**, confirmant que le trafic passe correctement.

Conclusion

La mise en place d'un **VPN GRE over IPSec** avec **routing dynamique OSPF** offre une solution sécurisée et flexible pour l'interconnexion des sites distants.