



5G核心網路的即時通訊應用

Instant Messaging in 5G Core Network

指導教授: 曾繁勛

組別: 3-5

組員: 張議隆 吳東驛



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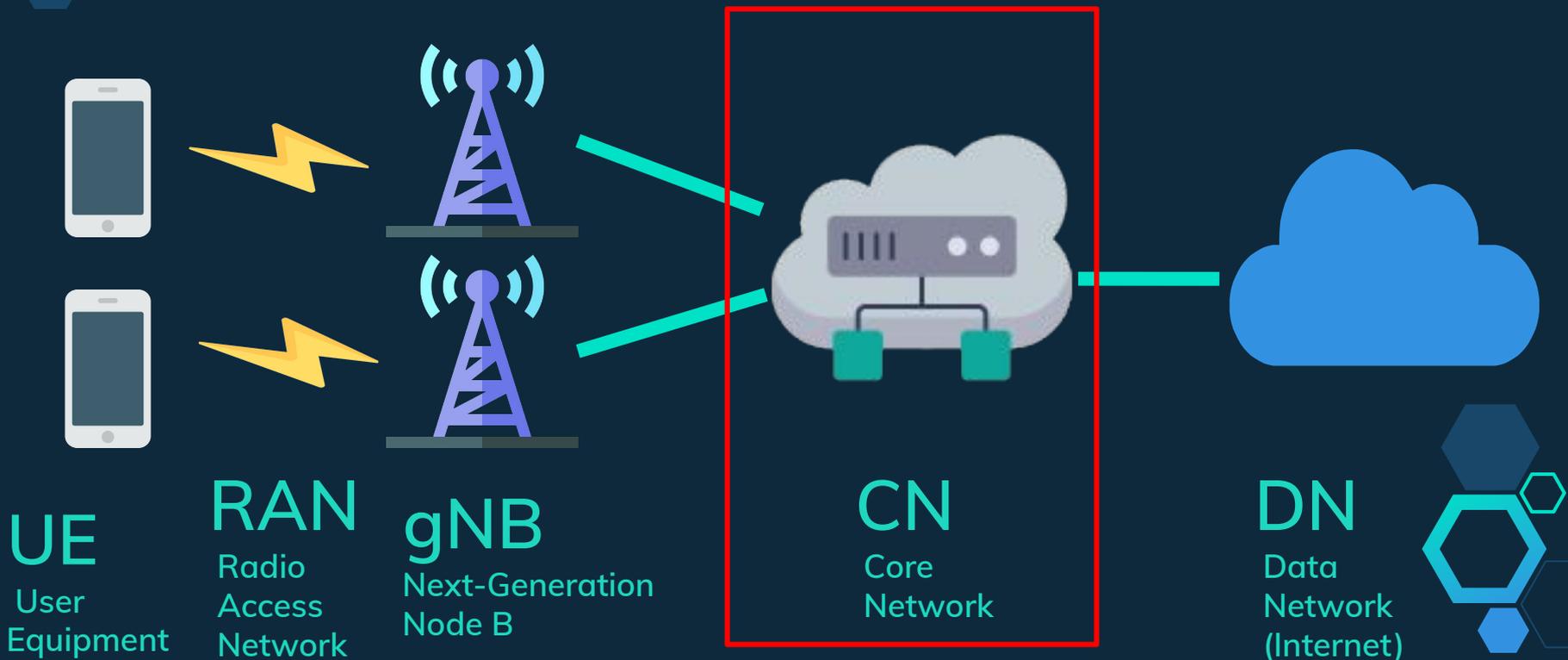


1

核心網路簡介



簡易網路架構



比較現有開放的5G CN

	 Open5GS	 OMEC OPEN MOBILE EVOLVED CORE
台灣研發 	韓國研發	國際組織
可架設實體網路	可與4G整合	功能較侷限
硬體需求低	硬體需求居中	硬體需求高
第一套開放原始碼5G核心網路	—	—

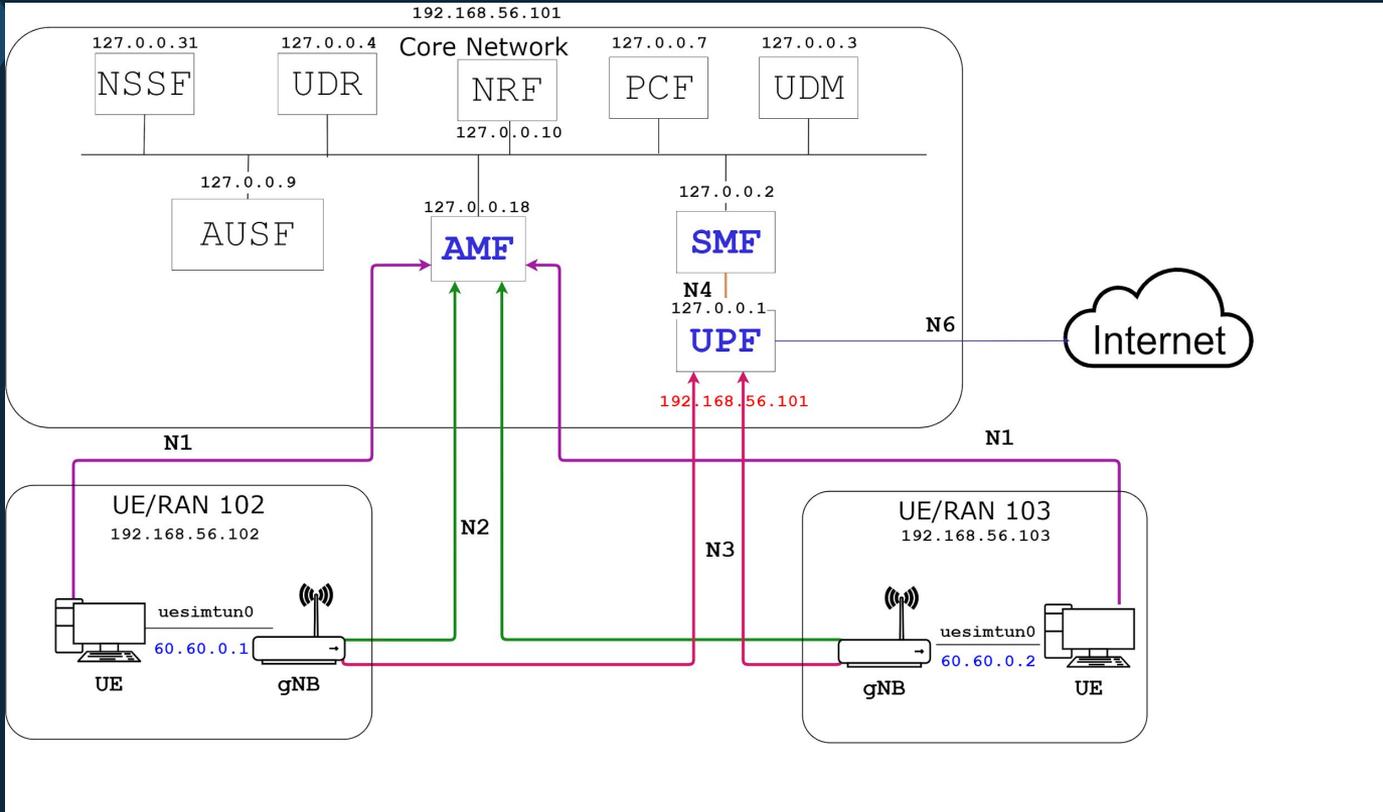


2

free5GC架構



網路系統架構圖





3

實驗過程及結果

開啟Core Network

```
ubuntu@free5gc:~$ free5GC version: v3.0.6-9-gbfe19d5
build time: 2022-01-23T12:50:08Z
commit hash: b23cd719
commit time: 2021-11-06T18:45:22Z
go version: go1.17.6 linux/amd64
2022-05-24T04:25:55Z [INFO][AUSF][Init] AUSF Log level is set to [info] level
2022-05-24T04:25:55Z [INFO][LIB][Path] set log level : info
2022-05-24T04:25:55Z [INFO][LIB][Path] set report call : false
2022-05-24T04:25:55Z [INFO][LIB][OAPI] set log level : info
2022-05-24T04:25:55Z [INFO][LIB][OAPI] set report call : false
2022-05-24T04:25:55Z [INFO][AUSF][CFG] config version [1.0.0]
2022-05-24T04:25:55Z [INFO][AUSF][Init] Server started
2022-05-24T04:25:55Z [INFO][AUSF][Init] ausfconfig Info: Version[1.0.0] Description[AUSF initial local configuration]
ausf context = &{({0 0} <nil>) map[] 0} ({0 0} <nil>) map[] 0} eec0cc81-a49c-4735-89df-7cdbc42a84fa ausfGroup001 8000 127.0.0.9 127.0.0.9 http:
//127.0.0.9:8000 http http://127.0.0.10:8000 map[nausf-auth:{eec0cc81-a49c-4735-89df-7cdbc42a84fa} nausf-auth 0xc00000cd20 http REGISTERED 0xc000
00cd08 [] <nil> [] [] <nil> 0 0 0 <nil> <nil> ]] [{208 93} {123 45}] 0xc0002c99a0 false
2022-05-24T04:25:55Z [INFO][NRF][MGMT] Handle NFRegisterRequest
2022-05-24T04:25:55Z [INFO][NRF][MGMT] urilist update
2022-05-24T04:25:55Z [INFO][NRF][MGMT] Create NF Profile
2022-05-24T04:25:55Z [INFO][NRF][MGMT] Location header: http://127.0.0.10:8000/nrf-nfm/v1/nf-instances/eec0cc81-a49c-4735-89df-7cdbc42a84fa
2022-05-24T04:25:55Z [INFO][NRF][GIN] | 201 | 127.0.0.1 | PUT | /nrf-nfm/v1/nf-instances/eec0cc81-a49c-4735-89df-7cdbc42a84fa |
2022-05-24T04:25:56Z [INFO][N3IWF][App] n3iwf
2022-05-24T04:25:56Z [INFO][N3IWF][App] N3IWF version:
free5GC version: v3.0.6-9-gbfe19d5
build time: 2022-01-23T12:51:02Z
commit hash: c85645f2
commit time: 2021-10-22T11:59:18Z
go version: go1.17.6 linux/amd64
2022-05-24T04:25:56Z [INFO][N3IWF][Init] N3IWF Log level is set to [debug] level
2022-05-24T04:25:56Z [INFO][LIB][NGAP] set log level : info
2022-05-24T04:25:56Z [INFO][LIB][NGAP] set report call : false
2022-05-24T04:25:56Z [INFO][LIB][Aper] set log level : info
2022-05-24T04:25:56Z [INFO][LIB][Aper] set report call : false
2022-05-24T04:25:56Z [INFO][LIB][Path] set log level : info
2022-05-24T04:25:56Z [INFO][LIB][Path] set report call : false
2022-05-24T04:25:56Z [INFO][N3IWF][CFG] config version [1.0.0]
2022-05-24T04:25:56Z [INFO][N3IWF][Init] Server started
2022-05-24T04:25:56Z [WARN][N3IWF][Context] No private key file path specified, load default key file...
2022-05-24T04:25:56Z [WARN][N3IWF][Context] Parse PKCS8 private key failed: x509: failed to parse private key (use ParsePKCS1PrivateKey instead fo
r this key format)
2022-05-24T04:25:56Z [INFO][N3IWF][Context] Parse using PKCS1...
2022-05-24T04:25:56Z [WARN][N3IWF][Context] No certificate authority file path specified, load default CA certificate...
2022-05-24T04:25:56Z [WARN][N3IWF][Context] No certificate file path specified, load default certificate...
[0] 0:bash: !pbash* "free5gc" 04:26 24-May-22
```

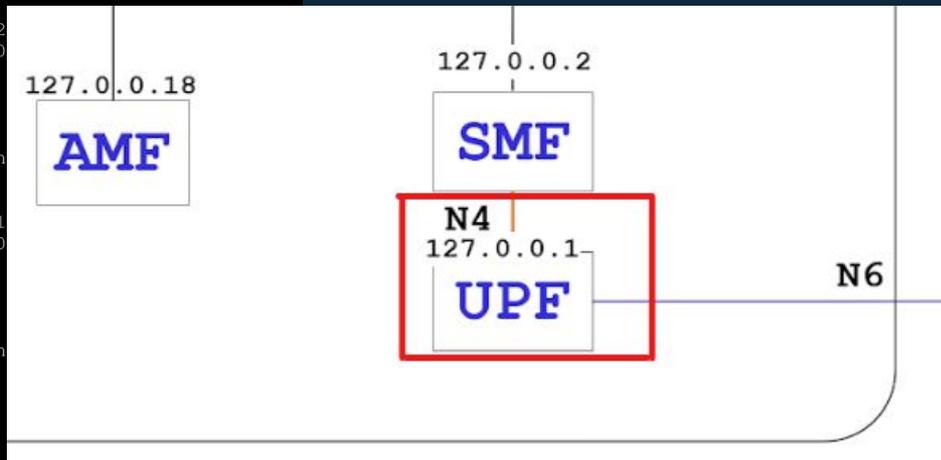
CN 虛擬機介面卡

```
ubuntu@free5gc:~/free5gc$ ifconfig
enp0s3: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 10.0.2.15 netmask 255.255.255.0 broadcast 10.0.2.255
    inet6 fe80::a00:27ff:feca:90da prefixlen 64 scopeid 0<link>
    ether 08:00:27:ca:90:da txqueuelen 1000 (Ethernet)
    RX packets 43 bytes 13070 (13.0 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 55 bytes 5918 (5.9 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collision 0

enp0s8: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 192.168.56.101 netmask 255.255.255.0 broadcast 192.168.56.255
    inet6 fe80::a00:27ff:fe2b:afa5 prefixlen 64 scopeid 0<link>
    ether 08:00:27:2b:af:a5 txqueuelen 1000 (Ethernet)
    RX packets 1162 bytes 95520 (95.5 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 1501 bytes 278691 (278.6 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collision 0

lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
    inet 127.0.0.1 netmask 255.0.0.0
    inet6 ::1 prefixlen 128 scopeid 0x10<host>
    loop txqueuelen 1000 (Local Loopback)
    RX packets 1477 bytes 351534 (351.5 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 1477 bytes 351534 (351.5 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

upf1tp: flags=4305<UP,POINTOPOINT,RUNNING,NOARP,MULTICAST> mtu 1500
    inet6 fe80::bdb7:3a5e:4173:cc37 prefixlen 64 scopeid 0x20<link>
    unspec 00-00-00-00-00-00-00-00-00-00-00-00-00-00-00-00 txqueuelen 1000 (UNSPEC)
    RX packets 0 bytes 0 (0.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 0 bytes 0 (0.0 B)
    TX errors 2 dropped 0 overruns 0 carrier 0 collisions 0
```



設置 UE 102

```
ubuntu@ue102:~$ ./UERANSIMS build/nr-gnb -c config/free5gc-gnb.yaml
UERANSIM v3.2.6
[2022-05-18 17:25:09.112] [sctp] [info] Trying to establish SCTP connection... (192.168.56.101:38412)
[2022-05-18 17:25:09.119] [sctp] [info] SCTP connection established (192.168.56.101:38412)
[2022-05-18 17:25:09.119] [sctp] [debug] SCTP association setup ascId[10]
[2022-05-18 17:25:09.119] [ngap] [debug] Sending NG Setup Request
[2022-05-18 17:25:09.123] [ngap] [debug] NG Setup Response received
[2022-05-18 17:25:09.123] [ngap] [info] NG Setup procedure is successful
[2022-05-18 17:25:23.272] [rrc] [debug] UE[1] new signal detected
[2022-05-18 17:25:23.280] [rrc] [info] RRC Setup for UE[1]
[2022-05-18 17:25:23.280] [ngap] [debug] Initial NAS message received from UE[1]
[2022-05-18 17:25:23.457] [ngap] [debug] Initial Context Setup Request received
[2022-05-18 17:25:23.816] [ngap] [info] PDU session resource(s) setup for UE[1] count[1]
total [1] cells in coverage
[2022-05-18 17:25:23.273] [nas] [info] UE switches to state [MM-DEREGISTERED/PLMN-SEARCH]
[2022-05-18 17:25:23.274] [nas] [info] Selected plmn[208/93]
[2022-05-18 17:25:23.274] [rrc] [info] Selected cell plmn[208/93] tac[1] category[SUITABLE]
[2022-05-18 17:25:23.274] [nas] [info] UE switches to state [MM-DEREGISTERED/PS]
[2022-05-18 17:25:23.275] [nas] [info] UE switches to state [MM-DEREGISTERED/NORMAL-SERVICE]
[2022-05-18 17:25:23.275] [nas] [debug] Initial registration required due to [MM-DEREG-NORMAL-SERVICE]
[2022-05-18 17:25:23.279] [nas] [debug] UAC access attempt is allowed for identity[0], category[MO_sig]
[2022-05-18 17:25:23.279] [nas] [debug] Sending Initial Registration
[2022-05-18 17:25:23.279] [rrc] [debug] Sending RRC Setup Request
[2022-05-18 17:25:23.280] [rrc] [info] RRC connection established
[2022-05-18 17:25:23.280] [rrc] [info] UE switches to state [RRC-CONNECTED]
[2022-05-18 17:25:23.280] [nas] [info] UE switches to state [MM-REGISTER-INITIATED]
[2022-05-18 17:25:23.280] [nas] [info] UE switches to state [CM-CONNECTED]
[2022-05-18 17:25:23.360] [nas] [debug] A
[2022-05-18 17:25:23.376] [nas] [debug] S
[2022-05-18 17:25:23.377] [nas] [debug] S
[2022-05-18 17:25:23.458] [nas] [debug] R
[2022-05-18 17:25:23.458] [nas] [info] UE switches to state [MM-REGISTERED/NORMAL-SERVICE]
[2022-05-18 17:25:23.459] [nas] [debug] Sending Registration Complete
[2022-05-18 17:25:23.460] [nas] [info] Initial Registration is successful
[2022-05-18 17:25:23.461] [nas] [debug] Sending PDU Session Establishment Request
[2022-05-18 17:25:23.462] [nas] [debug] UAC access attempt is allowed for identity[0], category[MO_sig]
[2022-05-18 17:25:23.804] [nas] [debug] PDU Session Establishment Accept received
[2022-05-18 17:25:23.805] [nas] [info] PDU Session establishment is successful PSI[1]
[2022-05-18 17:25:23.835] [app] [info] Connection setup for PDU session[1] is successful, TUN interface[uesimtun0, 60.60.0.1] is up.
```

gNB 102

UE 102



UE 102網路介面卡

```
ubuntu@uel02:~$ ifconfig
enp0s8: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 192.168.56.102 netmask 255.255.255.0 broadcast 192.168.56.255
    inet6 fe80::a00:27ff:fed2:fb9b prefixlen 64 scopeid 0x20<link>
    ether 08:00:27:d2:fb:9b txqueuelen 1000 (Ethernet)
    RX packets 942810 bytes 142481999 (142.4 MB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 446489 bytes 105899668 (105.8 MB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
    inet 127.0.0.1 netmask 255.0.0.0
    inet6 ::1 prefixlen 128 scopeid 0x10<host>
    loop txqueuelen 1000 (Local Loopback)
    RX packets 150461 bytes 8164414 (8.1 MB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 150461 bytes 8164414 (8.1 MB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

uesimtun0: flags=369<UP,POINTOPOINT,NOTRAILERS,RUNNING,PROMISC> mtu 1400
    inet 60.60.0.1 netmask 255.255.255.255 destination 60.60.0.1
    inet6 fe80::22eb:f104:cd76:8e70 prefixlen 64 scopeid 0x20<link>
    unspec 00-00-00-00-00-00-00-00-00-00-00-00-00-00-00-00 txqueuelen 500 (UNSPEC)
    RX packets 0 bytes 0 (0.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 15 bytes 832 (832.0 B)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
```



設置 UE 103

```
ubuntu@ue103:~$ cd ~/UERANSIMS; build/nr-gnb -c config/free5gc-gnb.yaml
UERANSIM v3.2.6
[2022-05-24 04:30:44.628] [sctp] [info] Trying to establish SCTP connection... (192.168.56.101:38412)
[2022-05-24 04:30:44.635] [sctp] [info] SCTP connection established (192.168.56.101:38412)
[2022-05-24 04:30:44.635] [sctp] [debug] SCTP association setup ascId[9]
[2022-05-24 04:30:44.635] [ngap] [debug] Sending NG Setup Request
[2022-05-24 04:30:44.638] [ngap] [debug] NG Setup Response received
[2022-05-24 04:30:44.638] [ngap] [info] NG Setup procedure is successful
[2022-05-24 04:30:52.228] [rrc] [debug] UE[1] new signal detected
[2022-05-24 04:30:52.234] [rrc] [info] RRC Setup for UE[1]
[2022-05-24 04:30:52.235] [ngap] [debug] Initial NAS message received from UE[1]
[2022-05-24 04:30:52.303] [ngap] [debug] Initial Context Setup Request received
[2022-05-24 04:30:52.614] [ngap] [info] PDU session resource(s) setup for UE[1] count[1]
[2022-05-24 04:30:52.229] [nas] [info] UE switches to state [MM-DEREGISTERED/PLMN-SEARCH]
[2022-05-24 04:30:52.229] [nas] [info] Selected plmn[208/93]
[2022-05-24 04:30:52.229] [rrc] [info] Selected cell plmn[208/93] tac[1] category[SUITABLE]
[2022-05-24 04:30:52.230] [nas] [info] UE switches to state [MM-DEREGISTERED/PS]
[2022-05-24 04:30:52.230] [nas] [info] UE switches to state [MM-DEREGISTERED/NORMAL-SERVICE]
[2022-05-24 04:30:52.230] [nas] [debug] Initial registration required due to [MM-DEREG-NORMAL-SERVICE]
[2022-05-24 04:30:52.233] [nas] [debug] UAC access attempt is allowed for identity[0], category[MO_sig]
[2022-05-24 04:30:52.234] [nas] [debug] Sending Initial Registration
[2022-05-24 04:30:52.234] [rrc] [debug] Sending RRC Setup Request
[2022-05-24 04:30:52.235] [rrc] [info] RRC connection established
[2022-05-24 04:30:52.235] [rrc] [info] UE switches to state [RRC-CONNECTED]
[2022-05-24 04:30:52.236] [nas] [info] UE switches to state [MM-REGISTER-INITIATED]
[2022-05-24 04:30:52.236] [nas] [info] UE switches to state [CM-CONNECTED]
[2022-05-24 04:30:52.263] [nas] [debug] A
[2022-05-24 04:30:52.269] [nas] [debug] S
[2022-05-24 04:30:52.269] [nas] [debug] S
[2022-05-24 04:30:52.304] [nas] [debug] R
[2022-05-24 04:30:52.305] [nas] [info] UE switches to state [MM-REGISTERED/NORMAL-SERVICE]
[2022-05-24 04:30:52.306] [nas] [debug] Sending Registration Complete
[2022-05-24 04:30:52.307] [nas] [info] Initial Registration is successful
[2022-05-24 04:30:52.307] [nas] [debug] Sending PDU Session Establishment Request
[2022-05-24 04:30:52.308] [nas] [debug] UAC access attempt is allowed for identity[0], category[MO_sig]
[2022-05-24 04:30:52.602] [nas] [debug] PDU Session Establishment Accept received
[2022-05-24 04:30:52.602] [nas] [info] PDU Session establishment is successful PSI[1]
[2022-05-24 04:30:52.632] [app] [info] Connection setup for PDU session[1] is successful, TUN interface[uesimtun0, 60.60.0.2] is up.
[0] 0:bash: t:psudo* "ue103" 04:30 24-May-22
```

gNB 103

UE 103



UE 103 網路介面卡

```
ubuntu@uel103:~/socket$ ifconfig
enp0s8: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 192.168.56.103 netmask 255.255.255.0 broadcast 192.168.56.255
    inet6 fe80::a00:27ff:fea7:2fe8 prefixlen 64 scopeid 0x20<link>
    ether 08:00:27:a7:2f:e8 txqueuelen 1000 (Ethernet)
    RX packets 179404 bytes 12182113 (12.1 MB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 552792 bytes 90894420 (90.8 MB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
    inet 127.0.0.1 netmask 255.0.0.0
    inet6 ::1 prefixlen 128 scopeid 0x10<host>
    loop txqueuelen 1000 (Local Loopback)
    RX packets 134192 bytes 7289778 (7.2 MB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 134192 bytes 7289778 (7.2 MB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

uesimtun0: flags=369<UP,POINTOPOINT,NOTRAILERS,RUNNING,PROMISC> mtu 1400
    inet 60.60.0.2 netmask 255.255.255.255 destination 60.60.0.2
    inet6 fe80::a398:b13b:7e60:3a5e prefixlen 64 scopeid 0x20<link>
    unspec 00-00-00-00-00-00-00-00-00-00-00-00-00-00-00-00 txqueuelen 500 (UNSPEC)
    RX packets 0 bytes 0 (0.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 9 bytes 544 (544.0 B)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
```



封包檢測工具:tshark

The logo for Wireshark, featuring a stylized shark fin above the word "WIRESHARK" in a bold, sans-serif font.

WIRESHARK

參數	-i <interface>	-t <format>
參數意義	選擇介面卡	更改輸出時間格式

透過CN互ping

```
ubuntu@free5gc:~$ sudo tshark -i upfgtp -t a
Running as user "root" and group "root". This could be dangerous.
Capturing on 'upfgtp'
  1 07:20:49.871911913    60.60.0.1 -> 60.60.0.2    ICMP 84 Echo (ping)
request id=0x0052, seq=1/256, ttl=64
  2 07:20:49.872021395    60.60.0.1 -> 60.60.0.2    ICMP 84 Echo (ping)
request id=0x0052, seq=1/256, ttl=63
  3 07:20:49.873179177    60.60.0.2 -> 60.60.0.1    ICMP 84 Echo (ping)
reply id=0x0052, seq=1/256, ttl=64 (request in 2)
  4 07:20:49.873238867    10.0.2.15 -> 60.60.0.2    ICMP 112 Redirect
(Redirect for host)
  5 07:20:49.873261211    60.60.0.2 -> 60.60.0.1    ICMP 84 Echo (ping)
reply id=0x0052, seq=1/256, ttl=63
```

CN upfgtp

```
ubuntu@ue102:~/socket$ ping -I uesimtun0 60.60.0.2 -c 1
PING 60.60.0.2 (60.60.0.2) from 60.60.0.1 uesimtun0: 56(84) bytes of data
64 bytes from 60.60.0.2: icmp_seq=1 ttl=63 time=2.47 ms

--- 60.60.0.2 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 2.465/2.465/2.465/0.000 ms
ubuntu@ue102:~/socket$
```

UE 102
ping
UE 103

```
ubuntu@ue102:~$ sudo tshark -i uesimtun0 -t a
Running as user "root" and group "root". This could be dangerous.
Capturing on 'uesimtun0'
  1 07:20:49.823742131    60.60.0.1 -> 60.60.0.2    ICMP 84 Echo (ping)
request id=0x0052, seq=1/256, ttl=64
  2 07:20:49.826194082    60.60.0.2 -> 60.60.0.1    ICMP 84 Echo (ping)
reply id=0x0052, seq=1/256, ttl=63 (request in 1)
  3 07:20:50.840209136 fe80::58c:d4c7:fce5:36 -> ff02::2    ICMPv6 48
Router Solicitation
```

UE 102
uesimtun0

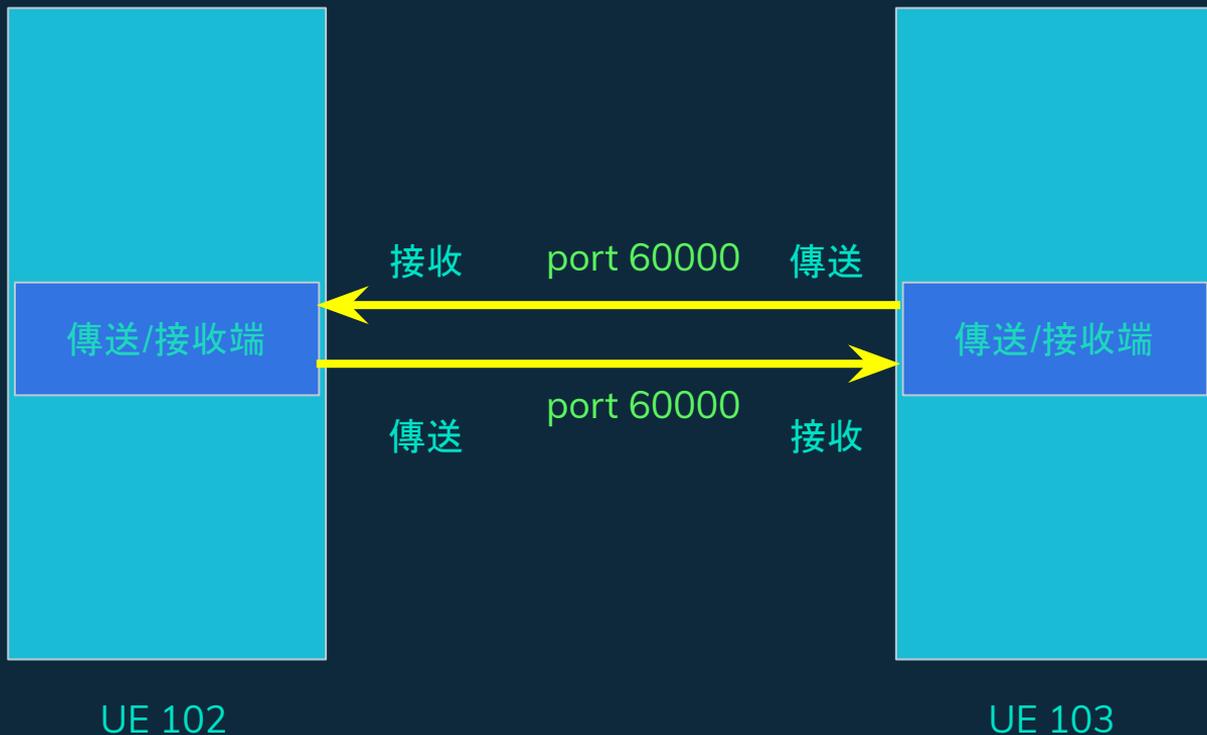
```
ubuntu@ue103:~$ sudo tshark -i uesimtun0 -t a
Running as user "root" and group "root". This could be dangerous.
Capturing on 'uesimtun0'
  1 07:20:49.867607267    60.60.0.1 -> 60.60.0.2    ICMP 84 Echo (ping)
request id=0x0052, seq=1/256, ttl=63
  2 07:20:49.867624960    60.60.0.2 -> 60.60.0.1    ICMP 84 Echo (ping)
reply id=0x0052, seq=1/256, ttl=64 (request in 1)
  3 07:20:49.868625478    10.0.2.15 -> 60.60.0.2    ICMP 112 Redirect
(Redirect for host)
```

UE 103
uesimtun0

[0] 0:~\$ 1:sudo- 2:~\$ 3:~\$

"ue102" 07:20 24-May-22

通過CN實現即時通訊(IM)



藉由IM傳送訊息

```
ubuntu@free5gc:~$ sudo tshark -i upfgtp -t a
Running as user "root" and group "root". This could be dangerous.
Capturing on 'upfgtp'
  1 07:50:44.430627594    60.60.0.1 → 60.60.0.2    TCP 59 60142 → 60000
    [PSH, ACK] Seq=1 Ack=1 Win=510 Len=7 TSval=255852167 TSecr=2282608875
  2 07:50:44.430671043    10.0.2.15 → 60.60.0.1    ICMP 87 Redirect
    (Redirect for host)
  3 07:50:44.430687636    60.60.0.1 → 60.60.0.2    TCP 59 [TCP Retransmission] 60142 → 60000 [PSH, ACK] Seq=1 Ack=1 Win=510 Len=7 TSval=255852167 TSecr=2282608875
  4 07:50:44.431796082    60.60.0.2 → 60.60.0.1    TCP 52 60000 → 60142
    [ACK] Seq=1 Ack=8 Win=506 Len=0 TSval=2282631900 TSecr=255852167
  5 07:50:44.431822964    10.0.2.15 → 60.60.0.2    ICMP 80 Redirect
    (Redirect for host)
  6 07:50:44.431835915    60.60.0.2 → 60.60.0.1    TCP 52 [TCP Dup ACK 4#1] 60000 → 60142 [ACK] Seq=1 Ack=8 Win=506 Len=0 TSval=2282631900 TSecr=255852167
```

CN upfgtp

```
ubuntu@ue102:~$ sudo tshark -i uesimtun0 -t a
Running as user "root" and group "root". This could be dangerous.
Capturing on 'uesimtun0'
  1 07:50:44.338431664    60.60.0.1 → 60.60.0.2    TCP 59 60142 → 6000
  0 [PSH, ACK] Seq=1 Ack=1 Win=510 Len=7 TSval=255852167 TSecr=2282608875
  2 07:50:44.339060211    10.0.2.15 → 60.60.0.1    ICMP 87 Redirect
    (Redirect for host)
  3 07:50:44.340207777    60.60.0.2 → 60.60.0.1    TCP 52 60000 → 6014
  2 [ACK] Seq=1 Ack=8 Win=506 Len=0 TSval=2282631900 TSecr=255852167
```

UE 102
uesimtun0

```
waiting for connection
connection setup
m for message, f for file, exit to exit program:
m
Enter message: testing
Enter message: █
```

UE 102
傳輸文字

```
ubuntu@ue103:~/socket$ sudo tshark -i uesimtun0 -t a
Running as user "root" and group "root". This could be dangerous.
Capturing on 'uesimtun0'
  1 07:50:44.403228908    60.60.0.1 → 60.60.0.2    TCP 59 60142 → 6000
  0 [PSH, ACK] Seq=1 Ack=1 Win=510 Len=7 TSval=255852167 TSecr=2282608875
  2 07:50:44.403238973    60.60.0.2 → 60.60.0.1    TCP 52 60000 → 6014
  2 [ACK] Seq=1 Ack=8 Win=506 Len=0 TSval=2282631900 TSecr=255852167
  3 07:50:44.404229436    10.0.2.15 → 60.60.0.2    ICMP 80 Redirect
    (Redirect for host)
```

UE 103
uesimtun0

```
waiting for connection
connection setup
m for message, f for file, exit to exit program:
Incoming message: testing
```

UE 103
接收文字

藉由IM傳送檔案

```
091 TSecr=260557292
537 09:09:09.601093392 60.60.0.2 → 60.60.0.1 TCP 52 60000 → 60166
[ACK] Seq=14 Ack=198185 Win=1779 Len=0 TSval=2287337092 TSecr=260557293
538 09:09:09.601113904 60.60.0.2 → 60.60.0.1 TCP 52 [TCP Dup ACK
537#1] 60000 → 60166 [ACK] Seq=14 Ack=198185 Win=1779 Len=0 TSval=2287337
092 TSecr=260557293
539 09:09:09.601712814 60.60.0.2 → 60.60.0.1 TCP 52 60000 → 60166
[ACK] Seq=14 Ack=200881 Win=1779 Len=0 TSval=2287337093 TSecr=260557295
540 09:09:09.601733641 60.60.0.2 → 60.60.0.1 TCP 52 [TCP Dup ACK
539#1] 60000 → 60166 [ACK] Seq=14 Ack=200881 Win=1779 Len=0 TSval=2287337
093 TSecr=260557295
541 09:09:09.602306735 60.60.0.2 → 60.60.0.1 TCP 52 60000 → 60166
[ACK] Seq=14 Ack=203577 Win=1779 Len=0 TSval=2287337093 TSecr=260557296
542 09:09:09.602327069 60.60.0.2 → 60.60.0.1 TCP 52 [TCP Dup ACK
541#1] 60000 → 60166 [ACK] Seq=14 Ack=203577 Win=1779 Len=0 TSval=2287337
093 TSecr=260557296
543 09:09:09.602834299 60.60.0.2 → 60.60.0.1 TCP 52 60000 → 60166
[ACK] Seq=14 Ack=204826 Win=1779 Len=0 TSval=2287337094 TSecr=260557299
544 09:09:09.602860425 60.60.0.2 → 60.60.0.1 TCP 52 [TCP Dup ACK
543#1] 60000 → 60166 [ACK] Seq=14 Ack=204826 Win=1779 Len=0 TSval=2287337
094 TSecr=260557296
```

CN upfgtp

UE 102

uesimtun0

```
[sudo] password for ubuntu:
waiting for connection
connection setup
m for message, f for file, exit to exit program:
f
enter filename: pi 200K.txt
file does NOT exist!, aborting
enter filename: pi 204K.txt
File transmission complete
enter filename: █
```

UE 102
傳輸檔案

```
[sudo] password for ubuntu:
waiting for connection
connection setup
m for message, f for file, exit to exit program:
File transmission complete
```

UE 103
接收檔案

```
000 [PSH, ACK] Seq=199533 Ack=14 Win=510 Len=1348 TSval=260557295 TSecr=
2287337080
267 09:09:09.596078338 60.60.0.2 → 60.60.0.1 TCP 52 60000 → 60166
6 [ACK] Seq=14 Ack=200881 Win=1779 Len=0 TSval=2287337093 TSecr=260557299
5
268 09:09:09.596537168 60.60.0.1 → 60.60.0.2 TCP 1400 60166 → 60
000 [ACK] Seq=200881 Ack=14 Win=510 Len=1348 TSval=260557296 TSecr=22873
37083
269 09:09:09.596660380 60.60.0.1 → 60.60.0.2 TCP 1400 60166 → 60
000 [ACK] Seq=202229 Ack=14 Win=510 Len=1348 TSval=260557296 TSecr=22873
37083
270 09:09:09.596667408 60.60.0.2 → 60.60.0.1 TCP 52 60000 → 60166
6 [ACK] Seq=14 Ack=203577 Win=1779 Len=0 TSval=2287337094 TSecr=260557299
6
271 09:09:09.597139109 60.60.0.1 → 60.60.0.2 TCP 52 60000 → 60166
000 [PSH, ACK] Seq=203577 Ack=14 Win=510 Len=1348 TSval=260557296 TSecr=
2287337083
272 09:09:09.597168512 60.60.0.2 → 60.60.0.1 TCP 52 60000 → 60166
6 [ACK] Seq=14 Ack=204826 Win=1779 Len=0 TSval=2287337094 TSecr=260557299
6
```

UE 103

uesimtun0

A decorative graphic on the left side of the slide consists of several hexagons of varying sizes and shades of blue and cyan. Some hexagons contain white icons: a lightbulb, a thumbs-up, a smartphone, a magnifying glass, and a gear. There is also a network-like icon with a central node and four connecting lines. The background is a dark blue gradient.

感謝聆聽