

- What do I do?

- Network topology (附註在程式裡)

- 創建 LTE 網路的主要流程 (有附註在程式旁針對每個 Class 進行解釋)

1. 建立 LteHelper 與 EPC object，並在建立 LTE 無線接入網路時一起設置 EPC 網路。
2. 透過 EPC object 自動創建和配置 PGW。
3. 創建 remotehost 節點並安裝 internet 協議。
4. 創建 p2ph 設備並安裝 PGW、remotehost。
5. 設置 remotehost 使用公共網路 7.0.0.0 以路由到 UE。
6. 創建 UE、eNB 節點，並為節點配置移動模型。
7. 為在 Ue 及 eNB 裝載 LTE 設備，並分配 IP address 給 Ue。
8. 安裝 UDP downlink/uplink app 在 Ue 上。
9. 在到 PGW 的 EPS bearer 上創建專屬的 TFT(traffic flow template)。
10. 每秒依序將 Ue attach 到 eNB 上。

- implement the project requirement

Each UE should be scheduled to **attach to eNodeB in every second**

1. 創建 Attach function 將每個 Ue attach 到 eNB 上。
2. 在 main function 中，使用 for 迴圈與 Simulator::Schedule 設定每秒去觸發 Attach function 以將每個 Ue attach 到 eNB 上。此外，有額外透過變數及限制條件讓 Ue 能夠平均的 attach 到不同的 eNB 上。

- Observe the command lines (以下根據較為特殊的進行解釋，重複部分便不再多加贅述)

```
+0.129214s /NodeList/6/DeviceList/0/LteUEBrc/ConnectionEstablished UE IMSI 1: connected to cell id 1 with RNTI 6
+0.129214s /NodeList/4/DeviceList/0/LteEnBrc/ConnectionEstablished eNB cell id 1: successful connection of UE with IMSI 1 RNTI 6
+0.13s IMSI 0, RNTI 4, Cell id 1, ENB RRC ConnectionRequestTimeout
+1.3e+08ns IMSI 0, RNTI 4, Cell id 1, UE context destroyed at eNodeB
+0.136s IMSI 0, RNTI 5, Cell id 1, ENB RRC ConnectionRequestTimeout
+1.36e+08ns IMSI 0, RNTI 5, Cell id 1, UE context destroyed at eNodeB
+0.440001s /NodeList/4/DeviceList/0/LteEnBrc/HandoverStart eNB Cellid 1: start handover of UE with IMSI 1 RNTI 6 to Cellid 2
+0.440001s UE with IMSI 1 RNTI 6 connected to cell 1 transitions from CONNECTED_NORMALLY to CONNECTED_HANDOVER
+0.440001s /NodeList/6/DeviceList/0/LteUEBrc/HandoverStart UE IMSI 1: previously connected to Cellid 1 with RNTI 6, doing handover to Cellid 2
+0.444214s UE with IMSI 1 RNTI 1 connected to cell 2 transitions from CONNECTED_HANDOVER to CONNECTED_NORMALLY
+0.444214s /NodeList/6/DeviceList/0/LteUEBrc/HandoverEndOk UE IMSI 1: successful handover to Cellid 2 with RNTI 1
+0.444215s /NodeList/5/DeviceList/0/LteEnBrc/HandoverEndOk eNB Cellid 2: completed handover of UE with IMSI 1 RNTI 1
+4.44215e+08ns IMSI 1, RNTI 6, Cell id 1, UE context destroyed at eNodeB
+1s UE with IMSI 2 RNTI 0 connected to cell 1 transitions from IDLE_START to IDLE_WAIT_MIB
+1.05021s UE with IMSI 2 RNTI 0 connected to cell 1 transitions from IDLE_WAIT_MIB to IDLE_CAMPED_NORMALLY
+1.05021s UE with IMSI 2 RNTI 0 connected to cell 1 transitions from IDLE_CAMPED_NORMALLY to IDLE_WAIT_SIB2
+1.056s UE with IMSI 2 RNTI 0 connected to cell 1 transitions from IDLE_WAIT_SIB2 to IDLE_RANDOM_ACCESS
+1.062s IMSI 2, Contention flag 1, preamble Tx Counter 1, Max Preamble Tx Limit 51, UE RA response timeout
+1.068s IMSI 2, Contention flag 1, preamble Tx Counter 2, Max Preamble Tx Limit 51, UE RA response timeout
+1.073s IMSI 0, RNTI 7, Cell id 1, ENB RRC ConnectionRequestTimeout
+1.073e+09ns IMSI 0, RNTI 7, Cell id 1, UE context destroyed at eNodeB
+1.074s IMSI 2, Contention flag 1, preamble Tx Counter 3, Max Preamble Tx Limit 51, UE RA response timeout
+1.078s IMSI 0, RNTI 8, Cell id 1, ENB RRC ConnectionRequestTimeout
```

紅色部分：在第 0 秒也就是一開始時，Ue(IMSI:1)與 eNB(cell id:1)透過 RNTI(6)成功進行連接，表示 Ue 有成功 attach 到 eNB 上並建立 RRC Connection。

黃色部份：在一般 Attach 的過程中，Ue 要能進行傳送之前，需要先做 Random Access，在 eNB 進行回應後，才能做 RRC Connection，而因為在前面 Ue(IMSI:0)與 eNB 並沒有進行 Attach 所以這邊的操作結果都是失敗 (Timeout)。

綠色部分：Ue(IMSI:1)開始嘗試要換手至 eNB(cell id:2)，因此在 Ue(IMSI:1)與 eNB(cell id:1)的連線 RNTI(6)會將狀態從一般轉換為換手模式，而 Ue(IMSI:1)與 eNB(cell id:2)要建立的 RNTI(1)會從換手模式切換為一般模式，如此 Ue 的換手便成功執行了，最後需要再將 Ue(IMSI:1)在 eNB(cell id:1)上的內容進行銷毀。

藍色部分：如同黃色部分一樣，因為 Ue(IMSI:2)並未與 eNB 進行 attach 與 RRC Connection，所以這部分的結果都為 timeout。

```
+1.08321s /NodeList/4/DeviceList/0/LteEnBrc/ConnectionEstablished eNB cell id 1: successful connection of UE with IMSI 2 RNTI 11
+1.084e+09ns IMSI 0, RNTI 9, Cell id 1, UE context destroyed at eNodeB
+1.09s IMSI 0, RNTI 10, Cell id 1, ENB RRC ConnectionRequestTimeout
+1.09e+09ns IMSI 0, RNTI 10, Cell id 1, UE context destroyed at eNodeB
+1.28321s IMSI 2, RNTI 11, Cell id 1, Notify out of sync, no of sync indications: 1
+1.32921e+09ns IMSI 1, RNTI 1, Cell id 2, radio link failure detected
+1.32921s UE with IMSI 1 RNTI 1 connected to cell 2 transitions from CONNECTED_NORMALLY to CONNECTED_PHY_PROBLEM
+1.32921s UE with IMSI 1 RNTI 1 connected to cell 2 transitions from CONNECTED_PHY_PROBLEM to IDLE_START
+1.32921s UE with IMSI 1 RNTI 1 connected to cell 2 transitions from IDLE_START to IDLE_CELL_SEARCH
+1.4s UE with IMSI 1 RNTI 0 connected to cell 0 transitions from IDLE_CELL_SEARCH to IDLE_WAIT_MIB_SIB1
+1.40021s UE with IMSI 1 RNTI 0 connected to cell 0 transitions from IDLE_WAIT_MIB_SIB1 to IDLE_WAIT_SIB1
+1.40521s UE with IMSI 1 RNTI 0 connected to cell 2 transitions from IDLE_WAIT_SIB1 to IDLE_CAMPED_NORMALLY
+1.40521s UE with IMSI 1 RNTI 0 connected to cell 2 transitions from IDLE_CAMPED_NORMALLY to IDLE_WAIT_SIB2
+1.44s /NodeList/4/DeviceList/0/LteEnBrc/HandoverStart eNB Cellid 1: start handover of UE with IMSI 2 RNTI 11 to Cellid 2
+1.44s UE with IMSI 2 RNTI 11 connected to cell 1 transitions from CONNECTED_NORMALLY to CONNECTED_HANDOVER
```

紅色部分：由於我們設定程式每秒會 attach Ue 到 eNB 上，因此在第一秒時，Ue(IMSI:2)與 eNB(cell id:1)透過 RNTI(11)成功進行連接，表示 Ue 有成功 attach 到 eNB 上並建立 RRC

Connection。

黃色部分：可以看到 Ue(IMSI:1)開始處於 idle 的狀態並且最後變成 IDLE_CELL_SEARCH，表示 Ue 開始自動化要做 cell selection。

```
+1.444s /NodeList/4/DeviceList/0/LteEnbRrc/HandoverStart eNB Cellid 1: start handover of UE with IMSI 2 RNTI 11 to cellid 2
+1.44s UE with IMSI 2 RNTI 11 connected to cell 1 transitions from CONNECTED_NORMALLY to CONNECTED_HANDOVER
+1.44s /NodeList/7/DeviceList/0/LteUeRrc/HandoverStart UE IMSI 2: previously connected to Cellid 1 with RNTI 11, doing handover to Cellid 2
+1.44421s UE with IMSI 2 RNTI 2 connected to cell 2 transitions from CONNECTED_HANDOVER to CONNECTED_NORMALLY
+1.44421s /NodeList/7/DeviceList/0/LteUeRrc/HandoverEndOk UE IMSI 2: successful handover to Cellid 2 with RNTI 2
+1.44421s /NodeList/5/DeviceList/0/LteEnbRrc/HandoverEndOk eNB Cellid 2: completed handover of UE with IMSI 2 RNTI 2
+1.44421e+09ns IMSI 2, RNTI 11, cell id 1, UE context destroyed at eNodeB
+1.456s UE with IMSI 1 RNTI 0 connected to cell 2 transitions from IDLE_WAIT_SIB2 to IDLE_RANDOM_ACCESS
+1.46021s UE with IMSI 1 RNTI 3 connected to cell 2 transitions from IDLE_RANDOM_ACCESS to IDLE_CONNECTING
+1.46021s UE with IMSI 1 RNTI 3 connected to cell 2 transitions from IDLE_CONNECTING to CONNECTED_NORMALLY
+1.46021s /NodeList/6/DeviceList/0/LteUeRrc/ConnectionEstablished UE IMSI 1: connected to cell id 2 with RNTI 3
+1.46021s /NodeList/5/DeviceList/0/LteEnbRrc/ConnectionEstablished eNB cell id 2: successful connection of UE with IMSI 1 RNTI 3
+2s UE with IMSI 3 RNTI 0 connected to cell 2 transitions from IDLE_START to IDLE_WAIT_MIB
+2.00021s UE with IMSI 3 RNTI 0 connected to cell 2 transitions from IDLE_WAIT_MIB to IDLE_CAMPED_NORMALLY
+2.00021s UE with IMSI 3 RNTI 0 connected to cell 2 transitions from IDLE_CAMPED_NORMALLY to IDLE_WAIT_SIB2
+2.016s UE with IMSI 3 RNTI 0 connected to cell 2 transitions from IDLE_WAIT_SIB2 to IDLE_RANDOM_ACCESS
+2.02021s UE with IMSI 3 RNTI 4 connected to cell 2 transitions from IDLE_RANDOM_ACCESS to IDLE_CONNECTING
+2.02021s UE with IMSI 3 RNTI 4 connected to cell 2 transitions from IDLE_CONNECTING to CONNECTED_NORMALLY
+2.02021s /NodeList/8/DeviceList/0/LteUeRrc/ConnectionEstablished UE IMSI 3: connected to cell id 2 with RNTI 4
+2.02021s /NodeList/5/DeviceList/0/LteEnbRrc/ConnectionEstablished eNB cell id 2: successful connection of UE with IMSI 3 RNTI 4
+2.28321s UE with IMSI 2 RNTI 2 connected to cell 2 transitions from CONNECTED_NORMALLY to CONNECTED_PHY_PROBLEM
+2.28321s UE with IMSI 2 RNTI 2 connected to cell 2 transitions from CONNECTED_PHY_PROBLEM to IDLE_START
+2.28321s UE with IMSI 2 RNTI 2 connected to cell 2 transitions from IDLE_START to IDLE_CELL_SEARCH
+2.28321e+09ns IMSI 2, RNTI 2, cell id 2, UE context destroyed at eNodeB
```

綠色部分：與第零秒的換手過程相同。

藍色部分：與前述連接一樣，由於我們設定程式每秒會 attach Ue 到 eNB 上，因此在第二秒

時，最後一個 Ue(IMSI:3)與 eNB(cell id:2)透過 RNTI(4)成功進行連接，而這邊為了讓 Ue 能夠平均連線到 eNB 因此在這邊設定是 attach 到 eNB(cell id:2)。

● Screenshot of my visualized simulation

