RE56 Labs

STUDENTS

DERRINGER ALINE
INACIO DAVID
GHNASSIA CLÉMENT

WORK SUBJECT

HO: HANDOVER AND SELECTION/RESELECTION IN GSM/UMTS

DOCUMENT VERSION

04/23/2014: First version of the document
18/12/2014: Second version of the document

TEACHER COMMENTS

Date:
Comments:

----

1. PURPOSE OF THE SYSTEM FUNCTION

In mobiles networks, handover and selection/reselection functionalities are needed to ensure mobility of users. Indeed, when a user move and change location, the network must be able to update the selected cell so the user does not lost the network and stay with a good connection. Handover and selection/reselection cover around the same needs but are used in different circumstances.

Selection is needed when the mobile has to select its first cell. It means that it's not currently connected to any network (the user switched it on or the network has been lost because of a lack of coverage). Reselection is used when the mobile is already connected and either idle or in packet switching (data transmission). Although the term reselection is used for both of the cases, reselection in idle mode and reselection in data transmission are different mechanisms and use different algorithms.

Handover is needed when the mobile user is currently used in circuit switching (classic voice call). Handover can be inter-system or intra-system. It is qualified by soft or hard depending on the conditions that you'll see in the table below.

Idle mode, when no network is not available yet: Selection		
	GSM	**UMTS**
Measures	RxLEV (Signal strength)	RxLEV (signal strength) Ec/Io (interferences)
Criteria	C1 criterion	SRxLev criterion SQual criterion

	Idle mode, when network is already available: Idle reselection	
	GSM	**UMTS**
Measures	RxLEV (signal strength)	RxLEV (signal strength) Ec/Io (interferences)
Criteria	C1 criterion C2 criterion	SRxLev criterion SQual criterion

	Circuit switching mode: Handover	
	GSM	**UMTS**
Measures	RxLEV (signal strength) SINR (interferences)	RxLEV (signal strength) Ec/Io (Interferences)
Criteria	C1 criterion C2 criterion	Active Set management with link addition and link removal

	Data packet transfer mode: Data reselection	
	GSM	**UMTS**
Measures	RxLEV (signal strength) SINR (interferences)	RxLEV (signal strength) Ec/Io (Interferences)
Criteria	C1' criterion C31 criterion C32 criterion	Active Set management with link addition and link removal

2. INPUT DATA AND PARAMETERS

There are a lot of input parameters that are decided at the network level or at mobile level, and that the user can change by modifying the application.xml file before running the software, are also by dynamically modifying the parameters using the right panel on the graphical user interface.

The different parameters area categorized depending at which element it is used. Basically, there is three levels: antenna, cell and mobile. There is no need for the user to enter all the parameters manually; default values will then be used.

Antenna parameters

- id: id of the antenna; each antenna id must be unique (only modified via xml file)
- x: x position of the center of the antenna (in meters)
- y: y position of the antenna (in meters)

Cell

Every cell belongs to an antenna and cannot be modified using the GUI. In our simulation, each antenna can have no more than one UMTS cell and no more than one GSM cell. Although it's not the case in the real world, it would be hard to see anything if every antenna has a lot of cells.

- id: id of the cell; each cell must have a different id (only modified via xml file)
- type: GSM or UMTS (only modified via xml file)
- power: Power of the cell (in dBm)
- frequency: frequency used by the cell (in MhZ)
- offset: channel used by the cell; this parameter is relevant only for GSM cells
- reselect offset: offset used to prioritize a cell
- reselect hysteresis: offset for avoiding changing location area too often
- access min: the minimum signal strength needed for the mobile to access to the cell
- access quality: the minimum quality required for attachment (relevant for UMTS cells only)
- active range: the maximum difference of quality between each cell of the active set (relevant for UMTS only)
- qsc and qsi: qsc and qsi parameters for the cell (relevant for GSM only)
- neighbors: list containing the ids of each neighbor cell
- enabled: we can enable or disable the cell in the GUI

Mobile

The parameters for the mobile can only be modified through the GUI. The numbers of parameters is limited because most of the decisions are taken by the network and the mobile has just to follow them.

- switch on button: we can switch on and switch off the phone at any time
- call button: we can give a call at any time the network is available
- data button: we can transmit data any time the network is available and the data transmission is available
- speed button: we can change the speed off the mobile
- mobile functionalities: we can change the functionalities supported by the mobile such as GSM / UMTS as well as GPRS and EDGE features

Using the drag and drop features, we can change the location of any cell, as well as the location of the mobile. We can also decide to used the keyboard arrows so the mobile is constrained to the speed given in the phone control panel. We can also change the scale of the area in order to have a better sight. By clicking on an antenna, we can modify most of its parameters.

3. DESCRIPTION OF FORMULA AND ALGORITHM

3.1 Measurements

Measurements are KPI on downlink done by the UE and on uplink done by the Base Station. The KPI are used in order to take the decision on the link control : received power level, data rate, quality etc. Decisions are power control : selection, reselection or handover.

1. Free space propagation - Friis formula

Calculate the power received at the mobile from an antenna depending on distance and frequency used

⇨ $$\mathbf{Pr = Pe + Ge + Gr + 27.55 - 20 \log(F) - 20\, N \log(d)}$$

Pr = Power received at the mobile (in dBm)
Pe = Power emitted by the base station (in dBm)
Ge = Gain at base station in (dBi), for the simulation, we don't use it
Gr = Gain at mobile station in (dBi), for the simulation, we don't use it
F = Frequency of the used wave (in MHz)
d = Distance between the mobile and the base station (in m)
N= Diffraction factor = 1.5

2. SINR calculation

Give the signal interference ratio at the mobile for an antenna depending on the others signals received at this location. This formula is used for GSM.

In order to understand how C/I on GSM is computed, we need to keep in mind that each antenna use a group of 8 frequencies with a width of 200 KHz each. Interference can come from other cells that use the same frequency, as well cells which use close frequencies, named adjacent cells. The adjacent cells have an impact on radio link quality because of the spreading due to multipath link between antenna and MS. Closer is the radio frequency used but the neighbor cell, greater is the impact on the quality link of the service cell. To ensure an overall C/I greater than 9dB, we use protection ratio depending on how close is the frequency of the neighbor cell with the frequency of the service cell.

We classify depending on the frequency used as below:

	A3	A2	A1	Co-Channel	A1	A2	A3	

Remember that each frequency is 200 KHz wide. So only the three closest frequencies signals are considered for C/I calculation (as well as co-channel frequency, i.e. signals with the same frequency). To take into account all these interference, we use this formula:

$$C/I = \frac{C}{\sum Icochannel + R1.\sum IA1 + R2.\sum IA2 + R3.\sum IA3}$$

$\sum Icochannel$ refers to the sum of signal strength interferences for frequencies using the same "channel", $\sum IA1$ refers to the sum of signal strength interferences for frequencies classified in A1, and so on.

R1, R2, and R3 are given fixed parameters also called protection ration: R1 = 0.015 / R2 = 10^{-5} / R3 = 10^{-6}

From the SINR calculation we are able to get an approximation of BER (Bit Error Rate). In the real world, BER is computed based on the bursts received by the MS and using some error detection algorithms. Since we will not have these data in our simulation, we will use the carrier to interference ratio as it is used for radio network planning. Indeed, there is a strong link between the C/I value and the BER that can be expected.

Finally, we can get a RxQUAL level which is a value between 0 and 7 and used as the main indicator in order to know the quality of the transmission and process actions when needed. Each value corresponds to an estimated number of bits errors in a number of bursts. Greater is RxQUAL, greater is the Bit Error Rate (and worse it the connection). There is a table of correspondence between RxQUAL, BER and SINR. The relations between these three measures can be summarized as below.

<table>
<tr><th>RXQUAL</th><th>BER</th><th>SINR</th></tr>
<tr><td>0</td><td>BER < 0.2 %</td><td>≥ 9 dB</td></tr>
<tr><td>1</td><td>0.2 % < BER < 0.4 %</td><td rowspan="2">7 - 8 dB</td></tr>
<tr><td>2</td><td>0.4 % ≤ BER < 0.8 %</td></tr>
<tr><td>3</td><td>0.8 % ≤ BER < 1.6. %</td><td rowspan="3">5 – 6 dB</td></tr>
<tr><td>4</td><td>1.6 % ≤ BER < 3.2 %</td></tr>
<tr><td>5</td><td>3.2 % ≤ BER < 6.4 %</td></tr>
<tr><td>6</td><td>6.4% ≤ BER < 12.8 %</td><td rowspan="2">< 5 dB</td></tr>
<tr><td>7</td><td>12.8 % ≤ BER</td></tr>
</table>

3. Signal Interference Noise Ratio (Ec/No)

This is the received energy per chip (Ec) of the pilot channel divided by the total noise power density (No). In other words, the Ec/No is the RSCP divided by the RSSI.

⇨ **Ec/No = 10*log (RSCP / RSSI)**

The better this value is, the better can a signal of a cell be distinguished from all overall noise. That is the indicator we use as the SINR (Signal to Interference Noise Ratio) for UMTS measurements.

4. Received Signal Code Power (RSCP)

RSCP is the power level the pilot channel of a cell is received and usually expressed in mW. With this parameter, difference cells using the same carrier can be compared and handover or cell reselection can be taken.

⇨ **RSCP = 10^(RXLev/10) * 256**

5. Received Signal Strength Indication (RSSI)

RSSI is the signal power (in mW) over the complete 5MHz carrier which includes all components received, including the signals from the current and neighboring cells on the same frequency.

⇨ **RSSI = Σ 10^(RXLev/10) + Noise**

To summarize, when can say that the better this value is, the better can a signal of a cell be distinguished from all overall noise. By analogy with GSM, that is the indicator we use as the SINR for UMTS measurements.

6. QSI/QSC

If the UMTS layer is covered by the GSM layer, the GSM always measures and the UMTS measurements are optional. QSI on idle mode and QSC on connected mode are parameters on the GSM RxLev of serving cell to control the measurement of UTRAN neighbor cells.

QSI / QSC	Value in dBm
0	< - 98
1	< -94
2	< -90
3	< -86
4	< -82
5	< -78
6	< -74
7	Always
8	> -78
9	> -74
10	> -70
11	> -66
12	> -62
13	> -58
14	> -54
15 (default)	never

3.2 Cell selection and reselection in idle mode (GSM)

Cell selection and reselection are processes, performed by a GSM mobile station in idle mode. Selection enables the MS to select the best suitable cell.

When the MS is turned on, it will try to contact a public GSM PLMN, the MS will select a proper cell and extract the control channel parameters and prerequisite system messages. The quality of radio channels is important. C1 > 0 ; C1 is computed every 5 seconds.

⇨ **C1 = RxLEV - RxLevAccessMin - MAX(MS_TxPwrMaxCCH – MS_MaxRFPower, 0)**

RxLev = the received signal level at the MS (in dBm)
RxLevAccessMin = the minimum received signal level the MS is allowed to access the network (in dBm)
MS_TxPwrMaxCCH = maximum emitted power allowed to the MS to access the BTS
MS_MaxRFPower = maximum emitted power of the MS defined by the MS class

Please notice that if the regarded cell is not in the same location area (LA) as the current selected cell, we will provide the C1 calculation with a negative offset. The reason is that changing LA requires changing location update (LU) procedure that consumes network signaling capacity.
Reselection consists of having the best fitted cell selected when the mobile station (MS) moves and change cell. To perform the reselection mechanism, the mobile station do measurements of the BCCH (Broadcast Control Channel) signals and keep the 6 strongest carriers based on their signal strength.
The C2 criterion is used for cell ranking in the GSM cell reselection process. Because we have hierarchical cell structures with micro-cells as well as larger cells covering the same areas, we improve the C1 parameter for micro-cells. This mechanism will avoid for a mobile station moving fast to get attached in micro-cell instead of a larger cell.

⇨ **If T < penality_time then**
C2 = C1 + Cell_Reselect_Offset – Temporary_Offset
Else
C2 = C1 + Cell_Reselect_Offset
End

T : timer triggered when the regarded cell is entering the 6 best candidate cells for reselection.
CELL_RESELECT_OFFSET : used to prioritize one cell in relation to the others
PENALTY_TIME and TEMPORARY_OFFSET : given by the BCCH. This is used to penalize the cell when its just enters the list of the strongest carriers.

Procedure for selection

1) Mobile computes C1 values for the closest cells. Strength measure used to compute C1 is an average for a fixed time. For example, it can be decided that an average of 10 measures in a window of 1 second is required in order to compute C1 criteria.
2) Mobile try to attach to the cell with the greatest C1 value (if positive).

Procedure for idle reselection

1) Mobile computes C1 and C2 values for the serving cell and the neighbor cells at least every 5 seconds. As for selection, measures used to compute C1 and C2 are both using averages for a fixed time.
2) If a neighbor cell has a positive C1 value and has a greater C2 value than the current service cell, the mobile will perform reselection towards this cell. If the path loss criteria for service cell has become too high (C1 < 0), a reselection is also triggered. Furthermore, if the serving cell has become barred, or downlink signaling failure is experienced, it can results to a reselection as well.

3.3 Cell selection and reselection in idle mode (UMTS)

Cell selection and reselection in idle mode for UMTS implement about the same procedures as for GSM except that the measures and the critera are a little different. Since in UMTS, quality of signal is the most important measure we compute also Ec/Io for selection and reselection as well.

The first criterion used for selection and reselection is SRxLev and use the signal strength received at MS. Only SRxLev is positive, the MS can be attached.

⇨ **SRxLev = QRxLev – (QRxLevMin + QRxLev_min_offset)**

QRxLev = the average received signal level at the MS (in dBm)
QRxLevMin = the minimum received signal level the MS allowed to access the network (in dBm)
QRxLev_min_offset = a parameter used for cell prioritization

The second criterion considers the level of interference rather than the pure strength. As for SRxLev, SQual must be positive in order for the MS to be attached.

⇨ **SQual= QQual – (QQualMin + QQual_min_offset)**

QQual = the average Ec/Io level at the MS (in dB)
QQualMin = the minimum Ec/Io level the MS allowed to access the network (in dB)
QQual_min_offset = a parameter used for cell prioritization

Procedure for idle selection

1) Mobile computes SRxLev and SQual values for the closest cells. Strength and interferences measures used for computation are averages for a fixed time. For example, it can be decided that an average of 10 measures in a window of 1 second is required in order to compute SRxLev and SQual criteria.
2) Mobile try to attach to the cell with the greatest SQual value with SRxLev and SQual values both positives.

Procedure for idle reselection

1) Mobile compute SRxLev and SQual values for the serving cell and the neighbor cells at least every 5 seconds. As for selection, measures used to compute SRxLev and sQual are both using averages for a fixed time.
2) If a neighbor cell has positives SRLev and SQual value and has a greater SQual value than the current service cell, the mobile will perform reselection towards this cell. If the path loss criteria for service cell has become too high (SRxLev < 0) or the level of interference is too high (SQual < 0), a reselection is also triggered. Furthermore, if the serving cell has become barred, or downlink signaling failure is experienced, it can results to a reselection as well.

3.4 Cell handover (GSM)

Basically, the measures and criteria used for handover are about the same as the criteria regarded for idle reselection. The main difference is that we also compute RxQUAL in order to measure the quality of the transmission that can be altered due to a low SINR. A level of RxQUAL greater than 3 is indeed not acceptable for having a call.
For cell ranking we also use C1 and C2 criteria under the same condition. Actually, when more than one cell have a C1 and C2 criteria positive, RxQuAL is the primary parameter for sorting them. Then, if two cell have the same RxQUAL level, the C2 parameter will give the new service cell.

While a cell reselection in idle mode occurs most of the time because of the RxLev level, handover can performed when one of the following event occurs :

- Quality is too low i.e. RxQUAL is too high (in uplink or downlink)
  RxQUAL_Uplink > L_RxQUAL_Uplink_H
  RxQUAL_Downlink > L_RxQual_DownLink_H

- Received level (RxLev) is too low (in uplink or downlink)

RxLEV_Uplink < R_RxLEV_Uplink_H
RxLEV_Downlink < R_RxLEV_DownLink_H

- Distance between MS and BTS is loo large (usually more than 35 km)
  MS_BS_Dist > MS_Range_Max

- A neighbor cell is more favorable
  RxQUAL_NCELL(n) > RxQUAL_DL
  RxQUAL_NCELL(n) equals RxQUAL_DL AND RXLEV_NCELL – RXEV_DL > HO_MARGIN

As we have seen in reselection, we can use a timer to prever a fast moving mobile phone to connect to micro-cell where a larger cell is available. We replace HO_MARGIN by HO_MARGIN_TIME as above

⇨ **If T < DELAY_TIME then**
HO_MARGIN_TIME(n) = HO_MARGIN(n) + HO_STATIC_OFFSET(n)
Else
HO_MARGIN_TIME(n) = HO_MARGIN(n) + HO_STATIC_OFFSET(n) - HO_DYA_OFFSET(n)
End

Finally, the algorithm of handover as we implemented it in our algorithm follows these line:

1) For the neighbor cells (in the list) take the one with a positive C1 value and the best C2 criterion. We will call it candidate cell.
   - If RxLEV of the service cell is too low (C1 negative) then we perform handover toward candidate cell due to level.
   - If MS_BS_DIST is too large, we perform handover toward candidate cell due to distance.
   - If RxQUAL of the service cell is greater than RxQUAL of the candidate cell, we perform handover toward candidate cell due to quality. In case RxQUAL of the service cell is the same as RXQual of the candidate cell, we perform handover only if the C2 value of candidate cell is better than C2 value of service cell due to power budget.

2) As soon as a handover is performed, we retrieve the list of neighbor cells (both GSM and UMTS) in order to do RxLEV and RxQUAL measurements in projection for a future handover.

3.5 Cell handover (UMTS)

For handover in UMTS, the measures remain SRxLev and SQual. The big difference is that the mobile is able to establish a connection with more than one cell, in order to improve the quality of the link. This feature is only used in case of connection, i.e. in voice call or in data transmission. The cells with which a connection is established is in an active set. The cell for which measurements are improved but are not in the active set because their SRxLev or SQual is not good enough are in a neighbor set. The main idea is that all the cells in the active set in the same time should not have a SQual too much different. In other terms, the absolute distance between the SQual of a cell and the SQual of any another cell should not be greater that this parameters. In order to implement this mechanisms, we are implementing what we call cell addition, cell removal and cell addition and removal as described below. The active set has a fixed size, and is most of the time between 1 and 6. For example, if the active set has a size of 3, no more than 3 cells can be in the active set at the same time. As we saw before, SRxLev and SQual are again average value for a fixed time.

Link removal
If any cell from the active set has negative SRxLev value, we remove it from active set.
If any cell from the active set has SQual value lower than the best SQual of any cell in the active set minus a fixed offset, we remove it from active set as well.

Link addition
If the active set is not full and any cell from the neighbor set has positive SRxLev and has a greater SQual than the best SQual value minus a fixed offset, we add into the active set.

Combined link addition and removal

If the best cell (regarding its SQual criterion) from the neighbor set having a positive SRxLev value has a better SQual value than the worst cell (regarding its SQual criterion), then the two cell are switched, i.e. the worst cell is removed from the active set and the best cell enters in the active set.

Finally, the process of handover as it is implemented in our software follows the following steps

Implementing link removal, link addition and combined link addition and removal following the rules as explain above. When the best cell in the active set change, we retrieve the neighbor list from this cell and we use it for cell measurement.

3.6 Cell reselection in data transmission mode (GSM)

The process of reselection in transmission mode follow the same steps as the process of handover, except that the criteria are a little different and improved, in order to match the data packet transmission requirements

The pass loss criterion C'1 is used as a minimum signal level criterion for GPRS cell reselection.

⇨ **C’1 = RXLEV – GPRS_RXLEV_ACCESS_MIN**

GPRS_RXLEV_ACCESS_MIN is provided by the BCCH of the regarded cell.

The signal level threshold criterion parameter C31 for hierarchical cell structure (HCS) is used to determine whether prioritize hierarchical GPRS cell reselection applies.

⇨ **C31(serv) = RxLev(serv) – HCS_THR(serv)**

If Priority_Class(neighbor) = Priority_Class(serv) then
C31(neighbor) = RxLev(neighbor) – HCS_THR(neighbor)
Else
If T < GPRS_Penality_Time then
C31(neighbor) = RxLev(neighbor) – HCS_THR(neighbor) - GPRS_Temporary_Offset
Else
C31(neighbor) = RxLev(neighbor) – HCS_THR(neighbor)
End if
End If

PRIORITY_CLASS : give cells different priory depending on their type
HCS_THR : signal threshold for applying HCS GPRS reselection
T : timer that is started from 0 at the time the cell inters in the list of strongest carriers.
GPRS_PENALTY_TIME : give a duration for which the temporary offset GPRS_TEMPORARY_OFFSET is applied.

The cell-ranking criterion parameter (C32) is used to select cells among those with the same priority and is defined for the serving cell and the neighbor cells

⇨ **C32(serv) = C’1(serv)**

If Priority_Class(neighbor) = Priority_Class(serv) then
If T < GPRS_Penality_Time then
C32(neighbor) = C1(neighbor) + GPRS_RESELECT_OFFSET(neighbor)
- GPRS_Temporary_Offset
Else
C32(neighbor) = C1(neighbor) + GPRS_RESELECT_OFFSET(neighbor)
End if
Else
C32(neighbor) = C1(neighbor) + GPRS_RESELECT_OFFSET(neighbor)
End If

As well as for C1 criterion, the parameter GPRS_CELL_RESELECT_HYSTERESIS cab be substracted from the C32 criteria of the neighbor cells. This hysteresis is also substracted from C31 criterion if requested by network.

When the neighbor cell does not belong to the same area location (LA) as the serving cell, RA_RESELECT_HYSTERESIS is substracted from the C32 criterion of the neighbor cell.
In case cell selection occurred within the previous 15 seconds, all neighbor cells are penalized by 5dB in oder to avoid ping-pong between cells.

Mobile computes the values for C'1, C31, C32 criteria for the serving cell and the non serving cells at least every second. A cell reselection is then triggered if one of the following events occurs:

- ⇨ The pass criterion parameter C'1 indicate that the pass loss to the cell has become too high (C'1 < 0)
- ⇨ A nonserving suitable cell is evaluated to be better than the serving cell. The best cell is the cell with the highest C32 value among
- ⇨ The cells that have the highest priority class among the cell that fulfill C31 >= 0
- ⇨ All cells, if no cell fulfill the criterion C31 >= 0
- ⇨ Downlink signaling failure is experienced
- ⇨ The cell on which the mobile is camping has become barred
- ⇨ A random access attempt is still unsuccessful adter MAX_RESTRANS_RATE attempt.

3.7 Cell reselection in data transmission mode (UMTS)

All of the informations that have been given from handover in UMTS are exactly the same for cell reselection in data transmission mode. The measurements, the parameters and the steps are exactly the same.

3.8 UMTS and GSM working together

One of the biggest issue is how we can make UMTS and GSM networks working together. Actually, it depends on the network operator. In our software, we decided to prioritize GSM network for idle selection, idle reselection and handover. It means that every-time the layer of GSM is available, it should be used. Only, if GSM is not available, then these procedures can happens within the UMTS layer. If the user begin a call into GSM layer and then get out of coverage, the UMTS layer (if it is available) is able to take over so the user can continue calling without suffering from any disruption.

Since the throughput for UMTS is pretty much better than GSM (using GPRS and EDGE), UMTS is prioritized for data transmission. It means, that every time the user want to receive or to send data, UMTS layer will be used if it is available. If the user then go out of UMTS coverage, GPRS and EDGE can take over so the user will not suffer for any interruption.

3.9 Pseudo-code

Only a few example of all the algorithms which are implemented in our software are explained here, because there is a plenty of different situation. The best method for the user to understand all the decisions taken is to use the software and see it with its own eyes.

```
Start

  /* The Mobile Station is turn off : idle mode */

  /* We have decided that GSM is the priority network for idle mode and voice call */
  /* We have decided that UMTS is the priority network for data transmission */

  /* Some measures like the hysteresis and the thresholds are write in the code, we chose the values
     according  on what we see during the TD. Their values won't change */
```

```
/* To be sure that a network is really available, we do the test five time, and then link up */

Turn on the MS
MS do measurements

/* CELL SELECTION */

If GSM is available based on C1 criteria
  Link up GSM Network
Else /* GSM is not available */
    If UMTS is available based on SRxLEV and SQual
      Link up to UMTS Network
    Else   /* GSM is not available UMTS is not either */
      No network available
    End
End

/* CELL RESELECTION ; Idle Mode */
/* The user is moving */
/* We stay in the same cell : nothing changes but the MS is always doing measurements */
/* When signal strength become too low, we move to another cell */

If idle reselection condition for GSM are fulfilled
  Perform GSM reselection
Else if GSM C1 criteria become too low and UMTS is available based on SRxLev and SQual
  Perform inter-system reselection toward UMTS
Else   /* GSM is not available UMTS is not either */
  Lose network coverage
End

/* CELL HANDOWER */
/* The user is now calling and moving */

If handover conditions for GSM are fulfilled
  Perform GSM handover
Else if GSM C1 criteria become too low or RxQual become too high and UMTS is available
   Perform inter-system handover towards UMTS
Else   /* GSM is not available UMTS is not either */
  Cut the call /* No network available */
End

  /* CELL RESELECTION ; Data packet transfer mode */
  /* The user uses data – UMTS is the priority network for data transmission */

If data reselection conditions for UMTS are fulfilled
  Perform UMTS handover
Else if SRxLev or SQual of UMTS cells become too low and GSM is available
    If EDGE is available
      Perform inter-system data reselection toward EDGE Network
    Else if GPRS is available
      Perform inter-system data reselection toward GPRS Network
    Else   /* No packet transmission in GSM layer */
      No data transmission available anymore
    End
Else   /* GPRS is not available UMTS is not either */
   No data transmission available anymore
End
End
```

4. OUTPUT DATA

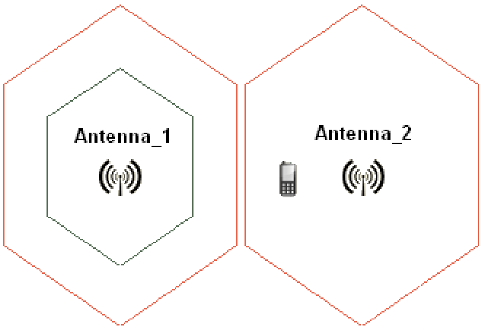
The main function simulates the operations that the mobile or network must take depending on the situation. The function performs simulation of selection/reselection on GSM and UMTS, soft handover (UMTS to UMTS) and hard handover (UMTS to GSM, GSM to UMTS, and GSM to GSM).

As result we know on which cell the mobile is connected, who the active cell's neighbors are etc.

Remark : We'll see it in details when we'll show the implementation and the results.

5. VALIDATION ON ONE EXAMPLE

5.1 The network



We have decided to use that network for our example. There are two GSM cells (the red one) and one UMTS cell (the black one). There is one mobile, turn off at the beginning.

To start, we turn on the mobile …

Remember : GSM Network is priority for idle mode and voice call.

5.2 The values to start

At the begging, when we turn on the mobile, we have this different value:

- The emitted strength (Pe) by the GSM antenna is 38dBm and the frequency is 900 MHz.
- The minimum received signal level the MS is allowed to access the network (RxLevAccessMin) = -90 dBm, and Cell_Reselect_Offset = 0, because they are the same GSM cells.

5.3 Measurements

We measure, 10 times, the RxLEV of the mobile with the antenna 1 and 2, then we do an average. The distance changes a little, because the mobile moves the measures. The formula uses to calculate RxLEV is the Friis formula:

RxLEV = Pe + 27.55 - 20 log(Frequency) – 20 * 1.5 log(Distance)

Distance between the mobile and the antenna 1 in meter	RxLEV with Antenna_1 (dBm)	Distance between the mobile and the antenna 2 in meter	RxLEV with Antenna_2 (dBm)
300	-67,8484878	100	-53,5348502
295	-67,6295107	105	-54,1705292
293	-67,5408788	107	-54,4163635
298	-67,7613381	102	-53,7928553
305	-68,0638454	95	-52,8665583
296	-67,6736015	104	-54,0458504
290	-67,4067901	110	-54,7766307
295	-67,6295107	105	-54,1705292
301	-67,8918451	99	-53,403906
299	-67,8049858	101	-53,6644914
Average	-67,7250794	Average	-53,8842564

After that, we calculate C1 with this formula:

⇨ **C1 = RxLEV – RxLevAccessMin**

For Antenna_1, C1 = 22,2749206 dBm. For Antenna_2, C1 = 36,1157436 dBm.

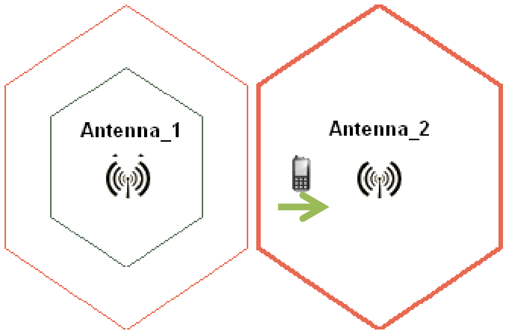
So C1 > 0, for the two antennas, we can measure C2 with this formula:

⇨ **C2 = C1 + Cell_Reselect_Offset**

For Antenna_1, C2 = 22,2749206 dBm. For antenna 2, C2 = 36,1157436 dBm.

The Antenna_2 has the best C2.

5.4 Decision



After the measurements, the mobile is going to join the Antenna_2 which has the best C2.

If we continue the simulation, we can decide that the mobile is going to go next to Antenna_1, as shown by the green arrow. Remark that the MS is always doing measurements. When it’s going to be next to border between the two cells it will redo the calculations for C1 and C2 criteria ...

If we are going to use data, the mobile will check if it is able to join UMTS Network …

6. BIBLIOGRAPHY USED

- UMTS, Services, Architectures et WCDMA, *Javier Sanchez and Mamadou Thioune*, Hermes
- Réseaux mobiles, *Sami Tabbane*, Hermes
- Simulating soft handover and power control for enhanced umts, *V. Vassiliou, J. Antoniou, A. Pitsillides, and G. Hadjipollas,* Department of Computer Science in University of Cyprus
- GSM UMTS Cell Reselection and Handover, *Ericsson*

7. SOFTWARE DEVELOPMENT

7.1 Computing language

To implement our software we chose use **java** language. Java is a computer programming language that is concurrent, class-based, object-oriented, and designed to eliminate language features that cause common programming errors in the others high level programming languages.

7.2 Environment

We used **Eclipse** to develop the application and we shared the sources thanks to **GitHub**.

Eclipse is an Integrated Development Environment developed by IBM. It's an open source IDE that works on all the operating systems. IDE are really useful because of the libraries : we just have to start to write a function and it helps to finish. It permits too to avoid unexpected errors.

GitHub is a web-based hosting service for software development projects, created in 2008, that use the Git revision control system. We used a free account for open source projects. That way, we can share the code with our co-workers, revise projects, edit other people’s work, and interact with the other members. It's really efficient, thanks to a version control application : multiple people are allowed to work simultaneously without work getting overwritten or erased.

7.3 Content of the different files

```
RE56_HO
  src
    (default package)
    config                      // Define the different parameters like cell's color and dimensions
    controllers                 // Management of different cells, area and menus
    events                      // Manage the user's interventions
    models.application          // Define the model app. : there is only one MS and it's a private network
    models.area                 // Delimit the area
    models.info
    models.menu
    models.mobile
      ActiveSet.java            // Neighbor list of the Active Set
      CellMeasurement.java
      Measure.java              //  RxLEV / Noise / Time etc.
      MeasurementSet.java       // Updates measurements
      Mobile.java               // State of the mobile / Position on the map / speed etc.
      Module.java               // Call the functions for the right use
      ModuleGSM.java
      ModuleUMTS.java
      Motion.java               // Manage the mobile moving on the map

    models.network
      Antenna.java              // Id, position, type, Location Area Controller
      AntennaManager.java       // Antenna management
      Cell.java                 // Each antenna is included in a cell which got its own parameters
      CellGSM.java
      CellManager.java
      CellUMTS.java
      LocationArea.java         // Location Area / Neighbors etc.
      LocationAreaManager.java
      Network.java              // GSM / GPRS / EDGE / UMTS
    models.network
    models.utilities
      Formulas.java             // Here are the ≠ tables, the conversion's formula.
      LoadImage.java            // Here are the ≠ pictures for the buttons
      ParseXMLFile.java
      SpringUtilities.java      // Used to bring into line and standardize the cells
    views.application           // Use to manage the display
    views.area
    views.info
    views.menu
  JRE System Library [jre7]
  config
  gimp
  img
```

7.4 Our program

Thanks to the MMI, the user is able to change few parameters like the power of the antenna, the offset, the hysteresis, the neighbors of a cell, the mobile's speed etc. (the right part of the application)

We can decide if the mobile is in idle mode or in calling or even data transmitting by selecting a mode on the right part of the application.

Once all parameters are ok, we can launch the application. The user is able to move the mobiles thanks to the keyboard's arrows or via the mouse.

The mobile is moving on the map, and when a cell is active, its outlines are bold.
At the bottom, we can see how fluctuate the RxReceived from the Antenna selected, how change the SINR.
And if we are in call or in data transmission mode, there is an indicator to show the throughput variations.

In that way we can see what kind of cell is selected : UMTS or GSM when we use the mobile for something or another thing ...

N.B : On the lower part of the screen, there is a console where we can see what happen for the mobile.

There are 10 905 lines of code at all.