.- Chapter 6: SIMULATIONS WITH OPNET

We have begun by learning to use the program OPNET 10.5 which we are going to work with. Once done this, and having done practice exercises with tutorials, we have analyzed and understood what is about the Phoenix Project.

In this Chapter will be explained all the simulations we have made, in order to understand the operation of this Project, and its behaviour when conditions change. So, we will be able to see if the results are coherent or not according to the set parameters.

The first task we have to do is to validate the performance of the proposed application controller algorithm, so we have built up a complex simulation scenario employing Opnet Modeler[13]. The purpose of the analysis is to measure the benefit of the application controller in the PHOENIX JSCC/D system with an estimation of the PSNR as the indicator of the received video quality.

The Basic Simulation Chain has been employed to generate bit error patterns used to feed the simulator and emulate the behaviour of a radio channel in different condition (i.e. different SNR value).

The most interesting scenario reproduced a real channel in time-variant conditions: good, fair, poor, very poor. The different conditions were obtained using the Simulation Chain with 4 different SNR values: 8 dB for good quality, 4 dB for fair quality, 2 dB for poor quality and 1 dB for very poor quality.

The application controller reacts to the change of the channel condition moving to a more efficient encoding scheme every time slot. “CSI BER value” and “Application Current File Index” graphics demonstrate that when the channel quality is degrading, is more convenient to use different MPEG encoding settings. However, when the channel is good, it is possible to encode with a higher bit rate. In poor channel condition, without the application controller the PSNR of the received video is very low.

6.1.- SCENARIO WITHOUT Mobility Module

The first scenario was like the next figure shows:

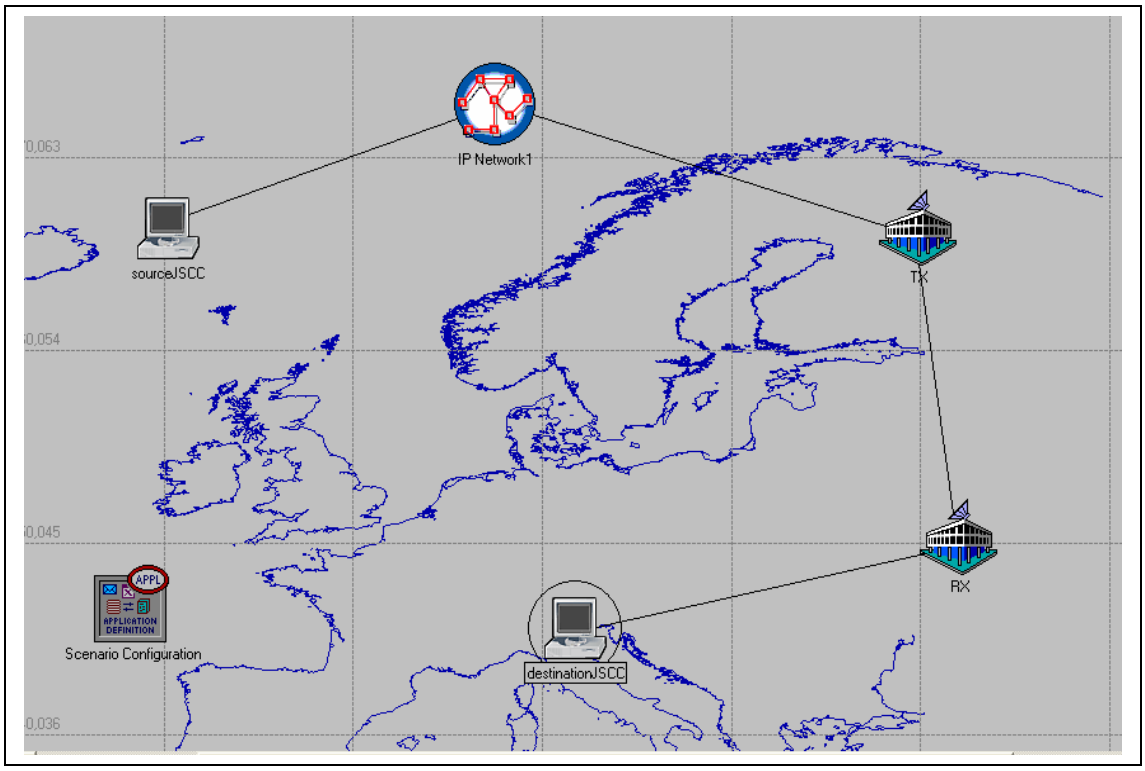


Figure 6.1- Scenario without Mobility

The modules that form this scenario are:
1.- JSCC/D Source
2.- IP Network
3.-Wireless Transmitter (Wi-Fi, UMTS)
4.-Wireless Receiver
5.- JSCC/D Destination
6.- Scenario Configurator

All of these nodes are explained in previous paragraphs, so we will not explain them in this section. There are certain configuration parameters that are constants in all the simulations. Also, all the parameters have been defined and set before, because of this, we are going to mention only the parameters that have been changed in each simulation.

6.1.1.-SIMULATION With Application Controller

Set Parameters:

Scenario Configurator
- Use Appl Ctrl : **Enabled**
- Appl Ctrl Cycle: 1000 msec

Source JSSC/D
- Video Source File
  Name:MPEG4
  Codec rate: 370 kbps
  Frame number: 100f

Frame rate: 30fps
Video size: CIF

- UEP mode : disabled
- PLR threshold: 0.05
- BER threshold: 0.3

IP Network

- Bottleneck rate: 2Mbps (50% free)
- Loss(%): noQoS

RX

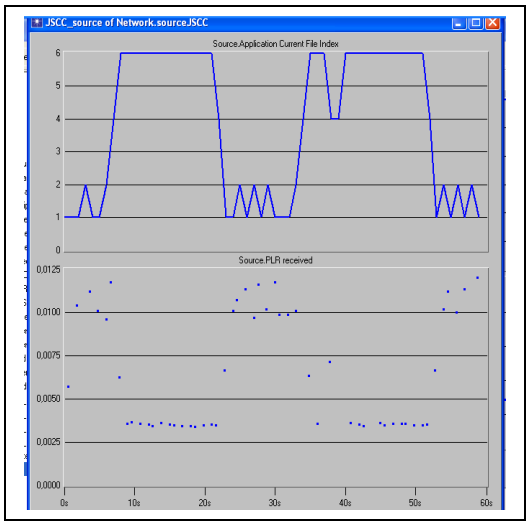
- Channel Conditions

Time: 0 – 20 sec State: **good**
Time: 20 – 30 sec State: **poor**
Time: 30 -40 sec State: **good**
Time: 40 – 50 sec State: **good**
Time: 50 – 60 sec State: **Very Poor**

With all these values it have been simulating this scenario during 60 seconds. The following graphics are the most relevant ones.

a) Application Current File Index and PLR received

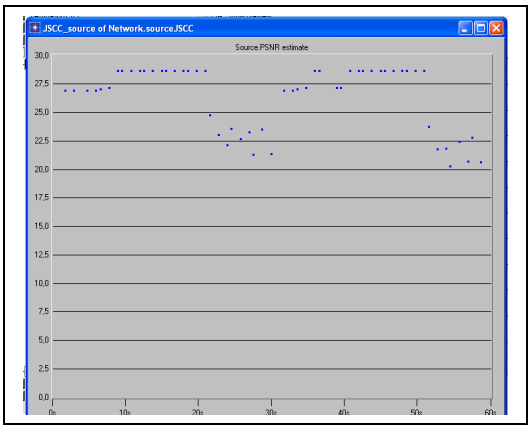
The better is the channel condition the higher is the Application Index



We can see that the PLR threshold is never exceeded. Also it can bee observed that PLR increases when channel conditions are bad (that is, when the current File Index is low).

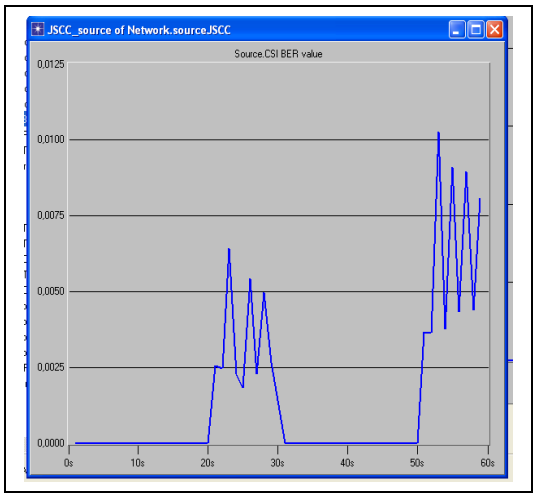
b) PSNR estimated

We can see clearly that the worse is the channel condition, the worse is the PSNR value. This is a logical result because the PSNR is calculated basing on BER and PER values received in Source JSCC/D.



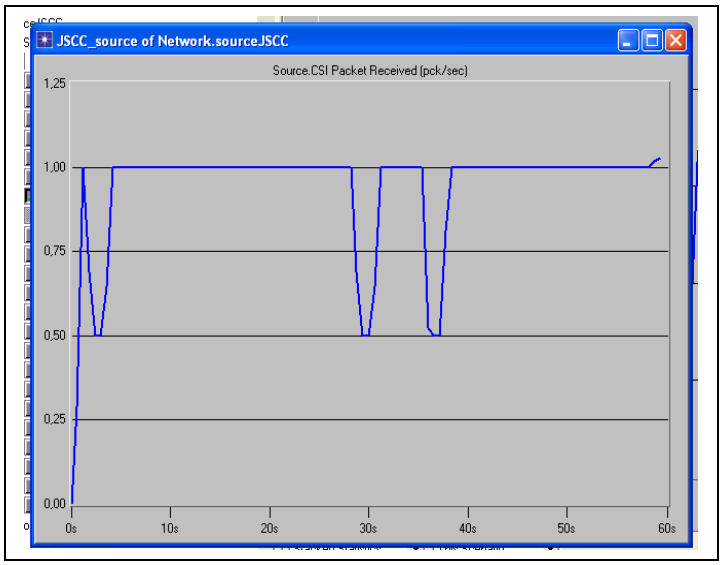
c) BER value in CSI information

The source receives the information about Bit error Rate in CSI packets. We can see that this value increases when the channel condition is worse.



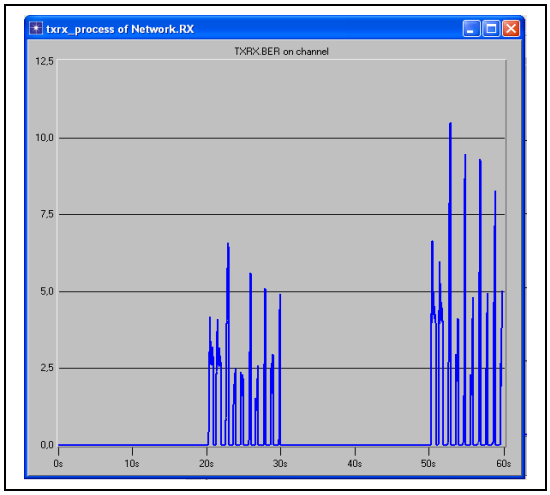
d) CSI Packet Received

We can control the packet rate of CSI information. The timer is setted as 1 packet per second, so these peaks that go down are because of the delay.



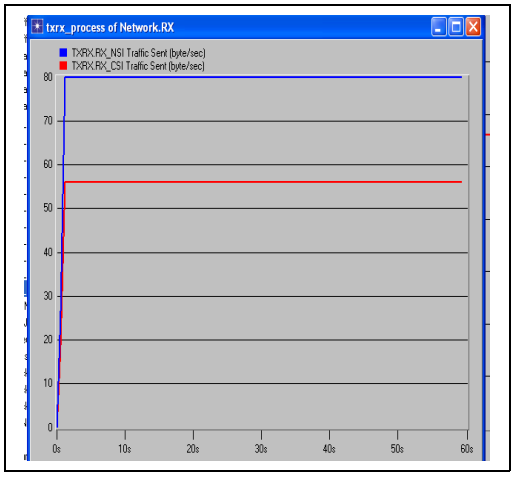
e) BER on channel

In RX node are set the channel conditions, therefore in this node are analyzed these statistics. It controls the Bit Error Rate **in the Radio Channel.**



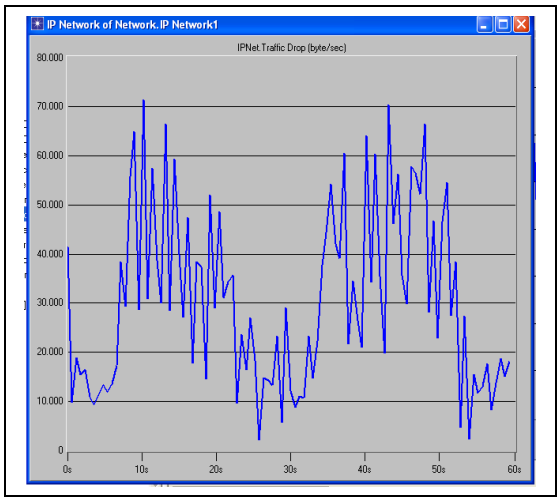
f) NSI/CSI Traffic sent

The RX node sends each second, NSI and CSI information to the JSCC/D Source. This information is feedback information that is needed by the Application and Physical Controller in order to select the Input File. The rate is measured in byte/sec.



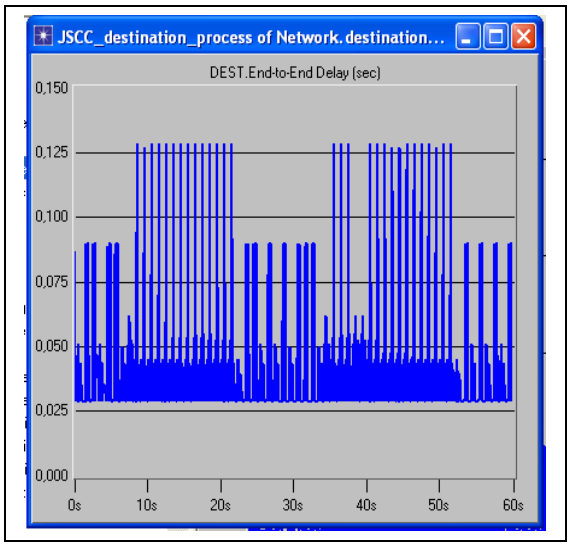
g) IPNet Traffic Drop

This graphic indicates the rate of packets lost in the Network. This parameter is set in the configuration by two ways; by setting the percentage of free channel (in this case is 50%) and by setting the parameter Loss (%) (In this case is “noQoS”)



h) End to End Delay

The destination node analyzes the total delay in the scenario, from the Source node to the Destination Node.

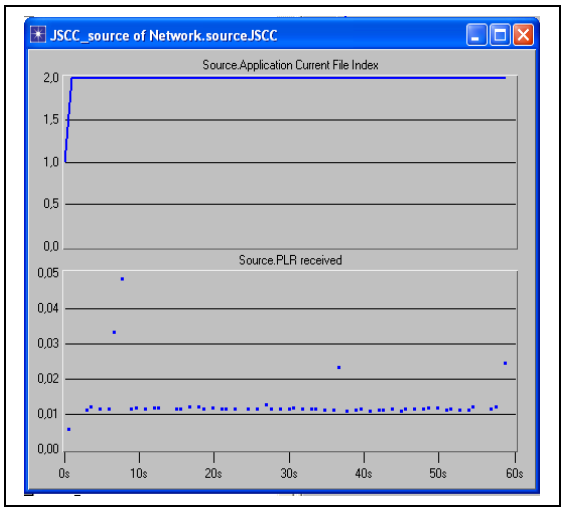


6.1.2.-SIMULATION (without Application controller)

Now we deactivate the Application Controller, so we have the first configuration but without Application Controller and without Bottleneck.

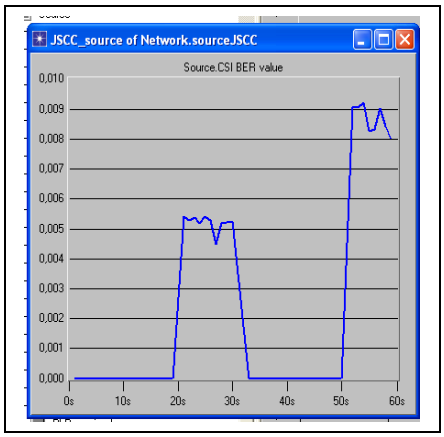
a) Source Application Current File Index and PLR received

As we can see, the Index is constant because the Application Controller is deactivated and it does not change its state. And also the PLR received is higher. These are the two first differences between activating or not the AC. We can conclude that the PLR level is improved with AC.
The adopted value of Application Current File Index depends on the initial conditions set into Scenario Configuration Node, like GOV, Application control State.



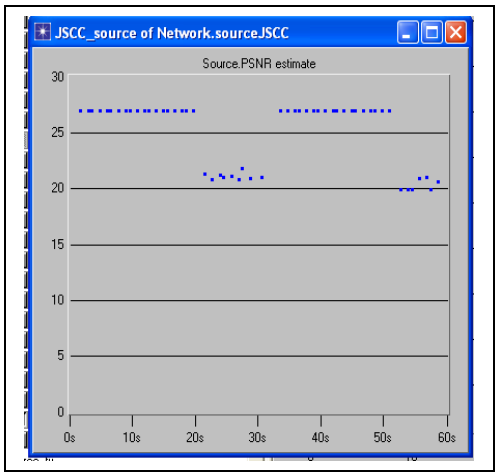
a) BER value in CSI

More or less, it reaches the same values as before, because there is a compound parameter in RX Node that sets the different channel states, and depending on this, load one file of errors in Radio Channel or another. After this, CSI packets are created and sent to the Source JSCC/D, but this is independent from the effects of the AC.



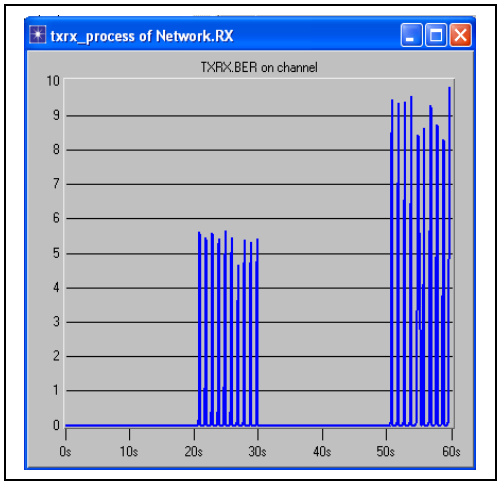
c) PSNR estimated

PSNR is calculated each period, independent from the activation of AC. We can appreciate that once the PSNR changes its value, it remains more or less constant. This means that the AC has no effects. It is not improved in one period without changing the channel state.



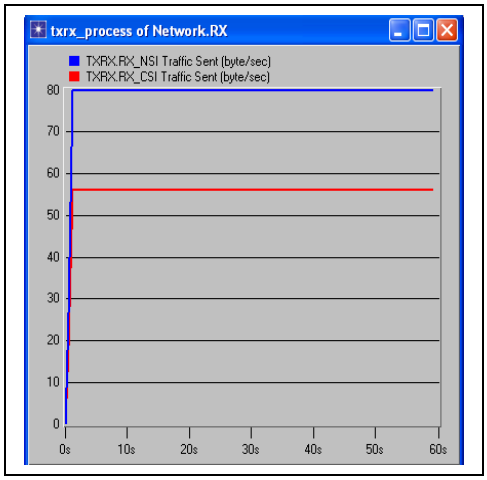
d) BER on channel

These values do not change a lot, are quite the same because these values are set in the configuration and are independents from AC effects.



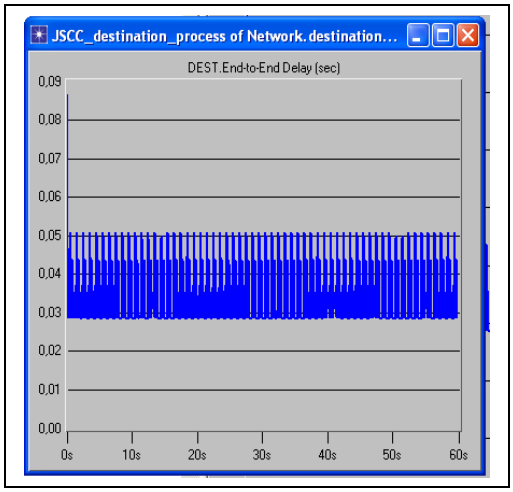
e) CSI/NSI Traffic Sent

We can notice that these graphics are always the same. Because of the reason we have said before (these signals are generated by a timer and these do not change).



f) END to End Delay

Now, the ETE Delay has changed, is lower than in the first simulation and also more constant. It can be seen that is cyclic**.** It could be because the AC is deactivated and therefore the time elapsed with its operations does not exist now.



6.1.3.-SIMULATION (With Application Controller and With Bottleneck)

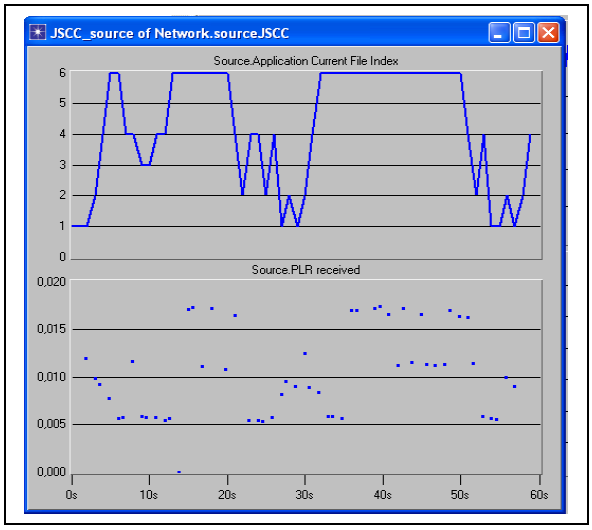
All the parameters are the same, except for the following:

IP Network

- Bottleneck rate: 2Mbps (15%free)

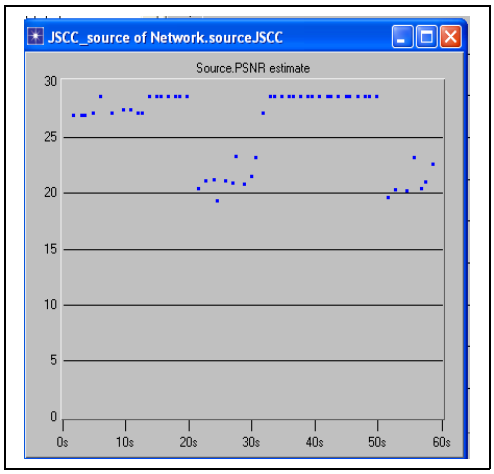
a) Application Current File Index and PLR received

We can notice that the PLR value have increased but not exceed the limit (0.05 in all the simulations.)Therefore the Current File Index depends only on the PSNR value (We can see it in the Application Controller code).



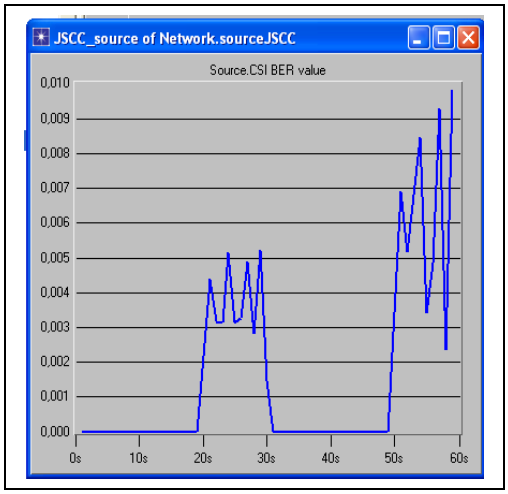
b) PSNR estimated

The PSNR values are quite the same but now these have decreased a bit. That can be caused due to absence of part of the information, lost in the IP Network.



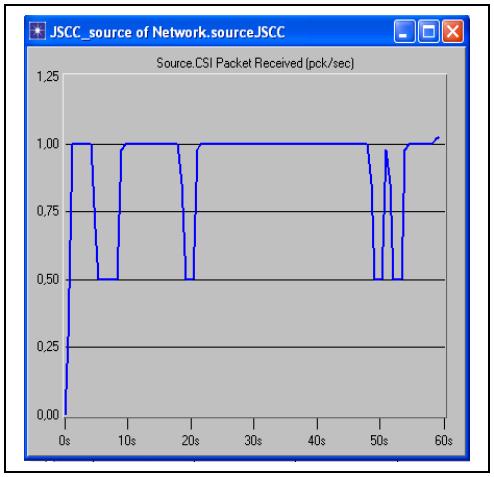
c) BER value in CSI packets

These values are more or less the same as before



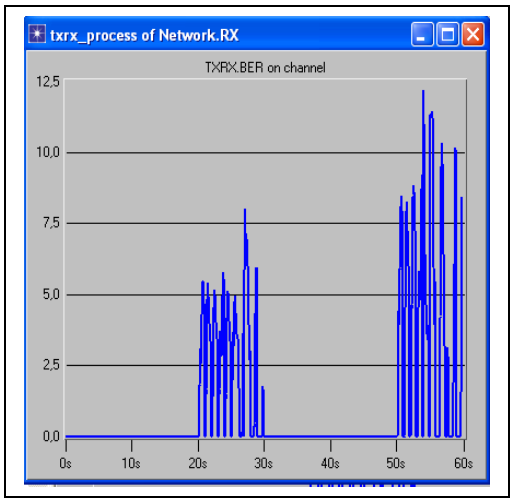
d) CSI packet Received in the Source

Also it is more or less similar to the another graphic before.



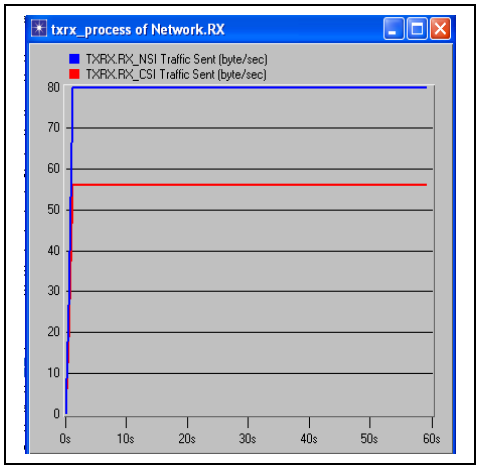
e)BER on Channel calculated in RX

More or less the same as the previous simulation. There is not relevant changes.



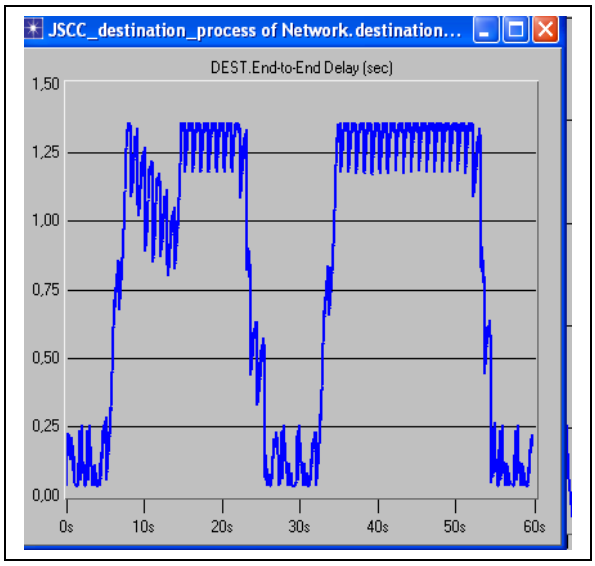
f) NSI/CSI Traffic Sent

The same as before due to the timer for them is the same as before



g) End to End delay

We can notice that now, the Delay is higher speaking in average terms. This can be produced by the Bottleneck in the Network, this would produce queuing delay, that is added to the total delay in Network.



6.1.4.- COMPARISON between SCENARIO with AC and without AC

In this section we will confront the more significant graphics in both scenarios (with and without AC).

N.B. :

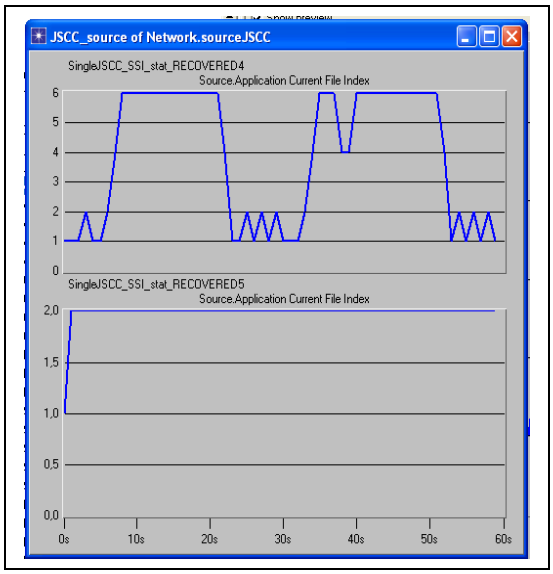
RECOVERED 4 → Scenario with AC

RECOVERED 5 → Scenario without AC

a)Application Current File Index

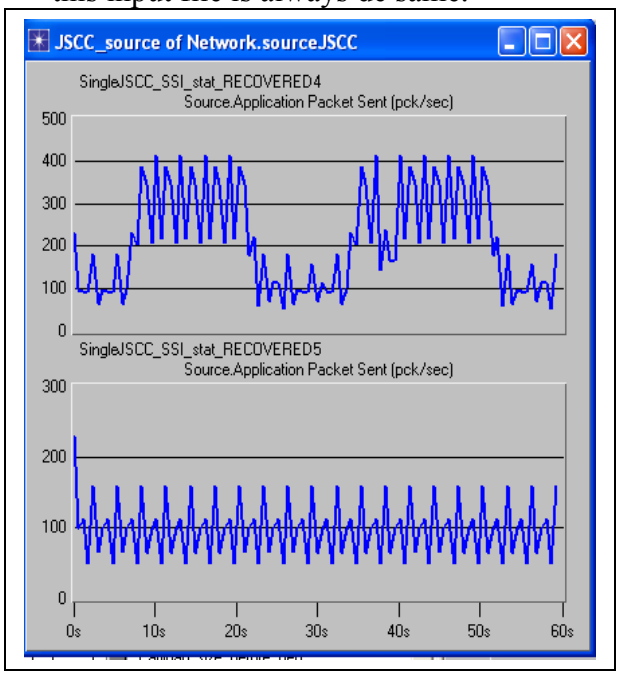
As said before, in the second scenario, the Index File remains deactivated. The adopted index depends on the initials conditions that we have set in the Scenario Configuration Node that are used in the AC algorithm (These parameters remain constant for all the simulation).

While in the first graphic the Current File Index varies in the time, in the second one (Scenario with A.C. deactivated) the graphic remains constant.



a) Application Packet Sent

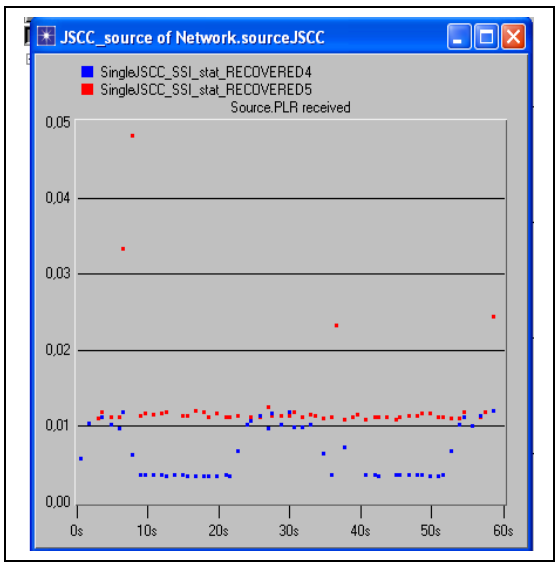
The packet Rate on the Application Controller is variable along the time in the first case (with AC), whereas on the second one is periodical. That is because the input file in the second case is always the same and therefore the bit rate indicated in this input file is always de same.



c) PLR received

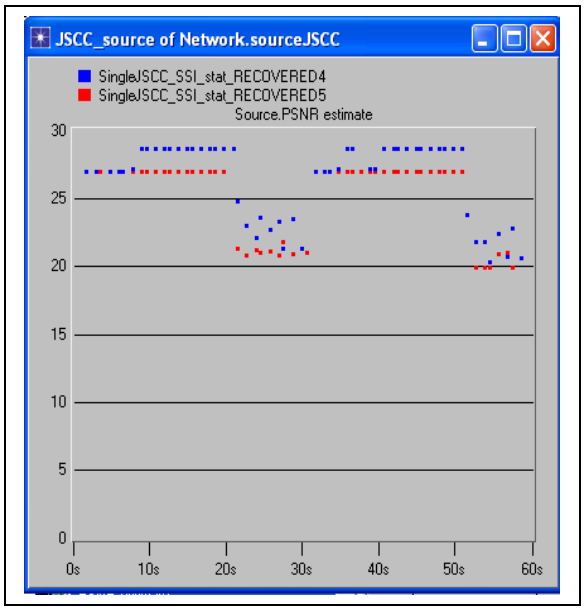
We can see an improvement in PLR with Application Controller as is showed in this graphic. Therefore we could say that AC helps to improve the PLR value. (Recovered 4 → With AC, Recovered 5→ Without AC).

If the AC see that the loss of packet is increasing, it tries to solve this problem loading a lower bit rate input file.



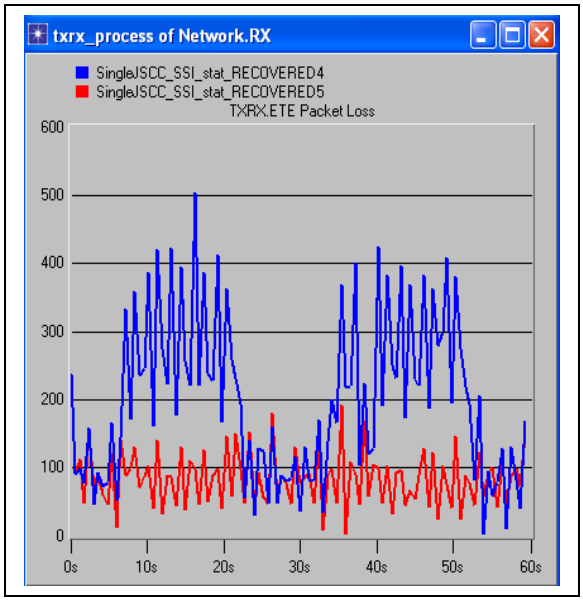
a) PSNR estimated

Also we can see an improvement in the PSNR estimated. The AC makes the BER and PER decrease and, as PSNR depends on these parameters, the PSNR estimated will be improved.



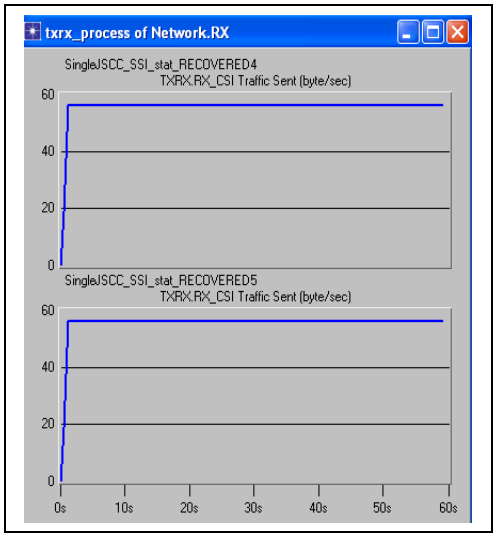
d) End to End packet Loss

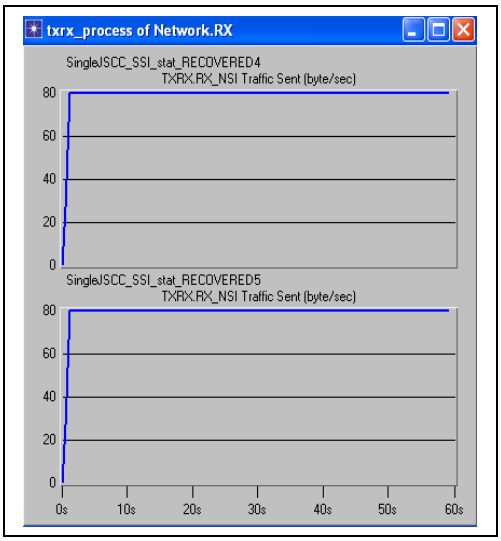
We can see in the following graphic that the packet loss rate is more or less constant without AC, whereas with AC it is not. That is because the bit rate is variable with AC, and constant without AC. So if the bit rate is higher, for an equal Loss% in the Network Node, the number of lost packet are higher in this case.



e) CSI/NSI Traffic Sent

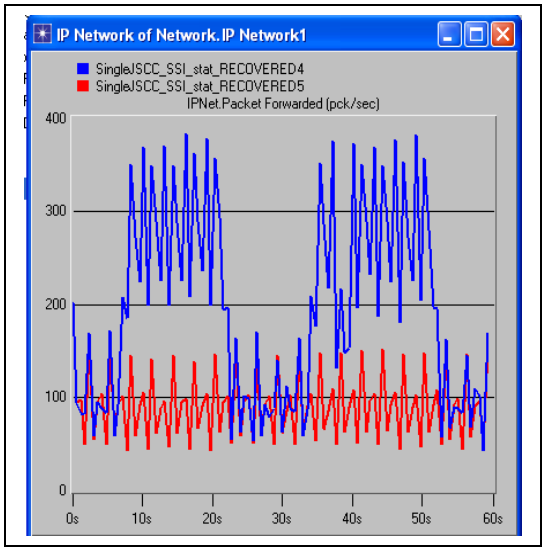
Note that CSI and NSI information rates are the same in both cases, because these informations have a fixed timer that controls its delivering.





f) IPNet Packet Forwarded

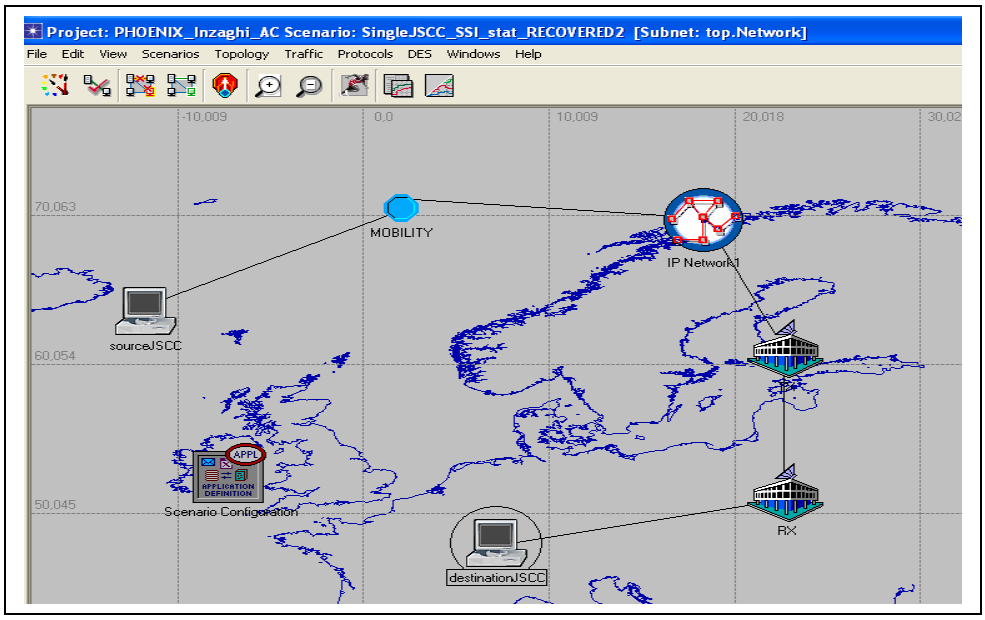
Also it can be seen that packet traffics in the IP Network are different in both scenarios. This is consistent with the previous graphics. The higher is the traffic, the higher is the loss of packets.



6.2.- SCENARIO WITH Mobility Module

6.2.1.-MOBILITY before IP Network

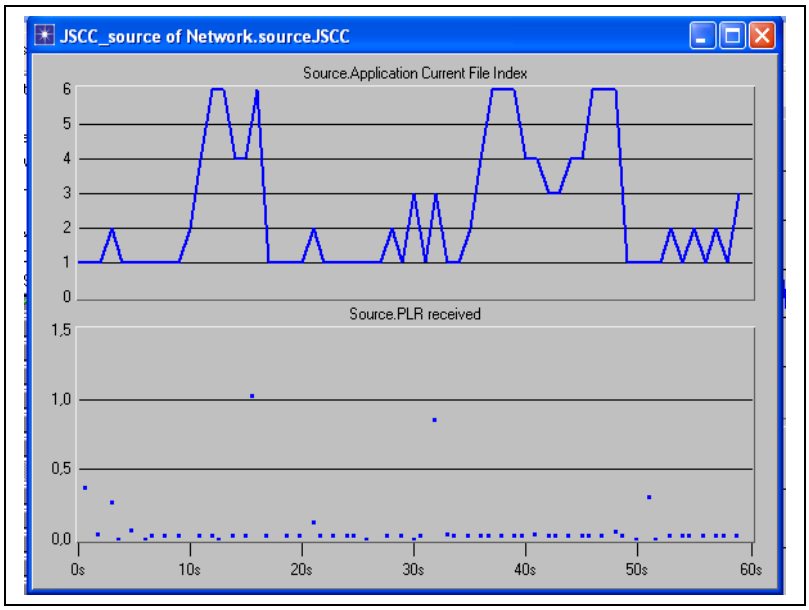
Now we have a different scenario- We have added MOBILITY module in which we will represent the looses and the delays due to a handover or a transmission period respectively. First it have been set between JSCC/D Source and IP Network modules



PARAMETERS:
- With Appl Ctrl
- Without bottleneck
- All the rest of the parameters are the same.

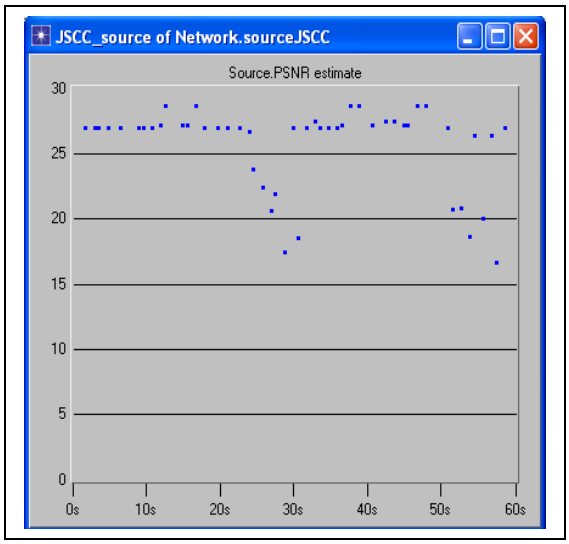
a) Application Current File Index and PLR

We can see that sometimes, the PLR value rises and exceed the limit value. That is because the MOBILITY module introduces a loss of packets. Also it can be seen that the Current File Index varies more than before because the PLR exceeds and so it must go down to level 1.



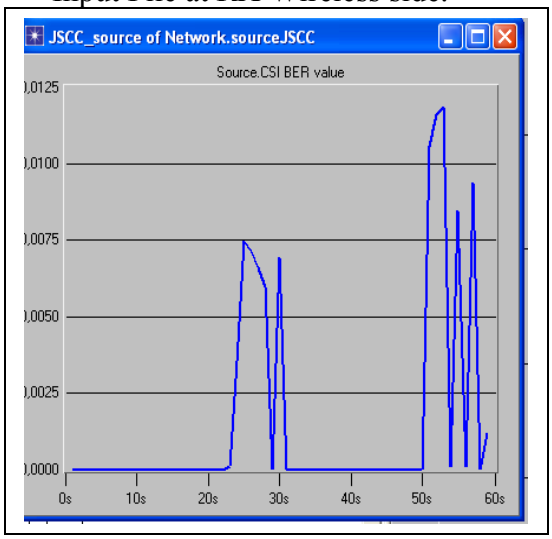
b) PSNR estimated

We can notice that when the channel condition is not good, the PSNR is lower. We could say that this loss would affect at the correct calculation of PSNR



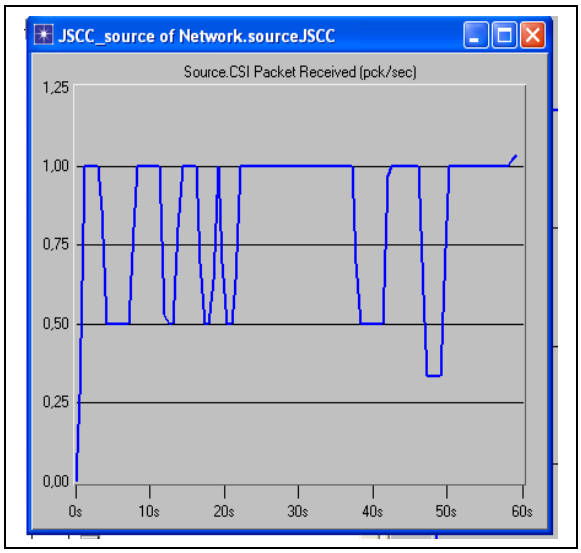
b) CSI_BER

Also this value is similar to the previous scenario. This value depends on the channel conditions that we have set in the initial configuration and therefore on the Input File at RX Wireless side.



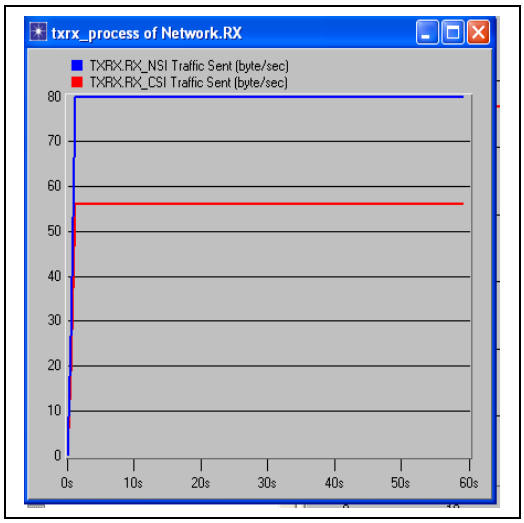
c) CSI Packet Received

We can see that sometimes the packet rate reduces, it is the effect of MOBILITY module, due to it loses also the feedback packets in the period of handover.



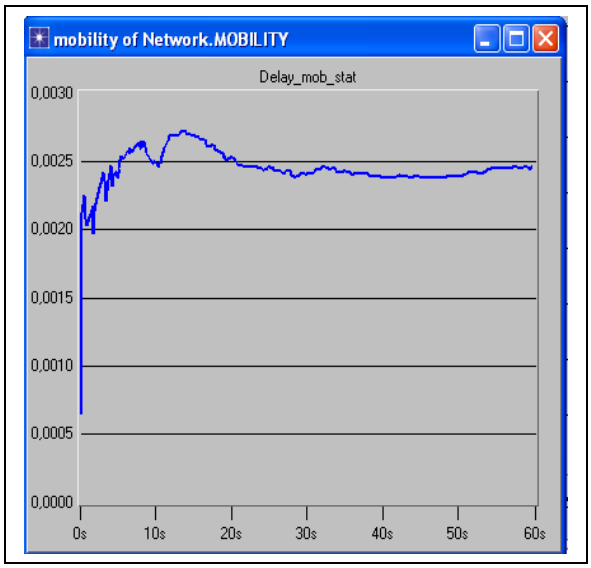
e) CSI/NSI Traffic sent

As explained before, these rates are constant because of the TIMER in RX node.



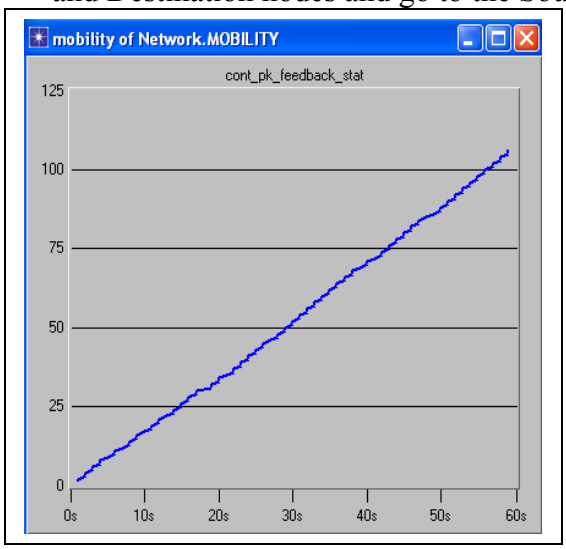
f) Delay_mob_stat

This graphic shows the delay introduced by the MOBILITY module in a transmission period. This delay is set as a statistic variable, a uniform variable with a 5msecs mean value.



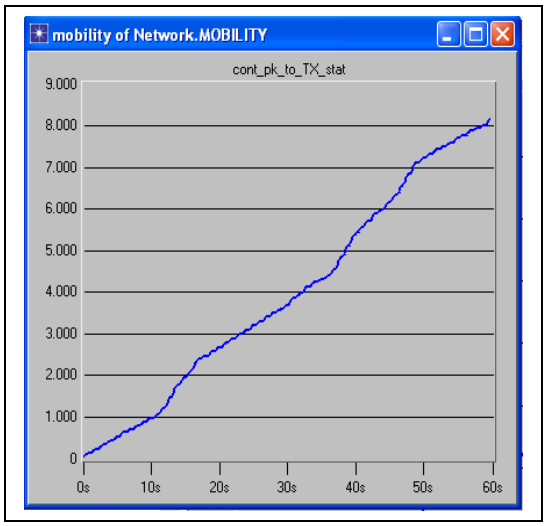
g) Feedback packet

We have a variable that counts the number of packets that come from the RX and Destination nodes and go to the Source JSSC/D.



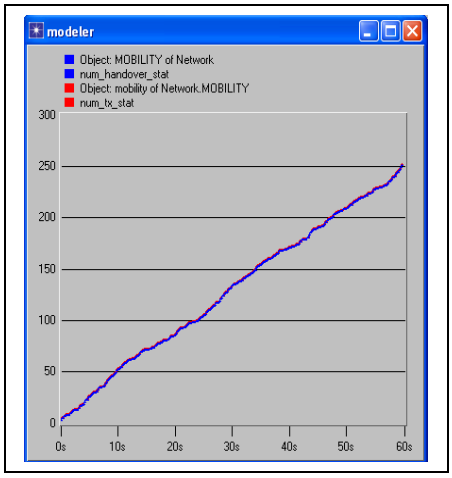
h) Packet to TX

We have another variable that counts the number of packet that are sent from the Source JSCC/D to the RX or Destination node. This variable logically reaches a higher value that the variable related to feedback packets.



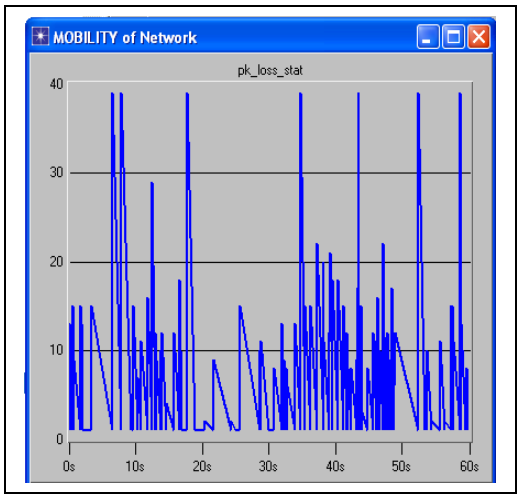
i)Number of Transmissions/ Number of Handovers

It can be observed that both graphics are practically the same. To simulate the period of transmission, we have created an exponential statistic variable, with a mean value of 220 msecs. And to simulate the period of Handover we have created a uniform statistic variable with a mean value of 60 msecs.



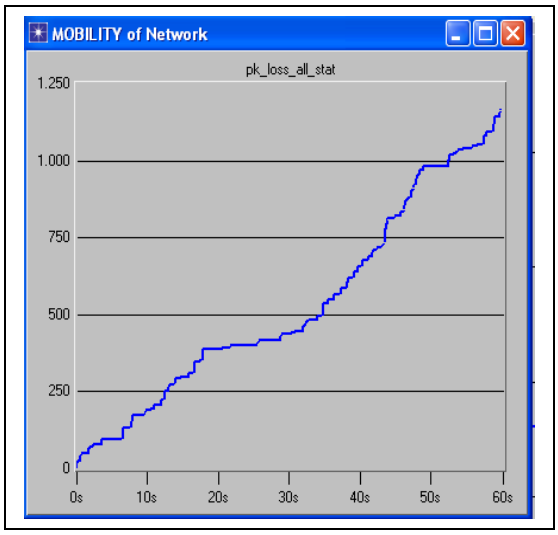
j) Packet loss

In this graphic we can control the number of lost packets in each Handover period. This value depends practically on the duration of each period and also on the bit rate.



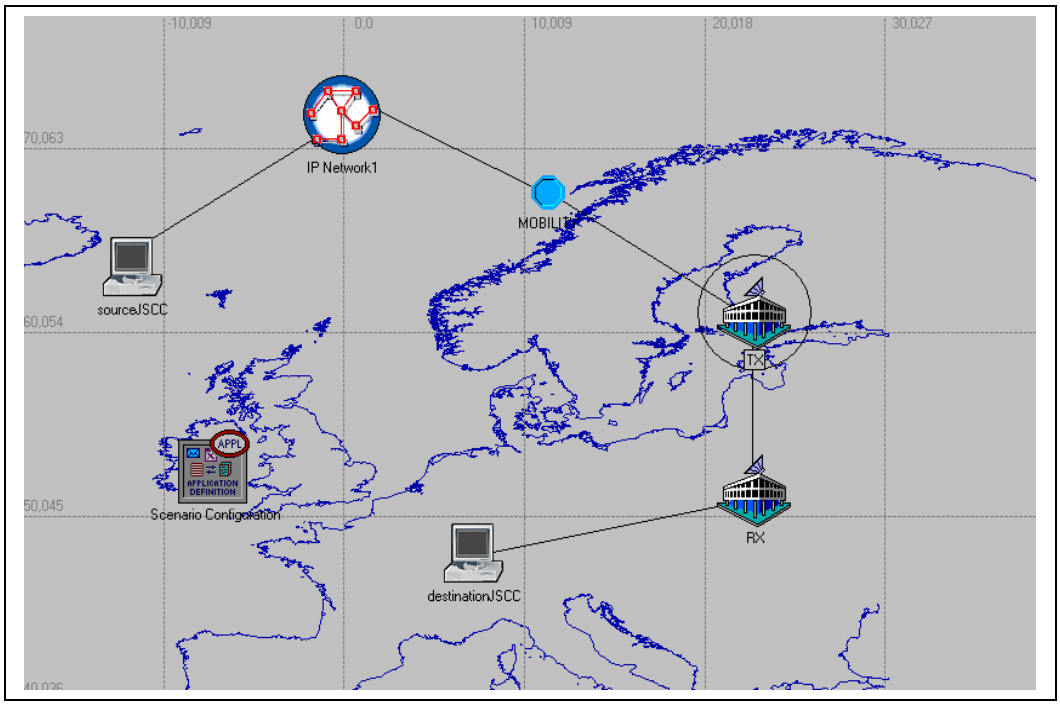
k) Packet Loss All

This is the sum of all lost packet in the time.



6.2.2.-MOBILITY Module after IP Network

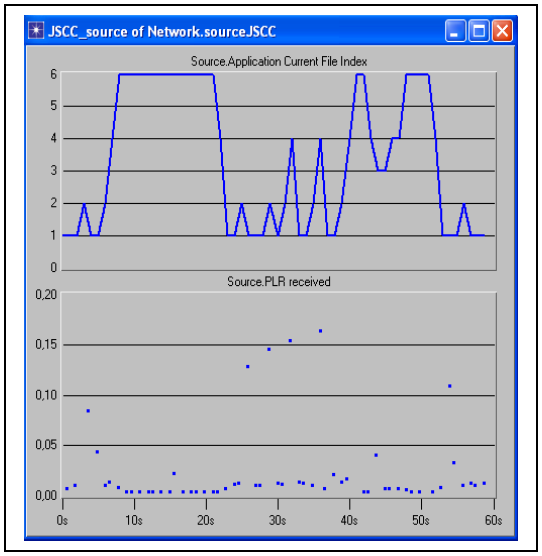
Now we have had to change the position of the MOBILITY module because of the exigencies of the Phoenix Project. We have moved it and we have situated it between the IPNetwork and TX Wireless module. Therefore we have this new scenario:



With the same parameters that we had before, it have been notice some differences that will be shown in the following graphics;
First of all, we will check if the AC works well, so this will be seen.
in the following graphics.

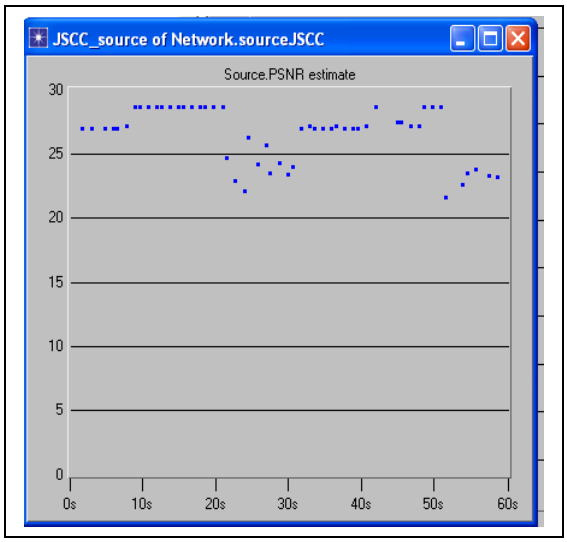
a) Application Current File Index and PLR received

We can see that the operation is correct. Although the channel condition is good, if the PLR exceed the threshold value, the Current File Index will be the minimum, that is, 1. Therefore, the lower bit rate input file will be loaded.



b) PSNR estimated

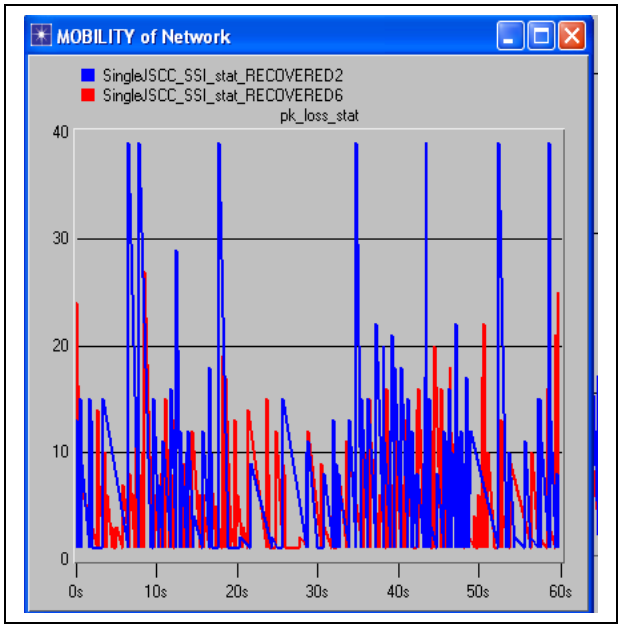
Also with this graphic we can see together with the two graphics above, that the AC operation is suitable. The AC acts when the channel conditions are not favourable.



But now we will see that there are some differences between locating before or after the IP Network:

1.-Packet loss in each Handover

In this graphic we can see the number of lost packets in each period of Handover. We can see that less packets are lost in RECOVERED 6



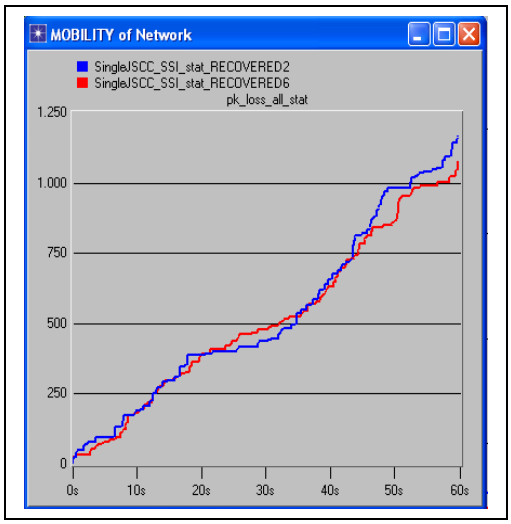
RECOVERED 2 : Mobility Module before IPNetwork
RECOVERED 6: Mobility Module after IPNetwork

It can be appreciated that in each period, the number of packet lost is higher when the MOBILITY is before the IP Network.

2) Total Packet Loss

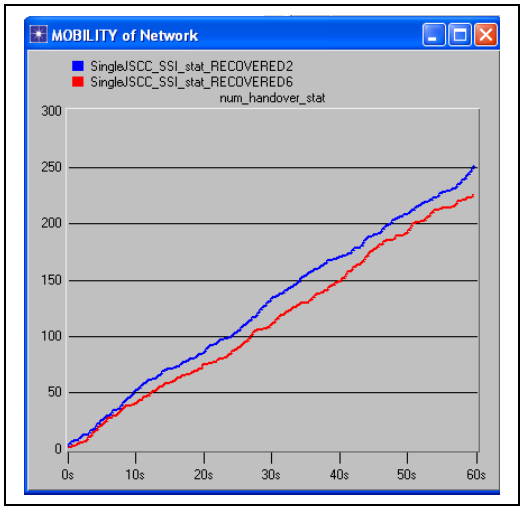
It is noticed that the total packet lost in MOBILITY is higher in the RECOVERED 2 scenario, that is , when the mobility module is before IPNetwork. That is because the packet rate after the Source is higher that which one that is after the IP Network. This is

caused by the Loss% in the IP Network. Therefore, if the MOBILITY module receives less bit rate, the loss will be minor.



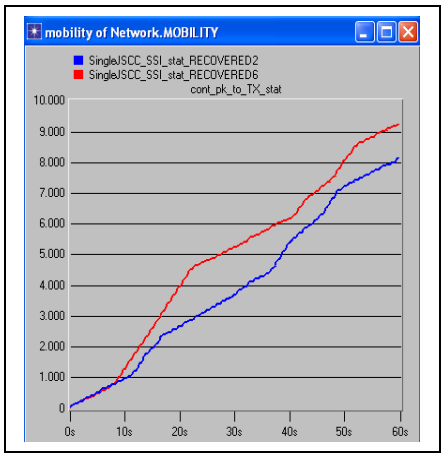
3) Num handover

The number of handovers is less in the second configuration (RECOVERED 6), so is reasonable that, part of the reason because of which, the loss is minor is this (number of handovers), apart from the bit rate.



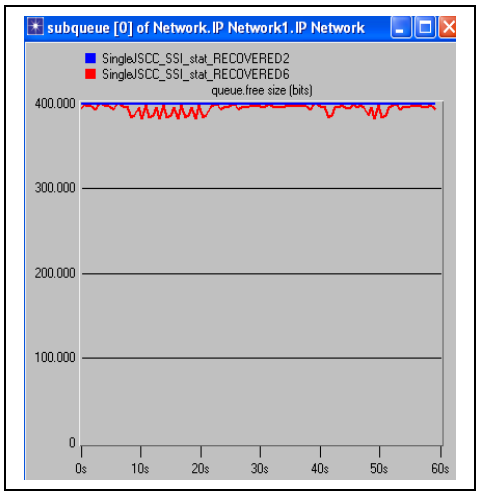
4) Num packet sent

Logically, if the number of handover is minor, the number of packet sent is higher…



5) Subqueue free size

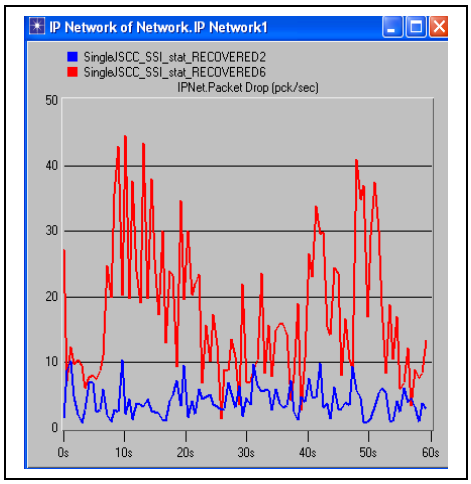
We can see that the queue in the IPNetwork is free when the MOBILITY is before this module giving the IP Network Module a minor bit rate whereas in the other case it is not totally free. This can be due to a minor throughput at the end of the MOBILITY module, in comparison with the throughput that IP Network receives directly from the Source JSCC/D, like it was in the Scenario 6.



So, if we put the mobility module after IPNetwork, the input rate for the mobility module will be minor that in the other configuration, therefore the loss rate will be minor.

6) IPNet Packet Drop

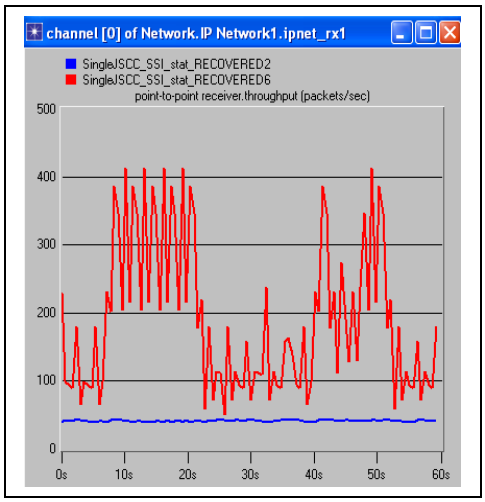
The same argument is valid for IPNetwork module. We can see here that the Packet drop rate in the IPNetwork module, when the MOBILITY is before, is minor due to the fact that the input rate for the IPNEtwork module is minor.



7) IPNet Throughput

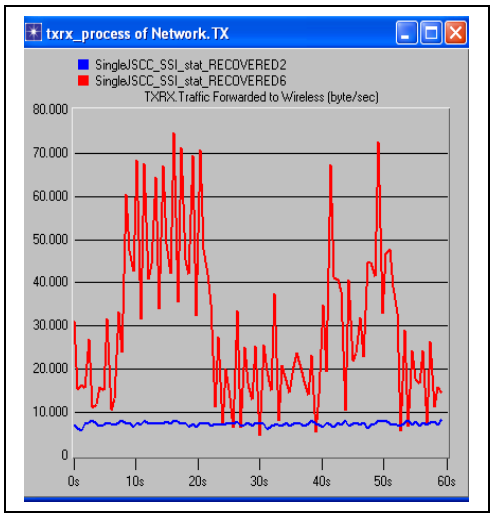
Also we can see that the throughput at the end of the IP Network is different depending on the position of the MOBILITY module.

When the MOBILITY is before, the Network throughput is minor, because its input is already minor due to the packet loss in MOBILITY. However, when the MOBILITY is after the Network, the network throughout is higher due to a higher input coming from the source.



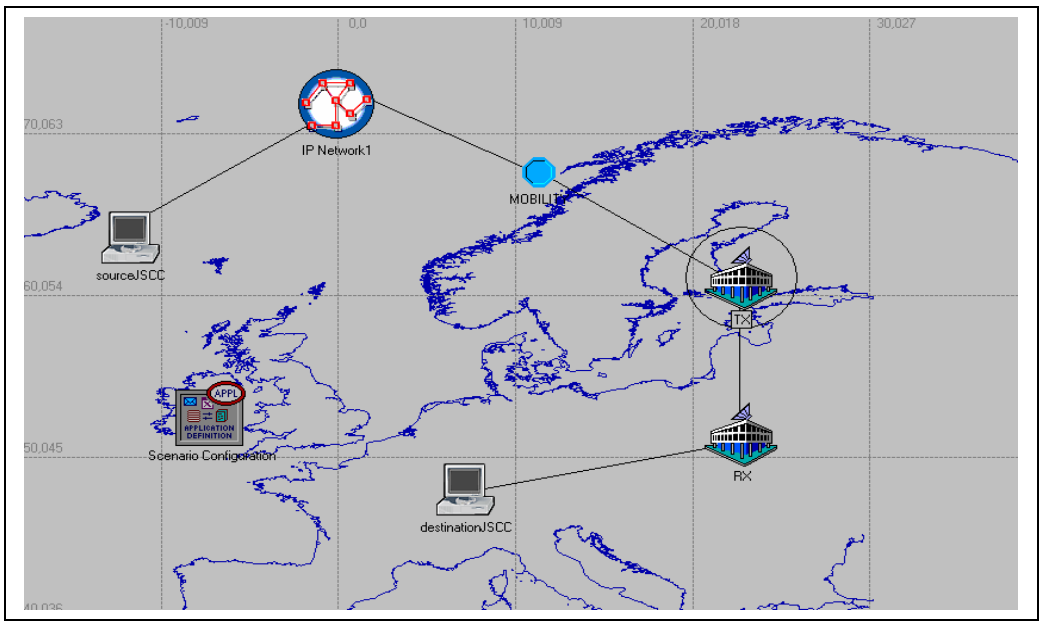
8) TX Traffic Forwarded to Wireless

Due to the fact that there are two different scenarios, and therefore, two different behaviours, is logic that the sum of all packets lost in each case is different. It can be seen in the following graphic, in which we see that the TX input is minor when the mobility module is before the IPNetwork. That means that the total packet loss is **higher** when the MOBILITY is before the Network.



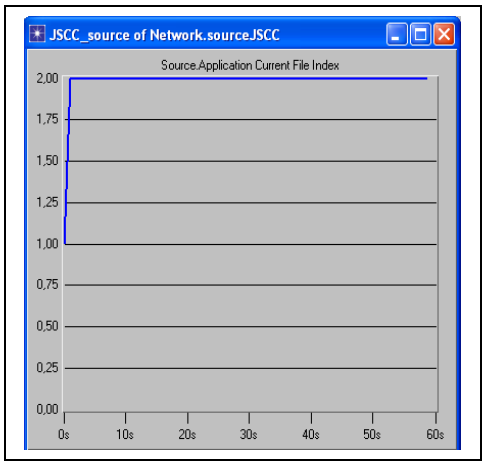
6.2.3.- Scenario 6.2.2.- but WITHOUT Appl. Ctr.

At the end, we will choose the scenario in which the MOBILITY module is after the IPNetwork, due to exigencies of Phoenix Project.



a) Application Current File Index

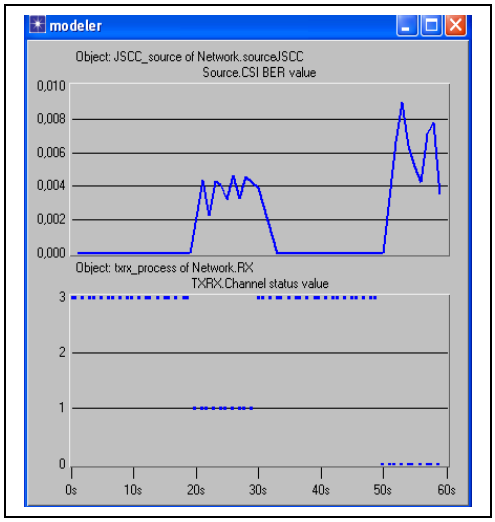
As seen before, the Application Current File Index remains constant, depending only on the initial conditions GOV, App control state.



We can see that the AC is not working, due to the fact that Index is constant along the time.

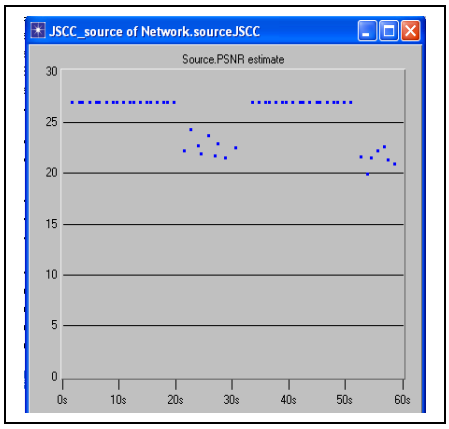
b) CSI BER and Channel Status Value

These values are consistent. We have just explained how the CSI is calculated and how is related to the AC.



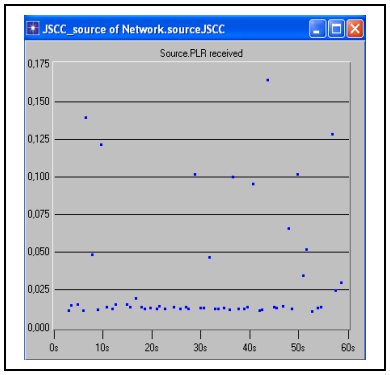
c) PSNR estimate

As we saw in the last scenarios without AC, the PSNR is calculated according to BER and PER, but these values are not improved in case of bad channel conditions. Also, it can be seen that PSNR value is constant and high when the channel condition is good.



c) PLR received

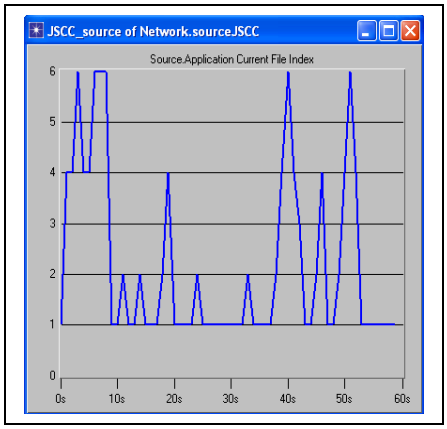
PLR value exceeds the limit more frequently than before. That means that the AC acts over this parameter reducing it when it is activated. This loss also affects the actual value of the estimes based on CSI, NSI, SSI …parameters.



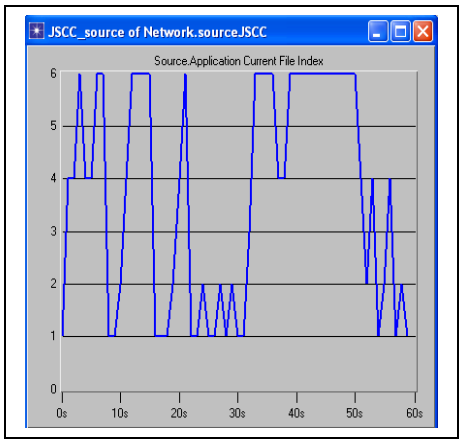
6.2.4.- SIMULATION : MOBILITY OVER FEEDBACK PACKETS

We apply mobility to the feedback information, that means that CSI, NSI, DRI… packets will be affected because some of them will be lost.

1) Application Current File Index



a) Applying MOBILITY to feedback

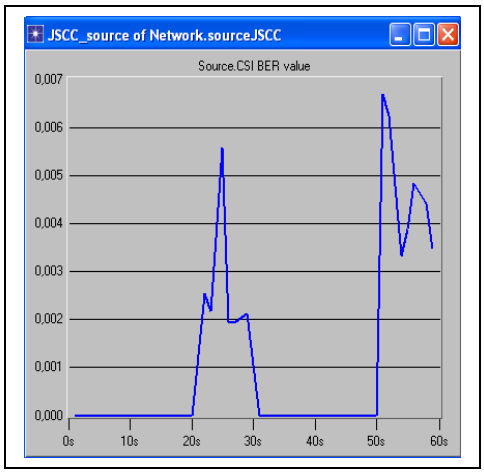


b) Without applying MOBILITY to feedback

We can see that in each period in which the channel conditions are constant, the File Index changes more than before. Now, mean information is lost, and therefore, the AC can not work well. If mean information is lost, the source doesn't know the actual system state**. Also we must add the effect of loosing from Source to destination.**
Channel Conditions are: 0 -20: good
20-30: poor
30-50: good
50-60: very poor

2) CSI BER value

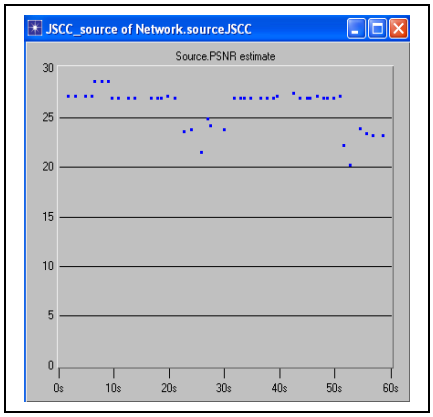
Also, the CSI BER value changes a little in comparison with the previous Scenario because not all the CSI packets arrive to the Source and so the calculations are not precise.



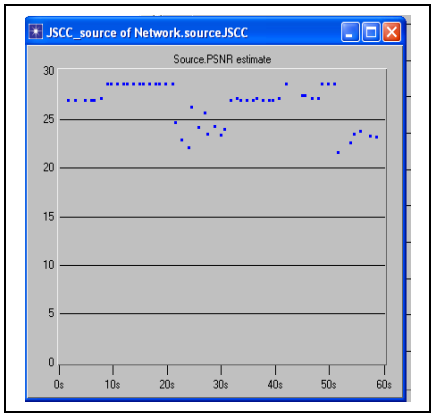
3) PSNR estimated

We have noticed that PSNR values change, and also I could say that when Mobility is applied over Feedback, these values are lower. Therefore these losses affect in a bad manner over PSNR values, A.C understands that the quality of received video is worse.

Anyway, looking the PSNR, Current File Index and PLR together, we can see that the Application Controller works correctly, coherently with the information that it receives from the other part of the Network.



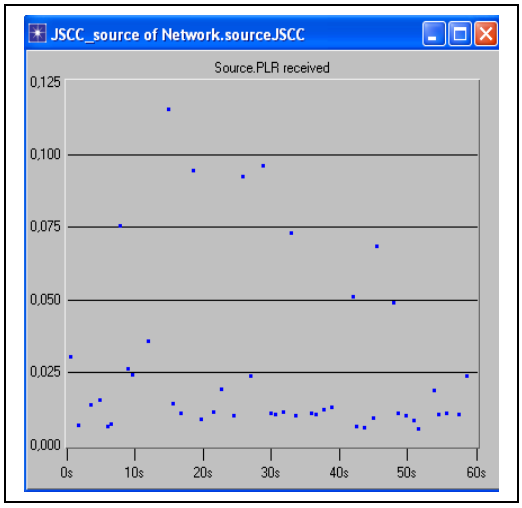
a) With MOB. Over feedback



b) Without MOB over feedback

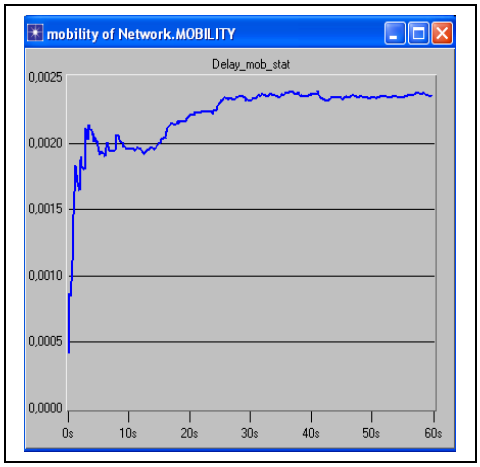
And without MOBILITY over feedback. (Generally, the values are higher)

3) PLR received



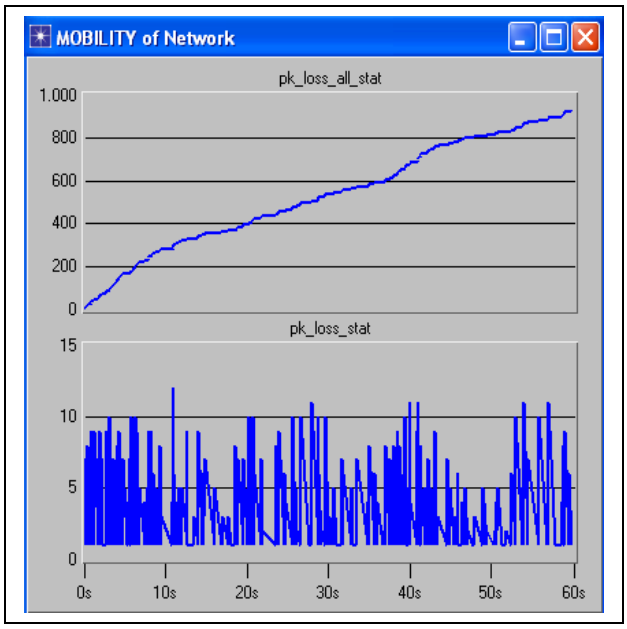
Due to the fact that PLR value is calculated at RX node (when it receives the packets from the TX node), these values do not change in comparison with the previous Scenario, where the MOBILITY was only applied in one sense. But the difference is that the Source does not receive one NSI packet from the RX each period because it would be lost. Therefore, the result is the following: the same values but not received always in each period.

5) MOBILITY delay



Delay has not significant changes. After the transitory, in all the simulations it reaches the same value, 0.0025 secs aprox.

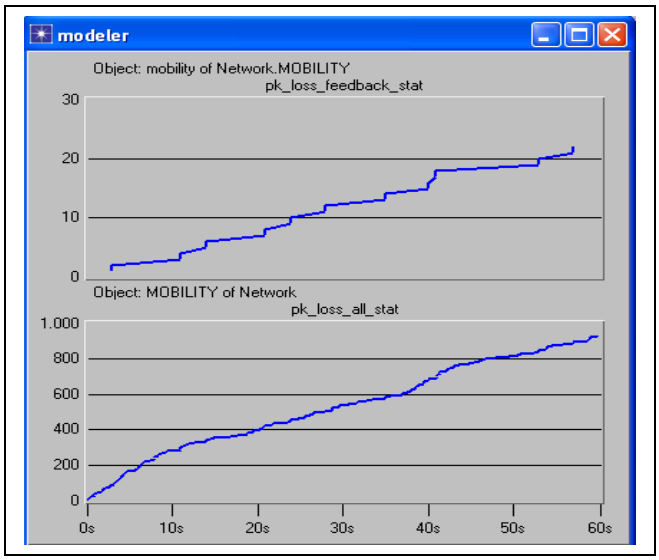
6) Packet loss in each Period and Total packet loss along the time



It can be observed that the number of lost packets have increased because Feedback packets are now included.

7) Packet Loss Feedback

Now we have individuated the Feedback packets to see how many of them are lost. The amount of feedback packets lost is small in comparison with the total packet lost in this module. The total feedback packets are 125 aprox. and 22 of them are lost, that means a 17% of loss in the Feedback flow, in which part of them will be CSI and part of them will be NSI information. The effects on PLR have been just said, and the effects on CSI is that the information of PSNR will not be exactly the really value of it.



CONCLUSIONS:

a) On one hand, in this simulation we can see that PLR has not changed because it is calculated at RX side and therefore it has not been taken into account the feedback looses. Only, the Source may not receive each period one NSI packet. Therefore, if in one period the AC made the PLR calculations, it will use the previous value. For

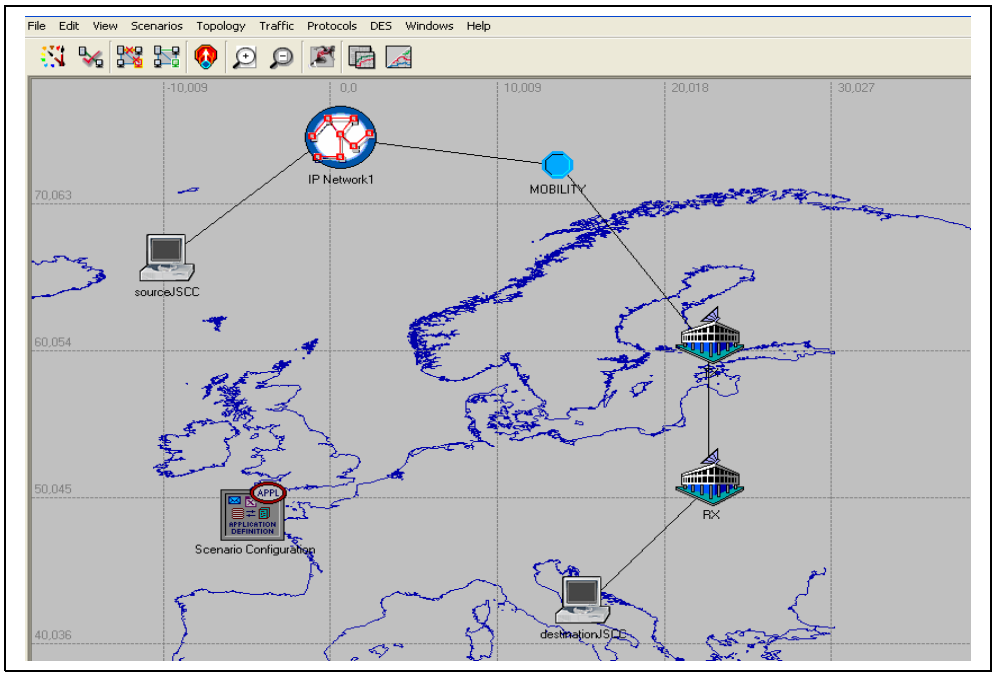
example, in the hypothetical case in which PLR threshold would be exceed, and the Source do not receive this packet, this information would not be taken into account and the Application Controller would not act reducing the Current File Index. In this case we could say that the AC is not acting correctly. If we do not reach the threshold, there will be no problem with the AC operation.

b) On the other hand, we have noticed that Feedback loss is not very high, but it may affects over the calculations made in the Source. That means that the source will not receive all the information about CSI and NSI each second but each more than one second. Or maybe one time will receive CSI information and after NSI information (but in different periods, therefore, the calculations made by the AC are wrong and The Application Current File Index will be incorrect).

6.2.5.-COMPARISON BETWEEN WITH / WITHOUT MOBILITY

In the comparison we will made now, we will have the new configuration of MOBILITY Scenario, that is, the MOBLIITY module will be after the IP Network module.

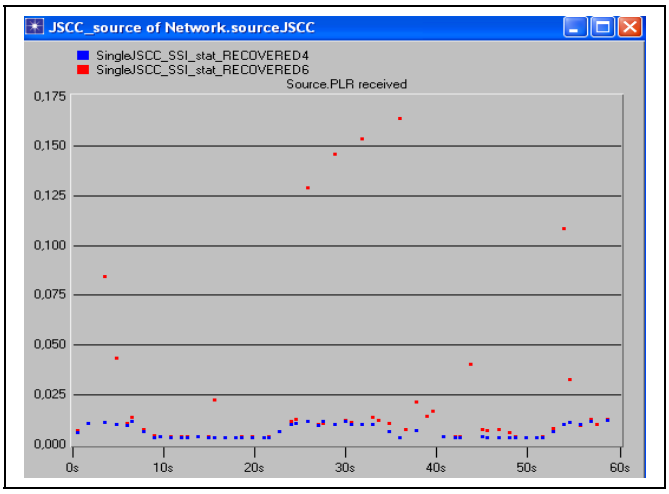
We will compare only main and more relevant aspects.



N.B. RECOVERED 4 → Scenario without MOBILITY
RECOVERED 6 → Scenario with MOBILITY

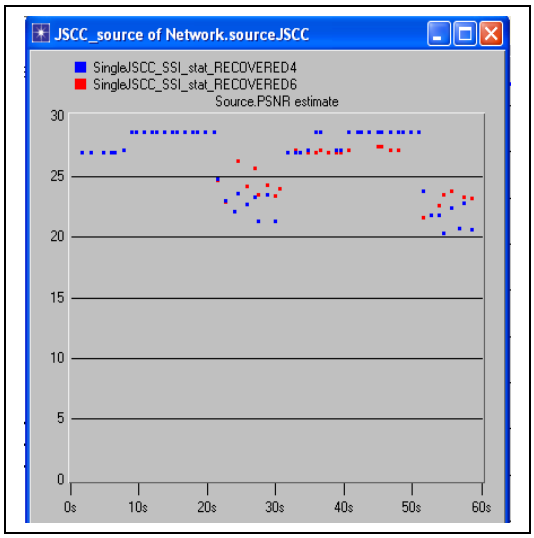
1) PLR Received

It can be observed that PLR values are eventually higher when we introduce the MOBILTY Module, and it exceed the limit of PLR value that we have set.



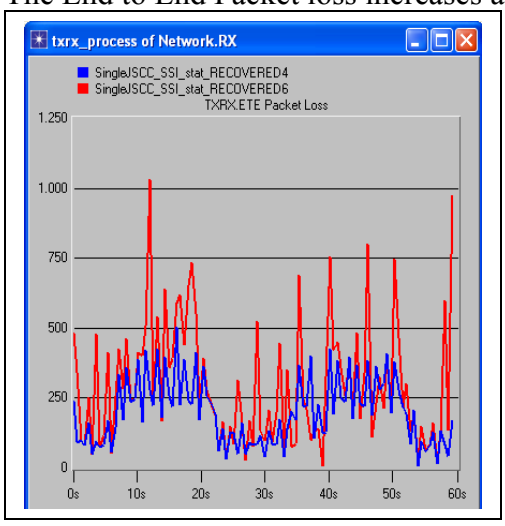
2) PSNR estimated

The PSNR values are lightly different but not a lot. Generally are different when the PLR rises.



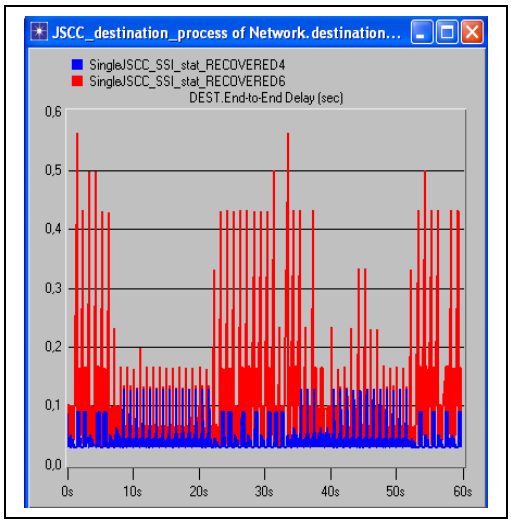
2) End-to-End Packet Loss

The End to End Packet loss increases as well.



4) End-to-End Delay

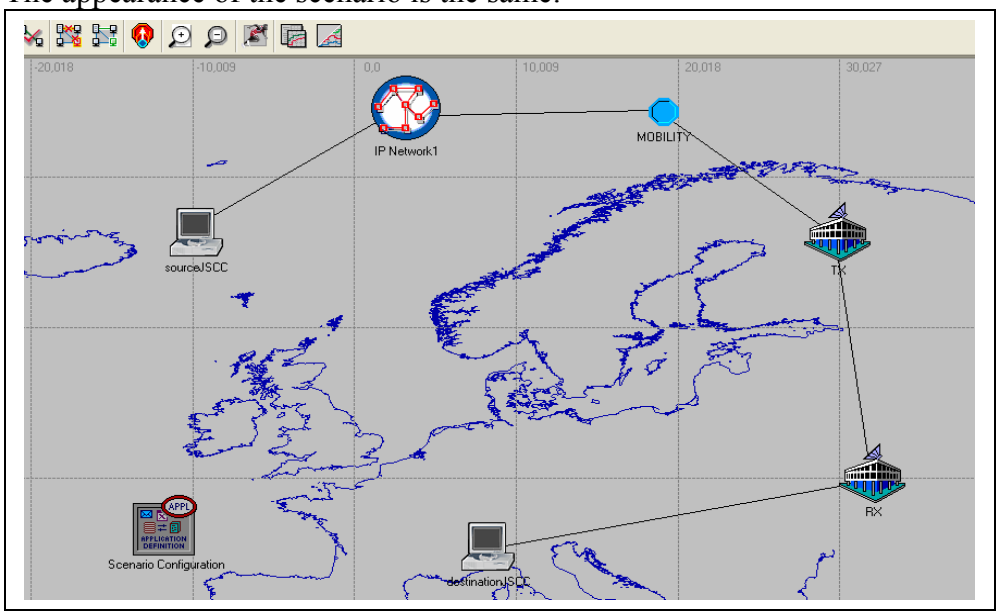
The effect of the mobility can be seen also in the Total Delay



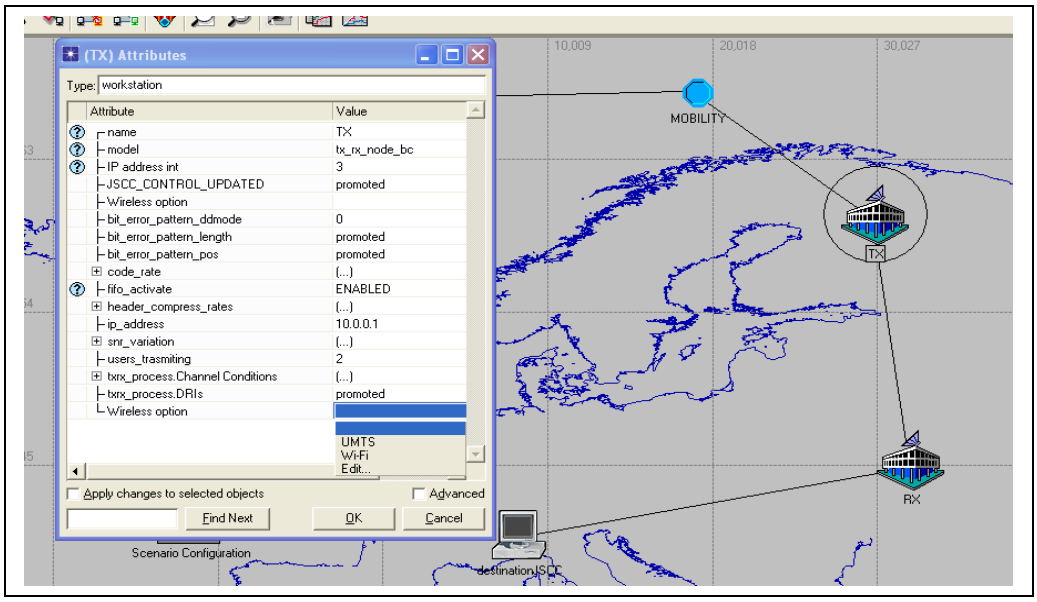
6.3.- SCENARIO WITH MOBILITY AND UMTS TECHNOLOGY

6.3.1.-MOBILITY AND UMTS Technology

We have modified the characteristics of the MOBILITY scenario. We have added the UMTS Wireless technology, setting a Node Attribute in TX node.
The appearance of the scenario is the same:



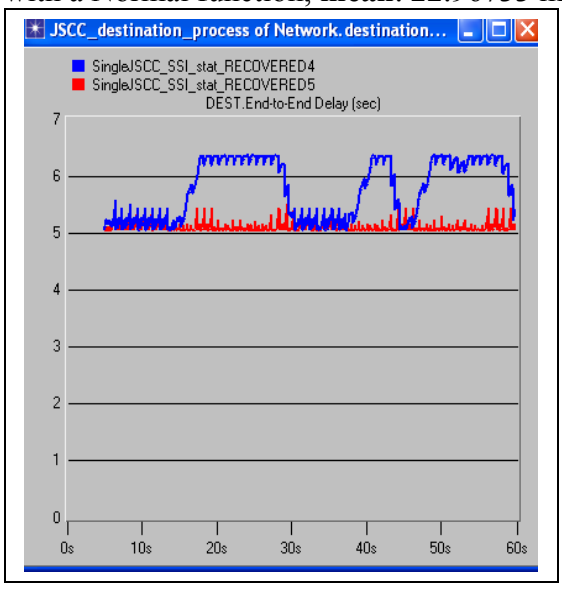
But now we add a new characteristic:



Therefore, the ETE Delay will be higher than before. After a 60 seconds simulation we can see the difference between the two delays:

1) ETE Delay

This UMTS Delay includes the retransmissions due to collisions in a CSMA/CA system. These times added in retransmissions are modeled with a statistical variable, with a Normal function, **mean**: 22.96733 msecs, **variance**: 12.61252msecs.



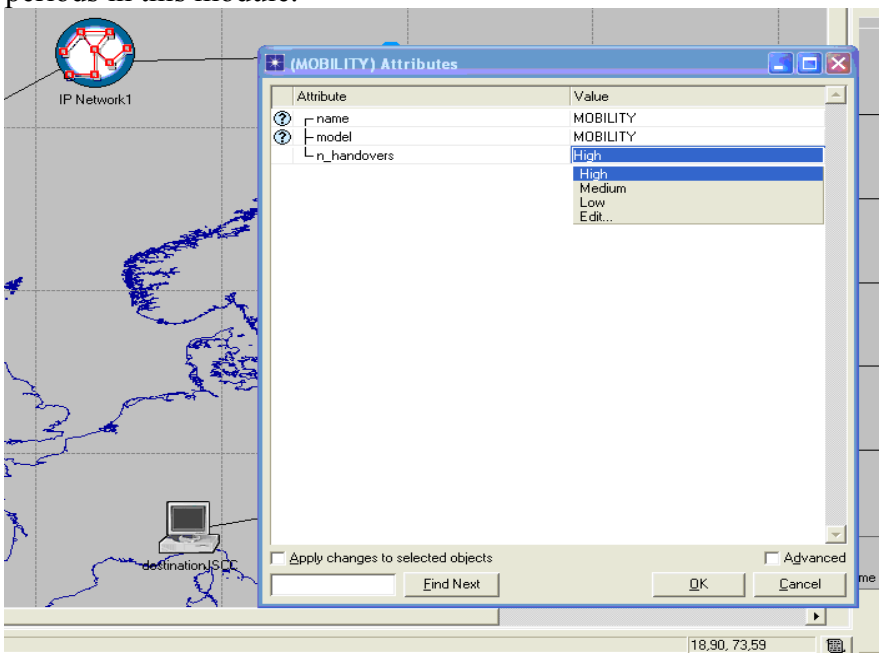
Recovered 4 → With UMTS delay
Recovered 5 → Without UMTS delay

6.4.-With MOBILITY, With UMTS, but Varying TX period in MOBILITY Module

Varying now the transmission periods and maintaining constant the handovers ones, we will see how these looses have influence over the system and over the transmitted information.

Channel conditions are the same as usual.
0-20sg: **good**
20-30sg: **poor**
30-50sg: **good**
50-60sg: **very poor**

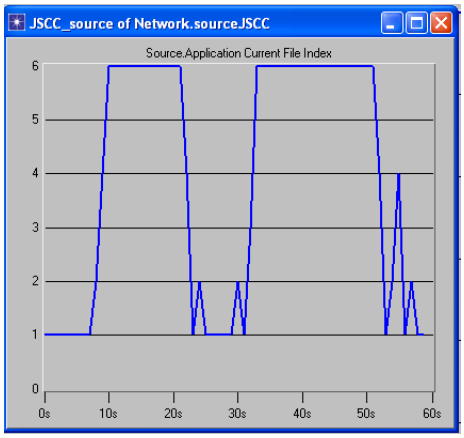
We have added a new MOBILITY attribute in which the level of handovers is indicated. There are three possible levels to indicate the duration of the transmission periods in this module.



6.4.1.-SIMULATION n_handovers= HIGH

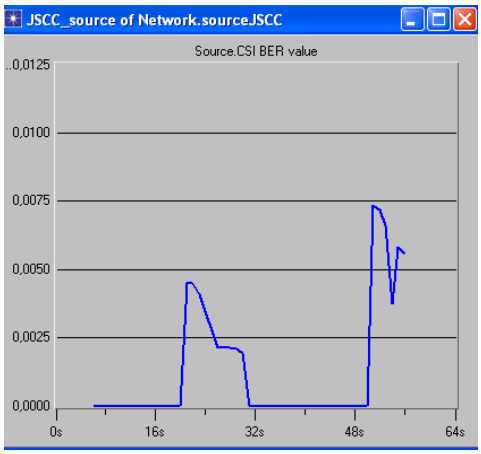
a) Current File Index

This graphic is coherent in relation to the channel conditions set in RX node.
0-20sg : good
20-30sg: poor
30-50sg: good
50-60sg:very poor



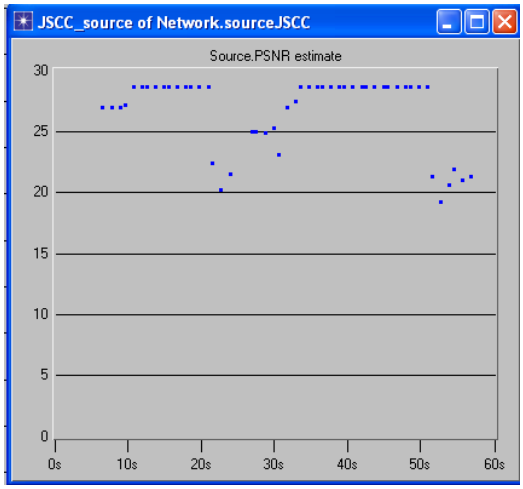
b)CSI VER Value

These values are a bit lower than before, without so many handovers

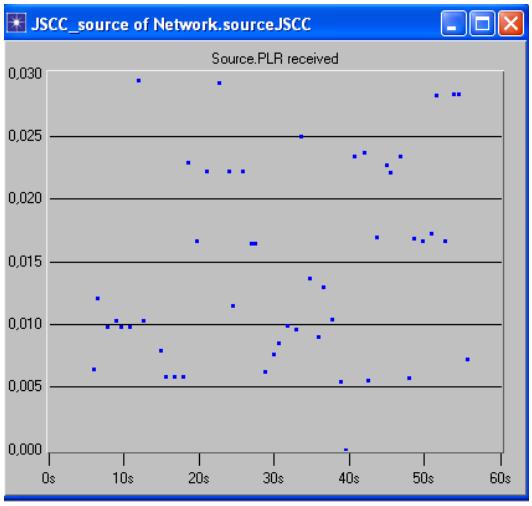


c)PSNR Estimated

We can see that values are correct with regard to values set into channel conditions and the Current File Index graphic.

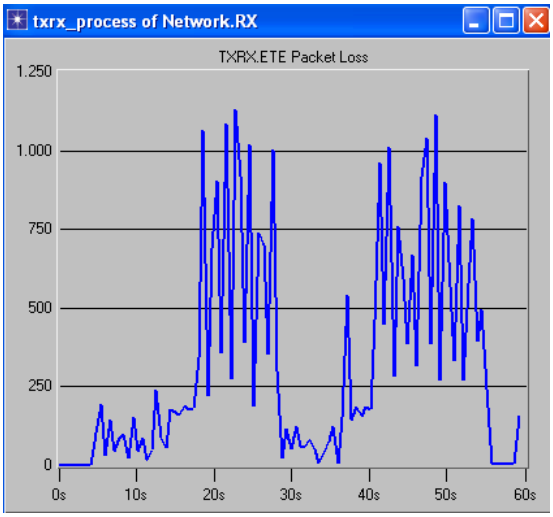


d)PLR Received

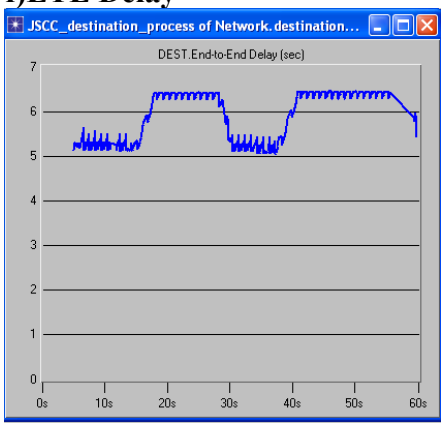


e) ETE Packet Loss

This parameter is calculated in RX node

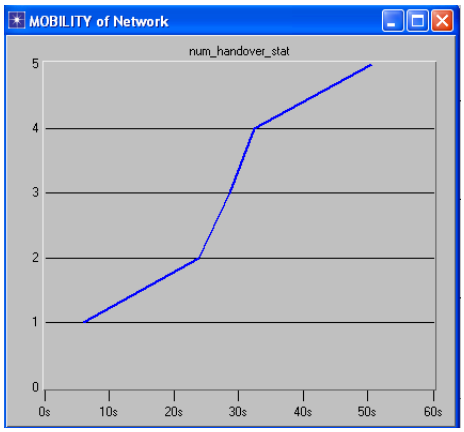


f)ETE Delay

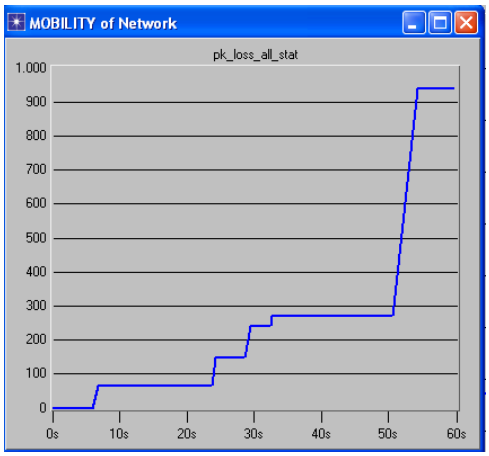


g)Num_handover

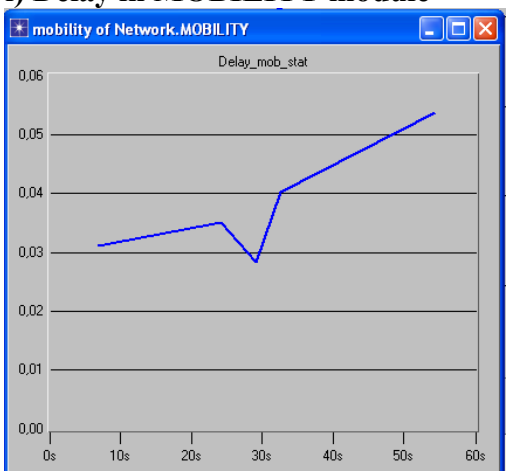
Here we can see the duration of Handover period.



h) Packet Loss in MOBILITY Module



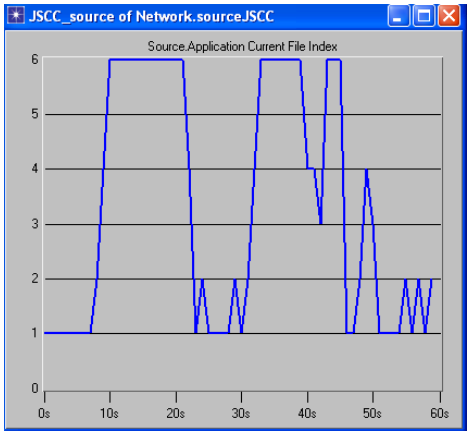
i) Delay in MOBILITY module



6.4.2.- SIMULATION n_handovers= MEDIUM

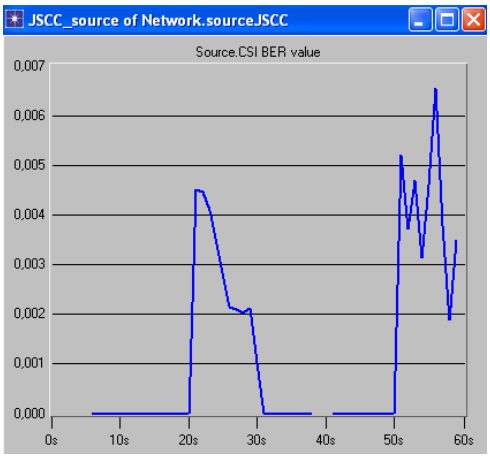
a)Application Current File Index

This graphic is a bit different from the graphic before, but it is due to the fact that there are less lost packets than before and therefore, the Source and at the same time, the Application Controller, have more information. That means that the graphic varies more along the time.



b) CSI BER Value

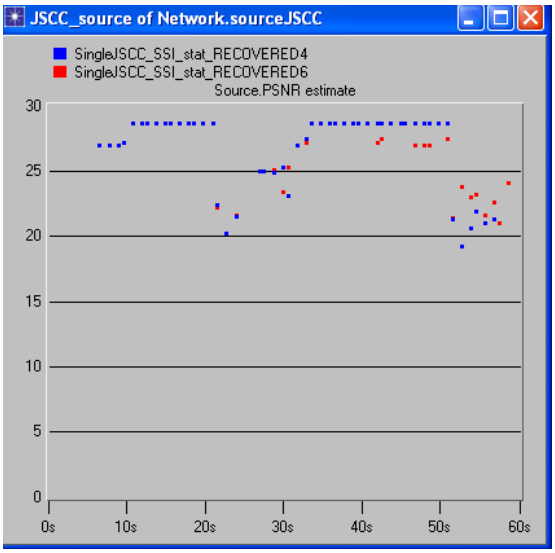
This graphic is quite similar to the graphic before



c) PSNR Estimated

We compare here the previous and the current scenario (RECOVERED 4 and RECOVERD 6 respectively)

We note that now, that we have more reliable information, the PSNR estimated in good channel conditions is a bit lower than before, and in poor or very poor channel conditions, the PSNR Estimated varies and in some cases is a bit higher.



In each period, the AC calculates the PSNR like this:

psnr = evaluate_PSNR(PER_sum/CSI_values,BER_sum/CSI_values);

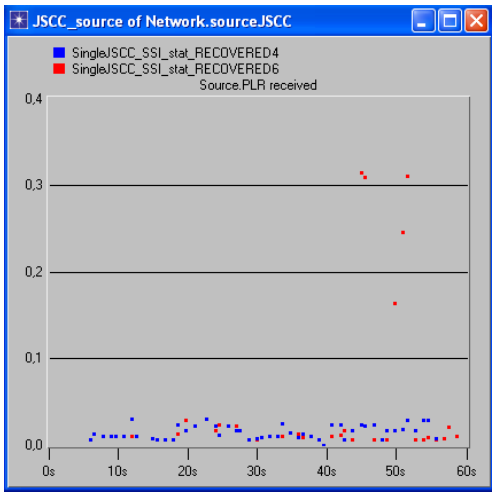
```
float evaluate_PSNR(float per, float ber)
    {
        char tmp[200];
        per /=1;//debug
        ber /=1;//debug
        psnr = psnr_coeff[int_app_state-1][2] * pow( psnr_coeff[int_app_state-1][1], ber ) * pow( psnr_coeff[int_app_state-1][0] , per)
        printf ("PSNR at time : %f = %f\n", op_sim_time() , psnr);
        op_stat_write ( PSNR_stathandle, psnr);

        sprintf(tmp, "PSNR: %f, per: %f, ber: %f",psnr,per,ber);
        mgr_warning(tmp);


    return psnr;
    }
```

We can see in the code that one of the parameters is “int_app_state”, and this value is different in both scenarios during this period, so this phenomenon is due to this fact.

d) PLR Received

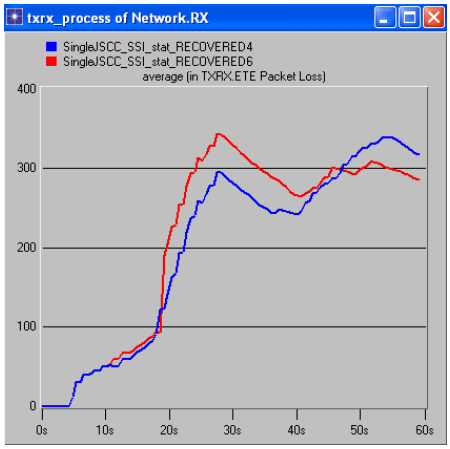
Often, the PLR values in the current scenario is lower, but in the last period is much higher.

WHY? It should be lower…



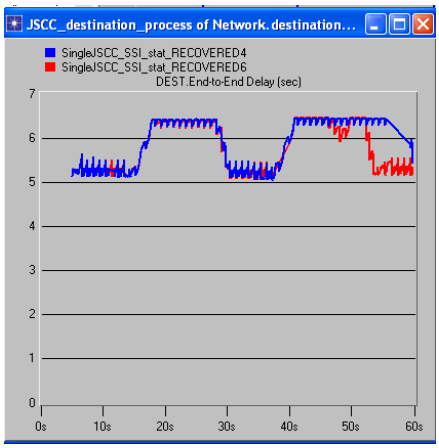
e) ETE Packet Loss

We have made the average along the time graphic because sometimes the loss is higher in the current scenario than in the previous one, and it can not be seen clearly which value is higher. Therefore, at the end, t=60sg it can be seen that the previous configuration looses more packets than the current one. So this is a logical result.



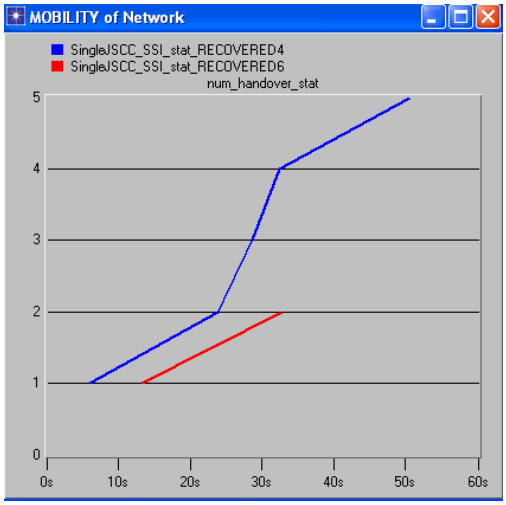
f) ETE Delay

These values have not changed a lot because the statistic variable has not changed.



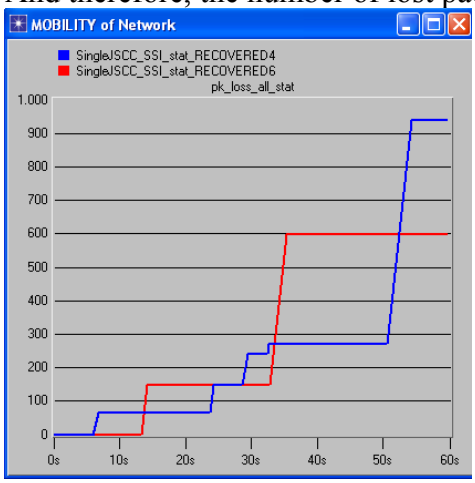
g) Num_handover

We can clearly see that the number of handover has decreased.



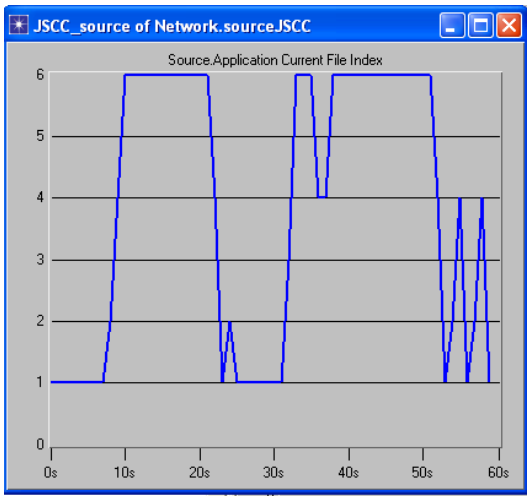
h) Packet Loss in MOBILITY module

And therefore, the number of lost packets is lower.



6.4.3.- SIMULATIION n_handovers= LOW

a) Appl.Current File Index



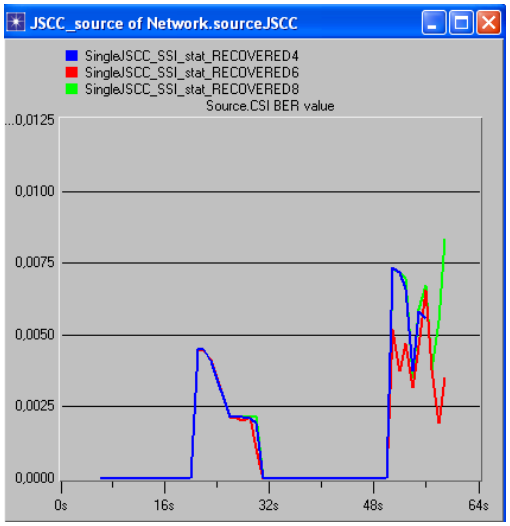
b) CSI_BER value

Recovered4→n_handovers = HIGH

Recovered6→n_handovers = MEDIUM

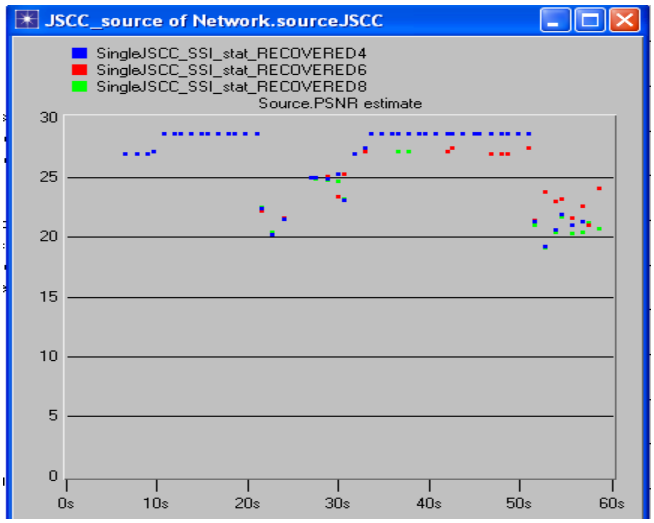
Recovered8→n_handovers = LOW

Values are the same more or less. The looses of this type of packets is not enough to make erroneous calculations.

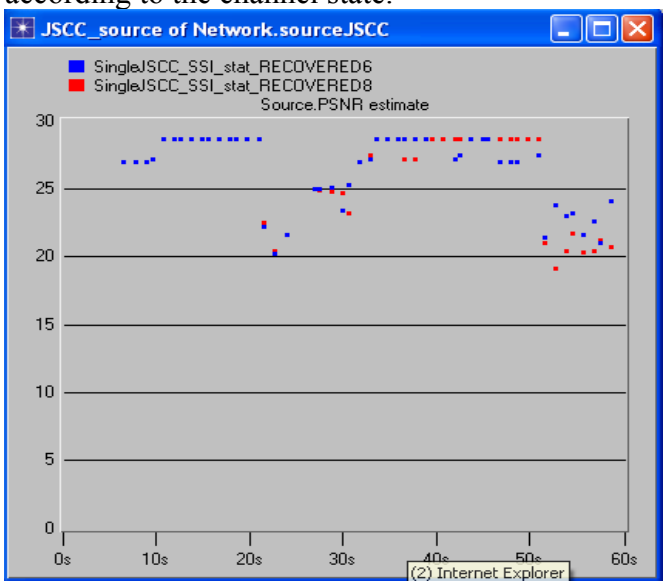


c) PSNR Estimated

Comparing the three scenarios:

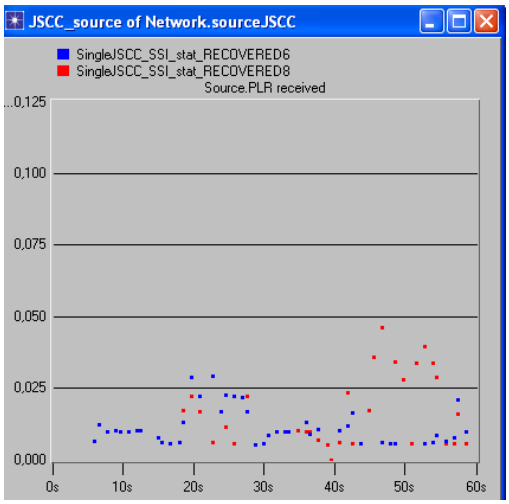


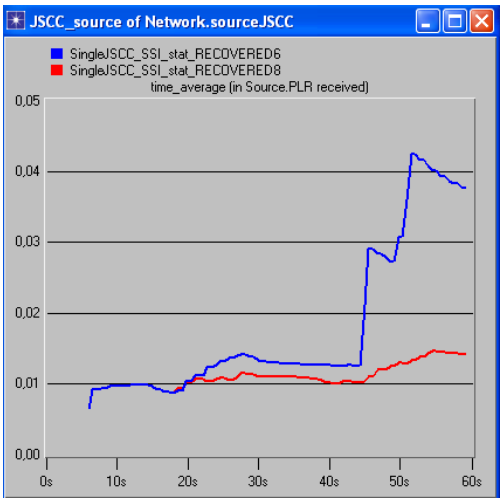
Comparing only with the MEDIUM number of handovers scenario:
We observe that when losses are lower, the PSNR reaches better values. That means that PSNR is more correctly calculated because less information is lost. Here we can see that the calculated values for PSNR are more approximated in the RECOVERED 8 according to the channel state.



d) PLR

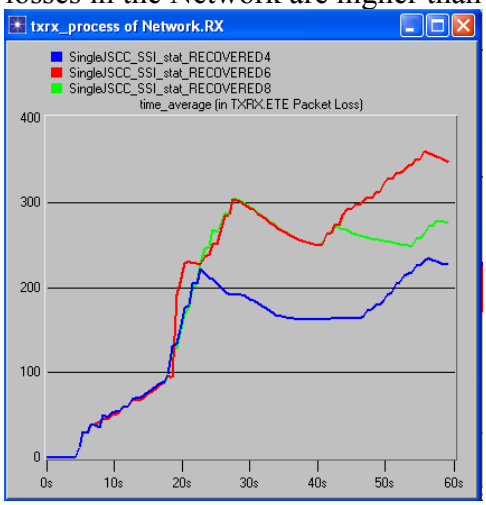
Sometimes PLR is higher in the current scenario although the number of handovers is lower, so we will show the average time graphic.





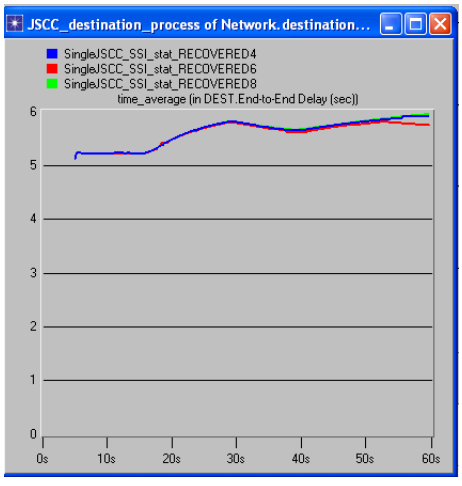
e) TXRX. ETE Packet Loss

The losses are lower in the last scenario, except for the last period. This can be produced due to the statistical variable which models the losses in the Network. The losses in the Network are higher than in the MOBILITY Module.



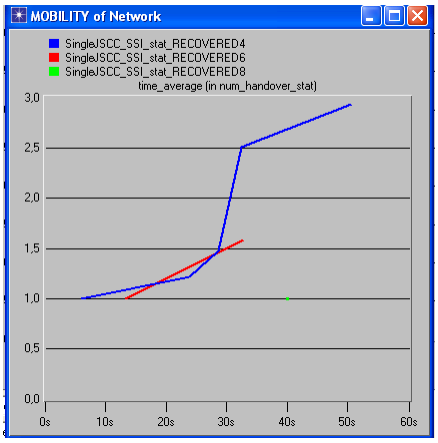
f) DEST. ETE Delay

In all the scenarios the values are similar because the statistical variable that models the Delay is the same in all the cases.



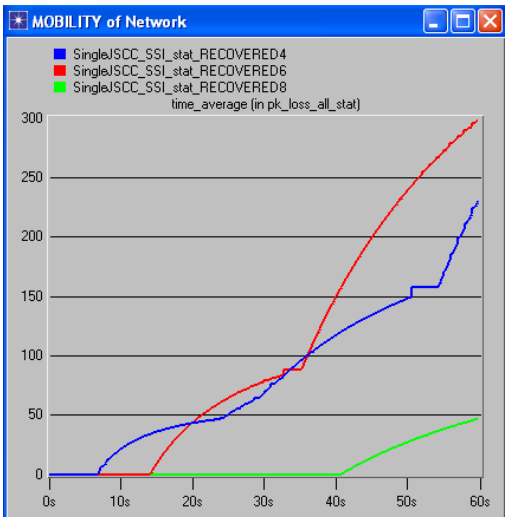
g) Num_Handover

We can see how the number of handovers reduces.



h) MOBILITY Packet Loss

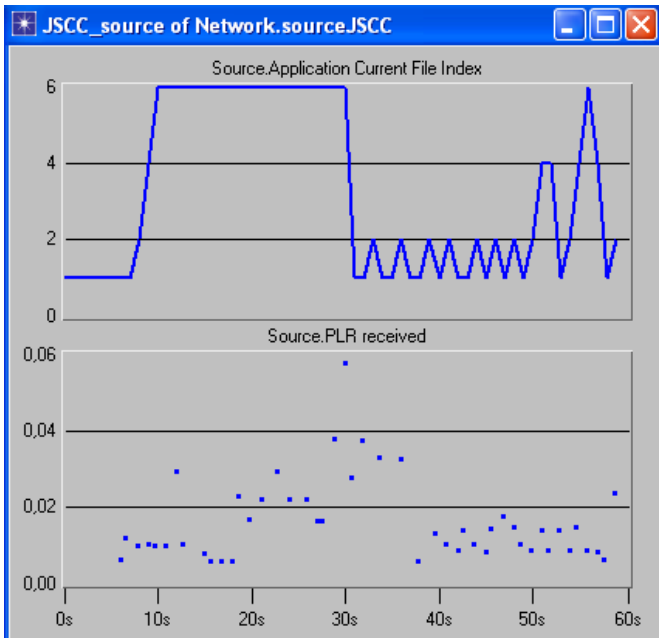
The losses in the last configuration is lower than in the previous scenarios, therefore, the reason because the losses of the last scenario in the "ETE Packet loss" graphic were higher must be because a great loss in the IP Network.



<u>As we obtain extrange results in PLR and Current File Index, we are going to remade the simulations with different channel conditions.</u>

The new conditions are:
0 -30sg: good
30-60sg:poor

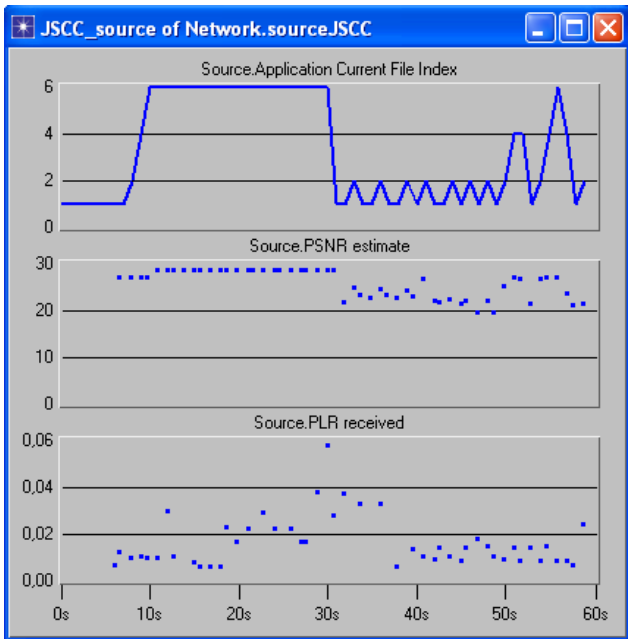
We can see that when the PLR exceed the limit (0.05), the AC low down to level 1. That is correct. But then it spends some time to recover itself from this state.
Therefore, we will try to confront also with PSNR graphic .



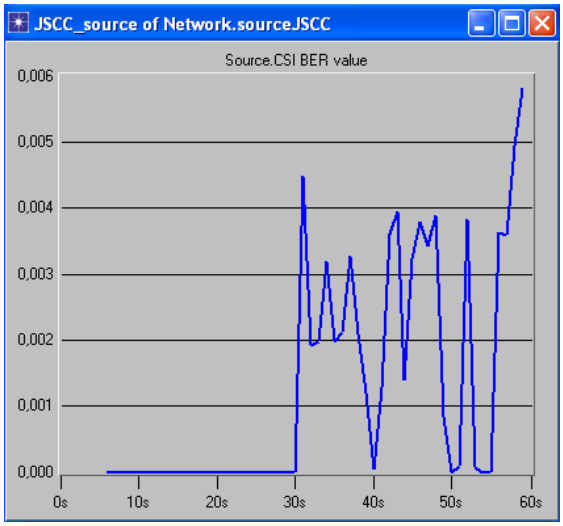
b) Confronting with PSNR

We can see that after having exceed the PLR limit, PSNR is no too good, so the AC takes into account the PSNR value. When this value reaches a certain value and it maintains constant, the AC increases its level of encode.

```
if ( psnr < psnr_old )
    {
        if ( (psnr > 25) && (psnr < 29) )
                app_cntr_state --;
        else
                if (psnr < 25)
                        app_cntr_state -= 2;
    }

if ( psnr > psnr_old )
    {
        if (psnr >= 30)
                app_cntr_state += 2;
        else if ( psnr < 30 )
                app_cntr_state ++;
    }
if (CSI_BER == 0)
    app_cntr_state++;
```



c) CSI_BER value



Now, seeing the C code of Application Controller we can understand the behaviour of it.

But anyway, when num_handovers is lower, we obtain more coherent results
We are going to explain the reason of this behaviour

APLYING MOBILITY OVER FEEDBACK INFORMATION

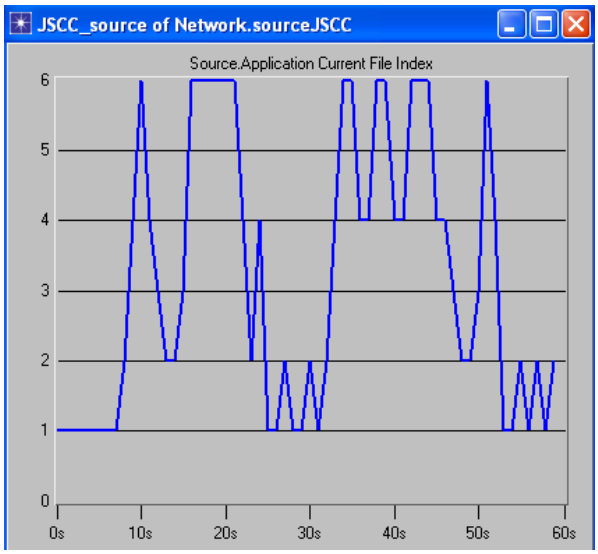
1º SIMULATION Num_Handovers =HIGH

Channel Conditions:

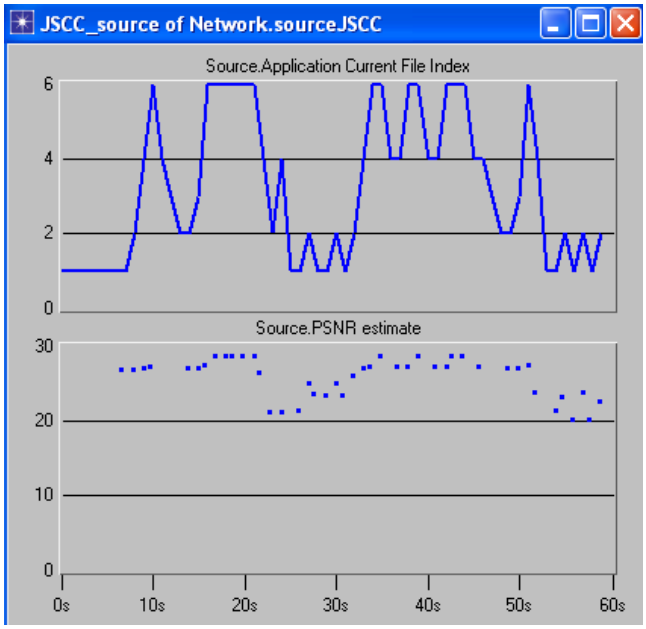
- 0 -20sg: good
- 20-30sg: poor
- 30-50sg: good
- 50-60sg: very poor

1) **Application Current File Index**

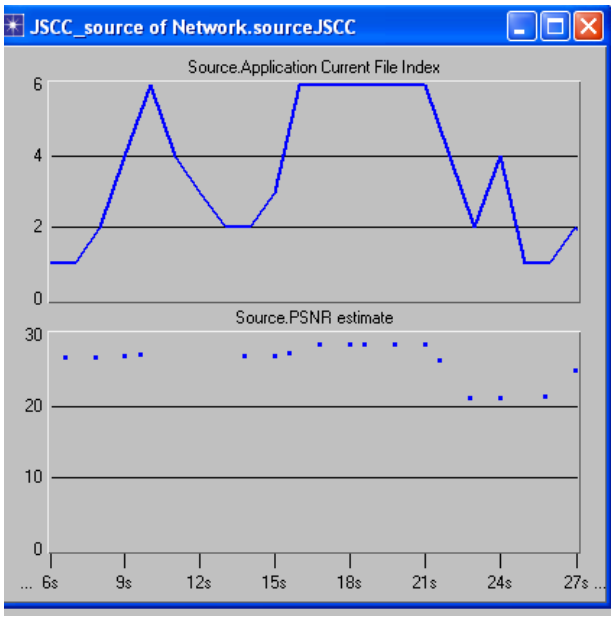
We can see that in this case this graphic changes more than before when there was not MOBILITY applied to feedback information. Now we will see PSNR and PLR graphic and we will try to explain this behaviour.



2) **PSNR Estimated**



With a bit more detail we observe one period in which there are not PSNR values.

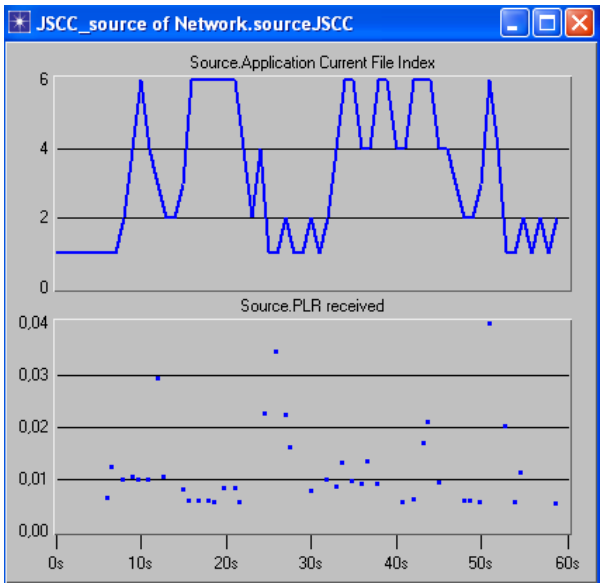


Therefore, although is a “good” channel condition period, the “Current File Index” go down. This graphic demonstrates that when the Source receives not valid values (“-1”) in CSI _Packets during a period, then the PSNR calculations are an indetermination (-1) and it does not paint it in the graphic. The AC decreases its “Current File Index” in two steps, as is written in the algorithm. That is, AC subtracts two levels to the current “Current File Index” each period in which happens.

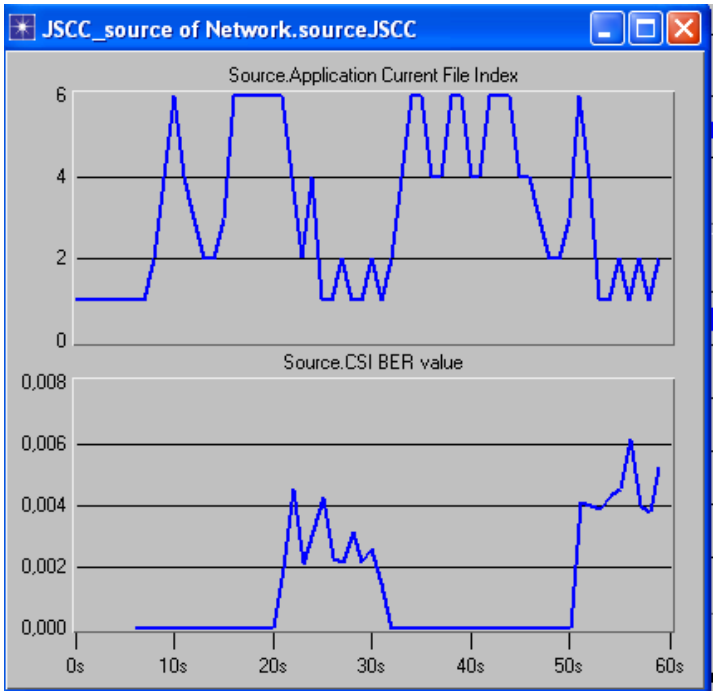
RX Wireless sends a “-1” value when it does not receive packets from the TX wireless. That is, when the packet is lost in the IPNetwork or in the link Wireless. Each period, the RX must send NSI and CSI packets, therefore the calculations are made based on the information received in this period and then initializes all the variables to zero. If the RX has not received any packet in this period, the calculations produce an indetermination (0/0), and this is the value that is sent in the packets.

The reaction of the system when it must paint the graphic is not to represent these indeterminations, and the AC decrease the level of its “Current File Index”.

3) PLR Received

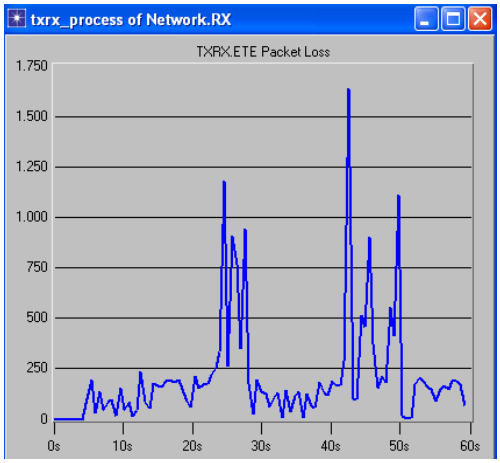


4) CSI_BER

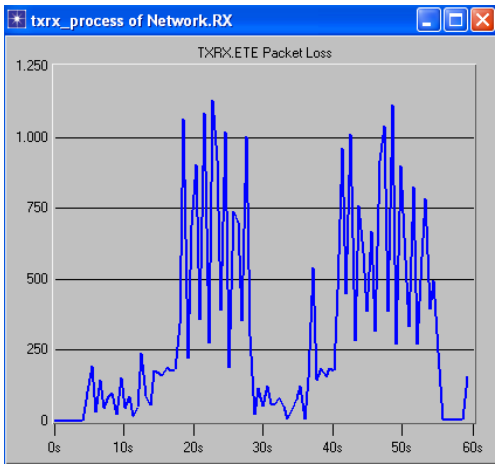


5) ETE Packet Loss

This graphic is more or less the same as the graphic with HIGH number of handovers without MOBILITY over feedback information. This is due to the fact that the RX calculates the losses and therefore it does not take into account the losses in the opposite direction.

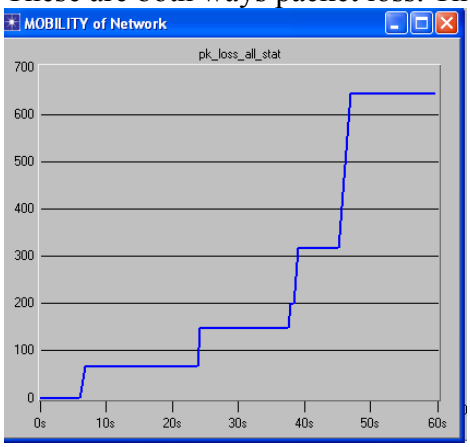


This is the graphic before, when it was not applied the MOBILITY over the feedback information.



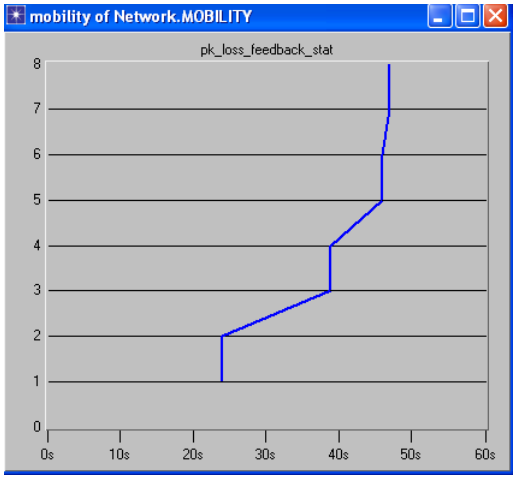
6) **MOBILITY Packet Loss**

These are both ways packet loss. The two senses are included.

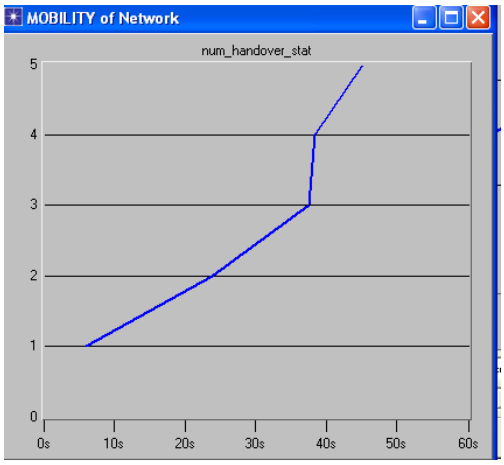


7) **MOBILITY Feedback Packet Loss**

There are only 8 lost packets coming from feedback. That means that in eight periods, the JSCC/D Source will not receive Feedback information.



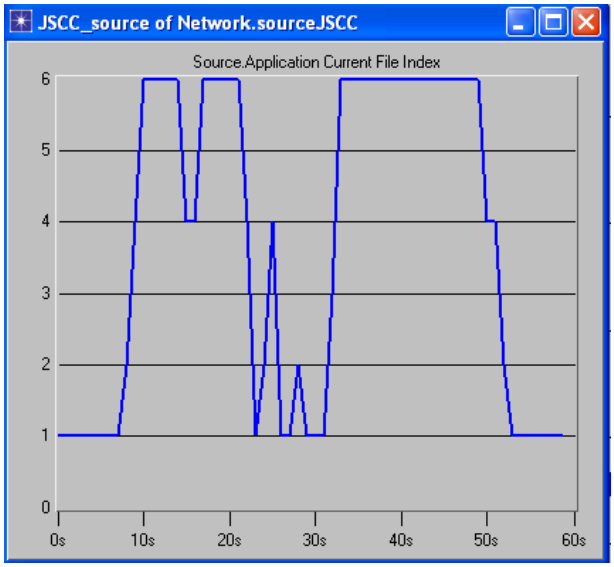
8) **MOBILITY Num_Handovers**



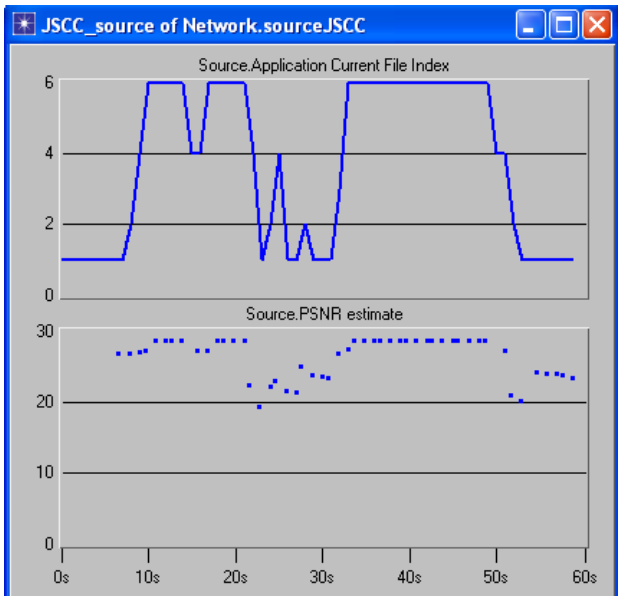
2º SIMULATION Num_Handovers = MEDIUM

1) **Application Current File Index**

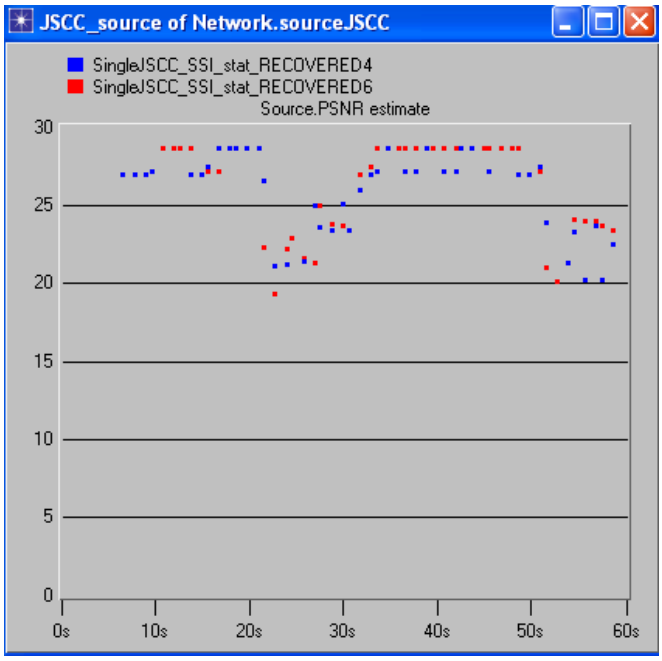
We notice that in this scenario "Current File Index" Values remain more constant when channel conditions remain constant.



2) **PSNR Estimated**

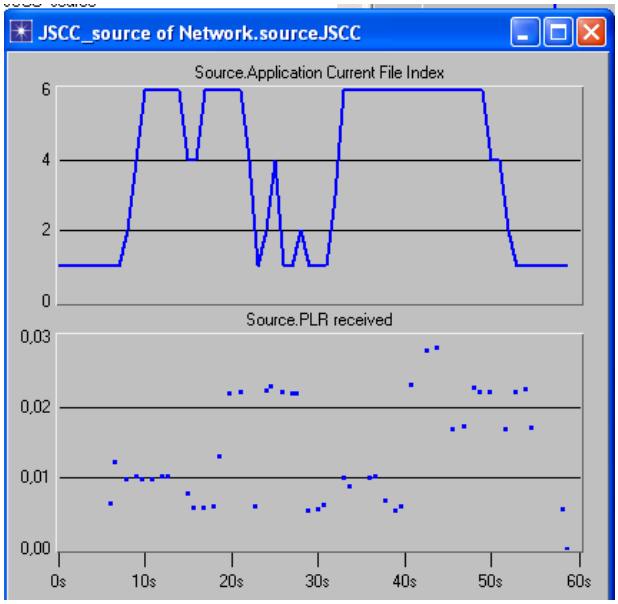


In comparison with the previous scenario we can say that PSNR values are better than before.

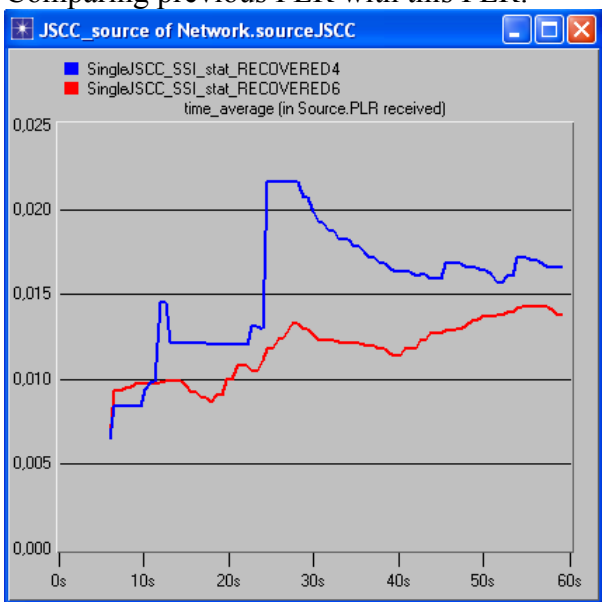


3) PLR Received

Looking at this graphic and the previous one, we can observe a correct operation of the AC, in relation with PSNR and PLR values. Only we can sense a strange fall on "Current File Index" in the first period. That is because what we have explained in the first simulation. And it will be seen in another graphic (*).

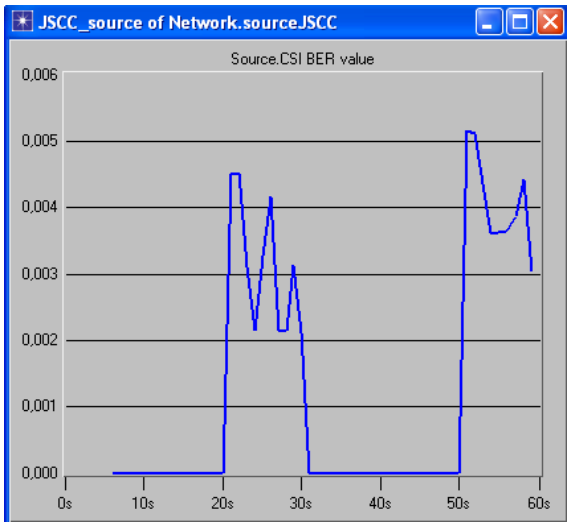


Comparing previous PLR with this PLR:



4) CSI_BER Value

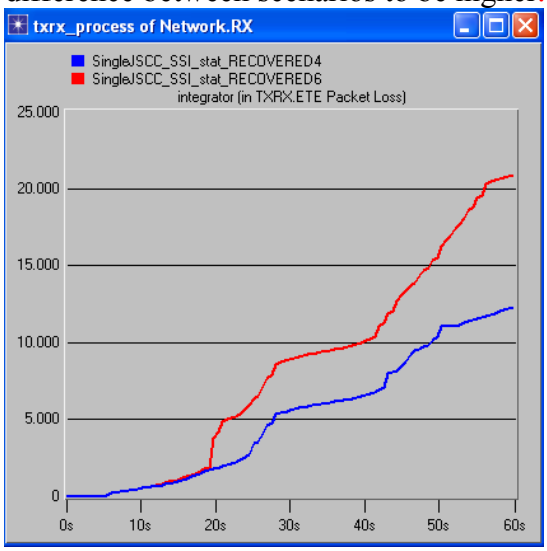
These values are coherent with the channel conditions.



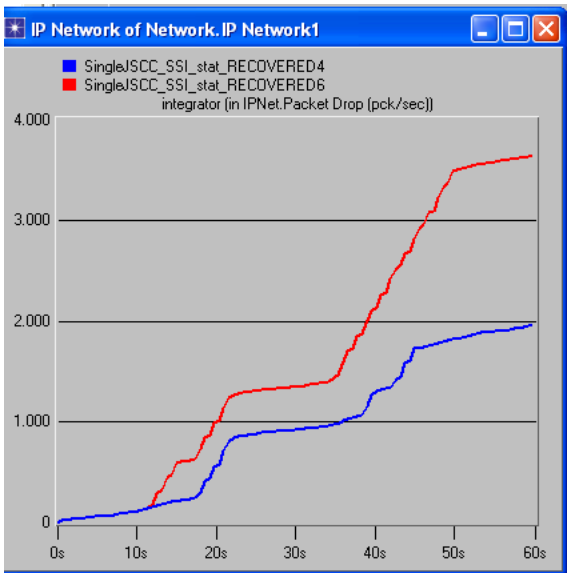
5) ETE Packet Loss

This graphic represents the cumulative Packet Loss. The two scenarios are represented.

But the extrange thing is that in the second scenario, that is supposed to have less loss, there are more lost packets.!
SOLUTION: We decrease the period between HANDOVERS in order for the difference between scenarios to be higher.



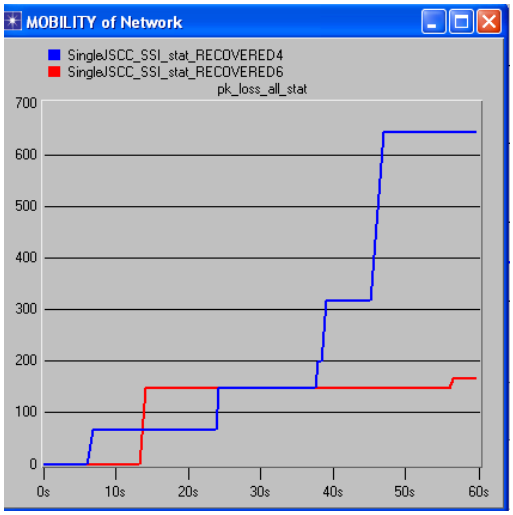
We will prove if the MOBILITY effect is not so big in comparison with IPNetwork losses….



We can see that also, the losses are higher in the second scenario, but this effect is not dominant (this effect represents only a 1/6 of total loss). Lets see the losses in MOBILITY module…

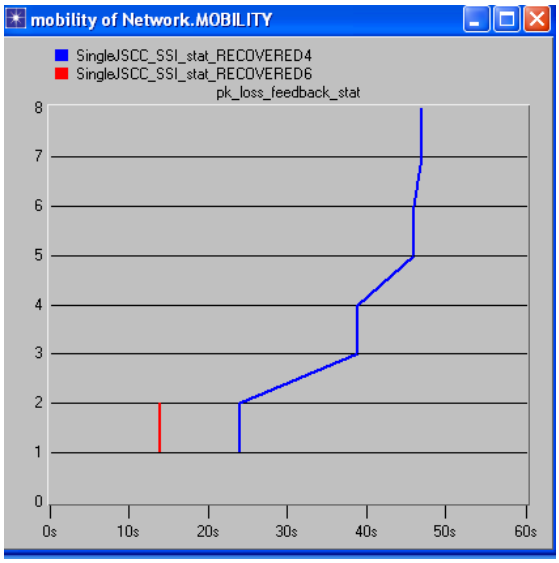
6) MOBILITY Packet Loss

This represents a logical result, because now (RECOVERED6), we have less handovers than before. In comparison with the graphic before, we would conclude that MOBILITY does not introduce the main losses in all the system, but is the Link Wireless which made it.



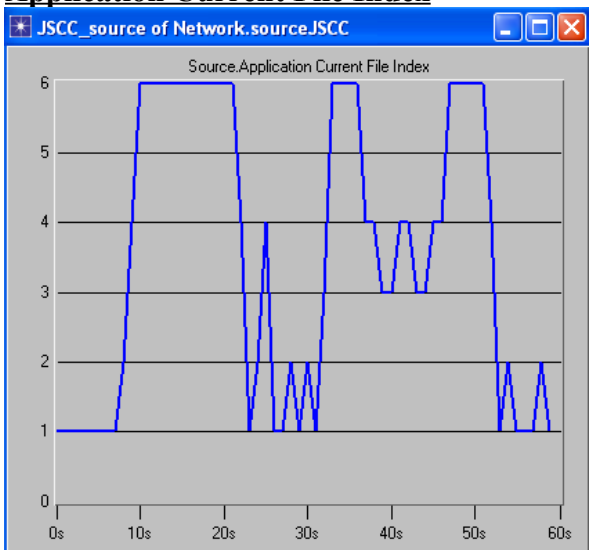
7) MOBILITY Feedback Packet Loss

(*) This is the graphic that we refer to before. It can be seen in the graphic that there is a loss over feedback information in second 14 more or less. In this instant we had noticed a decreasing in “Current File Index” graphic. That is because the AC does not receive a feedback packet (in this case CSI packet).
Also we see that the losses have decreased as we hoped.

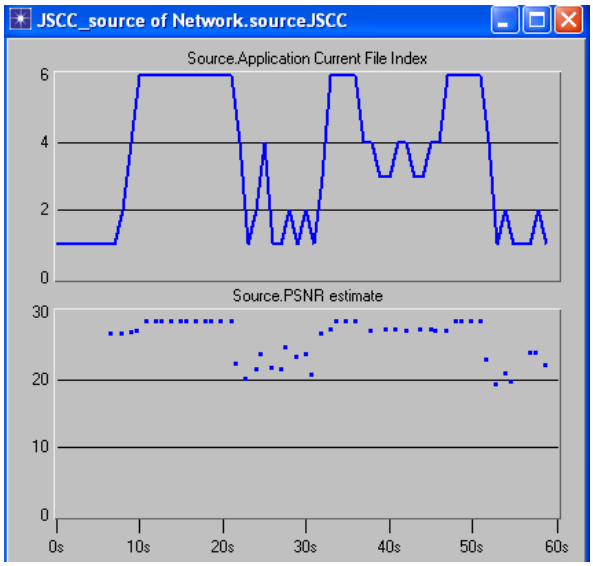


3° SIMULATION Num_Handovers = LOW

1) **Application Current File Index**

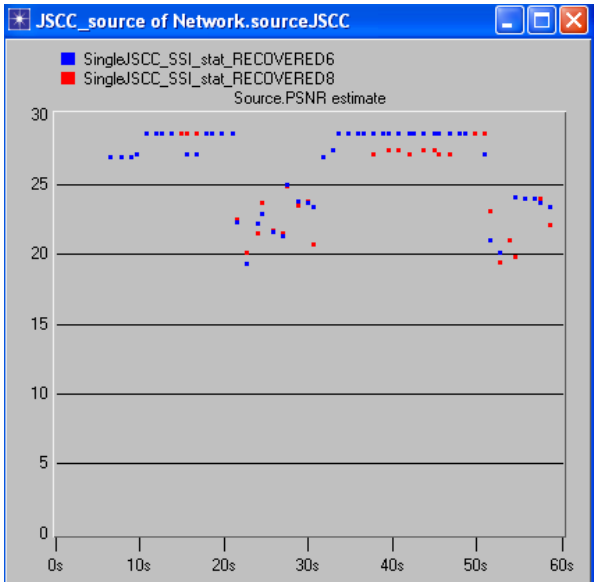


2) **PSNR Estimated**

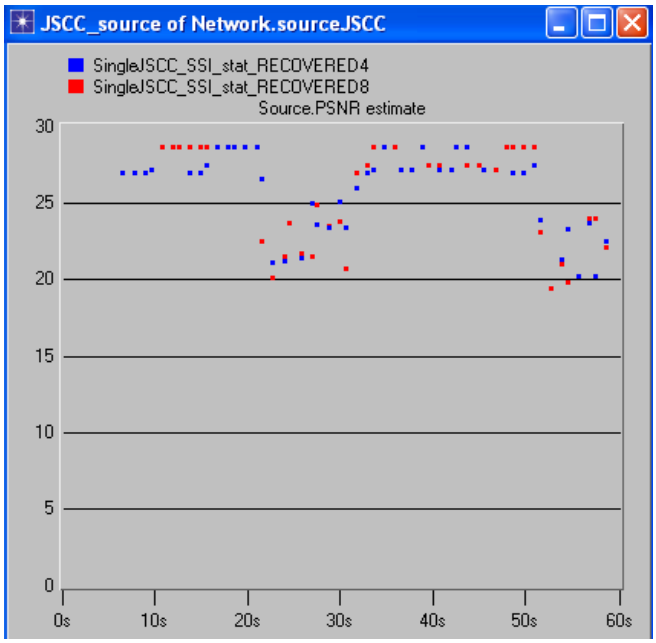


If we compare PSNR with the other values in previous scenarios:

Comparing with MEDIUM num_handover scenario(RECOVERED6):
We see that in some cases the current scenario has higher values but sometimes are lower. It depends on the received values on RX Wireless due to conditions in wireless channel.

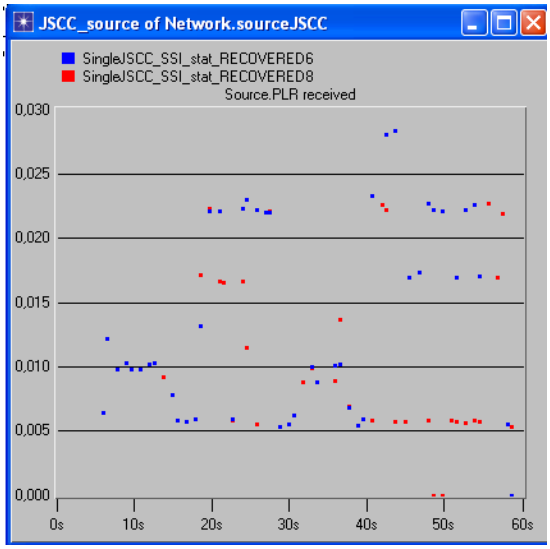


Comparing with HIGH num_handover scenario(RECOVERED4):
Almost always the current scenario has higher values.

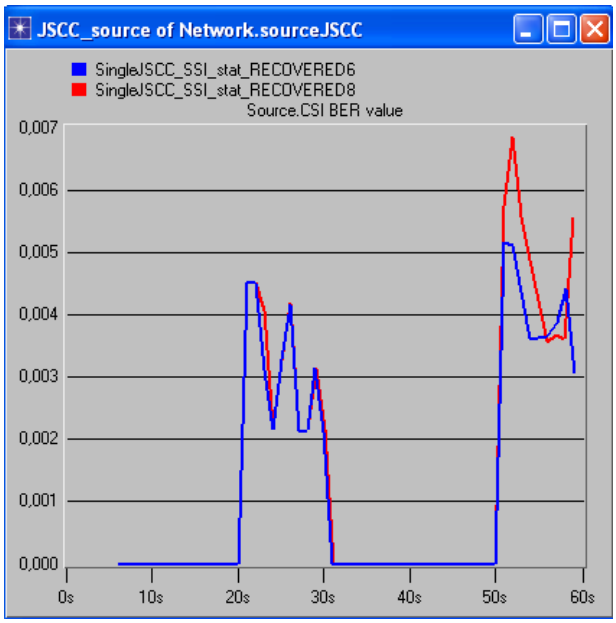


3) PLR Received

We can see that PLR values are lower than in the previous scenario. That is reasonable because number of handovers have decreased, therefore the number of lost packets also have decreased.

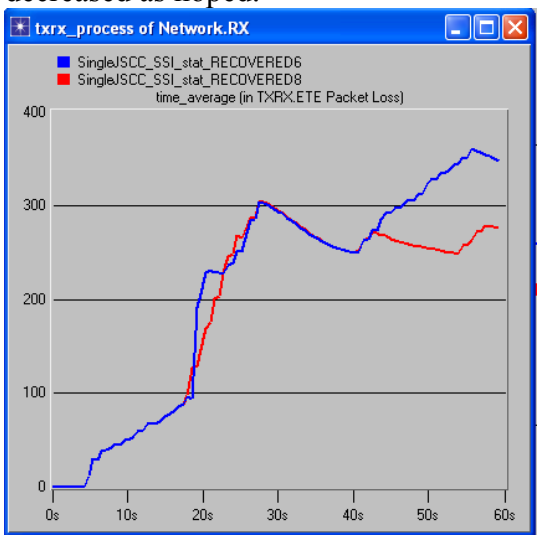


4) CSI_BER Value



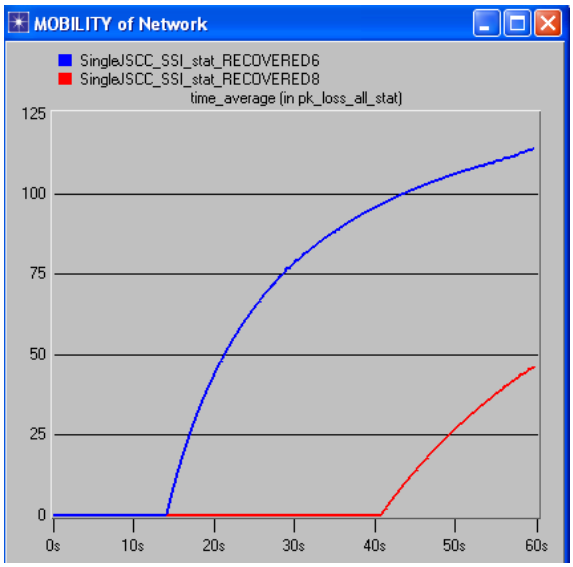
5) ETE Packet Loss

It can be seen better if we have a time-average graphic, and logically, losses have decreased as hoped.

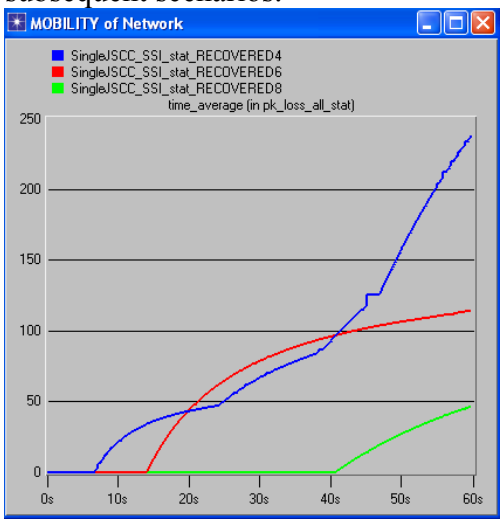


6) MOBILITY Packet Loss

Also it is seen that the losses are lower now.



But, what happens with the first scenario? Is logical, losses are higher than in both subsequent scenarios.



7) MOBILITY Feedback Packet Loss

There is no lost packet in this simulation, because OPNET has not created a graphic with a value. That means that there is no value related to this statistic to represent.