Chapter V

Summary and Conclusion

5.1 4G Networks

Fourth generation (4G) wireless networks stand for new infrastructure solutions to provide new services. 4G networks provide high data rate services to have room for multimedia applications such as video conference. 4G networks support global mobility. 4G networks present end-users with high-speed, large volume, good quality and global coverage. Everyone in this world would like to have a seamless connection anytime and anywhere through the best possible network. The 4G wireless system must have the competence to provide high data transfer rates, quality of services and seamless mobility.

In 4G, there is a large distribution of heterogeneous networks. The users would like to utilize heterogeneous networks for variety of applications on the basis of their preferences such as high availability, real time and elevated bandwidth. When connections have to switch between heterogeneous networks for high availability reasons and performance, seamless vertical handoff becomes highly essential.

In the 4G wireless environment, a mobile user is able to persist in using the mobile device when he moves from one point of attachment to another. This process is called handover. Handoff occurs when a Mobile Node (MN) moves from one wireless base station to another. It is the process of maintaining the active session of the user when a mobile terminal changes its connection point to the access network.

The handoff is classified into two main types depending upon the access network of each point of attachment. They are Horizontal handoff and Vertical handoff. Horizontal handoff takes place when MN moves among similar kind of wireless networks. Vertical handoff occurs when the movement of MN is between heterogeneous wireless networks.
The existing techniques on vertical handoff decision for heterogeneous networks concentrate on any one or some of the parameters like signal strength, network coverage area, data rate, battery efficiency, velocity of MT and network latency. But for effective handoff decision and network selection, all these parameters have to be considered together.

To perform the vertical handoff between pairs of different types of networks in the incidence of 2G, 3G, WLAN, WMAN, satellite, etc along with the fulfillment of quality of service (QoS) requirements is the main challenge in 4G networks. The lack of QoS can cause break in network during handoff or loss of network at remote condition.

In the present study, two different problems related to handoff mechanism in 4G networks are identified and a suitable proposal for each problem is defined and executed. They are explained as below.

To overcome the issues on the handoff mechanism in 4G network, a proposal on QoS based handoff management (QAVHD) model for 4G network is suggested in this study.

In this method, initially, when MT on movement finds a new network, it collects the QoS information of the respective network that includes signal strength, network coverage area, and data rate, and available bandwidth, velocity of MT and network latency. Then MT compares the estimated measurements with its old network and network, which provides the better QoS, which is selected as the current network. The old network then performs the data transmission to the new network. In the system design, UMTS and WiMAX networks are considered in which the vertical handoff is performed.

To provide a good solution on the problem of inefficient handoff latency, failure, and load balancing at time of vertical handoff, a new proposal “Efficient Service time Prediction and Bandwidth Reservation Technique “(ESPBR) is also suggested in the present study. An algorithm is also developed for connection management for seamless mobility that handles the handoff latency, failure and provides better resource allocation for mobile user in order to avoid any kind of overhead in the network. The proposed method (ESPBR) is divided into
two phases where in the phase an attempt is made to solve the latency and failure and the second phase of the proposed method is able to solve the problem of load balancing.

5.2 QoS Aware Vertical Handoff Management (QAVHD model)

The proposed QAVHD model is compared with the Inter-RAT model and the performance of QAVHD model is analysed in detail in terms of various metrics. By simulation results, it is shown that the proposed QAVHD model enhances the network throughput and minimizes the latency. The detailed summary of the obtained results is given below.

5.2.1 Performance Metrics - Based on Rate

**Handoff latency Vs Data rate (NRT)**

There is a linear increase in Handoff Latency against the data rate for both inter-RAT and QAVHD models. The handoff latency with non real time traffic has a maximum value of 2.1877 in case of inter-RAT model and has a maximum value of 1.3742 with the proposed QAVHD model. The delay is more in case of Inter-RAT model than the suggested QAVHD model. In the overall process of delay estimation, it is calculated that QAVHD model provides a less delay of 70.45% than Inter-RAT model. This shows that the proposed model QAVHD reduces the handoff latency.

**Throughput Vs Data Rate (NRT)**

There is a linear variation of data rate against throughput for the Non Real Time Traffic. When the data rate is the maximum, the throughput value is around 12.505 for QAVHD model and the value is 5.7267 for Inter-RAT model. In the overall analysis, we can observe that the proposed QAVHD technique has 53% more throughput than Inter-RAT when the rate is increased. This is mainly because the suggested QAVHD technique provides bandwidth priority for NRT flows.
Figure 5.1 gives a clear view of the comparative analysis of delay and throughput (NRT) against data rate for the proposed QAVHD model and Inter-RAT model. 

![Graph showing variation of delay and throughput against rate](image)

**Figure 5.1  Variation of Delay and Throughput against Rate (Non Real Time)**

**Handoff latency Vs Data rate (RT)**

There is a decrease in Handoff Latency against the rate in case of both inter-RAT and QAVHD models. The handoff latency with real time traffic has a minimum value of 0.2024 in case of inter-RAT model and has a minimum value of 0.2861 with the QAVHD model. The delay is more in case of Inter-RAT model than the suggested QAVHD model. In the overall process of delay estimation, it is calculated that QAVHD model provides a less delay of 19.61% than Inter-RAT model. This shows that the proposed model QAVHD reduces the handoff latency effectively.
Throughput Vs Data Rate (RT)

In the study of throughput against rate for the Real Time traffic, it is shown that the throughput increases with increase of data rate. It can be observed that our QAVHD technique yields better results than Inter-RAT by attaining 19.4% higher throughput. This is because, the suggested QAVHD technique provides transmission priority for RT flows than other models (Figure 5.2).

![Figure 5.2 Variation of Delay and Throughput against Rate (Real Time)]
**Data Rate Vs Delivery Ratio**

With increase in the data rate, the delivery ratio decreases more rapidly in the case of Inter-RAT model. It can be inferred that the increased traffic rate results in decreased delivery ratio for inter-RAT model. But in case of QAVHD model, the delivery ratio is more than inter-RAT model and almost it is uniform with increase in date rate. Also, QAVHD technique yields 41% less packet drop than Inter-RAT model. Hence, it is concluded that the proposed QAVHD technique has better packet delivery ratio.

(Figure 5.3)
Data Rate Vs Packet Drop

It can be observed that increased traffic rate results in increased packet drop in both the cases. The increase is very high in inter-RAT model at higher traffic (Figure 5.4). But the packet drop is more in case of Inter-RAT model than QAVHD model as seen from the graph. It is seen that QAVHD technique yields 41% less packet drops than Inter-RAT. Hence, it is concluded that the proposed QAVHD model is a better model for controlling packet drop.

Figure 5.4 Variation of Packets against Rate
5.2.2 Performance Metrics - Based on Time

**Time Vs Delay (NRT)**

As time increases, the handoff latency increases steeply with inter-RAT model whereas it shows less value with QAVHD model. It is observed that QAVHD technique is better than Inter-RAT when the time is increased. This is because our QAVHD technique provides bandwidth priority for NRT flows.

**Time Vs Throughput (NRT)**

The throughput increases linearly with increase in time in both the cases. Throughput value is much better in QAVHD model than inter-RAT model which suggests that QAVHD model is better (Figure 5.5)

![Figure 5.5 Variation of Throughput (NRT) against Time](image-url)
Handoff latency Vs time (Real time)

The handoff latency varies linearly with increase in time in both the cases. The handoff latency is less in QAVHD model compared to inter-RAT model. Hence it can be concluded that when compared to inter-RAT model, the performance of QAVHD model is better in terms of handoff latency (Figure 5.6).

Figure 5.6 Variation of Handoff Latency (RT) against Time
Time Vs Throughput (RT)

As the time increases the throughput value increases in both QAVHD and Inter-RAT models up to certain time value and beyond certain limit, the variation is maintained and almost uniform with respect to increase in time. It can be observed that our QAVHD technique yields better results than Inter-RAT when the time is increased. The throughput value is higher in QAVHD model than the results obtained from inter-RAT model. This is because our QAVHD technique provides transmission priority for RT flows.

Thus, in this work, we have proposed a QoS based handover management in 4G networks. Initially, when the mobile terminal (MT) on movement finds a new network, it collects the QoS information of the respective network that includes signal strength, network coverage area, data rate, available bandwidth, velocity of MT and network latency. Then MT compares estimated measurements with its old network and current network which provides better QoS is selected as current network. The old network then performs the data transmission to the new network. By simulation results, we have shown that the proposed QAVHD approach is a better model and this model enhances the network throughput and minimizes the latency.

5.3 Efficient Service time Prediction and Bandwidth Reservation Technique for Vertical Handoff [ESPBR model]

The main challenge in 4G networks is the vertical handoff between pairs of different types of networks along with the fulfillment of Quality of Service (QoS) requirements. The lack of QoS may result in break of network during handoff or loss of network at remote condition.

The existing EBBM technique provides an average solution for handoff latency and load balancing. But this model does not include service time prediction parameters like velocity, data rate, time threshold, etc. for minimizing unnecessary handovers.

To provide a better solution on the given problem of inefficient handoff latency, failure and load balancing at time of vertical handoff of EBBM model, a new solution is tried. The
The proposed new method is “Efficient Service time Prediction and Bandwidth Reservation Technique for Vertical Handoff” [ESPBR] model. This model is an enhanced version of existing EBBM model which includes service time prediction also. This model is able to give a better solution for all the existing limitations.

To provide latency and less failure, the service provider implements two phases of parallel procedure. These procedures are independent of another. The first phase of this ESPBR model provides the seamless handoff by solving latency and failure problems and the second phase is able to solve the problem of load balancing by providing an efficient bandwidth estimation technique.

The proposed method provides a better approach to guarantee QoS in the network by providing efficient bandwidth utilization. It also provides a mapping method that helps in improving the transmission quality. It further suggests a method to handle handoff failure in the network to provide continuity in the communication between the mobile users. Initially, when the Mobile Terminal (MT) is on a highly movable condition, an efficient service time prediction is done. It collects the distance, data rate, velocity and time threshold. According to the algorithm, an efficient service time provides seamless movement.
5.3.1 Metrics based on Data Rate

The delay of ESPBR and EBBM techniques for different rate scenario is analysed. As the rate increases, delay decreases in both techniques (Figure 5.7). But it is clearly seen that the delay is less by 24% for the proposed ESPBR approach than the EBBM approach. A significant decrease in the delay value in the proposed ESPBR model shows that this model is a better model in terms of delay than EBBM model.

Figure 5.7 Variation of Delay against Rate
From the delivery ratio of ESPBR and EBBM techniques for different rate scenario, it is concluded that the delivery ratio of the proposed ESPBR approach has 16% of higher than the EBBM approach. Thus it is seen that the proposed ESPBR model shows better delivery ratio compared to EBBM technique (Figure 5.8).

Figure 5.8 Variation of Delivery Ratio against Data Rate
The variation of packet drop (Figure 5.9) of ESPBR and EBBM techniques against rate shows that the packet drop of our proposed ESPBR approach has 29% better efficiency than the EBBM approach.

The variation of throughput of ESPBR and EBBM techniques (Figure 5.10) for different rate scenario is analysed. From this, we can conclude that the throughput of our proposed ESPBR approach has 0.5% better efficiency than the EBBM approach.
Thus it can be concluded that the proposed ESPBR model has better efficiency compared to EBBM model in terms of metrics like delay, delivery ratio, packet drop and throughput.
5.3.2 Metrics based on Time

The delay of ESPBR and EBBM techniques for different time scenario shows that the delay is less by 12% for the proposed ESPBR approach (Figure 5.11) than the EBBM approach.

Figure 5.11 Variation of Delay against Time
The variation of throughput of ESPBR and EBBM techniques against time shows that the throughput of the proposed ESPBR approach has 2% of better efficiency than the EBBM approach. (Figure 5.12)

Thus, it is concluded that the suggested ESPBR method seems to be a better method to guarantee QoS in the network by providing efficient bandwidth utilization method. It provides a mapping method that helps in improving the transmission quality. It also provides a method to handle handoff failure in the network to provide continuity in the communication between the mobile users.

Thus it is clearly evident from all the above results that the proposed ESPBR model, provides better effectiveness in all aspects than the existing EBBM model.
5.4 Scope for further work

The main challenges in executing this work and scope for further research are explained here. Maintaining high data rate, reducing packet loss and signaling overhead are the primary challenges in this study. In location management, issues like optimally handling diverse user calling and mobile patterns and better inter-network location coordination have to be handled properly. In handover management, challenges like reducing call droppings, disruptions, reducing handover time and optimizing effective call completion time require more attention. Multi-access interface, timing, data security and recovery, law enforcement requirements are also points of major concern. Reuse of high frequency leads to smaller cells due to reduced power levels that may result in intra-cell interference or higher noise figures. Interface with the ad hoc networks is to be sorted out to improve efficiency. Voice over multi-hop networks is an interesting problem because of the strict delay requirements of voice and further research is possible in these areas. All these challenges shall be taken care in our further research. Future work is also planned with a focus on giving a movable node level solution for 4G networks.
APPENDIX - 1

CODING OF Inter-RAT.TCL

# Define options

set opt(chan) Channel/WirelessChannel ;# channel type
set opt(prop) Propagation/TwoRayGround ;# radio-propagation model
set opt(netif) Phy/WirelessPhy ;# network interface type
set opt(mac) Mac/802_11 ;# MAC type
set opt(ifq) Queue/DropTail/PriQueue ;# interface queue type
set opt(ll) LL ;# link layer type
set opt(ant) Antenna/OmniAntenna ;# antenna model
set opt(ifqlen) 6000 ;# max packet in ifq
set opt(adhocRouting) DSDV ;# routing protocol
set opt(sc) "SCEN-N10" ;# node position file.
set opt(cp) "dcbr10-e" ;# connection pattern file
set opt(x) 500 ;# x coordinate of topology
set opt(y) 500 ;# y coordinate of topology
set opt(stop) 50 ;# time to stop simulation
set rate 50Kb
set flows 8
set psize 512
set nb_mn 20 ;# max number of mobile nodes
set users 8
set no_bs 4 ;# no.of base stations
set nn 1
set opt(nn) [expr $no_bs+$nb_mn+$rn] ;#total no.of nodes
set val(speed) 10.0
set f1 [open "RT-Delay-Inter-RAT" a]
set f2 [open "NRT-Delay-Inter-RAT" a]
set f3 [open "RT-thruput-Inter-RAT" a]
set f4 [open "NRT-thruput-Inter-RAT" a]

#creates the Base station for WiMax
$ns_ node-config -adhocRouting $opt(adhocRouting) \
-llType $opt(ll) \
-macType $opt(mac) \
-ifqType $opt(ifq) \
-ifqLen $opt(ifqlen) \
-antType $opt(ant) \
-propType $opt(prop) \
-phyType $opt(netif) \
-channel [new $opt(chan)] \
-topoInstance $stopo \
-wiredRouting ON \
-agentTrace ON \
-routerTrace ON \
-macTrace OFF \
-movementTrace OFF

set bstation(0) [$ns_ node 1.0.0]
$bstation(0) random-motion 0
#set agt [new Agent/IRAT]
#$ns_ attach-agent $agt $bstation(0)

#node creation
for {set i 0} {$i < 5} {incr i} {
  set k [expr $i+1]
#puts "i:$i domain1:$k"
set wl_node_($i) [ns_node 1.0.$k]
$wl_node_($i) random-motion 0 ;# disable random motion
$wl_node_($i) base-station [AddrParams addr2id [bstation(0) node-addr]]
ns_ at 0.0 "$wl_node_($i) label MN$i"
}
$wl_node_(1) base-station [AddrParams addr2id [bstation(2) node-addr]]

for {set i 5} {$i < 10} {incr i} {
set k [expr ($i-5)+1]
#puts "i:$i domain2:$k"
set wl_node_($i) [ns Node 2.0.$k]
$wl_node_($i) random-motion 0 ;# disable random motion
$wl_node_($i) base-station [AddrParams addr2id [bstation(1) node-addr]]
ns_ at 0.0 "$wl_node_($i) label MN$i"
}

# creation of the mobile nodes in UMTS

$ns_node-config -UmtsNodeType ue \
-radioButton $rnc

$ns_node-config -macType $opt(mac) \
-phyType $opt(netif) \
-wiredRouting OFF
for {set i 10} {$i < 15} {incr i} {
set k [expr ($i-10)+1]
#puts "i:$i domain3:$k"
set wl_node_($i) [ns_node 4.0.$k]
$wl_node_($i) random-motion 0 ;# disable random motion
$wl_node_($i) base-station [AddrParams addr2id [bstation(2) node-addr]]
$ns_ at 0.0 "$wl_node_(i) label MN$i"
}

#initial node size
for {set i 10} {$i < $nb_mn} {incr i} {
$ns_ initial_node_pos $wl_node_(i) 10
}

proc finish {} {
  global ns_ tf no_bs f1 f2 f3 f4 rate vdelay cdelay tbw1 tbw2 users
  set vdelay [expr $vdelay/2.0]
  #puts $f1 "$rate $vdelay"
  #puts $f2 "$rate $cdelay"
  #puts $f3 "$rate $tbw2"
  #puts $f4 "$rate $tbw1"
  $ns_ flush-trace
  close $tf
  puts "close"
  exit 0
}

puts "Starting Simulation..."
$ns_ run
CODING OF QAVHD.tcl

# Define options

set opt(chan)           Channel/WirelessChannel ;# channel type
set opt(prop)           Propagation/TwoRayGround ;# radio-propagation model
set opt(netif)          Phy/WirelessPhy ;# network interface type
set opt(mac)            Mac/802_11 ;# MAC type
set opt(ifq)            Queue/DropTail/PriQueue ;# interface queue type
set opt(ll)             LL ;# link layer type
set opt(ant)            Antenna/OmniAntenna ;# antenna model
set opt(ifqlen)         6000 ;# max packet in ifq
set opt(adhocRouting)   DSDV ;# routing protocol
set opt(sc)      "SCEN-N10" ;# node position file.
set opt(cp)  "dcbr10" ;# connection pattern file
set opt(x)       500 ;# x coordinate of topology
set opt(y)       500 ;# y coordinate of topology
set opt(stop)    50 ;# time to stop simulation
set rate  50Kb
set flows  8
set psize  512
set nb_mn  20 ;# max number of mobile nodes
#set users  8
set no_bs  4 ;# no.of base stations
set rn  1
set opt(nn)  [expr $no_bs+$nb_mn+$rn] ;#total no.of nodes
set val(speed)  10.0

# Create topography object

set topo  [new Topography]
$topo load_flatgrid $opt(x) $opt(y)
# set up for hierarchical routing (needed for routing over a basestation)
puts "start hierarchical addressing"
$ns_ node-config -addressType hierarchical
AddrParams set domain_num_ 5 ;# domain number
lappend cluster_num 1 1 1 1 1 ;# cluster number for each domain
AddrParams set cluster_num_ $cluster_num
lappend eilastlevel 6 6 6 6 6 ;# number of nodes for each cluster
AddrParams set nodes_num_ $eilastlevel

# creation of the mobile nodes in UMTS

$ns_ node-config -UmtsNodeType ue \ 
  -radioNetworkController $rnc

$ns_ node-config -macType $opt(mac) \ 
  -phyType $opt(netif) \ 
  -wiredRouting OFF

for {set i 10} {i < 15} {incr i} {
set k [expr ($i-10)+1]
#puts "i:$i domain3:$k"
set wl_node_($i) [\$ns_ node 4.0.$k]
$wl_node_($i) random-motion 0 ;# disable random motion
$wl_node_($i) base-station [AddrParams addr2id [\$bstation(2) node-addr]]
$ns_ at 0.0 "$wl_node_($i) label MN$i"
}

for {set i 15} {i < 20} {incr i} {
set k [expr ($i-15)+1]
#puts "i:$i domain4:$k"
set wl_node_(i) [ns_ node 5.0.$k]
$wl_node_(i) random-motion 0 ;# disable random motion
$wl_node_(i) base-station [AddrParams addr2id [$bstation(3) node-addr]]
$ns_ at 0.0 "$wl_node_(i) label MN$i"
}
$wl_node_(19) base-station [AddrParams addr2id [$bstation(1) node-addr]]

#measure bytes received by CBR flows
set bw1  [$null_(1) set bytes_ ]
set bw2  [$null_(3) set bytes_ ]
set bw3  [$null_(4) set bytes_ ]
set bw4  [$null_(6) set bytes_ ]
set bw7  [$null_(7) set bytes_ ]
set bw8  [$null_(8) set bytes_ ]

#measure bytes received by Video flows
set bw5  [$null_(2) set bytes_ ]
set bw6  [$null_(5) set bytes_ ]

#measure delay received by CBR flows
set tt1  [$null_(1) set lastPktTime_]
set tt2  [$null_(3) set lastPktTime_]
set tt3  [$null_(4) set lastPktTime_]
set tt4  [$null_(6) set lastPktTime_]
set tt7  [$null_(7) set lastPktTime_]
set tt8  [$null_(8) set lastPktTime_]

#measure delay received by video flows
set tt5  [$null_(2) set lastPktTime_]
set tt6  [$null_(5) set lastPktTime_]
CODING OF EBBM.TCL

# Define options

set opt(chan) Channel/WirelessChannel ;# channel type
set opt(prop) Propagation/TwoRayGround ;# radio-propagation model
set opt(netif) Phy/WirelessPhy ;# network interface type
set opt(mac) Mac/802_11 ;# MAC type
set opt(ifq) Queue/DropTail/PriQueue ;# interface queue type
set opt(ll) LL ;# link layer type
set opt(ant) Antenna/OmniAntenna ;# antenna model
set opt(ifqlen) 6000 ;# max packet in ifq
set opt(adhocRouting) DSDV ;# routing protocol
set opt(sc) "SCEN-N10" ;# scenario or node position file.
set opt(cp) "dcbr10" ;# connection pattern file
set opt(x) 500 ;# x coordinate of topology
set opt(y) 500 ;# y coordinate of topology
set opt(stop) 50 ;# time to stop simulation
set rate 250Kb
set flows 8
set psize 512
set nb_mn 20 ;# max number of mobile nodes
#set users 8
set no_bs 4 ;# no.of base stations
set rn 1
set opt(nn) [expr $no_bs+$nb_mn+$rn] ;#total no.of nodes
set val(speed) 10.0

#---------------------------------------------------

#create data files
set f1 [open "Delay-EBBM" a]
set f3 [open "Thruput-EBBM" a]

# set up for hierarchical routing (needed for routing over a basestation)
#puts "start hierarchical addressing"
$ns_ node-config -addressType hierarchical
AddrParams set domain_num_ 5 ;# domain number
lappend cluster_num 1 1 1 1 1 ;# cluster number for each domain
AddrParams set cluster_num_ $cluster_num
lappend eilastlevel 6 6 1 6 6 ;# number of nodes for each cluster
AddrParams set nodes_num_ $eilastlevel

#$ns_ node-config -UmtsNodeType rnc
# RNC Node address is 0
set rnc [$ns_ node 3.0.0]

$rnc set X_ 98.8559
$rnc set Y_ 174.051
$rnc set Z_ 0.00000
$ns_ at 0.0 "$rnc label RNC"
$ns_ at 0.0 "$rnc add-mark m1 red circle"
#creates the Base station for UMTS
$ns_ node-config -UmtsNodeType bs \\
-downlinkBW 32kbs \\
-downlinkTTI 10ms \\
-uplinkBW 32kbs \\
-uplinkTTI 10ms

$ns_ node-config -macType $opt(mac) \\
-phyType $opt(netif)

set bstation(2) [$ns_ node 4.0.0]
$bstation(2) random-motion 0
#set agt [new Agent/EBBM]
#$ns_ attach-agent $agt $bstation(2)

$ns_ at 0.0 "$bstation(2) add-mark m1 orange circle"
$ns_ at 0.0 "$bstation(2) label BS3"

set bstation(3) [$ns_ node 5.0.0]
$bstation(3) random-motion 0
#set agt [new Agent/EBBM]
#$ns_ attach-agent $agt $bstation(3)

$ns_ at 0.0 "$bstation(3) add-mark m1 orange circle"
$ns_ at 0.0 "$bstation(3) label BS4"

#node creation
for {set i 0} {$i < 5} {incr i} {
set k [expr $i+1]
#puts "i:$i domain1:$k"
set wl_node_($i) [ns_node 1.0.$k]
$wl_node_($i) random-motion 0 ;# disable random motion
$wl_node_($i) base-station [AddrParams addr2id [$bstation(0) node-addr]]
$ns_at 0.0 "$wl_node_($i) label MN$i"
}
$wl_node_(1) base-station [AddrParams addr2id [$bstation(2) node-addr]]

for {set i 5} {$i < 10} {incr i} {
set k [expr ($i-5)+1]
#puts "i:$i domain2:$k"
set wl_node_($i) [ns_node 2.0.$k]
$wl_node_($i) random-motion 0 ;# disable random motion
$wl_node_($i) base-station [AddrParams addr2id [$bstation(1) node-addr]]
$ns_at 0.0 "$wl_node_($i) label MN$i"
}

# creation of the mobile nodes in UMTS
$ns_node-config -UmtsNodeType ue -radioNetworkController $rnc

$ns_node-config -macType $opt(mac) -phyType $opt(netif) -wiredRouting OFF

for {set i 10} {$i < 15} {incr i} {
set k [expr ($i-10)+1]
#puts "i:$i domain3:$k"
set wl_node_($i) [ns_node 4.0.$k]
$wl_node_($i) random-motion 0 ;# disable random motion
$wl_node_($i) base-station [AddrParams addr2id [$bstation(2) node-addr]]
$ns_at 0.0 "$wl_node_($i) label MN$i"
}"}
CODING OF ESPBR.TCL

=========================================================
# Define options
=========================================================
set opt(chan)           Channel/WirelessChannel    ;# channel type
set opt(prop)           Propagation/TwoRayGround   ;# radio-propagation model
set opt(netif)          Phy/WirelessPhy            ;# network interface type
set opt(mac)            Mac/802_11                  ;# MAC type
set opt(ifq)            Queue/DropTail/PriQueue    ;# interface queue type
set opt(ll)             LL                         ;# link layer type
set opt(ant)            Antenna/OmniAntenna        ;# antenna model
set opt(ifqlen)         6000                       ;# max packet in ifq
set opt(adhocRouting)   DSDV             ;# routing protocol
set opt(sc)      "SCEN-N10"              ;# node position file.
set opt(cp)  "dcbr10-e"         ;# connection pattern file
set opt(x)       500                     ;# x coordinate of topology
set opt(y)       500                     ;# y coordinate of topology
set opt(stop)           50                      ;# time to stop simulation
set rate  250Kb
set flows  8
set psize  512
set nb_mn   20      ;# max number of mobile nodes
#set users  8
set no_bs  4       ;# no.of base stations
set rn   1
set opt(nn)  [expr $no_bs+$nb_mn+$rn] ;#total no.of nodes
set val(speed)  10.0
#======================================================
# create simulator instance
set ns_ [new Simulator]

# Create topography object
set topo [new Topography]
$topo load_flatgrid $opt(x) $opt(y)

# create trace and nam files
set nf [open out.nam w]
set tf [open out.tr w]
$ns_ namtrace-all-wireless $nf $opt(x) $opt(y)
$ns_ trace-all $tf

# create data files
set f1 [open "Delay-ESPBR" a]
set f3 [open "Thruput-ESPBR" a]

# set up for hierarchical routing (needed for routing over a base station)
# puts "start hierarchical addressing"
$ns_ node-config -addressType hierarchical
AddrParams set domain_num_ 5 ;# domain number
lappend cluster_num 1 1 1 1 1 ;# cluster number for each domain
AddrParams set cluster_num_ $cluster_num
lappend eilastlevel 6 6 1 6 6 ;# number of nodes for each cluster
AddrParams set nodes_num_ $eilastlevel

# Create God (general operational director)
create-god [expr ($nb_mn + $no_bs + $rn )];# base station and mobile nodes)

# creates the Base station for WiMax
$ns_ node-config -adhocRouting $opt(adhocRouting)
-llType $opt(ll)
-macType $opt(mac) \ 
-ifqType $opt(ifq) \ 
-ifqLen $opt(ifqlen) \ 
-antType $opt(ant) \ 
-propType $opt(prop) \ 
-phyType $opt(netif) \ 
-channel [new $opt(chan)] \ 
-topoInstance $topo \ 
-wiredRouting ON \ 
-agentTrace ON \ 
-routerTrace ON \ 
-macTrace OFF \ 
-movementTrace OFF

set bstation(0) [$ns_node 1.0.0]
$bstation(0) random-motion 0
#set agt [new Agent/ESPBR]
#$ns_attach-agent $agt $bstation(0)

$ns_at 0.0 "$bstation(0) add-mark m1 blue circle"
$ns_at 0.0 "$bstation(0) label BS1"

set bstation(1) [$ns_node 2.0.0]
$bstation(1) random-motion 0
#set agt [new Agent/ESPBR]
#$ns_attach-agent $agt $bstation(1)

$ns_at 0.0 "$bstation(1) add-mark m1 blue circle"
$ns_at 0.0 "$bstation(1) label BS2"
$ns_node-config -UmtsNodeType rnc
# RNC Node address is 0
set rnc [$ns_node 3.0.0]

$rnc set X_ 98.8559
$rnc set Y_ 174.051
$rnc set Z_ 0.00000

$ns_at 0.0 "$rnc label RNC"
$ns_at 0.0 "$rnc add-mark m1 red circle"

#creates the Base station for UMTS
$ns_node-config -UmtsNodeType bs \
-downlinkBW 32kbs \
-downlinkTTI 10ms \
-uplinkBW 32kbs \ 
-uplinkTTI 10ms

$ns_node-config -macType $opt(mac) \\ 
-phyType $opt(netif)

set bstation(2) [$ns_node 4.0.0]
$bstation(2) random-motion 0
#set agt [new Agent/ESPBR]
#$ns_attach-agent $agt $bstation(2)

$ns_at 0.0 "$bstation(2) add-mark m1 orange circle"
$ns_at 0.0 "$bstation(2) label BS3"

set bstation(3) [$ns_node 5.0.0]
$bstation(3) random-motion 0
#set agt [new Agent/ESPBR]
#$ns_ attach-agent $agt $bstation(3)

$ns_ at 0.0 "$bstation(3) add-mark m1 orange circle"
$ns_ at 0.0 "$bstation(3) label BS4"

#node creation
for {set i 0} {$i < 5} {incr i} {
    set k [expr $i+1]
    #puts "i:$i domain1:$k"
    set wl_node_($i) [$ns_ node 1.0.$k]
    $wl_node_($i) random-motion 0 ;# disable random motion
    $wl_node_($i) base-station [AddrParams addr2id [$bstation(0) node-addr]]
    $ns_ at 0.0 "$wl_node_($i) label MN$i"
}
$wl_node_(1) base-station [AddrParams addr2id [$bstation(2) node-addr]]

for {set i 5} {$i < 10} {incr i} {
    set k [expr ($i-5)+1]
    #puts "i:$i domain2:$k"
    set wl_node_($i) [$ns_ node 2.0.$k]
    $wl_node_($i) random-motion 0 ;# disable random motion
    $wl_node_($i) base-station [AddrParams addr2id [$bstation(1) node-addr]]
    $ns_ at 0.0 "$wl_node_($i) label MN$i"
}

# creation of the mobile nodes in UMTS

$ns_ node-config -UmtsNodeType ue \  
-radioNetworkController $rnc
$ns_node-config -macType $opt(mac) \
-phyType $opt(netif) \
-wiredRouting OFF

for {set i 10} {$i < 15} {incr i} {
set k [expr ($i-10)+1]
#puts "i:$i domain3:$k"
set wl_node_($i) [$ns_node 4.0.$k]
$wl_node_($i) random-motion 0 ;# disable random motion
$wl_node_($i) base-station [AddrParams addr2id [$bstation(2) node-addr]]
$ns_at 0.0 "$wl_node_($i) label MN$i"
}

# Load scenario file
puts "Loading scenario file..."
source ../scen/$opt(sc)
puts "Load complete..."
#load the connection pattern file
source ../scen/$opt(cp)

set tbw 0
set tbw 1.0
#record the status of receiver
proc record {} {
global totpkts totlost null_tbw tbw cdelay vdelay
global totbw tcpbw errate delay f6 f1 f2 f3 f4
# set the instance simulator
set ns_ [Simulator instance]
# time interval
set time 2.0
#set current time
set now [$ns_now]
# measure bytes received by CBR flows
set bw1  [$null_(1) set bytes_ ]
set bw2  [$null_(3) set bytes_ ]
set bw3  [$null_(4) set bytes_ ]
set bw4  [$null_(6) set bytes_ ]
set bw7  [$null_(7) set bytes_ ]
set bw8  [$null_(8) set bytes_ ]

# measure bytes received by Video flows
set bw5  [$null_(2) set bytes_ ]
set bw6  [$null_(5) set bytes_ ]
set bw9  [$null_(9) set bytes_ ]
set bw10 [$null_(10) set bytes_ ]
set bw11 [$null_(11) set bytes_ ]
set bw12 [$null_(12) set bytes_ ]

# measure delay received by CBR flows
set tt1  [$null_(1) set lastPktTime_]
set tt2  [$null_(3) set lastPktTime_]
set tt3  [$null_(4) set lastPktTime_]
set tt4  [$null_(6) set lastPktTime_]
set tt7  [$null_(7) set lastPktTime_]
set tt8  [$null_(8) set lastPktTime_]

# measure delay received by video flows
set tt5  [$null_(2) set lastPktTime_]
set tt6  [$null_(5) set lastPktTime_]
set tt9  [$null_(9) set lastPktTime_]
set tt10 [$null_(10) set lastPktTime_]
set tt11 [$null_(11) set lastPktTime_]
set tt12  [null(12) set lastPktTime_]

set delay1 [expr $now - $tt1]
set delay2 [expr $now - $tt2]
set delay3 [expr $now - $tt3]
set delay4 [expr $now - $tt4]
set delay5 [expr $now - $tt5]
set delay6 [expr $now - $tt6]
set delay7 [expr $now - $tt7]
set delay8 [expr $now - $tt8]
set delay9 [expr $now - $tt9]
set delay10 [expr $now - $tt10]
set delay11 [expr $now - $tt11]
set delay12 [expr $now - $tt12]

set cdelay [expr $delay1+$delay2+$delay3+$delay4+$delay5+$delay6+$delay7+$delay8+$delay9+$delay10+$delay11+$delay12]

set bw [expr $bw1 + $bw2 + $bw3 + $bw4 + $bw5 + $bw6+$bw7+$bw8+$bw9 + $bw10 + $bw11 + $bw12 ]

set mbw [expr $bw/$time*8/1000000]

set tbw [expr $tbw + $mbw]

puts $f1 "$now $cdelay"
puts $f3 "$now $tbw"

#reset the bytes
null(1) set bytes 0
null(2) set bytes 0
null(3) set bytes 0
null(4) set bytes 0
null(5) set bytes 0
# reschedule the procedure
$ns_ at [expr $now + $time] "record"
}

$ns_ at 0.0 "record"

$ns_ at $opt(stop).001 "finish"
$ns_ at $opt(stop).002 "puts \"NS EXITING...\" ; $ns_ halt"

# initial node size
for {set i 10} {$i < $nb_mn} {incr i} {
$ns_ initial_node_pos $wl_node_($i) 10
}

proc finish {} {
    global ns_ tf no bs f1 f2 f3 f4 rate vdelay cdelay tbw tbw users

    # puts $f1 "$rate $cdelay"
    # puts $f3 "$rate $tbw"
    $ns_ flush-trace
    close $tf
    puts "close"
    exit 0
}