Appendix B : A Listing File of Model II

Given $B = 1,000,000$, $a_1 = 334(kbps)$, $a_2 = 166(kbps)$, $a_3 = 56(kbps)$, $r_1 = 167(kbps)$, $r_2 = 83(kbps)$, and $r_3 = 28(kbps)$ where $\delta_i = a_i/r_i = 2$, $\forall i = 1, 2, 3$. Just like in Table 4.2, three different QoS classes are given, where class 1 has the highest priority and class 3 has the lowest priority. We change the numbers of connections in class 1 to $(J_1, J_2, J_3) = (190, 100, 100)$, and the numerical results are shown in Table 4.13.

Following is the listing file of the program Model II.

```
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


*Model II*



options
MINLP=BARON,
SOLVEOPT=REPLACE,
DECIMALS=8;

*Model II*

*宣告集合的大小 *
*****************
SETS
i " index of class 1 to 3 in Model II " /1*3/,
k " index of  another class 1 to 3 in Model II " /1*3/,
e " index of link 1 to 14 in Model II " /1*14/;

*Model II*

*宣告參數*
**********
PARAMETERS
J(i) " Number of connection of class i in Model II "
/
1        190
2        100
3        100

/,
o(k) " k in Model II "
/
1        1
2        2
3        3
```

```
/,


capital_B " Total budget in Model II " /1000000/,



U(e) " Capacity of link e in Model II "
/
1        230000
2        350000
3        100000
4        250000
5        210000
6        220000
7        200000
8        300000
9        210000
10        270000
11        150000
12        180000
13        300000
14        350000


/,
small_k(e) " The link cost of bandwidth for each link e in Model II "
/
1        5
2        6
3        10
4        5
5        4
6        11
7        6
8        8
9        6
10        7
11        12
12        6
13        5
14        6


/,
l(e) " Mean delay in Model II "
/
1        0.03
2        0.032
3        0.035
4        0.012
5        0.02
6        0.012
7        0.03
8        0.015
9        0.027
10        0.012
11        0.03
12        0.02
13        0.035
14        0.035

```

```
/,
capital_D(i) "  Maximal end-to-end delay in Model II "
/
1        0.89
2        1.02
3        2.34
/,
a(i) " Asp. Level in Model II "
/
1        334
2        166
3        56
/,
r(i) " Res. Level in Model II "
/
1        167
2        83
3        28
/,
s(i) " Mean Packet Size in Model II "
/
1        35
2        16.6
3        12.5
/,
b(i) " Bandwidth requirement of class i in Model II "
/
1        160
2        80
3        25
/;
*Model II*
*變數限制*
**********
free variable Z " Total utilijation sum in Model II ";
free variable t(k) " Free variable t(k) in Model II ";
free variable y(k) " Free variable y(k) in Model II ";
free variable f(i) " Free variable f(i) in Model II ";
positive variables q(i) " Bandwidth of each class i in Model II ";
positive variables v(k) " Weight w(i) of each class i, satisfies w(i)=sum(k=i to 3, v(k)) in Model II ";
positive variables hat_w(k) " Ordered weight of each class k in Model II ";
positive variables d(i,k) " The difference between t(k) and f(i) in Model II ";
binary variables x(i,e) " Binary variables in Model II ";
*Model II*
*宣告限制式*
************
EQUATIONS
```

```
OBJ  " Maximizing total utilijation sum in Model II ",
equal1(k) " y(k)=k*t(k)-sum(i=1 to 3, d(i,k)) in Model II ",
equal2(i) " f(i)=(log((q(i)+0.00001)/r(i)))/ (log(a(i)/r(i))) in Model II ",
small(i,k) " t(k)-d(i,k)<=f(i) in Model II ",
budg " Sum of q(i)*x(i,e) is smaller then budget in Model II ",
capa(e) " Smaller then capacity in Model II ",
dela(i) " Smaller then delay in Model II ",
requ(i) " q(i) bigger then bandwidth requirement b(i) in Model II ",
sour(i) " Source sum is 1 in Model II ",
inout2(i) " In equal out in node 2 in Model II ",
inout3(i) " In equal out in node 3 in Model II ",
inout4(i) " In equal out in node 4 in Model II ",
inout5(i) " In equal out in node 5 in Model II ",
inout6(i) " In equal out in node 6 in Model II ",
dest(i) " Destination sum is 1 in Model II ",
weig " Sum of h*v(h) equals 1 in Model II " ,
weig1 " v(3)=hat_w(3) in Model II " ,
weig2 "  v(2)+v(3)=hat_w(2) in Model II " ,
weig3 "  v(1)+v(2)+v(3)=hat_w(1) in Model II " ;

*Model II*

*目標函數與限制式表示 *
**********************

OBJ..
Z =e= SUM(k,v(k)*y(k));


equal1(k)..
y(k)=e=o(k)*t(k)-SUM(i,d(i,k));

equal2(i)..
f(i)=e=(log((q(i)+0.00001)/r(i)))/ (log(a(i)/r(i)));

small(i,k)..
t(k)-d(i,k)=l=f(i);

budg..
SUM((i,e),J(i)*small_k(e)*q(i)*x(i,e))=l=capital_B;

capa(e)..
SUM(i,J(i)*q(i)*x(i,e))=l=U(e);

dela(i)..
SUM(e,l(e)*x(i,e))=l=capital_D(i);


requ(i)..
q(i)=g=b(i);

sour(i)..
x(i,'1')+x(i,'2')+x(i,'3')=e=1;


inout2(i)..
x(i,'1')=e= x(i,'4')+ x(i,'5')+ x(i,'6');

inout3(i)..
x(i,'2')+x(i,'4')=e= x(i,'7')+ x(i,'8');

inout4(i)..
```

```
226  x(i,'5')+ x(i,'3')+x(i,'7')=e= x(i,'9')+ x(i,'11')+x(i,'10');
227
228  inout5(i)..
229  x(i,'6')+ x(i,'9')+x(i,'12')=e= x(i,'13');
230
231  inout6(i)..
232  x(i,'10')+ x(i,'8')=e= x(i,'12')+ x(i,'14');
233
234  dest(i)..
235  x(i,'13')+x(i,'11')+x(i,'14')=e=1;
236
237  weig..
238  SUM(k,o(k)*v(k))=e=1;
239
240  weig1..
241  v('3')=e=hat_w('3');
242
243  weig2..
244  v('2')+v('3')=e=hat_w('2');
245
246  weig3..
247  v('1')+v('2')+v('3')=e=hat_w('1');
248
249  *Model II*
250
251  *宣告模型 *
252  ***********
253  MODEL Model_II /ALL/;
254  SOLVE Model_II USING MINLP MAXIMIZING Z;
255  *結果呈現*
256  **********
257
258  display q.l;


COMPILATION TIME     =        0.000 SECONDS    3.2 Mb  WIN213-138 Feb 03, 2004


G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
Equation Listing    SOLVE Model_II Using MINLP From line 254


---- OBJ  =E=   Maximizing total utilijation sum in Model II

OBJ..  Z + (0)*y(1) + (0)*y(2) + (0)*y(3) + (0)*v(1) + (0)*v(2) + (0)*v(3) =E= 0
      ; (LHS = 0)


---- equal1  =E=   y(k)=k*t(k)-sum(i=1 to 3, d(i,k)) in Model II

equal1(1)..  - t(1) + y(1) + d(1,1) + d(2,1) + d(3,1) =E= 0 ; (LHS = 0)

equal1(2)..  - 2*t(2) + y(2) + d(1,2) + d(2,2) + d(3,2) =E= 0 ; (LHS = 0)

equal1(3)..  - 3*t(3) + y(3) + d(1,3) + d(2,3) + d(3,3) =E= 0 ; (LHS = 0)


---- equal2  =E=   f(i)=(log((q(i)+0.00001)/r(i)))/ (log(a(i)/r(i))) in Model II

equal2(1)..  f(1) - (144269.504088896)*q(1) =E= 0 ;

      (LHS = 23.9933447669109, INFES = 23.9933447669109 ***)
```

```
equal2(2)..  f(2) - (144269.504088896)*q(2) =E= 0 ;

      (LHS = 22.9846799057837, INFES = 22.9846799057837 ***)

equal2(3)..  f(3) - (144269.504088896)*q(3) =E= 0 ;

      (LHS = 21.4169953964944, INFES = 21.4169953964944 ***)


---- small  =L=   t(k)-d(i,k)<=f(i) in Model II

small(1,1)..  t(1) - f(1) - d(1,1) =L= 0 ; (LHS = 0)

small(1,2)..  t(2) - f(1) - d(1,2) =L= 0 ; (LHS = 0)

small(1,3)..  t(3) - f(1) - d(1,3) =L= 0 ; (LHS = 0)

REMAINING 6 ENTRIES SKIPPED


---- budg  =L=   Sum of q(i)*x(i,e) is smaller then budget in Model II

budg..  (0)*q(1) + (0)*q(2) + (0)*q(3) + (0)*x(1,1) + (0)*x(1,2) + (0)*x(1,3)

      + (0)*x(1,4) + (0)*x(1,5) + (0)*x(1,6) + (0)*x(1,7) + (0)*x(1,8)

      + (0)*x(1,9) + (0)*x(1,10) + (0)*x(1,11) + (0)*x(1,12) + (0)*x(1,13)

      + (0)*x(1,14) + (0)*x(2,1) + (0)*x(2,2) + (0)*x(2,3) + (0)*x(2,4)

      + (0)*x(2,5) + (0)*x(2,6) + (0)*x(2,7) + (0)*x(2,8) + (0)*x(2,9)

      + (0)*x(2,10) + (0)*x(2,11) + (0)*x(2,12) + (0)*x(2,13) + (0)*x(2,14)

      + (0)*x(3,1) + (0)*x(3,2) + (0)*x(3,3) + (0)*x(3,4) + (0)*x(3,5)

      + (0)*x(3,6) + (0)*x(3,7) + (0)*x(3,8) + (0)*x(3,9) + (0)*x(3,10)

      + (0)*x(3,11) + (0)*x(3,12) + (0)*x(3,13) + (0)*x(3,14) =L= 1000000 ;

      (LHS = 0)


---- capa  =L=   Smaller then capacity in Model II

capa(1)..  (0)*q(1) + (0)*q(2) + (0)*q(3) + (0)*x(1,1) + (0)*x(2,1) + (0)*x(3,1)
      =L= 230000 ; (LHS = 0)

capa(2)..  (0)*q(1) + (0)*q(2) + (0)*q(3) + (0)*x(1,2) + (0)*x(2,2) + (0)*x(3,2)
      =L= 350000 ; (LHS = 0)

capa(3)..  (0)*q(1) + (0)*q(2) + (0)*q(3) + (0)*x(1,3) + (0)*x(2,3) + (0)*x(3,3)
      =L= 100000 ; (LHS = 0)

REMAINING 11 ENTRIES SKIPPED


---- dela  =L=   Smaller then delay in Model II

dela(1)..  0.03*x(1,1) + 0.032*x(1,2) + 0.035*x(1,3) + 0.012*x(1,4)

      + 0.02*x(1,5) + 0.012*x(1,6) + 0.03*x(1,7) + 0.015*x(1,8) + 0.027*x(1,9)
```

```
      + 0.012*x(1,10) + 0.03*x(1,11) + 0.02*x(1,12) + 0.035*x(1,13)

      + 0.035*x(1,14) =L= 0.89 ; (LHS = 0)

dela(2)..  0.03*x(2,1) + 0.032*x(2,2) + 0.035*x(2,3) + 0.012*x(2,4)

      + 0.02*x(2,5) + 0.012*x(2,6) + 0.03*x(2,7) + 0.015*x(2,8) + 0.027*x(2,9)

      + 0.012*x(2,10) + 0.03*x(2,11) + 0.02*x(2,12) + 0.035*x(2,13)

      + 0.035*x(2,14) =L= 1.02 ; (LHS = 0)

dela(3)..  0.03*x(3,1) + 0.032*x(3,2) + 0.035*x(3,3) + 0.012*x(3,4)

      + 0.02*x(3,5) + 0.012*x(3,6) + 0.03*x(3,7) + 0.015*x(3,8) + 0.027*x(3,9)

      + 0.012*x(3,10) + 0.03*x(3,11) + 0.02*x(3,12) + 0.035*x(3,13)

      + 0.035*x(3,14) =L= 2.34 ; (LHS = 0)


---- requ  =G=   q(i) bigger then bandwidth requirement b(i) in Model II

requ(1)..  q(1) =G= 160 ; (LHS = 0, INFES = 160 ***)

requ(2)..  q(2) =G= 80 ; (LHS = 0, INFES = 80 ***)

requ(3)..  q(3) =G= 25 ; (LHS = 0, INFES = 25 ***)


---- sour  =E=   Source sum is 1 in Model II

sour(1)..  x(1,1) + x(1,2) + x(1,3) =E= 1 ; (LHS = 0, INFES = 1 ***)

sour(2)..  x(2,1) + x(2,2) + x(2,3) =E= 1 ; (LHS = 0, INFES = 1 ***)

sour(3)..  x(3,1) + x(3,2) + x(3,3) =E= 1 ; (LHS = 0, INFES = 1 ***)


---- inout2  =E=   In equal out in node 2 in Model II

inout2(1)..  x(1,1) - x(1,4) - x(1,5) - x(1,6) =E= 0 ; (LHS = 0)

inout2(2)..  x(2,1) - x(2,4) - x(2,5) - x(2,6) =E= 0 ; (LHS = 0)

inout2(3)..  x(3,1) - x(3,4) - x(3,5) - x(3,6) =E= 0 ; (LHS = 0)


---- inout3  =E=   In equal out in node 3 in Model II

inout3(1)..  x(1,2) + x(1,4) - x(1,7) - x(1,8) =E= 0 ; (LHS = 0)

inout3(2)..  x(2,2) + x(2,4) - x(2,7) - x(2,8) =E= 0 ; (LHS = 0)

inout3(3)..  x(3,2) + x(3,4) - x(3,7) - x(3,8) =E= 0 ; (LHS = 0)


---- inout4  =E=   In equal out in node 4 in Model II

inout4(1)..  x(1,3) + x(1,5) + x(1,7) - x(1,9) - x(1,10) - x(1,11) =E= 0 ;

      (LHS = 0)
```

```
inout4(2)..  x(2,3) + x(2,5) + x(2,7) - x(2,9) - x(2,10) - x(2,11) =E= 0 ;

      (LHS = 0)

inout4(3)..  x(3,3) + x(3,5) + x(3,7) - x(3,9) - x(3,10) - x(3,11) =E= 0 ;

      (LHS = 0)


---- inout5  =E=   In equal out in node 5 in Model II

inout5(1)..  x(1,6) + x(1,9) + x(1,12) - x(1,13) =E= 0 ; (LHS = 0)

inout5(2)..  x(2,6) + x(2,9) + x(2,12) - x(2,13) =E= 0 ; (LHS = 0)

inout5(3)..  x(3,6) + x(3,9) + x(3,12) - x(3,13) =E= 0 ; (LHS = 0)


---- inout6  =E=   In equal out in node 6 in Model II

inout6(1)..  x(1,8) + x(1,10) - x(1,12) - x(1,14) =E= 0 ; (LHS = 0)

inout6(2)..  x(2,8) + x(2,10) - x(2,12) - x(2,14) =E= 0 ; (LHS = 0)

inout6(3)..  x(3,8) + x(3,10) - x(3,12) - x(3,14) =E= 0 ; (LHS = 0)


---- dest  =E=   Destination sum is 1 in Model II

dest(1)..  x(1,11) + x(1,13) + x(1,14) =E= 1 ; (LHS = 0, INFES = 1 ***)

dest(2)..  x(2,11) + x(2,13) + x(2,14) =E= 1 ; (LHS = 0, INFES = 1 ***)

dest(3)..  x(3,11) + x(3,13) + x(3,14) =E= 1 ; (LHS = 0, INFES = 1 ***)


---- weig  =E=   Sum of h*v(h) equals 1 in Model II

weig..  v(1) + 2*v(2) + 3*v(3) =E= 1 ; (LHS = 0, INFES = 1 ***)


---- weig1  =E=   v(3)=hat_w(3)  in Model II

weig1..  v(3) - hat_w(3) =E= 0 ; (LHS = 0)


---- weig2  =E=    v(2)+v(3)=hat_w(2)  in Model II

weig2..  v(2) + v(3) - hat_w(2) =E= 0 ; (LHS = 0)


---- weig3  =E=    v(1)+v(2)+v(3)=hat_w(1)  in Model II

weig3..  v(1) + v(2) + v(3) - hat_w(1) =E= 0 ; (LHS = 0)



G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
Column Listing      SOLVE Model_II Using MINLP From line 254


---- Z   Total utilijation sum in Model II
```

```
Z
                (.LO, .L, .UP = -INF, 0, +INF)
        1       OBJ


---- t   Free variable t(k) in Model II

t(1)
                (.LO, .L, .UP = -INF, 0, +INF)
       -1       equal1(1)
        1       small(1,1)
        1       small(2,1)
        1       small(3,1)

t(2)
                (.LO, .L, .UP = -INF, 0, +INF)
       -2       equal1(2)
        1       small(1,2)
        1       small(2,2)
        1       small(3,2)

t(3)
                (.LO, .L, .UP = -INF, 0, +INF)
       -3       equal1(3)
        1       small(1,3)
        1       small(2,3)
        1       small(3,3)


---- y   Free variable y(k) in Model II

y(1)
                (.LO, .L, .UP = -INF, 0, +INF)
       (0)      OBJ
        1       equal1(1)

y(2)
                (.LO, .L, .UP = -INF, 0, +INF)
       (0)      OBJ
        1       equal1(2)

y(3)
                (.LO, .L, .UP = -INF, 0, +INF)
       (0)      OBJ
        1       equal1(3)


---- f   Free variable f(i) in Model II

f(1)
                (.LO, .L, .UP = -INF, 0, +INF)
        1       equal2(1)
       -1       small(1,1)
       -1       small(1,2)
       -1       small(1,3)

f(2)
                (.LO, .L, .UP = -INF, 0, +INF)
        1       equal2(2)
       -1       small(2,1)
       -1       small(2,2)
       -1       small(2,3)
```

```
f(3)
                (.LO, .L, .UP = -INF, 0, +INF)
        1       equal2(3)
       -1       small(3,1)
       -1       small(3,2)
       -1       small(3,3)


---- q   Bandwidth of each class i in Model II

q(1)
                (.LO, .L, .UP = 0, 0, +INF)
 (-144269.5041) equal2(1)
       (0)      budg
       (0)      capa(1)
       (0)      capa(2)
       (0)      capa(3)
       (0)      capa(4)
       (0)      capa(5)
       (0)      capa(6)
       (0)      capa(7)
       (0)      capa(8)
       (0)      capa(9)
       (0)      capa(10)
       (0)      capa(11)
       (0)      capa(12)
       (0)      capa(13)
       (0)      capa(14)
        1       requ(1)

q(2)
                (.LO, .L, .UP = 0, 0, +INF)
 (-144269.5041) equal2(2)
       (0)      budg
       (0)      capa(1)
       (0)      capa(2)
       (0)      capa(3)
       (0)      capa(4)
       (0)      capa(5)
       (0)      capa(6)
       (0)      capa(7)
       (0)      capa(8)
       (0)      capa(9)
       (0)      capa(10)
       (0)      capa(11)
       (0)      capa(12)
       (0)      capa(13)
       (0)      capa(14)
        1       requ(2)

q(3)
                (.LO, .L, .UP = 0, 0, +INF)
 (-144269.5041) equal2(3)
       (0)      budg
       (0)      capa(1)
       (0)      capa(2)
       (0)      capa(3)
       (0)      capa(4)
       (0)      capa(5)
       (0)      capa(6)
       (0)      capa(7)
       (0)      capa(8)
       (0)      capa(9)
```

```
       (0)      capa(10)
       (0)      capa(11)
       (0)      capa(12)
       (0)      capa(13)
       (0)      capa(14)
        1       requ(3)


---- v   Weight w(i) of each class i, satisfies w(i)=sum(k=i to 3, v(k)) in Mode
        l II

v(1)
                (.LO, .L, .UP = 0, 0, +INF)
       (0)      OBJ
        1       weig
        1       weig3

v(2)
                (.LO, .L, .UP = 0, 0, +INF)
       (0)      OBJ
        2       weig
        1       weig2
        1       weig3

v(3)
                (.LO, .L, .UP = 0, 0, +INF)
       (0)      OBJ
        3       weig
        1       weig1
        1       weig2
        1       weig3


---- hat_w   Ordered weight of each class k in Model II

hat_w(1)
                (.LO, .L, .UP = 0, 0, +INF)
       -1       weig3

hat_w(2)
                (.LO, .L, .UP = 0, 0, +INF)
       -1       weig2

hat_w(3)
                (.LO, .L, .UP = 0, 0, +INF)
       -1       weig1


---- d   The difference between t(k) and f(i) in Model II

d(1,1)
                (.LO, .L, .UP = 0, 0, +INF)
        1       equal1(1)
       -1       small(1,1)

d(1,2)
                (.LO, .L, .UP = 0, 0, +INF)
        1       equal1(2)
       -1       small(1,2)

d(1,3)
                (.LO, .L, .UP = 0, 0, +INF)
        1       equal1(3)
```

```
      -1       small(1,3)

REMAINING 6 ENTRIES SKIPPED

---- x   Binary variables in Model II

x(1,1)
                (.LO, .L, .UP = 0, 0, 1)
       (0)       budg
       (0)       capa(1)
        0.03     dela(1)
        1        sour(1)
        1        inout2(1)

x(1,2)
                (.LO, .L, .UP = 0, 0, 1)
       (0)       budg
       (0)       capa(2)
        0.032    dela(1)
        1        sour(1)
        1        inout3(1)

x(1,3)
                (.LO, .L, .UP = 0, 0, 1)
       (0)       budg
       (0)       capa(3)
        0.035    dela(1)
        1        sour(1)
        1        inout4(1)

REMAINING 39 ENTRIES SKIPPED


G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
Model Statistics    SOLVE Model_II Using MINLP From line 254


MODEL STATISTICS

BLOCKS OF EQUATIONS      19     SINGLE EQUATIONS       62
BLOCKS OF VARIABLES       9     SINGLE VARIABLES       70
NON ZERO ELEMENTS       325     NON LINEAR N-Z        138
DERIVATIVE POOL          52     CONSTANT POOL          40
CODE LENGTH            1011     DISCRETE VARIABLES     42


GENERATION TIME      =        0.031 SECONDS    4.0 Mb  WIN213-138 Feb 03, 2004


EXECUTION TIME       =        0.031 SECONDS    4.0 Mb  WIN213-138 Feb 03, 2004


G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
Solution Report     SOLVE Model_II Using MINLP From line 254


               S O L V E      S U M M A R Y

     MODEL   Model_II            OBJECTIVE  Z
     TYPE    MINLP               DIRECTION  MAXIMIZE
     SOLVER  BARON               FROM LINE  254

**** SOLVER STATUS     3 RESOURCE INTERRUPT
```

```
**** MODEL STATUS      8 INTEGER SOLUTION
**** OBJECTIVE VALUE               0.6617

 RESOURCE USAGE, LIMIT       1000.000      1000.000
 ITERATION COUNT, LIMIT         0         10000
 EVALUATION ERRORS              0             0

Baron 6.0     Jan 19, 2004 WIN.BA.NA 21.3 006.000.000.VIS P3PC

Branch And Reduce Optimization Navigator
Nikolaos Sahinidis and Mohit Tawarmalani
The Optimization Firm, LLC.

  Total time elapsed   :     000:16:40,    in seconds:       1000.00
       on parsing      :     000:00:00,    in seconds:          0.03
       on preprocessing:     000:00:00,    in seconds:          0.38
       on navigating   :     000:00:14,    in seconds:         13.84
       on relaxed      :     000:00:41,    in seconds:         41.38
       on local        :     000:11:56,    in seconds:        715.97
       on tightening   :     000:00:12,    in seconds:         11.88
       on marginals    :     000:00:00,    in seconds:          0.00
       on probing      :     000:03:37,    in seconds:        216.53

   Total no. of BaR iterations:  144561
   Best solution found at node:    1765
   Max. no. of nodes in memory:    4357


Solution      = 0.661749956769  found at node 1765
Best possible = 169.418332839
Absolute gap  = 168.756582882231  optca = 0.1
Relative gap  = 0.99609  optcr = 0.1


                       LOWER     LEVEL     UPPER    MARGINAL

---- EQU OBJ              .         .         .        1.000

  OBJ   Maximizing total utilijation sum in Model II

---- EQU equal1   y(k)=k*t(k)-sum(i=1 to 3, d(i,k)) in Model II

     LOWER     LEVEL     UPPER    MARGINAL

1      .         .         .         .
2      .         .         .         .
3      .         .         .       0.333

---- EQU equal2   f(i)=(log((q(i)+0.00001)/r(i)))/ (log(a(i)/r(i))) in Model II

     LOWER     LEVEL     UPPER    MARGINAL

1      .         .         .       0.333
2      .         .         .       0.333
3      .         .         .       0.333

---- EQU small   t(k)-d(i,k)<=f(i) in Model II

       LOWER     LEVEL     UPPER    MARGINAL

1.1     -INF       .         .         .
1.2     -INF       .         .         .
1.3     -INF       .         .       0.333
```

```
2.1     -INF     -0.301       .          .
2.2     -INF     -0.301       .          .
2.3     -INF       .          .        0.333
3.1     -INF     -1.869       .          .
3.2     -INF     -1.869       .          .
3.3     -INF       .          .        0.333

                        LOWER     LEVEL     UPPER    MARGINAL

---- EQU budg           -INF  1.0000E+6 1.0000E+6 2.4536E-6

  budg   Sum of q(i)*x(i,e) is smaller then budget in Model II

---- EQU capa   Smaller then capacity in Model II

      LOWER     LEVEL     UPPER    MARGINAL

1      -INF       .    2.3000E+5      .
2      -INF  50000.000 3.5000E+5      .
3      -INF       .    1.0000E+5      .
4      -INF       .    2.5000E+5      .
5      -INF       .    2.1000E+5      .
6      -INF       .    2.2000E+5      .
7      -INF       .    2.0000E+5      .
8      -INF  50000.000 3.0000E+5      .
9      -INF       .    2.1000E+5      .
10     -INF       .    2.7000E+5      .
11     -INF       .    1.5000E+5      .
12     -INF       .    1.8000E+5      .
13     -INF       .    3.0000E+5      .
14     -INF  50000.000 3.5000E+5      .

---- EQU dela   Smaller then delay in Model II

     LOWER     LEVEL     UPPER    MARGINAL

1     -INF      0.082     0.890       .
2     -INF      0.082     1.020       .
3     -INF      0.082     2.340       .

---- EQU requ   q(i) bigger then bandwidth requirement b(i) in Model II

     LOWER     LEVEL     UPPER    MARGINAL

1   160.000   160.000     +INF     -0.006
2    80.000    98.000     +INF  4.829E-10
3    25.000    98.000     +INF       .

---- EQU sour   Source sum is 1 in Model II

     LOWER     LEVEL     UPPER    MARGINAL

1     1.000     1.000     1.000    -0.373
2     1.000     1.000     1.000    -0.120
3     1.000     1.000     1.000    -0.120

---- EQU inout2   In equal out in node 2 in Model II

     LOWER     LEVEL     UPPER    MARGINAL

1      .         .         .         .
2      .         .         .         .
3      .         .         .         .
```

```
---- EQU inout3   In equal out in node 3 in Model II

     LOWER     LEVEL     UPPER    MARGINAL

1      .         .         .       -0.075
2      .         .         .       -0.024
3      .         .         .       -0.024

---- EQU inout4   In equal out in node 4 in Model II

     LOWER     LEVEL     UPPER    MARGINAL

1      .         .         .       -0.298
2      .         .         .       -0.096
3      .         .         .       -0.096

---- EQU inout5   In equal out in node 5 in Model II

     LOWER     LEVEL     UPPER    MARGINAL

1      .         .         .       -0.746
2      .         .         .       -0.240
3      .         .         .       -0.240

---- EQU inout6   In equal out in node 6 in Model II

     LOWER     LEVEL     UPPER    MARGINAL

1      .         .         .       -0.671
2      .         .         .       -0.216
3      .         .         .       -0.216

---- EQU dest   Destination sum is 1 in Model II

     LOWER     LEVEL     UPPER    MARGINAL

1     1.000     1.000     1.000    -1.119
2     1.000     1.000     1.000    -0.361
3     1.000     1.000     1.000    -0.361

                      LOWER     LEVEL     UPPER    MARGINAL

---- EQU weig          1.000     1.000     1.000     0.662
---- EQU weig1           .         .         .         .
---- EQU weig2           .         .         .         .
---- EQU weig3           .         .         .         .

  weig   Sum of h*v(h) equals 1 in Model II
  weig1   v(3)=hat_w(3) in Model II
  weig2    v(2)+v(3)=hat_w(2) in Model II
  weig3    v(1)+v(2)+v(3)=hat_w(1) in Model II

                      LOWER     LEVEL     UPPER    MARGINAL

---- VAR Z             -INF      0.662     +INF       .

  Z   Total utilijation sum in Model II

---- VAR t   Free variable t(k) in Model II

     LOWER     LEVEL     UPPER    MARGINAL
```

```
1     -INF     -0.062     +INF       .
2     -INF     -0.062     +INF       .
3     -INF      1.807     +INF       .

---- VAR y   Free variable y(k) in Model II

     LOWER     LEVEL     UPPER    MARGINAL

1     -INF     -0.062     +INF       .
2     -INF     -0.124     +INF       .
3     -INF      1.985     +INF       .

---- VAR f   Free variable f(i) in Model II

     LOWER     LEVEL     UPPER    MARGINAL

1     -INF     -0.062     +INF       .
2     -INF      0.240     +INF       .
3     -INF      1.807     +INF       .

---- VAR q   Bandwidth of each class i in Model II

     LOWER     LEVEL     UPPER    MARGINAL

1      .      160.000     +INF       .
2      .       98.000     +INF       .
3      .       98.000     +INF       .

---- VAR v   Weight w(i) of each class i, satisfies w(i)=sum(k=i to 3, v(k)) in
            Model II

     LOWER     LEVEL     UPPER    MARGINAL

1      .          .       +INF     -0.724
2      .          .       +INF     -1.447
3      .        0.333     +INF       .

---- VAR hat_w   Ordered weight of each class k in Model II

     LOWER     LEVEL     UPPER    MARGINAL

1      .        0.333     +INF       .
2      .        0.333     +INF       .
3      .        0.333     +INF       .

---- VAR d   The difference between t(k) and f(i) in Model II

       LOWER     LEVEL     UPPER    MARGINAL

1.1      .          .       +INF       .
1.2      .          .       +INF       .
1.3      .        1.869     +INF       .
2.1      .          .       +INF       .
2.2      .          .       +INF       .
2.3      .        1.568     +INF       .
3.1      .          .       +INF       .
3.2      .          .       +INF       .
3.3      .          .       +INF       .

---- VAR x   Binary variables in Model II

        LOWER     LEVEL     UPPER    MARGINAL
```

```
1.1     .      .      1.000    EPS
1.2     .    1.000    1.000    EPS
1.3     .      .      1.000  -0.075
1.4     .      .      1.000  -0.298
1.5     .      .      1.000    EPS
1.6     .      .      1.000  -0.075
1.7     .      .      1.000  -0.224
1.8     .    1.000    1.000    EPS
1.9     .      .      1.000    EPS
1.10    .      .      1.000  -0.149
1.11    .      .      1.000  -0.075
1.12    .      .      1.000  -0.373
1.13    .      .      1.000    EPS
1.14    .    1.000    1.000    EPS
2.1     .      .      1.000    EPS
2.2     .    1.000    1.000    EPS
2.3     .      .      1.000  -0.024
2.4     .      .      1.000  -0.096
2.5     .      .      1.000    EPS
2.6     .      .      1.000  -0.024
2.7     .      .      1.000  -0.072
2.8     .    1.000    1.000    EPS
2.9     .      .      1.000    EPS
2.10    .      .      1.000  -0.048
2.11    .      .      1.000  -0.024
2.12    .      .      1.000  -0.120
2.13    .      .      1.000    EPS
2.14    .    1.000    1.000    EPS
3.1     .      .      1.000    EPS
3.2     .    1.000    1.000    EPS
3.3     .      .      1.000  -0.024
3.4     .      .      1.000  -0.096
3.5     .      .      1.000    EPS
3.6     .      .      1.000  -0.024
3.7     .      .      1.000  -0.072
3.8     .    1.000    1.000    EPS
3.9     .      .      1.000    EPS
3.10    .      .      1.000  -0.048
3.11    .      .      1.000  -0.024
3.12    .      .      1.000  -0.120
3.13    .      .      1.000    EPS
3.14    .    1.000    1.000    EPS


**** REPORT SUMMARY :        0     NONOPT
                             0 INFEASIBLE
                             0  UNBOUNDED
                             0     ERRORS


G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
E x e c u t i o n


----     258 VARIABLE q.L   Bandwidth of each class i in Model II

1 1.600000E+2,    2 97.99999518,    3 98.00000482



EXECUTION TIME       =        0.000 SECONDS     2.9 Mb  WIN213-138 Feb 03, 2004
```

```
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**** FILE SUMMARY
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