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Appendix

```
clear all
close all
clc
result1= zeros(20,2);
Hr=1.5 ; Ht=32;
d1=1000;d2=3000 ;
d=round(d2-(d2-d1)*(rand(1,1)));
v=3*10^8;fc=150*10^6; g=12.67;w=v/fc;
SH2 =9; SH1=8; Lpen= 20; NF=9;
SHdb=round(SH2-(SH2-SH1)*(rand(1,1)));
Garea=10; Amu=30;Gt=14; Gr=0;
Pt=16;
Ght=20*log10(Ht/200);
Ghr=10*log10(Hr/3);

%pico cell befor expansion%
B_totalPICO=5*10^6;
B_pico= zeros(1,1);
for i=1:1
B_pico(i)=B_totalPICO/i;
B_picos1=sum(B_pico(i));
end
%pico cell expansion 1 %
B_totalPICO2=5*10^6;
B_pico2= zeros(1, 9);
for i=1:9
B_pico2(i)=B_totalPICO2/i;
B_picos2=sum(B_pico2(i));
end
 %pico cell expansion 2 %
B_totalPICO3=5*10^6;
B_pico3= zeros(1, 17);
for i=1:17
B_pico3(i)=B_totalPICO3/i;
B_picos3=sum(B_pico3(i));
end
%pico cell expansion 3 %
B_totalPICO4=5*10^6;
B_pico4= zeros(1, 25);
for i=1:25
```

```
B_pico4(i)=B_totalPICO4/i;
B_picos4=sum(B_pico4(i));
end
TH1=0;
for i=1:40
   d1=30; d2=3000;
d=round(d2-(d2-d1)*(rand(1,1)));
SH2 =9; SH1=8;
SH=round(SH2-(SH2-SH1)*(rand(1,1)));
 Plf=-10*log10((w^2*g)/(4*3.14*d)^2);
 Lp=Plf+Amu-Ght-Ghr-Garea;
 K=1.38*10^-23; t=290;
 B_total=20*10^6;
 B(i)=B_total/i;
 N=10*log10(K*t*B(i))+NF;
I1=1; I2=3;
I=round(I2-(I2-I1)*(rand(1,1)));
Pr=Pt+Gt+Gr-SH-Lp-Lpen;
SINR=Pr-N-I;
B1(i)=B_total/i;
if (SINR > 24)
   Rc=3/4;M=64;
   DR1(i)= B1(i)*Rc*log2(M);
   Se1(i)= DR1/B;
   TH1(i)=sum(DR1);
   BU1(i)=(sum(B1)+sum(B_pico))/(B_total+B_totalPICO)
elseif (SINR > 18)
    Rc=1/2;M=16;
    DR1(i)=B1(i)*Rc*log2(M);
    Se1(i)=DR1/B;
    TH1(i)=sum(DR1);
    BU1(i)=(sum(B1)+sum(B_pico))/(B_total+B_totalPICO)
elseif (SINR > 12)
    Rc=3/4; M=16;
    DR1(i)=B1(i)*Rc*log2(M);
    Se1(i)=DR1/B;
    TH1(i)=sum(DR1);
    BU1(i)=(sum(B1)+sum(B_pico))/(B_total+B_totalPICO)
elseif (SINR > 9)
    Rc=1/2; M=16;
    DR1(i)=B1(i)*Rc*log2(M);
    Se1(i)=DR1/B;
    TH1(i)=sum(DR1);
```

```
    BU1(i)=(sum(B1)+sum(B_pico))/(B_total+B_totalPICO)
elseif (SINR > 6)
    Rc=3/4; M=4;
    DR1(i)=B1(i)*Rc*log2(M);
    Se1(i)=DR1/B;
    TH1(i)=sum(DR1);
    BU1(i)=(sum(B1)+sum(B_pico))/(B_total+B_totalPICO)
end

if(i<=32)
   z=i;
else
   z=32;
end
  B2(i)=B_total/z
if (SINR > 24)
  Rc=3/4;M=64;
  DR2(i)= B2(i)*Rc*log2(M);
  Se2(i)= DR2/B;
  TH2(i)=sum(DR2);
  BU2(i)=(sum(B2)+sum(B_pico2))/(B_total+B_totalPICO2)
elseif (SINR > 18)
   Rc=1/2;M=16;
   DR2(i)=B2(i)*Rc*log2(M);
   Se2(i)=DR2/B;
   TH2(i)=sum(DR2);
   BU2(i)=(sum(B2)+sum(B_pico2))/(B_total+B_totalPICO2)
elseif (SINR > 12)
   Rc=3/4; M=16;
   DR2(i)=B2(i)*Rc*log2(M);
   Se2(i)=DR2/B;
   TH2(i)=sum(DR2);
   BU2(i)=(sum(B2)+sum(B_pico2))/(B_total+B_totalPICO2)
elseif (SINR > 9)
    Rc=1/2; M=16;
    DR2(i)=B2(i)*Rc*log2(M);
    Se2(i)=DR2/B;
    TH2(i)=sum(DR2);
    BU2(i)=(sum(B2)+sum(B_pico2))/(B_total+B_totalPICO2)
elseif (SINR > 6)
    Rc=3/4; M=4;
    DR2(i)=B2(i)*Rc*log2(M);
    Se2(i)=DR2/B;
```

```
    TH2(i)=sum(DR2);
    BU2(i)=(sum(B2)+sum(B_pico2))/(B_total+B_totalPICO2)
end

if(i<=24)
    n=i;
else
   n=24;
end
  B3(i)=B_total/n
if (SINR > 24)
  Rc=3/4;M=64;
  DR3(i)= B3(i)*Rc*log2(M);
  Se3(i)= DR3/B;
  TH3(i)=sum(DR3);
    BU3(i)=(sum(B3)+sum(B_pico3))/(B_total+B_totalPICO3)
elseif (SINR > 18)
   Rc=1/2; M=16;
   DR3(i)=B3(i)*Rc*log2(M);
   Se3(i)=DR3/B;
   TH3(i)=sum(DR3);
   BU3(i)=(sum(B3)+sum(B_pico3))/(B_total+B_totalPICO3)
elseif (SINR > 12)
   Rc=3/4; M=16;
   DR3(i)=B3(i)*Rc*log2(M);
   Se3(i)=DR3/B;
   TH3(i)=sum(DR3);
   BU3(i)=(sum(B3)+sum(B_pico3))/(B_total+B_totalPICO3)
elseif (SINR > 9)
   Rc=1/2; M=16;
   DR3(i)=B3(i)*Rc*log2(M);
   Se3(i)=DR3/B;
   TH3(i)=sum(DR3);
   BU3(i)=(sum(B3)+sum(B_pico3))/(B_total+B_totalPICO3)
elseif (SINR > 6)
   Rc=3/4; M=4;
   DR3(i)=B3(i)*Rc*log2(M);
   Se3(i)=DR3/B;
   TH3(i)=sum(DR3);
   BU3(i)=(sum(B3)+sum(B_pico3))/(B_total+B_totalPICO3)
   end

if(i<=16)
```

```
    m=i;
else
    m=16;
end

    B4(i)=B_total/m
if (SINR > 24)
   Rc=3/4;M=64;
   DR4(i)= B4(i)*Rc*log2(M);
   Se4(i)= DR4/B;
   TH4(i)=sum(DR4);
   BU4(i)=(sum(B4)+sum(B_pico4))/(B_total+B_totalPICO4)
elseif (SINR > 18)
    Rc=1/2;M=16;
    DR4(i)= B4(i)*Rc*log2(M);
    Se4(i)= DR4/B;
    TH4(i)=sum(DR4);
    BU4(i)=(sum(B4)+sum(B_pico4))/(B_total+B_totalPICO4)
elseif (SINR > 12)
     Rc=3/4; M=16;
     DR4(i)= B4(i)*Rc*log2(M);
     Se4(i)= DR4/B;
     TH4(i)=sum(DR4);
     BU4(i)=(sum(B4)+sum(B_pico4))/(B_total+B_totalPICO4)
elseif (SINR > 9)
     Rc=1/2; M=16;
     DR4(i)= B4(i)*Rc*log2(M);
     Se4(i)= DR4/B;
     TH4(i)=sum(DR4);
     BU4(i)=(sum(B4)+sum(B_pico4))/(B_total+B_totalPICO4)
elseif (SINR > 6)
    Rc=3/4; M=4;
     DR4(i)= B4(i)*Rc*log2(M);
     Se4(i)= DR4/B;
     TH4(i)=sum(DR4);
     BU4(i)=(sum(B4)+sum(B_pico4))/(B_total+B_totalPICO4)
end

result1(i,1)=i*10;
result1(i,2)=SINR;

values=1:40;
values2=1:40;
```

```
values3=1:40;
values4=1:40;
values5=1:40;

end
%%%%%%%%%%%%figuers%%%%%%%%%%%%%%%%
plot(result1(:,1),result1(:,2),'-k.','linewidth',2);
title('SINR')
xlabel('number of users')
ylabel('SINR')
grid on
figure
plot(values,B,'--k.',values2,B2,'--r.',values3,B3,'--m.',values4,B4,'--
b.','linewidth',2);
title('Bandwidth per user')
xlabel('number of users')
leg=legend('Bandwidth per 40 user','Bandwidth per 32 user','Bandwidth
per 24 user','Bandwidth per 16 user' );
ylabel('B')
grid on
figure
plot(values,DR1,'--k.',values2,DR2,'--r.',values3,DR3,'--
m.',values4,DR4,'--b.','linewidth',2);
title('Gradually network enhancement (Data Rate)')
xlabel('number of users')
ylabel('Data rate')
leg=legend('without Range Expansion','20% enhancement','40%
enhancement','60% enhancement');
grid on
figure
plot(values,Se1,'-k.',values2,Se2,'--r.',values3,Se3,'--m.',values4,Se4,'--
b.','linewidth',2);
title('Gradually network enhancement (Spectral Efficiency)')
xlabel('number of users')
ylabel('Spectral Efficiency')
leg=legend('without Range Expansion','20% enhancement','40%
enhancement','60% enhancement');
grid on
figure
plot(values,TH1,'-k.',values2,TH2,'--r.',values3,TH3,'--m.',values4,TH4,'-
-b.','linewidth',2);
title('Gradually network enhancement (Throughput)')
xlabel('number of users')
```

```
ylabel('Throughput')
leg=legend('without Range Expansion','20% enhancement','40% enhancement','60% enhancement');
grid on
figure
plot(values,BU1,'-k.',values2,BU2,'--r.',values3,BU3,'--m.',values4,BU4,'--b.','linewidth',2);
title('Gradually network enhancement (Bandwidth Utallization)')
xlabel('number of users')
ylabel('Bandwidth Utallization')
leg=legend('without Range Expansion','20% enhancement','40% enhancement','60% enhancement');
grid on
figure
plot(values,DR1,'-k.',values4,DR4,'--b.','linewidth',2);
title(' final network performance (Data rate signal)')
xlabel('number of users')
ylabel('Data rate')
leg=legend('without Range Expansion','with Range Expansion');
grid on
figure
plot(values,Se1,'-k.',values4,Se4,'--b.','linewidth',2);
title('final network performance (Spectral Efficiency)')
xlabel('number of users')
ylabel('Spectral Efficiency')
leg=legend('without Range Expansion','with Range Expansion');
grid on
figure
plot(values,TH1,'-k.',values4,TH4,'--b.','linewidth',2);
title('final network performance (Throughput)')
xlabel('number of users')
ylabel('Throughput')
leg=legend('without Range Expansion','with Range Expansion');
grid on
figure
plot(values,BU1,'-k.',values4,BU4,'--b.','linewidth',2);
title('final network performance (Bandwidth Utallization)')
xlabel('number of users')
ylabel('Bandwidth Utallization')
leg=legend('without Range Expansion','with Range Expansion');
grid on
```