Desempenho e Dimensionamento de Redes

Report 2

Connectivity performance of multi-hop wireless networks with mobile terminals

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1 Briefing

After going through point 1 a couple of times, overcoming our uncertainties and understanding our role on the project, we started by doing point 3 where the guide provides enough sources to create the algorithms where Initial Node Coordinates, Speed and Direction are given. Moving on to write the algorithms where the position and direction were updated, we came up with a simple code represented below, where it's first part updates the actual position of a node and the second inverts the direction(represented by the negativity of the speed or not) according if the position is out of bounds or not.

```
function [pos,vel]= UpdateCoordinates(pos,vel,delta)
%Updates the matrices �pos� and �vel� based on their input values and delta.

    for i = 1:size(pos,1)
      %Para movimento horizontal
      pos(i,1) = pos(i,1) + delta*vel(i,1);
      if pos(i,1) >= 300
        pos(i,1) = 300;
        vel(i,1) = -vel(i,1);
      elseif pos(i,1) <= 0
        pos(i,1) = 0;
        vel(i,1) = -vel(i,1);
      end

      %Para movimento Vertical
      pos(i,2) = pos(i,2) + delta*vel(i,2);
      if pos(i,2) > 200
        pos(i,2) = 200;
        vel(i,2) = -vel(i,2);
      elseif pos(i,2) <= 0
        pos(i,2) = 0;
        vel(i,2) = -vel(i,2);
      end
    end

end
```

After updating the coordinates and directions of each node it's important to mention that we needed to increment the APs to the the position array of nodes. This way it was possible to detect the most important connections, the ones to any AP.

Next, we made an algorithm that returns a 2 column matrix containing all the possible connection pairs represented on the picture below.

```
function L= ConnectedList(N,pos,W,AP)
%Computes a matrix �L� of 2 columns with the node pairs (mobile and AP nodes)
%such that their distance is not higher than W.

index=1;

for i = 1: N
    for j= i+1 : size(pos,1)
      if sqrt((pos(j,1)-pos(i,1))^2 + (pos(j,2)-pos(i,2))^2) <= W
        L(index,1)=i;
        L(index,2)=j;
        index = index+1;
      end

  end

end

end
```

Reaching this point, we faced the pivotal point of the project and, making use of the Labelling Algorithm given on the guide, we build the code shown below. This piece of code works and does as described on the guides point 4.

```
function o= AverageConnectedNodePairs(N,L, nAP)
%Computes a value �o� with the percentage number of connected node pairs based
%on the input matrix �L� of node pairs with direct links (see Section 4).

o = 0;

arrayAlg = [zeros(1,N) ones(1,nAP)];
repeat = 1;
counter = 0;


%Labelling Algorithm for Connectivity Computation
while repeat == 1

  repeat = 0;

  for i = 1:size(L,1)

    if arrayAlg(L(i,1))~= arrayAlg(L(i,2))
      arrayAlg(L(i,1)) = 1;
      arrayAlg(L(i,2)) = 1;
      repeat = 1;
    end
  end
end


% Counter = nr de pontos com acesso ´a internet
for h = 1 : N
  if arrayAlg(h) == 1
    counter = counter + 1;
   end
end

o = (counter / N) * 100;


end
```

In the end we wrote a little script that runs the simulation 10 times for each case, calculating afterwards the 90% confidence interval

```
N = 10; %número de simulações
results= zeros(1,N); %vetor com os N resultados de simulação

for it= 1:N
  results(it)= simulator();
end

alfa= 0.1; %intervalo de confiança a 90%
media = mean(results);
termo = norminv(1-alfa/2)*sqrt(var(results)/N);
fprintf('resultado = %.2e +- %.2e\n',media,termo)
```

2 Question 2

2.1 Question 2.2 - a)

Table 1: Test for 1 AP

Case	N	W (meters)	S (km/h)	Avg. no. of nodes with Internet access(%)	90% confidence iterval (+/-)
A	50	40	3	30.1	5.91
B	50	60	3	96.8	2.25
C	50	80	3	99.9	$1.39\text{x}10^{-1}$
D	100	40	3	77.1	2.38
E	100	60	3	99.9	$2.22\text{x}10^{-2}$
F	50	40	6	21.2	4.79
G	50	60	6	97.4	$3.15\text{x}10^{-1}$
H	50	80	6	99.9	$3.94\text{x}10^{-2}$
I	100	40	6	80.2	3.77
J	100	60	6	99.9	$4.3\text{x}10^{-3}$

Table 2: Test for 2 AP

Case	N	W (meters)	S (km/h)	Avg. no. of nodes with Internet access(%)	90% confidence iterval (+/-)
A	50	40	3	48.9	2.21
B	50	60	3	98.3	$3.78\text{x}10^{-1}$
C	50	80	3	99.9	$6.17\text{x}10^{-2}$
D	100	40	3	89.8	$5.26\text{x}10^{-1}$
E	100	60	3	99.9	$2.58\text{x}10^{-2}$
F	50	40	6	50.4	2.85
G	50	60	6	98.1	$4.86\text{x}10^{-1}$
H	50	80	6	99.9	$5.47\text{x}10^{-2}$
I	100	40	6	88.5	$6.58\text{x}10^{-1}$
J	100	60	6	99.9	$1.73\text{x}10^{-2}$

Table 3: Test for 3 AP

Case	N	W (meters)	S (km/h)	Avg. no. of nodes with Internet access(%)	90% confidence iterval (+/-)
A	50	40	3	50.4	2.59
B	50	60	3	98.9	$2.70\text{x}10^{-1}$
C	50	80	3	99.9	$2.59\text{x}10^{-2}$
D	100	40	3	90.4	$8.52\text{x}10^{-1}$
E	100	60	3	99.9	$1.69\text{x}10^{-2}$
F	50	40	6	48.5	2.94
G	50	60	6	98.7	$6.32\text{x}10^{-1}$
H	50	80	6	99.9	$3.58\text{x}10^{-2}$
I	100	40	6	90.2	1.04
J	100	60	6	99.9	$1.82\text{x}10^{-2}$

Table 4: Test for 4 AP

Case	N	W (meters)	S (km/h)	Avg. no. of nodes with Internet access(%)	90% confidence iterval (+/-)
A	50	40	3	67.2	8.16
B	50	60	3	99.1	4.82x10^{-1}
C	50	80	3	99.9	6.92x10^{-}3
D	100	40	3	94.1	7.75x10^{-1}
E	100	60	3	99.9	2.02x10^{-2}
F	50	40	6	71.8	3.17
G	50	60	6	99.3	2.15x10^{-1}
H	50	80	6	99.9	2.62x10^{-2}
I	100	40	6	93.8	5.03x10^{-1}
J	100	60	6	99.9	1.42x10^{-2}

2.2 Question 2.2 - b)

Q:Based on the results of the average number of nodes with Internet access, take conclusions about the influence of the maximum speed S, radio range W, number of mobile nodes N and number of APs on the connectivity performance of the wireless network. Whenever possible, justify your conclusions.

<u>About maximum speed S:</u> We concluded that the speed does not have much influence on the system performance because the faster/slower it gets, some nodes might disconnect faster but again, others might connect faster too. After making some personal tests changing the speed, we realized the results didn't differ much from the given ones.

<u>About radio range W:</u> We can assume that the radio range is the most important factor on the system performance. Comparing the results from cases A to B and F to G (where W grows from 40 to 60 meters), we can see that an increment of 20 meters improves the Average number of nodes connected by almost its double. Also from the cases B to C and G to H (where W grows from 60 to 80), it also improves but not so drastically. From this, we conclude that the relation between W and Avg. connected nodes is represented by a logarithmic function, since the bigger W is, the less growth the avg. connected nodes takes.

<u>About number of mobile nodes N:</u> We can see from the results that N is

also a very important variable. Theoretically speaking, the more nodes in the system, the more probability of connected nodes, which leads to a most likely connection to an AP. Checking the results and taking into consideration the particular cases where only N changes, like A and D, we can see that there was a significant grow (for all the AP configurations).

About number of APs: By increasing the number of APs on the system clearly increases the performance of it. In theory, the more APs, the bigger the area that provides internet access. Although there is a point where is not useful anymore to just increase the number of APs. The area that each AP covers will start overlapping on each other. With this, a new problem takes place. Internet access will not only depend on the distance between the nodes anymore, but also on the distance between nodes and APs. With this we conclude that it's healthy for the system, TO A POINT, to have a higher number of APs.

2.3 Question 2.2 - c)

Q: By analyzing the obtained 90% confidence intervals, what do you conclude on the influence of the different input parameters on the statistical confidence of the results?

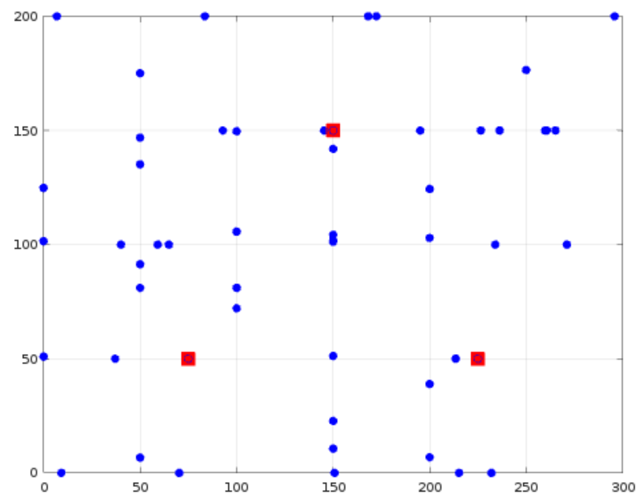
After a careful analysis of the results, it's possible to conclude that the parameters with most influence are clearly W and N. Once both are minimized we can see a substantial increase of the confidence interval. Once one of these two parameters is increased we can already see a lower 90% confidence interval, and if both are raised, the interval gets even shorter. Here we conclude that the bigger are the most impactful variables, smaller is the deviation of the results and bigger is the stability of the system.

2.4 Question 2.2 - d)

Q:Are the suggested AP configurations the best choice for each considered number of APs? Simulate possible alternatives in the cases you think better performance can be obtained.

Based on math knowledge and common sense we think that having symmetrical and equidistant configurations is advantageous for the system performance. With that said, for node configuration 1, 2 and 4, by running a couple of simulations with different AP locations, we proved our theory right since there was never a performance increase and sometimes, even got a decrease instead.

Although, for AP configuration 3 we thought that it would have a significant improvement by changing the AP location to represent a triangular shape as represented below (red squares):



After running a couple of simulations with it we cease that even though the performance would increase, there was never a radical change in it.

Table 5: Cases F, G adn H for all AP configurations

	Case	N	W (meters)	S (km/h)	Avg. no. of nodes with Internet access(%)	90% confidence iterval (+/-)
1 AP	F	50	40	6	21.2	4.79
	G	50	60	6	97.4	3.15×10^{-1}
	H	50	80	6	99.9	3.94×10^{-2}
2 AP	F	50	40	6	50.4	2.85
	G	50	60	6	98.1	4.86×10^{-1}
	H	50	80	6	99.9	5.47×10^{-2}
3 AP	F	50	40	6	48.5	2.94
	G	50	60	6	98.7	6.32×10^{-1}
	H	50	80	6	99.9	3.58×10^{-2}
4 AP	F	50	40	6	71.8	3.17
	G	50	60	6	99.3	2.15×10^{-1}
	H	50	80	6	99.9	2.62×10^{-2}

2.5 Question 2.2 - e)

Q:Assume now that the maximum speed of each node is S = 6 Km/h and that the number of mobile nodes is N = 50. For each of the 3 radio range values W = 40, 60 and 80 meters, determine the minimum required number of APs (and locations) such that the average number of nodes with Internet access is not lower than 99%. For each of the three cases, run an enough large number of simulations to reach an adequate 90% confidence interval.

Table 5 shows us the particular case study described on the question. From it we can see that for:

W=40 it is not possible to reach a 99% internet access, since the maximum it can get is with 4 APs (71.8%).

W=60 it is possible to reach a 99% internet access with a minimum of 4 APs, since it reached a value of 99.3%.

W=80 it is possible to reach a 99% internet access with a minimum of 1 AP, since it reached a value of 99.9%.