



AVAILABILITY PERFORMANCE OF MULTI-HOP WIRELESS NETWORKS WITH MOBILE TERMINALS

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João Coelho(80335) Javier Borrallo Fernández(92092)

3.a)

par.AP = [200 150];

Case	N	W(meters)	Average Availability	90% Confidence interval	Min Availability	90% Confidence interval
A	60	40	6.963e-02	6.96e-02+-8.57e-03	0.000e+00	0.00e+00+-0.00e+00
B	90	40	1.613e-01	1.61e-01+-1.67e-02	9.639e-03	9.64e-03+-2.89e-03
C	120	40	3.264e-01	3.26e-01+-3.23e-02	7.315e-02	7.32e-02+-9.92e-03
D	150	40	5.759e-01	5.76e-01+-2.15e-02	2.574e-01	2.57e-01+-3.31e-02
E	60	60	8.038e-01	8.04e-01+-1.96e-02	5.198e-01	5.20e-01+-3.28e-02
F	90	60	9.687e-01	9.69e-01+-2.73e-03	8.241e-01	8.24e-01+-2.62e-02
G	120	60	9.910e-01	9.91e-01+-6.00e-04	9.065e-01	9.07e-01+-1.01e-02
H	150	60	9.959e-01	9.96e-01+-3.55e-04	9.369e-01	9.37e-01+-8.81e-03
I	60	80	9.801e-01	9.80e-01+-2.67e-03	8.768e-01	8.77e-01+-1.82e-02
J	90	80	9.962e-01	9.96e-01+-5.45e-04	9.517e-01	9.52e-01+-6.82e-03
K	120	80	9.990e-01	9.99e-01+-1.59e-04	9.697e-01	9.70e-01+-7.58e-03
L	150	80	9.997e-01	1.00e+00+-8.88e-05	9.860e-01	9.86e-01+-4.03e-03

par.AP = [100 150;300 150];

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Case	N	W(meters)	Average Availability	90% Confidence interval	Min Availability	90% Confidence interval
A	60	40	1.518e-01	1.52e-01+-1.44e-02	3.042e-03	3.04e-03+-1.30e-03
B	90	40	2.437e-01	2.44e-01+-2.31e-02	3.475e-02	3.48e-02+-6.73e-03
C	120	40	4.742e-01	4.74e-01+-2.03e-02	1.723e-01	1.72e-01+-1.82e-02
D	150	40	6.779e-01	6.78e-01+-2.08e-02	3.071e-01	3.07e-01+-4.48e-02
E	60	60	8.617e-01	8.62e-01+-1.29e-02	5.543e-01	5.54e-01+-2.93e-02
F	90	60	9.700e-01	9.70e-01+-2.87e-03	8.017e-01	8.02e-01+-3.95e-02
G	120	60	9.904e-01	9.90e-01+-7.65e-04	8.980e-01	8.98e-01+-2.26e-02
H	150	60	9.960e-01	9.96e-01+-5.36e-04	9.352e-01	9.35e-01+-1.18e-02
I	60	80	9.840e-01	9.84e-01+-1.71e-03	8.830e-01	8.83e-01+-2.00e-02
J	90	80	9.962e-01	9.96e-01+-6.43e-04	9.465e-01	9.47e-01+-1.02e-02
K	120	80	9.989e-01	9.99e-01+-1.39e-04	9.664e-01	9.66e-01+-6.31e-03
L	150	80	9.995e-01	9.99e-01+-1.51e-04	9.780e-01	9.78e-01+-4.62e-03

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par.AP = [100 150;200 150;300 150];

Case	N	W (meters)	Average Availability	90% Confidence interval	Min Availability	90% Confidence interval
A	60	40	1.858e-01	1.86e-01 +- 1.62e-02	1.62e-02	3.62e-03 +- 2.33e-03
B	90	40	3.441e-01	3.44e-01 +- 1.92e-02	5.275e-02	5.27e-02 +- 1.01e-02
C	120	40	5.309e-01	5.31e-01 +- 2.18e-02	1.920e-01	1.92e-01 +- 1.83e-02
D	150	40	7.411e-01	7.41e-01 +- 9.85e-03	3.630e-01	3.63e-01 +- 3.91e-02
E	60	60	8.807e-01	8.81e-01 +- 1.03e-02	5.853e-01	5.85e-01 +- 3.17e-02
F	90	60	9.746e-01	9.75e-01 +- 1.97e-03	8.490e-01	8.49e-01 +- 1.62e-02
G	120	60	9.911e-01	9.91e-01 +- 9.07e-04	9.091e-01	9.09e-01 +- 1.28e-02
H	150	60	9.961e-01	9.96e-01 +- 4.79e-04	9.341e-01	9.34e-01 +- 1.10e-02
I	60	80	9.839e-01	9.84e-01 +- 1.94e-03	8.732e-01	8.73e-01 +- 2.56e-02
J	90	80	9.963e-01	9.96e-01 +- 8.58e-04	9.414e-01	9.41e-01 +- 1.73e-02
K	120	80	9.989e-01	9.99e-01 +- 2.25e-04	9.723e-01	9.72e-01 +- 6.67e-03
L	150	80	9.997e-01	1.00e+00 +- 9.84e-05	9.843e-01	9.84e-01 +- 3.08e-03

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par.AP = [100 100;300 100;100 200;300 200];

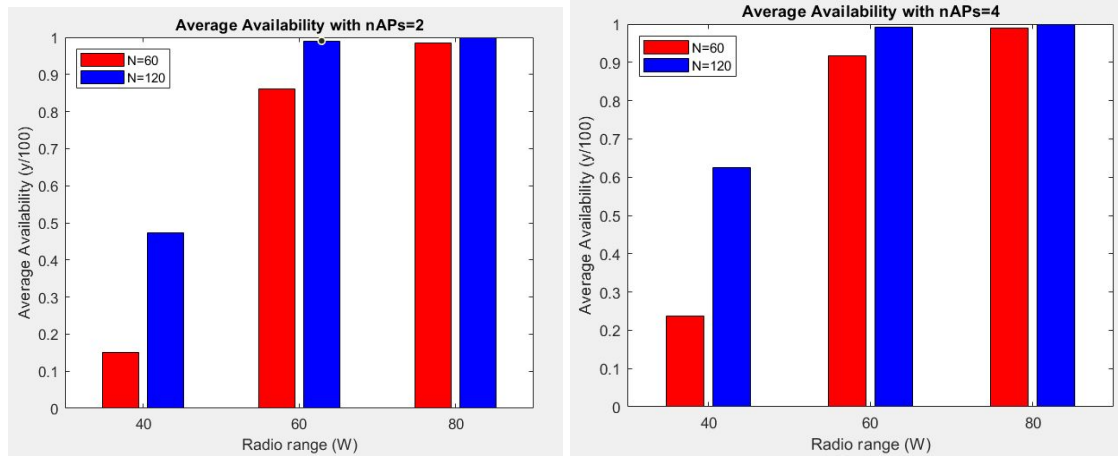
Case	N	W(meters)	Average Availability	90% Confidence interval	Min Availability	90% Confidence interval
A	60	40	2.369e-01	2.37e-01+-2.00e-02	1.311e-02	1.31e-02+-3.41e-03
B	90	40	4.215e-01	4.21e-01+-2.19e-02	9.219e-02	9.22e-02+-1.43e-02
C	120	40	6.240e-01	6.24e-01+-1.25e-02	2.393e-01	2.39e-01+-2.89e-02
D	150	40	7.919e-01	7.92e-01+-5.51e-03	4.151e-01	4.15e-01+-3.99e-02
E	60	60	9.176e-01	9.18e-01+-6.32e-03	6.387e-01	6.39e-01+-3.78e-02
F	90	60	9.782e-01	9.78e-01+-1.26e-03	8.272e-01	8.27e-01+-2.32e-02
G	120	60	9.912e-01	9.91e-01+-8.07e-04	9.065e-01	9.07e-01+-1.05e-02
H	150	60	9.959e-01	9.96e-01+-2.93e-04	9.359e-01	9.36e-01+-9.93e-03
I	60	80	9.885e-01	9.88e-01+-1.30e-03	8.961e-01	8.96e-01+-1.40e-02
J	90	80	9.967e-01	9.97e-01+-4.46e-04	9.524e-01	9.52e-01+-8.26e-03
K	120	80	9.988e-01	9.99e-01+-2.17e-04	9.698e-01	9.70e-01+-5.05e-03
L	150	80	9.996e-01	1.00e+00+-7.75e-05	9.826e-01	9.83e-01+-3.42e-03

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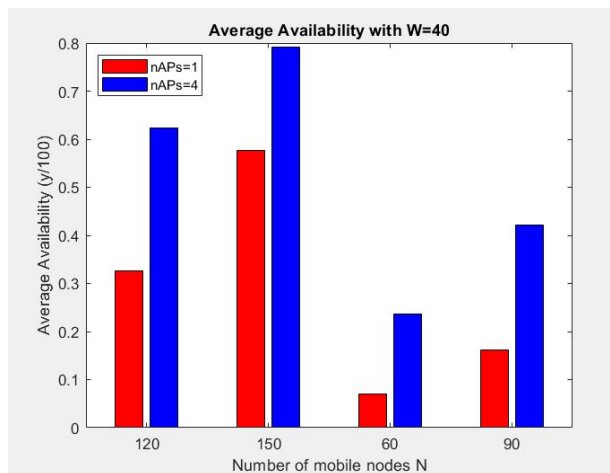
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3.b)

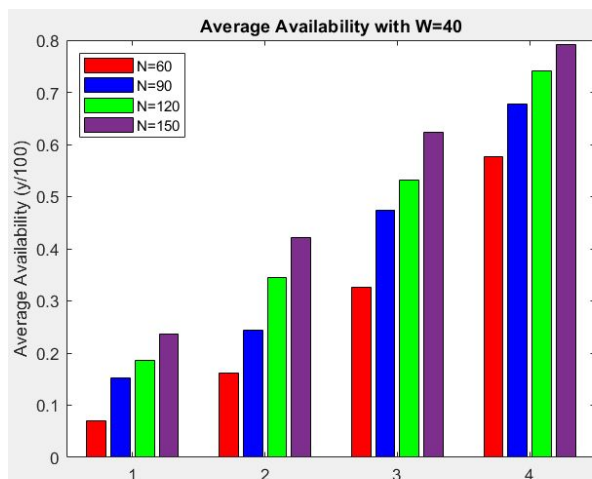
radio range W



number of mobile nodes N



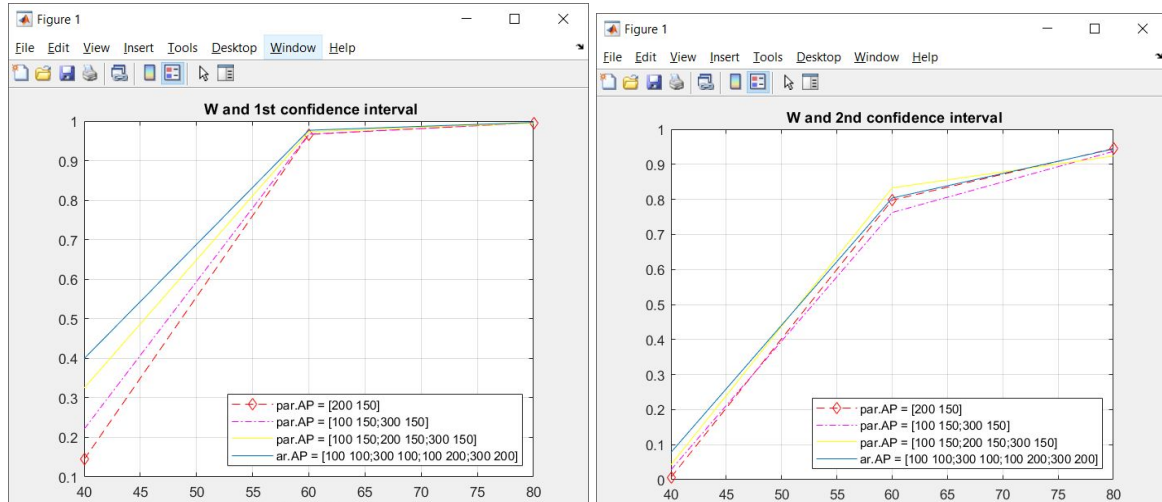
number of APs



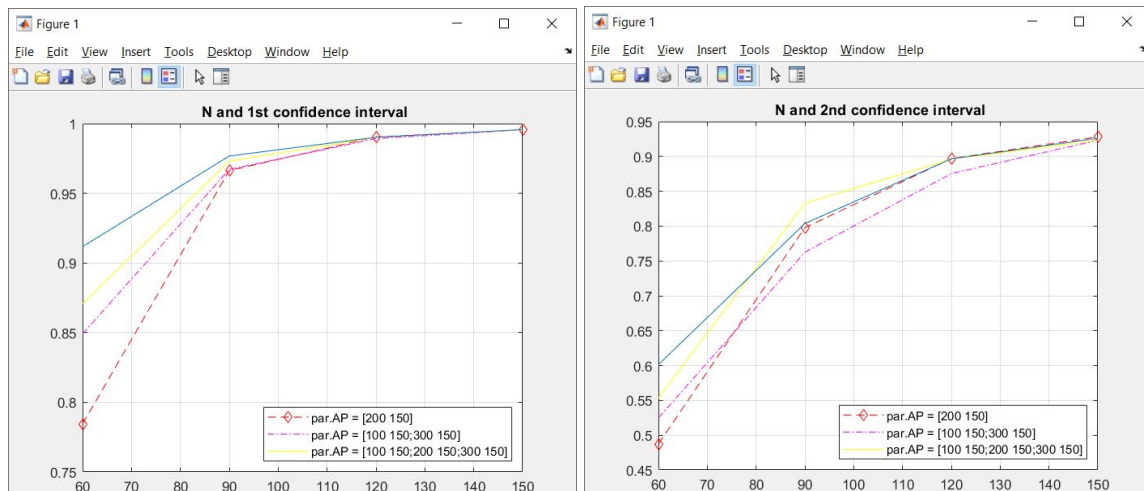
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Confidence Interval and W



Confidence Interval and N



3.c) Analyzing the obtained results it is observed that the **range (W)** has a considerable influence especially when the value of N is low, as we can see in the graphs. When its value is smaller, the average number of nodes with Internet access is also smaller, and when W has a higher value, the average number of nodes with an Internet connection also increases. **This is verified, for example, with the first two graphs presented on 3.b) where only the variable W changes and where it can be observed the described behavior.** This is justified by the fact that W is the reach/coverage of the network, and therefore the smaller the range provided by each AP, the smaller the average number of nodes with Internet connectivity because they are most likely to be in an area not covered with a W lower, and therefore the average number also decreases.

In the same way, the **N** has enough influence on the results. When defining an N with a higher value, the average number of nodes with an Internet connection also reaches higher values, as it happens on the **third graph where only the number of nodes changes and it has a great influence on the average availability.** This case is justified because one node can have connectivity to the Internet through another node, meaning that the more

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there are, the more nodes can be connected to each other and consequently the greater likelihood of having connectivity to the Internet.

The **number of APs** influences mainly in the cases A, E and I, which are the situations where the W is smaller (the coverage is smaller) but there are more APs. This factor (number of APs) increases the average number of nodes with Internet connectivity; however, even in cases where coverage is high, an improvement is also observed, as the number of APs increases. **This can be observed in the fourth graph where every time the number of APs increases, the average availability also increases.**

3.d)

We have observed that input parameters have a great influence on the outcome:

⇒ W, has a high influence on the confidence interval; if W is low, the confidence interval will also be low, we have also observed that it grows rapidly from 40 to 60, but it remains almost stable from 60 to 80.

⇒ N, we can observe almost the same as in with W; when N grows, confidence interval also grows, and in high values it remains stable.

3.e)

We think that for 1 and 2 nodes, the location given is the best one, but for 3 nodes it will be better if we do a triangle, we considered an (almost) equilateral triangle, using the following coordinates: [100 100;200 250;300 100]. As thought we obtained better results:

Case	N	W (m)	Old Average Availability	Average Availability	90% Confidence interval	Old Min Availability	Min Availability	90% Confidence interval
A	60	40	1.858e-01	2.269e-01	2.27e-01 +- 1.18e-02	1.62e-02	1.128e-02	1.13e-02 +- 4.31e-03
B	120	40	5.309e-01	5.771e-01	5.77e-01 +- 1.52e-02	1.920e-01	2.173e-01	2.17e-01 +- 2.21e-02
C	60	60	8.808e-01	9.073e-01	9.07e-01 +- 5.70e-03	5.853e-01	6.320e-01	6.32e-01 +- 3.23e-02
D	120	60	9.911e-01	9.913e-01	9.91e-01 +- 5.44e-04	9.091e-01	9.005e-01	9.01e-01 +- 1.21e-02
E	60	80	9.839e-01	9.866e-01	9.87e-01 +- 1.10e-03	8.732e-01	8.953e-01	8.95e-01 +- 1.44e-02
F	120	80	9.989e-01	9.991e-01	9.99e-01 +- 1.49e-04	9.823e-01	9.706e-01	9.71e-01 +- 5.46e-03

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For 4 nodes it will be better if we do a rectangle, we considered the same positions as before but a bit more spread so they can cover more ground, using the following coordinates: [100 70;300 70;100 230;300 230]. Like this, the APs between them have a distance of 160 meters which divided by 2 is 80 meters. For the 80m at least, it will be better. As thought we obtained better results:

Case	N	W (m)	Old Average Availability	Average Availability	90% Confidence interval	Old Min Availability	Min Availability	90% Confidence interval
A	60	40	2.369e-01	3.090e-01	3.09e-01+-2.70e-02	1.311e-02	3.000e-02	3.00e-02+-7.15e-03
B	120	40	6.240e-01	6.836e-01	6.84e-01+-9.49e-03	2.393e-01	3.046e-01	3.05e-01+-3.40e-02
C	60	60	9.176e-01	9.413e-01	9.41e-01+-5.08e-03	6.387e-01	6.741e-01	6.74e-01+-5.33e-02
D	120	60	9.912e-01	9.915e-01	9.92e-01+-6.45e-04	9.065e-01	9.138e-01	9.14e-01+-1.35e-02
E	60	80	9.885e-01	9.909e-01	9.91e-01+-1.01e-03	8.961e-01	8.935e-01	8.93e-01+-2.39e-02
F	120	80	9.988e-01	9.991e-01	9.99e-01+-1.97e-04	9.698e-01	9.753e-01	9.75e-01+-4.65e-03

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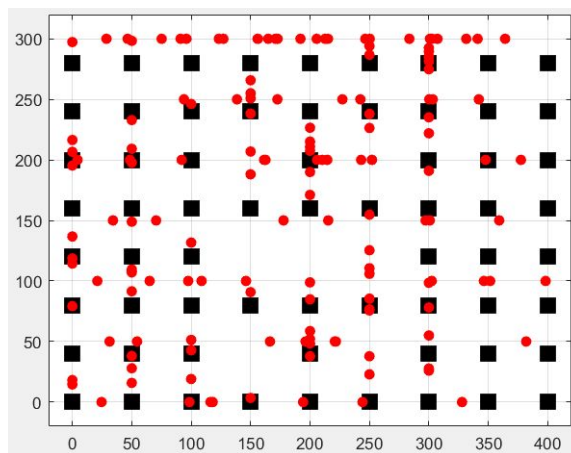
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3.f) N=150

W=40

For the value $W=40$, the number of AP's to obtain the minimum Internet access availability not lower than 99% is **65**, which coordinates are:

par.AP = [0 0; 0 40; 0 80; 0 120; 0 160; 0 200; 0 240; 0 280; 50 0; 50 40; 50 80; 50 120; 50 160; 50 200; 50 240; 50 280; 100 0; 100 40; 100 80; 100 120; 100 160; 100 200; 100 240; 100 280; 150 0; 150 80; 150 160; 150 240; 150 280; 200 0; 200 40; 200 80; 200 160; 200 200; 200 240; 200 280; 250 0; 250 80; 250 160; 250 240; 250 280; 300 0; 300 40; 300 80; 300 120; 300 160; 300 200; 300 240; 300 280; 350 0; 350 40; 350 80; 350 120; 350 160; 350 200; 350 240; 350 280; 400 0; 400 40; 400 80; 400 120; 400 160; 400 200; 400 240; 400 280];



With this setting, we do a network separated in 40m each, except in columns 150 and 250, that due to the high concentration of mobile nodes we can increase some of the distances to 80m.

We got the following results:

N= 150 W= 40 AvAv= 9.999e-01 90conf= 1.00e+00+-3.56e-05 **MinAv= 9.948e-01**
90conf= 9.95e-01+-1.83e-03

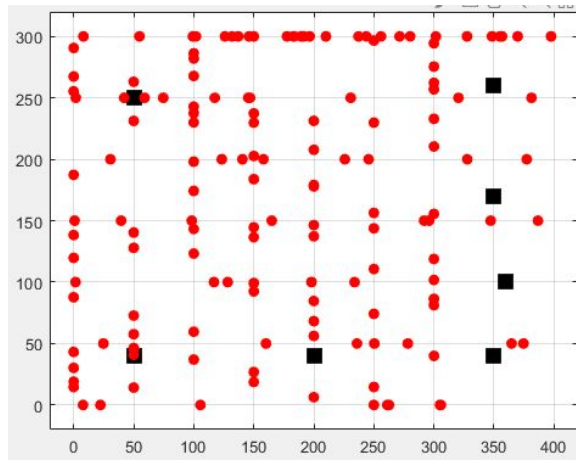
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W=60

For the value $W=60$, the number of AP's to obtain the minimum Internet access availability not lower than 99% is **7**, which coordinates are:

par.AP = [360 100;50 40;200 40; 50 250; 350 40;350 260;350 170];



After a lot of testing, we found out that with a really high value of N and with a considerable value of W , the more concerned areas of a node not having internet connection, are the corners especially the right hand side which is an area where not so many nodes are (or are alone).

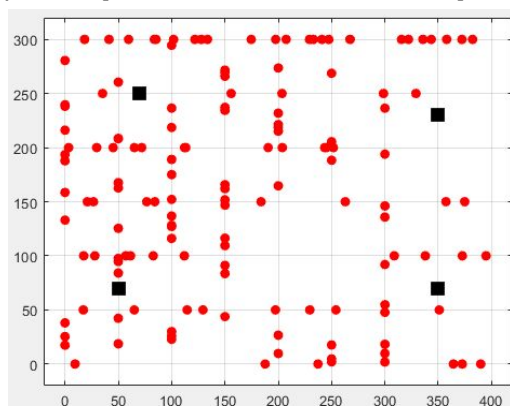
With this setting, this is the result:

$N= 150$ $W= 60$ $AvAv= 9.998e-01$ $90conf= 1.00e+00+-3.44e-05$ **MinAv= 9.913e-01** $90conf= 9.91e-01+-1.95e-03$

W=80

For the value $W=80$, we considered the same concerns with $W=60$ and paid special attention to the corners and to the left hand side part. The number of AP's necessary to obtain the minimum Internet access availability not lower than 99% is **4**, which coordinates are:

par.AP=[50 70;350 230;70 250;350 70];



With this setting, we managed to obtain a pretty good result with only 4 AP's:

$N= 150$ $W= 80$ $AvAv= 9.999e-01$ $90conf= 1.00e+00+-4.14e-05$ **MinAv= 9.911e-01** $90conf= 9.91e-01+-2.60e-03$