UNIVERSITÀ DI PISA

Performance Evaluation of Computer Systems and Networks project:
Epidemic broadcast

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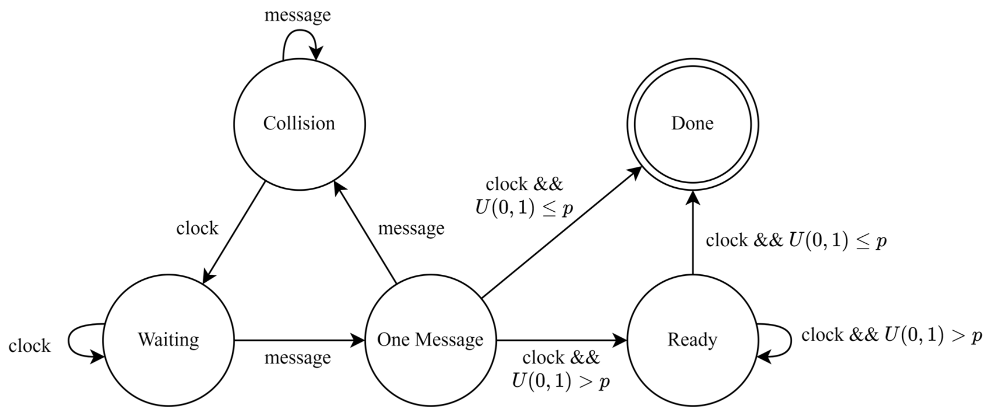
Introduction and users' behavior

We were tasked to model a system with the following characteristics:

- 2D floorplan where N users are randomly distributed
- Communication are slotted
- A random user broadcast an infection message to all its neighbors at the start
- User retransmit the message with a probability *p* at each time-slot
- User send the message to all other users within a defined radius *R*
- If a user has received correctly a message, it can retransmit from the next time-slot
- If a user receives more than one message in a time-slot, it goes into collision and cannot retransmit
- Users who have transmitted, conclude their operations

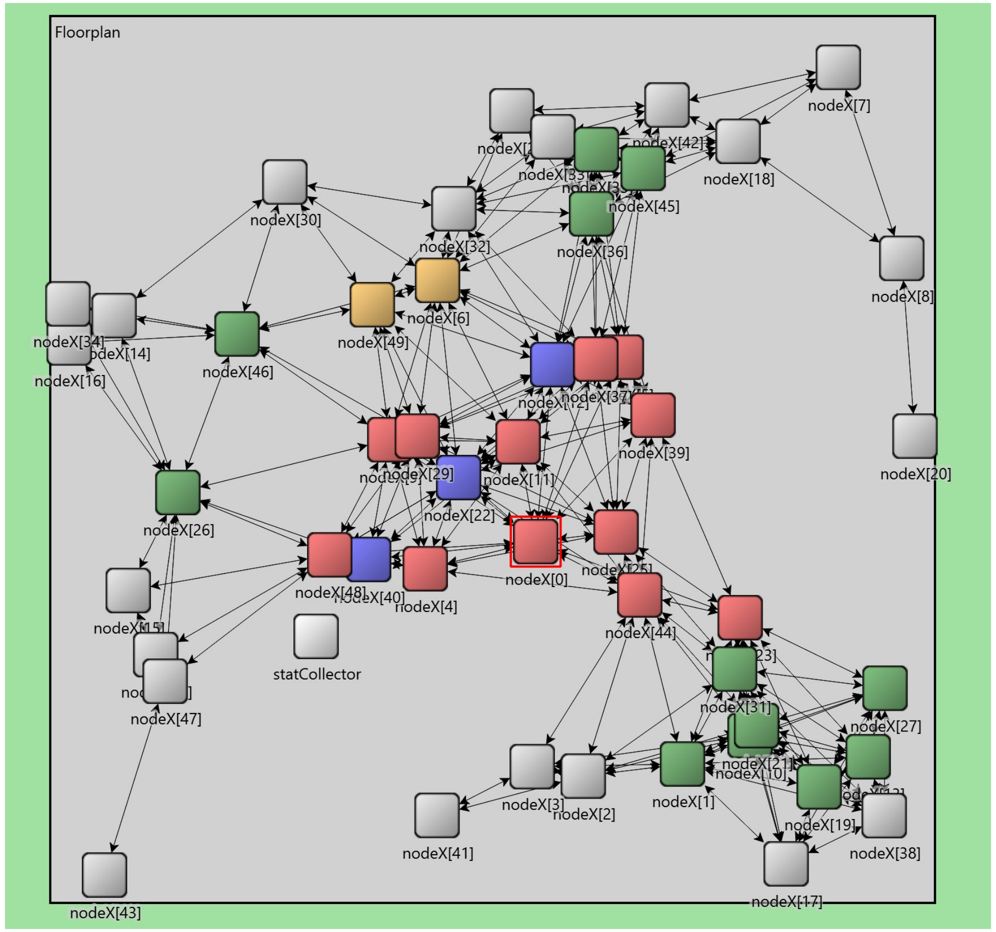
Users can be found in one of five statuses at each time-slot:

- Waiting: waits for a new message
- One message: has received a new message, but cannot transmit it yet because of impending collision
- Collision: has received a collision, cannot transmit
- Ready: Node is ready to transmit, but has failed the sending check
- Done: the node has sent the infection message and it now deactivates



Parameters and performance indexes

On a 100 x 100 floorplan with
uniformly distributed nodes



Parameter	#
Node	50,100,200,500,700
Radius	10,30,50,75,100
Probability	0.15,0.3,0.5,0.7,0.85,1

Priority	Performance index
1	Final coverage
2	Completion time
3	Avarage collisions

Each combination of parameters has
been simulated with 33 repetitions

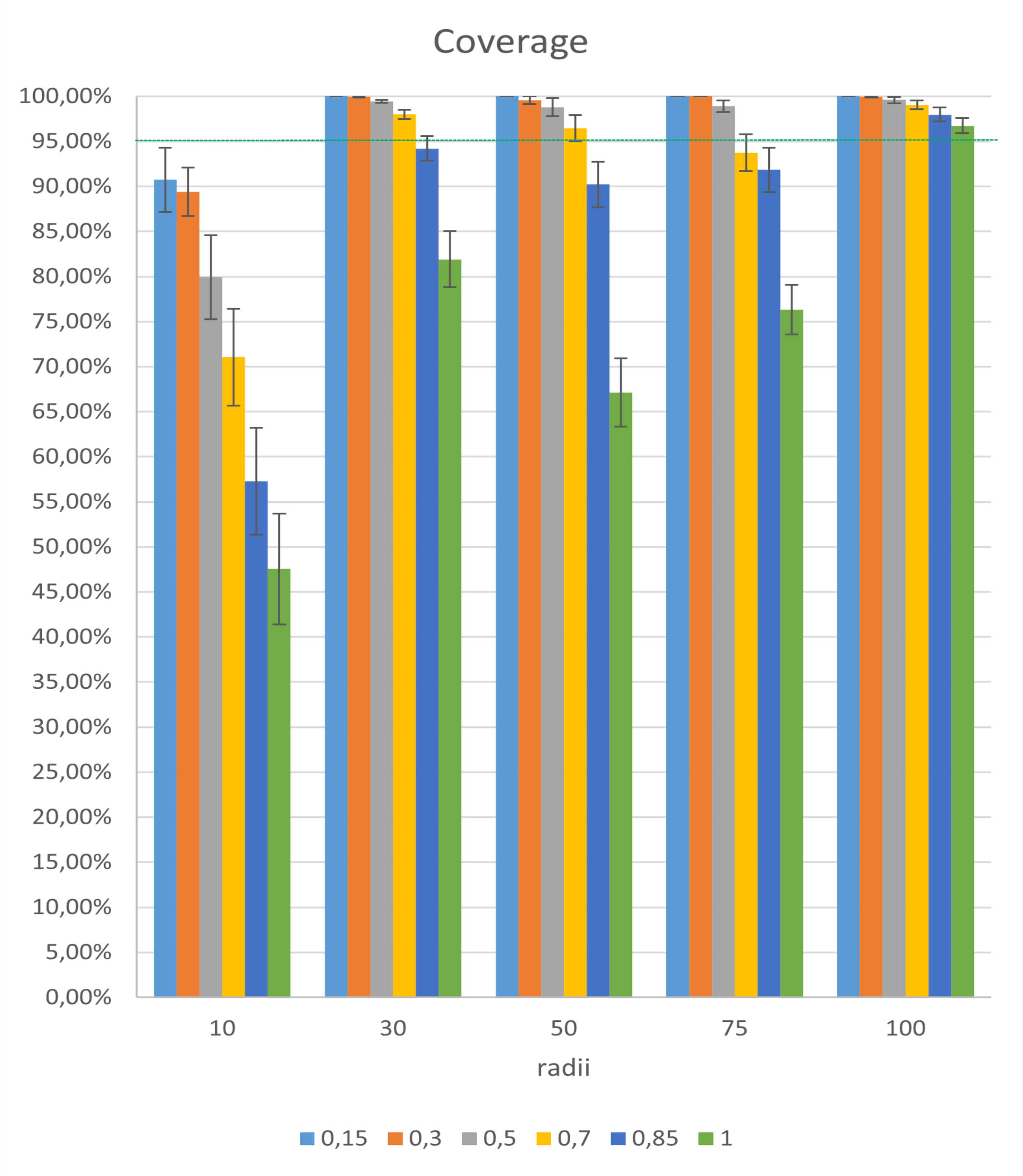
Case study: 200 Nodes

	r=10	r=30	r=50	r=75	r=100
p=0.15	0,9073	1	1	1	1
p=0.3	0,8938	0,9992	0,9956	1	0,9992
p=0.5	0,7991	0,9942	0,9880	0,9889	0,9959
p=0.7	0,7105	0,9798	0,9645	0,9373	0,9903
p=0.85	0,5730	0,9421	0,9021	0,9183	0,9797
p=1	0,4755	0,8191	0,6712	0,7630	0,9673

Mean coverage percentage

The graph shows the 90% CI for the mean coverage percentage

The green line is used as a threshold for «succesfull» runs

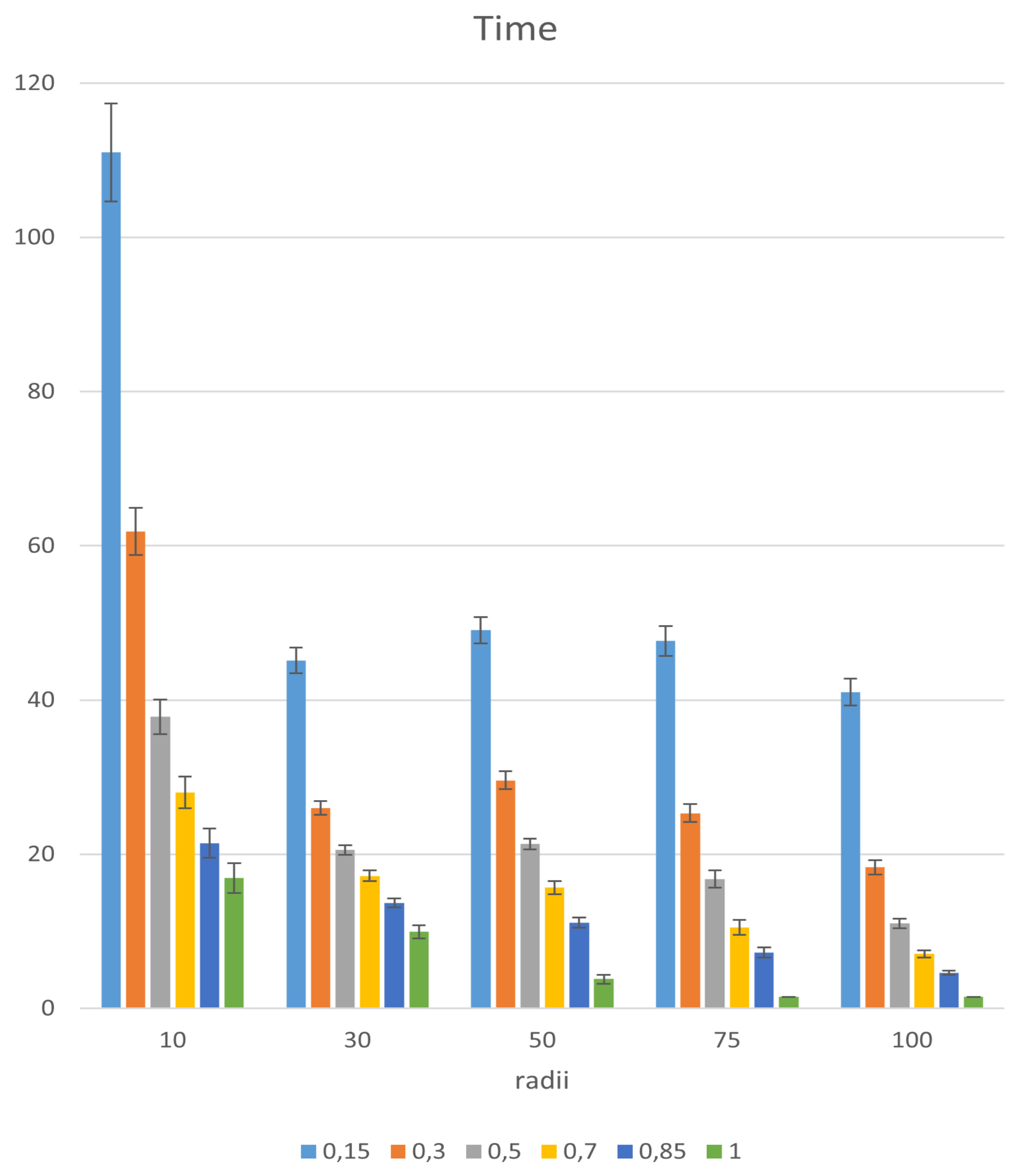


Case study: 200 Nodes

	r=10	r=30	r=50	r=75	r=100
p=0.15	111,0152	45,1364	49,0455	47,6515	41,0152
p=0.3	61,8636	26,0152	29,5909	25,3182	18,2879
p=0.5	37,8333	20,5606	21,3182	16,7727	11,0455
p=0.7	28,0152	17,1970	15,6515	10,5303	7,0758
p=0.85	21,4091	13,6818	11,1061	7,2576	4,6515
p=1	16,8939	9,9242	3,8030	1,5	1,5

Mean coverage time

The graph shows the 90% CI for the mean coverage time



Coverage time **decreases** as the probability **increases**

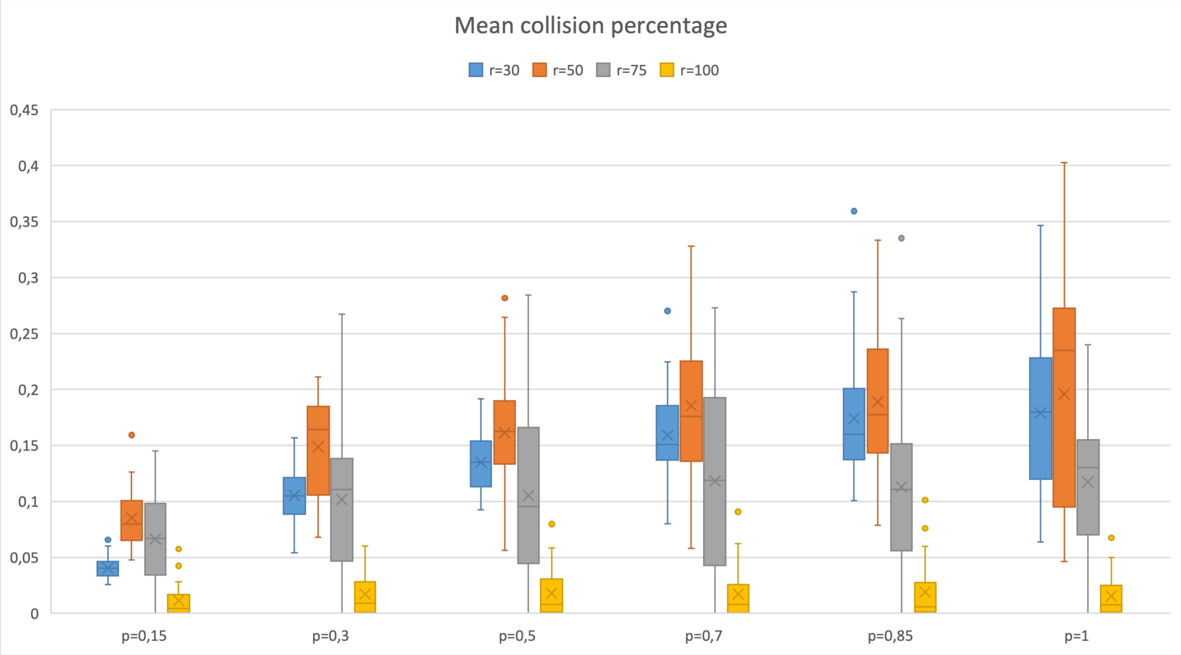
- higher probability translates into more nodes that can send the infection message

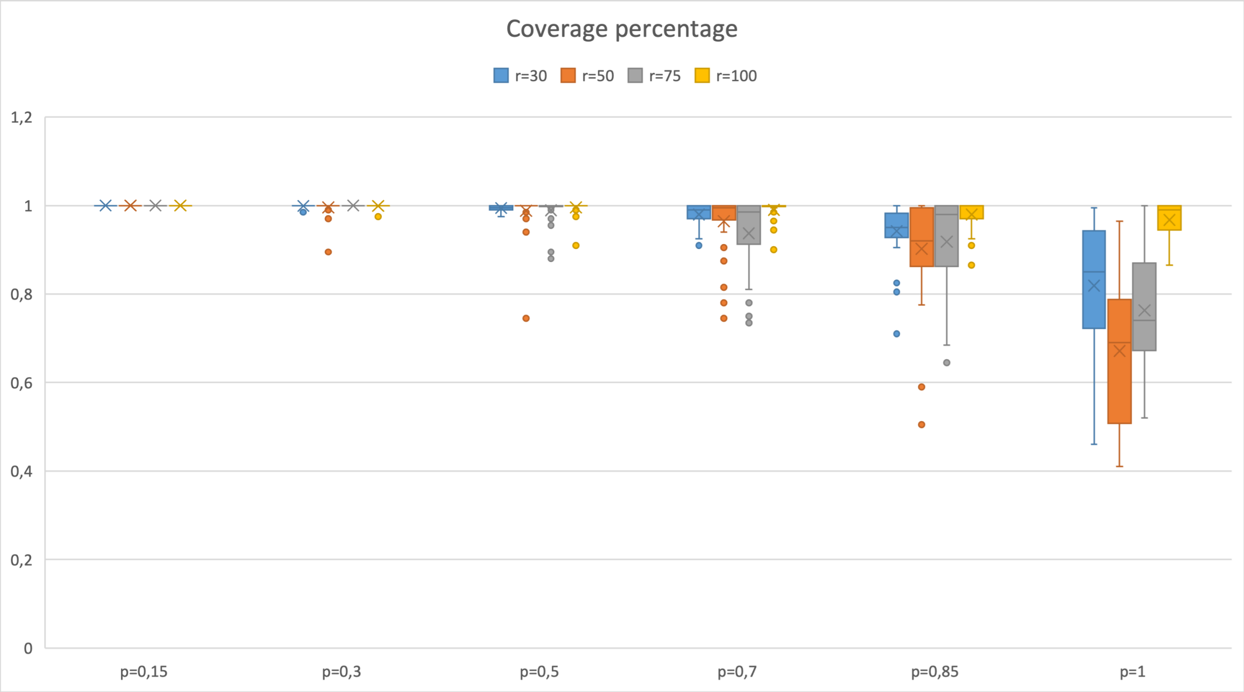
Collision index increases with probability

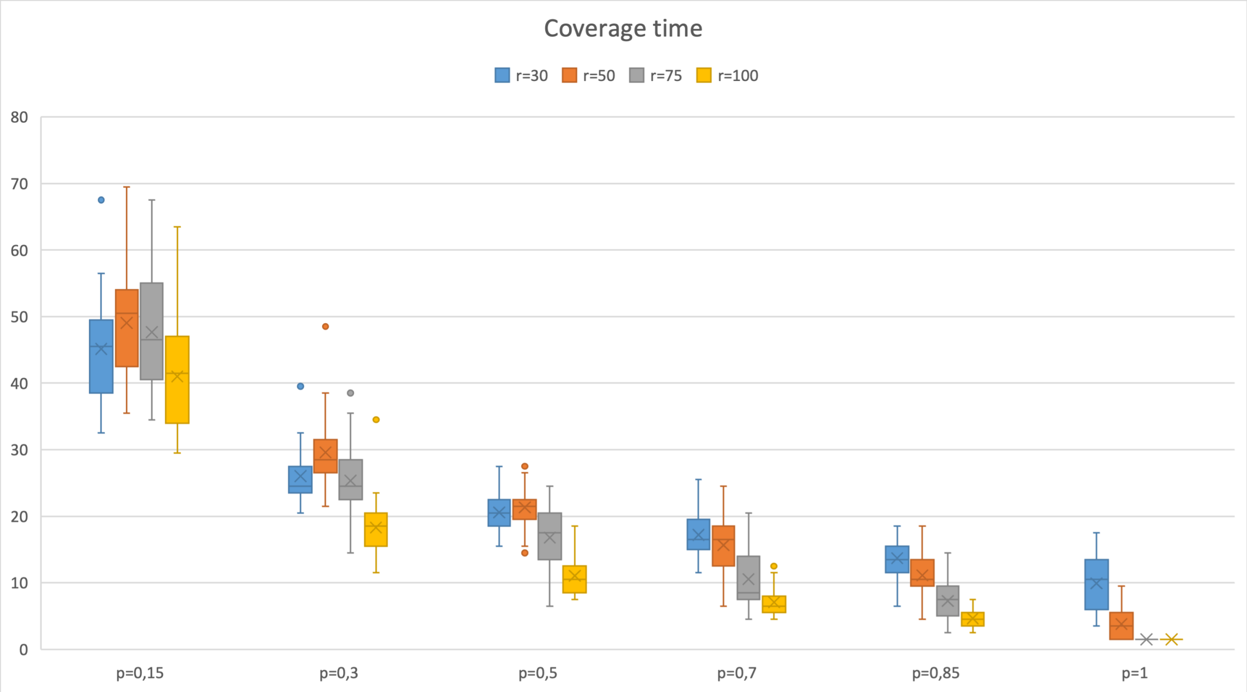
- more nodes can transmit the message in the same time-slot
- case 75-100 radii: the possibility of having many nodes reached by the infection message in the first instant is high

Increasing the probability **does not give better coverage** in most cases, as one would expect.

- as the probability increases, collisions also tend to increase accordingly







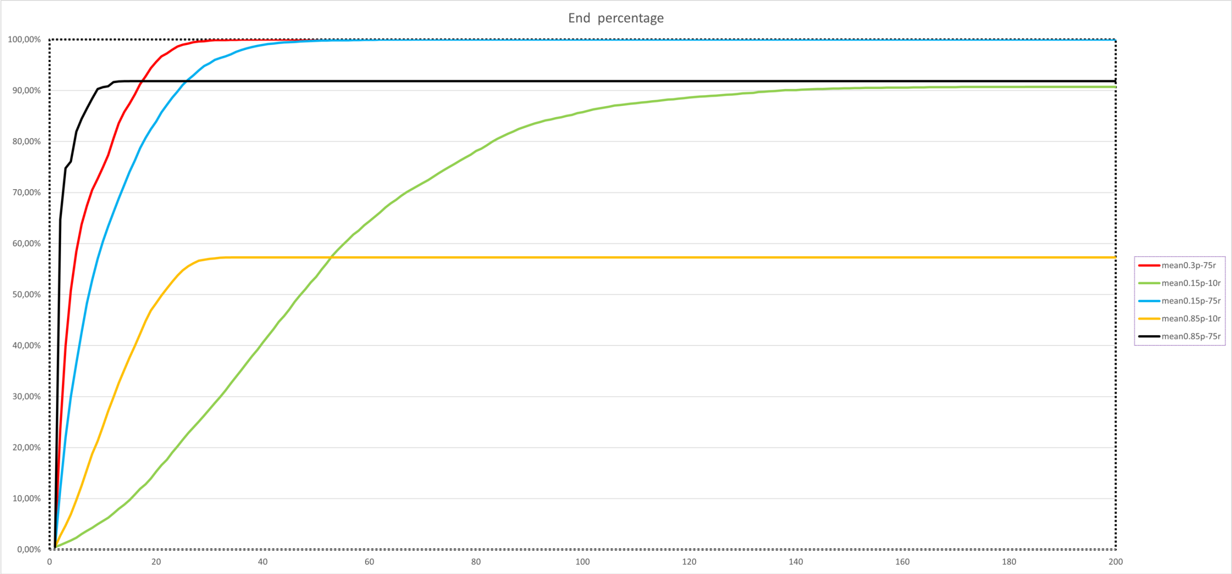
Time evolution

The graph on the right show the evolution of the coverage/end percentage for runs with different configurations.

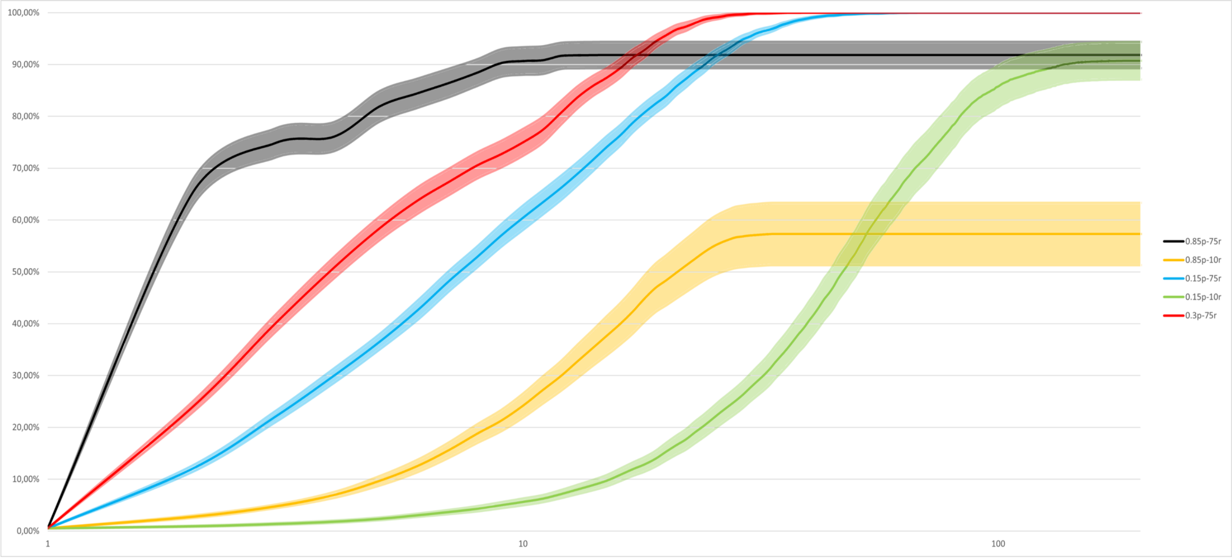
A factorial analysis was performed for the coverage percentage and coverage time to find the influence of the system parameters

Parameter	Probability	Radius	Combined
Coverage percentage	0,4036	0,4476	0,1488
Coverage time	0,6672	0,2372	0,0956

$$C.P. = 0{,}85 - 0{,}10*P + 0{,}11*R + 0{,}06*PR$$
$$C.T = 46{,}84 - 32{,}50*P - 19{,}38*R + 12{,}30*PR$$



Coverage percentage mean



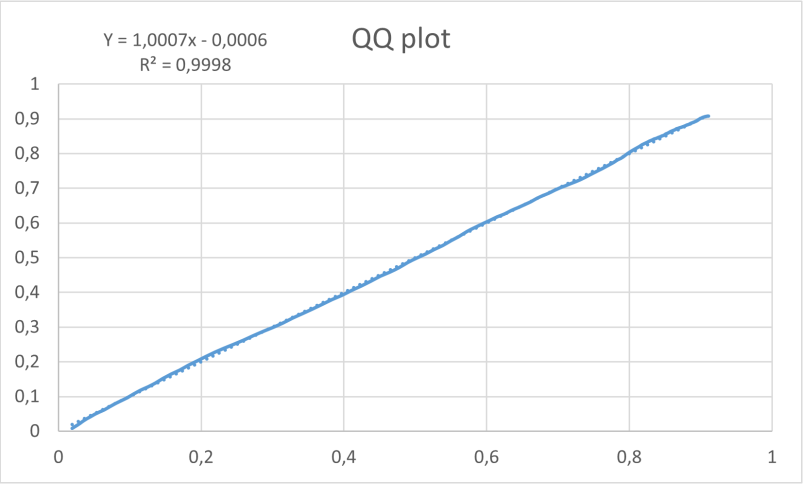
Coverage percentage (log scale) with 90% CIs shown

Model fitting

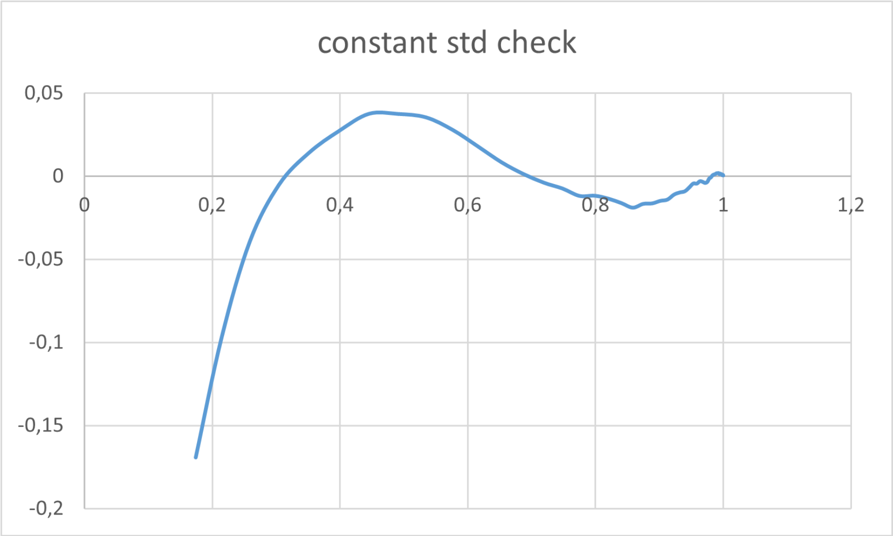
The Gompertz model results to be the most fitting one to describe the evolution of the system.

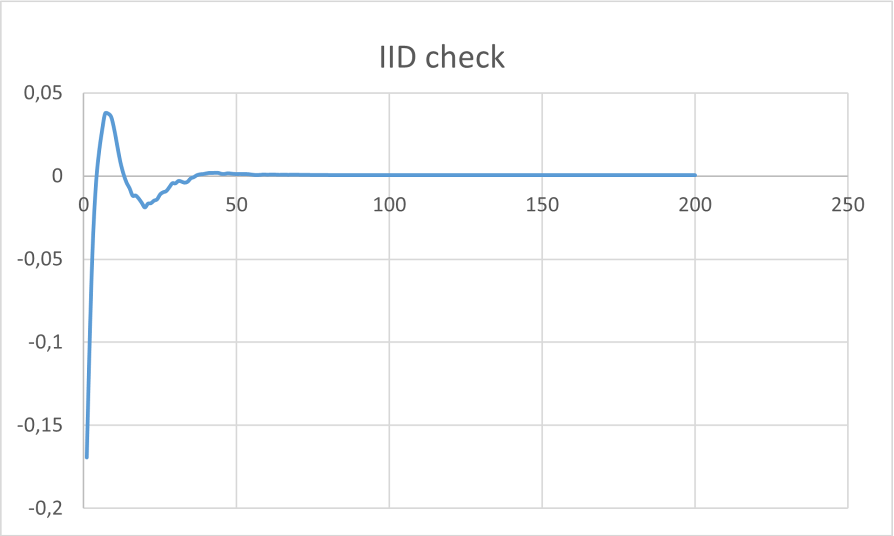
$$Y = ae^{-be^{-ct}}$$

Others were tested with a residual analysis and QQ plots.



QQ plot for the Gompertz model on runs with configuration p = 0.15 r = 10





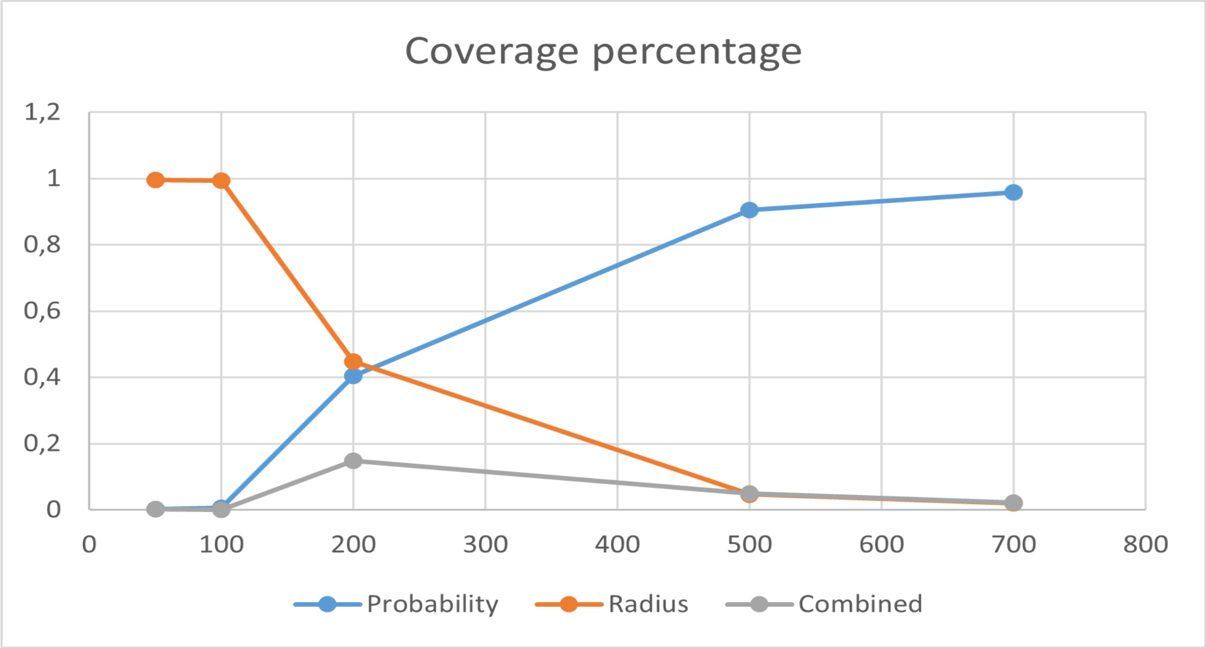
Unfortunately, the model do not pass the check for the assumption for the least squared minimization

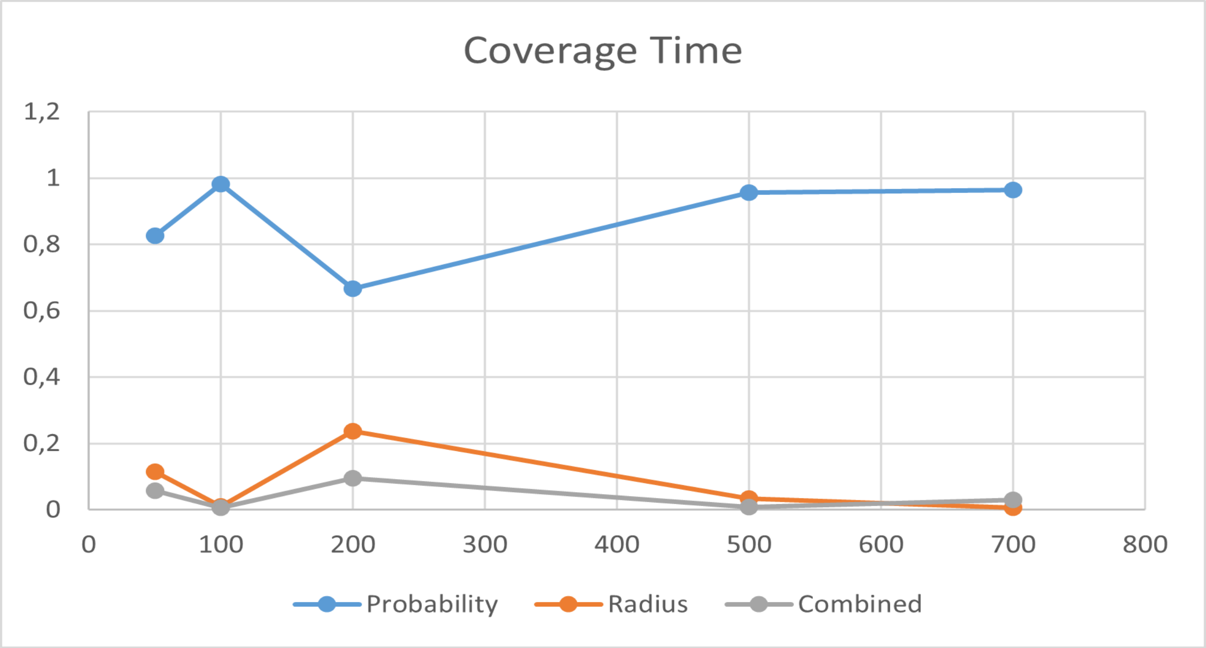
Varying nodes number

		Coverage percentage						Coverage time					
		Probability						Probabiliy					
r	n	0,15	0,3	0,5	0,7	0,85	1	0,15	0,3	0,5	0,7	0,85	1
10	50	0,024482	0,024482	0,024482	0,025843	0,025665	0,025665	17,16667	6,984848	4,560606	3,469697	2,80303	2,651515
10	100	0,02159	0,024533	0,017109	0,016526	0,018371	0,02299	41,37879	18,92424	11,71212	8,318182	6,590909	5,166667
10	200	0,747209	0,7723	0,588076	0,468021	0,304903	0,197414	111,0152	61,86364	37,83333	28,01515	21,40909	16,89394
10	500	0,998189	0,994068	0,978308	0,945551	0,906997	0,83855	65,62121	38,89394	28,43939	24,92424	21,89394	21,07576
10	700	0,999567	0,996217	0,98109	0,963497	0,93384	0,874377	62,01515	37,80303	27,95455	24,4697	21,92424	21,04545
30	50	0,86282	0,977003	0,92532	0,89483	0,74599	0,500591	33,71212	18,77273	13,98485	10,65152	9,621212	6,469697
30	100	1	0,98707	0,940233	0,912344	0,854607	0,574112	35,37879	23,25758	16,34848	13,80303	11,28788	7,833333
30	200	1	0,996414	0,987382	0,955466	0,881255	0,677805	45,13636	26,01515	20,56061	17,19697	13,68182	9,924242
30	500	1	0,999182	0,989961	0,956269	0,913185	0,695982	58,34848	40,22727	30,59091	24,22727	19,65152	13,13636
30	700	1	0,997563	0,990985	0,964937	0,935377	0,732669	64,95455	44,98485	34,65152	27,92424	21,92424	16,89394
50	50	1	0,985655	0,917359	0,875088	0,814974	0,499584	30,5303	16,62121	12,28788	9,136364	7,378788	3,439394
50	100	1	0,997956	0,950017	0,888699	0,7652	0,454022	35,56061	24,25758	16,4697	12,59091	8,560606	3,590909
50	200	1	0,976742	0,942634	0,898068	0,788035	0,500295	49,04545	29,59091	21,31818	15,65152	11,10606	3,80303
50	500	1	0,995504	0,985126	0,913678	0,749905	0,463861	67,71212	45,5303	30,5303	21,04545	13,89394	4,863636
50	700	1	1	0,957128	0,814391	0,824465	0,453678	77,07576	48,59091	33,37879	19,98485	15,5	5,19697
75	50	1	0,991825	0,94982	0,817595	0,823015	0,632061	29,65152	16,01515	10,83333	6,348485	4,893939	1,5
75	100	1	1	0,921545	0,896459	0,819265	0,649472	35,25758	22,40909	13,40909	9,106061	5,984848	1,5
75	200	1	1	0,96036	0,844924	0,806358	0,638544	47,65152	25,31818	16,77273	10,5303	7,257576	1,5
75	500	1	0,972766	0,915629	0,863574	0,760205	0,637793	61,28788	35,34848	22,56061	13,28788	8,045455	1,5
75	700	1	0,982774	0,91658	0,909074	0,828044	0,642411	66,68182	38,01515	23,37879	14,25758	9,621212	1,5
100	50	1	1	0,979562	0,95875	0,942408	0,926149	28,5	13,25758	8,227273	5,015152	3,378788	1,5
100	100	1	0,979562	0,984599	0,96916	0,954525	0,937334	31,62121	17,68182	9,893939	5,893939	4,378788	1,5
100	200	1	0,99489	0,979734	0,967563	0,944922	0,928947	41,01515	18,28788	11,04545	7,075758	4,651515	1,5
100	500	1	0,999591	0,979969	0,964415	0,957983	0,929607	48,04545	24,71212	13,28788	8,106061	5,772727	1,5
100	700	0,999124	0,99854	0,9784	0,967052	0,956693	0,931083	49,43939	24,71212	13,43939	9,227273	5,378788	1,5

Overview of all variable parameters and how they influence our performance indexes

Influences at different number of nodes





Nodes	Probability	Radius	Combined
50	0,0021	0,9961	*0,0018*
100	0,0054	0,9939	*0,0007*
200	0,4036	0,4476	0,1488
500	0,9048	0,0464	*0,0488*
700	0,9580	0,0208	*0,0212*

Nodes	Probability	Radius	Combined
50	0,8269	0,1148	0,0584
100	0,9819	0,0108	0,0073
200	0,6672	0,2372	0,0956
500	0,9571	0,0336	0,0092
700	0,9646	0,0060	0,0294

Conclusion

- High connectivity results in very fast and reliable transmission across the whole graph
  Large radii are always preferable and allow for higher sending probabilities if a lesser coverage percentage is acceptable
- Real world systems:
  - Radius is often limited for physical reasons (power, distances...)
  - Much lower probabilities are needed for a complete coverage
  - We've shown tradeoff with system speed of completion
- Possible future analysis
  - Different distribution of nodes in the floorplan
  - More precise parameters for specific use cases