CS3205 A3 Report

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April 2022

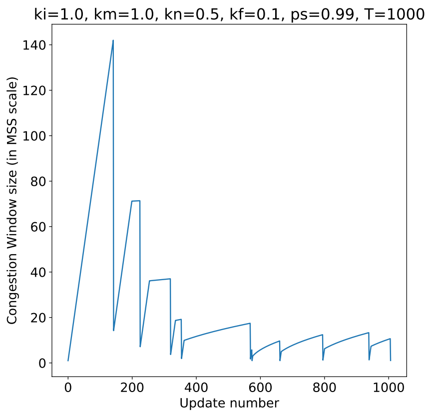
1 Task

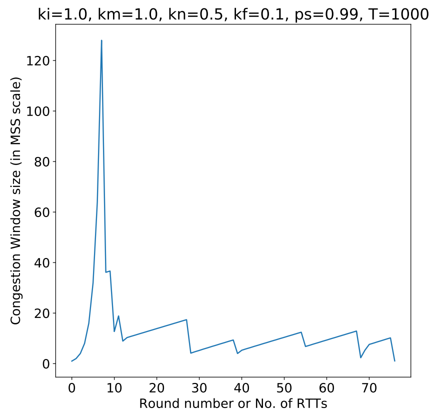
- Simulate TCP congestion control algorithm for given choices of parameters k_i, k_m, k_n, k_f, p_s.
- Plot the congestion window size after each update and after each round/RTT.
- Compare results and graphs obtained for the following parameter combinations $k_i = 1, 4, k_m = 1, 1.5, k_n = 0.5, 1, k_f = 0.1, 0.3, p_s = 0.99, 0.9999$.

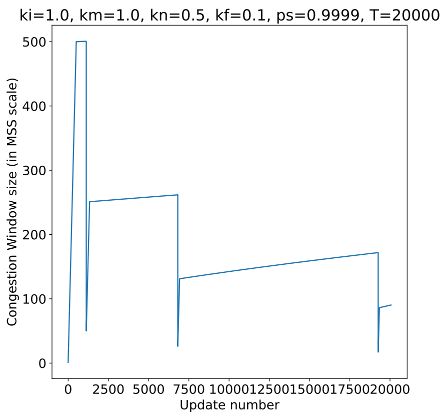
2 Approach

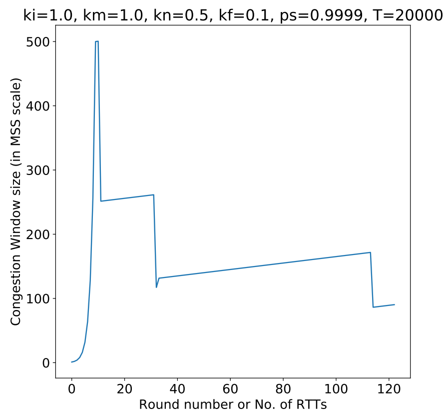
We will first explain the algorithm using a few plots and then show the plots for all 32 different configurations after which we will look at the effect that each parameter has on the plot obtained.

3 Algorithm









The parameters chosen have been shown in the title for each plot. The left plots show how the congestion window (CW) changes after each update. Note that the number of updates is equal to the number of segments sent which is 1000 when $ps = 0.99$ and 20000 when $ps = 0.9999$. The number of segments has been chosen differently for the different values of ps so that the plots look clearer.

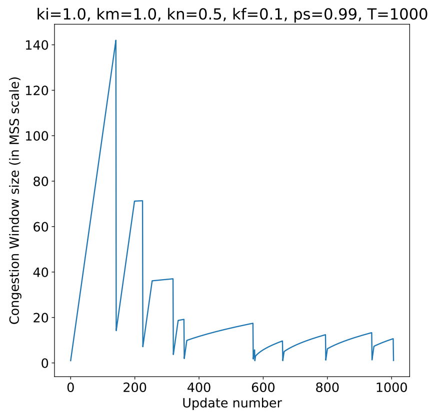
Updates rules:
Initially $CW = k_i * MSS$
When $CW < threshold$ i.e exponential region: $CW = min(CW + k_m * MSS, RWS)$
When $CW > threshold$ i.e linear region: $CW = min(CW + k_n * MSS * MSS/CW, RWS)$
When timeout: $CW = max(1, k_f * CW)$

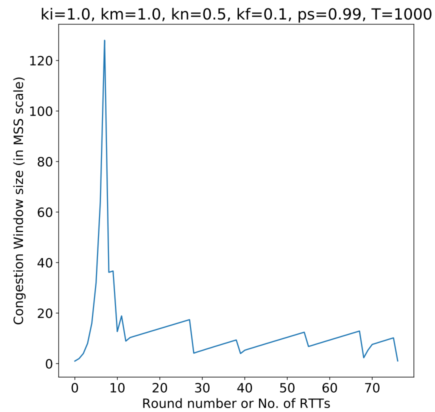
Explaination of plots
The left plots i.e CW vs updates plot consists of steep linear regions(when

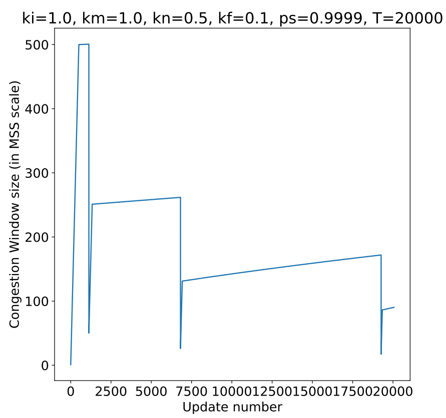
$CW < threshold$) and almost constant regions (when $CW > threshold$) as expected from the update rules for CW.
The right plots show CW after every round i.e after every RTT time units. This plot will contain both exponential (when $CW > threshold$) and linear regions (when $CW < threshold$) and follows the additive increase multiplicative decrease mechanism i.e AIMD mechanism.

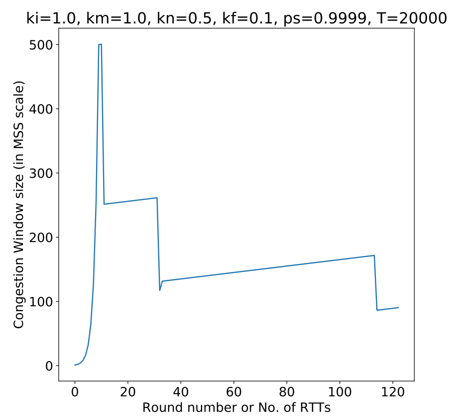
As we can see in the top left plot, timeout occurs when CW=140 MSS due to which the CW drops to $CW * k_f = 140 * 0.1 = 14$ and the threshold becomes half of 140 i.e 70. Then CW increases steeply till it reaches the threshold i.e 70 after which it increases slowly or almost remains constant since $CW > threshold$. When timeout occurs the next time, CW again drops to $CW * k_f = 70 * 0.1 = 7$ approx and so on.The right plot shows how CW changes after each RTT. Here we can see that CW initially increases exponentially, reaches 140 at which point a timeout occurs, falls to 14 and by the end of the next RTT, it gets updated to something around 40. Since we are plotting CW only after RTT units, not all updates to CW can be seen in this plot since every RTT will have number of updates proportional to the CW size and we can only see the value of CW after all these updates have occured.

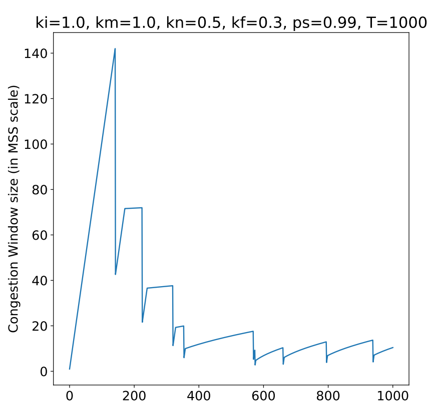
4 Plots for all 32 configurations

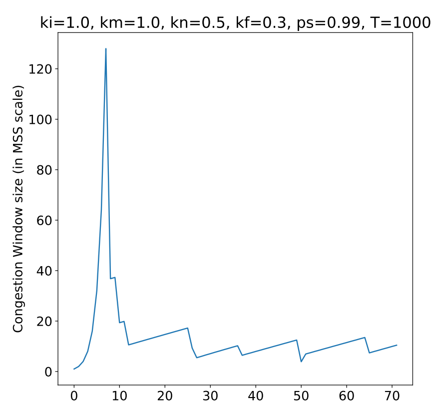


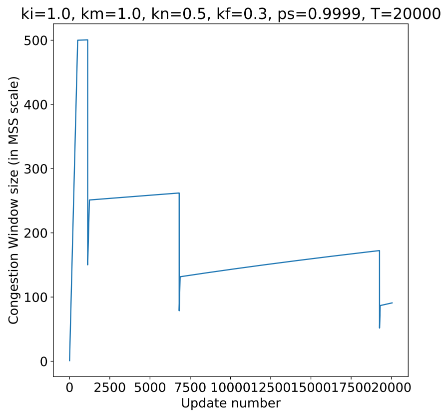








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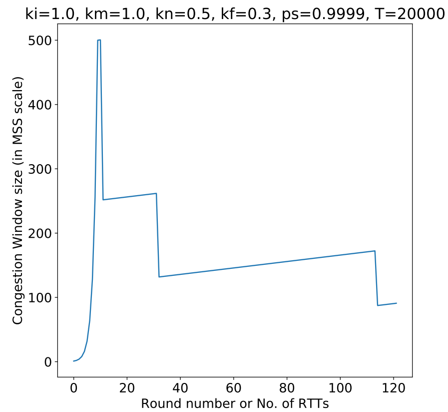
Congestion Window size (in MSS scale)
Update number
0
100
200
300
400
500
0 2500 5000 7500 100001250015000175002000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Round number or No. of RTTs
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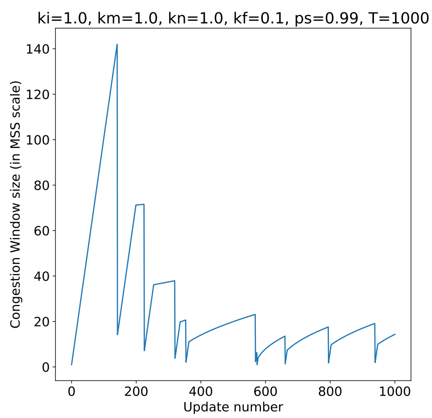
100
200
300
400
500
0 20 40 60 80 100 120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Congestion Window size (in MSS scale)
Update number
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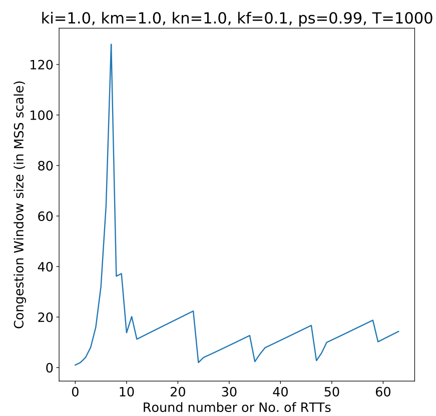
40
60
80
100
120
140
0 200 400 600 800 1000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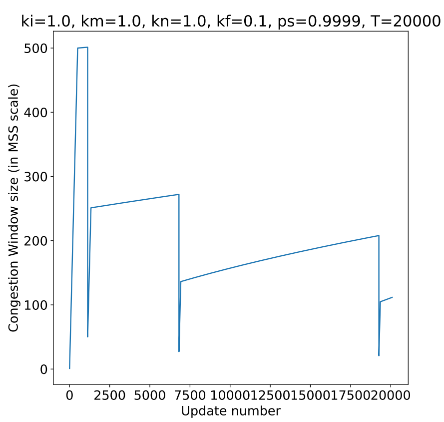
Congestion Window size (in MSS scale)
Round number or No. of RTTs
0
20
40
60
80
100
120
0 10 20 30 40 50 60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Congestion Window size (in MSS scale)
Update number
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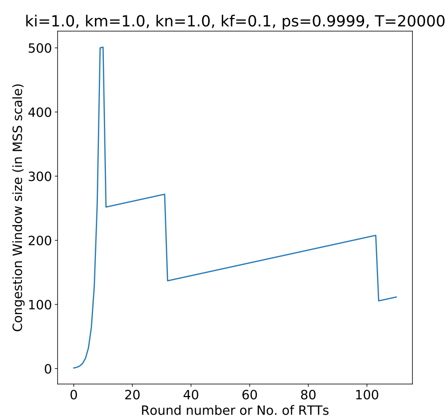
300
400
500
0 2500 5000 7500 100001250015000175002000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Congestion Window size (in MSS scale)
Round number or No. of RTTs
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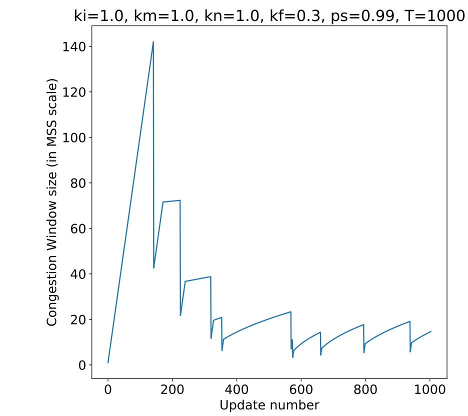
100
200
300
400
500
0 20 40 60 80 100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Congestion Window size (in MSS scale)
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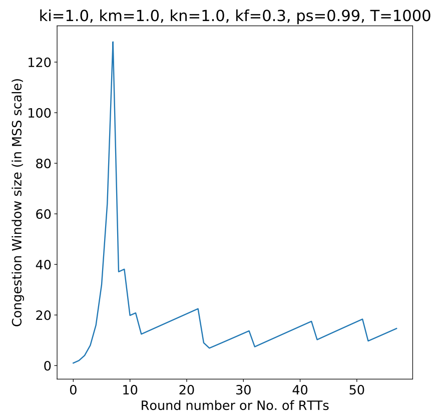
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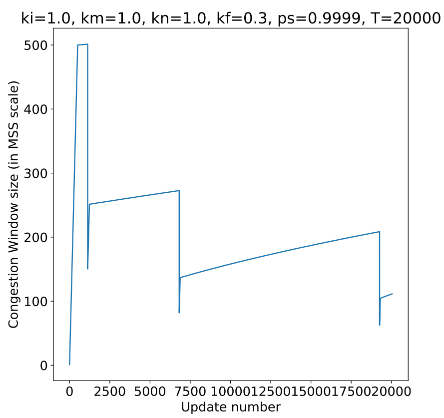
Congestion Window size (in MSS scale)
Round number or No. of RTTs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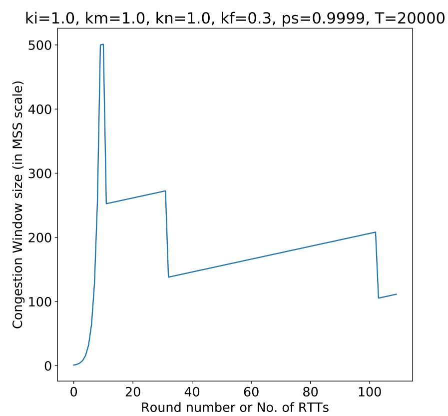
Congestion Window size (in MSS scale)
Update number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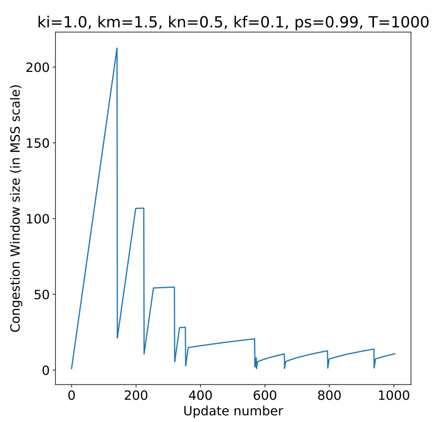
Congestion Window size (in MSS scale)
Round number or No. of RTTs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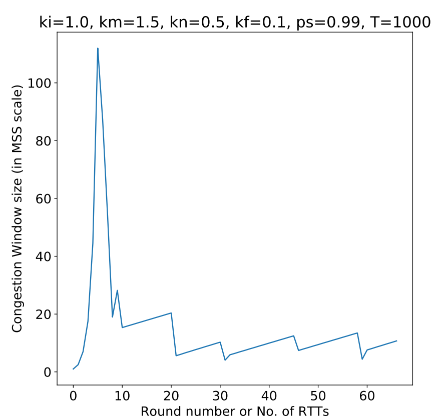
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Congestion Window size (in MSS scale)
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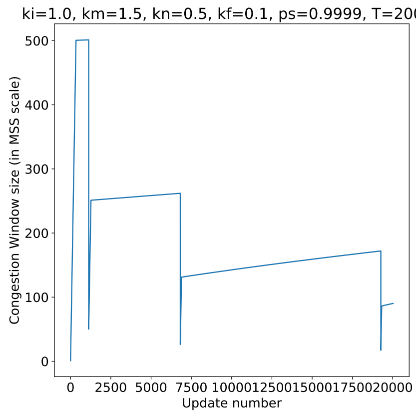
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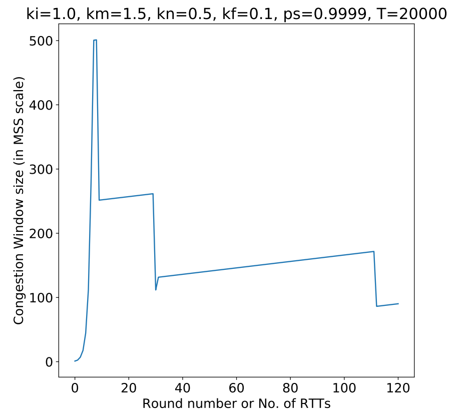
Congestion Window size (in MSS scale)
Update number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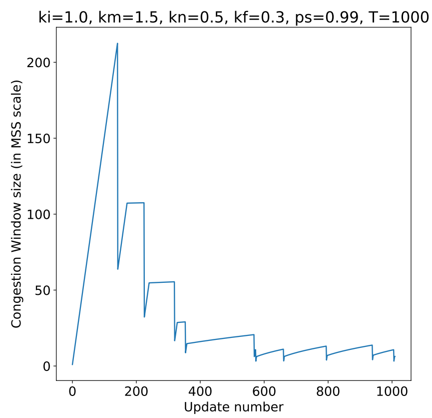
Congestion Window size (in MSS scale)
Round number or No. of RTTs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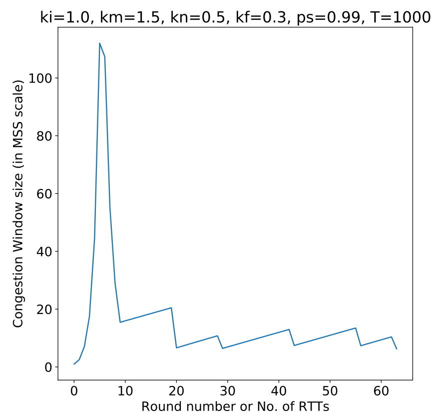
Congestion Window size (in MSS scale)
Update number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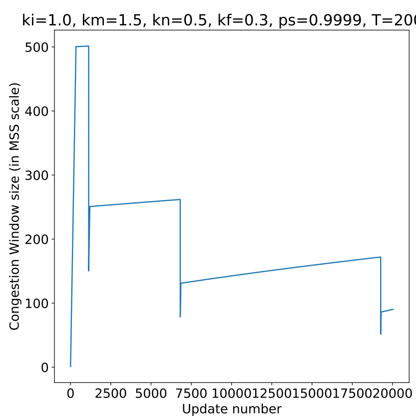
Congestion Window size (in MSS scale)
Round number or No. of RTTs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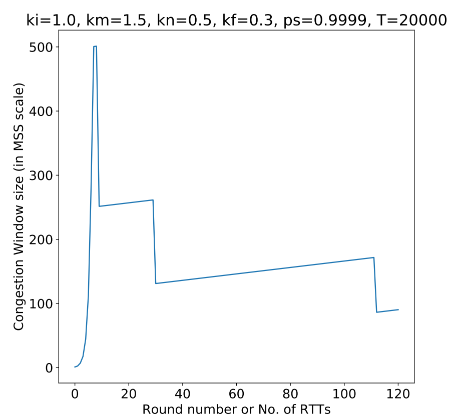
Congestion Window size (in MSS scale)
Update number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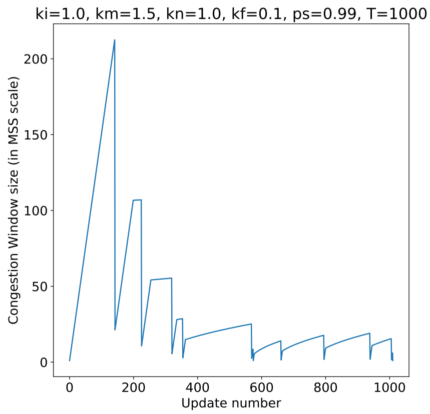
Congestion Window size (in MSS scale)
Round number or No. of RTTs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Congestion Window size (in MSS scale)
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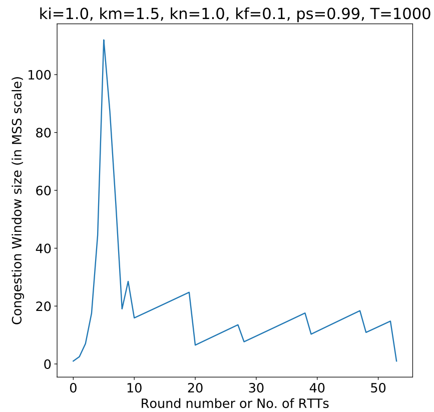
100
150
200
0
200
400
600
800
1000
Update number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Congestion Window size (in MSS scale)
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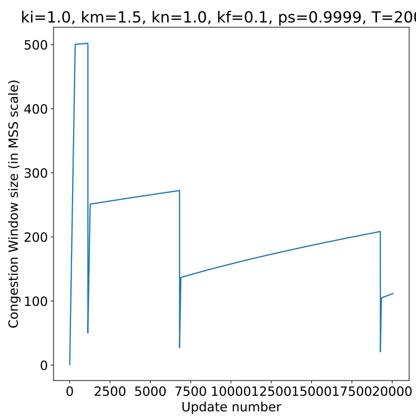
100
0
10
20
30
40
50
Round number or No. of RTTs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Congestion Window size (in MSS scale)
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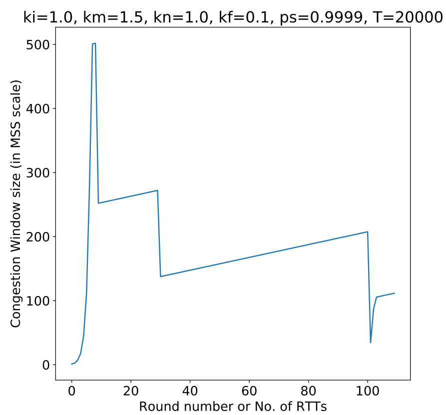
Update number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Congestion Window size (in MSS scale)
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100
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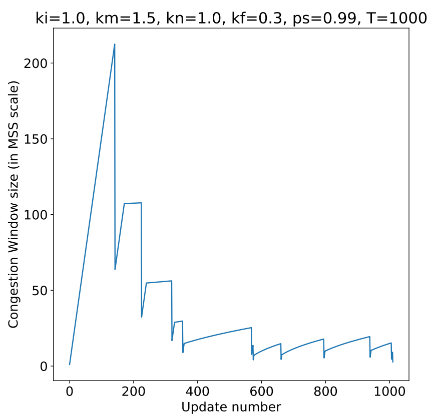
20
40
60
80
100
Round number or No. of RTTs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Congestion Window size (in MSS scale)
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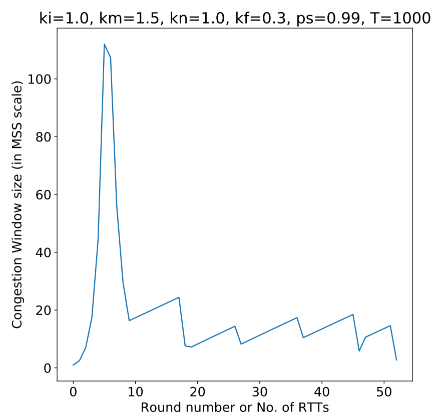
400
600
800
1000
Update number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Congestion Window size (in MSS scale)
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60
80
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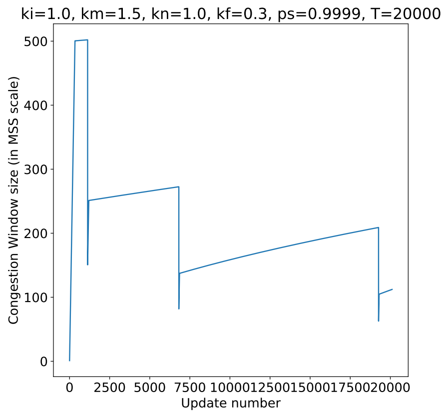
10
20
30
40
50
Round number or No. of RTTs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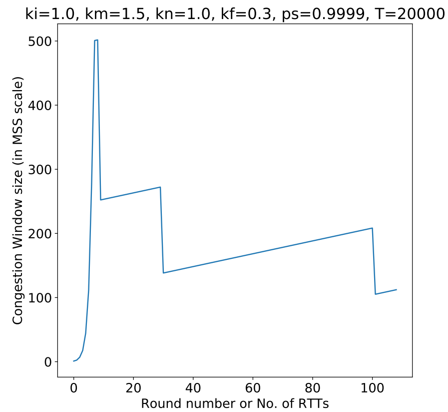
Congestion Window size (in MSS scale)
Update number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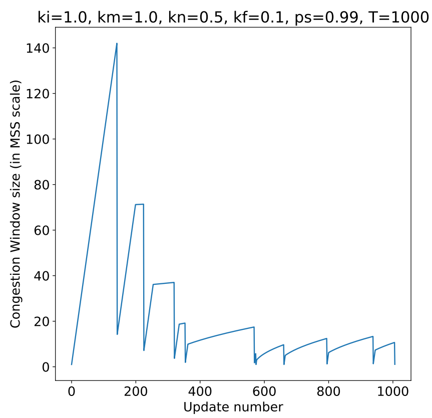
Congestion Window size (in MSS scale)
Round number or No. of RTTs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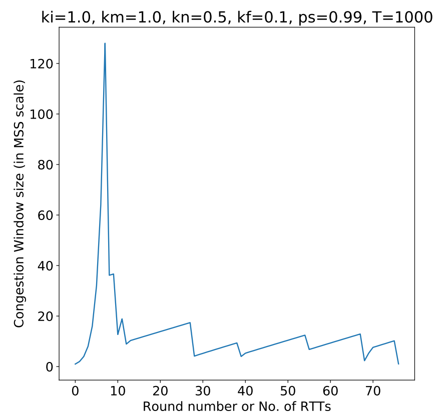
Congestion Window size (in MSS scale)
Update number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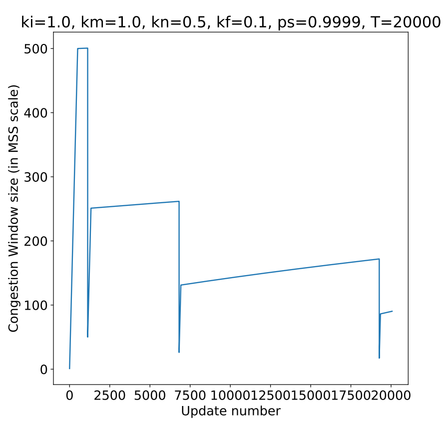
Congestion Window size (in MSS scale)
Round number or No. of RTTs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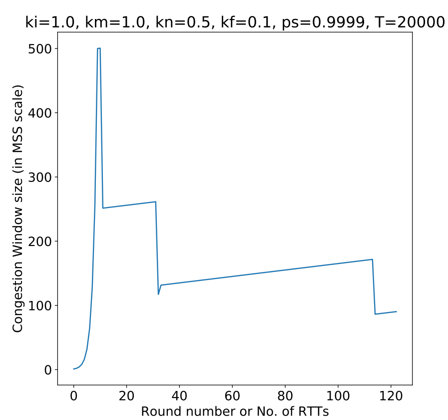
Congestion Window size (in MSS scale)
Update number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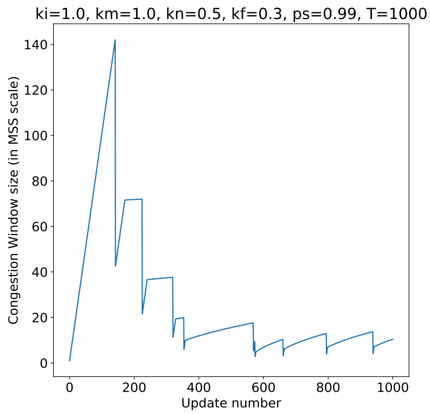
Congestion Window size (in MSS scale)
Round number or No. of RTTs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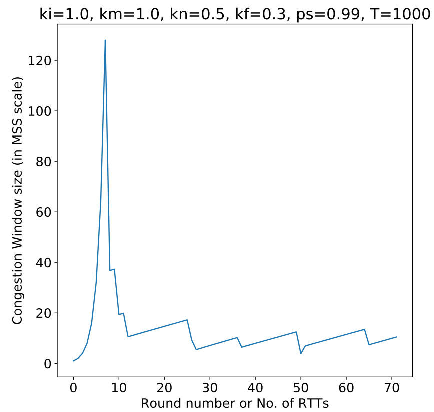
Congestion Window size (in MSS scale)
Update number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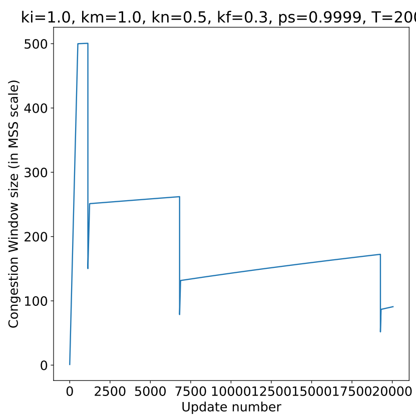
Congestion Window size (in MSS scale)
Round number or No. of RTTs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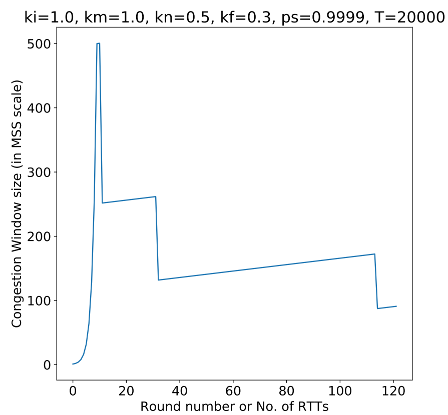
Congestion Window size (in MSS scale)
Update number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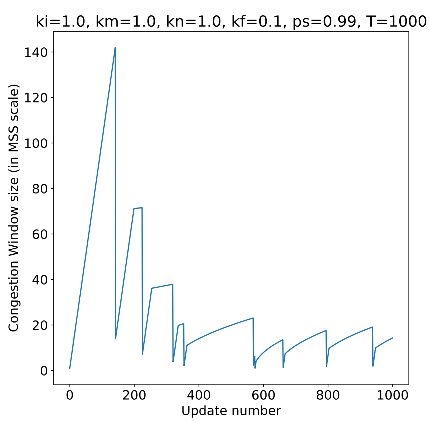
Congestion Window size (in MSS scale)
Round number or No. of RTTs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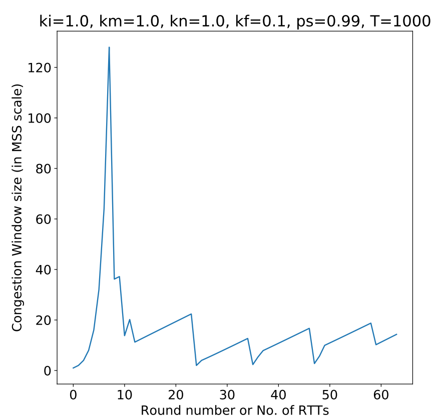
Congestion Window size (in MSS scale)
Update number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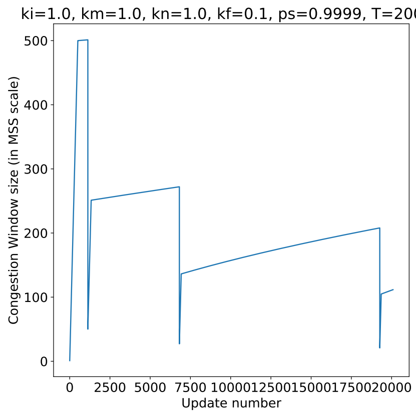
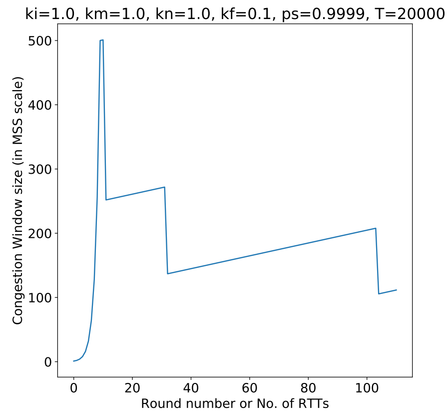
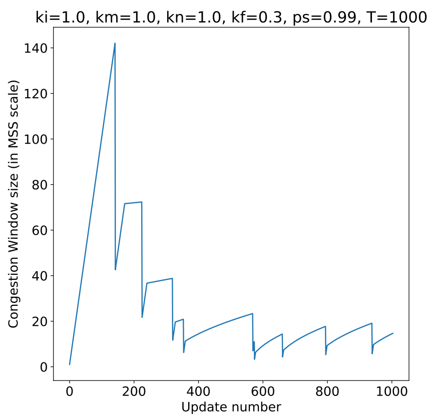
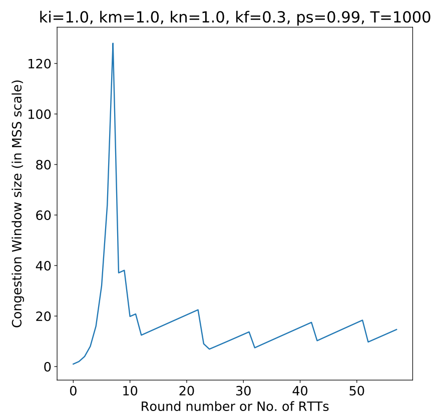
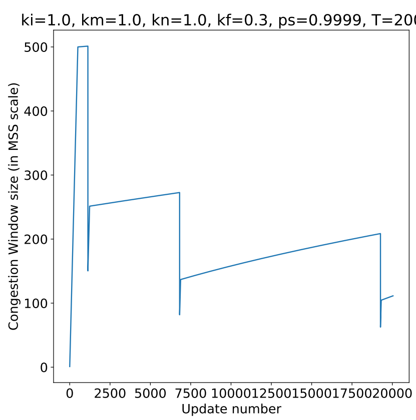
Congestion Window size (in MSS scale)
Round number or No. of RTTs

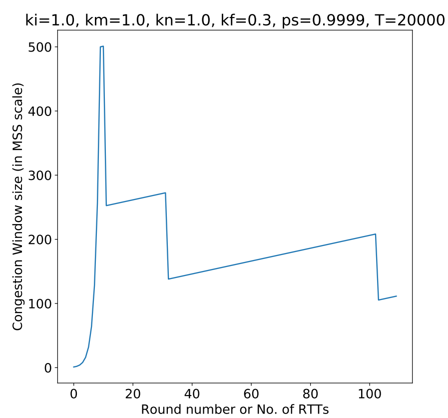

ki=1.0, km=1.0, kn=1.0, kf=0.1, ps=0.9999, T=20000
Congestion Window size (in MSS scale)
0
100
200
300
400
500
0 2500 5000 7500 10000125001500017500 20000
Update number

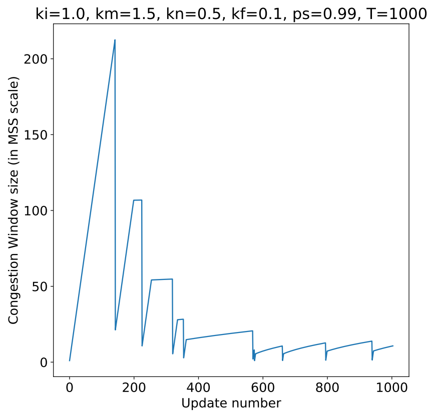

ki=1.0, km=1.0, kn=1.0, kf=0.1, ps=0.9999, T=20000
Congestion Window size (in MSS scale)
0
100
200
300
400
500
0 20 40 60 80 100
Round number or No. of RTTs

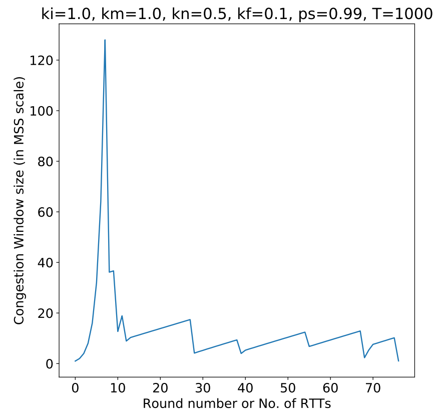

ki=1.0, km=1.0, kn=1.0, kf=0.3, ps=0.99, T=1000
Congestion Window size (in MSS scale)
0
20
40
60
80
100
120
140
0 200 400 600 800 1000
Update number

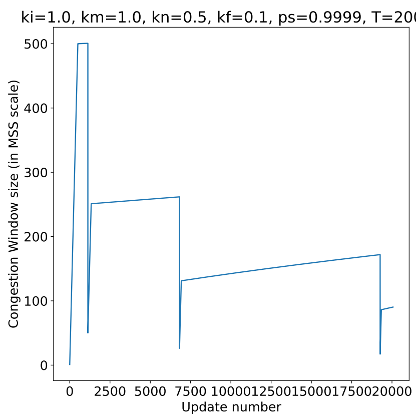

ki=1.0, km=1.0, kn=1.0, kf=0.3, ps=0.99, T=1000
Congestion Window size (in MSS scale)
0
20
40
60
80
100
120
0 10 20 30 40 50
Round number or No. of RTTs

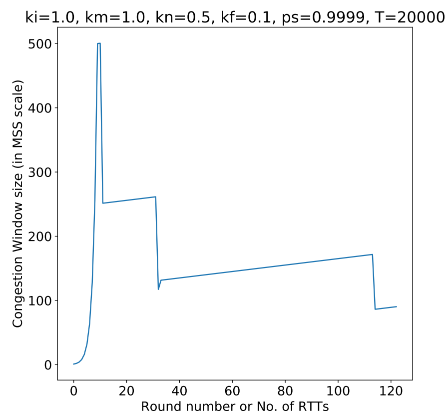

ki=1.0, km=1.0, kn=1.0, kf=0.3, ps=0.9999, T=20000
Congestion Window size (in MSS scale)
0
100
200
300
400
500
0 2500 5000 7500 10000125001500017500 20000
Update number

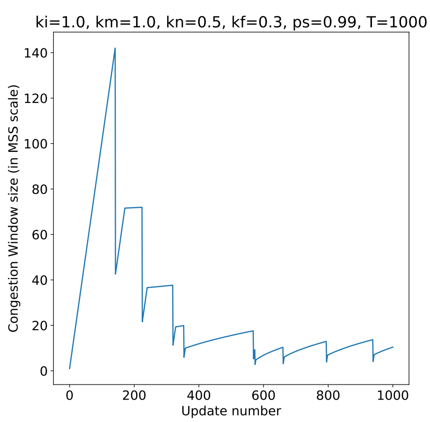

ki=1.0, km=1.0, kn=1.0, kf=0.3, ps=0.9999, T=20000
Congestion Window size (in MSS scale)
0
100
200
300
400
500
0 20 40 60 80 100
Round number or No. of RTTs

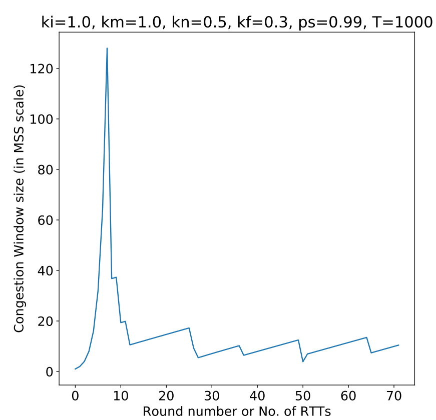

ki=1.0, km=1.5, kn=0.5, kf=0.1, ps=0.99, T=1000
Congestion Window size (in MSS scale)
0
50
100
150
200
0
200
400
600
800
1000
Update number

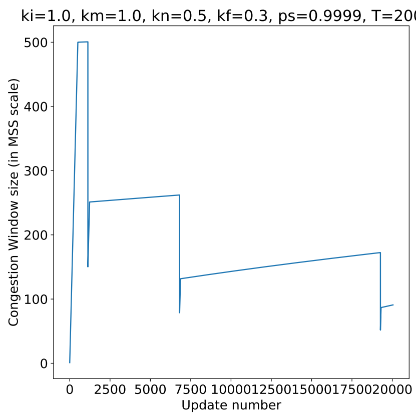

ki=1.0, km=1.0, kn=0.5, kf=0.1, ps=0.99, T=1000
Congestion Window size (in MSS scale)
0
20
40
60
80
100
120
0
10
20
30
40
50
60
70
Round number or No. of RTTs

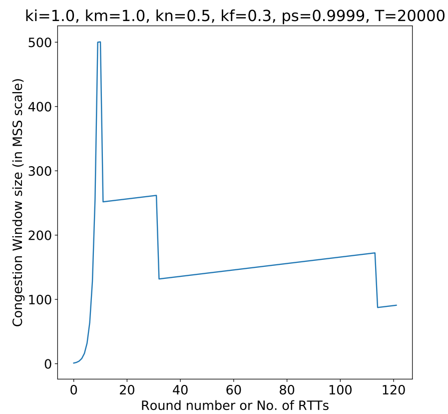

ki=1.0, km=1.0, kn=0.5, kf=0.1, ps=0.9999, T=20000
Congestion Window size (in MSS scale)
0
100
200
300
400
500
0
2500
5000
7500
10000125001500017500200000
Update number

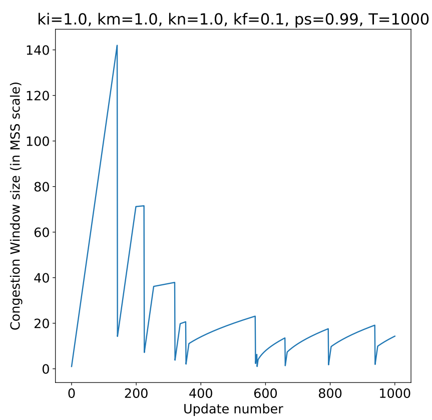

ki=1.0, km=1.0, kn=0.5, kf=0.1, ps=0.9999, T=20000
Congestion Window size (in MSS scale)
0
100
200
300
400
500
0
20
40
60
80
100
120
Round number or No. of RTTs

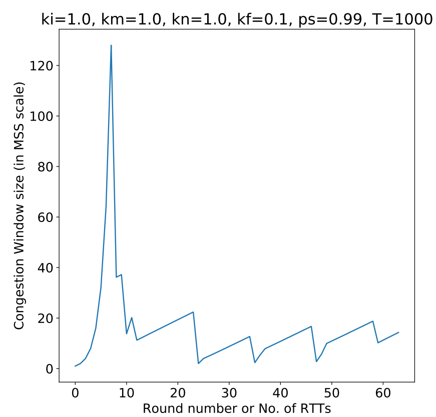

ki=1.0, km=1.0, kn=0.5, kf=0.3, ps=0.99, T=1000
Congestion Window size (in MSS scale)
0
20
40
60
80
100
120
140
0
200
400
600
800
1000
Update number

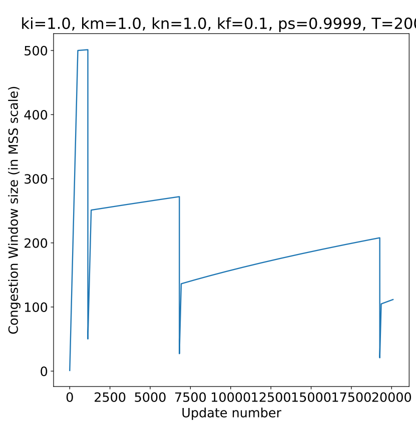

ki=1.0, km=1.0, kn=0.5, kf=0.3, ps=0.99, T=1000
Congestion Window size (in MSS scale)
0
20
40
60
80
100
120
0
10
20
30
40
50
60
70
Round number or No. of RTTs

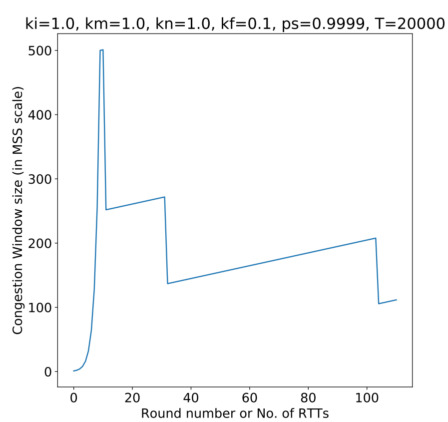

ki=1.0, km=1.0, kn=0.5, kf=0.3, ps=0.9999, T=20000
Congestion Window size (in MSS scale)
Update number

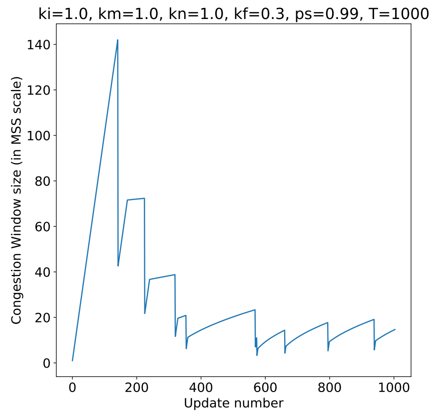

ki=1.0, km=1.0, kn=0.5, kf=0.3, ps=0.9999, T=20000
Congestion Window size (in MSS scale)
Round number or No. of RTTs

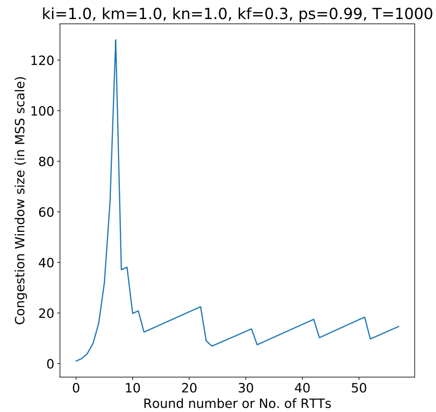

ki=1.0, km=1.0, kn=1.0, kf=0.1, ps=0.99, T=1000
Congestion Window size (in MSS scale)
Update number

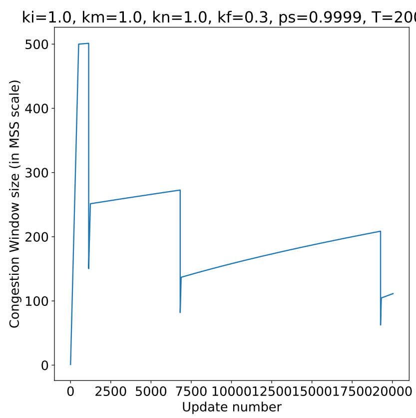

ki=1.0, km=1.0, kn=1.0, kf=0.1, ps=0.99, T=1000
Congestion Window size (in MSS scale)
Round number or No. of RTTs

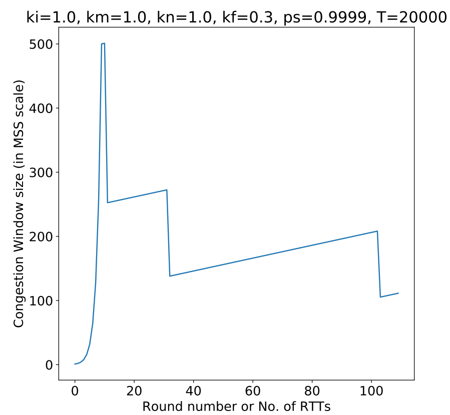

ki=1.0, km=1.0, kn=1.0, kf=0.1, ps=0.9999, T=20000
Congestion Window size (in MSS scale)
Update number


ki=1.0, km=1.0, kn=1.0, kf=0.1, ps=0.9999, T=20000
Congestion Window size (in MSS scale)
Round number or No. of RTTs



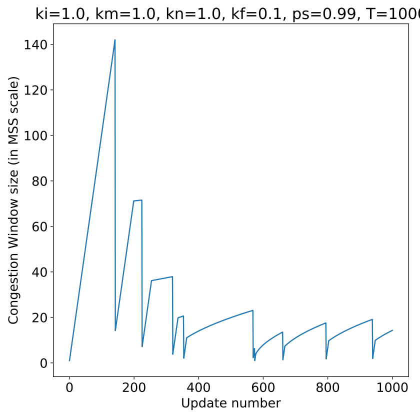


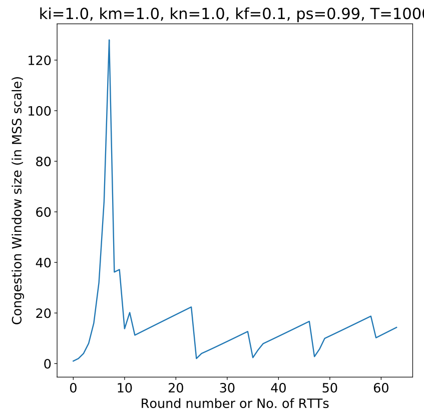


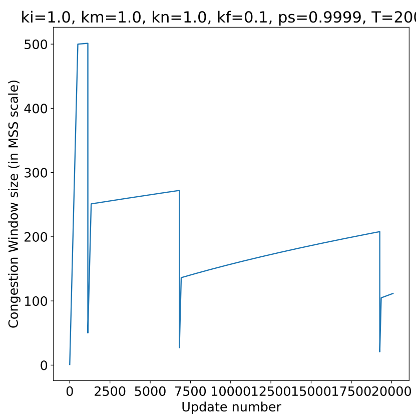


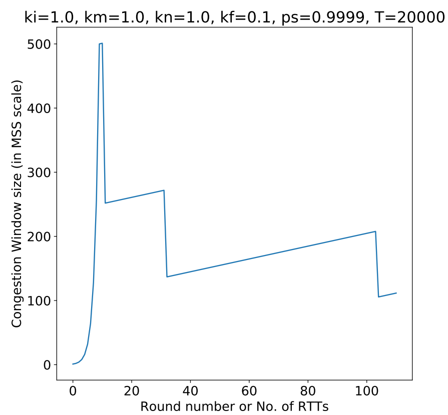
5 Effect of ps

ps is the probability that a segment is acknowledged before timeout. Increase in ps will reduce the frequency of the congestion window falling due to timeout. Therefore the average size of congestion window will increase and the number of RTTs taken to transmit a given number of segments will be less. This can be seen in the two plots given below, one where $ps = 0.99$ and another where $ps = 0.9999$ with the remaining parameters held constant except T.



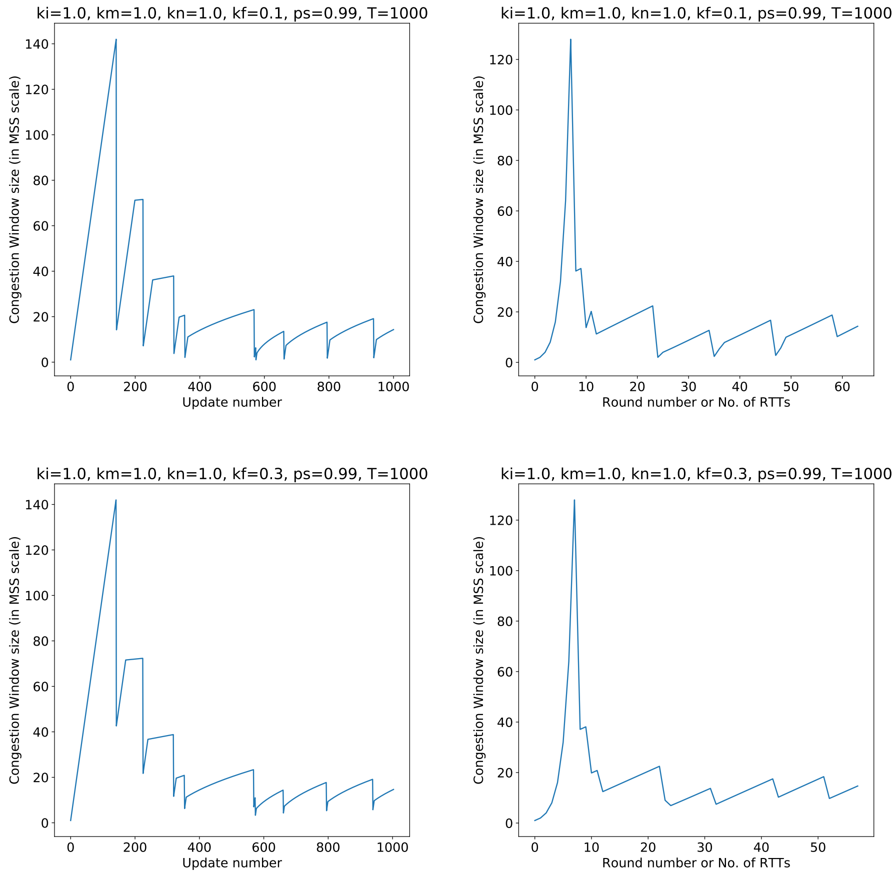






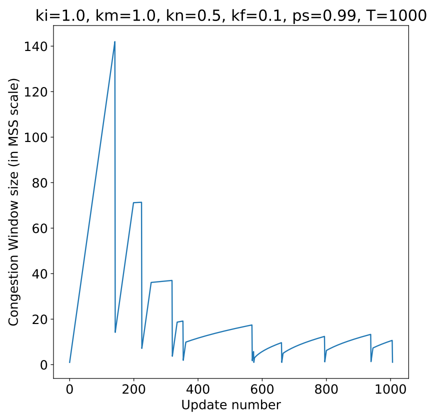
As we can see when $ps = 0.99$, it takes close to 63 RTTs to send $T = 1000$ segments i.e around 15.87 segments every RTT. When $ps = 0.9999$, it takes around 110 RTTs to send $T = 20000$ segments which is around 181.81 segments every RTT. We can also see that the number of times timeout occurs or CW falls is lower when $ps = 0.9999$.

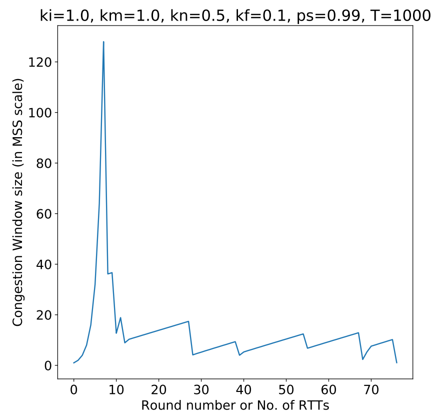
6 Effect of k_f

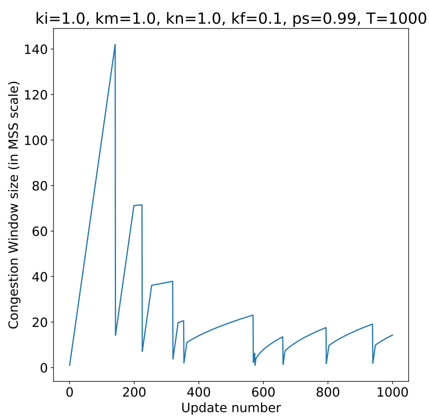


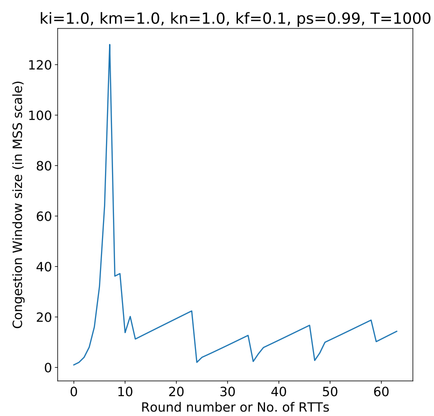
As k_f increases, the drop in CW when timeout occurs reduces as can be seen in the left plots. When $k_f = 0.1$, CW falls from 140 to 14 whereas when $k_f = 0.3$, CW falls from 140 to 47. Also the number of RTTs taken to send 1000 segments is less when k_f is high. This implies that the average size of the congestion window is more in this case. When $k_f = 0.1$, total number of RTTs=63 whereas when $k_f = 0.3$, number of RTTs=57.

7 Effect of k_n



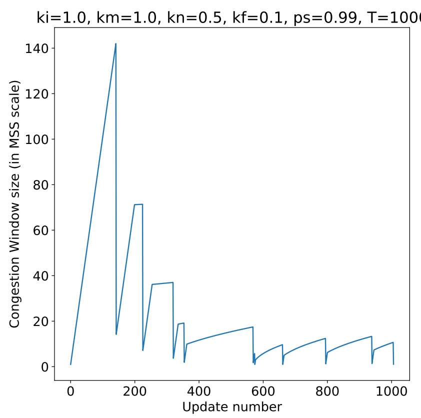


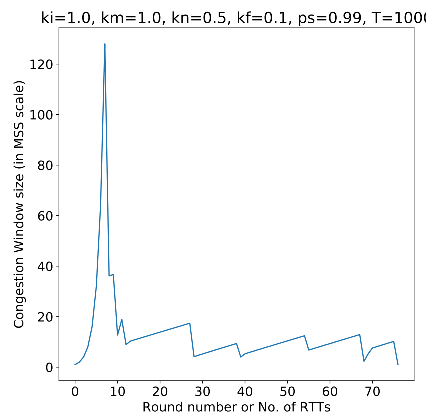


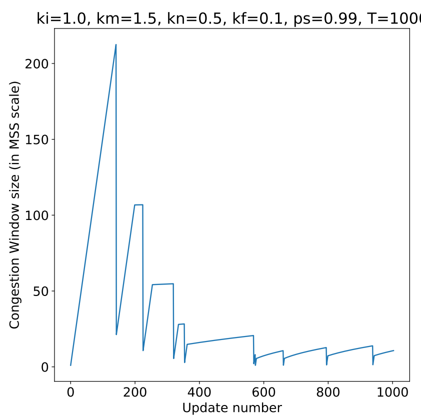


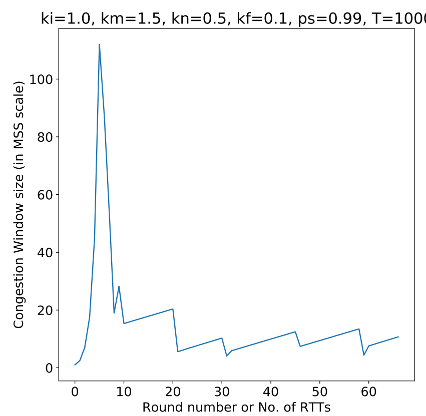
We can see in the right plots that as k_n increases, the slope in the linear regions (when $CW > threshold$) is more. Therefore CW increases faster in the linear regions for larger values of k_n. Also the number of RTTs taken to send all segments reduces with increase in k_n. When $k_n = 0.5$, it took 76 RTTs and when $k_n = 1.0$, it took only 63 RTTs.

8 Effect of k_m



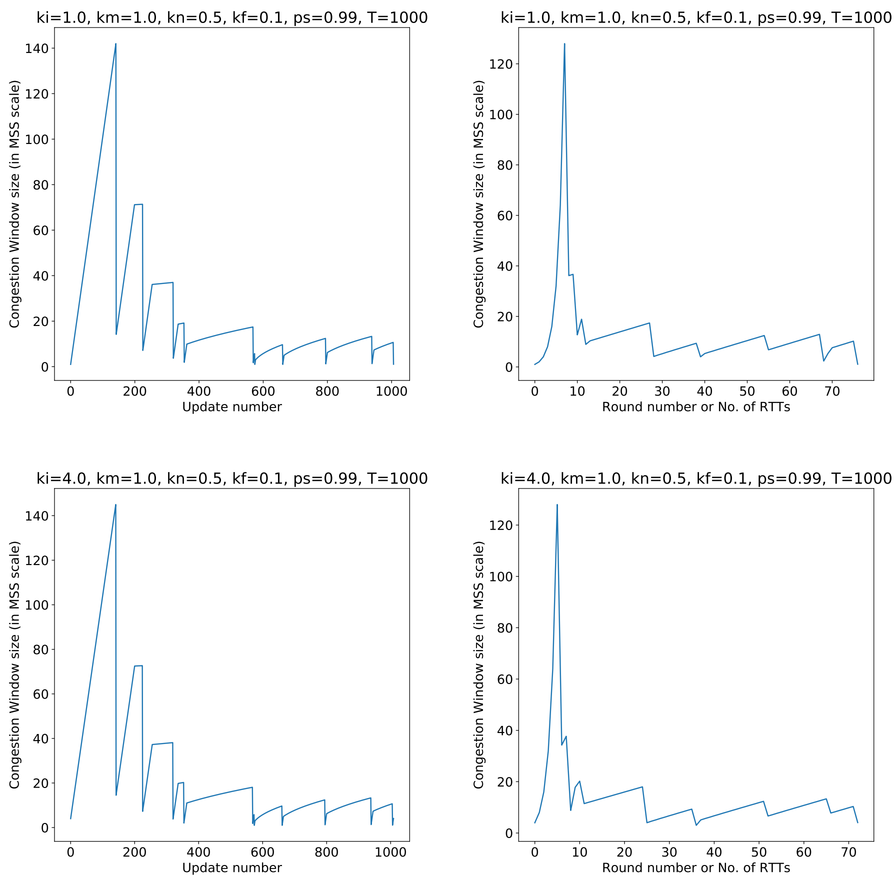






We can see in the left plots that as k_m increases, the slope in the exponential regions (when $CW < threshold$) is more. Therefore CW increases faster in the exponential regions for larger values of k_m. When $k_m = 1.0$, CW increased upto 140 and when $k_m = 1.5$, CW went upto 200 before falling down due to timeout. Also the number of RTTs taken reduces with increase in k_m. When $k_m = 1.0$, it takes 76 RTTs but when $k_m = 1.5$, it takes only 66 RTTs to send 1000 segments.

9 Effect of k_i



We can see that k_i doesn't have much effect on RTTs taken or on the slopes of the linear and exponential regions. It only changes the starting value of CW which is given by $k_i * MSS$.