NS2 Project Report

Submitted by:

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Lab Group: A_1
LEVEL - 3, TERM - 2

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Tasks Performed:

- Simulated networks in ns2.
- Computed and plotted results of simulation in ‘gnuplot’.
- Modified source files in simulators to observe impact on performance metrics.

Networks under simulation:

- Wired
- Wireless 802.15.4 (static)
- Satellite
- Wired-and-Wireless 802.11

Parameters under variation:

Wired	Wireless 802.15.4 (Static)
I. Number of Nodes II. Number of flows III. Number of packets per second	I. Number of Nodes II. Number of flows III. Number of packets per second IV. Coverage area V. Transmission range of each node

Metrics variation Graphs observed for each parameter variation:

Wired	Wireless 802.15.4 (static)
● Network throughput ● End-to-end delay ● Packet delivery ratio ● Packet drop ratio	● Network throughput ● End-to-end delay ● Packet delivery ratio ● Packet drop ratio ● Energy consumption (Total) ● *Energy per byte* ● *Jitter* ● *Per node throughput*

Modifications made in the simulator:

1. **Change in AODV Protocol**

Affected Network:

Wireless 802.15.4

Intuition:

As AODV routing protocol is an on-demand routing protocol it broadcasts its **RREQ** packet to all of its neighbor when a route is required. Thus a network becomes congested with repeating redundant RREQ packets while in most of the cases only a single RREQ packet would be enough to find a route. These redundant RREQ packets can lead to dropping of data packets due to congestion. So, here the simulator is modified according to this article to limit the amount of broadcasting of RREQ packets comparing a random number with drop factor to decide whether to forward a RREQ packet or drop it. Thus it is expected to reduce congestion and hence to improve network throughput and delay metrics.

Modified files:

aodv.h, **aodv.cc**

***Expected outcome*:**

Increase in throughput and decrease in average end-to-end delay

Consequences:

Decrease in both throughput and average end-to-end delay

2. **Change in Droptail Queue**

Affected Network:

Wired, Wireless 802.15.4

Intuition:

In our simulation both networks use Droptail queue which drops the packet arrived first when the queue becomes full. But sometimes queue may have some redundant protocol packets in queue which are not necessary. Hence, we treat those packets as less important than data packets. So instead of dropping the first arrived packet, the **packet with least important is dropped** from queue. (AODV packet in wireless and RTPROTO packet in wired network) < ARP packet < Data Packet, is considered as the sequence of importance.

Modified files:

queue.h, drop-tail.h, **drop-tail.cc**

***Expected outcome*:**

Decrease in drop-ratio.

Consequences:

Decrease in drop-ratio.

3. **Change in calculation mechanism of average RTT**

Affected Network:

Wired

Intuition:

Mechanism of average calculation of rtt is modified from Exponential moving average to an inferior **simple average calculation model based on only last five sample values**. Moreover, **RTO** is also affected due to change in average RTT and tends to **change frequently** due as average is calculated on less sample values.

Modified files:

tcp.h, **tcp.cc**

***Expected outcome*:**

Decrease in throughput

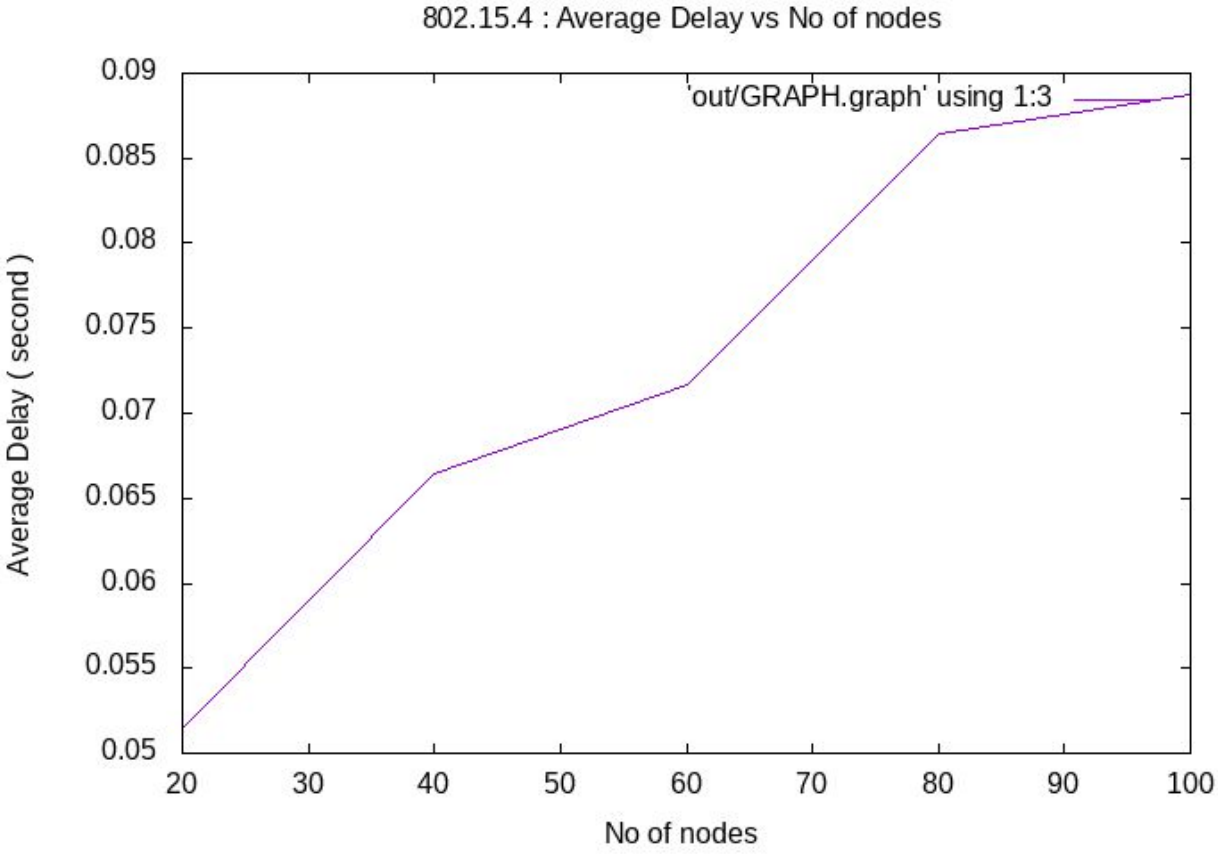
Consequences:

Decrease in throughput.

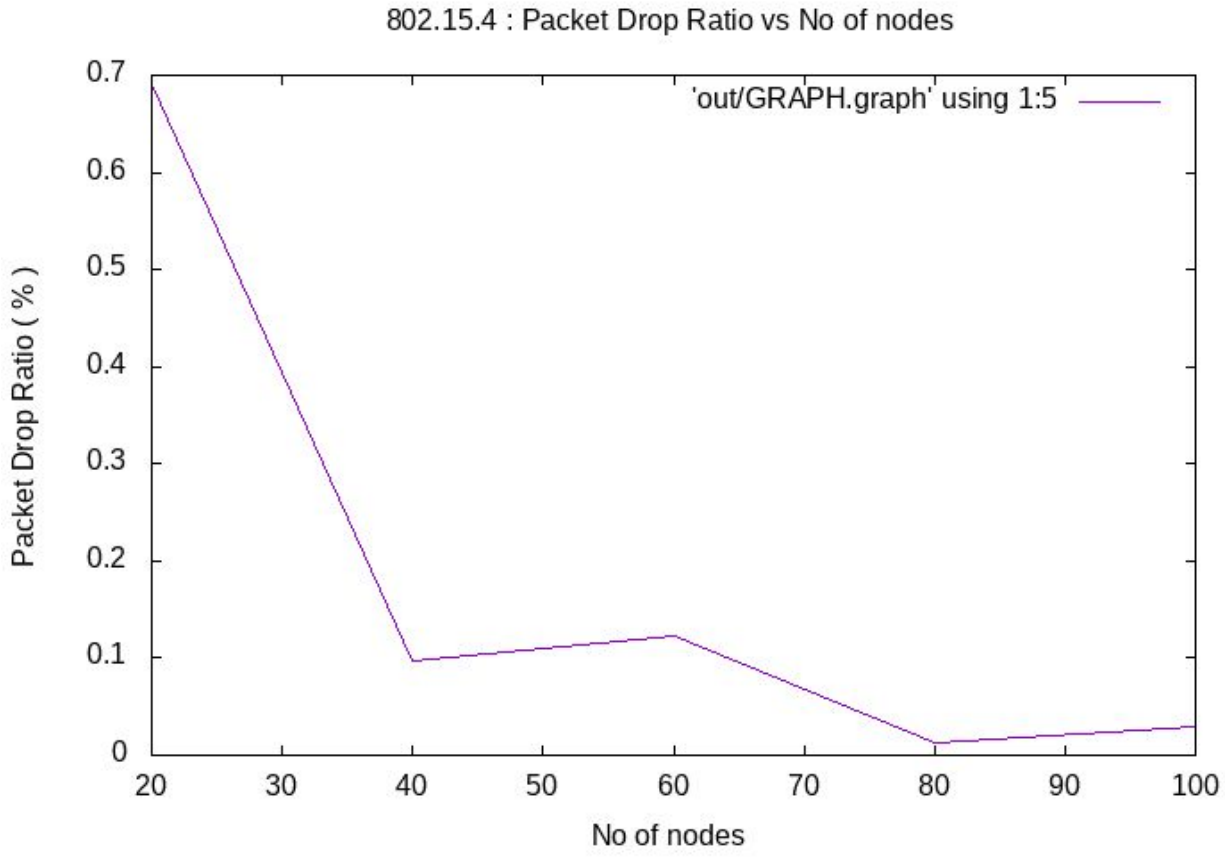
Results with Graphs:

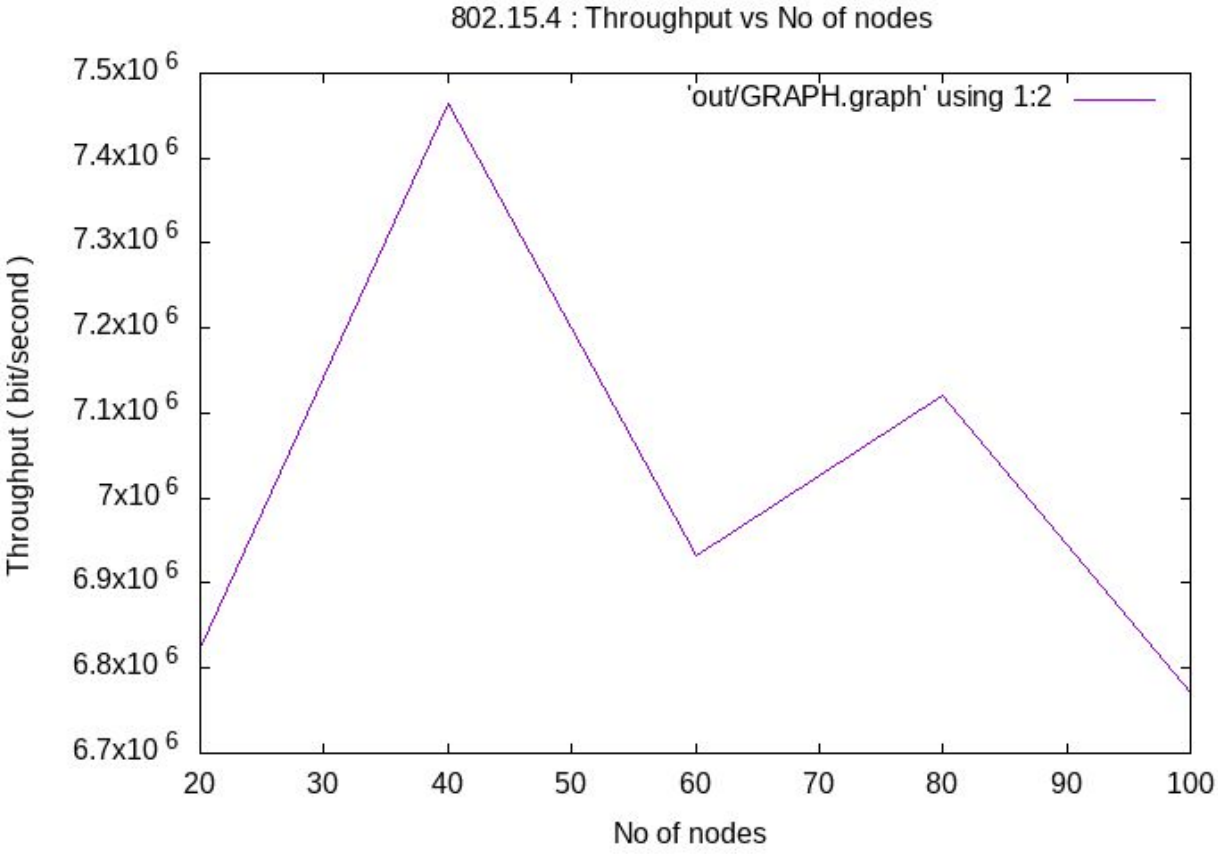
Graphs reflecting variation of metrics with respect to variation of parameters has been attached below.

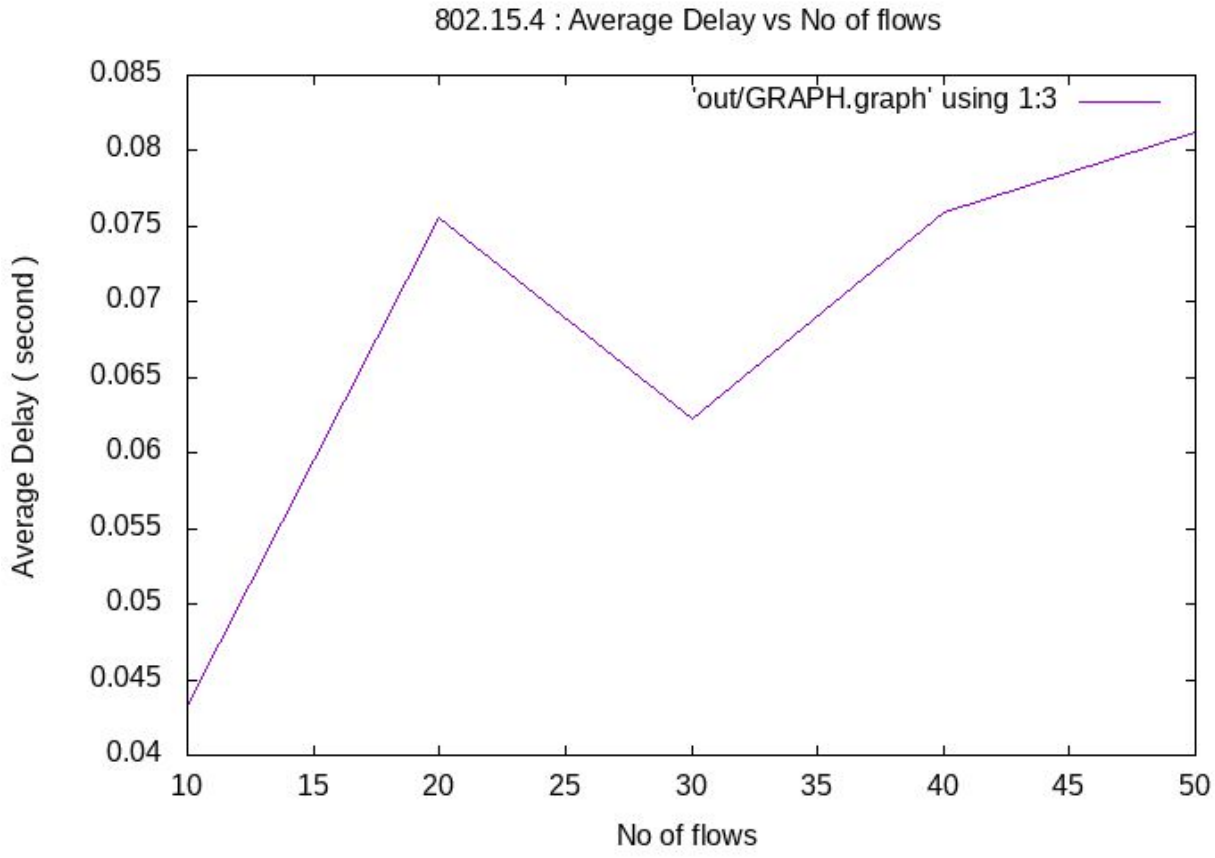
Wired


802.15.4 : Average Delay vs No of nodes
'out/GRAPH.graph' using 1:3
Average Delay (second)
No of nodes
0.09
0.085
0.08
0.075
0.07
0.065
0.06
0.055
0.05
20
30
40
50
60
70
80
90
100

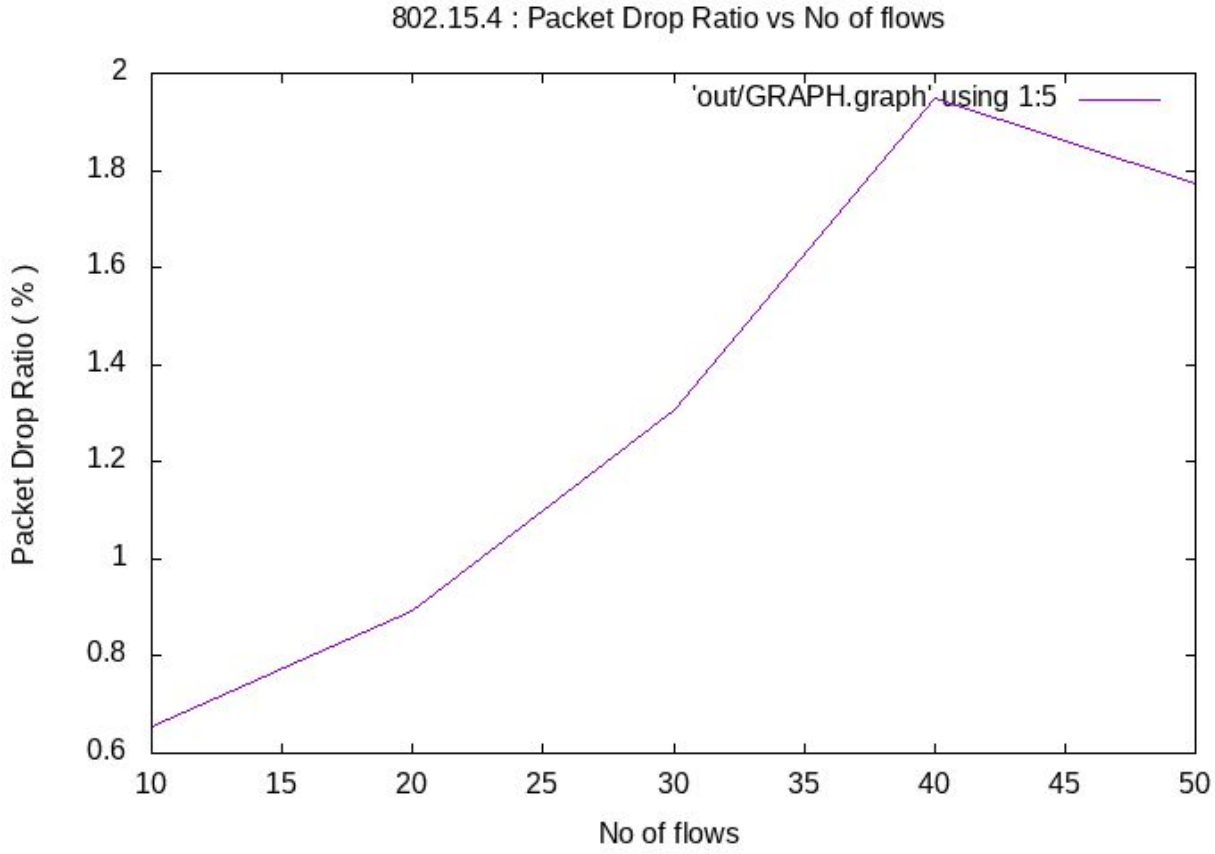

802.15.4 : Packet Delivery Ratio vs No of nodes
'out/GRAPH.graph' using 1:4
Packet Delivery Ratio (%)
No of nodes
99.6
99.55
99.5
99.45
99.4
99.35
99.3
99.25
99.2
99.15
99.1
99.05
20
30
40
50
60
70
80
90
100

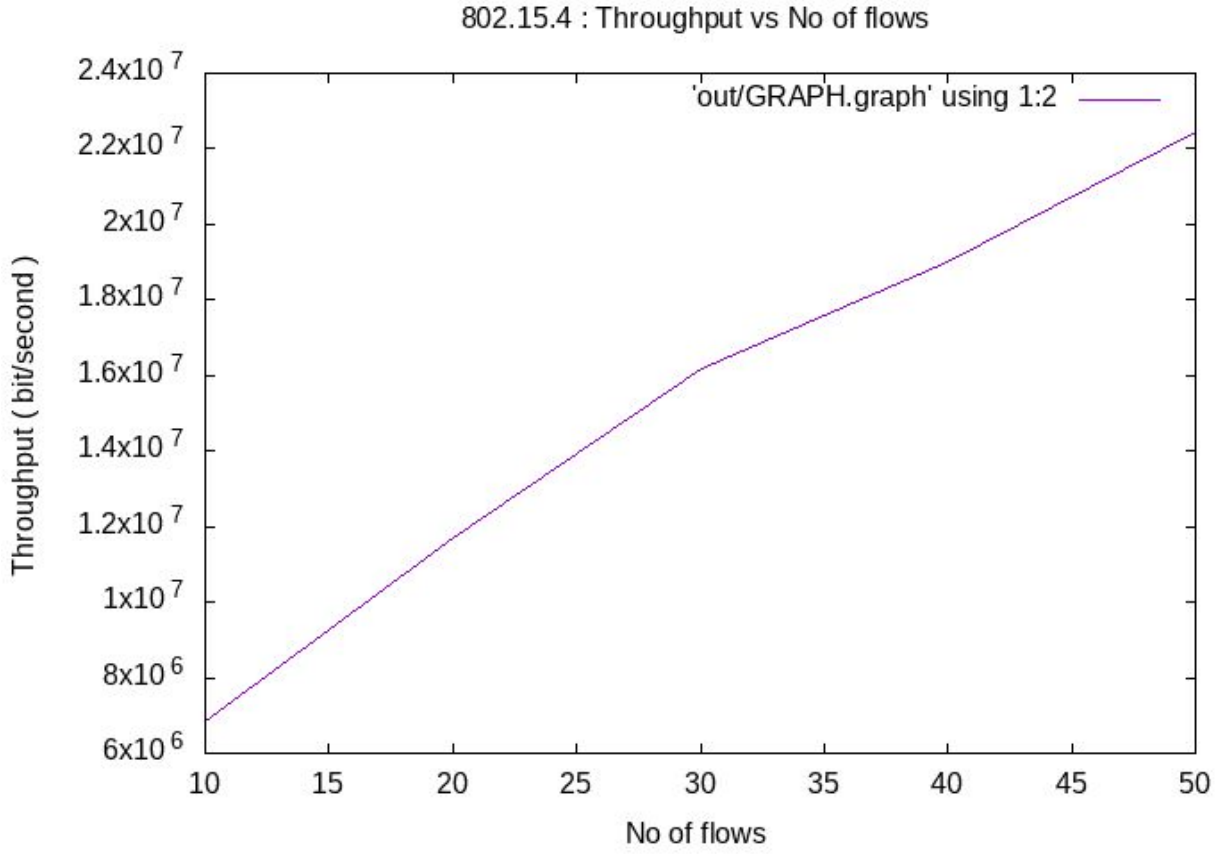

802.15.4 : Packet Drop Ratio vs No of nodes
'out/GRAPH.graph' using 1:5
Packet Drop Ratio (%)
No of nodes
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
20
30
40
50
60
70
80
90
100

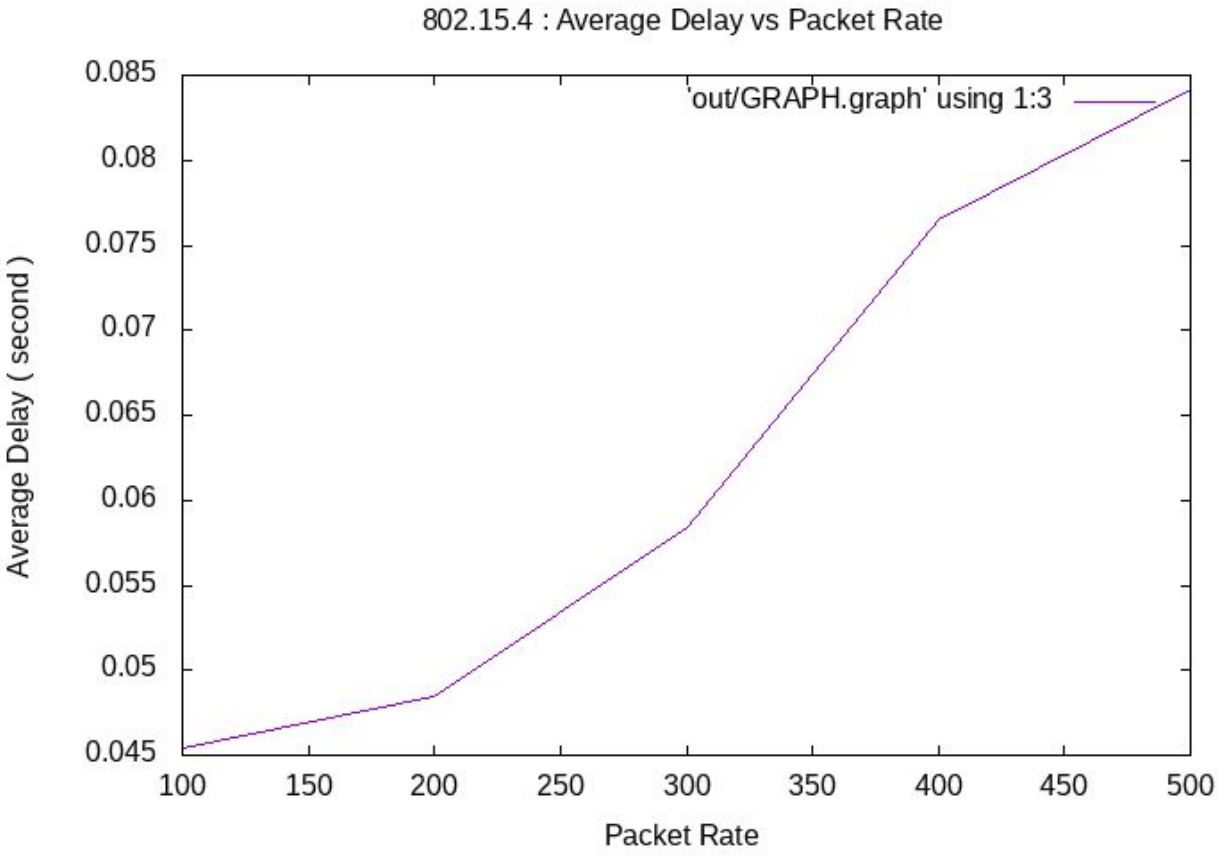

802.15.4 : Throughput vs No of nodes
'out/GRAPH.graph' using 1:2
Throughput (bit/second)
7.5x10 6
7.4x10 6
7.3x10 6
7.2x10 6
7.1x10 6
7x10 6
6.9x10 6
6.8x10 6
6.7x10 6
20
30
40
50
60
70
80
90
100
No of nodes

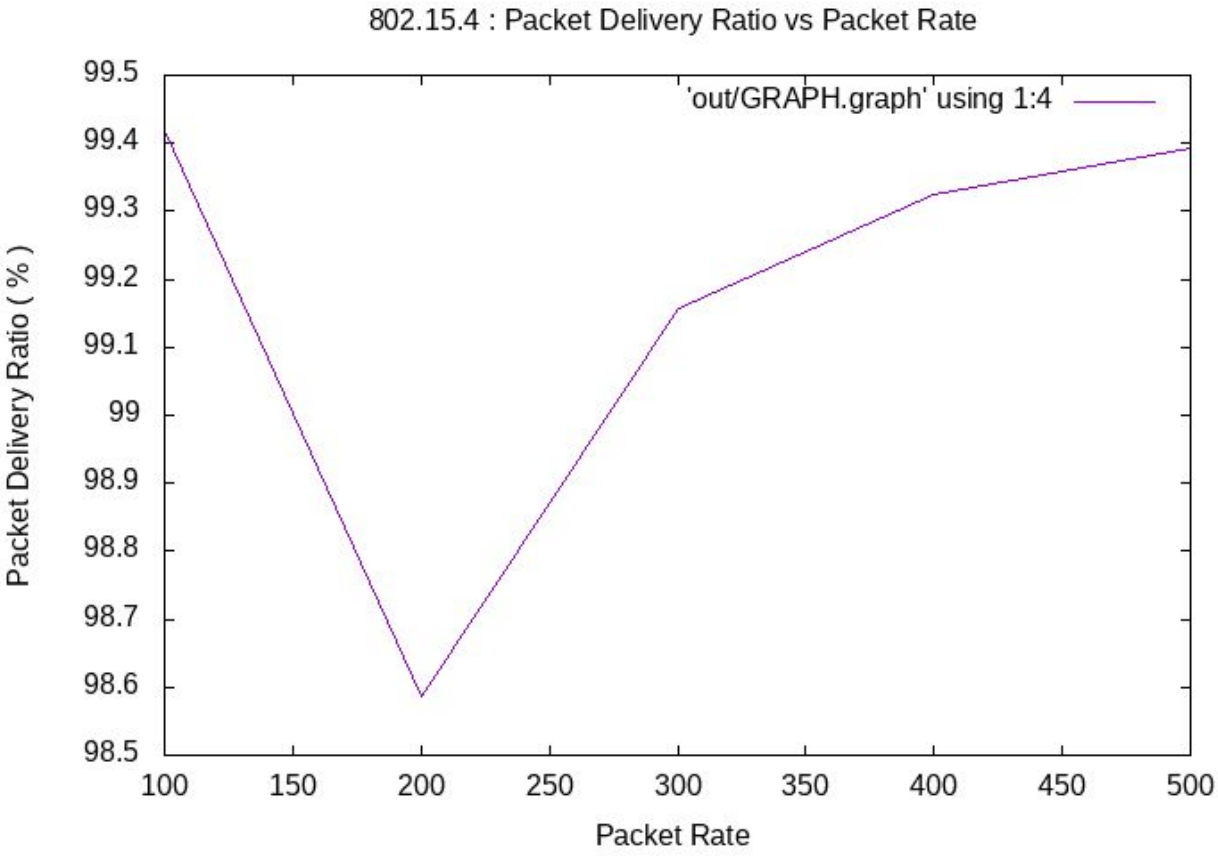

802.15.4 : Average Delay vs No of flows
'out/GRAPH.graph' using 1:3
Average Delay (second)
No of flows
0.085
0.08
0.075
0.07
0.065
0.06
0.055
0.05
0.045
0.04
10
15
20
25
30
35
40
45
50

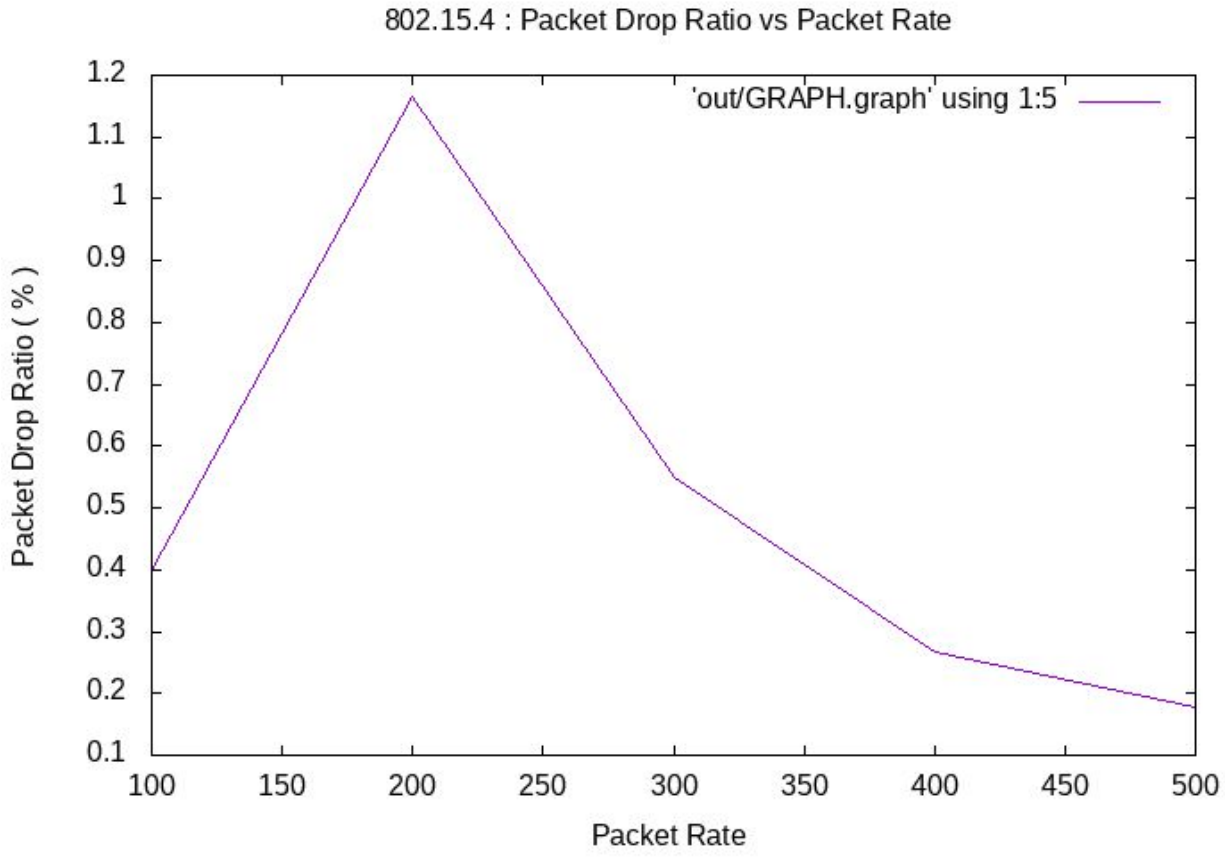

802.15.4 : Packet Delivery Ratio vs No of flows
'out/GRAPH.graph' using 1:4
Packet Delivery Ratio (%)
No of flows
99.2
99
98.8
98.6
98.4
98.2
98
97.8
97.6
10
15
20
25
30
35
40
45
50

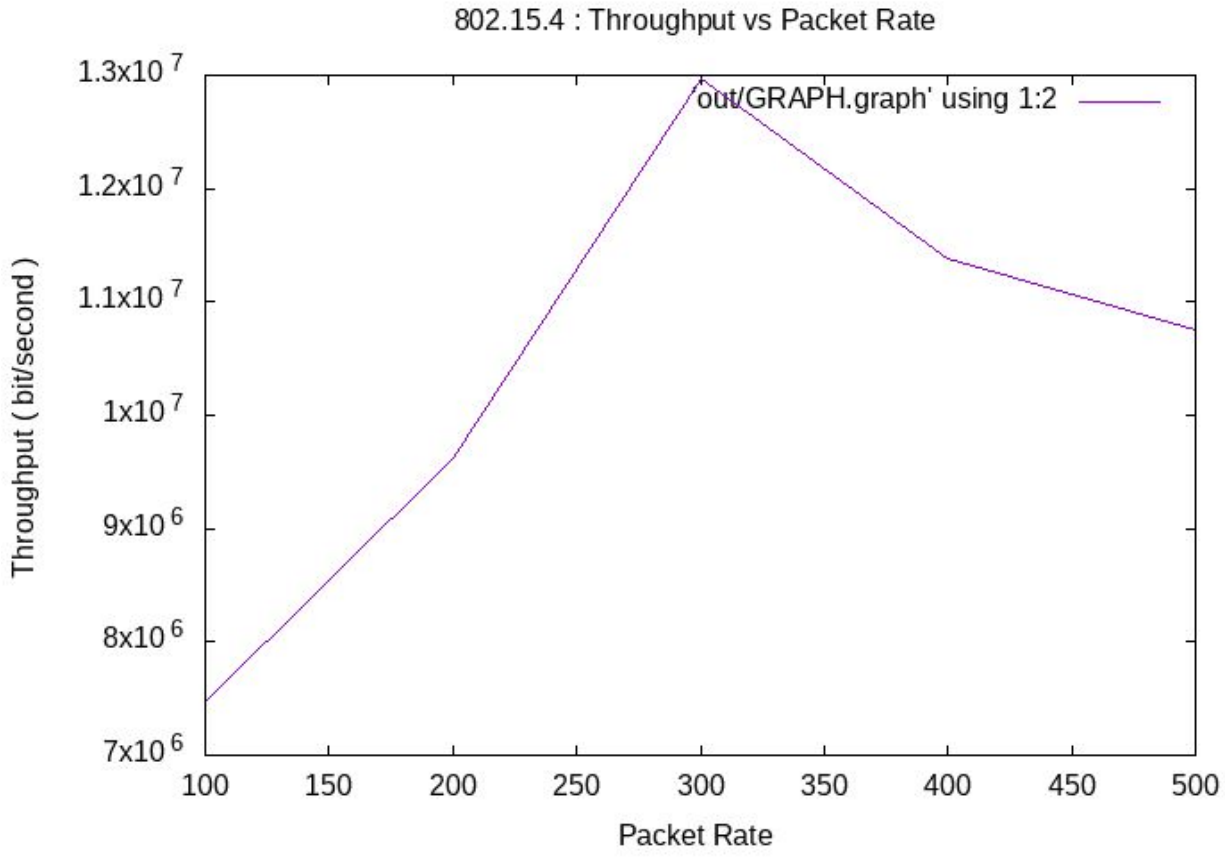

802.15.4 : Packet Drop Ratio vs No of flows
'out/GRAPH.graph' using 1:5
Packet Drop Ratio (%)
No of flows
2
1.8
1.6
1.4
1.2
1
0.8
0.6
10
15
20
25
30
35
40
45
50


802.15.4 : Throughput vs No of flows
'out/GRAPH.graph' using 1:2
Throughput (bit/second)
2.4x10 7
2.2x10 7
2x10 7
1.8x10 7
1.6x10 7
1.4x10 7
1.2x10 7
1x10 7
8x10 6
6x10 6
10
15
20
25
30
35
40
45
50
No of flows


802.15.4 : Average Delay vs Packet Rate
'out/GRAPH.graph' using 1:3
Average Delay (second)
Packet Rate
0.085
0.08
0.075
0.07
0.065
0.06
0.055
0.05
0.045
100
150
200
250
300
350
400
450
500

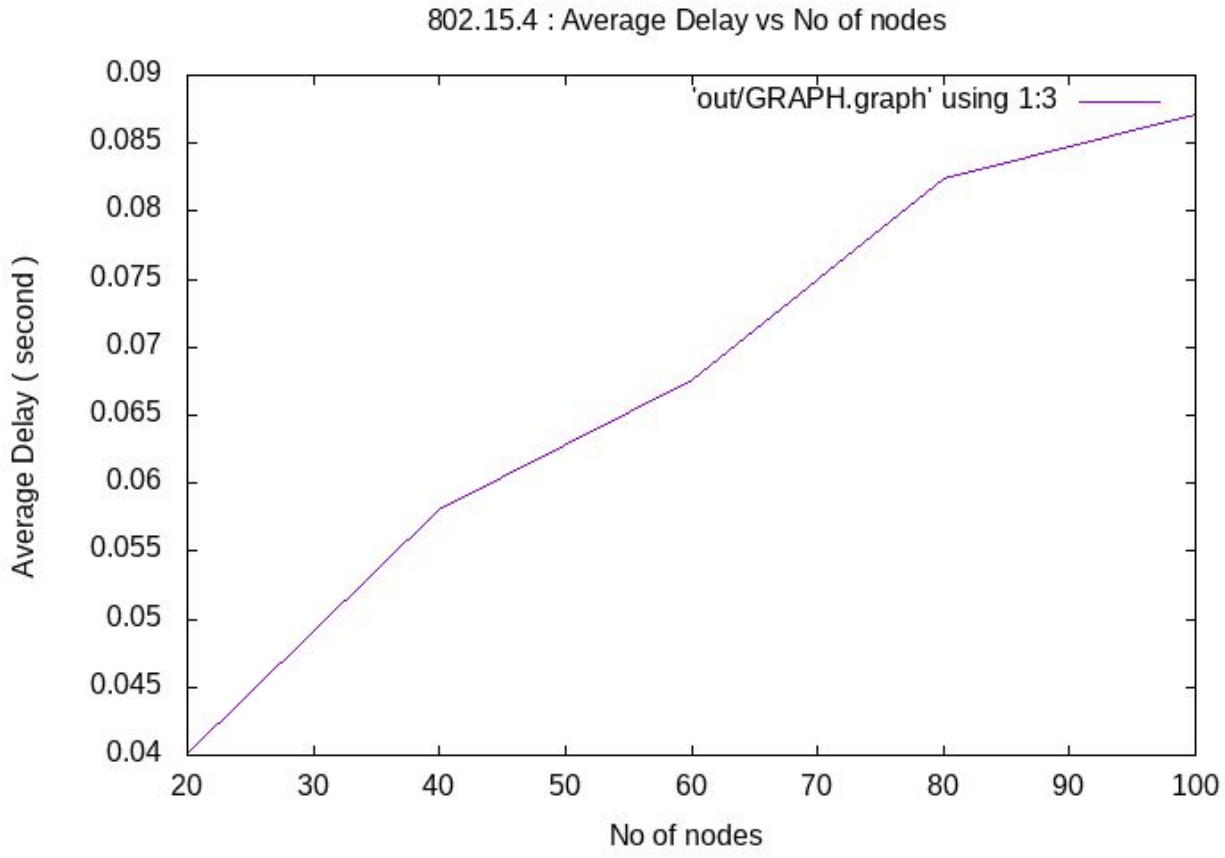

802.15.4 : Packet Delivery Ratio vs Packet Rate
'out/GRAPH.graph' using 1:4
Packet Delivery Ratio (%)
Packet Rate
99.5
99.4
99.3
99.2
99.1
99
98.9
98.8
98.7
98.6
98.5
100
150
200
250
300
350
400
450
500

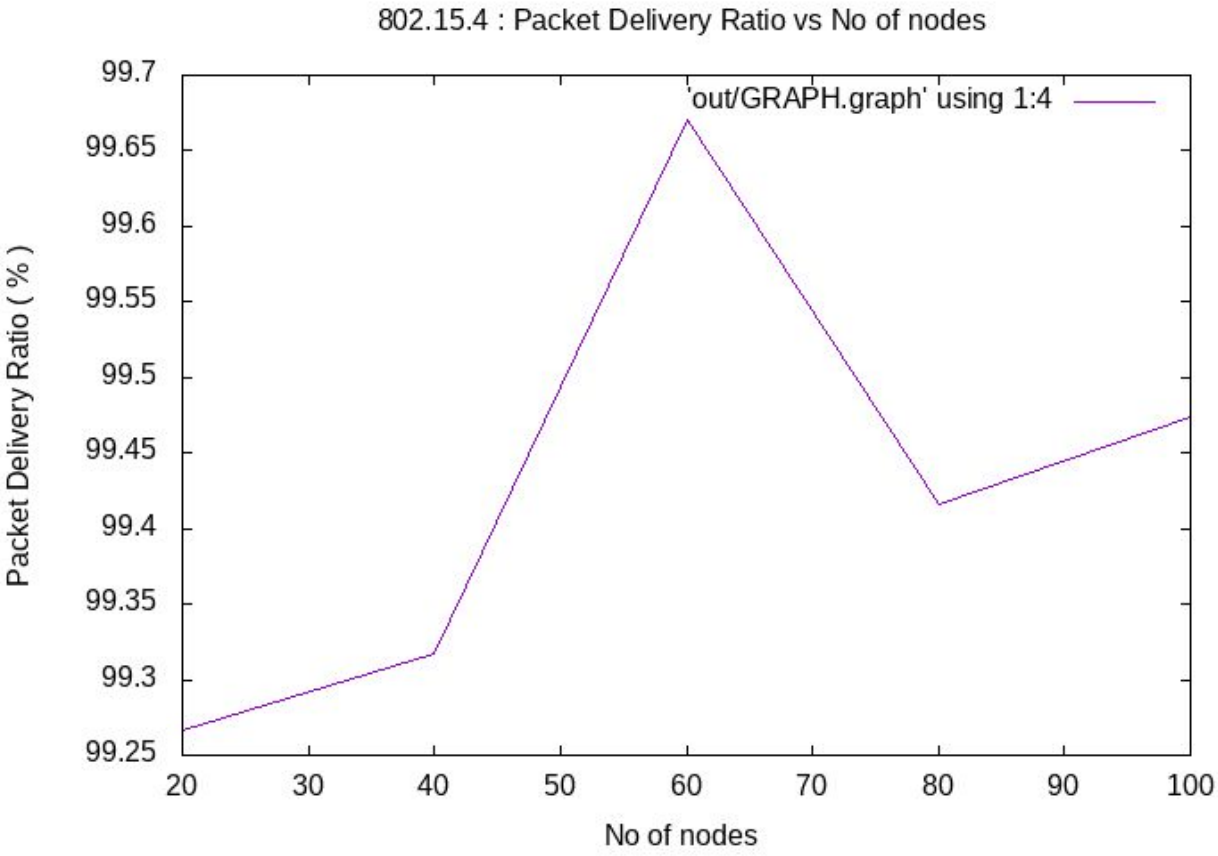

802.15.4 : Packet Drop Ratio vs Packet Rate
'out/GRAPH.graph' using 1:5
Packet Drop Ratio (%)
Packet Rate
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
100
150
200
250
300
350
400
450
500

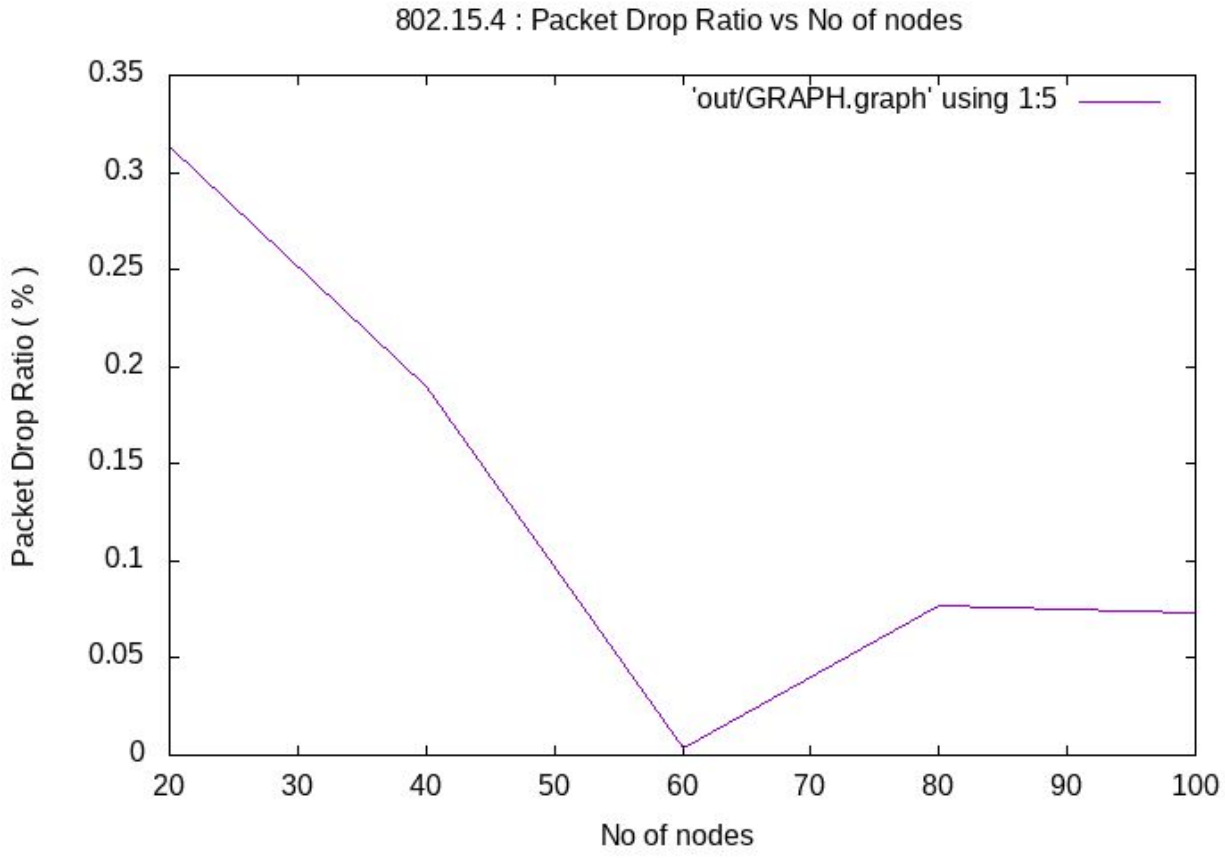

802.15.4 : Throughput vs Packet Rate
out/GRAPH.graph' using 1:2
Throughput (bit/second)
1.3x10 7
1.2x10 7
1.1x10 7
1x10 7
9x10 6
8x10 6
7x10 6
100
150
200
250
300
350
400
450
500
Packet Rate

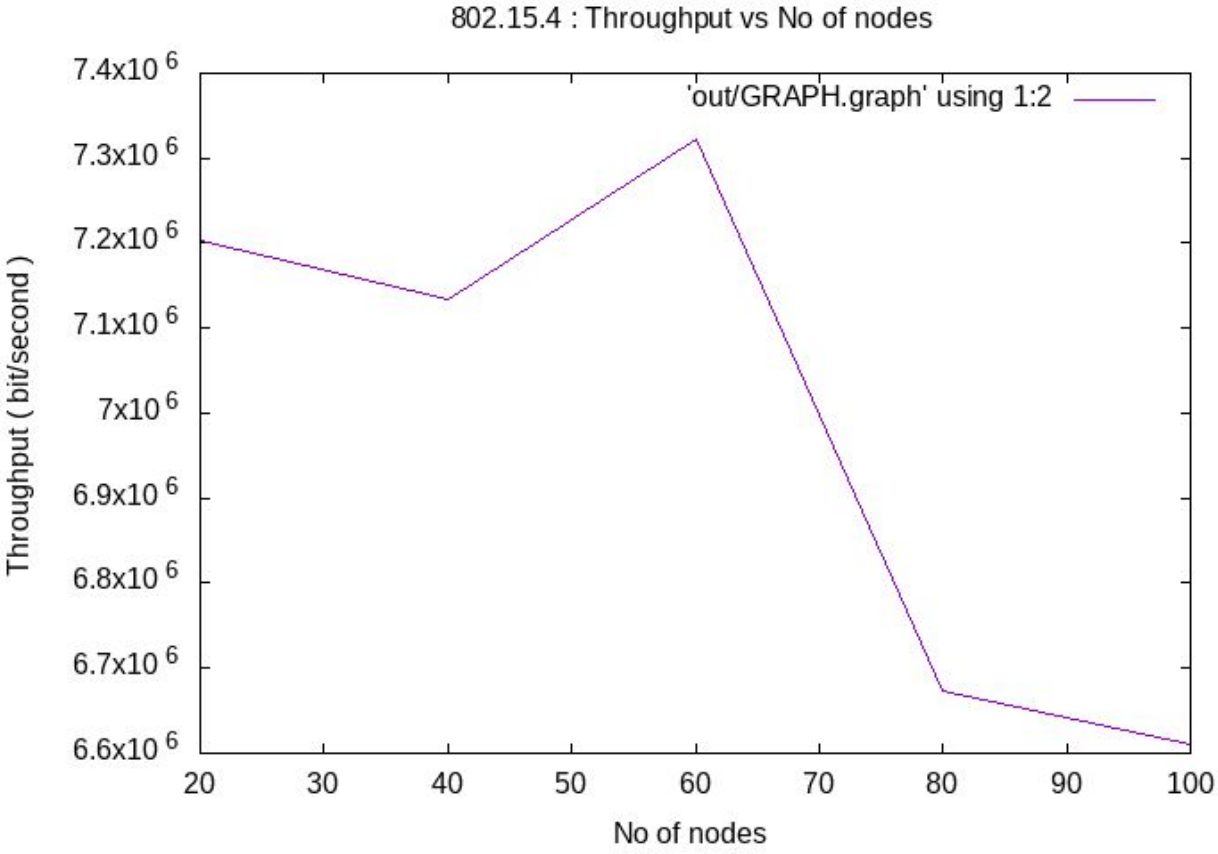
Wired

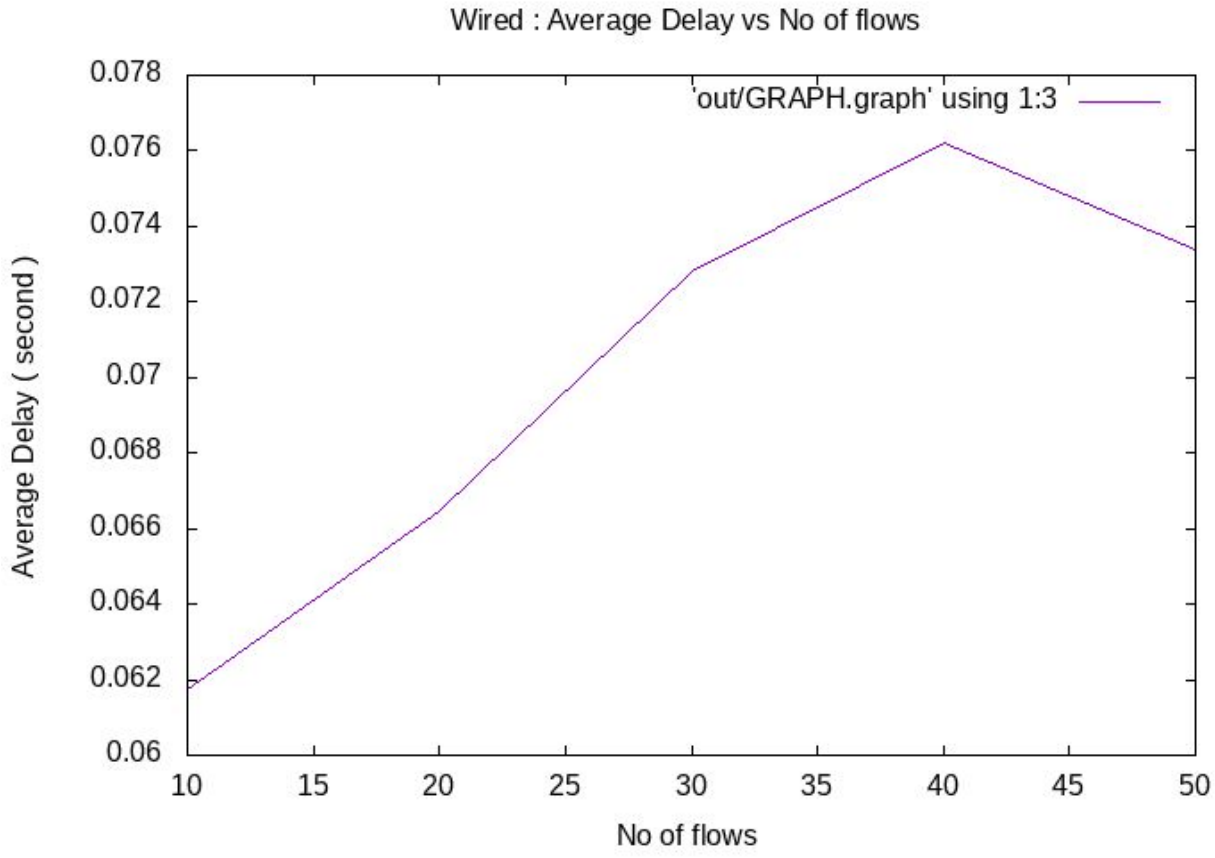
(Modified)


802.15.4 : Average Delay vs No of nodes
'out/GRAPH.graph' using 1:3
Average Delay (second)
No of nodes
0.09
0.085
0.08
0.075
0.07
0.065
0.06
0.055
0.05
0.045
0.04
20
30
40
50
60
70
80
90
100

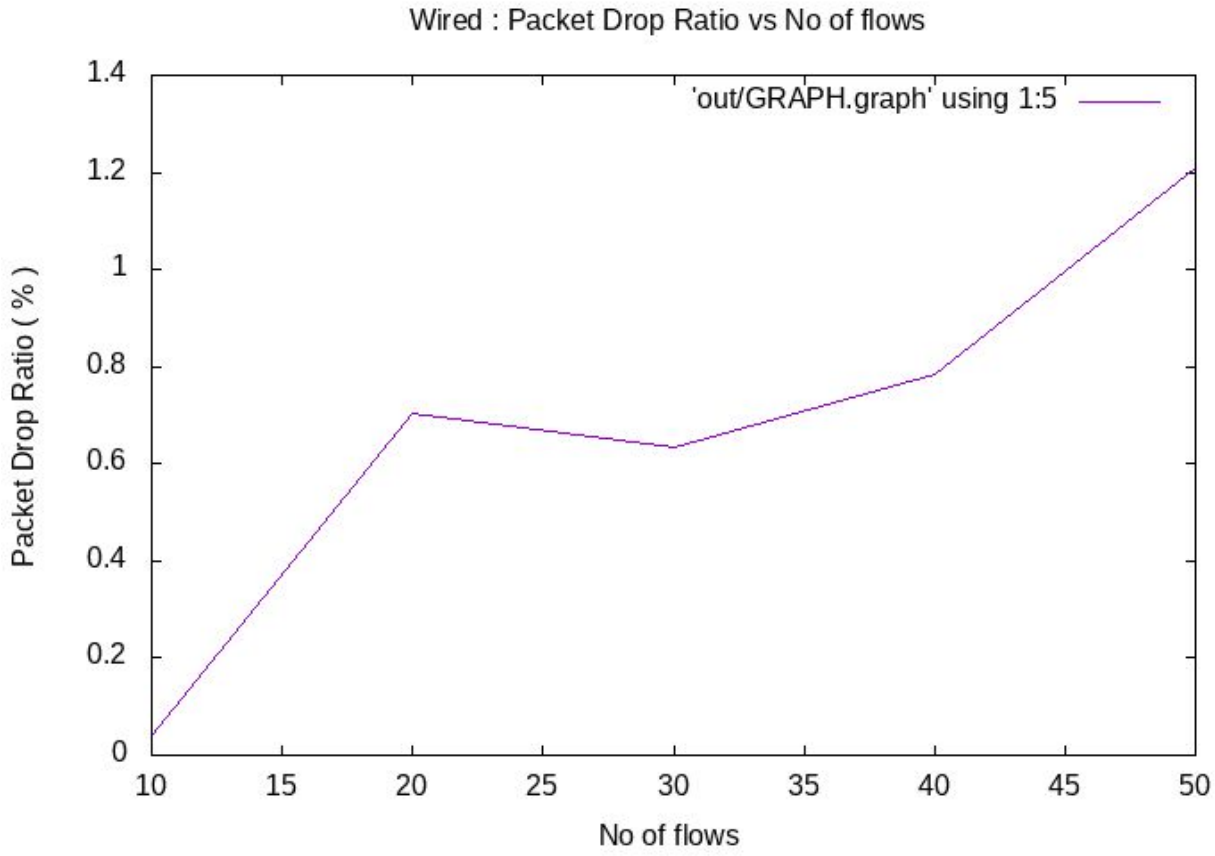

802.15.4 : Packet Delivery Ratio vs No of nodes
'out/GRAPH.graph' using 1:4
Packet Delivery Ratio (%)
No of nodes
99.7
99.65
99.6
99.55
99.5
99.45
99.4
99.35
99.3
99.25
20
30
40
50
60
70
80
90
100

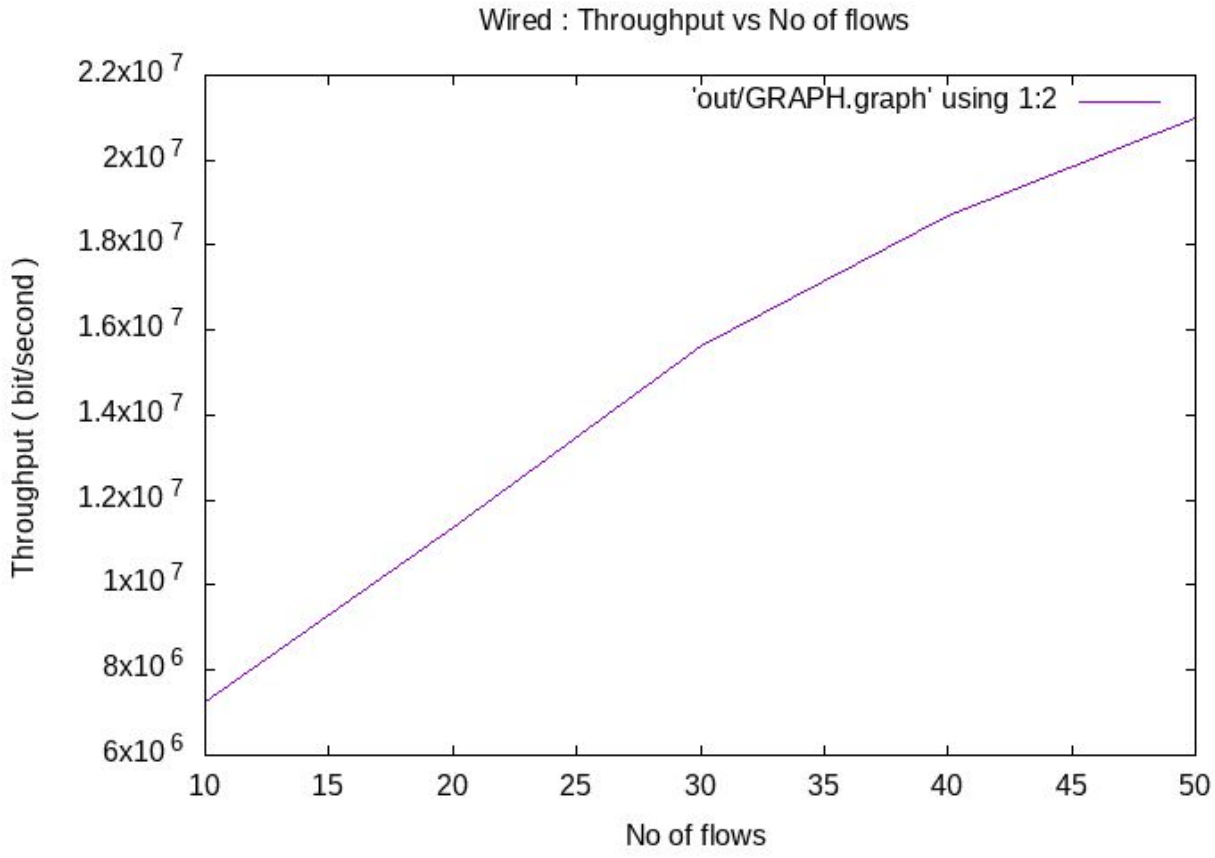

802.15.4 : Packet Drop Ratio vs No of nodes
'out/GRAPH.graph' using 1:5
Packet Drop Ratio (%)
No of nodes
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
20
30
40
50
60
70
80
90
100

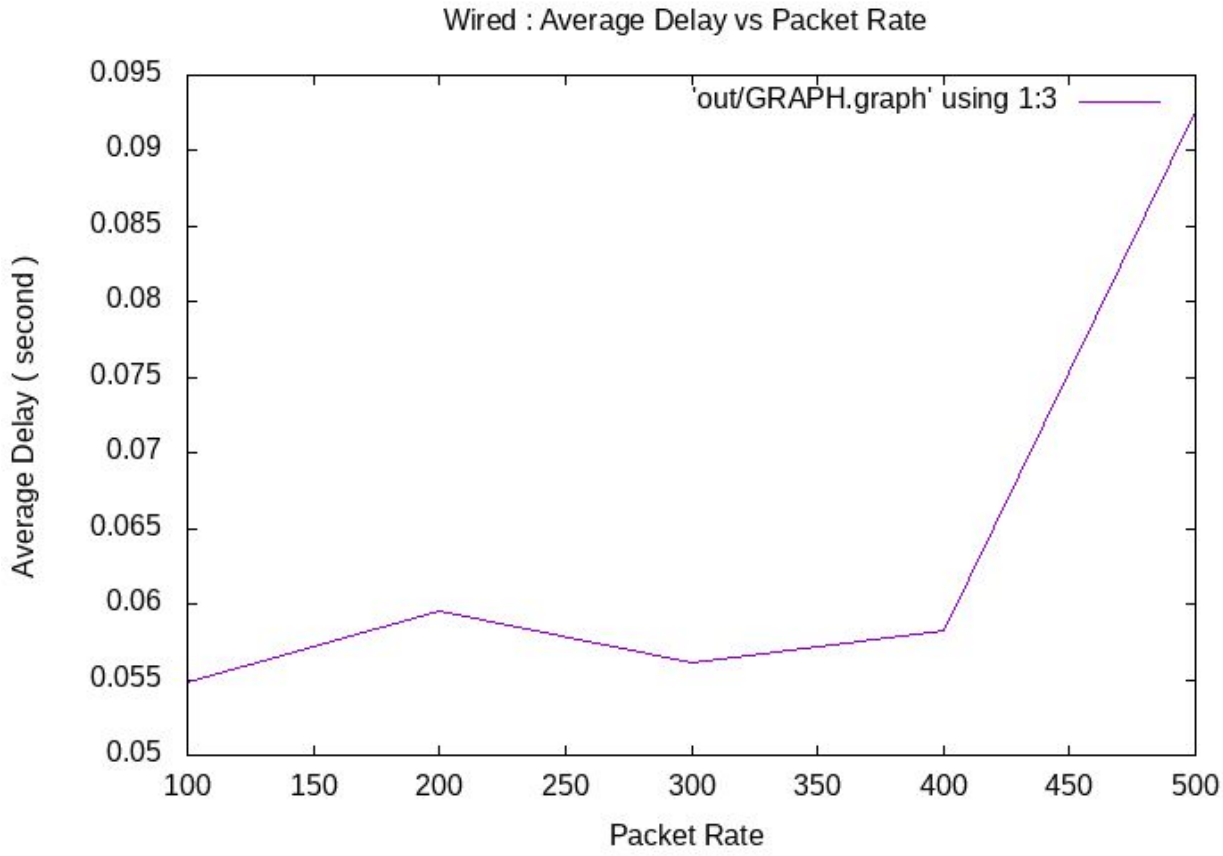

802.15.4 : Throughput vs No of nodes
'out/GRAPH.graph' using 1:2
Throughput (bit/second)
7.4x10 6
7.3x10 6
7.2x10 6
7.1x10 6
7x10 6
6.9x10 6
6.8x10 6
6.7x10 6
6.6x10 6
20
30
40
50
60
70
80
90
100
No of nodes

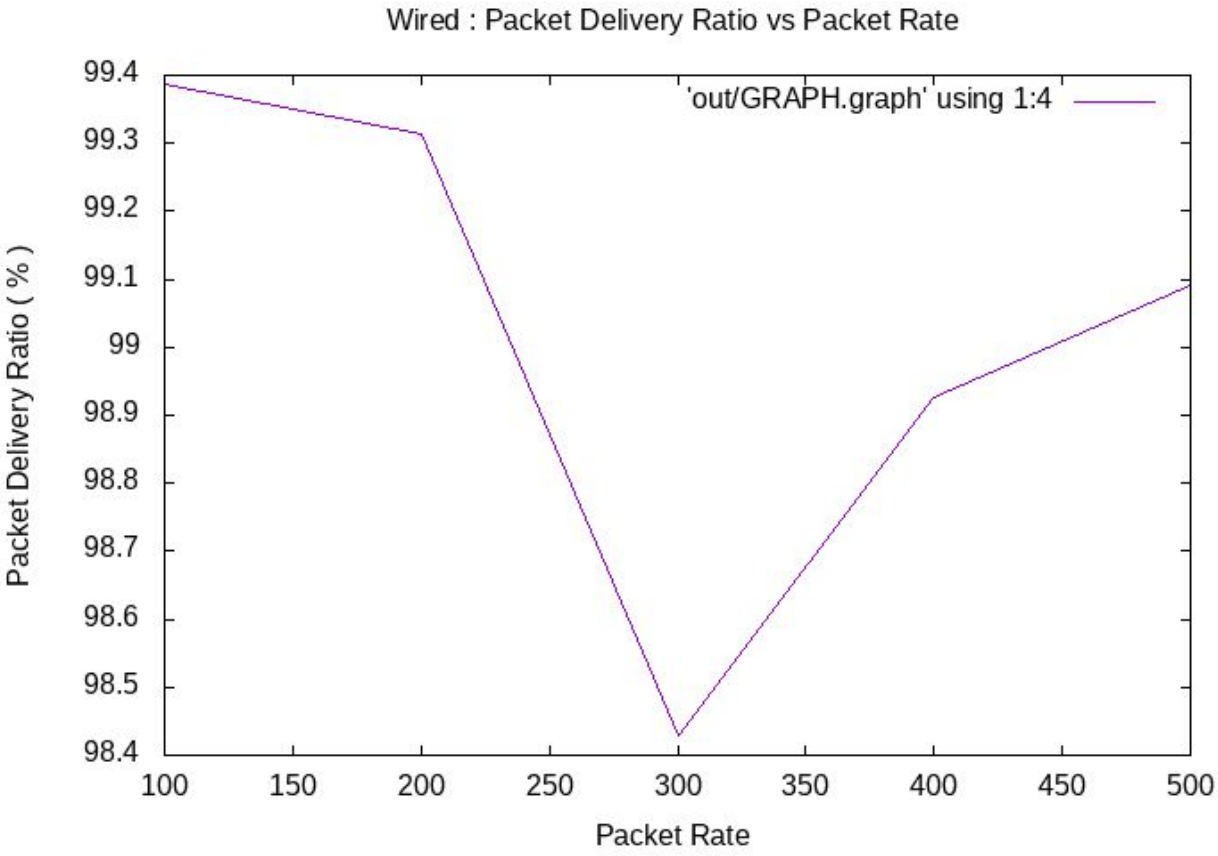

Wired : Average Delay vs No of flows
'out/GRAPH.graph' using 1:3
Average Delay (second)
No of flows
0.078
0.076
0.074
0.072
0.07
0.068
0.066
0.064
0.062
0.06
10
15
20
25
30
35
40
45
50

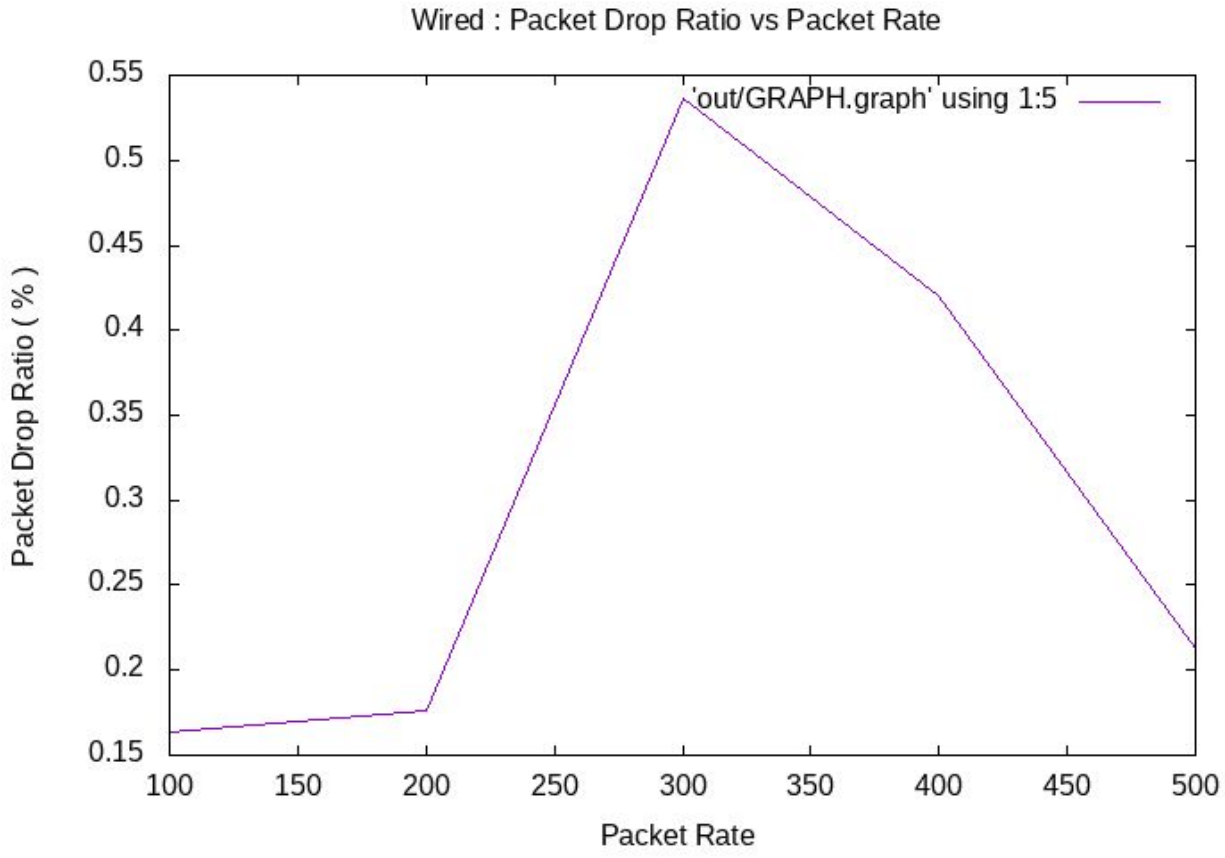

Wired : Packet Delivery Ratio vs No of flows
'out/GRAPH.graph' using 1:4
Packet Delivery Ratio (%)
No of flows
100
99.5
99
98.5
98
97.5
97
10
15
20
25
30
35
40
45
50

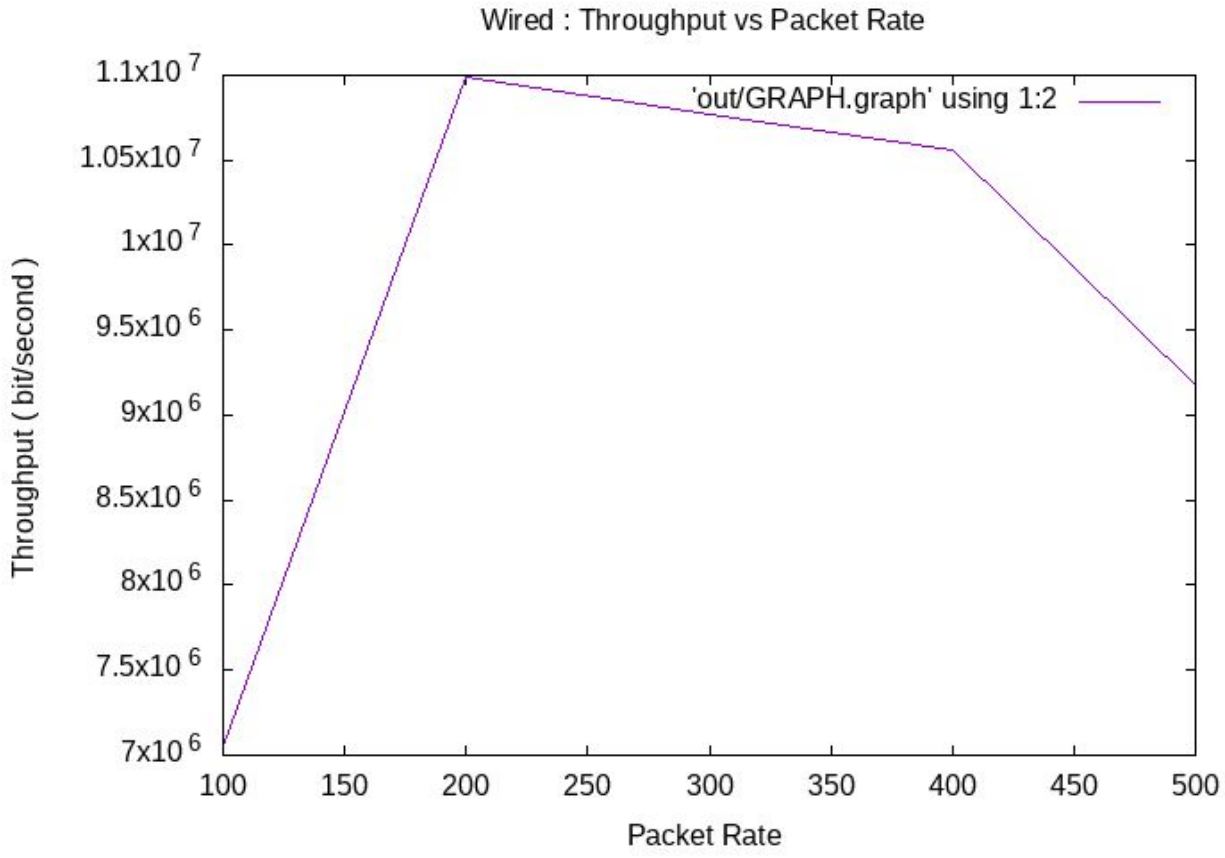

Wired : Packet Drop Ratio vs No of flows
'out/GRAPH.graph' using 1:5
Packet Drop Ratio (%)
No of flows
0
0.2
0.4
0.6
0.8
1
1.2
1.4
10
15
20
25
30
35
40
45
50


Wired : Throughput vs No of flows
'out/GRAPH.graph' using 1:2
Throughput (bit/second)
2.2x10 7
2x10 7
1.8x10 7
1.6x10 7
1.4x10 7
1.2x10 7
1x10 7
8x10 6
6x10 6
10
15
20
25
30
35
40
45
50
No of flows


Wired : Average Delay vs Packet Rate
'out/GRAPH.graph' using 1:3
Average Delay (second)
Packet Rate
0.095
0.09
0.085
0.08
0.075
0.07
0.065
0.06
0.055
0.05
100
150
200
250
300
350
400
450
500

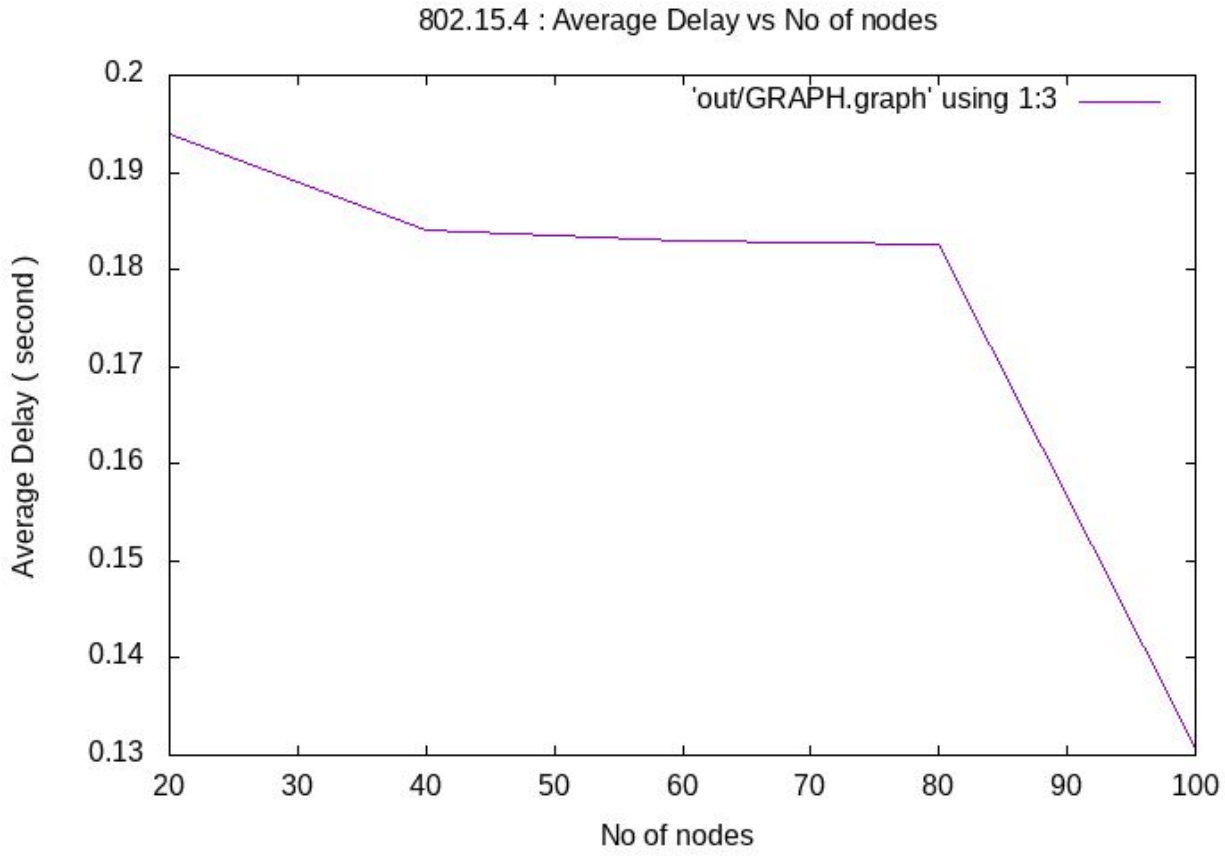

Wired : Packet Delivery Ratio vs Packet Rate
'out/GRAPH.graph' using 1:4
Packet Delivery Ratio (%)
Packet Rate
99.4
99.3
99.2
99.1
99
98.9
98.8
98.7
98.6
98.5
98.4
100
150
200
250
300
350
400
450
500

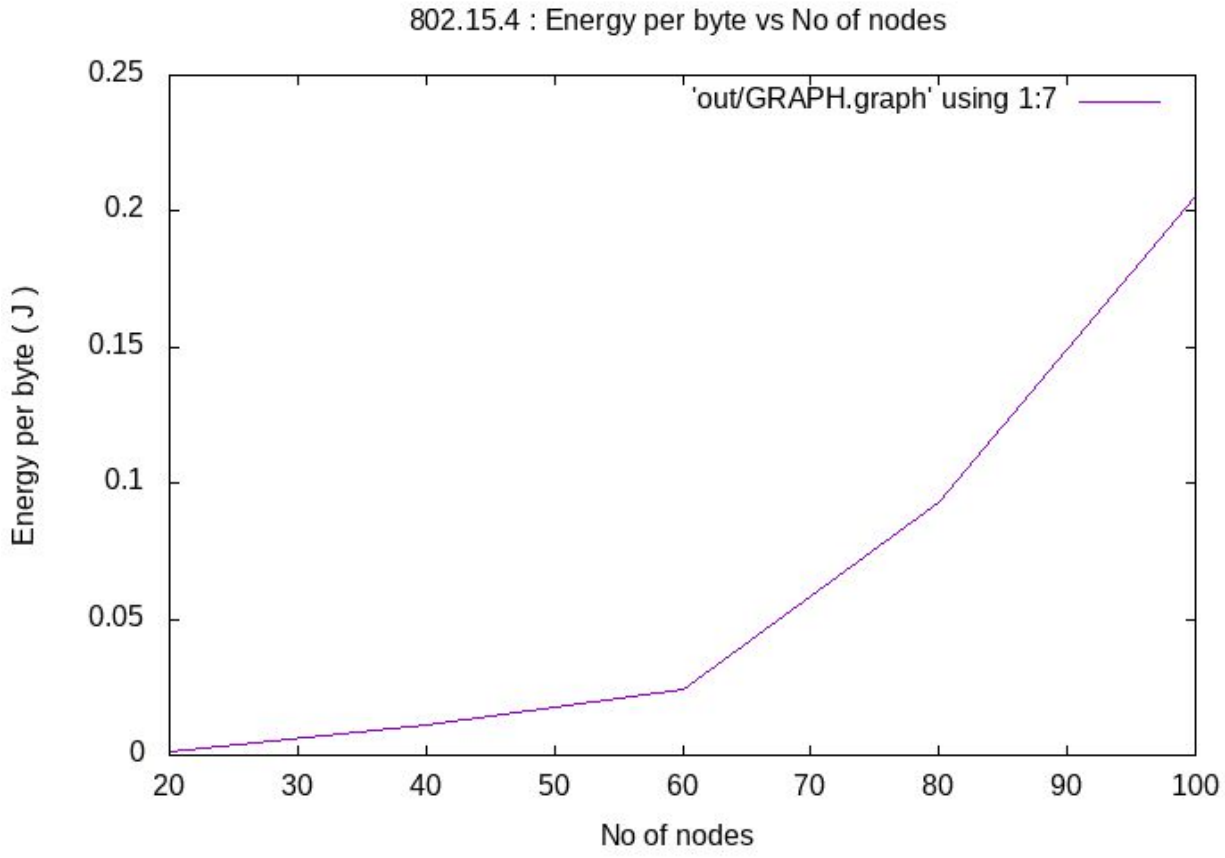

Wired : Packet Drop Ratio vs Packet Rate
'out/GRAPH.graph' using 1:5
Packet Drop Ratio (%)
Packet Rate
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
100
150
200
250
300
350
400
450
500

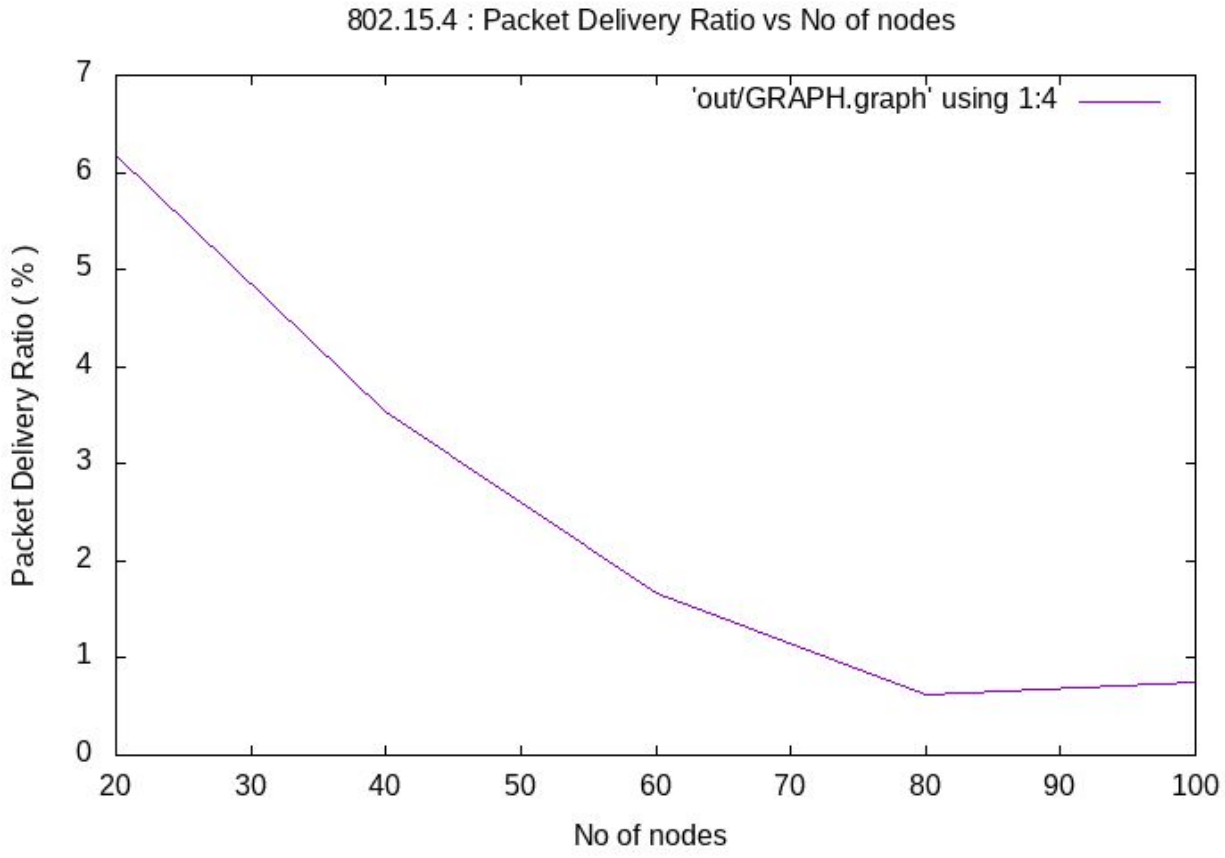

Wired : Throughput vs Packet Rate
'out/GRAPH.graph' using 1:2
Throughput (bit/second)
1.1x10 7
1.05x10 7
1x10 7
9.5x10 6
9x10 6
8.5x10 6
8x10 6
7.5x10 6
7x10 6
100
150
200
250
300
350
400
450
500
Packet Rate

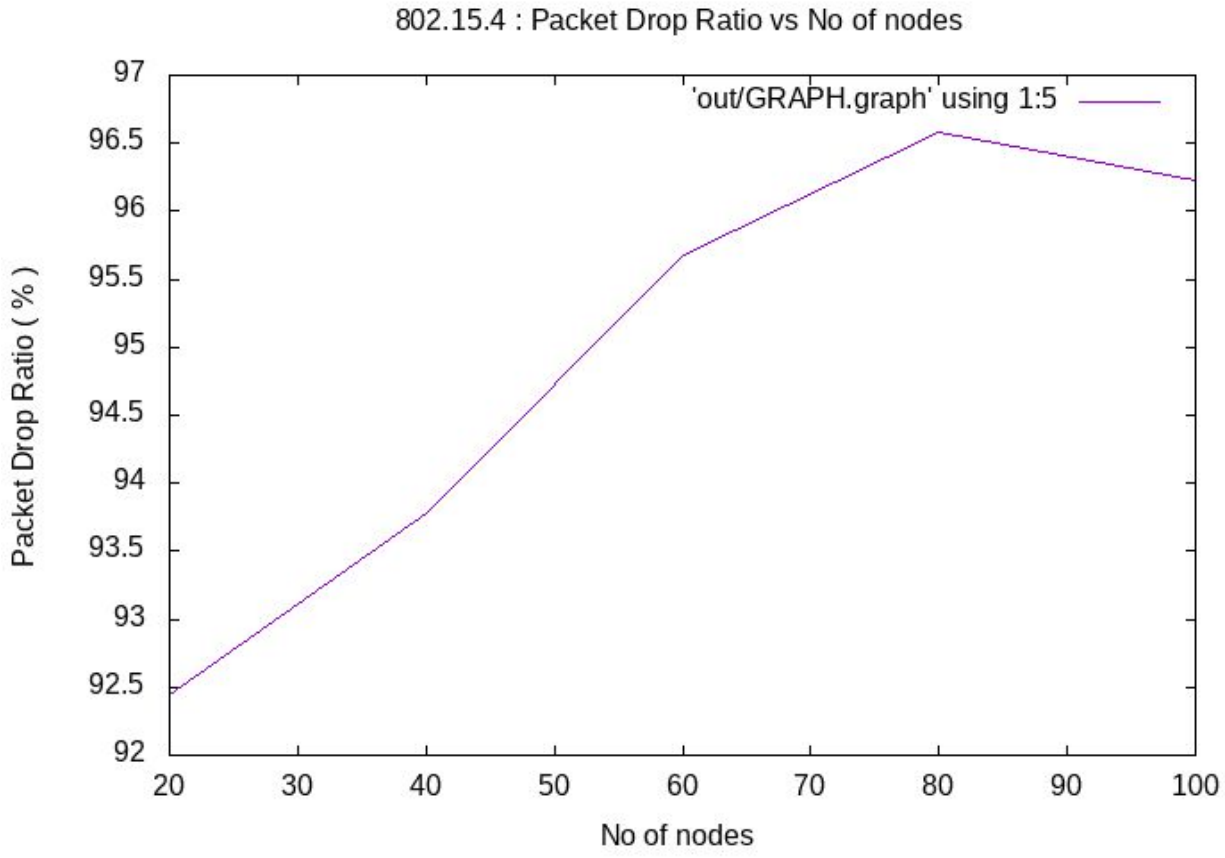
802.15.4

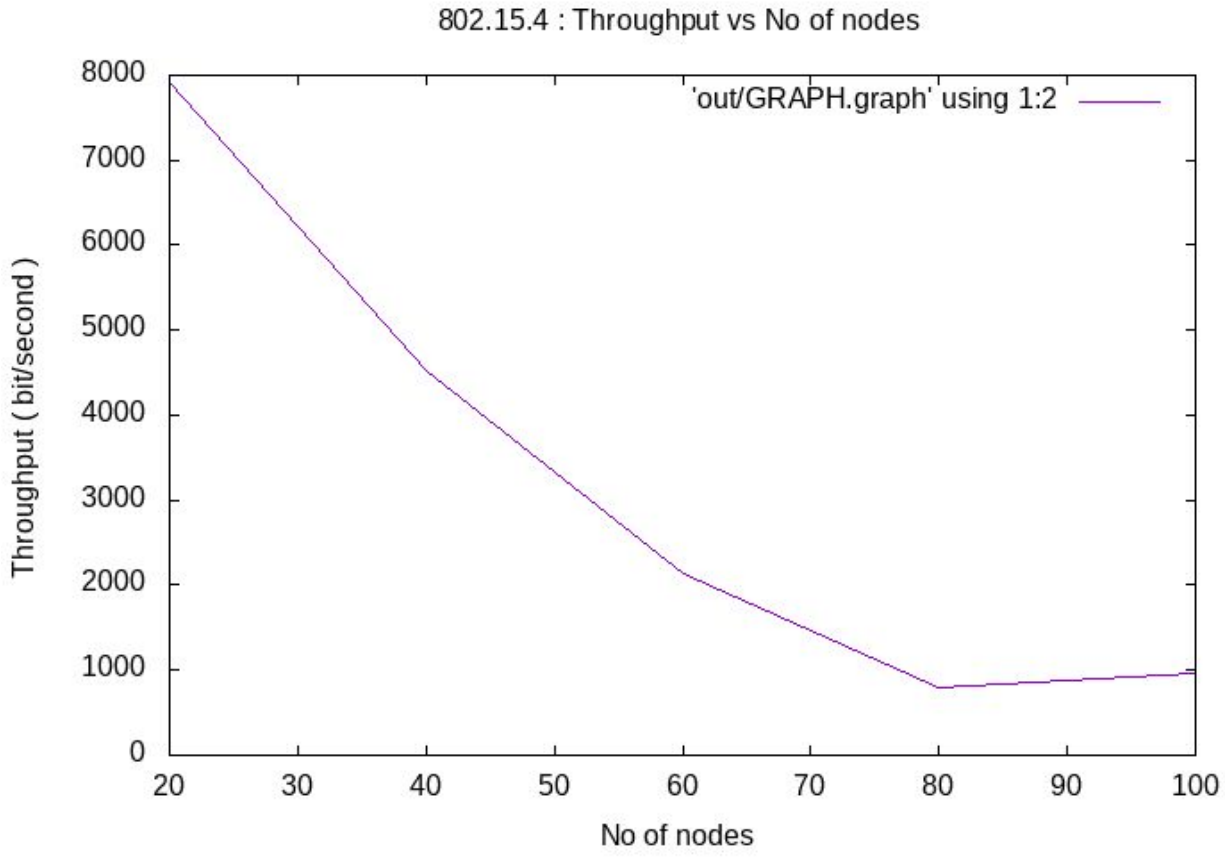
(AODV)

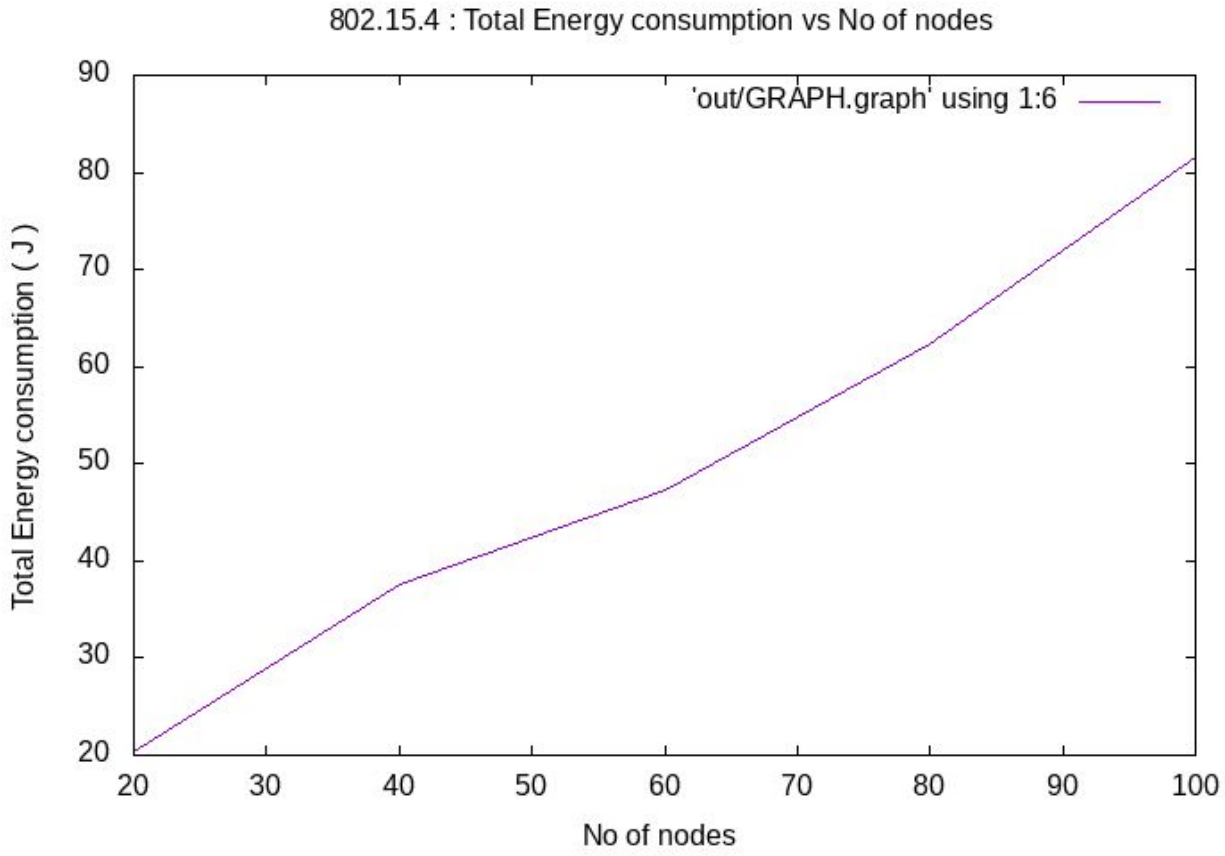

802.15.4 : Average Delay vs No of nodes
'out/GRAPH.graph' using 1:3
Average Delay (second)
No of nodes
0.2
0.19
0.18
0.17
0.16
0.15
0.14
0.13
20
30
40
50
60
70
80
90
100

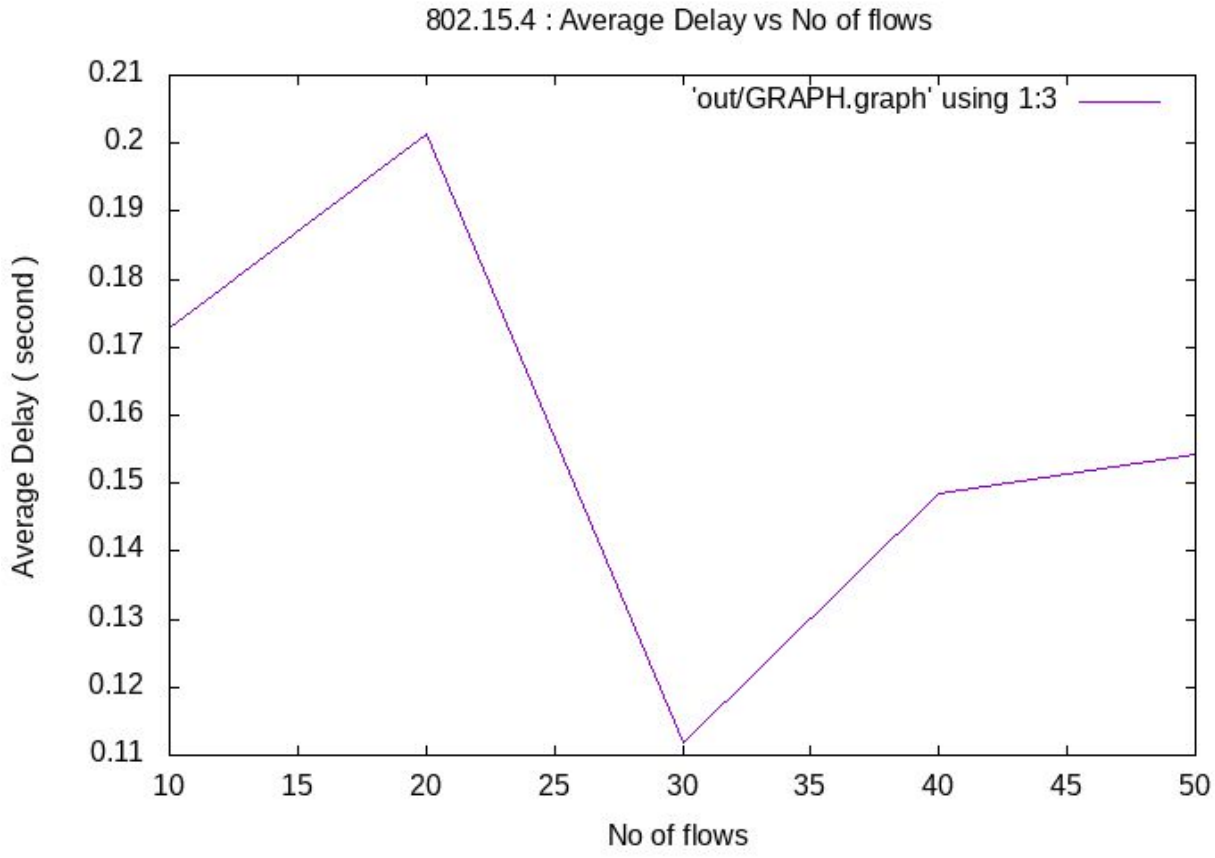

802.15.4 : Energy per byte vs No of nodes
'out/GRAPH.graph' using 1:7
Energy per byte (J)
No of nodes
0.25
0.2
0.15
0.1
0.05
0
20
30
40
50
60
70
80
90
100

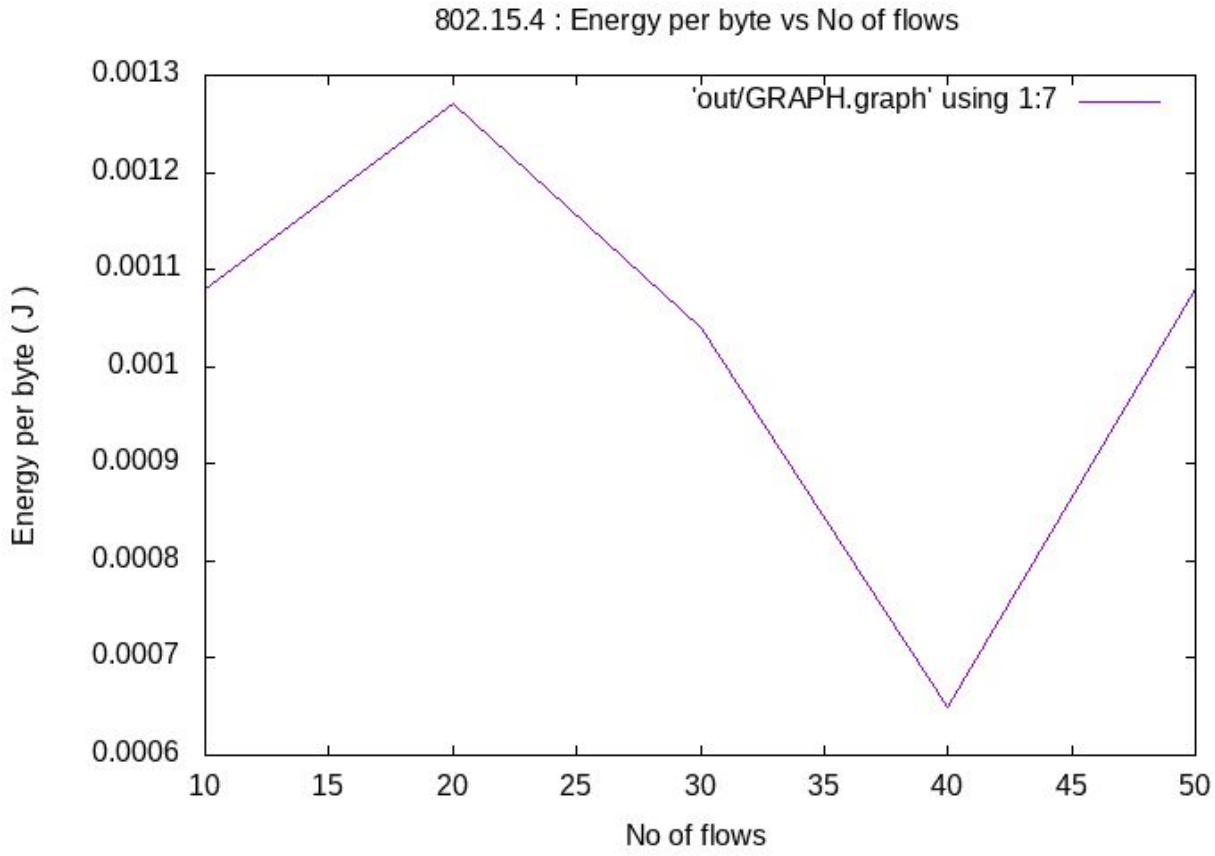

802.15.4 : Packet Delivery Ratio vs No of nodes
'out/GRAPH.graph' using 1:4
Packet Delivery Ratio (%)
No of nodes
0
1
2
3
4
5
6
7
20
30
40
50
60
70
80
90
100

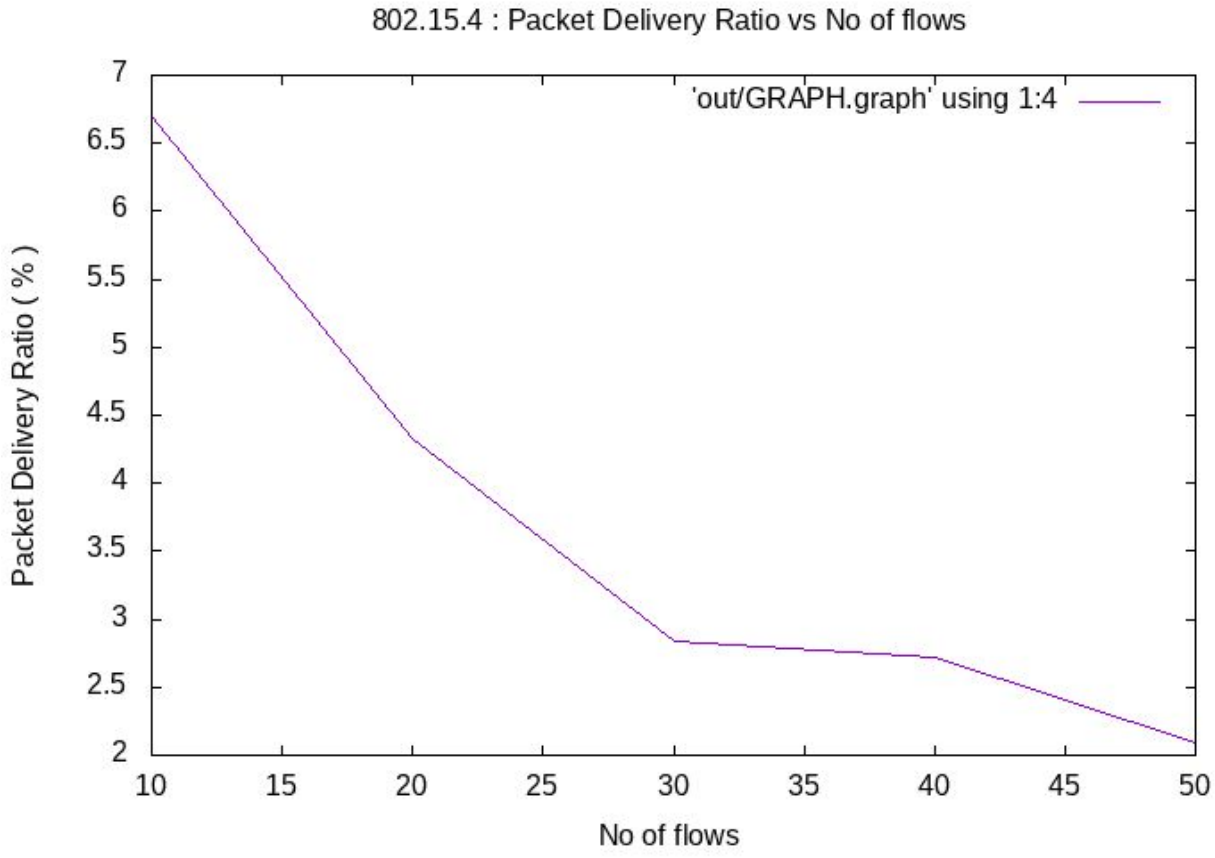

802.15.4 : Packet Drop Ratio vs No of nodes
'out/GRAPH.graph' using 1:5
Packet Drop Ratio (%)
No of nodes
97
96.5
96
95.5
95
94.5
94
93.5
93
92.5
92
20
30
40
50
60
70
80
90
100

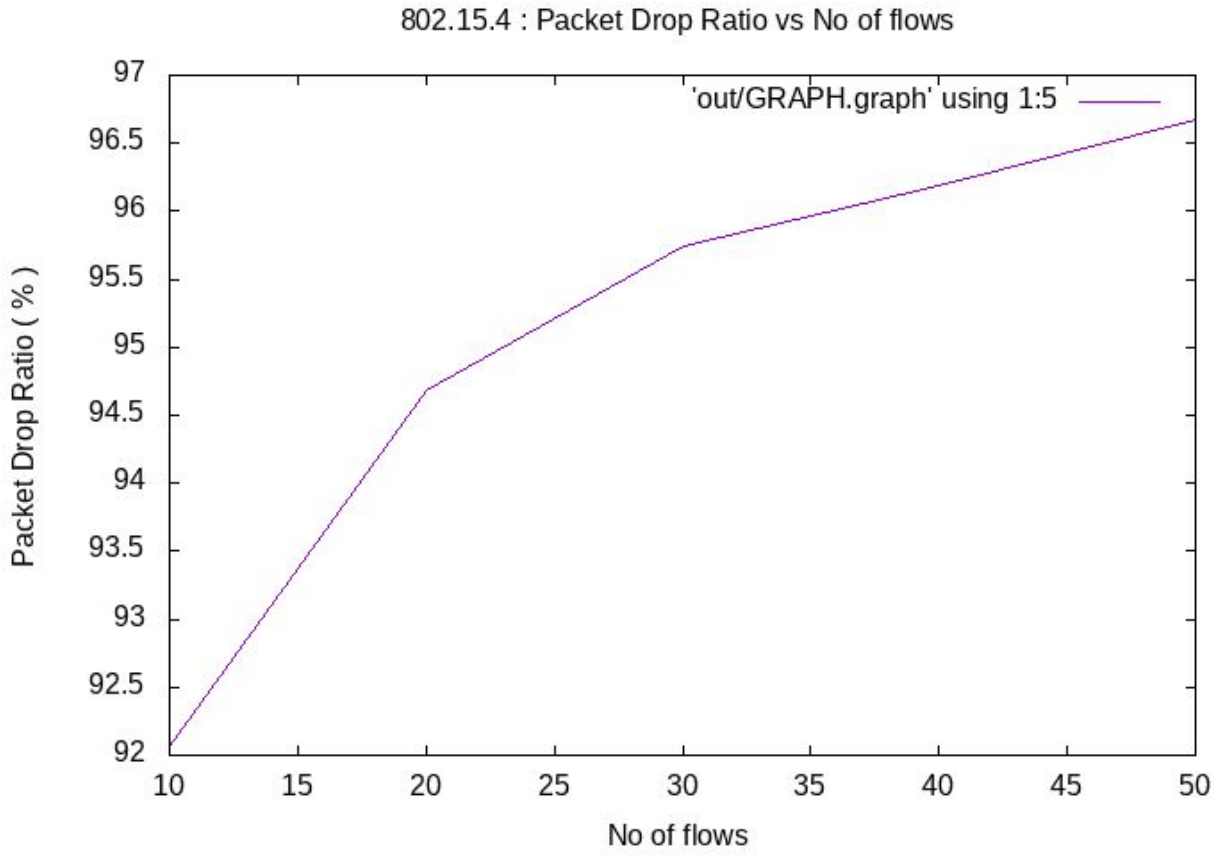

802.15.4 : Throughput vs No of nodes
'out/GRAPH.graph' using 1:2
Throughput (bit/second)
No of nodes
8000
7000
6000
5000
4000
3000
2000
1000
0
20
30
40
50
60
70
80
90
100

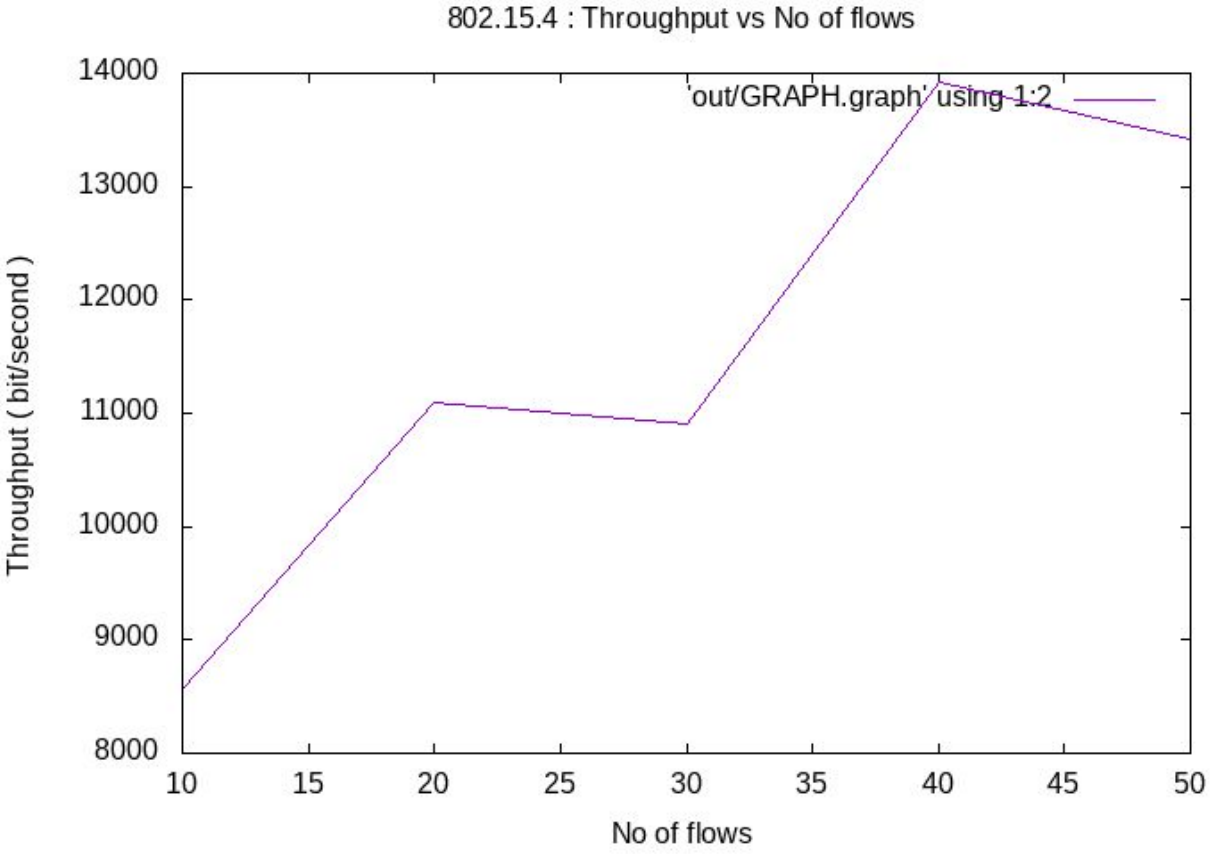

802.15.4 : Total Energy consumption vs No of nodes
'out/GRAPH.graph' using 1:6
Total Energy consumption (J)
No of nodes
90
80
70
60
50
40
30
20
20
30
40
50
60
70
80
90
100

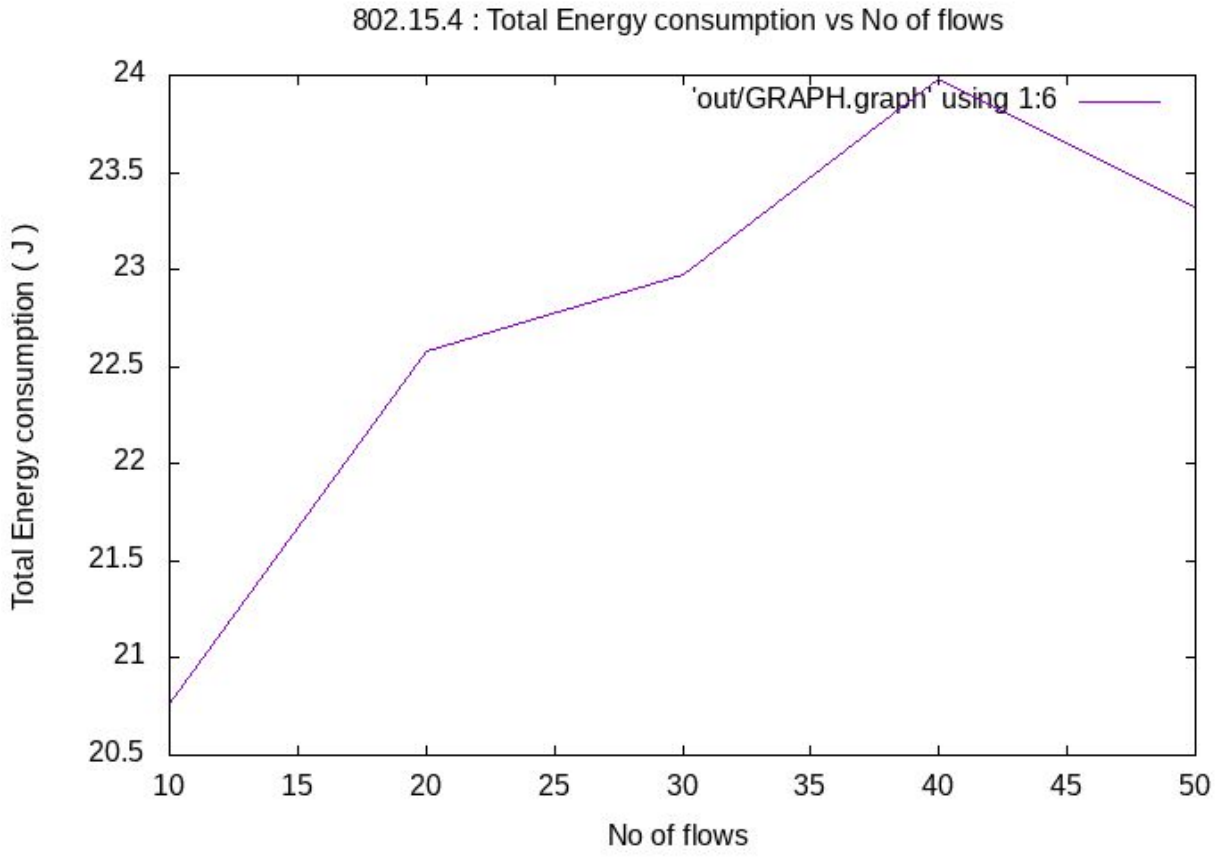

802.15.4 : Average Delay vs No of flows
'out/GRAPH.graph' using 1:3
Average Delay (second)
No of flows
0.21
0.2
0.19
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
10
15
20
25
30
35
40
45
50

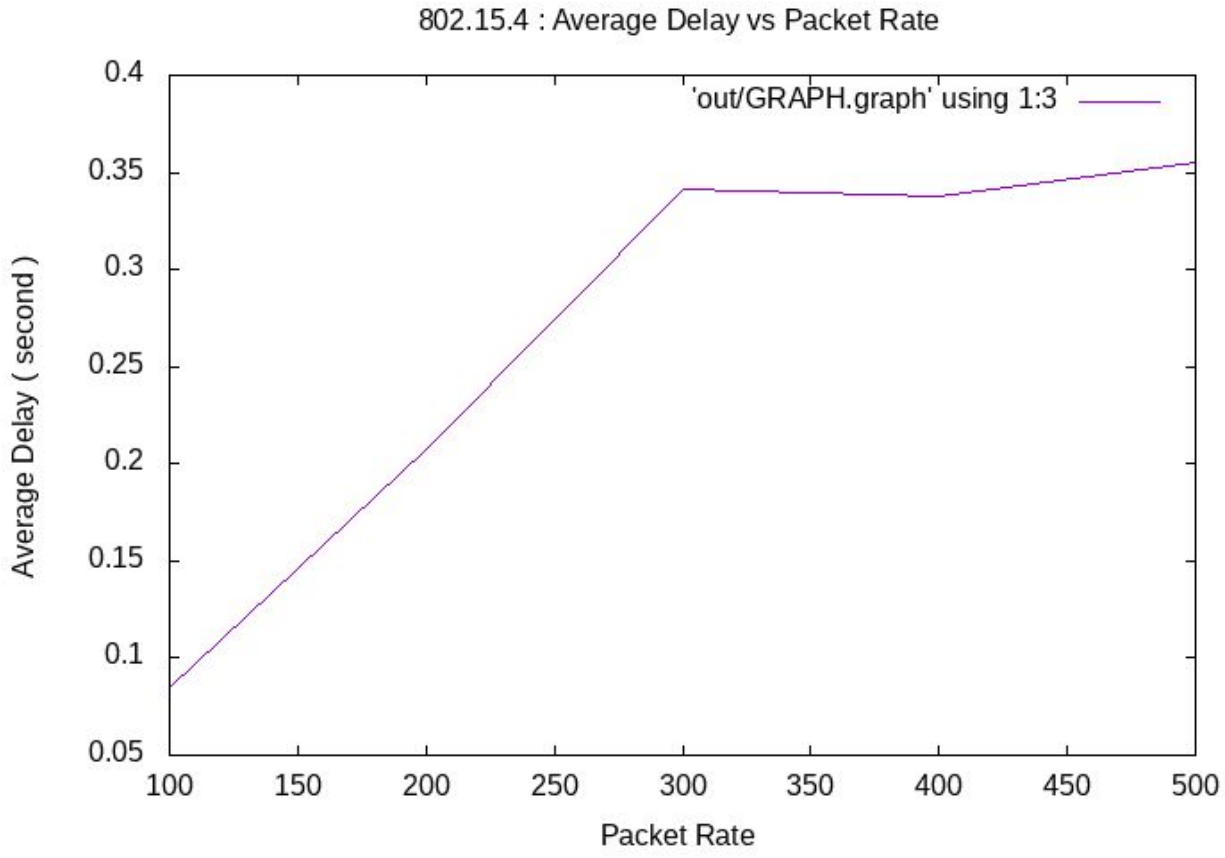

802.15.4 : Energy per byte vs No of flows
'out/GRAPH.graph' using 1:7
Energy per byte (J)
No of flows
0.0013
0.0012
0.0011
0.001
0.0009
0.0008
0.0007
0.0006
10
15
20
25
30
35
40
45
50

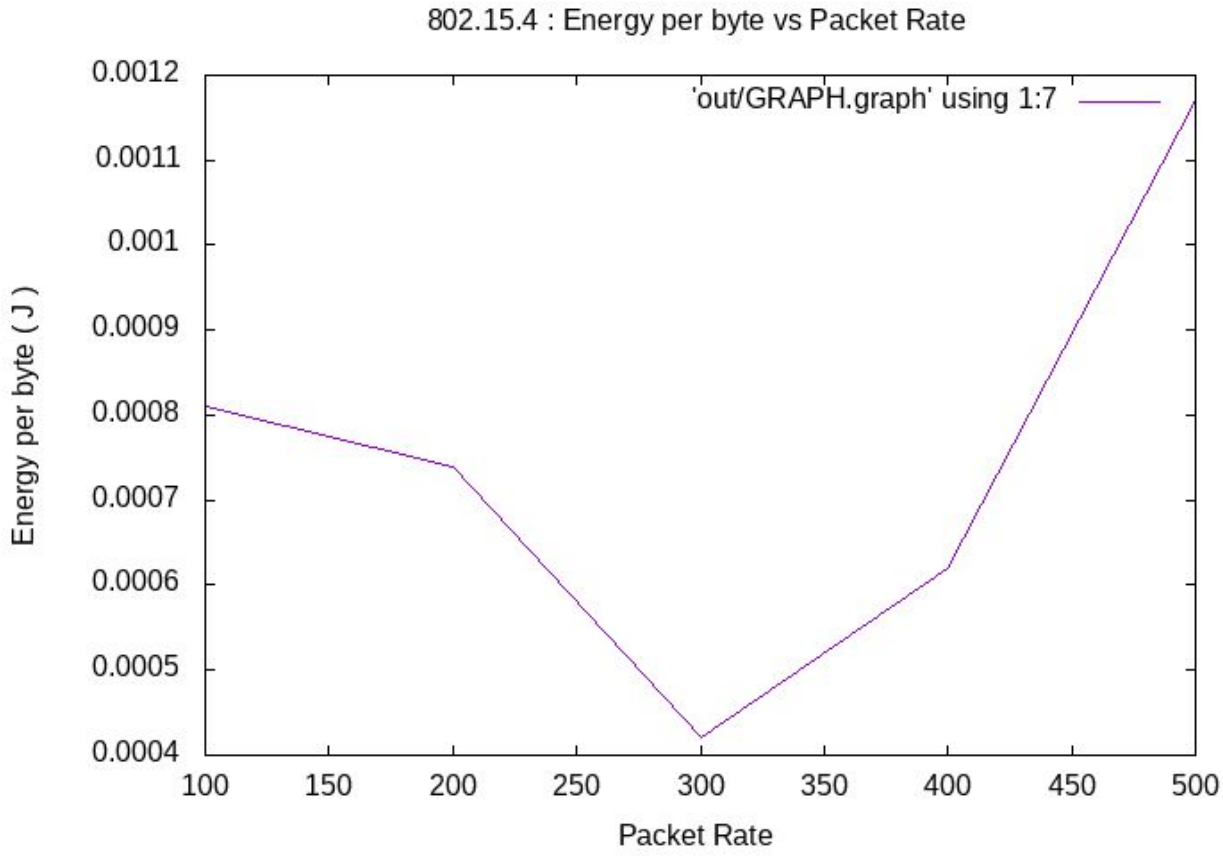

802.15.4 : Packet Delivery Ratio vs No of flows
'out/GRAPH.graph' using 1:4
Packet Delivery Ratio (%)
No of flows
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
10
15
20
25
30
35
40
45
50

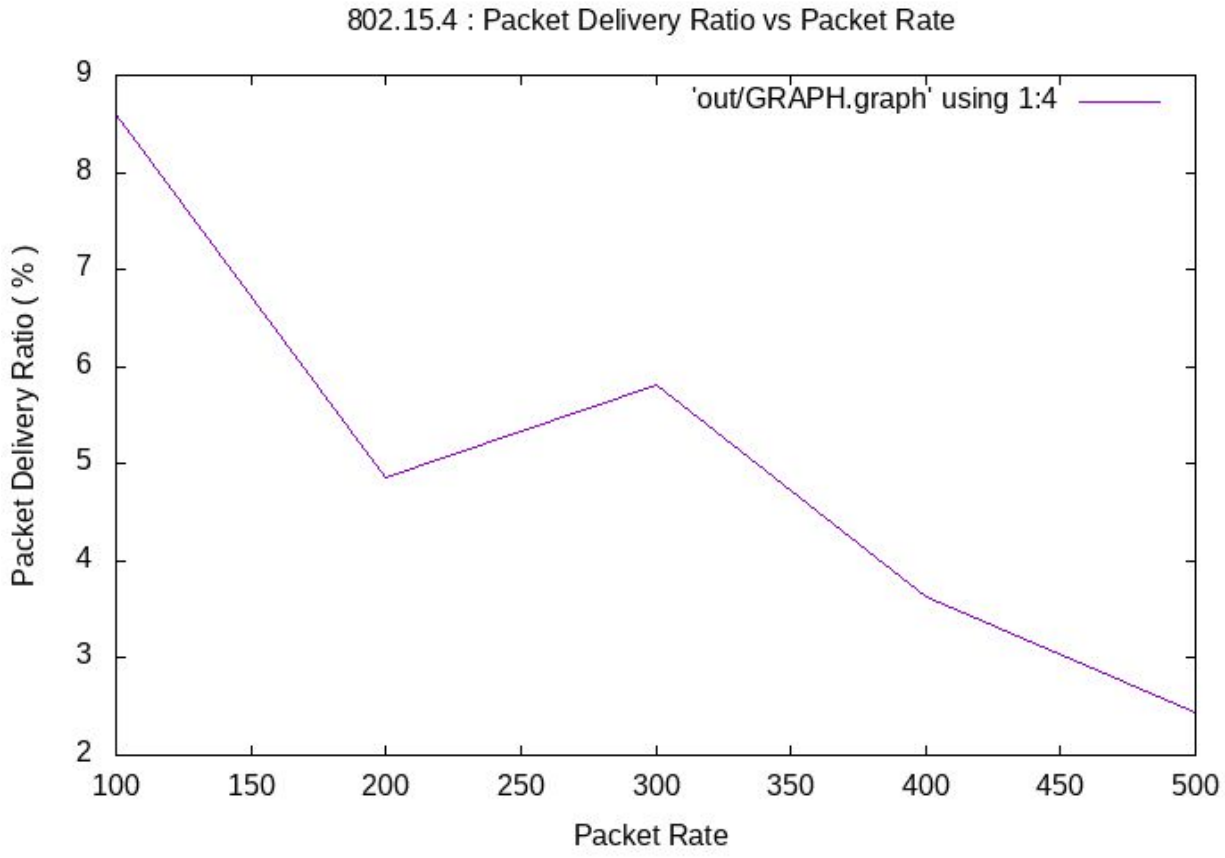

802.15.4 : Packet Drop Ratio vs No of flows
'out/GRAPH.graph' using 1:5
Packet Drop Ratio (%)
No of flows
97
96.5
96
95.5
95
94.5
94
93.5
93
92.5
92
10
15
20
25
30
35
40
45
50

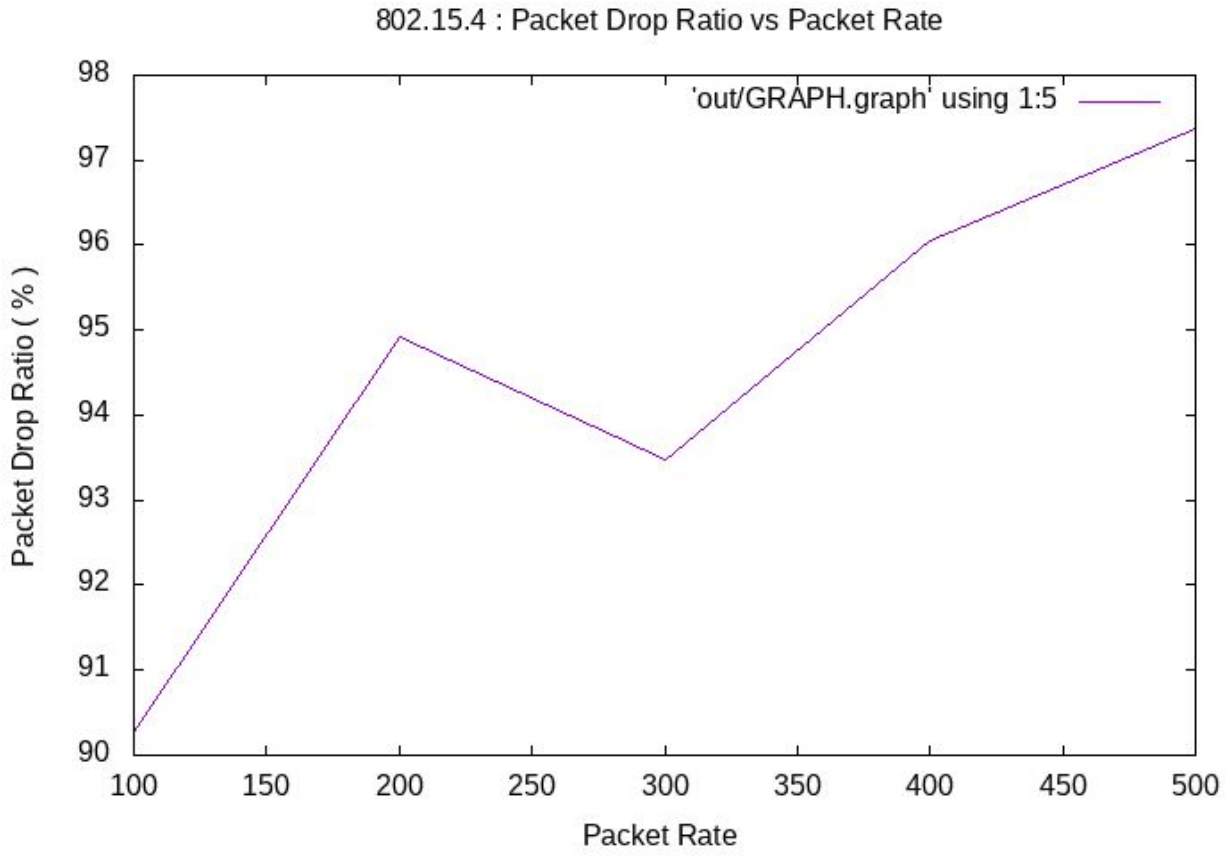

802.15.4 : Throughput vs No of flows
'out/GRAPH.graph' using 1:2
Throughput (bit/second)
No of flows
14000
13000
12000
11000
10000
9000
8000
10
15
20
25
30
35
40
45
50

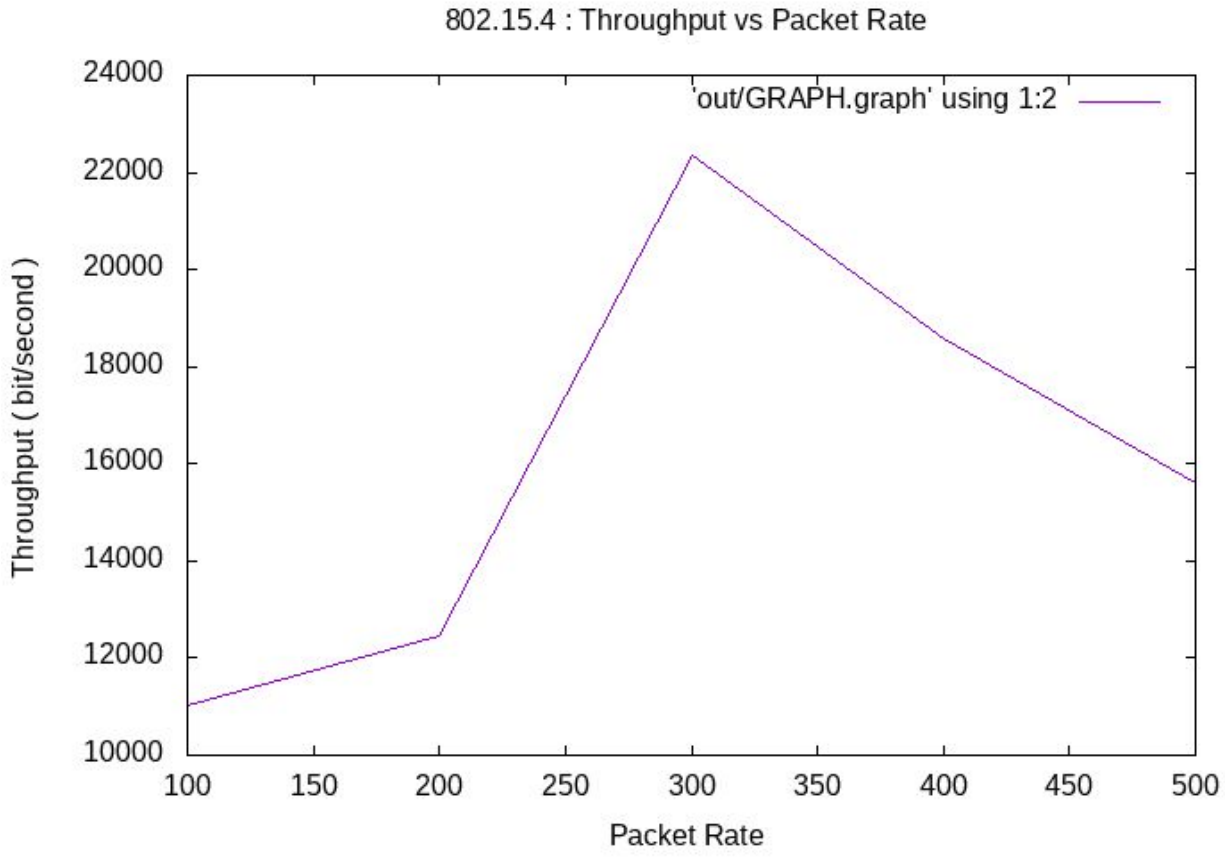

802.15.4 : Total Energy consumption vs No of flows
'out/GRAPH.graph' using 1:6
Total Energy consumption (J)
No of flows
24
23.5
23
22.5
22
21.5
21
20.5
10
15
20
25
30
35
40
45
50

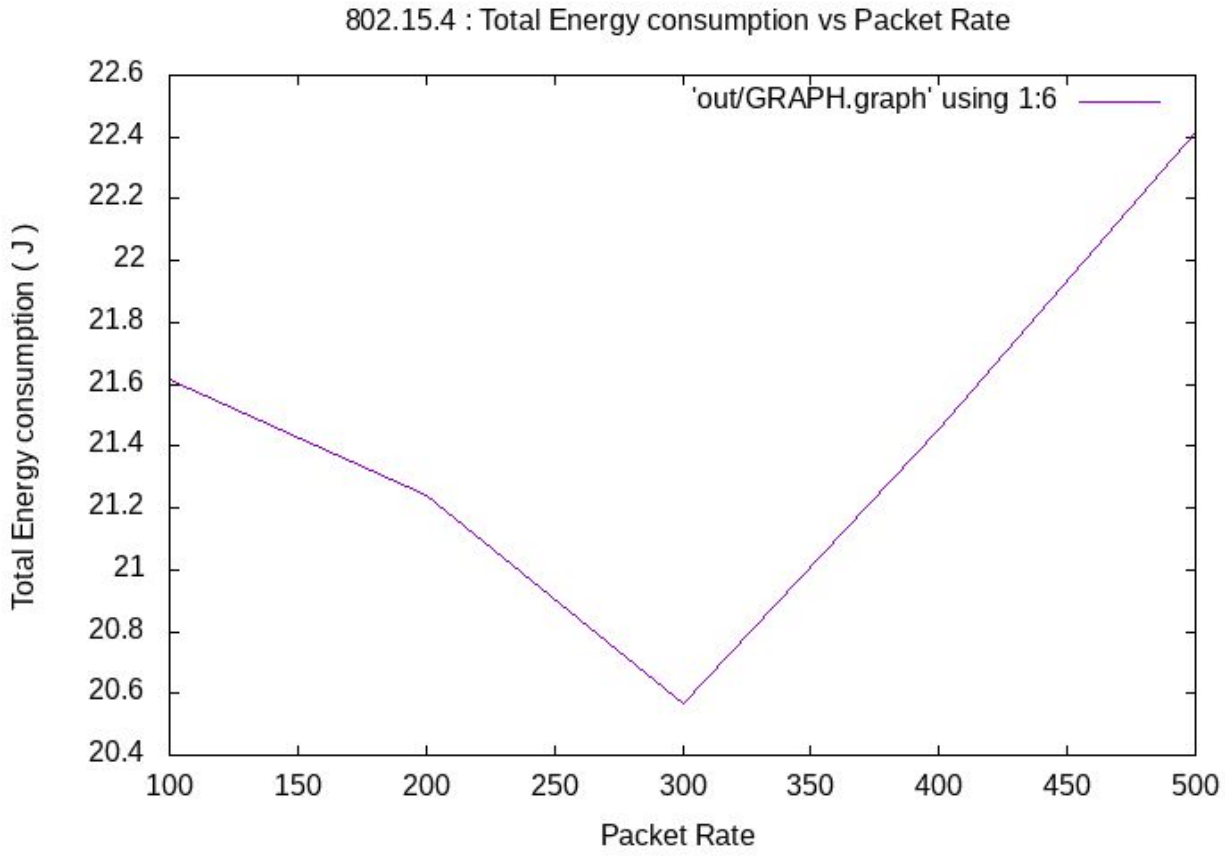

802.15.4 : Average Delay vs Packet Rate
'out/GRAPH.graph' using 1:3
Average Delay (second)
Packet Rate
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
100
150
200
250
300
350
400
450
500

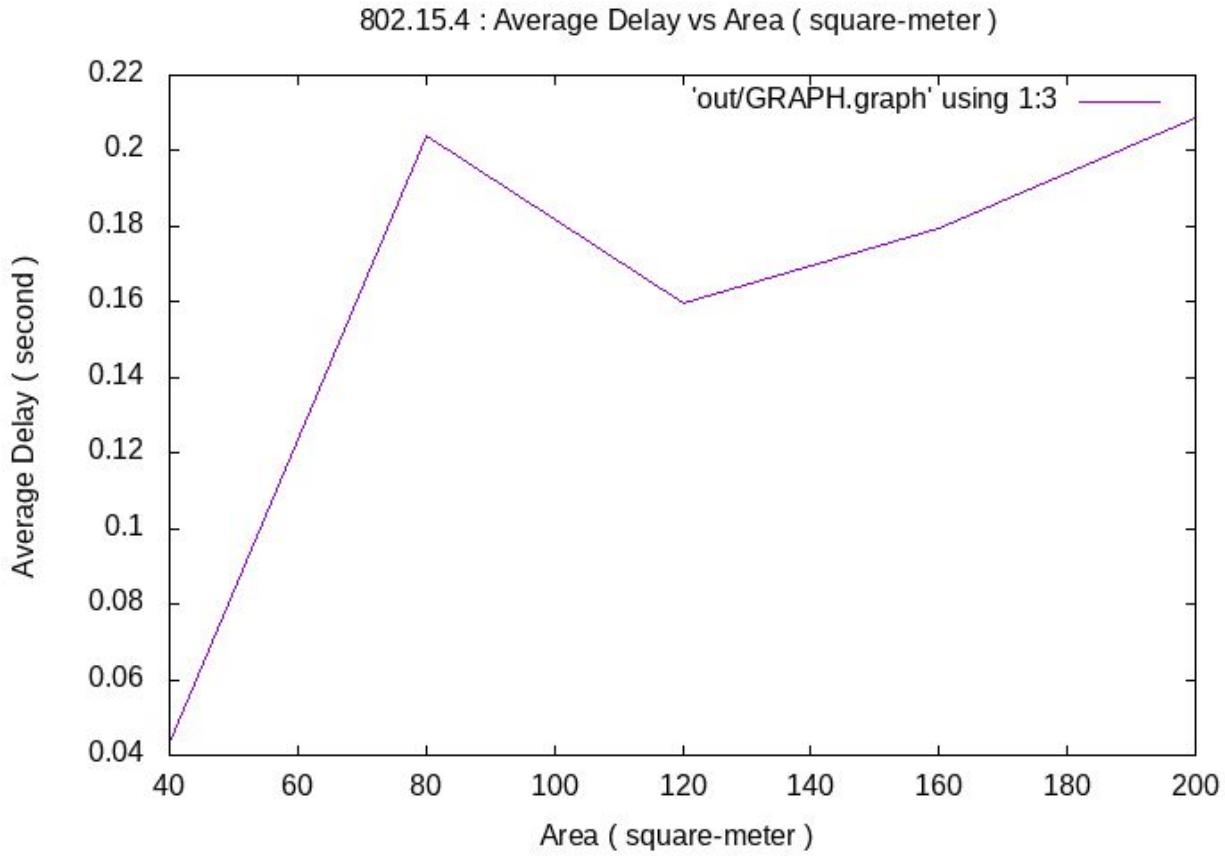

802.15.4 : Energy per byte vs Packet Rate
'out/GRAPH.graph' using 1:7
Energy per byte (J)
0.0012
0.0011
0.001
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
100
150
200
250
300
350
400
450
500
Packet Rate

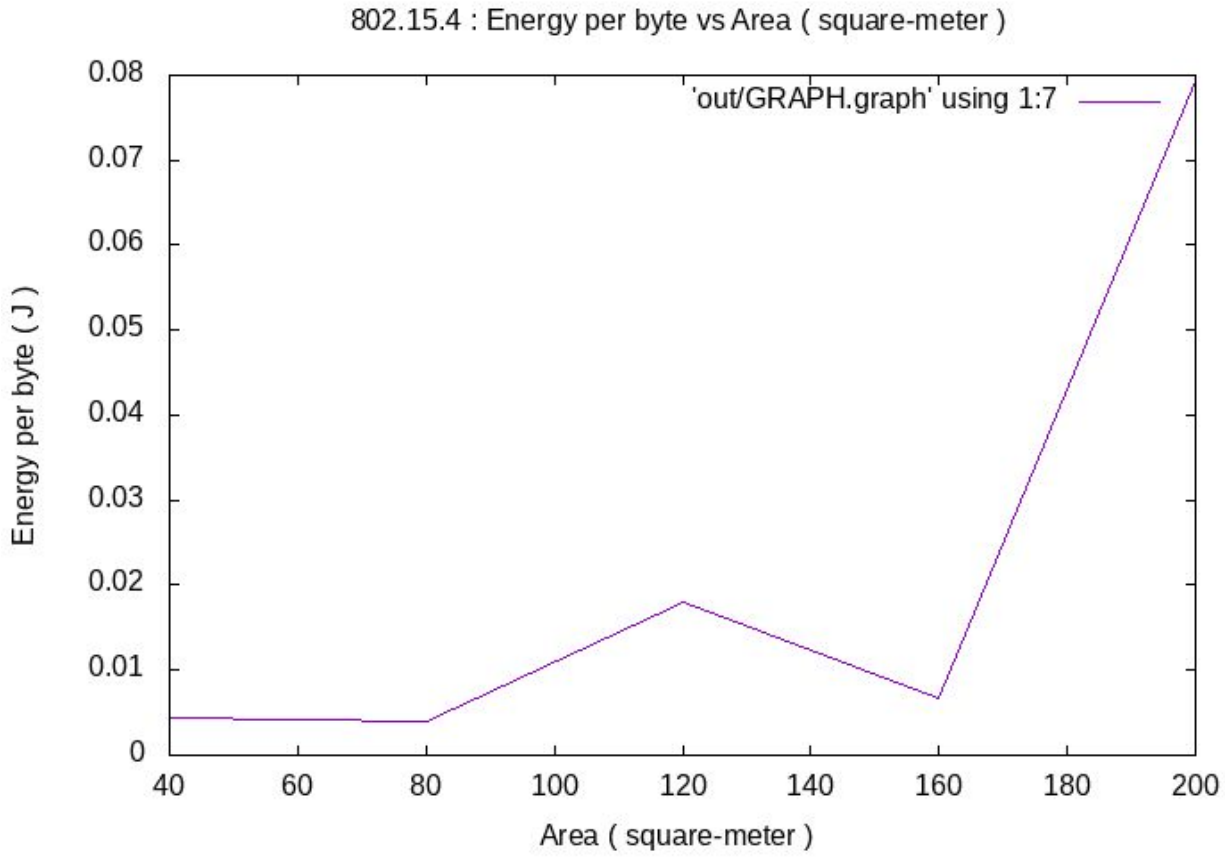

802.15.4 : Packet Delivery Ratio vs Packet Rate
'out/GRAPH.graph' using 1:4
Packet Delivery Ratio (%)
Packet Rate
9
8
7
6
5
4
3
2
100
150
200
250
300
350
400
450
500

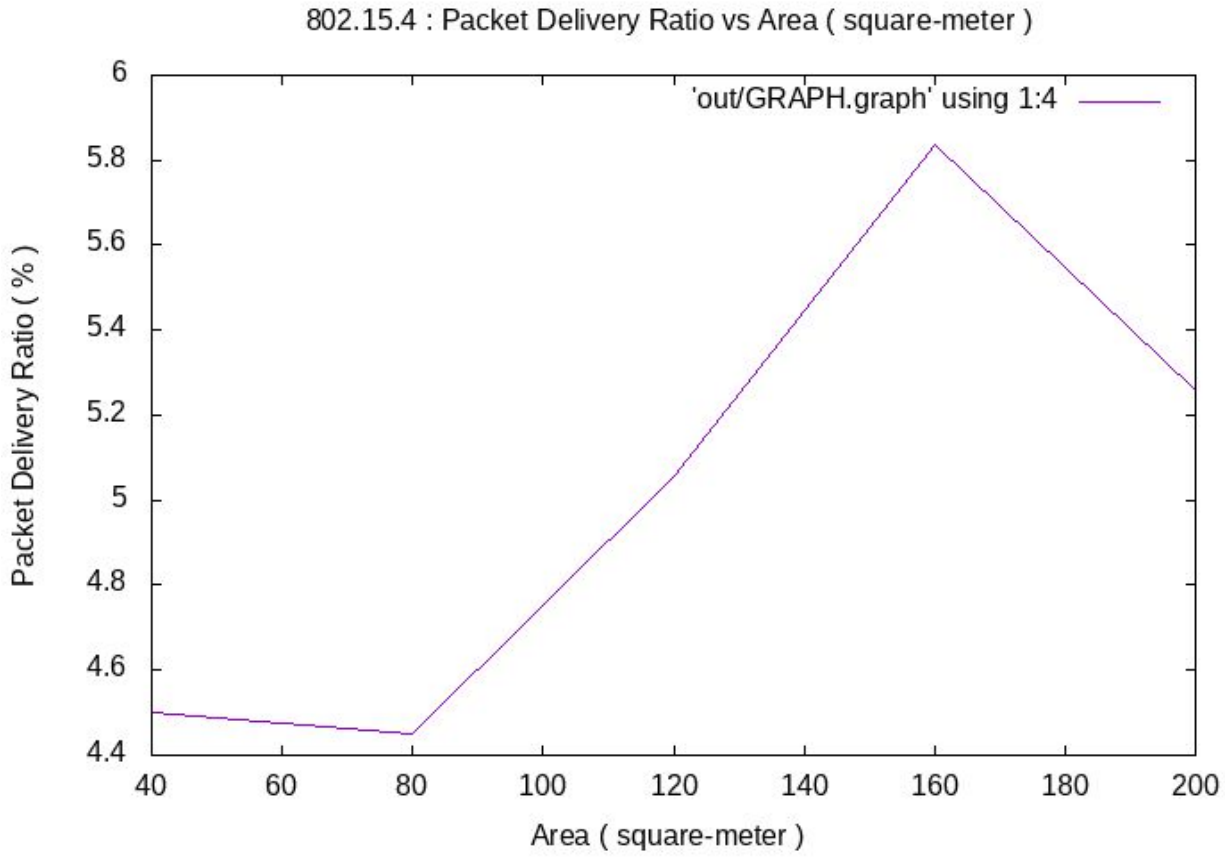

802.15.4 : Packet Drop Ratio vs Packet Rate
'out/GRAPH.graph' using 1:5
Packet Drop Ratio (%)
Packet Rate
98
97
96
95
94
93
92
91
90
100
150
200
250
300
350
400
450
500

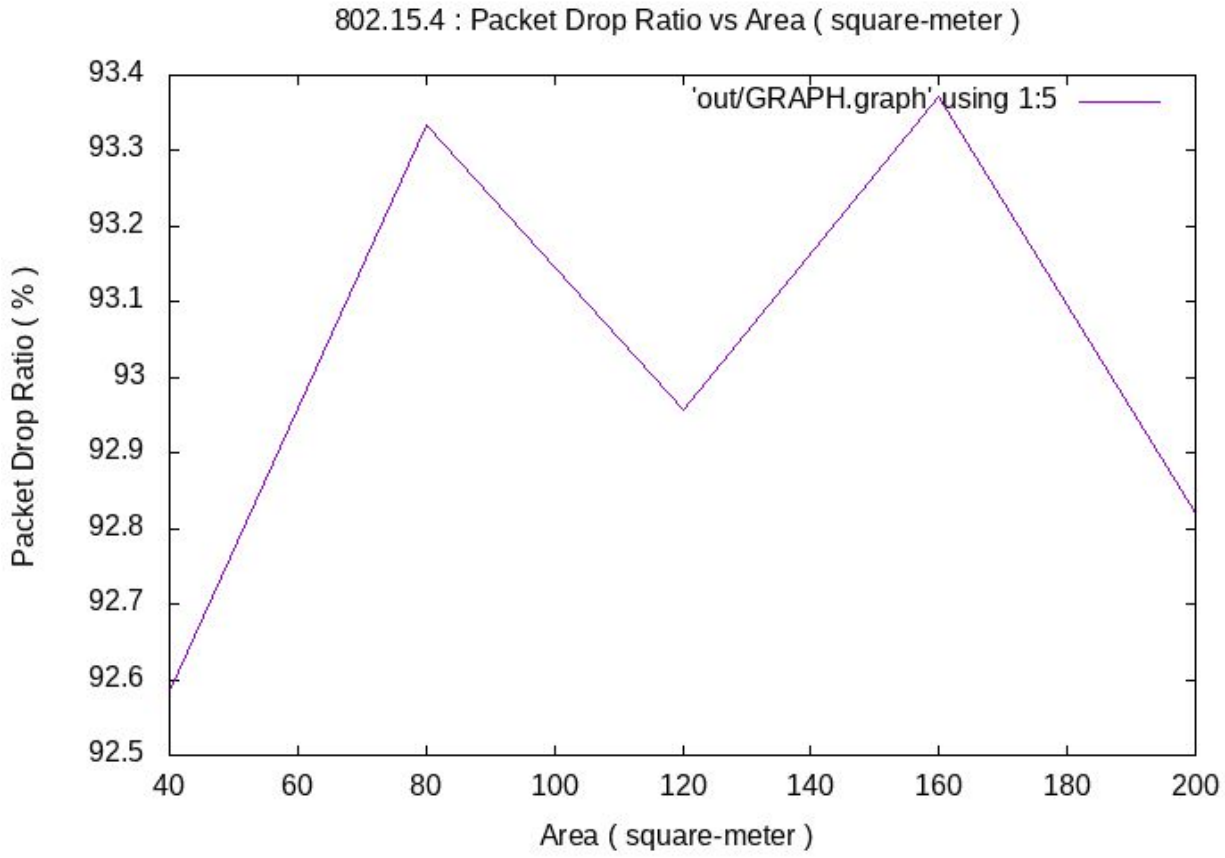

802.15.4 : Throughput vs Packet Rate
'out/GRAPH.graph' using 1:2
Throughput (bit/second)
Packet Rate
24000
22000
20000
18000
16000
14000
12000
10000
100
150
200
250
300
350
400
450
500

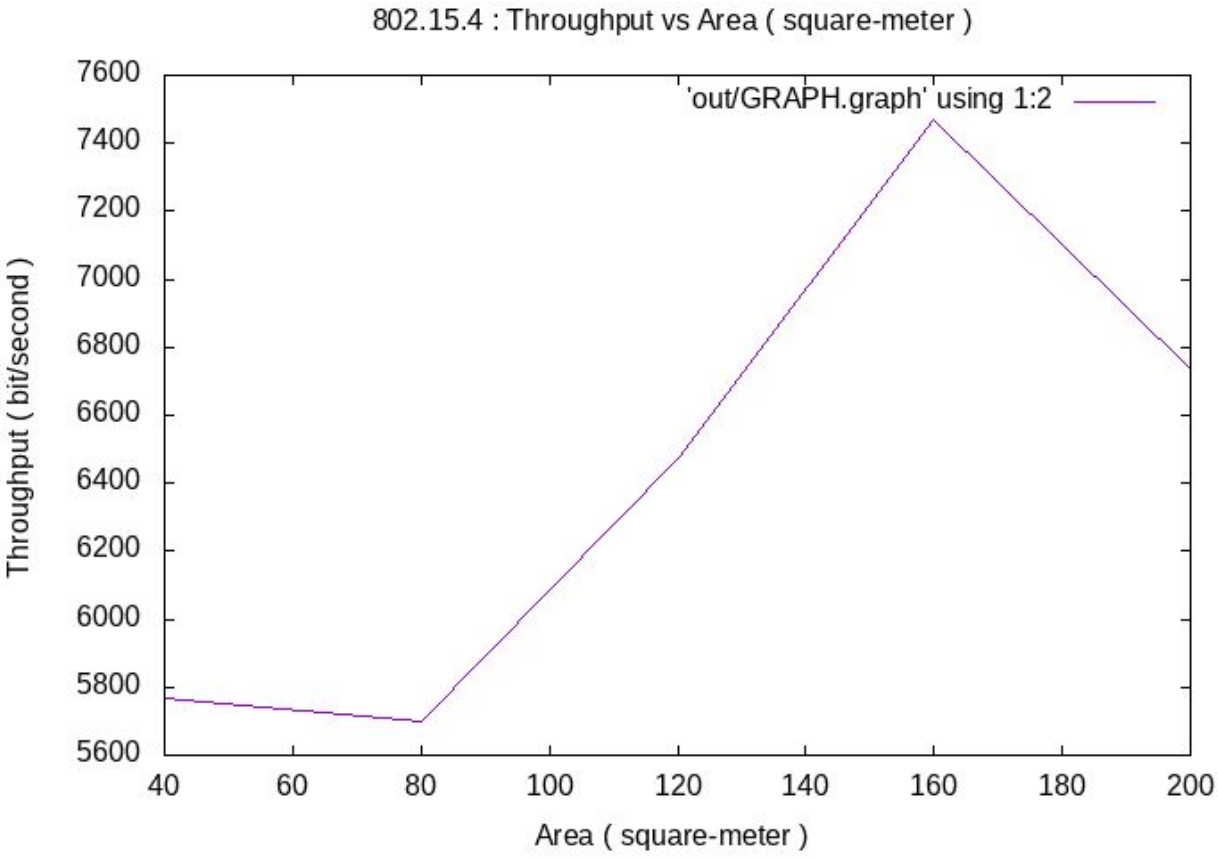

802.15.4 : Total Energy consumption vs Packet Rate
'out/GRAPH.graph' using 1:6
Total Energy consumption (J)
Packet Rate
22.6
22.4
22.2
22
21.8
21.6
21.4
21.2
21
20.8
20.6
20.4
100
150
200
250
300
350
400
450
500

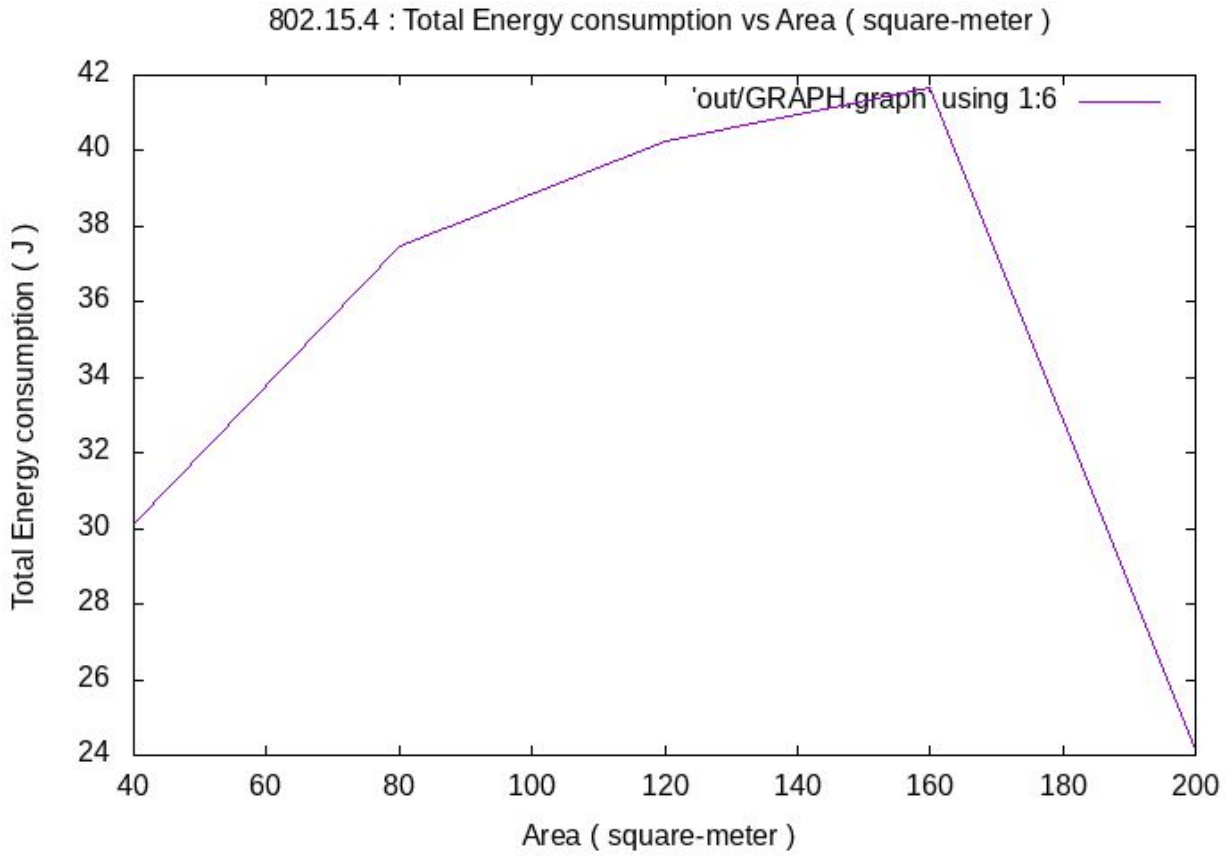

802.15.4 : Average Delay vs Area (square-meter)
'out/GRAPH.graph' using 1:3
Average Delay (second)
Area (square-meter)
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
40
60
80
100
120
140
160
180
200


802.15.4 : Energy per byte vs Area (square-meter)
'out/GRAPH.graph' using 1:7
Energy per byte (J)
Area (square-meter)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
40
60
80
100
120
140
160
180
200


802.15.4 : Packet Delivery Ratio vs Area (square-meter)
'out/GRAPH.graph' using 1:4
Packet Delivery Ratio (%)
Area (square-meter)
6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
40
60
80
100
120
140
160
180
200

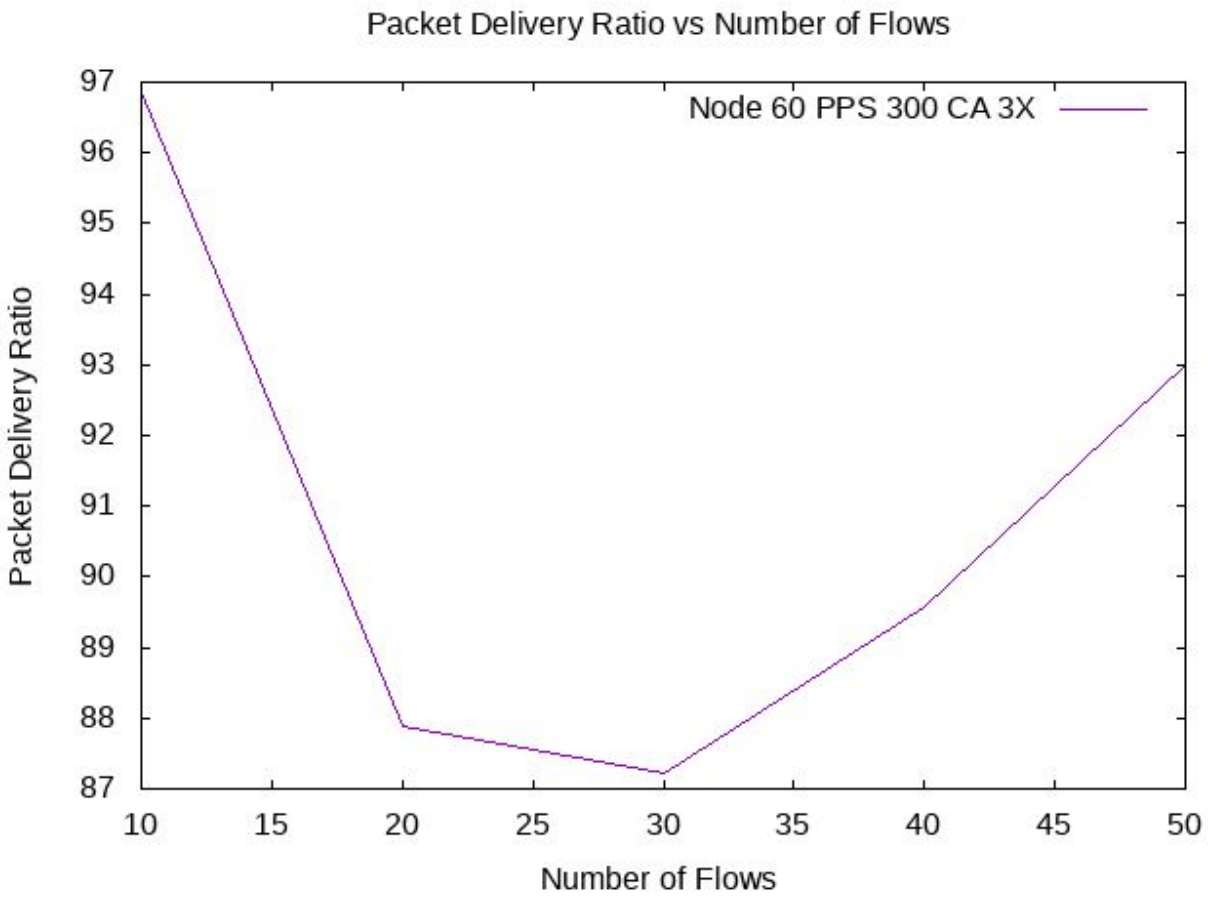

802.15.4 : Packet Drop Ratio vs Area (square-meter)
'out/GRAPH.graph' using 1:5
Packet Drop Ratio (%)
Area (square-meter)
93.4
93.3
93.2
93.1
93
92.9
92.8
92.7
92.6
92.5
40
60
80
100
120
140
160
180
200

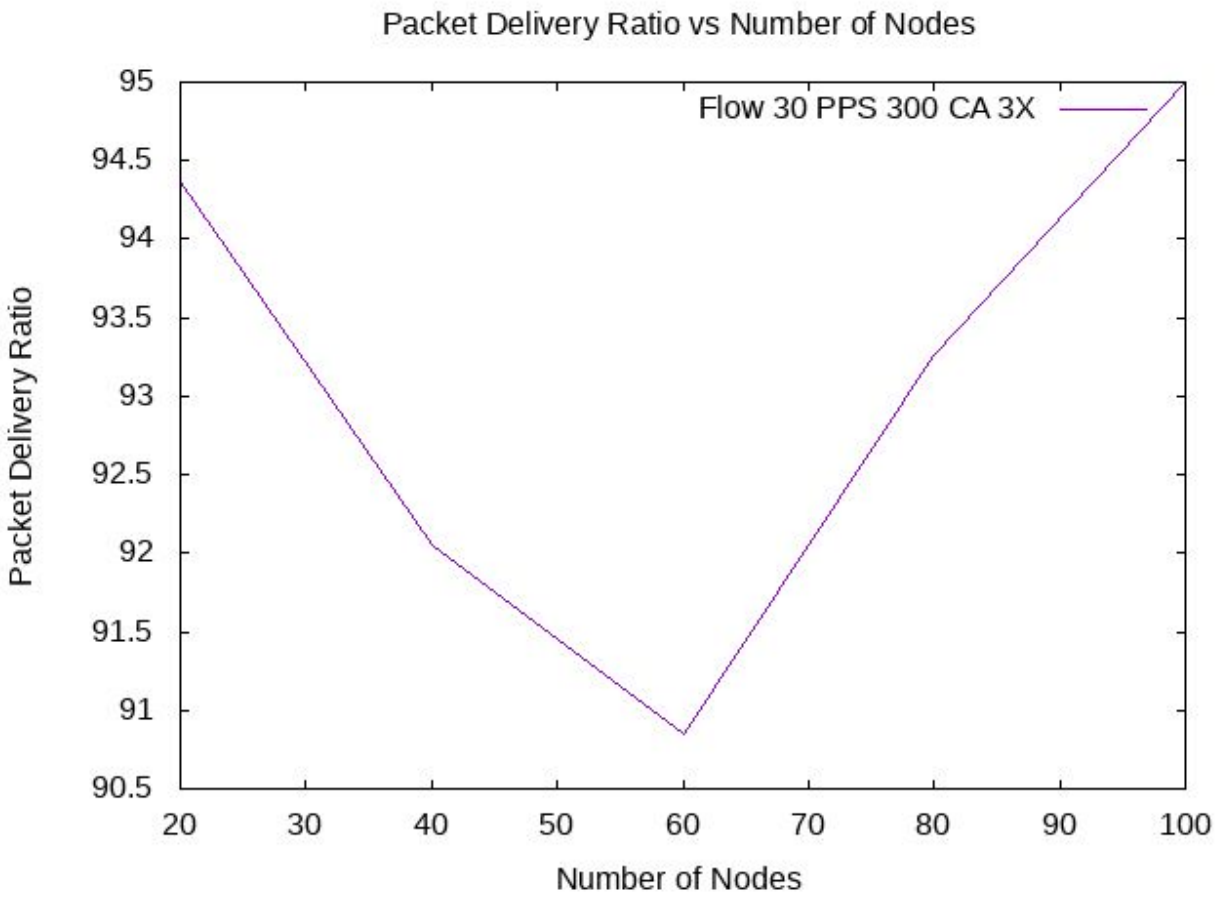

802.15.4 : Throughput vs Area (square-meter)
'out/GRAPH.graph' using 1:2
Throughput (bit/second)
Area (square-meter)
7600
7400
7200
7000
6800
6600
6400
6200
6000
5800
5600
40
60
80
100
120
140
160
180
200

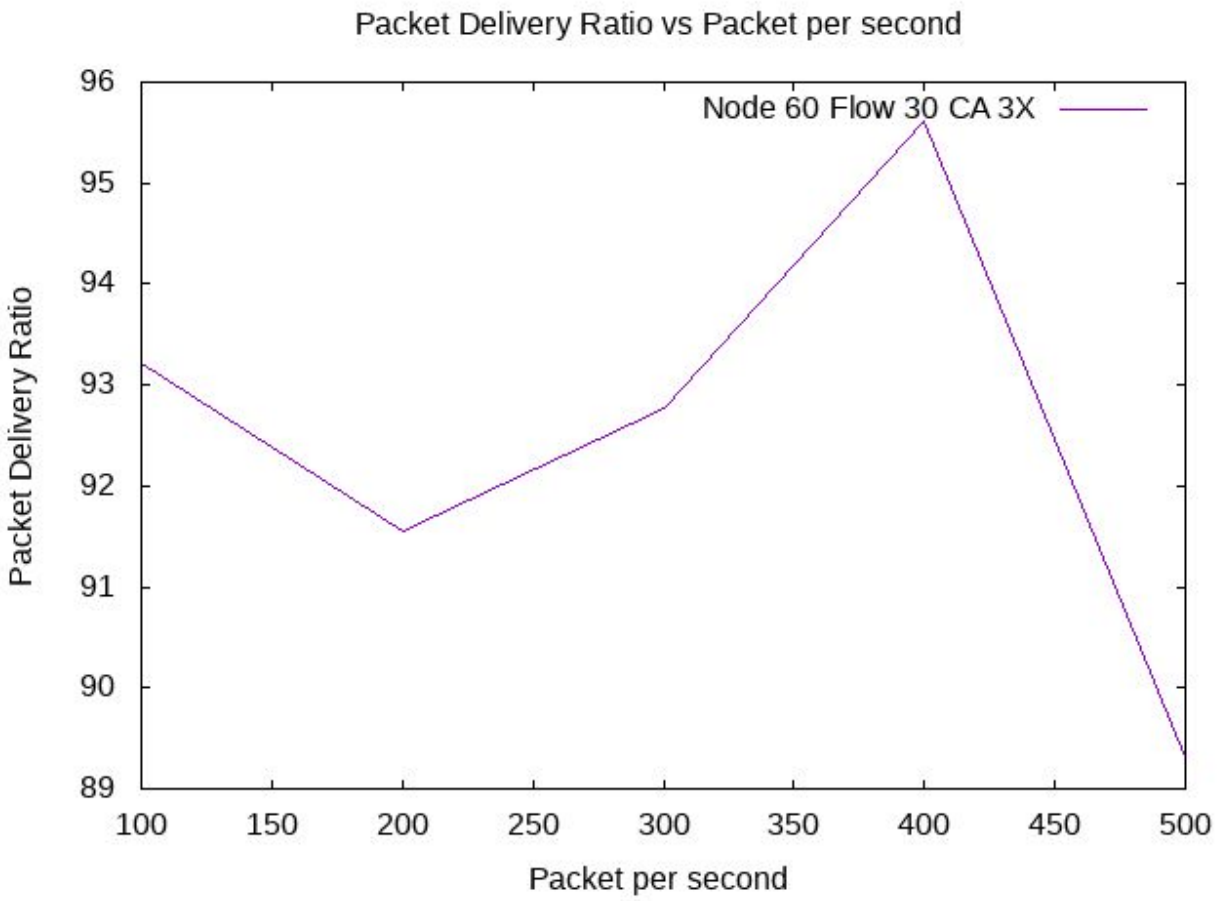

802.15.4 : Total Energy consumption vs Area (square-meter)
'out/GRAPH.graph' using 1:6
Total Energy consumption (J)
Area (square-meter)
42
40
38
36
34
32
30
28
26
24
40
60
80
100
120
140
160
180
200

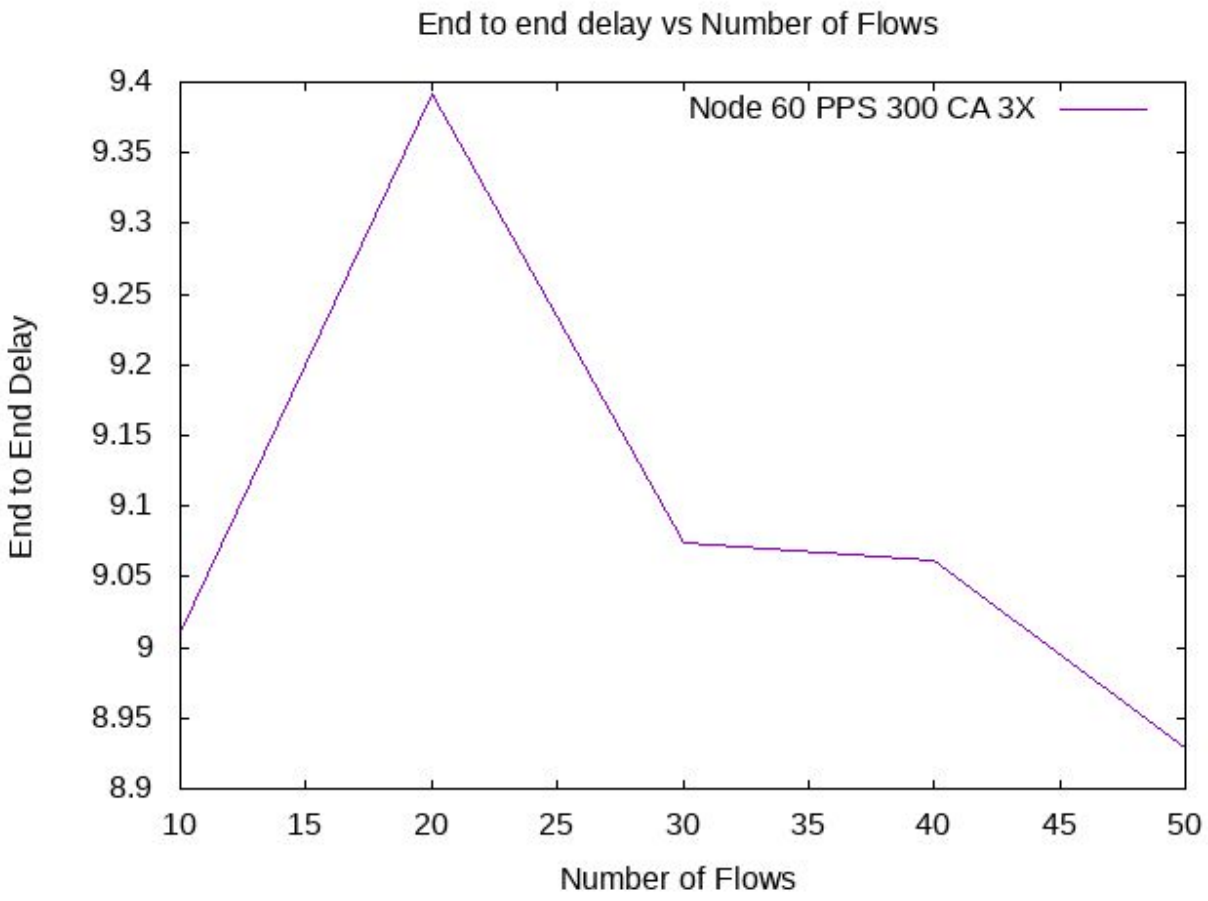
802.15.4

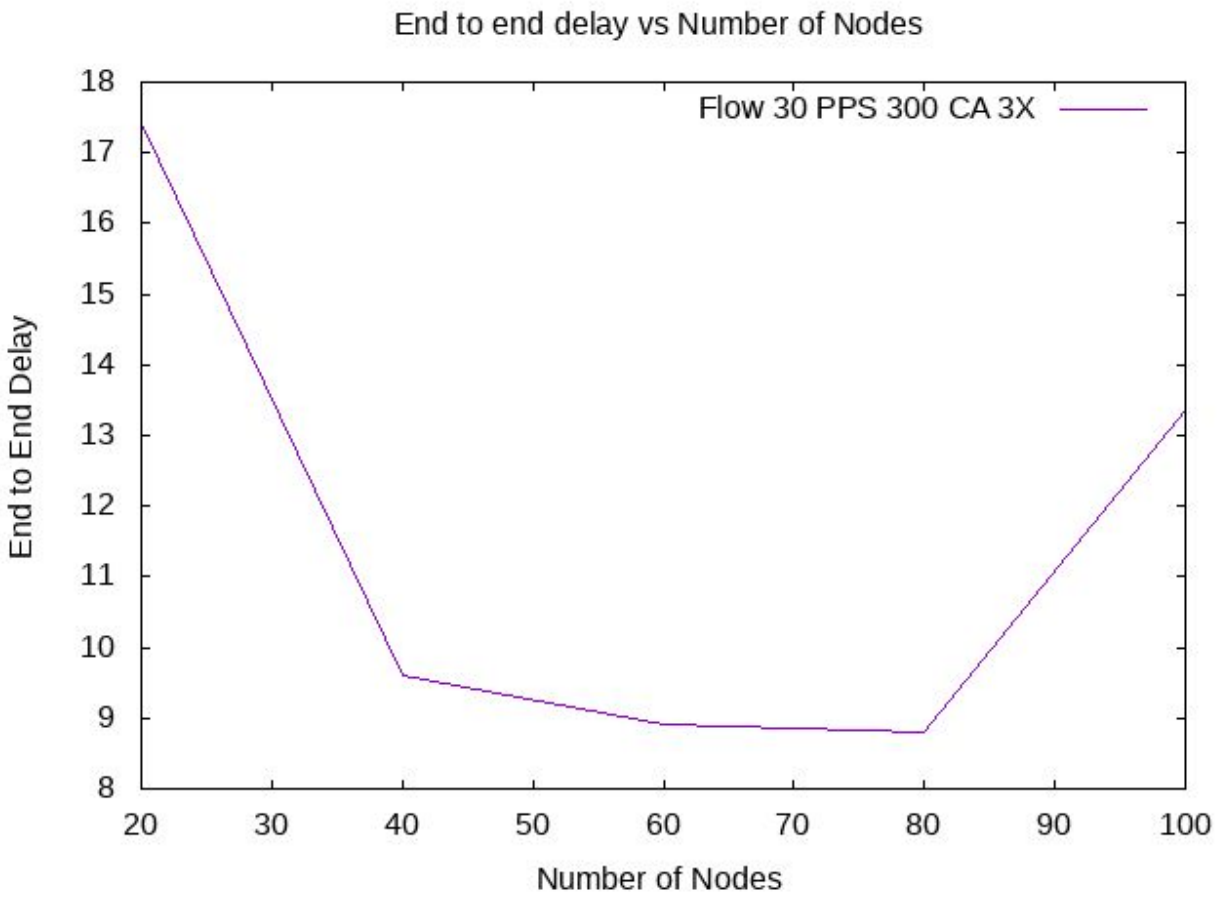
(DSDV with larger Transmission Range)

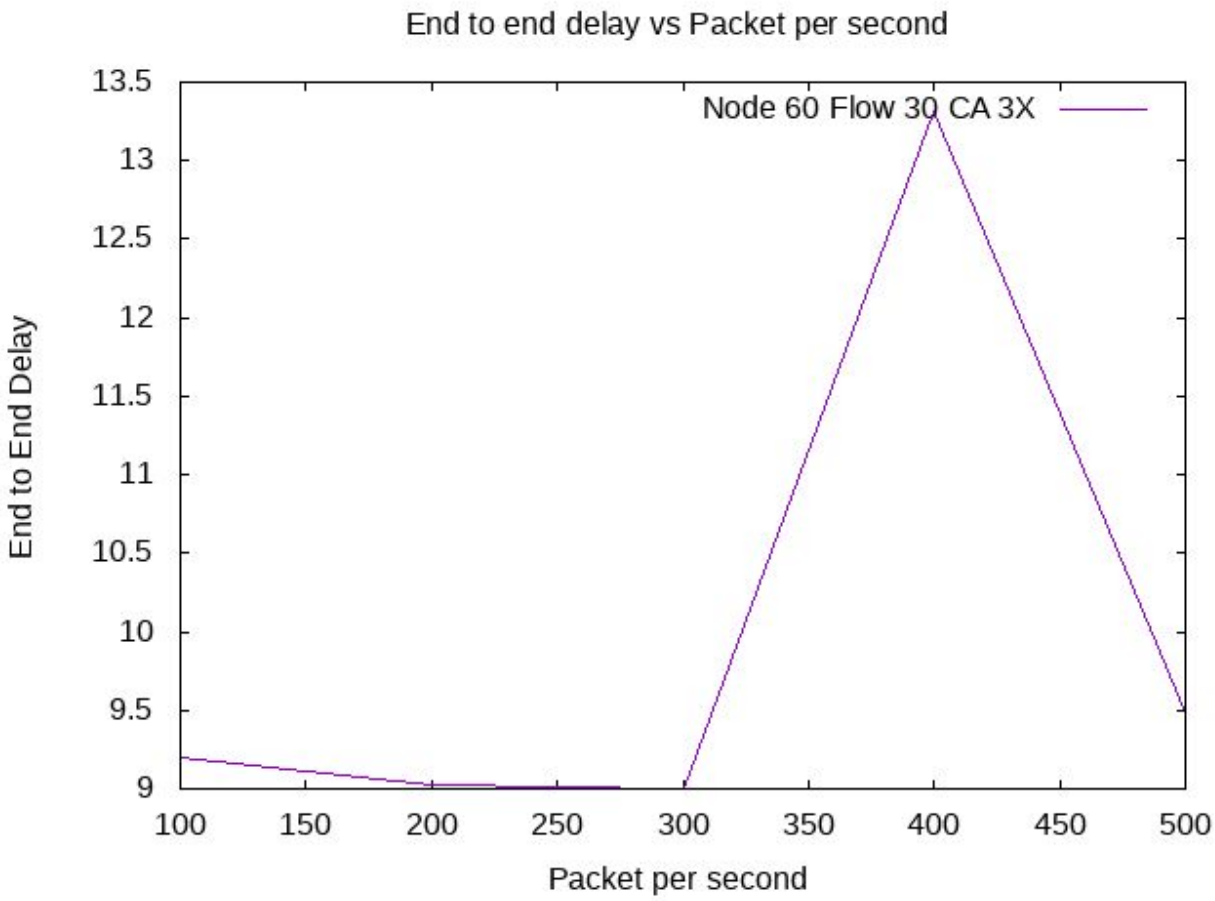

Packet Delivery Ratio vs Number of Flows
Node 60 PPS 300 CA 3X
Packet Delivery Ratio
Number of Flows
97
96
95
94
93
92
91
90
89
88
87
10
15
20
25
30
35
40
45
50

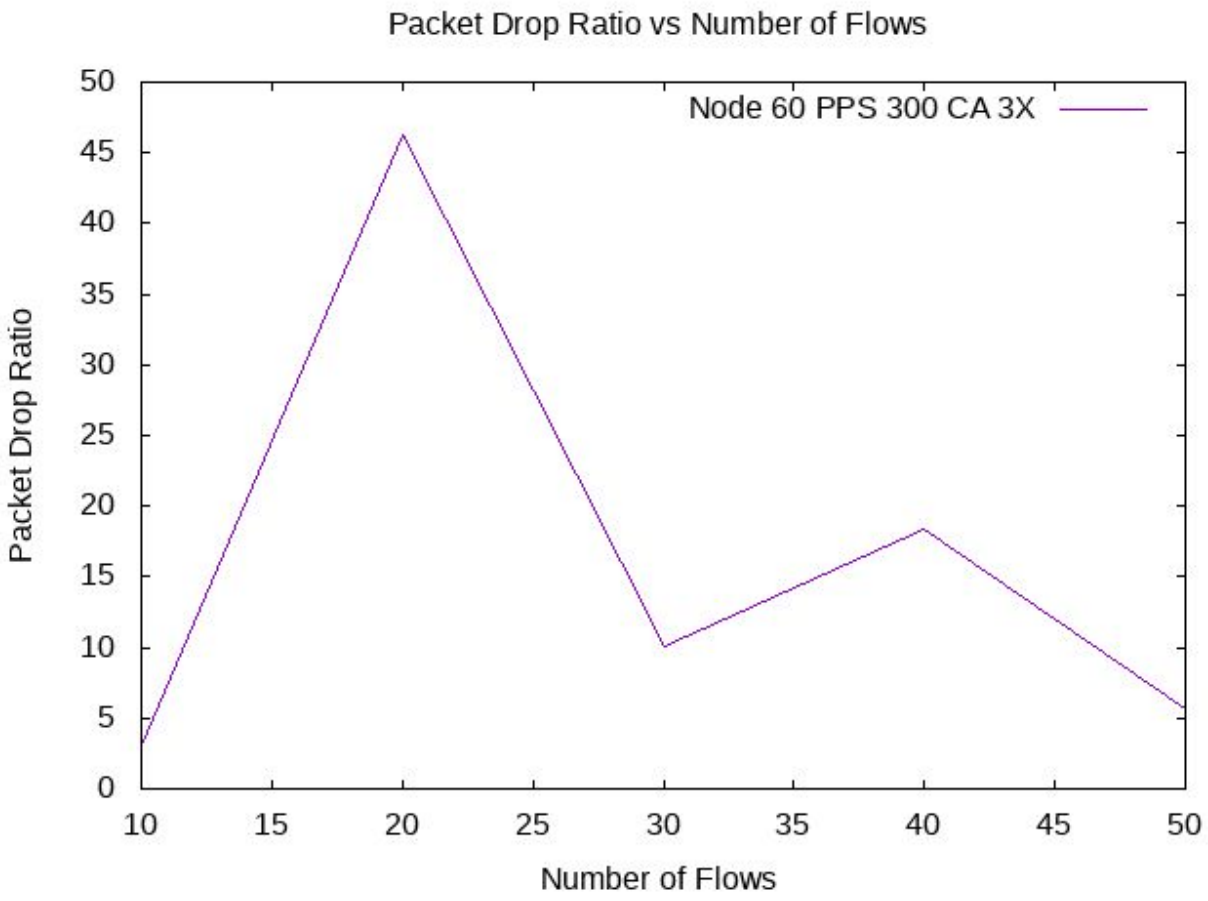

Packet Delivery Ratio vs Number of Nodes
Flow 30 PPS 300 CA 3X
Packet Delivery Ratio
Number of Nodes
95
94.5
94
93.5
93
92.5
92
91.5
91
90.5
20
30
40
50
60
70
80
90
100

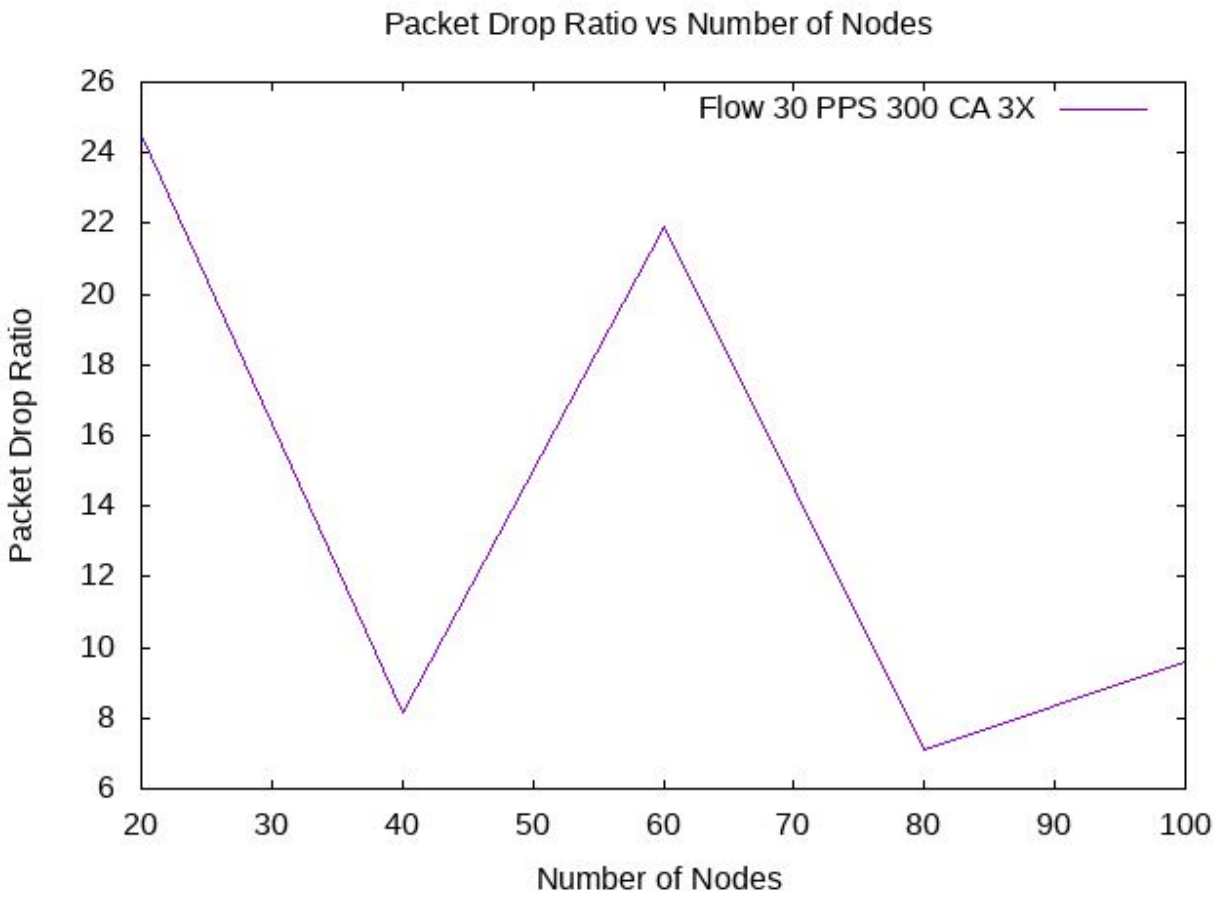

Packet Delivery Ratio vs Packet per second
Node 60 Flow 30 CA 3X
Packet Delivery Ratio
Packet per second
96
95
94
93
92
91
90
89
100
150
200
250
300
350
400
450
500

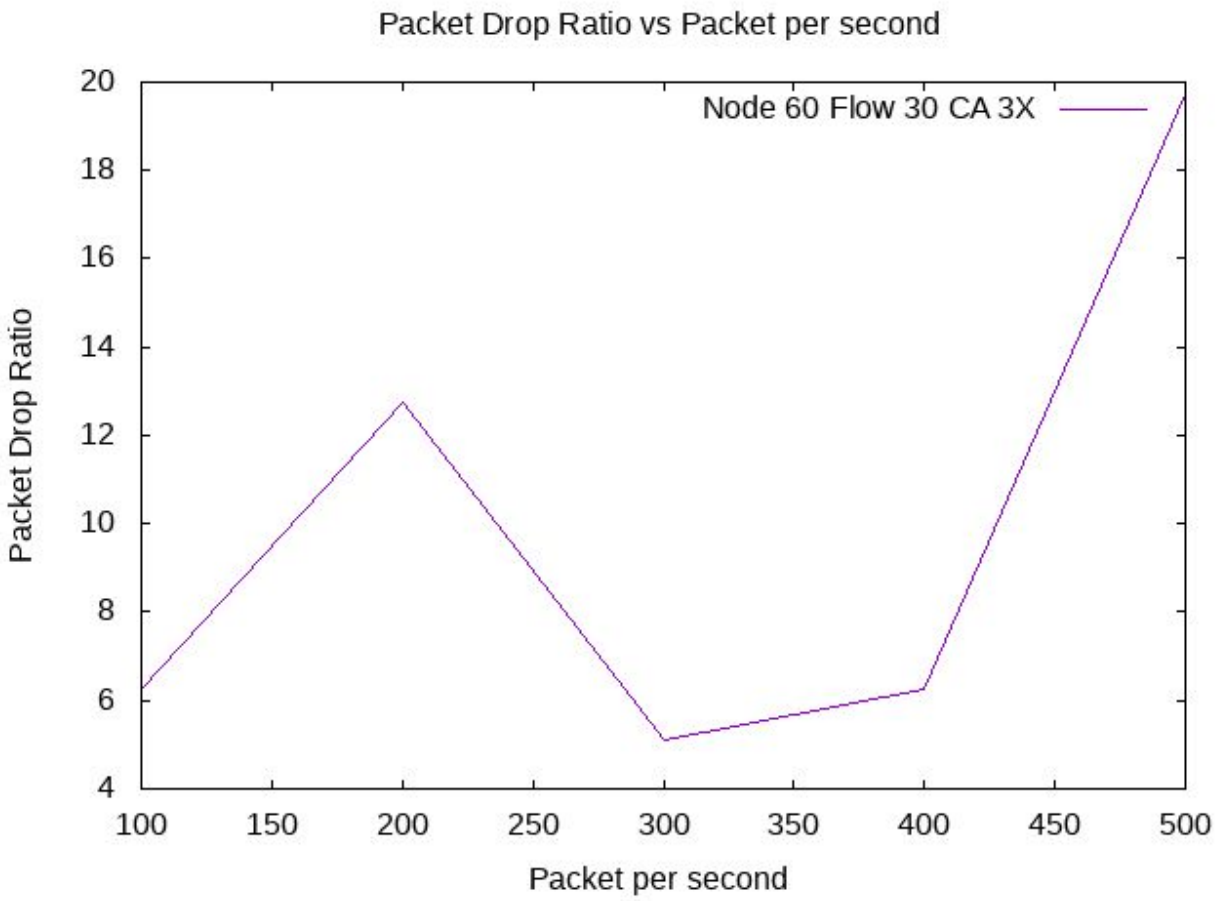

End to end delay vs Number of Flows
Node 60 PPS 300 CA 3X
End to End Delay
Number of Flows
9.4
9.35
9.3
9.25
9.2
9.15
9.1
9.05
9
8.95
8.9
10
15
20
25
30
35
40
45
50

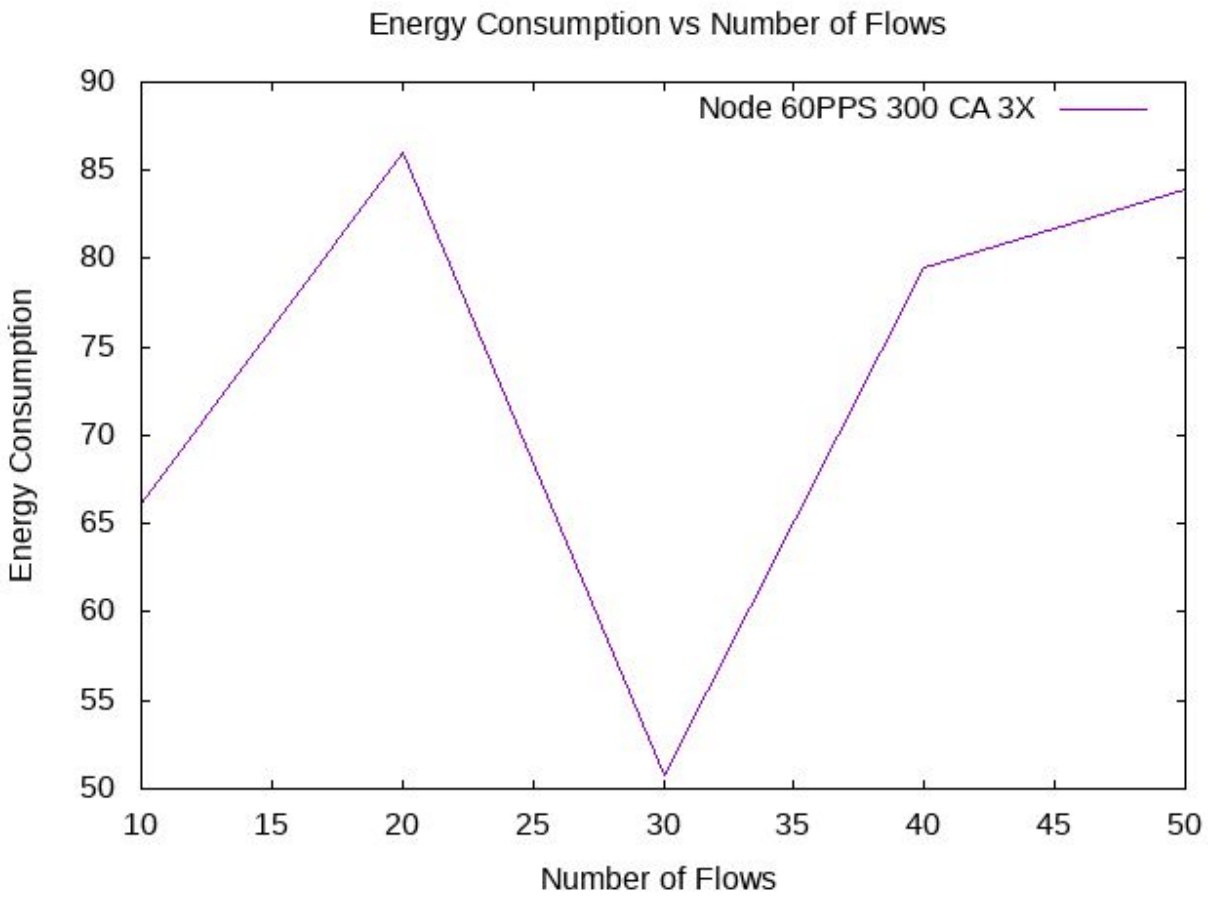

End to end delay vs Number of Nodes
Flow 30 PPS 300 CA 3X
End to End Delay
Number of Nodes
18
17
16
15
14
13
12
11
10
9
8
20
30
40
50
60
70
80
90
100

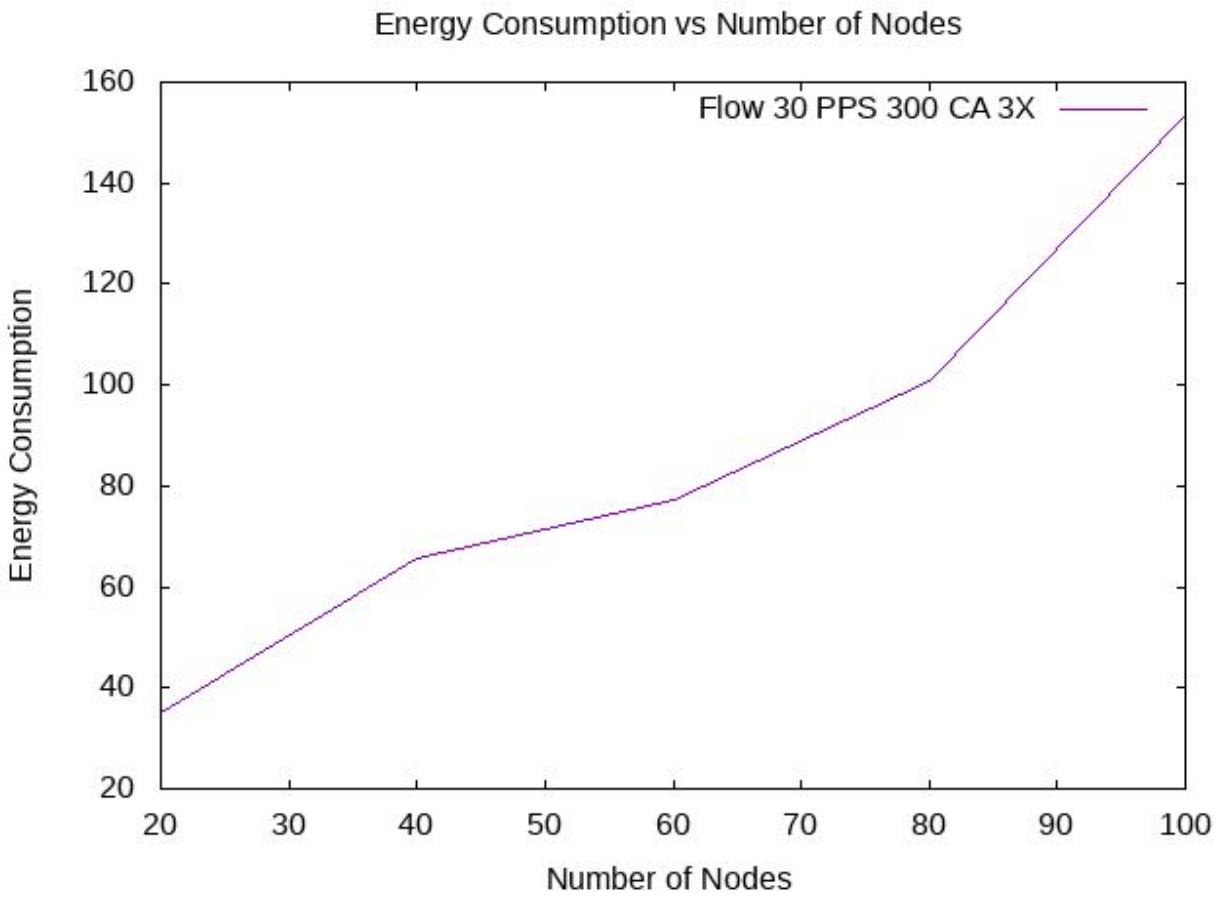

End to end delay vs Packet per second
Node 60 Flow 30 CA 3X
End to End Delay
Packet per second
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
100
150
200
250
300
350
400
450
500

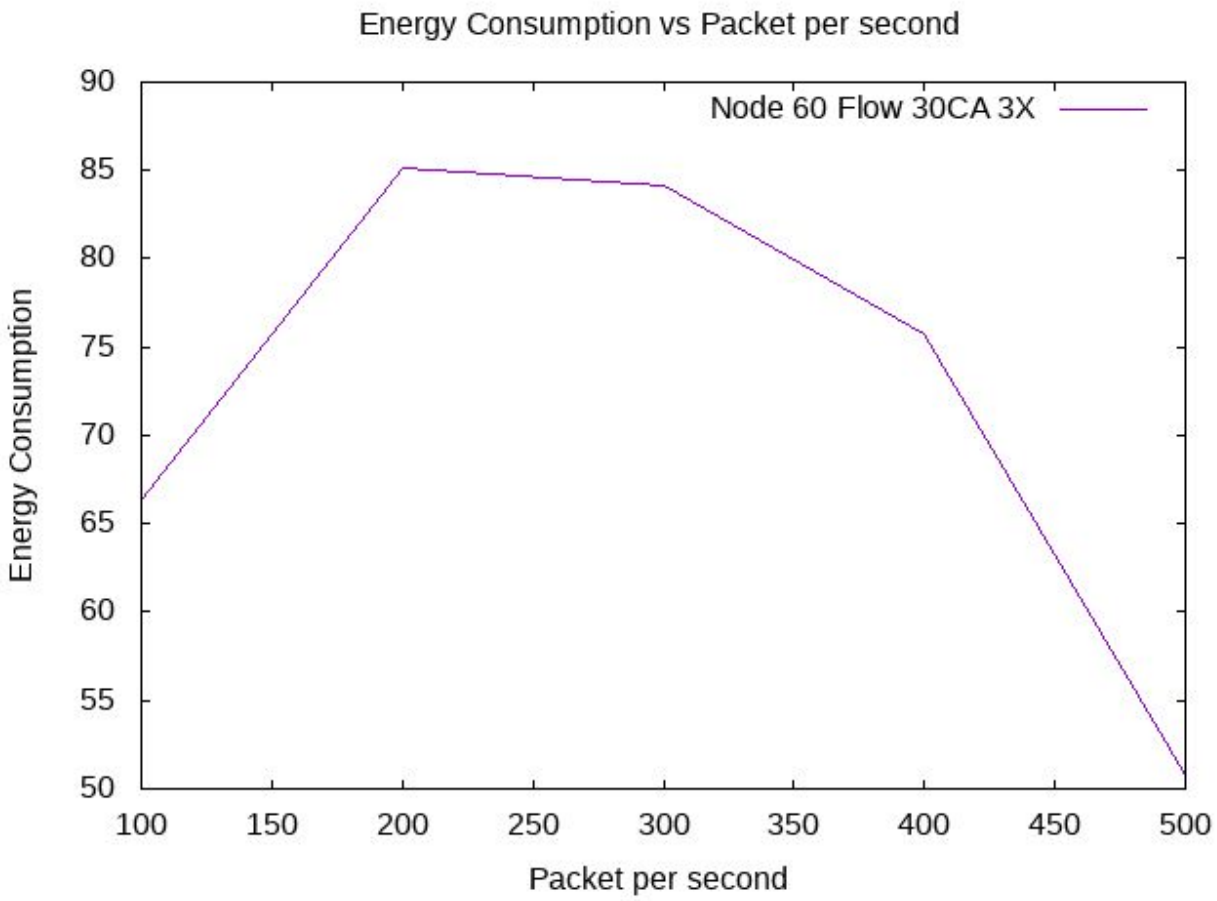

Packet Drop Ratio vs Number of Flows
Node 60 PPS 300 CA 3X
Packet Drop Ratio
Number of Flows
0
5
10
15
20
25
30
35
40
45
50
10
15
20
25
30
35
40
45
50

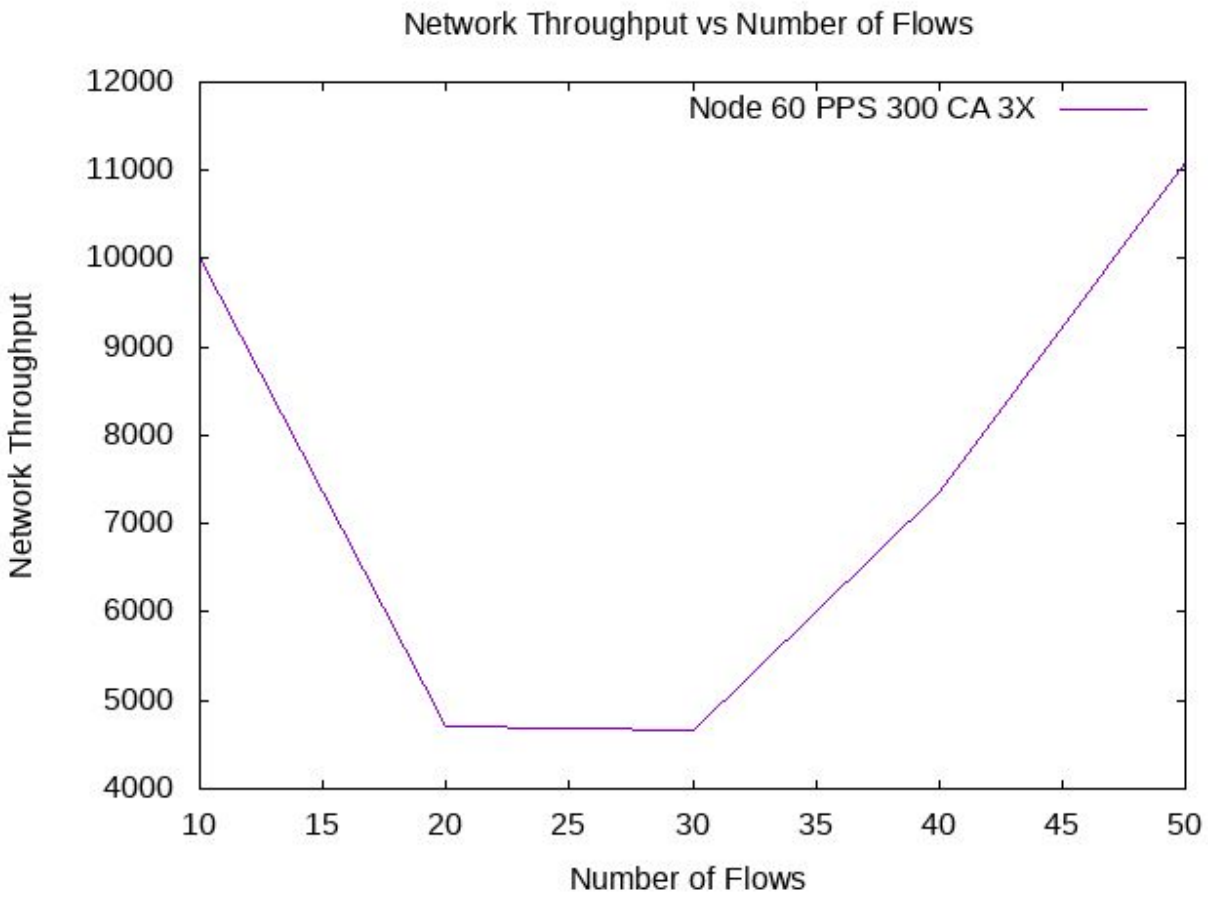

Packet Drop Ratio vs Number of Nodes
Flow 30 PPS 300 CA 3X
Packet Drop Ratio
Number of Nodes
26
24
22
20
18
16
14
12
10
8
6
20
30
40
50
60
70
80
90
100

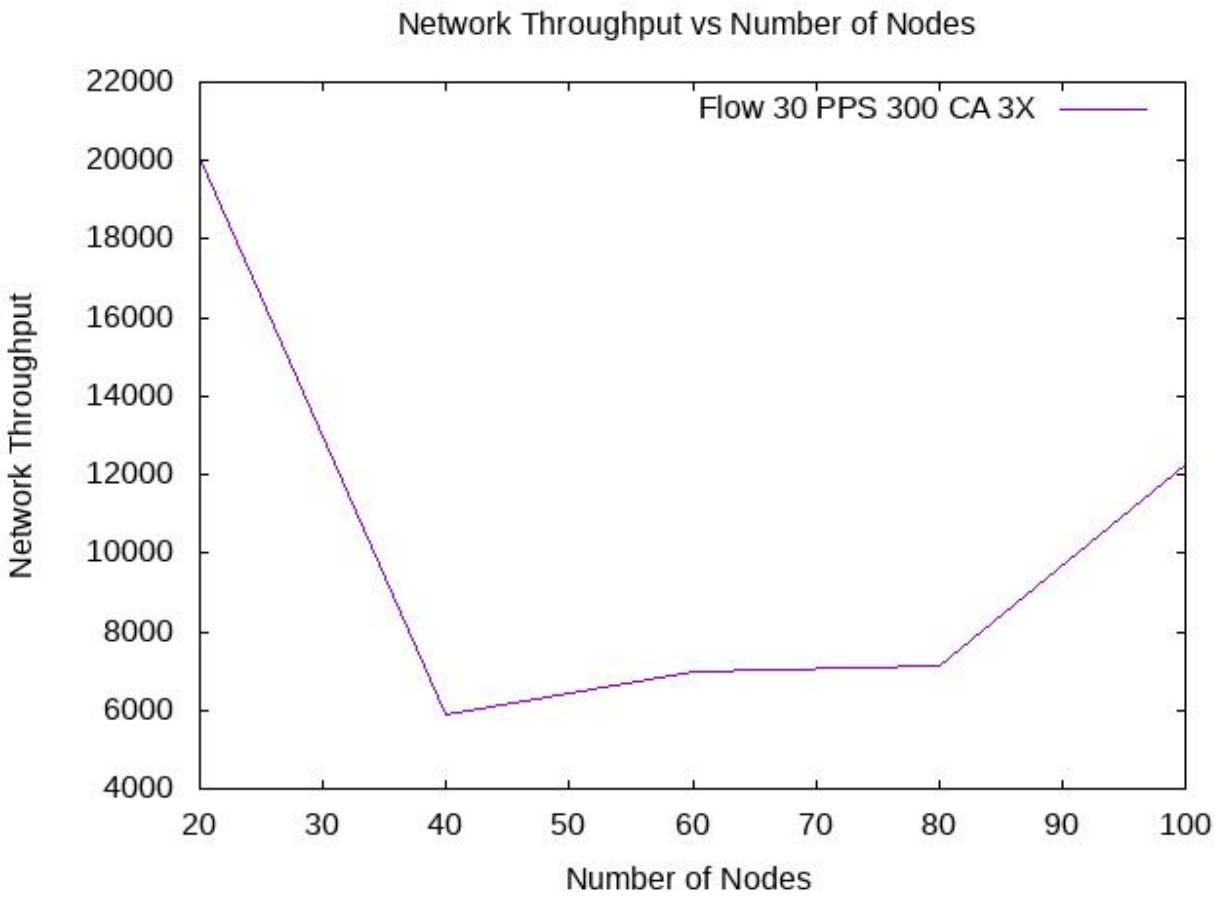

Packet Drop Ratio vs Packet per second
Node 60 Flow 30 CA 3X
Packet Drop Ratio
Packet per second
20
18
16
14
12
10
8
6
4
100
150
200
250
300
350
400
450
500

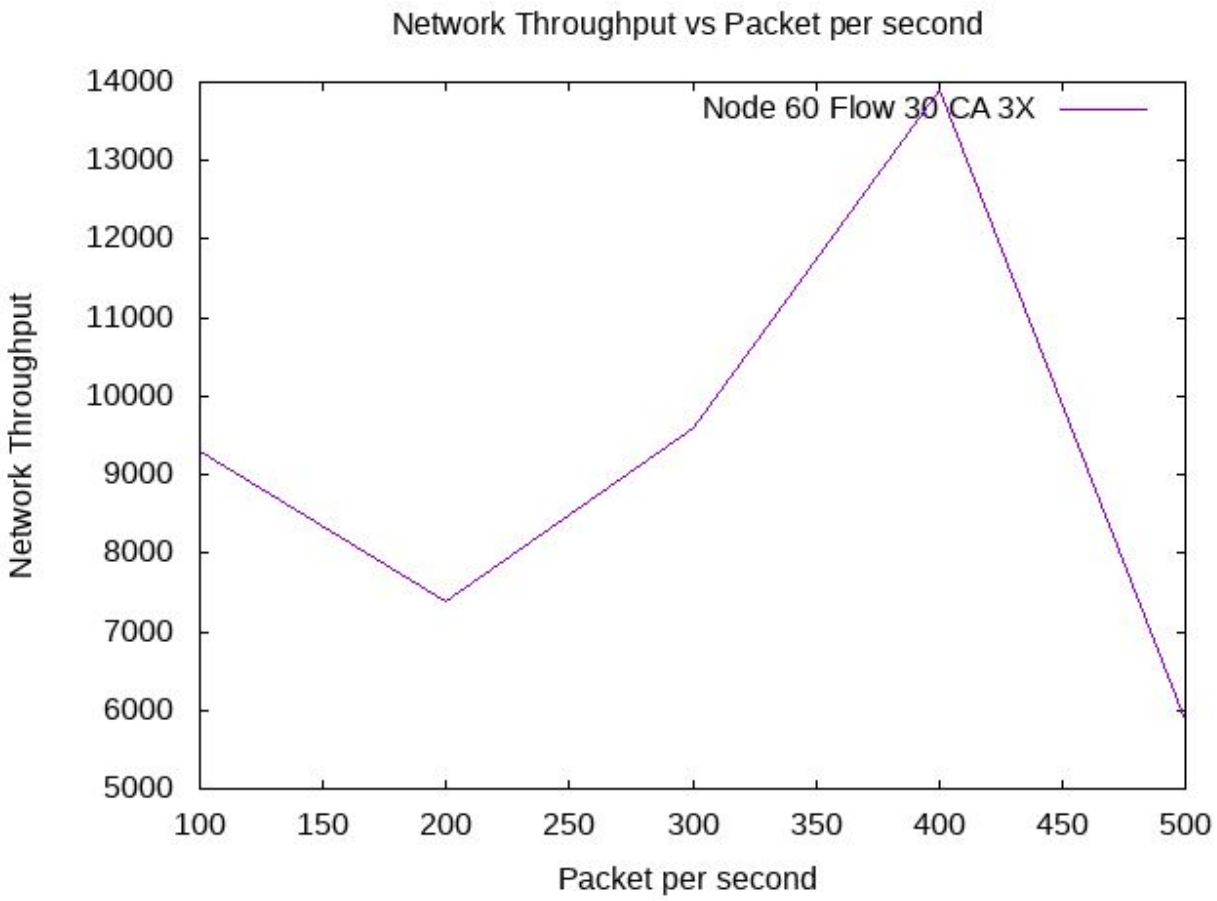

Energy Consumption vs Number of Flows
Node 60PPS 300 CA 3X
Energy Consumption
Number of Flows
90
85
80
75
70
65
60
55
50
10
15
20
25
30
35
40
45
50

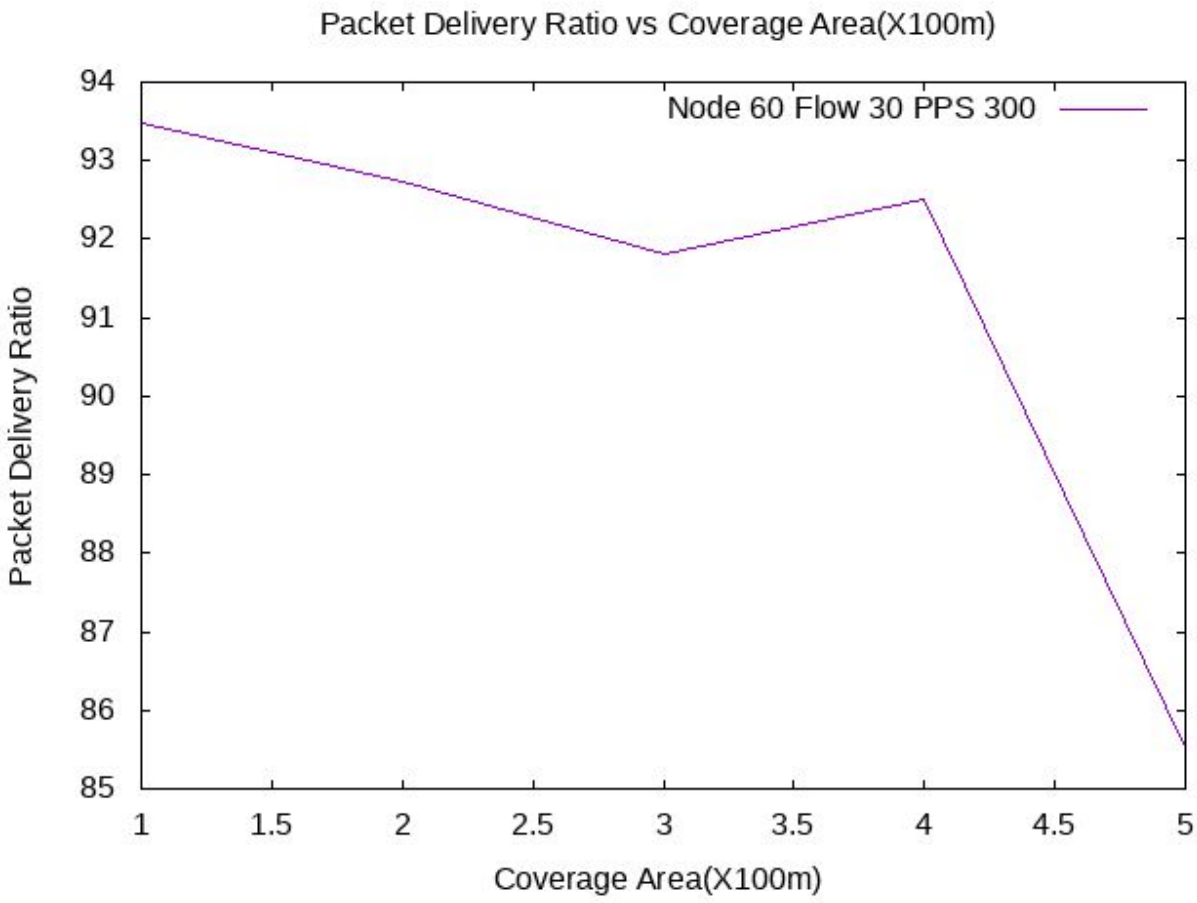

Energy Consumption vs Number of Nodes
Flow 30 PPS 300 CA 3X
Energy Consumption
Number of Nodes
160
140
120
100
80
60
40
20
20
30
40
50
60
70
80
90
100

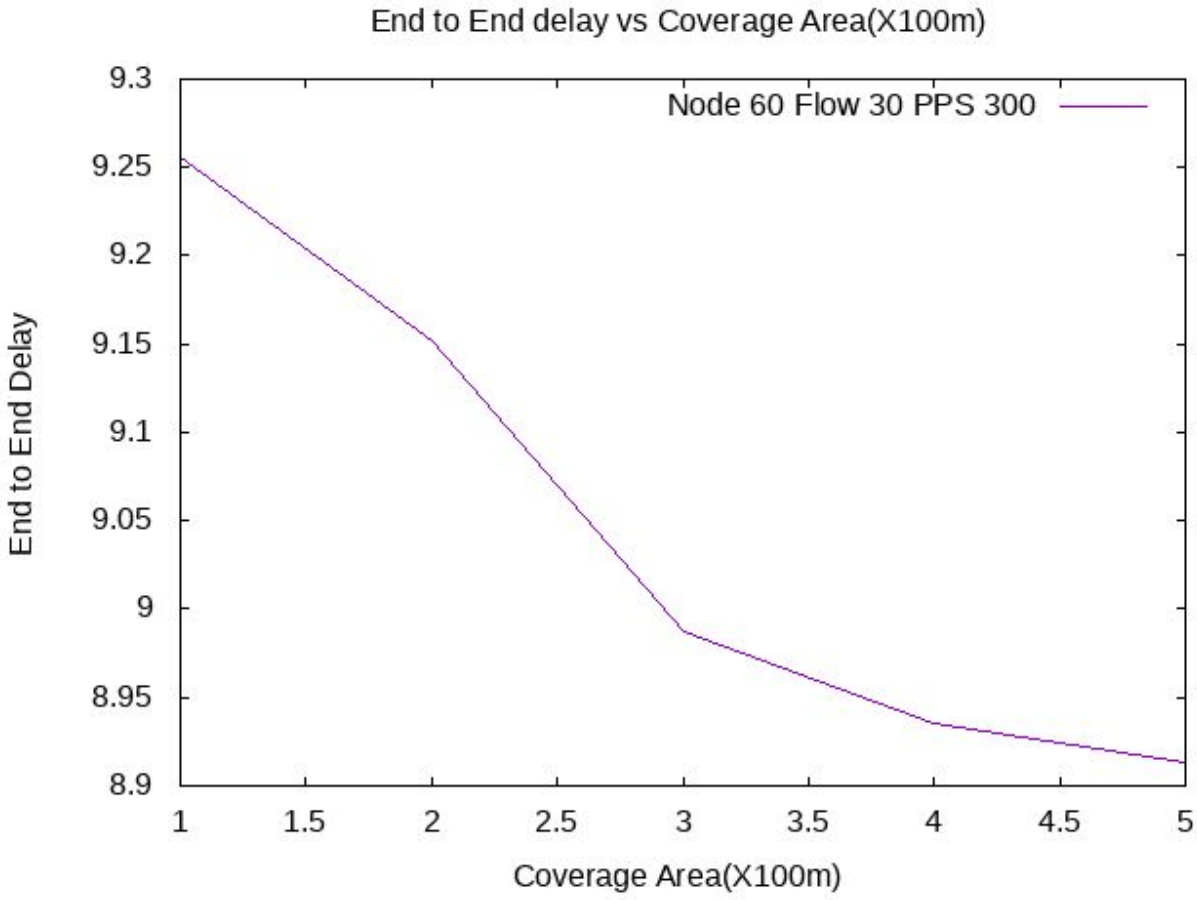

Energy Consumption vs Packet per second
Node 60 Flow 30CA 3X
Energy Consumption
Packet per second
90
85
80
75
70
65
60
55
50
100
150
200
250
300
350
400
450
500

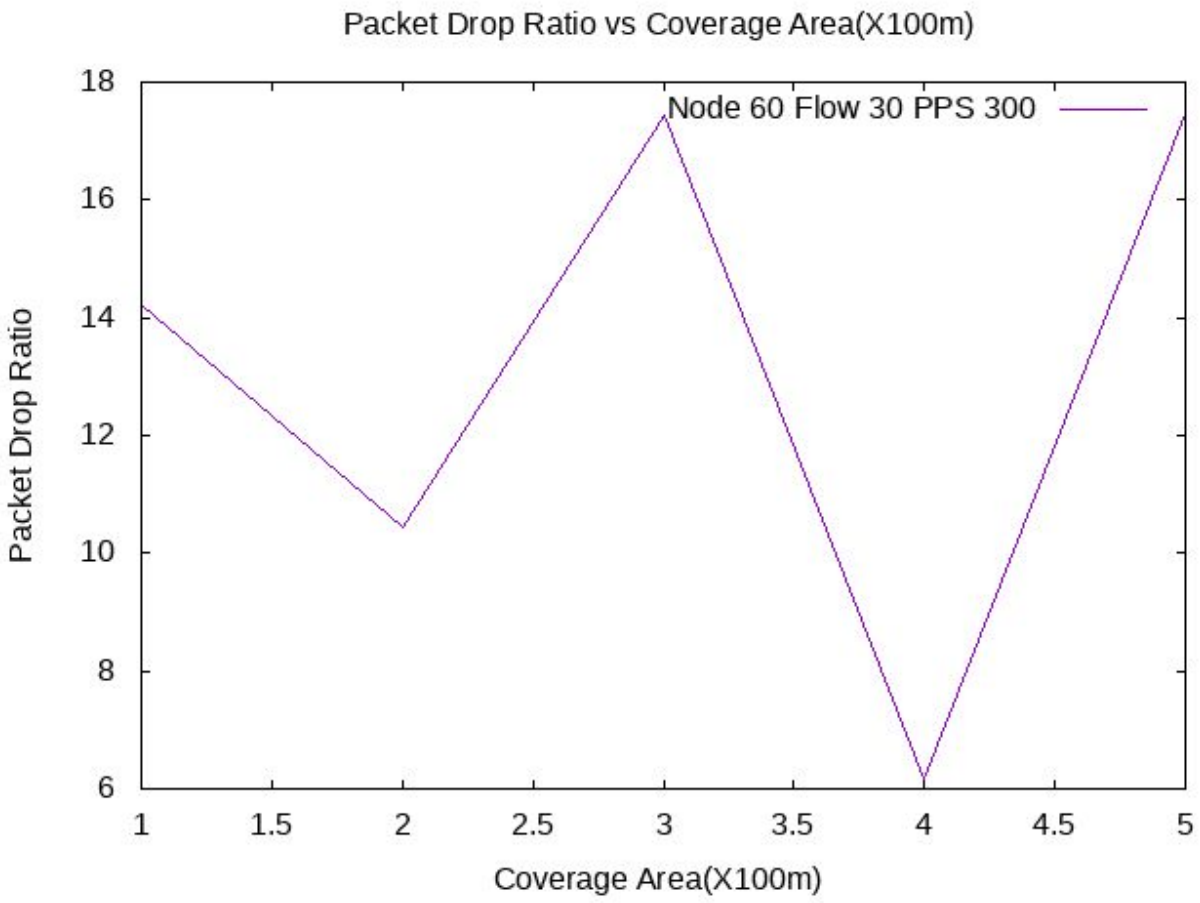

Network Throughput vs Number of Flows
Node 60 PPS 300 CA 3X
Network Throughput
Number of Flows
12000
11000
10000
9000
8000
7000
6000
5000
4000
10
15
20
25
30
35
40
45
50

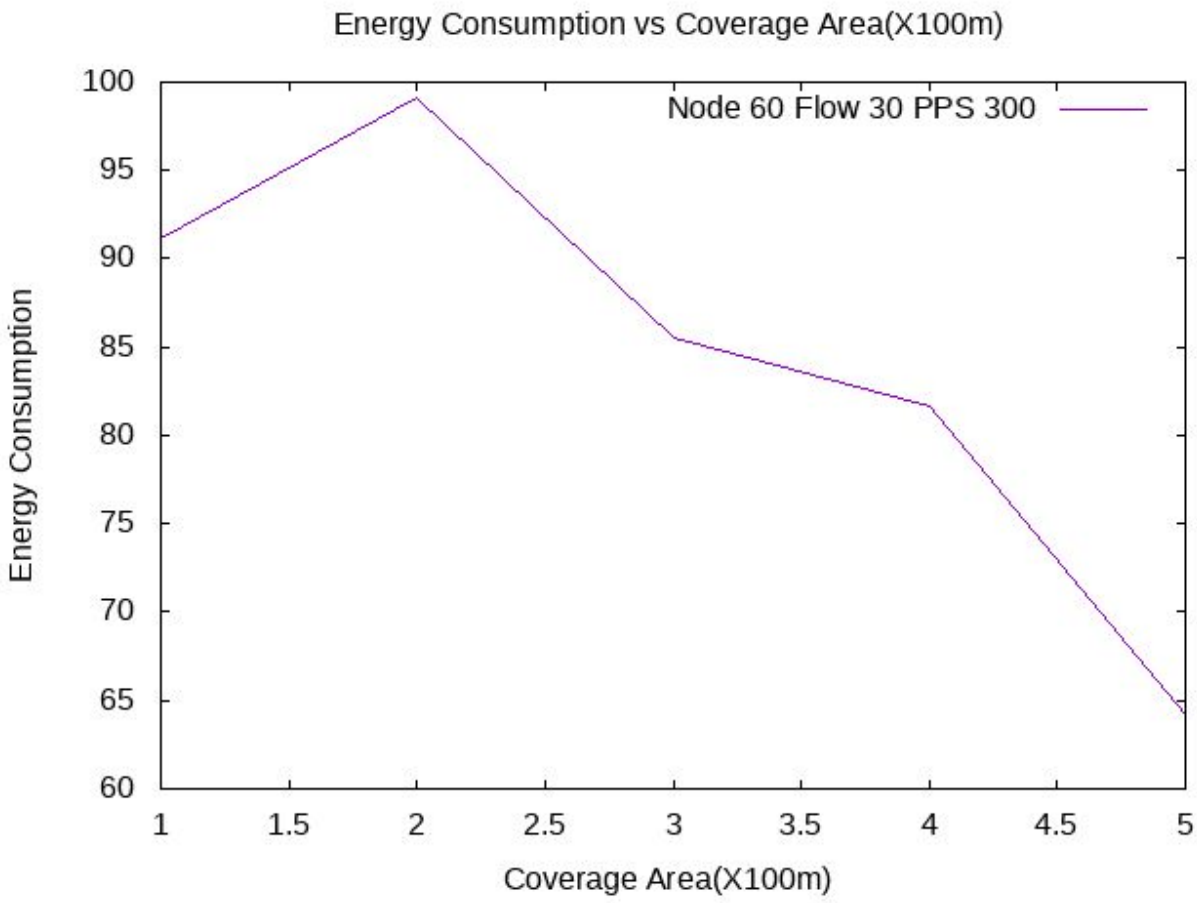

Network Throughput vs Number of Nodes
Flow 30 PPS 300 CA 3X
Network Throughput
Number of Nodes
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
20
30
40
50
60
70
80
90
100

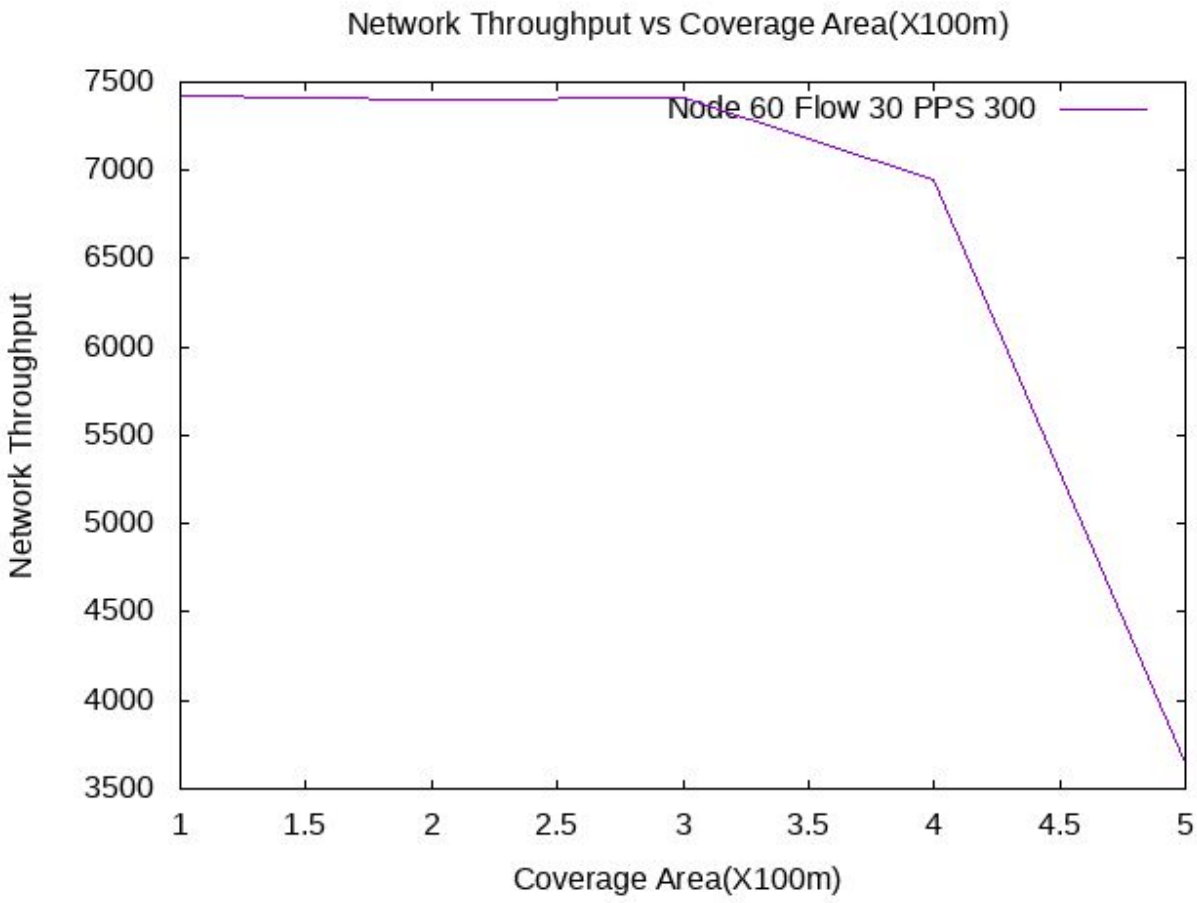

Network Throughput vs Packet per second
Node 60 Flow 30 CA 3X
Network Throughput
Packet per second
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
100
150
200
250
300
350
400
450
500


Packet Delivery Ratio vs Coverage Area(X100m)
Node 60 Flow 30 PPS 300
Packet Delivery Ratio
94
93
92
91
90
89
88
87
86
85
1
1.5
2
2.5
3
3.5
4
4.5
5
Coverage Area(X100m)


End to End delay vs Coverage Area(X100m)
Node 60 Flow 30 PPS 300
End to End Delay
Coverage Area(X100m)
9.3
9.25
9.2
9.15
9.1
9.05
9
8.95
8.9
1
1.5
2
2.5
3
3.5
4
4.5
5

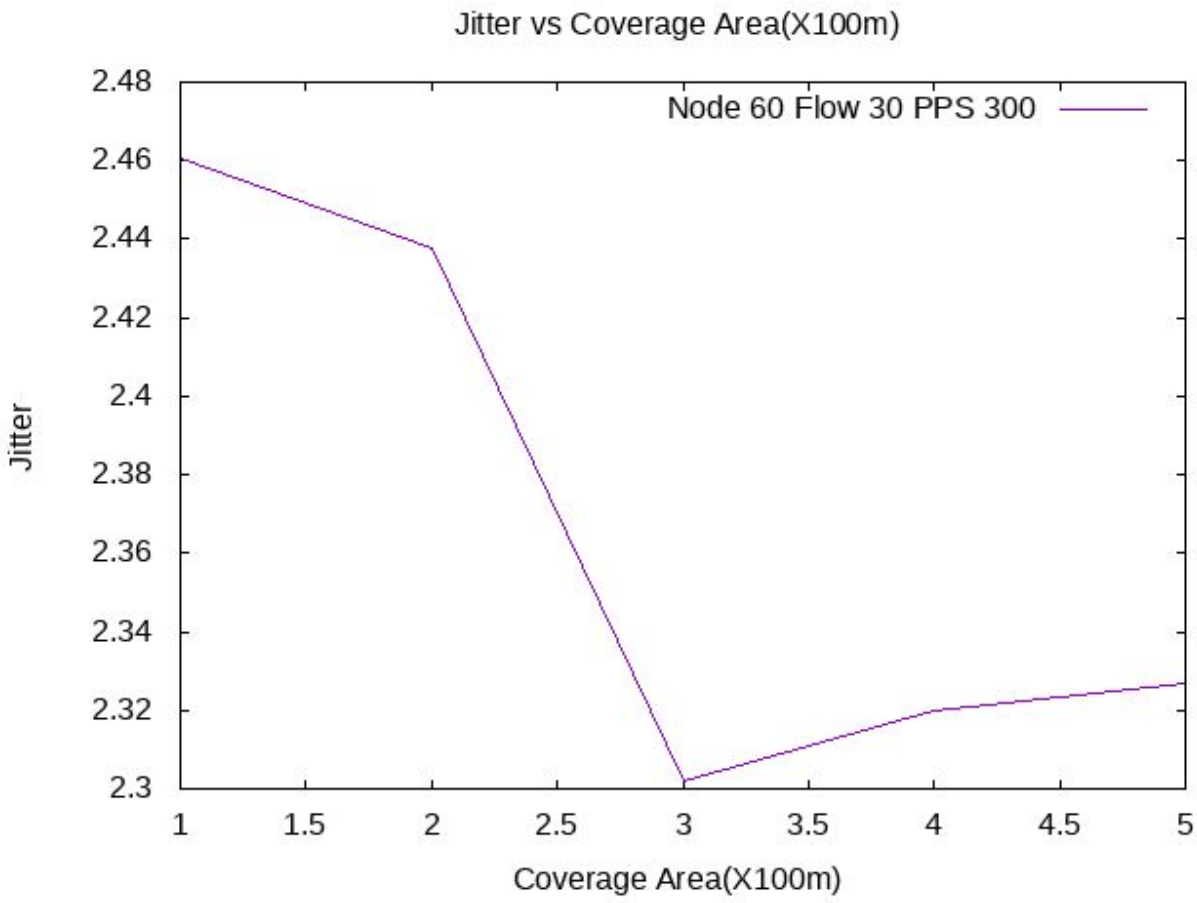

Packet Drop Ratio vs Coverage Area(X100m)
Node 60 Flow 30 PPS 300
Packet Drop Ratio
Coverage Area(X100m)
18
16
14
12
10
8
6
1
1.5
2
2.5
3
3.5
4
4.5
5

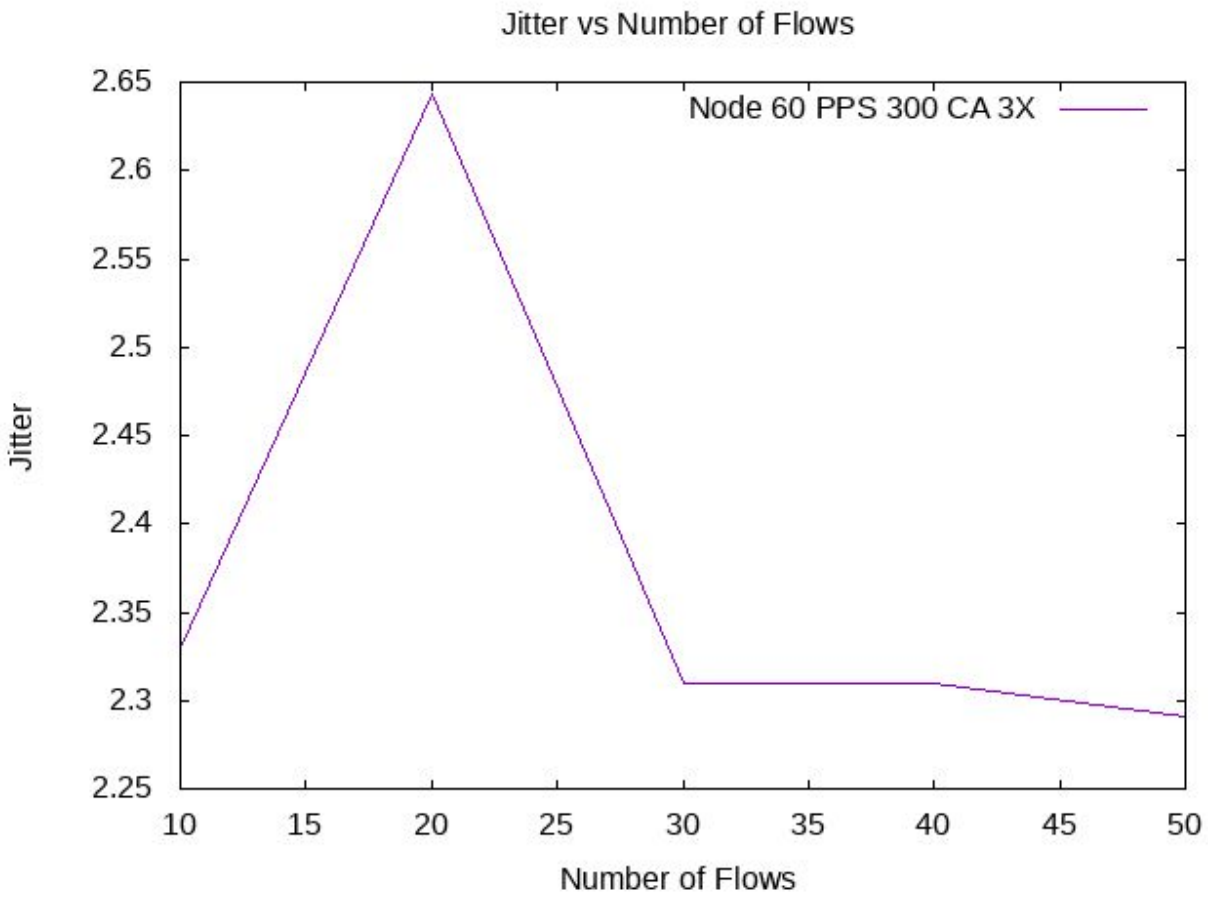

Energy Consumption vs Coverage Area(X100m)
Node 60 Flow 30 PPS 300
Energy Consumption
Coverage Area(X100m)
100
95
90
85
80
75
70
65
60
1
1.5
2
2.5
3
3.5
4
4.5
5

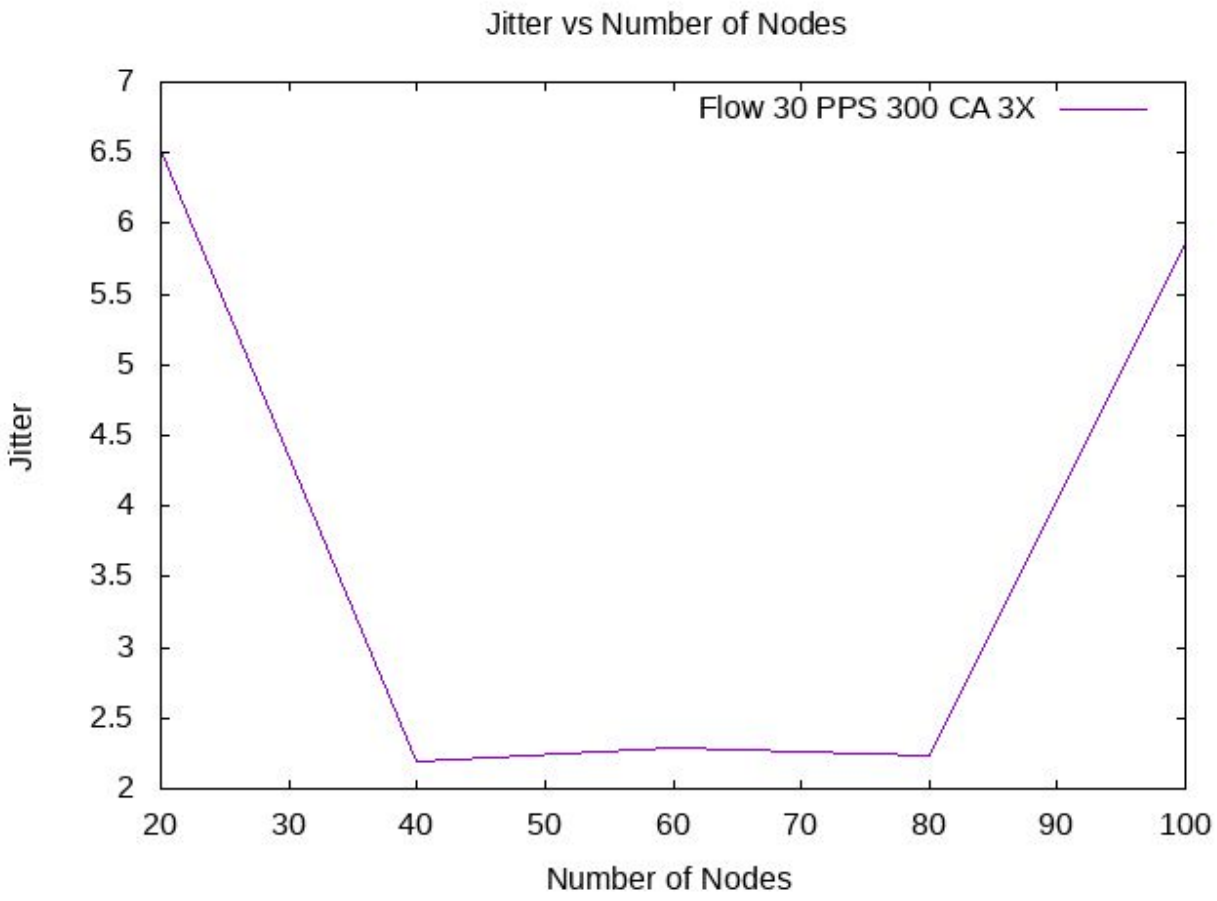

Network Throughput vs Coverage Area(X100m)
Node 60 Flow 30 PPS 300
Network Throughput
Coverage Area(X100m)
7500
7000
6500
6000
5500
5000
4500
4000
3500
1
1.5
2
2.5
3
3.5
4
4.5
5

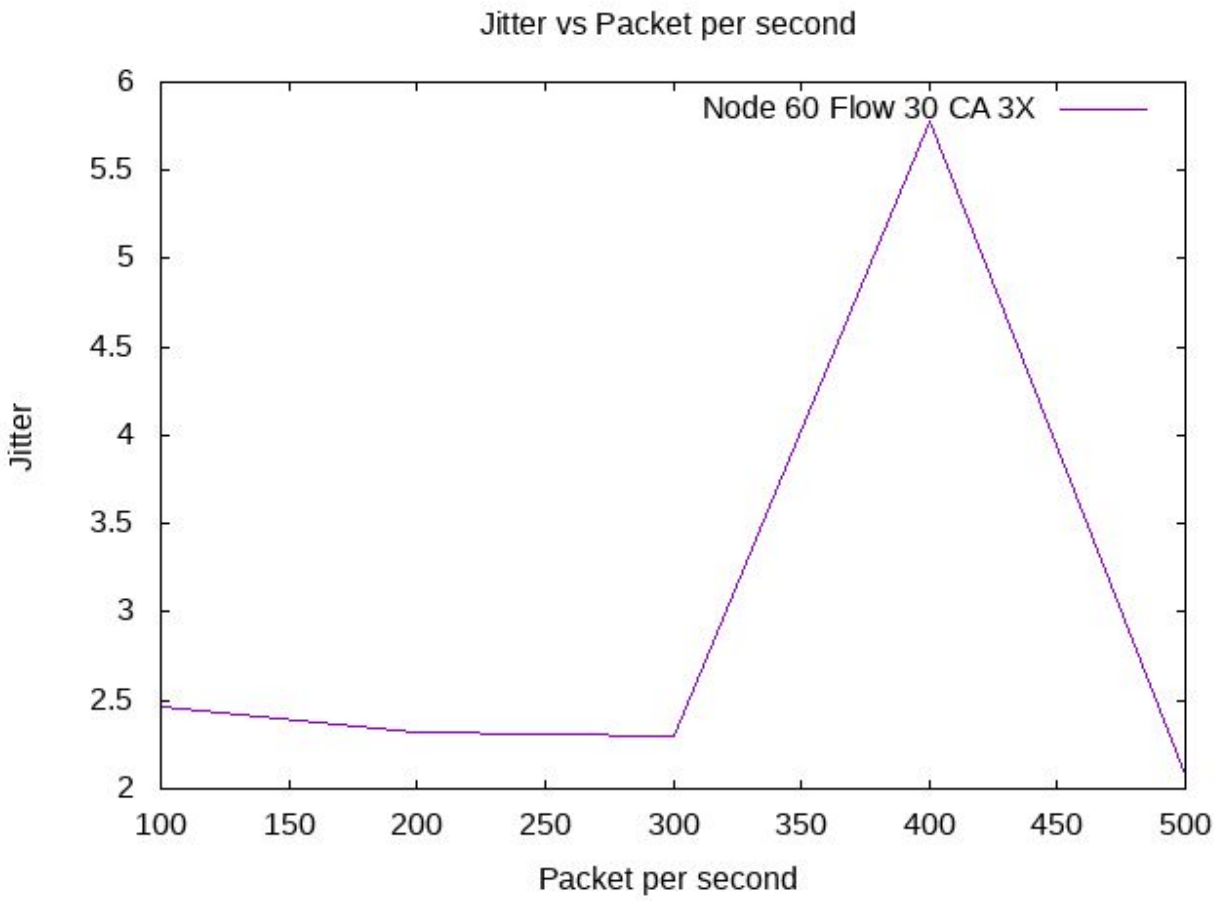
802.15.4

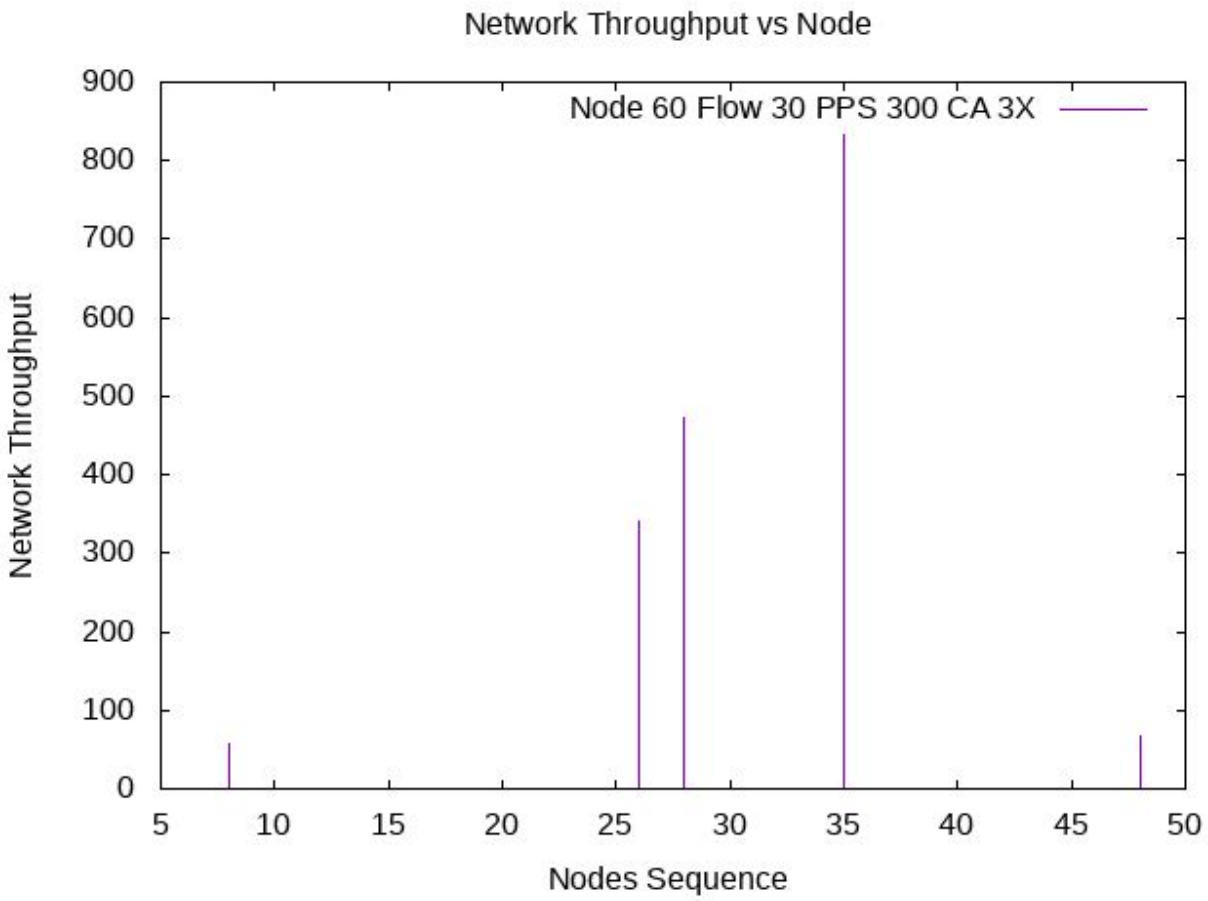
(Bonus Metrics)


Jitter vs Coverage Area(X100m)
Node 60 Flow 30 PPS 300
Jitter
Coverage Area(X100m)
2.48
2.46
2.44
2.42
2.4
2.38
2.36
2.34
2.32
2.3
1
1.5
2
2.5
3
3.5
4
4.5
5


Jitter vs Number of Flows
Node 60 PPS 300 CA 3X
Jitter
Number of Flows
2.65
2.6
2.55
2.5
2.45
2.4
2.35
2.3
2.25
10
15
20
25
30
35
40
45
50

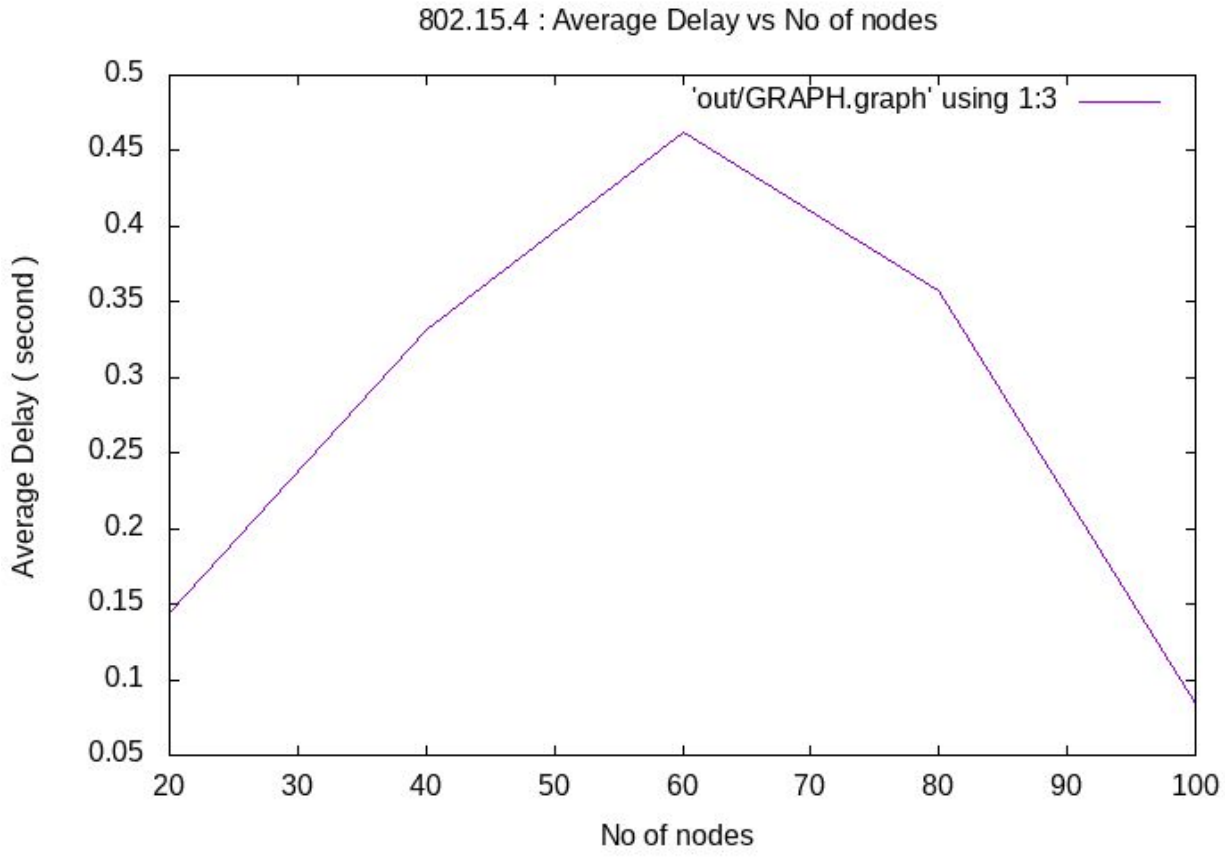

Jitter vs Number of Nodes
Flow 30 PPS 300 CA 3X
Jitter
Number of Nodes
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
20
30
40
50
60
70
80
90
100

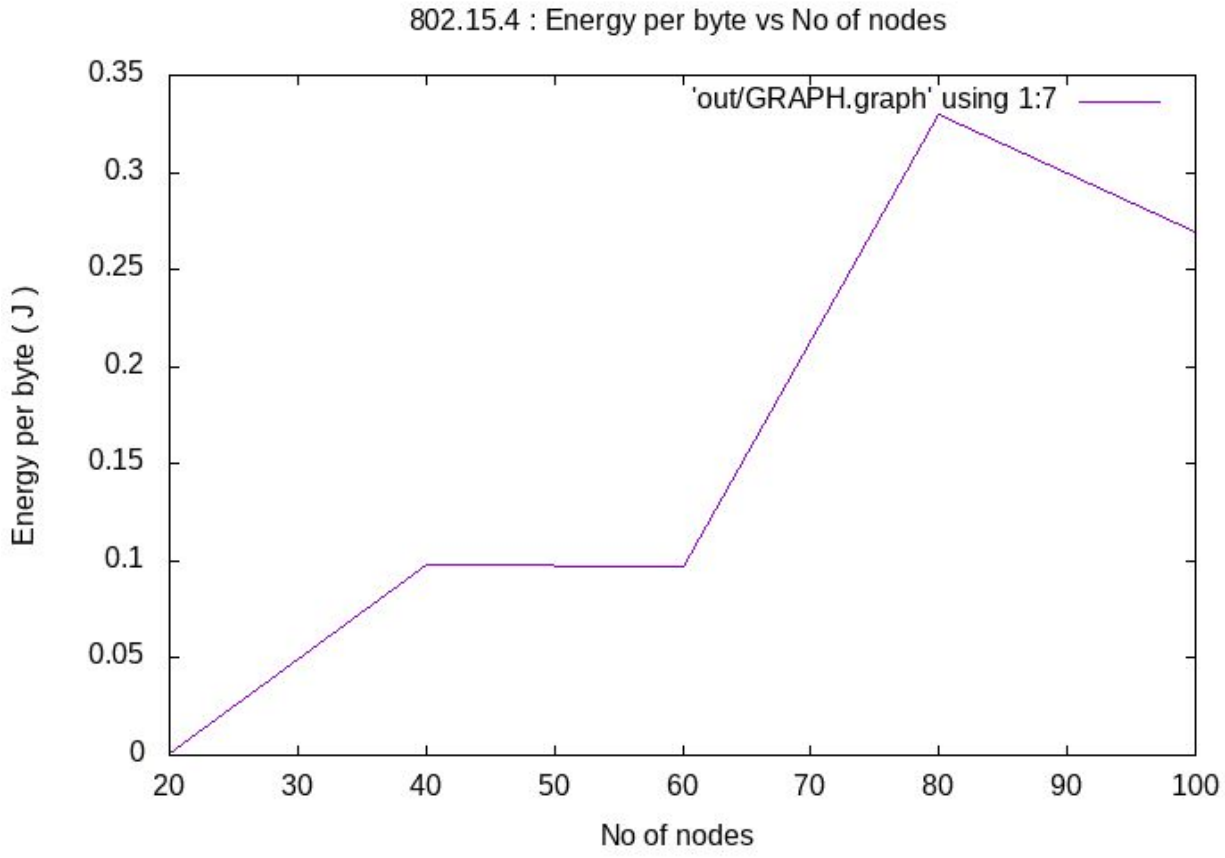

Jitter vs Packet per second
Node 60 Flow 30 CA 3X
Jitter
Packet per second
6
5.5
5
4.5
4
3.5
3
2.5
2
100
150
200
250
300
350
400
450
500

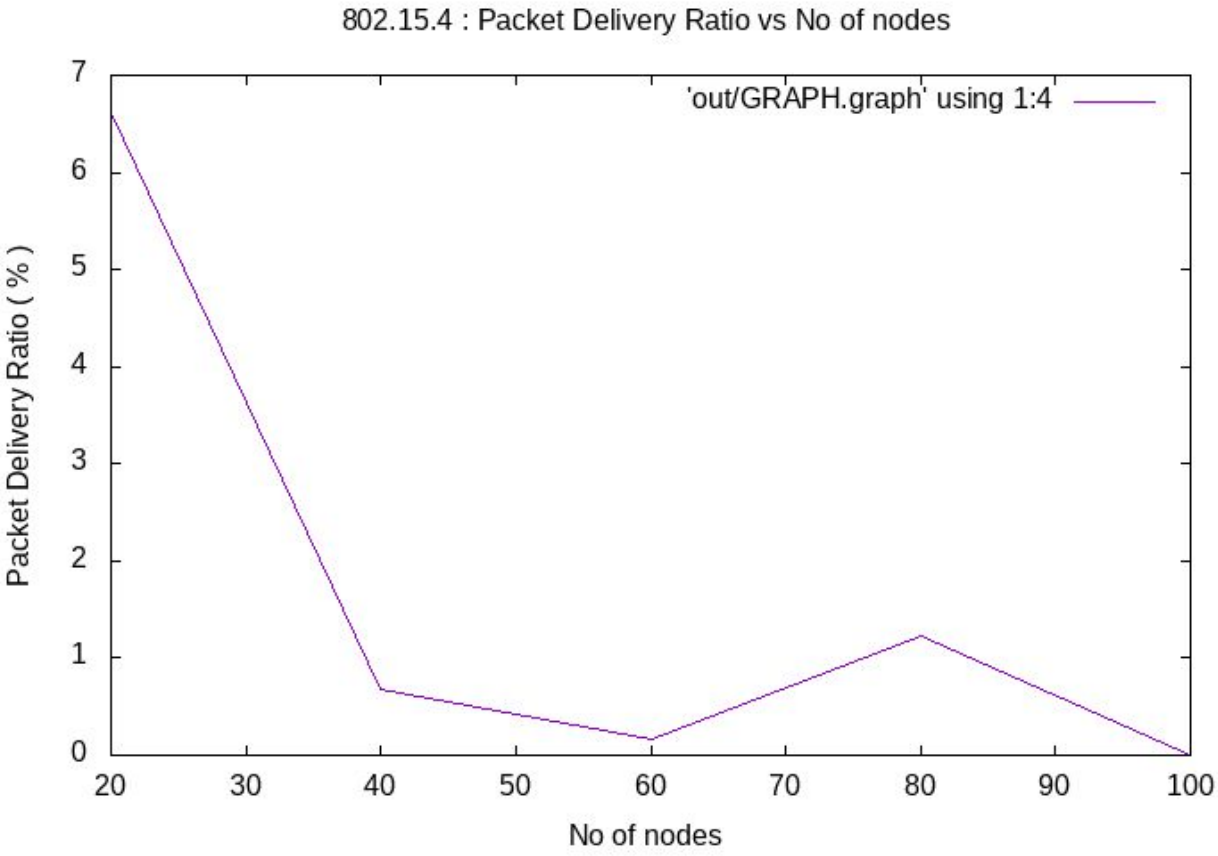

Network Throughput vs Node
Node 60 Flow 30 PPS 300 CA 3X
Network Throughput
Nodes Sequence
900
800
700
600
500
400
300
200
100
0
5
10
15
20
25
30
35
40
45
50

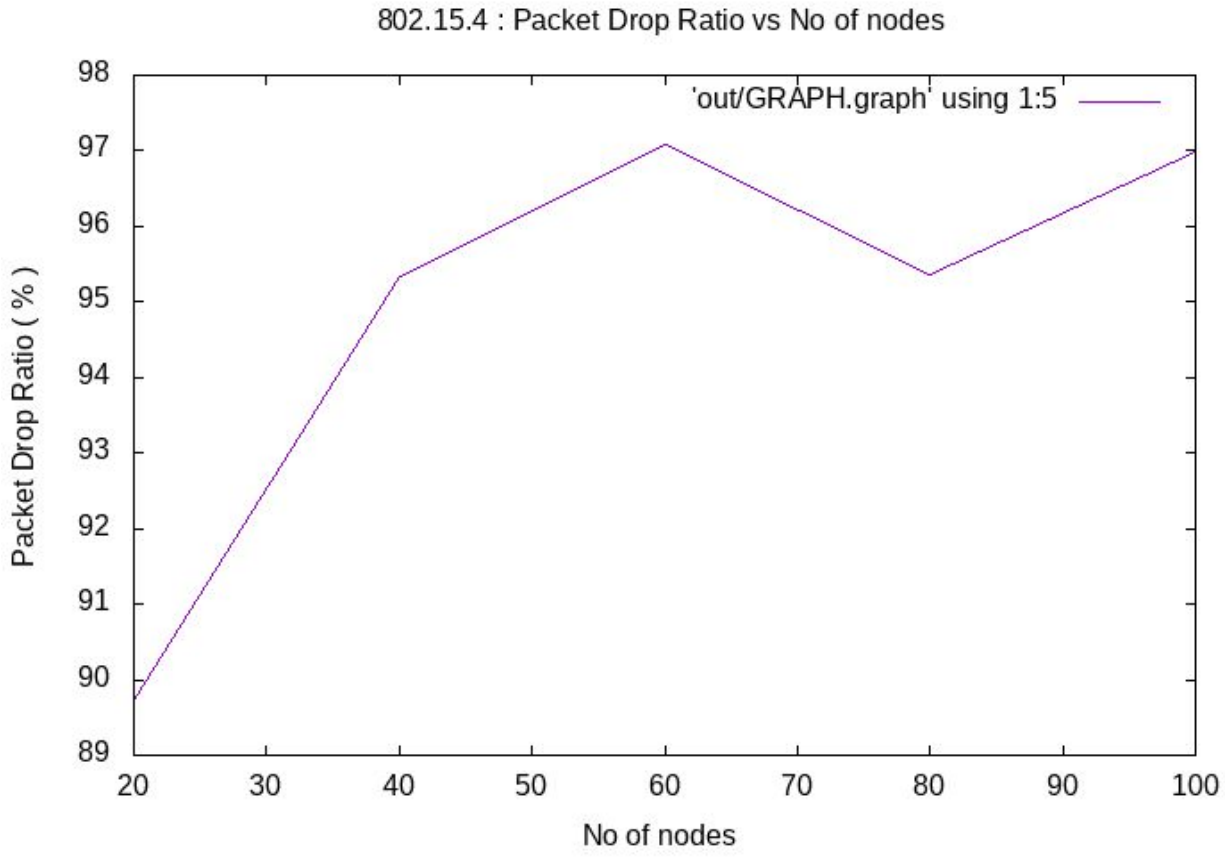
802.15.4

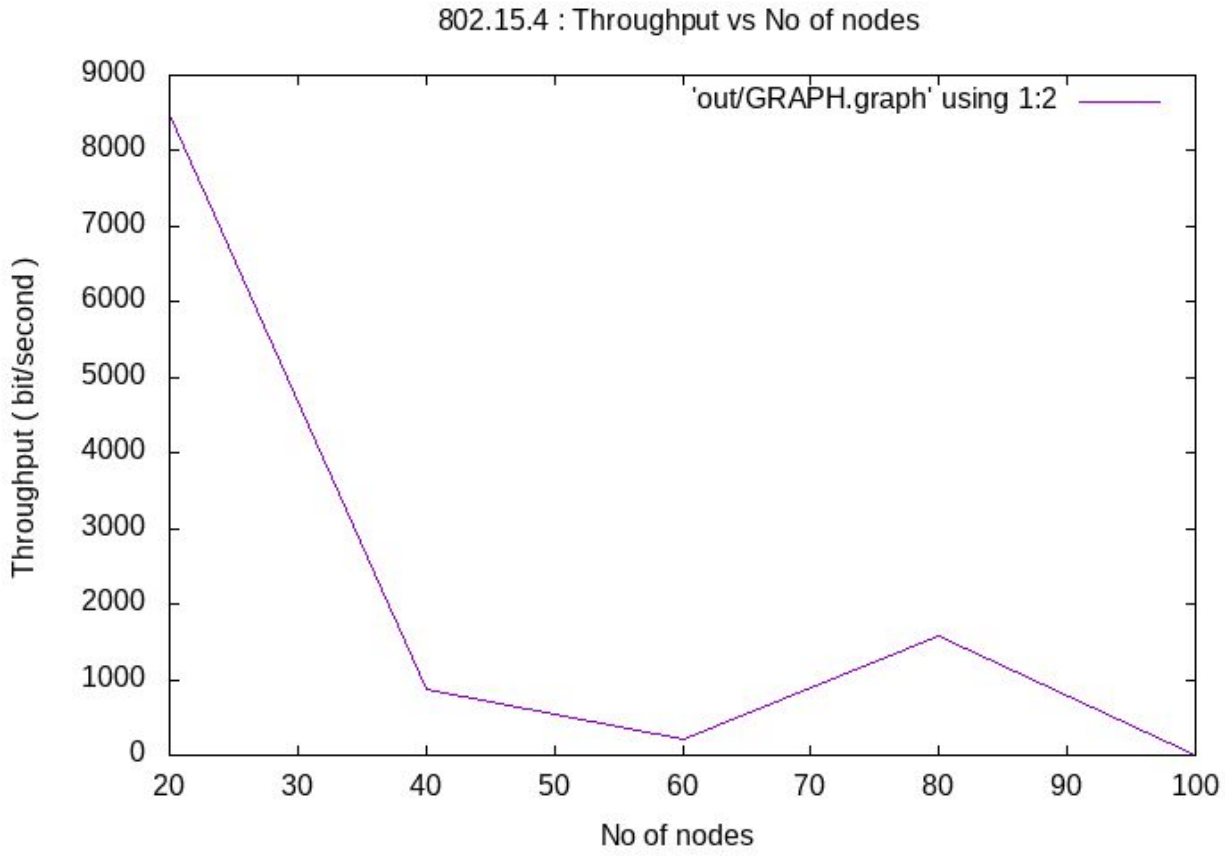
(Modified)

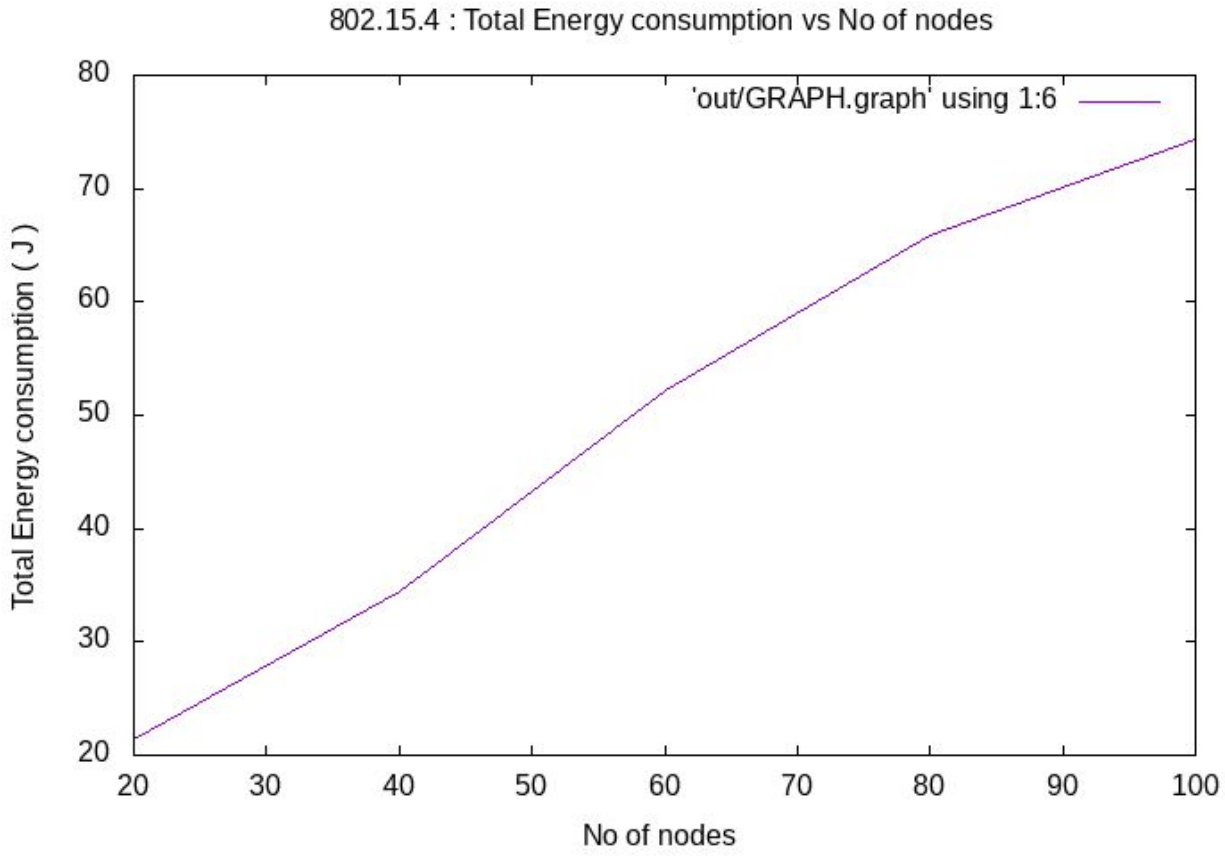

802.15.4 : Average Delay vs No of nodes
'out/GRAPH.graph' using 1:3
Average Delay (second)
No of nodes
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
20
30
40
50
60
70
80
90
100

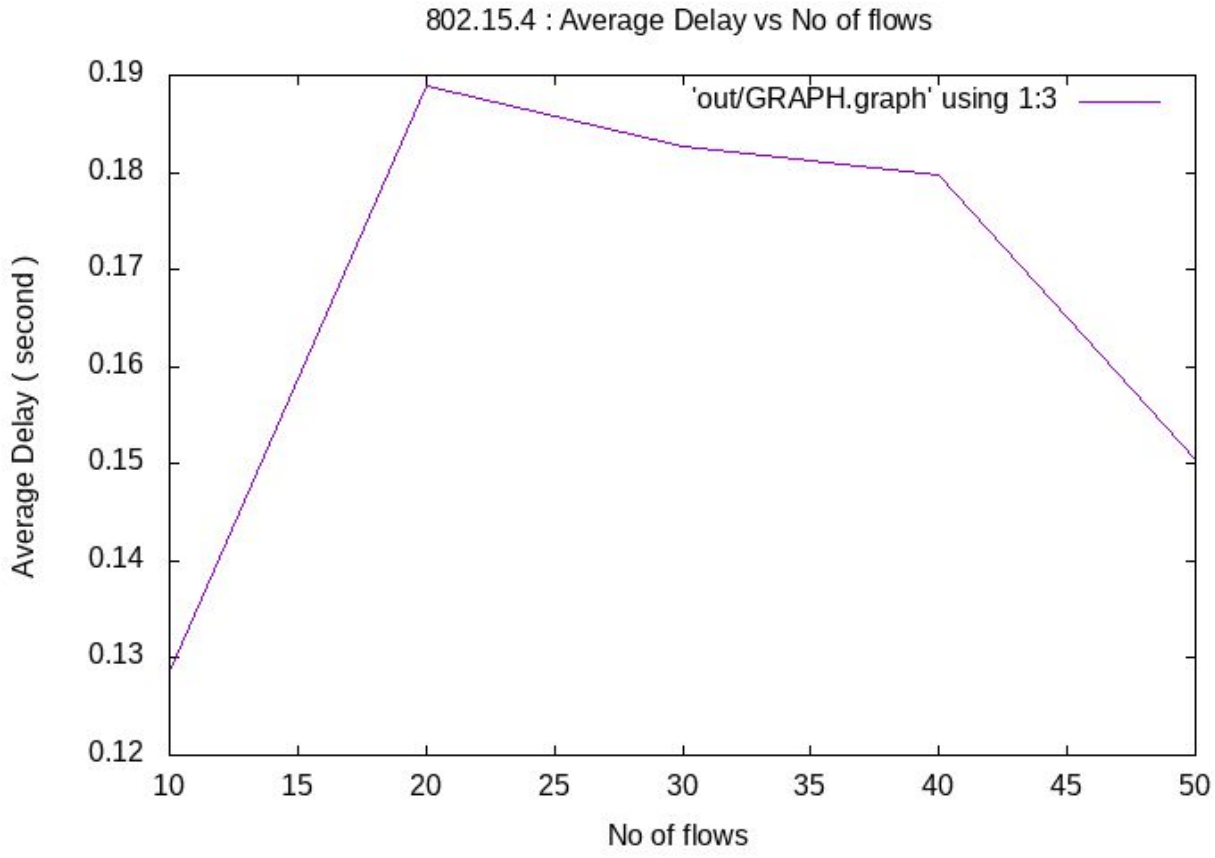

802.15.4 : Energy per byte vs No of nodes
'out/GRAPH.graph' using 1:7
Energy per byte (J)
No of nodes
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
20
30
40
50
60
70
80
90
100

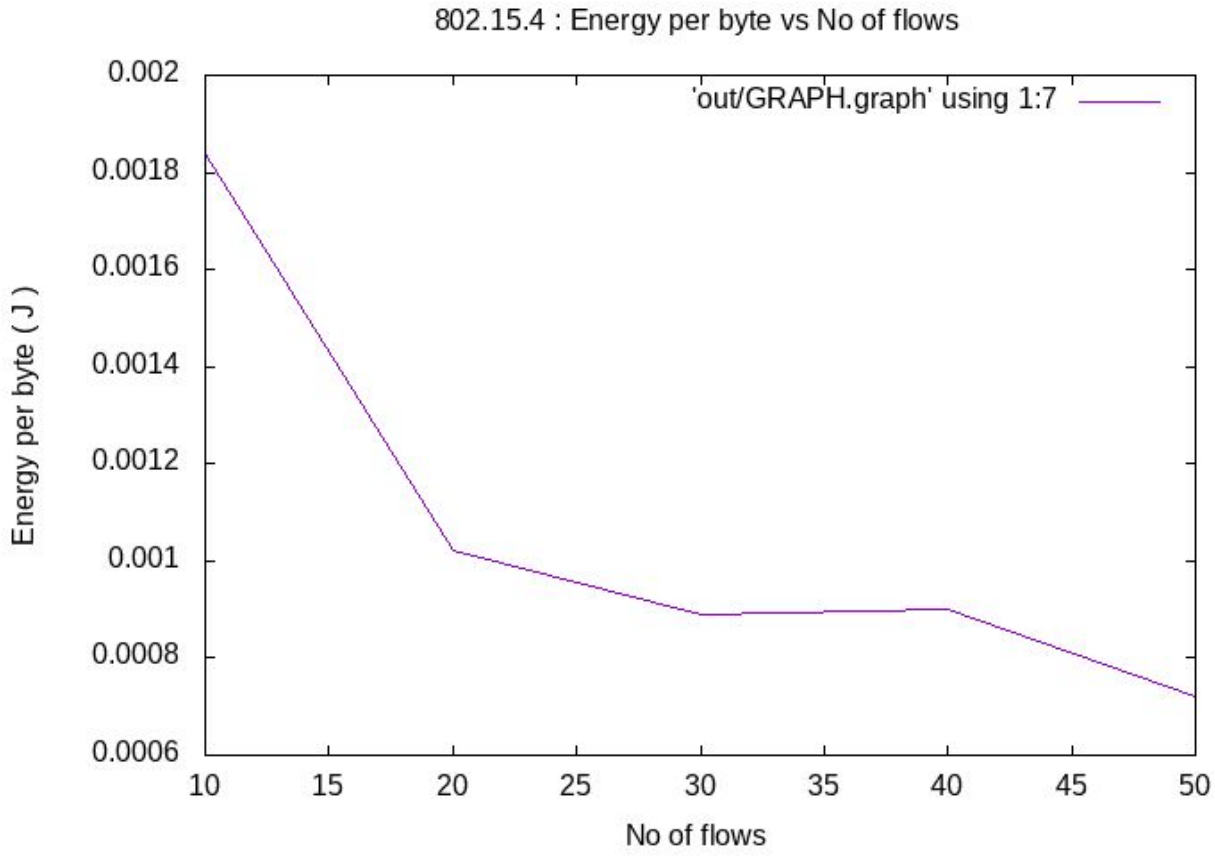

802.15.4 : Packet Delivery Ratio vs No of nodes
'out/GRAPH.graph' using 1:4
Packet Delivery Ratio (%)
No of nodes
0
1
2
3
4
5
6
7
20
30
40
50
60
70
80
90
100


802.15.4 : Packet Drop Ratio vs No of nodes
'out/GRAPH.graph' using 1:5
Packet Drop Ratio (%)
No of nodes
98
97
96
95
94
93
92
91
90
89
20
30
40
50
60
70
80
90
100

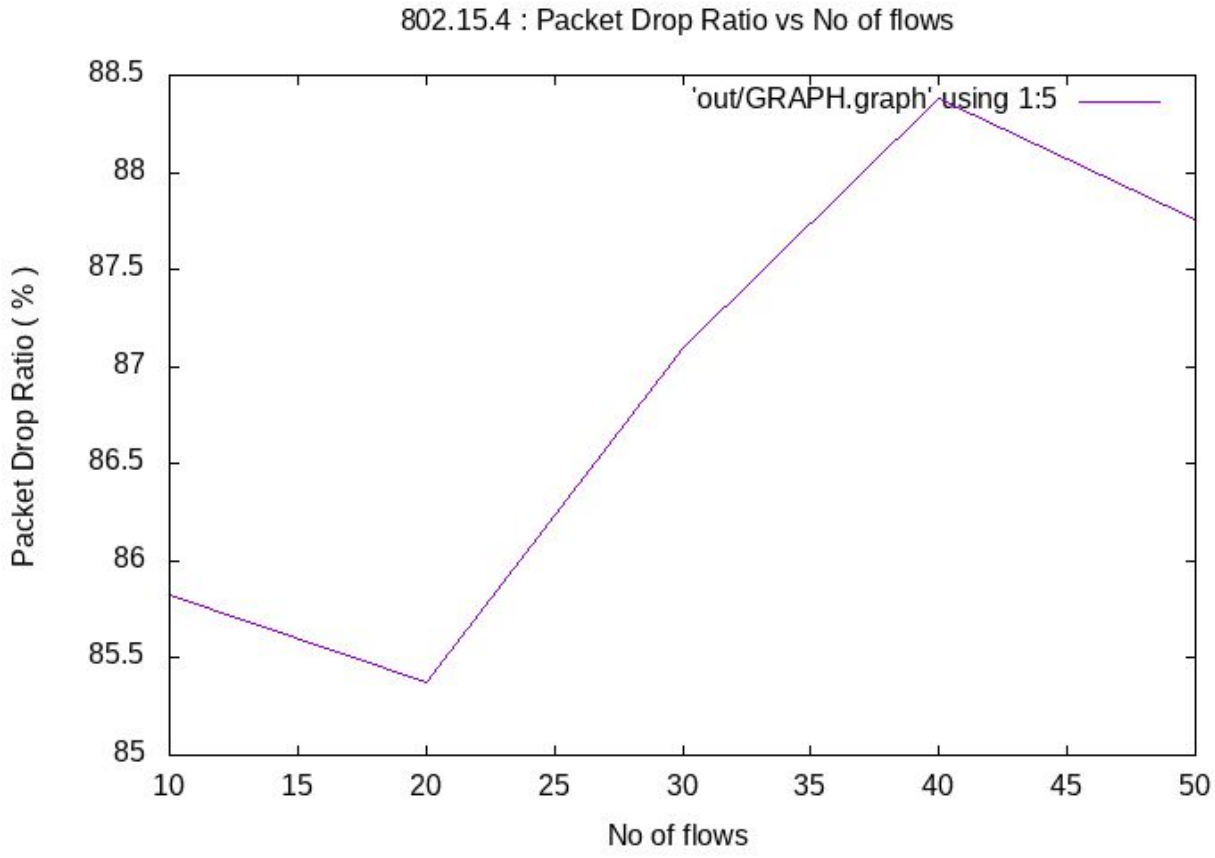

802.15.4 : Throughput vs No of nodes
'out/GRAPH.graph' using 1:2
Throughput (bit/second)
No of nodes
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
20
30
40
50
60
70
80
90
100

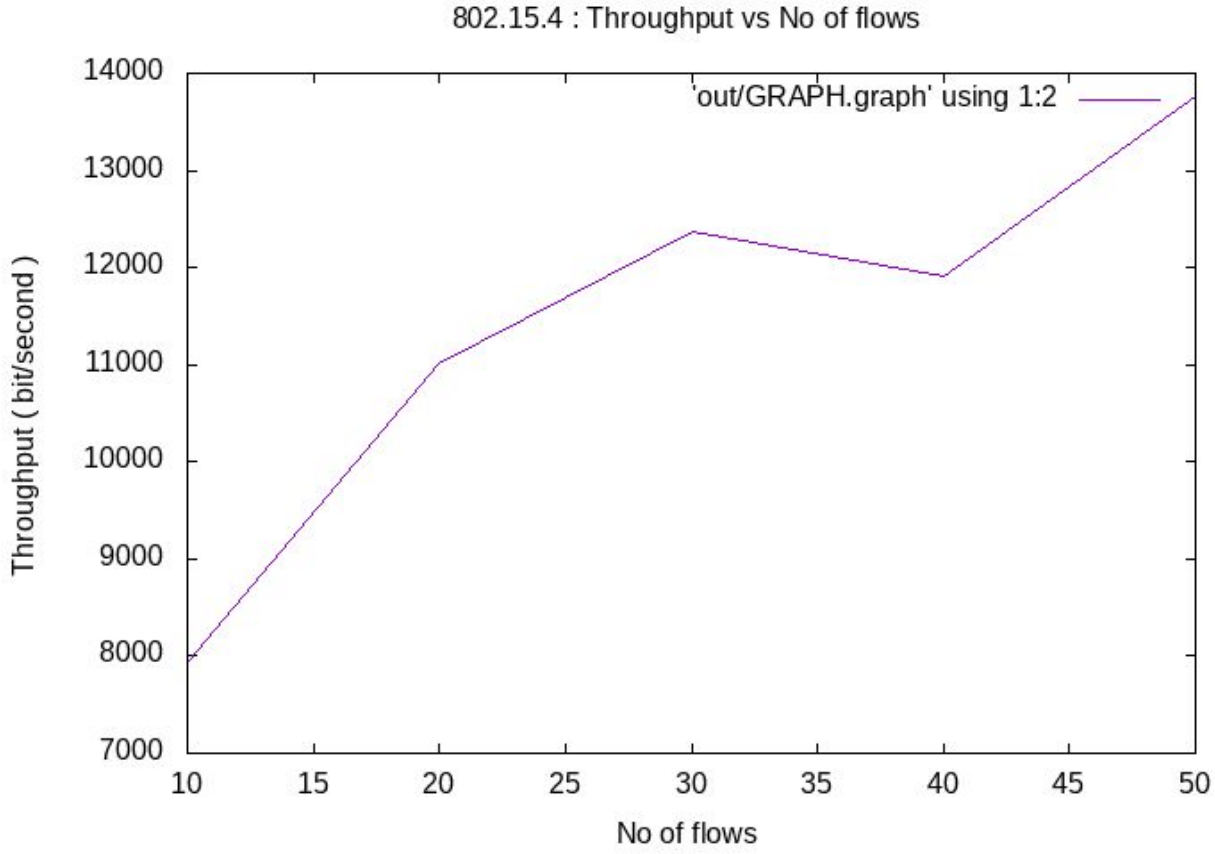

802.15.4 : Total Energy consumption vs No of nodes
'out/GRAPH.graph' using 1:6
Total Energy consumption (J)
No of nodes
80
70
60
50
40
30
20
20
30
40
50
60
70
80
90
100

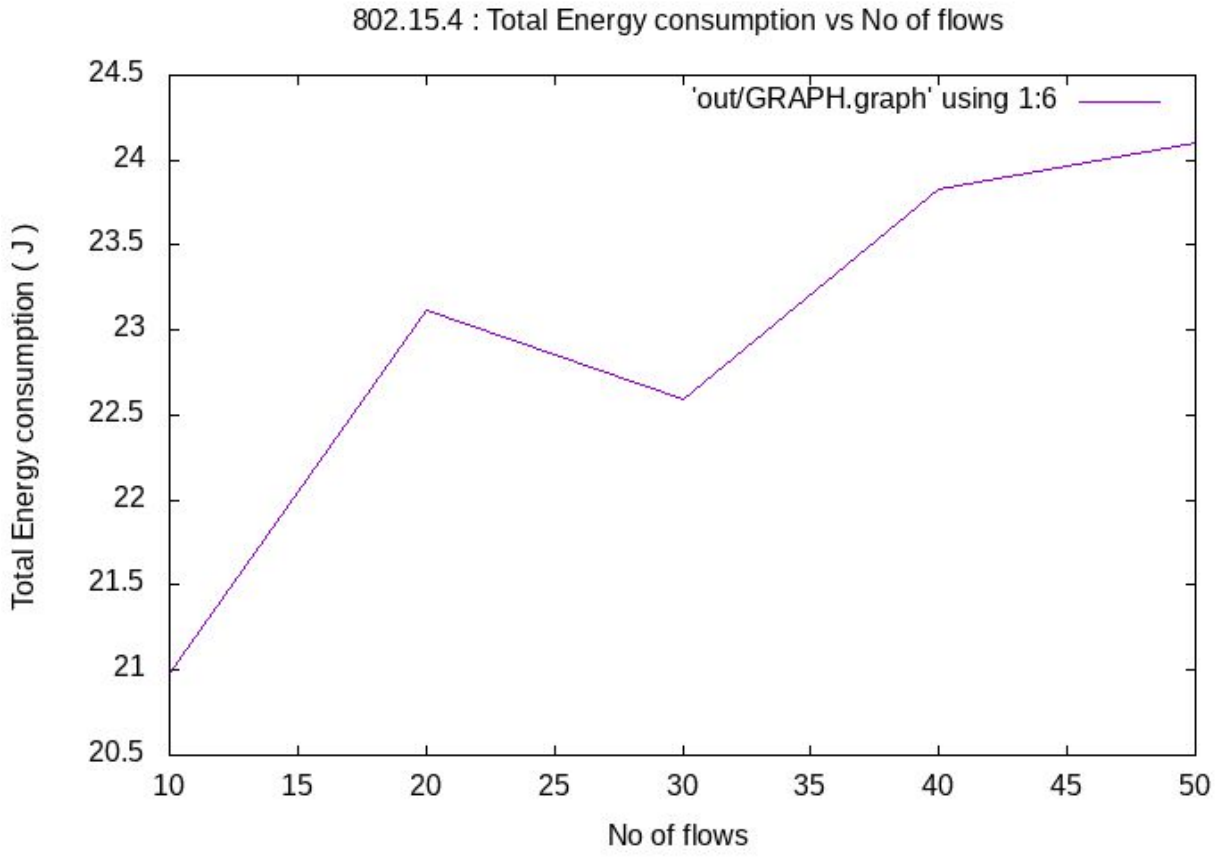

802.15.4 : Average Delay vs No of flows
'out/GRAPH.graph' using 1:3
Average Delay (second)
No of flows
0.19
0.18
0.17
0.16
0.15
0.14
0.13
0.12
10
15
20
25
30
35
40
45
50

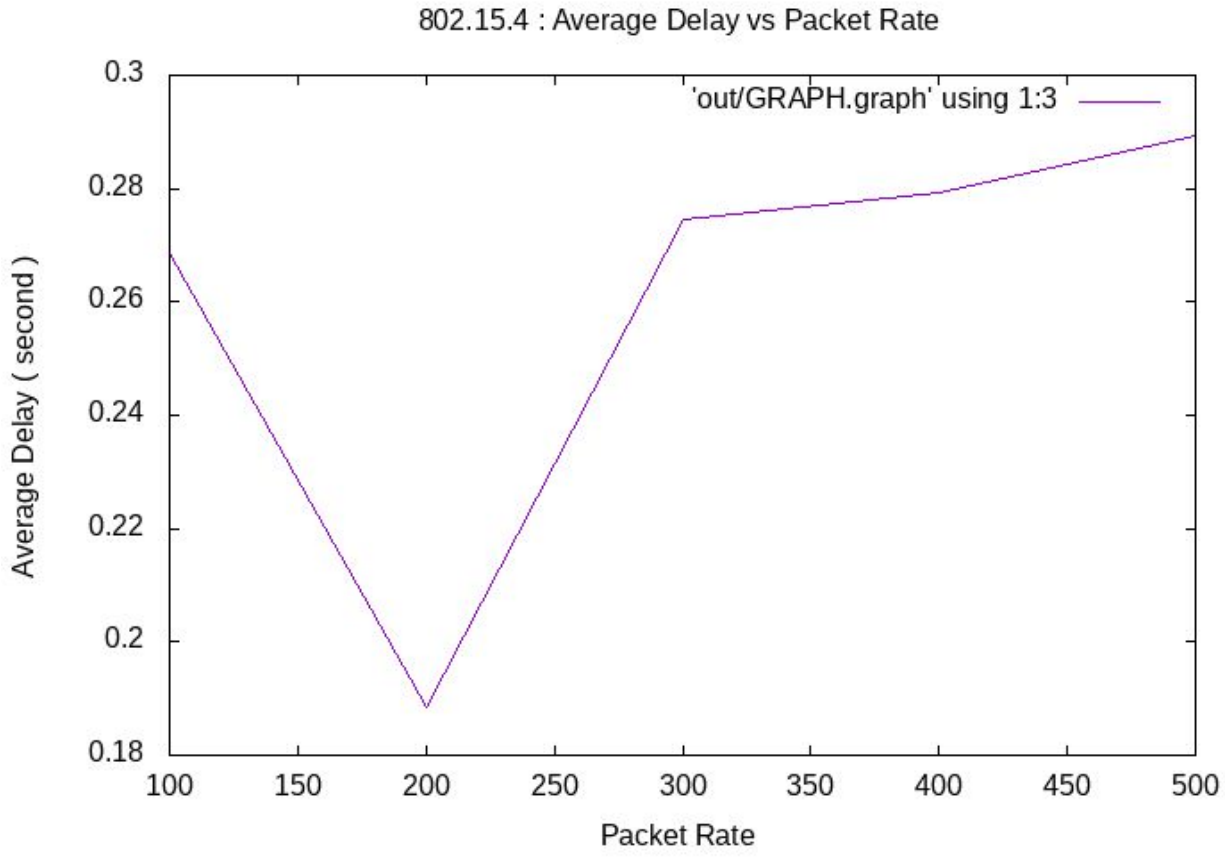

802.15.4 : Energy per byte vs No of flows
'out/GRAPH.graph' using 1:7
Energy per byte (J)
No of flows
0.002
0.0018
0.0016
0.0014
0.0012
0.001
0.0008
0.0006
10
15
20
25
30
35
40
45
50

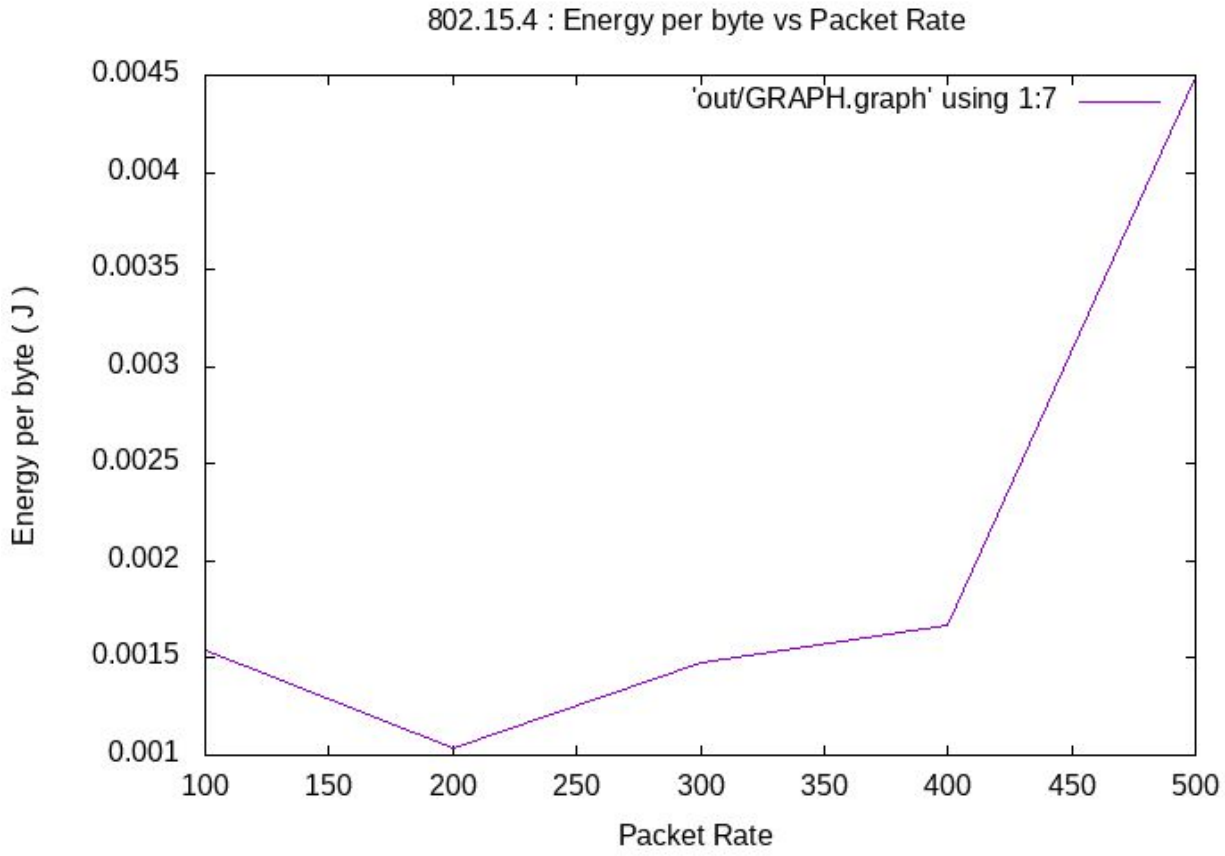

802.15.4 : Packet Delivery Ratio vs No of flows
'out/GRAPH.graph' using 1:4
Packet Delivery Ratio (%)
No of flows
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
10
15
20
25
30
35
40
45
50

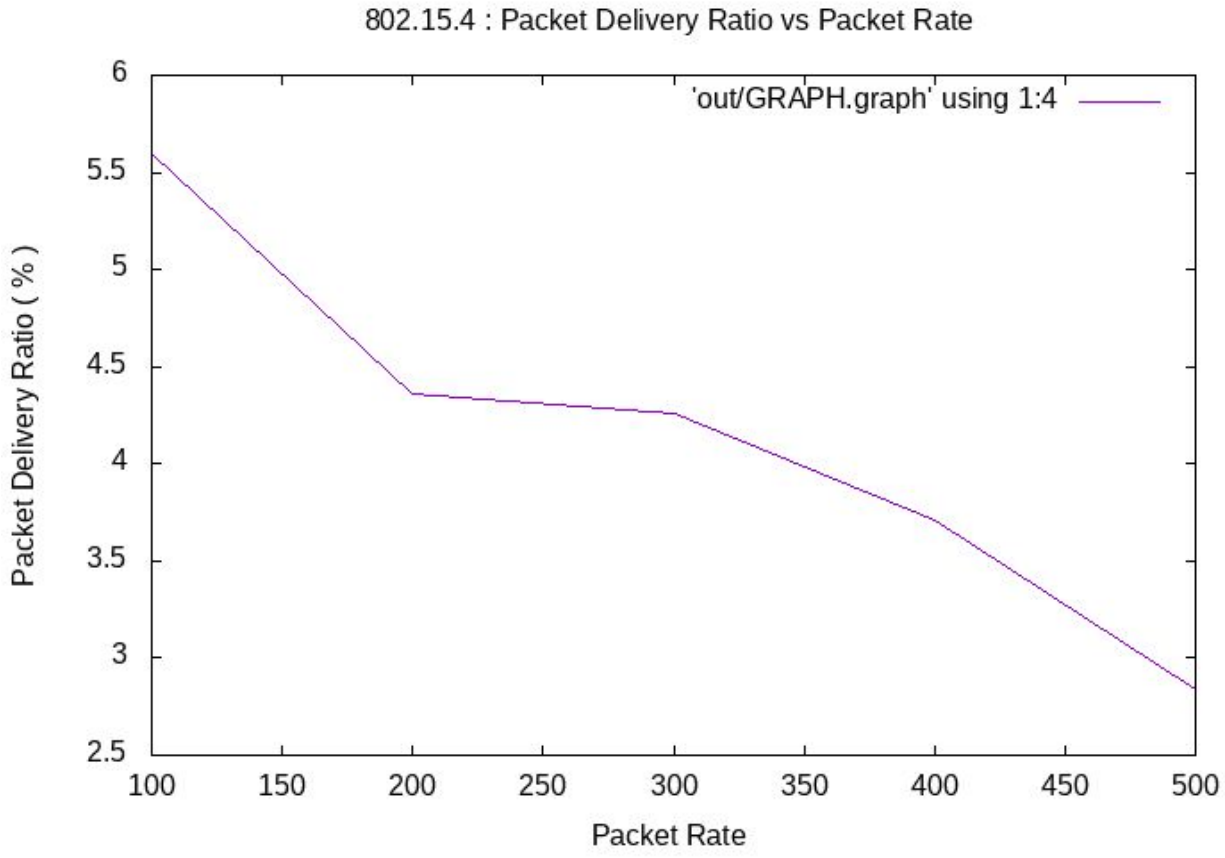

802.15.4 : Packet Drop Ratio vs No of flows
'out/GRAPH.graph' using 1:5
Packet Drop Ratio (%)
No of flows
88.5
88
87.5
87
86.5
86
85.5
85
10
15
20
25
30
35
40
45
50

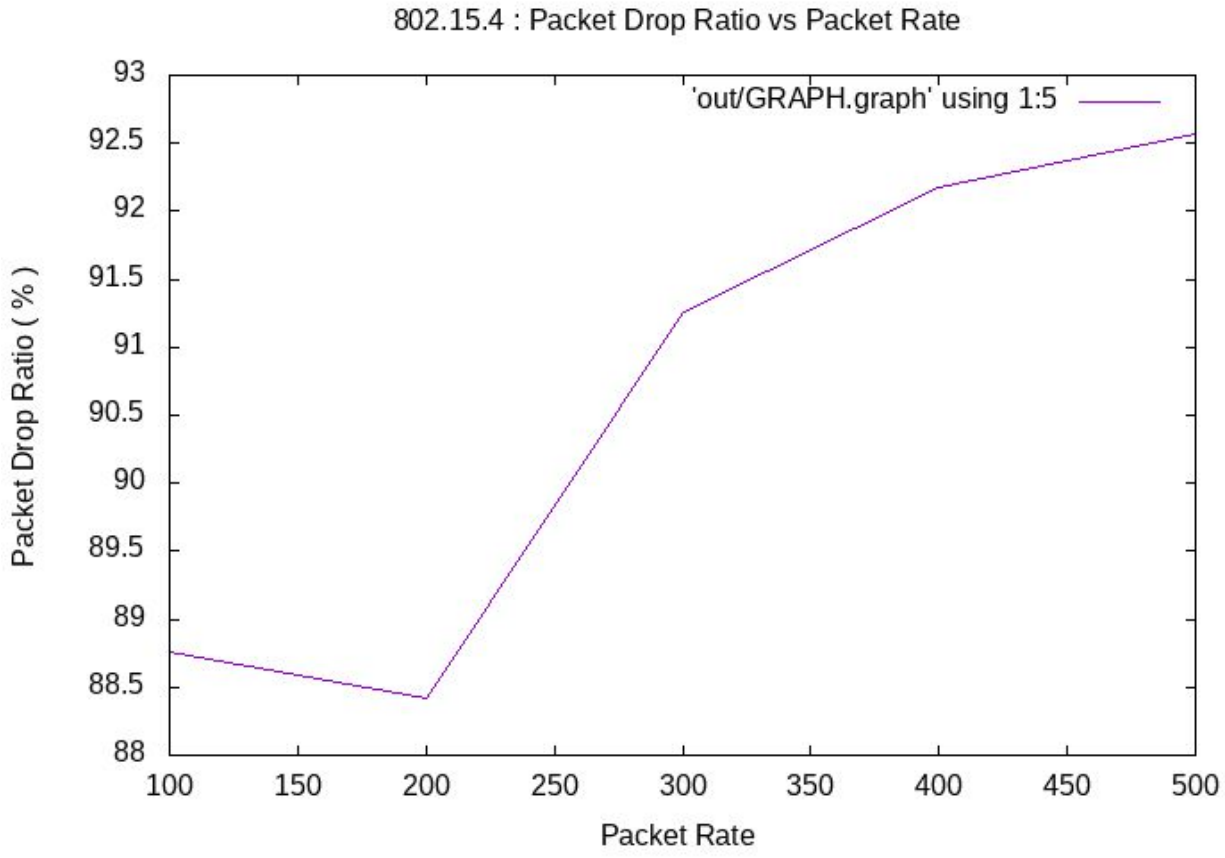

802.15.4 : Throughput vs No of flows
'out/GRAPH.graph' using 1:2
Throughput (bit/second)
No of flows
14000
13000
12000
11000
10000
9000
8000
7000
10
15
20
25
30
35
40
45
50

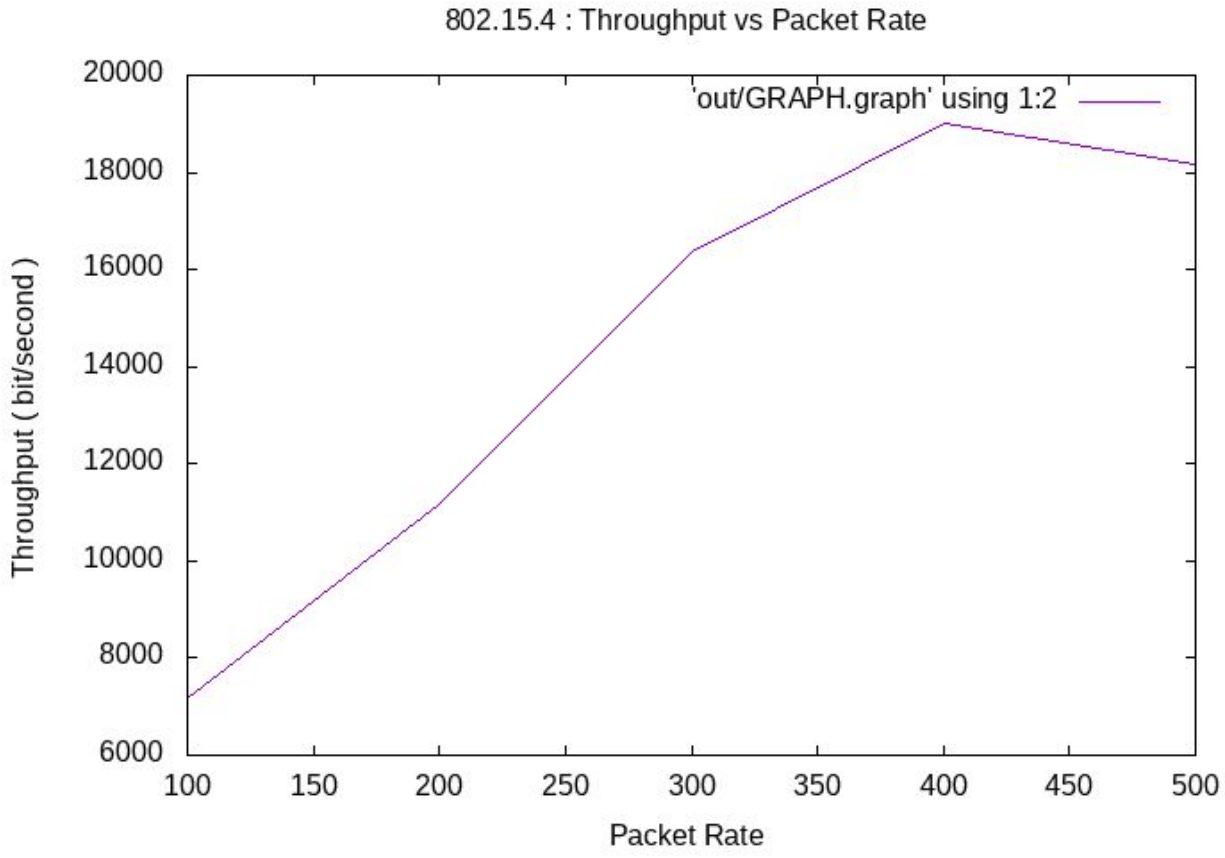

802.15.4 : Total Energy consumption vs No of flows
'out/GRAPH.graph' using 1:6
Total Energy consumption (J)
No of flows
24.5
24
23.5
23
22.5
22
21.5
21
20.5
10
15
20
25
30
35
40
45
50

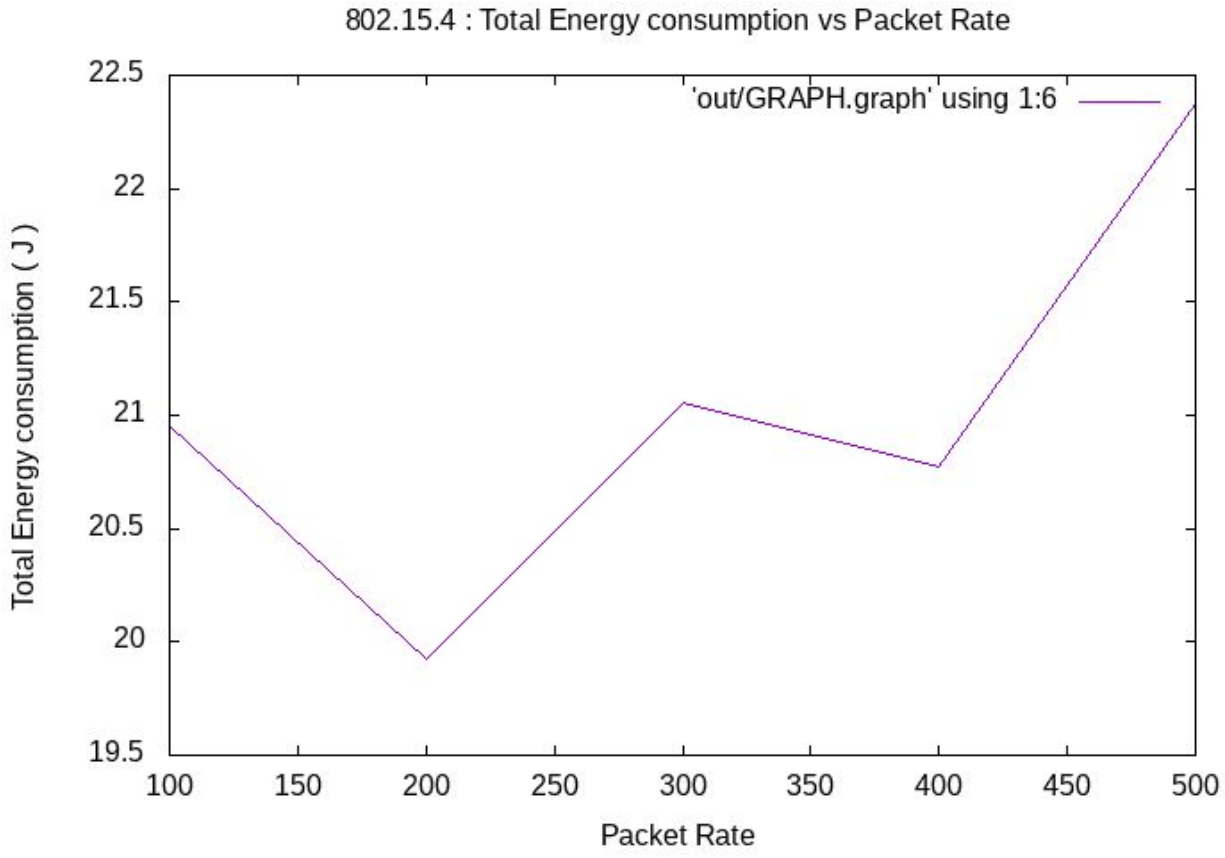

802.15.4 : Average Delay vs Packet Rate
'out/GRAPH.graph' using 1:3
Average Delay (second)
Packet Rate
0.3
0.28
0.26
0.24
0.22
0.2
0.18
100
150
200
250
300
350
400
450
500

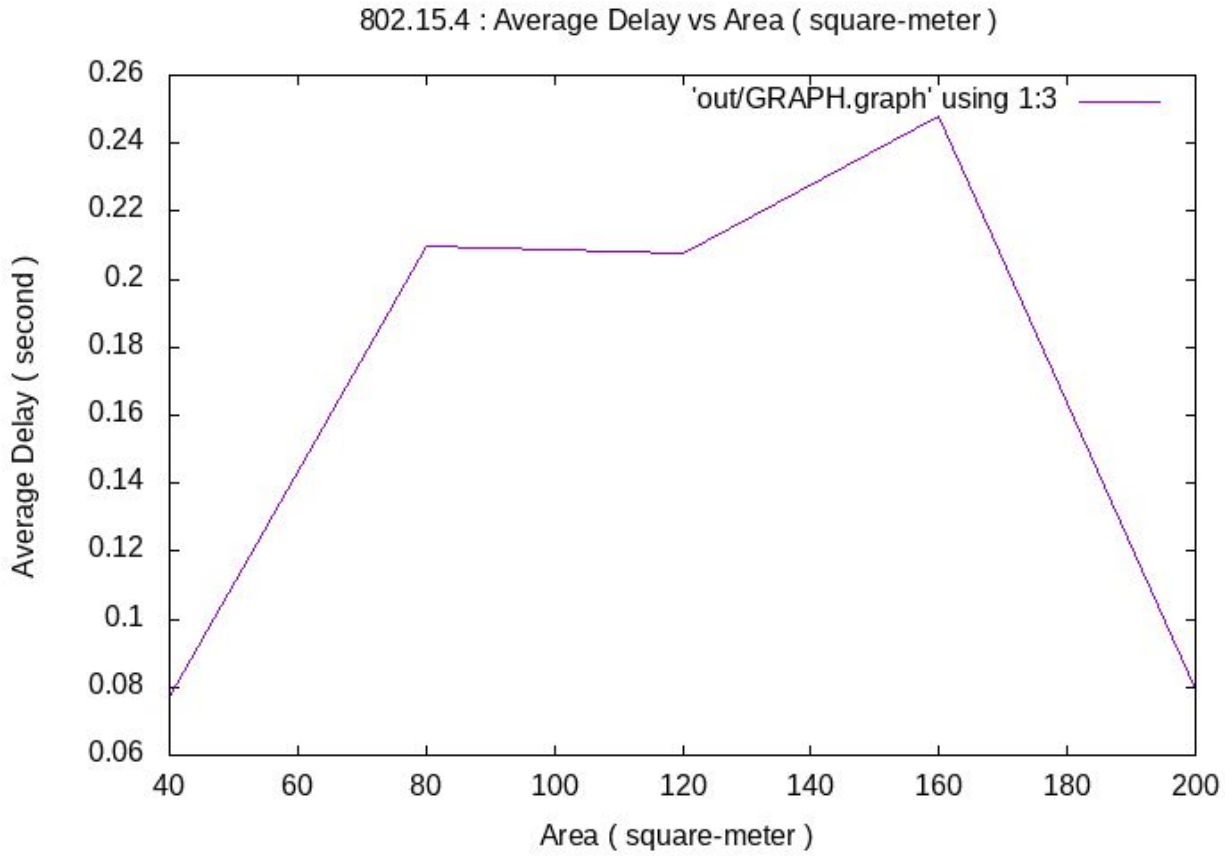

802.15.4 : Energy per byte vs Packet Rate
'out/GRAPH.graph' using 1:7
Energy per byte (J)
Packet Rate
0.0045
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
100
150
200
250
300
350
400
450
500

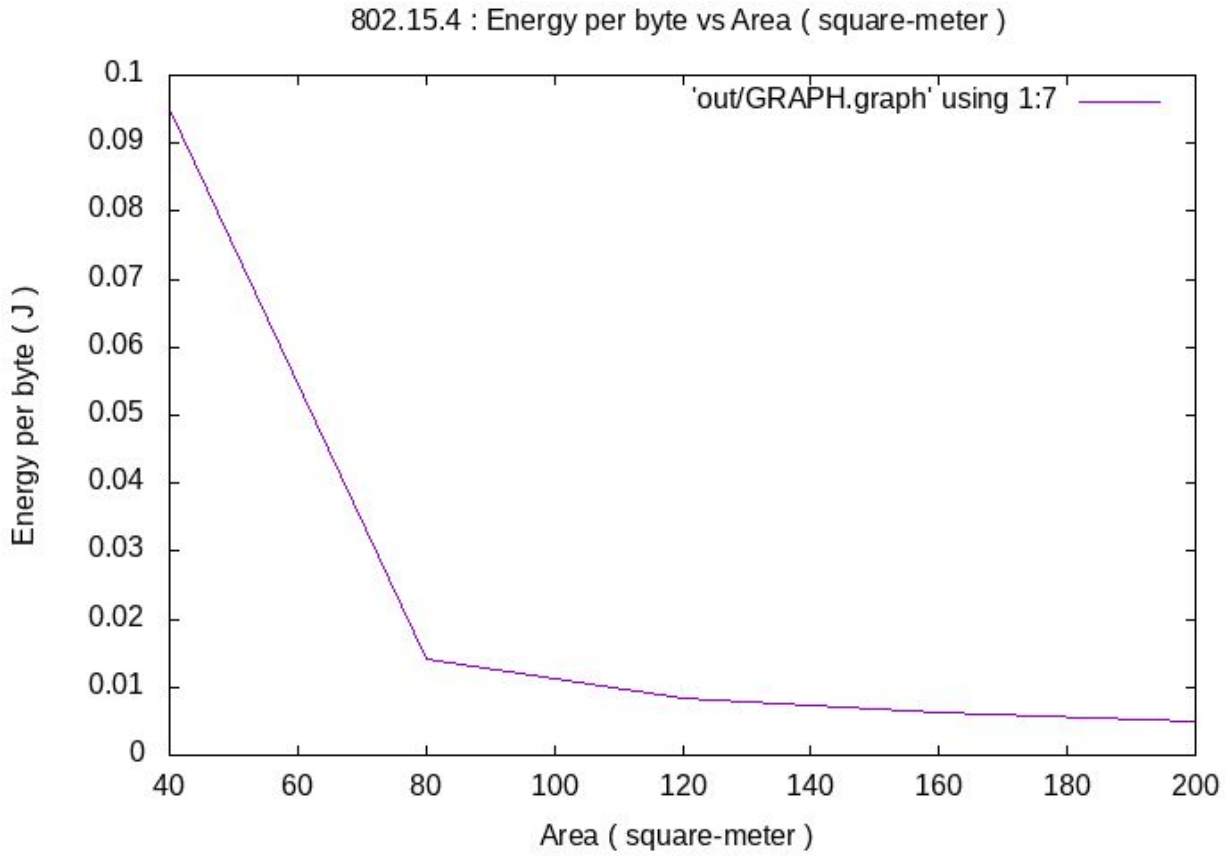

802.15.4 : Packet Delivery Ratio vs Packet Rate
'out/GRAPH.graph' using 1:4
Packet Delivery Ratio (%)
Packet Rate
6
5.5
5
4.5
4
3.5
3
2.5
100
150
200
250
300
350
400
450
500

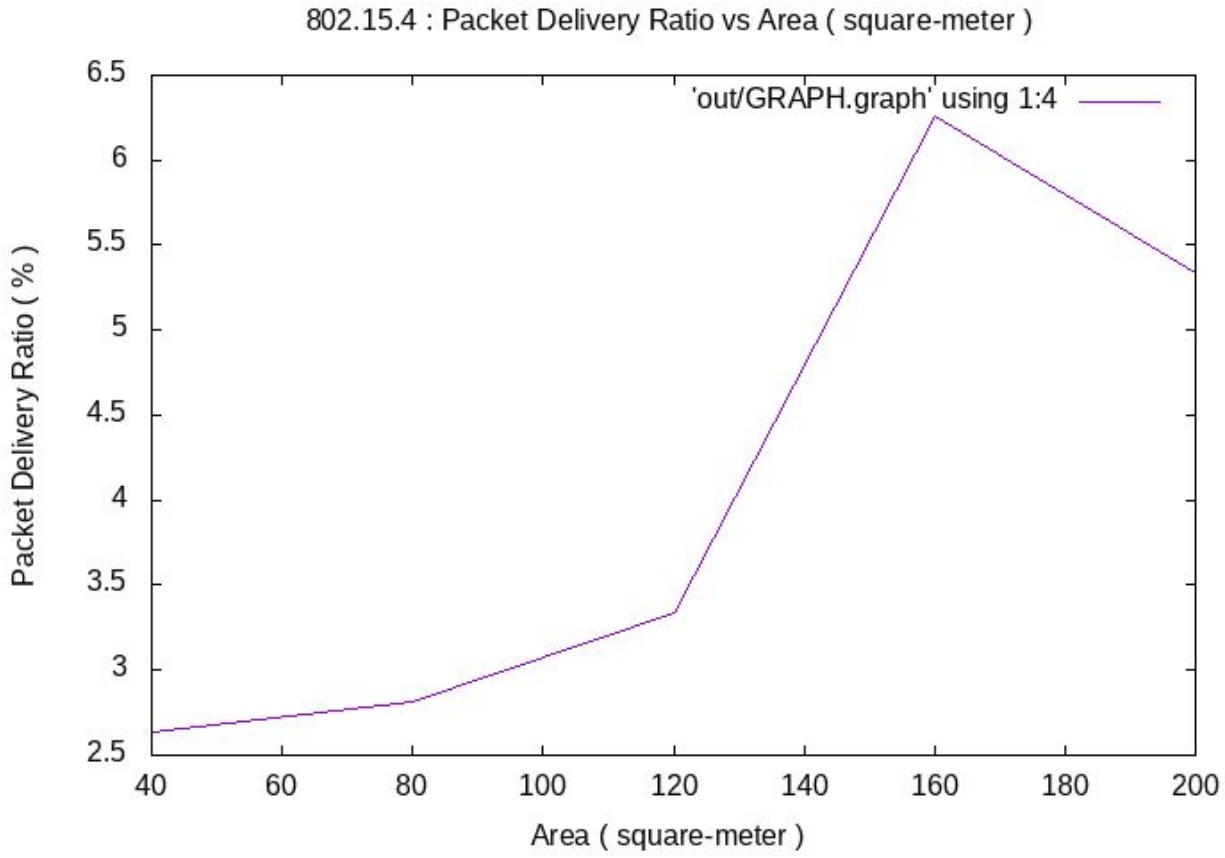

802.15.4 : Packet Drop Ratio vs Packet Rate
'out/GRAPH.graph' using 1:5
Packet Drop Ratio (%)
Packet Rate
93
92.5
92
91.5
91
90.5
90
89.5
89
88.5
88
100
150
200
250
300
350
400
450
500

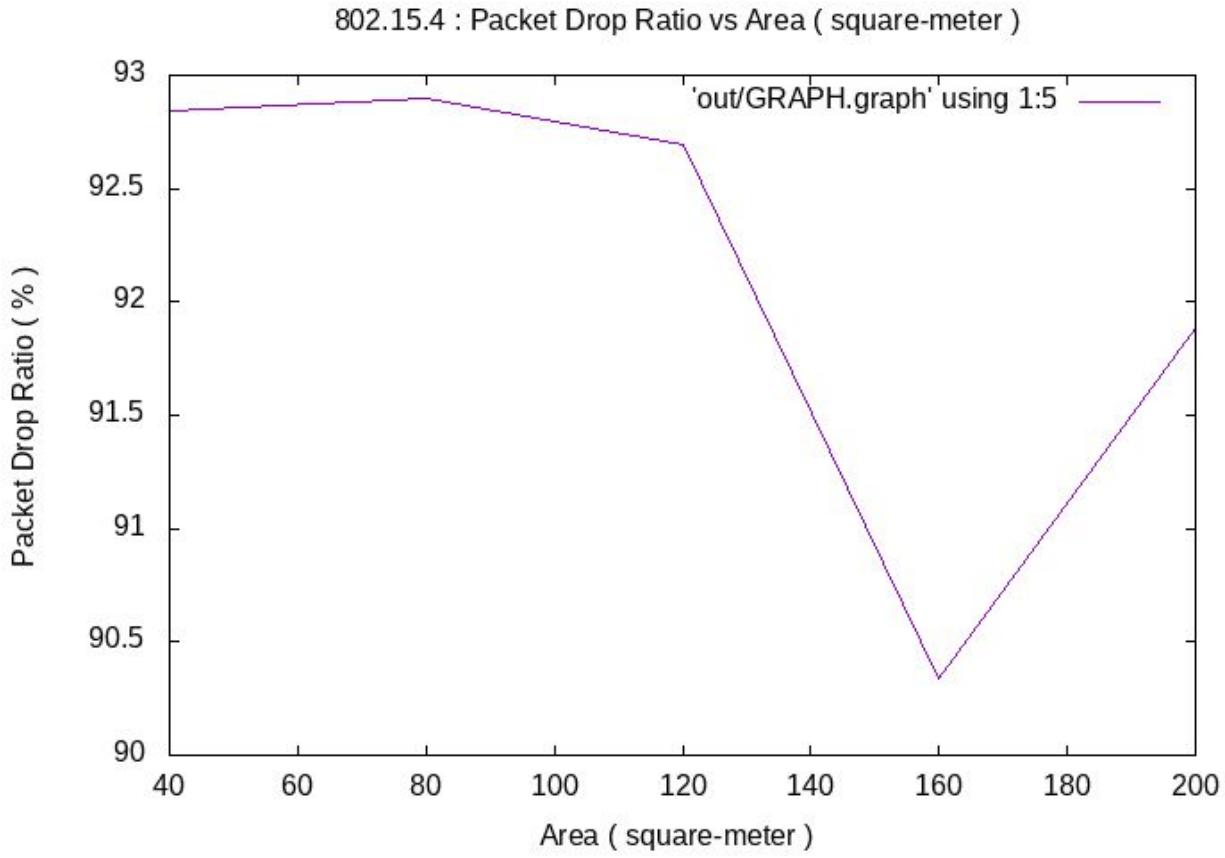

802.15.4 : Throughput vs Packet Rate
'out/GRAPH.graph' using 1:2
Throughput (bit/second)
Packet Rate
20000
18000
16000
14000
12000
10000
8000
6000
100
150
200
250
300
350
400
450
500

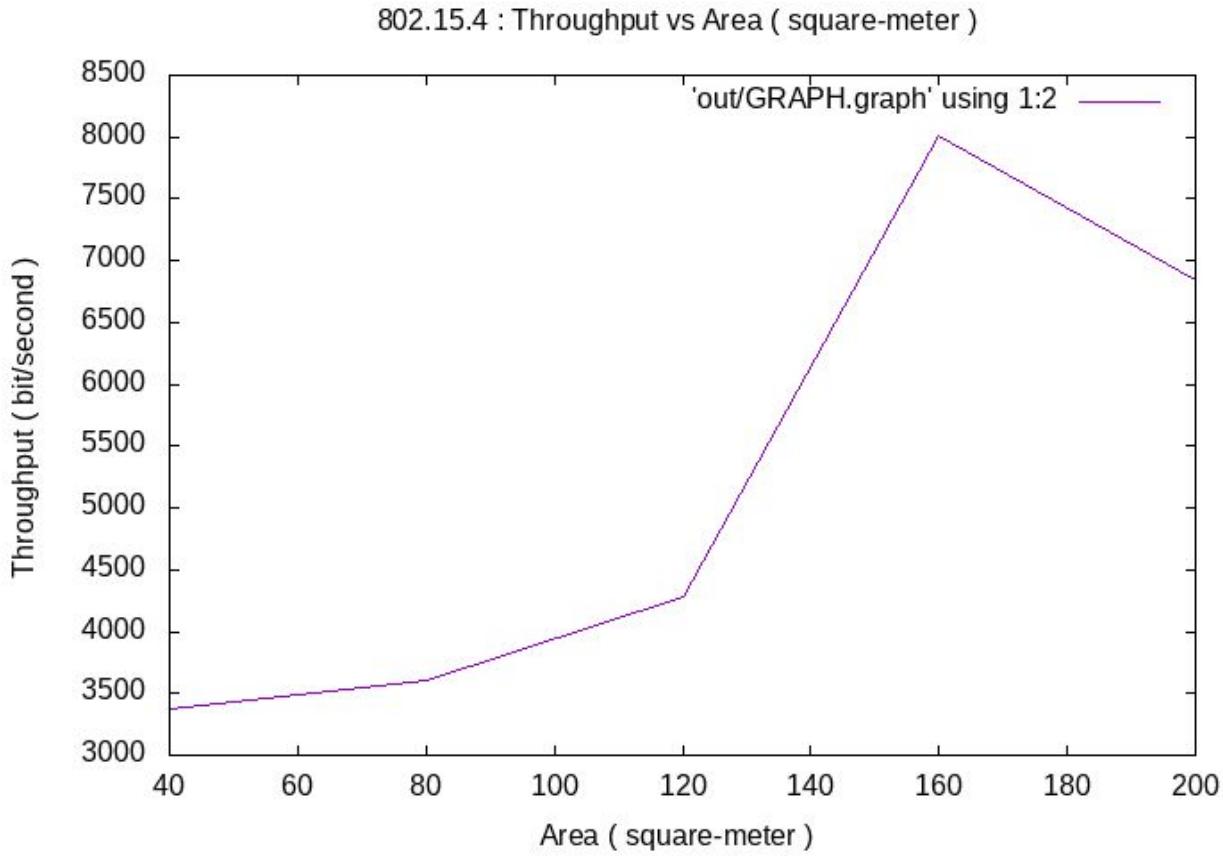

802.15.4 : Total Energy consumption vs Packet Rate
'out/GRAPH.graph' using 1:6
Total Energy consumption (J)
Packet Rate
22.5
22
21.5
21
20.5
20
19.5
100
150
200
250
300
350
400
450
500

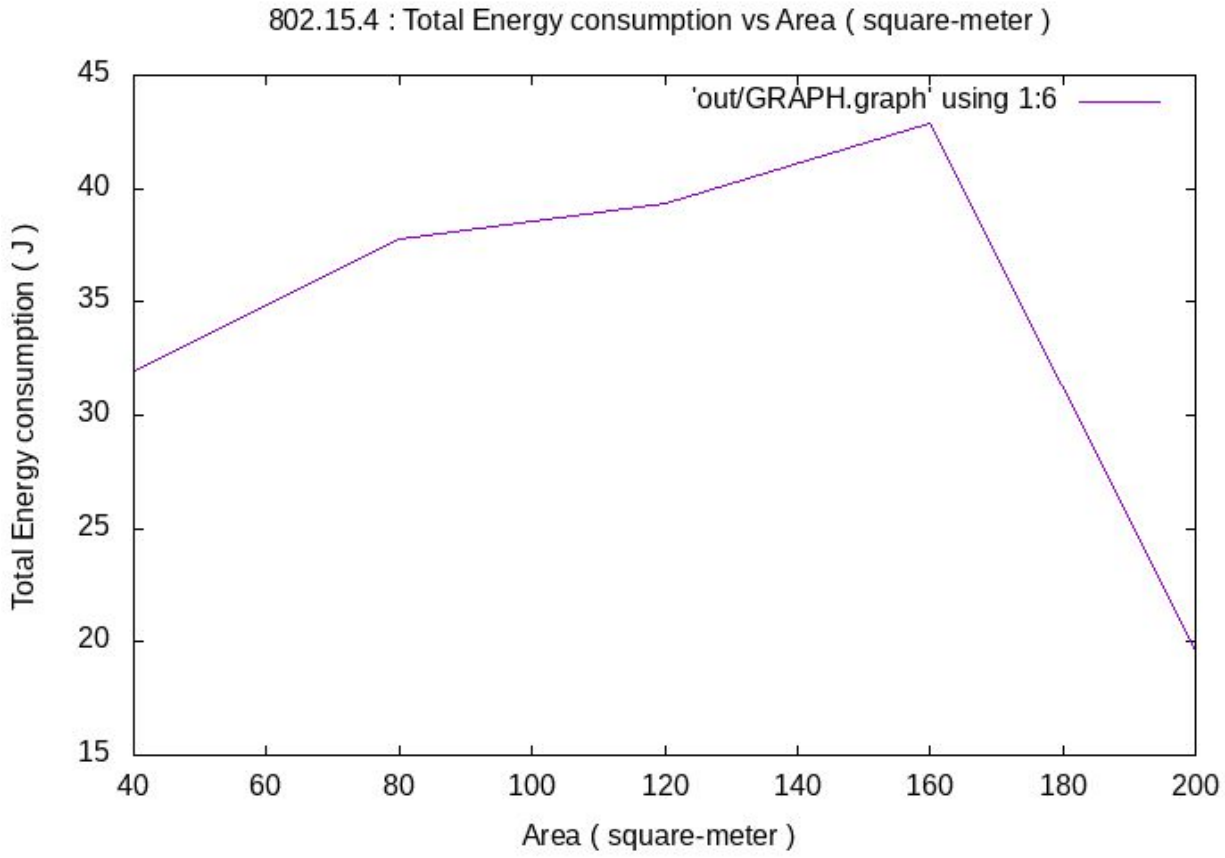

802.15.4 : Average Delay vs Area (square-meter)
'out/GRAPH.graph' using 1:3
Average Delay (second)
Area (square-meter)
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
40
60
80
100
120
140
160
180
200


802.15.4 : Energy per byte vs Area (square-meter)
'out/GRAPH.graph' using 1:7
Energy per byte (J)
Area (square-meter)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
40
60
80
100
120
140
160
180
200


802.15.4 : Packet Delivery Ratio vs Area (square-meter)
'out/GRAPH.graph' using 1:4
Packet Delivery Ratio (%)
Area (square-meter)
6.5
6
5.5
5
4.5
4
3.5
3
2.5
40
60
80
100
120
140
160
180
200


802.15.4 : Packet Drop Ratio vs Area (square-meter)
'out/GRAPH.graph' using 1:5
Packet Drop Ratio (%)
Area (square-meter)
93
92.5
92
91.5
91
90.5
90
40
60
80
100
120
140
160
180
200


802.15.4 : Throughput vs Area (square-meter)
'out/GRAPH.graph' using 1:2
Throughput (bit/second)
Area (square-meter)
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
40
60
80
100
120
140
160
180
200

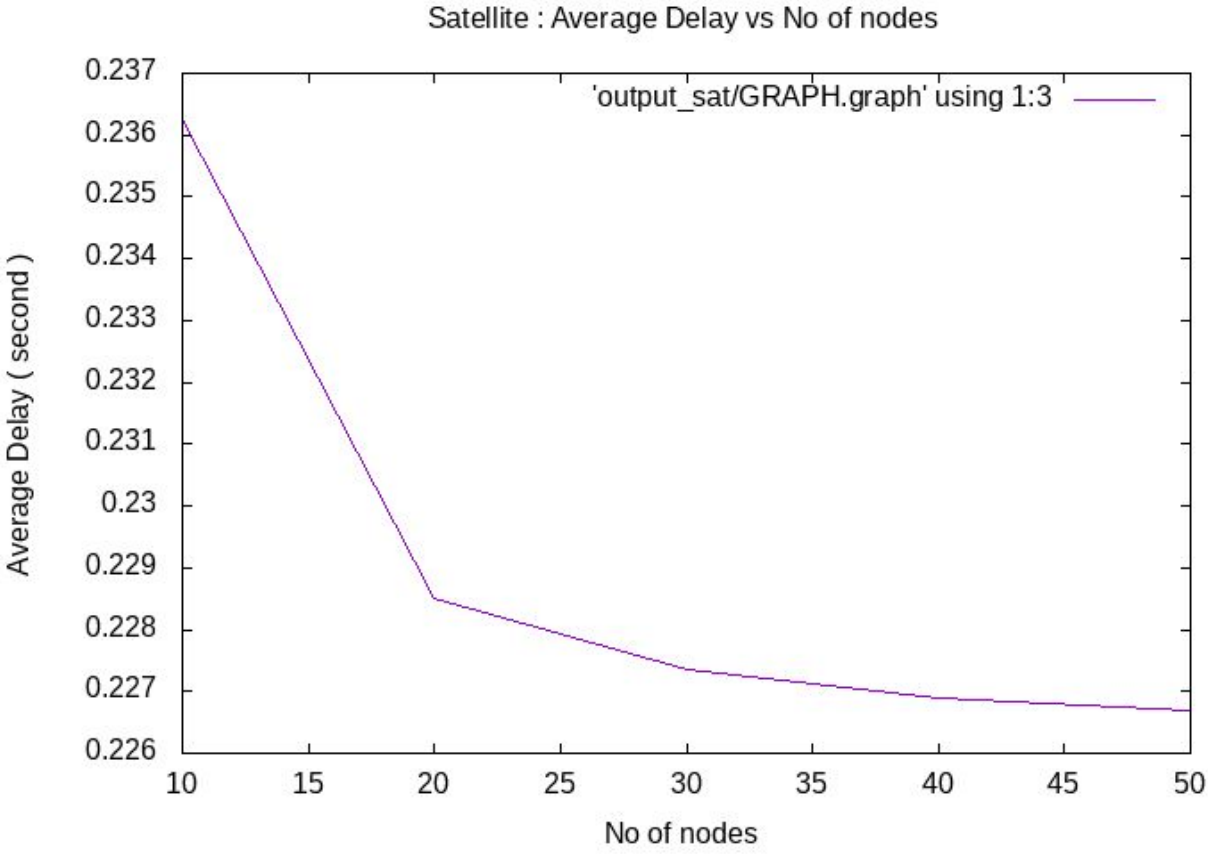

802.15.4 : Total Energy consumption vs Area (square-meter)
'out/GRAPH.graph' using 1:6
Total Energy consumption (J)
Area (square-meter)
45
40
35
30
25
20
15
40
60
80
100
120
140
160
180
200

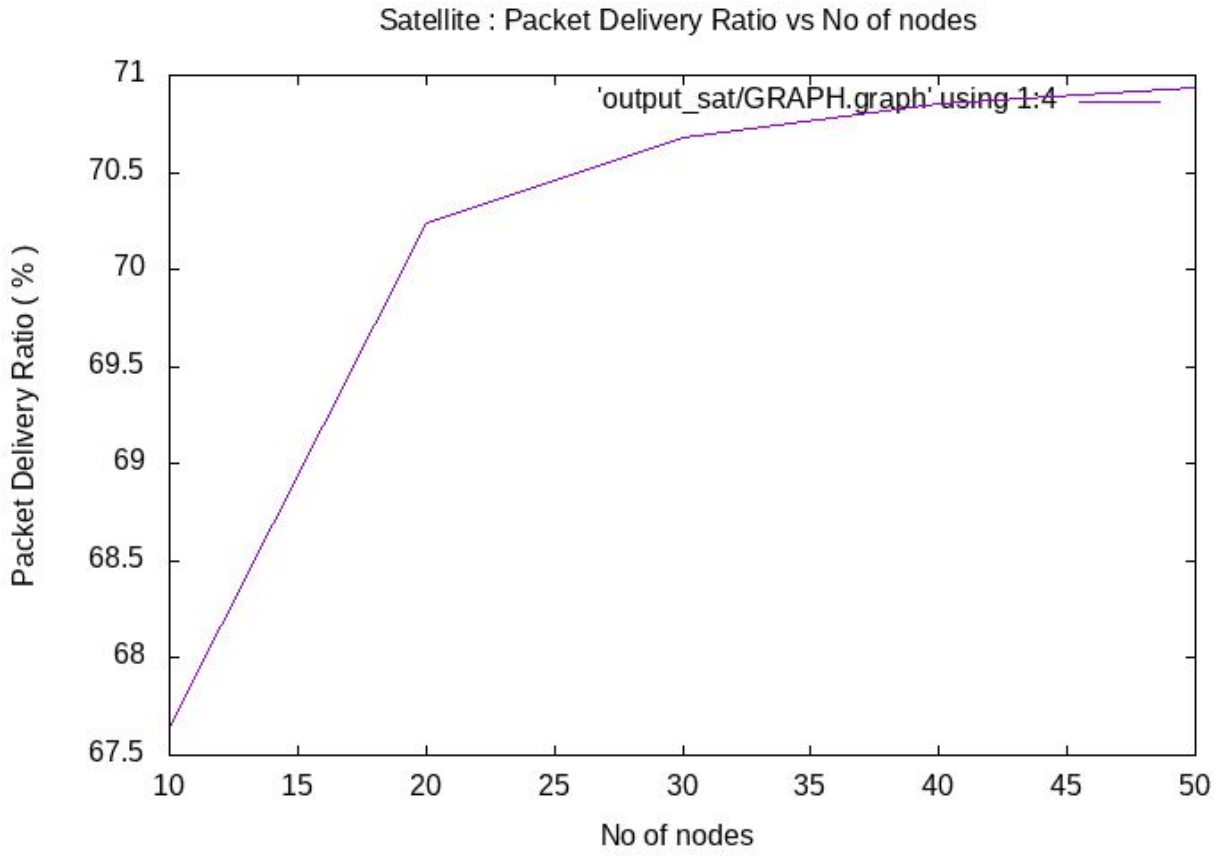
Satellite

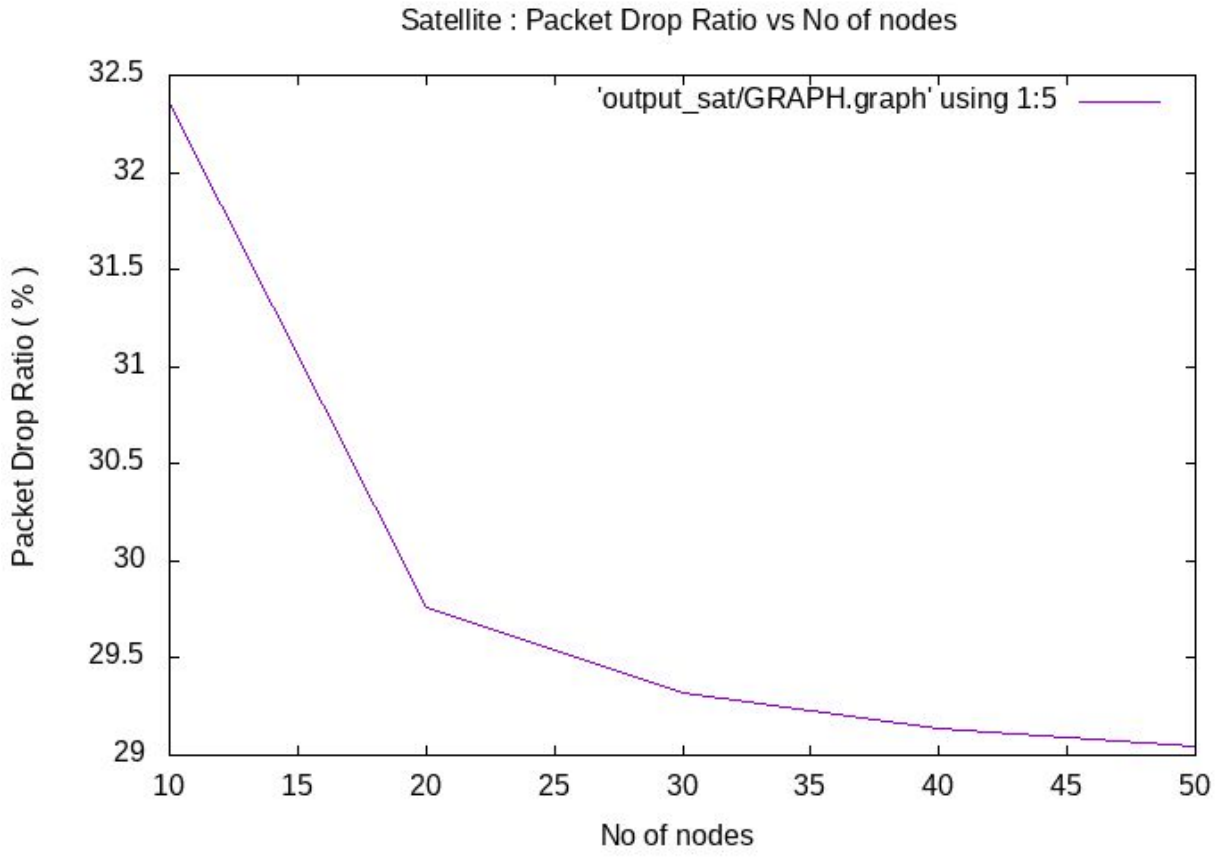
(Bonus)

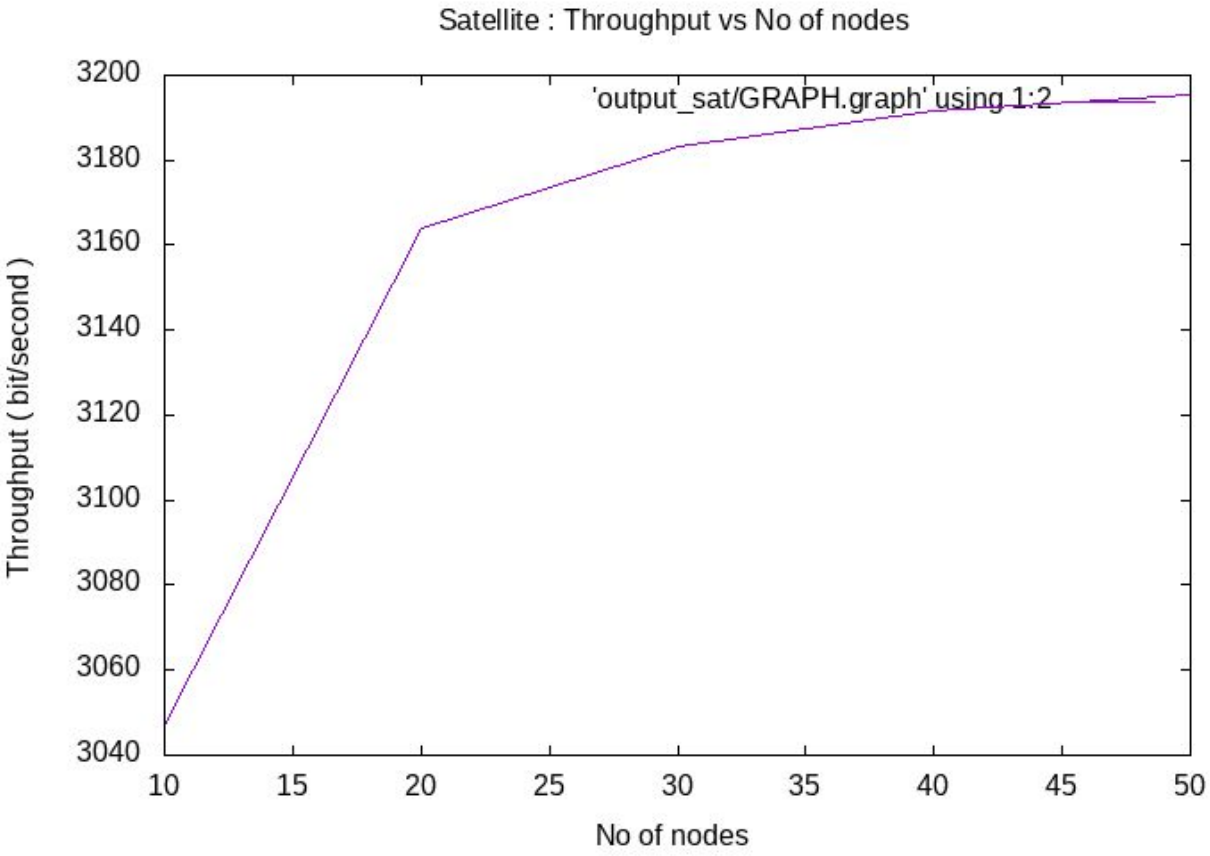
Measured metrics vs parameter:

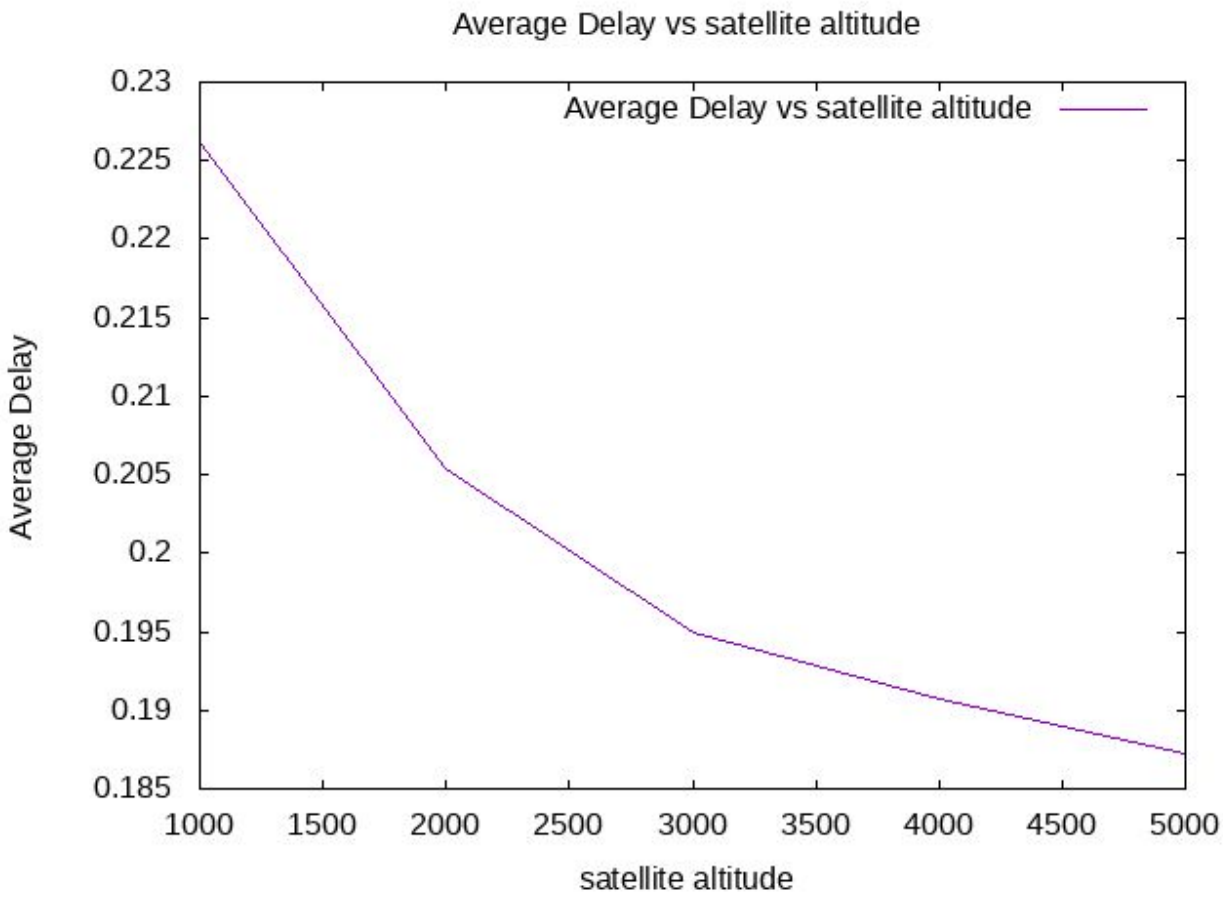
- ➢ Average delay vs number-of-nodes
- ➢ Packet delivery ratio vs number-of-nodes
- ➢ Packet drop ratio vs number-of-nodes
- ➢ Throughput vs number-of-nodes
- ➢ Average delay vs satellite altitude


Satellite : Average Delay vs No of nodes
'output_sat/GRAPH.graph' using 1:3
Average Delay (second)
No of nodes
0.237
0.236
0.235
0.234
0.233
0.232
0.231
0.23
0.229
0.228
0.227
0.226
10
15
20
25
30
35
40
45
50


Satellite : Packet Delivery Ratio vs No of nodes
'output_sat/GRAPH.graph' using 1:4
Packet Delivery Ratio (%)
No of nodes
71
70.5
70
69.5
69
68.5
68
67.5
10
15
20
25
30
35
40
45
50


Satellite : Packet Drop Ratio vs No of nodes
'output_sat/GRAPH.graph' using 1:5
Packet Drop Ratio (%)
No of nodes
32.5
32
31.5
31
30.5
30
29.5
29
10
15
20
25
30
35
40
45
50


Satellite : Throughput vs No of nodes
'output_sat/GRAPH.graph' using 1:2
Throughput (bit/second)
No of nodes
3200
3180
3160
3140
3120
3100
3080
3060
3040
10
15
20
25
30
35
40
45
50

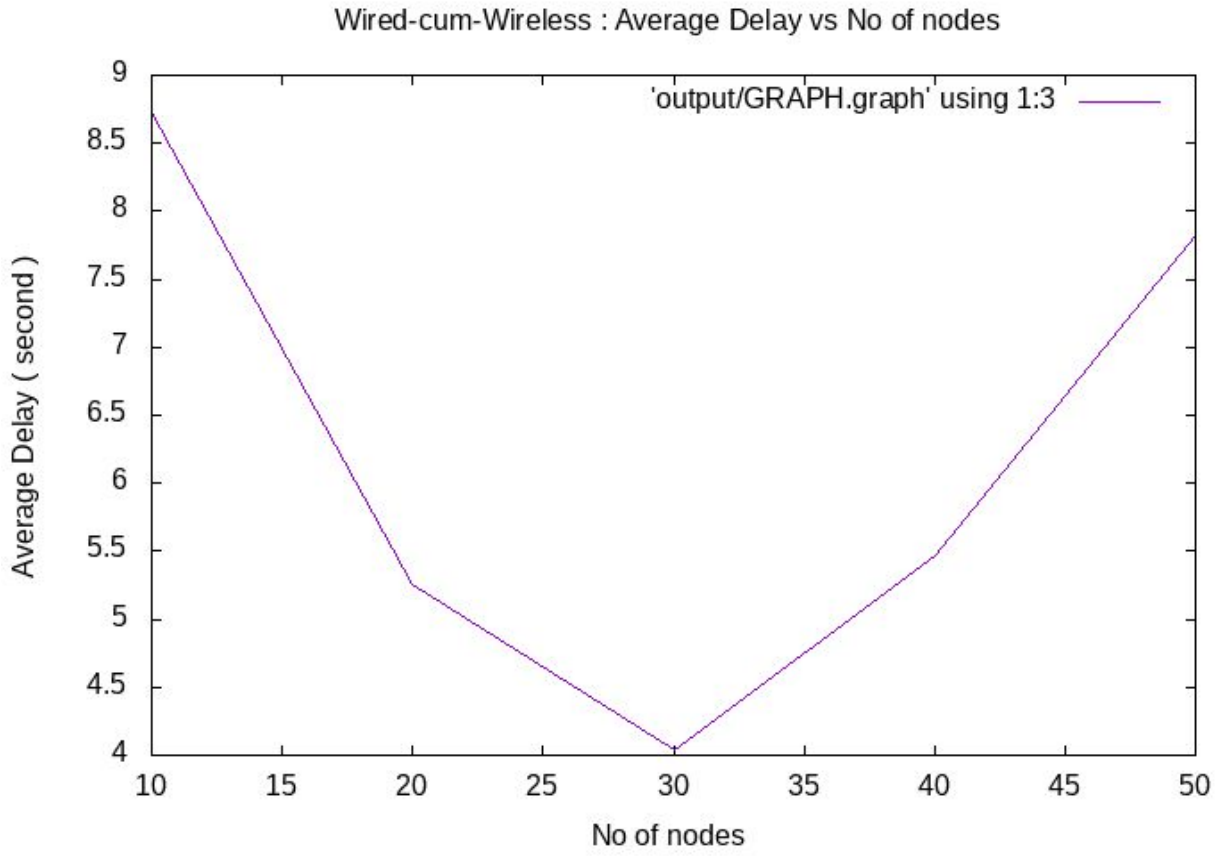

Average Delay vs satellite altitude
Average Delay vs satellite altitude
Average Delay
0.23
0.225
0.22
0.215
0.21
0.205
0.2
0.195
0.19
0.185
1000
1500
2000
2500
3000
3500
4000
4500
5000
satellite altitude

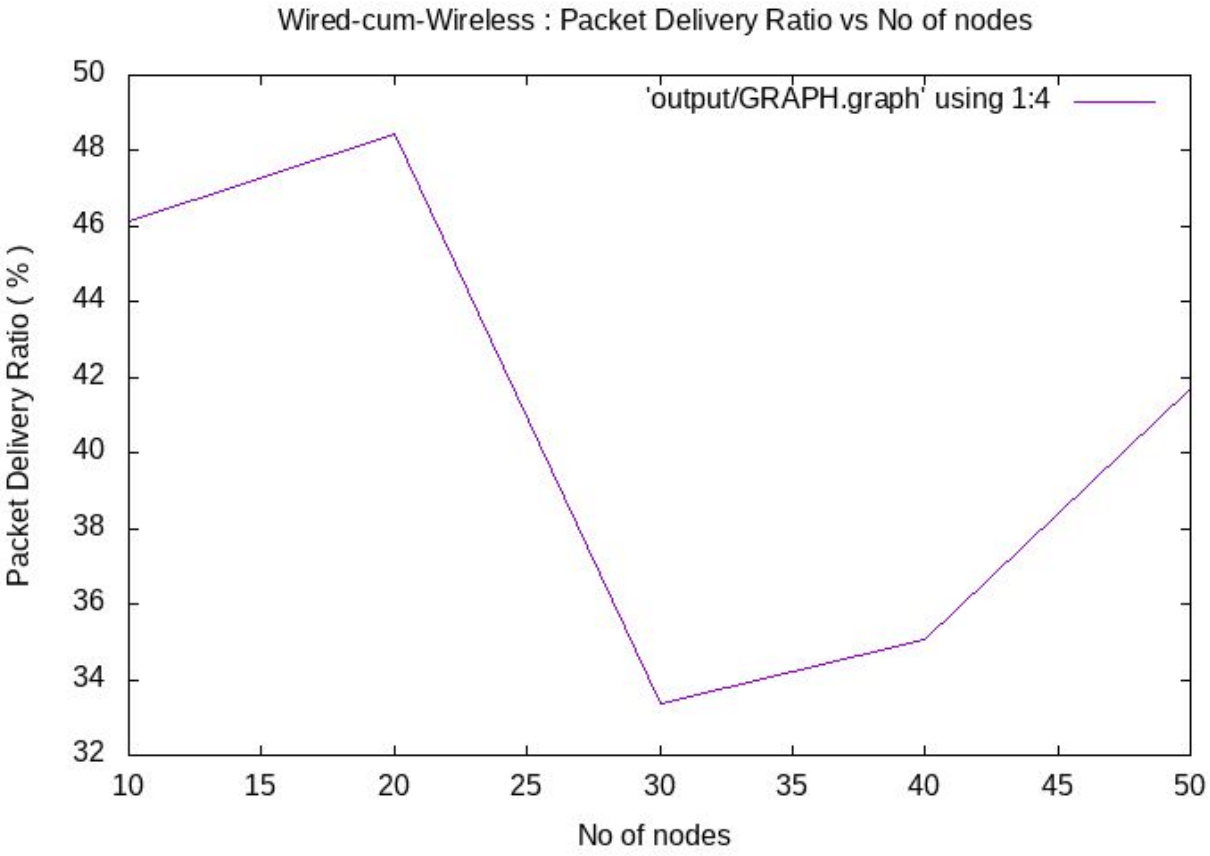
Wired-to-802.11

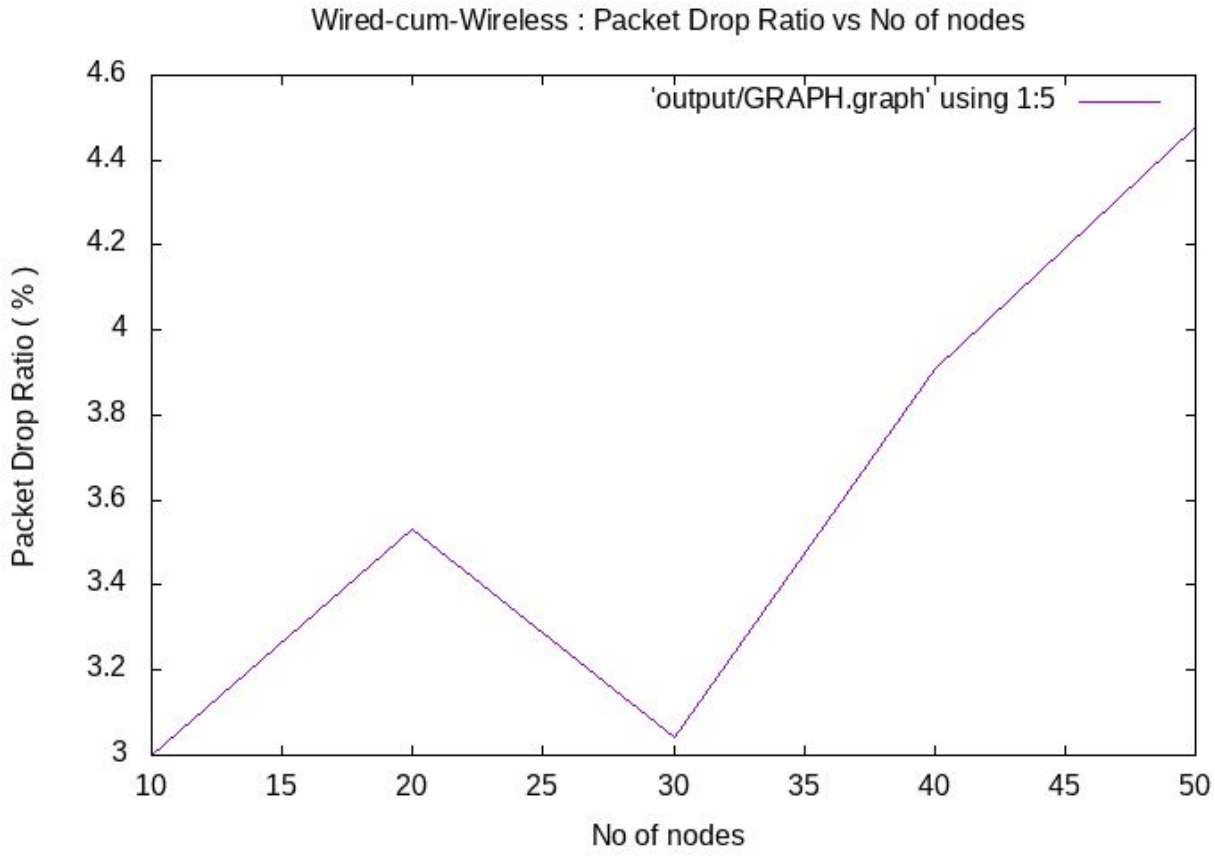
(Bonus)

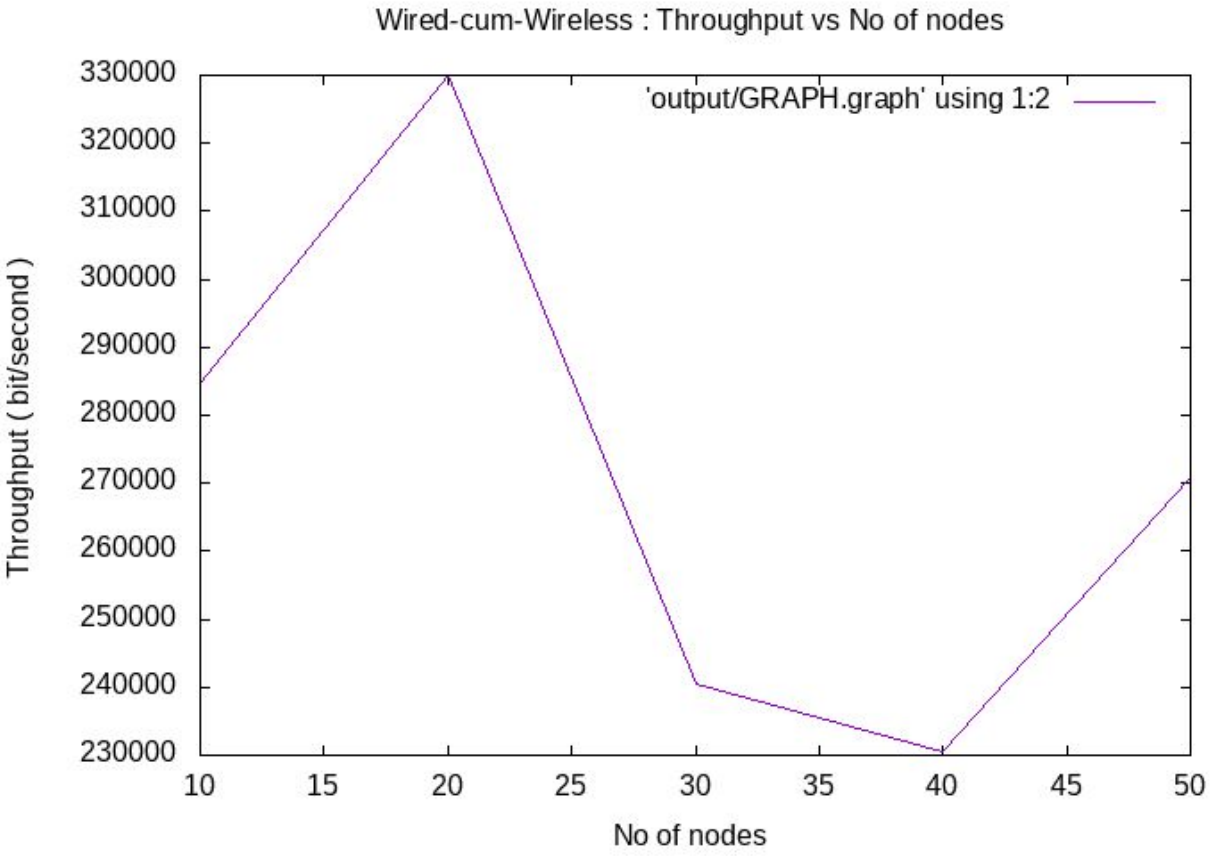
Measured metrics vs parameter:

- ➢ Average delay vs number-of-nodes
- ➢ Packet delivery ratio vs number-of-nodes
- ➢ Packet drop ratio vs number-of-nodes
- ➢ Throughput vs number-of-nodes


Wired-cum-Wireless : Average Delay vs No of nodes
'output/GRAPH.graph' using 1:3
Average Delay (second)
No of nodes
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
10
15
20
25
30
35
40
45
50


Wired-cum-Wireless : Packet Delivery Ratio vs No of nodes
'output/GRAPH.graph' using 1:4
Packet Delivery Ratio (%)
No of nodes
50
48
46
44
42
40
38
36
34
32
10
15
20
25
30
35
40
45
50


Wired-cum-Wireless : Packet Drop Ratio vs No of nodes
'output/GRAPH.graph' using 1:5
Packet Drop Ratio (%)
No of nodes
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
10
15
20
25
30
35
40
45
50


Wired-cum-Wireless : Throughput vs No of nodes
'output/GRAPH.graph' using 1:2
Throughput (bit/second)
No of nodes
330000
320000
310000
300000
290000
280000
270000
260000
250000
240000
230000
10
15
20
25
30
35
40
45
50

Summary Finding:

- Packet delivery ratio and throughput are much higher in Wired network than 802.15.4.
- Dropping less important packet from drop-tail queue instead of dropping packet at tail always significantly decreased drop ratio in wired network. Another, notable thing is that here RTPROTO and AODV routing packets are considered only because only these are associated with protocols routing mechanism we are simulating.
- However, change in drop-tail queue could not affect 802.15.4 drop ratio mentionably because most of the packets dropped in 802.15.4 was not due to queue.
- Changing average RTT calculation mechanism from Exponential Moving Average to an inferior simple mechanism contributed to increase of end-to-end delay as expected.
  It is because of Exponential Moving Average is more adaptable to real time scenario.
  It is clearly observable in wired network simulation as it has been simulated using tcp.
- Modification in AODV protocol was expected to increase throughput and reduction of end-to-end delay in Wireless 802.15.4 simulation but the simulation did not reflect that. Instead a randomness included and on average throughput decreased in most of cases and delay increased in almost all cases.
- The later graphs of 802.15.4 simulated with DSDV routing protocol has better delivery ratio than AODV but lesser than wired. Hence, DSDV is a better wireless routing protocol than AODV. But the energy consumption is much higher in DSDV than AODV.