IEEE 802.11 CSMA/CA study with ns3

1. Download the ns3 code file lab05-wifi-2hidden-stns.cc. This file models 3 stations n0, n1 and n2, in a configuration such n1-n0 can hear each other, n2-n0 can hear each other, but n1 - n2 cannot. Thus n1, n2 are *hidden terminals w.r.t. each other.*
   Study the code - it is well-commented, make sure you understand every line. The basic concept of an abstract helper object which gets installed on some concrete object representing an actual networking entity is the same as you studied in the previous lab. Move the file to scratch directory and run it as you learnt in the previous lab. Now answer the following questions (download this as odt, and answer by making space below the question). Wherever applicable answer all questions for with and without RTS/CTS.
   a. What is the mechanism used in the code to achieve the topology of 'hidden-ness' vs reachability of the nodes? **First a default large loss of 200dB is set. This would disconnect all links. Then the loss for n0 -- n1 and n0 -- n2 link is set to 50dB. Thus, only these two links are live i.e n0 -- n1 can communicate, n0 -- n2 can communicate**
   b. Which particular one of the 802.11 family of protocols is selected in this simulation (for PHY layer)? **802.11a**
   c. What is the data rate of the channel? **54Mbps**

   d.e. What is the flow configuration? (Who's sending what to whom?) What are the flow parameters?
      i. **n1 → n0 CBR via UDP 2200Bpayload 10Mbps startTime 1.01s**
      ii. **n2 → n0 CBR via UDP 2200Bpayload 10Mbps startTime 1.02s**

      At t=0.001s one packet of size 10B is sent as n1 → n0
      At t=0.002s one packet of size 10B is sent as n2 → n0
      The single packets have to be sent to workaround lack of perfect ARP

For the above parameters, what's the per node throughput? What's the total channel throughput?

Without RTS/CTS **n1 → n0 : 9.4289**
n2 → n0 : 8.91709
Total channel: 18.346
With RTS/CTS **n1 → n0 : 10.1113**
n2 → n0 : 10.096
Total channel: 20.2073

Change the values so that the total data rate offered to the channel is about 10% of the channel data rate, equally divided among all sources. Keep increasing it to 20%, 30%

… 90%. What's the maximum throughput achieved for each value? What is the trend of the throughput vs offered load? Tabulate/plot the values and paste here.(For these experiments you may want to change the code to take values as input, not hardcoded, else recompiling will take time).

	input load per node (Mbps)	n1 tput	n2 tput	Total tput
w/o CTS/RTS	2.7	2.72962	2.72453	5.45414
with CTS/RTS		2.72962	2.72453	5.45414
w/o CTS/RTS	5.4	5.37012	5.33956	10.7097
with CTS/RTS		5.45924	5.4516	10.9108
w/o CTS/RTS	8.1	8.18885	8.17867	16.3675
with CTS/RTS		8.18885	8.17867	16.3675
w/o CTS/RTS	10.8	8.78978	9.57913	18.3689
with CTS/RTS		10.5136	10.8854	21.399
w/o CTS/RTS	13.5	9.55112	8.94256	18.4937
with CTS/RTS		10.6027	11.4252	22.0279
w/o CTS/RTS	16.2	9.33723	9.28121	18.6184
with CTS/RTS		11.3157	10.7173	22.033
w/o CTS/RTS	18.9	9.05205	9.52056	18.5726
with CTS/RTS		10.9236	11.2291	22.1527
w/o CTS/RTS	21.6	8.94001	9.5995	18.5395
with CTS/RTS		13.4597	8.70066	22.1603
w/o CTS/RTS	24.3	9.4238	9.01385	18.4377
with CTS/RTS		7.84765	14.3483	22.196
w/o CTS/RTS	27	9.69626	8.76941	18.4657
with CTS/RTS		9.01131	13.1668	22.1781
MAX	w/o CTS/RTS	**9.69626**	**9.5995**	**18.6184**
	with CTS/RTS	**13.4597**	**14.3483**	**22.196**

All the throughputs roughly increase with input load upto a certain point and then start decreasing with further increase in load (decrease is due to increase in traffic causing interference and packet losses)

Q) Find out the maximum throughput possible when there is no contention (only one source).

	input load per node (Mbps)	n1 tput = total tput
w/o CTS/RTS		25.6156
with CTS/RTS	32.4	22.611
w/o CTS/RTS		25.72
with CTS/RTS	43.2	22.5448
w/o CTS/RTS		25.7277
with CTS/RTS	54	22.5575
w/o CTS/RTS		25.6029
with CTS/RTS	64.8	22.5372
w/o CTS/RTS		25.6666
with CTS/RTS	75.6	22.5754
w/o CTS/RTS		25.6615
with CTS/RTS	86.4	22.555
w/o CTS/RTS		25.5876
with CTS/RTS	97.2	22.5474
w/o CTS/RTS		25.6538
with CTS/RTS	108	22.5703
	w/o CTS/RTS	**25.7277**
MAX	with CTS/RTS	**22.611**

Note that the values are greater than the tput values obtained with contention

Q) Make any observations of the numbers with and without RTS/CTS

When there is no contention, not using RTS/CTS gives higher tput
WIth contention, using RTS/CTS (if nodes hidden) gives better tput values for lower offered loads. As offered load and traffic increases, interferences and packet losses are high. Thus, for larger loads with contention, avoiding RTS/CTS helps since the additional latency due to using RTS/CTS protocol is huge.

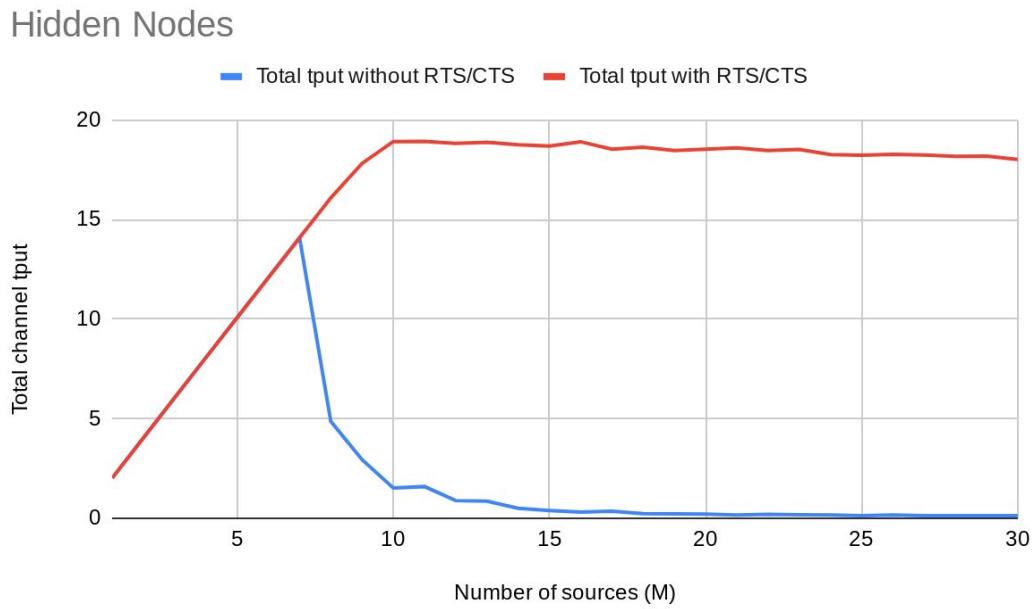
Q) RTS/CTS was designed mainly to solve the hidden terminal problem. So perhaps it is not very useful when there aren't hidden terminals? Modify the code and design and run experiments to validate/invalidate this hypothesis. Paste all results and conclusions below:
Same table when n1 n2 can see each other

	input load per node (Mbps)	n1 tput	n2 tput	Total tput
w/o CTS/RTS	2.7	2.72962	2.72453	5.45414
with CTS/RTS		2.72962	2.72453	5.45414
w/o CTS/RTS	5.4	5.45924	5.4516	10.9108
with CTS/RTS		5.45924	5.4516	10.9108
w/o CTS/RTS	8.1	8.18885	8.17867	16.3675
with CTS/RTS		8.18885	8.17867	16.3675
w/o CTS/RTS	10.8	10.921	10.9032	21.8242
with CTS/RTS		10.9185	10.9032	21.8217
w/o CTS/RTS	13.5	13.5488	13.3655	26.9142
with CTS/RTS		12.6092	12.4997	25.1089
w/o CTS/RTS	16.2	12.9453	14.165	27.1103
with CTS/RTS		12.5277	12.7824	25.3101
w/o CTS/RTS	18.9	13.5361	13.7499	27.286
with CTS/RTS		12.5455	12.7009	25.2464
w/o CTS/RTS	21.6	13.8238	13.2407	27.0645
with CTS/RTS		12.6449	12.5175	25.1624
w/o CTS/RTS	24.3	13.4062	13.4367	26.8429
with CTS/RTS		12.6958	12.5506	25.2464
w/o CTS/RTS	27	13.6634	13.755	27.4184
with CTS/RTS		12.8486	12.4412	25.2897
MAX	w/o CTS/RTS	**13.8238**	**14.165**	**27.4184**
	with CTS/RTS	**12.8486**	**12.7824**	**25.3101**

It can be seen that for low offered tput, using CTS/RTS does not affect observed tputs. However, as offered load increases, not using CTS/RTS is beneficial. Thus, the above values validate the hypothesis. CTS/RTS is effectively unnecessary when the "hidden node problem" does not arise.

2. Modify the code to model a given *M* number of source nodes in the configuration that n1,....nM are all sending data to n0. Let all of n1...nM be hidden from each other. Each one can be just like the source nodes n1,n2 in the given file. Study the following - again, with and without RTS/CTS, and in fact wherever applicable study what effect RTS/CTS has on the throughput.
    a. Total channel throughput as a function of increasing number of nodes. Start with each node bring a low offered rate (e.g. only 2Mbps).Paste the

table and plot here.



b. Now make all n1 to nM such that they are no longer hidden - all are audible to each other. Now do the same analysis, and compare with when hidden and RTS/CTS effect on the throughput in both case.