COM503-Homework_1

March 4, 2019

```
In [1]: import numpy as np
        %matplotlib inline
        import matplotlib.pyplot as plt
        import csv
        import pandas as pd
        import requests
        import bs4
        from ipywidgets import interact,IntSlider,interactive,HBox
        from IPython.display import display
        import random
        import time
        import threading
        from pprint import pprint
        import requests
        import csv
```

1 Data retrieval

First of all, we need to retrieve the data from the simulation. For that, we first run the below script. It runs the simulation for every possible loads (request/s), first for 1 AP and 1 server, then for 1 AP and 2 server, and so on. Each measure is made 3 times, to avoid at most some "unlucky" or "too lucky" simulation that would distort the analysis.

```
In [ ]: NUM_THREADS = 10
        URL = "http://tcpip.epfl.ch/output.php"


        class MyThread(threading.Thread):
            """
            Subclass to threading.Thread for multithreading purpose.
            """

            def __init__(self, ap, servers, thread_id):
                super().__init__()
                self.ap = ap
                self.servers = servers
                self.thread_id = thread_id
```

```python
        self.data = []
        self.client=0

    def run(self):
        for self.client in range(1,1001):
            payload = {"sciper":"236079",
                       "clients":self.client,
                       "apoints":self.ap,
                       "servers":self.servers}
            for k in range(3): #take each measure 3 times
                resp = requests.post(URL, data=payload)
                soup = bs4.BeautifulSoup(resp.content)
                table = soup.find("table")
                rows = table.find_all("tr")
                data_point = []
                for row in rows:
                    cols = row.find_all("td")
                    cols = [ele.text.strip() for ele in cols]
                    if not "values" in cols[0]:
                        data_point.append(cols)
                self.data.append(data_point)
            if self.client%100 == 0:
                print("[{}] {} - {} - {}".format(self.thread_id,
                                                 self.ap,
                                                 self.servers,
                                                 self.client))

    def join(self):
        super().join()
        return self.data

try:
    df = pd.read_csv('pandas_data.csv', index_col="index")
    df['Access points'] = pd.to_numeric(df['Access points'])
    df['Servers'] = pd.to_numeric(df['Servers'])
    empty=False
except FileNotFoundError:
    df = pd.DataFrame()
    empty=True
for ap in range(1,11): #for each AP configuration
    threads_list = []
    for num_thread in range(NUM_THREADS):
        #assign a thread to a count of servers
        servers = num_thread+1
        if not empty:
            specific_df = df[(df['Servers'] == servers) &
                             (df['Access points'] == ap)]
            if len(specific_df) >= 1000:
```

```python
                #if already enough data, don't launch thread
                print("ignoring combination {}-{}".format(ap,servers))
                continue
            print("Launching new thread for {} AP and {} servers".format(ap, servers))
            thread = MyThread(ap, servers, num_thread)
            thread.start()
            threads_list.append(thread)

        #Join threads
        for thread in threads_list:
            print("Joining thread {}".format(thread.thread_id))
            data = thread.join()
            #read joined data, and append to current DataFrame
            for i in data:
                df = df.append(pd.Series([x[1] for x in i], [x[0] for x in i]),
                               ignore_index=True)
            #save intermediate result
            df.to_csv("pandas_data.csv", index_label="index")
```

1.1 Results exploration

In [3]:
```python
df.head()
```

Out[3]:
```
       Access points  Collision probability     Delay  Packets per second  \
index
0                  1               0.000013  0.143996               3.245
1                  1               0.000012  0.115127               0.000
2                  1               0.000014  0.123098               0.000
3                  1               0.000014  0.147046               3.894
4                  1               0.000013  0.138540               9.439

       Requests per second  Sciper ID provided  Servers  Theta
index
0                        1              236079        1  0.972
1                        1              236079        1  0.944
2                        1              236079        1  0.993
3                        2              236079        1  1.943
4                        2              236079        1  1.883
```

In [4]:
```python
df.describe()
```

Out[4]:
```
       Access points  Collision probability          Delay  \
count  300000.000000          300000.000000  300000.000000
mean        5.500000               0.279587     155.781832
std         2.872286               0.419075     333.378683
min         1.000000               0.000009       0.021352
25%         3.000000               0.000261       0.623686
50%         5.500000               0.006141       2.555264
75%         8.000000               0.783901      30.798532
```

```
max        10.000000               1.000000    1082.849096

       Packets per second  Requests per second  Sciper ID provided  \
count       300000.000000        300000.000000            300000.0
mean          2176.337510           500.500000            236079.0
std           1284.483024           288.675471                 0.0
min              0.000000             1.000000            236079.0
25%           1206.448750           250.750000            236079.0
50%           2039.977000           500.500000            236079.0
75%           3120.555750           750.250000            236079.0
max           5523.136000          1000.000000            236079.0

             Servers          Theta
count  300000.000000  300000.000000
mean        5.500000     404.318171
std         2.872286     249.965069
min         1.000000       0.930000
25%         3.000000     197.328750
50%         5.500000     366.695500
75%         8.000000     588.684000
max        10.000000     999.000000
```

2 Question 1

Clearly, making the same simulation multiple times will not yield every time the same results. As we can see two cells above, the "simplest" case (1 AP, 1 server, 1 request/second) yields different outputs (e.g. delays of 5.288, 11.005 and 0). As in every simulation, there are a lot of hidden factors at play. Hopefully, they are nothing but nuisance factors, and only create a small variance in every result, that is evenly distributed in each simulation.

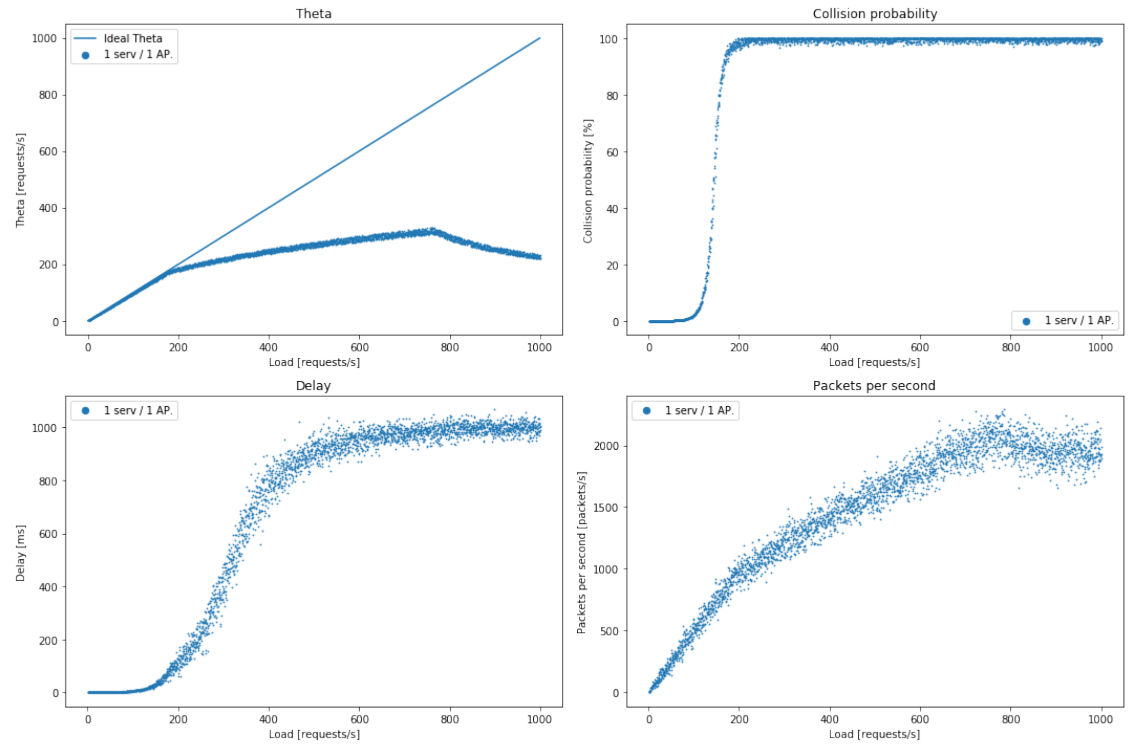
3 Question 2

First, we need to make a script to easily plot and visualize the representation

```
In [5]: def plot_comparison(df, nums_servers, nums_aps):
            """
            Plots multiple configurations on a single figure

            Example:
                plot_comparison(df, [1,2], [3,4]) will create a graph with 2 configuration:
                first with 1 server and 3 access points,
                second with 2 servers and 4 access points.

            args:
            df -- pandas.DataFrame: dataframe where to select the data
            nums_servers -- list[int]: numbers of servers for each
                configuration to display (order matters)
```

```
        nums_aps -- list[int]: numbers of access points for each
            configuration to display
        """

        if len(nums_servers) != len(nums_aps):
            print("Error, length of configurations must be the same")
            return

        ylabel = {
            "Theta": "Theta [requests/s]",
            'Collision probability': "Collision probability [%]",
            'Delay': "Delay [ms]",
            'Packets per second': "Packets per second [packets/s]"
        }

        fig = plt.figure(figsize=(15,10))
        for num, metric in enumerate(ylabel): #iterate through metrics
            fig.add_subplot(2,2,num+1)
            #iterate through configurations
            for serv, ap in zip(*(nums_servers, nums_aps)):
                #get data
                df_temp = df[(df['Servers'] == serv) & (df['Access points'] == ap)]
                plt.scatter(df_temp['Requests per second'],
                            df_temp[metric] * (100 if "Collision" in metric else 1),
                            s=0.5,
                            label="{} serv / {} AP.".format(serv, ap))

            if metric == "Theta":
                # plot ideal theta line if needed
                plt.plot(np.arange(1000), label="Ideal Theta")

            plt.title("{}".format(metric))
            plt.ylabel(ylabel[metric])
            plt.xlabel("Load [requests/s]")
            plt.legend(markerscale=9.)
        plt.tight_layout()
```

```
In [6]: plot_comparison(df, [1], [1])
```



3.1 First observations

3.1.1 Delay

We see that the delay first is consistently small, then grows exponentially until reaching an horizontal asymptote. The asymptote is at 1’000 ms, because above that the request is dropped, otherwhise we would have an ever increasing load (as each request is re-made every second). Ideally, we would like to keep the delay as low as possible (ideally close to 0)

3.1.2 Collision probability

As before, the collision probability is close to 0%, but at some threshold (between 120 and 160 requests/s) it explodes and comes consistently close to 100%. Again, we are wishing for a probability close to 0%

3.1.3 Theta

As expected, the number of requests served is linear and follows the “ideal” line: (almost) as many requests per second are queried and served. But once a threshold around 200 is reached, the delay augments (see 3rd plot), and thus the number of served requests per seconds can’t follow the load. Finally, a second threshold around 800 is reached, and now the server is under too much pressure, and can’t handle it: requests get dropped, but too much is lost in overhead. The service is degrading proportionally to the load, reaching the asymptote at 200 (the “max” it can handle)

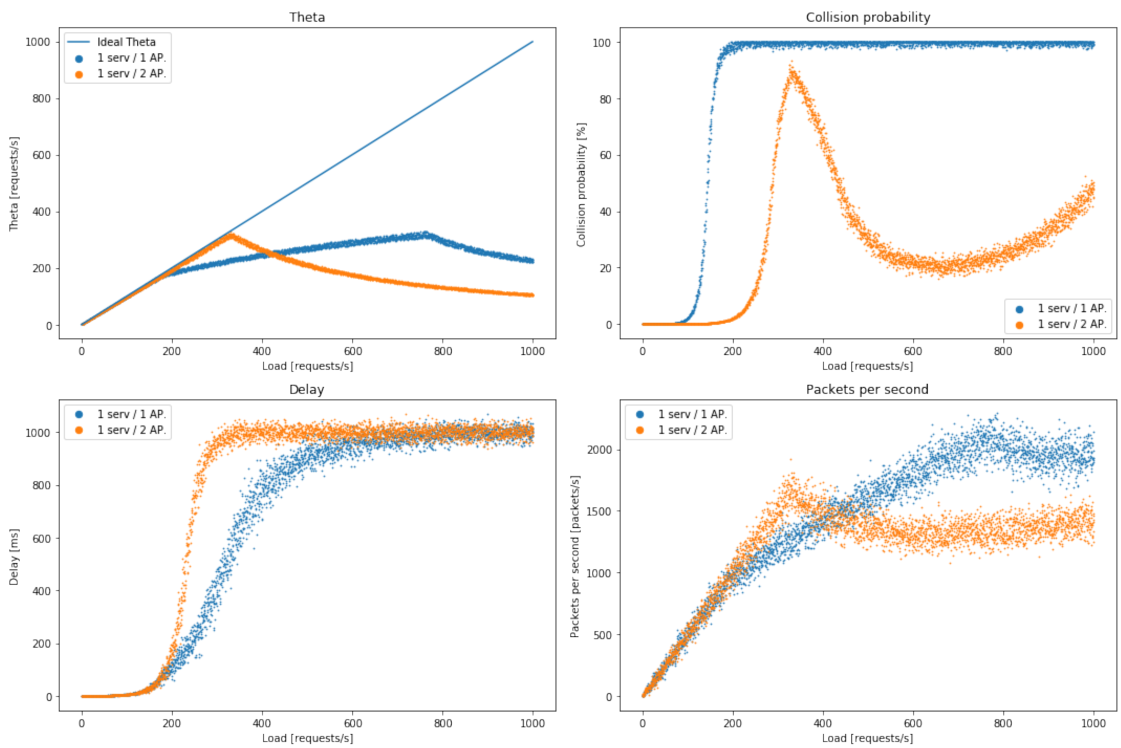
3.2 Conclusions

It is hard to conclude anything serious with only one configuration. What we see, is that between 180 and 200 requests per second, everything starts to break and takes a new form. We'd need a second configuration to see which factor is a bottleneck at 180 requests/s.

4 Question 3

Now we compare our first results with a second configuration: still one server, but 2 access points.

```
In [7]: plot_comparison(df, nums_servers=[1,1], nums_aps=[1,2])
```



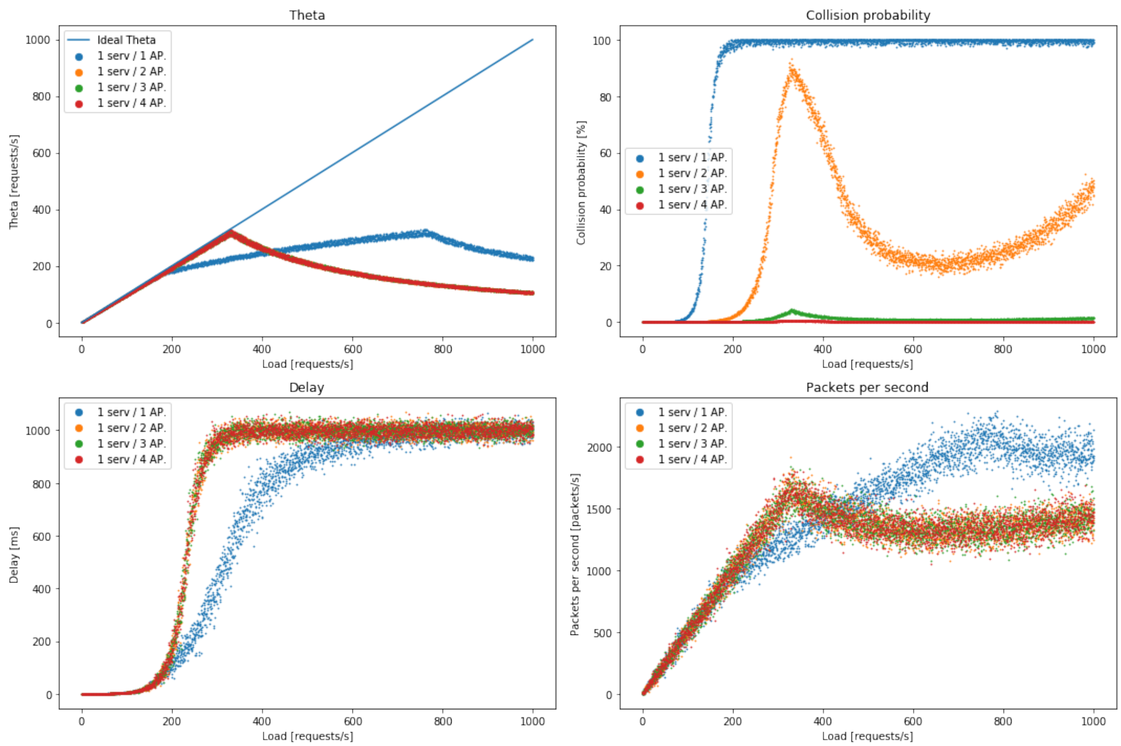
This yields a lot of information. * First of all, the least surprising result: the collision probability never reaches the same heights as before. It "only" goes up to 90%, then goes down. This is typical to a CSMA/CD protocol, where when a collision is detected, the first sender will wait for some time to avoid future collision. * This is coherent with the *Delay* graph, showing a greater delay: when a collision is detected, the access point will wait until it can transmit again. The delay is thus going up quicker, but the collision stays low. * From ~600 requests/second, the collision probability starts going up, as the delay is already too high and the protocol will transmit again, ignoring the collisions.

So doubling the number of access points is not an perfect solution, but we do have some enhancements.

Only from this, we can suppose that * with more access points, the theta grows for longer before "crashing", * The delay augments with the access points, * Packets/s grow linearly for longer, but "crash harder" when their limit is reached, * Collision probability benefits more access points.

We try to those claims with some more simulations:

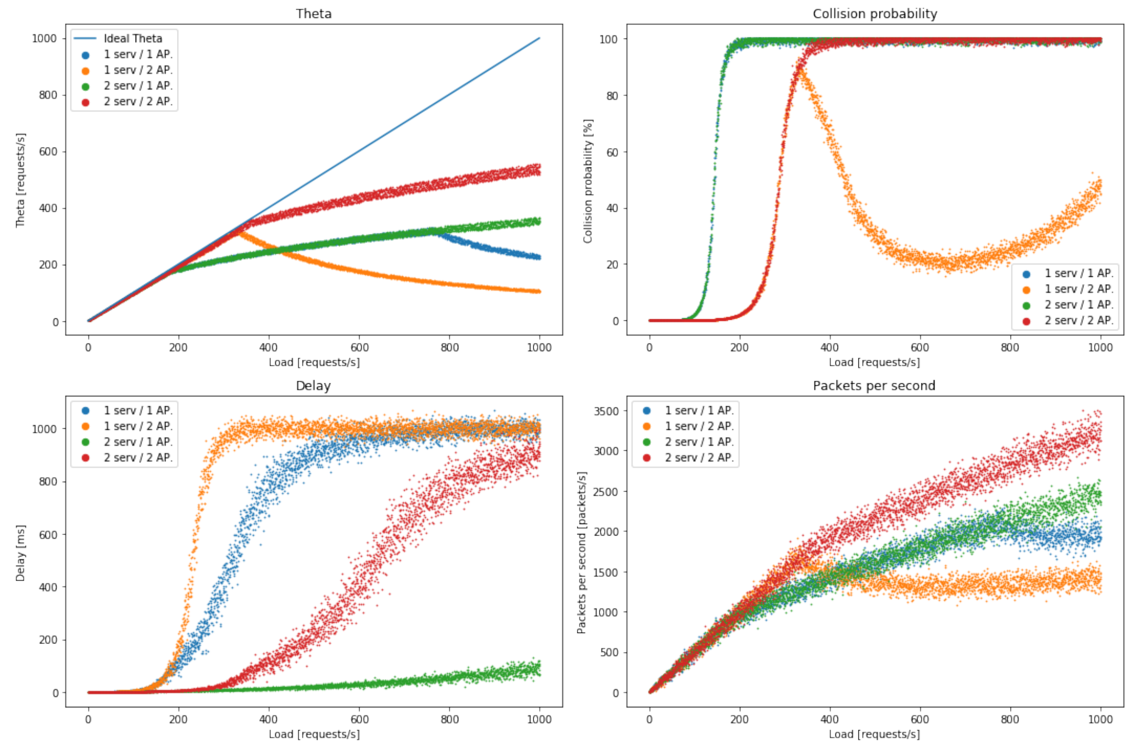
```
In [8]: plot_comparison(df, [1,1,1,1], [1,2,3,4])
```



It becomes clear that more access points will decrement the collision probability goes down, no matter what. But if one more access points "unlocked" some performances, they are now locked, probably bottlenecked by the server count, as every access point count > 1 follows the same performances in all the metrics (except collision probability)

In order to understand better, we plot two new configurations to compare: 2 servers / 1 AP and 2 servers / 2 AP

```
In [9]: plot_comparison(df, [1,1,2,2], [1,2,1,2])
```



With this, we can draw some thumb rules: * A server can serve up to ~380 requests per second * But an AP can only serve ~190 requests per second

The other interesting observation we can do, is that the green configuration has the same collision probablity than the blue one. So this is not a function of the servers number, but only the access points (as already asserted before)

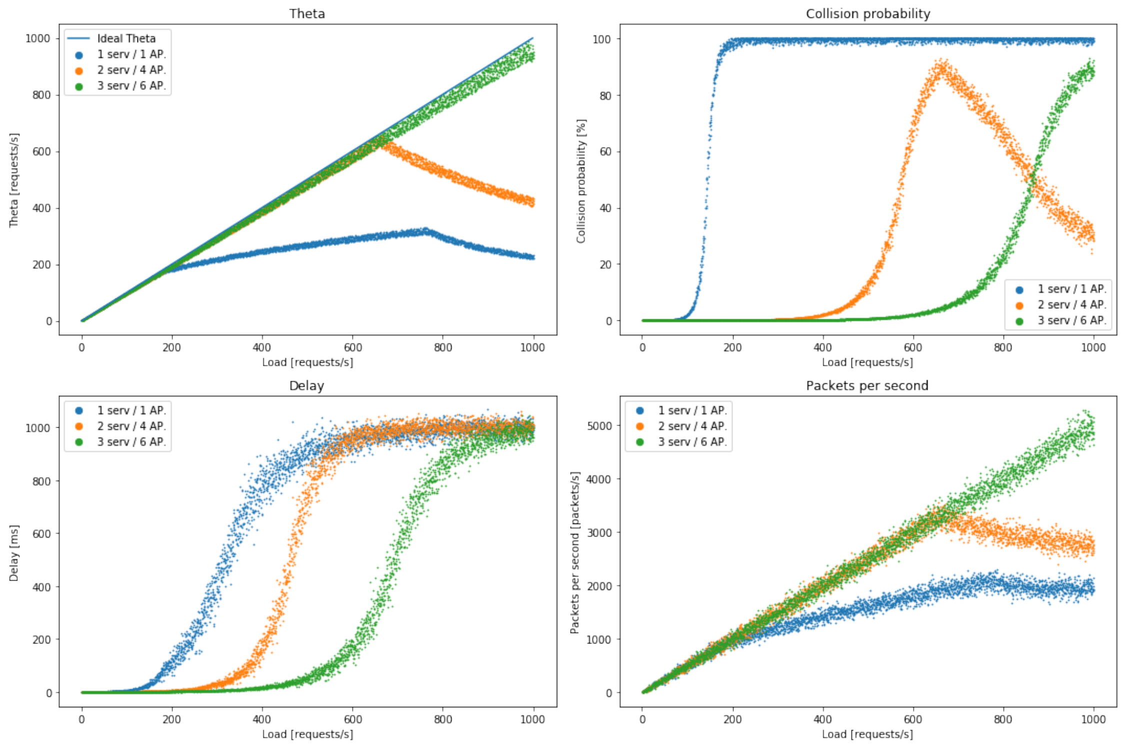
Then, we see in the *Delay* graph that the "heaviest" solution (2 AP and servers) does not lead to the best result. The more servers compared to the number of AP, the least delay we'll obtain,

5 Question 4

So, only looking at the Theta above, we'd need about $\frac{requests/s}{380}$ servers, and twice as many access points. So in the worst case, we'd need about $1000/380 \simeq 3$ servers and 6 access points.

But the above configuration will lead to high collision probability and delay in higher loads. They stay at acceptable levels (as they don't influence the Theta and Packets/s), but we way want to reduce them nonetheless. For this, we need to add more servers to reduce the delay, and AP to reduce the collision probability.

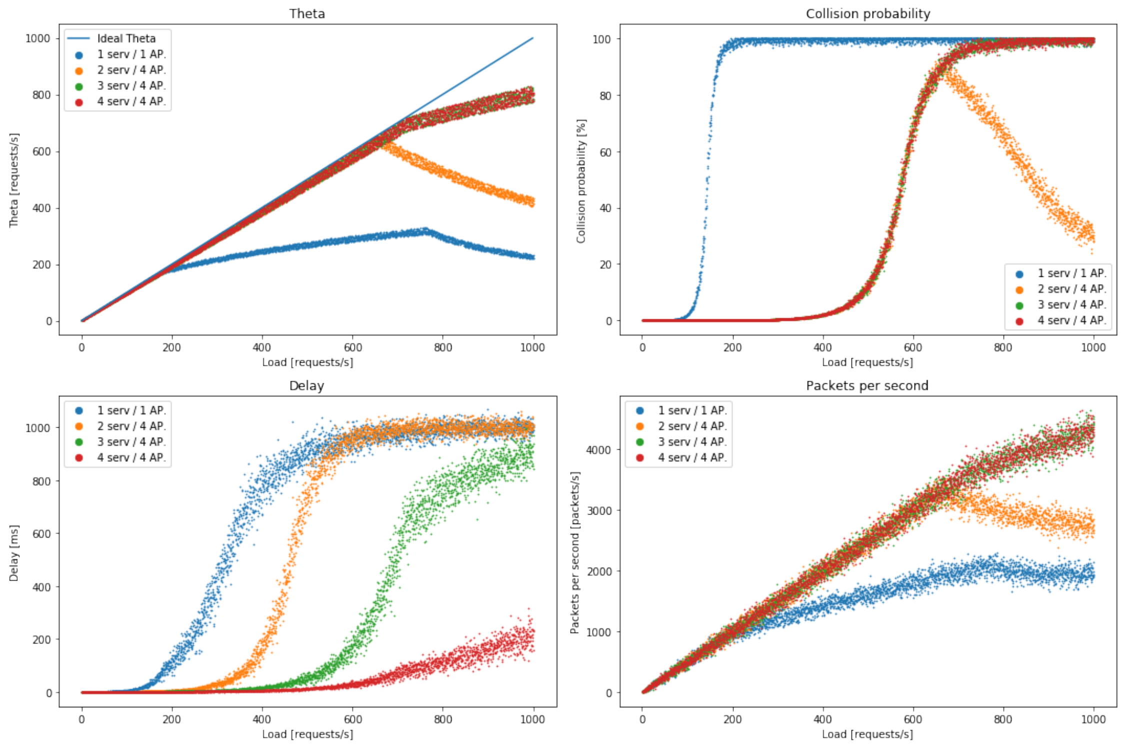
```
In [10]: plot_comparison(df, [1,2,3], [1,4,6])
```



Indeed, the green configuration seems to cover the needs in terms of Theta. and packets/s The orange configuration is mainly sufficient for 600 requests/s, as predicted.

To reduce some delay, we can add servers. We take the orange configuration as a reference.

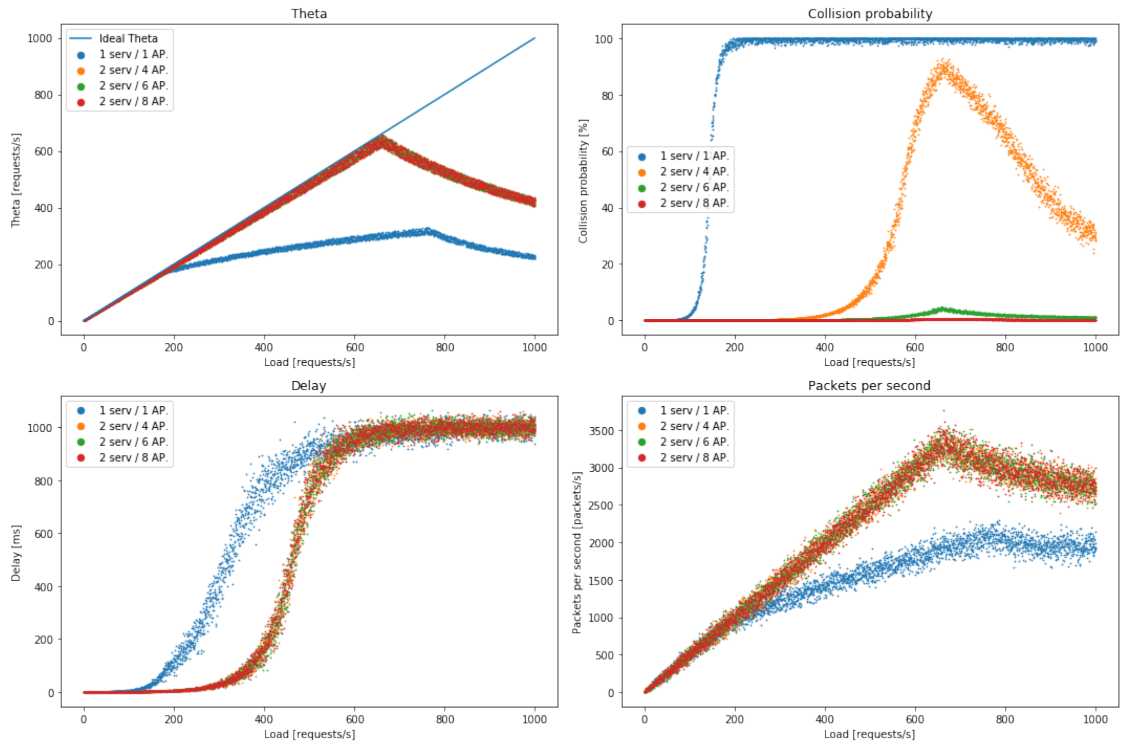
```
In [11]: plot_comparison(df, [1,2,3,4], [1,4,4,4])
```



As predicted the delay has gone down with the number of servers, while the collision probability barely changes. Only change there: at the "break point" of our orange reference configuration, instead of absorbing the collisions and going down, it stays high.

Varying the count of access points (in reference to our 2 serv / 4 AP configuration), we obtain the following results:

```
In [12]: plot_comparison(df, [1,2,2,2], [1,4,6,8])
```



Which matches our expectations.

6 Conclusion

The engineering rule we can give to Joe, is our rule from above:

$$\#servers = \frac{load}{380} \quad AP = 2 \cdot servers$$

This is the minimal configuration to have the maximum *throughput* (Theta and packets/s). If Joe wished to reduce the delay of each request, he can then augment the number of servers, and if he wishes to reduce the collision probability, he can augment the count of access points.

7 Bonus: slider of sliders to compare configurations

```
In [13]: @interact(n_weights=(1,7,1))
         def nice_plotter(n_weights):
             weight_sliders = [(IntSlider(
                         value=1,
                         min=1,
                         max=10,
                         step=1,
                         description='serv config %d' % i,
                         disabled=False,
```

```
            continuous_update=False,
            orientation='horizontal',
            readout=True
        ), IntSlider(
            value=1,
            min=1,
            max=10,
            step=1,
            description='AP config %d ' % i,
            disabled=False,
            continuous_update=False,
            orientation='horizontal',
            readout=True
        )) for i in range(n_weights)]
    serv_kwargs = {'server{}'.format(i):s_slider
                   for i, (s_slider, _) in enumerate(weight_sliders)}
    ap_kwargs = {'ap{}'.format(i):ap_slider
                 for i, (_, ap_slider) in enumerate(weight_sliders)}
    kwargs = {**serv_kwargs, **ap_kwargs}

    def wrapper(**kwargs):
        serv = [kwargs[x] for x in kwargs if 'server' in x]
        ap = [kwargs[x] for x in kwargs if 'ap' in x]
        plot_comparison(df, serv, ap)

    ip = interactive(wrapper, **kwargs)
    for i in range(n_weights):
        display(HBox([ip.children[i], # show controls in pairs
                      ip.children[(i+n_weights)%(n_weights*2)]]))
    display(ip.children[-1])#Show the output
```

```
interactive(children=(IntSlider(value=4, description='n_weights', max=7, min=1), Output()), _do
```