

## Assignment 4 Report

Group Number: 20

Group Members:

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Task Number: 2

Task Description:

Compare the performance of TCP over wired and wireless networks. Consider a topology as described below. The network consists of two TCP sources Node0 and Node2, corresponding to two TCP destinations Node1 and Node3 respectively. Node2 and Node3 come in wired domain with two routers R1 and R2 (connected by a {10 Mbps, 50 ms} wired link) between them. Both the routers use drop-tail queues with queue size set according to bandwidth-delay product. Node0 comes in domain of Base Station 1 (BS1) and Node1 comes in domain of Base Station 2 (BS2). BS1 and BS2 are connected by a (10 Mbps, 100 ms) wired link. The hosts, i.e. Node0, Node1, Node2, Node3 are attached with (100 Mbps, 20ms) links to routers or base stations (as shown in the figure below). The sources (Node0 and Node2)) use three TCP agents (i.e. TCP Westwood, TCP Veno and TCP Vegas) to generate three different TCP flows. Study and plot the fairness index (Jain's fairness index) and throughput change when the TCP packet size is varied; all the other parameter values are kept constant. You should use the following TCP packet size values (in Bytes): 40, 44, 48, 52, 60, 250, 300, 552, 576, 628, 1420 and 1500 for your experiments. The throughput (in Kbps) and fairness index must be calculated at steady-state. Make appropriate assumptions wherever necessary.

Approach:

- We have created 2 files. One simulating the wired network (wired.cc) and the other simulating the wireless network (wireless.cc).
- We have used these simulated networks to send data for 2 types of applications, namely Bulk and OnAndOff.  
Sample command to choose the application:  

```
$ ./waf --run "scratch/wireless --Application=Bulk"
```

  
The default application is OnAndOff.
- We have used these simulated networks to work with various TCP agents, namely Westwood, Veno and Vegas.  
Sample command to choose the agent:  

```
$ ./waf --run "scratch/wireless --TCP_Protocol=Veno"
```

  
The default is Vegas.
- Only fairness index and throughput data is added in the report to ensure it is precise and clear. Detailed data (eg. Tx packets, Rx bytes etc) can be displayed by using:  

```
$ export NS_LOG=Wired_Script=info  
$ export NS_LOG=Wireless_Script=info
```

  
before running the file.
- The plots have been added in the report. To generate these plots (as PNG files) from the PLT files that have been submitted, we can use:  

```
$gnuplot <file_name>
```

## Plots And Data for Wired TCP

### 1. Application: OnAndOff a. TCP Protocol: Vegas

Packet Size: 40  
Jain's Fairness Index: 1  
Average Throughput: 63.9216

Packet Size: 44  
Jain's Fairness Index: 1  
Average Throughput: 66.6948

Packet Size: 48  
Jain's Fairness Index: 1  
Average Throughput: 69.4678

Packet Size: 52  
Jain's Fairness Index: 1  
Average Throughput: 72.2407

Packet Size: 60  
Jain's Fairness Index: 1  
Average Throughput: 77.7859

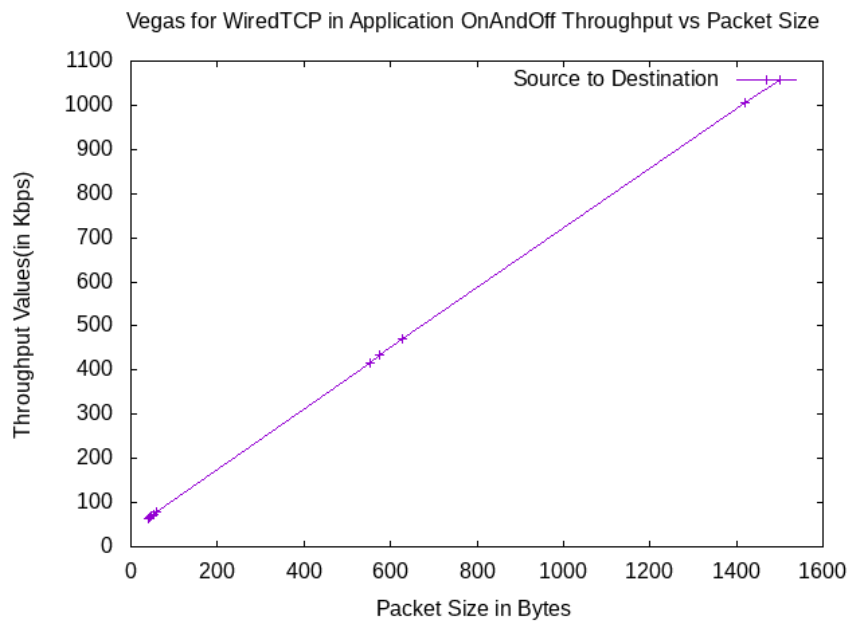
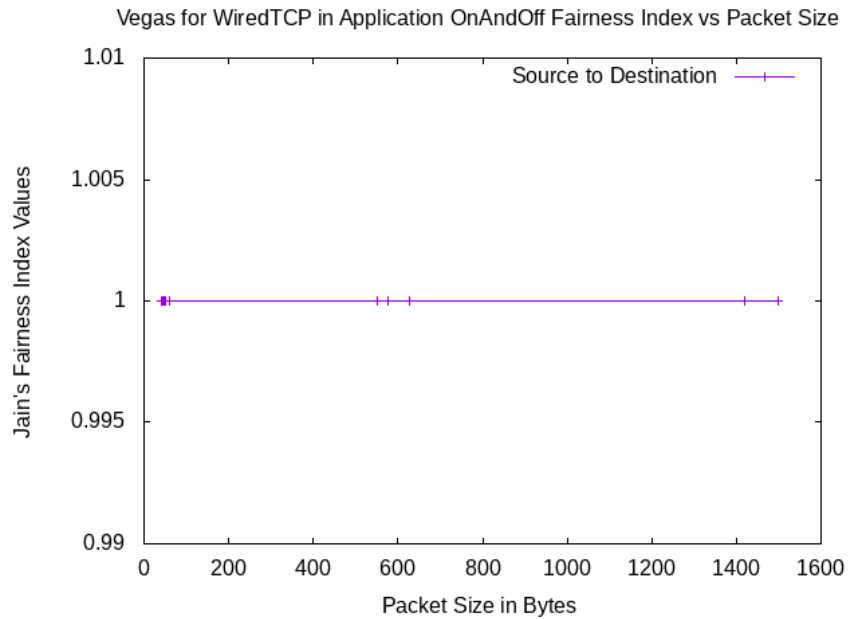
Packet Size: 552  
Jain's Fairness Index: 1  
Average Throughput: 417.604

Packet Size: 576  
Jain's Fairness Index: 1  
Average Throughput: 434.119

Packet Size: 628  
Jain's Fairness Index: 1  
Average Throughput: 469.884

Packet Size: 1420  
Jain's Fairness Index: 1  
Average Throughput: 1004.47

Packet Size: 1500  
Jain's Fairness Index: 1  
Average Throughput: 1056.32



## b. TCP Protocol: Veno

Packet Size: 40  
Jain's Fairness Index: 1  
Average Throughput: 4933.04

Packet Size: 44  
Jain's Fairness Index: 1  
Average Throughput: 6039.77

Packet Size: 48  
Jain's Fairness Index: 1  
Average Throughput: 6060.89

Packet Size: 52  
Jain's Fairness Index: 1  
Average Throughput: 6081.69

Packet Size: 60  
Jain's Fairness Index: 1  
Average Throughput: 6122.43

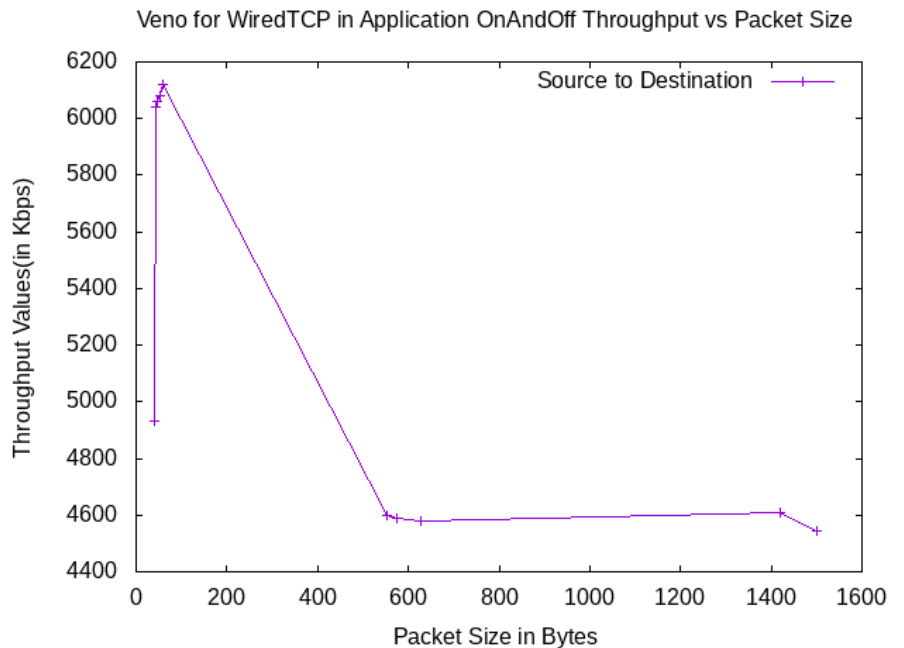
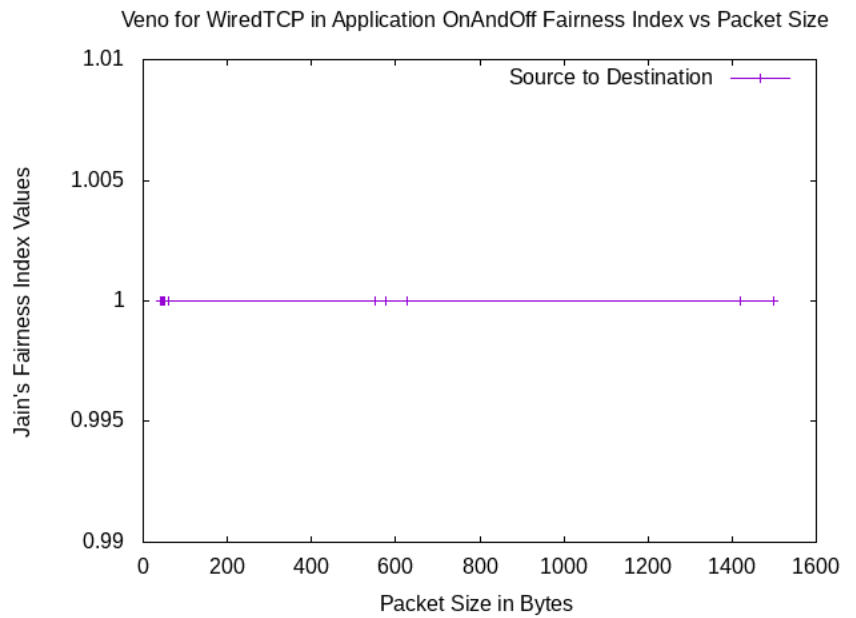
Packet Size: 552  
Jain's Fairness Index: 1  
Average Throughput: 4596.8

Packet Size: 576  
Jain's Fairness Index: 1  
Average Throughput: 4590.34

Packet Size: 628  
Jain's Fairness Index: 1  
Average Throughput: 4579.67

Packet Size: 1420  
Jain's Fairness Index: 1  
Average Throughput: 4607.44

Packet Size: 1500  
Jain's Fairness Index: 1  
Average Throughput: 4545.8



### c. TCP Protocol: Westwood

Packet Size: 40  
Jain's Fairness Index: 1  
Average Throughput: 1137.24

Packet Size: 44  
Jain's Fairness Index: 1  
Average Throughput: 6039.77

Packet Size: 48  
Jain's Fairness Index: 1  
Average Throughput: 6060.89

Packet Size: 52  
Jain's Fairness Index: 1  
Average Throughput: 6081.69

Packet Size: 60  
Jain's Fairness Index: 1  
Average Throughput: 6122.43

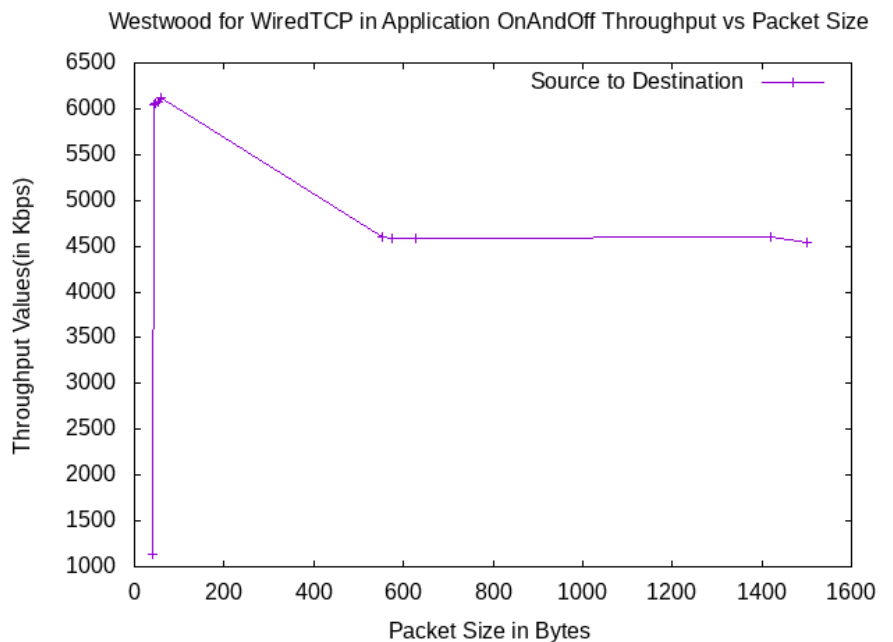
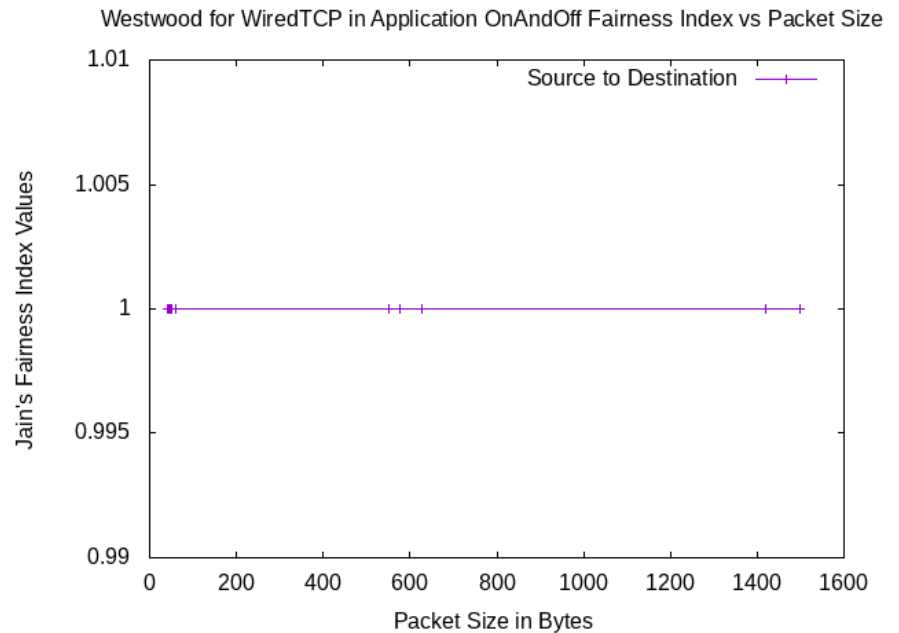
Packet Size: 552  
Jain's Fairness Index: 1  
Average Throughput: 4596.8

Packet Size: 576  
Jain's Fairness Index: 1  
Average Throughput: 4590.34

Packet Size: 628  
Jain's Fairness Index: 1  
Average Throughput: 4579.67

Packet Size: 1420  
Jain's Fairness Index: 1  
Average Throughput: 4607.44

Packet Size: 1500  
Jain's Fairness Index: 1  
Average Throughput: 4545.8



## 2. Application: Bulk

### a. TCP Protocol: Vegas

Packet Size: 40  
Jain's Fairness Index: 1  
Average Throughput: 64.7752

Packet Size: 44  
Jain's Fairness Index: 1  
Average Throughput: 67.5859

Packet Size: 48  
Jain's Fairness Index: 1  
Average Throughput: 70.319

Packet Size: 52  
Jain's Fairness Index: 1  
Average Throughput: 72.8845

Packet Size: 60  
Jain's Fairness Index: 1  
Average Throughput: 77.9596

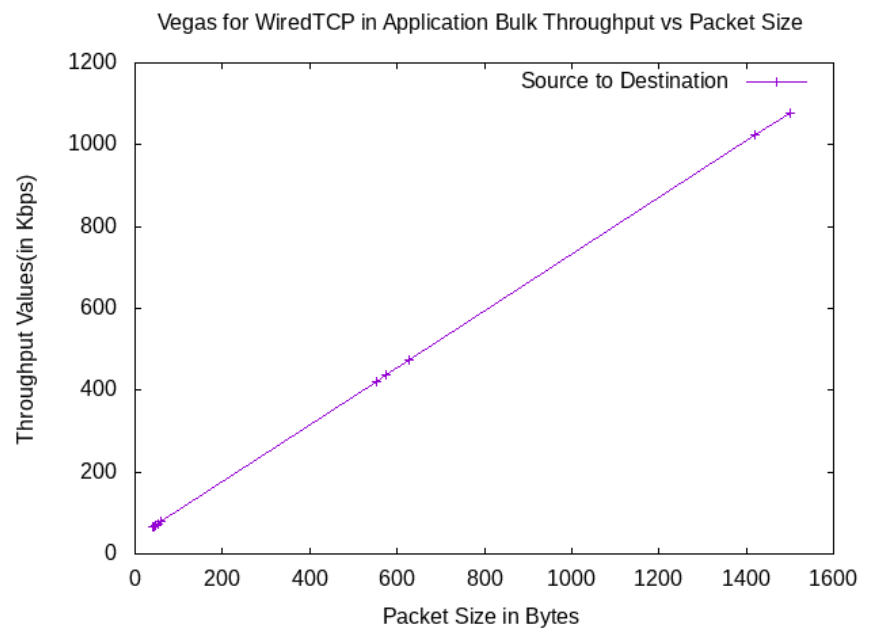
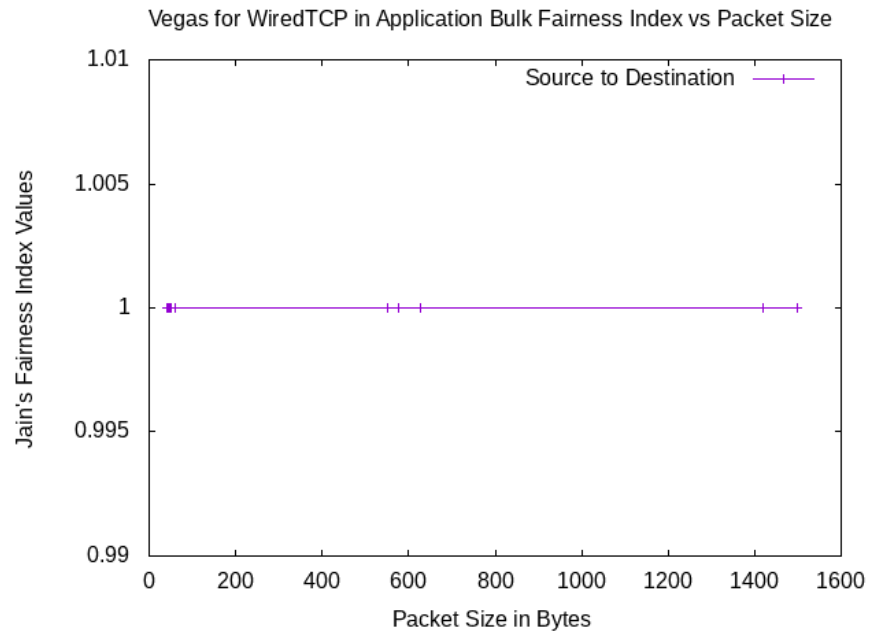
Packet Size: 552  
Jain's Fairness Index: 1  
Average Throughput: 422.426

Packet Size: 576  
Jain's Fairness Index: 1  
Average Throughput: 439.135

Packet Size: 628  
Jain's Fairness Index: 1  
Average Throughput: 475.317

Packet Size: 1420  
Jain's Fairness Index: 1  
Average Throughput: 1023.18

Packet Size: 1500  
Jain's Fairness Index: 1  
Average Throughput: 1078.4



## b. TCP Protocol: Veno

Packet Size: 40  
Jain's Fairness Index: 1  
Average Throughput: 1245.78

Packet Size: 44  
Jain's Fairness Index: 1  
Average Throughput: 1297.62

Packet Size: 48  
Jain's Fairness Index: 1  
Average Throughput: 1349.29

Packet Size: 52  
Jain's Fairness Index: 1  
Average Throughput: 1400.77

Packet Size: 60  
Jain's Fairness Index: 1  
Average Throughput: 1503.2

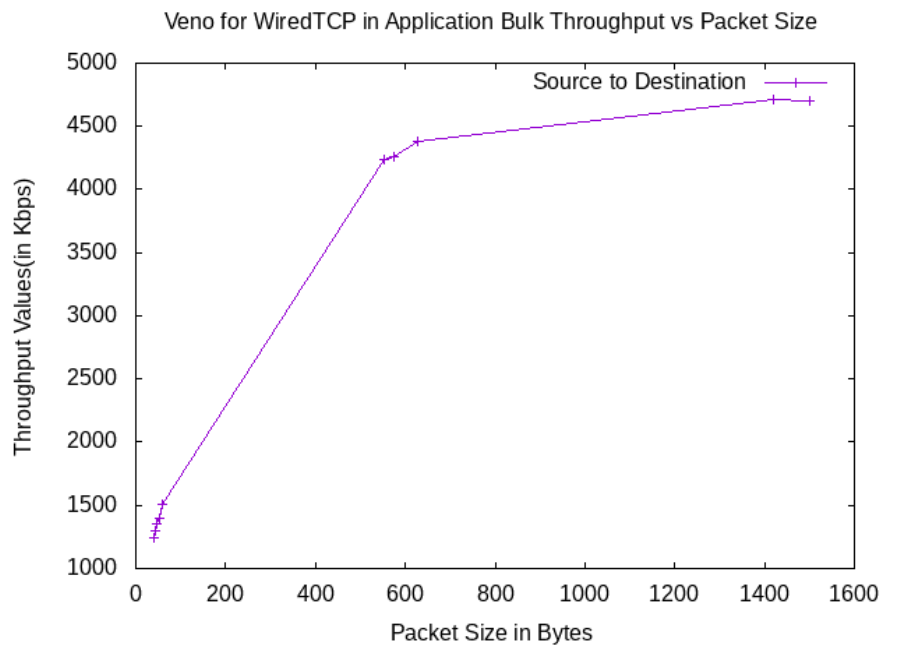
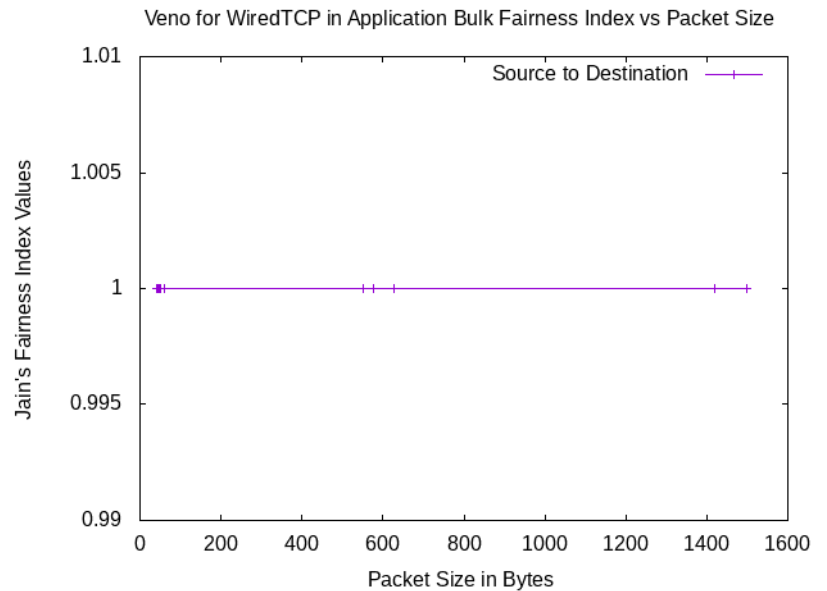
Packet Size: 552  
Jain's Fairness Index: 1  
Average Throughput: 4238.99

Packet Size: 576  
Jain's Fairness Index: 1  
Average Throughput: 4259.77

Packet Size: 628  
Jain's Fairness Index: 1  
Average Throughput: 4378.13

Packet Size: 1420  
Jain's Fairness Index: 1  
Average Throughput: 4710.98

Packet Size: 1500  
Jain's Fairness Index: 1  
Average Throughput: 4703.62



### c. TCP Protocol: Westwood

Packet Size: 40  
Jain's Fairness Index: 1  
Average Throughput: 1245.78

Packet Size: 44  
Jain's Fairness Index: 1  
Average Throughput: 1297.62

Packet Size: 48  
Jain's Fairness Index: 1  
Average Throughput: 1349.29

Packet Size: 52  
Jain's Fairness Index: 1  
Average Throughput: 1400.77

Packet Size: 60  
Jain's Fairness Index: 1  
Average Throughput: 1503.2

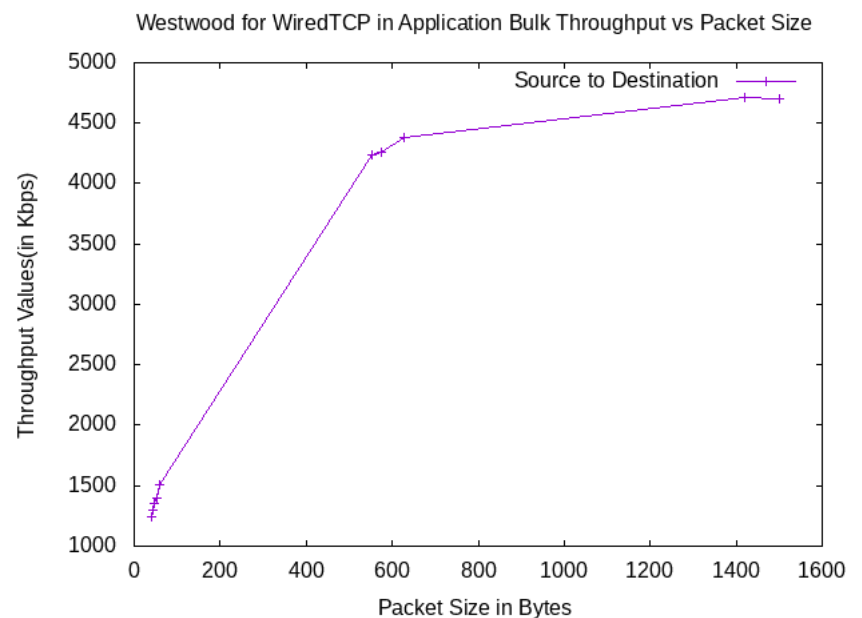
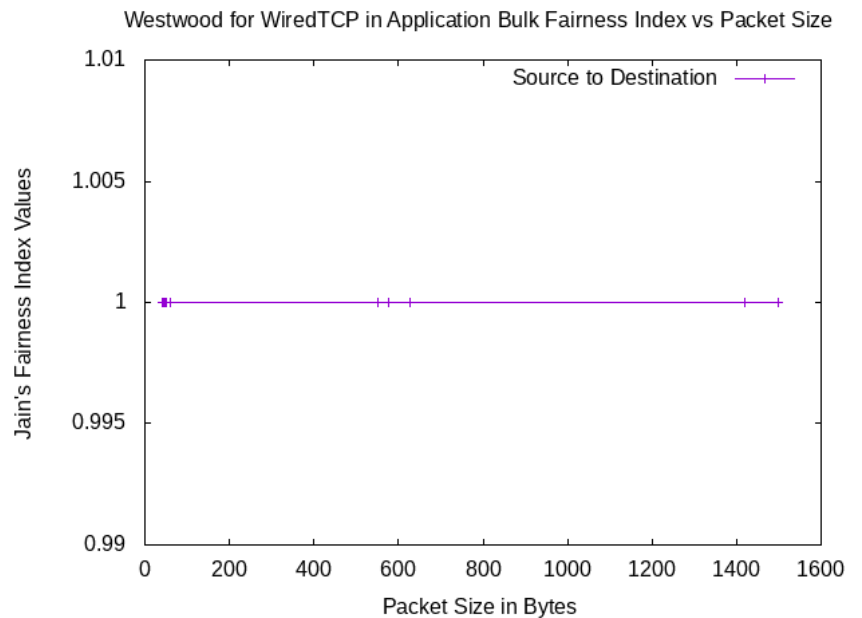
Packet Size: 552  
Jain's Fairness Index: 1  
Average Throughput: 4238.99

Packet Size: 576  
Jain's Fairness Index: 1  
Average Throughput: 4259.77

Packet Size: 628  
Jain's Fairness Index: 1  
Average Throughput: 4378.13

Packet Size: 1420  
Jain's Fairness Index: 1  
Average Throughput: 4710.98

Packet Size: 1500  
Jain's Fairness Index: 1  
Average Throughput: 4703.62



## Plots And Data for Wireless TCP

### 1. Application: OnAndOff

#### a. TCP Protocol: Vegas

Packet Size: 40

Jain's Fairness Index: 1

Average Throughput: 118.647

Packet Size: 44

Jain's Fairness Index: 1

Average Throughput: 123.851

Packet Size: 48

Jain's Fairness Index: 1

Average Throughput: 128.949

Packet Size: 52

Jain's Fairness Index: 1

Average Throughput: 134.106

Packet Size: 60

Jain's Fairness Index: 1

Average Throughput: 144.341

Packet Size: 552

Jain's Fairness Index: 1

Average Throughput: 764.018

Packet Size: 576

Jain's Fairness Index: 1

Average Throughput: 3120.49

Packet Size: 628

Jain's Fairness Index: 1

Average Throughput: 3374.78

Packet Size: 1420

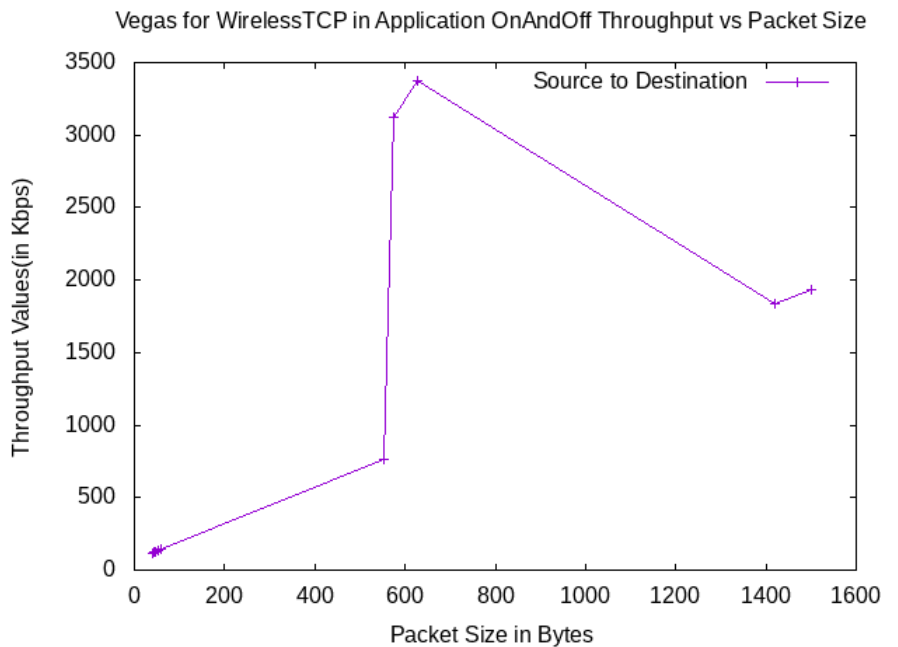
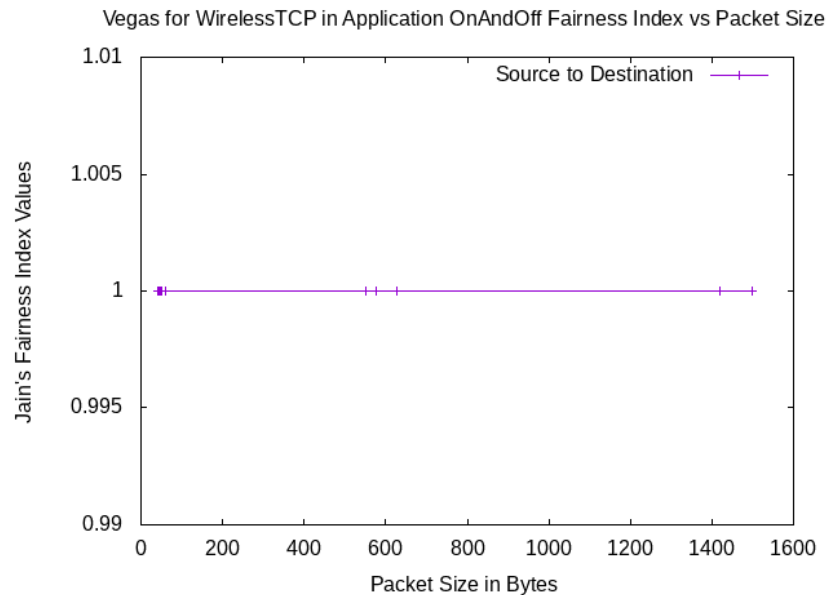
Jain's Fairness Index: 1

Average Throughput: 1838.87

Packet Size: 1500

Jain's Fairness Index: 1

Average Throughput: 1934.27





## b. TCP Protocol: Veno

Packet Size: 40  
Jain's Fairness Index: 1  
Average Throughput: 5524.47

Packet Size: 44  
Jain's Fairness Index: 1  
Average Throughput: 5555.95

Packet Size: 48  
Jain's Fairness Index: 1  
Average Throughput: 5583.12

Packet Size: 52  
Jain's Fairness Index: 1  
Average Throughput: 5607.53

Packet Size: 60  
Jain's Fairness Index: 1  
Average Throughput: 5529.12

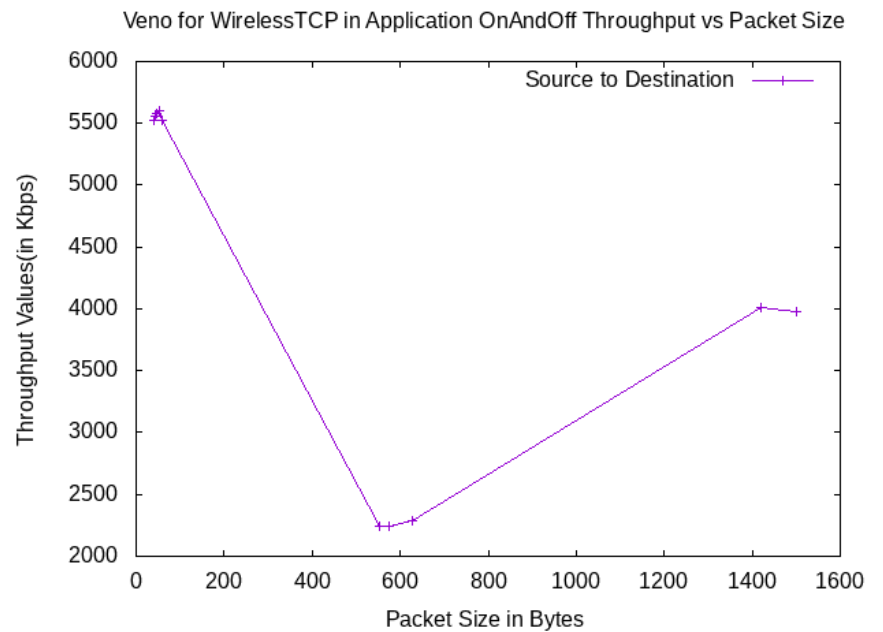
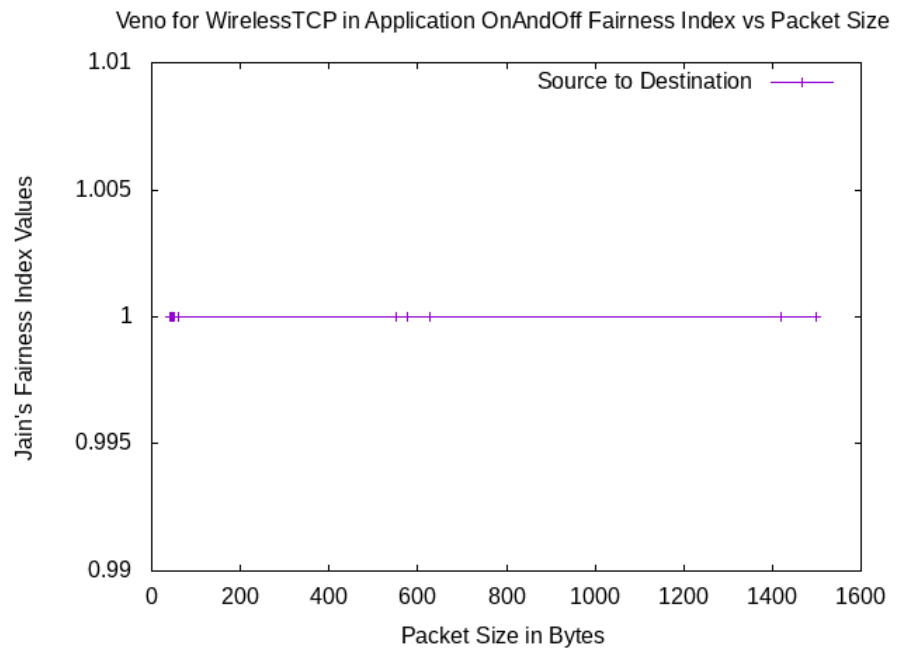
Packet Size: 552  
Jain's Fairness Index: 1  
Average Throughput: 2241.08

Packet Size: 576  
Jain's Fairness Index: 1  
Average Throughput: 2247.82

Packet Size: 628  
Jain's Fairness Index: 1  
Average Throughput: 2288.98

Packet Size: 1420  
Jain's Fairness Index: 1  
Average Throughput: 4014.13

Packet Size: 1500  
Jain's Fairness Index: 1  
Average Throughput: 3983.31



### c. TCP Protocol: Westwood

Packet Size: 40  
Jain's Fairness Index: 1  
Average Throughput: 5524.47

Packet Size: 44  
Jain's Fairness Index: 1  
Average Throughput: 5555.95

Packet Size: 48  
Jain's Fairness Index: 1  
Average Throughput: 5583.12

Packet Size: 52  
Jain's Fairness Index: 1  
Average Throughput: 5607.53

Packet Size: 60  
Jain's Fairness Index: 1  
Average Throughput: 5529.12

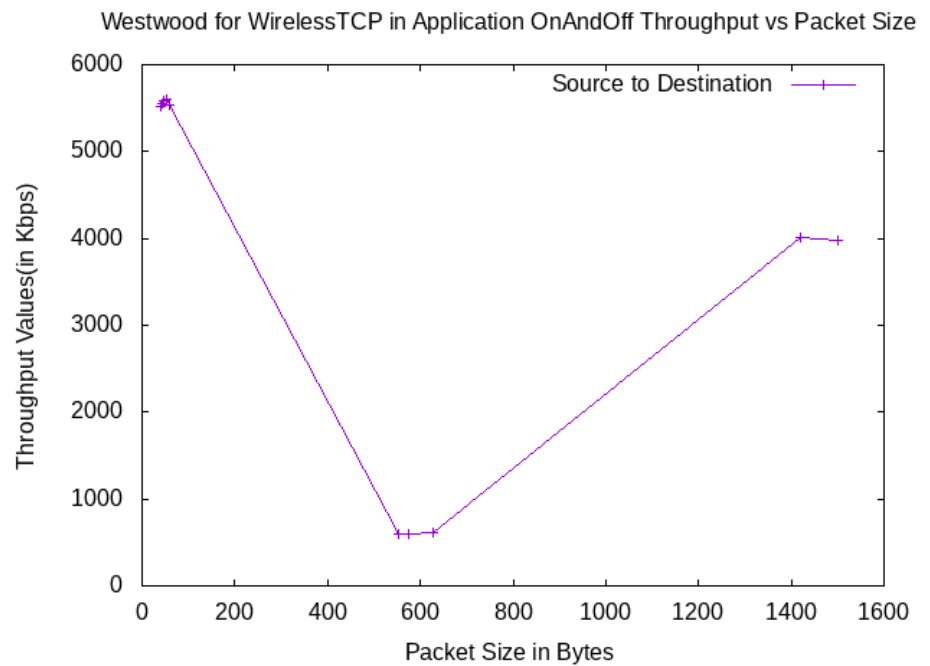
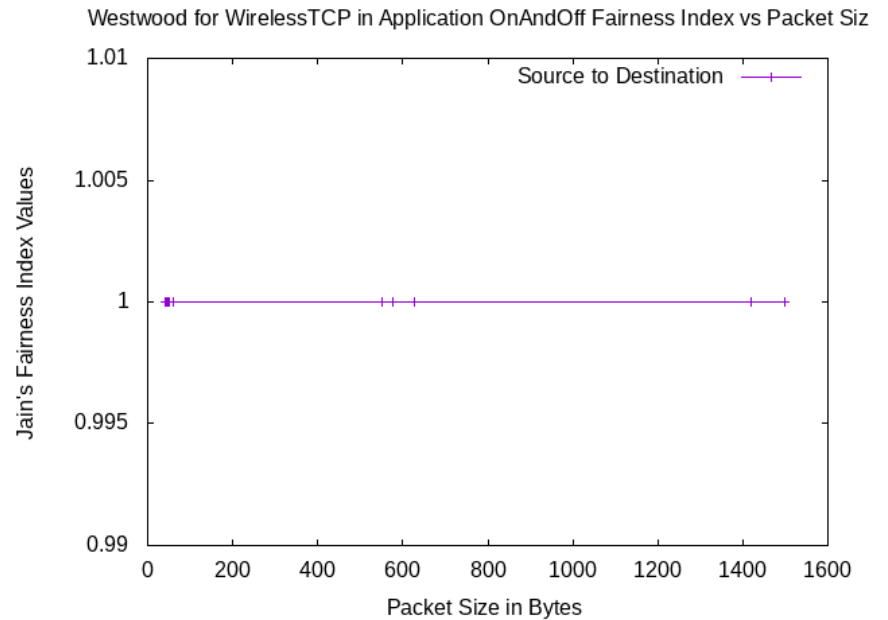
Packet Size: 552  
Jain's Fairness Index: 1  
Average Throughput: 591.695

Packet Size: 576  
Jain's Fairness Index: 1  
Average Throughput: 593.596

Packet Size: 628  
Jain's Fairness Index: 1  
Average Throughput: 607.918

Packet Size: 1420  
Jain's Fairness Index: 1  
Average Throughput: 4014.13

Packet Size: 1500  
Jain's Fairness Index: 1  
Average Throughput: 3983.31



## 2. Application: Bulk

### a. TCP Protocol: Vegas

Packet Size: 40  
Jain's Fairness Index: 1  
Average Throughput: 514.368

Packet Size: 44  
Jain's Fairness Index: 1  
Average Throughput: 71.6019

Packet Size: 48  
Jain's Fairness Index: 1  
Average Throughput: 74.6035

Packet Size: 52  
Jain's Fairness Index: 1  
Average Throughput: 77.5996

Packet Size: 60  
Jain's Fairness Index: 1  
Average Throughput: 83.5052

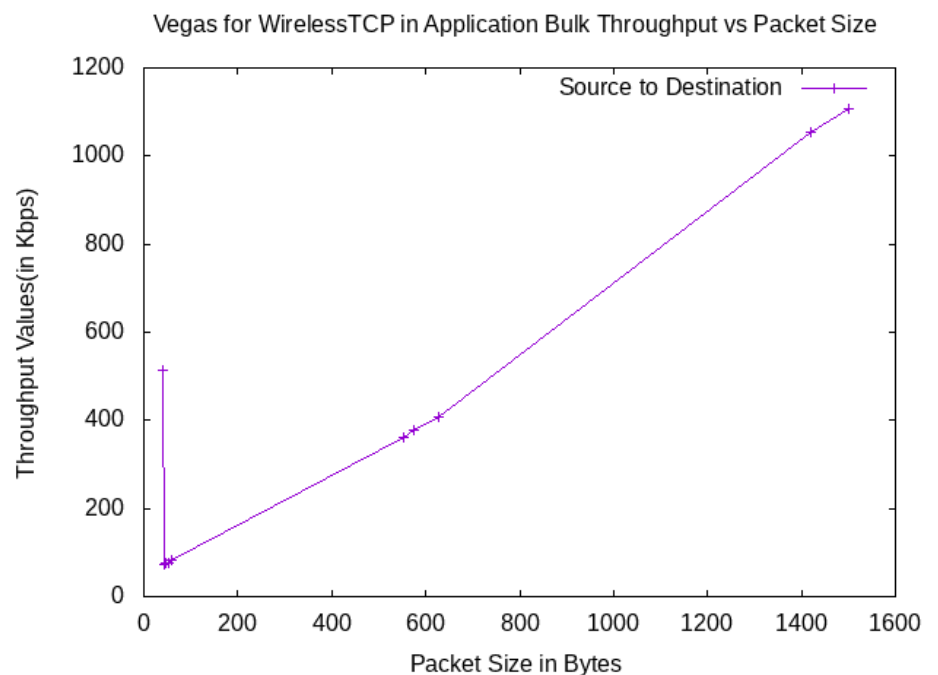
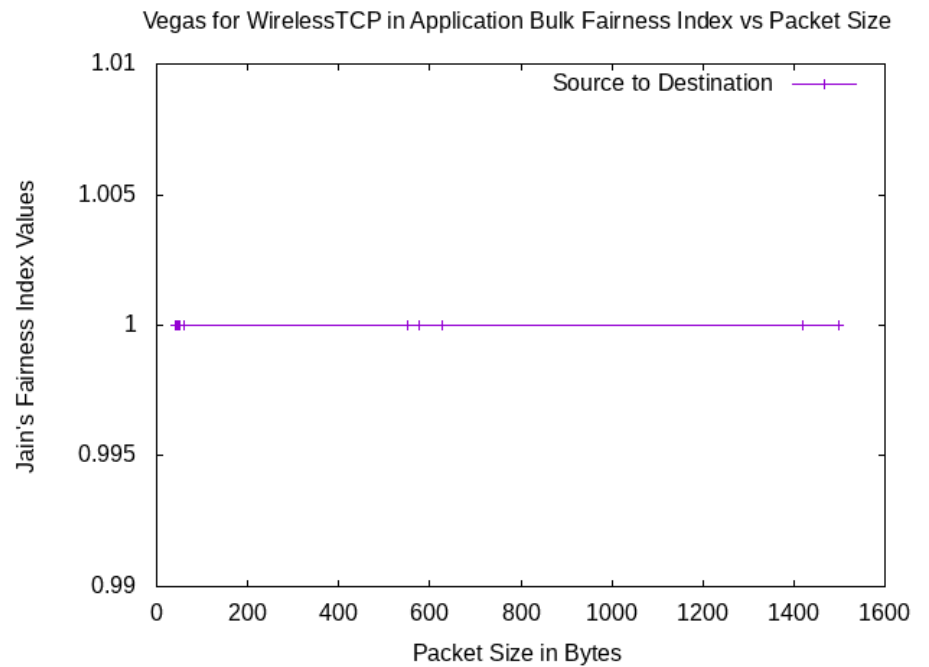
Packet Size: 552  
Jain's Fairness Index: 1  
Average Throughput: 362.791

Packet Size: 576  
Jain's Fairness Index: 1  
Average Throughput: 377.091

Packet Size: 628  
Jain's Fairness Index: 1  
Average Throughput: 408.258

Packet Size: 1420  
Jain's Fairness Index: 1  
Average Throughput: 1053.05

Packet Size: 1500  
Jain's Fairness Index: 1  
Average Throughput: 1108.64



## b. TCP Protocol: Veno

Packet Size: 40  
Jain's Fairness Index: 1  
Average Throughput: 670.077

Packet Size: 44  
Jain's Fairness Index: 1  
Average Throughput: 698.598

Packet Size: 48  
Jain's Fairness Index: 1  
Average Throughput: 727.61

Packet Size: 52  
Jain's Fairness Index: 1  
Average Throughput: 756.209

Packet Size: 60  
Jain's Fairness Index: 1  
Average Throughput: 812.263

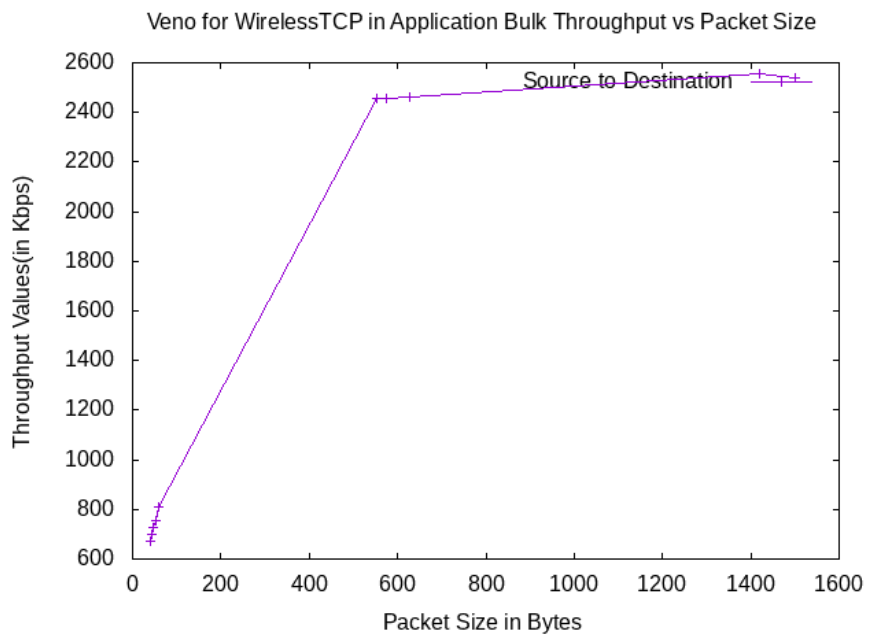
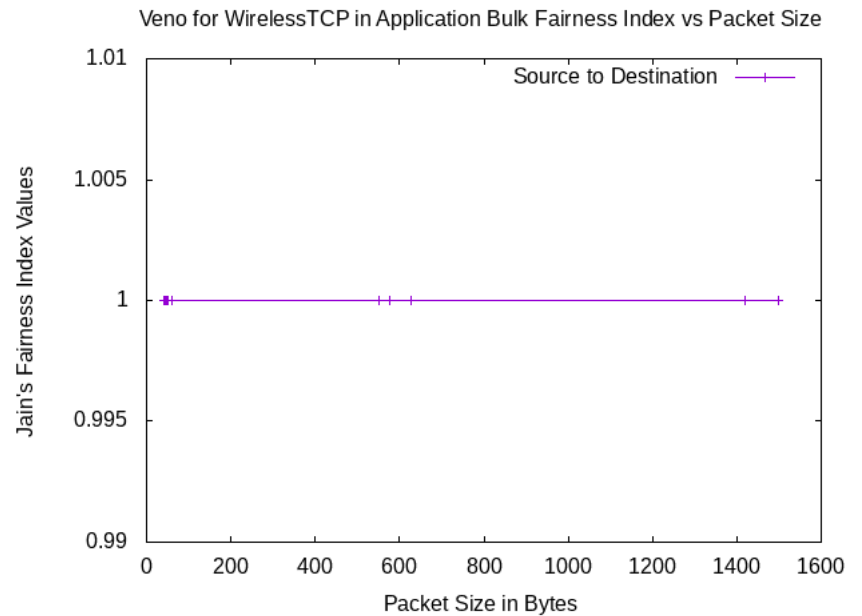
Packet Size: 552  
Jain's Fairness Index: 1  
Average Throughput: 2454.86

Packet Size: 576  
Jain's Fairness Index: 1  
Average Throughput: 2456.71

Packet Size: 628  
Jain's Fairness Index: 1  
Average Throughput: 2461.99

Packet Size: 1420  
Jain's Fairness Index: 1  
Average Throughput: 2557.5

Packet Size: 1500  
Jain's Fairness Index: 1  
Average Throughput: 2540.01



### c. TCP Protocol: Westwood

Packet Size: 40  
Jain's Fairness Index: 1  
Average Throughput: 670.077

Packet Size: 44  
Jain's Fairness Index: 1  
Average Throughput: 698.598

Packet Size: 48  
Jain's Fairness Index: 1  
Average Throughput: 727.61

Packet Size: 52  
Jain's Fairness Index: 1  
Average Throughput: 756.209

Packet Size: 60  
Jain's Fairness Index: 1  
Average Throughput: 812.263

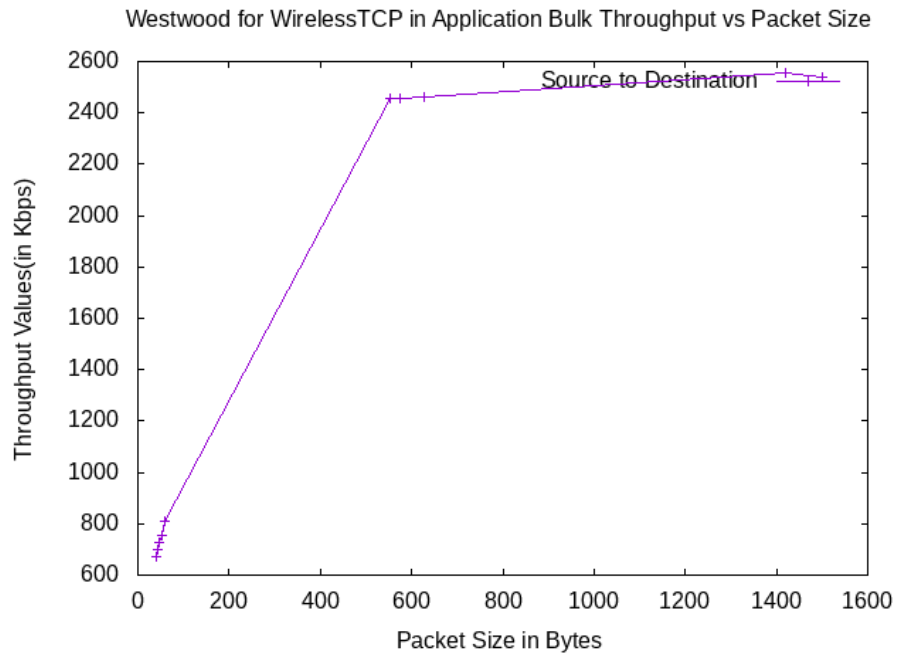
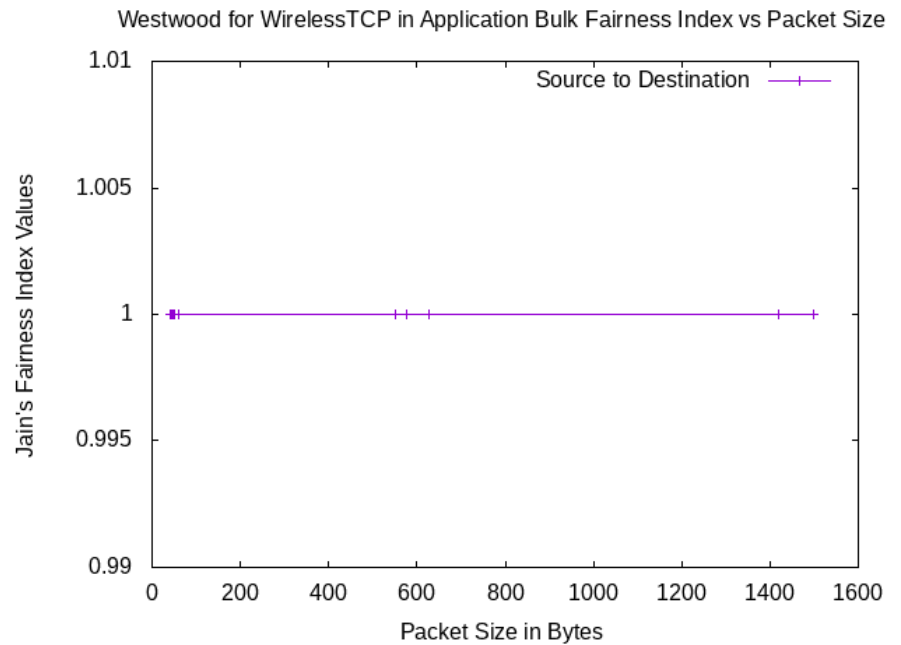
Packet Size: 552  
Jain's Fairness Index: 1  
Average Throughput: 2454.86

Packet Size: 576  
Jain's Fairness Index: 1  
Average Throughput: 2456.71

Packet Size: 628  
Jain's Fairness Index: 1  
Average Throughput: 2461.99

Packet Size: 1420  
Jain's Fairness Index: 1  
Average Throughput: 2557.5

Packet Size: 1500  
Jain's Fairness Index: 1  
Average Throughput: 2540.01



## Conclusions

### 1. Throughput vs Packet Size:

- > It can be observed that, in most cases, initially as the packet size is increased, the throughput increases. As the size of the transmitted packet is increased beyond some limit, the throughput starts to degrade.
- > With increasing packet length, packet loss rate also grows. Theoretically, the throughput decreases with the increasing of the packet loss rate. But since growth rate of packet is greater than the growth rate of the packet loss rate, there is an upward trend of throughput of TCP traffic.
- > However, there are certain deviations in this pattern. This maybe because because the TCP protocol involves a mix of very long and very short packet lengths (long packets downstream, short acknowledgment packets upstream). Thus, a value somewhere in the middle doesn't necessarily describe the actual mix of long and short packet lengths.
- > Short packets mean there is more work for a device to process per unit of time. With many devices, each new packet represents a software interrupt; the more packets.
- > Long packets are a good way to stress a network. With long packets, the ratio between packet payload and packet headers is higher; therefore, it is easier to fill up a pipe with longer packets.
- > Thus, the larger size packets of the TCP stream are more likely to have behavior of packet loss, but large packets are more likely to get higher throughput, so a rational choice of packet size plays a critical role in performance of TCP flows.

### 2. OnAndOff vs Bulk Sender:

- > OnAndOff specifies a data rate and transmits data at random intervals.
- > Bulk Sender sends data in minimum time with maximum data rate.

### 3. Wired vs Wireless TCP:

- > Some factors like installing a wireless link requires less physical preparation, physical cables have the advantage of stability and higher resistance to external interference, wireless signals are greatly affected by EMI and inclement weather, do not come to play in our experiments since a simulation is used.
- > However, we observe the performance of wireless generally cannot match that of a wired link. Wireless mostly offers slower speeds than wired links.
- > In-Channel and Co-Channel Interference is a major reason for worse performance of wireless links. There is also a decrease in bandwidth and signal strength with an increase in performance that affects the performance of wireless networks.

### 4. Vegas vs Veno vs Westwood:

- > Vegas: One of the smoothest TCP algorithms, it increases the timeout delay for packets, which allows more to be received, but at a higher rate. It also has set timeouts, which helps with speed because it's constantly being refreshed. Thus Vegas has higher throughput and also suffers more losses. With heavier congestion, it's performance increases since it employs more aggressive congestion recovery mechanisms.
- > Veno: Veno is closely related to Vegas, it is a combination of Vegas and Reno in order to enhance TCP performance over Wireless networks. Since it monitors the network congestion level and uses that information to decide whether packet losses are likely to be due to congestion or random bit errors, it achieves throughput improvements in wireless links.
- > Westwood: A newer version of Reno. Westwood is a more realistic bandwidth estimation in comparison to TCP flows, which significantly increases TCP throughput. It controls parameters better, helping out streaming and overall quality of browsing the internet. One of the most fair and efficient algorithms to date.