CHAPTER IV

SIMULATION MODELS AND EXPERIMENT RESULTS

This chapter presents the simulation models and the results gathered from the simulations. The traffic prediction (Neural Network) and the bandwidth re-allocation among the over-loading and under-loading connections (Fuzzy Logic) are simulated based on ABR traffic in ATM network. The proposed solution models simulate the ABR traffic between two nodes in the ATM network.

In order to compare their performance (bandwidth utilisation, buffer overflow, and buffer occupancy), two simulation models are used. The first model simulates the conventional static and average re-allocation method. The second model simulates maximum and minimum re-allocation method. All the results will be captured, gathered, and presented at the end of this chapter.

4.1 Objectives of Simulations

The objectives and detailed characteristics shared by the two simulations mentioned above are presented in this sub-section.

The simulations are carried out with three main objectives:

1. To investigate the performance of the Neural-Fuzzy in dynamic bandwidth allocation algorithm in ABR service class.
2. To investigate the performance of different dynamic re-allocation methods.
3. To compare the performances of static bandwidth and dynamic bandwidth.

To fulfil these three objectives, the following steps are carried out:

1. Three series of ABR traffic must be generated. ABR traffic is generated using the method introduced in the previous chapter.

2. The proposed Neural-Fuzzy model is constructed and trained.
3. Three Neural Networks are trained to predict the average, maximum, or minimum value of next incoming traffic.
4. The next step is to implement the bandwidth re-allocation, capture the result, and measure the performance. Implement the static bandwidth allocation, capture the result, and measure the performance.
5. No artificial intelligence are integrated in the static bandwidth allocation simulation (bandwidth allocated is constant throughout whole session).

The two simulation models are:
1. Simulation 1: Re-allocate bandwidth with the predicted average incoming traffic of next period and compare with the conventional static bandwidth allocation.
2. Simulation 2: Re-allocate bandwidth with the predicted maximum and minimum incoming traffic of next period.

4.2 Simulation Model

Throughout this research, terms are referred as below:

- Bandwidth – in terms of packets per second, pps (not bps)
- Buffer – in terms of number of packets
- Slot – 0.1 seconds
- Session – time interval in which the session is alive (from the time in which the first packets of the session arrives at the Adaptation Layer until the last packets leaves the Adaptation Layer)
- Period – 10 seconds or 100 slot

The proposed solution model (stated in the previous chapter) is to solve the dynamic bandwidth allocation problem in ATM network. This ATM network consists of 2 nodes (as shown in the Figure 4.1). One is the source and the other one is the destination. The proposed model can foresee the whole connection path. The intermediate nodes (switches) are ignored. In this environment the intermediate nodes can support the bandwidth capacity initiated by the source node.

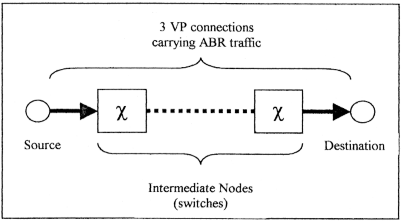

Figure 4.1 Simulation environment.

In setting up an ABR service's connection, a peak cell rate (PCR) and minimum cell rate (MCR) must be specified. If the permission is granted then the applications will receive at least the MCR that they requested. To regulate the ABR traffic from violating traffic contract, the maximum and minimum bandwidth must be specified. Some of the ATM network environment criteria are as follows:

- One source node
- One destination node
- Three VP connections carrying ABR traffic from the source node to the destination node
- Buffers are per-VP basis
- Maximum bandwidth for ABR class
- Minimum bandwidth for ABR class
- Maximum bandwidth for each VP must be specified
- Maximum buffer for each VP must be specified
- One Neural Network predictor per-VP
- One Fuzzy Logic per service class (ABR)

Three series of ABR traffic will be generated using the method proposed in the previous chapter. Every data in these series is the average number of packets that arrive in 0.1 seconds (slot). Every one hundred slots in these series will become one period. The average, minimum, and maximum bandwidth of each period for all three series will be calculated. Later, these calculated values would be fed into the Neural Network for training purpose. The well-trained Neural Network can predict average, maximum, or minimum packets arrival in the next period with certain precision. One Neural Network predictor will be incorporated with one VP, and a Fuzzy Logic will be incorporated with one service class (ABR in this research), which will reduce the management cost by grouping the same traffic characteristic (service class) connections. The input for Fuzzy Logic, Bandwidth Available, will be updated frequently to show the available bandwidth capacity.

4.3 Simulation using Matlab

The specification of the simulation, are as follows:

- Maximum bandwidth for service class = 44.5 pps (packets per second)
- Minimum bandwidth for service class = 1 pps
- Maximum bandwidth for connection 1 = 25 pps
- Maximum bandwidth for connection 2 = 13 pps
- Maximum bandwidth for connection 3 = 6.5 pps
- Maximum buffer for connection 1 = 25 p (packets)
- Maximum buffer for connection 2 = 13 p
- Maximum buffer for connection 3 = 6 p
- Learning rate for Neural Network = 0.000001
- Defuzzification technique = Centre of Gravity method

The maximum bandwidth of the three connections is set accordingly to the level of bandwidth availability:

- Connection 1 is able to transmit all the packets with zero number packets dropped.
- Connection 2 is able to transmit all the packets with moderate number packets dropped.
- Connection 3 is able to transmit all the packets with high number packets dropped.

4.3.1 Simulations of Static and Dynamic Bandwidth Allocation

The Neural Network is trained to predict the average packets arrival for the next period. Simulations have been conducted. The Fuzzy Logic re-allocated the bandwidth based on

Buffer Available, Bandwidth Predicted, and Bandwidth Available, which have been stated in the previous chapter. The results are captured as below:

- Total slot generated for training– 35700
- Total slot generated for simulation – 8700 or Session duration – 870 seconds
- Total number feed into Neural Network for training – 357 periods
- Total number for simulation – 87 periods

Figure 4.2 shows the result captured from the simulation of Connection 1. The bandwidth utilisation of different methods is shown in Figure 4.2. The parameters of Connection 1 are set as below:

- Static bandwidth - 25 pps
- Maximum bandwidth – 25 pps
- Minimum bandwidth – 1 pps
- Buffer – 25 packets

The actual value of bandwidth utilisation for the whole transmission session is:

- Static – 16.45%
- Average – 44.74%
- Maximum – 74.55%
- Minimum – 99.32%

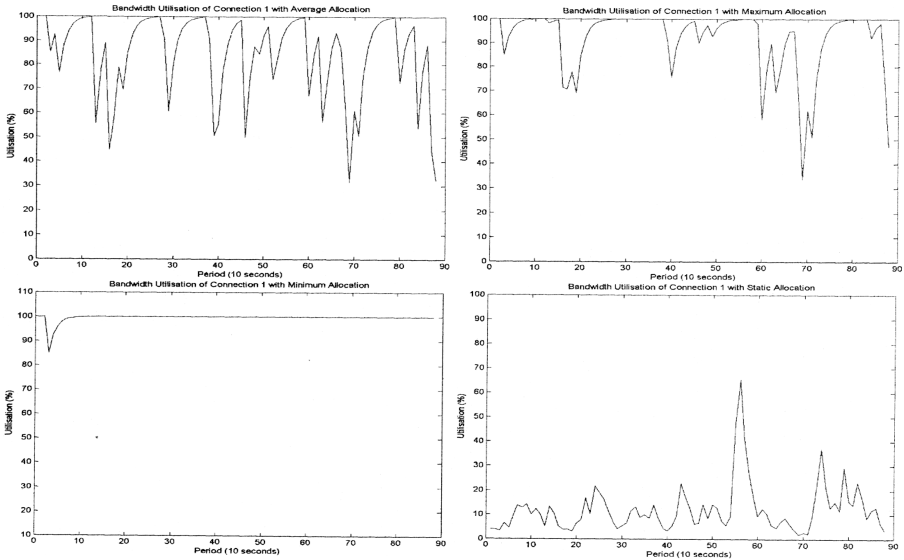

Figure 4.2 Bandwidth Utilisation for Connection 1 during transmission.

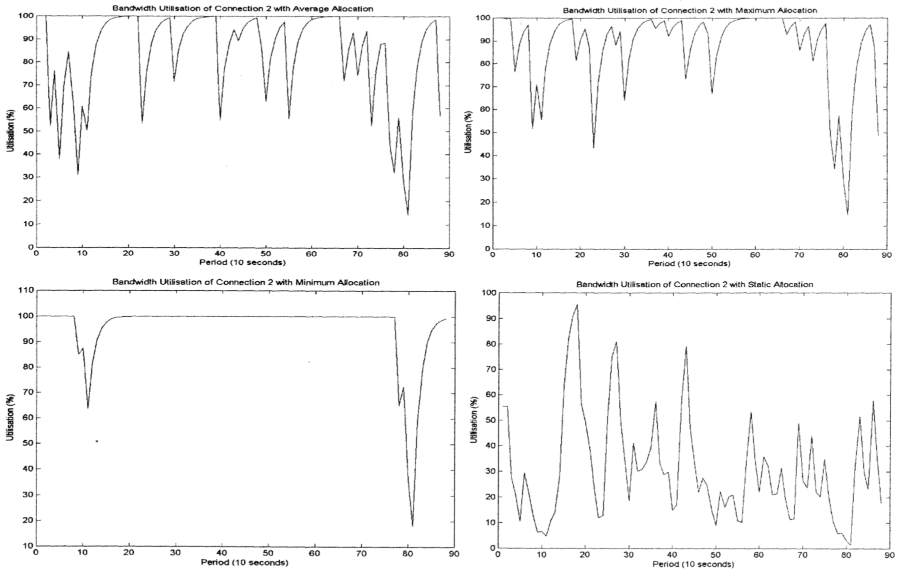

Figure 4.3 Bandwidth Utilisation for Connection 2 during transmission.

Figure 4.3 shows the result captured from the simulation of Connection 2. The bandwidth utilisation of different methods is shown in Figure 4.3. The parameters of Connection 2 are set as below:

- Static bandwidth – 13 pps
- Maximum bandwidth – 13 pps
- Minimum bandwidth – 1 pps
- Buffer – 13 packets

The actual value of bandwidth utilisation for the whole transmission session is:

- Static – 35.05%
- Average – 89.66%
- Maximum – 87.48%
- Minimum – 98.72%

Figure 4.4 shows the result captured from the simulation of Connection 3. The bandwidth utilisation of different methods is shown in Figure 4.4. The parameters of Connection 3 are set as below:

- Static bandwidth – 6.5 pps
- Maximum bandwidth – 6.5 pps
- Minimum bandwidth – 1 pps
- Buffer – 6 packets

The actual value of bandwidth utilisation for the whole transmission session is:

- Static – 70.43%
- Average – 87.90%
- Maximum – 87.61%
- Minimum – 95.00%

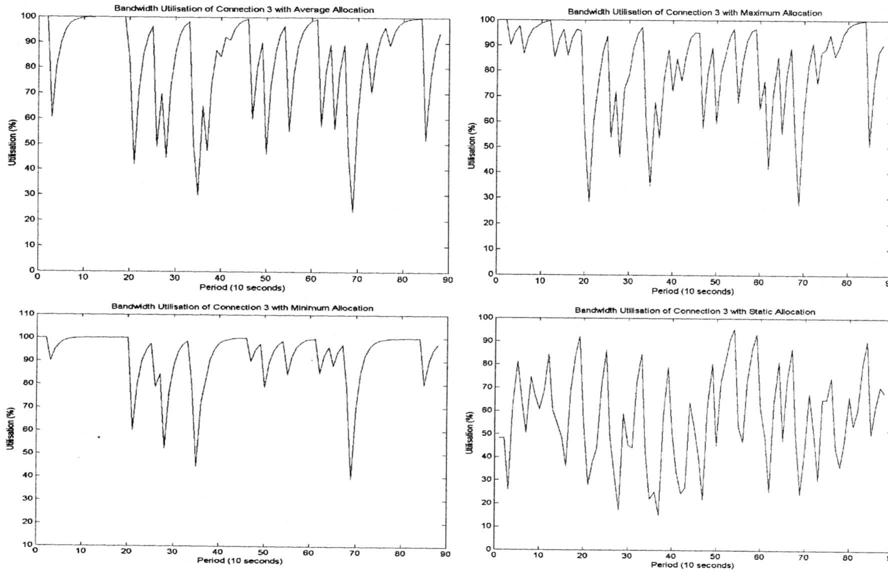

Figure 4.4 Bandwidth Utilisation for Connection 3 during transmission.

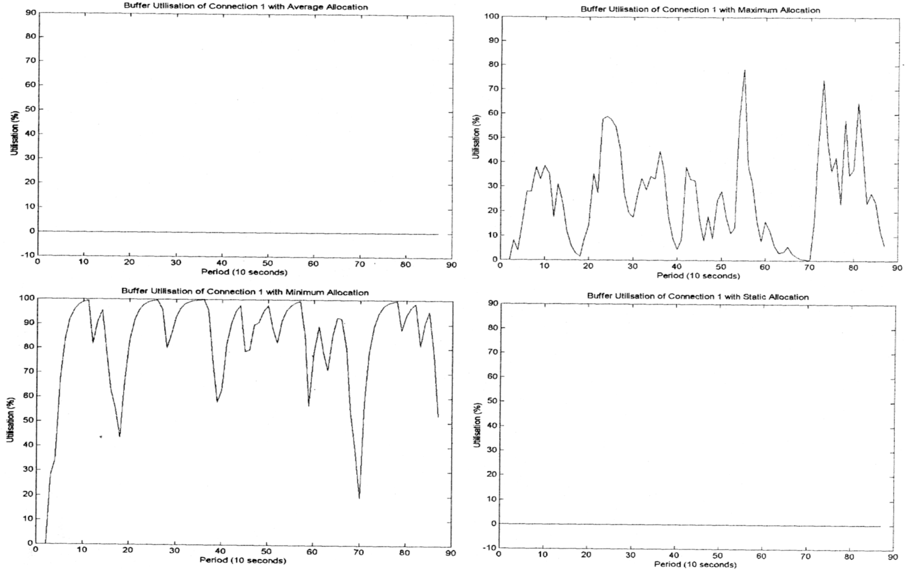

Figure 4.5 Buffer Utilisation for Connection 1 during transmission.

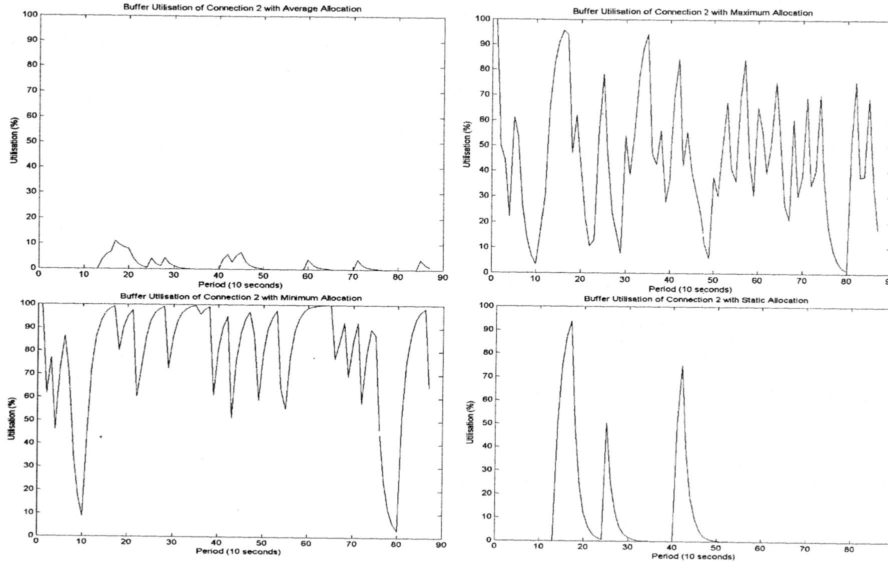

Figure 4.6 Buffer Utilisation for Connection 2 during transmission.

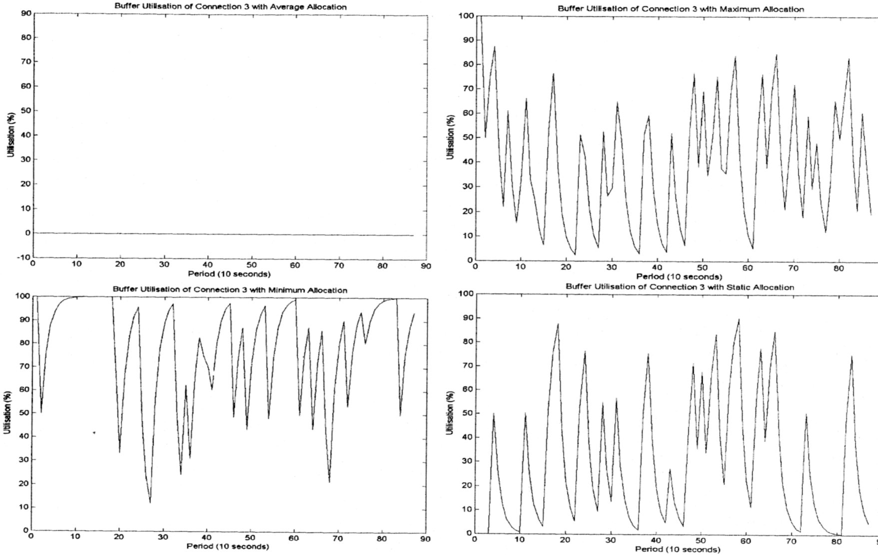

Figure 4.7 Buffer Utilisation for Connection 3 during transmission.

Figure 4.5, Figure 4.6, and Figure 4.7 show the results captured from the simulation of Connection 1, Connection 2, and Connection 3. In those figures, the diagrams show the buffer utilisation of the three re-allocation methods and the conventional method. The actual value of buffer utilisation for the whole transmission session is shown in Table 4.1.

Table 4.1 Buffer Utilisation

	Static (%)	Average (%)	Maximum (%)	Minimum (%)
Connection 1	0.00	0.05	26.29	82.83
Connection 2	8.05	3.50	45.26	78.73
Connection 3	30.27	0.04	40.72	78.16

Figure 4.8, Figure 4.9 and Figure 4.10 summarise the results measured in the simulations.

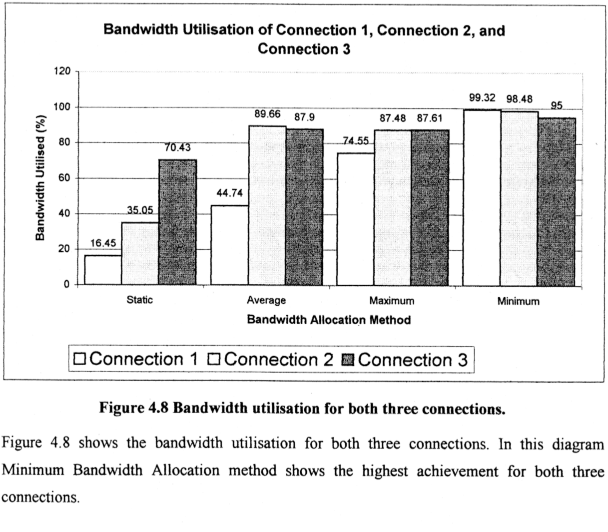

Figure 4.8 Bandwidth utilisation for both three connections.

Figure 4.8 shows the bandwidth utilisation for both three connections. In this diagram Minimum Bandwidth Allocation method shows the highest achievement for both three connections.

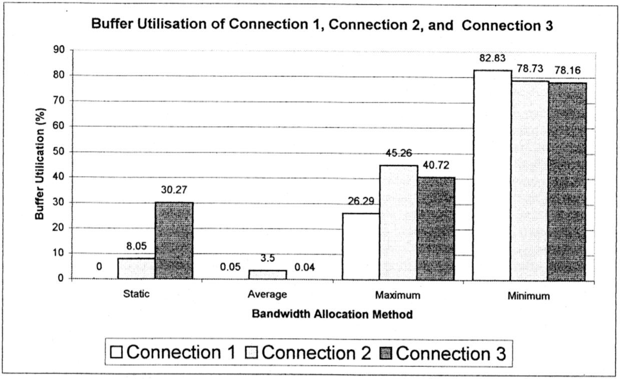

Figure 4.9 Buffer utilisation for both three connections.

Figure 4.9 shows the Buffer Utilisation for both three connections. In this diagram, Buffer Utilisation for Connection 1 with static bandwidth allocation is 0%. Buffer utilisations for Connection 1 and Connection 2 with Average re-allocation method are too insignificant (<1%) to show in the chart.

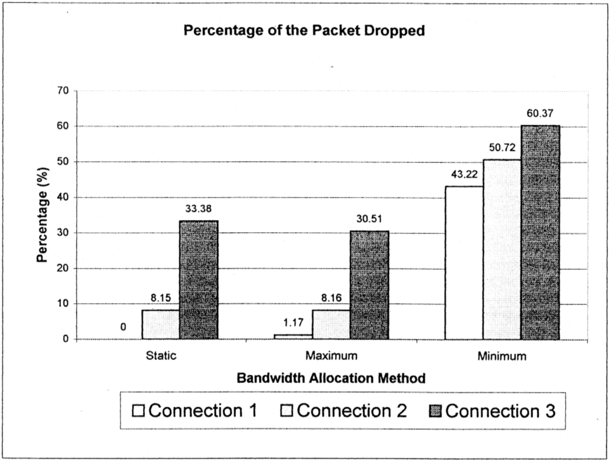

Figure 4.10 Percentage of packets dropped for both three connections.

Figure 4.10 shows the Percentage of packets dropped for both three connections. In this diagram, Average Allocation method is omitted from the chart. This method has 0% packets dropped rate for both three connections.

Figure 4.11, Figure 4.12, and Figure 4.13 show the number of packets dropped during the simulation.

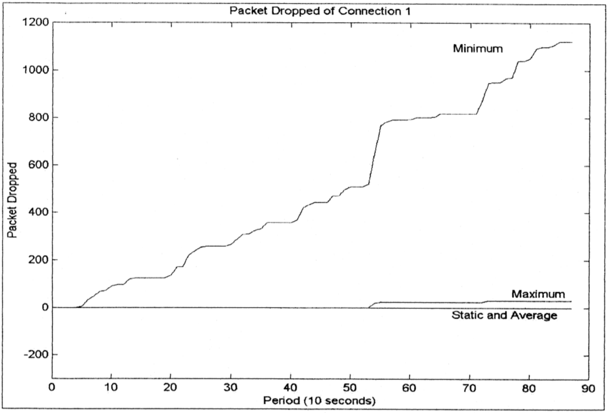

Figure 4.11 Packets dropped for Connection 1 during transmission.

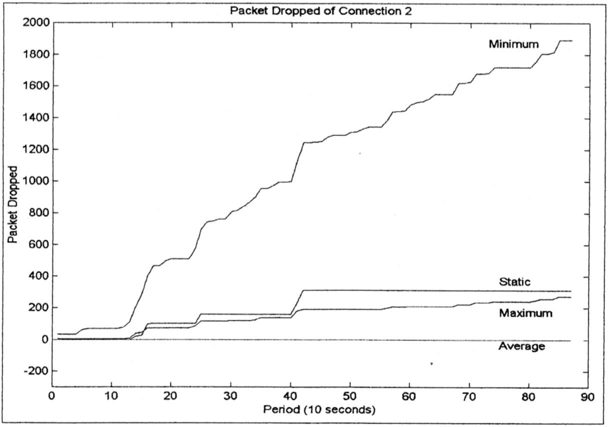

Figure 4.12 Packets dropped for Connection 2 during transmission.

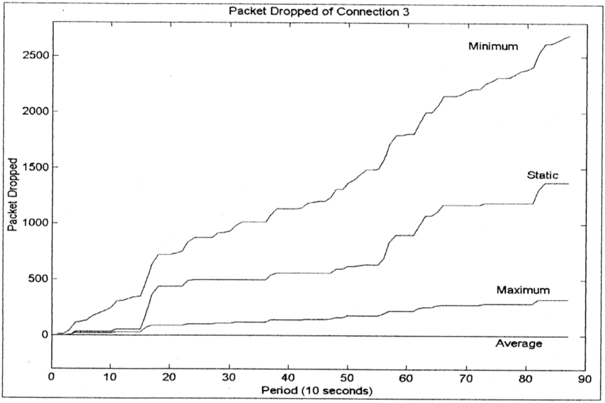

Figure 4.13 Packets dropped for Connection 3 during transmission.

Table 4.2 shows the percentage of the number of packets dropped. Table 4.3 shows the packets dropped in terms of the number of packets.

Table 4.2 Packets Dropped (%)

	Static (%)	Average (%)	Maximum (%)	Minimum (%)
Connection 1	0.00	0.00	1.17	43.22
Connection 2	8.15	0.00	8.16	50.72
Connection 3	33.38	0.00	7.57	60.37

Table 4.3 Total Number of Packets Dropped

	Total	Static	Average	Maximum	Minimum
Connection 1	2651	0	0	31	1146
Connection 2	3773	308	0	282	1914
Connection 3	4503	1503	0	1347	2718

4.4 Chapter Summary

In this chapter, the simulation models and the results gathered from the simulations are presented. The following chapter concludes this research and discusses some suggestions for further study.