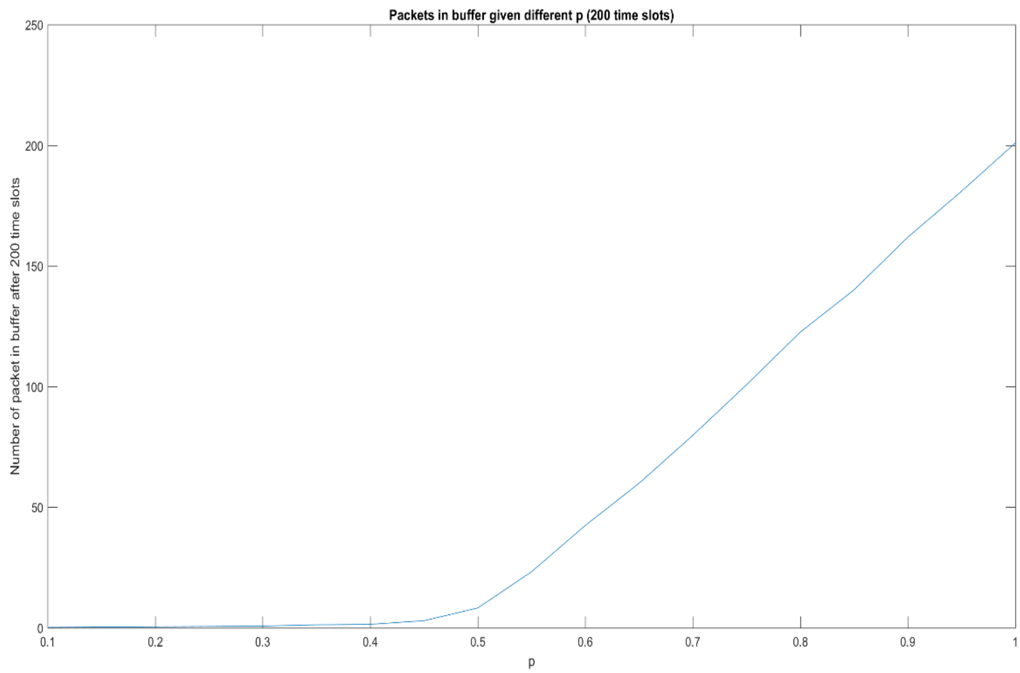
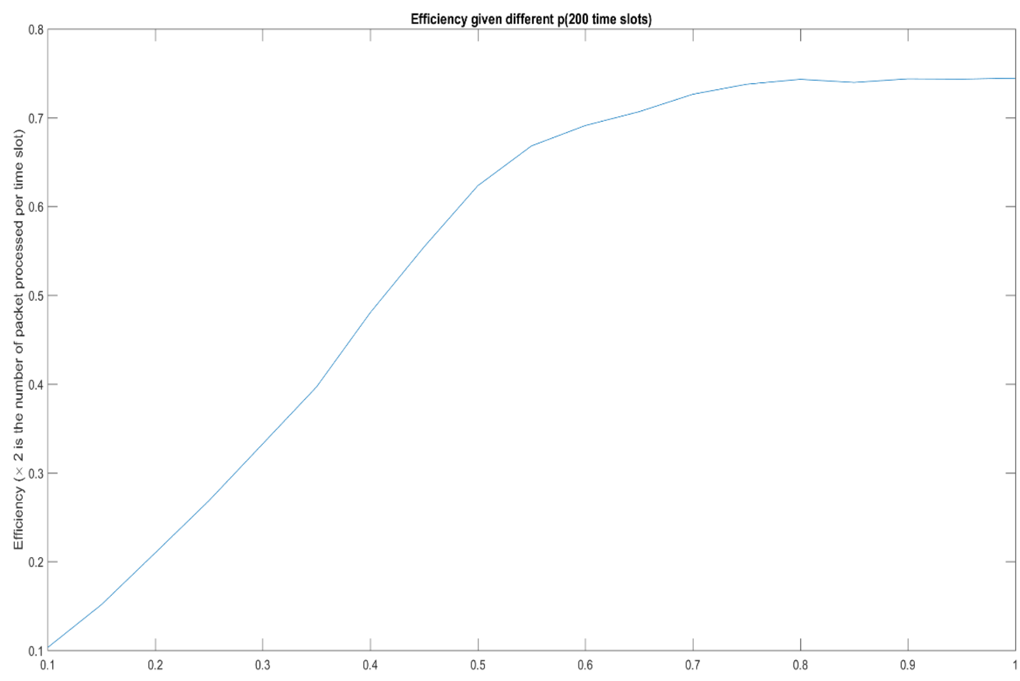
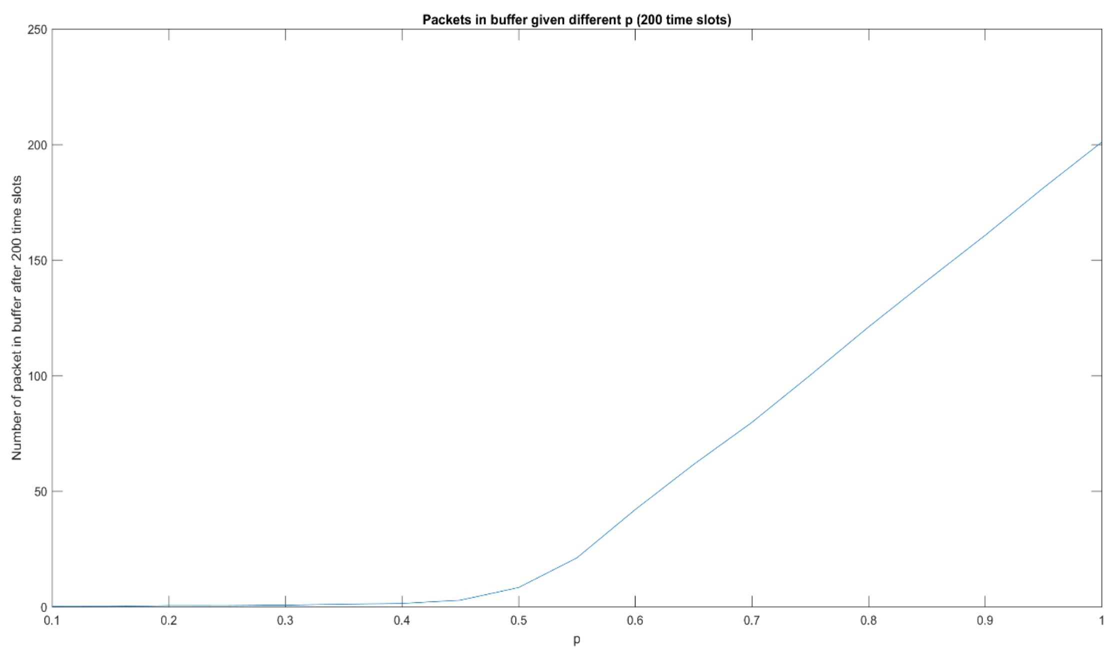
For a 2x2 switch,





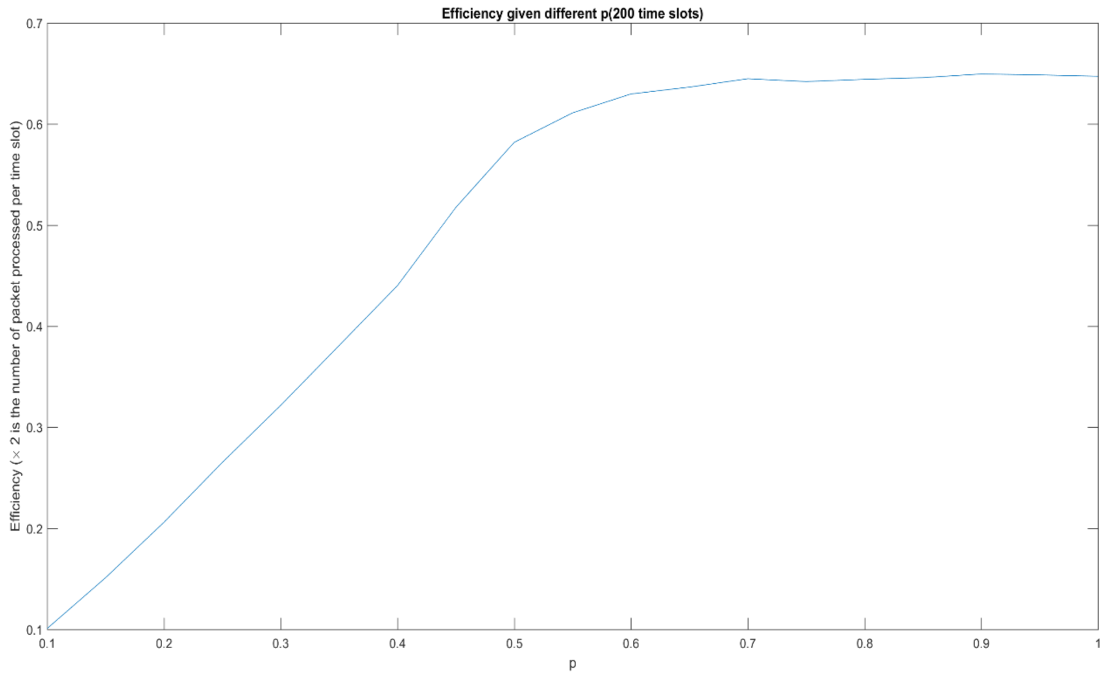
Therefore, when p > 0.7, the efficiency seems to be steady to be around 0.75. We can conclude that if we choose the p to be 0.7, the packet may not pile up in the buffer and still the switch has a good efficiency. To compute the 95% confidence interval we choose p from 0.1 to 0.9,

p	CI efficiency (%)
0.1	[6.25,12.5]
0.2	[15.50,23.25]
0.3	[25.50,33.75]
0.4	[35.50,45.50]
0.5	[44.50,54.25]
0.6	[54.25,64.25]
0.7	[65.75,72.50]
0.8	[70.0,77.0]
0.9	[71.0,78.0]



We just change the parameter r1,r2 in the function and we can get the switch's behaviour when r1 = 0.75 and r2 = 0.25.

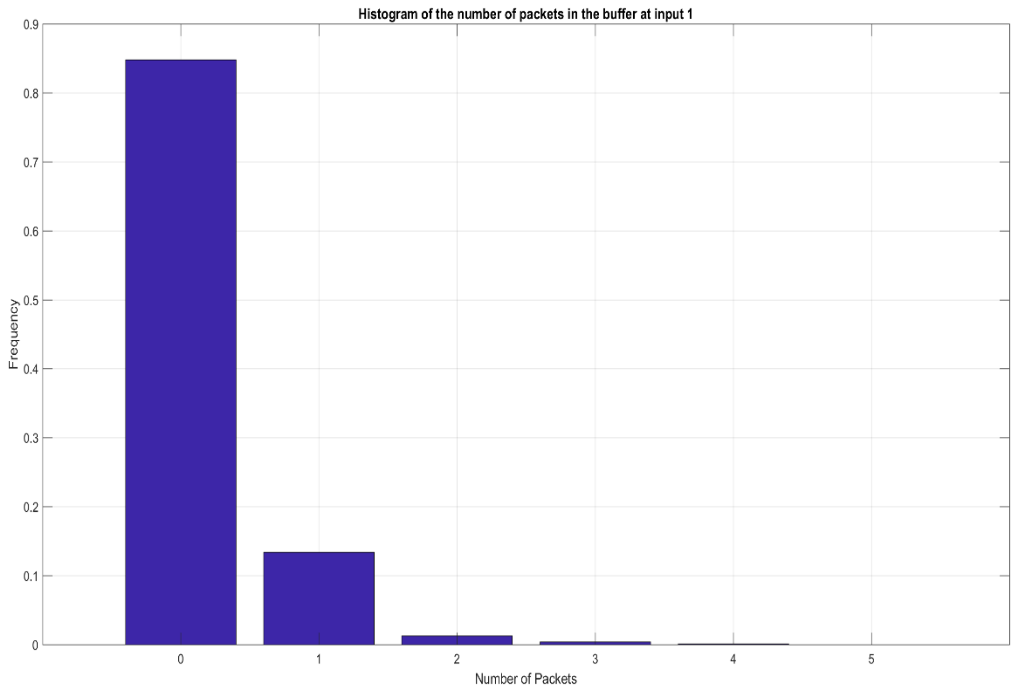
Clearly, the efficiency decreases and it is more easily for the buffer to pile up packets.

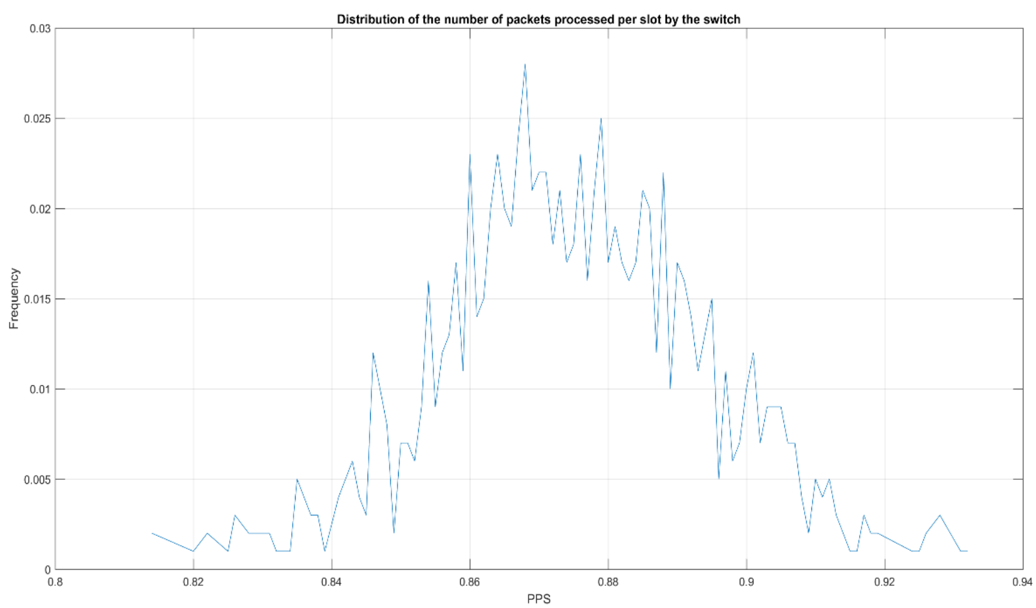


p	CI efficiency (%)
0.1	[7.75,12.75]
0.2	[16.75,23.75]
0.3	[25.50,34.50]
0.4	[35.25,45.25]
0.5	[43.75,53.75]
0.6	[55.25,62.75]
0.7	[60.75,67.00]
0.8	[61.25,65.50]
0.9	[60.75,70.55]

Mean_N1_pkt = 0.1573

Mean_Throughput = 0.8754





The distribution of the number of packets in buffer is a geometric distribution; and to my expectation, the distribution of the number of packets processed per slot is a normal distribution. This can be explained by the Central limit theorem.

For a 4x4 switch with balanced traffic, throughput = 2.6060 pps

For a 8x8 switch with balanced traffic, throughput = 4.9820 pps

5. CODES

For 2x2 Switch

(i)

```
function [nstate, efficiency1, efficiency2] = Input(p,r1,r2,tend)
%
% nstate: record how many packets are present in input1 and input2
% p: the arriving probability
% r1: the probability to target at output 1
% r2: the probability to target at output 2
% tend: continue until tend

% nstate how many packet in each of the input
nstate = [p > rand(1) , p > rand(1) ];
passed = 0;
maxpassed = 0;

% r1 = 0.5; r2 = 0.5;
% nInput1 = nstate(1);
attempt = [r1 > rand(1) , r1> rand(1)];
nextAttempt = [r1 > rand(1) , r1> rand(1)];

% nInput2 = nstate(2);
priority = 1;
t = 1;

while t<tend
    if sum(nstate) > 0
        if nstate(1) > 0 && nstate(2) == 0
            nstate(1) = nstate(1) - 1;
            passed = passed + 1;
            maxpassed = maxpassed + 1;
        else
            if nstate(1) == 0 && nstate(2) > 0
                nstate(2) = nstate(2) - 1;
                passed = passed + 1;
                maxpassed = maxpassed + 1;
            else % when both have packets at the input
                if attempt (1) ~= attempt (2)
                    nstate(1) = nstate(1) - 1;
                    nextAttempt = [r1 > rand(1) , r1 > rand(1)];
                    passed = passed + 2;
                    maxpassed = maxpassed + 2;
                else
                    if priority == 1
                        nstate(1) = nstate(1) - 1;
                        priority = - priority;
                        nextAttempt = [r1 > rand(1) , attempt(2)];
                    else
                        nstate(2) = nstate(2) - 1;
                        priority = - priority;
                        nextAttempt = [attempt(1) , r1 > rand(1)];
                    end
                    passed = passed + 1;
                    maxpassed = maxpassed + 2;
```

```
                end
            end
        end
        % else
        %     nextAttempt = [r1 > rand(1) , r2 > rand(1)];
    end

    % New packet arrives
    nstate = nstate + [p>rand(1) ,p>rand(1)];
    attempt = nextAttempt;
    t = t+1;

    % efficiency = passed/t;
    % nstate

end

efficiency1 = passed/maxpassed;
efficiency2 = passed/(t*2);
```

(ii)

```
buffer = zeros(1,100);
k = 1;

for p = 0.1:0.05:1
    for i = 1:100
        [nstate,efficiency1,efficiency2] = Input(p,0.5,0.5,200);
        buffer(i) = sum(nstate);
        efficiency(i) = efficiency2;
    end

    recordNumber(k) = mean(buffer);
    recordEfficiency(k) = mean(efficiency);
    k = k+1;
end

figure,
plot (0.1:0.05:1 ,recordNumber);
title ( 'Packets in buffer given different p (200 time slots)');
xlabel ( 'p' );
ylabel( 'Number of packet in buffer after 200 time slots');

figure,
plot (0.1:0.05:1 ,recordEfficiency);
title ( 'Efficiency given different p(200 time slots)');
xlabel ( 'p' );
ylabel( 'Efficiency (\times 2 is the number of packet processed per time
slot)');
```

(iii)

```
close all;
clear;
```

```
clc;

times = 1000;
casei = 1;

for p = 0:0.1:1

    N1_pkt = zeros(1,times);
    N2_pkt = zeros(1,times);
    throughput = zeros(1,times);

    for i = 1:times
        [N1_pkt(i), N2_pkt(i), throughput(i)] = Load_Data(p,casei);
    end

    p
    Mean_N1_pkt = mean(N1_pkt)
    Mean_throughput = mean(throughput)
end
```

(iv)

```
function [N1,N2,throughput] = Load_Data(p, casei)

n_slot = 1000;
P1 = rand(1,n_slot);
P2 = rand(1,n_slot);
R11 = rand(1,n_slot);
R21 = rand(1,n_slot);

% Packets processed per slot
pps = zeros(1,n_slot);
throughput = 0;
N1 = 0;             % Number of packets in buffer 1
N2 = 0;             % Number of packets in buffer 2

if casei == 1
    r = 0.5;
else
    r = 0.75;
end

for i = 1:n_slot
    % Situation that input 1 and input 2 both have packets

    if(P1(i)<p && P2(i)<p)
        % Input 1 switches to output 1 and input 2 switches to output 2

        if(R11(i)<r && R21(i)>r)
            pps(i) = 2;
            [N1] = popbuffer(N1);
            [N2] = popbuffer(N2);
        end

        % Input 1 switches to output 1 and input 2 switches to output 2
```

```
    if(R11(i)>r && R21(i)>r)
        P_sel = rand(1);

        % Select packet with the same probability
        if P_sel <= 0.5
            pps(i) = 1;
            [N1] = popbuffer(N1);
            [N2] = pushbuffer(N2);
        else
            pps(i) = 1;
            [N1] = pushbuffer(N1);
            [N2] = popbuffer(N2);
        end
    end

    % Input 1 switches to output 2 and input 2 switches to output 1

    if(R11(i)>r && R21(i)<r)
        pps(i) = 2;
        [N1] = popbuffer(N1);
        [N2] = popbuffer(N2);
    end

    % Input 1 switches to output 1 and input 2 switches to output 1

    if(R11(i)<r && R21(i)<r)
        P_sel = rand(1);

        % Select packet with the same probability
        if P_sel <= 0.5
            pps(i) = 1;
            [N1] = popbuffer(N1);
            [N2] = pushbuffer(N2);
        else
            pps(i) = 1;
            [N1] = pushbuffer(N1);
            [N2] = popbuffer(N2);
        end
    end
end

% Situation that input 1 has packet but input 2 doesn't

if(P1(i)<p && P2(i)>p)
    pps(i) = 1;
    [N1] = popbuffer(N1);
end

% Situation that input 2 has packet but input 1 doesn't

if(P1(i)>p && P2(i)<p)
    pps(i) = 1;
    [N2] = popbuffer(N2);
end

% Situation that input 1 and input 2 both don't have packet
```

```
    if(P1(i)>p && P2(i)>p)
        pps(i) = 0;
    end
end
throughput = sum(pps)/n_slot;
end
```

(v)

```
function [N1] = popbuffer(N1)
% if the number of packets in buffer > 1 then pop one packet out
% if number <= 0 then number becomes 0 after pop

if N1>1
    N1 = N1 - 1;
else
    N1 = 0;
end
```

(vi)

```
function [N1] = pushbuffer(N1)
% Push one packet into buffer, number increases by 1

N1 = N1 + 1;
End
```

(vii)

```
close all;
clear;
clc;

times = 1000;
p = 0.5;
casei = 1;

N1_pkt = zeros(1,times);
N2_pkt = zeros(1,times);
throughput = zeros(1,times);

for i = 1:times
    [N1_pkt(i), N2_pkt(i), throughput(i)] = Load_Data(p,casei);
end

Mean_N1_pkt = mean(N1_pkt)

figure,
A = 0:1:5;
[a,b] = hist(N1_pkt,A);
bar(b,a/sum(a));
grid on;
title('Histogram of the number of packets in the buffer at input 1');
xlabel('Number of Packets');
ylabel('Frequency');

Mean_throughput = mean(throughput);
```

```
figure,
A = unique(throughput);
dist_throughput = histc(throughput,A);
a = dist_throughput/sum(dist_throughput);
plot(A,a);
grid on;
title('Distribution of the number of packets processed per slot by the
switch');
xlabel('PPS');
ylabel('Frequency');
```

(viii)

```
close all;
clear;
clc;

times = 1000;
casei = 1;

for p = 0:0.1:1

    N1_pkt = zeros(1,times);
    N2_pkt = zeros(1,times);
    throughput = zeros(1,times);

    for i = 1:times
        [N1_pkt(i), N2_pkt(i), throughput(i)] = Load_Data(p,casei);
    end

    p
    Mean_N1_pkt = mean(N1_pkt)
    Mean_throughput = mean(throughput)
End
```

Generalizing to NxN switch

(i)

Balanced Traffic :

```
close all;
clear;
clc;

prompt = 'What is the size of the switch?';
N = input(prompt)

Hash = zeros(1,N);
total = 0;
steps = 1000;
num = N;

for j = 1:steps
```

```
    empty = randi([1,N],1,num)
    for i = 1:num
        Hash(empty(i)) = Hash(empty(i)) + 1;
    end
    num = 0;

    for i = 1:N
        if Hash(i) > 0
            Hash(i) = Hash(i) - 1;
            num = num + 1;
        end
    end

    total = total + num;
end

pps = total/steps;
```

(ii)

Hot-Spot Traffic :

```
close all;
clear;
clc;

prompt = 'What is the size of the switch?';
N = input(prompt)

Hash = zeros(1,N);
total = 0;
steps = 1000;
num = N;
k = 2;

for j = 1:steps

    empty = randsrc(1,num,[1,2,3,4;1/k,(k-1)/(k*(N-1)),(k-1)/(k*(N-1)),(k-
1)/(k*(N-1))])
    for i = 1:num
        Hash(empty(i)) = Hash(empty(i)) + 1;
    end
    num = 0;

    for i = 1:N
        if Hash(i) > 0
            Hash(i) = Hash(i) - 1;
            num = num + 1;
        end
    end

    total = total + num;
end

pps = total/steps;
```