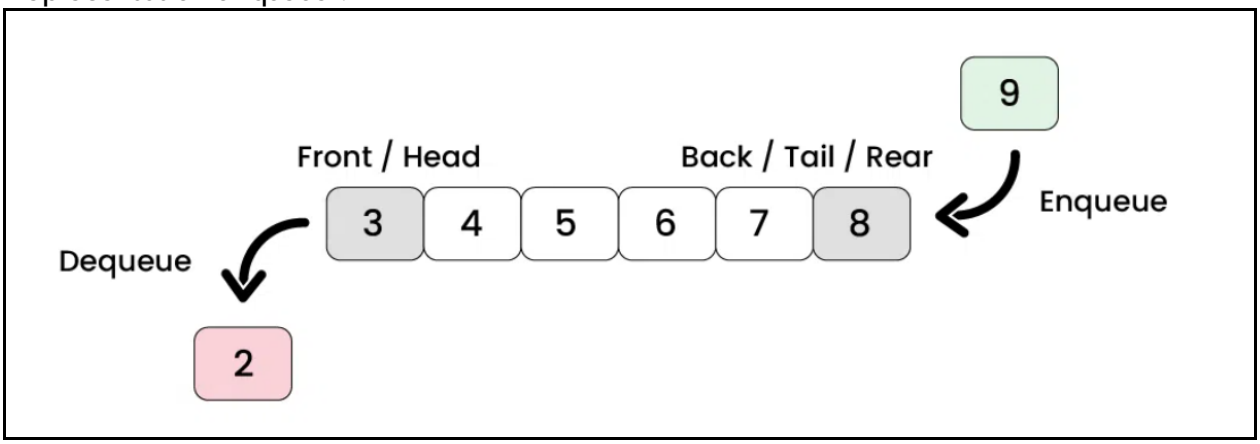
UNIT-IV : QUEUES

Introduction to queues :

A queue is a linear data structure where elements are stored in the FIFO (First In First Out) principle where the first element inserted would be the first element to be accessed. A queue is an Abstract Data Type (ADT) similar to stack, the thing that makes queue different from stack is that a queue is open at both its ends. The data is inserted into the queue through one end and deleted from it using the other end.

Representation of queue :



Operations of queues :

These are all built-in operations to carry out data manipulation and to check the status of the queue.

Enqueue: Insert an element at the end of the queue.
Dequeue: Simply remove an element from the front of the queue.
IsEmpty: Used to check if the queue is completely empty.
IsFull: Used to check if the queue is completely full.

Peek: Without removing it, obtain the value from the front of the queue.

Queues can be implemented by using arrays and linked list.

Enqueue Operation in Queue:

Enqueue() operation in Queue adds (or stores) an element to the end of the queue.Addition of an element to the queue. Adding an element will be performed after checking whether the queue is full or not. If rear < n which indicates that the array is not full then store the element at arr[rear] and increment rear by 1but if rear == n then it is said to be an Overflow condition as the array is full.

The following steps should be taken to enqueue (insert) data into a queue:

Step 1: Check if the queue is full.

Step 2: If the queue is full, return overflow error and exit.

Step 3: If the queue is not full, increment the rear pointer to point to the next empty space.

Step 4: Add the data element to the queue location, where the rear is pointing.

Step 5: return success.

Algorithm

Step 1: IF REAR = MAX - 1

Write OVERFLOW

Go to step [END OF IF]

Step 2: IF FRONT = -1and REAR = -1

SET FRONT = REAR = 0

ELSE

SET REAR = REAR + 1

[END OF IF]

Step 3: Set QUEUE[REAR] = NUM

Step 4: EXIT

Dequeue Operation in Queue:
Removes (or access) the first element from the queue.

Removal of an element from the queue. An element can only be deleted when there is at least an element to delete i.e. rear > 0. Now, the element at arr[front] can be deleted but all the remaining elements have to shift to the left by one position in order for the dequeue operation to delete the second element from the left on another dequeue operation.
The following steps are taken to perform the dequeue operation:

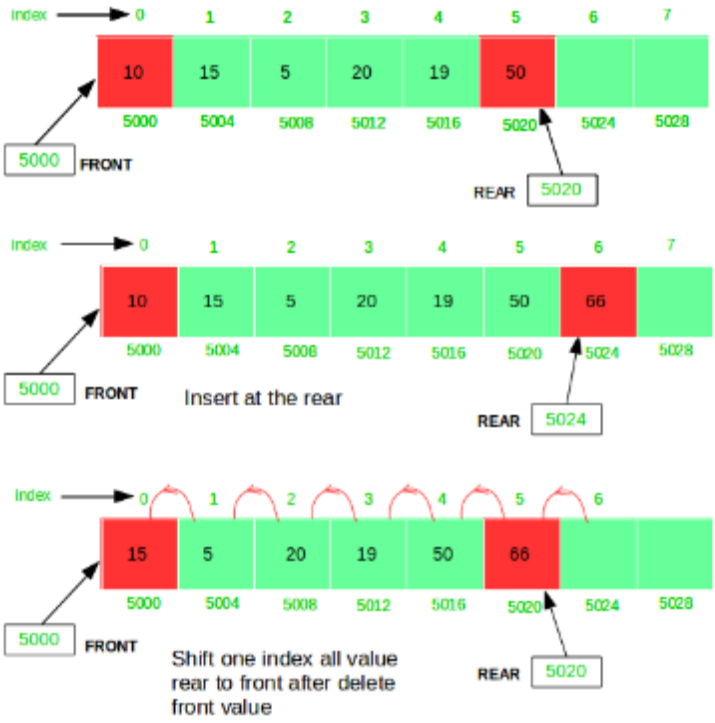
Step 1 Check if the queue is empty.

Step 2: If the queue is empty, return the underflow error and exit.

Step 3: If the queue is not empty, access the data where the front is pointing.

Step 4: Increment the front pointer to point to the next available data element.

Step 5: The Return success.



Algorithm

```
IF(FRONT==-1||FRONT==REAR+1)

RETURN

ELSE

QUEUE[FRONT]=0

FRONT=FRONT+1
```

Implementation of queue using arrays

Advantages of implementing queues using arrays:

Memory Efficient: Array elements do not hold the next elements address like linked list nodes do.

Easier to implement and understand: Using arrays to implement queues require less code than using linked lists, and for this reason it is typically easier to understand as well.

Disadvantages in not using arrays to implement queues:

Fixed size: An array occupies a fixed part of the memory. This means that it could take up more memory than needed, or if the array fills up, it cannot hold more elements. And resizing an array can be costly.

Shifting cost: Dequeue causes the first element in a queue to be removed, and the other elements must be shifted to take the removed elements' place. This is inefficient and can cause problems, especially if the queue is long.

Alternatives: Some programming languages have built-in

Implementing queues using arrays

Procedure 2:

```
#include<stdio.h>
#include<stdlib.h>
#define maxsize 5
void insert();
void delete();
void display();
int front = -1, rear = -1;
int queue[maxsize];
```

```
void main ()
{
    int choice;
    while(choice != 4)
    {
        printf("\n1insert an element\n2.Delete an element\n3.Display the queue\n4.Exit\n");
        printf("\nEnter your choice ?");
        scanf("%d",&choice);
        switch(choice)
        {
            case 1:
            insert();
            break;
            case 2:
            delete();
            break;
            case 3:
            display();
            break;
            case 4:
            exit(0);
            break;
            default:
            printf("\nEnter valid choice??\n");
```

```
        }
    }
}

void insert()
{
    int item;
    printf("\nEnter the element\n");
    scanf("\n%d",&item);
    if(rear == maxsize-1)
    {
        printf("\nOVERFLOW\n");
        return;
    }
    if(front == -1 && rear == -1)
    {
        front = 0;
        rear = 0;
    }
    else
    {
        rear = rear+1;
    }
    queue[rear] = item;
```

```
    printf("\nValue inserted ");
    }
void delete()
{
    int item;
    if (front == -1 || front > rear)
    {
        printf("\nUNDERFLOW\n");
        return;
    }
    else
    {
        item= queue[front];  //copy the element first before overwritten
        if(front == rear)
        {
            front = -1;
            rear = -1;
        }
        else
        {
            front = front + 1;
        }
        printf("\nvalue deleted ");
    }
```

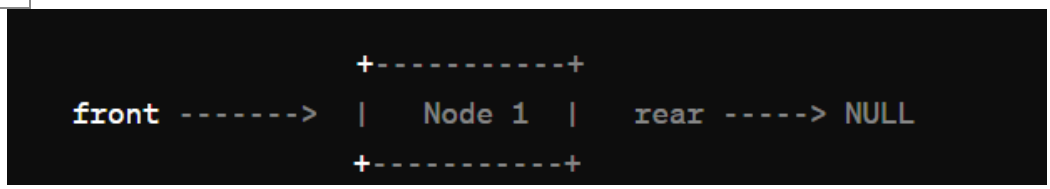
```
}
void display()
{
    int i;
    if(rear == -1)
    {
        printf("\nEmpty queue\n");
    }
    else
    {   printf("\nprinting values .....\n");
        for(i=front;i<=rear;i++)
        {
            printf("\n%d\n",queue[i]);
        }
    }
}
```

Queues using linked list

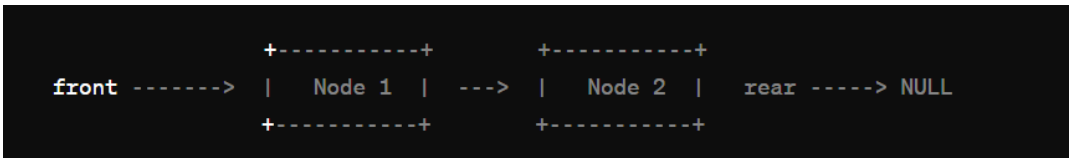
There are two basic operations which can be implemented on the linked queues. The operations are Insertion and Deletion.

Process

1. First allocate the memory to a new node pointer.
2. Inserting an element has two scenarios
   2.1 the condition front = NULL becomes true. Now, the new element will be added as the only element of the queue and the next pointer of front and rear pointer both, will point to NULL.



2.2 The condition front = NULL becomes false. In this scenario, we need to update the end pointer rear so that the next pointer of rear will point to the new node ptr. Since, this is a linked queue, hence we also need to make the rear pointer point to the newly added node ptr. We also need to make the next pointer of the rear point to NULL.



Algorithm

Step 1: Allocate the space for the new node PTR

Step 2: SET PTR -> DATA = VAL

Step 3: IF FRONT = NULL

SET FRONT = REAR = PTR

SET FRONT -> NEXT = REAR -> NEXT = NULL

ELSE

SET REAR -> NEXT = PTR

SET REAR = PTR

SET REAR -> NEXT = NULL

[END OF IF]

Step 4: END

```
#include<stdio.h>
#include<stdlib.h>
struct node
```

```
{
    int data;
    struct node *next;
};
struct node *front;
struct node *rear;
void insert();
void delete();
void display();
void main ()
{
    int choice;
    while(choice != 4)
    {               printf("\n1insert an element\n2.Delete an element\n3.Display the
queue\n4.Exit\n");
        printf("\nEnter your choice ?");
        scanf("%d",& choice);
        switch(choice)
        {
            case 1:
            insert();
            break;
            case 2:
            delete();
```

```
            break;
            case 3:
            display();
            break;
            case 4:
            exit(0);
            break;
            default:
            printf("\nEnter valid choice??\n");
        }
    }
}
void insert()
{
    struct node *ptr;
    int item;
    ptr = (struct node *) malloc (sizeof(struct node));
    if(ptr == NULL)
    {
        printf("\nOVERFLOW\n");
        return;
    }
    else
    {
```

```
        printf("\nEnter value?\n");
        scanf("%d",&item);
        ptr -> data = item;
        if(front == NULL)
        {
            front = ptr;
            rear = ptr;
            front -> next = NULL;
            rear -> next = NULL;
        }
        else
        {
            rear -> next = ptr;
            rear = ptr;
            rear->next = NULL;
        }
    }
}
void delete ()
{
    struct node *ptr;
    if(front == NULL)
    {
        printf("\nUNDERFLOW\n");
```

```
        return;
    }
    else
    {
        ptr = front;
        front = front -> next;
        free(ptr);
    }
}
void display()
{
    struct node *ptr;
    ptr = front;
    if(front == NULL)
    {
        printf("\nEmpty queue\n");
    }
    else
    {   printf("\nprinting values .....\n");
        while(ptr != NULL)
        {
            printf("\n%d\n",ptr -> data);
            ptr = ptr -> next;
        }
```

```
    }
}
```

Applications of queues in breadth-first search

Breadth First Search is an algorithm which is a part of an uninformed search strategy. This is used for searching for the desired node in a tree. The algorithm works in a way where breadth wise traversal is done under the nodes. It starts operating by searching starting from the root nodes, thereby expanding the successor nodes at that level. Then it moves to the other node by expanding along with its neighbouring breadth. The algorithm requires a considerable amount of memory space and time for its execution in the case where the required node lies at the bottom of the tree or graph. The BFS algorithm requires the usage of First in First Out queue for its implementation. The BFS strategy works without any domain knowledge.

Algorithm

Step 1: We take an empty queue.

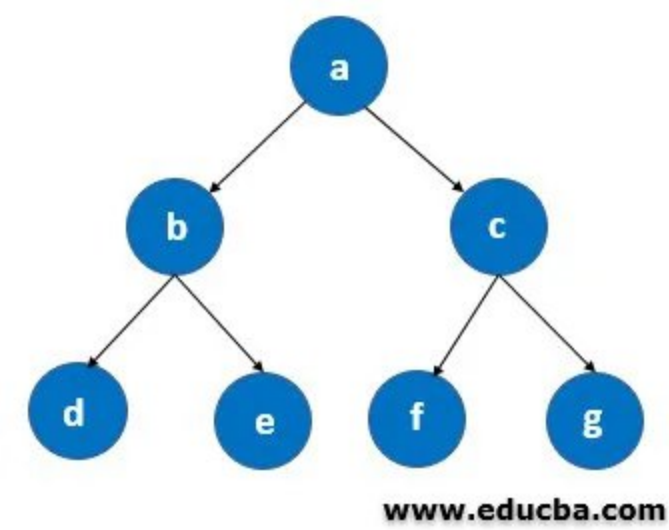
Step 2: Then, we select a starting point or root node to start with and insert the data from the node into the queue.

Step 3: If the queue is not empty, then we extract the node from the neighbouring nodes in breadth wise fashion and insert its child nodes into the queue.

Step 4: Then, we can print the extracted nodes.

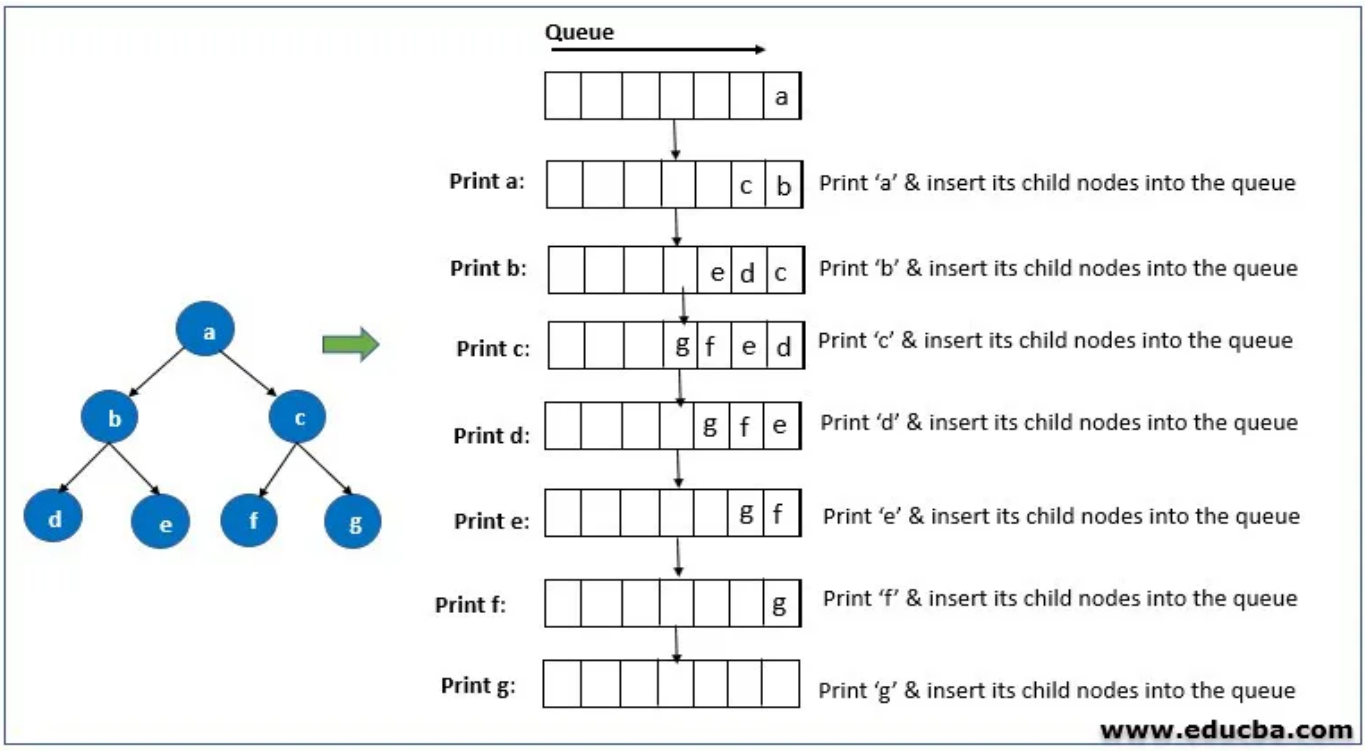
Example of Breadth First Search

We will now see the steps of the above BFS strategy into this example. We take a look at the graph below. We will use the BFS strategy to traverse the graph.



Working of BFS algorithm

We can allocate ‘ a’ as the root node. Then we start searching for the goal node in the downward direction following the steps mentioned above.



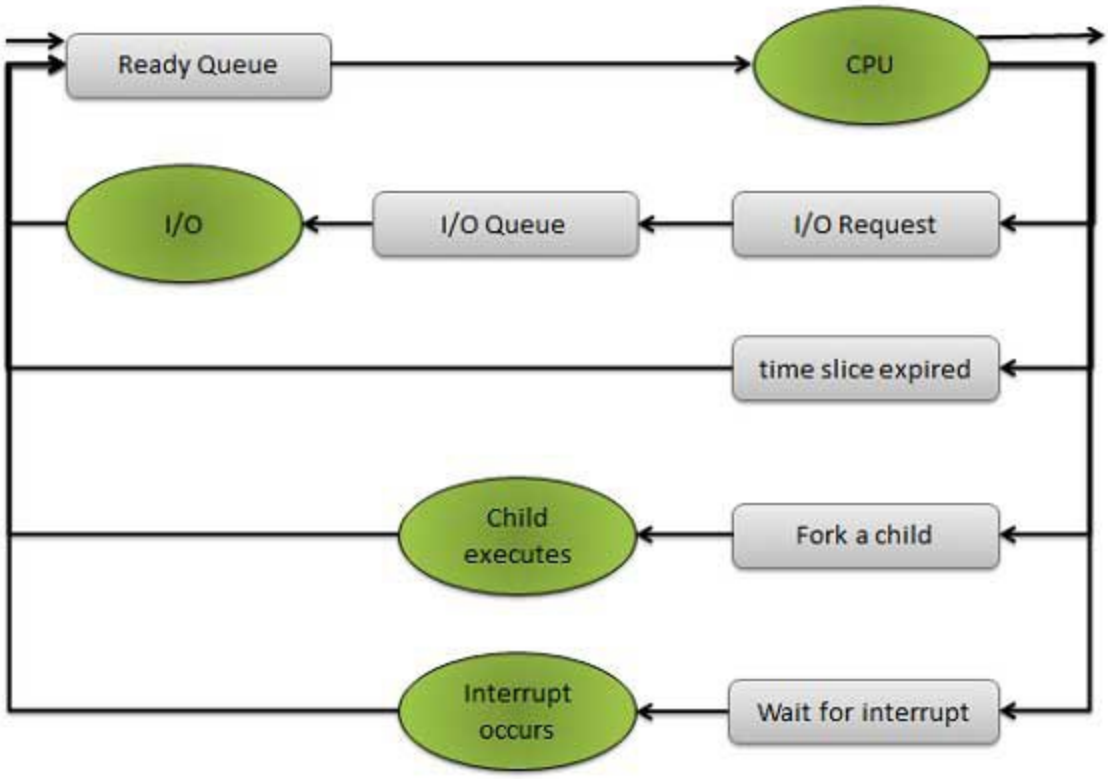
Applications of queues in Scheduling

Process scheduling is an essential part of a Multiprogramming operating system. Such operating systems allow more than one process to be loaded into the executable memory at a time and loaded process shares the CPU using time multiplexing.

Scheduling Queues

Scheduling queues refers to queues of processes or devices. When the process enters into the system, then this process is put into a job queue. This queue consists of all processes in the system. The operating system also maintains other queues such as device queue. Device queue is a queue for which multiple processes are waiting for a particular I/O device. Each device has its own device queue.
This figure shows the queuing diagram of process scheduling.

Queue is represented by rectangular box.
The circles represent the resources that serve the queues.
The arrows indicate the process flow in the system.



Queues are of two types

Ready queue
Device queue

A newly arrived process is put in the ready queue. Processes waits in ready queue for allocating the CPU. Once the CPU is assigned to a process, then that process will execute. While executing the process, any one of the following events can occur.
The process could issue an I/O request and then it would be placed in an I/O queue.
The process could create new sub process and will wait for its termination.
The process could be removed forcibly from the CPU, as a result of interrupt and put back in the ready queue.

Schedulers

Schedulers are special system softwares which handles process scheduling in various ways. Their main task is to select the jobs to be submitted into the system and to decide which process to run. Schedulers are of three types

Long Term Scheduler
Short Term Scheduler
Medium Term Scheduler

Long Term Scheduler

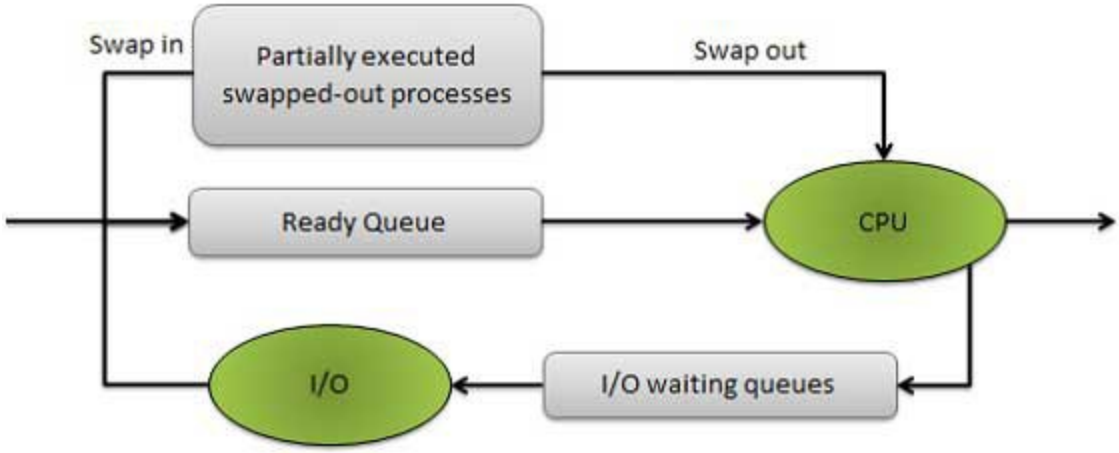
It is also called job scheduler. Long term scheduler determines which programs are admitted to the system for processing. Job scheduler selects processes from the queue and loads them into memory for execution. Process loads into the memory for CPU scheduling. The primary objective of the job scheduler is to provide a balanced mix of jobs, such as I/O bound and processor bound. It also controls the degree of multiprogramming. If the degree of multiprogramming is stable, then the average rate of process creation must be equal to the average departure rate of processes leaving the system.
On some systems, the long term scheduler may not be available or minimal. Time-sharing operating systems have no long term scheduler. When process changes the state from new to ready, then there is use of long term scheduler.

Short Term Scheduler

It is also called CPU scheduler. Main objective is increasing system performance in accordance with the chosen set of criteria. It is the change of ready state to running state of the process. CPU scheduler selects process among the processes that are ready to execute and allocates CPU to one of them.
Short term scheduler also known as dispatcher, execute most frequently and makes the fine grained decision of which process to execute next. Short term scheduler is faster than long term scheduler.

Medium Term Scheduler

Medium term scheduling is part of the swapping. It removes the processes from the memory. It reduces the degree of multiprogramming. The medium term scheduler is in-charge of handling the swapped out-processes.



Running process may become suspended if it makes an I/O request. Suspended processes cannot make any progress towards completion. In this condition, to remove the process from memory and make space for other process, the suspended process is moved to the secondary storage. This process is called swapping, and the process is said to be swapped out or rolled out. Swapping may be necessary to improve the process mix.

Deque

Deque is a type of queue in which insert and deletion can be performed from either front or rear. It does not follow the FIFO rule. It is also known as double-ended queue

Representation of deque

Types of deque

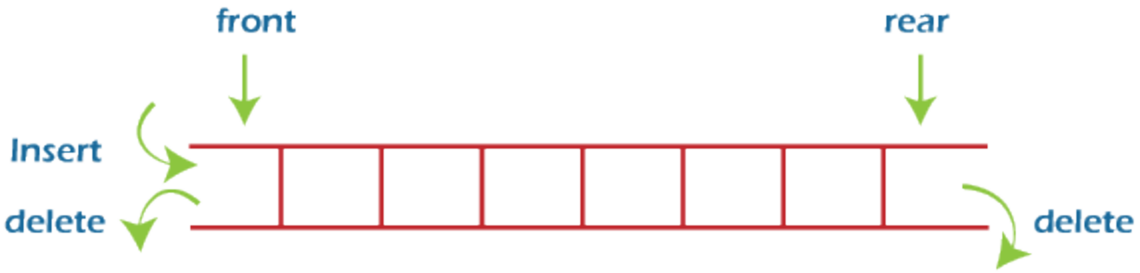
There are two types of deque -

Input restricted queue

Output restricted queue

Input restricted Queue

In input restricted queue, insertion operation can be performed at only one end, while deletion can be performed fromboth ends.



input restricted double ended queue

Output restricted Queue

In output restricted queue, deletion operation can be performed at only one end, while insertion can be performed fromboth ends.

Output restricted double ended queue

Operations on Deque:

Deque consists of mainly the following operations:

Insert Front

Insert Rear

Delete Front

Delete Rear

in addition to the above operations, following operations are also supported in deque -

Get the front itemfromthe deque

Get the rear itemfromthe deque

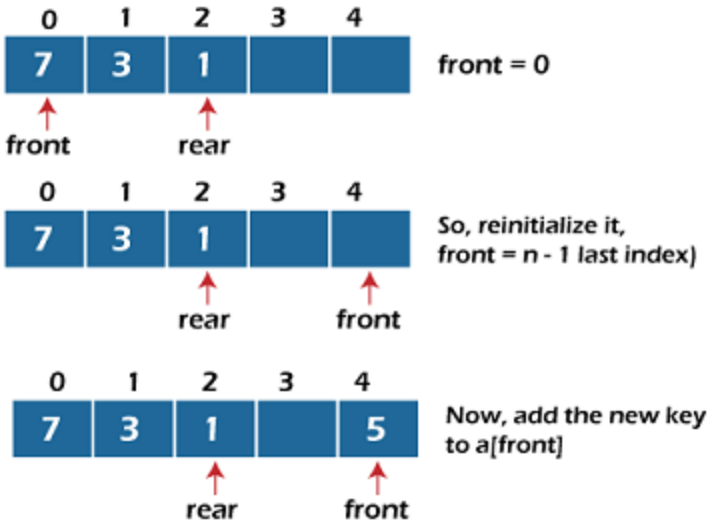
Check whether the deque is full or not

Checks whether the deque is empty or not

1 Insert at the Front: In this operation, the element is inserted fromthe front end of the queue. Before implementing the operation, we first have to check whether the queue is full or not. If the queue is not full, then the element can be inserted fromthe front end by using the below conditions -

If the queue is empty, both rear and front are initialized with 0. Now, both will point to the first element.

Otherwise, check the position of the front if the front is less than 1(front < 1), then reinitialize it by front = n - 1, i.e., the last index of the array.

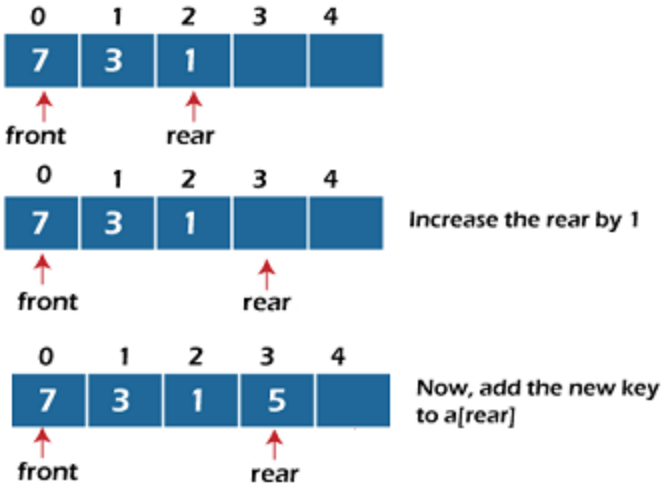


2. Insert at the Rear: In this operation, the element is inserted fromthe rear end of the queue. Before implementing the operation, we first have to check again whether the queue is

full or not. If the queue is not full, then the element can be inserted from the rear end by using the below conditions -

If the queue is empty, both rear and front are initialized with 0. Now, both will point to the first element.

Otherwise, increment the rear by 1. If the rear is at last index (or size - 1), then instead of increasing it by 1, we have to make it equal to 0.



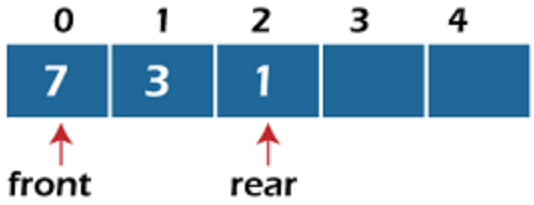
3. Delete from the Front: In this operation, the element is deleted from the front end of the queue. Before implementing the operation, we first have to check whether the queue is empty or not.

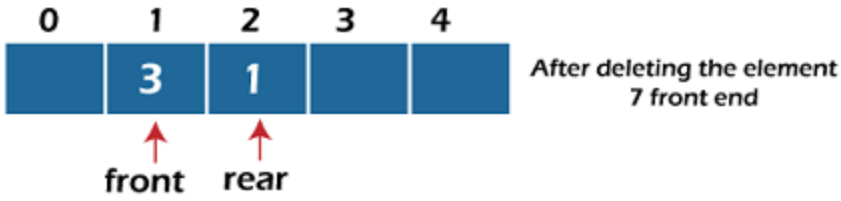
If the queue is empty, i.e., front = -1, it is the underflow condition, and we cannot perform the deletion. If the queue is not full, then the element can be inserted from the front end by using the below conditions -

If the deque has only one element, set rear = -1 and front = -1.

Else if front is at end (that means front = size - 1), set front = 0.

Else increment the front by 1, (i.e., front = front + 1).





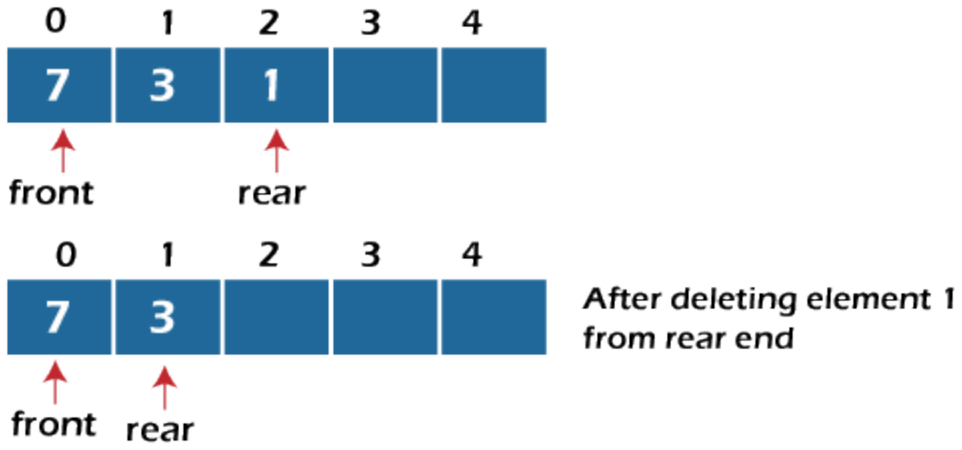
4. Delete from the Rear: In this operation, the element is deleted from the rear end of the queue. Before implementing the operation, we first have to check whether the queue is empty or not.

If the queue is empty, i.e., front = -1, it is the underflow condition, and we cannot perform the deletion.

If the deque has only one element, set rear = -1 and front = -1

If rear = 0 (rear is at front), then set rear = n - 1

Else, decrement the rear by 1 (or, rear = rear -1).



Check empty

This operation is performed to check whether the deque is empty or not. If front = -1, it means that the deque is empty.

Check full

This operation is performed to check whether the deque is full or not. If front = rear + 1, or front = 0 and rear = n - 1 it means that the deque is full.

The time complexity of all of the above operations of the deque is O(1), i.e., constant.

Properties of Deque:

Deque is a generalized version of the queue which allows us to insert and delete the element at both ends.

It does not follow FIFO (first in first out) rule.

Applications of Deque:

It is used in job scheduling algorithms.

It supports both stack and queue operations.

The clockwise and anti-clockwise rotation operations in deque are performed in O(1) time which is helpful in many problems.

Real-time Application of Deque:

In a web browser's history, recently visited URLs are added to the front of the deque and the URL at the back of the deque is removed after some specified number of operations of insertions at the front.

Storing a software application's list of undo operations.

In graph traversal algorithms such as breadth-first search (BFS). BFS uses a deque to store nodes and performs operations such as adding or removing

nodes from both ends of the deque.

In task management systems to manage the order and priority of incoming tasks. Tasks can be added to the front or back of the deque depending on their priority or deadline.

In queueing systems to manage the order of incoming requests. Requests can be added to the front or back of the deque depending on their priority or arrival time.

In caching systems to cache frequently accessed data. Deques can be used to store cached data and efficiently support operations such as adding or removing data from both ends of the deque.

Advantages of Deque:

You are able to add and remove items from the both front and back of the queue.

Deques are faster in adding and removing the elements to the end or beginning.

The clockwise and anti-clockwise rotation operations are faster in a deque.

Dynamic Size: Deques can grow or shrink dynamically.

Efficient Operations: Deques provide efficient O(1) time complexity for inserting and removing elements from both ends.

Versatile: Deques can be used as stacks (LIFO) or queues (FIFO), or as a combination of both.

No Reallocation: Deques do not require reallocation of memory when elements are inserted or removed.

Thread Safe: Deques can be thread-safe if used with proper synchronization.

Cache-Friendly: Deques have a contiguous underlying storage structure which makes them cache-friendly.

Disadvantages of Deque:

Deque has no fixed limitations for the number of elements they may contain. This interface supports capacity-restricted deques as well as the deques with no fixed size limit.

They are less memory efficient than a normal queue.

Memory Overhead: Deques have higher memory overhead compared to other data structures due to the extra pointers used to maintain the double-ended structure.

Synchronization: Deques can cause synchronization issues if not used carefully in multi-threaded environments.

Complex Implementation: Implementing a deque can be complex and error-prone, especially if implementing it manually.

Not All Platforms: Deques may not be supported by all platforms, and may need to be implemented manually.

Not Suitable for Sorting: Deques are not designed for sorting or searching, as these operations require linear time.

Limited Functionality: Deques have limited functionality compared to other data structures such as arrays, lists, or trees.

Implementation of deque

```
#include <stdio.h>
#define size 5
int deque[size];
```

```
int f = -1, r = -1;
//  insert_front function will insert the value fromthe front
void insert_front(int x)
{
    if((f==0 && r==size-1) || (f==r+1))
    {
        printf("Overflow");
    }
    else if((f==-1) && (r==-1))
    {
        f=r=0;
        deque[f]=x;
    }
    else if(f==0)
    {
        f=size-1;
        deque[f]=x;
    }
    else
    {
        f=f-1;
        deque[f]=x;
    }
}

// insert_rear function will insert the value fromthe rear
void insert_rear(int x)
{
    if((f==0 && r==size-1) || (f==r+1))
    {
        printf("Overflow");
    }
    else if((f==-1) && (r==-1))
    {
        r=0;
        deque[r]=x;
    }
    else if(r==size-1)
    {
        r=0;
        deque[r]=x;
```

```
    }
    else
    {
        r++;
        deque[r]=x;
    }

}

// display function prints all the value of deque.
void display()
{
    int i=f;
    printf("\nElements in a deque are: ");

    while(i!=r)
    {
        printf("%d ",deque[i]);
        i=(i+1)%size;
    }
     printf("%d",deque[r]);
}

// getfront function retrieves the first value of the deque.
void getfront()
{
    if((f==-1) && (r==-1))
    {
        printf('Deque is empty');
    }
    else
    {
        printf("\nThe value of the element at front is: %d", deque[f]);
    }

}

// getrear function retrieves the last value of the deque.
void getrear()
{
    if((f==-1) && (r==-1))
```

```
    {
        printf('Deque is empty');
    }
    else
    {
        printf("\nThe value of the element at rear is %d", deque[r]);
    }

}

// delete_front() function deletes the element fromthe front
void delete_front()
{
    if((f==-1) && (r==-1))
    {
        printf('Deque is empty');
    }
    else if(f==r)
    {
        printf("\nThe deleted element is %d", deque[f]);
        f=-1;
        r=-1;

    }
     else if(f==(size-1))
     {
         printf("\nThe deleted element is %d", deque[f]);
         f=0;
     }
     else
     {
          printf("\nThe deleted element is %d", deque[f]);
          f=f+1;
     }
}

// delete_rear() function deletes the element fromthe rear
void delete_rear()
{
    if((f==-1) && (r==-1))
    {
```

```
        printf('Deque is empty');
    }
    else if(f==r)
    {
        printf("\nThe deleted element is %d", deque[r]);
        f=-1;
        r=-1;

    }
     else if(r==0)
     {
         printf("\nThe deleted element is %d", deque[r]);
         r=size-1;
     }
     else
     {
          printf("\nThe deleted element is %d", deque[r]);
          r=r-1;
     }
}

int main()
{
    insert_front(20);
    insert_front(10);
    insert_rear(30);
    insert_rear(50);
    insert_rear(80);
    display();  // Calling the display function to retrieve the values of deque
    getfront();  // Retrieve the value at front-end
    getrear();  // Retrieve the value at rear-end
    delete_front();
    delete_rear();
    display(); // calling display function to retrieve values after deletion
    return 0;
}
```

OUTPUT:

Elements in a deque are: 10 20 30 50 80

The value of the element at front is: 10

The value of the element at rear is 80

The deleted element is 10

The deleted element is 80
Elements in a deque are: 20 30 50

Applications of queues

1CPU scheduling- to keep track of processes for the CPU
2.Handling website traffic - by implementing a virtual HTTP request queue
3.Printer Spooling - to store print jobs
4.In routers - to control how network packets are transmitted or discarded
5.Traffic management - traffic signals use queues to manage intersections

CPU Scheduling
This is one of the most common applications of queues where a single resource is shared among multiple consumers, or asked to perform multiple tasks.

Imagine you requested a task first before your friend, but your friend got the output first? Wouldn't you call it a corrupt system? (quite literally!)

CPU page replacement algorithm doesn't let that happen. It lets the operating system store all the processes in the memory in the form of a queue.

It makes sure that the tasks are performed on the basis of the sequence of requests. When we need to replace a page, the oldest page is selected for removal, underlining the First-In-First-Out (FIFO) principle.

Algorithm:
Start traversing the pages.

If a frame holds fewer pages than its full allocation capacity-

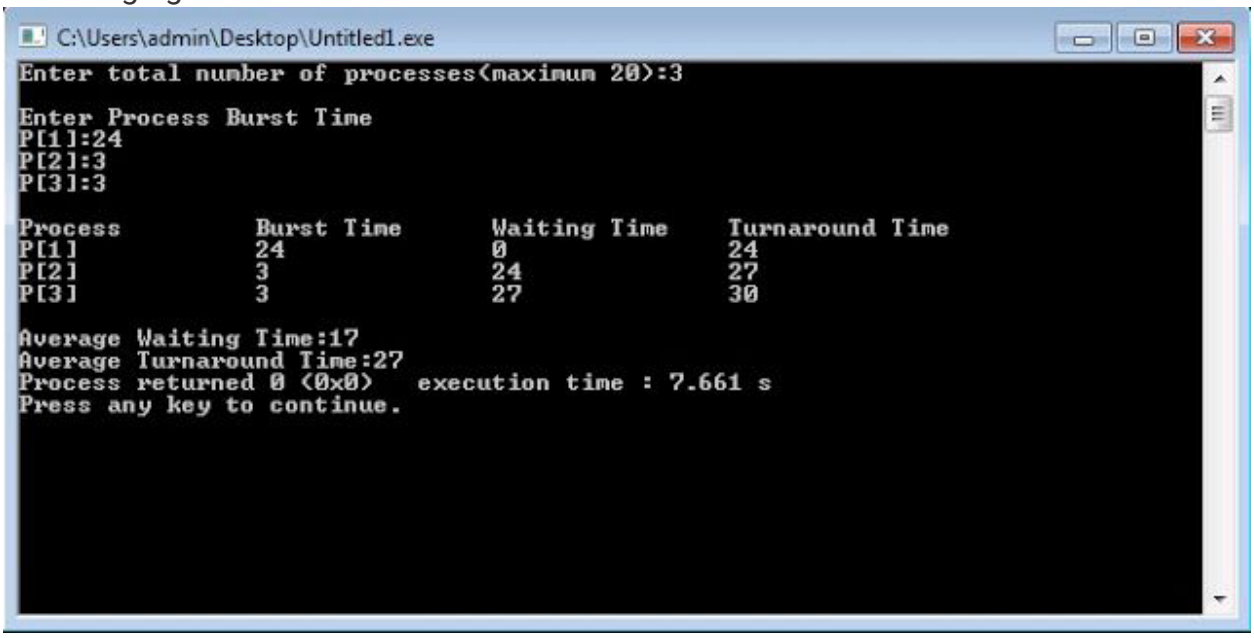
Insert pages into the set one by one until the size of the set reaches capacity or all page requests are processed
Update the pages in the queue to perform First Come-First Serve
Increment page fault
Else

If the current page is present in the set, do nothing.

Else

Remove the first page from the queue.
Replace it with the current page in the string and store the current page in the queue.
Increment page faults.
Return page faults.

This First Come First Serve (FCFS) method offers both non-preemptive and pre-emptive scheduling algorithms.



FCFS method in CPU scheduling
FCFS CPU Scheduling

Breadth First Search Algorithm
This search operation traverses all the nodes at a single level/hierarchy before moving on to the next level of nodes. BFS algorithm starts at the first node and traverses all adjacent nodes before proceeding to the next level repeating the same process.

It uses the queue data structure to find the shortest path in the graph. In this method, one vertex is selected and marked when it's visited, then its adjacent vertices are visited and stored in the queue.

Here's the algorithm for the same:
Step 1: Set the status=1(ready state) for each node in G.

Step 2: Insert the first node A and set its status = 2(waiting state).

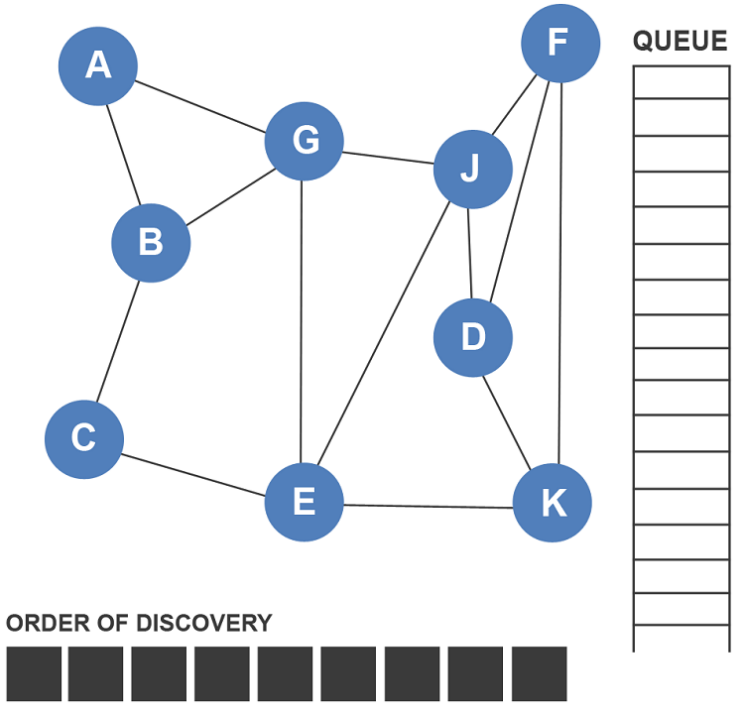
Step 3: Now, repeat steps 4 and 5 until the queue is empty

Step 4: Dequeue a node, process it, and set its status = 3(processed state)

Step 5: Insert all the neighbors of N that are in the ready state(staus=1) and set their status = 2(waiting state)

(END OF LOOP)

Step 6: EXIT



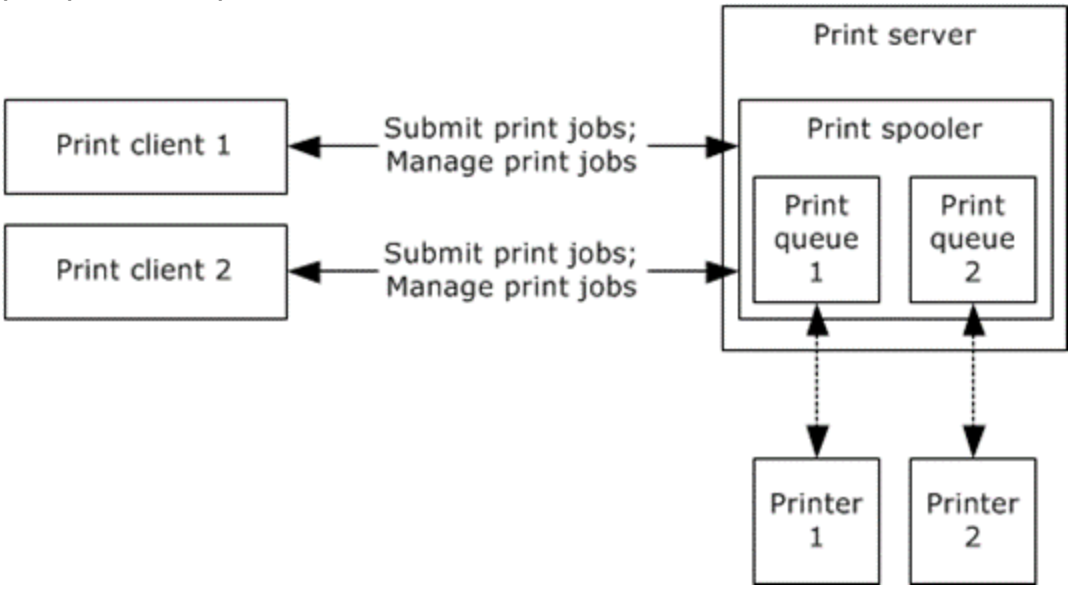
Printer Spooling
Another important example of applications of queues is printer spooling. Now, what do we mean by printer spooling?

It's crucial to understand from the outset that printers have much less memory than you might think. Even in this day and age, some only have a few megabytes of RAM available.

By using printer spooling, we can send one or more large document files to a printer without having to wait for the current task to be completed. Consider it as a cache or buffer. It's a location where your papers can "queue up" and prepare for printing when another printing activity has been finished.

All print tasks in the queue are managed by a program known as a "spooler". It will send the line

of documents to the printer in the sequence they were received using the First In First Out principle of the queue.



Applications of Queue- Printer Spooling
If not for spooling, each computer would have to manually wait for the printer to become accessible. Most people take it for granted because it's handled automatically in the background.

Spooling can make it simple to delete documents before they are printed because there is a queue in the order that they were received. You can choose to delete a particular job from the queue, for example, if you accidentally printed the wrong page or needed to format it slightly differently. While there could be several ways to accomplish this, queues provide the most efficient solution.

Handling Website Traffic
Increasing website traffic is the primary goal for websites. And why not, since more traffic means more engagement and more sales? However, extreme spikes in internet traffic frequently cause website infrastructure to fail. Particularly, the inventory systems and payment gateways are two of the most vulnerable systems needed to be preserved.

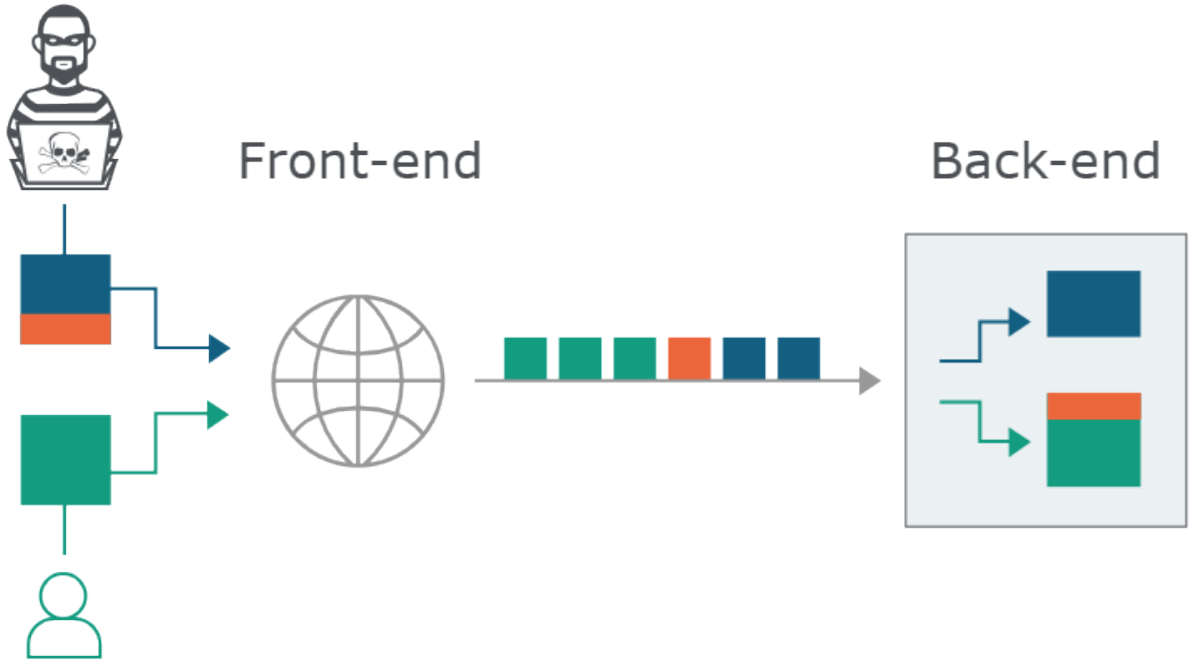
Another common concern is to ensure good user experience and fairness in terms of directing users from one webpage to another, in heavy-traffic situations.

One of the best website traffic management solutions is by implementing a virtual HTTP request queue, thus making it one of the most used applications of queues.

How does HTTP request queue work?
Visitors who exceed the capacity of your website or app are transferred to a waiting room on a third party' s infrastructure (Queue-it and Netprecept are a few of the industry-popular web

traffic management solutions).

The waiting room then directs the customers who waited in line back to your website in the proper, sequential order at the throughput rate you configure.



How HTTP response queue works
Image Source: PortSwigger
The online queue informs users of wait durations and the number of individuals in front of them in the virtual line.

Routers in Networking
Routers are essential pieces of networking hardware that regulate how data moves within a network. The input and output interfaces on routers are where packets are received and transmitted.

A router might not be able to handle newly arriving packets because of its limited memory.

When the rate at which packets enter the router's memory exceeds the rate at which they leave, there will be issues. In this case, older packets will be deleted while newer packets will be ignored.

Therefore, to control how packets are kept or discarded as needed, routers must incorporate

some form of queuing discipline into their resource allocation algorithms.

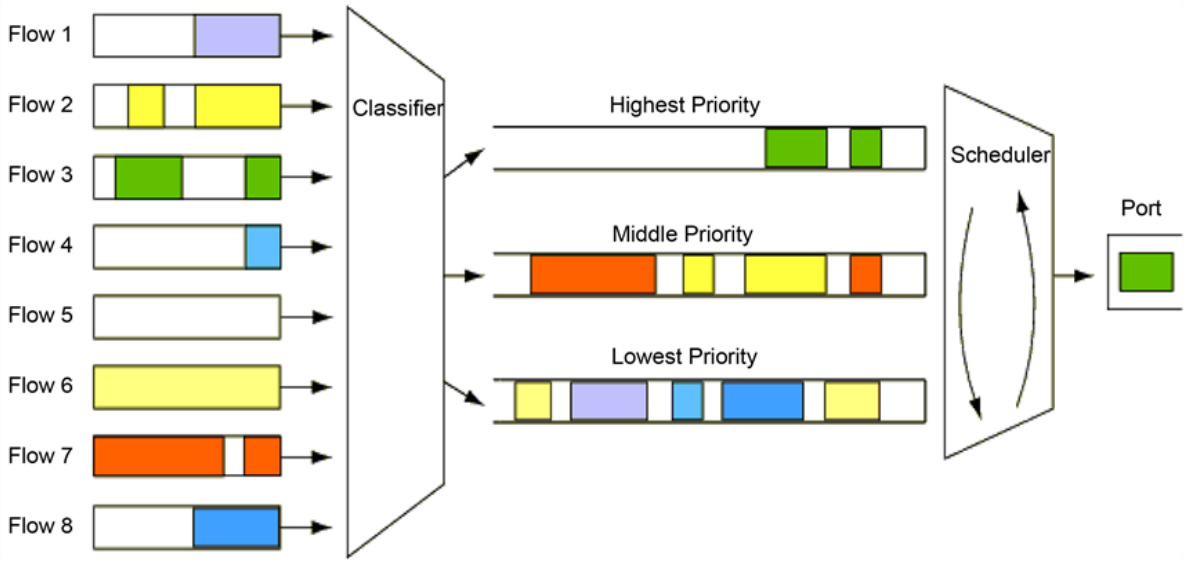
Following are a few queueing disciplines routers use to select which packets to keep and which ones to drop in times of congestion:

First-In-First-Out Queuing (FIFO)
Most routers' default queuing strategy is FIFO. This often requires minimal to no setup on the server. In FIFO, every packet is handled in the order that it enters the router. When the memory is full, new packets trying to enter the router are rejected (tail drop).

Such a system, however, is not appropriate for real-time applications, especially in crowded areas.

Prioritization of Queuing (PQ)
Instead of using a single queue, the router divides the memory into several queues according to some metric of priority in priority queuing. Following that, each queue is handled via FIFO, with each queue being cycled through one at a time. Depending on their priority, the queues are categorized as High, Medium, or Low. Always, the medium queue packets are processed after the high queue packets.

Priority Queue in routers
Image Credits: Scientific Research
Fair Weighted Queuing (WFQ)



Based on traffic patterns, WFQ (Weighted Fair Queuing) creates queues and assigns bandwidth to them according to priority. The sub-queues bandwidths are dynamically assigned. Assume there are three active queues, each of which has a bandwidth percentage of 30%, 40%, and 60%.