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Improving Congestion Control in Data Communication Network Using Queuing Theory Model.

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Abstract: *Congestion in data Communication networks poses a serious problem especially in situations where efficiency and link reliability is needed for optimum performance of the network devices. In this Paper, Congestion Control Problem is solved using the concept of Queuing theory. The network planning engineer would find the developed computational software useful in network planning. The software would enable him decide on the choice of routers 49and other Physical network devices to run his desired Algorithms on. The designed software computes the needed parameters based on the M/M/1 queuing Model.*
Keywords: *Congestion Control, Data Communication, Data Packets,Java, Queuing Theory.*

I. Introduction

Congestion control is a worldwide problem in data communication networks that deals with the efficient usage of network devices at peak load. According to [1], congestion control is used to describe the efforts made by network modes to prevent or respond to over load conditions. In other words, it refers to the control of entry into any telecommunications network (be it data or voice network), in order to avoid a congestive collapse of the processing capacity of the network modes and facilitate efficient resource sharing. It is important to note that congestion control is different from flow control as both terms seem to be misused. Flow control is a fundamental feedback control congestion problem [2] management technique that manages data transfer rate.

Congestion is a problem that has to be overcome in networks so that the networks can be reliable and efficient to the subscribers of such networks. In data networks, resource allocation is necessary through scheduling tasks so as to improve the general reliability. However, the question that has to be answered remains this, how can congestion be avoided in a data network communication system. This question can be answered when we look at congestion control as a scheduling problem that can be solved by using the queuing theory approach.49The theory of congestion control was pioneered by Frank Kelly, of the University of Cambridge who in [3] applied the principles of microeconomic theory and optimization to describe how individuals could control their rate to achieve an optimal network wide rate allocation.

In recent times a lot of research work has done a lot of in-depth study of congestion control for wireless sensor networks. [4], [5] tells us about congestion avoidance and detection [COAD] protocol which detects congestion based on buffer occupancy as well as wireless load channel. [4] provides a scheme that considers current buffer occupancy status and buffer changing trends. [6] uses an approximation method to evaluate the reliability of large telecommunication networks based on planning indices and as defined in availability and expected lost traffic. Network reliability is paramount, so congestion must be controlled.
Network reliability is defined as some connectivity measure and problems are NP-hard. [7,8,9,10]. In a data network, reliability is outlined by three main characteristics.

1. The high reliability of the network components.
2. The substantial size of the network.
3. The multiflow: the rerouting makes it necessary to take into account the multiflow characteristics of the traffic.

Also, a modified TCP based equation has been proposed using a controller implementing the traditional GREEN algorithm [11] to solve congestion control problems in Queue Management System. [12] addresses managing a virtual dynamic Backbone, the algorithm used focused on maintaining network connectivity. [1] defines the three salient features of the network model used in defining the network arch leaders of a potential bottleneck router as shown in figure 1.

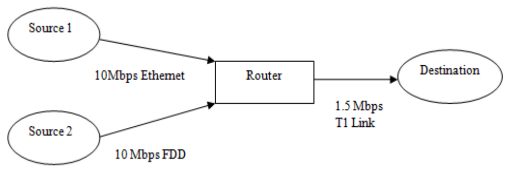

Fig1: Congestion in a packet switched network.

Active Queue Management (AQM) strategy for congestion avoidance in Transmission Control Protocol (TCP) networks to regulate queue size close to a reference [13]. It all boils down to the same question earlier asked. How can congestion be avoided?

Several techniques can be used in congestion detection and avoidance. These include

- **Warning Bit:**This is a special but that is set by the router to warn the source when congestion is detected.
- **Choke Packets:**This is a control packet that is generated at a congested node and transmitted to restrict traffic flow. An example of a choke packet is the ICMO source quench packet.
- **Traffic Shaping:**This controls the rate at which data packets are sent in ATM and integrated services network. It is another method of congestion control. Two traffic shaping algorithms are:

i. Leaky Bucket algorithm
ii. Token Bucket algorithm

Leaky Bucket algorithm is used to control rate in a network. It is implemented as a single server queue with constant service time. If the bucket (buffer) overflows then packets are discarded. Leaky bucket enforces a constant output rate regardless of the business of the input.

Token Bucket algorithm allows the output rate to very depending on the size of the burst, here, the bucket holds tokens. To transmit a packet, the host must capture and destroy one token.

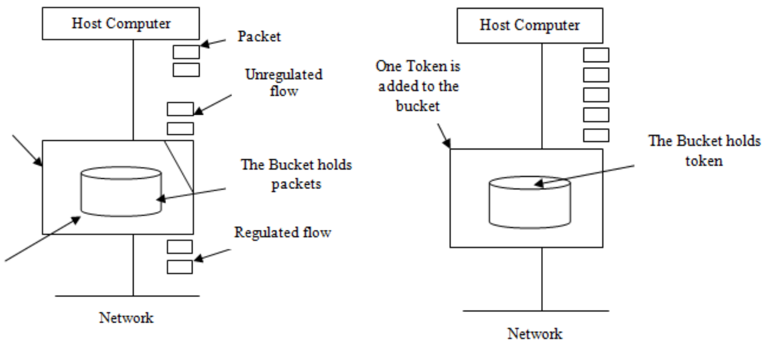

Fig 2

a. Leaky Bucket with Packets **b. Token Bucket**

II. Congestion Control Techniques

Research directions and recent solutions solving the congestion problem in wireless sensor networks were studied [14]. The fact that most part of discovered sources is that classical TCP based congestion detection and avoidance technique is not suitable for wireless sensor networks.

Thus it can be inferred that TCP based congestion detection and avoidance would not be feasible for data networks. In trying to control congestion in data networks layer if the Open System Interconnect (OSI) layer.

A large number of techniques exist which were invented for the wireless sensor networks. These methods are deployed by different layers of the OSI stack. Examples of these network congestion control techniques include:

- **Router Centric:**Here the internal network routers are responsible for the packets to forward and which packets to drop. Queuing theory algorithm is a typical example of the router centric technique.
- **Host Centric:**In this technique, the hosts adjust their behaviour based on network condition observations. Example is the TCP congestion control mechanism.
- **Reservation Based:**Here, the end host asks the network to reserve a small amount of capacity at the time flow is established. The reservation can be receiver based or sender-based.
- **Feedback Based**: In this approach, the host begins transmitting without reserving any capacity at the time flow is established. However, the transmit rate is adjusted according to the feedback received. If the feedback is explicit, then it means the router is involved in the resource allocation scheme. If the feedback is implicit, the router drops the packets when they become congested.
- **Window Based:**Here, the receiver sends an advertised window to the sender which is used to reserve buffer space in networks.
- **Rate Based:**The sender's rate is controlled by the receiver indicating the bits per second it can absorb.

For an effective resource allocation, the two principal metrics of networking namely throughput and delay must be considered [4]. The relationship is defined by a ration that is referred to as the power of the network mathematically

Power= Throughput/Delay. - - - (1)

The theory behind the power of the network is the queuing theory.

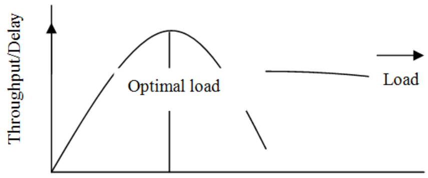

Fig 3: Ratio of Throughput to Delay as a function of Load.

III. Methodology

3.1 Queuing Theory Model

The basic definition of a queue is a waiting line for customers waiting to be serviced. In a queuing situation the principal players are the customers who arrive at a facility from a source. On arrival, the customer can start service immediately or wart in a queue if the facility is busy. This basic scenario occurs in data communication networks where packets are operated upon. The queuing theory model could also be applicable in such scenarios to improve congestion control by efficient planning and calculating ones queuing algorithm depending on the model chosen. The basic queue system is as described in figure 4 below

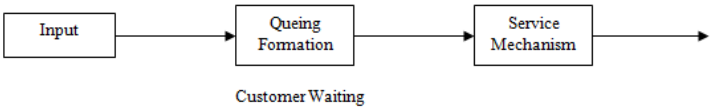

Fig 4: Basic Queuing System

The input describes the pattern in which the packets arrive.
The queue formation is a waiting line in which the packets join while waiting to the transmitted.
The service mechanism refers to the queue discipline which represents the order in which packets are selected from a queue is a crucial factor in the analysis of queuing models. The most common ones are

i. First Come, First Served (FCFS): packets are served in the order of their arrival.
ii. Last Come, First Served (LCFS): packets that arrived last are served first.
iii. Service in Random Order (SIRO): packets are served in random order.
iv. Service in some priority procedure.

Using queuing theory in congestion control has to do with Active Queue Management of data packets. There are various models used in queue theory such as

- Pure birth death model.
- Standard multi server model
- Single Earlang model.
- Finite queue multi server model.

Etc

This work focuses on the birth and death model which is a core problem in operations research.

3.1 Modelling Of Pure Birth And Death Model

In modelling this system, we have to note that the pure birth model deals with arrivals only while the death models deals with departure. Both models combined are described by a poisson distribution

We define the following
n =Number of packets in the system
$\boldsymbol{I_n}$= Arrival rate
μ_n = Departure rate
P_n= Steady- state probability of n packets
$P_n$is a function of$\boldsymbol{I_n}$ and μ_n.
These probabilities used to determine the system measures of performance.

Under steady condition (n>0), the expected rates of flow into the state and not of the state must be equal. On the knowledge that the state can be changed from n-l to n+l, we obtain.

$$[\text{Expected rate p of flow into state (n)}] = \lambda_{n-1}P_{n-1} + \mu_{n+1}P_{n+1} \qquad ---(2)$$

$$[\text{Expected rate of flow into state (n)}] = (\lambda_n + \mu_n)P_n \quad --- \ (3)$$

Equating equations (2)and (3) , we get

$$\lambda_{n-1}P_{n-1} + \mu_{n+1}P_{n+1} = (\lambda_n + \mu_n)P_n \quad --- \ (4)$$

$forn = 1, 2, ...$

Using the state transition diagram given below,

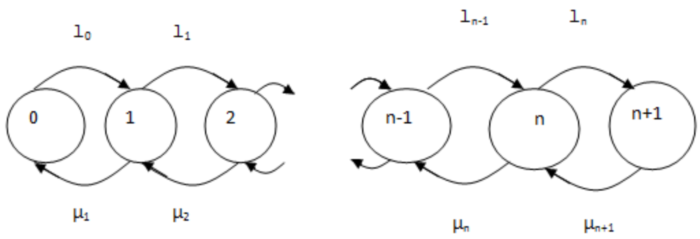

Fig 5: Poisson queues transition diagram.

Equation (4) when n=0, becomes,

$\lambda_0 + P_0 = \mu_1 P_1$ - (5)

Equation (5) is so. . -- . .ecursively in terms of $P_o.forn = 0, wehave$

$$P_1 = \left(\frac{\lambda_0}{\mu_1}\right) P_0 \qquad ---(6)$$

For n=1, we have from equation (4)

$$\lambda_0 + P_0 + \mu_2 P_2 = (\lambda_1 + \mu_1) P_1 ---(7)$$

Substituling $P_1 \left(\frac{\lambda_0}{\mu_0}\right) P_0 intoequation(6), weget$

$$P_2 \left(\frac{\lambda_1 \lambda_0}{\mu_2 \mu_1}\right) P_0 ---(8)$$

We can show by induction that

$$P_0 = \left(\frac{\lambda_{n-1}\lambda_{n-2} \dots \lambda_0}{\mu_n \mu_{n-1} \dots \mu_1}\right) P_0 --- \quad (9)$$

For n= 1, 2, - - -

P_0 is determined from the equation

$$\sum_{n=0}^{\infty} P_n = 1 \qquad --- \quad (10)$$

3.2 Software Design

The queuing theory model computational software was developed using Java programming language on the Netbeans 8.0 Integrated Development Environment (IDE).

Based on equations (2) – (10) an application program was developed to compute the necessary parameters used in queue theory.

The computed parameters from the application include: Average entities in the system, queue length, waiting time Average probability of empty, probability of system being busy, etc.

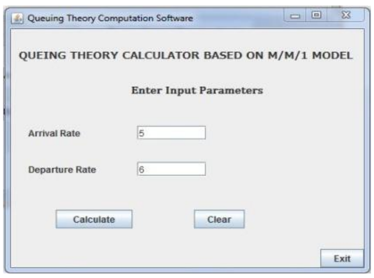

Fig 6: Input Parameters Form for Software

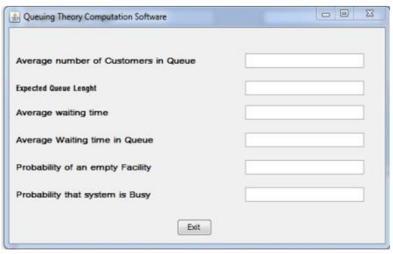

Fig 7: Result Parameter Form for Software.

IV. Conclusion

This paper looks at how Congestion can be controlled in a data communication environment by using Queuing theory model. The Model enables the network planning engineer to effectively plan the network for efficient operation. The software developed can aid the network planning engineer to better optimise the network planning to reduce congestion problems.

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