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**THE EFFECT OF SELF-SIMILAR TRAFFIC ON
THE PERFORMANCE OF PLAYTHROUGH RING NETWORKS**

by

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What can you expect to learn from this talk?

- ❑ What is PLAYTHROUGH ring, how does it operate and why is it attractive?
- ❑ What is self-similarity and why do we want to take it into account in performance analysis?
- ❑ What are heavy-tailed distributions, and why do we want to use them in our study?
- ❑ An application of queuing theory to the performance of PLAYTRHOUGH ring.

SO STAY TUNED!

What is the Motivation for our Research?

- ❑ Prior models for the PLAYTHROUGH ring have assumed exponentially distributed interarrival times for traffic and exponential-type (such as geometric) message length to study the performance of the PLAYTHROUGH ring.
- ❑ It has been shown that traffic TCP traffic exhibits self-similar behavior, which is inconsistent with the above assumptions.
- ❑ Studies have shown that distributions with heavy tails for interarrival time and/or message length more suitably model self-similar traffic than other distributions.
- ❑ Heavy tailed distributions include the Weibull and the Pareto distribution.
- ❑ Our goal is to find an analytical model of the Playthrough ring with self-similar traffic using the Weibull distribution for message length.

A Concise Statement of the Proposed Problem

- Find an analytical model for the waiting time using exponentially distributed interarrivals and Weibull distributed message length, compare the model to previous models, and validate the model with simulations.

Overview of the PLAYTHROUGH Ring

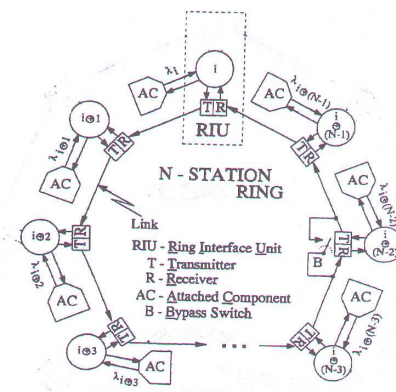


Figure 1 : An N station ring

Overview of the PLAYTHROUGH Ring (Continued)

- ❑ A PLAYTHROUGH ring is a type of ring network.
- ❑ The simplest and most widespread type of ring is token ring.
- ❑ A PLAYTHROUGH ring differs from a token ring in that it allows stations to transfer packets concurrently [Hen98].
- ❑ Multiple messages can be transmitted simultaneously over contiguous but nonoverlapping ring segments.
- ❑ A station participates in a PLAYTHROUGH ring through its ring interface unit (RIU).
- ❑ There are 3 classes of messages in a PLAYTHROUGH ring with varying priorities, which are from the lowest to highest priority, data messages, the synchronizing token (called GO), and update control messages.
- ❑ Update control messages include START/STOP messages and acknowledgement messages.
- ❑ Data messages are user data to be sent to a particular node.
- ❑ The token and update messages are used to implement the PLAYTHROUGH protocol.
- ❑ A message with higher priority can preempt, i.e. insert itself ahead of a message with lower priority.
- ❑ At any given time, the status of a station in a PLAYTHROUGH ring can either be a source, a destination, a bridge, or an idle node.

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Overview of the PLAYTHROUGH Ring (Continued)

- ❑ Messages travel from a source to a destination and nodes between a source and a destination are called bridges.
- ❑ An idle node is neither a destination nor a bridge.
- ❑ In an N-node ring, stations are numbered from 0 to N-1, and a node position number is called its address.
- ❑ Each station's RIU maintains two registers, a status register and a range register.
- ❑ A status register is used to keep the status of a station, either source, destination, bridge, or idle.
- ❑ A given node keeps another node in its range register if all nodes between the two are idle.
- ❑ A station can send a data message to any node within the range specified by its range register.
- ❑ At ring start up, all stations are idle and every station's range register includes all other stations.

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Overview of the PLAYTHROUGH Ring (Continued)

- ❑ A control frame bracketed by a leading FLAG and a trailing GO symbol is circulated perpetually around the ring, and each station receives it at a regular time interval.
- ❑ When a station has a message to transmit, it first check its range register to ensure that the destination message is in its range. If it is, the station waits for the GO symbol.
- ❑ When GO arrives, the station inserts an update control message in front of it.
- ❑ The update control message includes the node number of the station (the source of the message), the destination node number, and a START command to initiate a virtual circuit between the source and the destination.
- ❑ The GO symbol preceded by the control message continues to circulate around the ring until it reaches the destination station, updating status and range registers of nodes on its path and establishing a virtual circuit between the source and the destination.
- ❑ At the destination, the START control message is changed into an acknowledgement message and continues to travel around the ring back to the source, updating registers on its path.
- ❑ When the acknowledged START control message arrives back at the source, the source removes the control message and continues sending the data message characters to the destination right after GO departs the station.

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PLAYTHROUGH Specifications

- ❑ We assume uniform symmetric traffic (same arrival rate and same average message length at every station.)
- ❑ λ_i : arrival rate at station i .
- ❑ Total arrival rate to the ring is: $\lambda = \sum_{i=0}^{N-1} \lambda_i$
- ❑ M : Message lengths are in character.
- ❑ All time units are in character time, the time it take to transmit one character.
- ❑ N : number of stations participating in PLAYTHROUGH ring.
- ❑ k_G : size of an empty control frame.
- ❑ k_R : the delay experienced by a stream of characters in the receiver buffer of a station on PLAYTHROUGH ring.
- ❑ k_{T_i} : propagation delay on the link from station i to its neighbor.
- ❑ τ_i : total latency at station i .
 - $\tau_i = k_R + k_{T_i}$

CS 756 ❑ The total nominal ring latency τ is the sum of the station latencies for all N

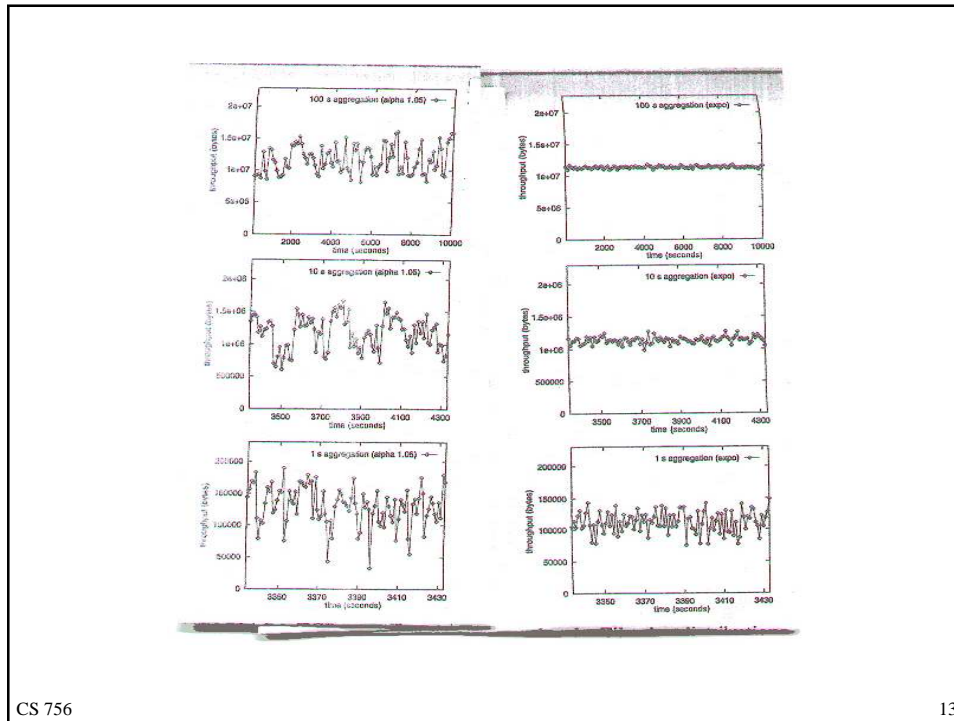
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What is self similarity?

- ❑ Self-similarity refers to the fact that traffic displays similar characteristics at different time scales.
- ❑ Specifically, self-similar traffic is characterized by its high variance or burstiness.
- ❑ Recent examinations have shown, that Internet traffic is highly variable over a wide range of time scales [PF95].
- ❑ The variability over wide time scales implies, that bursts do not average out over long enough time scales.

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Self-Similarity and heavy-tailed distributions

- ❑ Studies have shown that distributions with heavy tails such as the Weibull, Pareto, and lognormal distribution yield better models for file size in file systems [AW96], [CB96], [Irl93], [PF94].
- ❑ Studies have also shown that the TCP transfer of files drawn from heavy-tailed distributions, such as the Weibull and the Pareto distribution causes self-similarity in network traffic [PKC96a], [PKC96b], [PKC97], [PKC00].
- ❑ A random variable X is said to be heavy-tailed if:
 $1-F(x)=\Pr[X>x]\sim 1/x^a$ as $x \rightarrow \infty, 0<a$.
- ❑ Heavy tailed distributions have high or even infinite variance and therefore show extreme variability over all time scales.

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- ❑ More intuitively heavy tailed distributions show a wide

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Derivation of Service Time Minipackets statistics

- ❑ A station i transmitting a packet of size M requires $n_G = (M+h)/m$ ($m = \tau - k_G$) minipackets to transmit its payload.
- ❑ If we assume that M follows a Weibull distribution and $h=0$, n_G follows a Weibull distribution with mean $E[M]/m$.

Derivation of Control Frame Round Trip Time

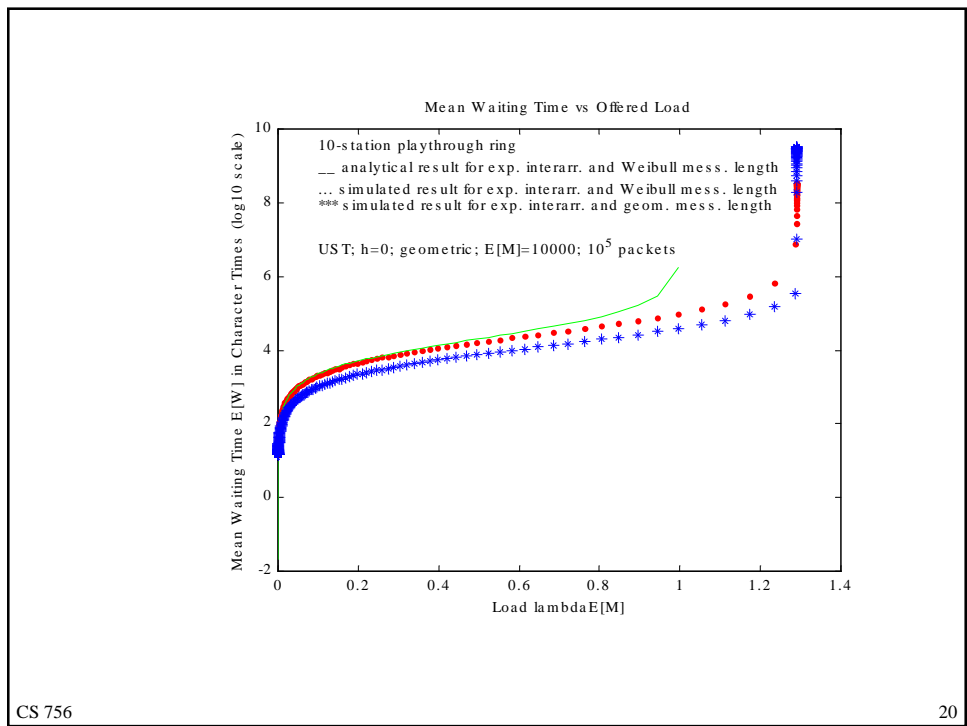
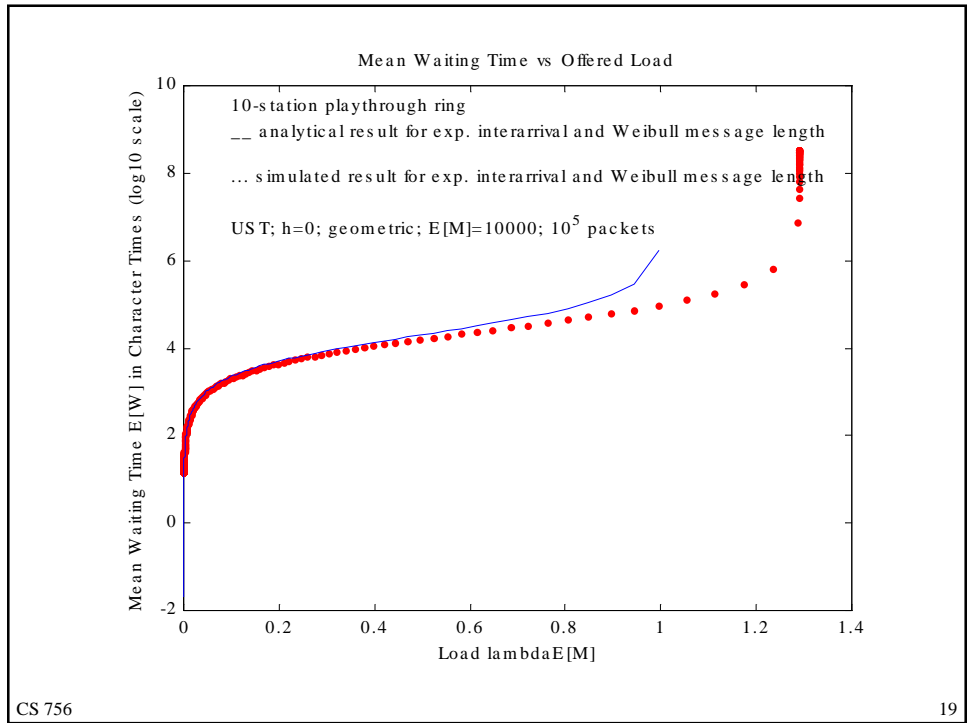
- ❑ The control Frame Round Trip Time is given by:
 - $S_{GO} = \tau + \eta k_D$
 - $E[S_{GO}] = ?$
 - $E[S_{GO}^2] = ?$

Service Time

- The Packet service time is given by $S = n_G S_{GO} + \tau + k_D$
 - $E[S] = ?$
 - $E[S^2] = ?$

Waiting Time

- The average waiting time of a M/G/1 system is given by:
 - $E[W] = \lambda E[S^2] / (2(1 - \rho))$ [Kle75]
 - Where:
 - $\rho = \lambda * E[S]$



APPENDIX A: PROBABILITY DISTRIBUTIONS

1. Definition of Several Probability Distributions

Distribution	Distribution Function	Density Function	Mean
Exponential	$1 - e^{-\lambda x}$	$\lambda e^{-\lambda x}$	$1/\lambda$
Weibull	$1 - \left(\frac{x}{\lambda}\right)^{-k}$	$\frac{k}{\lambda} \left(\frac{x}{\lambda}\right)^{-k-1}$	$\frac{\lambda}{k} \left(\frac{k}{k-1}\right)$
Gamma	$\frac{x^k e^{-x/\lambda}}{\lambda^k \Gamma(k)}$	$\frac{x^{k-1} e^{-x/\lambda}}{\lambda^k \Gamma(k)}$	$\lambda \Gamma(k)$
Lognormal	$\frac{1}{\sqrt{2\pi\sigma^2}} \ln\left(\frac{x}{\mu}\right) e^{-\frac{1}{2\sigma^2} \left(\ln\left(\frac{x}{\mu}\right)\right)^2}$	$\frac{1}{x\sqrt{2\pi\sigma^2}} \ln\left(\frac{x}{\mu}\right) e^{-\frac{1}{2\sigma^2} \left(\ln\left(\frac{x}{\mu}\right)\right)^2}$	$\mu e^{\frac{\sigma^2}{2}}$

$$f(x) = \frac{d}{dx} F(x) = \lambda e^{-\lambda x}$$

2. Derivations of the Expressions for the Exponential and the Weibull Distributions Used in the Simulator

For the exponential distribution (Fig.72):

The cumulative distribution of the exponential distribution in the table above is given by:

$$F(x) = 1 - e^{-\lambda x} \quad (1)$$

Since y ranges from 0 to 1, $F(x)$ varies from 0 to 1. So we can substitute $F(x)$ for y and then solve equation (1) for x to obtain:

$$y = 1 - e^{-\lambda x} \quad (2)$$

Letting $\ln = \ln$, and $F(x) = y$, we can write:

$$F(x) = 1 - e^{-\lambda x} = y \quad (3)$$