

SIEMENS

Dimensioning of IP Networks - A still incomplete Framework

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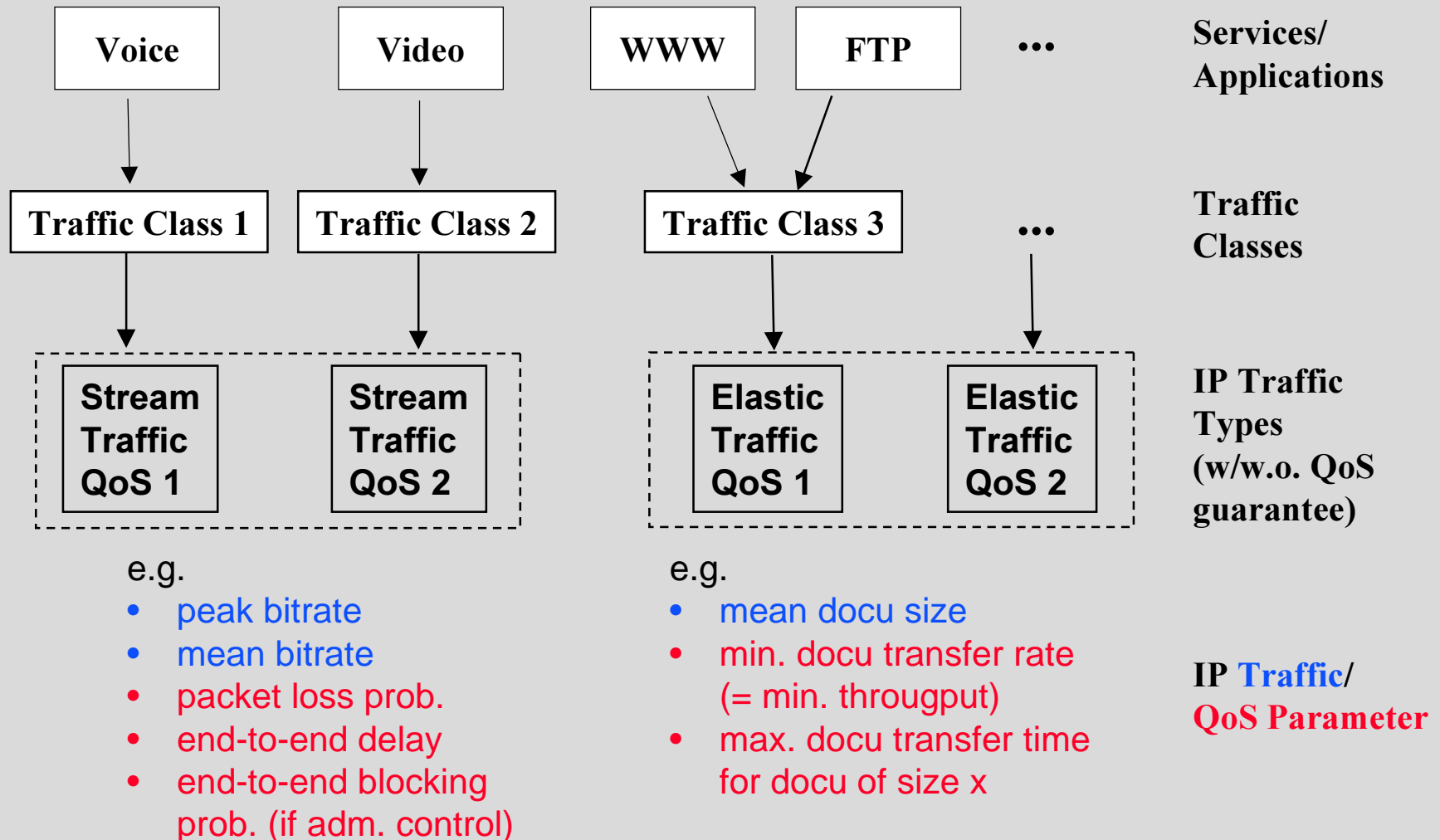
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1. Introduction

Introduction

Basic IP Traffic Classification



Introduction

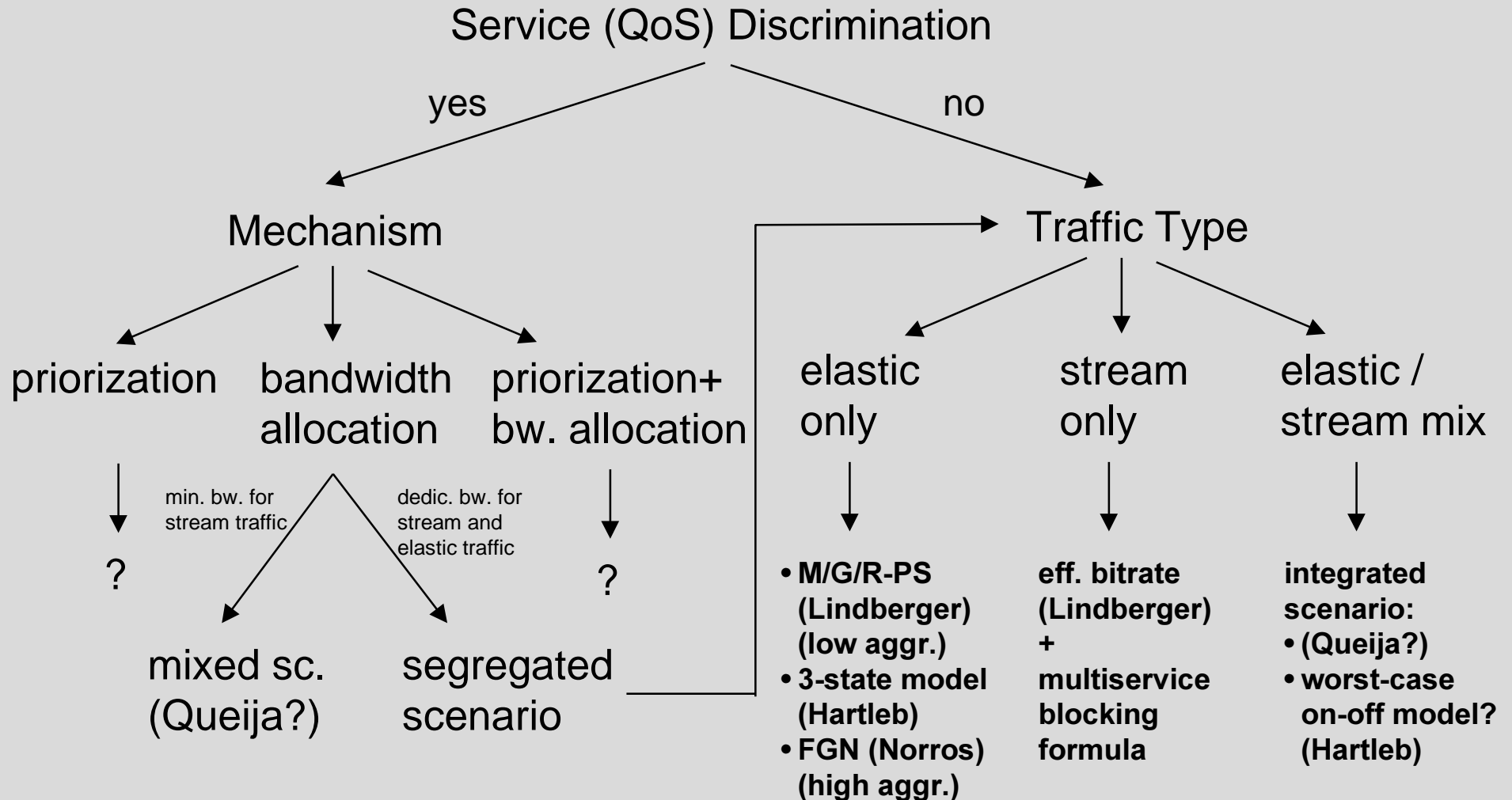
IP Link Dimensioning - Basic Classification Criteria

Basic Classification Criteria:

- Elastic (TCP) vs. stream (UDP) traffic
- Service (QoS) discrimination:
 - complete sharing
 - prioritization only
 - bandwidth reservation only
 - prioritization and bw. reservation
 -
- Degree of traffic aggregation:
 - source models (e.g. Web-traffic)
 - models for low aggregated traffic (e.g. on access links)
 - models for high aggregated traffic (e.g. on backbone links)

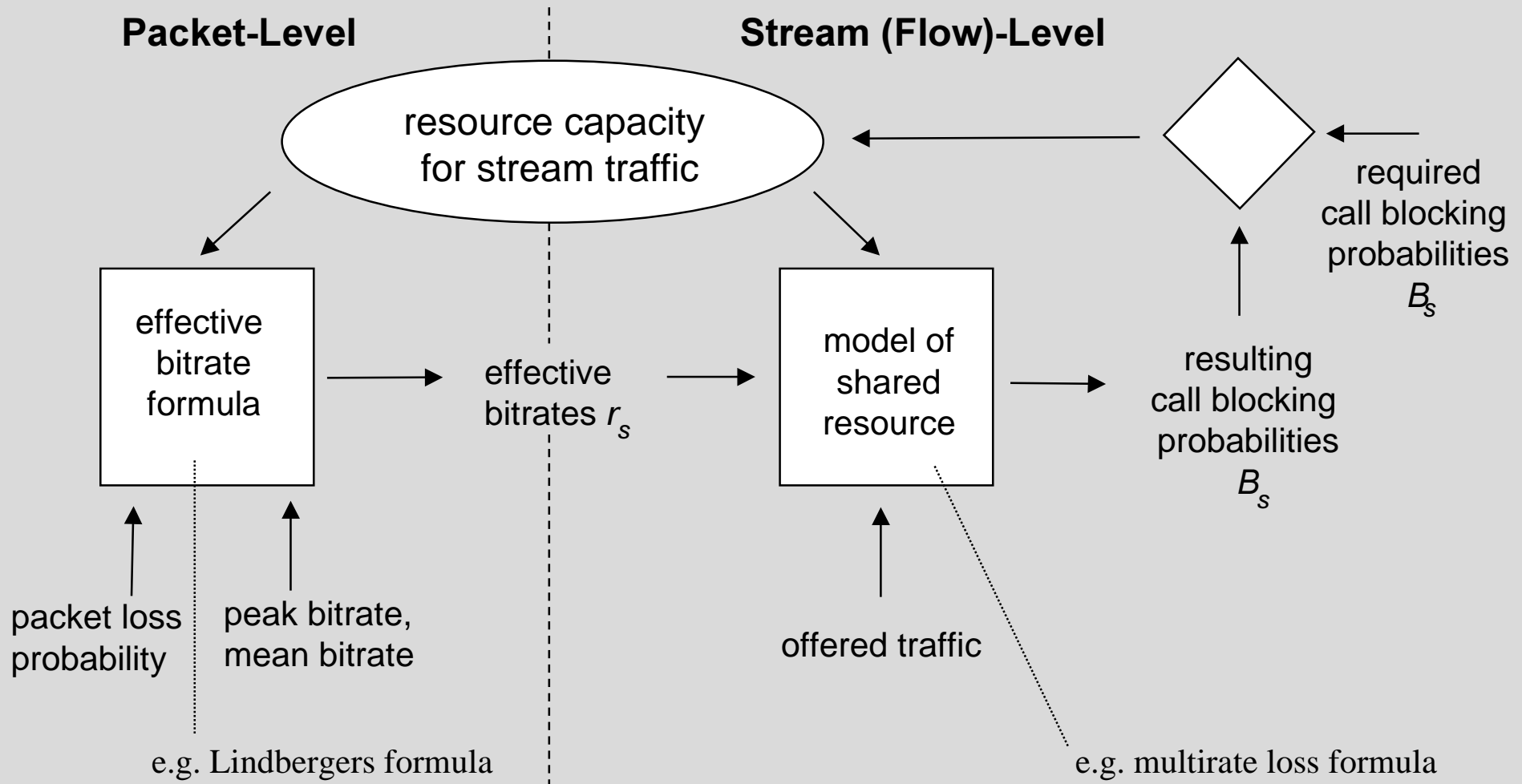
Introduction

IP Link Dimensioning - Overview



2. Dimensioning for Stream Traffic

Link Dimensioning for Stream Traffic



Link Dimensioning for Stream Traffic

Example: Lindbergers Effective Bitrate Formula

$$r(C) = \begin{cases} \gamma MBR & \text{if } 0 \leq C \leq n^* \\ \gamma MBR \left(1 + 3\eta^2 PBR \cdot \frac{PBR - MBR}{C^2} \right) & \text{if } n^* \leq C \leq n^{**} \\ \gamma MBR \left(1 + 3\eta \cdot \frac{PBR - MBR}{C} \right) & \text{if } C \geq n^{**} \end{cases}$$

with: $\gamma = 1 + \eta / 100$
 $\eta = -2 \log P_{loss}$

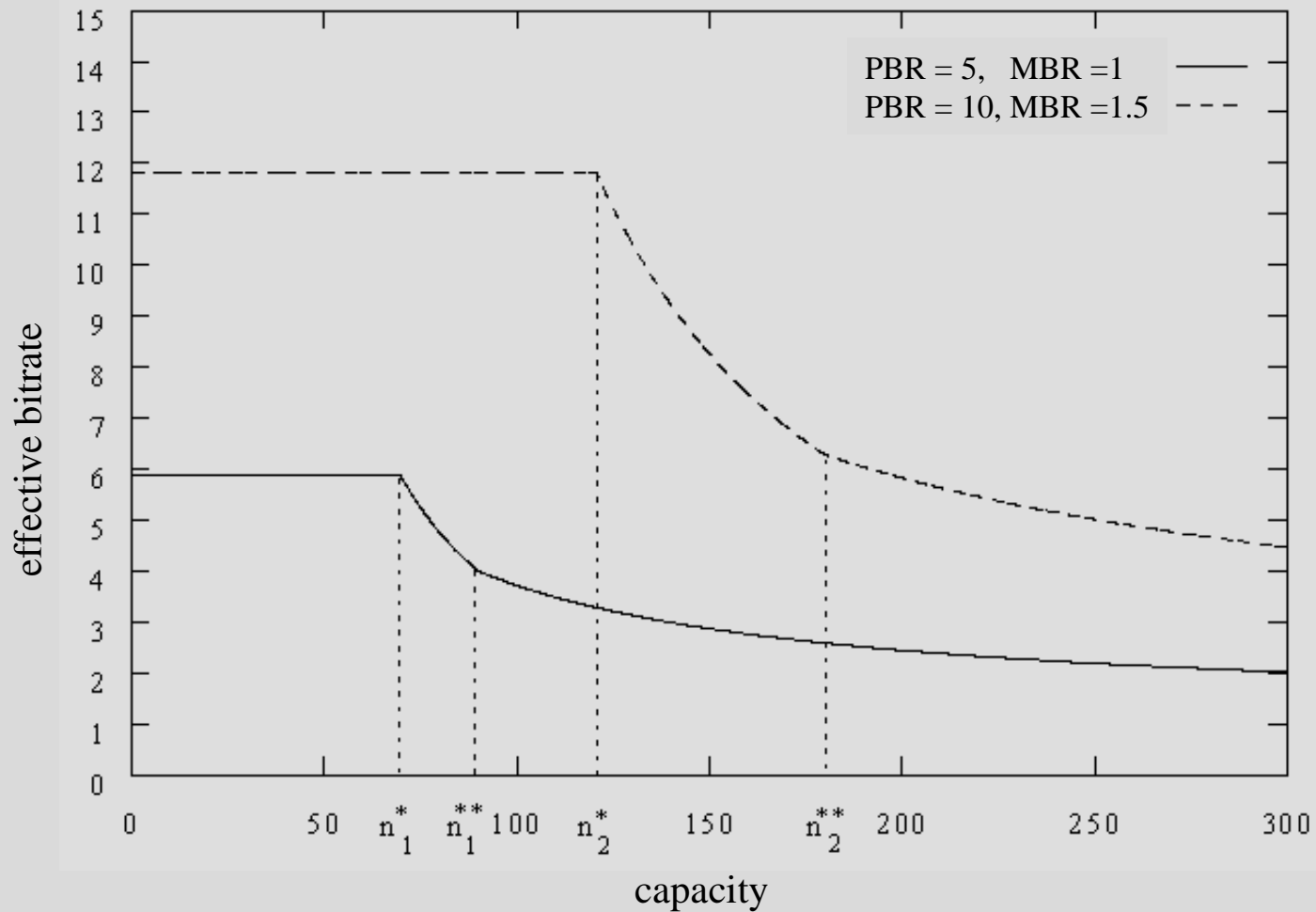
$$\eta^* = \begin{cases} \eta \sqrt{3MBR \cdot PBR} & \text{if } PBR \geq 3MBR \\ 3\eta MBR & \text{else} \end{cases}$$

$$\eta^{**} = \begin{cases} \eta PBR & \text{if } PBR \geq 3MBR \\ \eta^* & \text{else} \end{cases}$$

PBR = peak bitrate
 MBR = mean bitrate
 C = link (resource) capacity
 r = effective bitrate of traffic class s
 n^*, n^{**} = threshold values

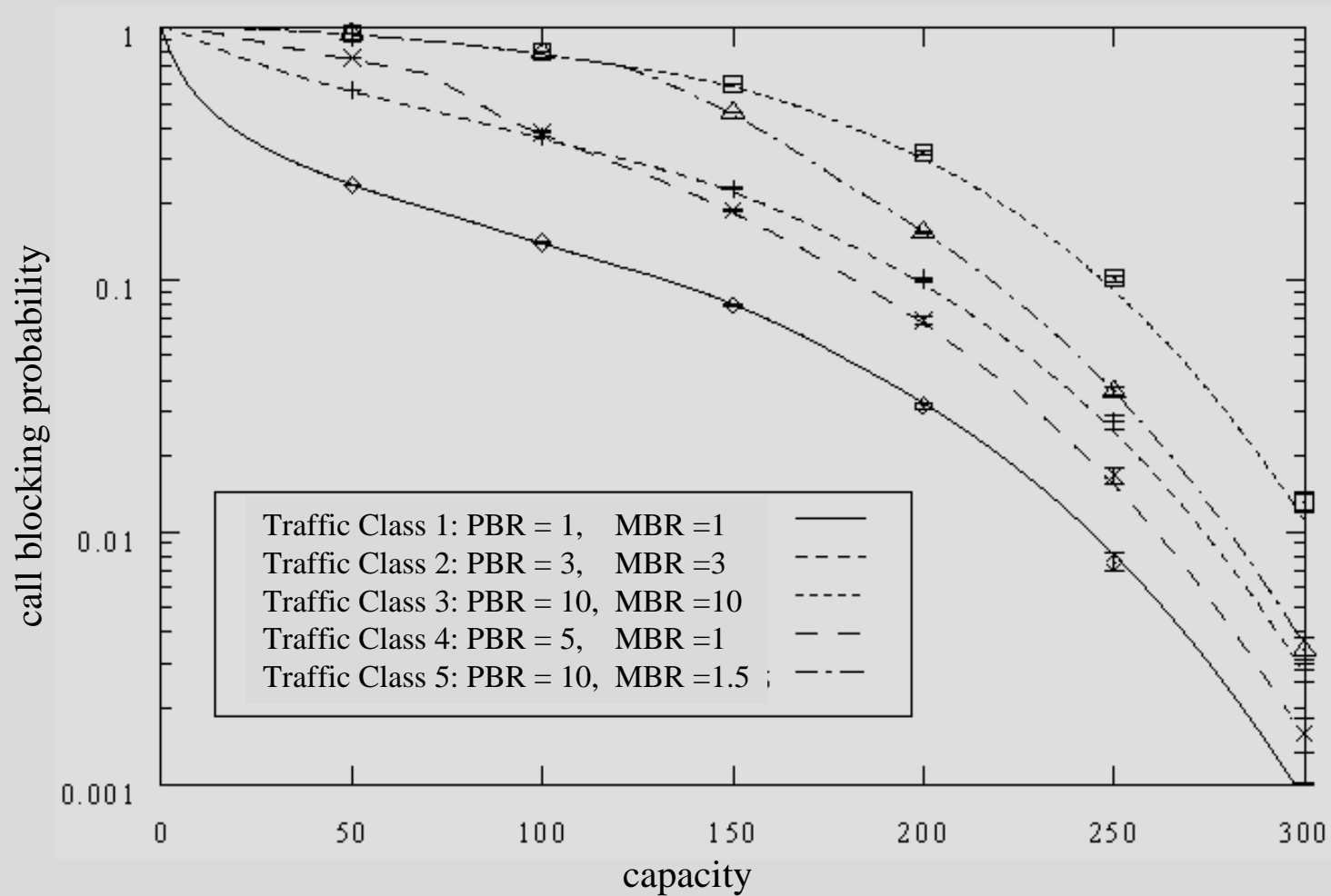
Link Dimensioning for Stream Traffic

Example: Lindbergers Effective Bitrate Formula



Link Dimensioning for Stream Traffic

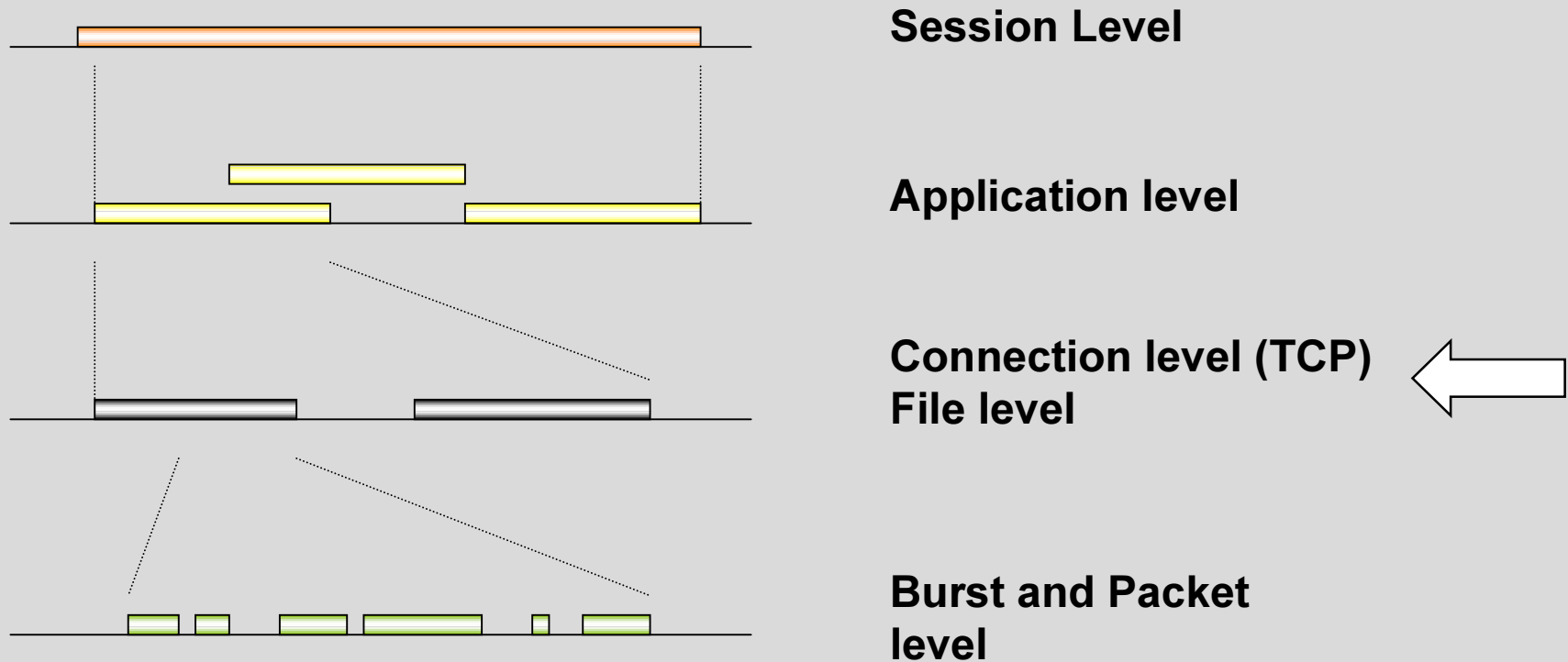
Blocking Probability vs. Link Capacity



3. Dimensioning for low aggregated Elastic Traffic

Dimensioning for low aggregated Elastic Traffic

Activity Model for Elastic Traffic



Dimensioning for low aggregated Elastic Traffic

Elastic Traffic Characteristics (Example: Web-Traffic)

Measurements in educational and corporate environment, Spain 1997/98

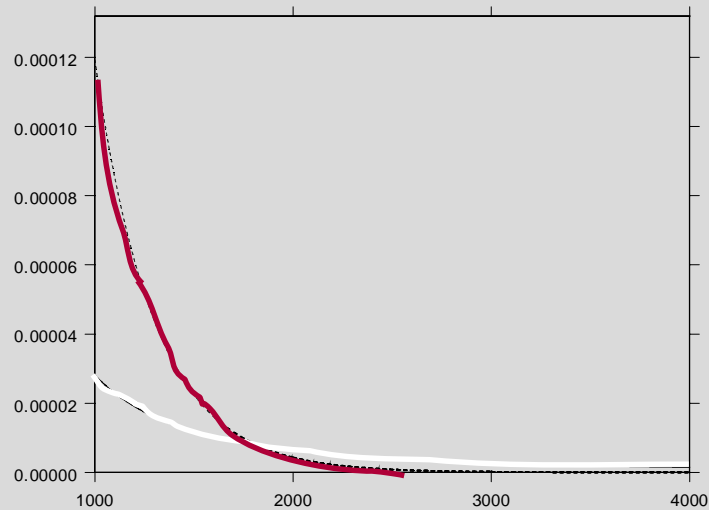
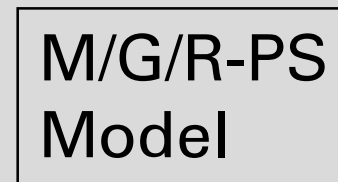
Source: A. Reyes-Lecuona, E. Gonzalez-Parada, E. Casilari, J.C. Casasola, A. Diaz-Estrella, A page-oriented WWW traffic model for wireless system simulations, International Teletraffic Congress ITC-16, Edinburgh, 1999

	Distribution	Mean	Standard Deviation
Session interarrival time	Neg.-exponential	Traffic dependent	
Pages/session	Log-Normal	23 ... 26	80 ... 170
Time between pages	Gamma	25 ... 35 s	135 ... 150 s
Page size	Pareto	40 ... 56 kByte	190 ... 200 kByte
Page delivery time	Network dependent	35 ... 75 s	
Packet size	Multimodal	40, 552, 576, 1500 Byte	
Packet interarrival time	Exponential	0,75 ... 1,2 s	

Dimensioning for low aggregated Elastic Traffic M/G/R-PS Model - Motivation

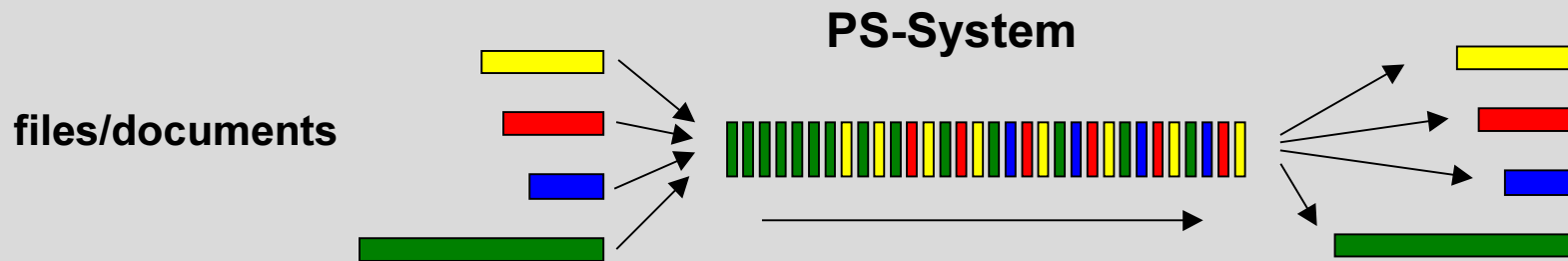
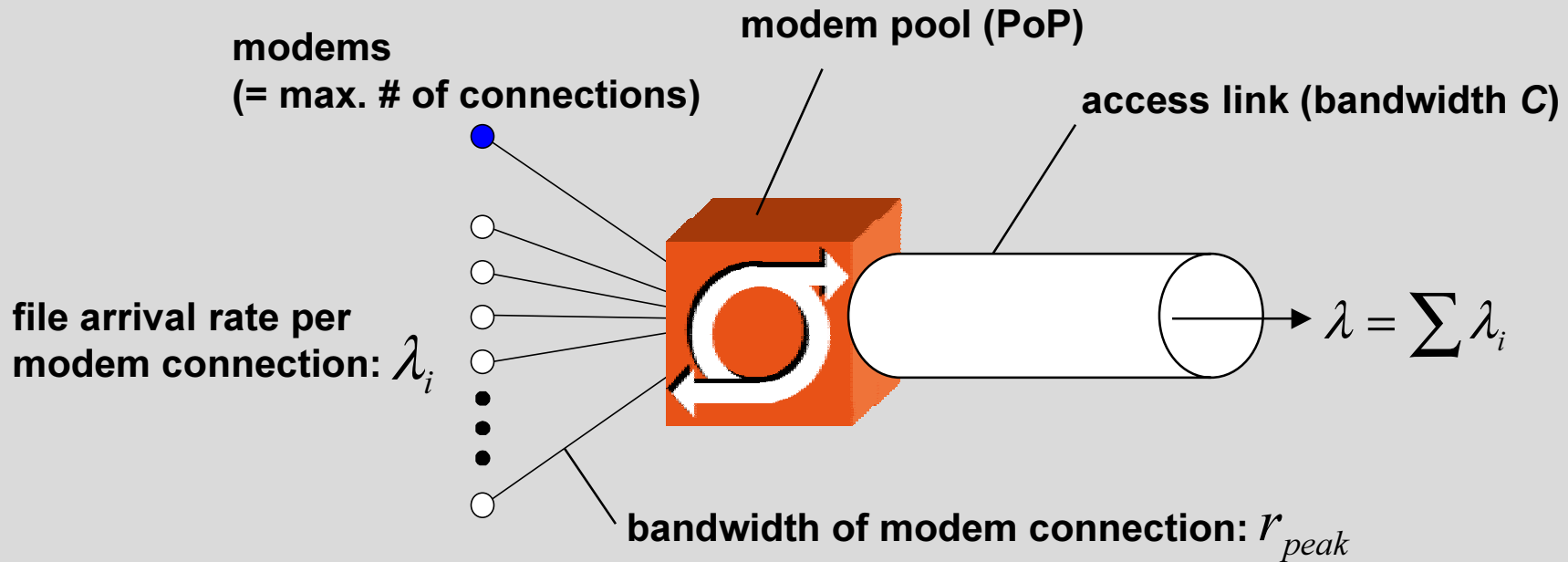
Characteristics:

- Elastic traffic call $\hat{=}$ single file to be transferred
- Poisson arrival process of files
- Heavy tailed file size distribution (Pareto distribution)
- Restricted bitrate of single source
- TCP/IP control loop



Pareto distribution vs.
neg. exponential distribution

Dimensioning for low aggregated Elastic Traffic M/G/R-PS Model



Dimensioning for low aggregated Elastic Traffic M/G/R-PS Model

Required Input:

- IP flow characterized by:
 - document (file) arrival rate (neg. exp. distributed): λ
 - mean file size: x_{mean}
- max. bitrate of single source: $r_{peak} < C$
(C = access line bandwidth)

Dimensioning Objective:

- determine the link capacity C to guarantee an average transfer time $E\{T(x)\}$ for a file of size x
- or:**
- determine the link capacity C to guarantee an certain average throughput for all file transactions

Link Dimensioning with M/G/R-PS-Model

Expected Transfer Time as Dimensioning Objective

Expected sojourn time (or transfer time)
 $E\{T(x)\}$ for a file of size x :

$$E\{T(x)\} = \frac{x}{r_{peak}} \left(1 + \frac{E_2(R, R\rho)}{R(1-\rho)} \right) = \frac{x}{r_{peak}} \cdot f_R$$

where: $R = C/r_{peak}$ (# of servers)

$\rho = \lambda \cdot x_{mean}/C$ (link utilization)

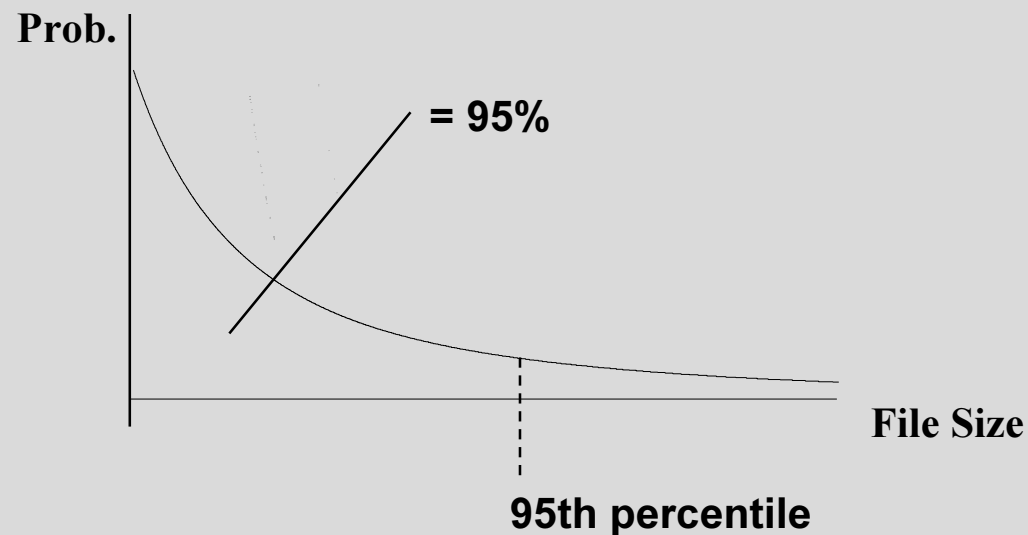
E_2 = Erlang's second formula (Erlang C formula)

"delay factor"

Link Dimensioning with M/G/R-PS-Model Expected Transfer Time as Dimensioning Objective

Question: Which file size x should be taken for $E\{T(x)\}$?

Proposal: Take the 95th percentile of an assumed file size distribution e.g. a Pareto distribution.



Link Dimensioning with M/G/R-PS-Model Average Throughput as Dimensioning Objective

Average bitrate (throughput) D during the file transfer phase:

$$D = \frac{r_{peak}}{\left(1 + \frac{E_2(R, R\rho)}{R(1-\rho)}\right)} = \frac{r_{peak}}{f_R}$$

Link Dimensioning with M/G/R-PS-Model

Possible Solutions for different Access Peak Rates r_{peak}

$$1) \quad (\lambda_1 + \lambda_2) \quad \text{with} \quad \bar{r}_{peak} = \frac{1}{\rho} (\rho_1 r_{peak1} + \rho_2 r_{peak2}) \quad \rightarrow \quad C$$

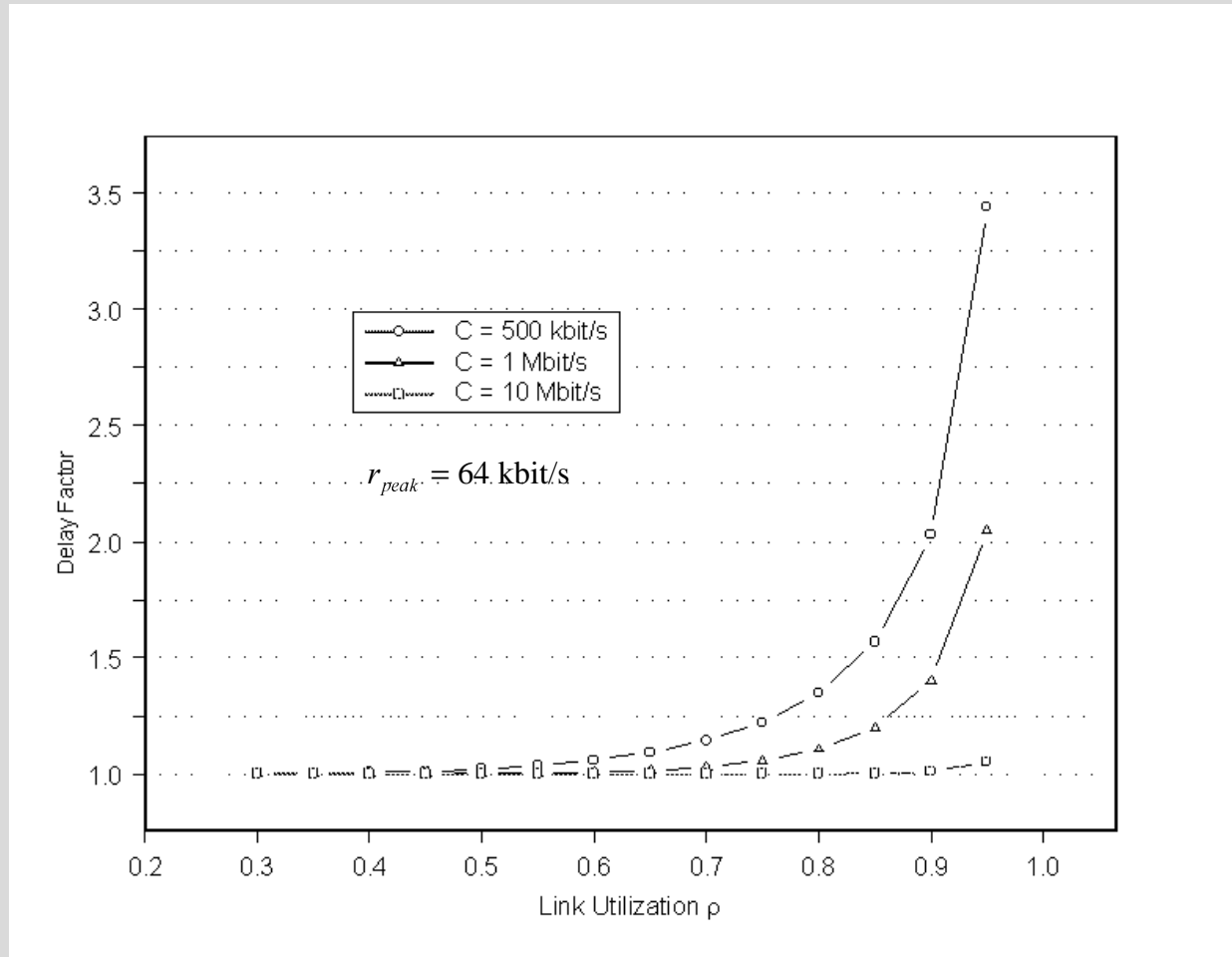
$$2) \quad \left. \begin{array}{l} \lambda_1 \quad \text{with} \quad r_{peak1} \quad \rightarrow \quad C_1 \\ \lambda_2 \quad \text{with} \quad r_{peak2} \quad \rightarrow \quad C_2 \end{array} \right\} \quad C = C_1 + C_2$$

$$3) \quad \left. \begin{array}{l} (\lambda_1 + \lambda_2) \quad \text{with} \quad r_{peak1} \quad \rightarrow \quad C_1 \\ (\lambda_1 + \lambda_2) \quad \text{with} \quad r_{peak2} \quad \rightarrow \quad C_2 \end{array} \right\} \quad C = \max(C_1, C_2)$$

- Assumptions:
- same file size x
 - same target delay factor

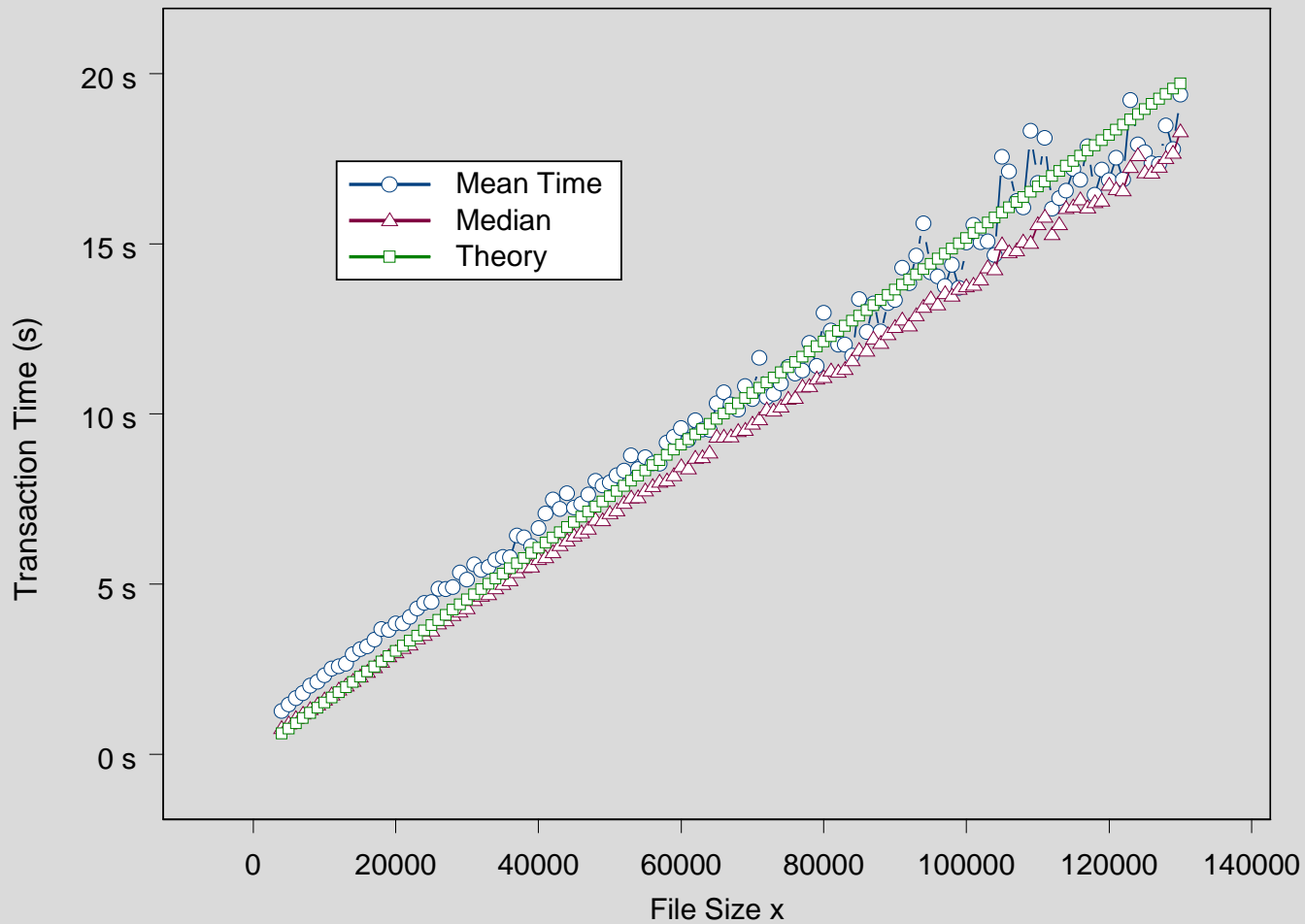
Link Dimensioning with M/G/R-PS Model

Delay Factor wrt. Link Utilization and Link Capacity



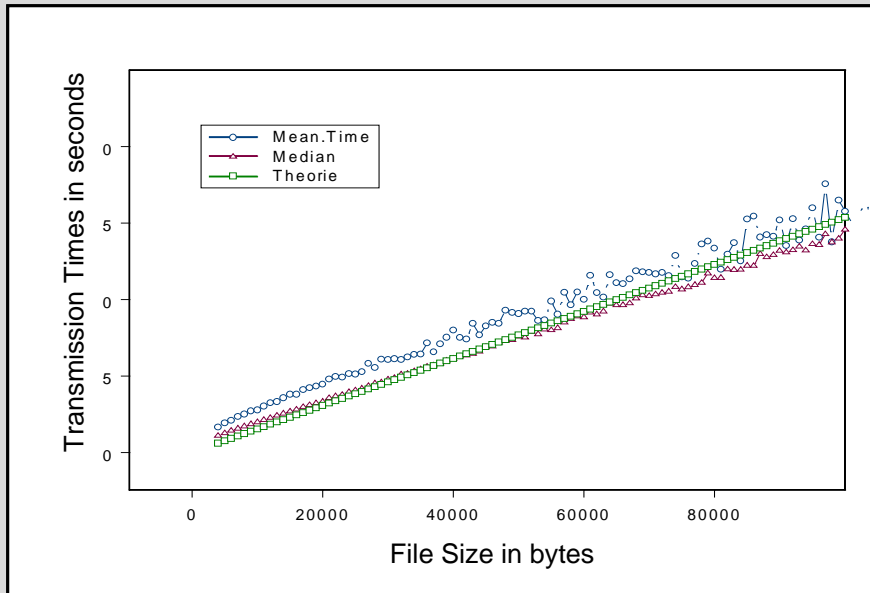
Link Dimensioning with M/G/R-PS Model

Simulation Results: Transaction Time vs. File Size

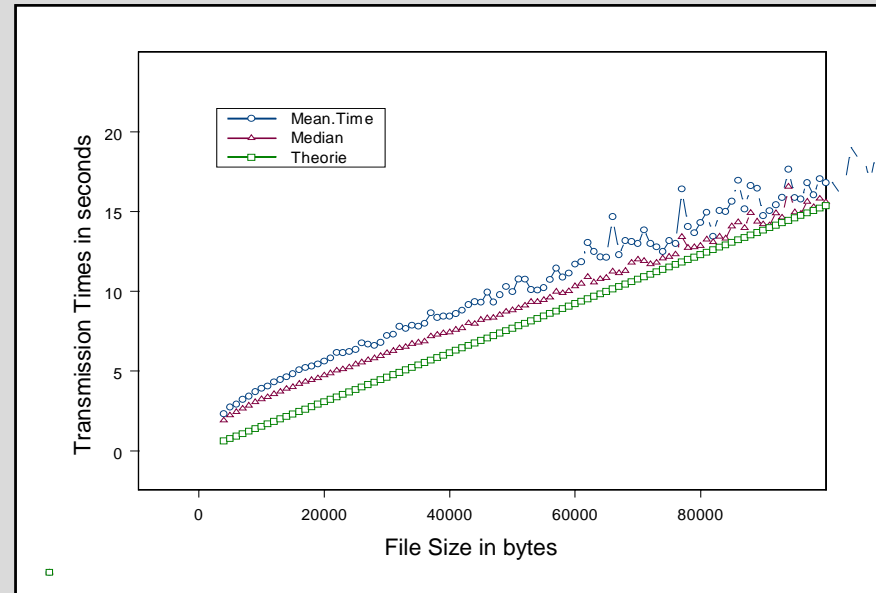


Link Dimensioning with M/G/R-PS Model

Transaction Time vs. File Size wrt. Round Trip Time



RTT = 30ms



RTT = 300ms

4. Dimensioning for high aggregated (mixed) Traffic

Dimensioning for high aggregated (mixed) Traffic FGN Traffic Model

Fractional Gaussian Noise (FGN) Traffic Model:

IP flow i (self similar traffic) characterized by:

- mean bit rate: m_i
- normalized variance: $a_i = \text{var}_i / m_i$
- Hurst-parameter: H_i

Dimensioning for high aggregated (mixed) Traffic Link Dimensioning with FGN Model

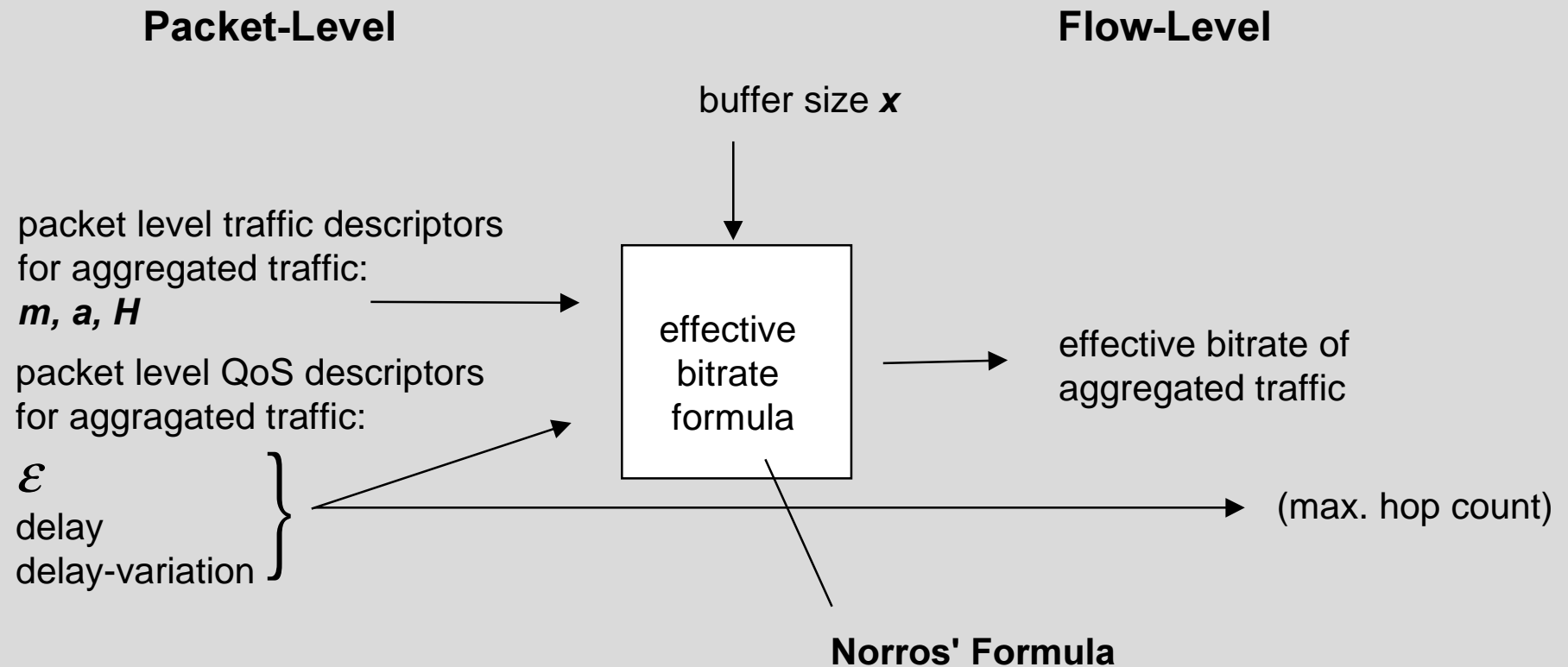
Norros effective bitrate formula for self similar traffic (which can be described by a FGN model):

$$C = m + \left(\kappa(H) \sqrt{-2 \ln \varepsilon} \right)^{1/H} a^{1/(2H)} x^{-(1-H)/H} m^{1/(2H)}$$

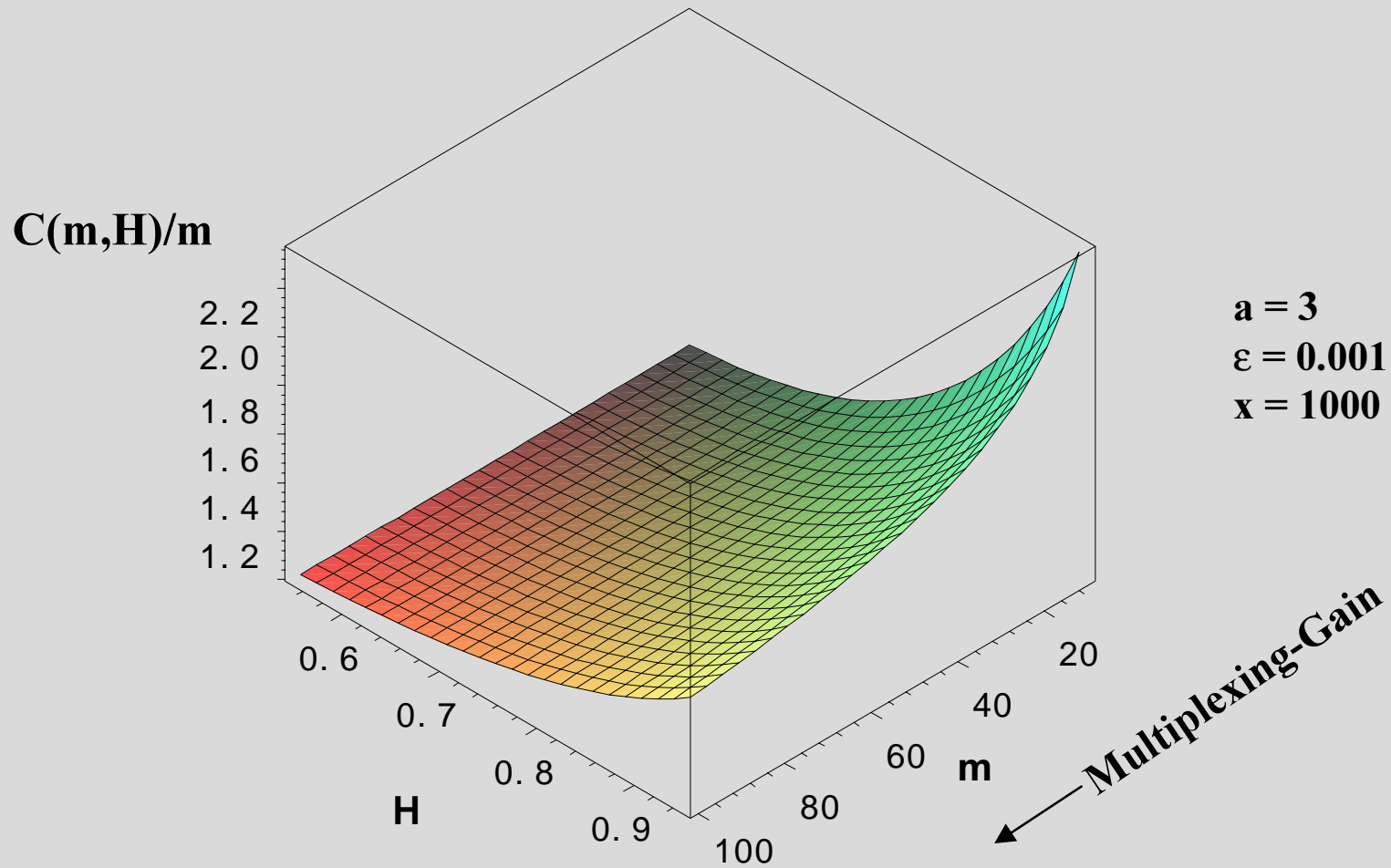
with: $\kappa(H) = H^H (1-H)^{1-H}$

- m : mean bitrate of input traffic (sum of m_i)
- a : normalized variance of input traffic
(assumed to be equal for all flows i)
- H : Hurst parameter of input traffic ($H = \max_i(H_i)$)
- x : buffer size
- ε : buffer overflow probability

Dimensioning for high aggregated (mixed) Traffic FGN Model: Packet and Flow Level Parameter Mapping



Dimensioning for high aggregated (mixed) Traffic Capacity vs. mean Bitrate and Hurst Parameter



5. IP Network Dimensioning

IP Network Dimensioning

Core Network Dim. with Mean/Effective Bitrate Model*

determine flow paths (for each o/d traffic relation) according to the given routing scheme



determine aggregate traffic on each network link (e.g. sum of mean bitrates of IP flows)



individual dimensioning of each link (with single-link dimensioning formula)

*) Assumption:
given routing scheme,
given topology

remark:
max. end-to-end delay
is guaranteed by max.
hop count

IP Network Dimensioning

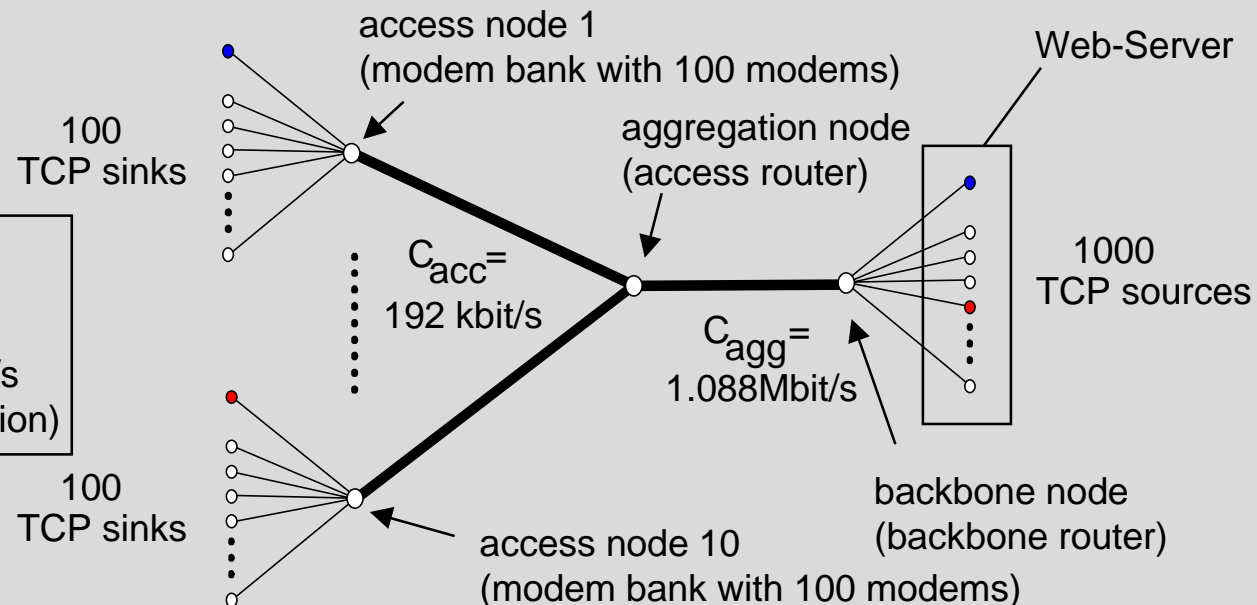
Access Network Dimensioning with M/G/R-PS Model*

*) for elastic traffic

- The whole access network is regarded as a single processor sharing system
- The model is based on a single link model described by a M/G/R-PS queue
- Each link is dimensioned to have the same delay factor

Example:

$C_{\text{modem}} = 64 \text{ kbit/s}$
 file size: 12KByte
 file arrival rate: 0,009788 1/s
 (per active modem connection)



6. Summary

Summary

IP Link Dimensioning - Open Issues

- Improve M/G/R-PS model to take into account different r_{peak} values, different RTT (no fair sharing!) and influence of the TCP start and congestion avoidance behaviour.
- Investigate application field of FGN (Norros) model: under which conditions is it suitable for high aggregated (mixed elastic/stream) traffic?
- Which dimensioning formula works well in the low aggregated mixed elastic/stream traffic scenario?
- Find dimensioning formulas for scenarios where prioritization and/or bandwidth reservation is applied (i.e. scenarios with service discrimination).