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Fun Factor Dimensioning for Elastic Traffic

Joachim Charzinski
Siemens Information and Communication Networks
joachim.charzinski@icn.siemens.de

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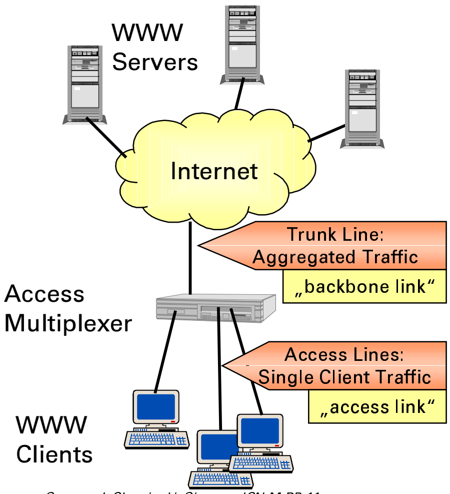
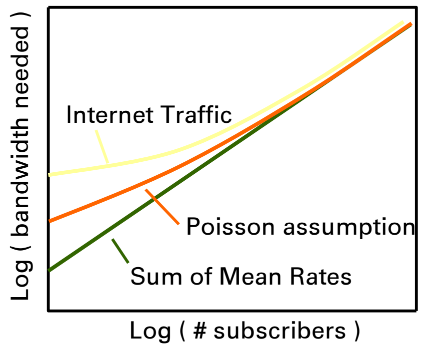
- Introduction
- Fun Factors
- Models for Analysis and Simulation
- Results

Access Scenario
Dimensioning Trunk Lines





Source: J. Charzinski, Siemens ICN M RP 11

Dimensioning

- Tuning of trunk to access line capacities
  - residential access
  - radio access network
- Matching of capacities within network element
  - processor vs. line capacity
  - line card vs. backplane bit rates
- Evaluation of user perceived quality of service
  - for SLAs
  - for advertising

Stream versus Elastic Traffic

- Utility Function
  - stream traffic: usability only with high bit rate
  - elastic traffic: (nearly) always usable
- Kelly, Roberts, Lindberger:
  - customers only pay for usability
  - only minimum rate guarantees should be given to elastic traffic
- Hartleb
  - customers pay for new high-speed access media
  - want to use services at higher bit rates

➔ fun factor is paid for (“fun pricing” ?)

Traditional QoS Parameters

- Packet (cell) loss probability
- Delay and/or delay variation
  - unrealistic due to TCP flow control
- Total transfer delay
- Reaction time
  - unrealistic due to extreme variance of data volumes
- Problem: in contrast to stream apps, elastic apps still work, even if the perceived QoS is low
  -> hard to find the right parameter

→ A new QoS parameter is needed for elastic traffic!

Traditional Dimensioning Targets

- Buffer size
- Processing capacity
- Link bandwidth

→ Buffer size does not help to reduce packet loss with self-similar traffic

Traditional Solutions

- Shaping
  - should co-operate with TCP, otherwise it is inefficient
- Admission control
  - introduces complexity into each network node
  - connection parameters must be known

Introduction

Fun Factors

Models for Analysis and Simulation

Results

Fun Factors

- ... should capture user perceived QoS
- ... should help predicting and evaluating system performance
- ... should allow comparison of different systems
- ... should be 100% in an ideal situation
  ... and less otherwise

- can also be viewed as “line efficiency” or the like to sound more serious

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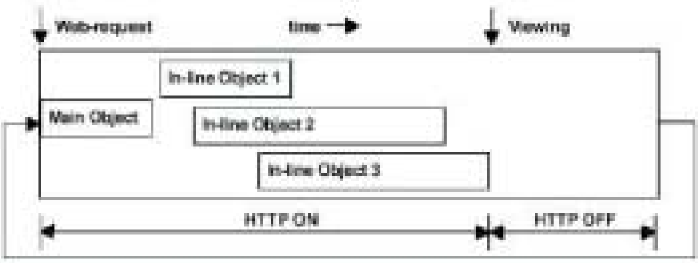
Elastic Traffic

- Waiting time until Web page is loaded (e.g. Choi/Limb)
  - Plus time varying bit rate



→ consider QoS per (H2H) flow or burst, not per packet!

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Definition of the Fun Factor

- Access Fun Factor φ_A
  - Ratio of ideal to real download time

$$\varphi_A = \frac{t_{ideal}}{t_{observed}}$$

  - Mean bandwidth during downloads over access link rate

$$\varphi_A = \frac{E[B \mid B > 0]}{C_{AL}}$$

- other Fun Factors can be defined correspondingly relative to other measures (e.g. rate available from the Internet)

Introduction

Fun Factors

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Worst-Case (low loss) models

- Make sure that the considered link is not a bottleneck
  - make the loss rate on this link low enough
  - -> TCP will not be influenced by this link
  - use bufferless burst scale model to make sure small packet scale buffers will suffice

- Example: Engset Rate Loss Model
  - n ON/OFF sources with ON probability β and rate r_{ON}

$$p_{loss} = \sum_{i=\lceil c_L / r_{ON} \rceil}^{n} \binom{n}{i} \beta^i (1-\beta)^{n-i} \frac{i\, r_{ON} - C_L}{\rho C_L}$$

Rate Convolution

- Input traffic
  - n variable-rate fluid traffic streams
  - continuous distribution of bit rate per source
    $C_R(x) = P\{R_{ON} > x\}$
  - independent sources -> n-fold convolution
    $C_R^{(n)}(x) = P\{\sum R_{ON} > x\}$
  - measured rate distribution from real (overdimensioned) Internet access or target rate distribution can be used
- Bufferless loss model (Rate Envelope Multiplexing)
  - simple approximation for "non-bottleneck" link
  - target: keep loss probability very low

$$p_{Loss} = \frac{1}{nE[R_{ON}]} \int_{x=C_L}^{\infty} C_R^{(n)}(x)dx$$

Norros' Fractional Brownian Motion Model

- Input traffic is FBM with drift
  $A_t = mt + \sqrt{ma}Z_t$
  - mean rate m, Hurst parameter H, variance coefficient a
- Captures long-range dependence
  - buffer can be dimensioned including LRD effects
  - several approximations reduce accuracy of results
  - rate dimensioning results do not differ significantly from approaches that take the variance into account but ignore LRD

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

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M/G/r-PS
Processor Sharing Model

- Input traffic
  - Poisson arrivals of fluid ON/OFF traffic streams
  - arrival rate λ, maximum ON rate r_{ON}
  - generally distributed (e.g. heavy-tailed) ON volume
- TCP flow control modeled by Processor Sharing discipline
  - simple approximation for TCP behaviour on a single link
  - result: (time) mean of delay factor f_R

$$f_R = 1 + \frac{\rho}{r(1-p_0)}\left(\frac{1}{1-\rho} + r_g - r\right)\frac{\frac{(r\rho)^{r_g}}{r_g!}}{(1-\rho)\sum_{i=0}^{r_g-1}\frac{(r\rho)^i}{i!} + \frac{(r\rho)^{r_g}}{r_g!}}$$

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Burst Level Fluid Flow Simulation

- Program A
  - unelastic fluid traffic and finite buffer size
- Program B
  - bufferless model
  - fair re-distribution of bandwidth after each ON or OFF event under overload

Summary of Models

Model	sources	buffer	r_{ON}	source	rate sharing
Engset Rate	n	0	r_{ON}	ON/OFF	no
Norros FBM	(n)	x	unlimited	FBM	no
M/G/r-PS	∞	enough	r_{ON}	ON/OFF	yes
Rate Conv.	n	0	$C_R(x)$	open	no
Simulation A	n	x	r_{ON}	ON/OFF	no
Simulation B	n	0	$C_R(x)$	ON/OFF	yes

Introduction

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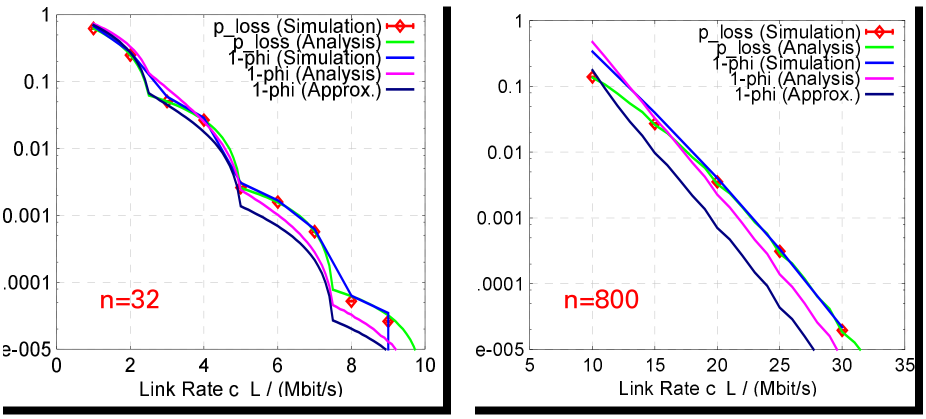
Parameters

- Common parameters for all models are derived from the ADSL trial measurement in Münster, Germany
  - access trunk line was overdimensioned (100Mbit/s for 100 users)

Parameter	Symbol	Value
Mean Rate	m	10.5kbit/s
Access Line Rate	r_{ON}	2.5Mbit/s
Activity Factor	β	0.042
Variance Coefficient	a	$4.4 \cdot 10^5$bit·s
Hurst Parameter	H	0.915

QoS Indicator Results



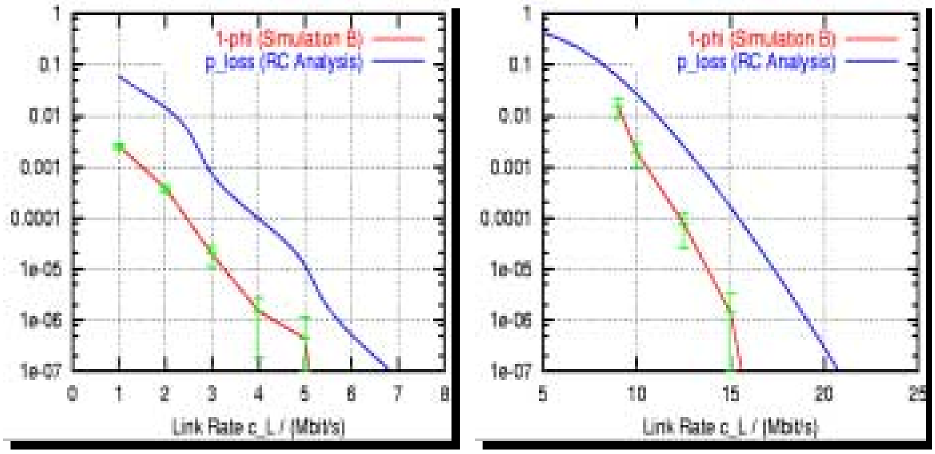
Homogeneous sources:
Results for p_{loss} and 1-φ are similar

QoS Indicator Results (2)

Consideration of φ is important if flows have different maximum rates

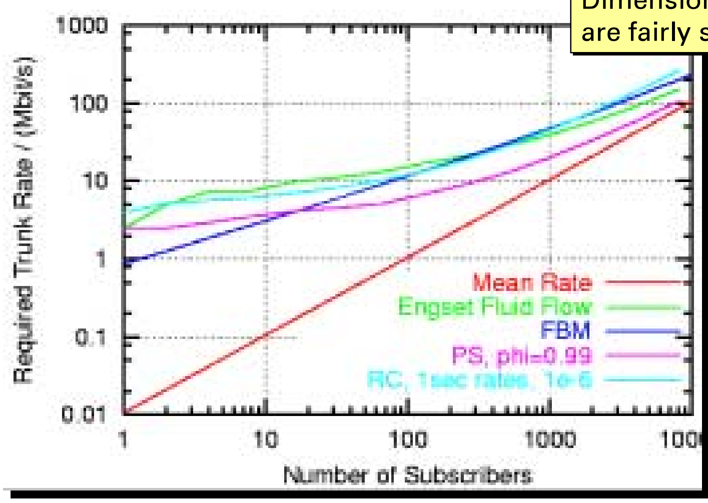
n=32

n=800



Dimensioning Results

Dimensioning results are fairly similar



Summary

- Parts of the Internet or of IP networks can be dimensioned
- Fun Factor can be a measure for user perceived QoS
  - realistic target values can be found
- Dimensioning for loss probabilities does not really help
- Dimensioning for Fun Factor is possible
  - M/G/r-PS
  - continuous PS model

Future Work and Outlook

- Use the Fun Factor for online quality measurement
  - tool
- SLAs for Fun Factors
- Modifications of Fun Factor
  - include reaction times (e.g. DNS, connection set-up)
  - include multiple parallel TCP connections
- Fun Factor Analysis
  - difference between time mean and per connection mean
    -> emphasis on long or short connections
  - difference between delay factor mean and fun factor mean
- Check validity of flow analyses for TCP