“An on-line Estimation Procedure for Cell-Loss Probabilities in ATM links”

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Outline

- Introduction
- The model and the CLP formula
- The on-line estimation methodology
- Implementation issues
- Conclusion

Introduction

- ATM networks support a variety of services
- A QoS measure is **Cell Loss Probability (CLP)**
  - this probability should be very small, of the order of 10^{-6} to 10^{-9}
- *Traffic and Congestion Control* mechanism:
  - maximise resource usage
  - maintain Quality of Service (QoS)
- *Connection Admission Control* function

  decides, in real time, if a request for a connection can be satisfied without having QoS degradation in the network based on:
  - call's traffic characteristics and QoS requirements
  - **on the current network status**

Introduction (cont.)

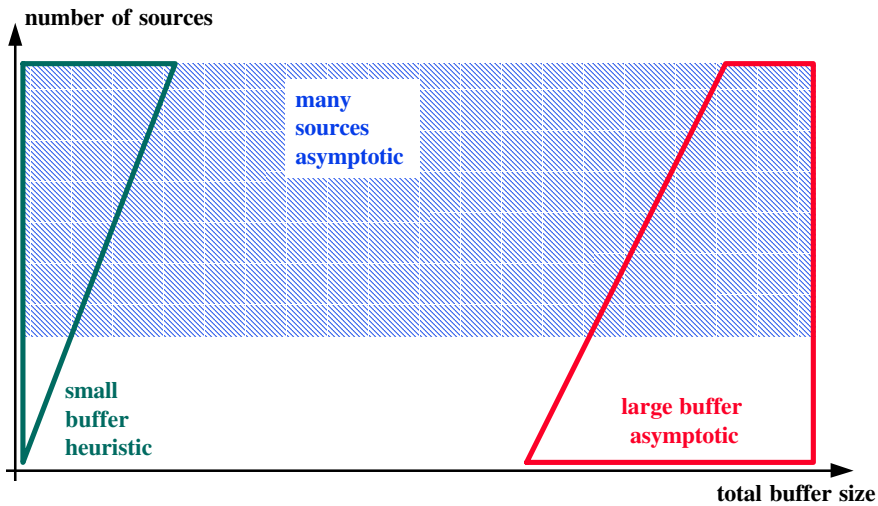
- Need for a mechanism that provides CLP estimates
- Requirements of CLP estimators:
  - accuracy
  - **timeliness**
- Any direct brute-force on-line estimation procedure would fail because of the large time required to make an accurate estimate
  - e.g., Assume that cell loss events are i.i.d. Then, for a 155 Mbps link with an anticipated CLP of the order of 10^{-6}, the estimate would require 10^4 seconds of network time.
  - such a time is impractical

Introduction (cont.)

- Need for indirect statistical estimation procedures, based on:
  - Queueing theory
  - Large deviation theory

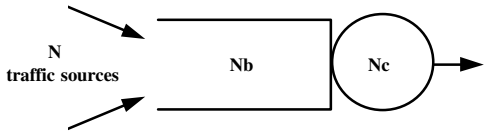
- **Large deviation theory**:
  - capture essential aspects of multiplexing different types of traffic
  - fairly accurate calculation of CLPs for many complex traffic models
  - become **asymptotically** exact for **large systems**

Large deviation asymptotic results



Many sources asymptotic

- Weiss (1986), for ON/OFF Markov fluid models
  Courcoubetis and Weber (1994), for general stationary sources
- output link model:



Φ(N) = Cell Loss Probability

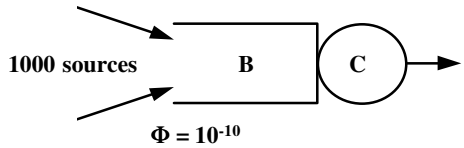
- $\Phi(N) = e^{-NI+o(N)} \approx AN^{\xi} e^{-NI} \Leftrightarrow \log\Phi(N) = \log A + \xi \log N - IN$

the unknown coefficients

The on-line estimation methodology

- basic idea:

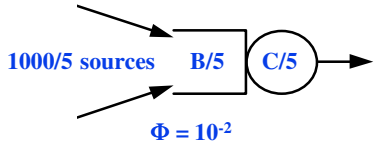
real system:



Φ = 10^{-10}

it is difficult to measure such a small CLP directly

"virtual subsystem":



Φ = 10^{-2}

CLP can be measured with small variance in a short time

- *How do we get the CLP value of the real system using the CLP estimates of the "virtual subsystems"?*

The on-line estimation methodology (cont.)

$\Sigma = \{1,...,N\}$ is our real system

$\Sigma_i \subseteq \Sigma$ is a subsystem of size N_i

- Our methodology is described by the following steps:

1st) Select K "virtual subsystems" Σ_1 ,..., Σ_K

2nd) Estimate the Φ_i directly, for each subsystem Σ_i

3rd) Determine the unknown coefficients by solving the K linear equations

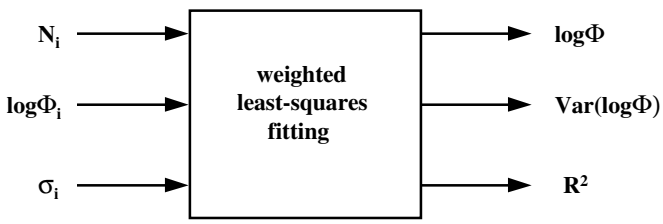
$$\log\Phi_i = \log\Phi(N_i) = \log A + \xi \log N_i - IN_i$$

4th) Calculate the desired quantity

$$\log\Phi(N) = \log A + \xi \log N - IN$$

Determination of the unknown coefficients

- the solution of linear equations is based on the regression analysis



- R^2 measures the goodness-of-fit.

  R^2 must lie between 0 and 1, and the closer it is to 1, the better the fit.

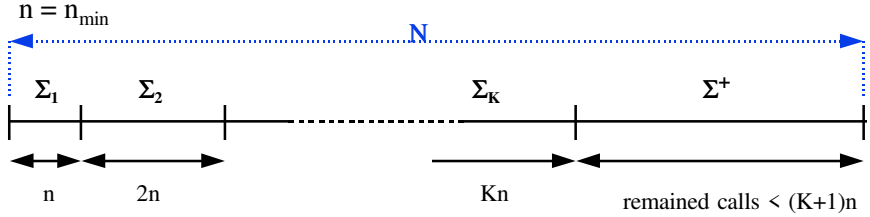
Selection of the “virtual subsystems”

Σ_1 , Σ_2 ,..., Σ_K subsystems are ordered such that $N_1 < N_2 < ... < N_K$

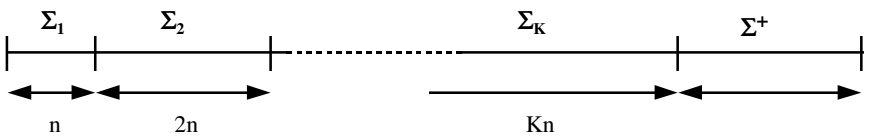
- The following conditions must be satisfied:
  - the CLP estimators must be mutually independent, i.e., the subsystems must not serve common calls
  - the sizes N_i must be evenly spaced in the range [N_1 , N_K]
- We like to select as many subsystems as possible
- We desire a large degree of statistical multiplexing in each subsystem
  - n_{min} : a lower threshold of the number of calls that each subsystem should serve

Selection of the “virtual subsystems” (cont.)

- $n = n_{min}$



- n++



- repeat until $|\Sigma^+|$ is minimised

The problem of Outliers

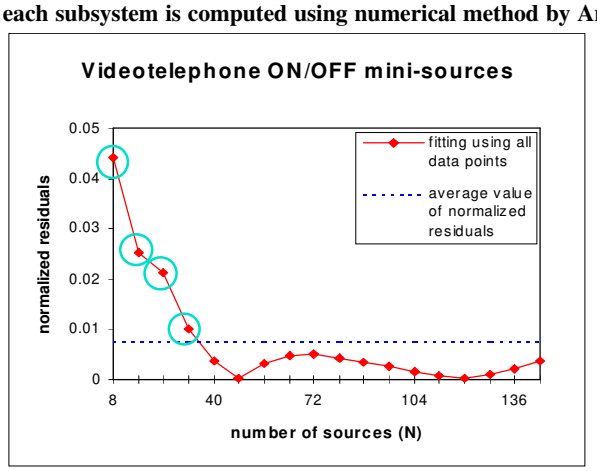
- The choice of the constant n_{min} should be done empirically, so it is possible to select subsystems, called **outliers**, where the large degree of statistical multiplexing assumption does not hold.
- Outliers can easily turn the result of least-squares fit into **nonsense**.
- Use **regression diagnostics**, which are certain quantities computed from the data points with the purpose of pinpointing the outliers
  - i.e., normalised residual $\frac{|\log \Phi_i - \log \Phi(N_i)|}{|\log \Phi_i|}$

The problem of Outliers (example)

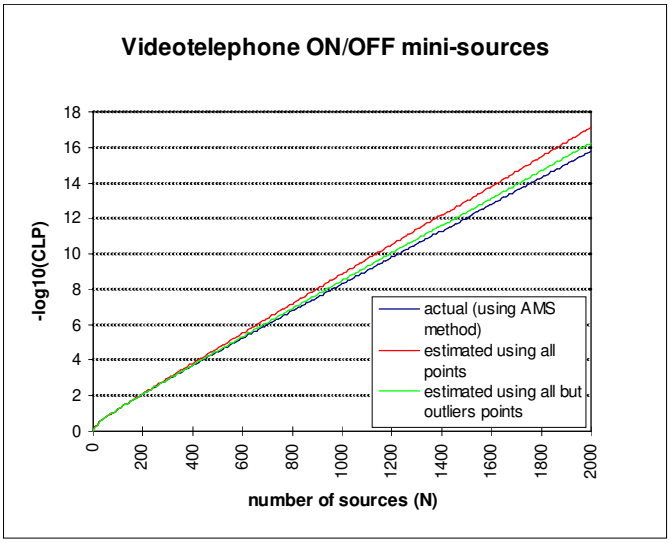
N = 1400 videotelephone ON/OFF mini-sources & n_{min} = 8

K = 18 subsystems of size {8, 16, 24, .., 144}

CLP in each subsystem is computed using numerical method by Anick, Mitra and Sondhi



The problem of Outliers (example - cont.)



for N = 1400 :

actual CLP = $10^{-11.3}$

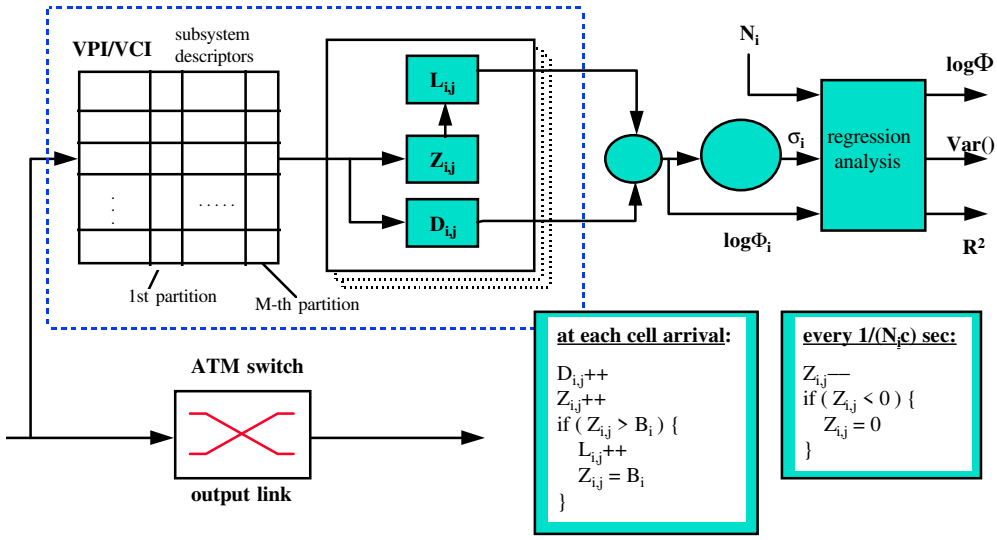
all points CLP = $10^{-12.2}$

all but outliers CLP = $10^{-11.6}$

Estimation of CLP measurement errors in subsystems

- use multiple “instances” for each subsystem :
  - make M different partitions of the set of calls served by the ATM link, i.e., $U_j = \{\Sigma_{1,j}, \Sigma_{2,j}, ..., \Sigma_{K,j}, \Sigma^{+}_{j}\}$
  - $\Sigma_{i,j}$ denotes the i-th subsystem that belongs to the j-th partition
  - we have M subsystems of the same size, each serving a different set of calls
- make a crude estimate of the variance of the $\log\Phi_i$ estimator

Implementation issues



Conclusions

- We proposed an on-line estimation methodology for the Cell Loss Probabilities in ATM links
- It can be used by Connection Admission Control and Routing procedures in ATM networks. Also, it can be used for speeding up the simulation time for large systems.
- An exhaustive simulation study could be conducted in order to study its effectiveness
- We intend to implement that methodology in an ATM switch (ACTS project ASICCOM)