Efficient Traffic Generation for Modeling, Management and Verification

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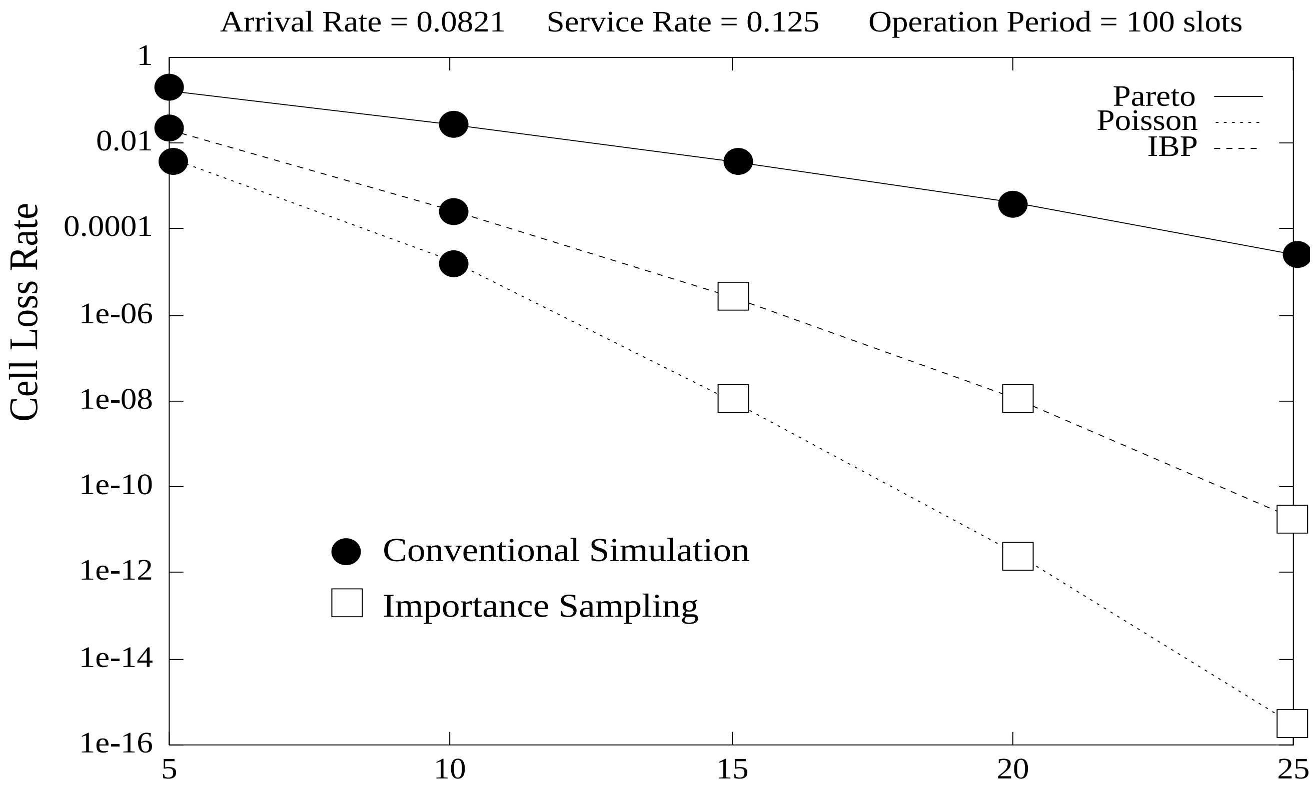
Why is Traffic Modeling Important?

- Accurate performance testing requires realistic traffic streams
- Traffic models match real traces, are more efficient to use
- Most traffic types in high-speed networks are *bursty*
- Burstiness is mainly due to *autocorrelation*
- Renewal models assume autocorrelation away for tractability
- Performance testing in ATM non-realistic without burstiness

Impact of Long-Range Dependence

- Implications to network design and control may be crucial
- Self-similar models: burstiness across time-scales
- Cell loss probability:



Traffic Modeling

Motivation:

Better models required for performance studies in:

QoS, CAC, testing

Goal:

Accurate models of the **statistical behavior** of the traffic

Computationally **efficient** models of the traffic

Traffic Modeling Expertise at Carleton

- Modeling of source and network traffic
- AMP and self-similar (long-range dependent) models
- VBR video (MPEG-2, H.261)
- Inter-LAN data
- Software for automated traffic modeling

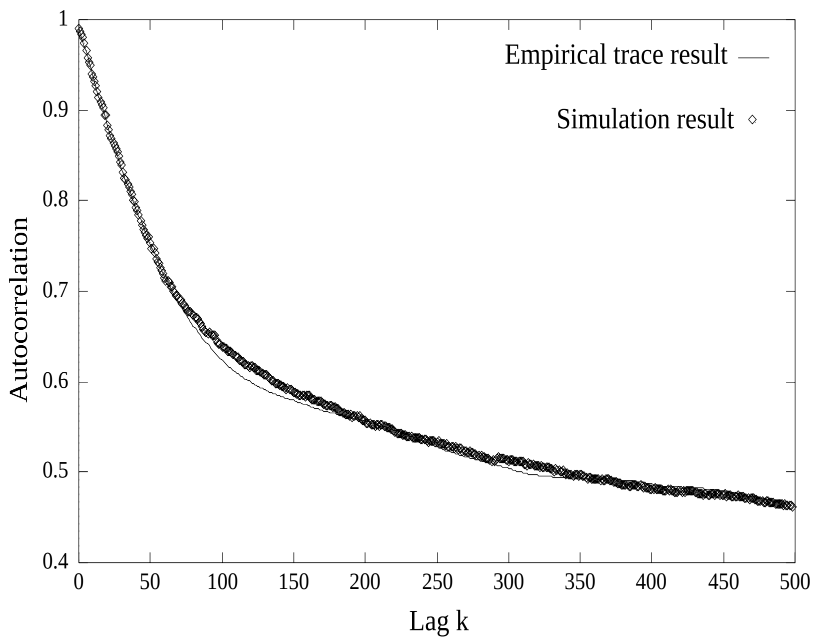
Measurements of VBR Video

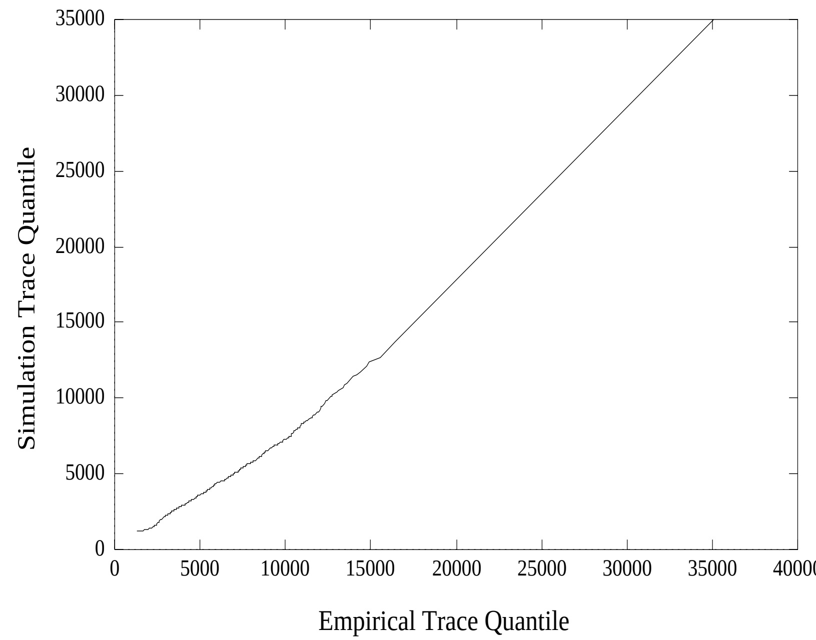
Table 1: Parameters of "LAST ACTION HERO" trace

Coder	MPEG-1
Duration	2 hours, 12 min, 36 sec
Number of frames	238,626
Frame dimensions	320x240 pixels
Resolution	8 bits/pixel (3-band color)
Format	YUV colorspace, CCIR 601-2
Frame rate	30 per second
Slice rate	15 per frame

Modeling VBR Video

- Comparisons of built model and empirical data trace
- Match marginal distributions and autocorrelation functions



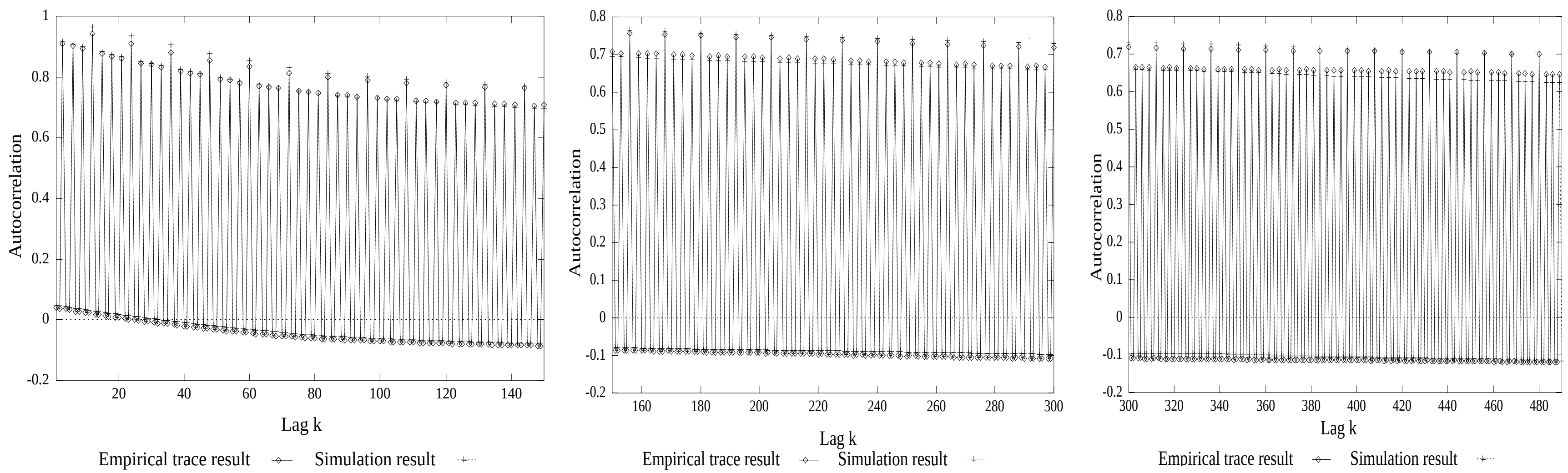


Modeling VBR Video (cont'd)

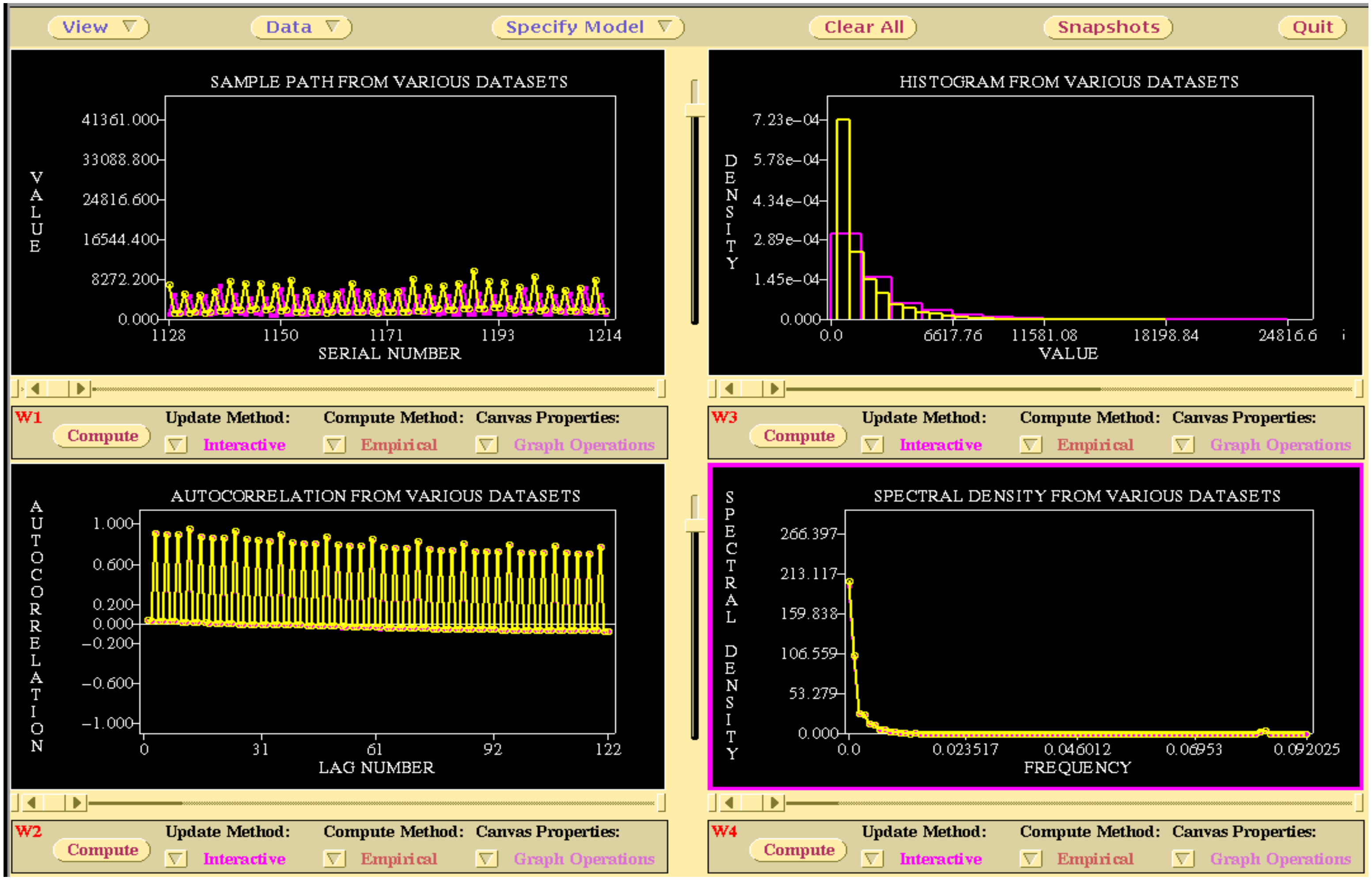
- Modeling VBR video with interframe compression:
- Step 1: Isolate I frame and modeling the I-frame process
- Step 2: Rescale the estimated autocorrelation of the I frames

$$r(k) = r_I\left(\frac{k}{K_I}\right)$$

- Step 3: Generate foreground process using different transforms for I, B, P frames based on their marginal distributions



Self-Similar MPEG VBR Video Traffic Model

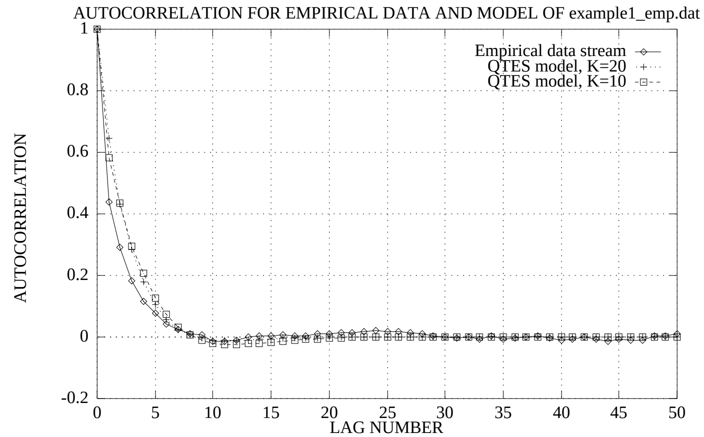


Automated QTES Traffic Modeling

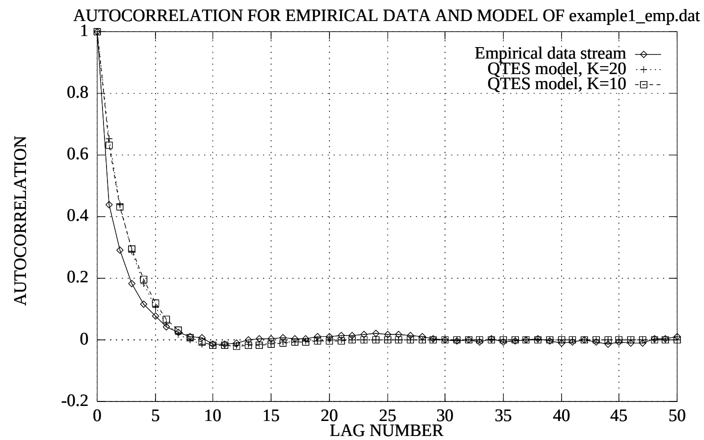
- Researched and implemented *QTES*, a background/foreground scheme for modeling “bursty” real data in high-speed networks.
- Built an automated software package for the modeling of real traffic in broadband networks:
  - uses initial search followed by non-linear optimization techniques
  - matches the autocorrelation function and marginal distribution of the empirical data
- Implemented a correlated traffic generator using the QTES modeling methodology.
- Used real data traffic (VBR MPEG video streams) for validation and testing.

Automated Traffic Modeling: "BBC News"

- Using a "blind" or exhaustive initial search:

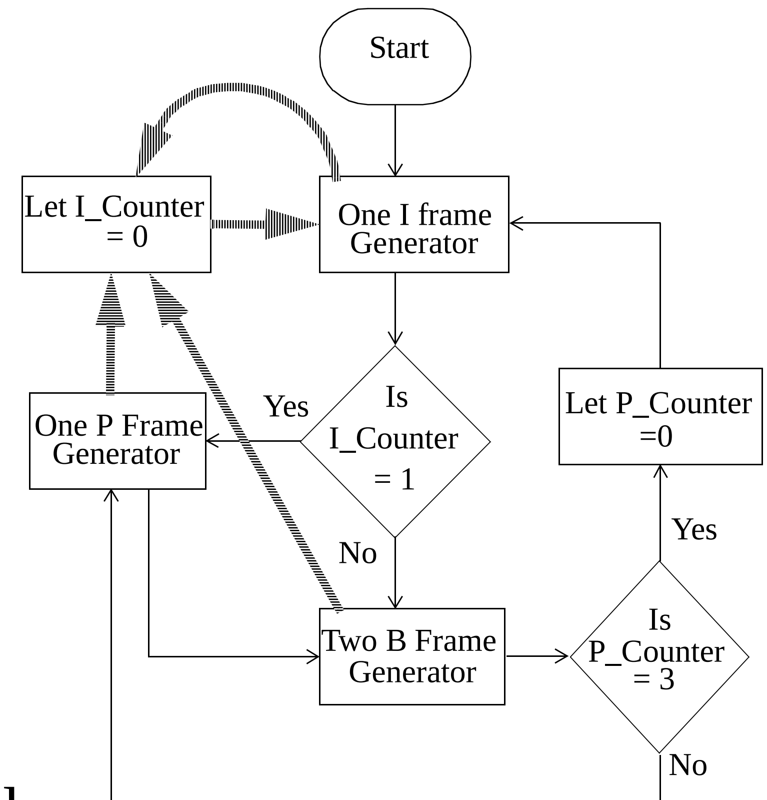


- Using a "randomized" initial search (less time-consuming):



VBR Video Traffic Modeling

- Difficulty: MPEG stream very complex, has periodic components
- Solution: Frame-level AMP model, modulate with slice distribution
- AMP for high priority
- I, B, P frames interleaved according to MPEG standard:



- Similar results for H.261 video

AMP-Based MPEG VBR Video Traffic Model

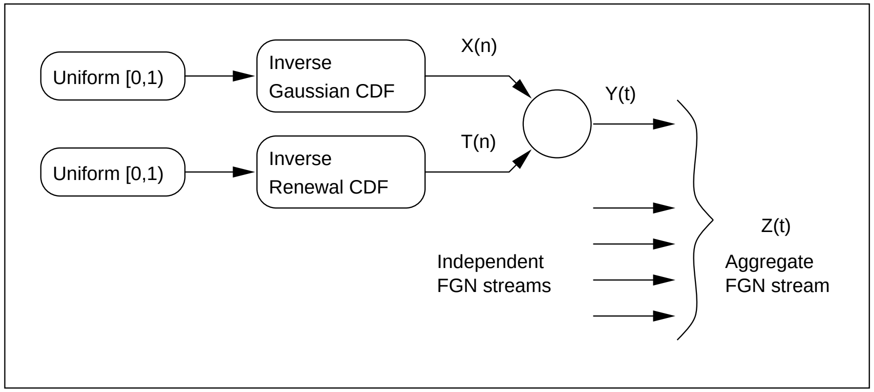
InterLAN Traffic Model

- InterLAN Traffic Model:
  - Using *QTES* process to model the streams of packet sizes
  - Using Poisson process to model packet arrival pattern

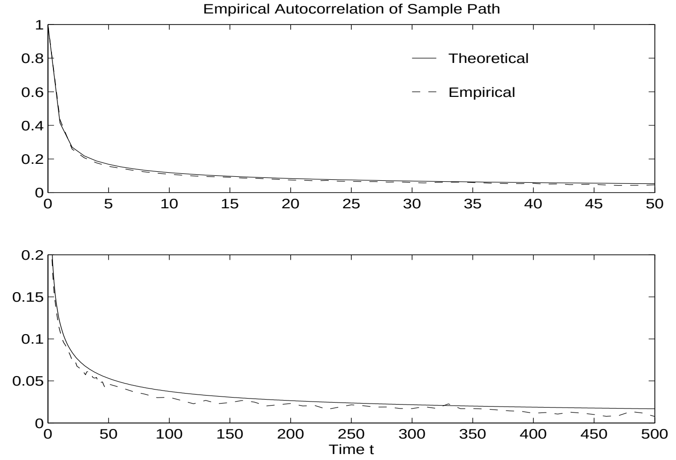
- On-Off model:
  - Geometric distributed ON period
  - Geometric distributed OFF period

Fractional Gaussian Noise Simulation

- Based on the Spatial Renewal Process

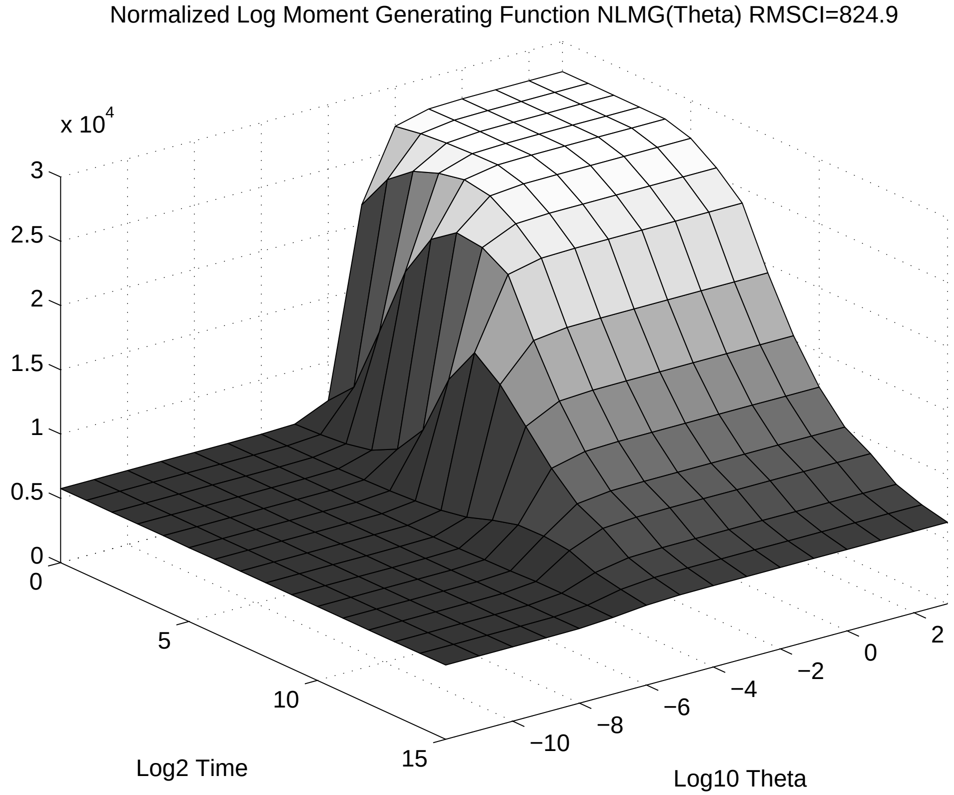


- Autocorrelation matches very well



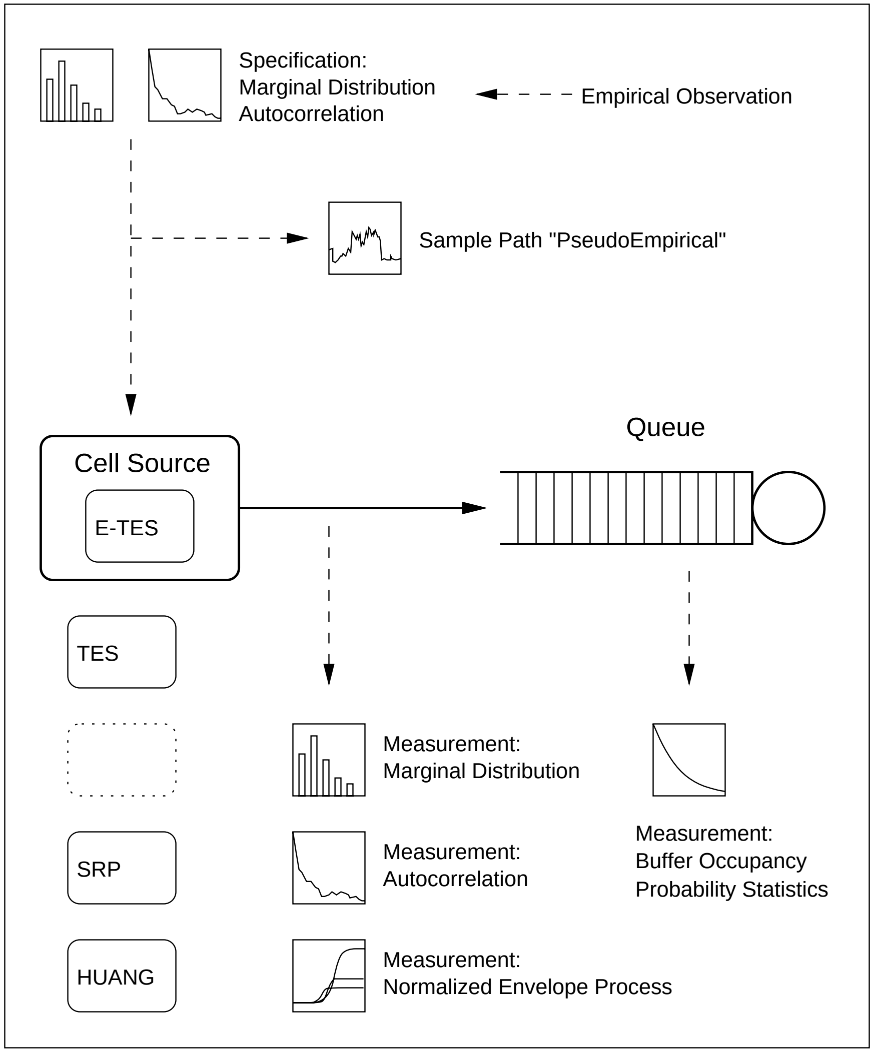
Queueing Comparison of Traffic Models-1

- Experimenting with new methods of traffic characterization based on the *Log-Moment-Generating* function.
- Related to the traffic-queueing technique of *Effective Bandwidths*.



Queueing Comparison of Traffic Models-2

- Buffer occupancy curve, as predicted by analysis or simulation, depends greatly on the input traffic and the accuracy of its characterization.
- Preliminary simulation results support that marginal and autocorrelation alone might not be sufficient to match real traffic for *network analysis*.



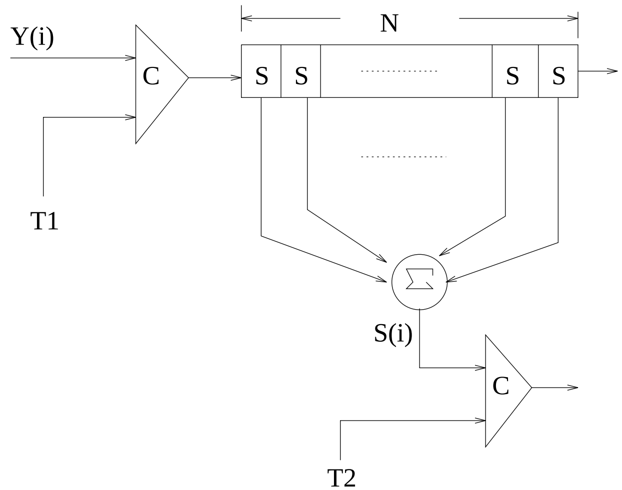
DTMW Control: Overview

Double Threshold Moving Window (DTMW) algorithm:

- Predicts traffic streams with LRD structure robustly
- Insensitive to marginal distributions, SRD structure
- Easy to integrate
- Allows easy and realistic Call Admission Control

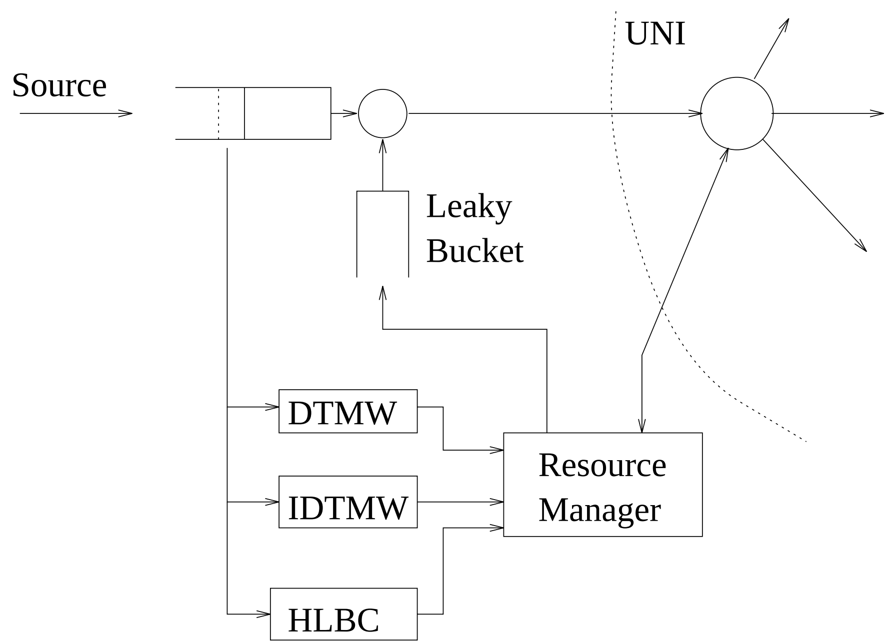
DTMW Control: Implementation

- Principles of operation: Dual thresholds
  - Smooths burstiness at small time scales
  - Identifies burstiness at long time scales
- Implementation



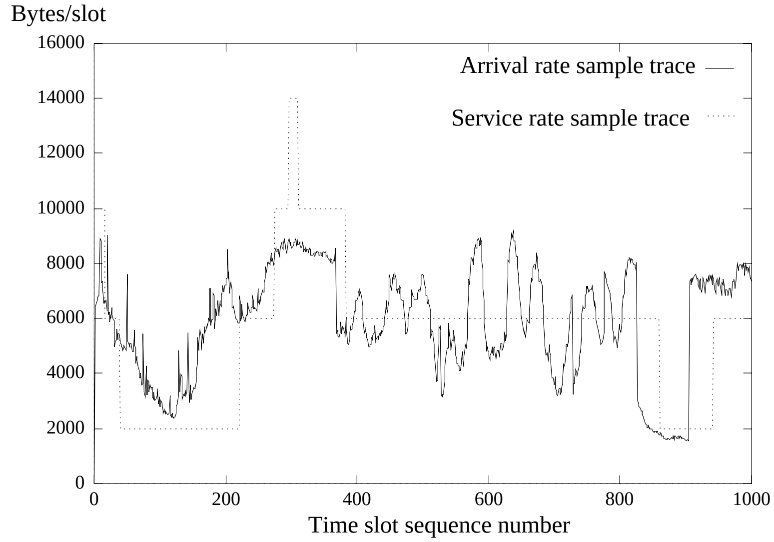
DTMW Control: Compatibility

- Controllable leaky bucket traffic shaper
- Easy to adopt in standards



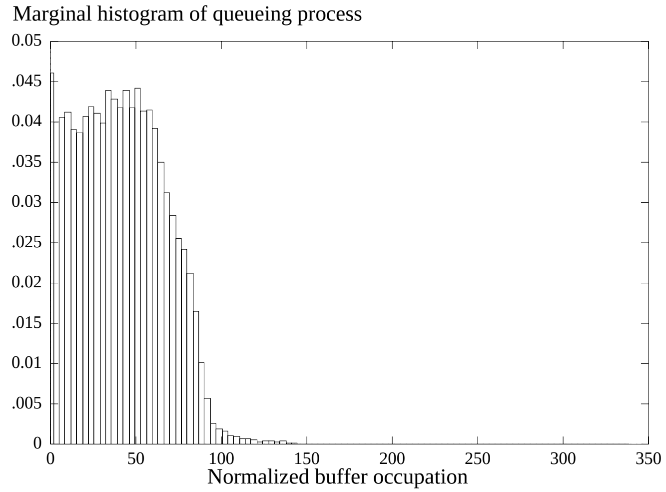
DTMW Control: Results - 1

- Controlled rate process

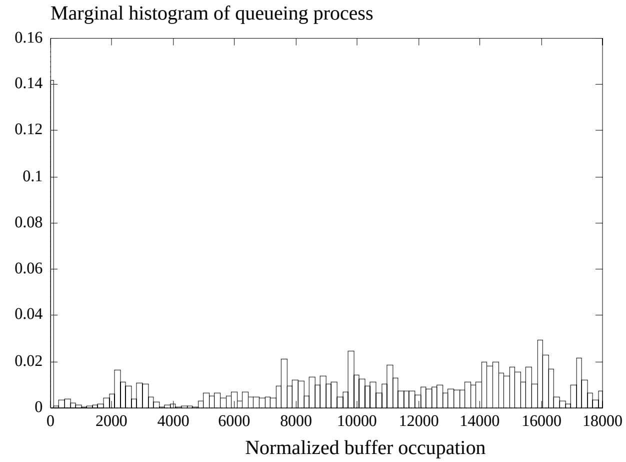


DTMW Control: Results - 2

- Controlled Queue histogram

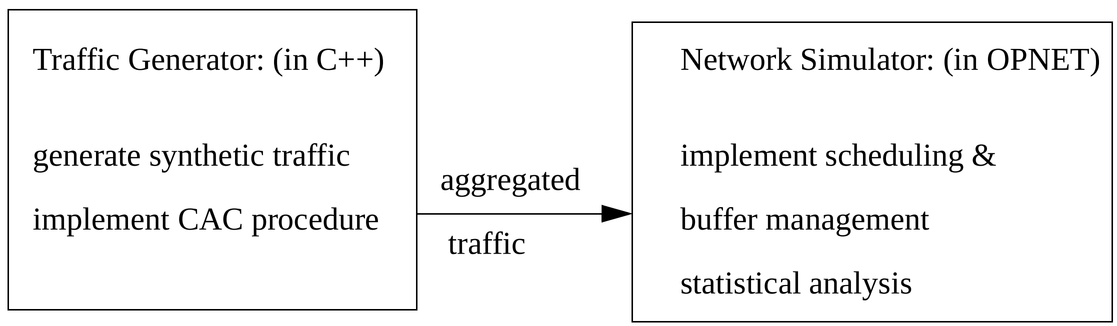


- Compare to uncontrolled case



VCPB: Simulation Set-Up

- *Cell level*: fluid model; *Burst level*: On-Off model, TES model for Video; *Connection level*: Markovian model



- Compare three scheduling and buffer management algorithms: FIFO scheduling & FCFU buffer; VirtualClock & FCFU buffer; VCPB
- Performance comparison: Mean Delay & Cell loss Probability

Technology Transfer

- GN Nettest (Software for InterWATCH 96000)
- Spar Aerospace (Software for traffic modeling modules in Opnet)
- Newbridge Networks Co. (Traffic modeling software)

Current and Future Directions

- Extend library of efficient traffic generation models and software to other broadband applications including broadband Internet
- Investigate impact of self-similarity on congestion control and provisioning
- Devise and implement more efficient generators; already in progress
  - Self-similar generator based on aggregation
  - Generator based on chaotic maps
- Experiment with on-line traffic generation, on-line monitoring
- Implement importance sampling within traffic generation library for fast simulation of rare events (e.g., ATM cell losses)