LOSS CONCEALMENTS OF SUBBAND CODED IMAGES FOR REAL-TIME TRANSMISSIONS IN THE INTERNET

Benjamin Wah and Xiao Su

Department of Electrical and Computer Engineering
and the Coordinated Science Laboratory
University of Illinois, Urbana-Champaign
Urbana, IL 61801
Email: *wah@manip.crhc.uiuc.edu*

August 29, 2002

Outline

- Introduction
- Internet loss and delay behavior
- ORB-ST for concealing bursty losses
- Delay-quality trade-offs of coding and transmission schemes
  - UDP delivery of MDC coded Images
  - Combined TCP/UDP delivery of SDC/MDC images

Motivation

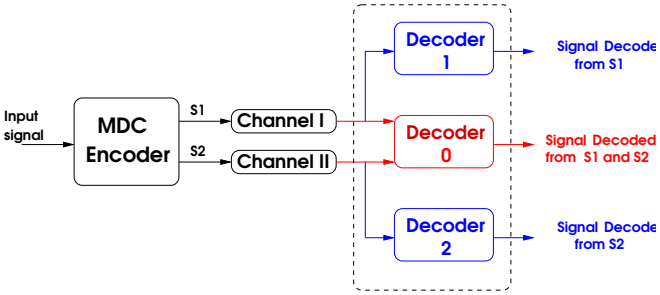
- Two measures to assess image transmissions
  - Quality
  - Delay
- Conventional TCP delivery from Web servers *only* emphasizes good quality
- Our objective:
  - Design coding and transmission schemes with good quality *and* short delays

Previous Work: An Overview

- Image transmission schemes from Web servers
  - Reliable but slow TCP
- Loss concealment schemes
  - Sender-based
  - Receiver-based
  - Sender-receiver based

Sender Side: Two Types of Robust Coding

- Layered coding
  - Base and enhancement layers + priority assignment
- Multiple description coding (MDC)
  - Equally important streams: attractive approach for best-effort Internet



Receiver Side: Loss Concealment

- Receiver-based schemes:
  - Spatial domain recovery
    - ∗ Assumes smoothness in certain regions and image structures
  - Temporal domain recovery
    - ∗ Not applicable in image transmissions
  - Frequency domain recovery
    - ∗ Not enough correlation to yield good quality

Sender-Receiver Based Schemes

- Joint source channel coding
  - Joint design of quantizer and channel coder, based on given channel model
  - The Internet does not have a well defined channel model
- Interleaving and reconstruction
  - Simple and efficient
  - Interleaving is done independent of reconstruction algorithms
- No existing schemes take into account reconstruction process

Outline

- Introduction
- Internet loss and delay behavior
- ORB-ST for concealing bursty losses
- Delay-quality trade-offs of coding and transmission schemes
  - UDP delivery of MDC coded Images
  - Combined TCP/UDP delivery of SDC/MDC images

Collecting Packet Traces

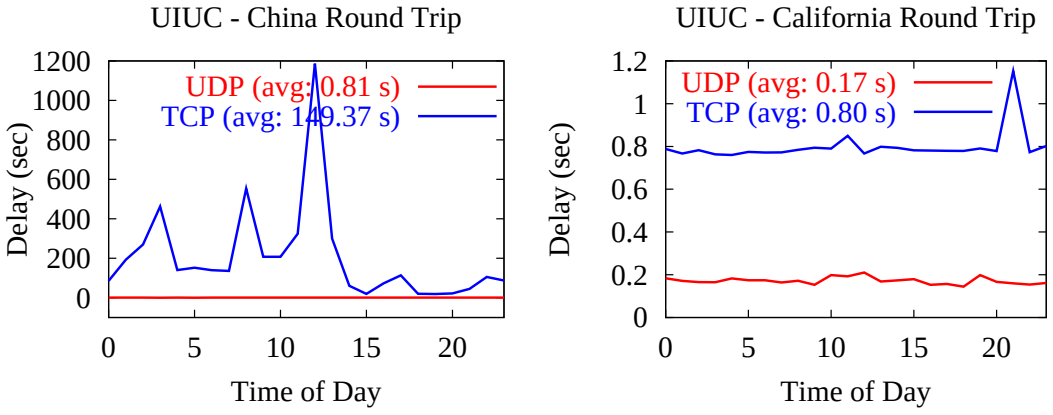
- Choose destination sites

Location	Host Name	Characteristics
California	`daedalus.cs.berkeley.edu`	low-loss
China	`www.shmu.edu.cn`	high-loss

- Send packets to destination echo ports, simulating image transmissions
- Collect packet traces on losses and delays
- To fairly compare TCP and UDP:
  - Modify Linux kernel
  - Encapsulate TCP packets in UDP ones

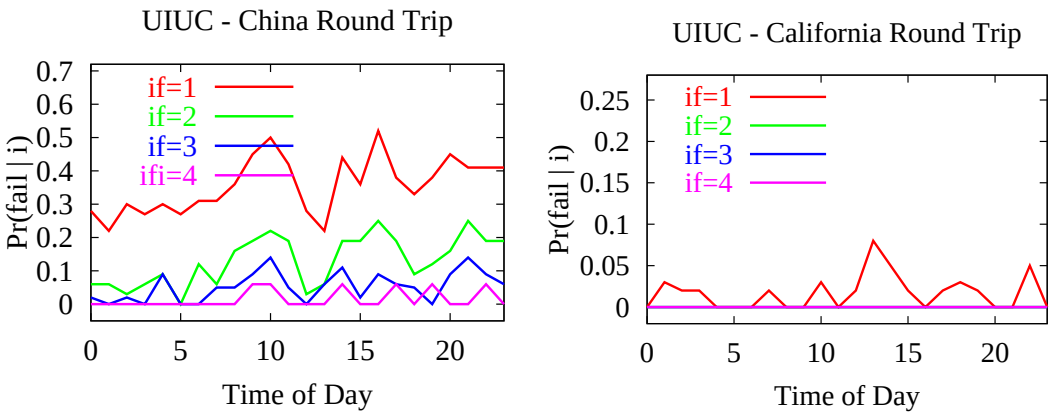
Comparisons of Round-Trip TCP and UDP Delays

512-by-512 image, 8:1 ratio, 512-byte packets $\Longrightarrow$ 64 packets



- UDP delivery has shorter delays and smaller jitters

Characteristics of UDP bursty Losses

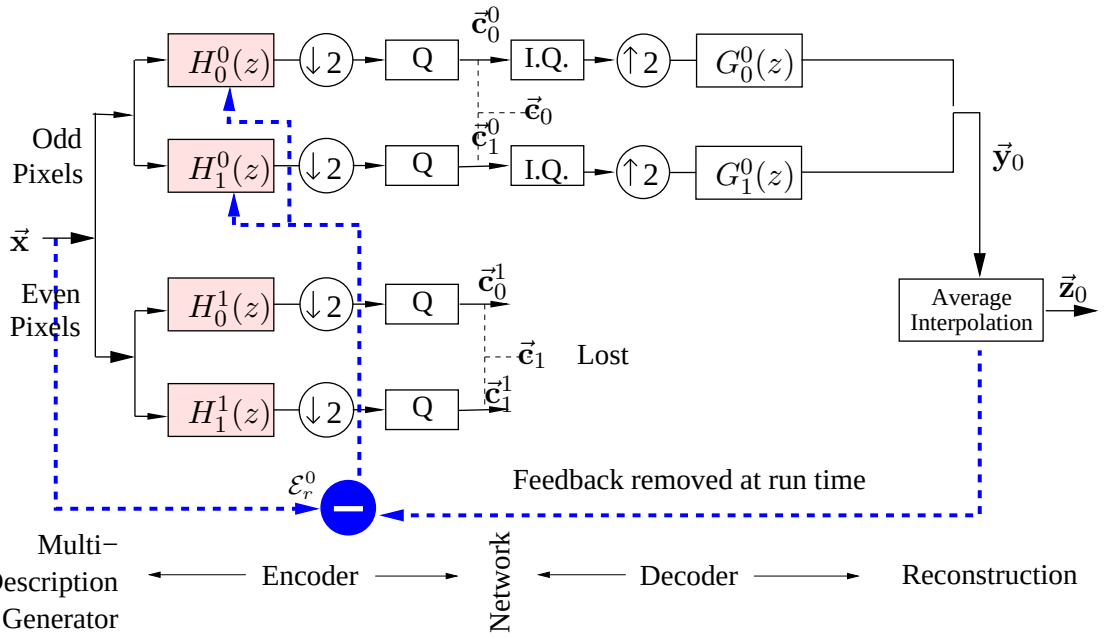


- UDP packet losses can be concealed using
  - Interleaving factor of four in high-loss connections
  - Interleaving factor of two in low-loss connections

Outline

- Introduction
- Internet loss and delay behavior
- ORB-ST for concealing bursty losses
- Delay-quality trade-offs of coding and transmission schemes
  - UDP delivery of MDC coded Images
  - Combined TCP/UDP delivery of SDC/MDC images

Basic Building Blocks of ORB-ST Coders



Derivations of ORB-ST

Objective: Find $H(x)$ to minimize reconstruction error under packet losses

Derivation Steps (while ignoring quantization):

1. Derive $\vec{\mathbf{y}}_0$ after synthesis filtering

$$\vec{\mathbf{y}}_0 = \hat{\mathsf{G}}\, \vec{\mathbf{c}}_0$$

where $\hat{\mathsf{G}}$ represents synthesis filtering in spatial domain

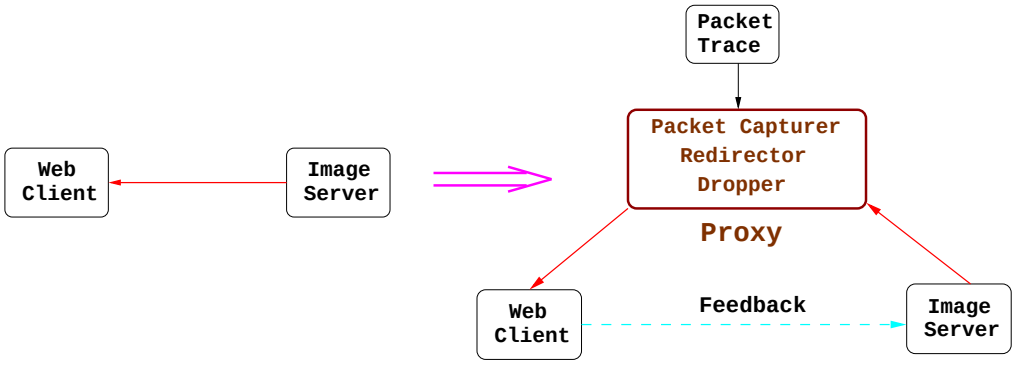
2. Derive $\vec{\mathbf{z}}_0$ after average interpolation

$$\vec{\mathbf{z}}_0 = \mathbf{U}\, \hat{\mathsf{G}}\, \vec{\mathbf{c}}_0$$

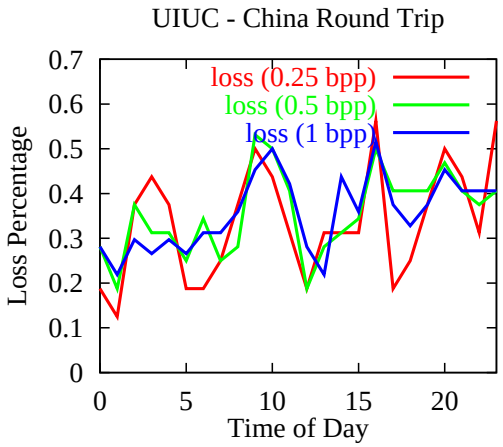
where $\mathbf{U}$ represents average interpolation

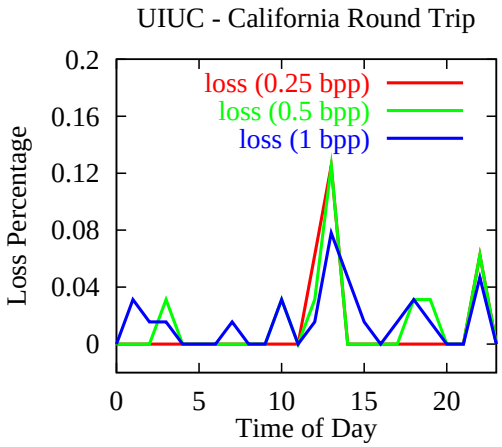
Comparing Original ST and ORBST

- Challenge: *How to fairly compare two different schemes?*
- Trace-based comparisons
  - Compare systems under the same traffic conditions
  - Evaluate visual quality at the same bit rate

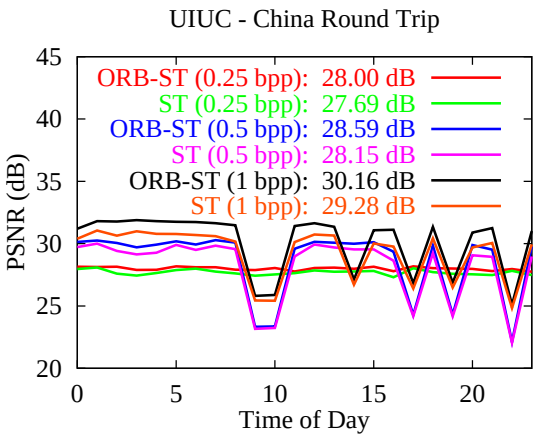


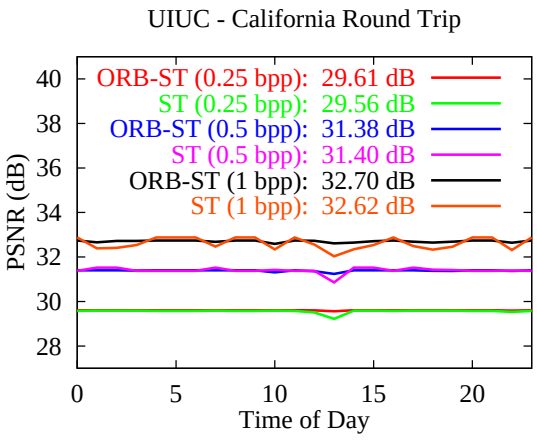
Comparison Results: Loss Rates





Comparison Results: Reconstruction Quality

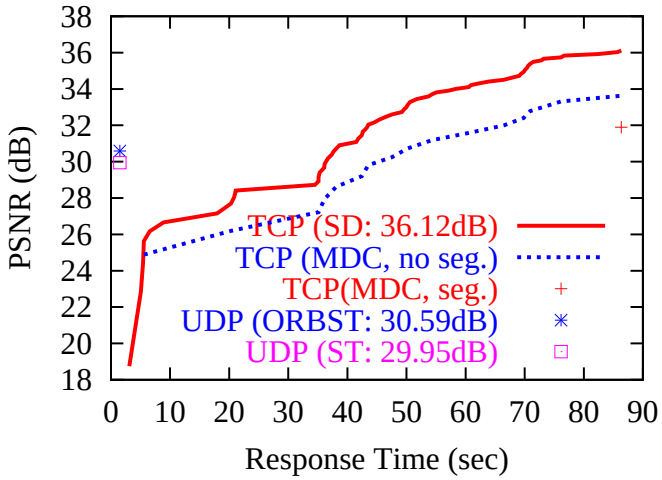




Outline

- Introduction
- Internet loss and delay behavior
- ORB-ST for concealing bursty losses
- Delay-quality trade-offs of coding and transmission schemes
  - UDP delivery of MDC coded Images
  - Combined TCP/UDP delivery of SDC/MDC images

Delay-Quality Trade-offs in Delivery of Goldhill to China



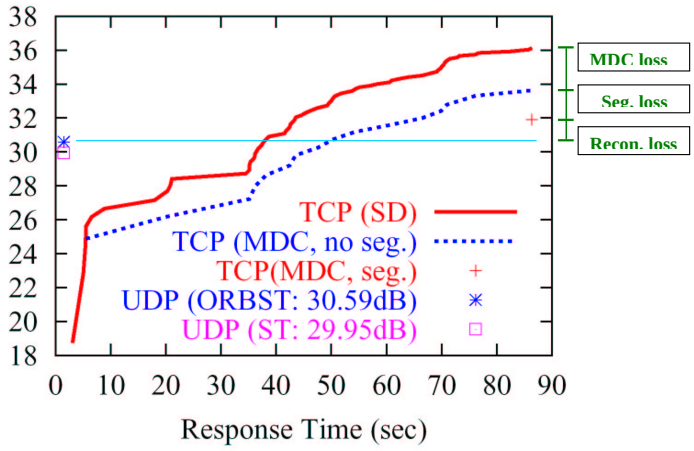
- Given the same time of UDP delivery, TCP delivery leads to poorer quality

Comparison of Image Quality

Goldhill to China by TCP
PSNR: 36.12 dB

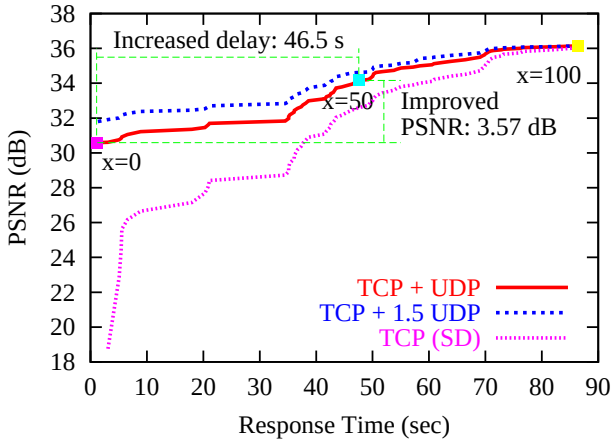
Goldhill to China by UDP
PSNR: 30.59 dB

Analysis of Delay-Quality Trade-offs



- MDC: 1 to 3.5 dB
- Suboptimal segmentation: 2 to 3.5 dB
- Packet losses and reconstruction: 1 to 2 dB

Delay-Quality Trade-offs of Combined Delivery to China



Improved quality than pure UDP delivery of MDC images

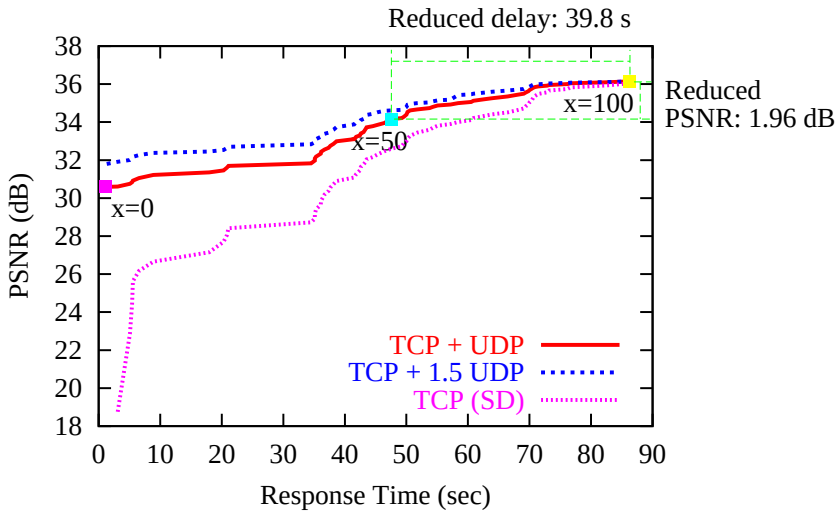
- Combined TCP/UDP delivery:
  - $x\%$ is coded by SDC and delivered by TCP
  - $(100 - x)\%$ is coded MDC and delivered by UDP

Comparison of Image Quality

Goldhill to China
by 0.5 TCP + 0.5 UDP
PSNR: 34.16 dB

Goldhill to China by UDP
PSNR: 30.59 dB

Comparison with Pure TCP Delivery of SDC Images



- Improved quality than pure UDP delivery of MDC images
- Reduce delay than TCP delivery of SDC images

Conclusions and Future Work

Conclusions:

- Image transmission involves a trade-off between delay and quality
- Proposed optimized reconstruction-based subband transform
- Explored several coding and delivery algorithms

Future Work:

- Choose (delay, quality) points based on user resources
- TCP-friendly transmissions to avoid network congestion