A New Adaptive FEC Loss Control Algorithm for Voice Over IP Applications

Chinmay Padhye, Kenneth Christensen and Wilfirdo Moreno
Department of Computer Science and EE
University of South Florida
Tampa, FL

IEEE Intl. Perf, Computing and Comm Conf
Feb 2000

Introduction

- Voice over IP effort driven by potential cost savings
- Successful: NeVoT, RAT and Free Phone
- Must have:
  - End-to-End delay of 250-500 ms
  - Packet loss of 5% or less
- Typically, 20 ms sample rate
  - Human phoneme is 80-100 ms
- Use FEC to compensate for loss
  - But existing FEC doesn't work in all situations

→ A New Adaptive FEC algorithm

Outline

- Introduction
- *Related Approach (Bolot)*
- New Approach (USF)
- Evaluation
- Conclusion

Repair Technique Choices

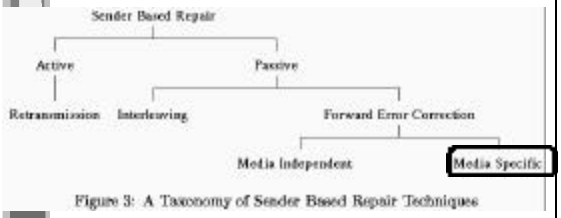
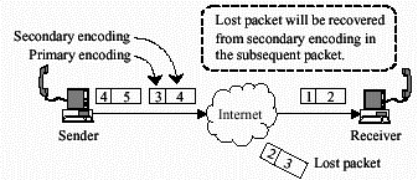


Figure 3: A Taxonomy of Sender Based Repair Techniques

- Media specific FEC repairs well and has low delay

Media Specific FEC



- Lower quality repair
- If packet *N* carries redundant of *N-i* and *N-i* is lost then will have delay of *I*
- What if (3,4) also lost?
- Can increase redundancy to recover from multiple losses
- But can waste bandwidth, so only when needed

Adaptive FEC: The Bolot Algorithm

- Maintain the loss rate between LOW and HIGH loss rate limits
  - (*Is this TCP Friendly?)*
- Add redundancy if above HIGH and remove if below LOW
  - (*Why not just one threshold?)*
- Amount to add looked up in table

Bolot FEC Combinations

Combination	Packets sent	Reward
0	0	1
1	0,1	2.5
2	0,2	6
3	0,1,2	6
4	0,1,3	10
5	0,1,2	6
6	0,1,3	10
7	0,1,2,3	18
8	0,1,2,3	18
9	0,1,2,3,4	18
10	0,1,2,4	18
11	0,1,3	10
12	0,1	2.5
13	0,2	6

- (0,1) means *primary* packet 0 and *redundancy* packet 1
- *Reward* is %loss before / %loss after - empirically

Bolot Algorithm

- RTCP packets carry number packets loss last 5 seconds

```
For each RTCP packet received do
   1. Calculate the percentage of
      packets lost before
      reconstruction, Pb
      Pb = Number of packets lost before
      reconstruction / Number of
      packets expected
   2. Calculate the percentage of
      packets lost after
      reconstruction, Pa
      Pa = Pb / Reward associated with
      current combination number
   3. If (Pa > HIGH) then
         Increment combination
   4. If (Pb < LOW) then
         Decrement combination
```

(Note! No notion of low quality)

Shortcomings of Bolot Algorithm

- Reward is based on empirical results
  - Current network may be different
- Many burst losses of 10 or greater packets
  - FEC cannot recover
  - Increasing redundancy a waste of bwidth
- Even with LOW and HIGH may still have cyclic (add/remove redundancy) behavior

Adaptive FEC: The New USF Algorithm

- "Build upon" Bolot (key phrase)
- Use RTCP with two extensions
  - Number of packets lost after reconstruction
  - Number of packets lost in loss bursts

Combination	Packets sent
0	0
1	0, 1
2	0, 2
3	0, 1, 2
4	0, 1, 3
5	0, 1, 2, 3
6	0, 1, 2, 4
7	0, 1, 3, 4
8	0, 1, 2, 3, 4

- Increase delay first
- Increase redundancy next

USF Alg.

```
For each RTCP packet received do
   1. Calculate packet loss after
      reconstruction, Pa
      Pa = Number of packets lost after
      reconstruction / Number of
      packets expected
   2. Calculate packet loss before
      reconstruction, Pb
      Pb = Number of packets lost before
      reconstruction / Number of
      packets expected
   3. If (Pa > HIGH) then
         Subtract packets lost in loss
         bursts and recalculate Pa
   4. If (Pa > HIGH) then
         Increment combination
   5. If (Pa < LOW) then
         Loss difference = Pb(previous)
         - Pb
   6. If (Loss difference >
         MINIMUM_THRESHOLD) then
         Decrement combination
   5. Set Pb(previous) = Pb
```

- Avoid adding during bursts
- Should prevent cycles

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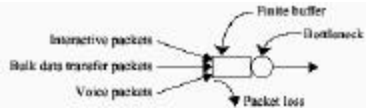
Evaluation: Simulate Effect on Network

- Simulate network with empirical traces
  - Audio conference
    - + (used probes, too?)
  - Receiver at Umass Amherst
  - Sender at LA, Seattle (20 ms) and Atlanta (40 ms)
  - Synthetic (queuing model)
  - Loss rates 1.4% to 3.8%
- Simulate network with synthetic traces
  - Get higher loss rates 1.7% to 35%



- 4:6 interactive To bulk
- Audio 20 ms, others expn.

Simulation Results on Internet Traces

- LOW and HIGH at 3% for USF and Bolot
- MINIMUM_THRESHOLD 3% for USF

#	Network Loss	Loss w/ Bolot	Loss w/ USF	Ratio
1	1.69 %	1.54 %	0.61 %	2.5
2	3.76	2.64	0.91	2.9
3	1.38	1.27	0.66	1.9
4	3.37	2.47	0.86	2.8
5	2.22	1.94	1.07	1.8

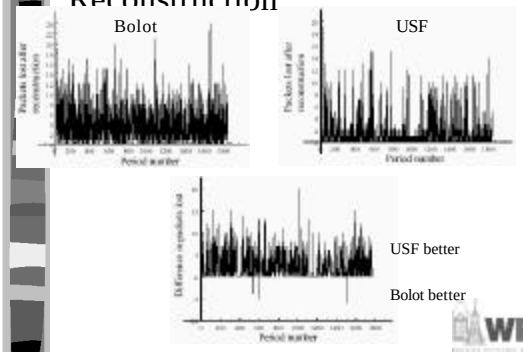
- USF has ½ to 1/3 as much loss

Simulation Results on Internet Traces

- How often loss above HIGH mark?

#	Total Periods	Total Above	Above w/ Bolot	Above w/ USF
1	1775	196	167	50
2	1510	922	583	132
3	1773	118	101	40
4	1512	489	356	94
5	4320	865	689	322

Packets Lost After Reconstruction

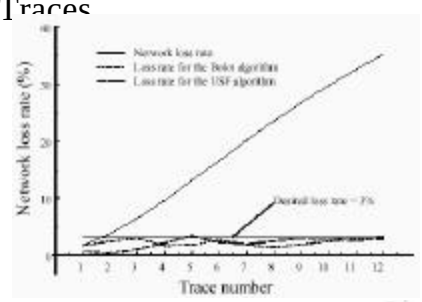


Simulation Results on Synthetic Traces

Network Loss	Loss w/ Bolot	Loss w/ USF	Ratio
1.67 %	1.66 %	0.56 %	2.9
3.67	2.41	0.28	8.6
6.53	2.90	1.02	2.8
9.61	1.67	2.13	0.8
13.11	1.76	3.36	0.5
16.57	2.60	2.18	1.2
20.04	1.80	1.92	0.9
23.42	1.36	2.42	0.5
26.62	1.86	2.96	0.6
29.63	2.39	2.93	0.8
32.44	2.78	2.51	1.1
35.09	3.18	2.80	1.1

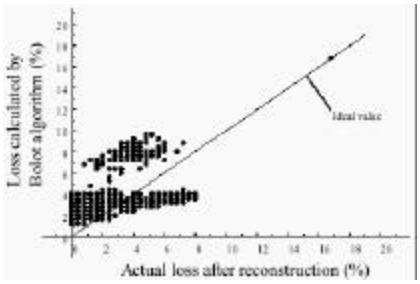
- Target loss rate is 3%
- USF better for low loss.
- Same for high loss

Simulation Results on Synthetic Traces



(Accuracy of Bolot reward prediction?)

Error in Packet Loss by Bolot



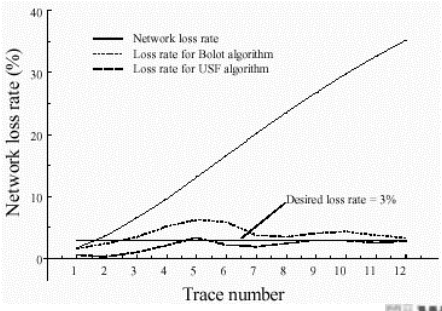
(If we fix this (specific for these traces), better?

Tuned Bolot Algorithm

Network Loss	Loss w/ Bolot	Loss w/ USF	Ratio
1.67 %	1.64 %	0.56 %	2.9
3.67	2.43	0.28	8.6
6.53	3.49	1.02	3.4
9.61	5.18	2.13	2.4
13.11	6.25	3.36	1.8
16.57	5.91	2.18	2.7
20.04	3.72	1.92	1.9
23.42	3.5	2.42	1.4
26.62	4.08	2.96	1.3
29.63	4.32	2.93	1.4
32.44	3.76	2.51	1.5
35.09	3.32	2.80	1.2

• USF still better

Tuned Bolot Algorithm



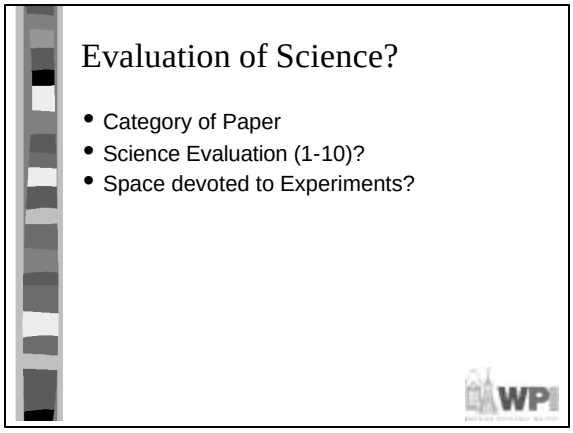
(Me: implied benefits from combos or bursts…)

Conclusions

- Bolot uses empirical trace and independent loss assumption
- USF dynamically changes redundancy in stream based on loss measured
- Detects bursts of loss and ignores
- USF works better than Bolot for loss rates of 1.5% to 35%

Future Work

- Quantify bandwidth savings
  - FEC had no impact on loss here
- More packet traces
- Quantify setting thresholds
- Benefits to real audio in user study
- (Me: Adaptive FEC based on *available* bandwidth)


Evaluation of Science?
• Category of Paper
• Science Evaluation (1-10)?
• Space devoted to Experiments?
WPI