A Service Provider's Approach for Improving Performance of Aggregate VoIP Traffic

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Motivation

- ? Concerns about quality
  - Packet audio
    - ? Unpredictability in delay – hampers interactivity
    - ? High/bursty losses – deteriorates call quality
- ? Susceptibility to Denial-of-Service (DoS)
  - Vulnerabilities in VoIP equipment
  - Internal/external threats from hacking
  - DoS attacks, worms, viruses, Trojans

Motivation

- Current defenses of FEC are applied at endhost
- Limited options for service providers to improve quality on their own
  - Better quality links
    - VPNs, dedicated bandwidth links, QOS
- Most Providers rely on carrier links
  - How to protect against DOS attacks?

Motivation

- Many Providers use public Internet in some parts of the network
  - Best Effort Service
  - More susceptible for DOS attacks
- Need mechanisms for service providers to distinguish from each other
  - Providing better QOS
  - Providing better DOS protection

Background -- Call Quality

? MOS: human ratings
  - 1 (poor) – 5 (excellent)

? Network characteristics

	Good	Acceptable	Poor
Delay	0ms -150ms	150ms - 300ms	> 300ms
Jitter	0ms - 20ms	20ms - 50ms	> 50ms
Loss	0% - 0.5%	0.5% - 1.5%	> 1.5%

? E-model (R) – telecommunications networks
  - Additive effect of impairments

Speech Codecs

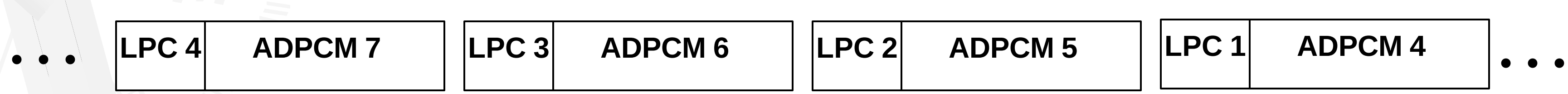
- Waveform coders
  - High quality, high bandwidth
- Vocoders
  - Synthetic quality, very low bandwidth
- Hybrid

Codec	**PCM**	**ADPCM**	**GSM**	**LPC**
Rate (kbps)	64	16 - 40	13	4.8
MOS	4.4	2 - 4.3	3.7	2.6
R	94.3	39 - 90	70	50
MIPS	0.01	2	6	7

Signal Processing-Based FEC

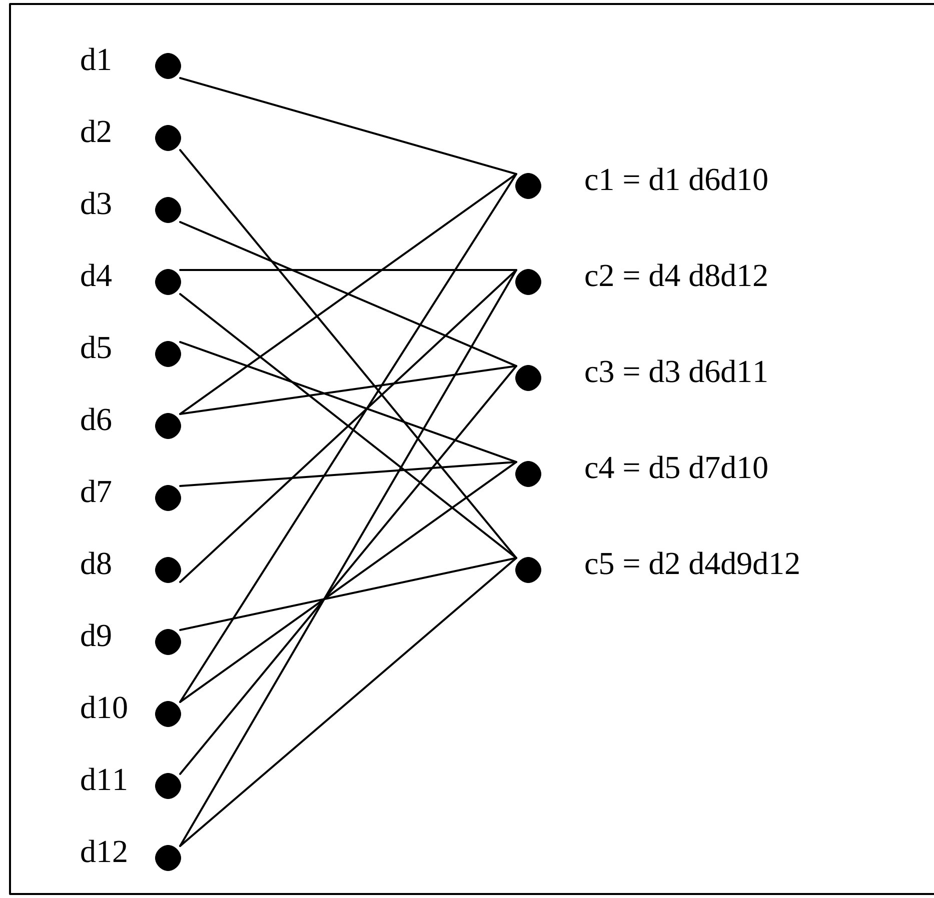
? Original Stream
- PCM
- ADPCM

? Redundant Streams
- GSM or LPC
- Variable number of streams



Low-Density Parity Check (LDPC)

- Transmits close to channel capacity
- Linear encoding and decoding times
- Larger block sizes improve recovery



FEC Terms

- Original data of k bits
- Redundant data of m bits
- Rate is k/(k+m)
- Redundancy is m/k
- Overhead is m/(k+m)

Proposed Scheme

Proposed Scheme

- ? Aggregate traffic at the ingress
- ? Protect aggregate traffic through coding along forwarding paths
- ? De-aggregate at the egress
- ? Can be done through overlays or at the switches
- ? Coding for larger amount of aggregate traffic more flexible than endhost single stream

Proposed Scheme

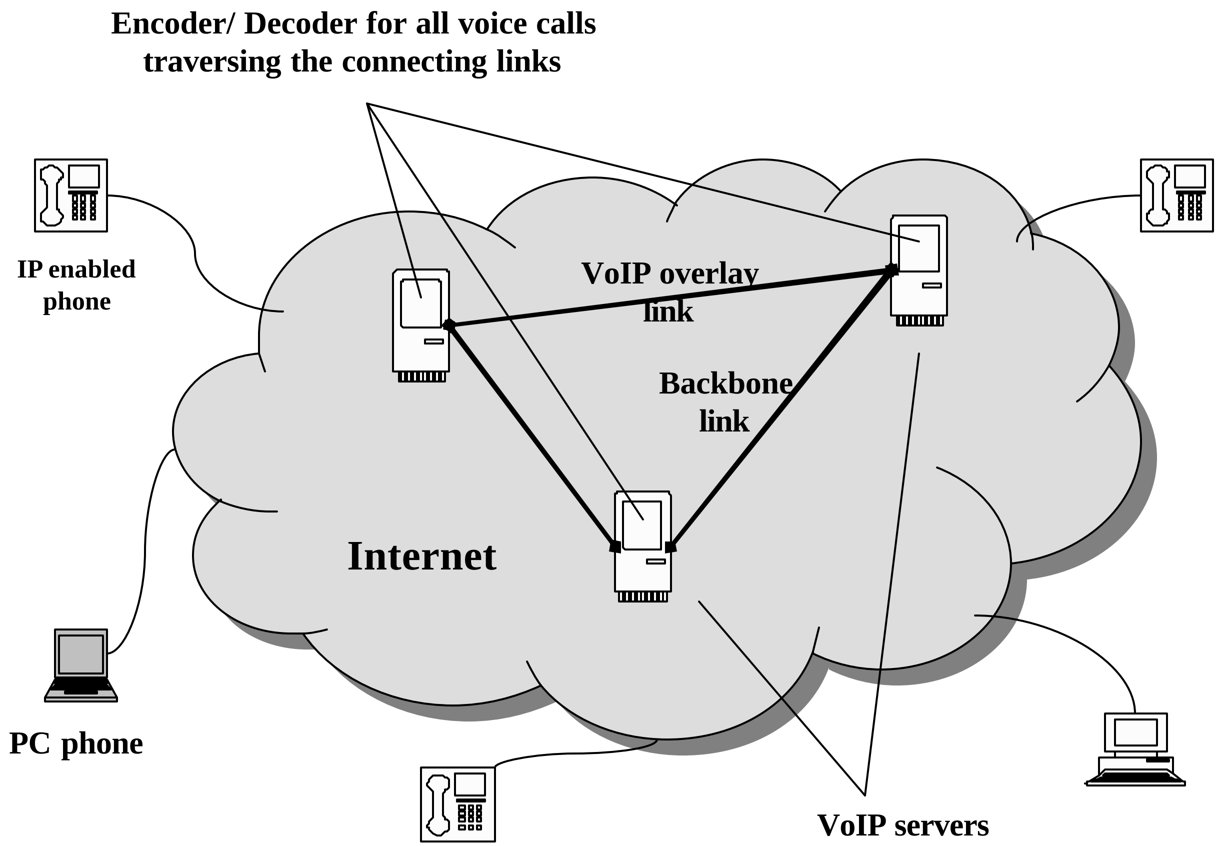
? Large volume of aggregated traffic enables

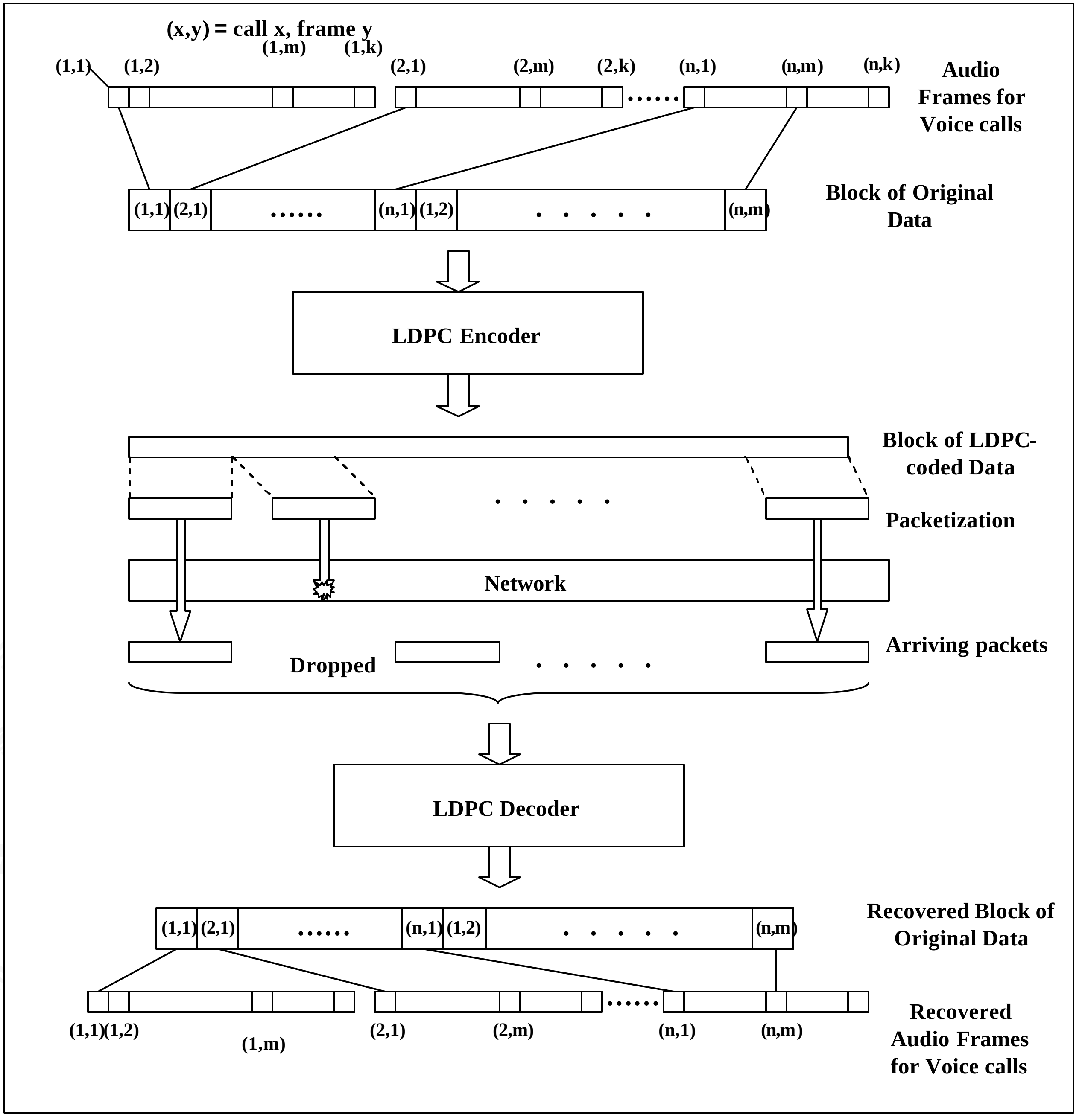
- More sophisticated coding without significant end to end delays for individual streams
- Enables more efficient coding of larger blocks of data
- Enables spreading data of single call across multiple packets
  - ? Improving packet loss and attack resiliency

Proposed Scheme

- ? In particular, considered LDPC codes
- ? Considered delays up to 50ms for aggregation
- ? At higher link capacities, larger amount of data and hence more efficient coding
  - Alternately, lower delays for same amount of data

Aggregation with LDPC

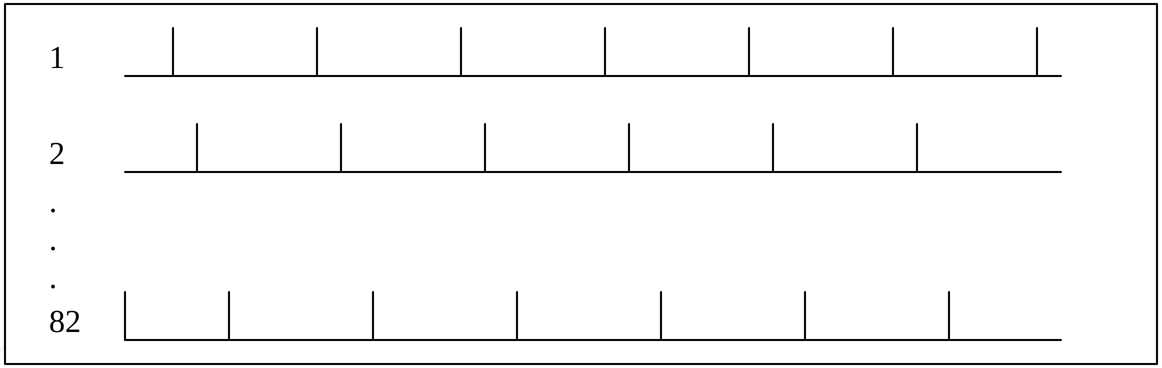



(x,y) = call x, frame y
(1,1)
(1,2)
(1,m)
(1,k)
(2,1)
(2,m)
(2,k)
(n,1)
(n,m)
(n,k)
Audio Frames for Voice calls
(1,1) (2,1) ...... (n,1) (1,2) . . . . . . (n,m)
Block of Original Data
LDPC Encoder
Block of LDPC-coded Data
Packetization
Network
Arriving packets
Dropped
LDPC Decoder
(1,1) (2,1) ...... (n,1) (1,2) . . . . . . (n,m)
Recovered Block of Original Data
(1,1)(1,2)
(1,m)
(2,1)
(2,m)
(n,1)
(n,m)
Recovered Audio Frames for Voice calls

Results and Evaluation

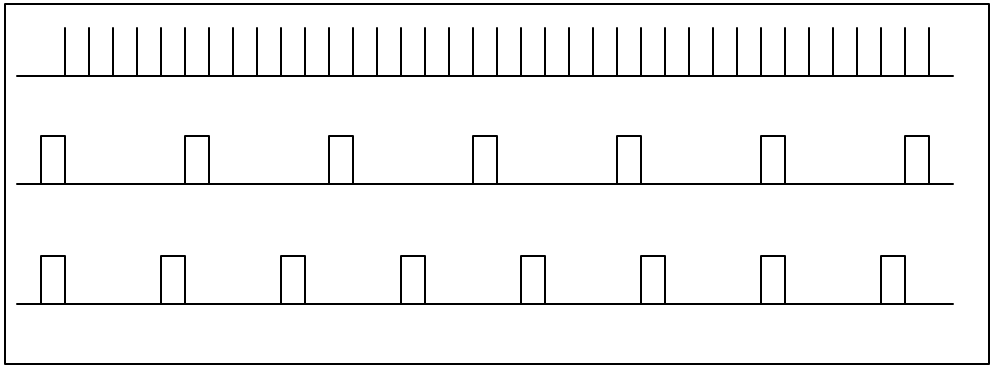
Simulation Setup

? Voice Traffic: 82 flows, 128B, 64 kbps



? Opposing Traffic:

- Single Flow
- Multiple Flows



SFEC options

		Original Stream			Redundant Stream				
SFEC Encoding		Codec	Bit-rate	R	Copies	Codec	Bit-rate	R	Rate
SFEC1	ADPCM /GSM1	ADPCM	16-40 kbps	50 -90	1	GSM	13 kbps	70	0.71
SFEC2	ADPCM /GSM3	ADPCM	16-40 kbps	50 -90	3	GSM	13 kbps	70	0.45
SFEC3	ADPCM /LPC1	ADPCM	16-40 kbps	50 -90	1	LPC	4.8 kbps	50	0.87
SFEC4	ADPCM /LPC3	ADPCM	16-40 kbps	50 -90	3	LPC	4.8 kbps	50	0.69

Single Flow Overload Traffic

Coding	Rate	Loss	Average R	% Toll
SFEC1	0.710	0.026	89.0	91.5
SFEC2	0.450	0.021	89.9	97.6
SFEC3	0.870	0.026	87.4	91.5
SFEC4	0.690	0.021	88.3	97.6
LDPC	0.833	0.003	92.9	100.0
LDPC	0.842	0.044	82.2	100.0

Resulting Quality for a load of 20% (11% loss) for a single CBR flow

Single attack flow observations

? Small VOIP packets can easily find enough buffers

? Large attack packets more likely dropped than smaller VOIP packets

? Attack flows need to resemble VOIP flows

Multiple Flows - Parameters

Scenario #	1	2	3	4	5	6	[redacted]
Link Load (%)	110	120	110	110	120	110	120
Packet Size (B)	128	64	128	64	64	128	64
Bit-rate (kbps)	64	32	128	64	64	146	[redacted]
# of CBR Flows	90	211	45	90	106	40	[redacted]
CBR Loss (%)	8.5	4.9	5.2	0.3	0.2	9.1	6.7
VoIP Loss (%)	9.9	32.4	13.5	18.9	38.4	10.6	30.0

Multiple Flows – Case 1

Coding	Rate	Loss	Average R	% Toll	% Acceptable
SFEC1	0.710	0.0635951	82.5	85.4	85.4
SFEC2	0.450	0.0337716	86.3	87.8	87.8
SFEC3	0.870	0.0635951	81.8	85.4	85.4
SFEC4	0.690	0.0337716	85.3	85.4	85.4
LDPC	0.850	0.0721328	76.2	0.0	100.0
LDPC	0.833	0.0431331	82.3	100.0	100.0
LDPC	0.800	0	94.3	100.0	100.0

Scenario 1: losses focused on subset of flows (loss 9.9%)

Multiple Flows – Case 2

Coding	Rate	Loss	Average R	% Toll	% Acceptable
SFEC1	0.710	0.170736	77.8	82.9	82.9
SFEC2	0.450	0.170736	77.8	82.9	82.9
SFEC3	0.870	0.170736	77.4	79.3	82.9
SFEC4	0.690	0.170736	77.4	79.3	82.9
LDPC	0.769	0.059484	78.9	0.0	100.0
LDPC	0.727	0	94.3	100.0	100.0

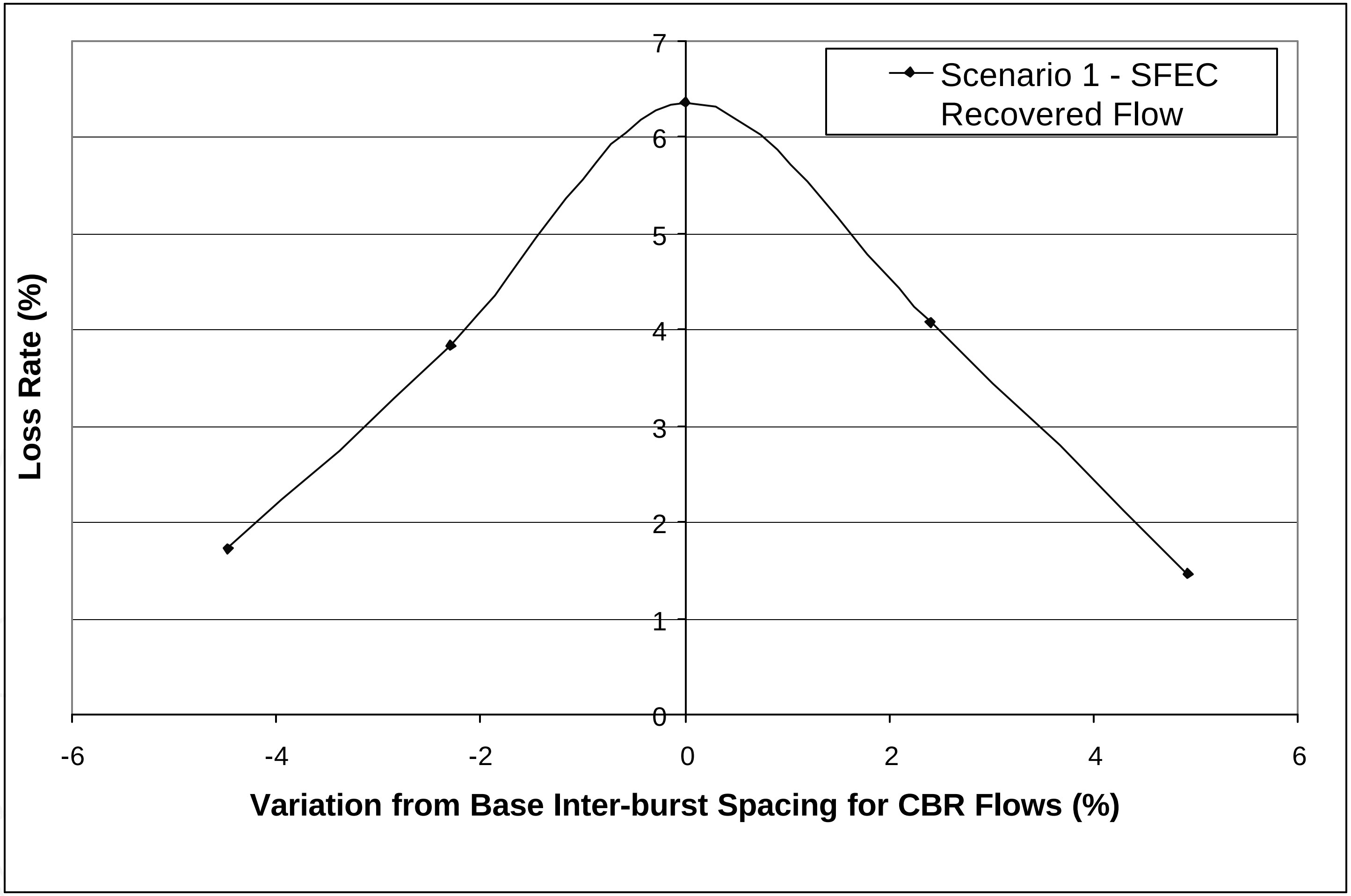
Scenario 4: losses focused on subset of flows (loss 18.9%)

Multiple Flows – Case 3

Coding	Rate	Loss	Average R	% Toll	% Acceptable
SFEC1	0.710	0.008768	89.3	97.6	100.0
SFEC2	0.450	0.000024	91.7	100.0	100.0
SFEC3	0.870	0.008768	87.3	97.6	100.0
SFEC4	0.690	0.000024	89.6	100.0	100.0
LDPC	0.875	0.069391	76.8	0.0	100.0
LDPC	0.850	0.039055	83.2	100.0	100.0
LDPC	0.833	0.028601	85.4	100.0	100.0
LDPC	0.800	0	94.3	100.0	100.0

Scenario 6: losses spread out among the flows (loss 10.6%)

Changing Parameters - CBR bit-rate

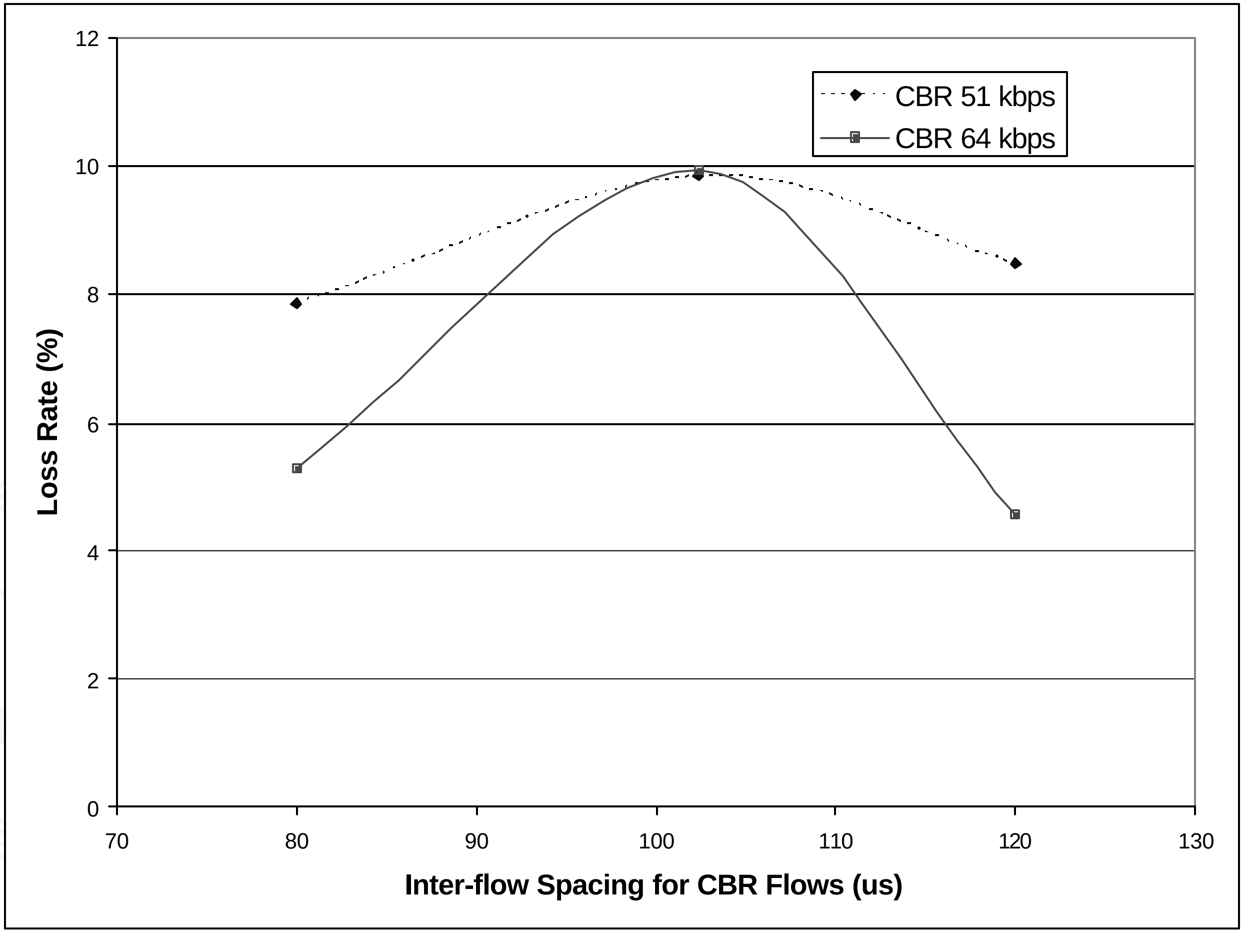


Changing Parameters - CBR bit-rate

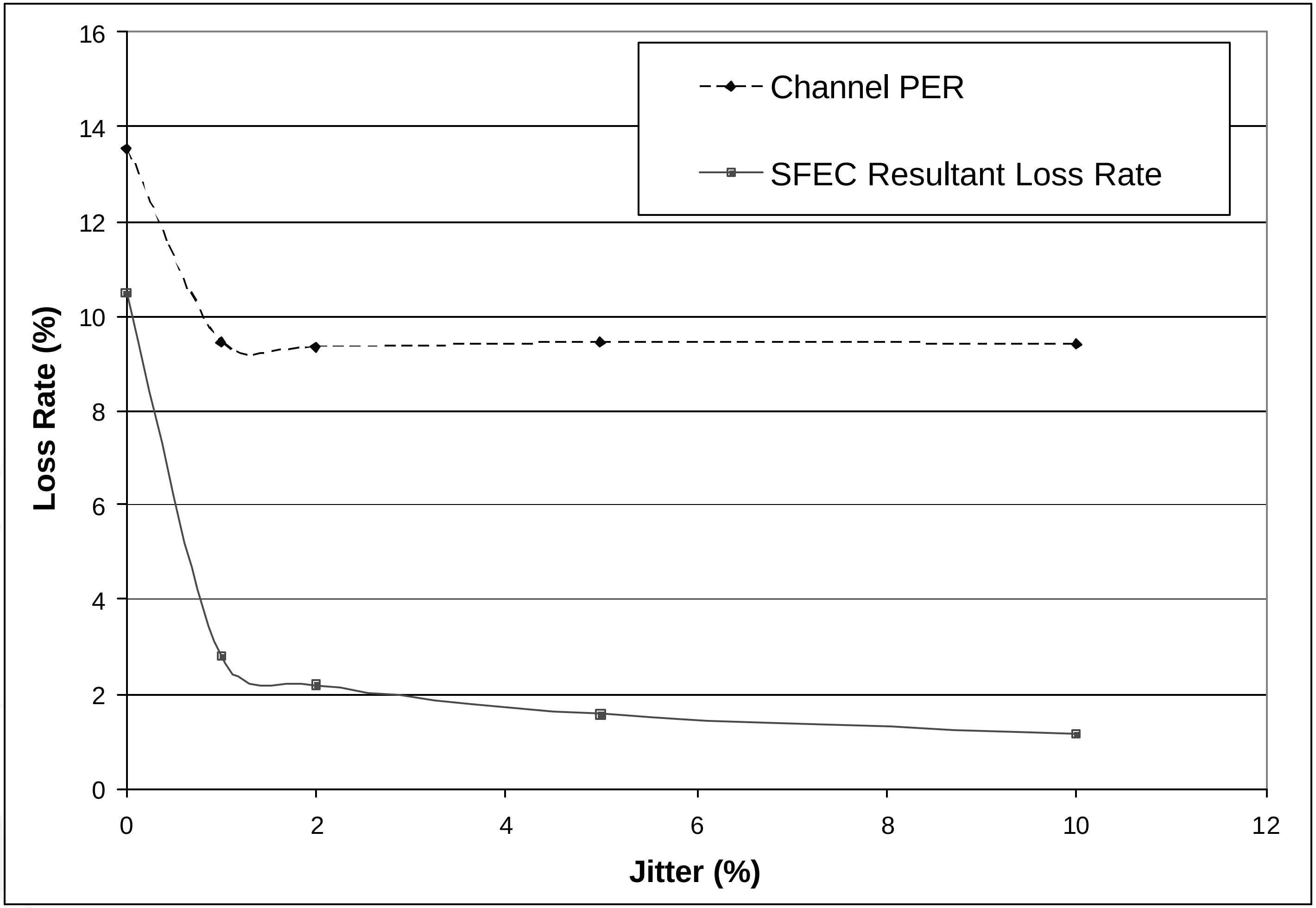
Coding	Rate	Loss	Average R	% Toll	% Acceptable
SFEC1	0.710	0.01727	86.3	98.8	100.0
SFEC3	0.870	0.01727	84.6	92.7	100.0
LDPC	0.850	0.01400	88.5	100.0	100.0

Performance of SFEC vs. LDPC with
-5% variation (loss = 9.8%)

Changing Parameters – Inter-flow spacing



Changing Parameters - Jitter



Changing Parameters - Jitter

Coding	Rate	Loss	Average R	% Toll	% Acceptable
SFEC1	0.710	0.01567	86.2	100.0	100.0
SFEC3	0.870	0.01567	84.6	100.0	100.0
LDPC	0.850	0.00263	93.0	100.0	100.0
LDPC	0.875	0.02979	85.1	100.0	100.0

Effect of a Jitter of 5% on Loss Recovery in Scenario 3

Conclusions

? Service providers can aggregate traffic and protect aggregate traffic

? Coding for aggregate traffic provides certain benefits over endhost FEC

- Better quality
- Lower redundancy
- Even distribution of losses
- Delay: comparable to SFEC
- Jitter: more controlled than SFEC
- Tolerance to burst errors and DOS attacks