LIANE—Composition for Active Networks

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http://www.cc.gatech.edu/projects/canes

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Active Networking

Active networks provide a *dynamically programmable* **user-network interface**

- *Users* supply both *programs* and data
- Network nodes both forward data and execute user programs

Benefits:

- Rapid and unilateral deployment of new protocols and algorithms
- Mechanism to exploit application-specific **and** network-layer information

Service Composition in Active Networks

- Network exposes a *programming interface*
- An “underlying program” executes at each node
- Users *inject* computations into the network

Questions:

- How does the injected program “bind” to the underlying program?
- How is the interaction between the underlying and injected programs controlled?
- Is it possible to reason about the composite computation?

Answer: It depends. . . on the programming interface and supported programming model.

The Processing Slot Programming Model

A general programming model for active networks:

- **Underlying program** encapsulates uniform per-packet processing and is resident at each node
- Underlying program identifies **Processing Slots**

Processing Slots:

- Slots specify **when and where injected programs** may execute
- Underlying program **raises** a slot iff slot-specific conditions hold
- Injected programs **bind** to specific slots

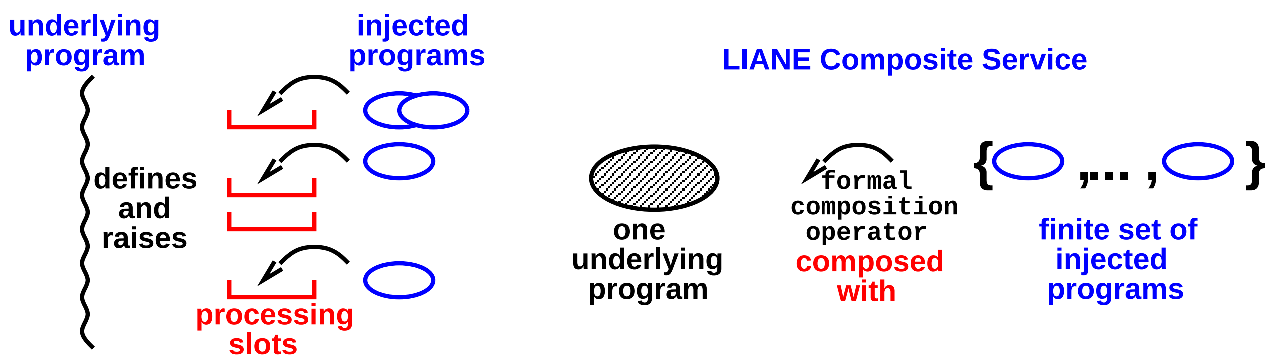
Multiple injected programs may bind to a single slot

All programs bound to a slot execute concurrently when the slot is raised

Reasoning about Active Networks

LIANE Language Independent Active Network Environment:

- A formal model in UNITY notation and logic
- Underlying programs identify resource bounds, restrictions and obligations of injected code for each slot
- Transformation technique to form composite



Injection preserves all properties of underlying programs

Unless resource bounds are violated, properties of injected algorithm are preserved as well

LIANE Example: Generalized Forwarding Function

Parse packet, obtain source s, destination d

⟨**Slot 0:[null]**⟩ {trace route, caching, select route table, discard}

i := **Lookup**(d, `route table` R)

if $i = \perp$ then ⟨**Slot 1:[null]**⟩ {error messages to source}

⟨**Slot 2:[null]**⟩ {send route back, select alternate interface}

if i is congested then ⟨**Slot 3:[discard]**⟩ {cong. control algorithm}

else ⟨**Slot 4:[null]**⟩ {scheduling algorithm}

enqueue packet for i.

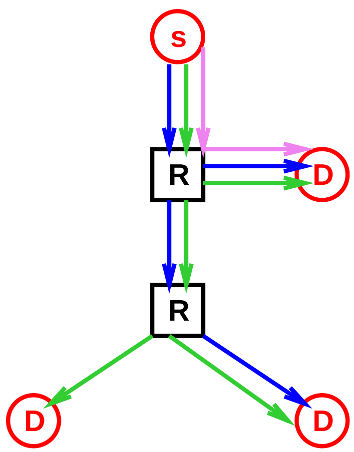
Figure 1: Example Underlying Program with processing slots

Example Injected Program: **Mobility, Congestion Control Algorithms**

Application: Network Support for Multicast Video

Multicast video over best effort networks:

- Three locations for adaption: Sender, Receiver, *Network*



Receiver-based adaption:

- Media is partitioned into layers
- Receivers join different multicast groups corresponding to video layers
- Receivers adapt to network conditions by joining and leaving different multicast groups

In-network adaptation:

- Media-specific reduction techniques installed in routers

Overview of Experiments

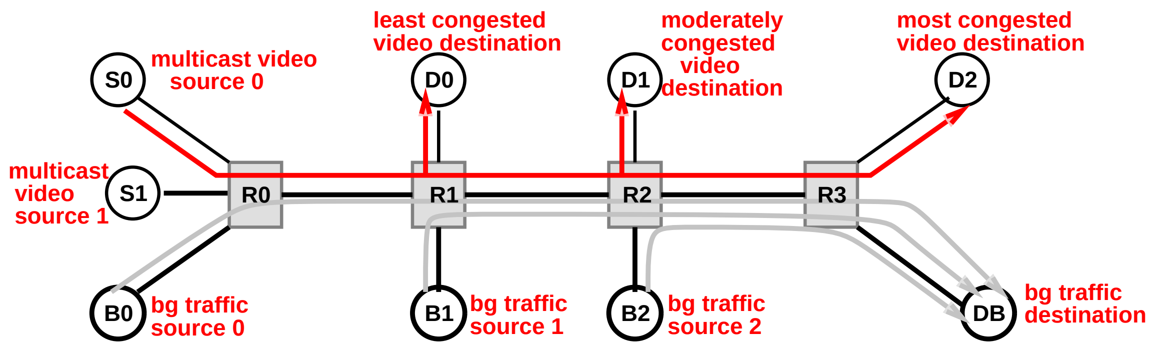


Figure 2: Experimental Topology

Simulation experiments using ANSWER:

- All multicast group actions were instantaneous
- MPEG video simulated: 3 layers, 615 Kbps, 30 fps
- Experiments with different:
  - background traffic scenarios, number and priority of sources, decoding schemes, capabilities at routers

Multicast Result: Single Video Source

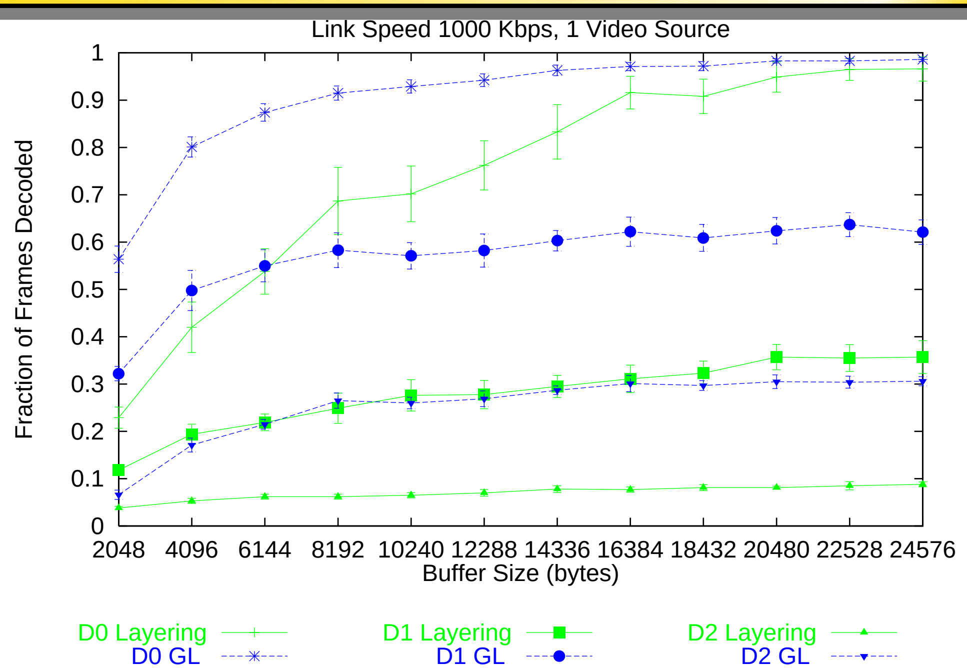


Figure 3: Fraction of frames decoded with varying buffer size at routers

- For uncongested destinations, receiver-based adaptation requires larger buffers to provide similar performance
- For congested destinations, network-based adaptation provides 2-3 *times* better performance

Detail Snapshot: Single Video Source

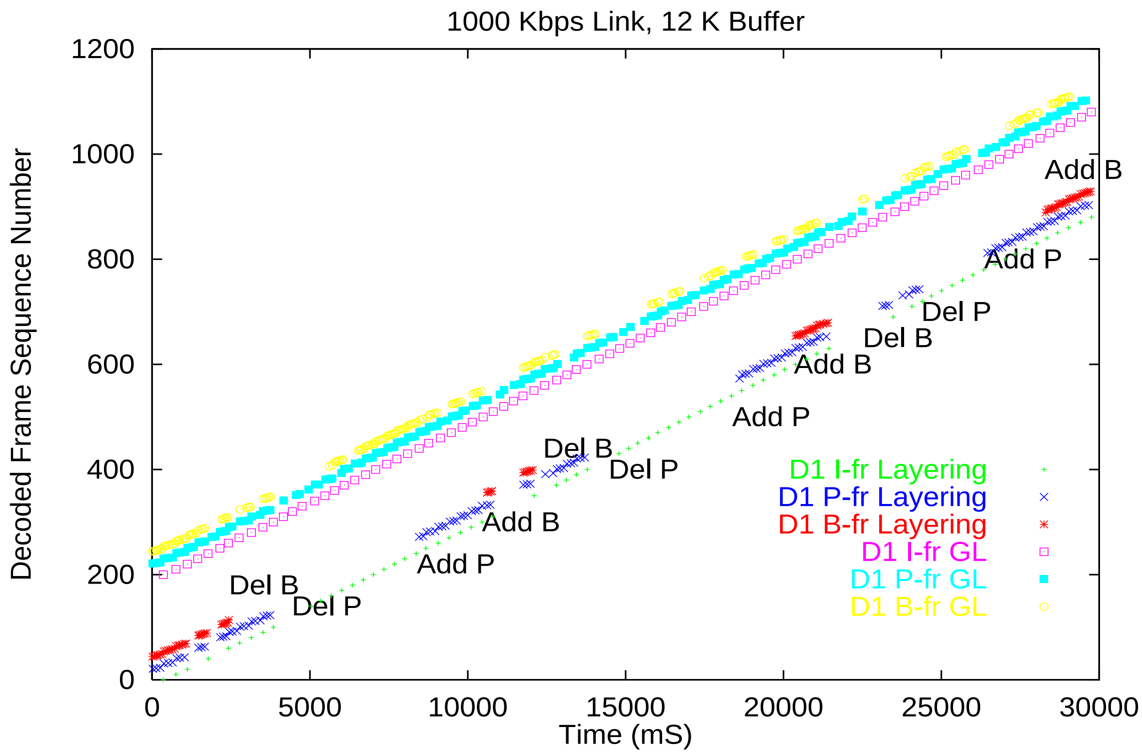


Figure 4: Sequence of frames received at receiver D1

Multiple Sources with Priority

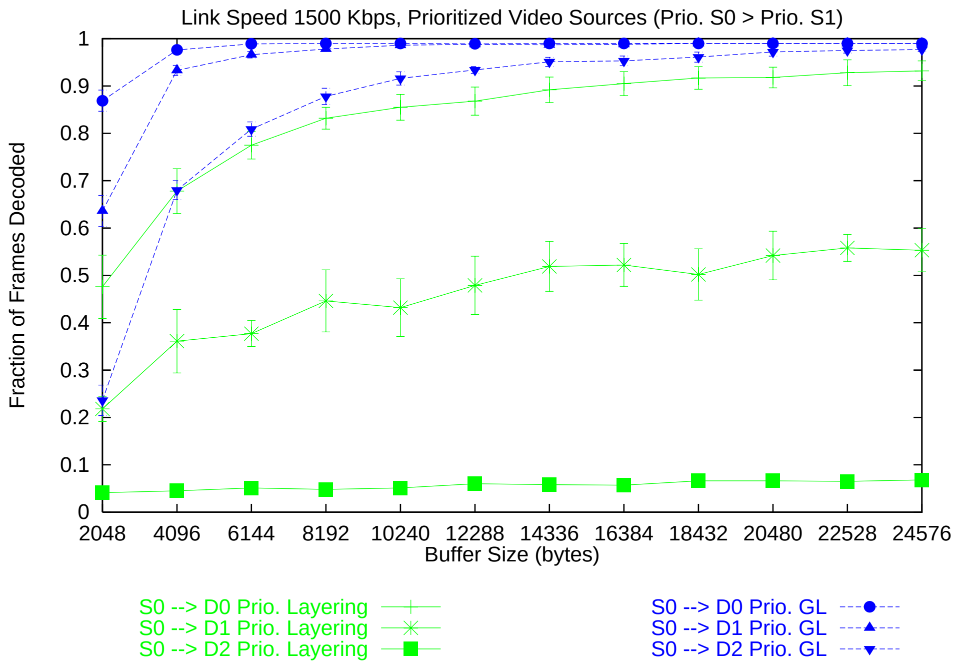


Figure 5: Fraction of frames decoded for high priority source

- Difficult to eliminate effects of the lower priority sources under receiver-based adaptation — join experiments of lower priority sources disrupt the high priority traffic

Citizenship

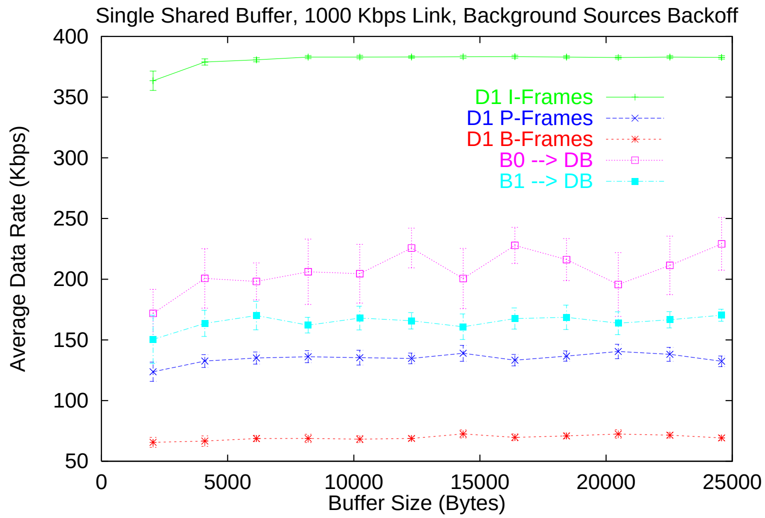


Figure 6: Single Shared Buffer

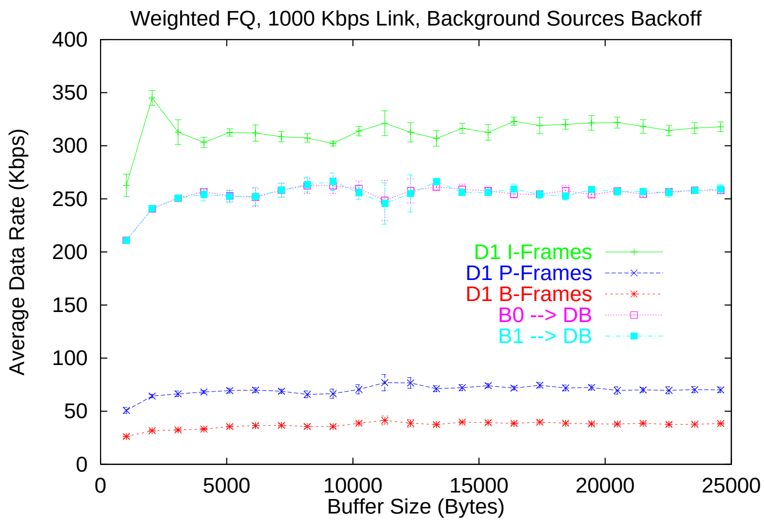


Figure 7: Weighted Fair Queue

- Bandwidth is shared unfairly with in a shared buffer
- Weighted fair queuing *equalizes* the bandwidth allocation

Current Work

LIANE

- Discrete-event simulator ANSWER implemented using the slot model
- ANSWER allows experimentation with slot-processing model
- Implementation of LIANE

Applications

- Work on other applications: Virtual Topologies, Anycasting
- Larger topologies
- “Partially active” networks