Green Domino Incentives: Impact of Energy-aware Adaptive Link Rate Policies in Routers

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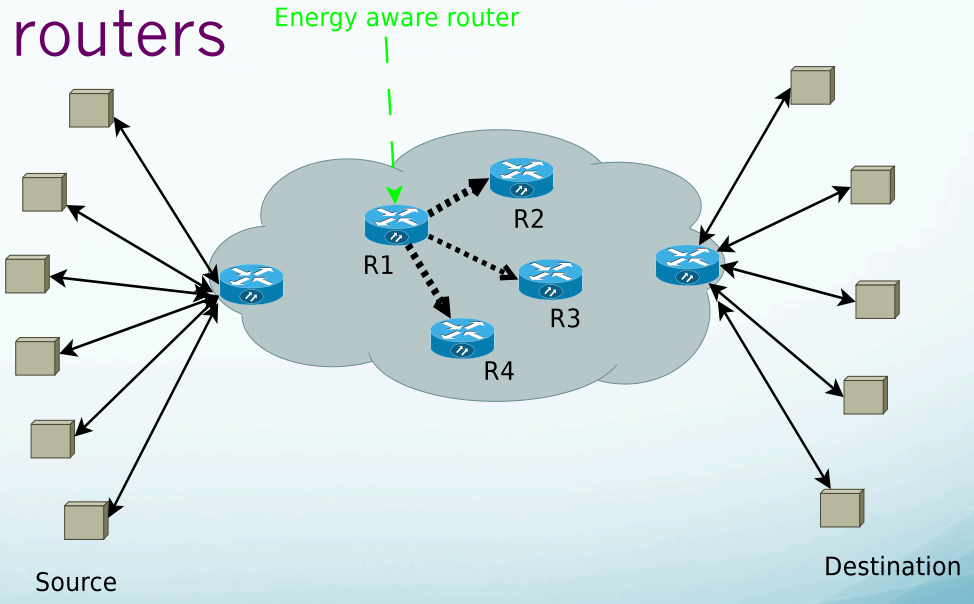
Motivation

- Energy savings in Internet routers
  - Over-provisioned to meet peak traffic
  - Hence, often under utilized
- Effect on downstream routers
  - Positive or negative
  - Energy and Delay



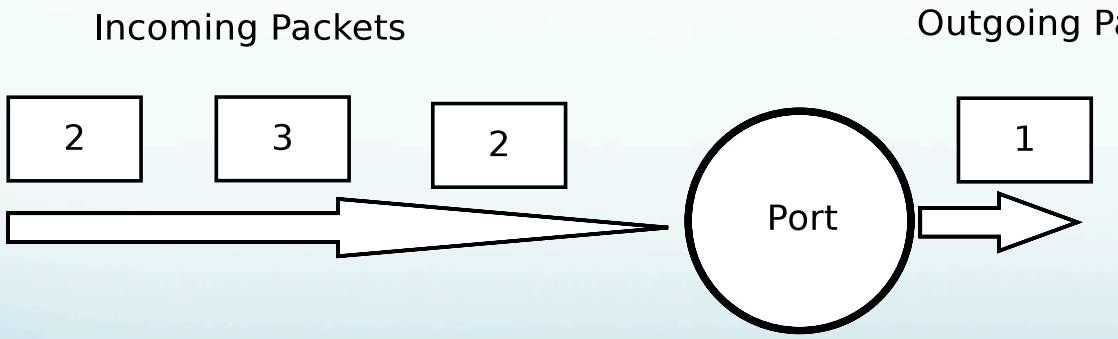
Contribution

- Evaluation Framework
  - Router Model
  - Policy Model
  - Energy Model
  - Traffic Model
- Trace based simulation
  - Capture real traffic characteristics
- Analysis on immediate downstream router
  - Delay
  - Improvement in energy savings

Adaptive Link Rate (ALR)

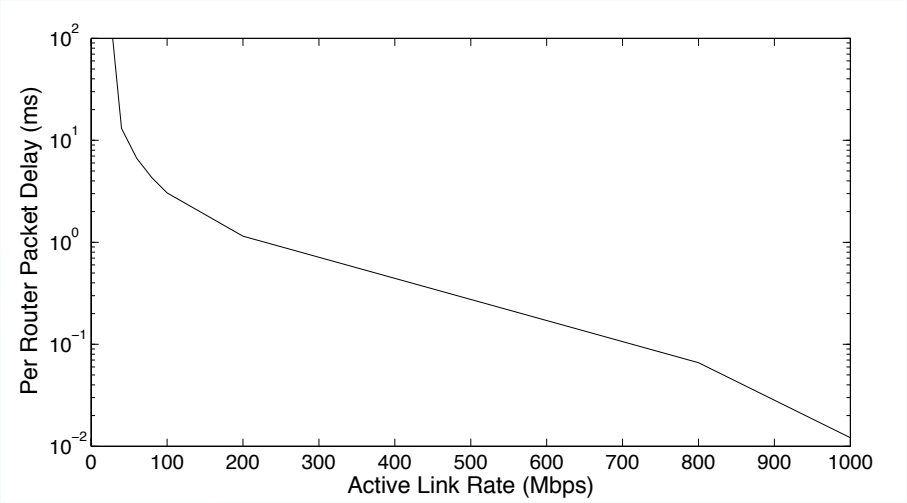
- Energy saving techniques
  - Rate scaling
  - Active/idle toggling
    - IEEE 802.3az
  - Commercial
    - Cisco Catalyst 4500E Switch

48-port Line Card (Photo Courtesy: Cisco)

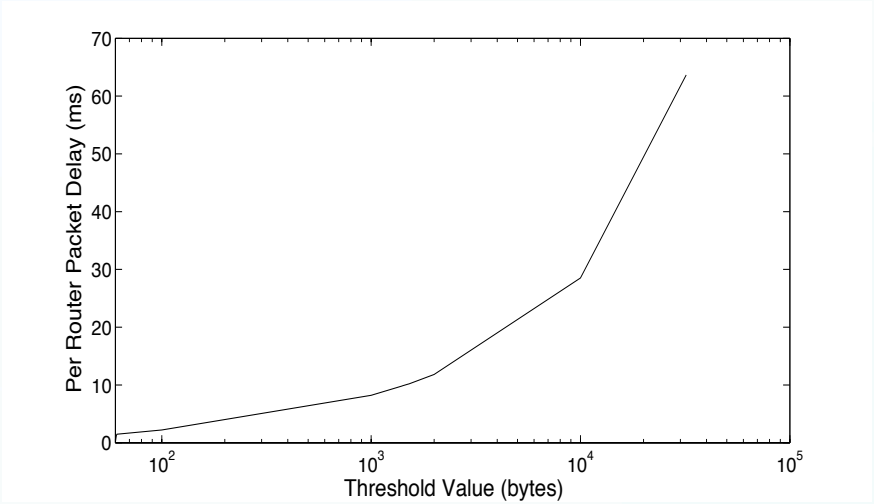


Symbolic representation of port operation

Policy Parameters & Delay



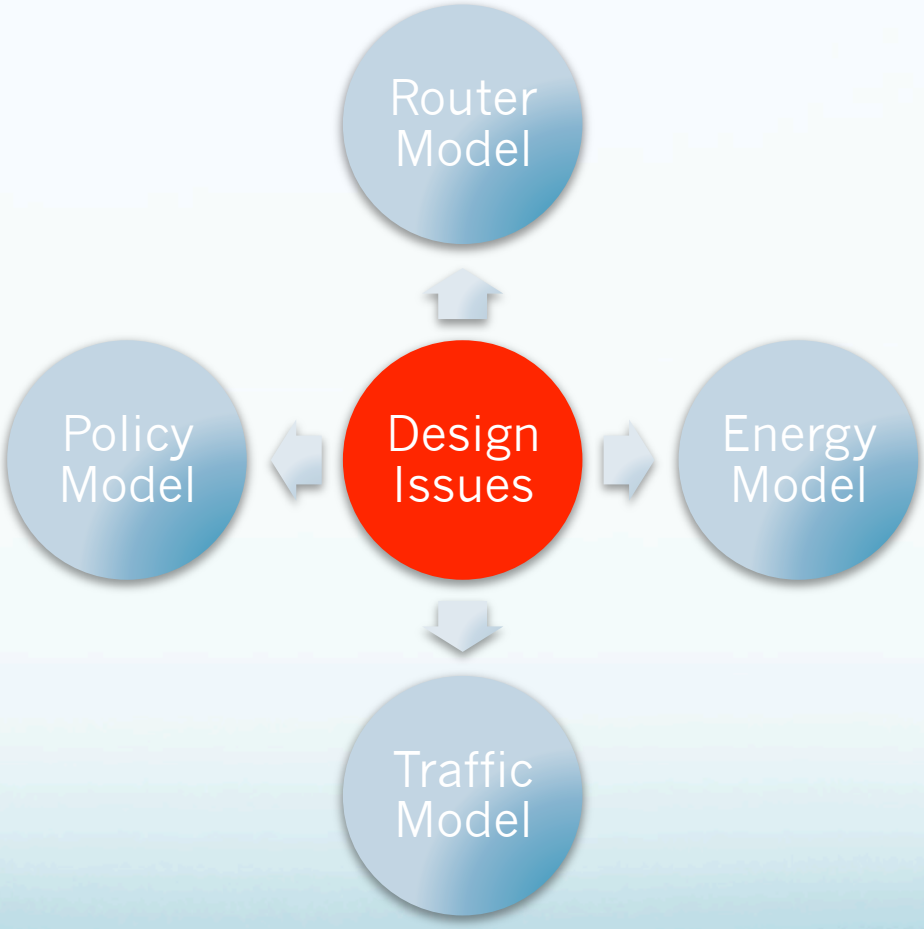
Rate Scaling



Active/Idle Toggling

- Rate scaling
  - Service rate or port speed
  - Reduction in speed ⇒ Energy Savings
- Active/Idle Toggling
  - Queue threshold
  - Amount of idle time ⇒ Energy Savings

Evaluation Framework

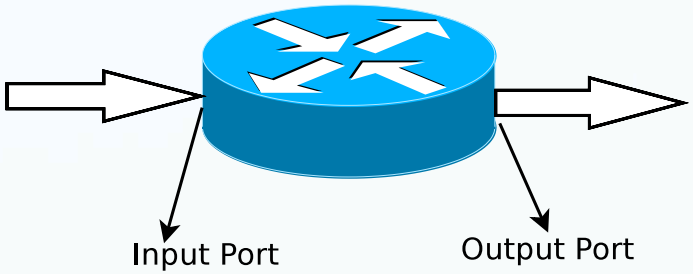


Policy Model

- Tail delay (99th percentile)
  - Between .01ms and 100ms
- Vary policy parameters
  - Port rate
  - Queue threshold
- Hybrid
  - Port rate
  - Queue threshold < Smallest packet

Router Model

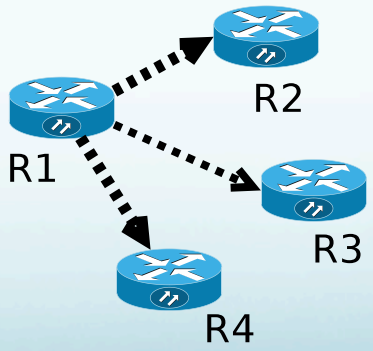
- Delay
  - Switch Fabric
  - Queue
  - Transmit
- Model by Hohn et al. 2009
  - Switch fabric delay: 10 – 50 microseconds
  - Delay constraints in milliseconds
  - Delay = Queue delay + Transmit delay
  - Infinite queue
  - Tail delay



Router

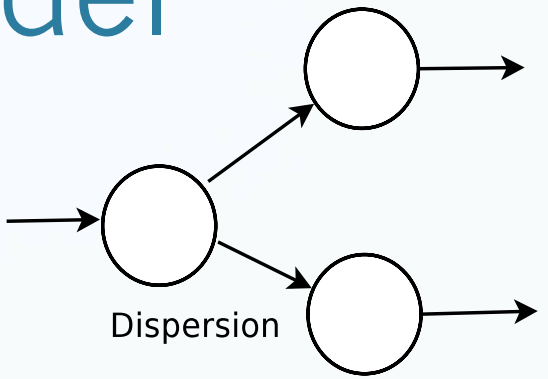
Energy Model

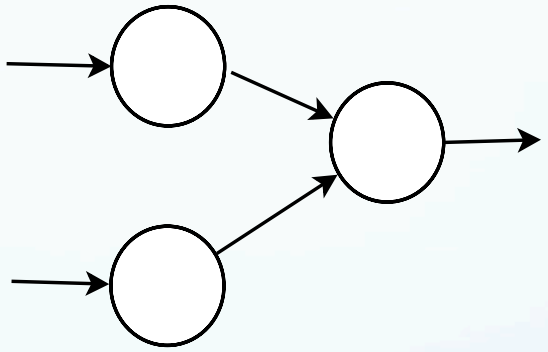
- Proportional Model
- Interested in ⟹ Relative energy consumption
- **NOT absolute**
- **Relative increase/decrease in energy savings**
  - **At R2, R3 and R4**
    - **R1 runs green techniques**
    - **R1 does not**

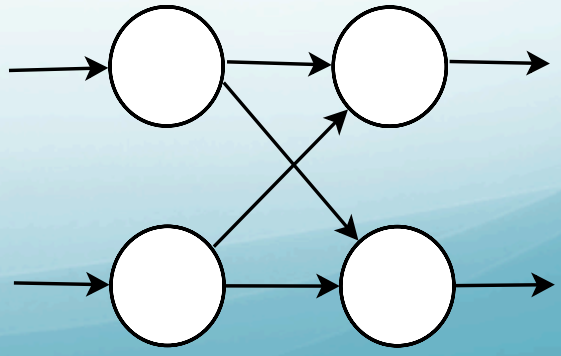


Traffic Model

- Traffic scenarios
  - Dispersion: 1*2
  - Aggregation: 2*1
  - Multiplexing: 1*1, 2*2 (shown), 3*3
- Packet traces (public)
  - Waikato trace (edge)
  - MAWI (core)

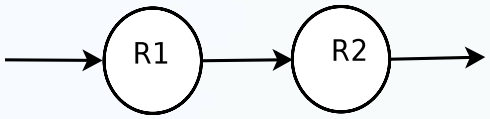


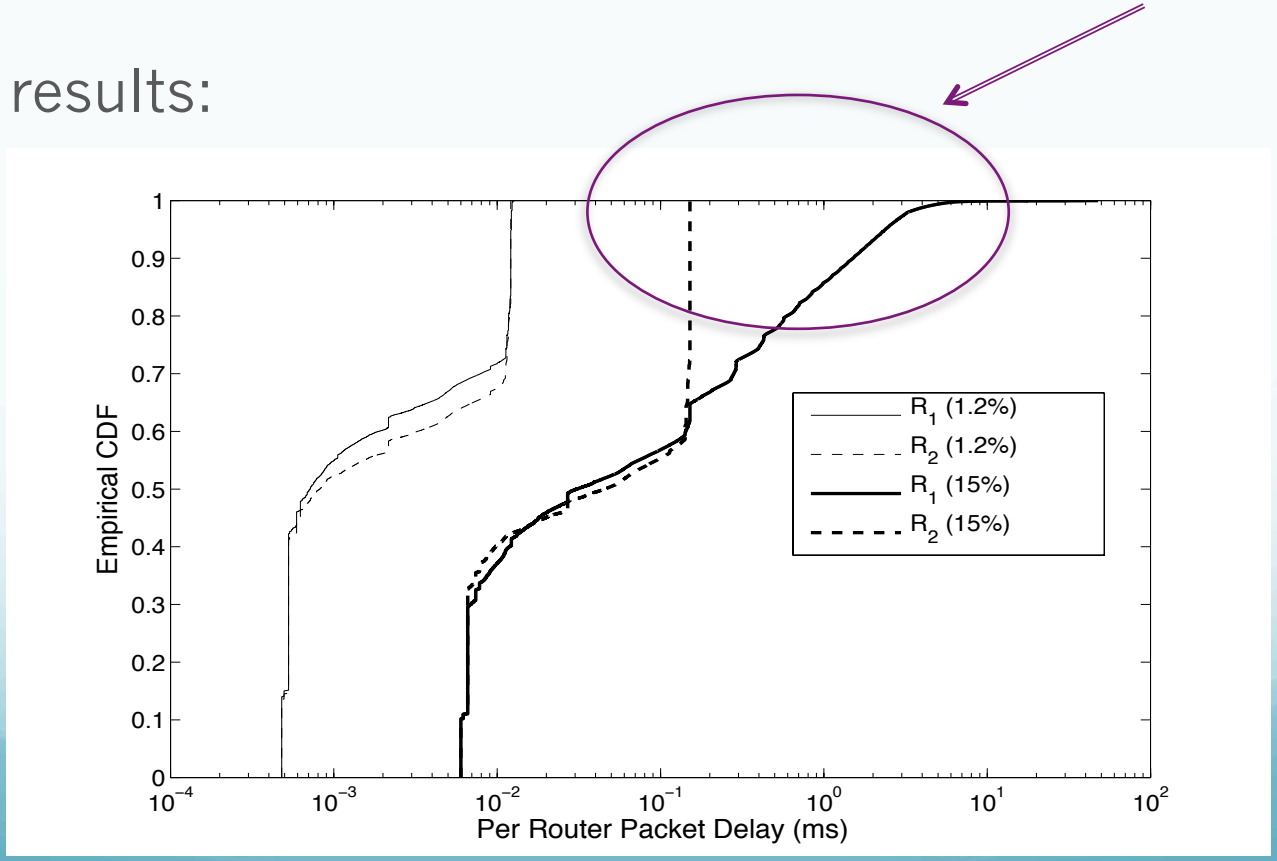




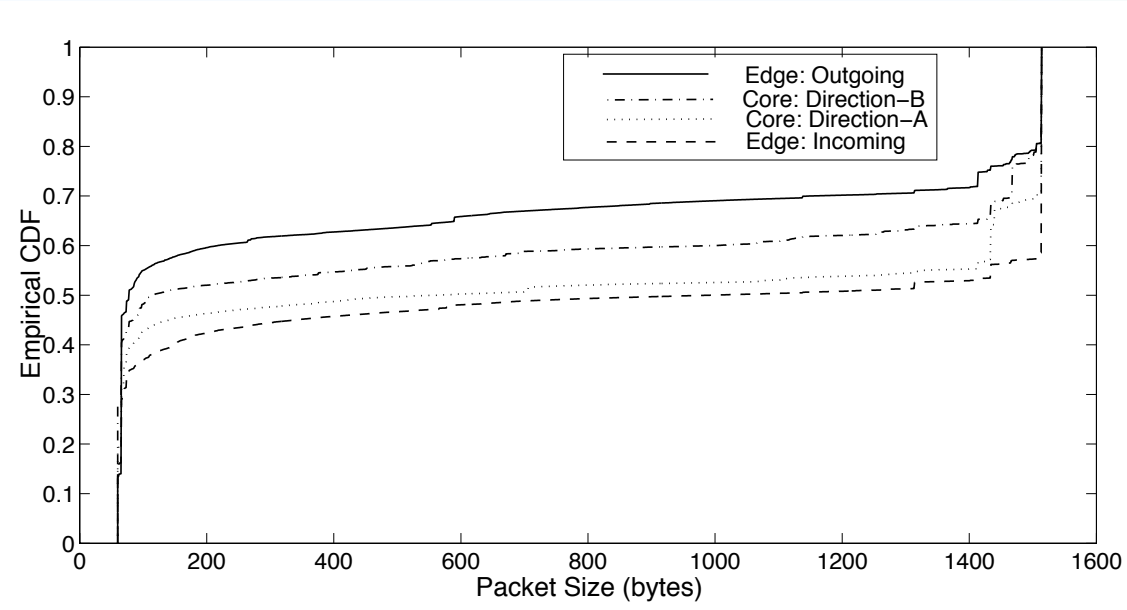
Simple Back-to-Back Case

- Past studies on tandem queues
  - Increased delay at R2 for (utilization < 60%)
  - Continuous and independent service time
- Our results:





Bimodal Distribution



- Most packet sizes are either small (<100 bytes) or large (>1400 bytes)
- Incoming edge traffic has more large packets

Back-to-Back Probability

Small:<= 100 byes
Large: >=1400 bytes
Medium: > 100 and < 1400

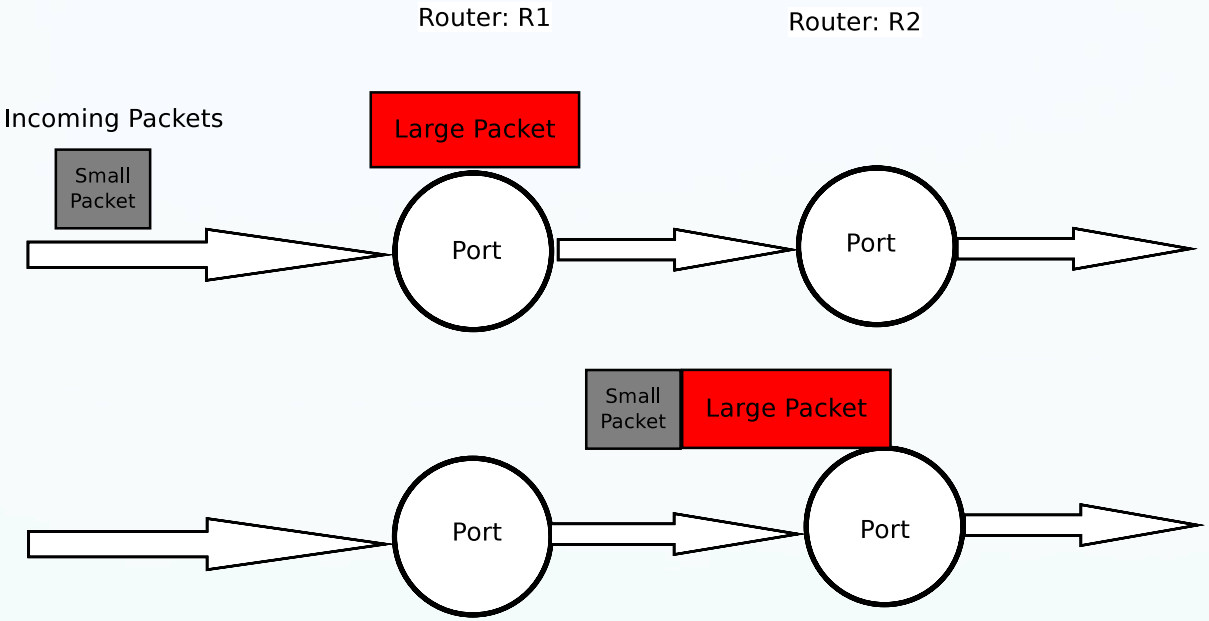
	Small	Medium	Large
Small	**0.39**	0.11	0.04
Medium	0.10	**0.06**	0.03
Large	0.05	0.02	**0.20**

Edge, Outgoing

	Small	Medium	Large
Small	**0.23**	0.05	0.07
Medium	0.04	**0.02**	0.04
Large	0.08	0.03	**0.45**

Core, one direction

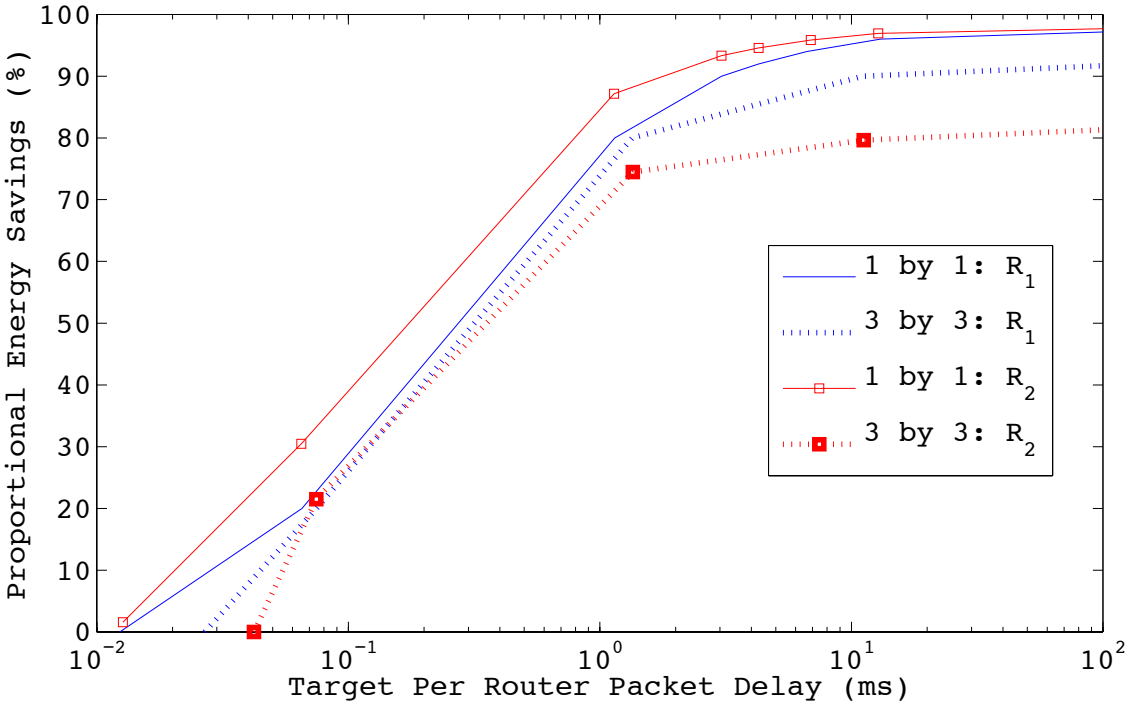
Example Scenario



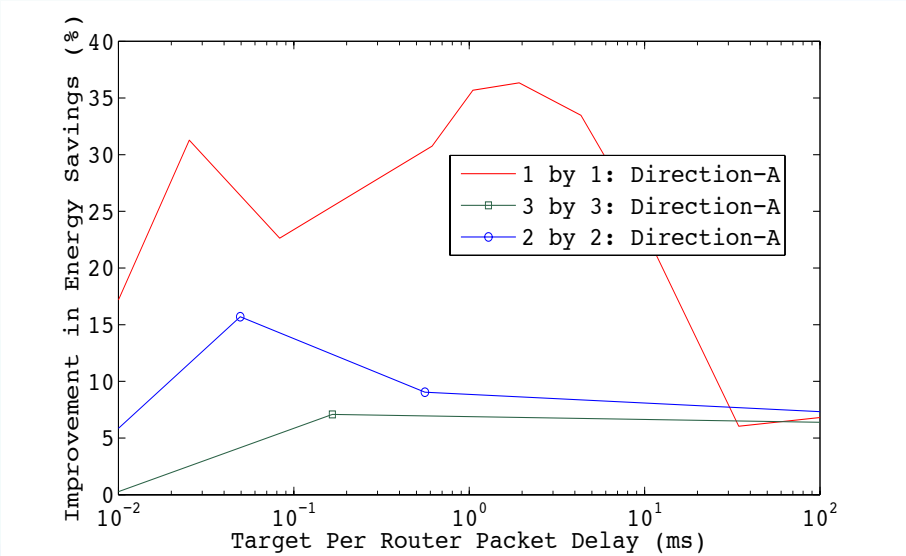
- Small packet has negligible processing delay
- Small packet experience larger delay at R2 than R1

Proportional Energy Savings

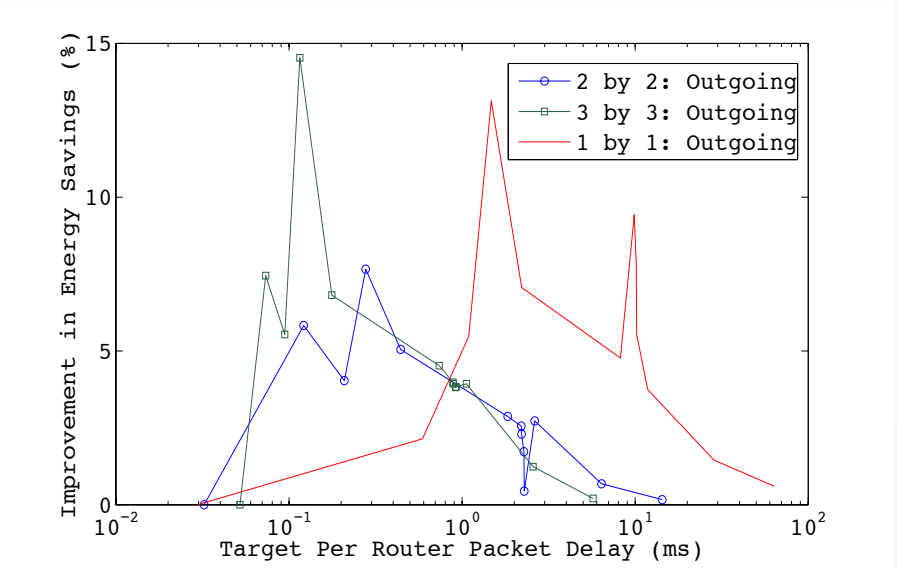
- Reduced delay at R2 ⟹ **More energy savings at R2**
- **Increase in multiplexing impact energy savings**
- Relative savings at R2?



Cascading (Domino) Effect



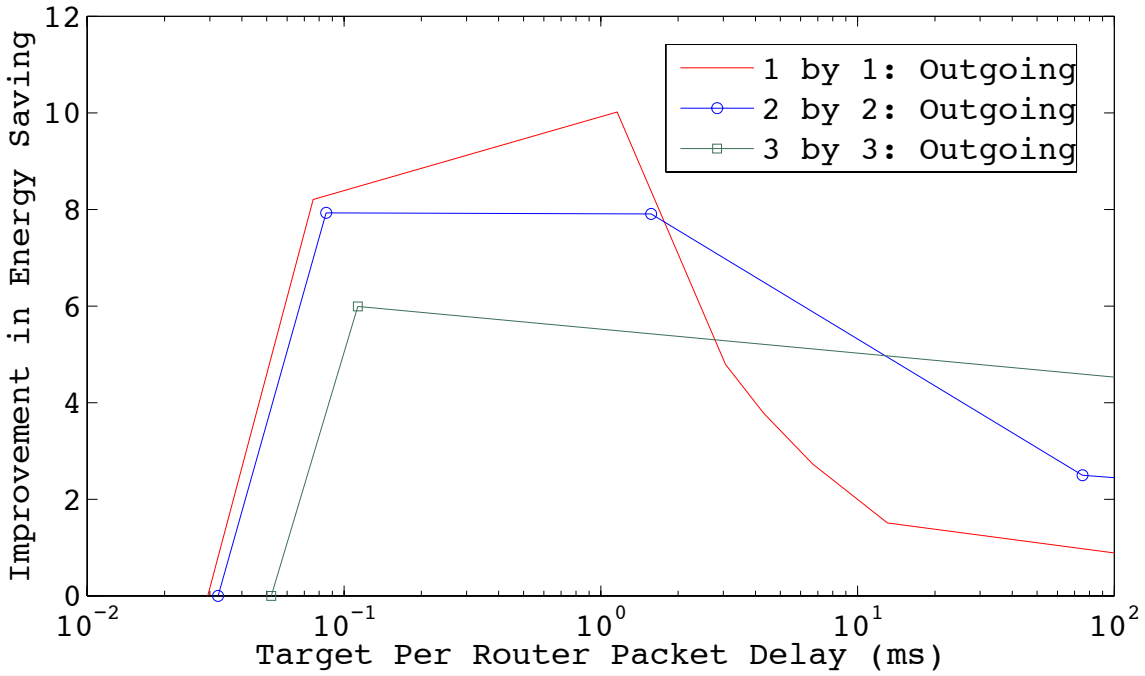
Rate Scaling: Core



Active/Idle: Edge

- **Improvement in energy savings**
  - **Rate Scaling: Up to 35%**
  - **Active/Idle Toggling: Up to 15%**

Hybrid Case



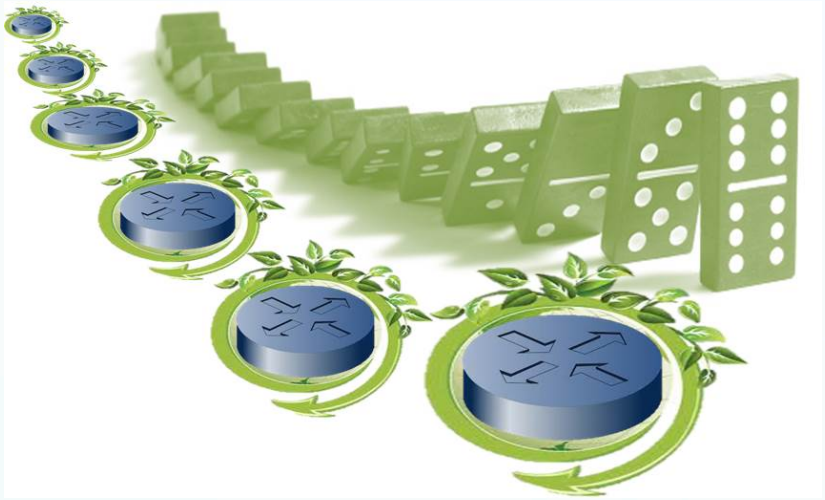
Hybrid: Edge

- **Improvement of up to 10% observed for hybrid**
- **Multiplexing reduces improvement in all three classes of algorithms**

Conclusion

- Performance evaluation framework
- Trace based analysis
- Effect of ALR policies on neighboring routers
  - **Cascading (domino) energy improvement**
  - **Up to 30% energy savings (rate scaling)**
  - **Influenced by traffic characteristics**
- Future Work:
  - Variability
  - Large scale deployment study
  - Interactions with higher layer protocols & applications

Thank You



Questions?

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