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

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Presented by Martin Arlitt, HP Labs
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

- Rate scaling
  - Service rate or port speed
  - Reduction in speed → Energy Savings

Active/Idle Toggling

- Active/Idle Toggling
  - Queue threshold
  - Amount of idle time → Energy Savings
Policy Model

- Tail delay (99\textsuperscript{th} 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
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 bytes
Large: >= 1400 bytes
Medium: > 100 and < 1400

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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

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

Rate Scaling: Core

Active/Idle: Edge
Hybrid Case

- 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

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