Reducing Forwarding State in Content-Centric Networks with Semi-Stateless Forwarding

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Outline

• The problem: Does the PIT scale in CCN?
  – As is, very unlikely!

• A semi-stateless forwarding scheme
  – Interest tracking
  – Bloom filter-based Data forwarding

• Evaluation
  – Unicast & Multicast

• Conclusions
A CCN Primer

- Hop-by-hop Interest forwarding (FIB)
- Pending Interests Table (PIT)
- Stateful forwarding advantages
PIT Scalability

• # entries: bandwidth x RTT / packet
  – Example: 40 Gbps, 80 ms, 1 Kbyte
  – 400K PIT entries, longer than IP addresses
  – Even more in live streaming and pub/sub
  – Realistic estimates indicate millions of entries

• Large memory requirements for PIT
  – Does not fit in on-chip memory
  – Bad performance with main memory
Reducing PIT size

• DiPIT: combine entries with Bloom filters
  – Drops per Interest information
• ENPT: uses a trie to encode Interests
  – Lookup time depends on name size
• CONET: Interests accumulate source routes
  – Drops all benefits of stateful forwarding
  – No multicast or adaptive forwarding
  – No dropping of unwanted Data
Semi-Stateless Forwarding

• Track Interests at *some* on-path routers
  – On average, every $d$ hops
  – For $N$-hop paths, Interest tracked at $N/d$ routers

• Stateless forwarding between stateful routers
  – Using in-packet Bloom filters
Interest Tracking: Requirements

- Spread state across routers
  - Avoid bottleneck points
  - Routers should track $1/d$ of forwarded Interests
- Efficient multicast rendezvous
  - Aggregate Interests for the Same Data
1. Probabilistic Tracking

- Router tracks Interest with probability $1/d$
  - Interest aggregation: check if entry exists
  - Upper bound on stateless hops
    - Avoid large stateless parts
    - Uses hop counter in Interests
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2. Hash-based Tracking

- Router tracks Interest of $h \mod d == 0$
  - $h = \text{hash} (\text{content\_name} + \text{router\_suffix})$
  - Deterministic selection of storage points
  - Also needs upper bound on stateless hops
3. Hop Counter-based Tracking

• Both previous policies require hop counters
• Why not use only the hop counters?
  – Much simpler to implement
  – Stateless paths never get long
• Select initial value randomly in [0, d-1]
  – Spread state across routers
• Check PIT for pre-existing entry
  – Aggregate entries as soon as possible
Data Forwarding: Bloom filters

- Track reverse path information in routers
  - Each link has a random ID (LID)
  - Add (OR) reverse LID at each hop
  - Store the Bloom filter (BF) in the PIT
  - Add (OR) the BF to aggregate paths
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Tradeoffs

• Larger Interest & Data packets
  – Need to carry BFs in headers

• Additional Interests with multicast
  – Aggregation beyond first common router
  – Does not influence Data transmissions

• Additional Data
  – False positives in BFs

• Fewer but larger PIT entries
Evaluation

• Simulations using AS 224
  – Similar results with other ASes
  – 500 hosts distributed to access routers
  – 128 bit Bloom filters for forwarding

• Metrics
  – Reduction in PIT entries
  – Reduction in PIT size (bytes)
  – Additional Interests and Data
• Simple file transfer
  – 66% reduction in PIT entries (HC, d=3)
  – 54-61% reduction in PIT size (HC, d=3, small/large)
Multicast: PIT entries

- Live media streaming
  - 1000 groups, Zipf distribution of sizes
  - 52% reduction in PIT entries (HC, d=3)
• Live media streaming
  – 34% smaller PIT size (5k groups, d=3, small names)
  – 45% smaller PIT size (5k groups, d=3, large names)
• **Live media streaming**
  – 25% additional Interests (HC, d=3)
  – 5% additional Data (HC, d=3)
Multicast: Total Overhead

- Live media streaming
  - 9% more bandwidth (5K groups, d=3, 1.5K pkt)
  - 6% more bandwidth (5K groups, d=3, 8K pkt)
Evaluation overview

• Significant PIT size reduction achieved
  – 54-61% compared to CCN for unicast
  – 34-45% compared to CCN for unicast

• Small bandwidth penalty
  – No penalty at all for unicast
  – 6-9% extra bandwidth on multicast

• The HC policy works best with $d=3$ or $4$
  – $d$ trades off PIT size against bandwidth overhead
Conclusion

• Semi-stateful forwarding reduces PIT size
• Qualitative aspects of CCN are maintained
  – Multicast, dropping unwanted packets
• Only Interest & Data processing changes
  – LIDs are constructed autonomously
• Future work
  – Resort to semi-stateless only as PIT fills up
  – Vary $d$ per router to minimize overhead
Thank you

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