Implementation and End-to-end Throughput Evaluation of an IEEE 802.11 compliant version of the Enhanced-Backpressure algorithm

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Introduction

- The efficiency of a multi-hop mesh network is directly related to its routing & scheduling protocols.

- The majority of the wireless multi-hop networks is operating using WiFi (OSI layer 2) and IP (layer 3).
  - The scheduling policy of WiFi is the CSMA/CA protocol, which is distributed and relies on the MAC of each node.
  - The routing algorithm is again a distributed protocol and depends on the necessities of the network traffic.

Routing Protocols

- A shortest-path routing algorithm aims at minimum e2e delays.
- A load-balancing routing algorithm aims at maximum throughput.
- Backpressure (BP) achieves max. throughput operating on a time-slotted & centralized schedule.
- Enhanced-Backpressure (EBP) reduces e2e delays, maintaining throughput efficiency.

Enhanced-Backpressure features

- Packets are related to *commodities*, that correspond to destinations or pairs of source-destination, etc.
  - In our case commodity (c) ↔ destination (dst).
- Separate network layer queue for each commodity.
- *Maximum Weight Matching* based on particular *link-commodity weights*.
  - Routing without routes, multi-path & load-balanced.

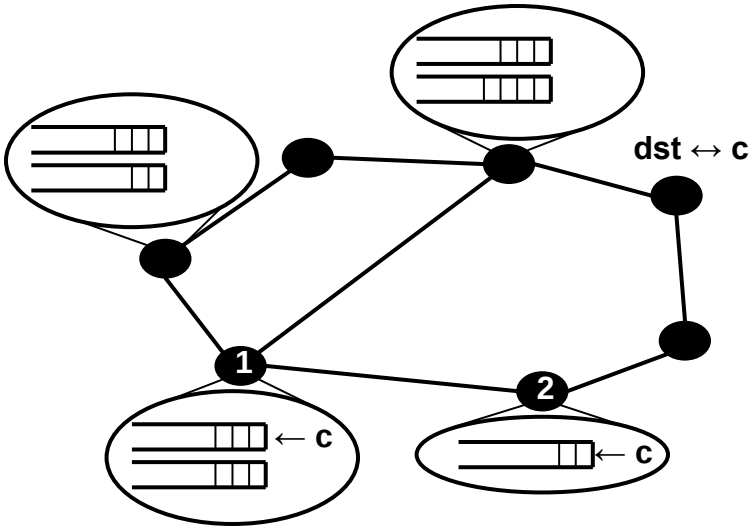
BP weight:

- $w_{12} = \max\{(Q_1^c - Q_2^c)\, R_{12}, 0\}$

EBP weight:

- $\hat{w}_{12} = \max\{(Q_1^c - Q_2^c + E_1^c - E_2^c)\, R_{12}, 0\}$

  - Q_1^c : E_1^c and R_{12} are *backlog* of c at 1
  - E_1^c : distance between 1 and dst
  - R_{12} : actual rate through link (1,2)



Enhanced Backpressure over WiFi (EBoW)

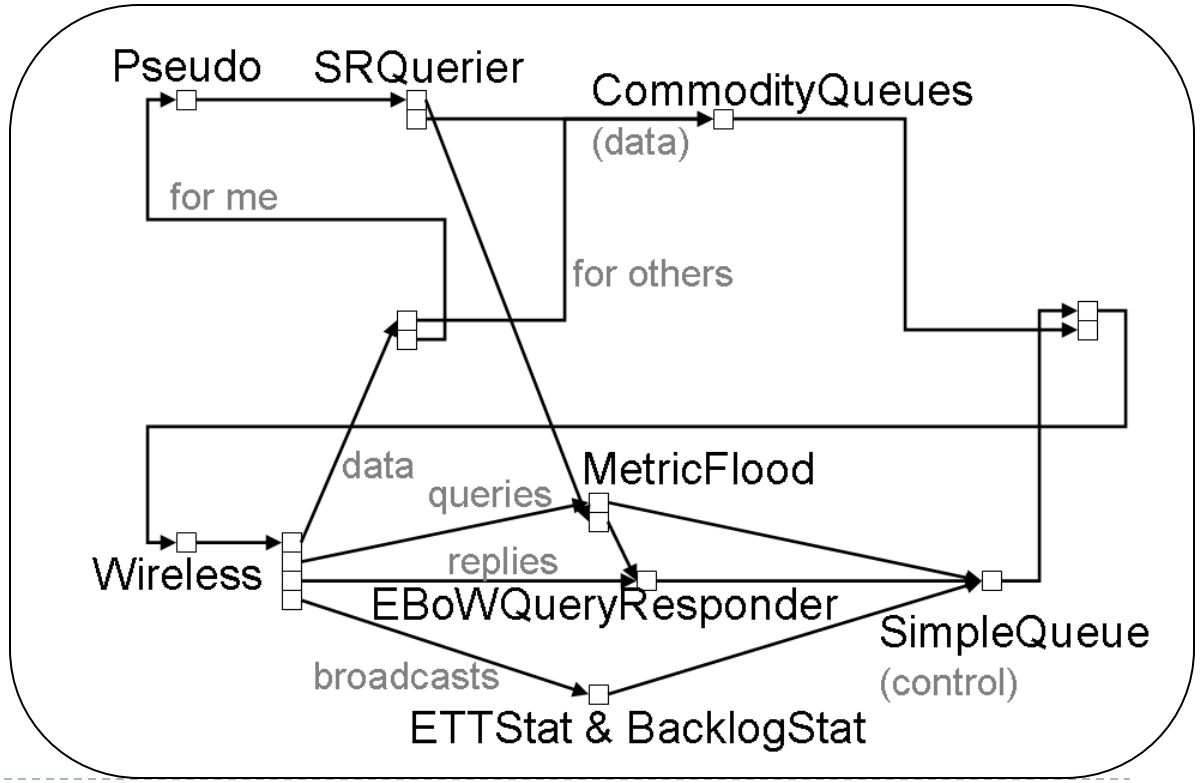
- EBoW is implemented in a distributed manner and operates in continuous time (WiFi).
- It shares a lot of similarities with EBP.
- Each node finds the maximum weighted pair of an adjusting link and an existing commodity.
  - EBoW weight: $\hat{W}_{kl} = (Q_k^c - Q_l^c + E_k^c - E_l^c) R_{kl}$
- However, k doesn't schedule transmission to l, of a packet associated with c, if:
  - $(Q_k^c - Q_l^c) <= 0$ or
  - $(E_k^c - E_l^c) < 0$
- This practice enhances CSMA/CA scheduling.

Other Routing protocols…

- Shortest-path approach:
  - SRCR by Roofnet (state-of-the-art)
- Load-Balancing approaches:
  - Horizon (BP inspired, distance-vector)
  - CDP (distance-vector)
- They don't include scheduling enhancements.
- They are implemented using the Click Modular Router framework.

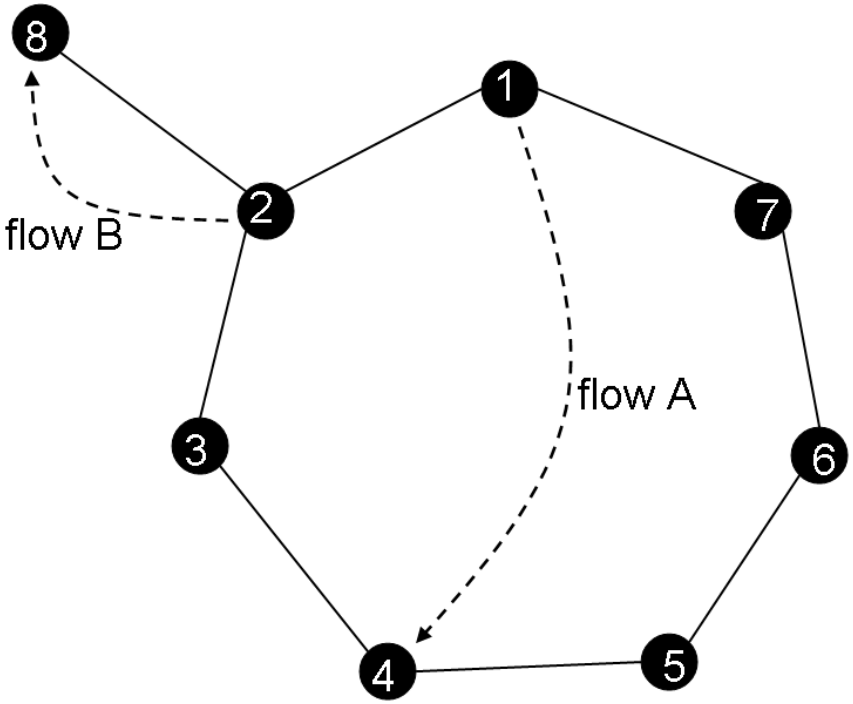
Implementation Details

- Click Modular Router.
- Ath9k (compat-wireless) driver patched.
- Modified Roofnet configuration.
- NITOS testbed.
- Verification of the results comparing with the NS-3 ones.

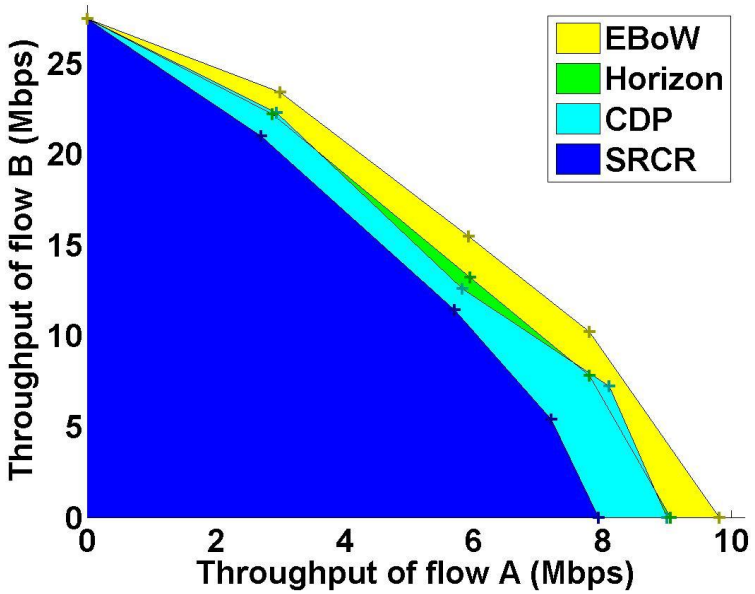


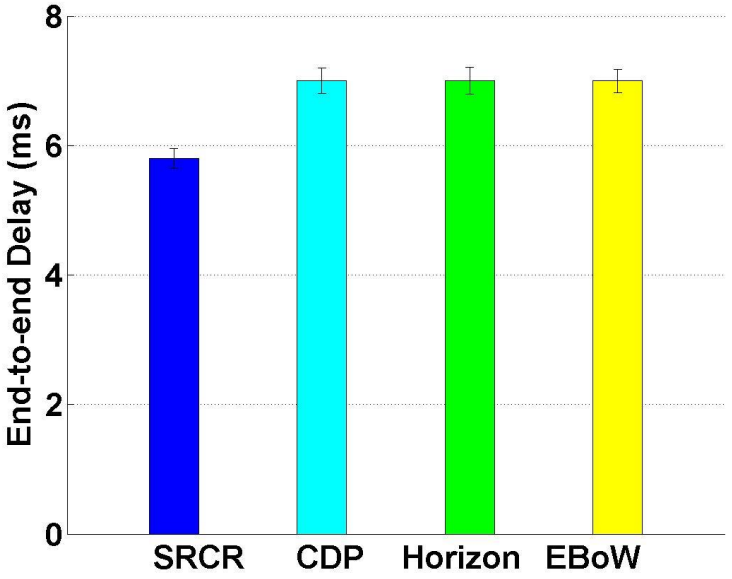
Experiment I

- Estimate the capacity region of EBoW, Horizon, CDP & SRCR.
  - The pairs of throughput that flows A and B are able to achieve simultaneously.
- Estimate the e2e delay for flow A.
  - The average e2e delay of a packet that is delivered to destination node 4.



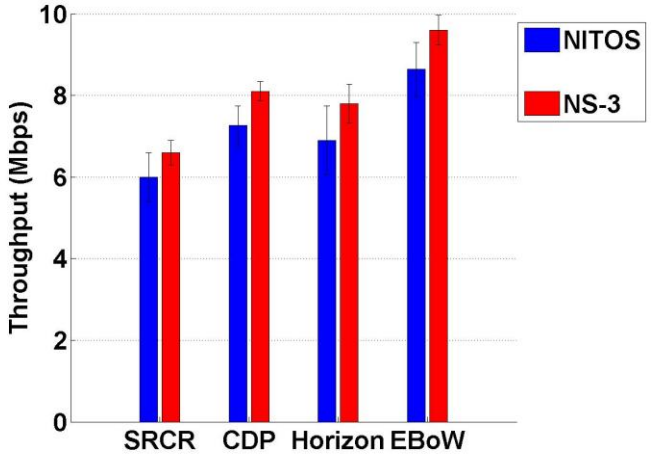
Results of Experiment I

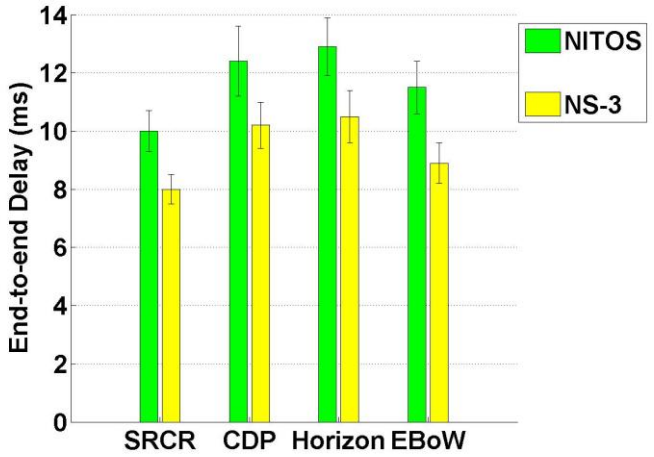




Experiment II and Results

- Experimentation in a random setup including 20 nodes of NITOS.
- 3 randomly selected 4-hop (shortest-path) flows.
- Average throughput and e2e delay performance achieved for the 3 flows, across the different schemes.
- Comparison between NITOS and NS-3 results





Conclusion

- EBoW is an implemented EBP inspired scheme that exploits:
  - Multi-path flow forwarding.
  - Better throughput performance than the other state-of-the-art routing protocols.
  - Low e2e delay close to the delay of the shortest-path routing protocols.

- Extension of the current work towards two directions:
  - Comparison of EBoW with centralized EBP based approaches.
  - Combination of the proposed scheme with more sophisticated scheduling EBP inspired policies that will be implemented in a distributed manner.
    - The scheduling should be based on prioritization schemes of 802.11 such as those proposed in 802.11e.