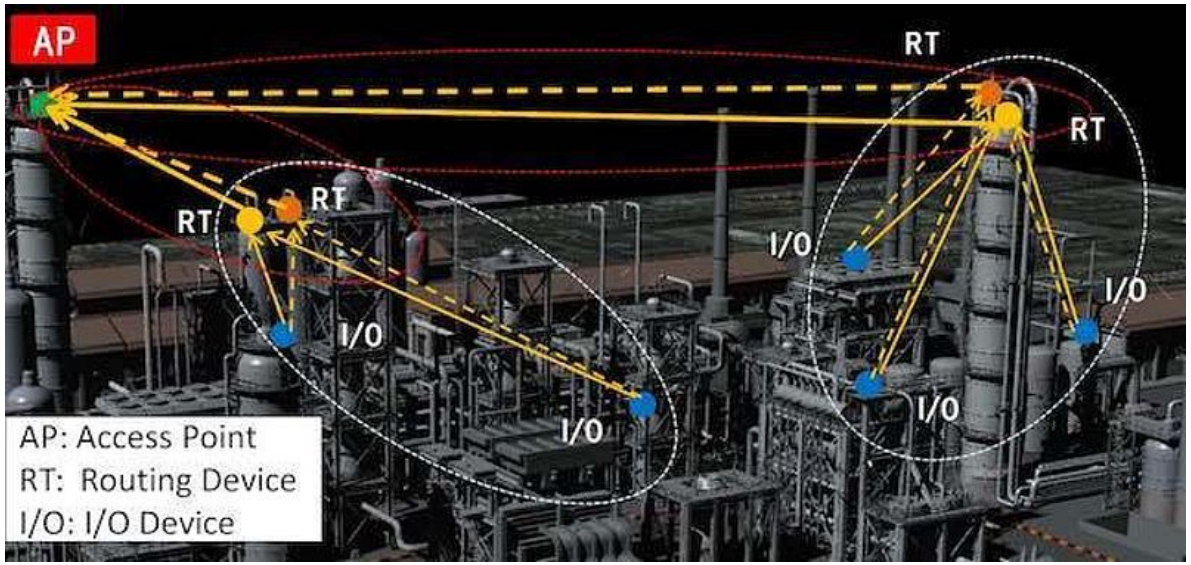
Recorp: Receiver-Oriented Policies for Industrial Wireless Networks

Ryan Brummet*, Octav Chipara,
Ted Herman

Industrial Wireless Networks

- **Applications**
  - process control systems
- **Workload**
  - stable periodic flows
  - known period, deadline, and phase
- **Strict performance requirements**
  - predictability
  - high reliability
  - real-time



plantengineering.com

Challenges: Network Dynamics

- **Moving machinery**

Tesla Automation

- **Moving workers**

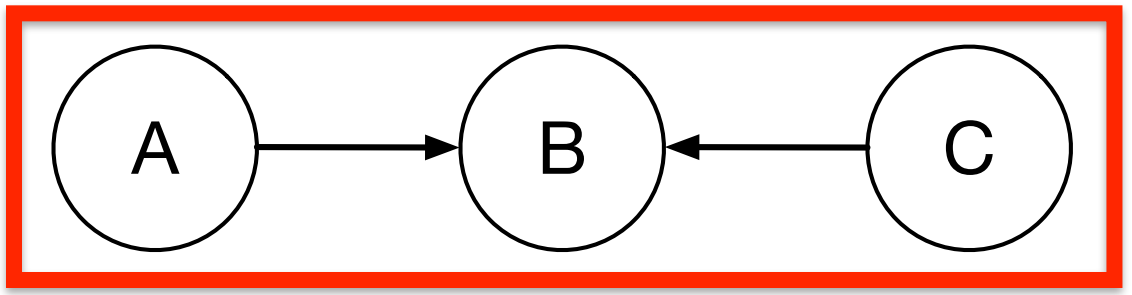
Ford Motor Company

- **Outdoor environments**

Automation.com

TSCH Schedules

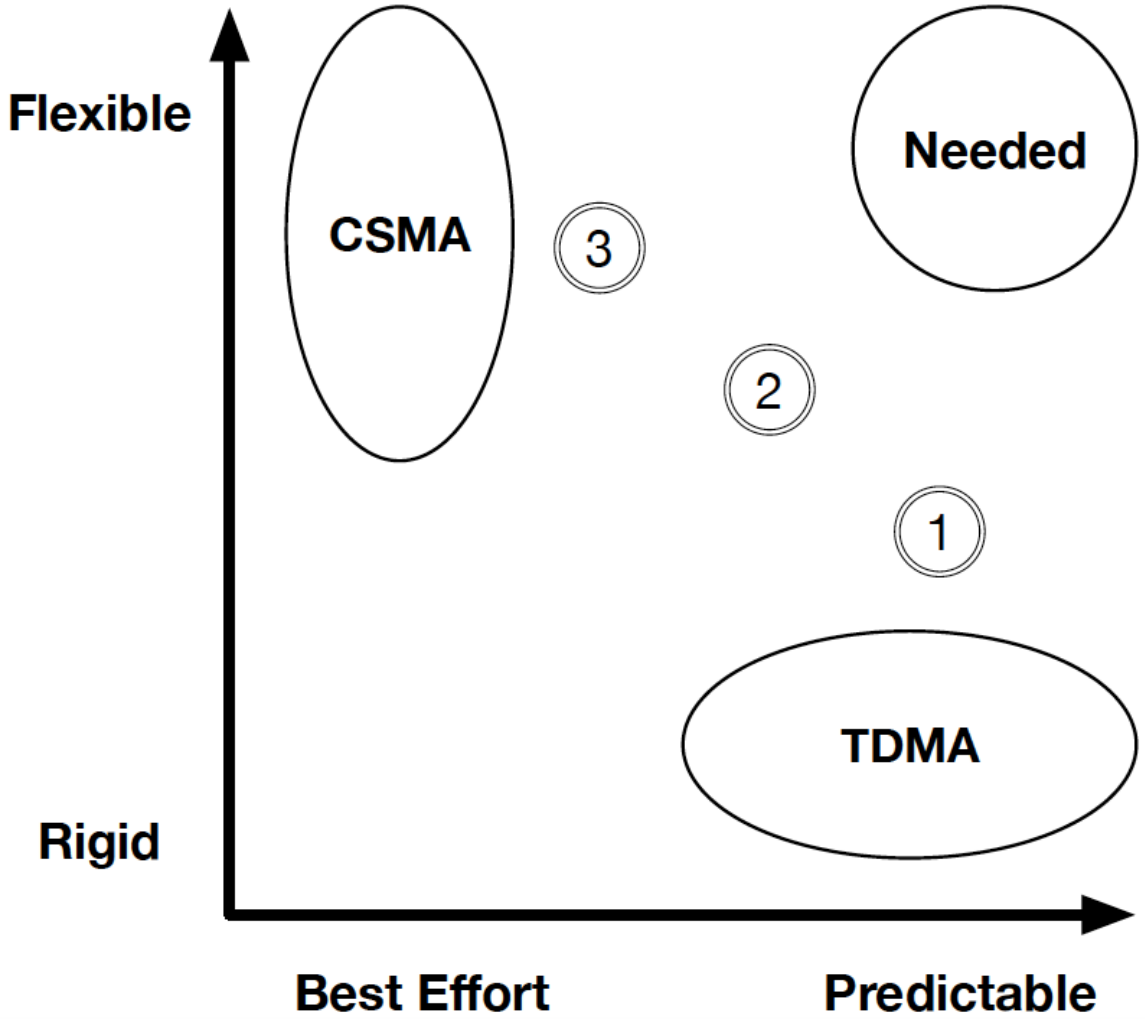
- **Time Slotted Channel Hopping**
  - time division multiple access with channel hopping
  - predictable
  - centralized
- **Limited Flexibility**
  - overprovisioned retransmissions to handle link variability



Slot	0	1	2	3
CH 0	F_0: AB			F_1: CB
CH 1		F_0: AB		
CH 2			F_1: CB	

TSCH Schedules

- **State of the art**
  - sacrifice predictability for flexibility
  - examples
    - (1) slot stealing
    - (2) hybrid TDMA with CSMA
    - (3) low likelihood transmissions in the same slot
- **Can we do better?**

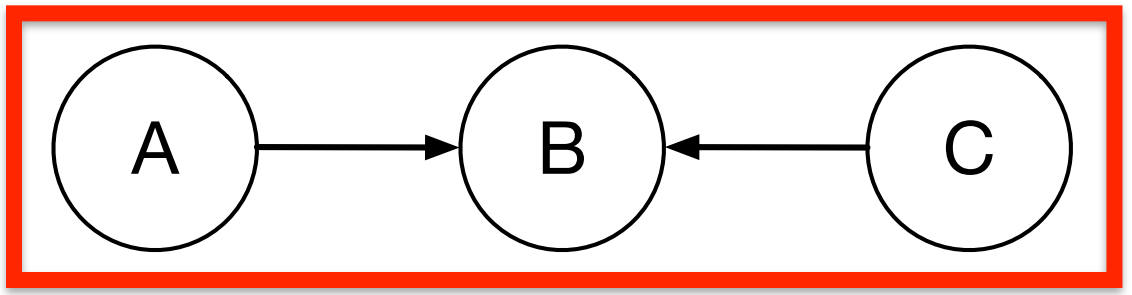


Key Insight

Allow transmissions to be reallocated conditioned on the local state at runtime

Key Insight

- **Coordinator initiates transmissions**
  - coordinator pulls for packets
  - packet transmitted upon pull reception
- **Transmissions selected via local state**
  - selections prioritized via a priority ordered service list of transmissions
- **Offline synthesis**
  - coordinators and service lists ensure reliable packet delivery



Slot	0	1	2	3
CH 0	F_0: AB			F_1: CB
CH 1		F_0: AB F_1: CB		
CH 2			F_0: AB F_1: CB	

Run-Time Adaptation

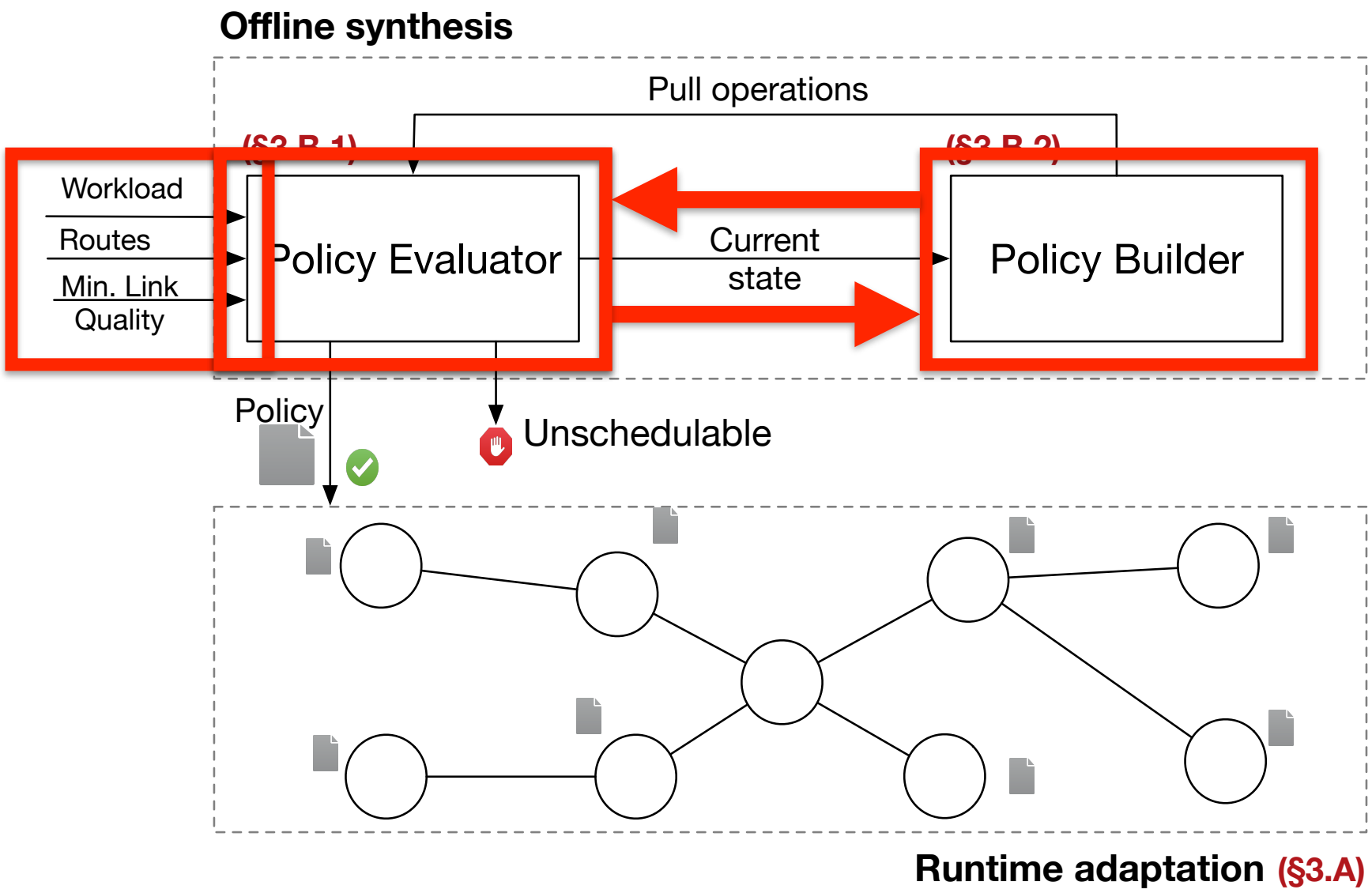
- **Schedule**
  - packets dropped in two traces

Spec	F_0: AB	F_0: AB	F_1: CB	F_1: CB
Slot	0	1	2	3
Trace 1	F_0: AB	--	F_1: CB	--
Trace 2	F_0: AB	F_0: AB	F_1: CB	--
Trace 3	F_0: AB	--	F_1: CB	F_1: CB

- **Recorp policy**
  - no packets dropped

Spec	F_0: AB	F_0: AB F_1: CB	F_0: AB F_1: CB	F_1: CB
Slot	0	1	2	3
Trace 1	F_0: AB	F_1: CB	--	--
Trace 2	F_0: AB	F_0: AB	F_0: AB	F_1: CB
Trace 3	F_0: AB	F_1: CB	--	--

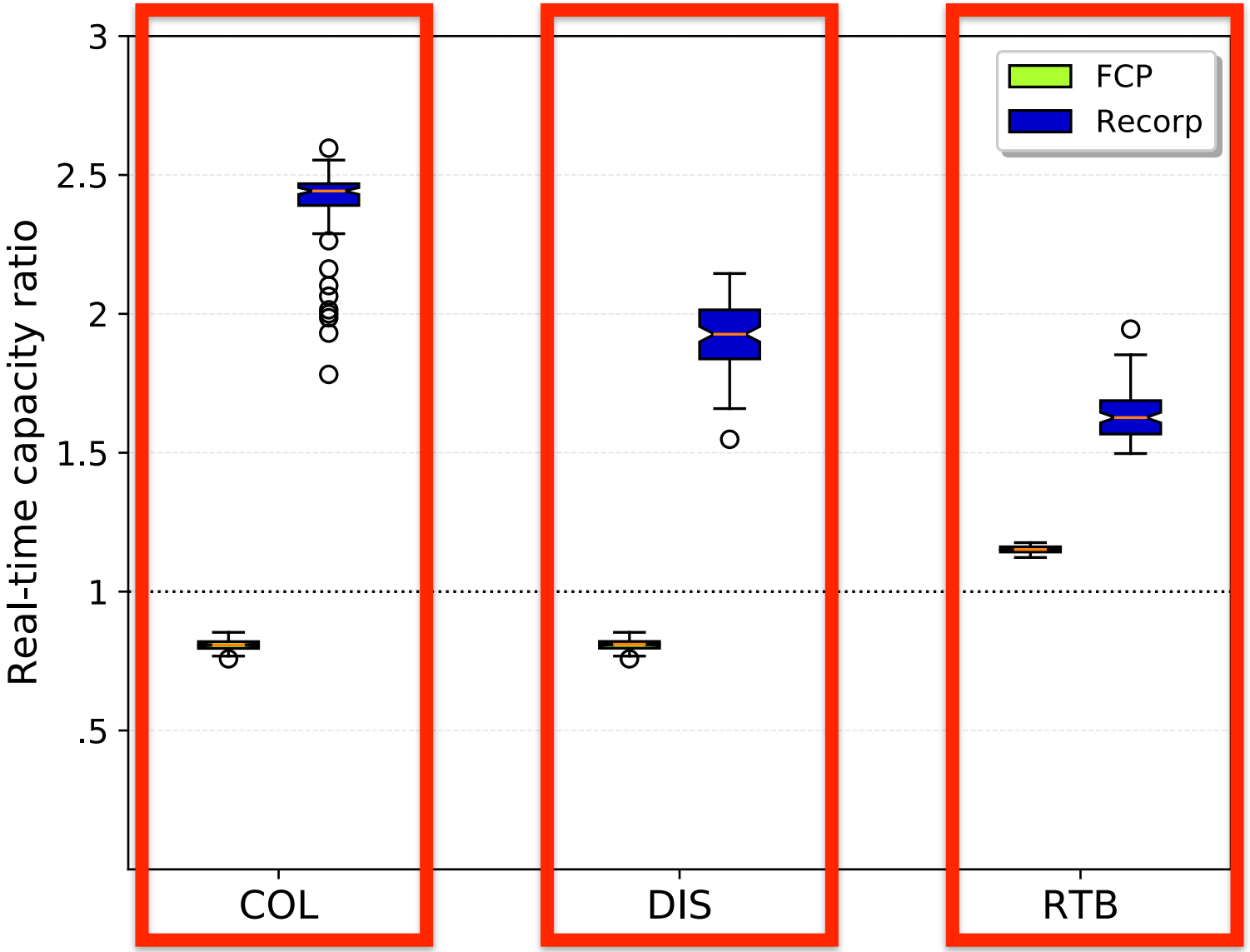
Recorp Design



Evaluation

- **Simulation**
  - 41 nodes, 1 base station
  - 50 flows
  - 3 flow periods
  - 3 different workload scenarios
  - 100 runs
  - ensure 99% end-to-end reliability
- **Workload Scenarios**
  - collection (COL)
  - dissemination (DIS)
  - route through the base station (RTB)
- **Comparison**
  - schedules
  - flow centric policies (FCP)
- **Measurement**
  - real-time capacity
  - relative to schedule performance

Real-Time Capacity



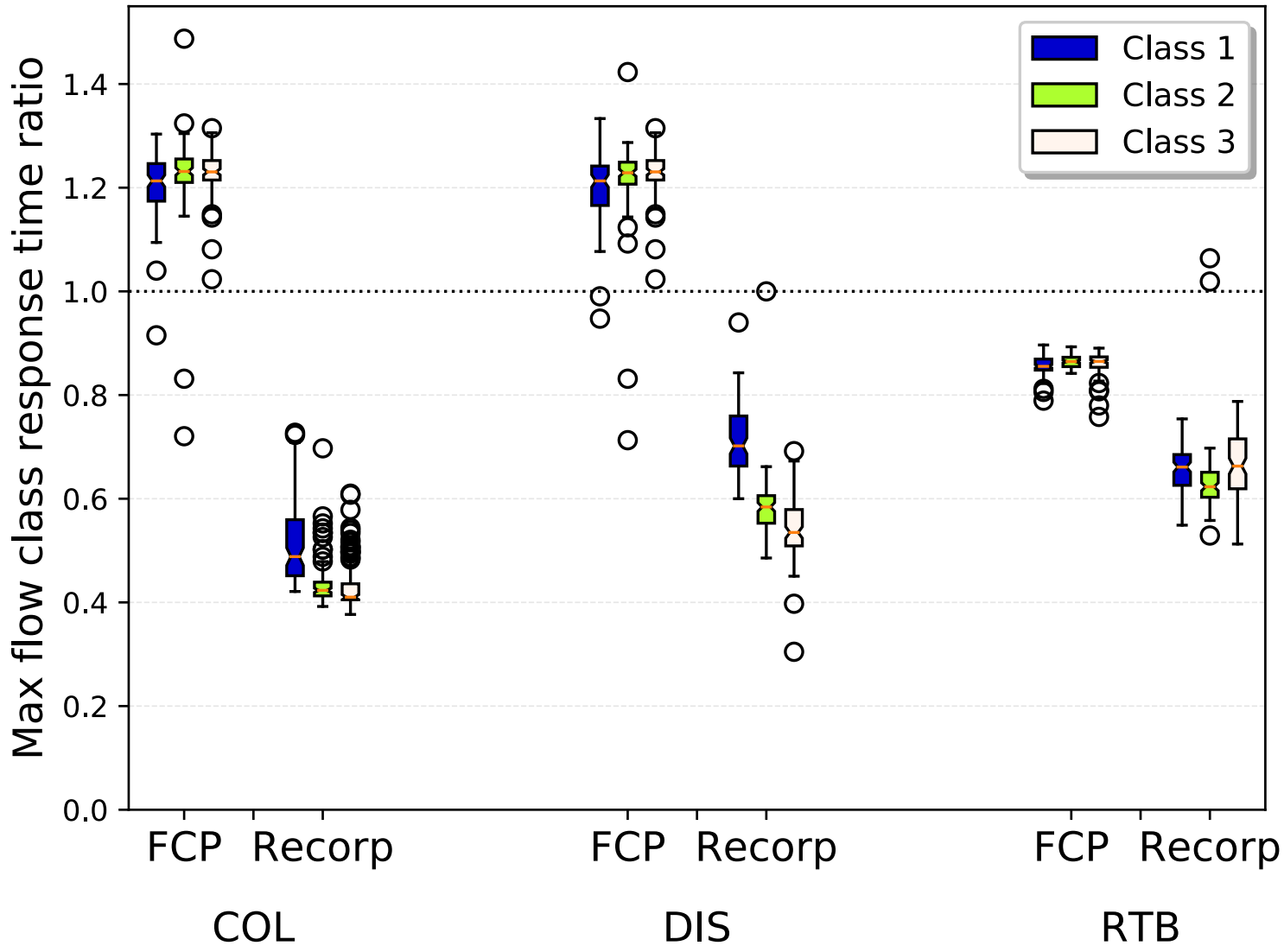
Conclusion

- **Recorp policies**
  - distribute retransmissions at run-time in response to network dynamics
  - utilize local adaptation to distribute allocated transmissions

- **Significant performance improvement compared to state-of-the-art**
  - 1.63 to 2.44 times median increase in real-time capacity

- **For more details please see our paper**

Worst-Case Response Time



State Example