On QoS-aware Scheduling of Data Stream Applications over Fog Computing Infrastructures

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Introduction

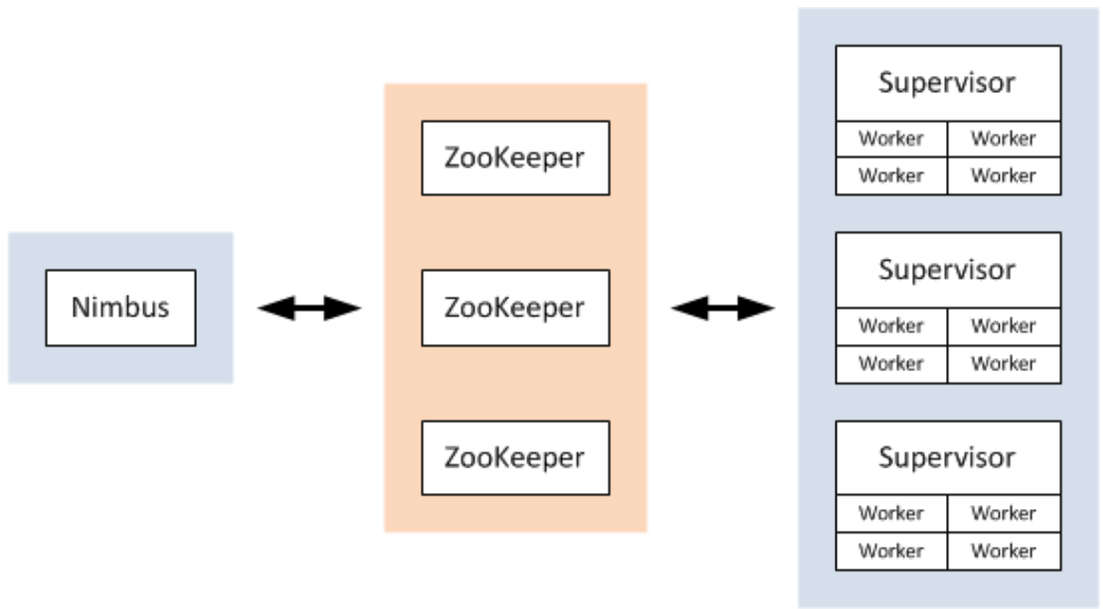
- Motivation
  - Data stream processing (DSP) in fog computing
  - Extract the useful information from raw data to improve urban services
- Challenges
  - Network and system heterogeneity
  - Dynamic geographic distribution
  - Non-negligible network latencies

Data Stream Processing in Storm

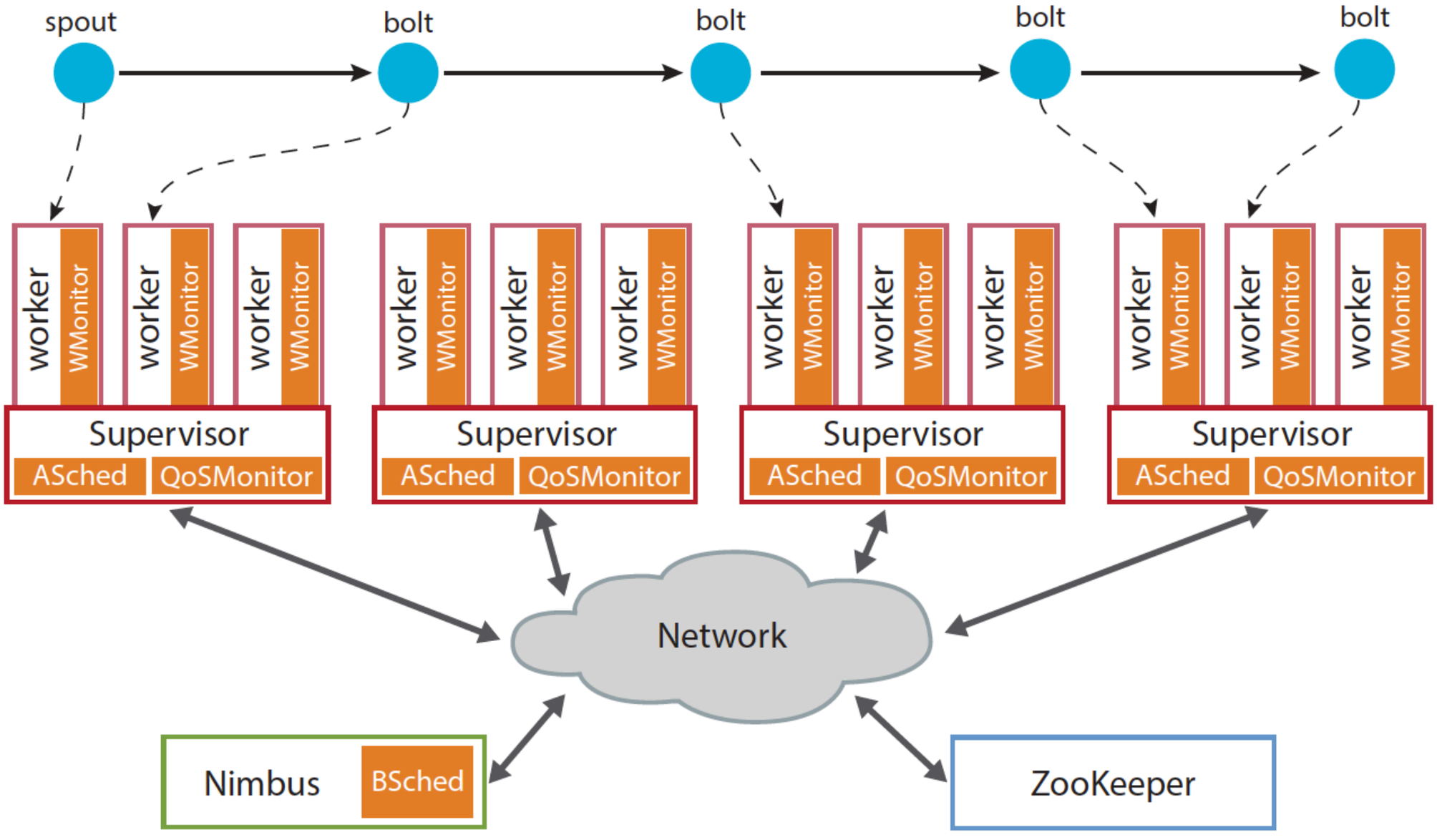
- An open source, real-time, and scalable DSP system maintained by the Apache Software Foundation
- Three types of entities to execute a topology
  - Task - An instance of an application operator
  - Executor - One or more tasks related to the same operator
  - Worker Process - Runs one or more executors of the same topology

Data Stream Processing in Storm

- Worker node - Generic computational resource
- Zookeeper - Shared memory service for managing configuration information and enabling distributed coordination
- Nimbus - Centralized component in charge of coordinating the topology execution
- Supervisor - Starts or terminates worker processes on the basis of the Nimbus assignments



Distributed Scheduling in Storm



Monitoring Compoents

- QoSMonitor
  - Estimates the network latency with respect to the other system nodes and monitors node availability and its resources utilization
- WorkerMonitor
  - Computes the data rate exchanged among the application components
- Nodes will share their informations with each others

AdaptiveScheduler

- Executes the distributed QoS-aware scheduling algorithm on every worker node
- Reassign executors to improve the application performance
- MAPE
  - Monitor - Identifies the set of local executors that could be moved
  - Analyze - Determines if the movable candidate will be effectively moved to another position
  - Plan - Determines a worker node that will execute the candidate executor
  - Execute

BootstrapScheduler

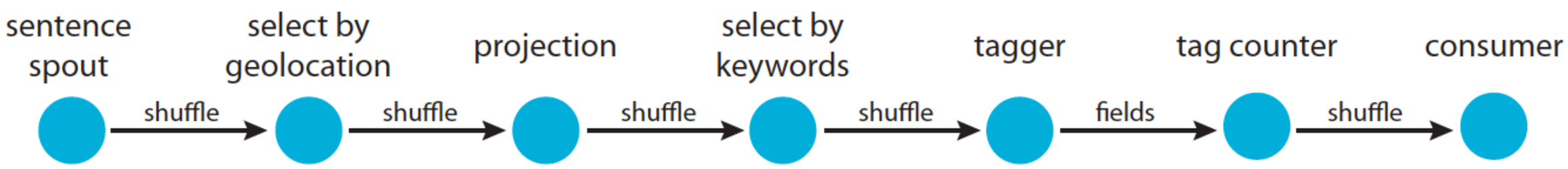
- A centralized scheduler, which defines the initial assignment of the application, monitors its execution, and restarts failed executors

Experimental Results

- DSP system is deployed on a network with not negligible latency and is subject to changes in the QoS of the nodes
- Focus only on network latency and node utilization
- Testbed
  - Apache Storm 0.9.3
  - 8 Worker nodes
  - 2 Further nodes for Nimbus and ZooKeeper.
  - Using “netem” to emulate wide-area network latencies
- Two sets of applications
  - simple topology with different requirements
  - well known applications

Adaptation Capabilities

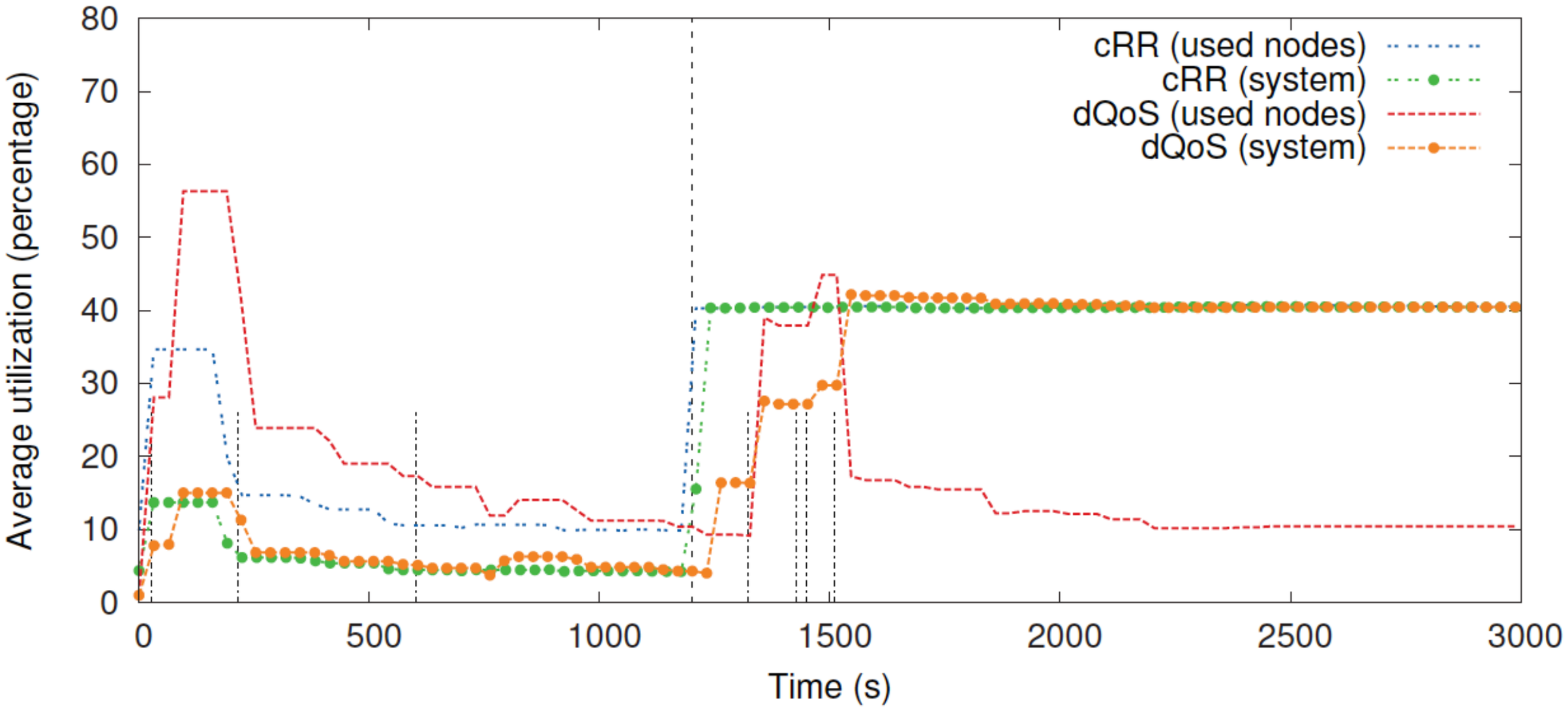
- Compare the two schedulers when the load experienced by the worker nodes changes during the application execute
- Use a simple application which tags and counts sentences produced by a data source



Base Line

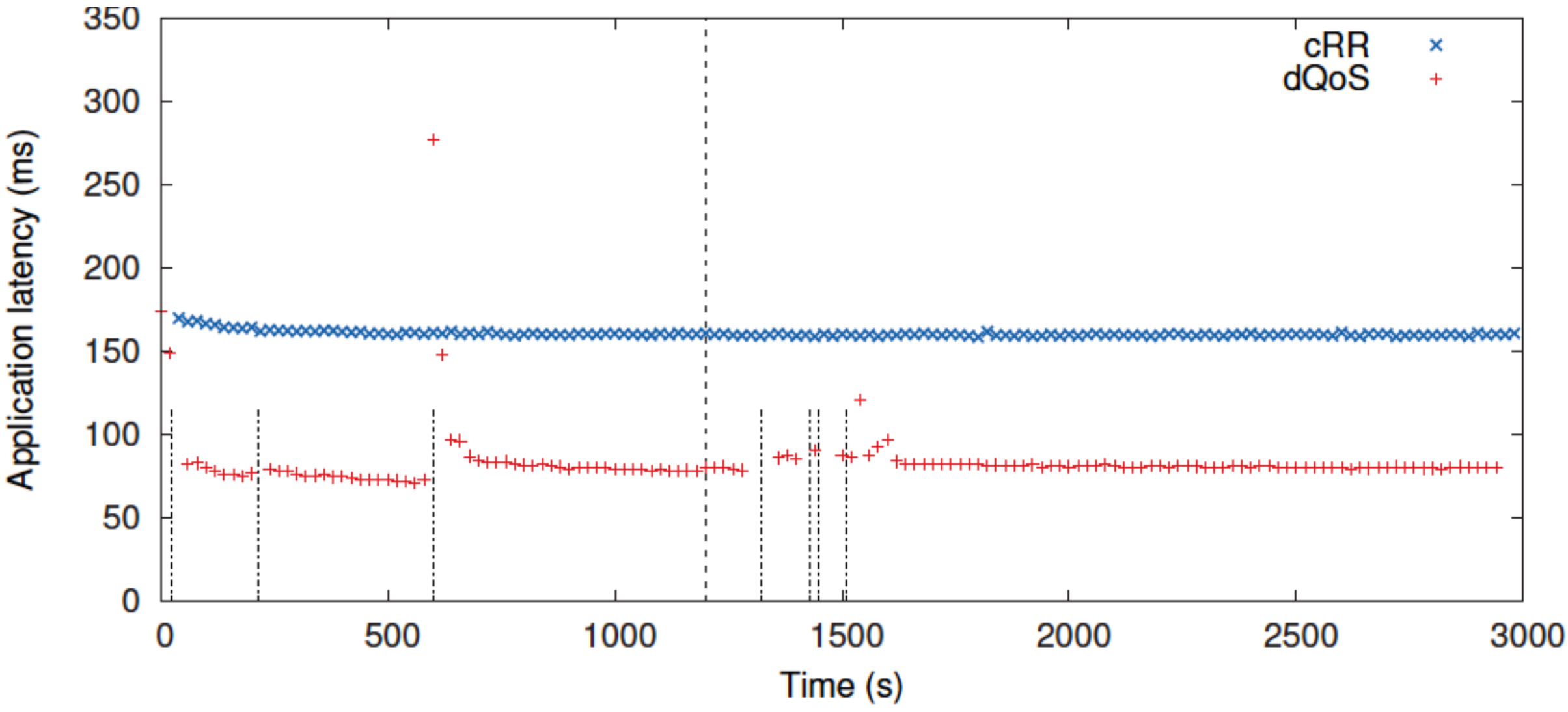
- A single executor for each operator
- After 1200 s, they artificially increase the load on a subset of three nodes using the Linux tool “stress”

Base Line



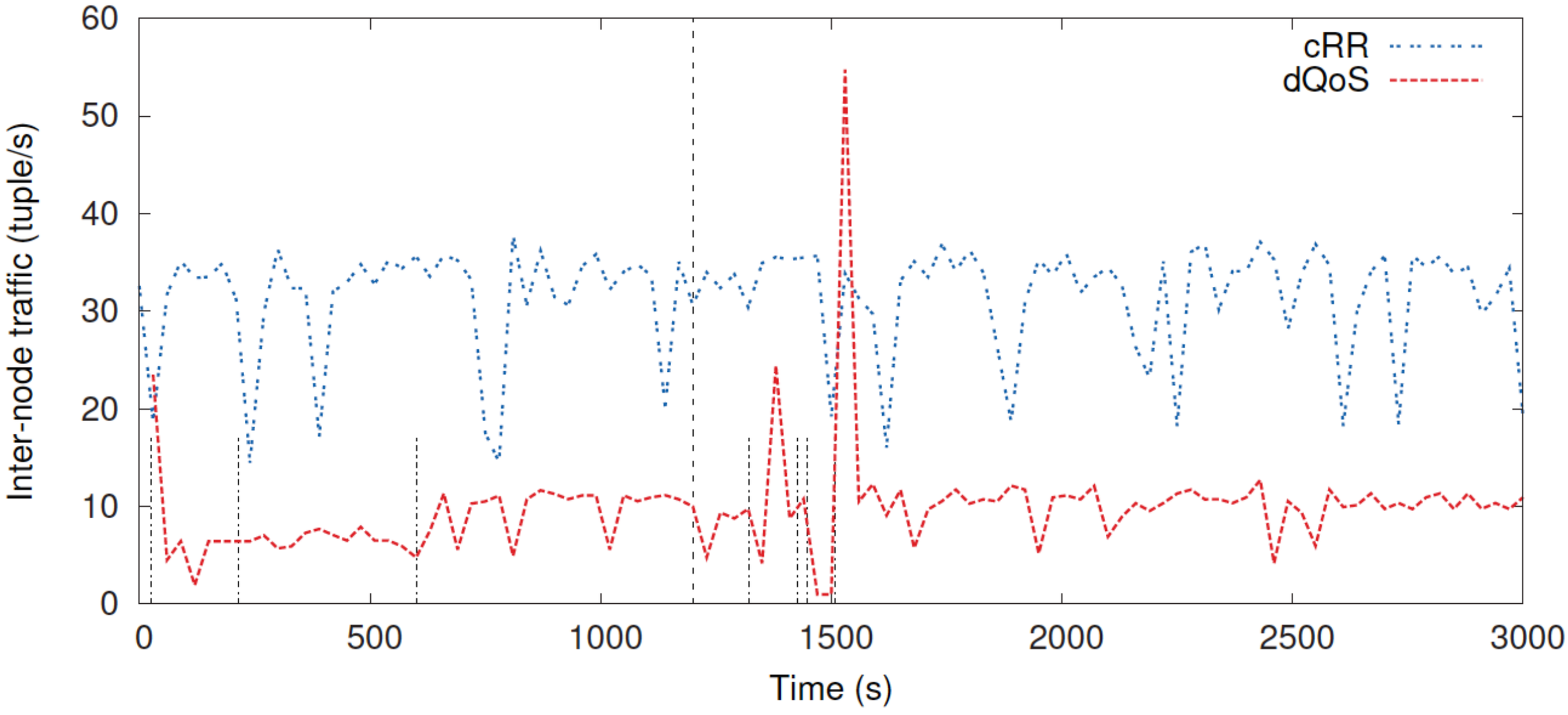
(a) Average node utilization

Base Line



(b) Application latency

Base Line



(c) Inter-node traffic

Heavy Application

- They modify the operators of the tag-and-count topology in order to waste some CPU time
- Load stress event is launched at 2450 s

Heavy Application

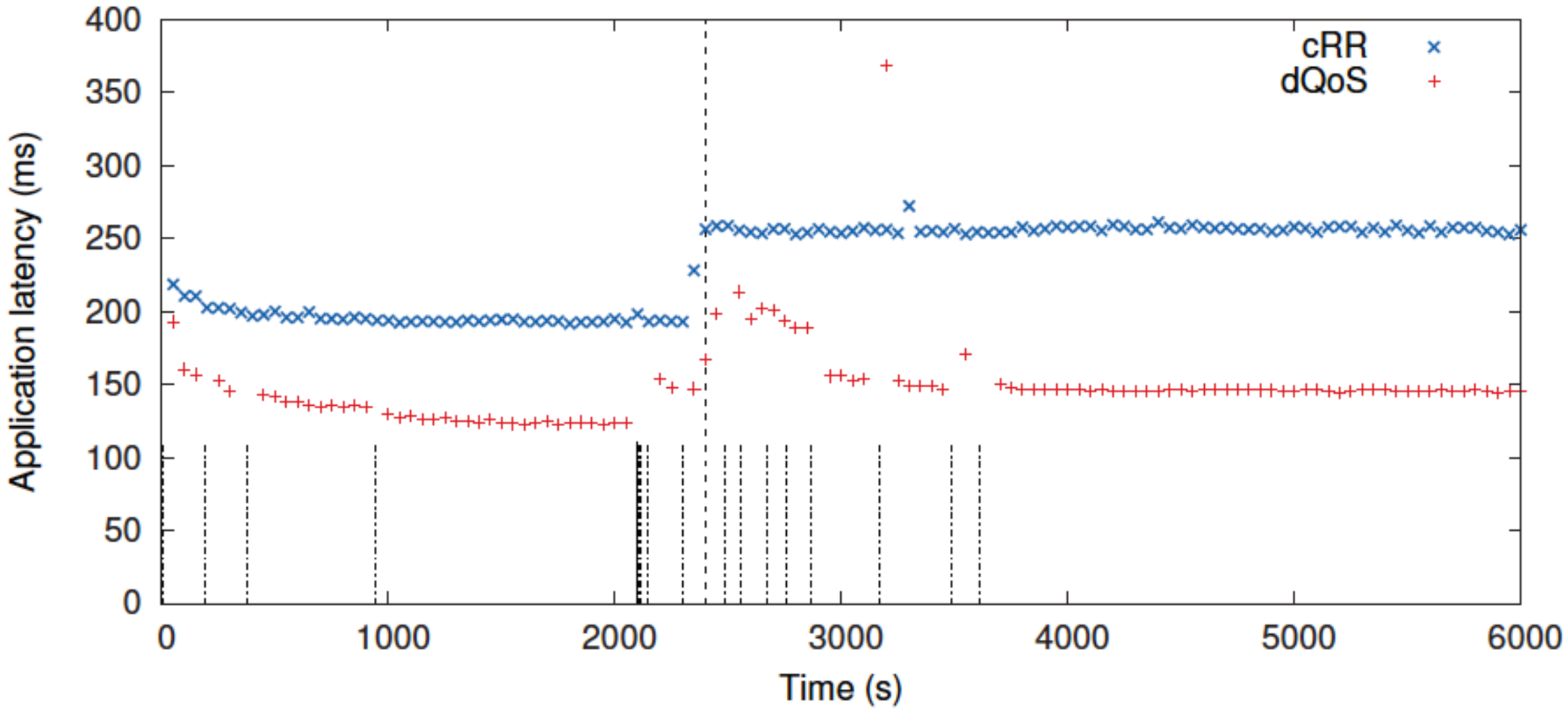
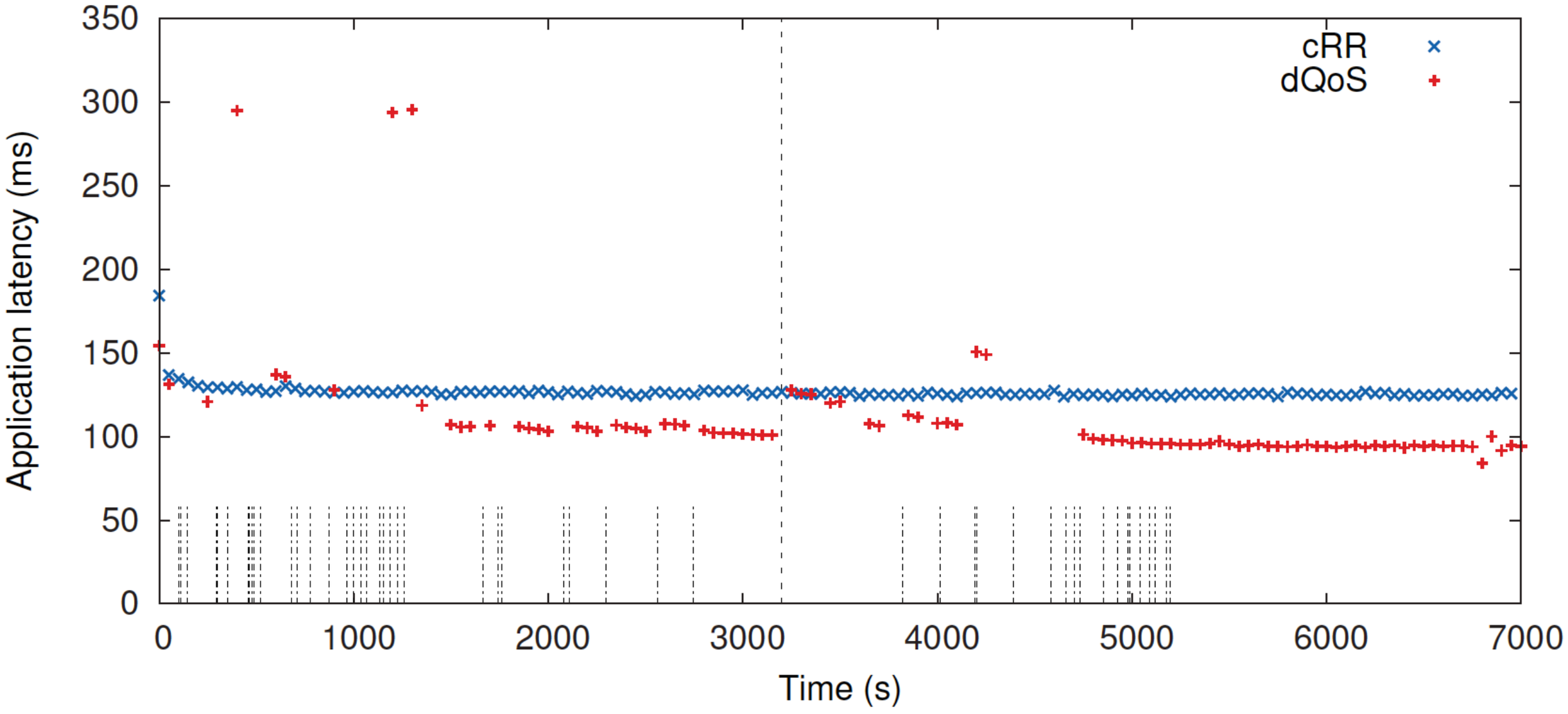


Fig. 4: Average latency of the "heavy" version of the tag-and-count topology when the nodes' utilization changes

Replicated Operators

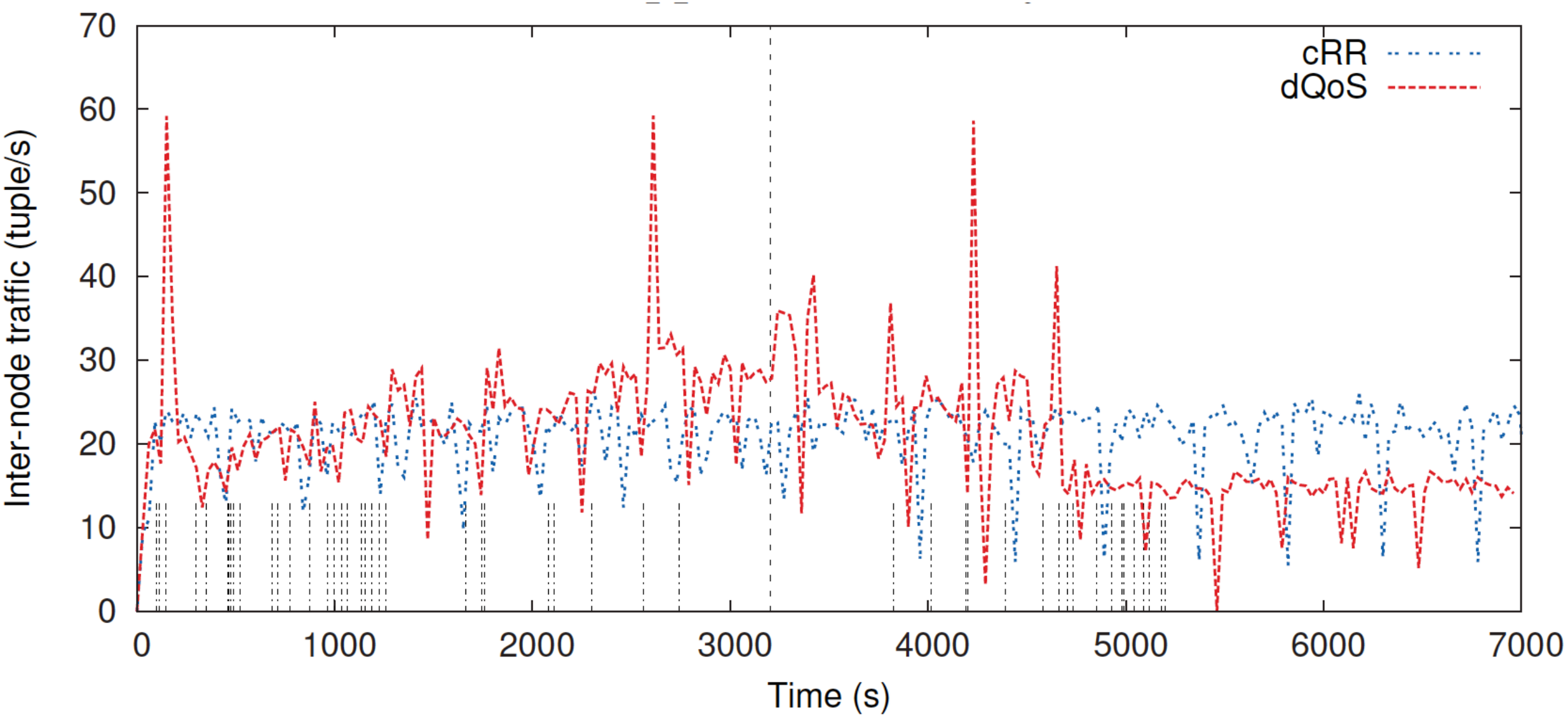
- Two executors are assigned to each operator
- The stress event is launched at 3200 s

Replicated Operators



(a) Application latency

Replicated Operators

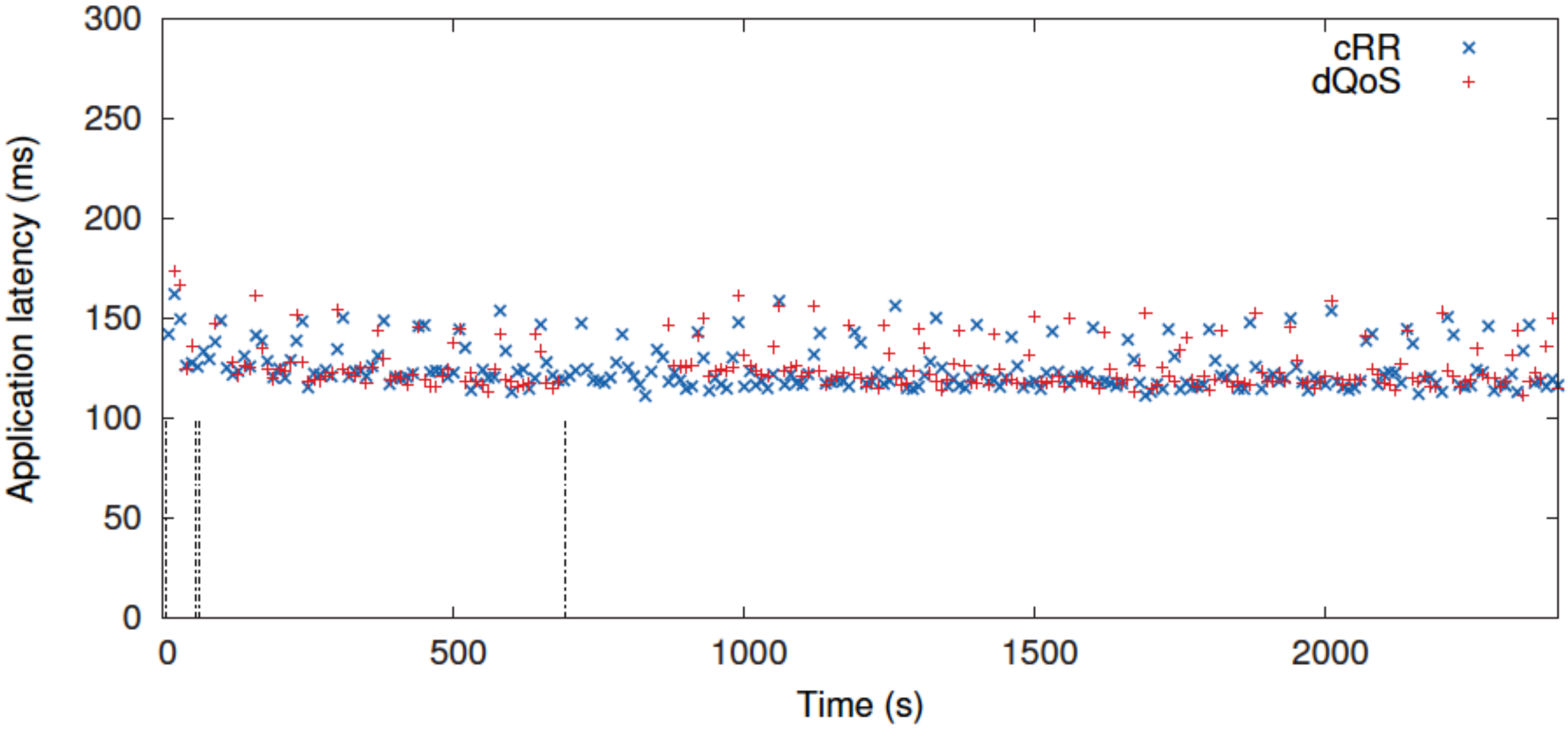


(b) Inter-node traffic

Well-known Applications (Word Count)

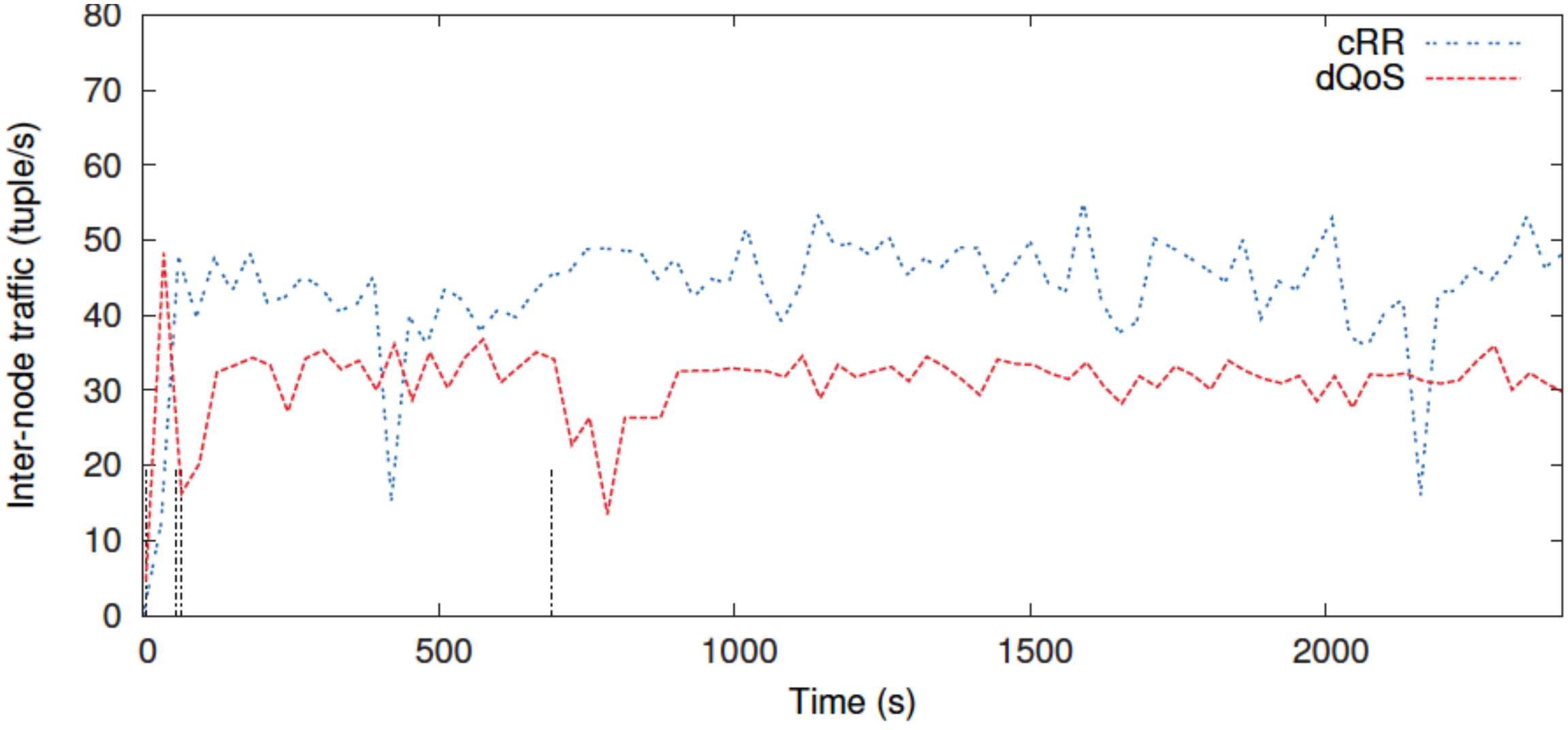
- Composed by a sequence of a source, two operators, and a consumer.
- The first operator splits the sentence into words and feeds the next one, which counts the occurrence of each word; each update of the counters is notified to the consumer
- Assign two executors to the source and three executors to each other operator

Well-known Applications (Word Count)



(a) Application latency

Well-known Applications (Word Count)



(b) Inter-node traffic

Well-known Applications (Log Processing)

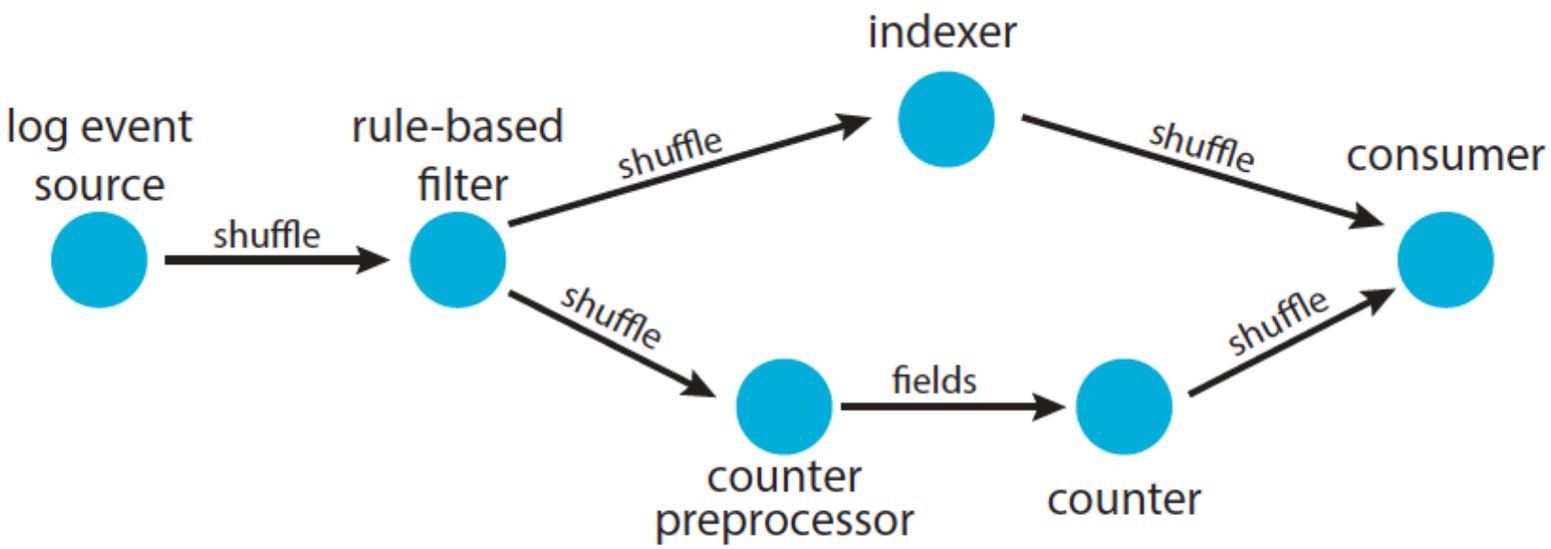
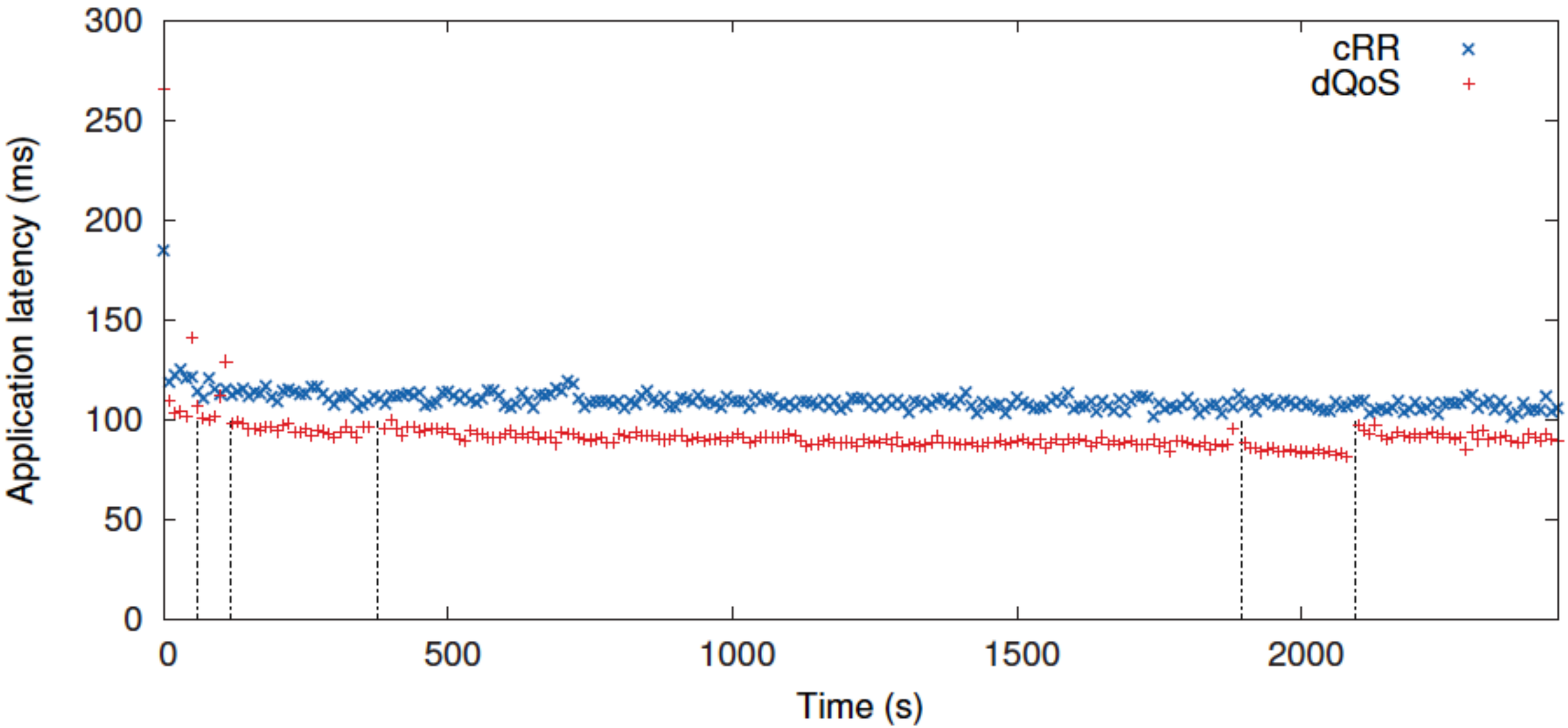


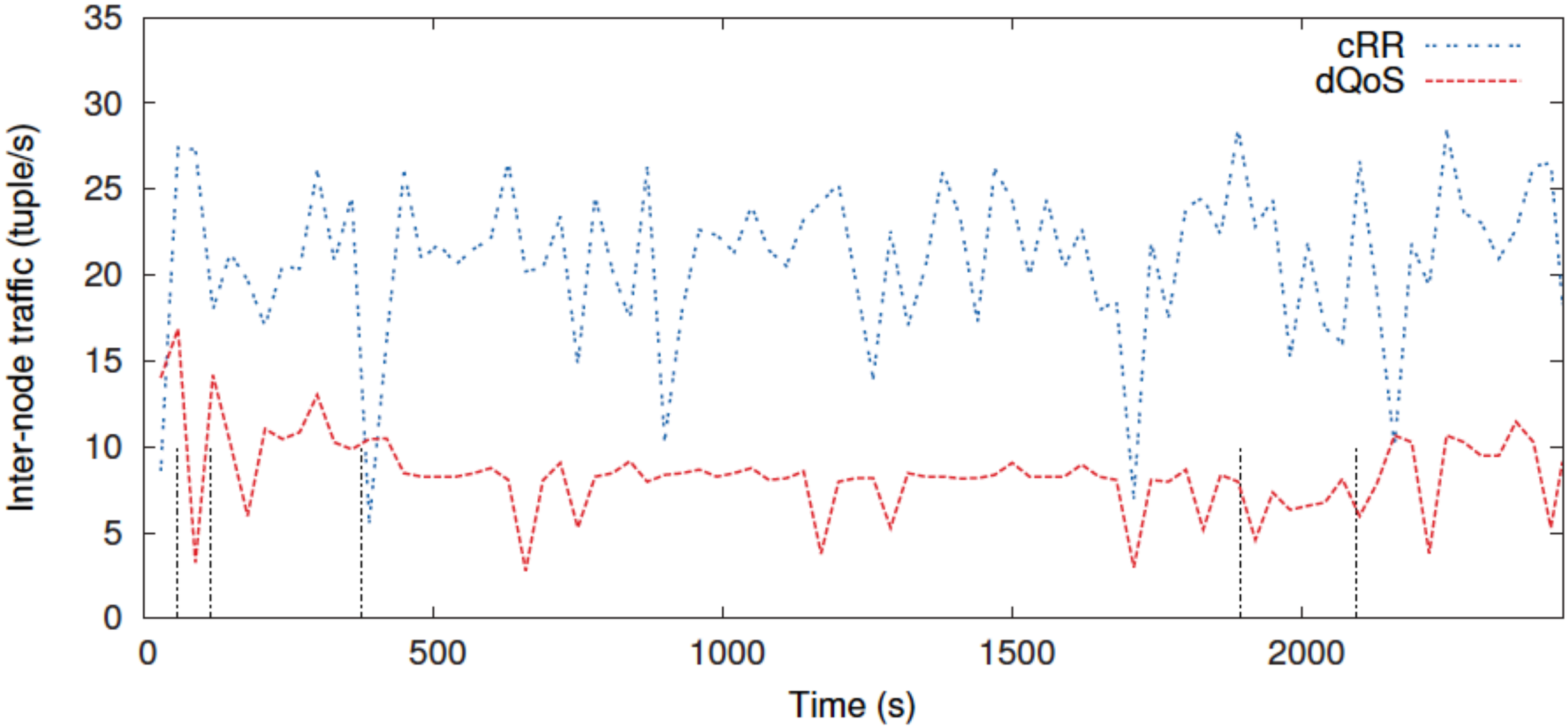
Fig. 7: Log Processing topology

Well-known Applications (Log Processing)



(a) Application latency

Well-known Applications (Log Processing)



(b) Inter-node traffic

Conclusion

- They have used two sets of applications evaluated the distributed QoS-aware scheduler for DSP systems based on Storm with
- The results show that their scheduler outperforms the Storm default one, improving the application performance
- Each placement decision is taken in a independent manner, for complex topologies involving many operators, it can determine some instability that affects negatively the application availability