Adaptive Optimistic Total-Order Protocols for Wide-Area Database Replication

Large-Scale Distributed Systems and Middleware (LADIS)

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March 21, 2007

Road-map

The GORDA Project

- GORDA (Open Replication of Databases) is an IST STREP project.
  - U. do Minho, U. della Svizzera Italiana, U. de Lisboa, INRIA Rhône-Alpes, and Emic Networks OY.
- Replication as a means to offer:
  - High availability, disaster recovery, load balance (read transactions).
- Different replication strategies:
  - Many of these strategies rely on total order protocols.

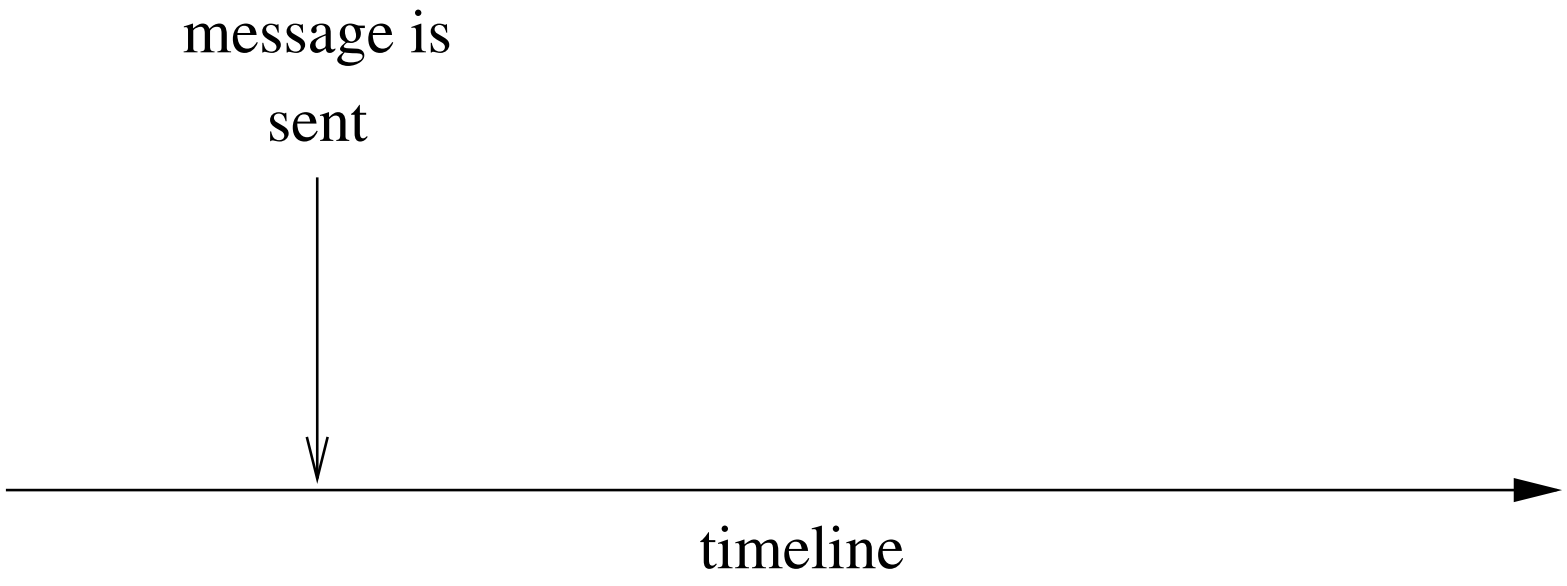
Optimistic Total Order

- Total Order (TO) is a communication primitive that, usually, involves several communication steps.
- Optimistic total order:
  - Provides an early estimate of the final order.
  - Application steps may be executed in parallel with the communication steps of the TO algorithm.
- Issues:
  - Which is the best optimistic protocol for wide-area operation?
  - How to switch in run time between two protocols?

Road-map

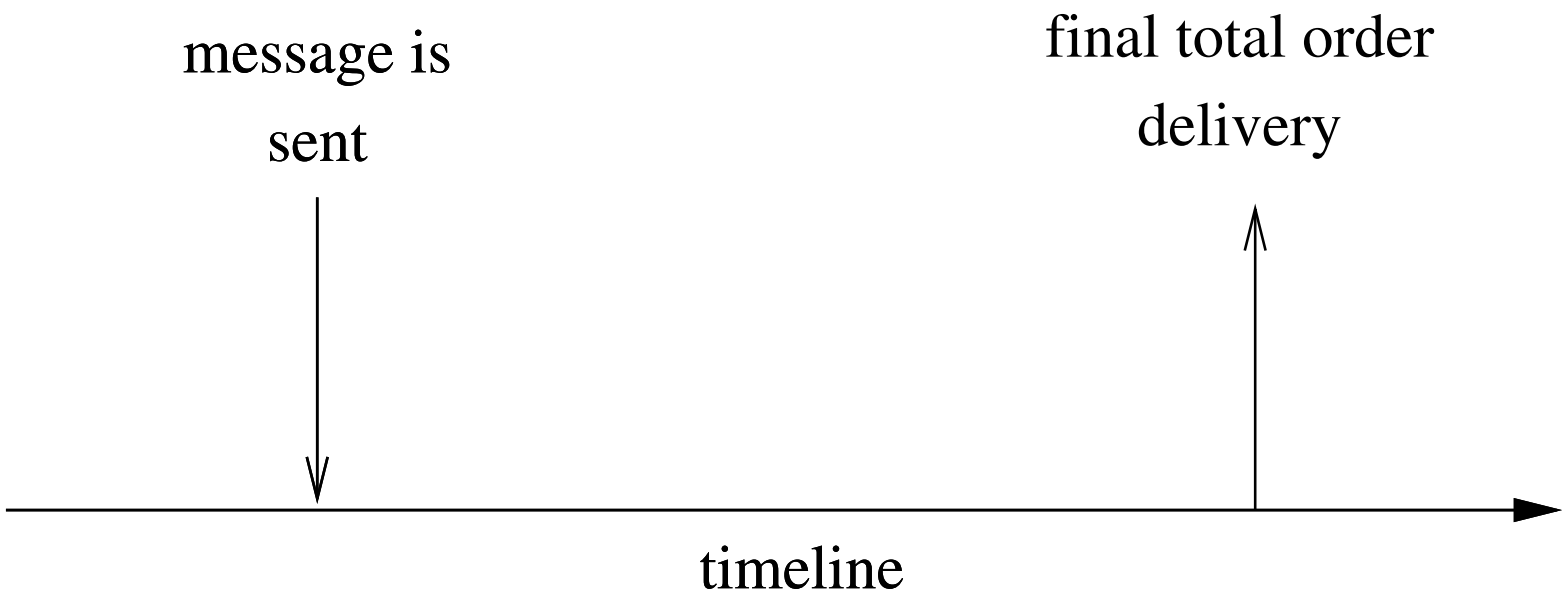
Optimism in Total Order Deliveries

- Message is sent.



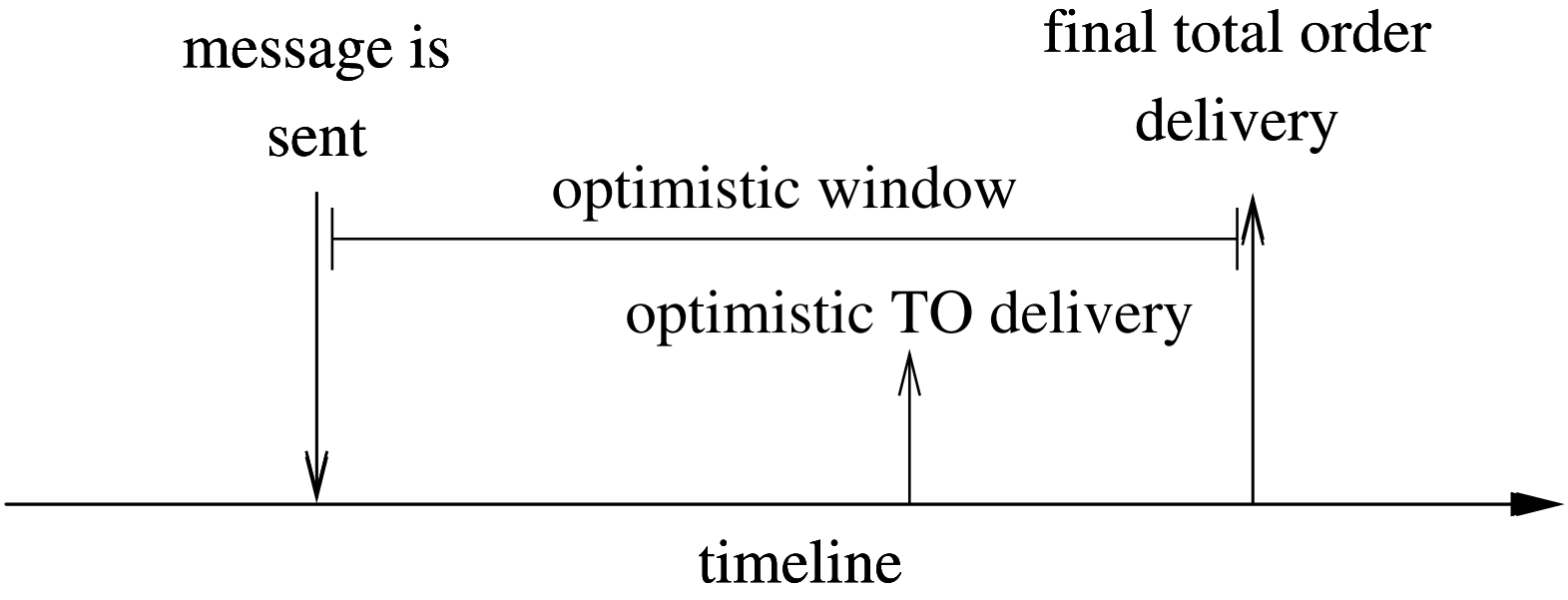
Optimism in Total Order Deliveries

- Message is sent.
- Message final delivery occurs.



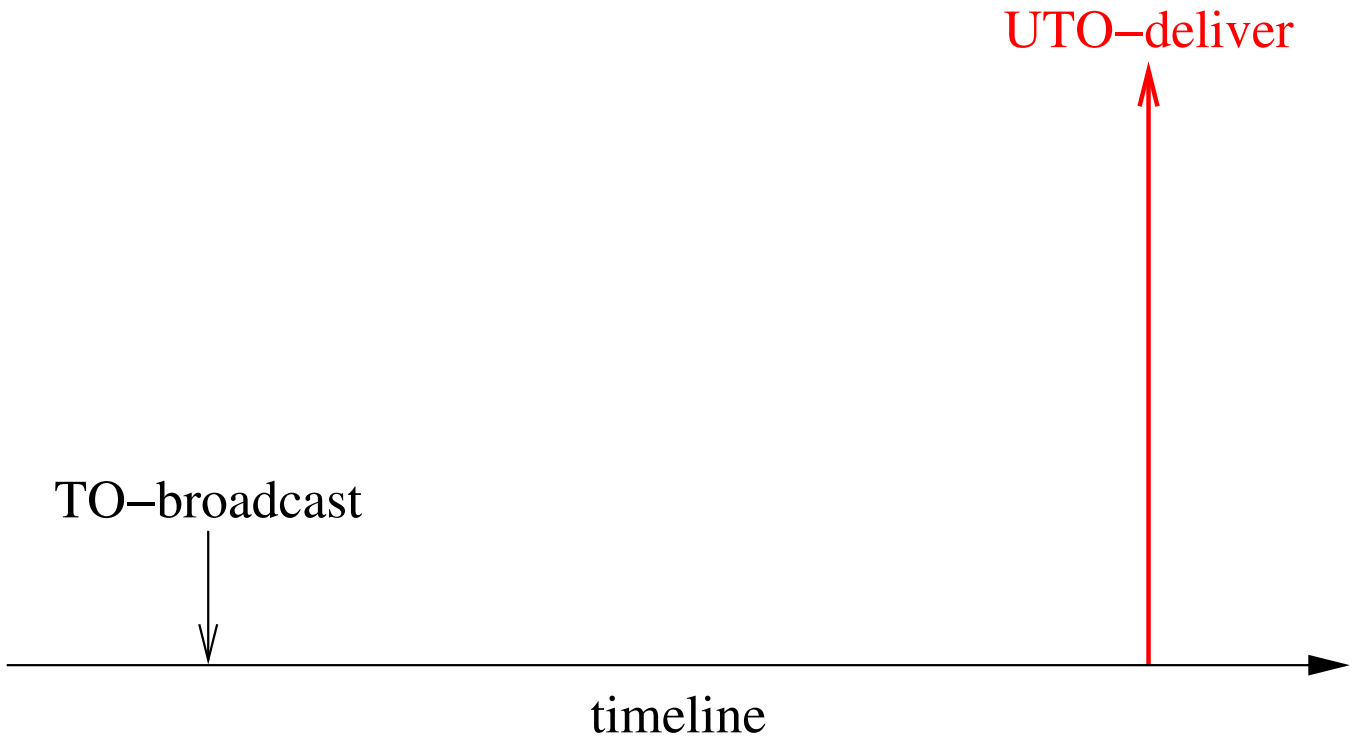
Optimism in Total Order Deliveries

- Message is sent.
- Message final delivery occurs.
- Optimistic delivery occurs.



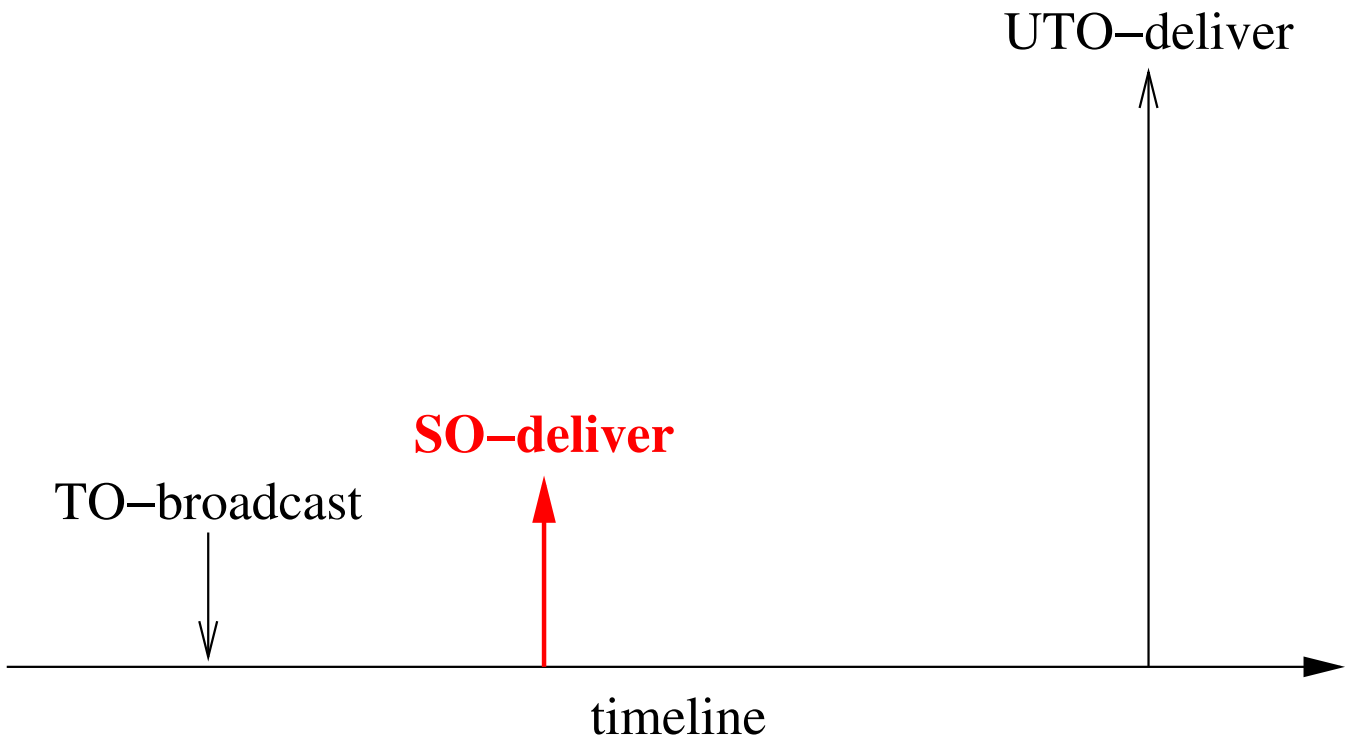
Timeline for Optimistic Deliveries

- Uniform delivery:
  - Final delivery for the database application (stronger guarantees).
  - If a process delivers all correct processes deliver.



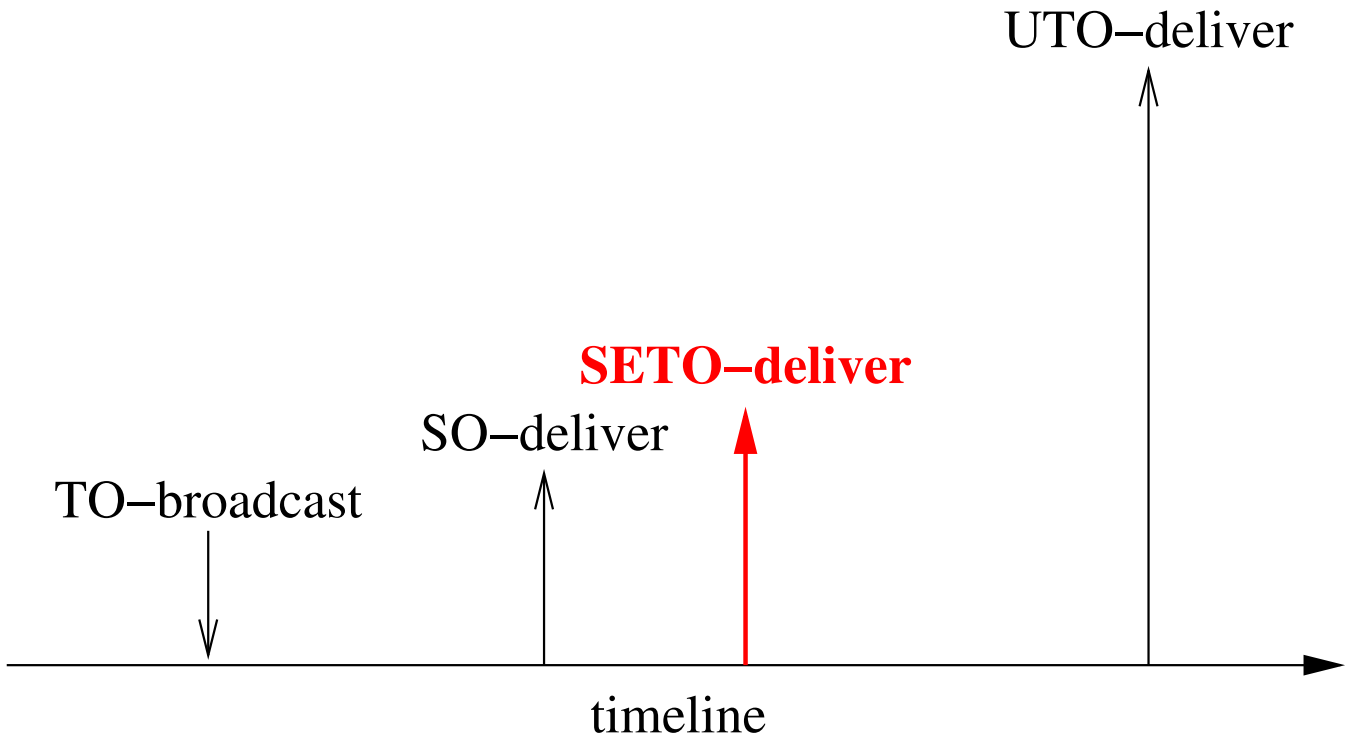
Timeline for Optimistic Deliveries

- Spontaneous order:
  - The order by which messages are received from the network.
  - Inaccurate estimate of final order..



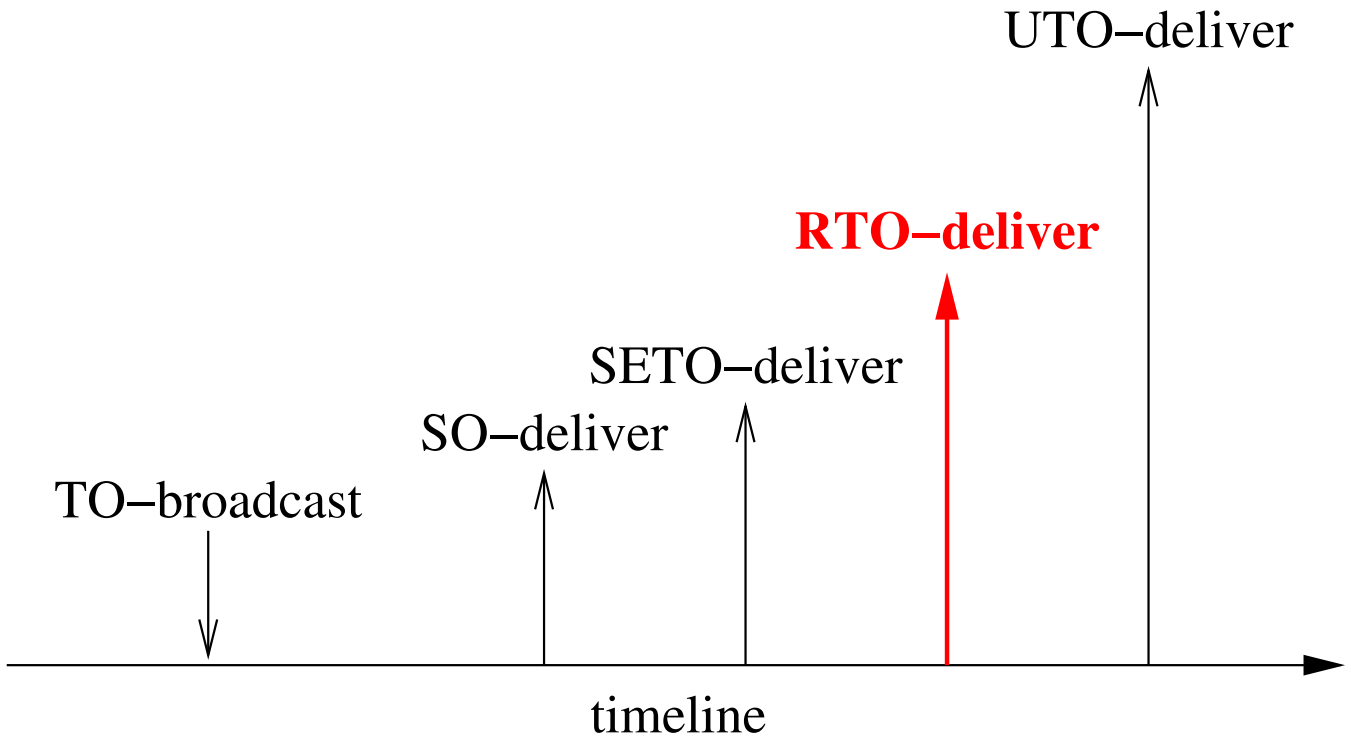
Timeline for Optimistic Deliveries

- Statistically Estimated Total Order (SETO):
  - An optimistic total order protocol for wide area networks was proposed by [Sousa et al. 2002].
  - Accurate in stable networks (but is it the best?).



Timeline for Optimistic Deliveries

- Regular Total Order:
  - Any “classical” total order mechanism (sequencer, token hybrid, etc).
  - Estimate only fails if crashes occur (accurate but slower).

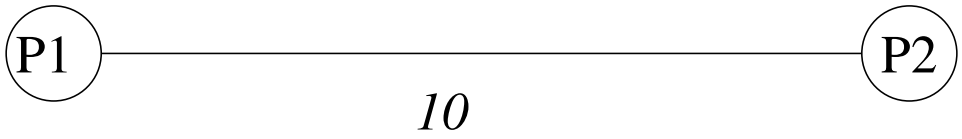


Goal

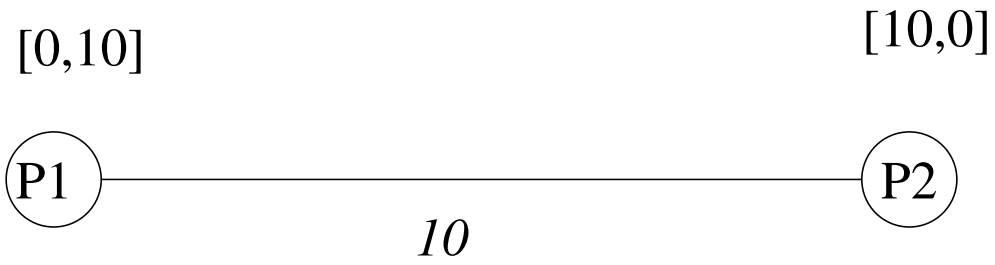
- Use a SETO variant when the network is stable.
- Use a regular variant when the network is unstable.
- Dynamically switch among different approaches with minimum overhead.

Road-map

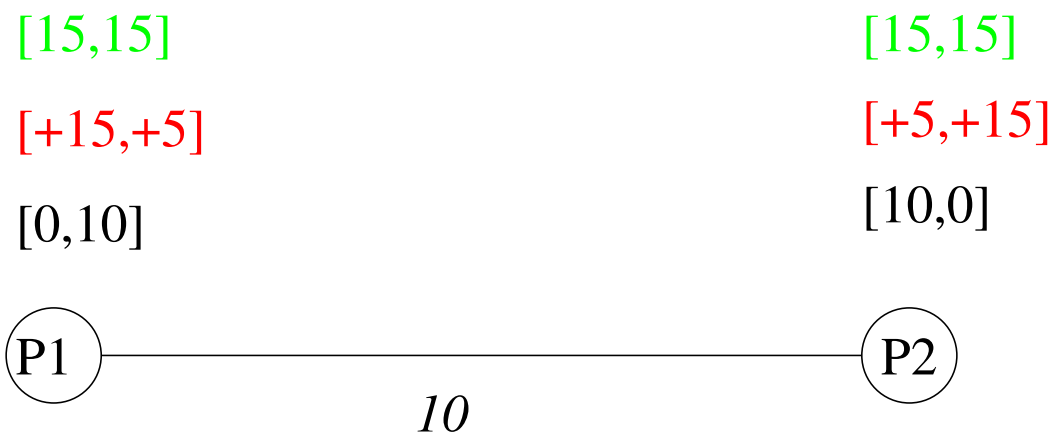
Simple Network



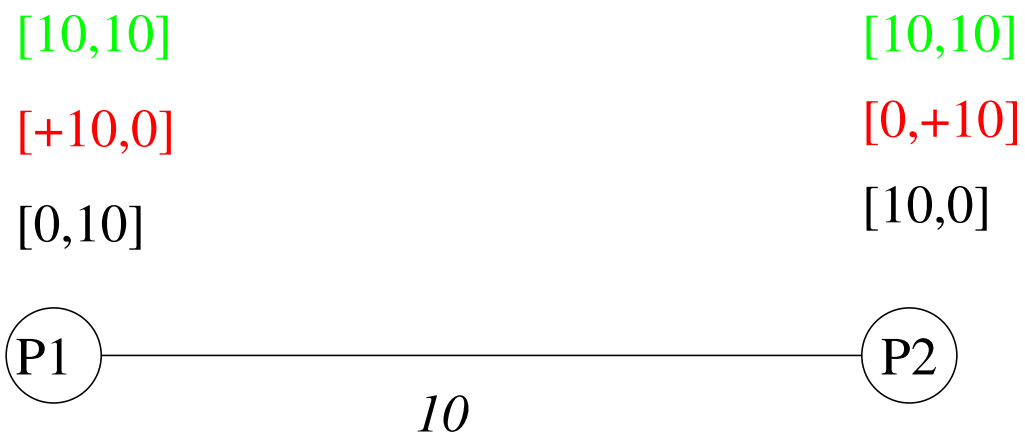
Spontaneous Order



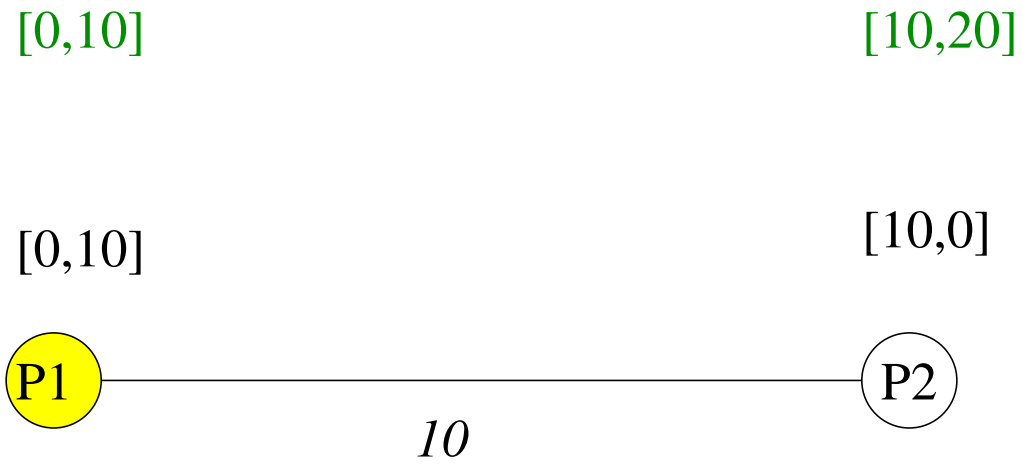
Delay Assignment 1



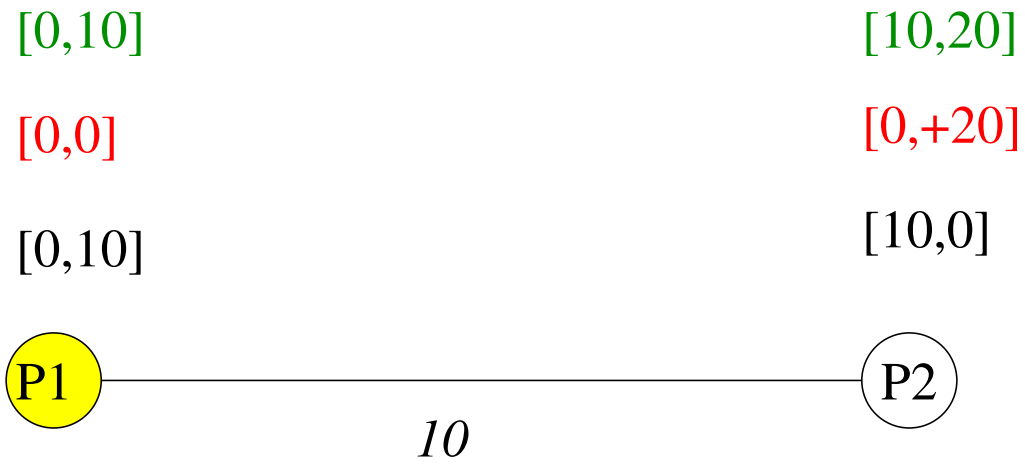
Delay Assignment 2



Sequencer Based Order



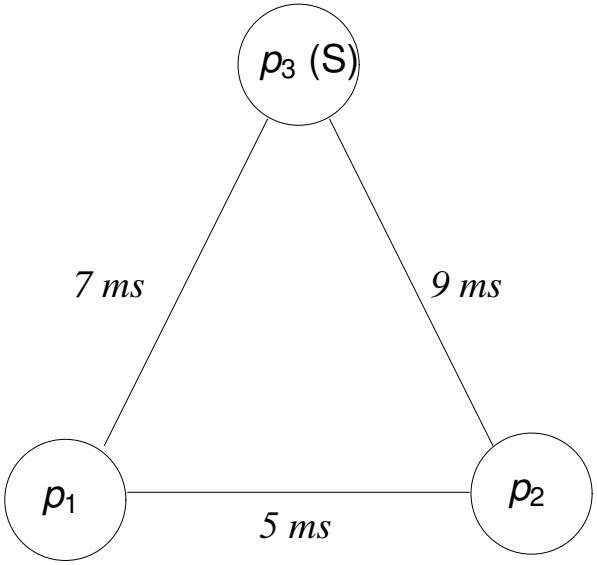
Sequencer Based Order



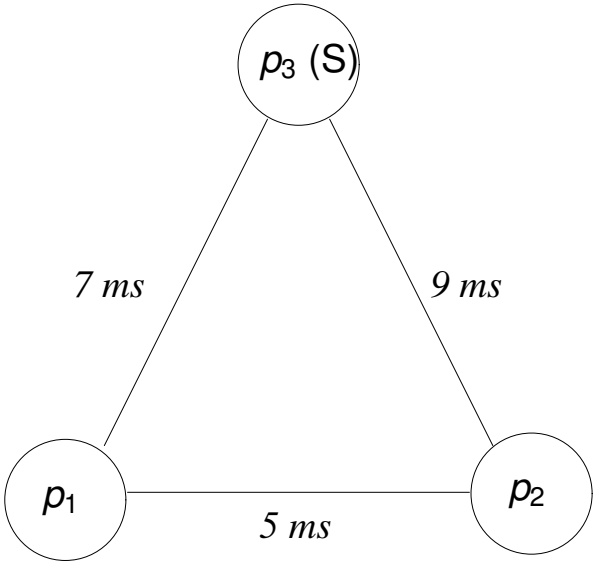
Statistically Estimated TO (SETO)

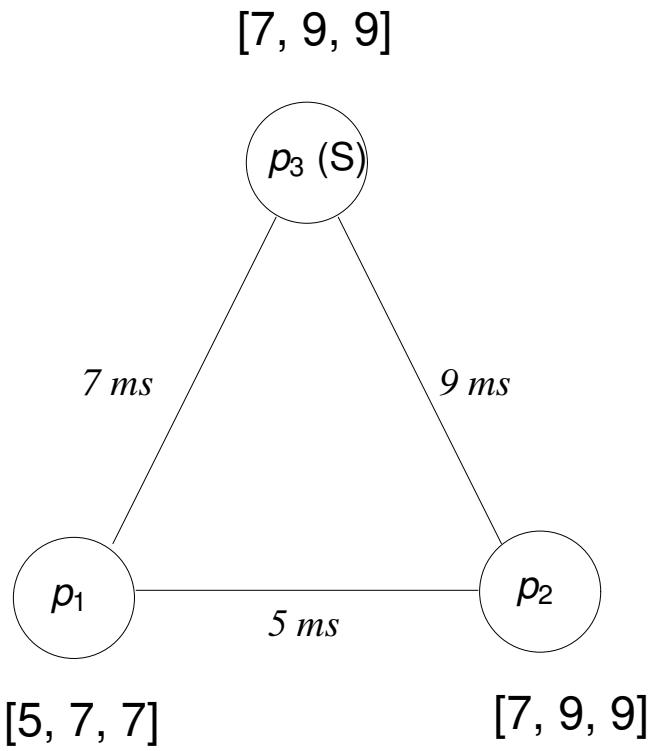
- Proposed by [Sousa *et al.* 2002].
- Optimistic variant of the sequencer based algorithm.
  - The authoritative total order is the spontaneous order observed by the sequencer process.
- Each node cleverly delays received messages to mimic the spontaneous order observed by the sequencer.
- The delay calculation relies on a statistically estimation of the latency among nodes.

SETO Delay Assignment

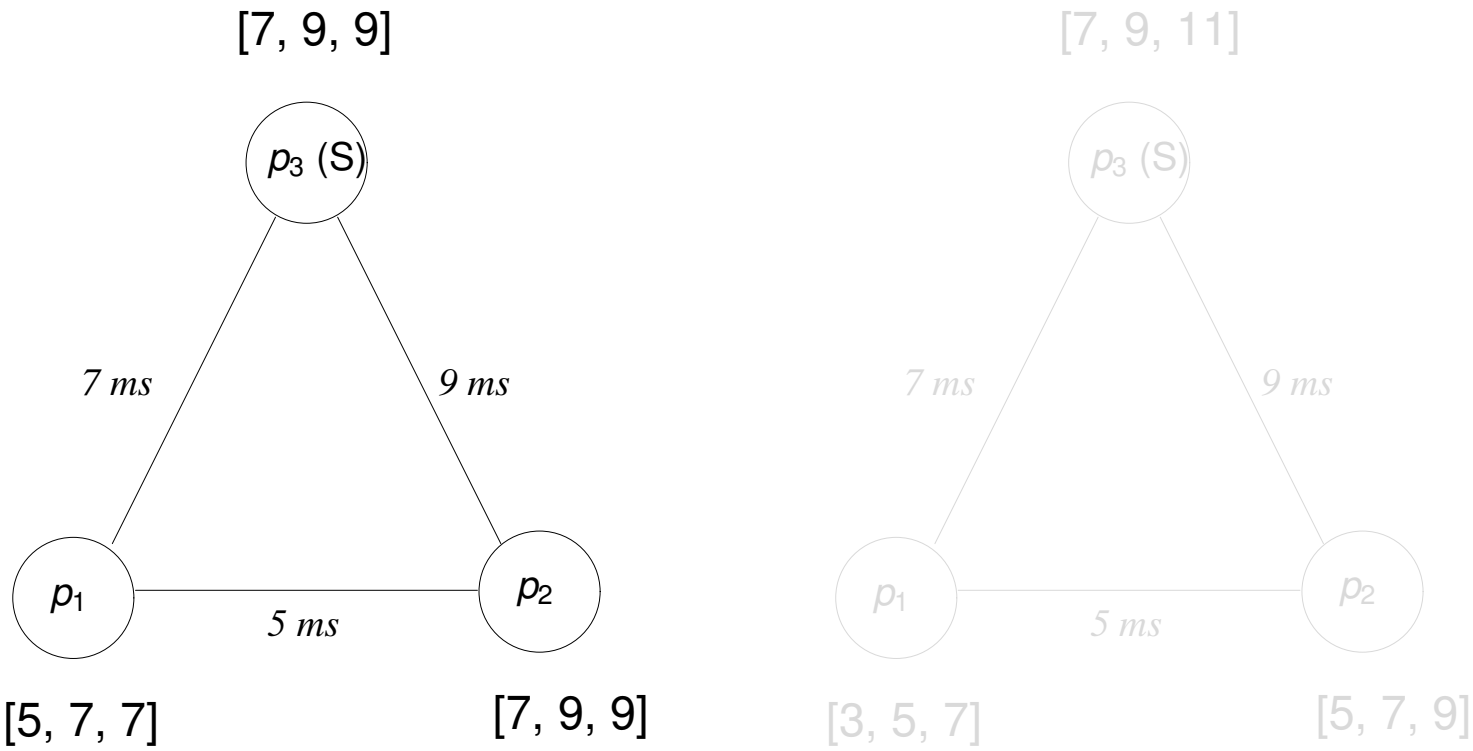


SETO Delay Assignment





Is SETO Optimal?



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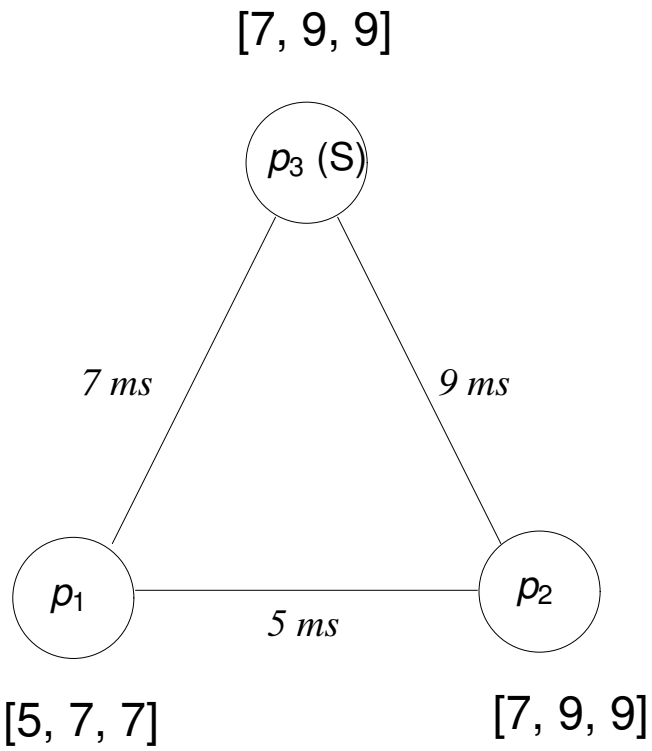
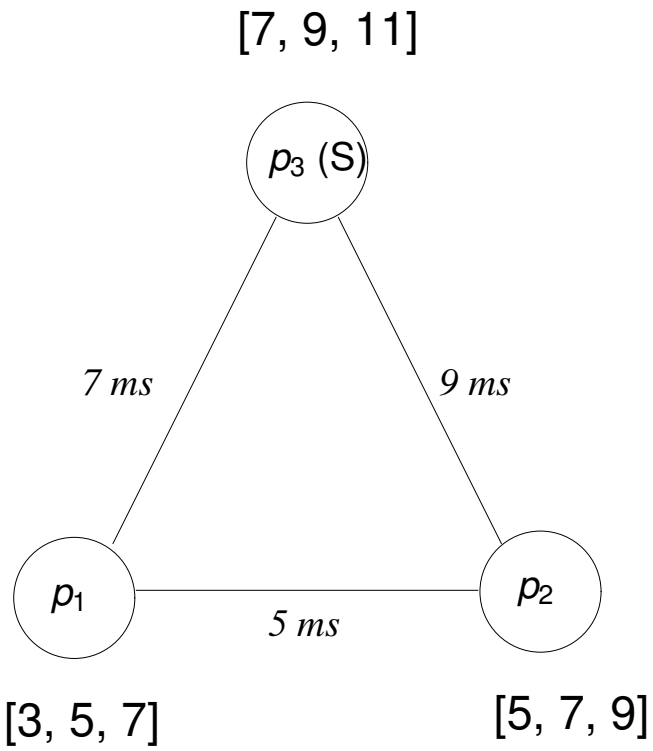




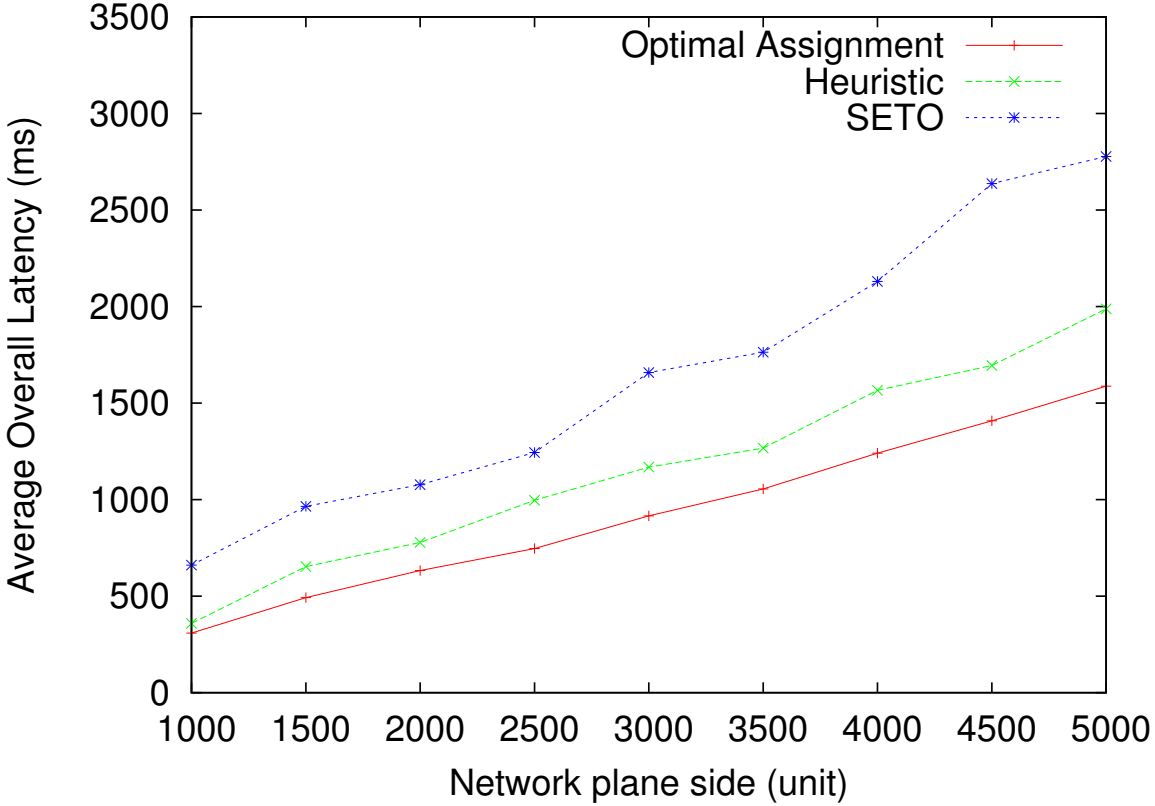
What we did

- Shown that optimal the optimal solution can be formulated as a linear programming problem.
- Designed a heuristic to approximate the optimal solution.
  - Executed when the use of a solver is not feasible or impractical.
- Designed an algorithm to compute and deploy the assignment.

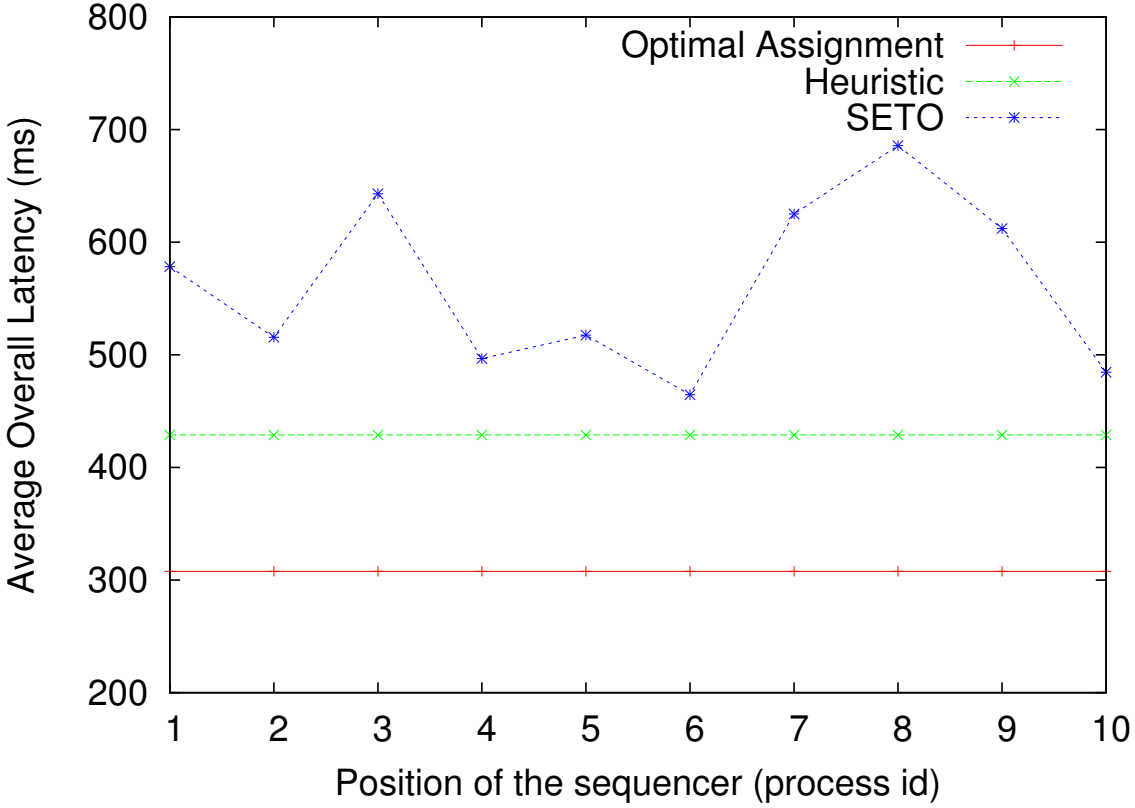
Evaluation

- Tests performed in a simulated environment consisting of:
  - Network topologies
  - Transmission rates
  - Models that execute the three algorithms at stake
- Network topologies where generated in BRITE
- Networks of 30 nodes

Network Plane Size



Sequencer Position



Road-map

Switching Protocols

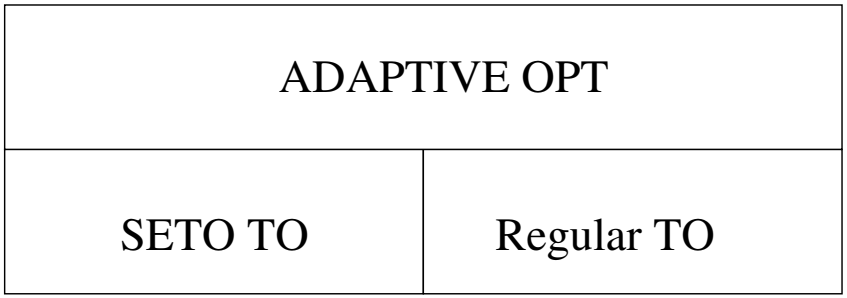
- Allow for the execution of the most suitable total order algorithm, at any point in time

Previous approaches usually involve:

- the message flow to be explicitly stopped ([Renesse *et al.*, 1998])
- the buffering of messages ([Liu & Renesse, 2000], [Chen *et al.*, 2001])
- the implicit delay in the communication during the transition phase ([Rutti *et al.*, 2006])

Our Approach

- The transition is non-disruptive regarding the communication flow
- Adaptation is transparent to the application
- The total order algorithms are executed without any modifications
  - A wrapping layer coordinates the transition between algorithms



Protocol

- Premise: switch from TO-A to TO-B
- Switching protocol:
  - Control message is broadcast to all processes
  - When received, the process starts transmitting using both algorithms at the same time
  - First message to be sent is *flagged*
  - Messages received from TO-A are delivered
  - Messages received from TO-B are buffered in order
  - When a *flagged* message is received from every node:
    - Discard all buffered messages already delivered by TO-A
    - Deliver the remaining messages in order
  - From this point forward:
    - Messages received by TO-A are simply discarded
    - Only TO-B is used to receive and send messages

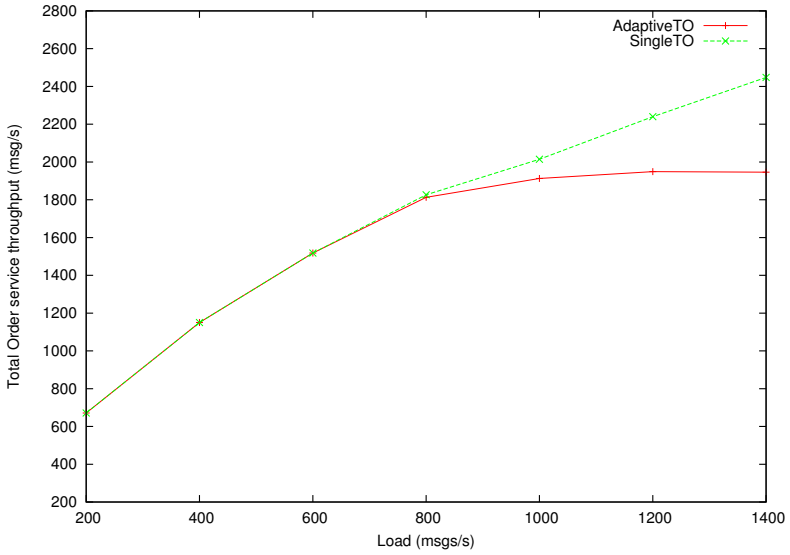
Evaluation

- Simulations performed using SSFNet
- Simulation scenario:
  - Multiple nodes in a WAN (4 senders).
  - Periodic replacements ($2ms$) of the same total order algorithm

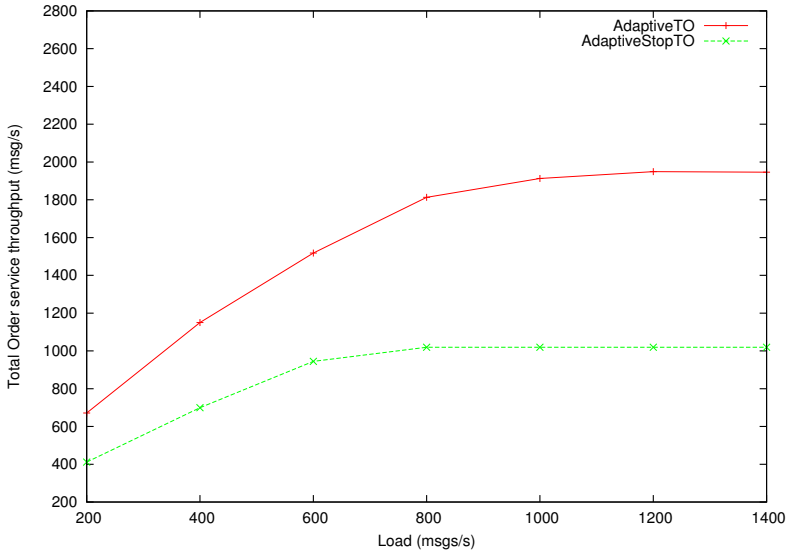
Switching Protocols Used

- Stoppage based protocol
  - Node coordinates traffic stoppage in all nodes
  - When all traffic is stopped all nodes start using the new TO algorithm
- Protocol by [Rutti *et al.*, 2006]
  - Control message is broadcast in total order
  - When received, each node re-transmits all the messages it has not received yet, using the new algorithm

Transmission Rate

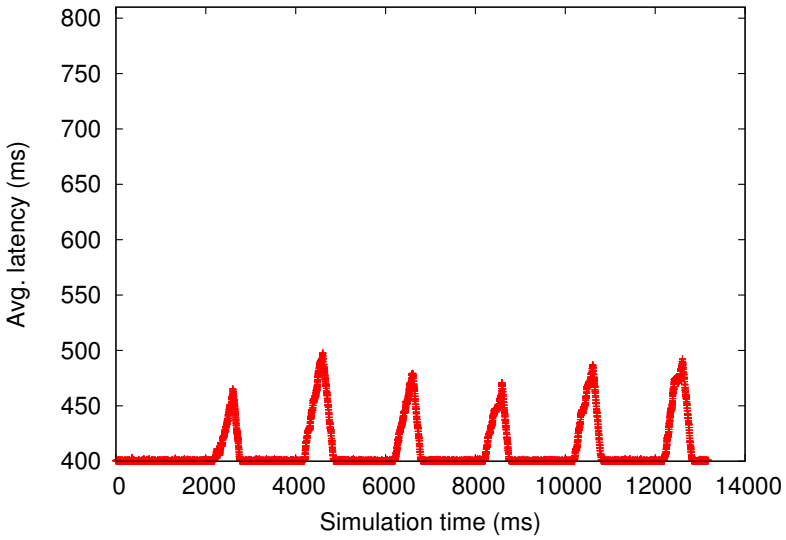


With and without replacement

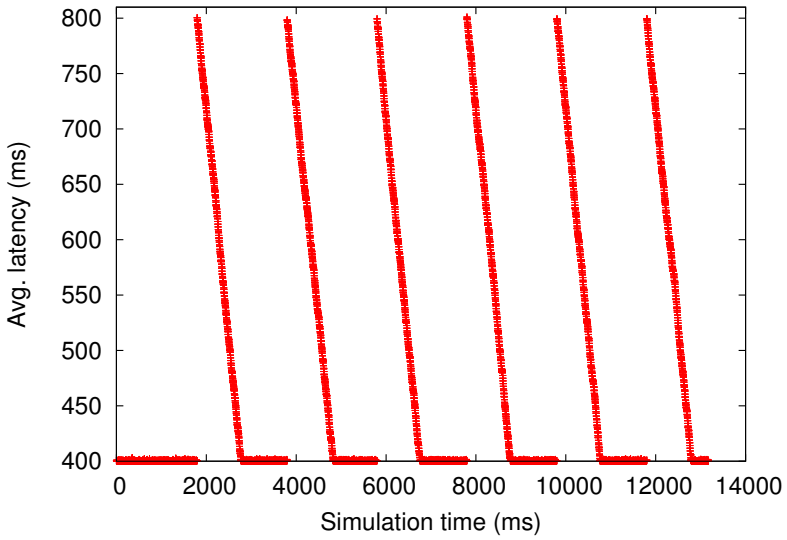


Proposed protocol *VS* stoppage based approach

Message Transmission Latency

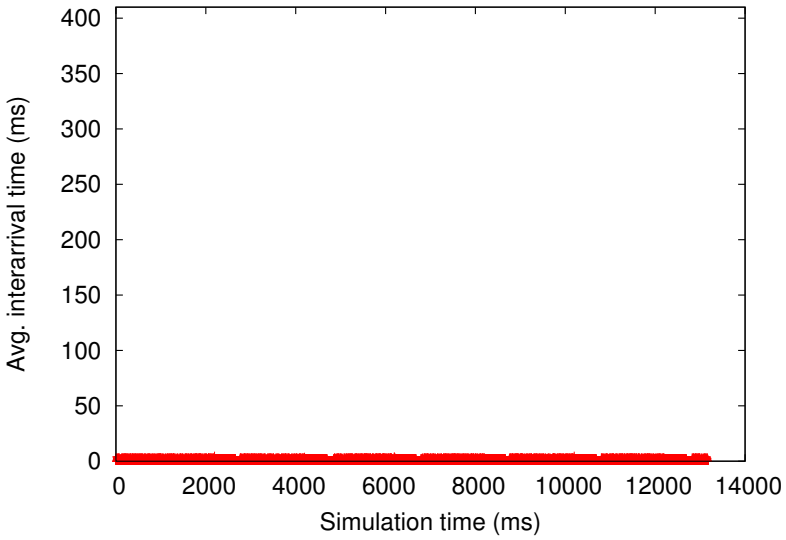


Proposed protocol

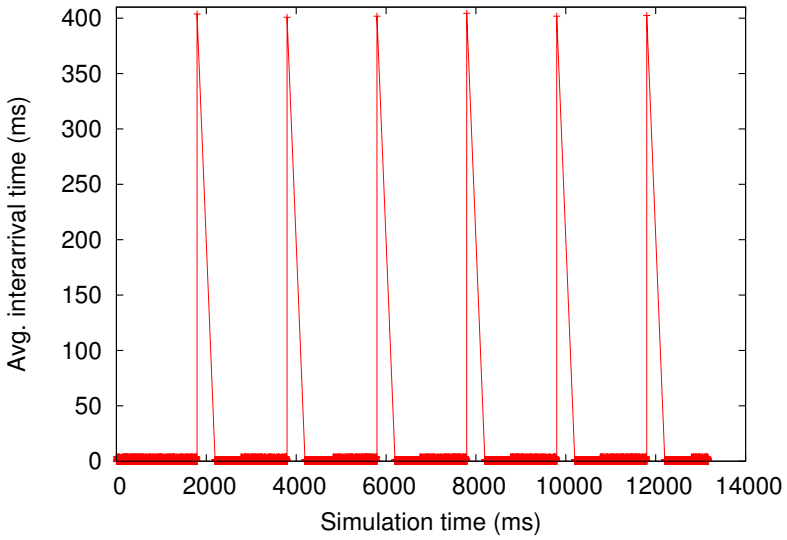


Protocol by [Rutti *et al.*, 2006]

Message Inter-arrival Time



Proposed protocol



Protocol by [Rutti *et al.*, 2006]

Road-map

Conclusions and Future Work

Conclusions

- New (optimized) SETO algorithm.
- New switching algorithm.

Future Work

- Integrate with the GORDA's replication protocols.

Bibliography

- J. Mocito, A. Respício, L. Rodrigues. On Statistically Estimated Optimistic Delivery in Large-Scale Total Order Protocols. In *Proceedings of the 12th IEEE International Symposium on Pacific Rim Dependable Computing (PRDC'06).* University of California, Riverside, USA December, 2006.
- J. Mocito and L. Rodrigues. Run-Time Switching Between Total Order Algorithms, In *Proceedings of the Euro-Par 2006*, Dresden, Germany, August 2006.
- L. Rodrigues and J. Mocito and N. Carvalho. From Spontaneous Total Order to Uniform Total Order: different degrees of optimistic delivery. In *Proceedings of the 21st ACM Symposium on Applied Computing (SAC'06)*, Dijon, France, April 2006. ACM Press.