Broadcast and Consensus in Stochastic Dynamic Networks with Byzantine Nodes and Adversarial Edges*

Antoine El-Hayek
Faculty of Computer Science
UniVie Doctoral School Computer Science DoCS
University of Vienna, Austria

Monika Henzinger
ISTA, Austria

Stefan Schmid
TU Berlin, Germany

Broadcast and Consensus are most fundamental tasks in distributed computing. These tasks are particularly challenging in dynamic networks where communication across the network links may be unreliable, e.g., due to mobility or failures. Over the last years, researchers have derived several impossibility results and high time complexity lower bounds for these tasks. Specifically for the setting where in each round of communication the adversary is allowed to choose one rooted tree along which the information is disseminated, there is a lower as well as an upper bound that is linear in the number n of nodes for Broadcast and for $n \geq 3$ the adversary can guarantee that Consensus never happens. This setting is called the *oblivious message adversary for rooted trees*. Also note that if the adversary is allowed to choose a graph that does not contain a rooted tree, then it can guarantee that Broadcast and Consensus will never happen.

However, such deterministic adversarial models may be overly pessimistic, as many processes in real-world settings are stochastic in nature rather than worst-case.

This paper studies Broadcast on *stochastic* dynamic networks and shows that the situation is very different to the deterministic case. In particular, we show that if information dissemination occurs along random rooted trees and directed Erdős–Rényi graphs, Broadcast completes in $O(\log n)$ rounds of communication with high probability. The fundamental insight in our analysis is that key variables are mutually independent.

We then study two adversarial models, (a) one with Byzantine nodes and (b) one where an adversary controls the edges. (a) Our techniques without Byzantine nodes are general enough so that they can be extended to Byzantine nodes. (b) In the spirit of smoothed analysis, we introduce the notion of *randomized oblivious message adversary*, where in each round, an adversary picks $k \leq 2n/3$ edges to appear in the communication network, and then a graph (e.g. rooted tree or directed Erdős–Rényi graph) is chosen uniformly at random among the set of all such graphs that include these edges. We show that Broadcast completes in a finite number of rounds, which is, e.g., $O(k + \log n)$ rounds in rooted trees.

We then extend these results to All-to-All Broadcast, and Consensus, and give lower bounds that show that most of our upper bounds are tight.

*This work has been submitted to PODC'24