Stochastic and Deterministic Fault Detection for Randomized Gossip Algorithms

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Objectives

•Compute the average of the initial states in finite-time

•Guarantee fault detection and bounds on the maximum possible deviation from an attack

•Incorporate the transmissions stochastic information in the fault detection mechanism.

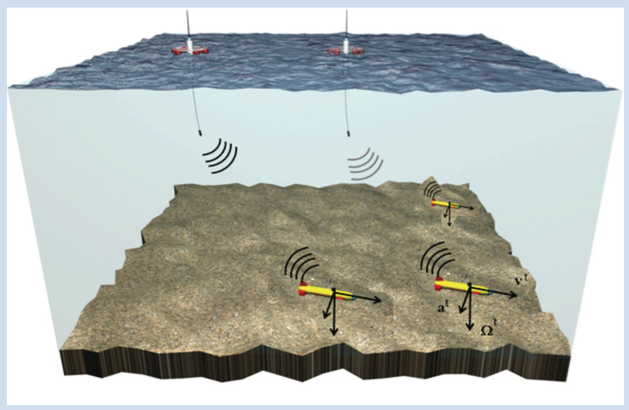
① Motivation

Nodes need to distributedly agree on a common value:

•Smart Grids when deciding the needed power

•Robot swarms to find rendezvous points

•Social Networks making a pool about a subject.



In all these examples a single node can drift the entire network to any desired value!

② Problem Statement

The objective is to compute the average of some quantity of interest. If faulty, any node must detect the fault using only local information communicated from their neighbors.

$G = (V, E) \qquad E \subseteq V \times V$

$$S^i : \begin{cases} x(k+1) = \left(A_0 + \sum_{\ell=1}^{n_\Delta} \Delta_\ell(k) A_\ell\right) x(k) + B(k)u(k) \\ y^i(k) = C^i(k)x(k) \end{cases}$$

n_Δ number of uncertainties

Each S^i is a Linear Parameter-Varying (LPV) system

$\Delta_\ell(k)$ are scalar uncertainties

Byzantine Consensus Problem:

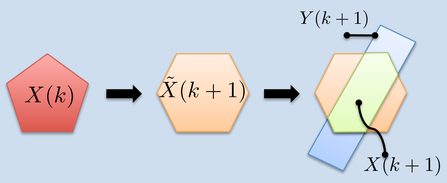
Either detect non-zero signals $u(k)$ using $y(k)$ without the knowledge of $B(k)$ or compute the final consensus value.

③ Proposed Solution

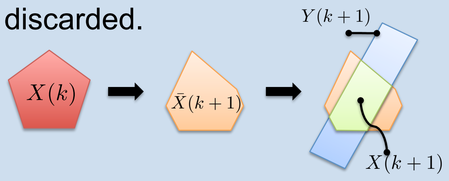
Each node runs a Stochastic Set-Valued Observer (SSVO). The estimates are intersected as to produce less conservative polytopes.

1) Compute the next set-valued estimates

Example of a SVO update for horizon 1.



Example of a SSVO update where low probability events are discarded.



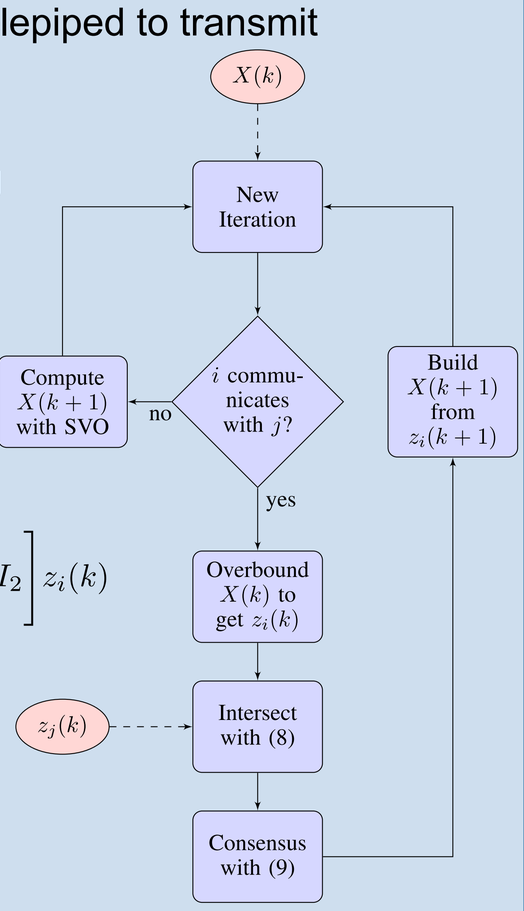
2) Overbound using a hyper-parallelepiped to transmit estimates to neighbors

3) Intersect estimates by performing

$$z_i(k) = z_j(k) = \max(z_i(k), z_j(k))$$

4) Perform a consensus update on the estimates interval

$$z_i(k+1) = \left[\left(\frac{1}{2}(e_i - e_j)(e_j - e_i)^\intercal + I_{n_x}\right) \otimes I_2\right] z_i(k)$$



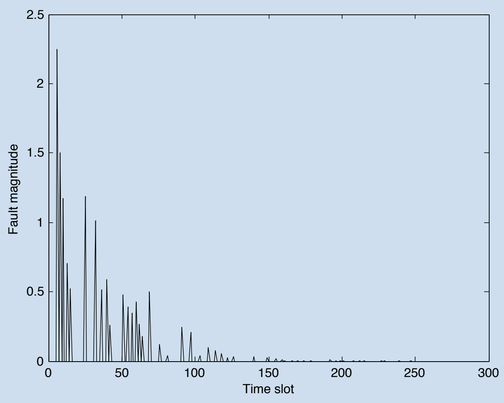
Flowchart of the proposed algorithm

Remark:

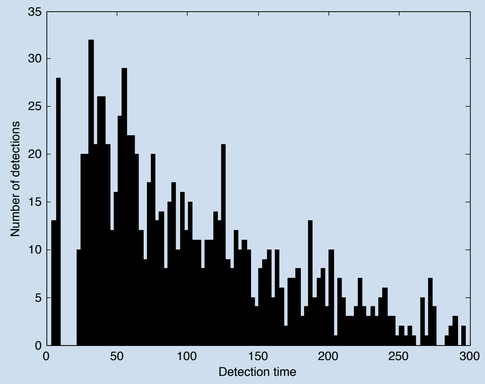
Fault detection consists in checking if the result of the intersection in step 3) is the empty set.

④ Results

• The magnitude of an attacker fault signal is bounded.



• Faults are more likely to be detected as time increases.



• Finite-time consensus is achieved.

• Less conservative set-valued estimates.

Main result:

The algorithm can either detect and intruder or compute the average consensus in finite-time.

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