Epidemic Control with Learning & Optimization

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Context

- Software-defined networking enables full automated control over network topology.
- Networked systems face propagation of malware, cascading hardware failures, DDoS.

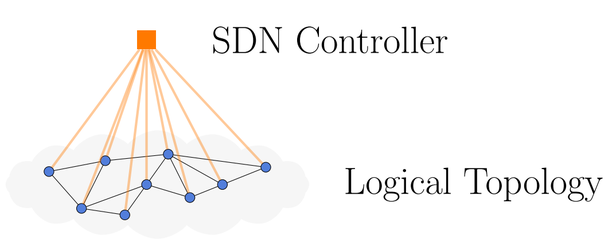

Fig. 1: SDN Controller supervising a software-defined network

Model

- Epidemics spreading on undirected graphs.
- Markov process with transition rates depending on neighbour state.

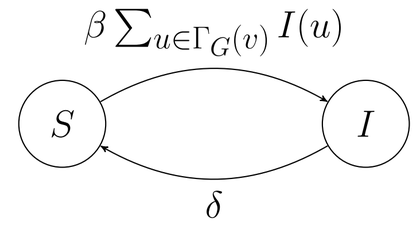

Fig. 2: SIS(β, δ) of a node v

General framework

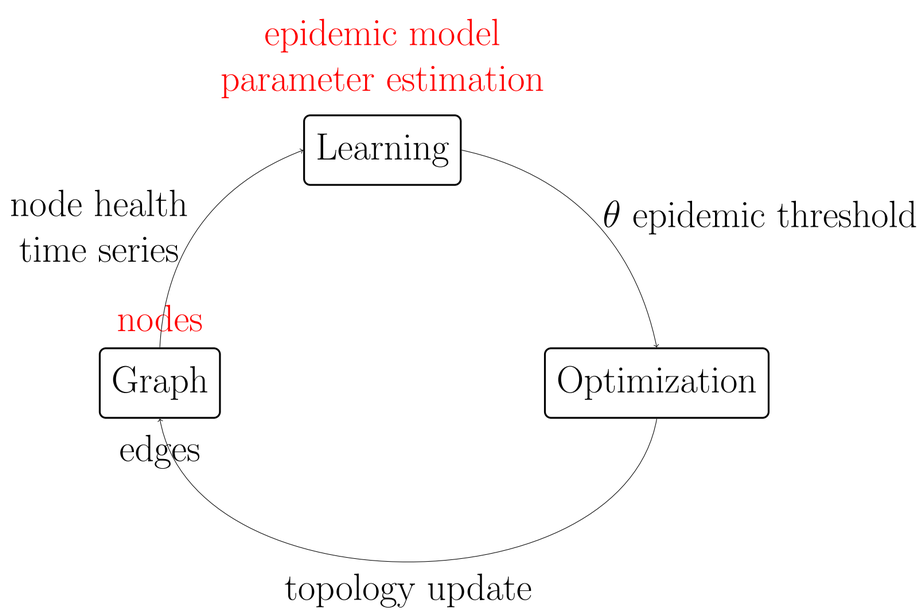

Fig. 3: Control loop

Turning a theorem into a control system

Theorem (Ganesh et al., 2005)
For any propagation model of threshold θ on a graph G, the epidemic dies out in logarithmic time if

$$\lambda_{\max}(G) < \theta.$$

Instead of applying local security measures, we leverage the control on the software-defined network topology to extinguish a propagating threat.

Learning the epidemic threshold

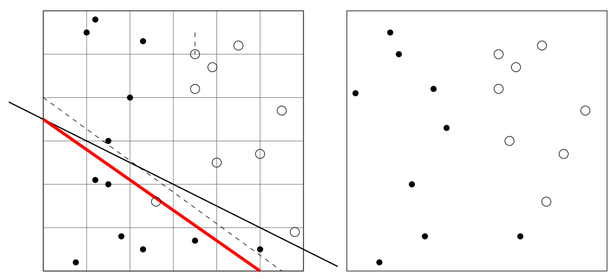

Fig. 4: One Class SVM for Anomaly Detection

SDN Controller running a parameter estimation algorithm

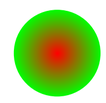

Fig. 5: Closed walks of size $\log n$

Optimizing the spectral radius

$$\begin{aligned} \max & \sum_{e \in E} x_e \\ & A(x) \preceq tI \\ & x \in \{0,1\}^m \end{aligned} \tag{1}$$

Combinatorics: subgraphs and closed walks

Random Matrix Theory: randomized algorithms relying on concentration of measure

Polynomials: real-stable polynomials and interlacing families