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A Web-Based System for Contagion Simulations on Networked Populations

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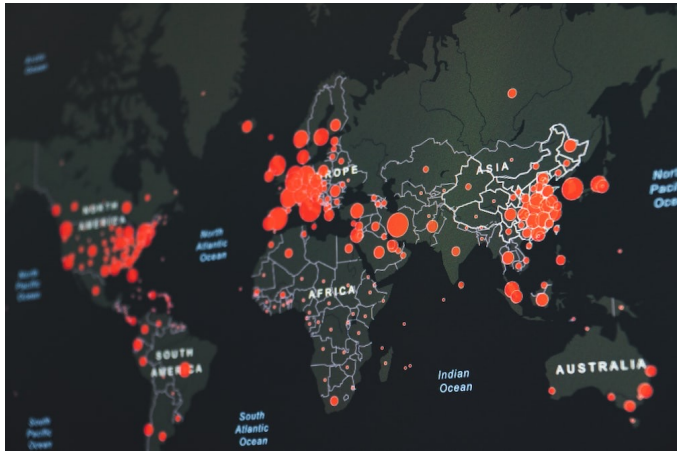
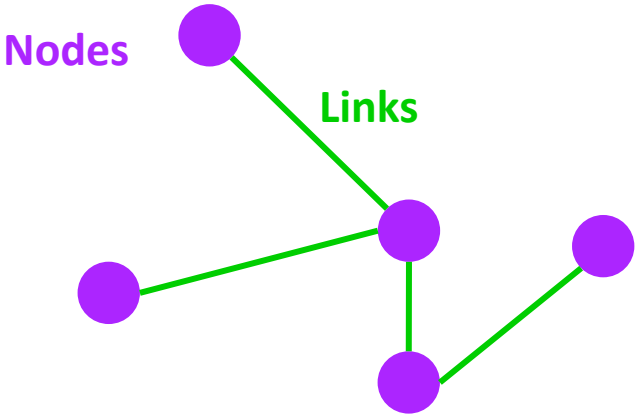
Outline

- Motivation
- System Architecture
- Performance Evaluation
- Case Studies
- Related Work
- Conclusions
- Limitations & Future Directions

Introducing Networks

- Networks are everywhere.
- Many situations can be represented by entities (nodes) & relationships (links).
- Network models and simulations are widely used.





Motivation

- Many **social processes** can be formulated as **contagion dynamics on networks**.
- **Agent-based simulation tools** are commonly used for networked systems.
- People need **software development experience** to **build and run** such tools.
- Some simulations require **high performance computing** resources.
- **Modeling and Simulation as a Service (MSaaS)** can alleviate many issues.

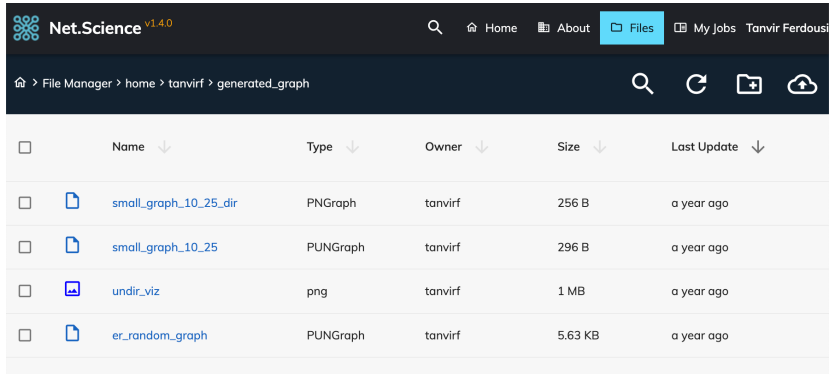
Highlights of Our Solution

- Network Simulation as a Service (NetSimS).
- Web-based open access system.
- Simulation module for contagion dynamics on networks.
- Graph seeding module for network state initialization.

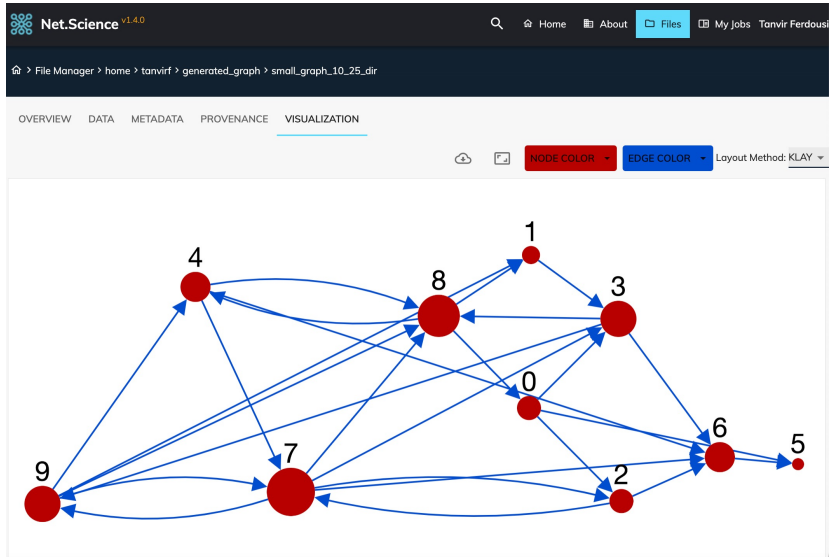
A Cyberinfrastructure for Network Science

- Open to public and accessible at: http://net.science
- Features
  - Modeling & Simulation as a Service (MSaaS).
  - Intuitive GUI & accessible APIs.
  - On demand high performance computing (HPC).
- The results in paper were generated using net.science.

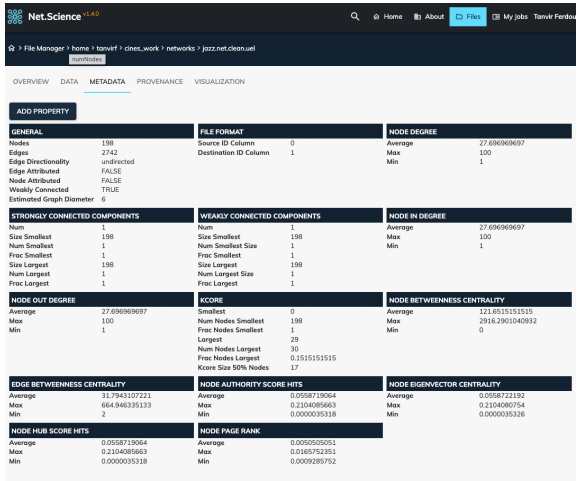
File System Browser



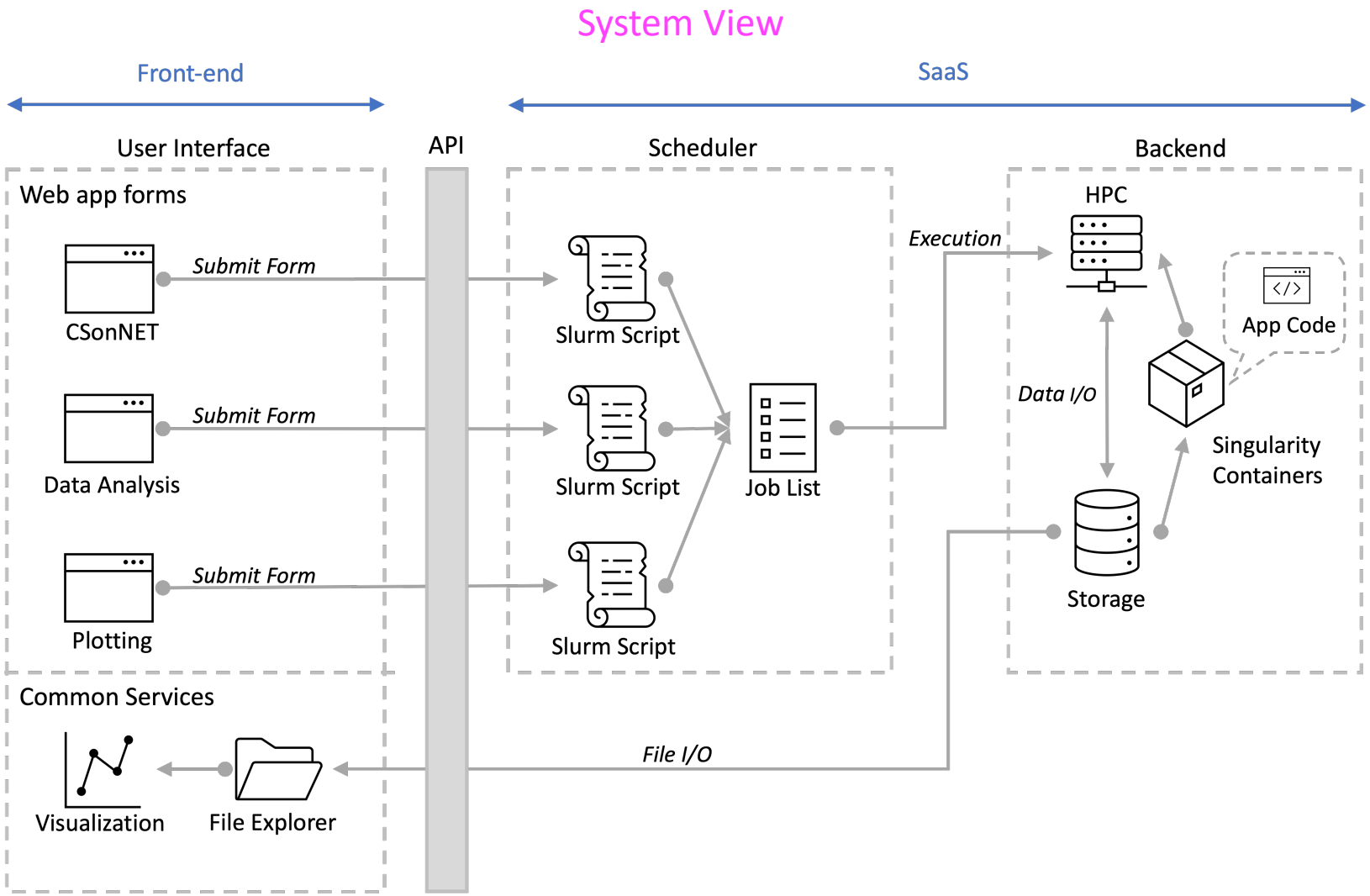
Interactive Graph Visualization



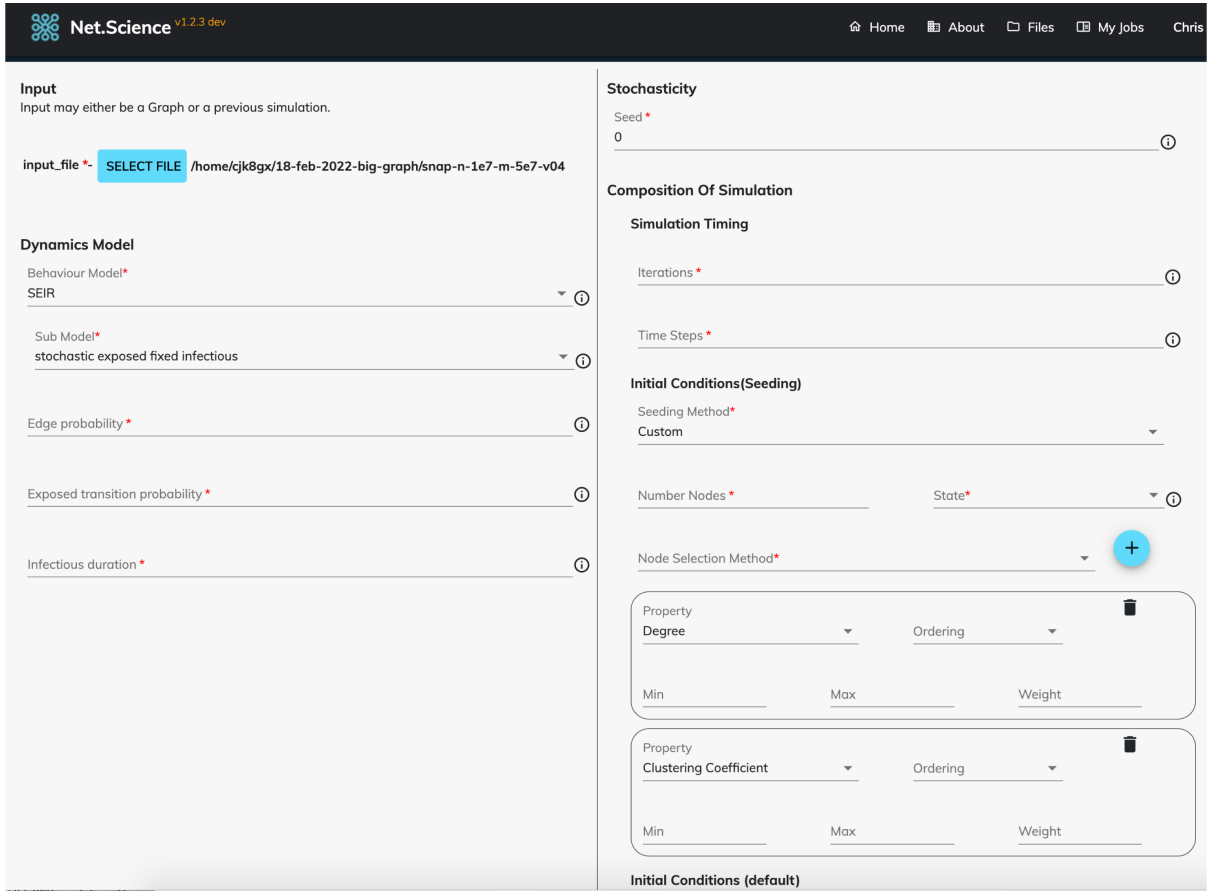
Graph Metadata



Network Simulation as a Service (NetSimS)

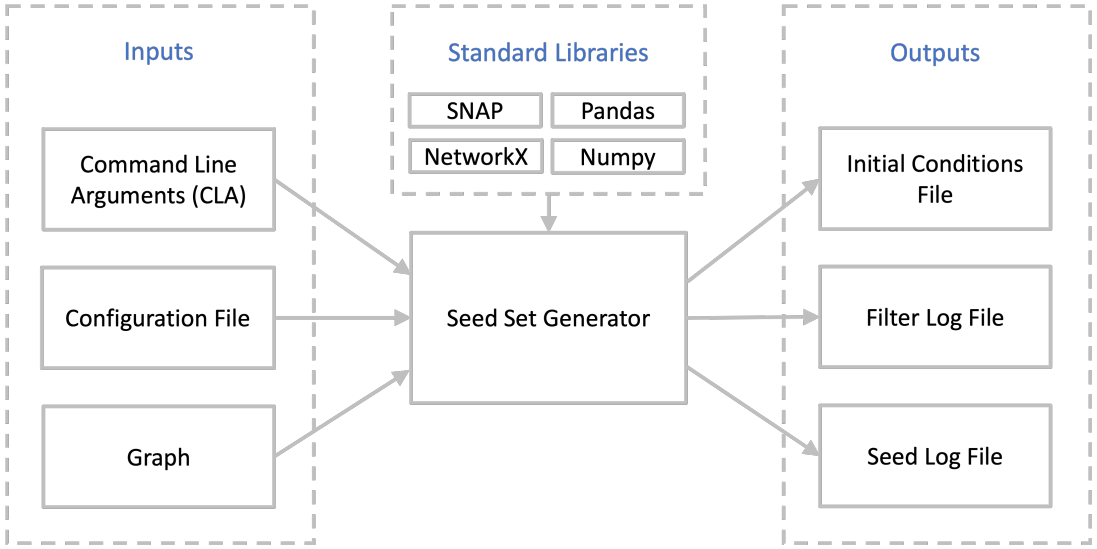


Web Interface



- Representative inputs for simulation
  - Agent model and parameters
  - Network
  - Number of iterations, time per iteration
  - Initial conditions
- Many types of web forms
  - Contagion simulation
  - Post-processing simulation data
  - Plotting
- Web app uses same API as other 3rd party tools.

Initial Conditions Module



seed.config.01

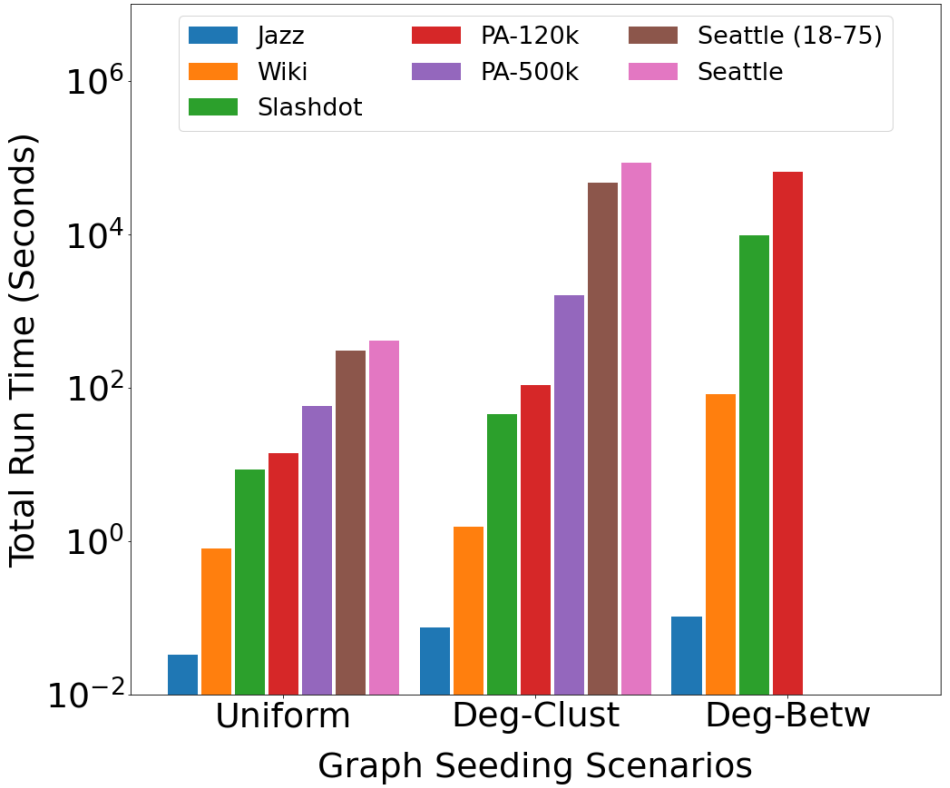
```
#graph_metric,sort_method,metric_min,metric_max,metric_weight
outdeg,high,3,4,1
betwcnt,high,0.2,6,1
clustcf,high,0.4,0.8,1
```

- Initialize graph node states.
  - Compute graph metrics.
  - Filter, sort nodes using metrics.
- Combine multiple metrics.
- Generate multiple seed sets
  - Deterministic
  - Stochastic
- 11 graph metrics are supported
  - Including degree, betweenness, clustering coefficient, pagerank, and hub/authority scores.

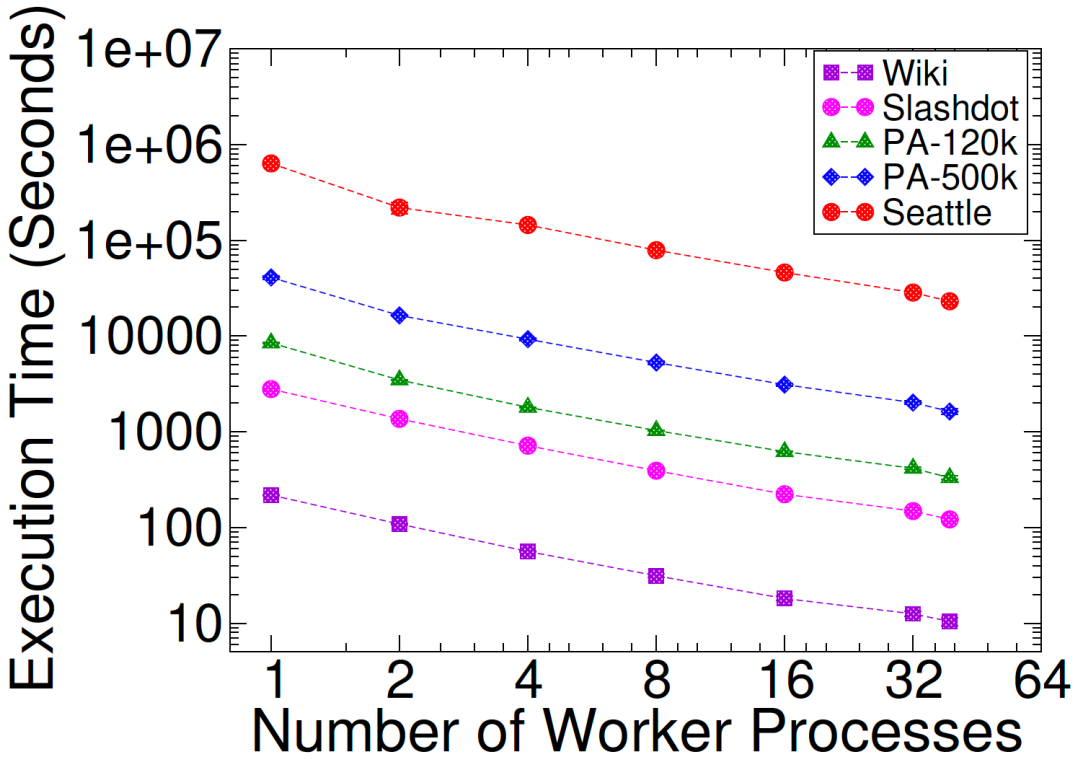
Performance Evaluation – Network Initialization

Network	Structural Properties				
	Num. Nodes	*Num. Edges*	*Avg. Degree*	*Max. Degree*	*Largest k-core*
Jazz, M	198	2,742	27.7	100	29
Wiki, M	7,066	100,736	28.51	1,065	53
Slashdot, M	77,360	469,180	12.13	2,539	54
PA-120k, S	120,000	2.4 M	39.99	2,686	20
PA-500k, S	500,000	9.99 M	39.99	5,405	20
Seattle (18-75), C	2.56 M	40.34 M	31.49	664	42
Seattle, C	3.52 M	66.51 M	37.82	879	43

M: Mined, C: Constructed, S: Synthetic

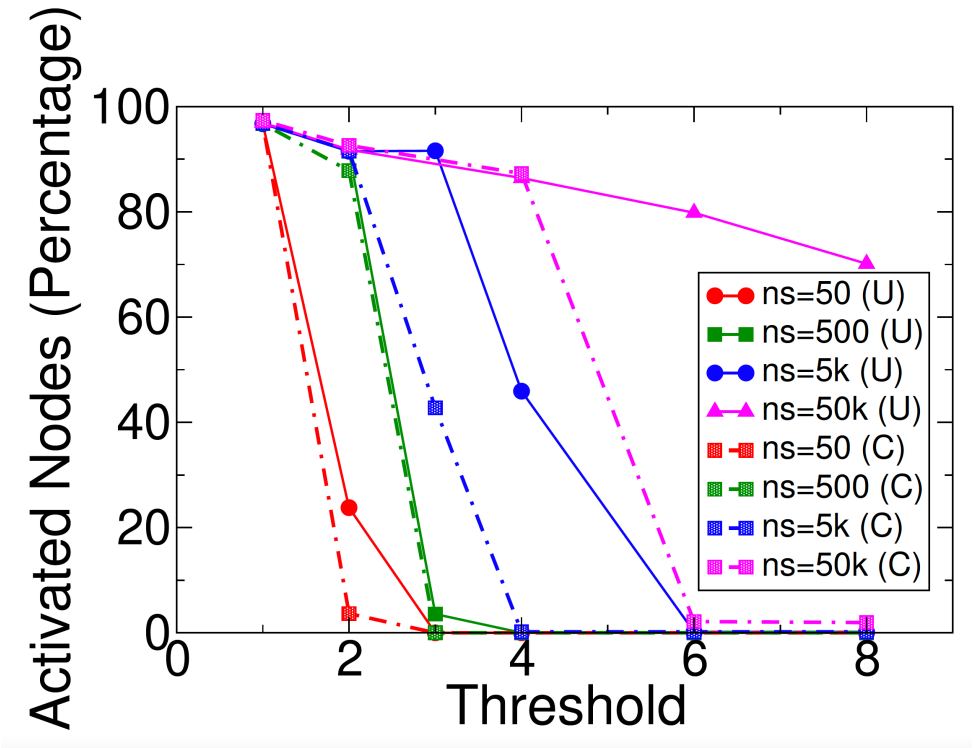


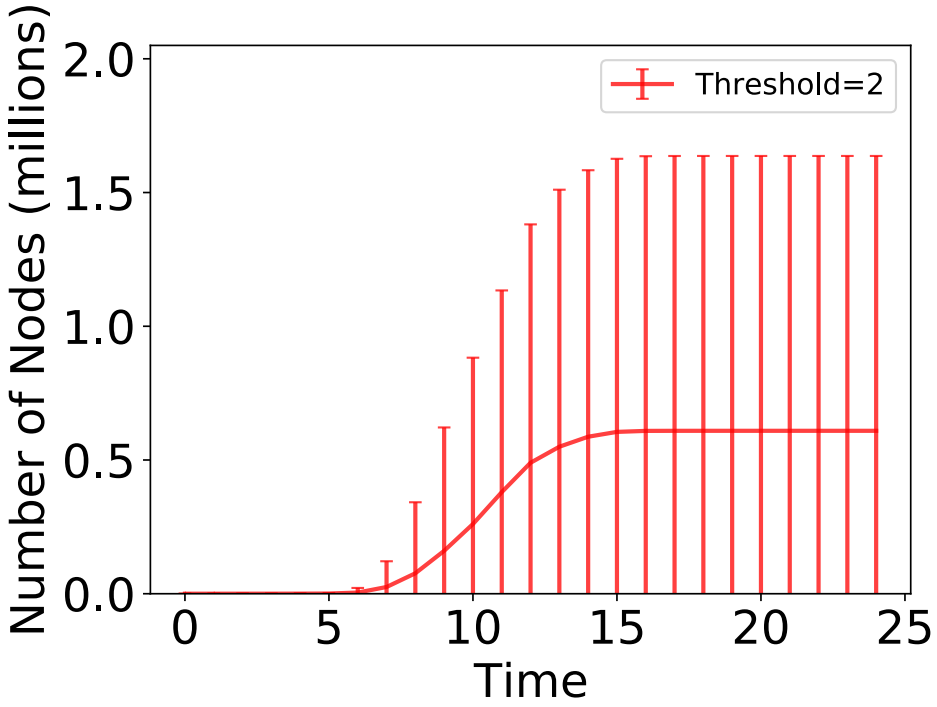
Strong Scaling Study – Agent-Based Simulation



- Uses SIR model
  - Transmission probability: 0.004
  - Infectious duration: 4 days
- Y-Axis: total time to run 100 iterations of 100 timesteps
- 300 nodes initialized as infected (I).
- The system exhibits strong scaling.

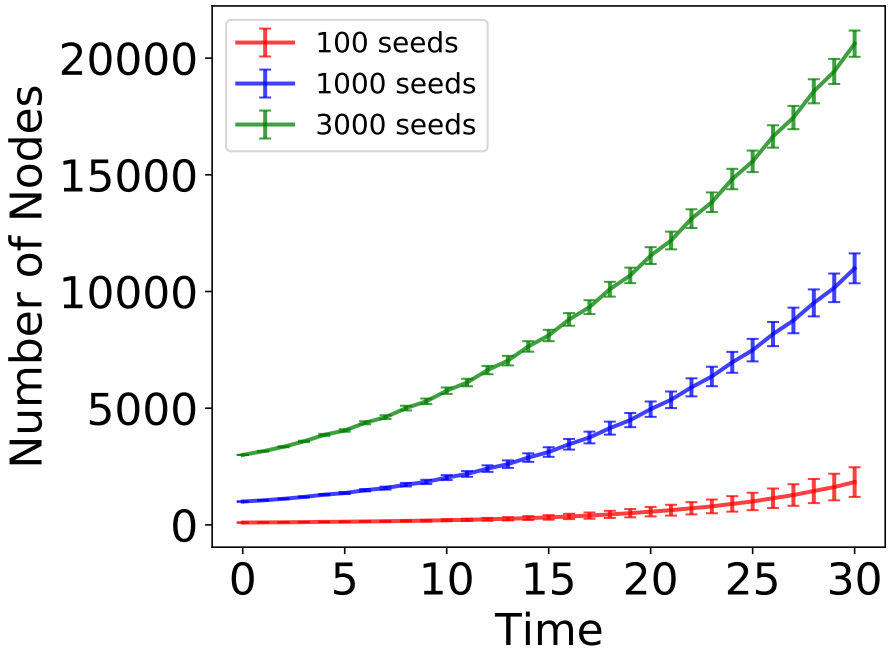
Case Study I – Simulation of Social Protests

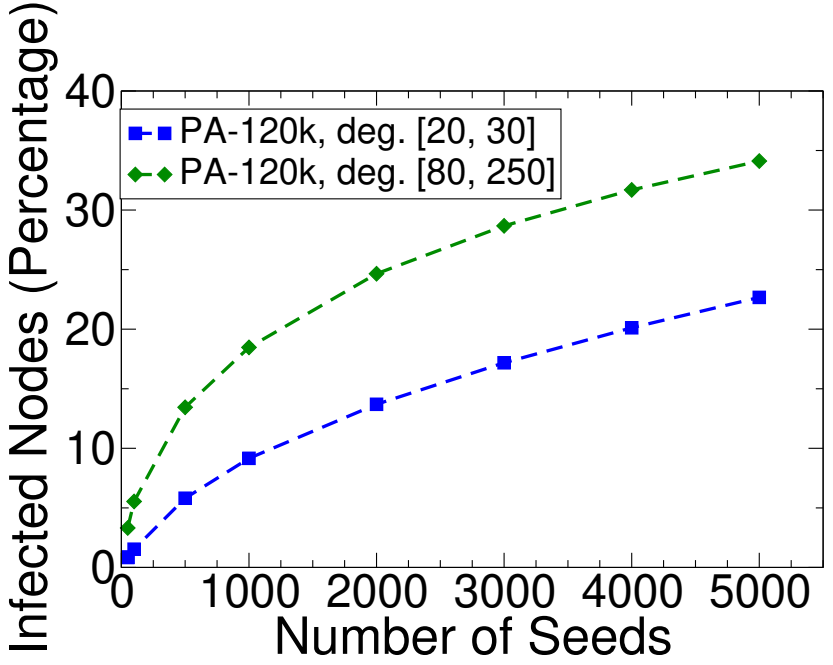




- Simulated using the Granovetter (1978) threshold model.
- Seattle (18-75) network was used.
- Two different seed node sampling methods were used (U, C).

Case Study II – Simulation of Virus Transmission





- (Left) Cumulative infection for SIR on PA-120k with three seed configurations with degree in [20,30].
- (Right) Final fraction of infected nodes after 30 days using two seeding configurations.

Related Work

- With IDE/GUI
  - Repast Simphony [North et al., 2013]
  - NetLogo [Wilensky, 2011]
- Geared towards parallel and high-performance computing
  - Repast HPC [Collier et al., 2013]
  - µsik [Perumalla, 2005]
- Modeling and Simulation as a Service (MSaaS)
  - Anylogic [http://anylogic.com]
  - CloudSME [Taylor et al., 2018]

Conclusions

- A system that generates initial conditions and runs contagion simulations on networks.
- On demand high performance computing (HPC).
- Open access, versatile simulation framework within net.science.
- Can benefit researchers, educators, and students.

Limitations & Future Directions

- Addition of new models requires working on both front and backends.
- Input network sizes are limited by available memory and processing power.
- Parallelization of graph analysis algorithms in the initial conditions module to improve performance.

Questions ?

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