Physics-Inspired Modeling and Validation Approaches for Pharmaceutical Security

Tim Burt

UH Physics Research Day 2024

2/24/2024

Overview

1. Goal
2. Background
3. Method
4. Pipeline
5. Results
6. Future Research Work
7. Conclusions

Goal

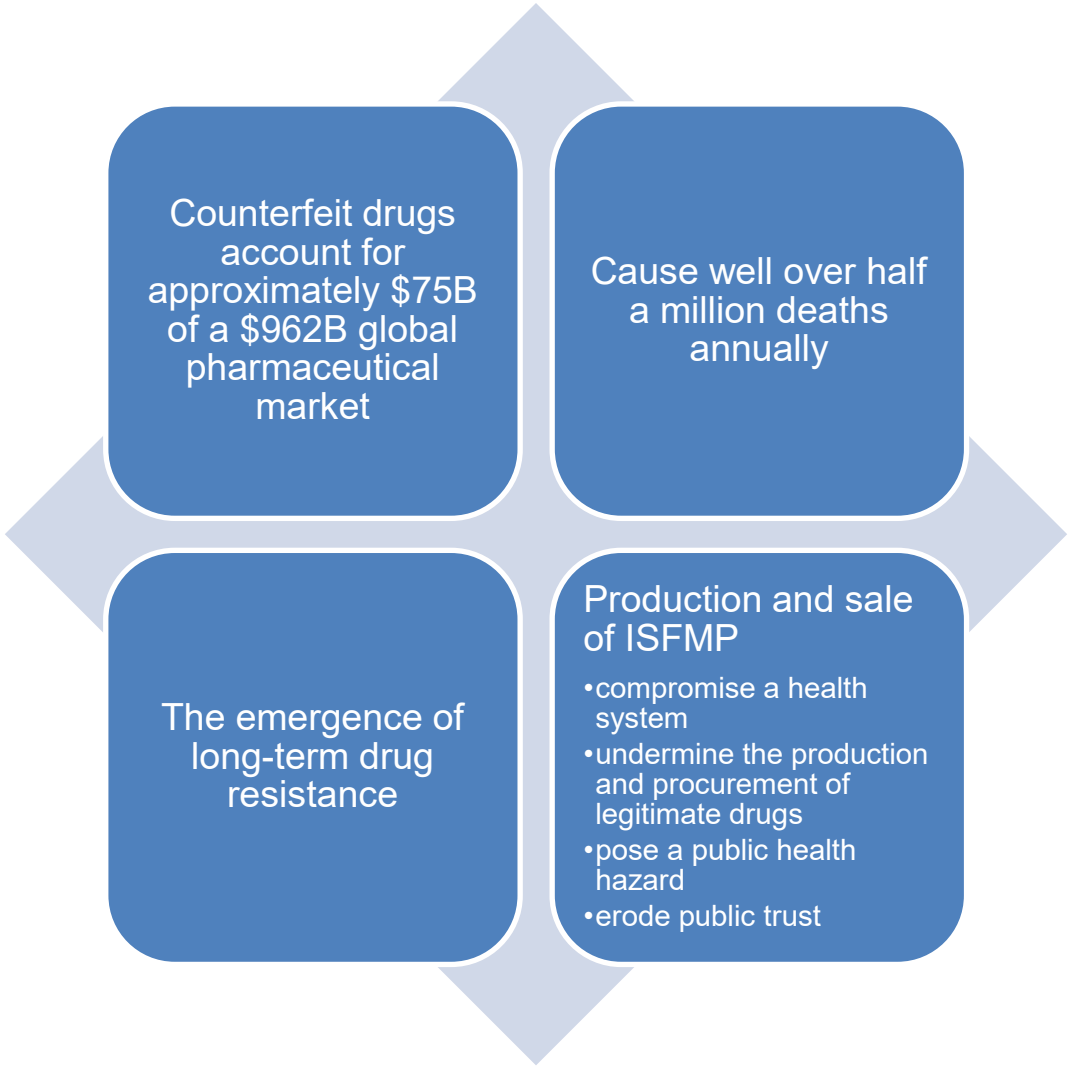
- Develop the approaches to
  - Identify
  - Intervene
  - Disrupt

Networks that facilitate procurement and sale of Illicit, Substandard, and Falsified Medicinal Products (ISFMP)

Background: What are ISFMP?

- **Illicit, Substandard, and Falsified Medical Products (ISFMP)** include medical products which are:
  - Stolen
  - Diverted
  - Price-gouged
  - Unregistered
  - Unlicensed
  - Counterfeit
- Examples include toxic or ineffective:
  - Prescription drugs
  - Dietary supplements
  - Face masks
  - Vaccines
  - Testing kits

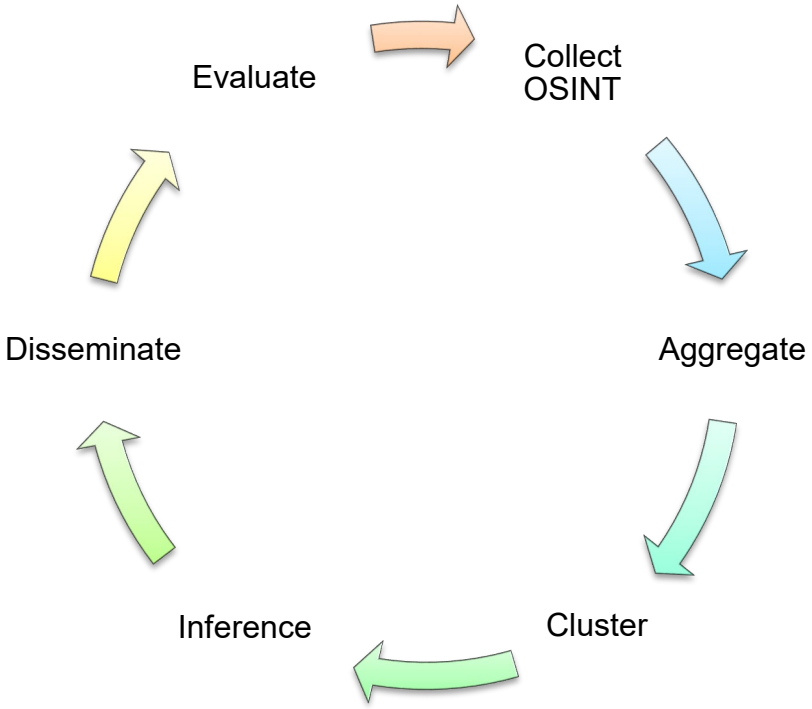
Background: Why are ISFMP a problem?

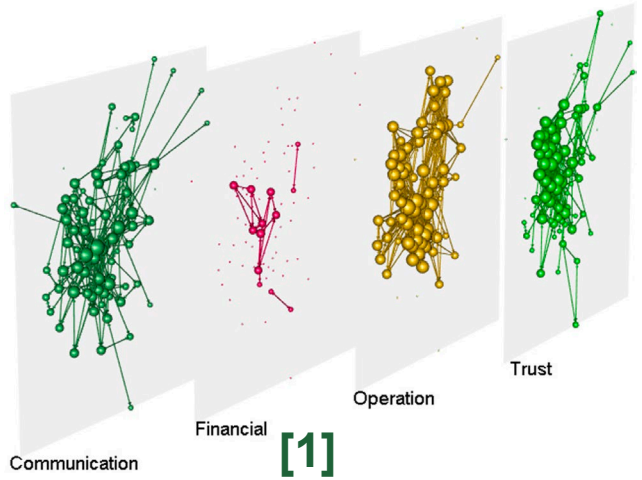


Background: ISFMP Detection Challenges

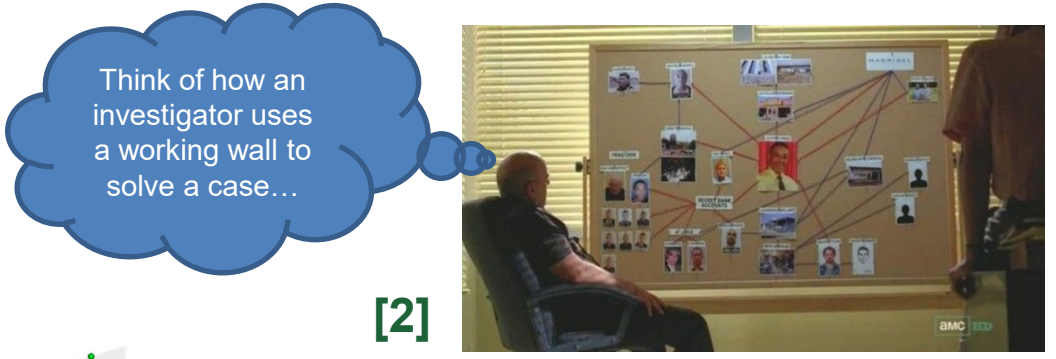
- Current strategies to tackle counterfeit drug trade (to the best of our knowledge)
  - do not integrate
    - the plurality of internet-available data
    - intervention approaches

Method: Finding "Weak" Links

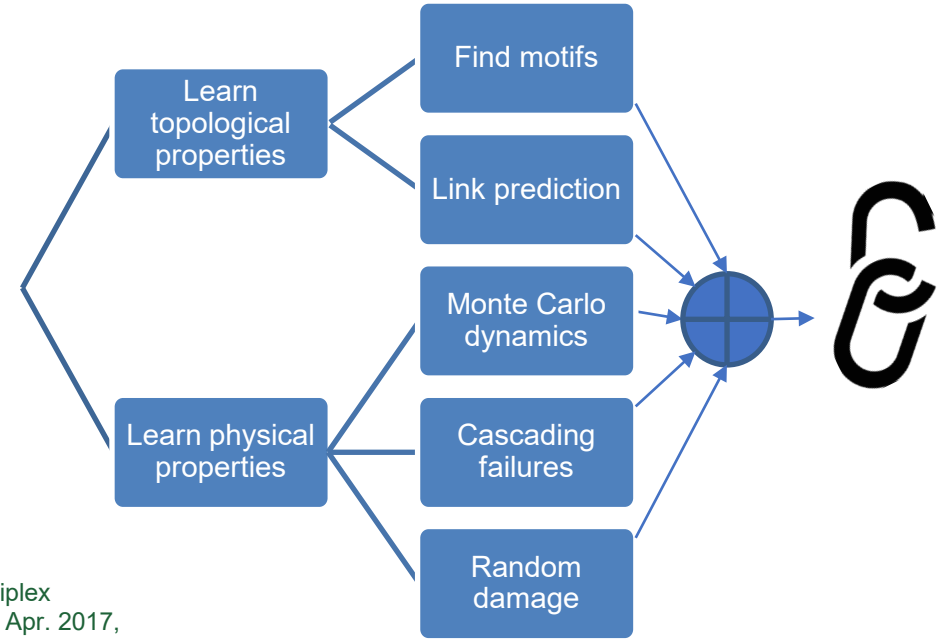




[1]



[2]



[1] X. Wang and J. Liu, "A layer reduction based community detection algorithm on multiplex networks," *Physica A: Statistical Mechanics and its Applications*, vol. 471, pp. 244–252, Apr. 2017, doi: 10.1016/j.physa.2016.11.036.
[2] "Breaking Bad," High Bridge Productions, Gran Via Productions, Sony Pictures Television, Jan. 20, 2008.

AI-SNIPS: Pipeline

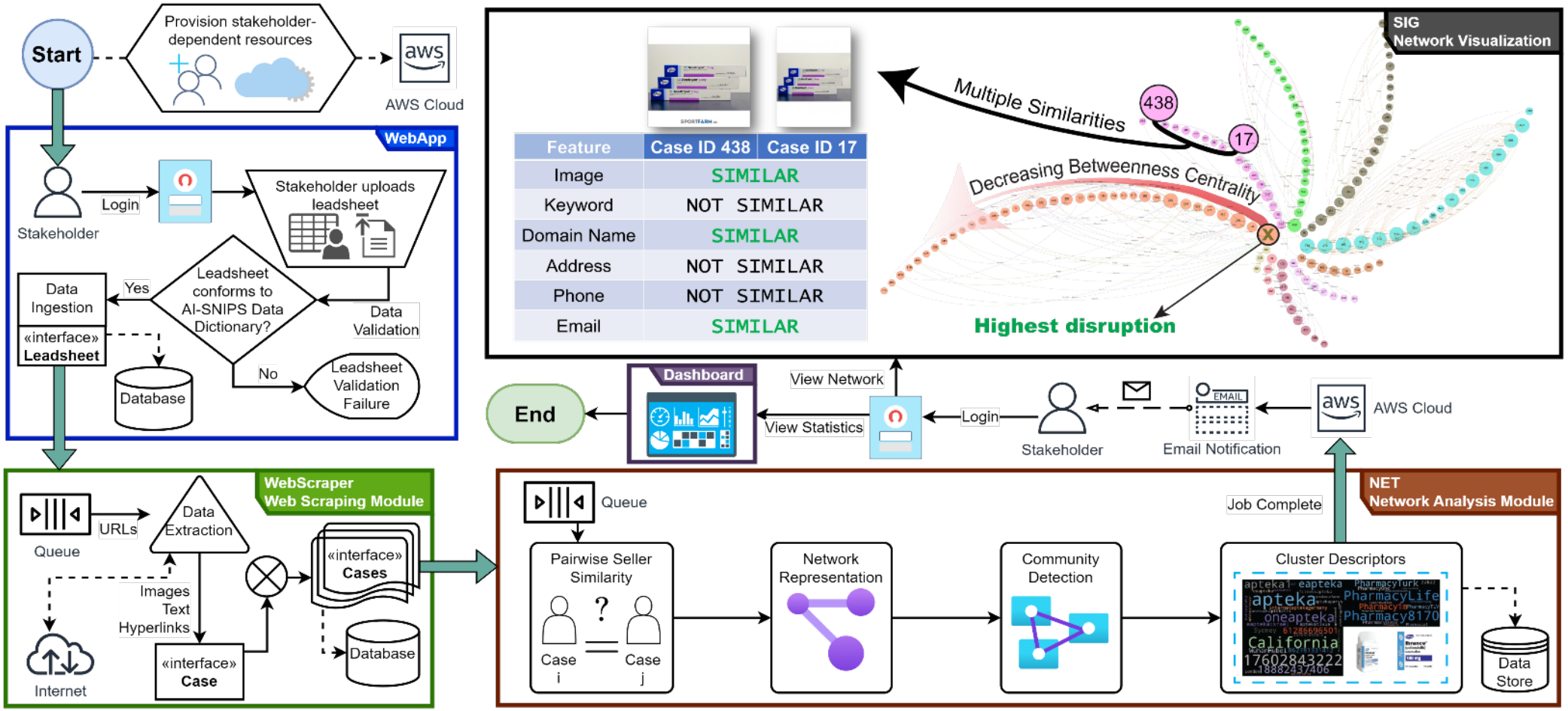


Illustration of the AI-SNIPS pipeline after completion of the core functionality milestone.

T. A. Burt, N. Passas, and I. A. Kakadiaris, "AI-SNIPS: A Platform for Network Intelligence-Based Pharmaceutical Security," *AAAI*, vol. 37, no. 13, pp. 16407–16409, Jun. 2023, doi: 10.1609/aaai.v37i13.27061.

AI-SNIPS: Input

- Case
  - Required (1 attribute)
    - One or more URLs suspected of ISFMP activity
  - Optional (47 attributes)
    - Seller PII, case notes, outcomes
- One Case represents
  - One node in the output network
  - One row in the stakeholder-provided lead sheet
- One lead sheet consists of
  - Rows: cases
  - Columns: attributes

- Aggregate of all ISFMP case attributes encountered to date
- Most not currently used to link sellers
- New attributes can be added upon stakeholder request

AI-SNIPS: Output

Output

- Clustered Cases
  - Cases that had no similarities with other cases (i.e., no edges) are discarded

Output, Optional

- Cluster Descriptors
  - Summarize the most prominent cluster similarities
- Metrics from network analysis

Results

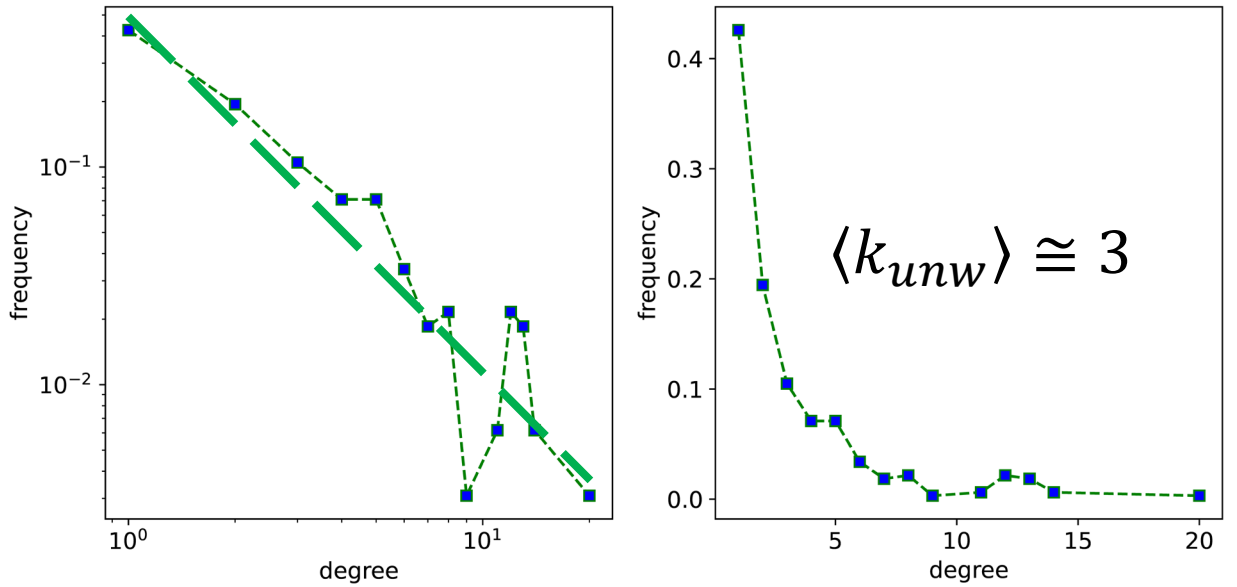
- Natural period of about two weeks in the availability of ISFMP items
  - Emerges regardless of lead type or initial scraping date

Results (2)

- Small-world (or scale-free) behavior in the network's degree distribution p(k)

$\Longrightarrow$ Implies the existence of a scaling law between seller connectivity and network size

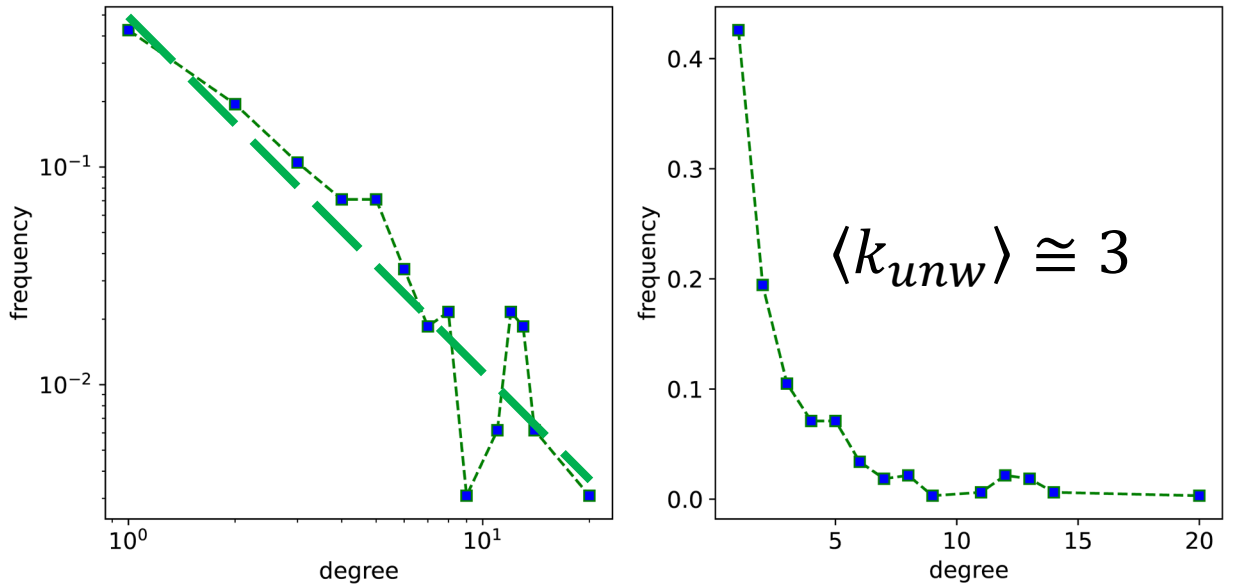
Degree distribution p(k) of clustered nodes (degree k ≥ 1, unweighted)



Results (3)

- The average unweighted degree of similar seller groups is approximately 3

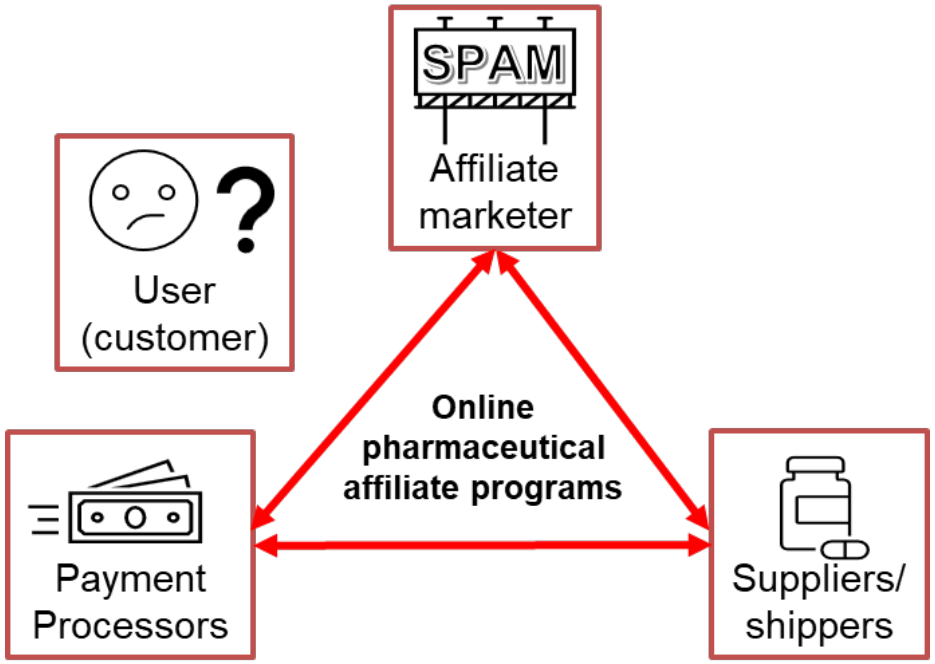
Degree distribution p(k) of clustered nodes (degree k ≥ 1, unweighted)



Results (4)

- The average unweighted degree of similar seller groups is approximately 3

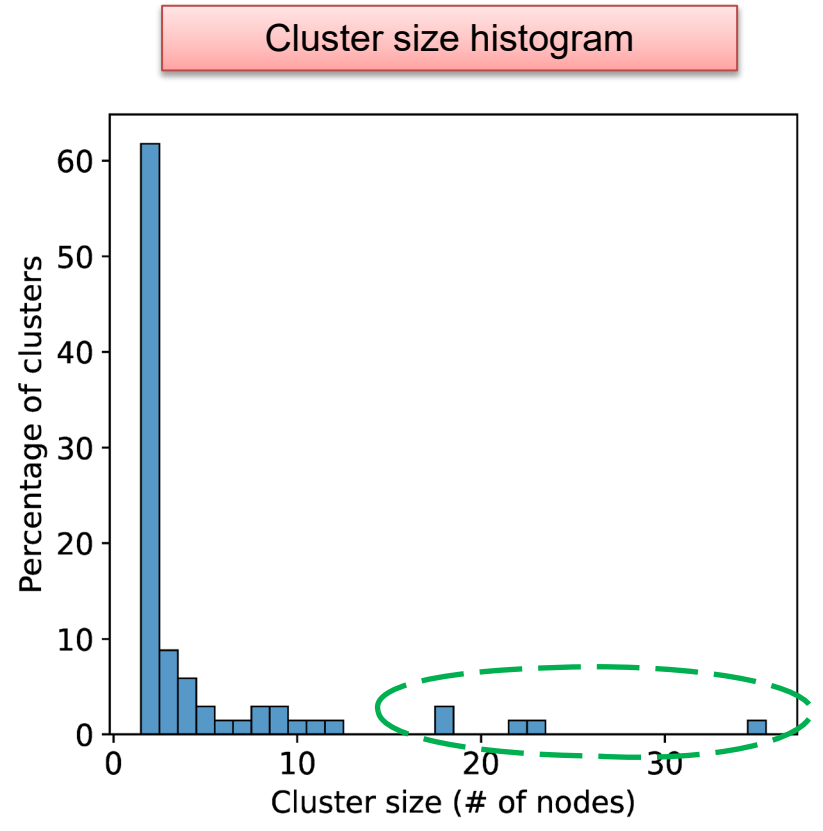
$\Longrightarrow$ Agrees with other studies that pharmaceutical affiliate programs often consist of interactions between three dependent entity types at a single point in time



Results (5)

- Clustered nodes distribution supports that most ISFMP seller groups come in pairs of two (≅ 60%) (might be an artifact…)

⟹ Heavy tail implies a handful of the groups are much larger and probably involved in spamming/pharmaceutical affiliate programs (PAP)



Future Research Work

- Dynamics } Module
  - Disruptions } Layers
  - Validation

Conclusions

- AI-SNIPS hopes to incorporate strategies from physics and machine learning into pharmaceutical security
- Validation of network disruption strategies is the hardest (and most time-consuming) part
- Important to address the root causes and global conditions that lead to pharmaceutical counterfeiting to make true progress

Acknowledgements

Contributors

- Bera, Abhijit
- Covarrubias, Andres

Advisor

- Kakadiaris, Ioannis

This work is supported by the National Science Foundation Awards IIS-2039946, CMMI-2146335

Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors. They do not necessarily reflect the views of the National Science Foundation, other funders, the position, or the policy of the Government, and no official endorsement should be inferred.