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Evaluation of Effectiveness of Regulatory Sampling Locations During Emergency Response Scenarios

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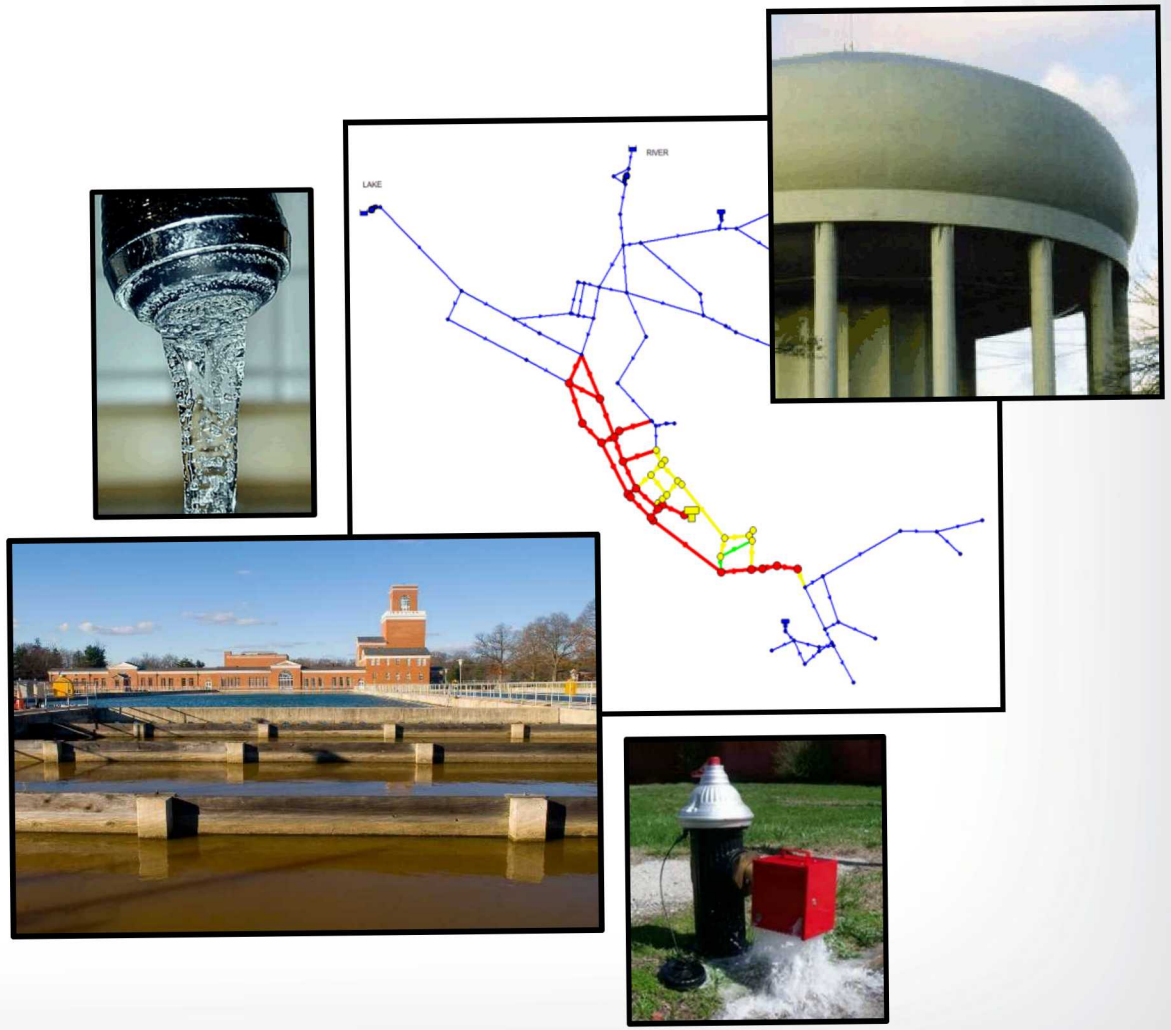
Outline

- Background
- Formulation
- Approach
- Results
- Conclusions/Next Steps



Background

- Drinking water utilities take grab samples to ensure high quality, potable water and meet regulatory requirements
- Water distribution system modeling approaches can help identify regulatory and emergency sampling locations
- Scenario coverage is metric used to optimally identify locations

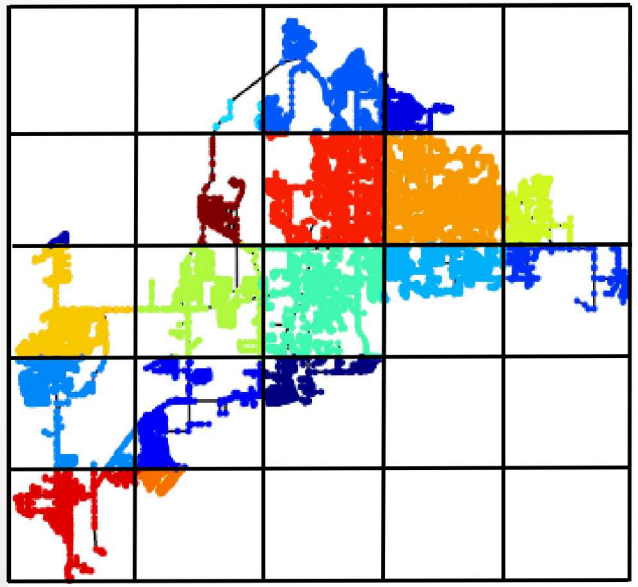
Coverage Formulation

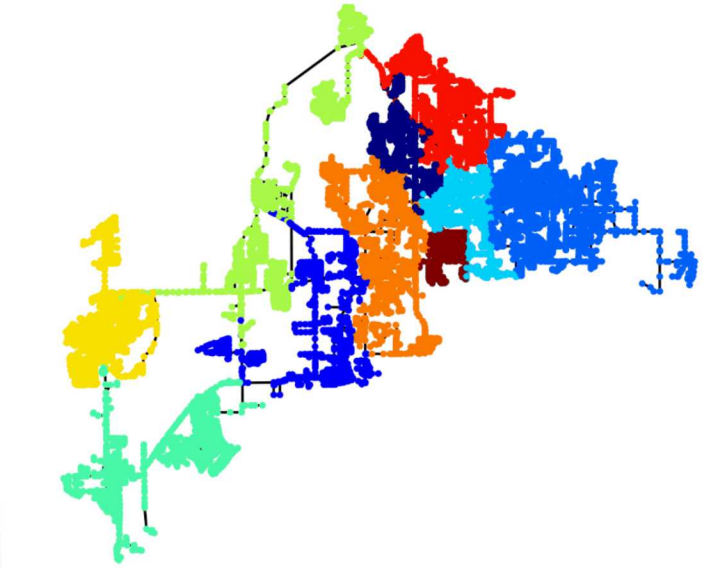
- **Extended coverage formulation from Lee and Deininger [1992] to identify grab sample locations**
- **Included constraints to spatially distribute locations via grid, clustering, water age**

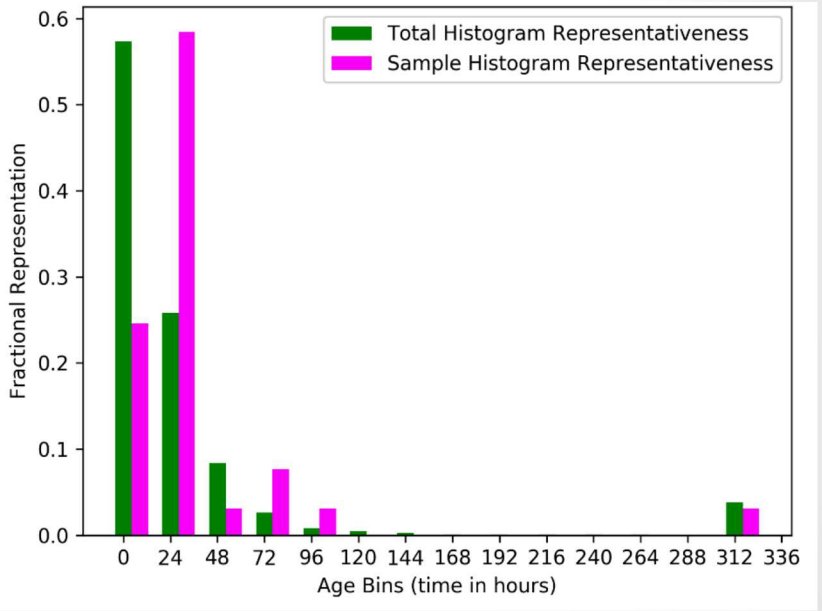
$$
\begin{aligned}
\text{maximize} \quad & \sum_{a \in A} \alpha_a x_a \\
\text{subject to} \quad & x_a \leq \sum_{i \in \mathcal{L}_a} s_i && \forall a \in A \\
& \sum_{i \in L} s_i \leq N \\
& \sum_{i \in \mathcal{B}_j} s_i \leq M_j && \forall j \in B \\
& s_i \in \{0,\ 1\} && \forall i \in L \\
& 0 \leq x_a \leq 1 && \forall a \in A
\end{aligned}
$$

Diversity Constraints

- Uniform square grid layout
- Clustering (community) algorithms
- Water age diversity

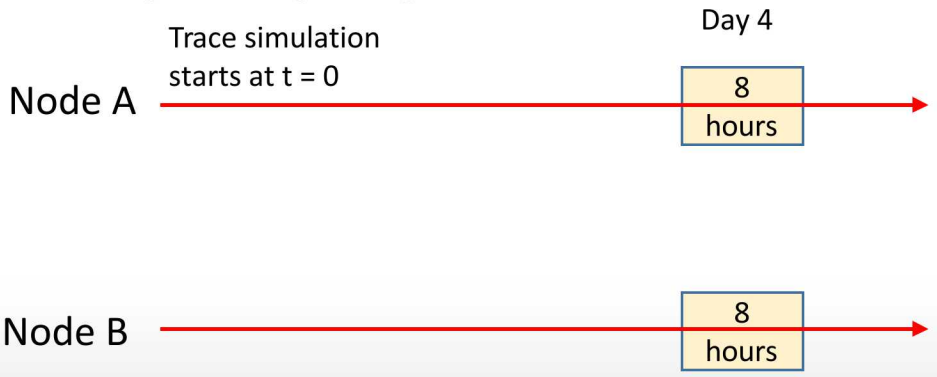






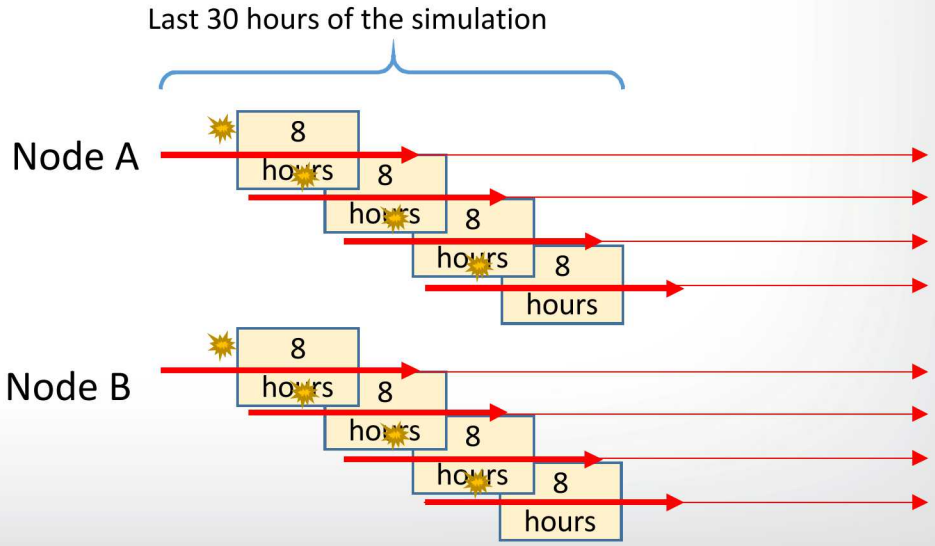
Regulatory Approach

- Simulated persistent water quality issue using tracers
- Assumed samples taken during standard working day (8 hours)
- Modeled representative day
- Selected locations that maximized scenario coverage
- Considered covered if positive detection at all times during 8 hours
- Pre-determined regulatory sampling locations



Security Approach

- Simulated acute water quality issue using contaminant pulse injection (24 hour injection)
- Initiated by alarm near contaminant source (4 hour delay)
- Assumed samples taken within 8 hours after initial alarm, regardless of time of day
- Selected locations that maximized scenario coverage
- Considered covered if positive detection at all times during 8 hours
- Pre-determined security sampling locations
- Assumed all samples cannot be take at once



Simulation Approach

- Solved coverage optimization problem using regulatory scenarios for 1 to 30 locations
- Evaluated regulatory sample locations on security scenarios
- Adjusted objective value using 5 closest locations for each security scenario to determine if scenario is still detected
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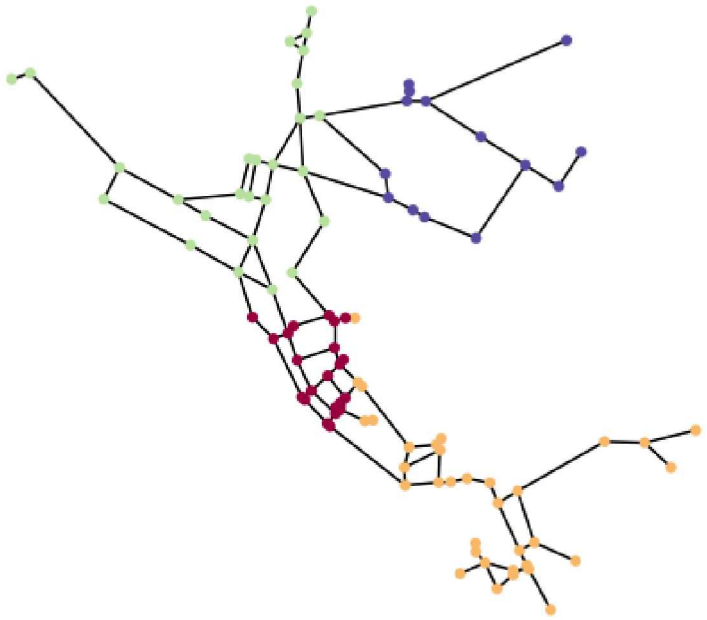
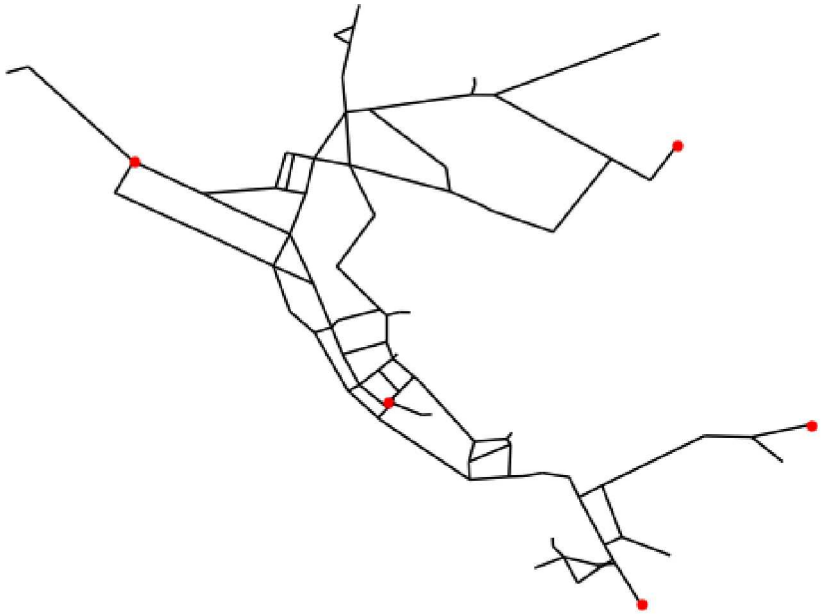
Example Network # 1

- **EPANET Network 3**

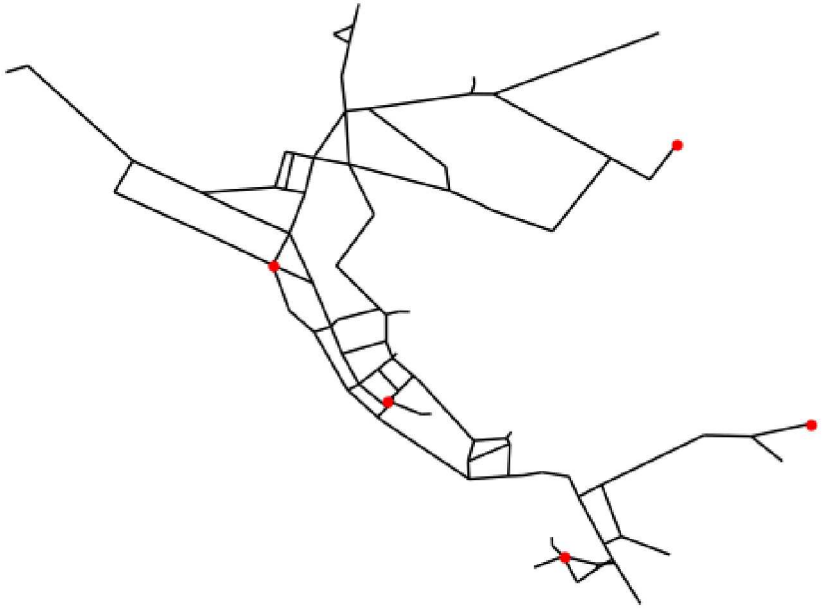
Grid bins



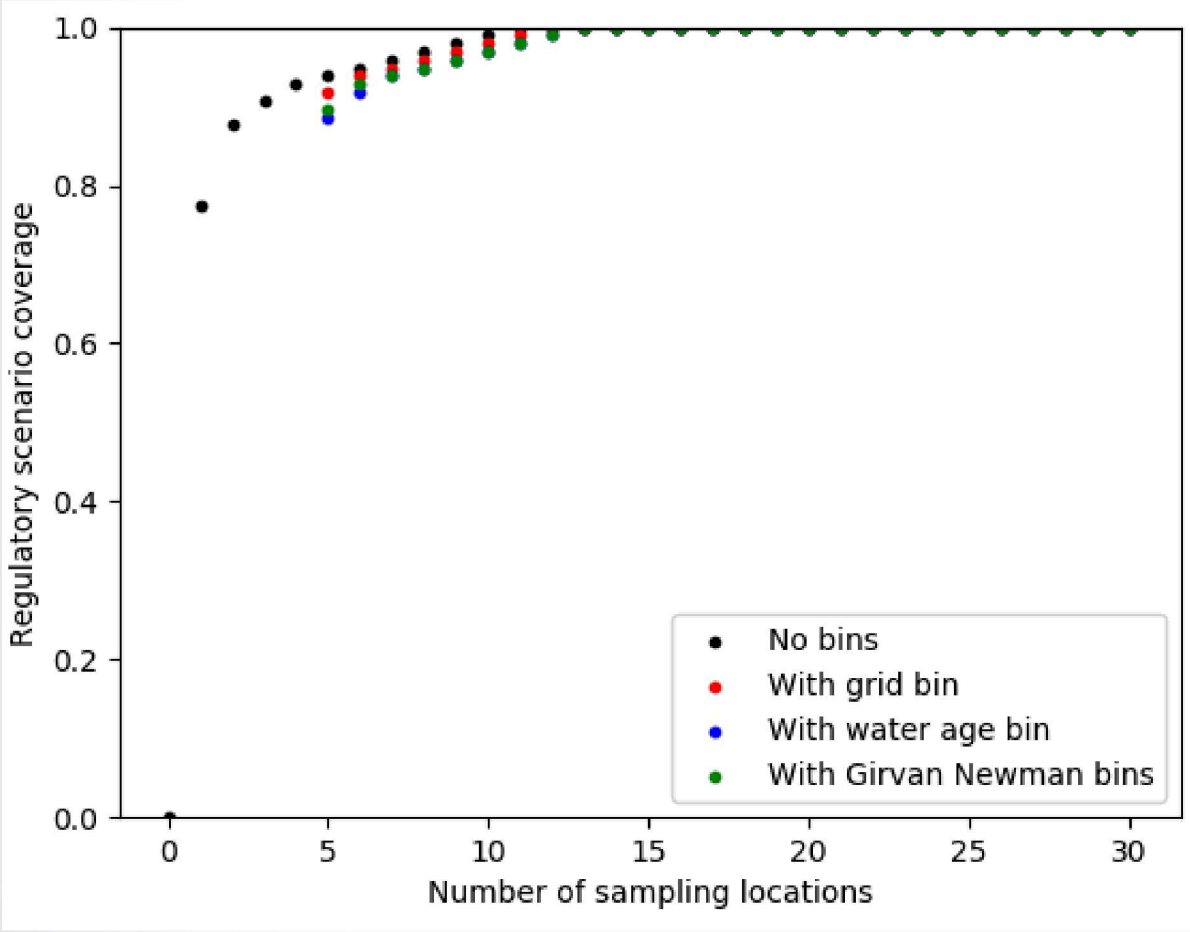
Regulatory sample locations, Grid bins

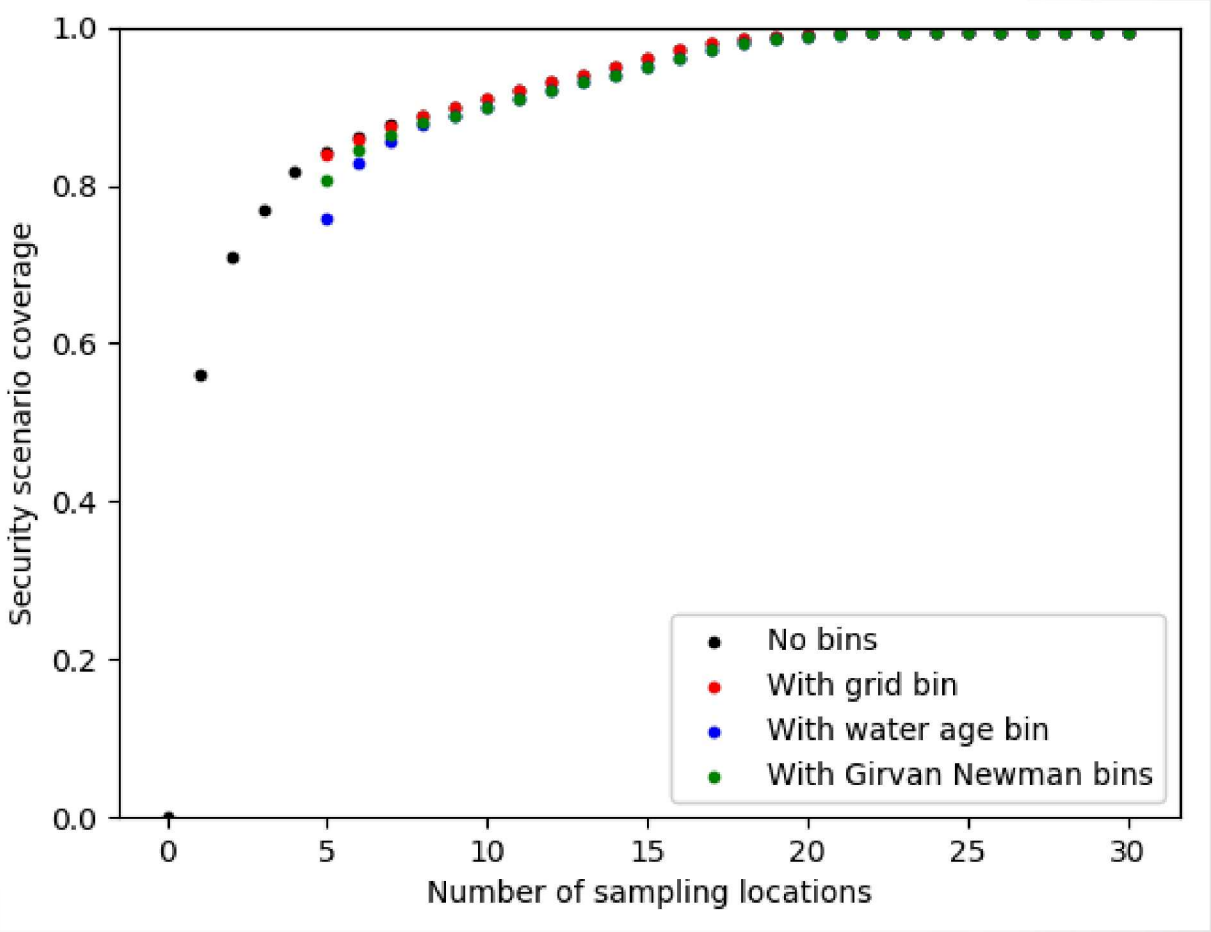


Security sample locations, Grid bins

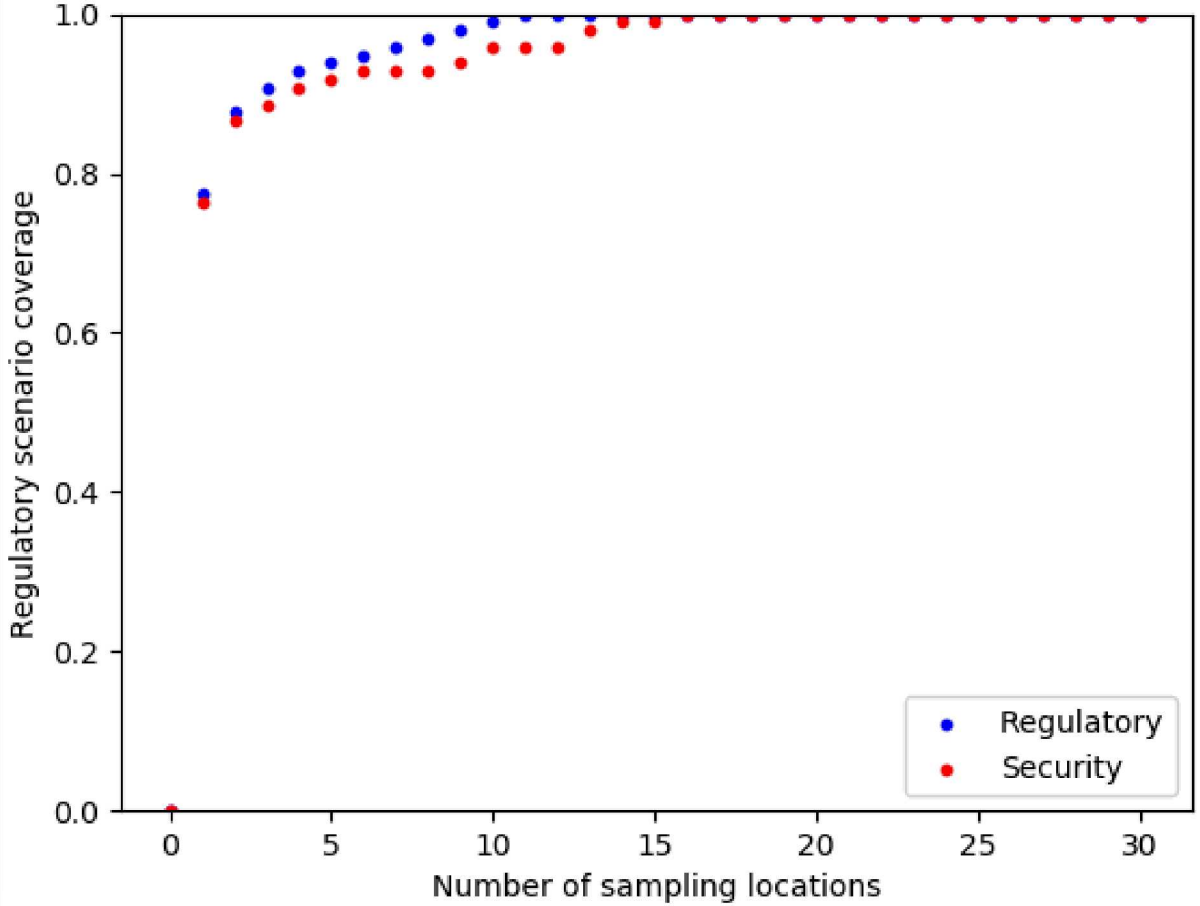


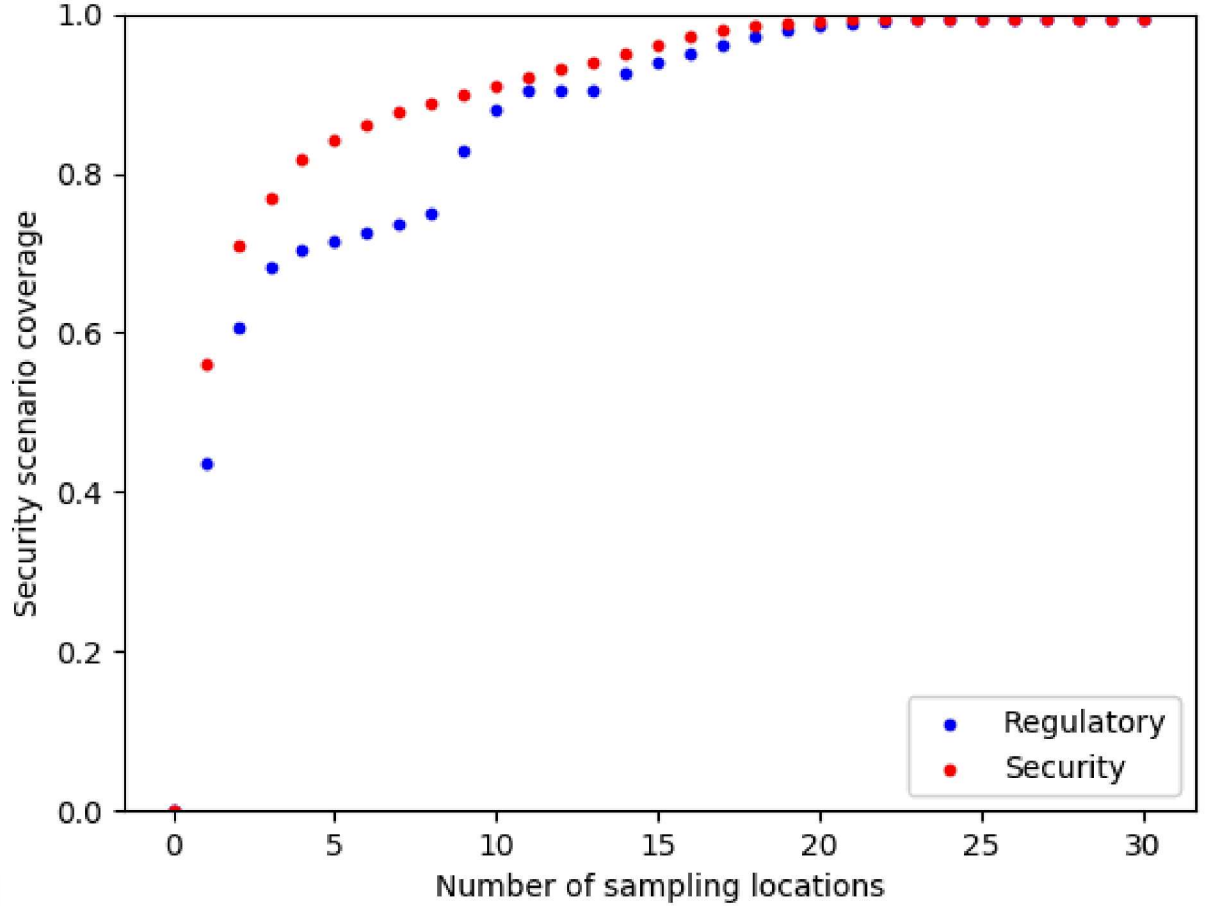
Example # 1 Binning Results



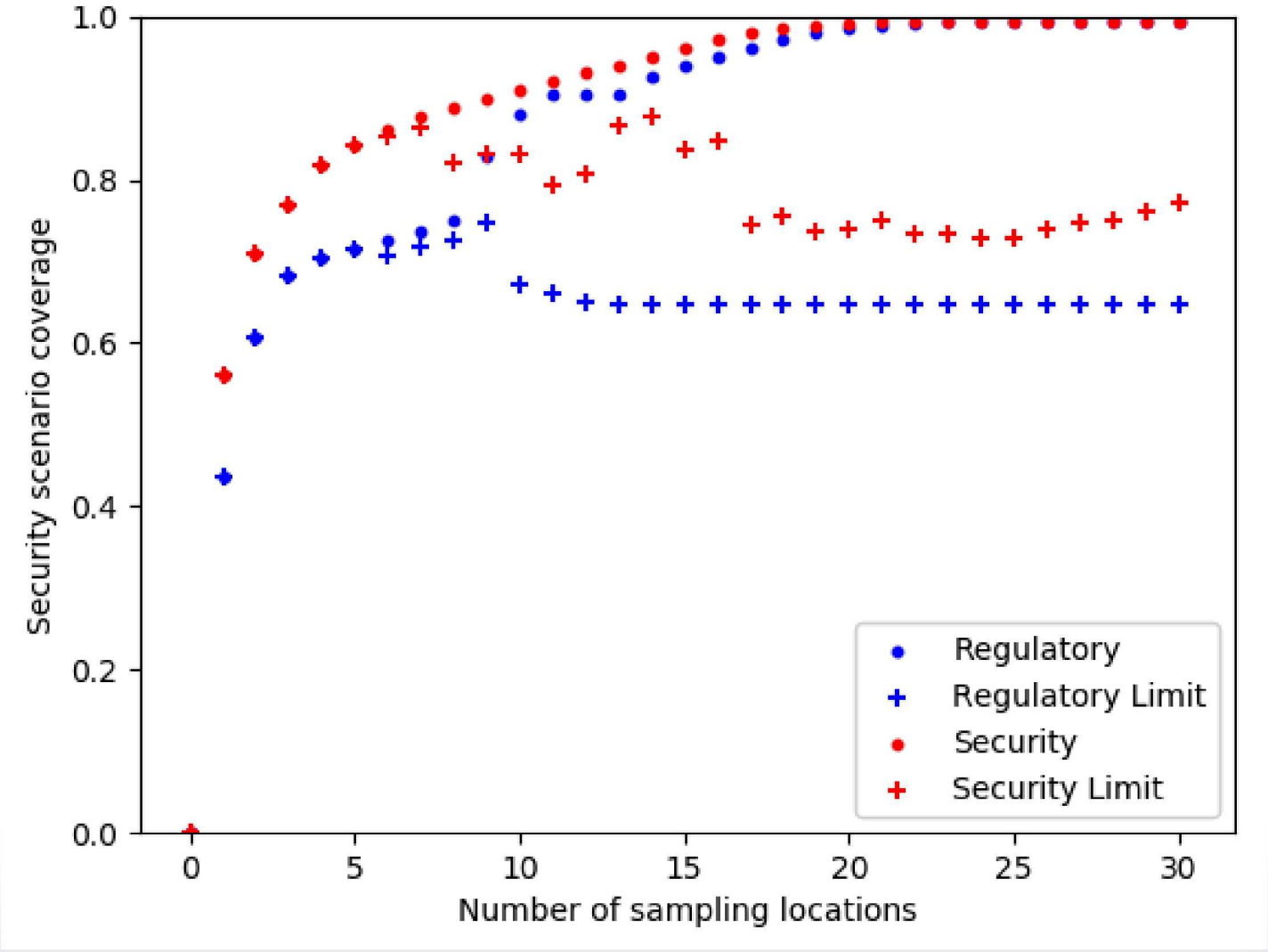


Example # 1 Evaluation Results





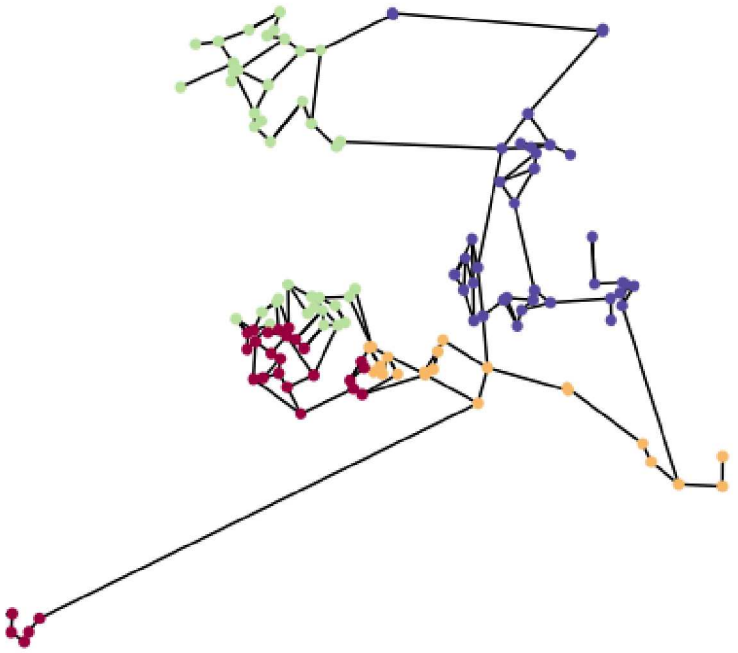
Example # 1 Evaluation with Limitations



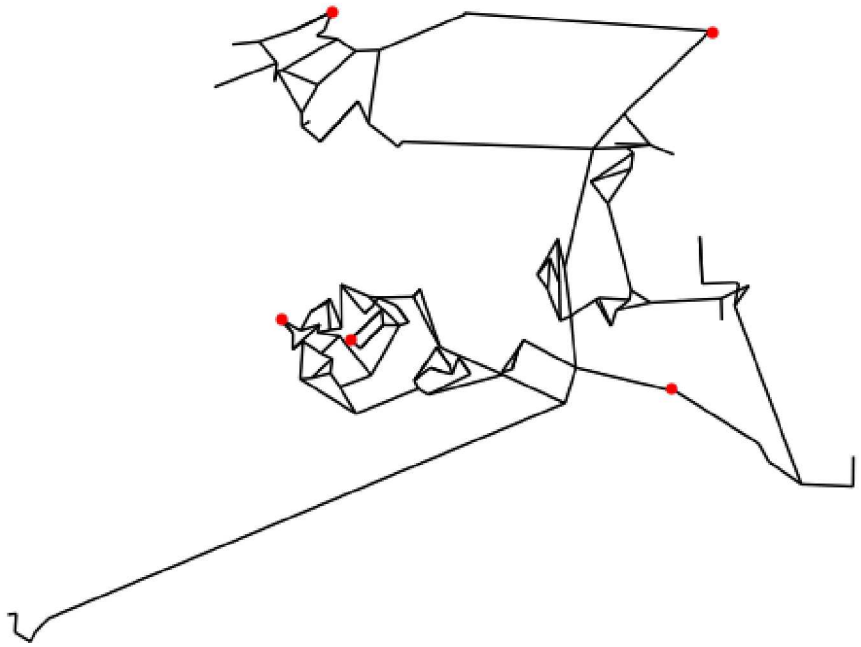
Example Network # 2

- **Battle of Water Sensor Networks (BWSN) Network 1**

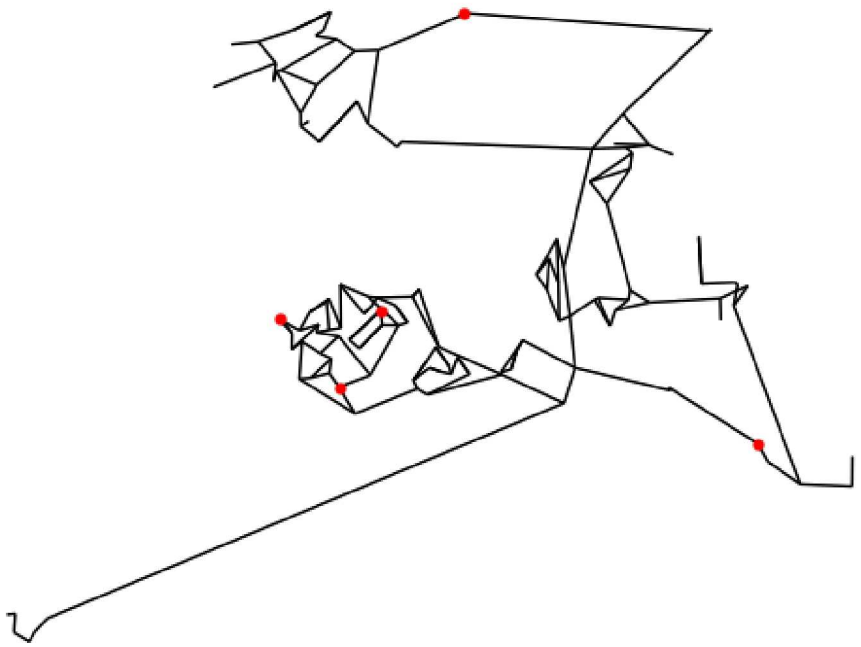
Grid bins



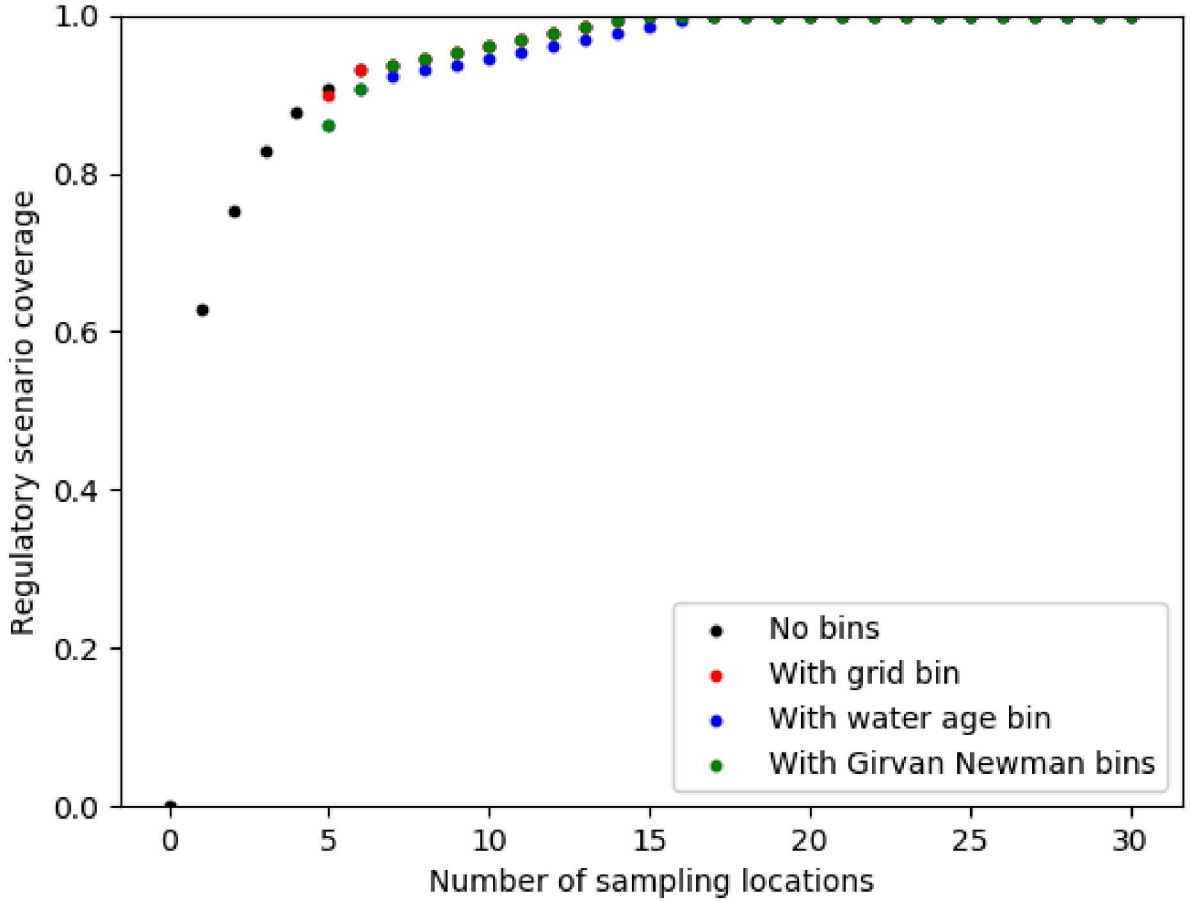
Regulatory sample locations, Grid bins

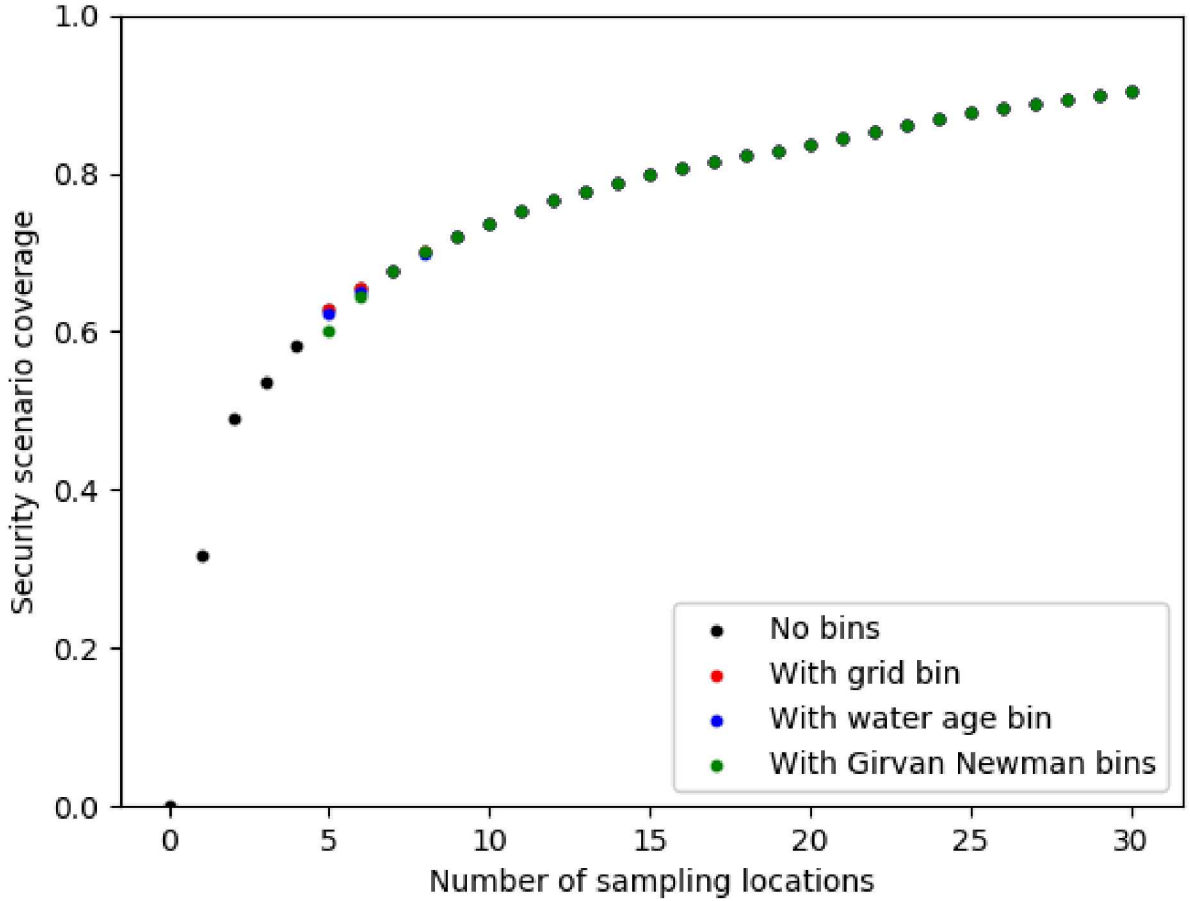


Security sample locations, Grid bins

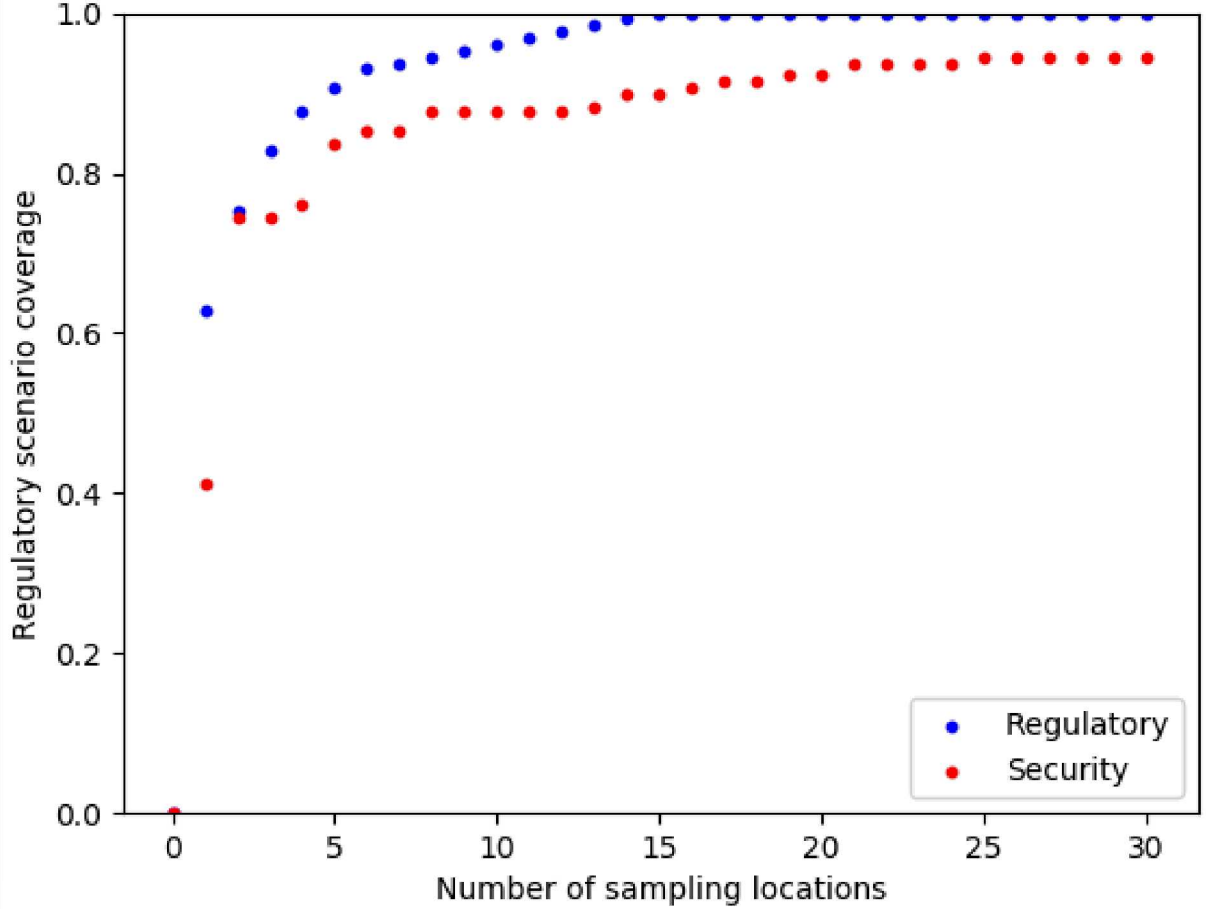


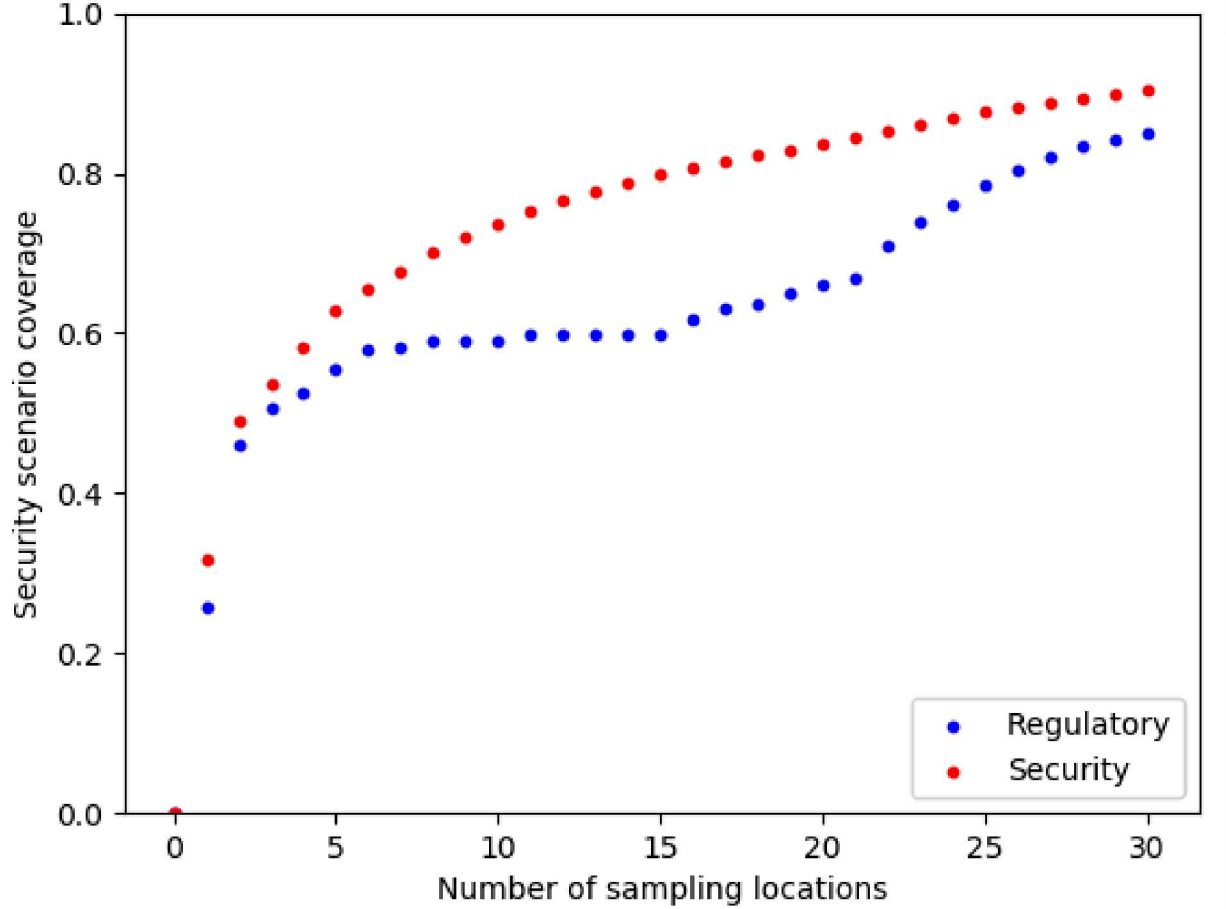
Example # 2 Binning Results



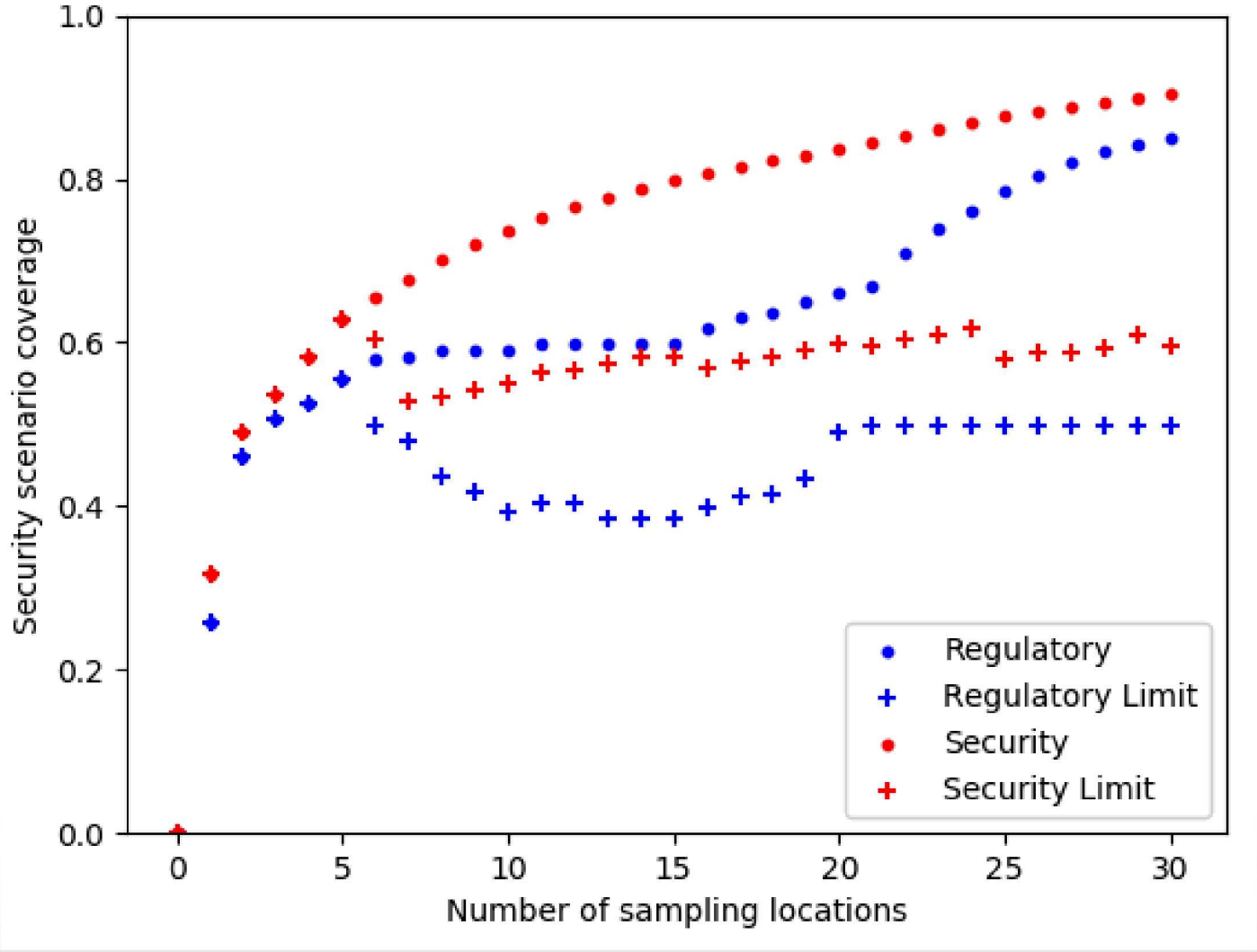


Example # 2 Evaluation Results





Example # 2 Evaluation with Limitations



Conclusions/Next Steps

- If grab sample locations are determined using security scenarios, they will still be good locations for regulatory purposes
- If grab sample locations are determined using regulatory scenarios, they will not perform as well for security
- Binning constraint did not have much affect on coverage
- Additional studies are needed
  - With larger, more detailed networks
  - Include equal distribution in bins
  - Include binning constraints in evaluation