Optimal Networks for Siting Bio-Samplers in Buildings

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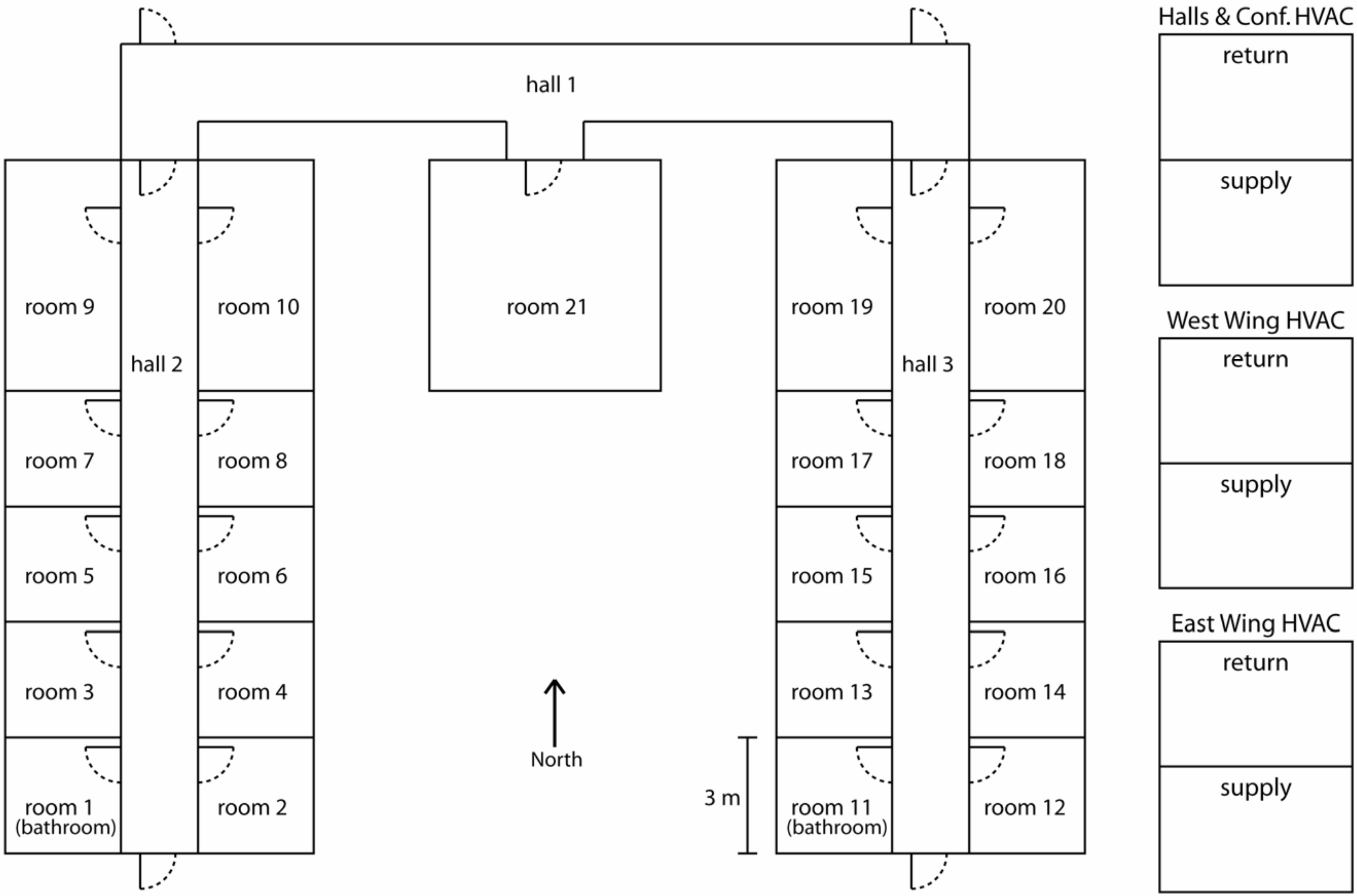
Objectives and Goals of Monitoring System

- Where do you place samplers in complex buildings to maximize the probability of detecting a biological event?
- How do you account for uncertainties that might affect sampler network performance? Uncertainties include:
  - release conditions (e.g, locations, amounts, durations)
  - building and environmental conditions (e.g, HVAC operation, meteorology)
  - model parameters
  - sampler performance characteristics (e.g, effect of fouling on filter)
- How do you identify "blind spots" (difficult-to-monitor locations)?

Application to 33-Room Building



Probability of Detecting an Event

Probability(network detection) =

P(detector 1 = on, detector 2 = off) +
P(detector 1 = off, detector 2 = on) +
P(detector 1 = on, detector 2 = on)

= 1 - P(network not detecting release)

Overview of Siting Algorithm

1. Develop “event tree” identifying all uncertain variables and their probability distributions

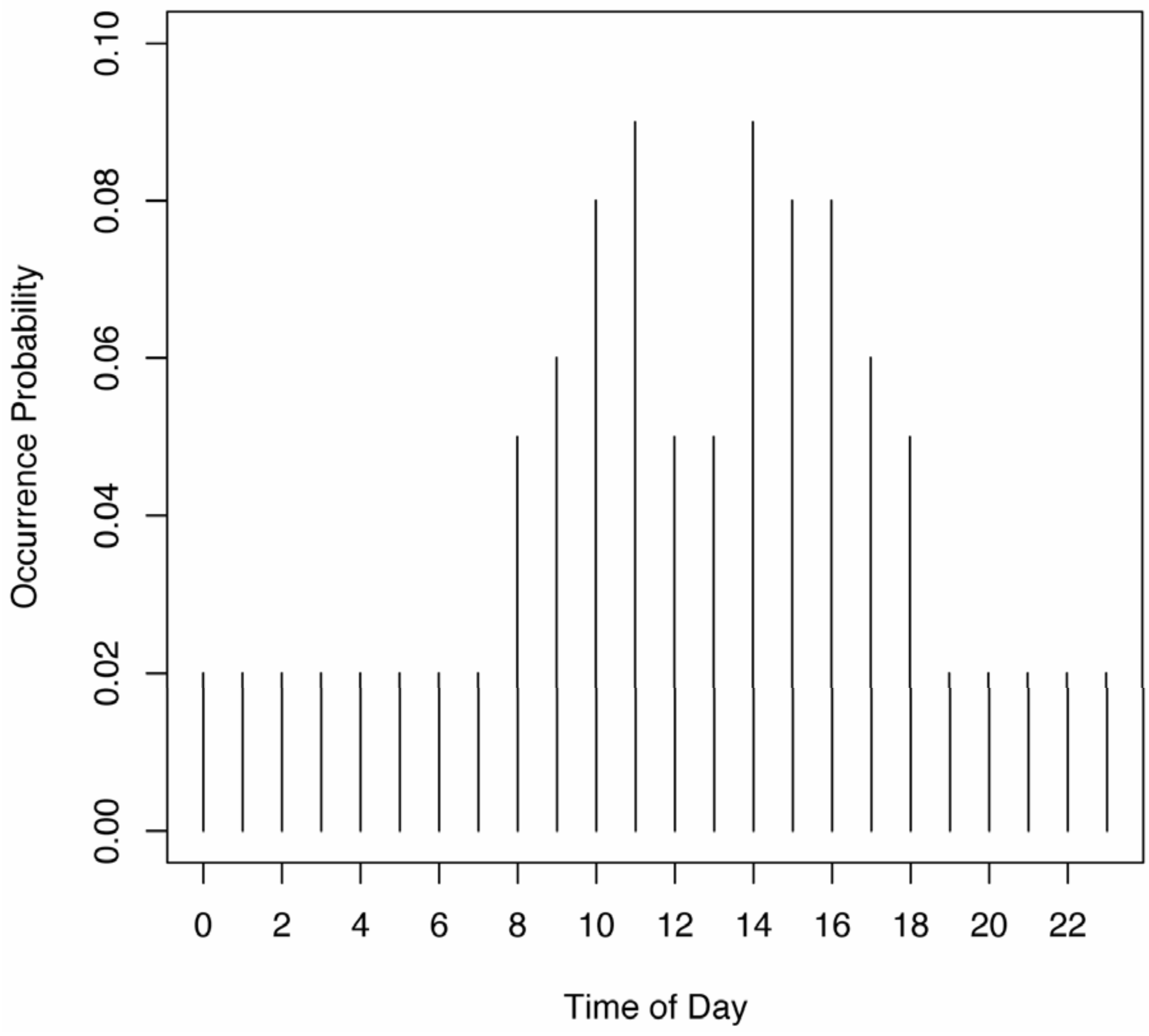
2. Predict airflow and agent dispersion
   – for each scenario
   – at all candidate sampler locations

3. Estimate probability that a hypothetical sampler will detect each scenario

4. Choose sampler locations
   – maximize probability that the network will detect an unknown release
   – account for event occurrence and sampler detection probabilities

(Sohn, MD and Lorenzetti, DM (2007). Siting Bio-Samplers in Buildings. *Risk Analysis*, accepted)

Release Time Probabilities

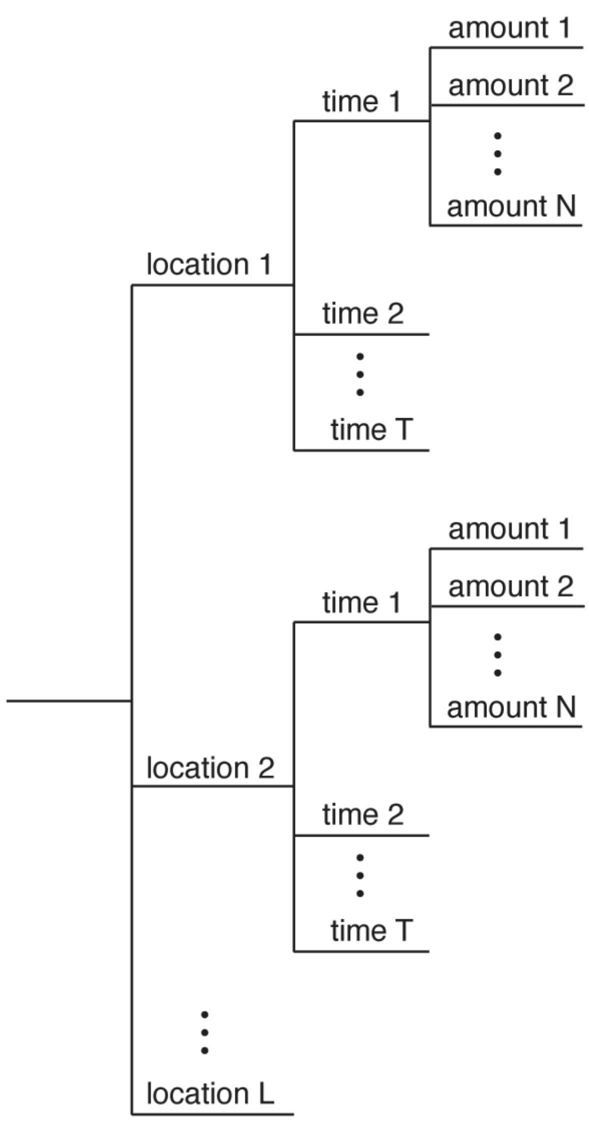


Release Mass and Location Probabilities

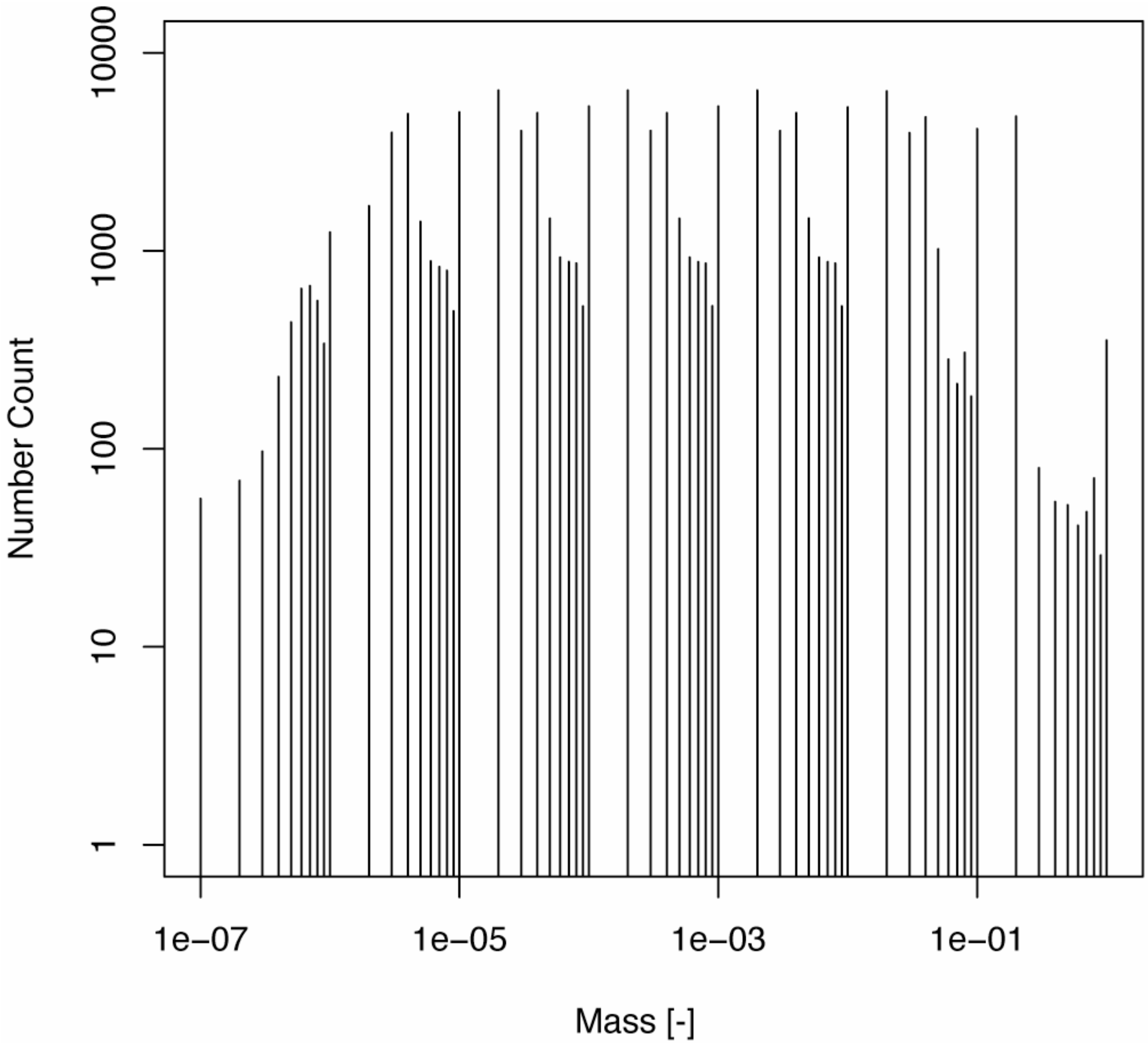
Mass [gram]	Probability
0.001	5%
0.005	5%
0.01	10%
0.05	20%
0.1	20%
0.5	10%
1	10%
5	10%
10	5%
50	5%

Location	Probability	Number Count
Hallways	3%	3
Conf. Room	2%	1
Offices	1%	20
HVAC Supply	8%	3
HVAC Return	10%	3
Ceiling Plenum	5%	3

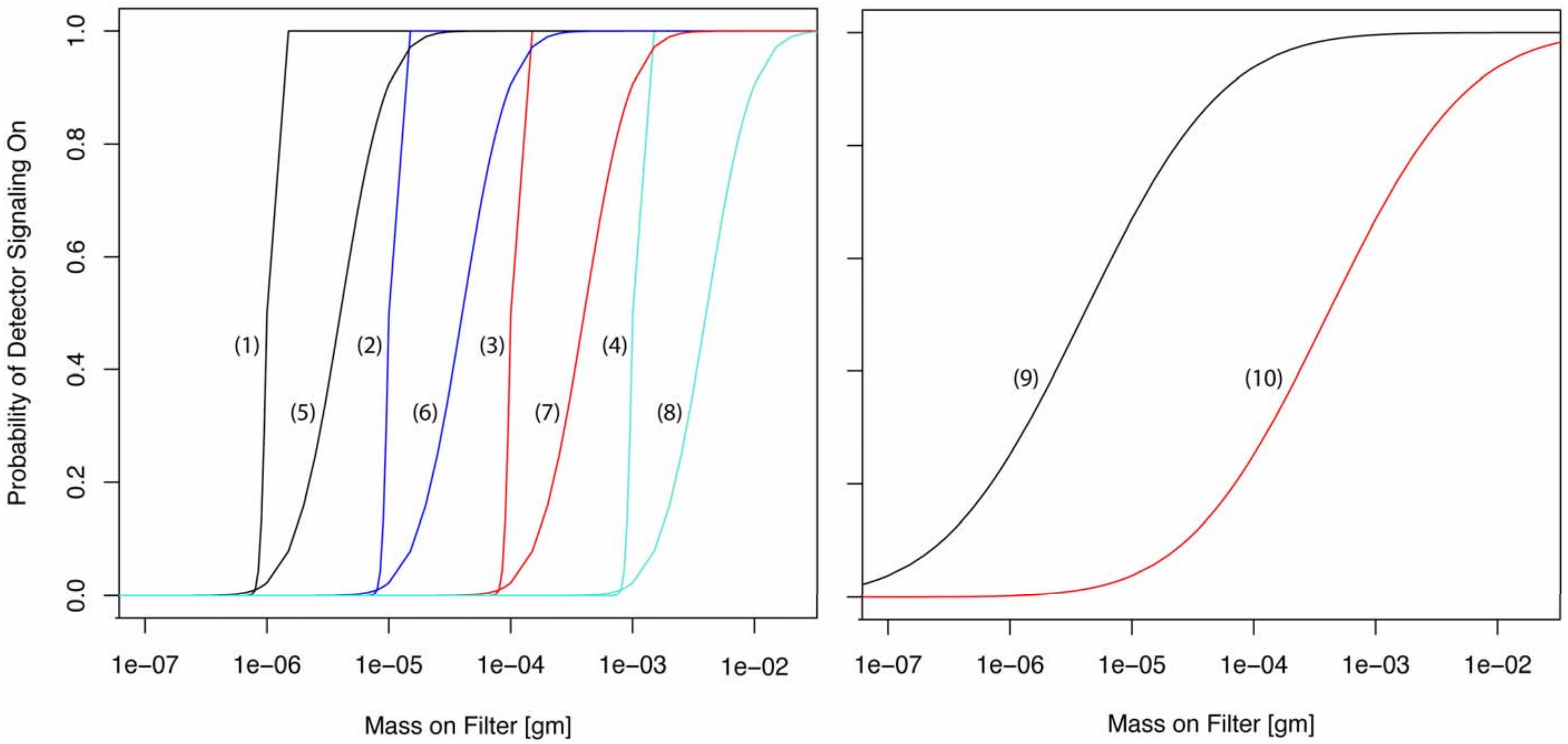
Event Tree


amount 1
amount 2
amount N
time 1
location 1
time 2
time T
amount 1
amount 2
amount N
time 1
location 2
time 2
time T
location L

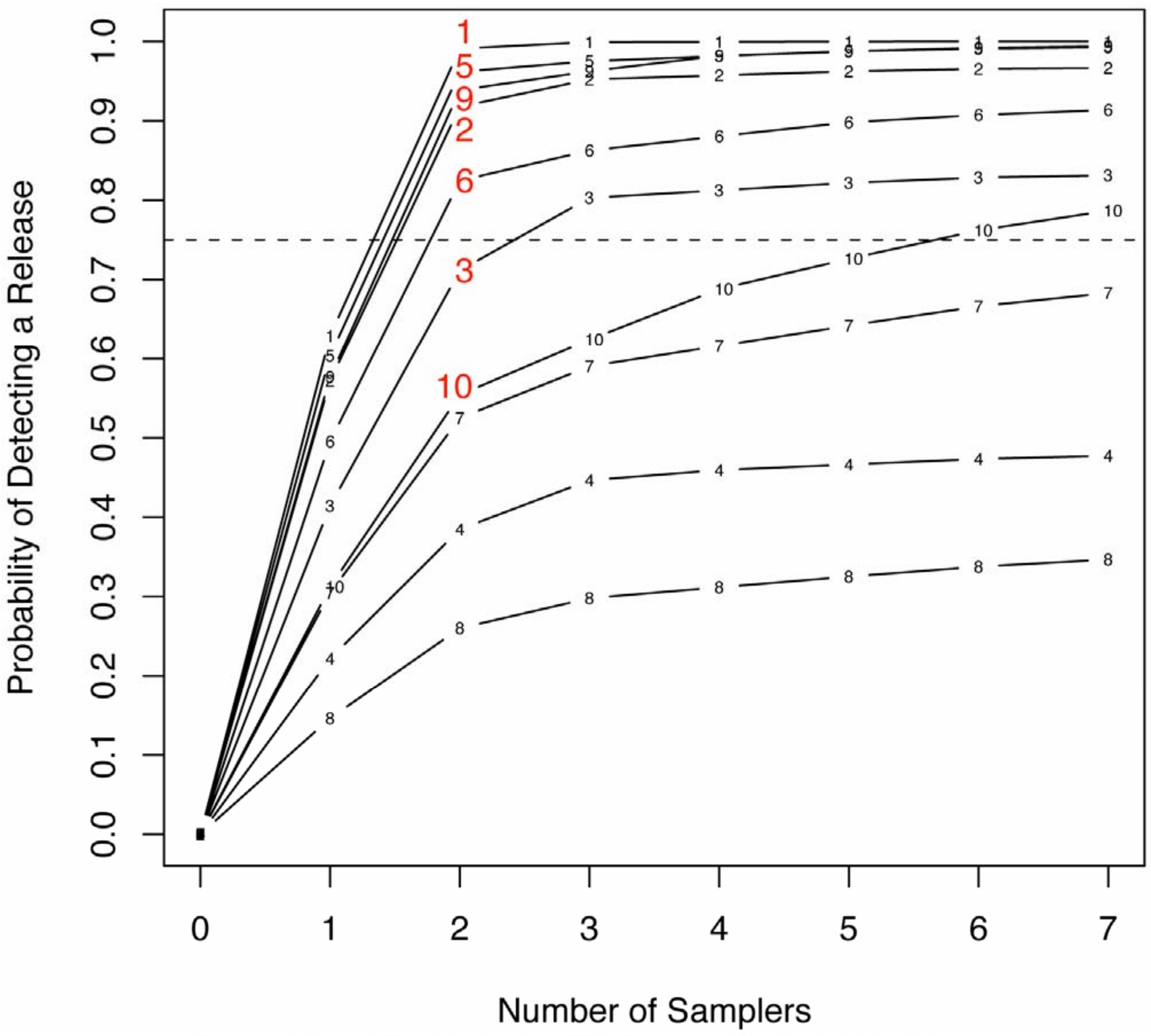
Mass Predicted on Filters



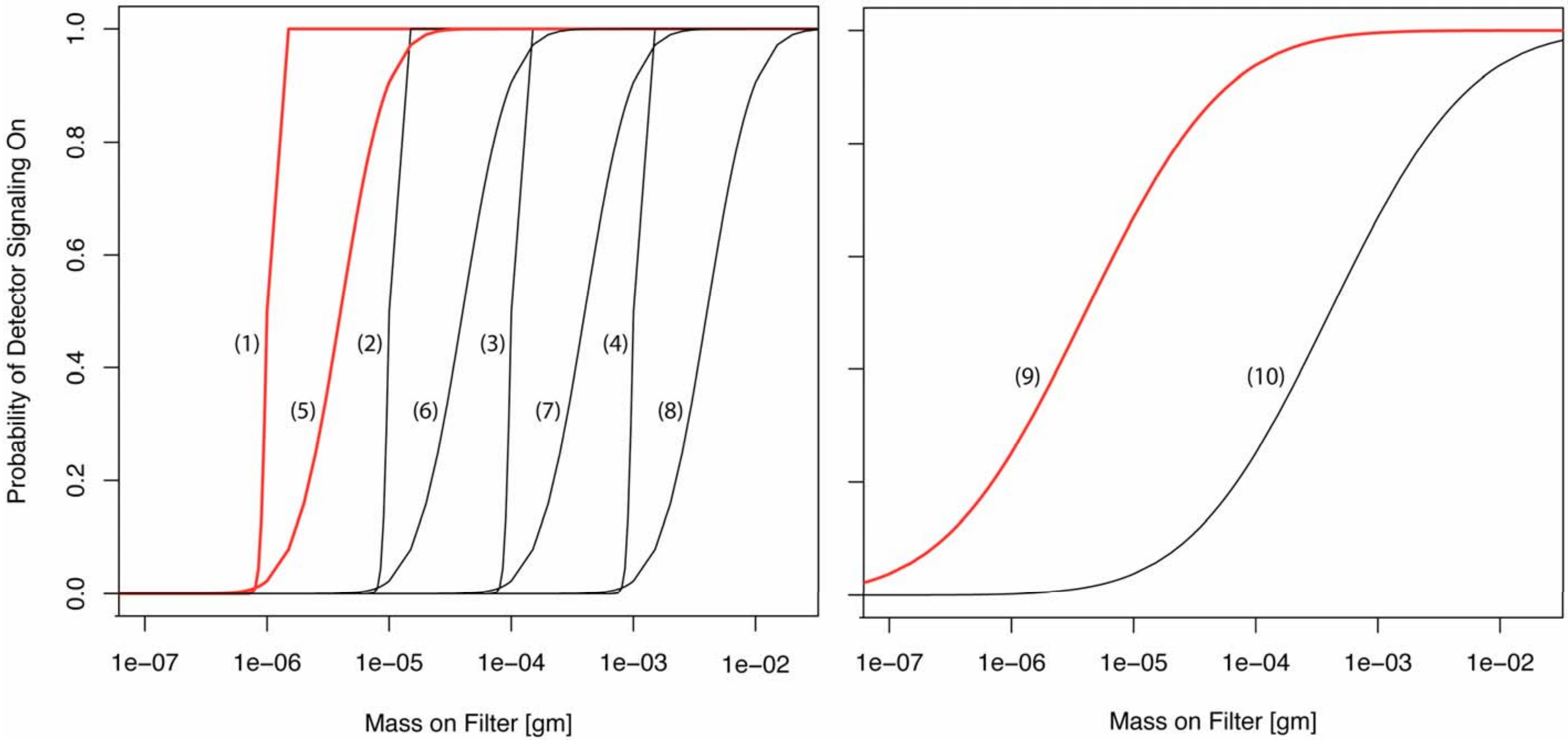
Sampler Performance Curves



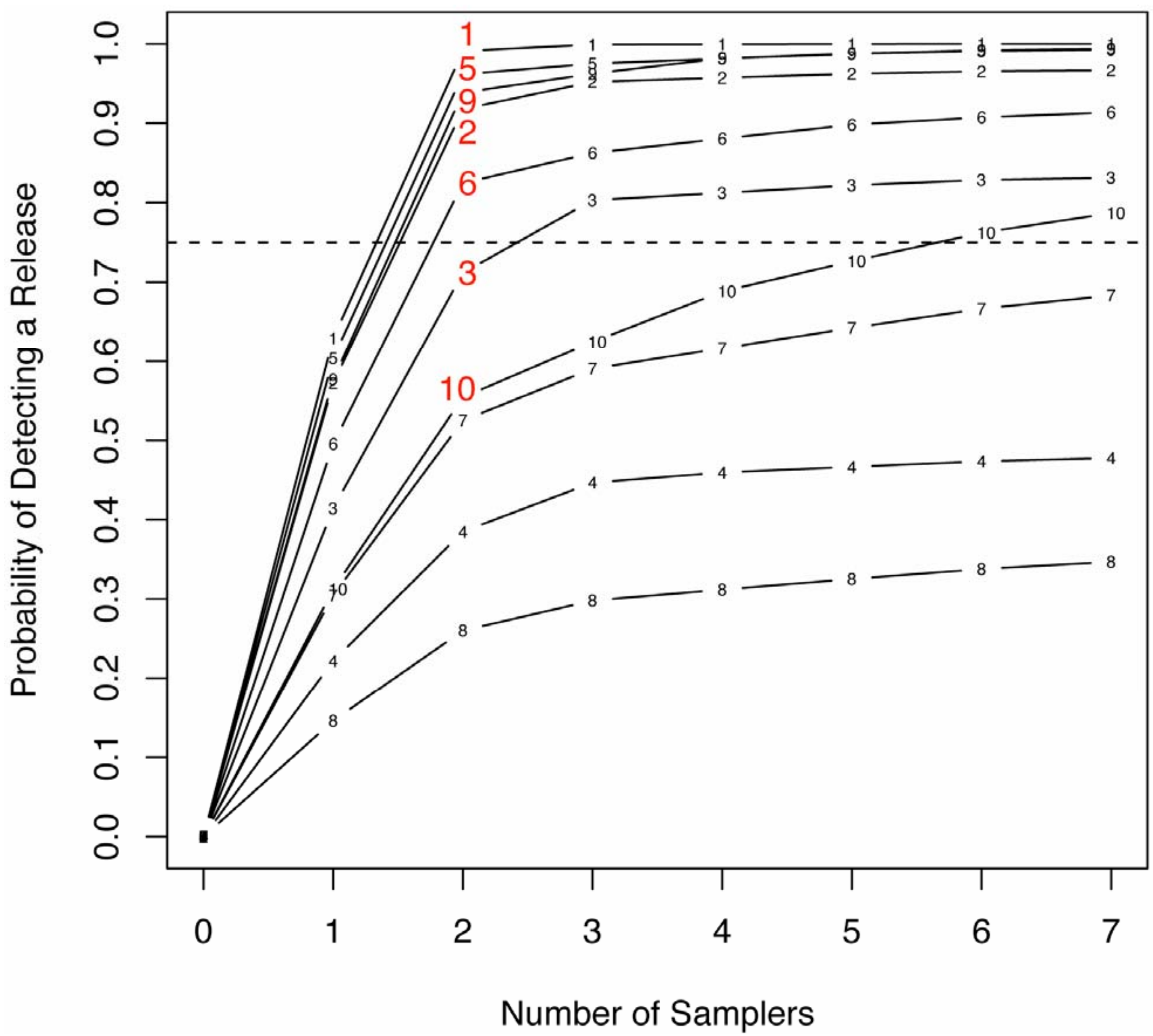
Probability of Network Detecting Release



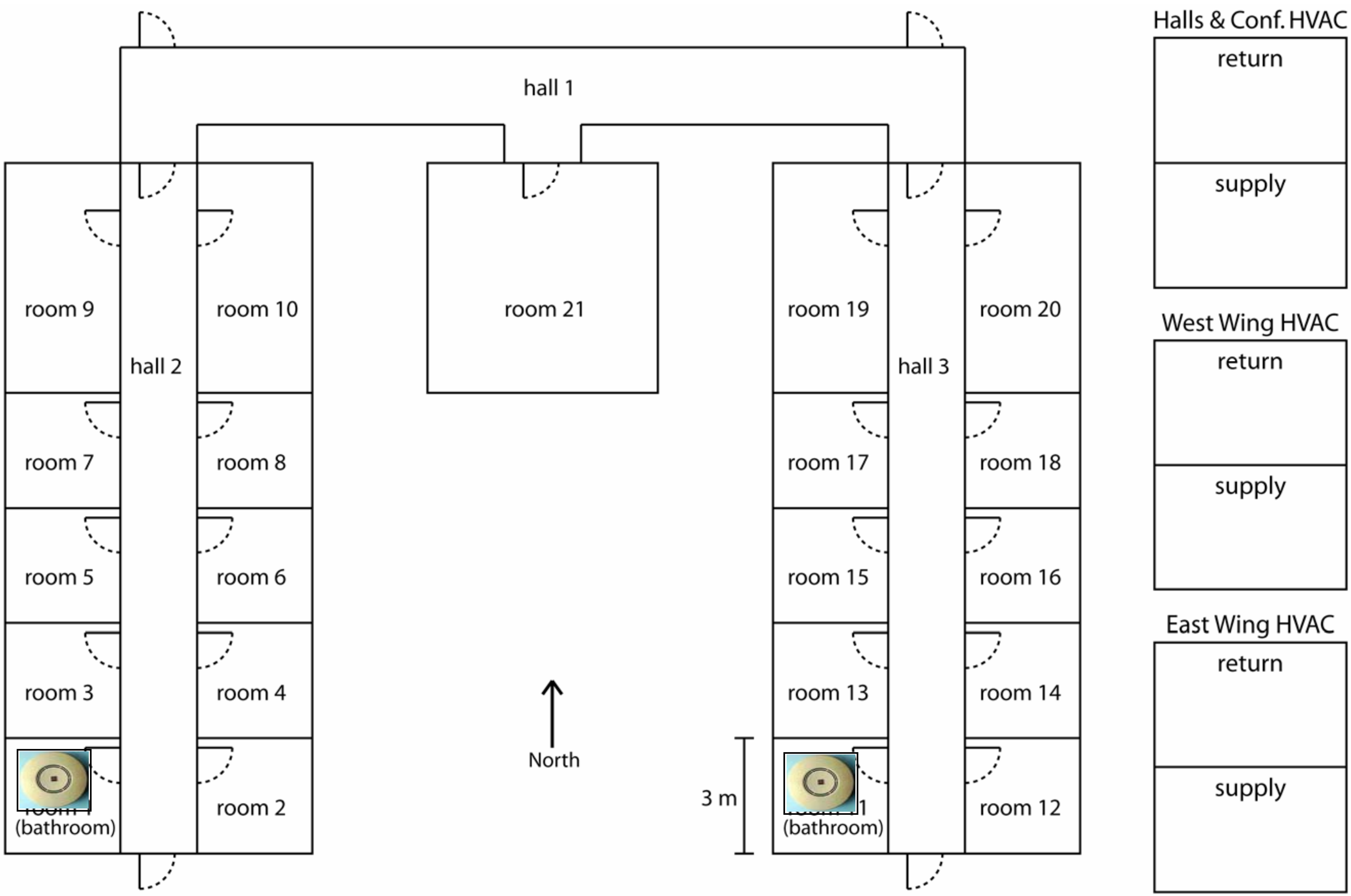
Sampler Performance Curves



Probability of Network Detecting Release



Optimal Placement of 2 Samplers



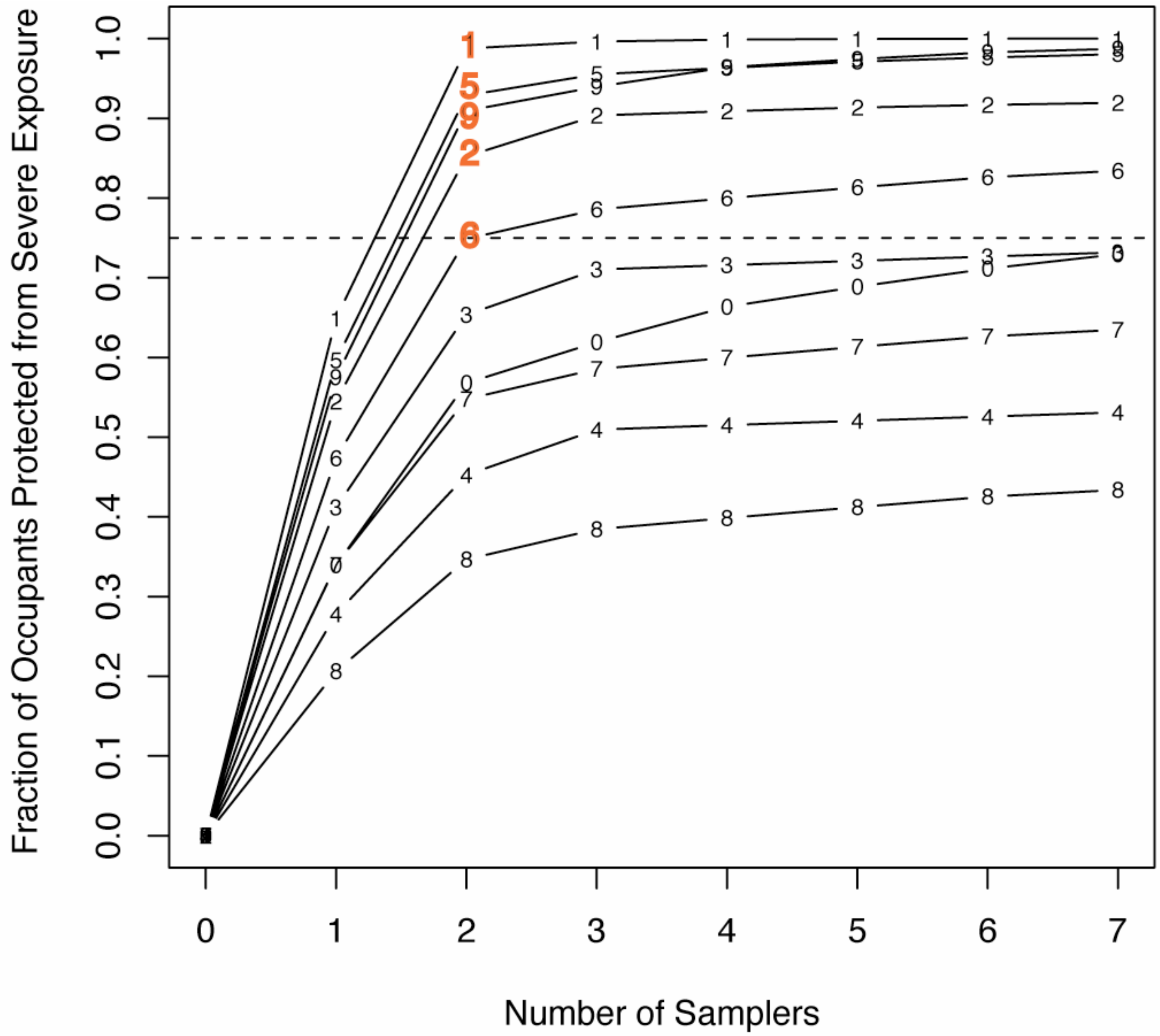
Minimum Number of Samplers Needed for at Least 75% Probability of Detection

Curve	Optimal Sampler Locations
1	Room 1, Room 11
5	Room 1, Room 11
9	Room 1, Room 11
2	Room 1, Room 11
6	Return (East), Return (West)
3	Return (East), Return (West), Return (North)
10	Return (East), Return (East) Return (West), Return (West) Room 1, Room 11

Minimize Casualties Due to an Undetected Attack

- If an attack is detected, health care can be provided. Otherwise, an undetected leads to casualties.
- Select optimal sampler placements that minimize the expected number of casualties due to an undetected attack.
- Requires statistical estimates of occupancy and toxicity of agent.

Fraction of Occupants Protected from Severe Exposure



Minimum Number of Samplers Needed for at Least 75% Protection

Curve	Optimal Sampler Locations
1	Hall (East), Hall (West)
5	Return (East), Return (West)
9	Return (East), Return (West)
2	Return (East), Return (West)
6	Return (East), Return (West) Conference Room

Summary and Concluding Remarks

- Optimal placement of samplers requires a probabilistic algorithm to:
  - account for uncertainties in event scenarios
  - estimate probability that a candidate network will detect scenarios
- Approach can compare sampler characteristics:
  - investigate tradeoff between cost and quality of samplers
  - investigate combinations of sensor and sampler types
- Illustrative application shows:
  - optimal locations may be not be obvious
  - detection sensitivity may be more important than certainty
  - efficient software implementation important