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# Node Distribution: The Forgotten Factor

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Multi-Service Networks 2012

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# Introduction

- Wireless Sensor Network research relies on simulation
- Practical - cheap, quick and easy
- Desirable - repeatable, gradual increase in complexity/realism
- Can vary important factors and analyse

**But never node distribution**

(the positions of the nodes inside the network)

# Node Distribution

- Researchers fix distribution in advance
- Most common is Poisson point process / uniform
- Distribution is an important factor that is ignored

- How to measure it?
- How to vary it?
- How to control it?

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# Measuring Distribution I

- Well studied in graphics literature
- No agreement on which metric is best
- Different requirements in network research
- Maybe one metric is insufficient

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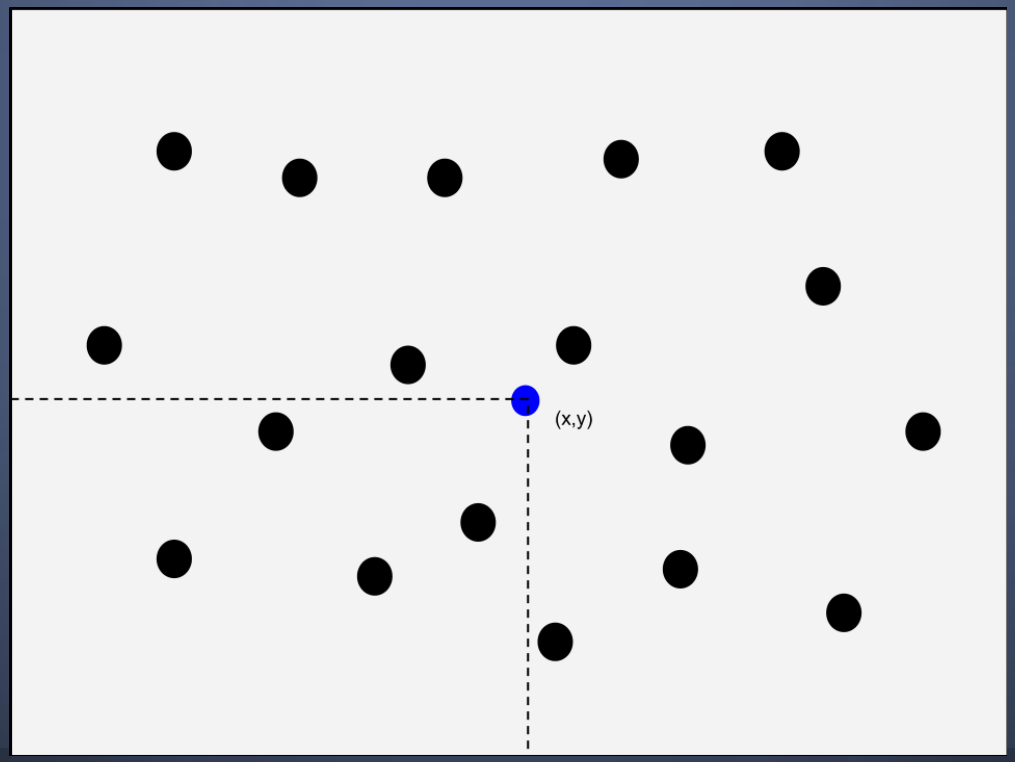
# Measuring Distribution II

**Star-Discrepancy:**

$$d(x_i, y_i) = \left| \frac{n}{N} - \frac{x_i y_i}{A} \right|$$



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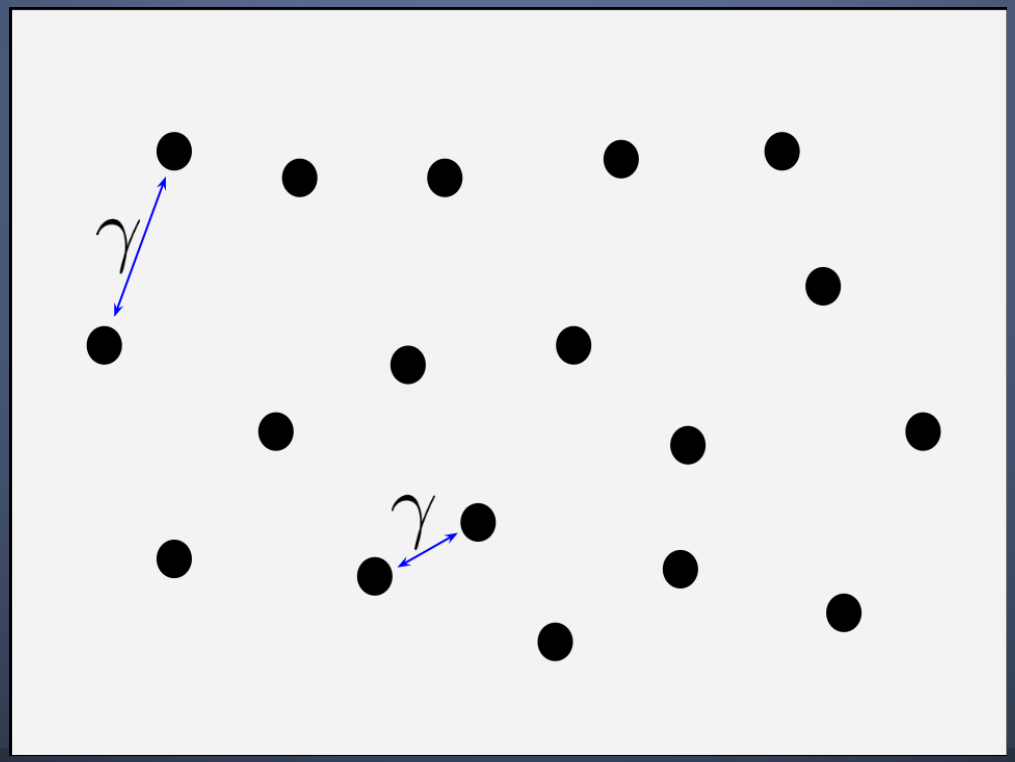
# Measuring Distribution III

## Coverage Measure:

$$\lambda = \frac{1}{\bar{\gamma}} \sqrt{\frac{1}{N} \left( \sum_{i=1}^{N} (\gamma_i - \bar{\gamma})^2 \right)}$$



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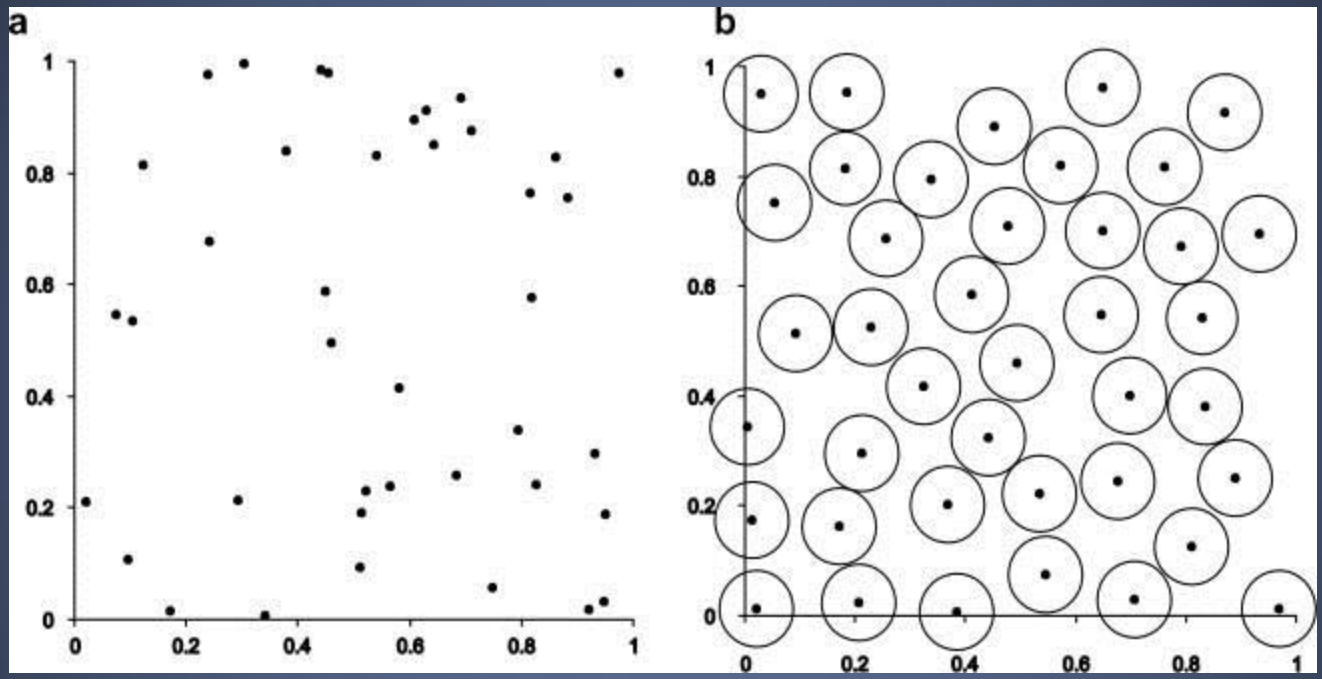
# Distribution Options




Poisson Point Process

Poisson Disk Distribution

Image from: Krzysztof Kazimierczuk, Anna Zawadzka, Wiktor Koźmiński, Optimization of random time domain sampling in multidimensional NMR, Journal of Magnetic Resonance, Volume 192, Issue 1, May 2008, Pages 123-130

# Poisson Disk Distribution

- Square of length L, with N nodes, maximum minimum distance between nodes:

$$r_{max} = 2L\sqrt{\frac{1}{2N\sqrt{3}}}$$

- Specify minimum distance as proportion of max min distance
- No more than 0.7 of max for practical algorithms

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# Importance of Distribution

- 50m x 50m network with 100 nodes
- 10m transmission range
- Vary relative minimum distance 0 ... 0.7
- Measure balance for load balancing protocol DECOR and shortest-path routing

Result: Change in balance of 15.9% and 22.6%

Result: Relative difference falls from ~30% to ~20%

# Hidden Factor?

- 
- Density is a common variable
- Balance has strong correlation with density, $t(5)=0.9233$
- But stronger correlation with distribution, $t(5)=-0.975$

Is performance variation because of density or distribution?

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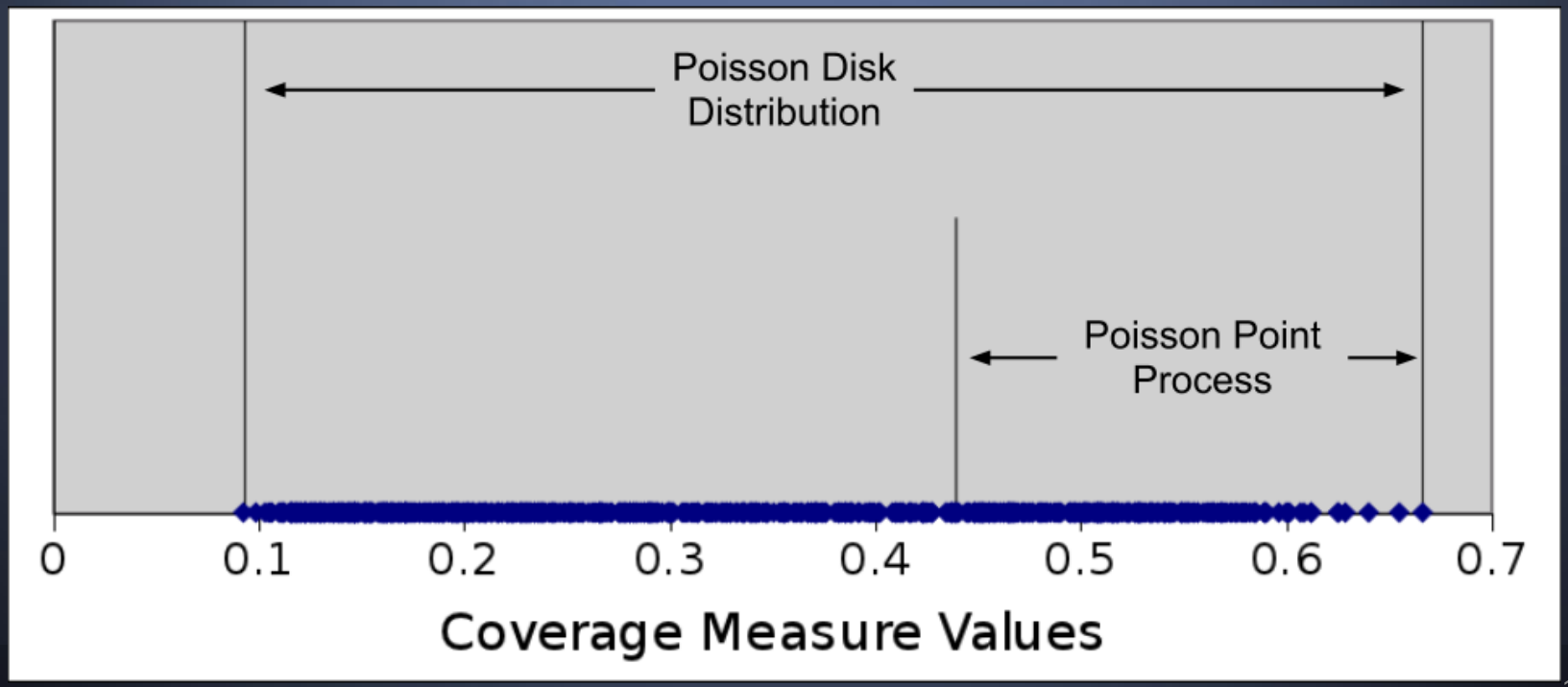
# Coverage

Only using Poisson Point Process covers less than half of the distribution metric values produced by varying minimum distance



# Repeatability

- Only stating point generation method doesn't make the simulations repeatable
- 20 seeds, Java RNG = 7.6% variation
- Same seeds, Python RNG = 45% variation

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# Conclusion

- Distribution of nodes is an important factor
- Sometimes a hidden factor
- Should be included in analysis
- Must be explicitly measured for repeatability

- Metrics for measuring
- Methods for varying
- Techniques for generating required distribution