On the path coverage by a non homogeneous random sensor field

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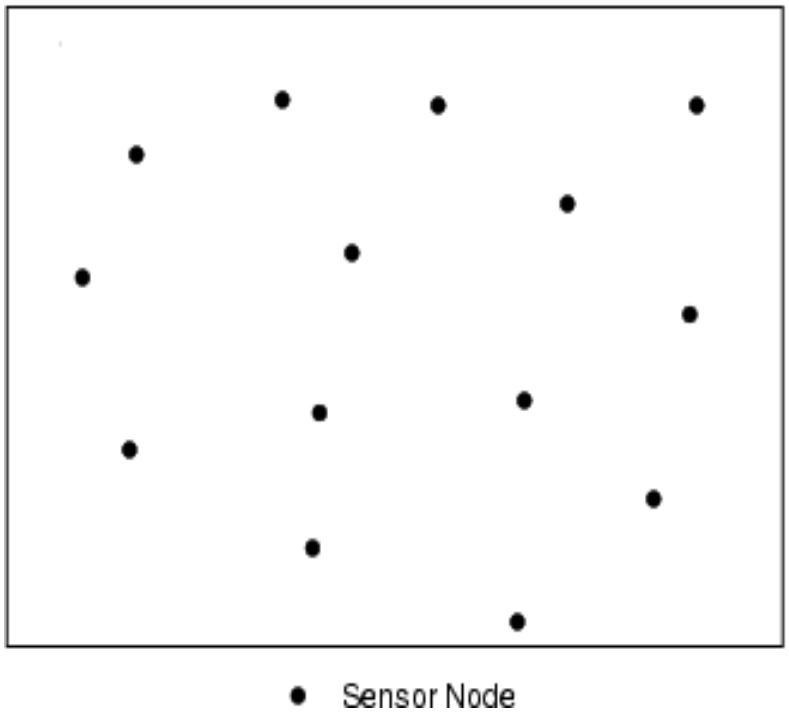
Outline

Coverage : fundamental issue

How well do the sensors observe (or sense) the physical space (or sensor field) in the sensor network ?

Outline

Fixed/random sensor network



Fixed/given network

Sensor locations and coverages are assumed to be known.

Random network

Sensor locations are random and form a point process on a line, plane or in 3-dimensional space. Coverages are random sets.

Coverage analysis

Coverage by a given network

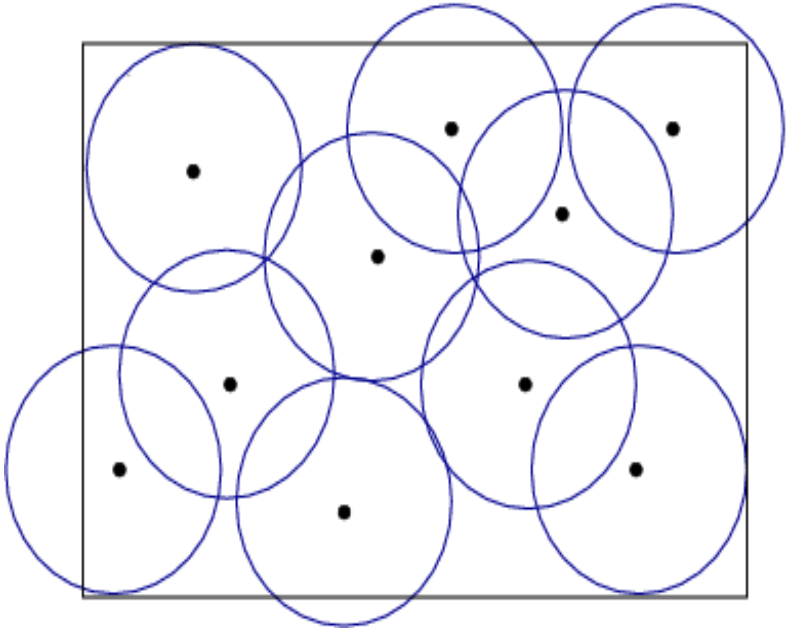
Algorithmic (deterministic) study using techniques from computational geometry like Voronoi and Delaunay tri-angulation.

Coverage by a random network

Stochastic analysis using techniques from stochastic geometry and spatial random processes.

Outline

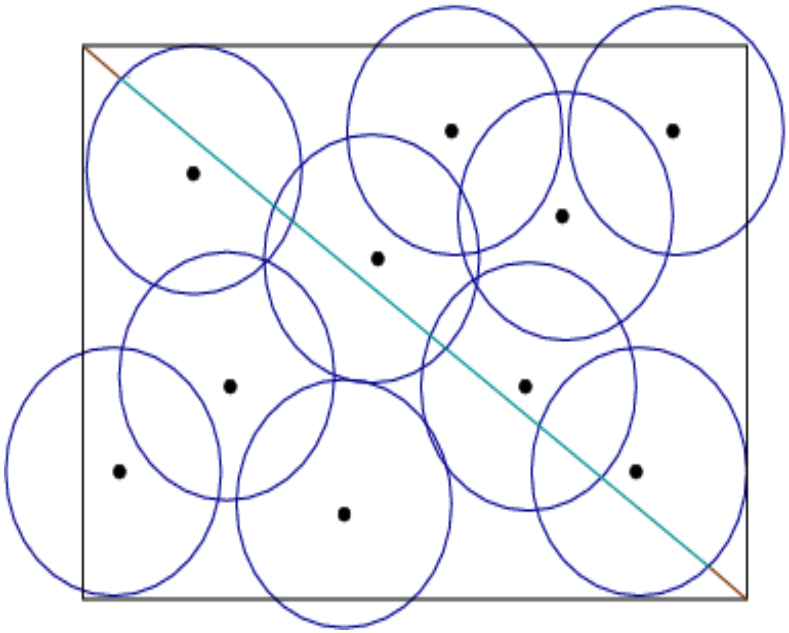
Coverage by sensor field



Coverage of d-dimensional volume

- Area coverage: fraction of geographical area covered
- Line/path coverage: fraction of the line covered
- Node coverage: fraction of sensors that can be removed

Coverage by sensor field



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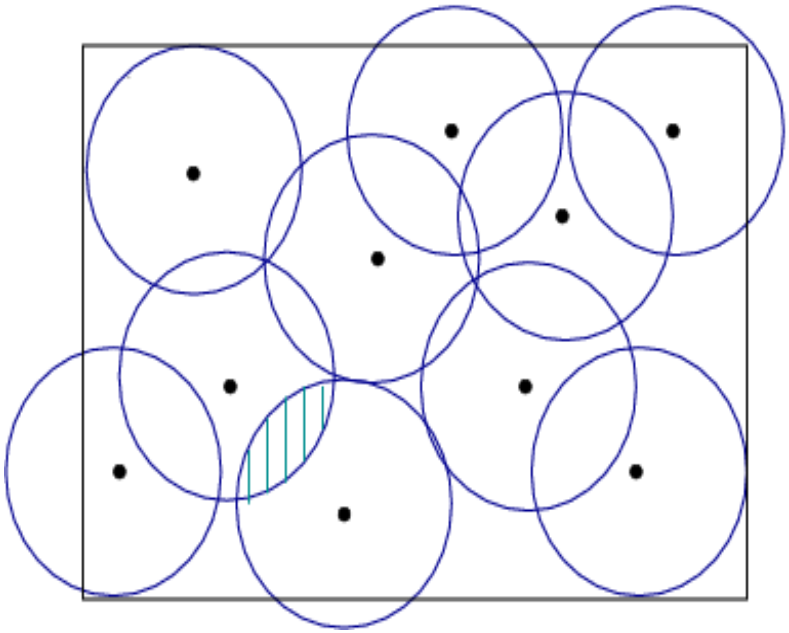

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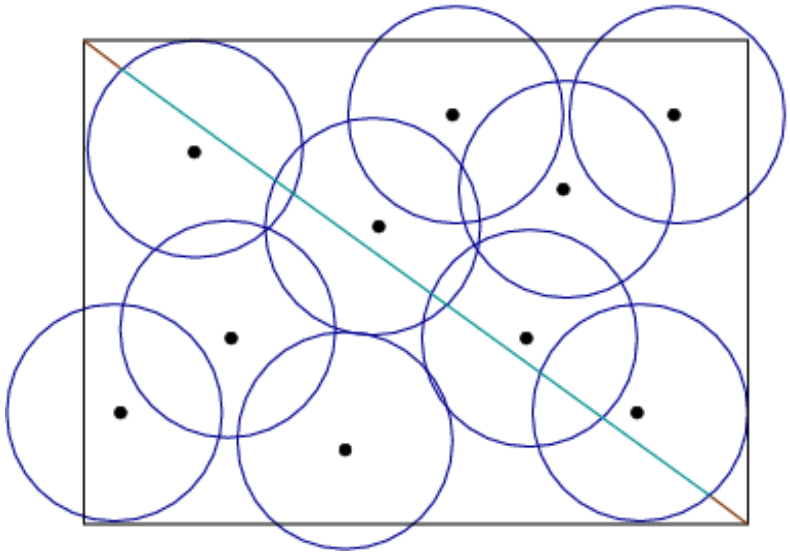
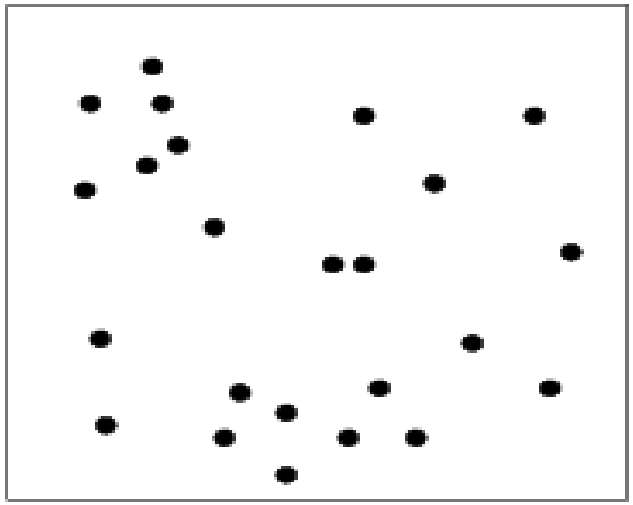
Motivation



Path coverage

- *Coverage of a one-dimensional path induced by a two-dimensional random network.*
- *Applications like intrusion detection, target tracking*

Motivation Cont.

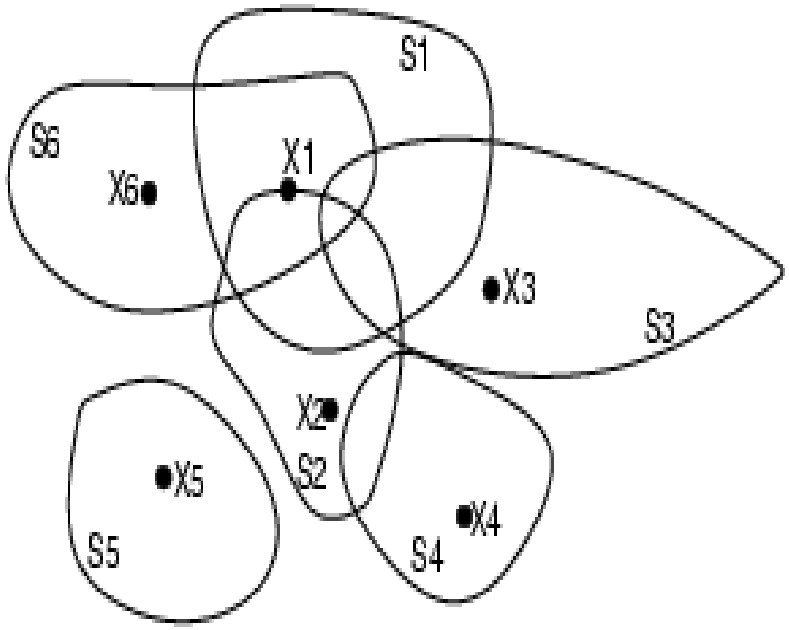


Stochastic analysis: Non homogeneous

- *Due to non homogeneous degradation of the network*
- *Application specific non homogeneous placement of nodes.*

Outline

Stochastic model



Coverage process[Hall1988]

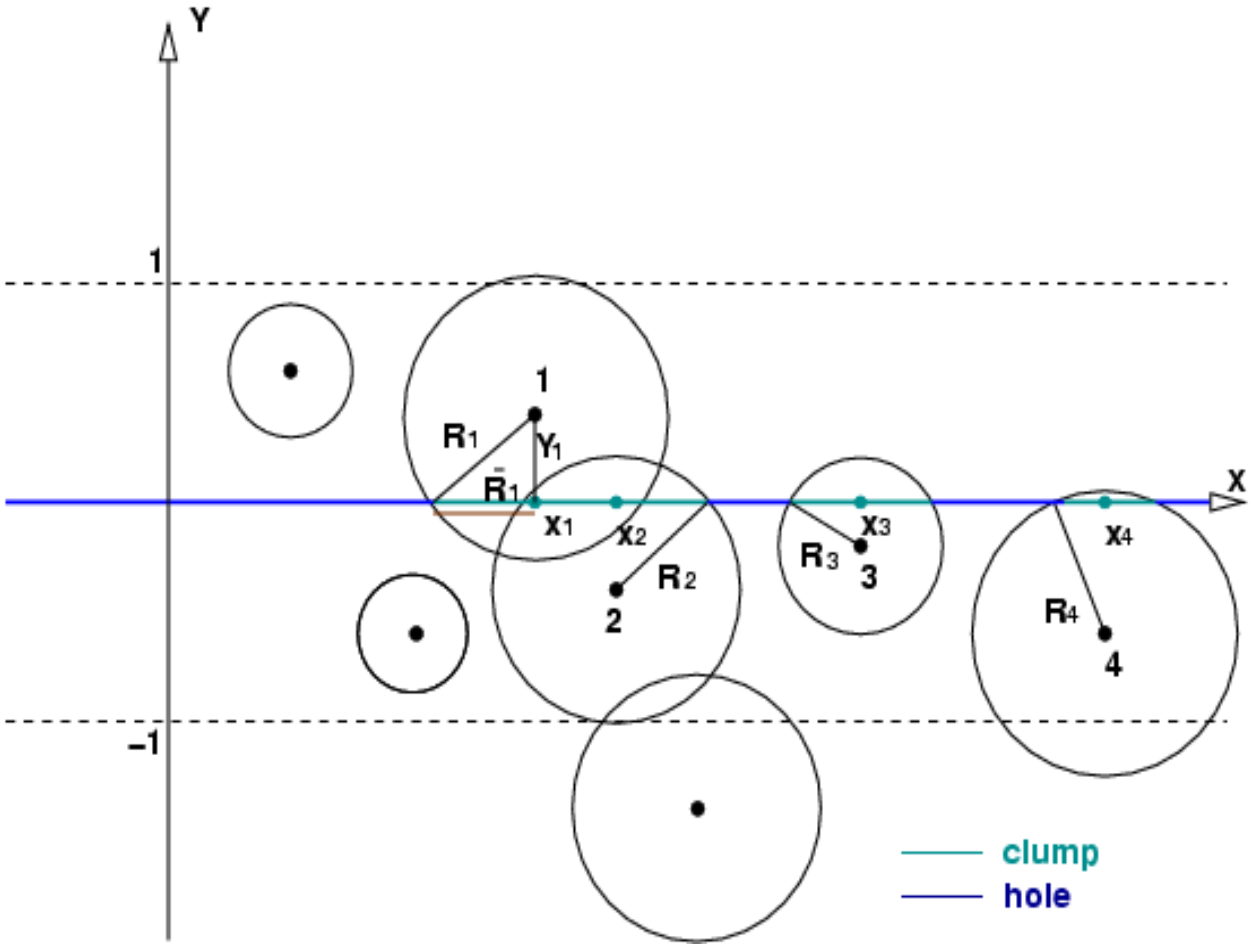
- *Countable collection of points*
- *Countable collection of nonempty sets*

Coverage process

Non homogeneous spatial process

- *Set of sensor locations:* $P = \{X_i\}$, $X_i \in \Re^d$. *P is a non stationary spatial Poisson process of intensity* $\lambda(x, y)$.
- *Thresholded sensing with sensing area as circle of radius* R_i *and* $\{R_i\}$ *are identically distributed with density* $f_R(r)$
- *The coverage process,* $C := \{X_i + R_i, i \geq 1\}$ *is the Non homogeneous Boolean Model.*
- *Support of* R_i *is* $[0, 1]$

Coverage process on $x-$axis



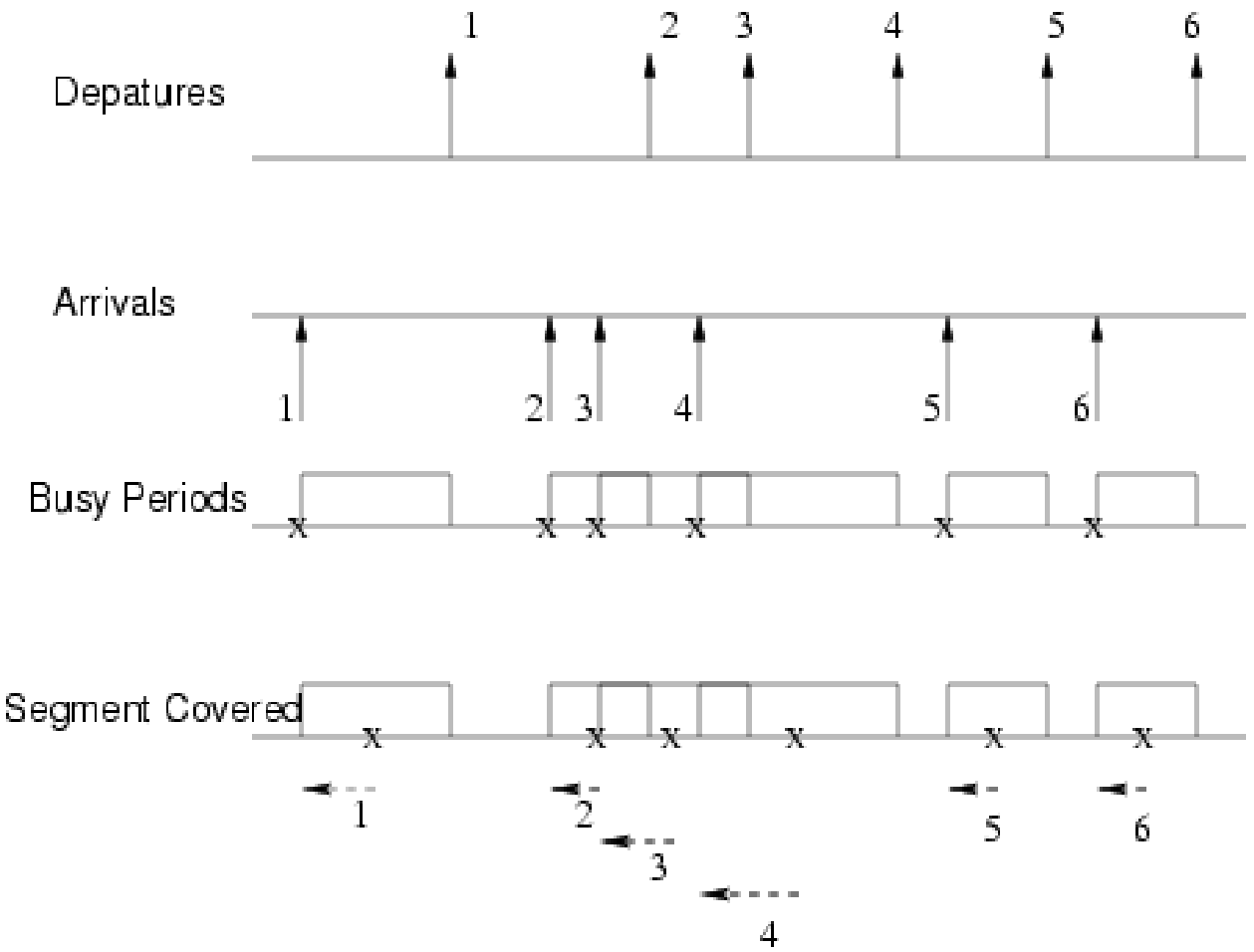
Induced coverage process

One-dimensional spatial process

- *Induced coverage process in one dimension (WLOG x-axis) shown to be one-dimensional non homogeneous Boolean model.*
- *Clump: A contiguous segment on a line that is sensed, or 'covered', by one or more sensors*
- *A contiguous segment that is not covered by any sensor is called a hole.*
- *Vacancy of the segment is the sum of the hole lengths.*

Outline

Coverage process and M/G/∞ queue



Coverage process and M/G/∞ queue

Clumps are busy periods

- *Number in service at time x = Number of sensors sensing the point x*
- *Coverage statistics for non homogeneous sensor field same as busy period statistics of $M_t/G_t/\infty$ queue*
- *Corresponding $M_t/G_t/\infty$ queue (arrival rate and service time density) are derived.*

Outline

Point $k-$coverage

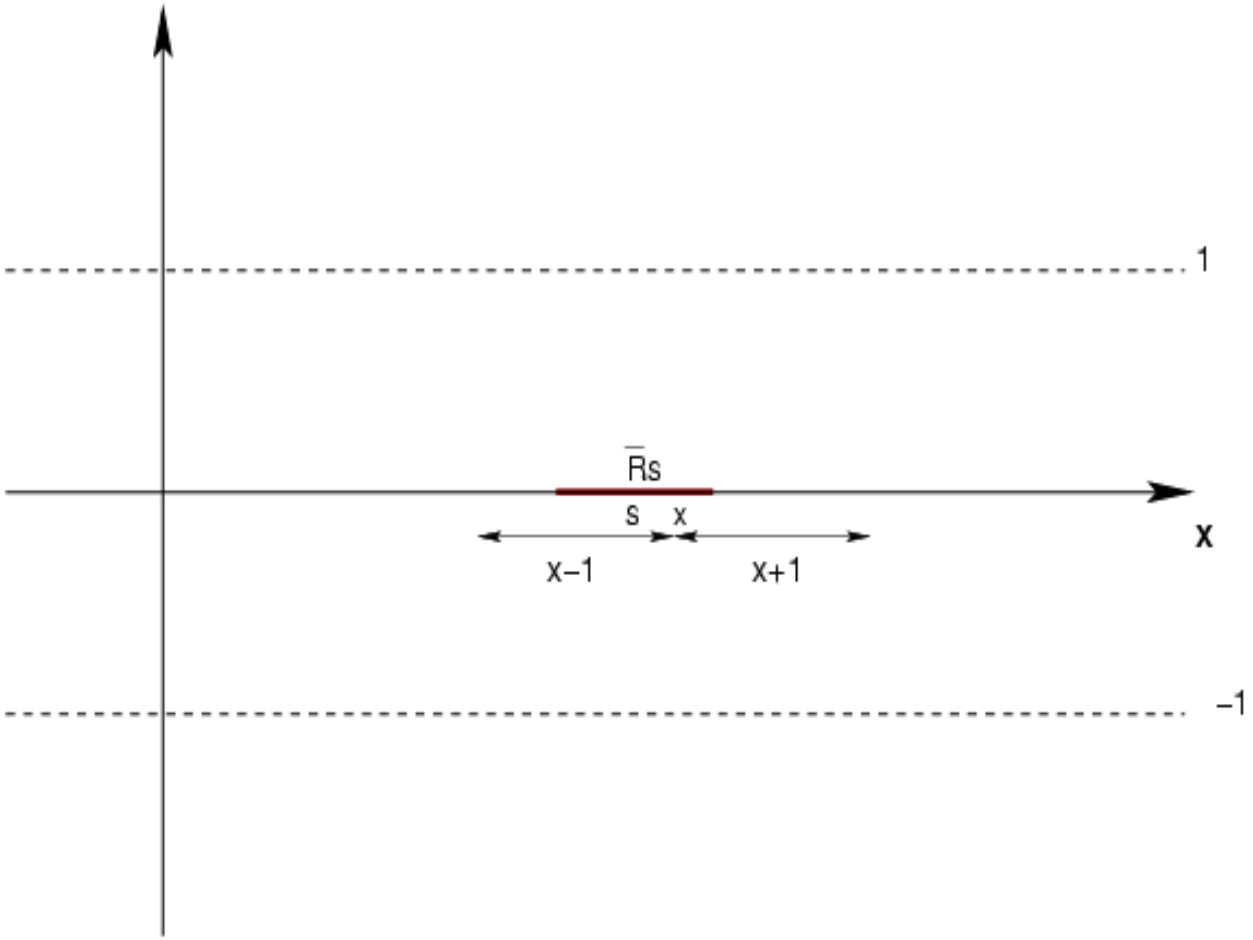
$p_k(x)$, Poisson distributed

- *With expected number of sensors covering the point x*

$$m(x) = \int_{x-1}^{x+1} \bar{\lambda}(s)\gamma(x,s)\, ds$$

- $\gamma(x,s)$ *is the probability that point x is covered by a sensor at s.*

Point $k-$coverage



$k-$coverage

Results

- *Fraction of the segment covered : Expected vacancy and variance of vacancy obtained.*
- *Complete coverage of the segment : Bounds obtained.*
- *Residual hole and clump lengths*

Numerical study

'Laplacian' intensity function, $\lambda(x,y) = \theta e^{-\mu(|x|+|y|)}$ and $R_i = 1$

$$\bar{\lambda}(x) = \frac{2\theta(1-e^{-\mu})}{\mu} e^{-\mu|x|}, \quad f_{\bar{R}_x}(\bar{r}) = \frac{\bar{r}e^{-\mu(\sqrt{1-\bar{r}^2})}}{\frac{(1-e^{-\mu})}{\mu}\sqrt{1-\bar{r}^2}}$$

Summary

Path coverage by random networks

- *k-coverage analysis for a non homogeneous random sensor network.*
- *Preliminary results published.[Globecom2006]*
- *Further analysis in progress.*

References I

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John Wiley and Sons, 1988.

Pallavi Manohar, S. Sundhar Ram and D. Manjunath
On the Path Coverage by a Non Homogeneous Sensor Field
Proc. of Globecom, 2006.

Thank You