Bespoken: A Protocol for Data Search in Wireless Sensor Networks

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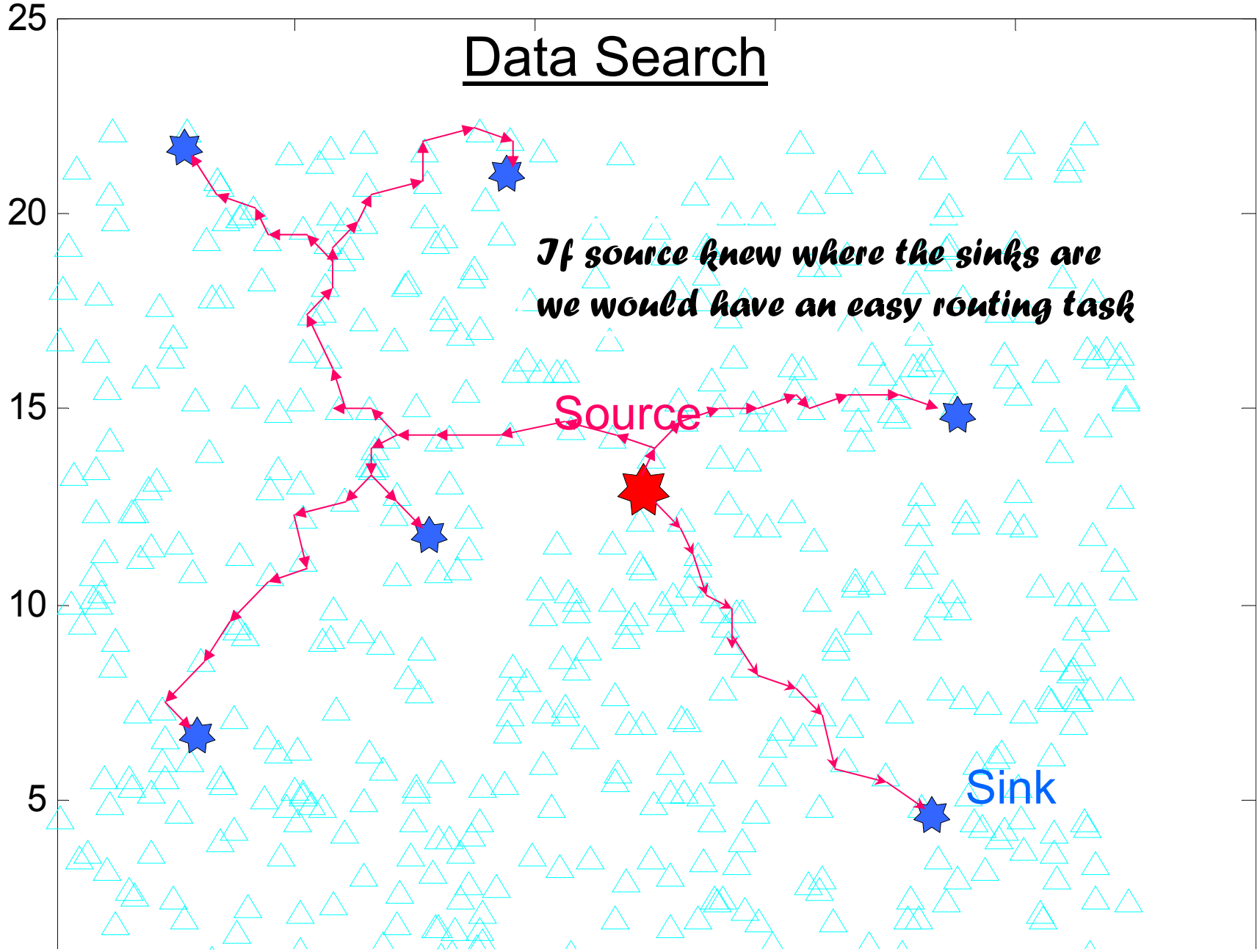
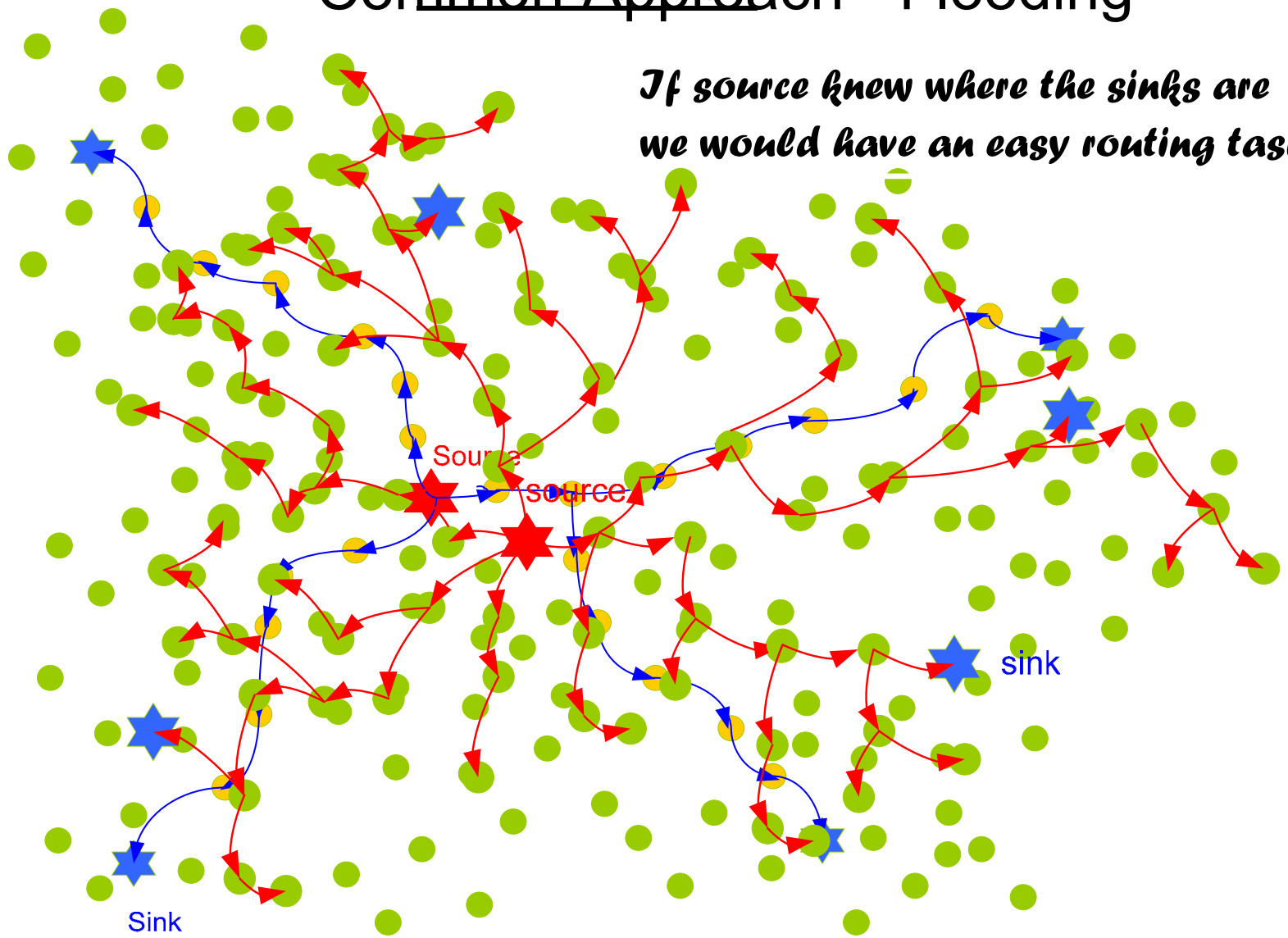
Research Area



Research Area

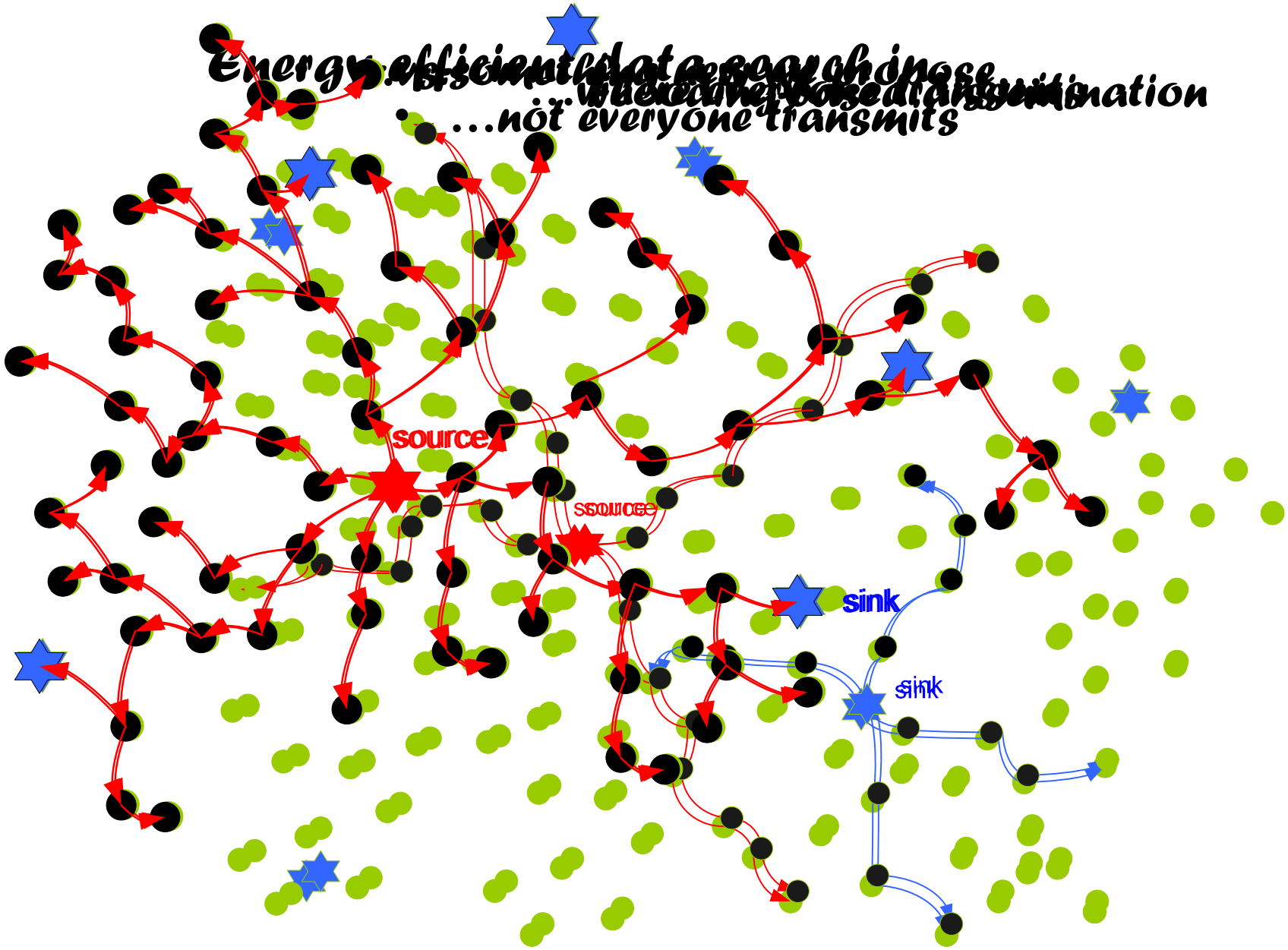
Data Search

Common Approach - Flooding

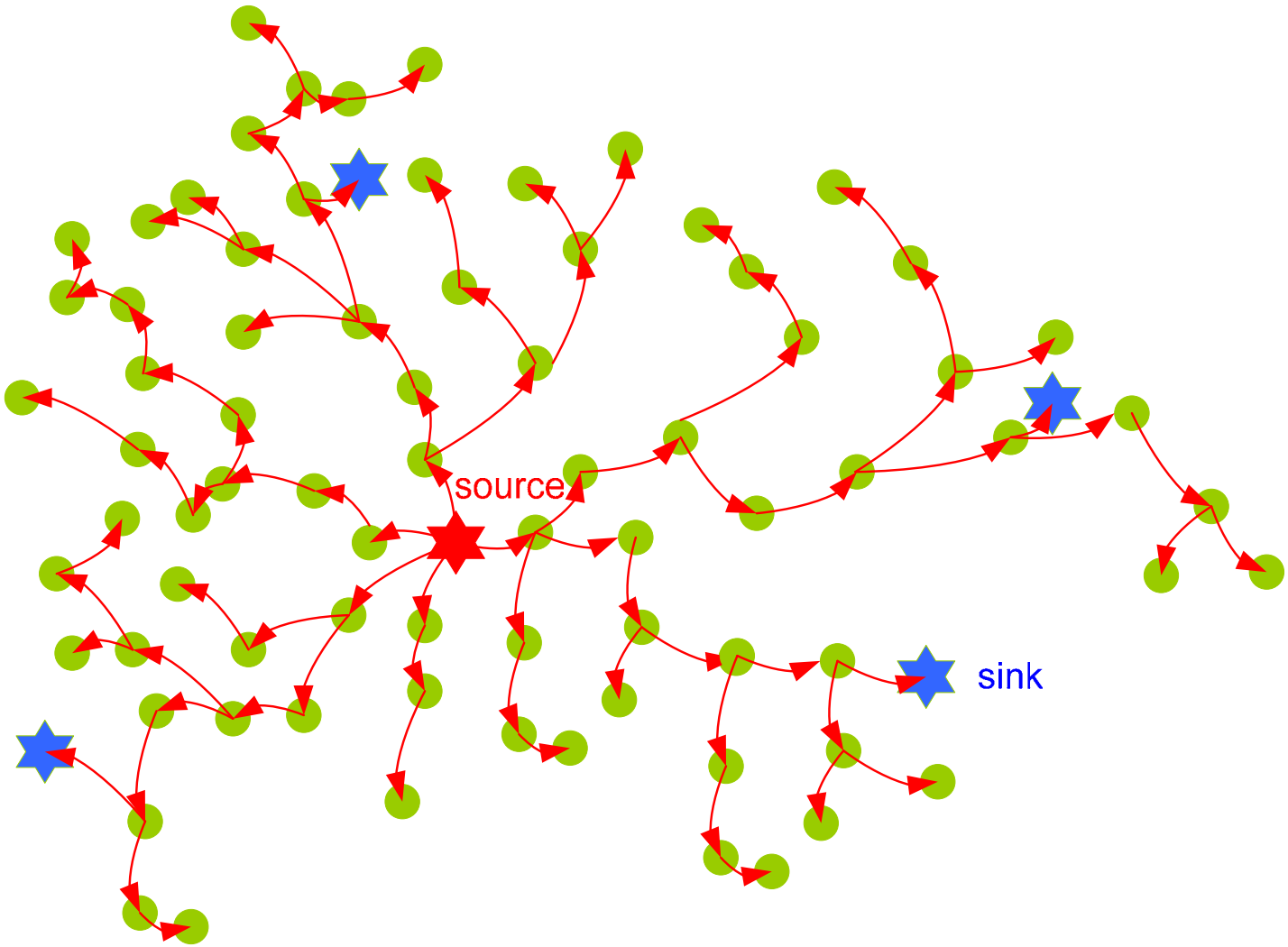


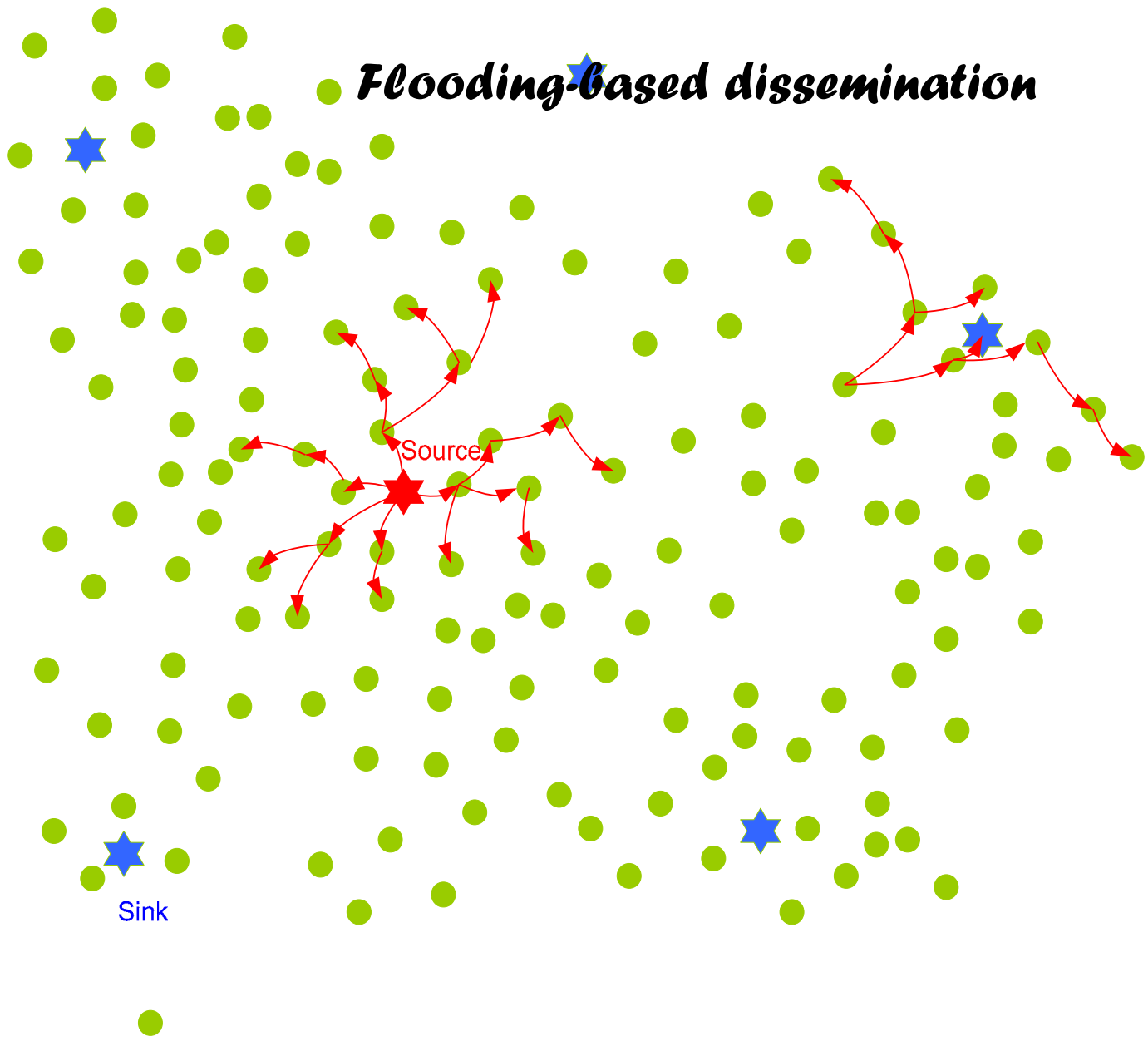
Research Area

Problem



Flooding Strategy



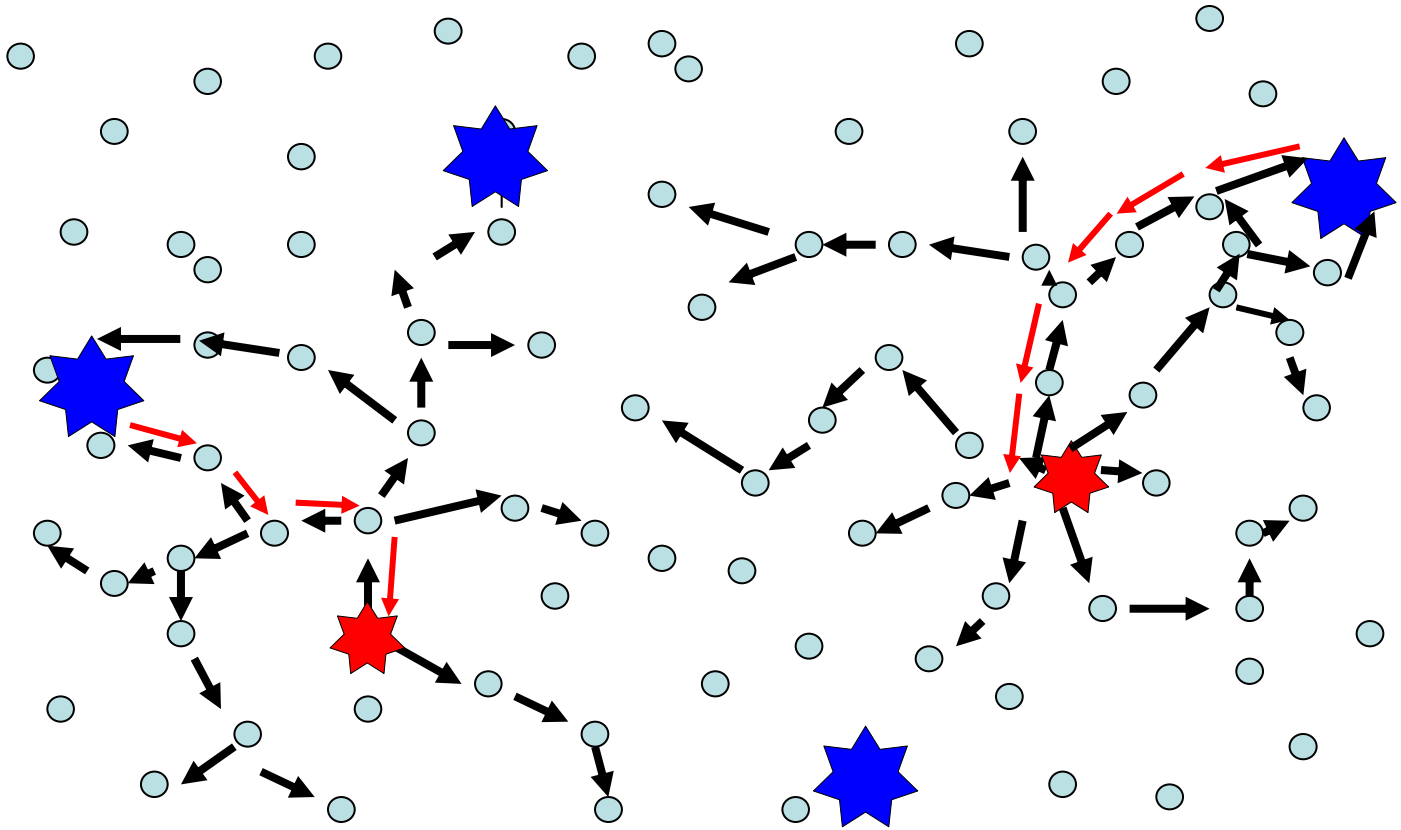

Flooding-based dissemination
Source
Sink

What have we learned from prior work?

Directed diffusion/ Push-Pull

[Intanagonwiwat et al. ,2003; Heidemann et al.,2003]

Push-based Strategy

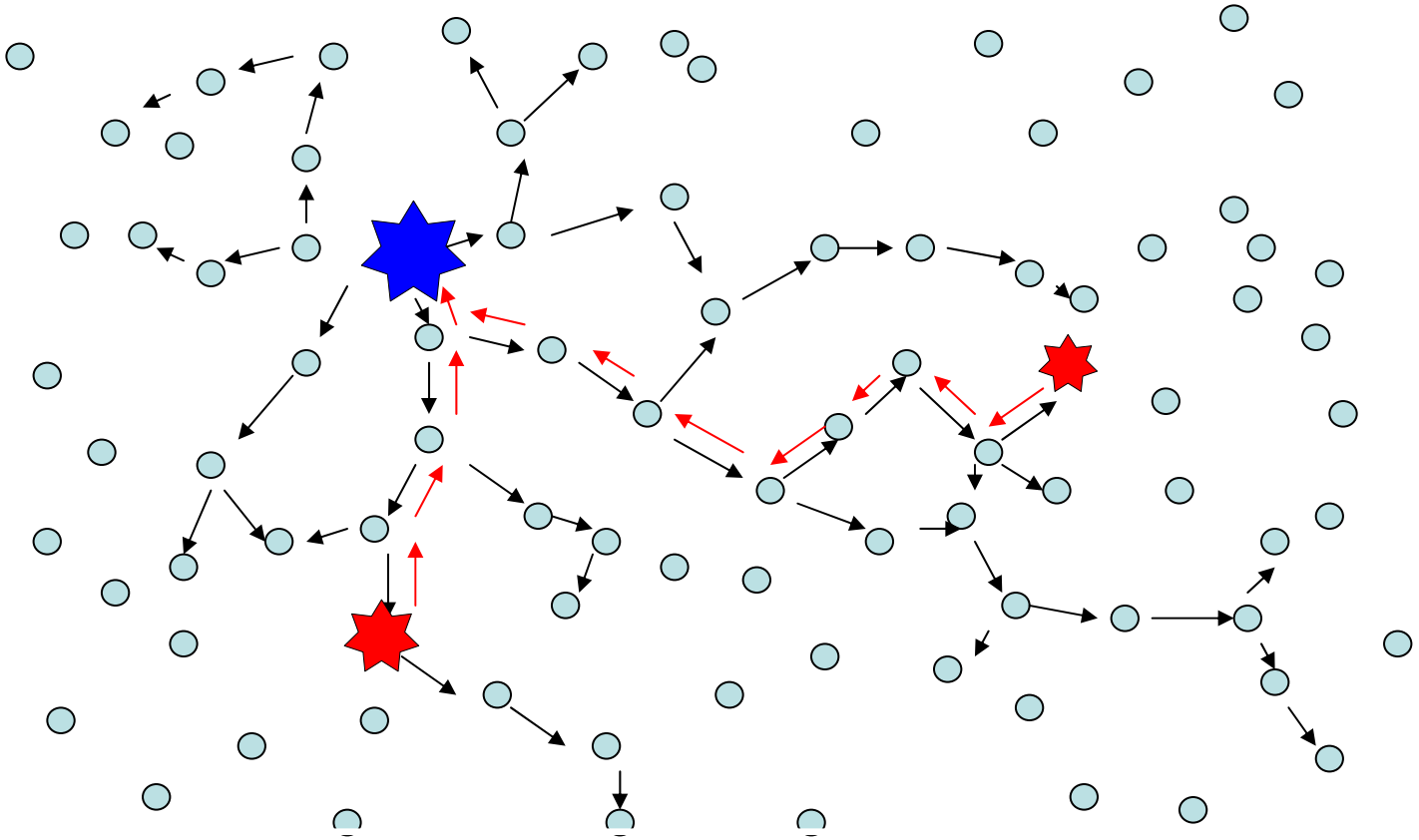


Efficient if number of sources smaller than number of sinks

Directed diffusion/ Push-Pull

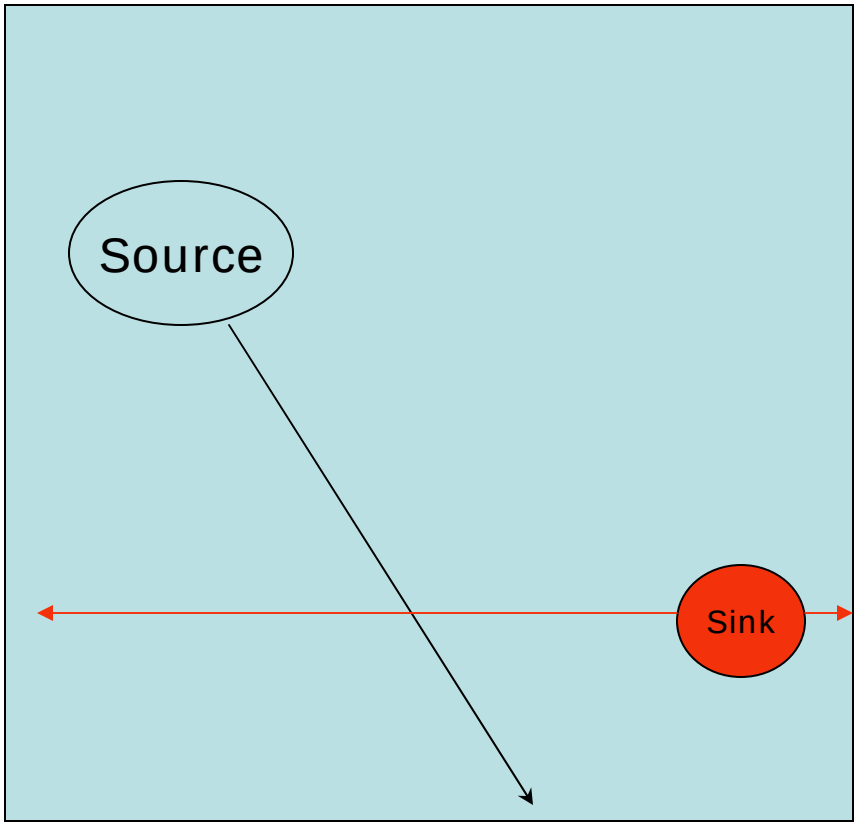
[Intanagonwiwat et al. ,2003; Heidemann et al.,2003]

Pull-based Strategy



Efficient if number of sinks smaller than number of sources

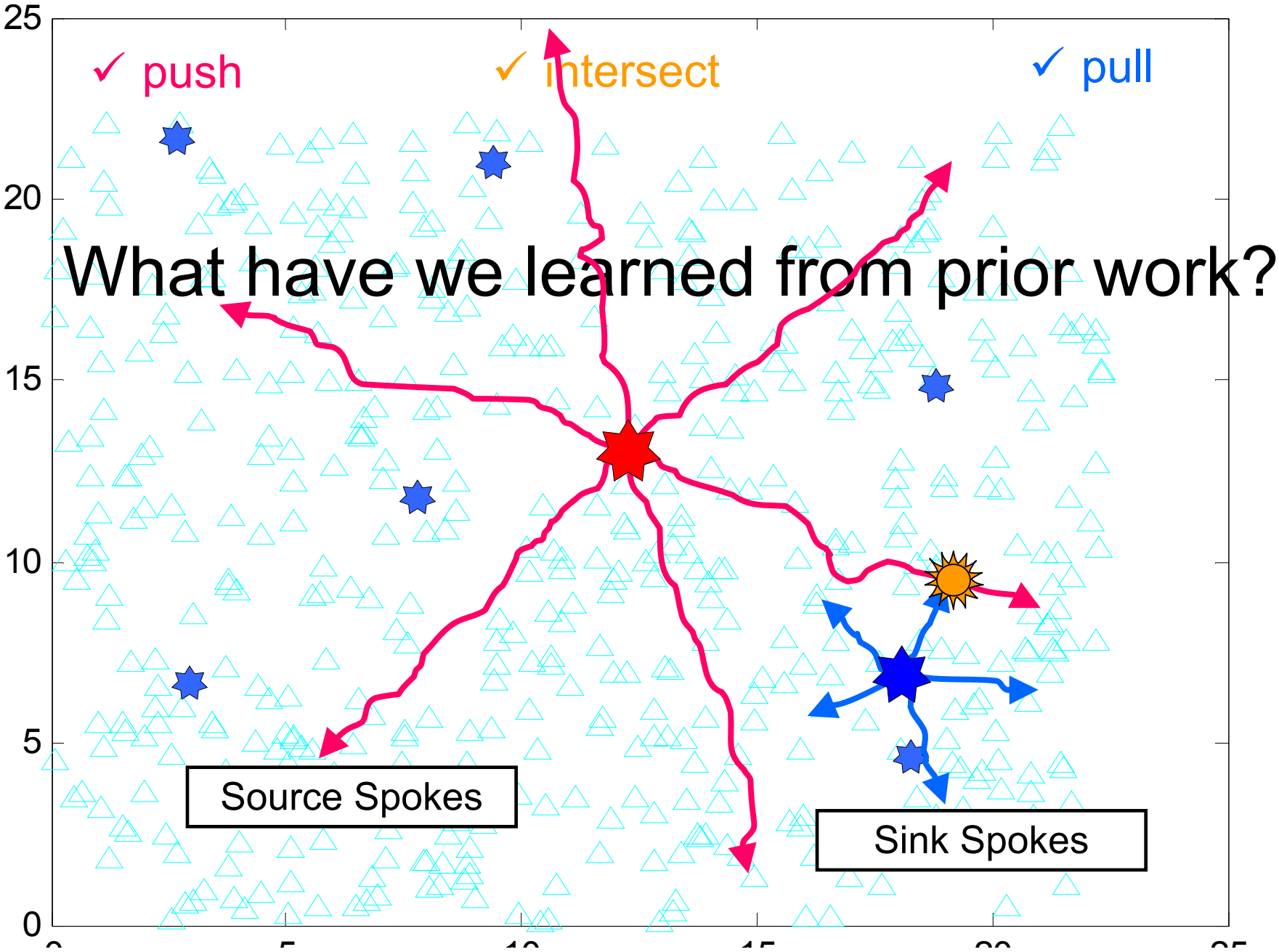
Basis for Random Walk Search Strategies



Observation

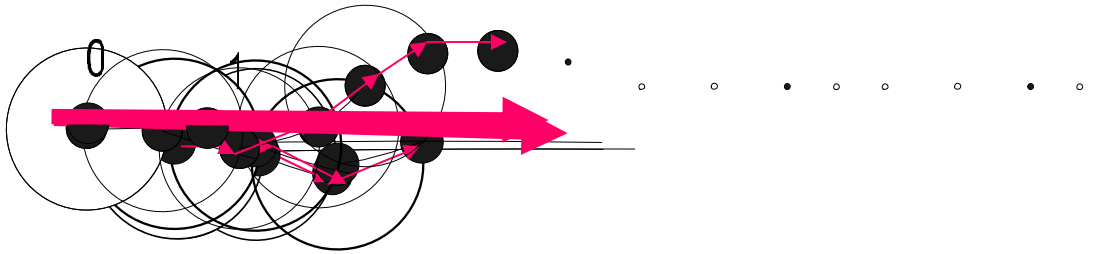
Two lines in a bounded rectangle have a 69% chance of intersecting
(simulation result of ***Rumor Routing, Braginsky,Estrin 2002***)

Research Area Problem Solution



A brief introduction to spoke-building…

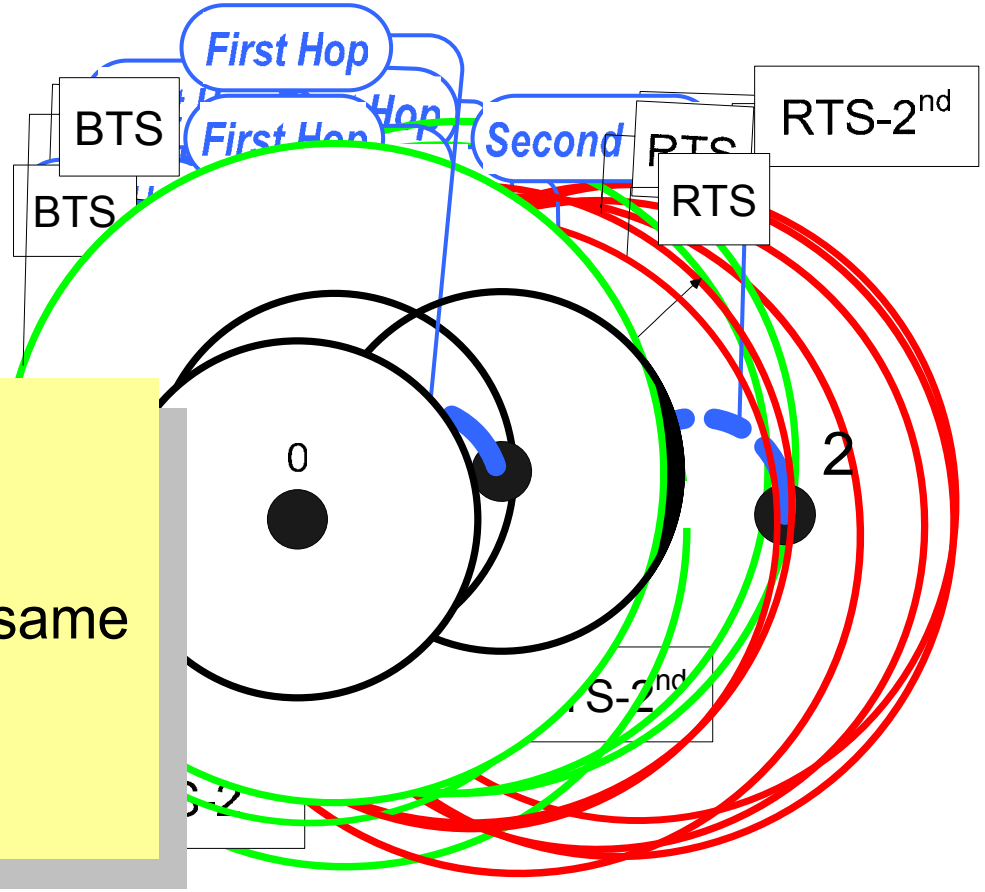
…or how to follow direction set by the first two retransmissions without any external geographic reference such as compass or GPS



- Any two successive retransmitting nodes are called pivot and leading relay
  - First pivot and first leading relay define the direction (or axis) of the spoke

...and for that we need some control frames

r: data range
R: control range



- All nodes are ***homogeneous*** – same transmission power

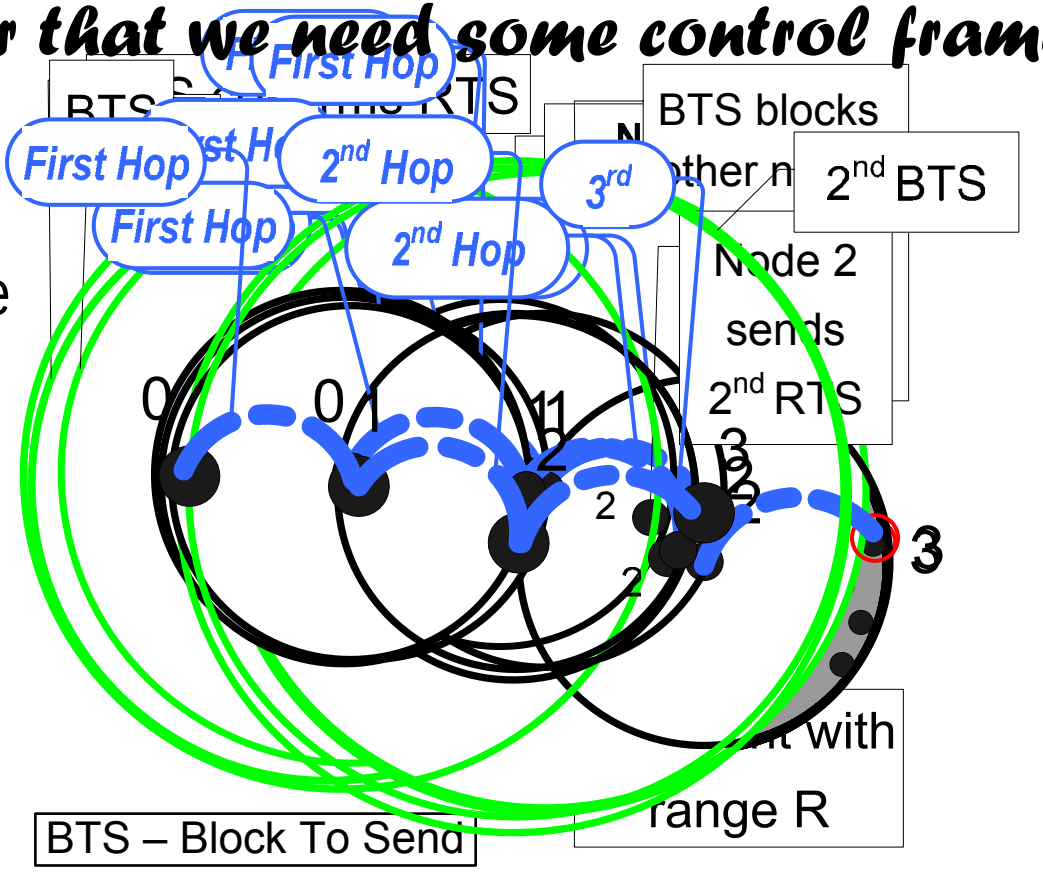
$$r \leq R \leq 2r$$

- ***Spoke generation***: sequence of data hops in a particular direction starting with the source node as node ***0***.

…and for that we need some control frames

r: data range

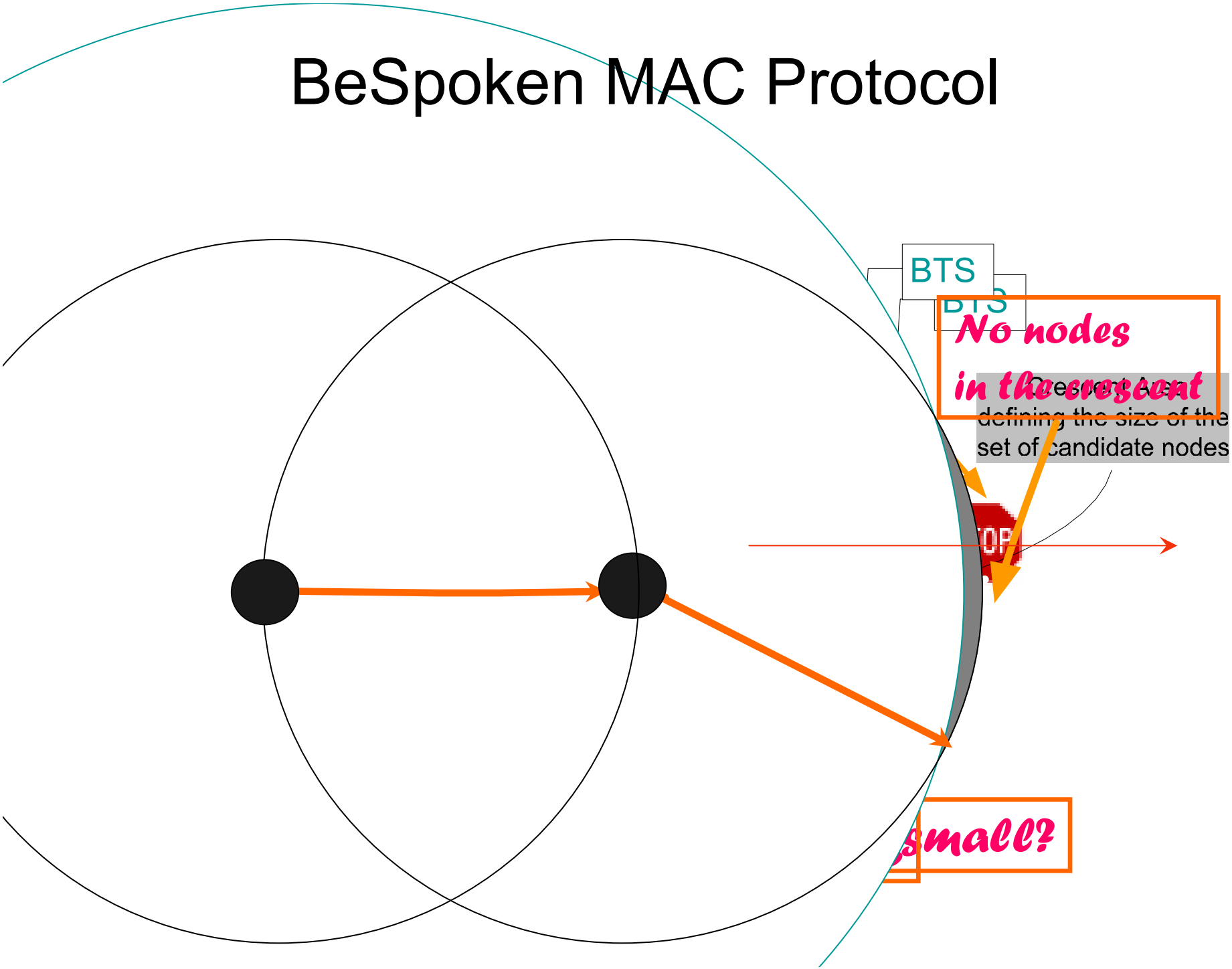
R: control range



- ***Spoke generation***: sequence of data hops in a particular direction starting with the source node as node ***0***.

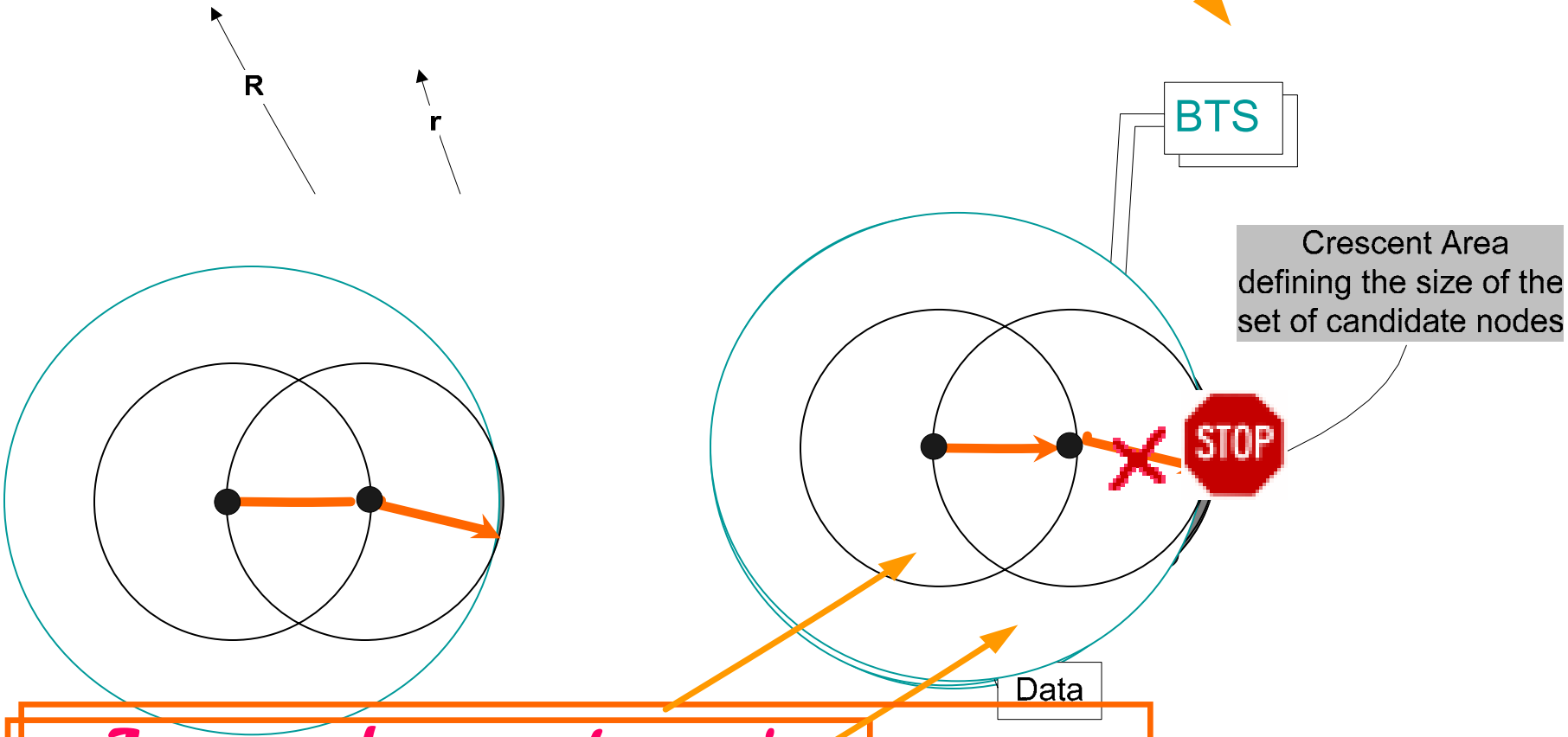
$r < R < 2r$

BeSpoken MAC Protocol



BeSpoken MAC Protocol

- medium access scheme utilized by the protocol is CSMA/CA based



- Crescent too small - the spoke stops prematurely
- Increased crescent area increases maximum throughput for the spoke axis

Important: What if we make the crescent very small?

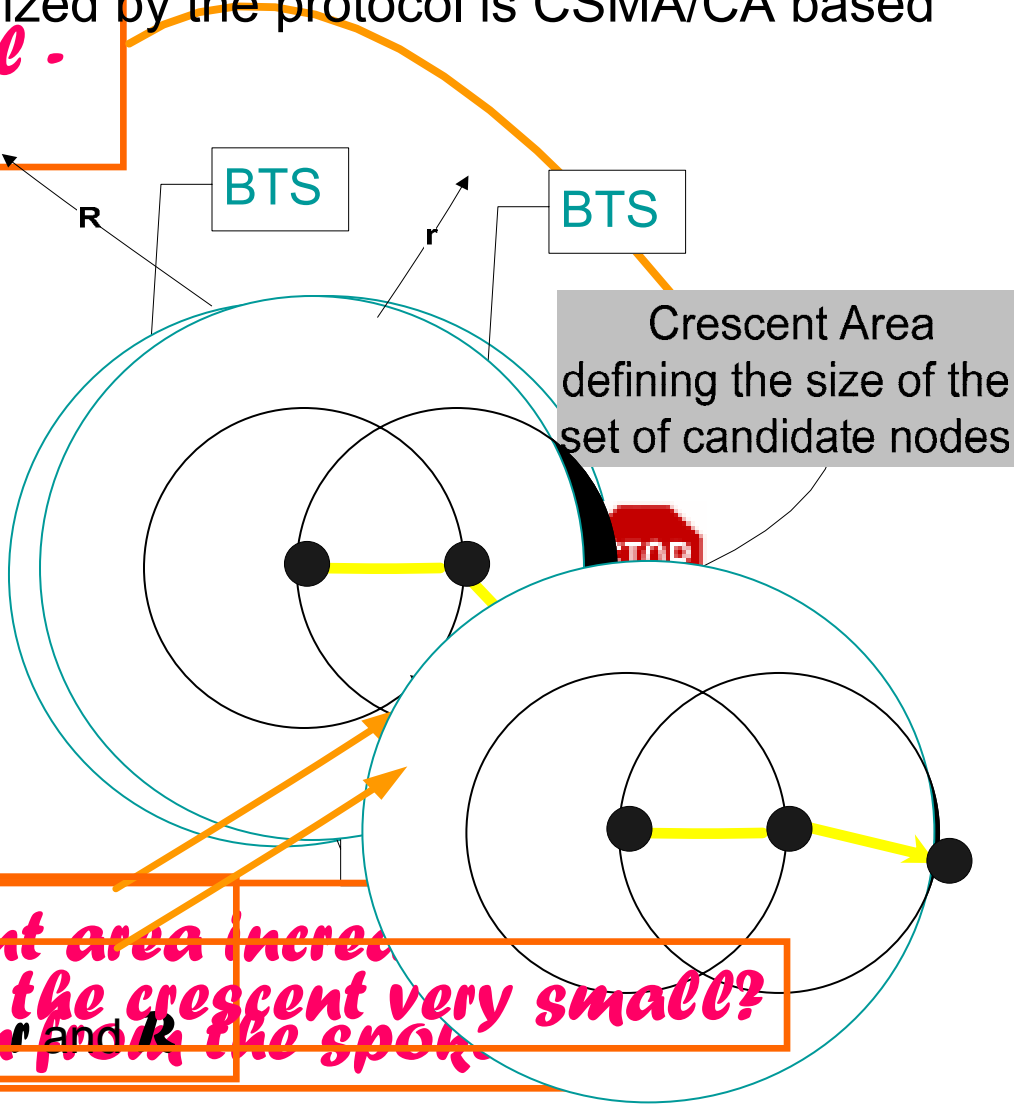
Design of data and control ranges, r and R

BeSpoken MAC Protocol

- medium access scheme utilized by the protocol is CSMA/CA based

• *Crescent too small -*

the spoke stops prematurely



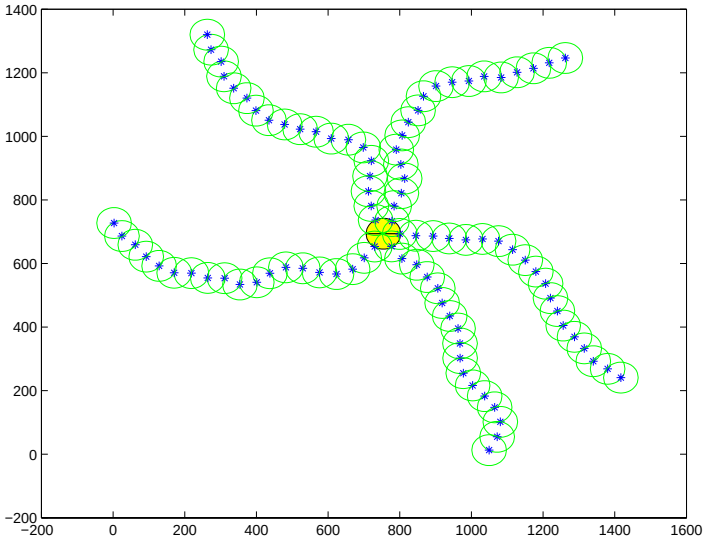
• *Increased crescent area increases the probability of collision*

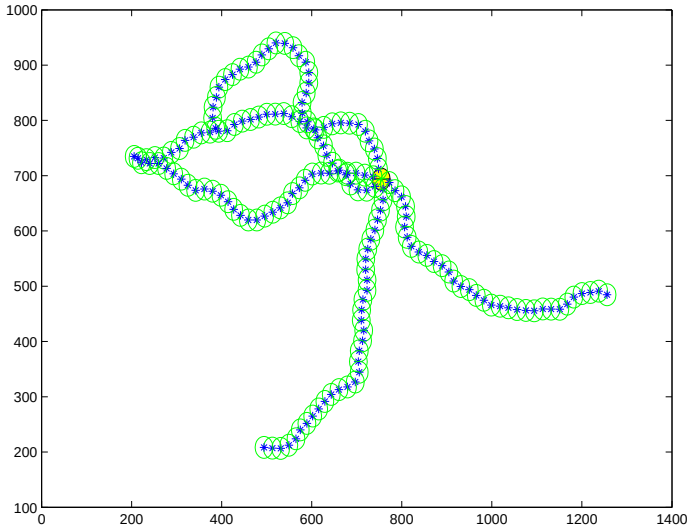
• *What if we make the crescent very small?*

Design of data and control ranges, *r* and *R*

Data Range Design

- Connectivity:
  - Identify data range r which guarantees that the spoke will propagate to the network perimeter
- Straightness:
  - We would like the spokes to have relatively little wobble with respect to the spoke axis

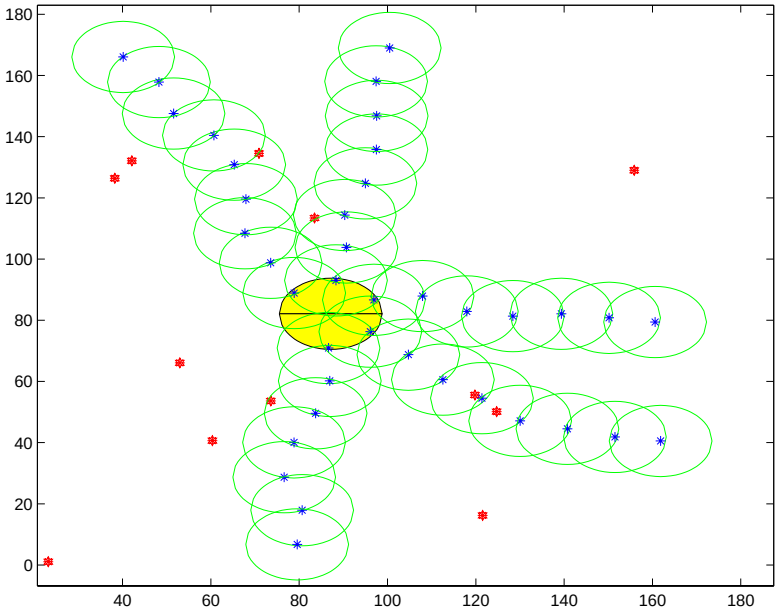




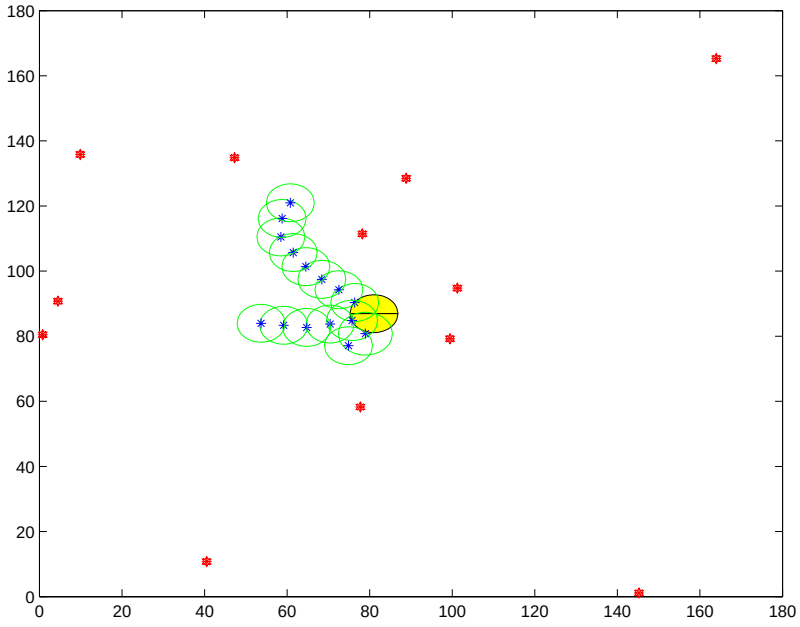
Data Range Design

- Connectivity:
  - Identify data range r which guarantees that the spoke will propagate to the network perimeter

Range r by design

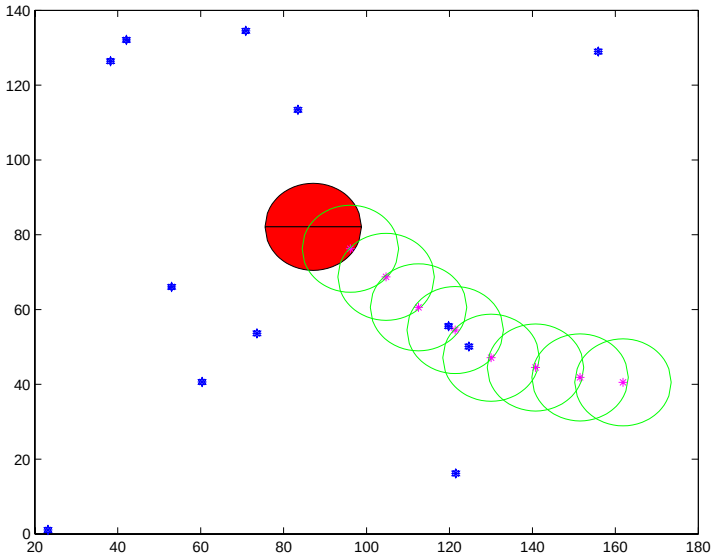


Range r decreased by half

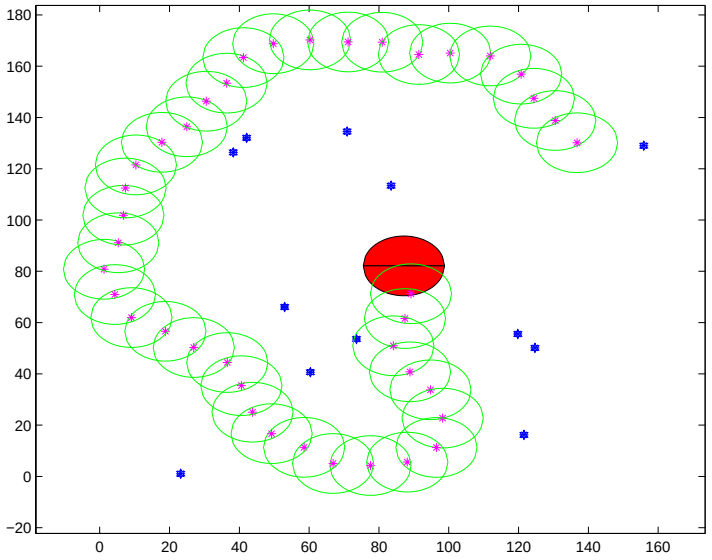


Data Range Design

- Connectivity:
  - Identify data range r which guarantees that the spoke will propagate to the network perimeter
- Straightness:
  - Spokes to have relatively little wobble with respect to the spoke axis

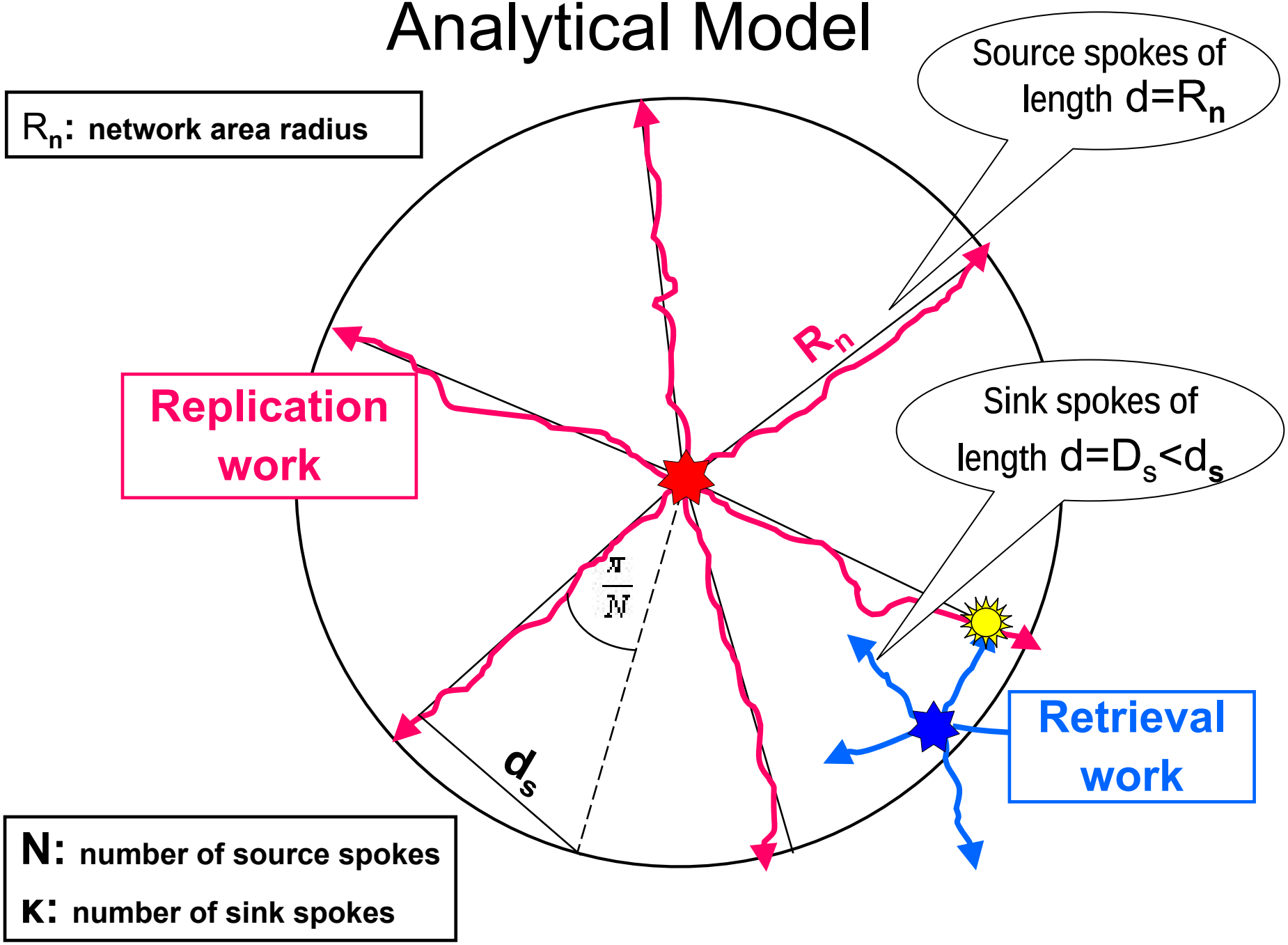


Range R by design



Range R decreased

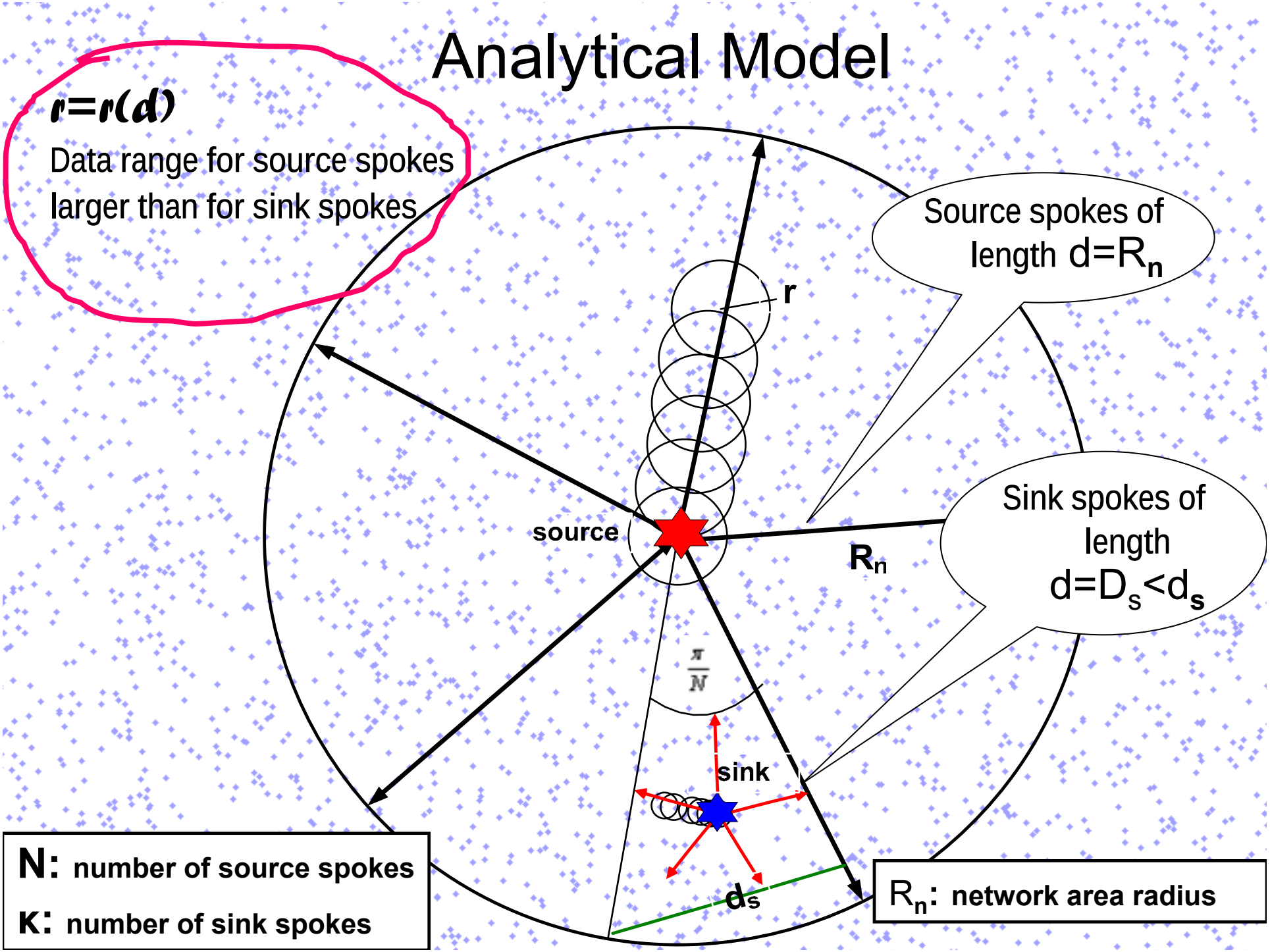
Analytical Model



Analytical Model

$r=r(d)$

Data range for source spokes larger than for sink spokes

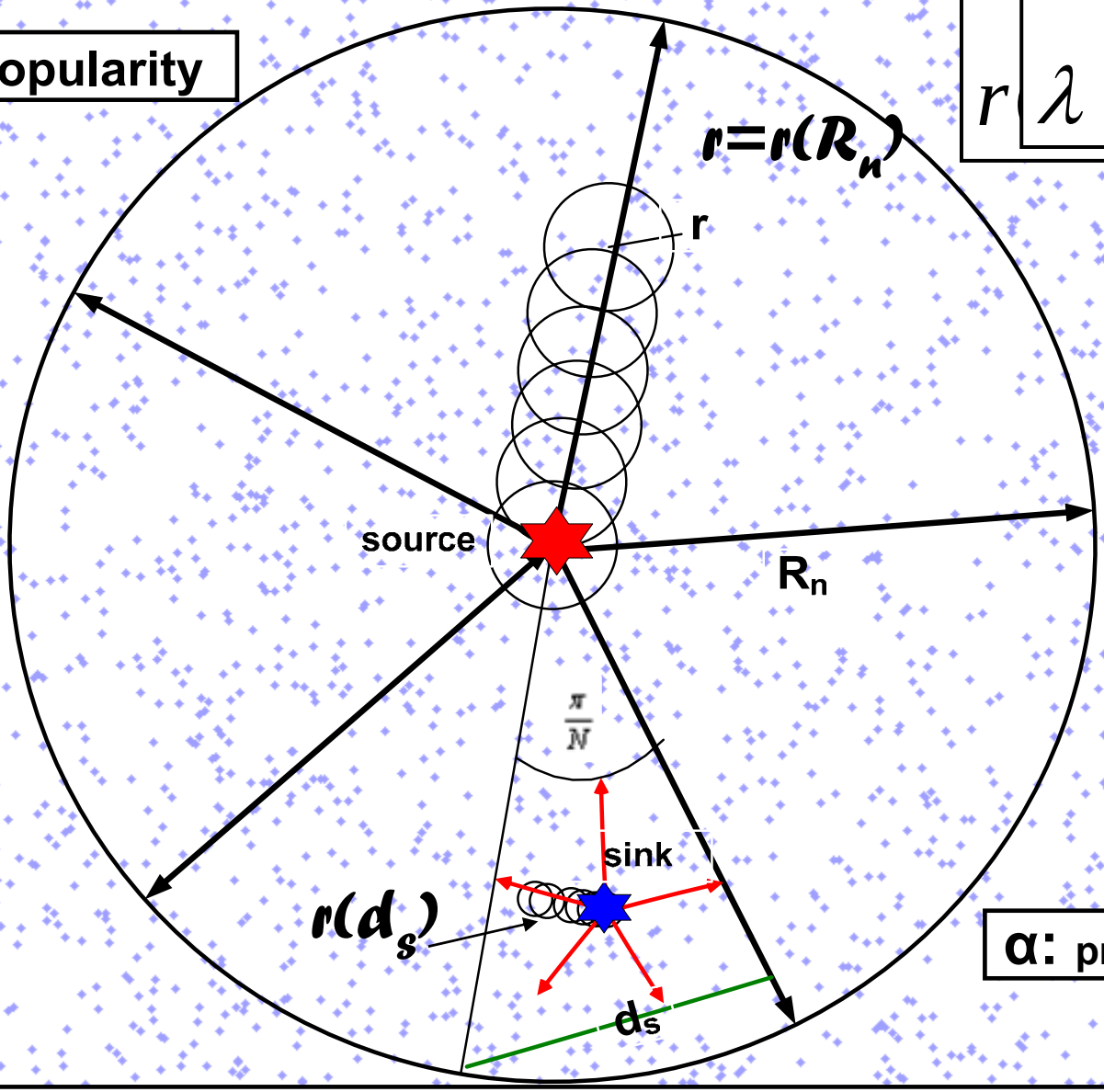


Analytical Model

$$R_n = \lambda R_n^{\,2} \pi$$

$$r(\lambda = 1)$$

p: data popularity



α: propagation loss

n: expected number of network nodes distributed as Poisson point process of intensity λ

20 30 40 50 60

Total Work

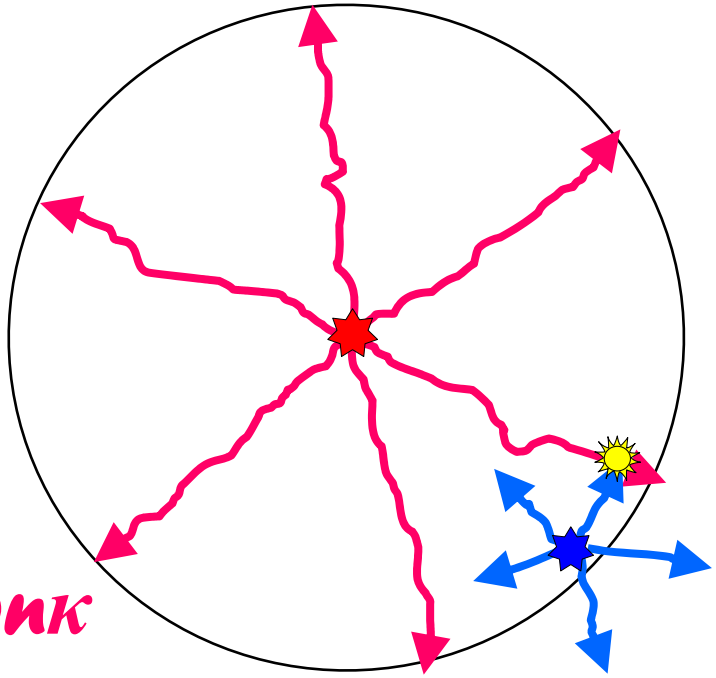
$$W = \underbrace{NW_{sp}(R_n, \alpha)}_{\text{replication work}} + \underbrace{2MW_{sp}(d_s, \alpha)\frac{E(D_s)}{d_s}}_{\text{retrieval work}}$$

$$W_{sp}(d, \alpha) = \frac{d}{r(d)} W_h = O\left(d^{\frac{7+3(\alpha-1)}{7}} \right)$$

- For $\alpha = 2$, the work growth is roughly $d^{10/7}$
- For $\alpha = 3$ the growth $d^{13/7}$ is almost quadratic

Optimal number of source spokes N

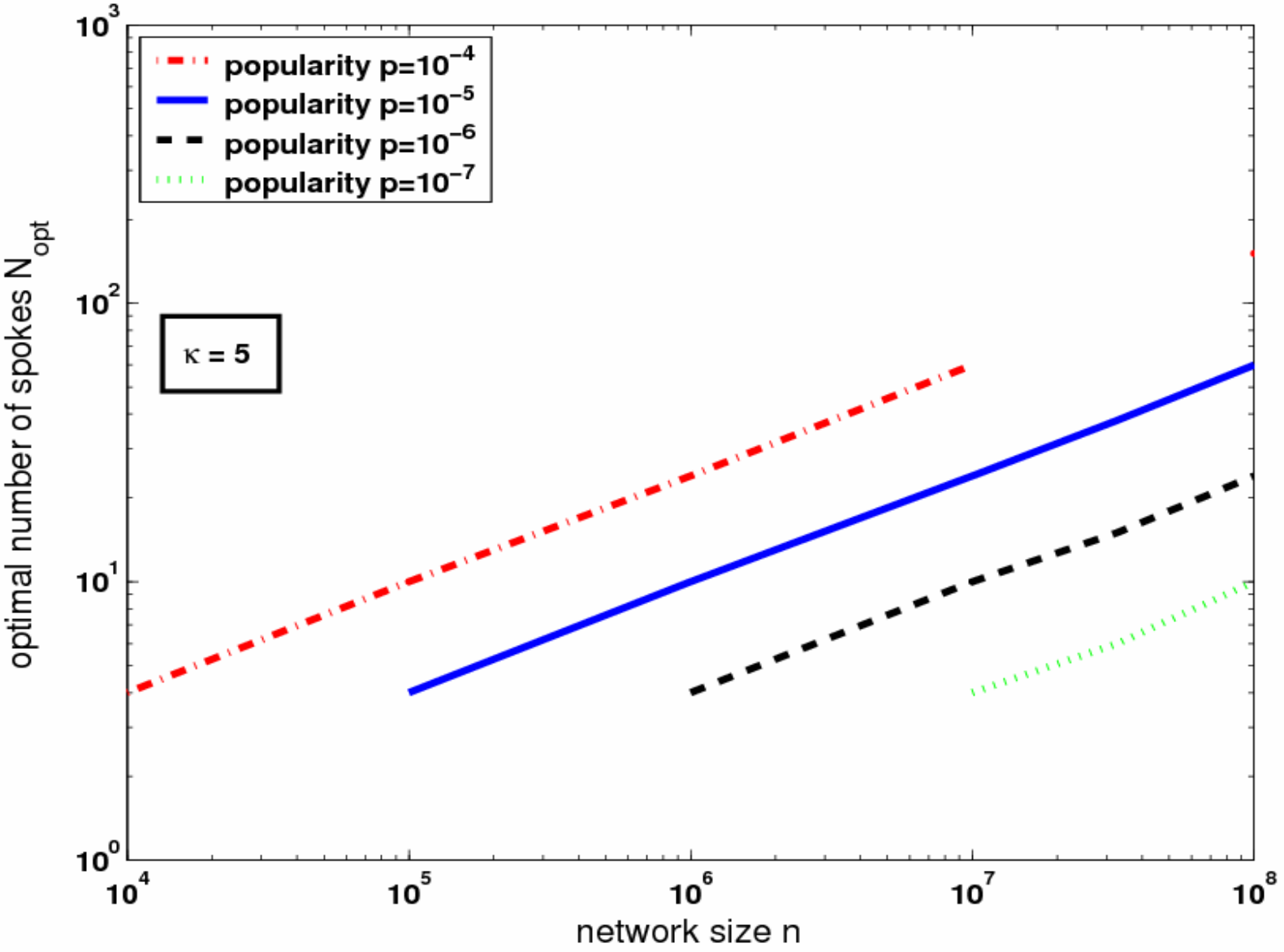
$$N_{opt} = \min_{N}\{W\} = f(M, \alpha, n)$$



- total number of sink spokes $M = pnk$

- N_{opt} grows with M at a rate defined by α

Optimal number of source spokes N_{opt}



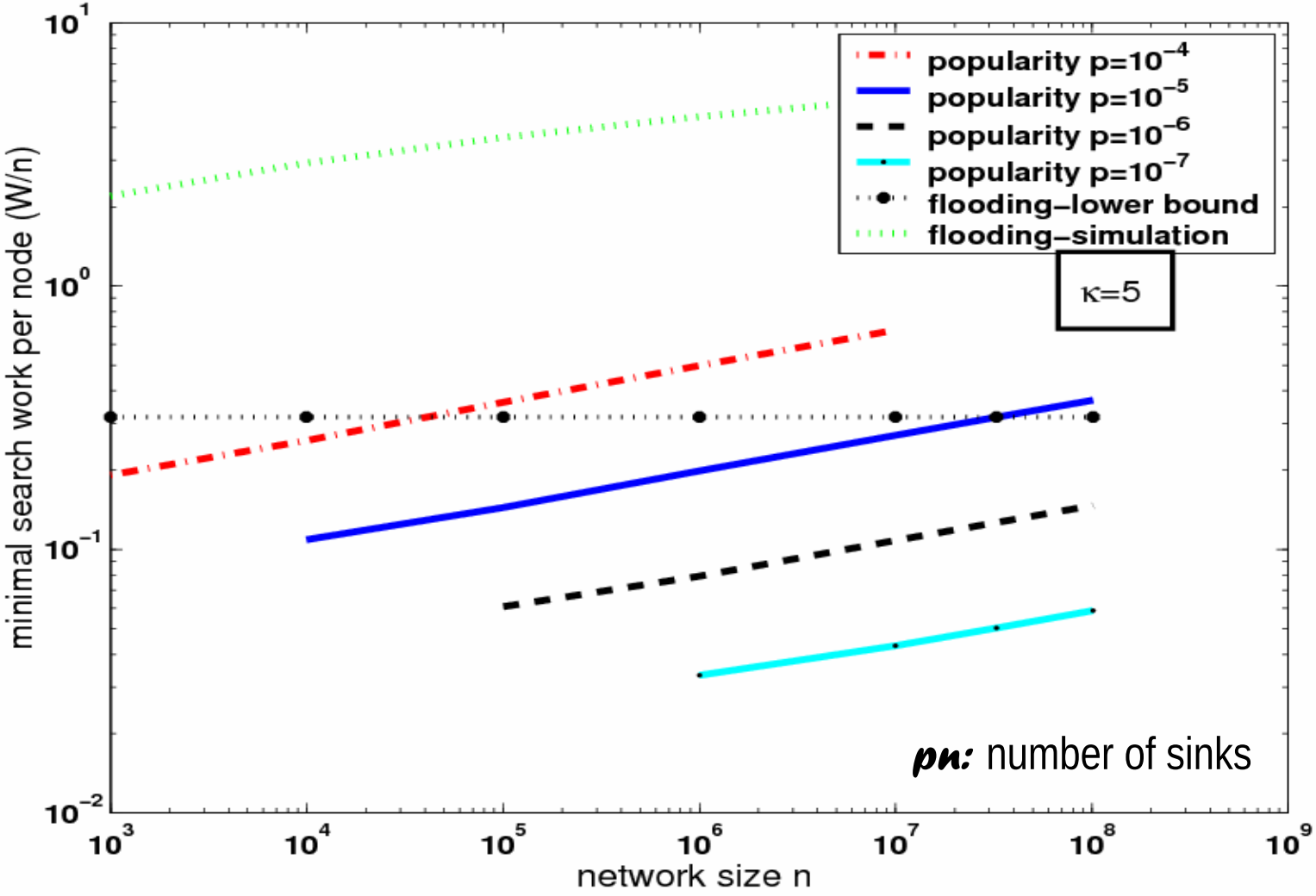
Total Work Bound

$$W \le W_{opt} = W_{sp}(R_n, \alpha)\left[\frac{2}{3}np\kappa\right]^{G(\alpha)} F(\alpha)$$

$G(\alpha), F(\alpha)$ - functions of α

$$W = O\left(n^{5/7}\right) \quad \text{for } \alpha = 2$$

Comparing BeSpoken Total Work vs. Flooding



-For small pn, BeSpoken work growth with n, is slower than linear

-Flooding work growth is faster than linear

Total Energy: Observations

- Total work depends on three main factors:
  - *network size n,*
  - *expected number of sink spokes pnK,*
  - *propagation exponent*
- Growth rate is significantly smaller for small ***p***
- Select the smallest possible κ (5 is enough)
- ***Energy consumption*** of BeSpoken is favorable in large networks when data popularity is small

Future Work

- **Analyze energy consumption and model robustness under relaxed wobbliness constraints**
- **Analyze BeSpoken performance under fading channel model (shadow fading)**
- **BeSpoken allows branching of spokes at a desired angle, at any depth away from the source…**

…modify the wheel pattern of data dissemination by adding lateral paths that branch off of spokes

The End