# Hierarchical Spatial Gossip for Multi-Resolution Representations in Sensor Networks

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# Multi-Resolution Representations

➢ Goal : Find aggregates in the network

➢ Max, Min, Sum, Average...

# Multi-Resolution Representations

➢ Find aggregates for exponentially larger neighborhoods

➢ Store the aggregates for the regions of size

$$2^i, \quad i = 1, 2, 3 \ldots$$

➢ Surrounding each node.

# Multi-Resolution Representations

➢ Gain a locally relevant picture of the network

➢ Decide what is important.

# The Problem

Create multi-resolution aggregates

- Fast, in a small number of rounds
- At a low communication cost
- For all nodes simultaneously

Flooding works, but at a high cost..

# Use Gossip

➢ Select a node randomly

➢ Exchange information

➢ Repeat every round
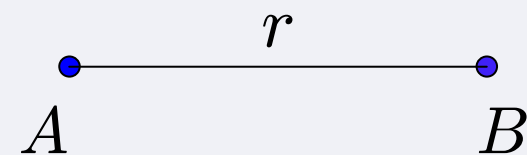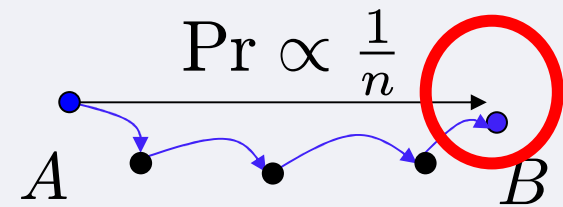

➢ Simple

➢ Distributed

➢ Robust

# Types of Gossip

➢ **Uniform/Geographic gossip**

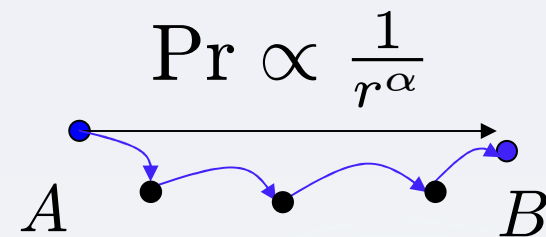- Select a node uniformly randomly and gossip

Ref : Dimakis, Sarwate, Wainwright IPSN 06

➢ **Spatial Gossip**

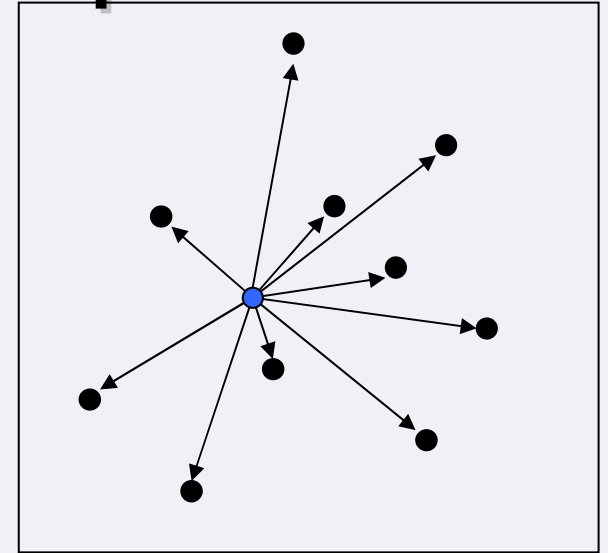- Select node at distance $r$ with probability $\propto \dfrac{1}{r^\alpha}$

Ref : Kempe, Kleinberg, Demers STOC 01

$$\text{Pr} \propto \frac{1}{n}$$

$A \qquad\qquad\qquad B$

$$r$$

$A \qquad\qquad\qquad B$

$$\text{Pr} \propto \frac{1}{r^\alpha}$$

$A \qquad\qquad\qquad B$
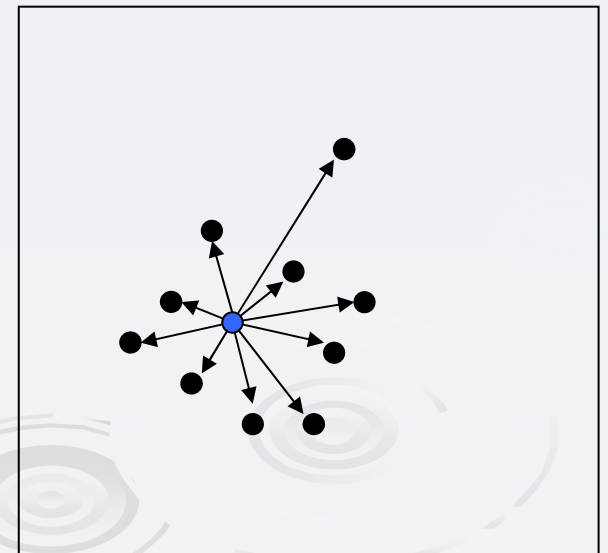
# Types of Gossip



➢ **Uniform/Geographic gossip**

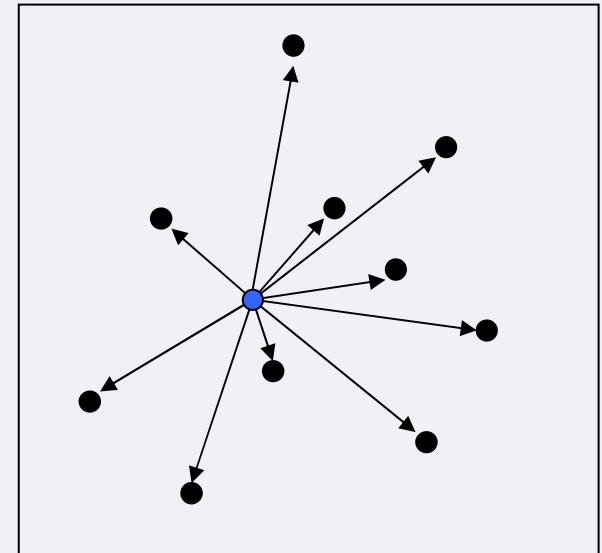- Select a node uniformly randomly and gossip

➢ **Spatial Gossip**

- Select node at distance $r$ with probability $\propto \dfrac{1}{r^{\alpha}}$

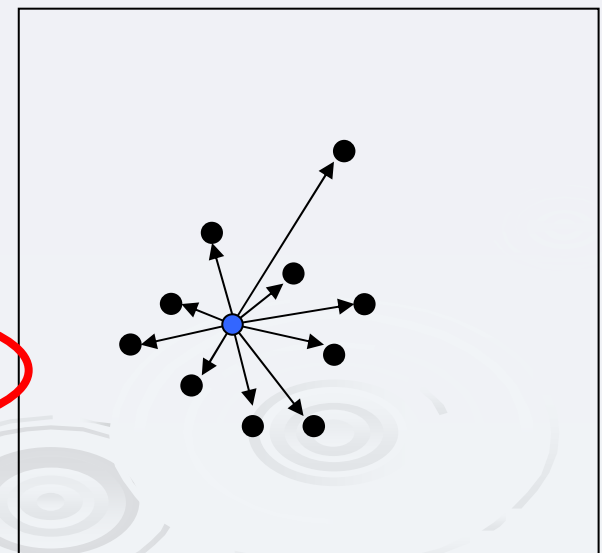# Average Communication Cost



➤ Uniform/Geographic gossip
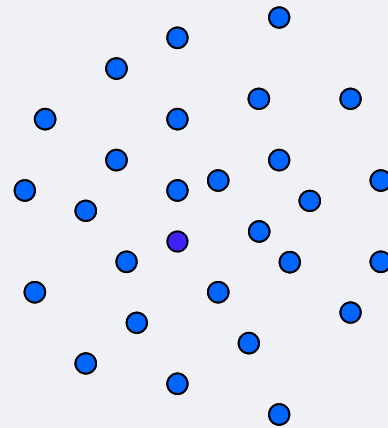- Cost $\quad \tilde{O}(\sqrt{n})$

➤ Spatial Gossip
- $\Pr \propto \frac{1}{r^2} \quad$ cost $\quad O(\sqrt{n})$
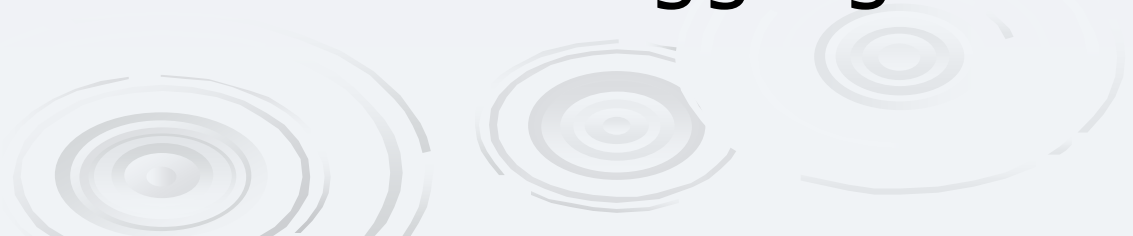- $\boxed{\Pr \propto \frac{1}{r^3}} \quad$ cost $\quad \boxed{O(\log n)}$
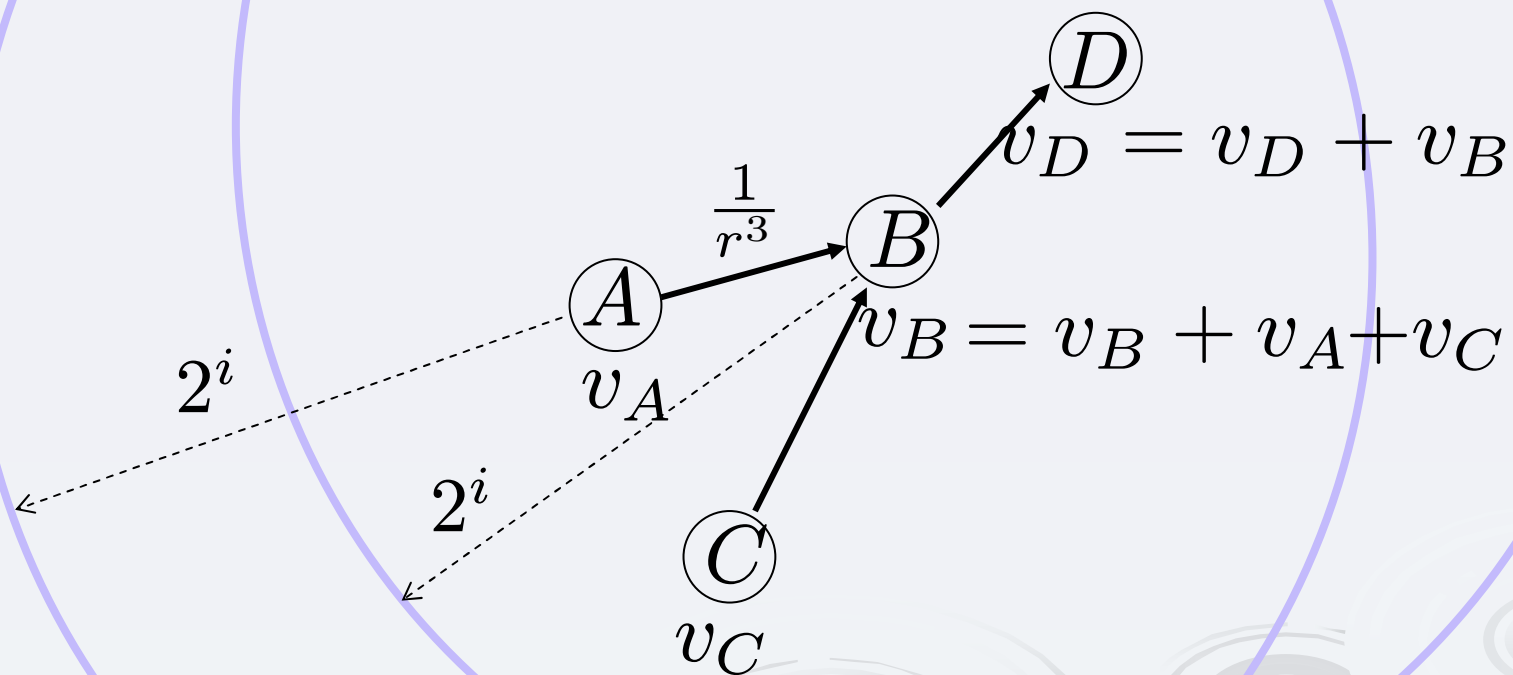
# Spatial Gossip
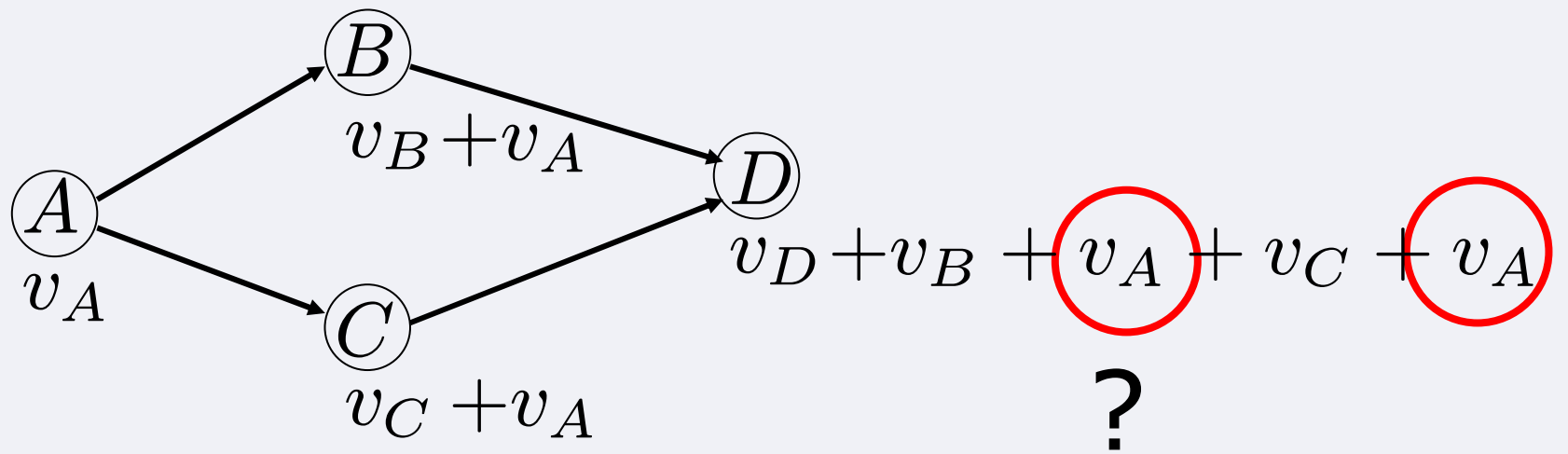
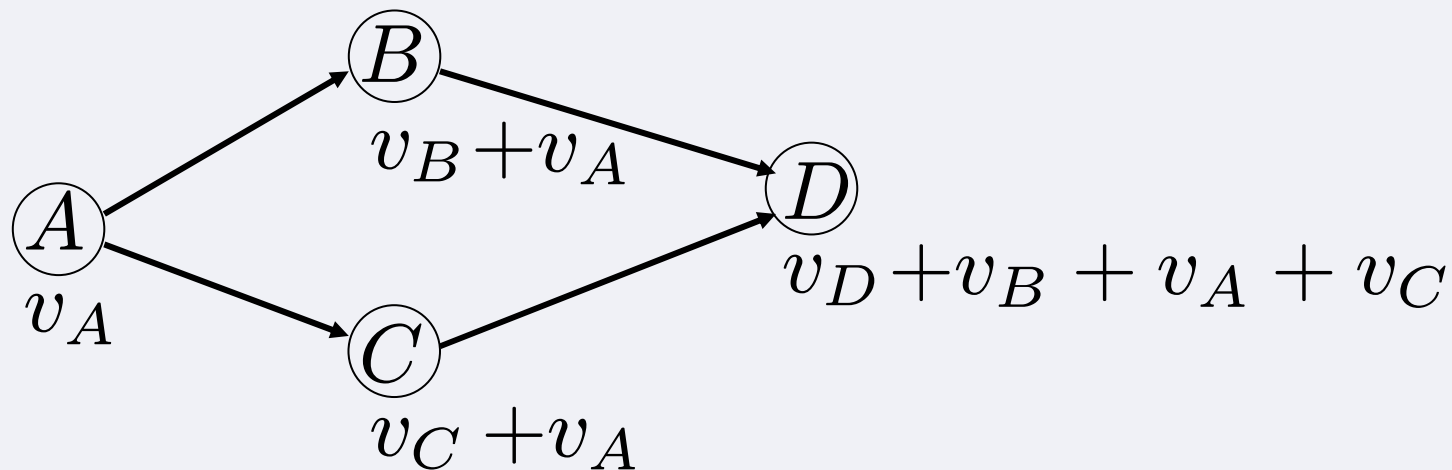## Expanding Neighborhood

➢ Use for multi-resolution aggregates

# Our Method :
# Hierarchical Spatial Gossip

➢ $\log n$ phases

➢ Phase $i$ builds aggregates for neighborhood size $2^i$ around each node

$v_D + v_B + \boxed{v_A} + v_C + \boxed{v_A}$

?

# Use Order and Duplicate Insensitive Aggregation

# Order and Duplicate Insensitive Synopses

➢ Min, Max are natural ODI aggregates

➢ ODI Synopses exist for other aggregates like sum, average, count..

Ref : Nath, Gibbons, Seshan, Anderson        SenSys 04
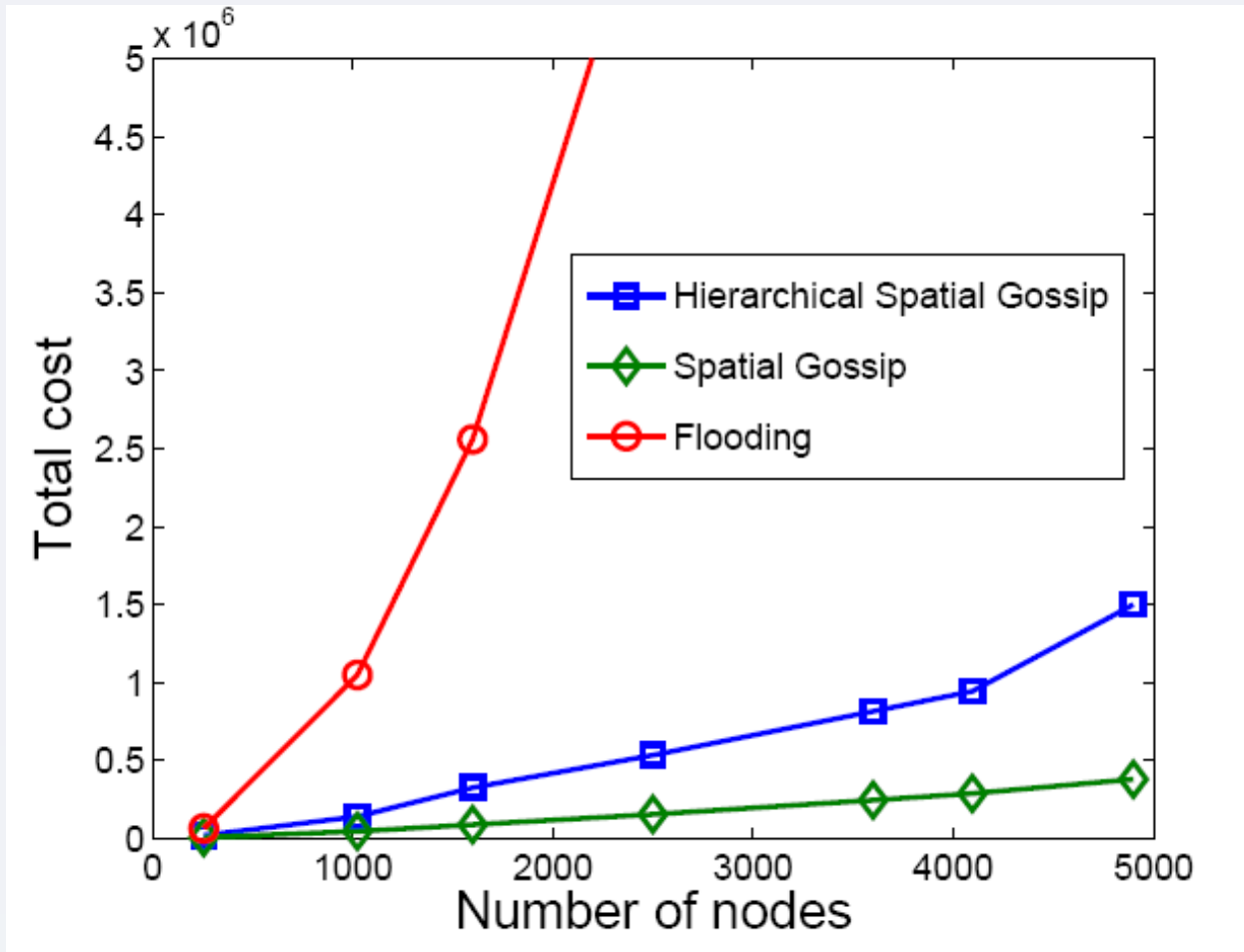
Considine, Kollios, Byers        ICDE 04
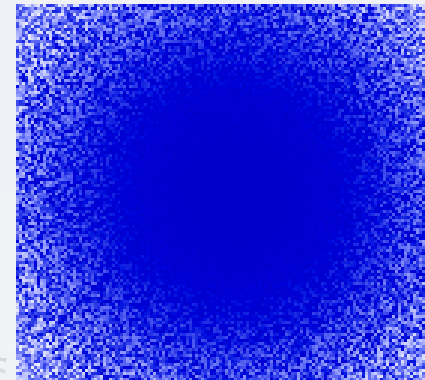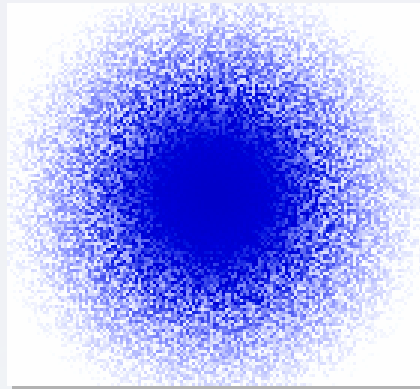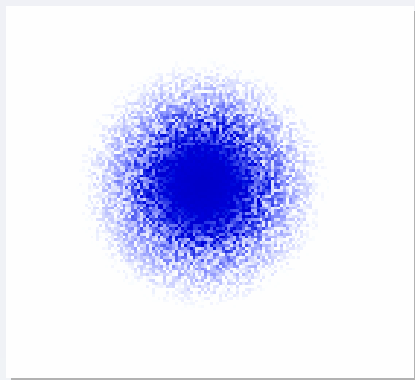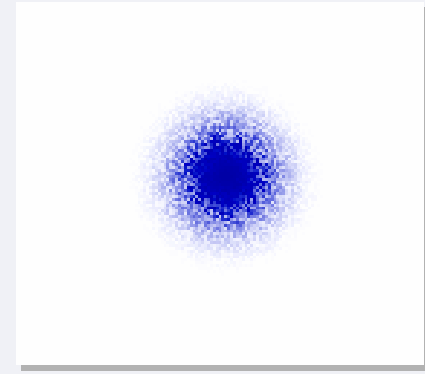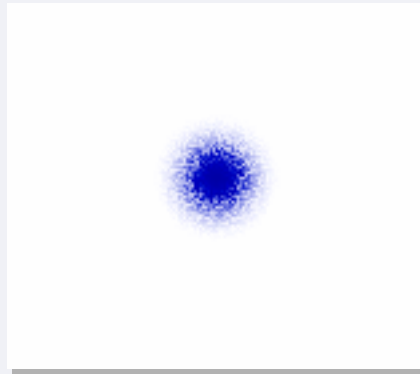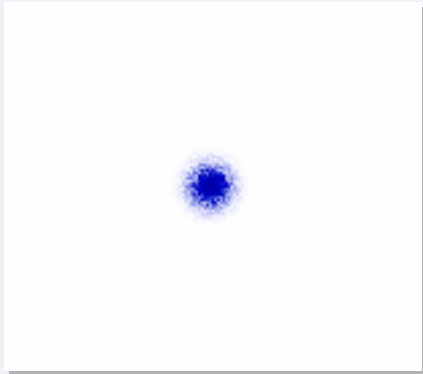
# Overall Efficiency

➢ $O(\log^{4.4} n)$ rounds

➢ $O(n \log^{5.4} n)$ communication

➢ $O(\log n)$ aggregates per node

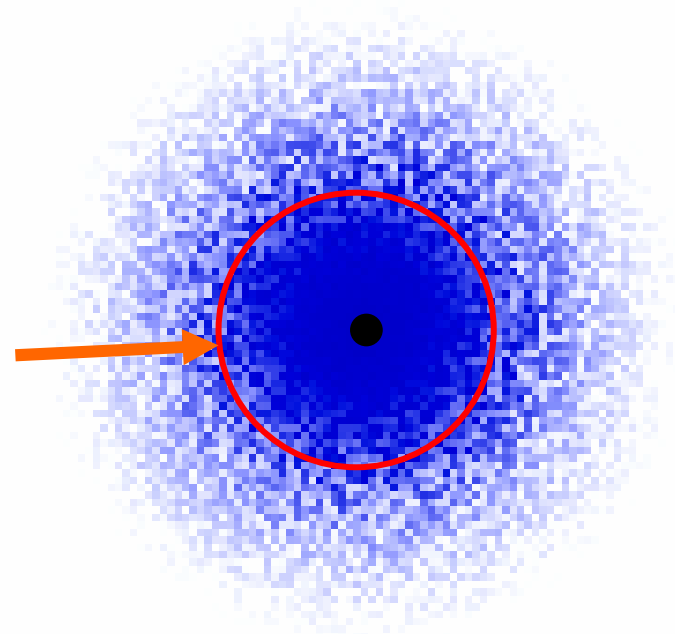# Communication Cost

# Data Distribution in Phases



Phases 1 to 6

# Property of Algorithm: Information Spreads Fast



➤ In phase $i$

➤ Information spreads to distance $2^i$

➤ Within $O(i^{3.4})$ rounds *With High Probability*

Ref : Kempe, Kelinberg, Demers STOC 01

# The Price of Accurate Computation

➢ **Sharp Multi-resolution requires a high communication cost**

$$\Omega(n^{\sqrt{n}})$$

Reduce the communication cost
by sacrificing a little on accuracy!

# Property 2: Information Does Not Spread Too Far
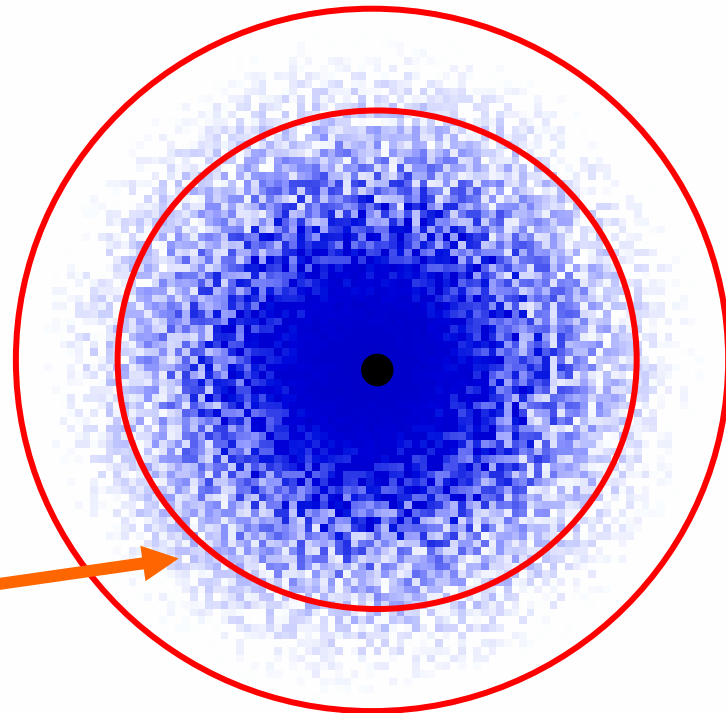


- In phase $i$
  with $O(i^{3.4})$ rounds

- Information does not
  spread beyond

  $$O(i^{3.4}2^i)$$

- Does not spread beyond
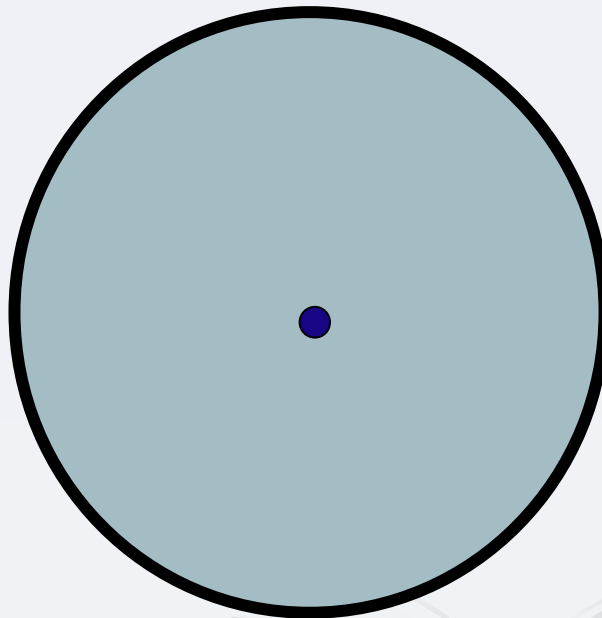
  $$O(i^{2.4}2^i) \ w.h.p$$

- Produces the pollution free
  Multi-Resolution
  aggregates

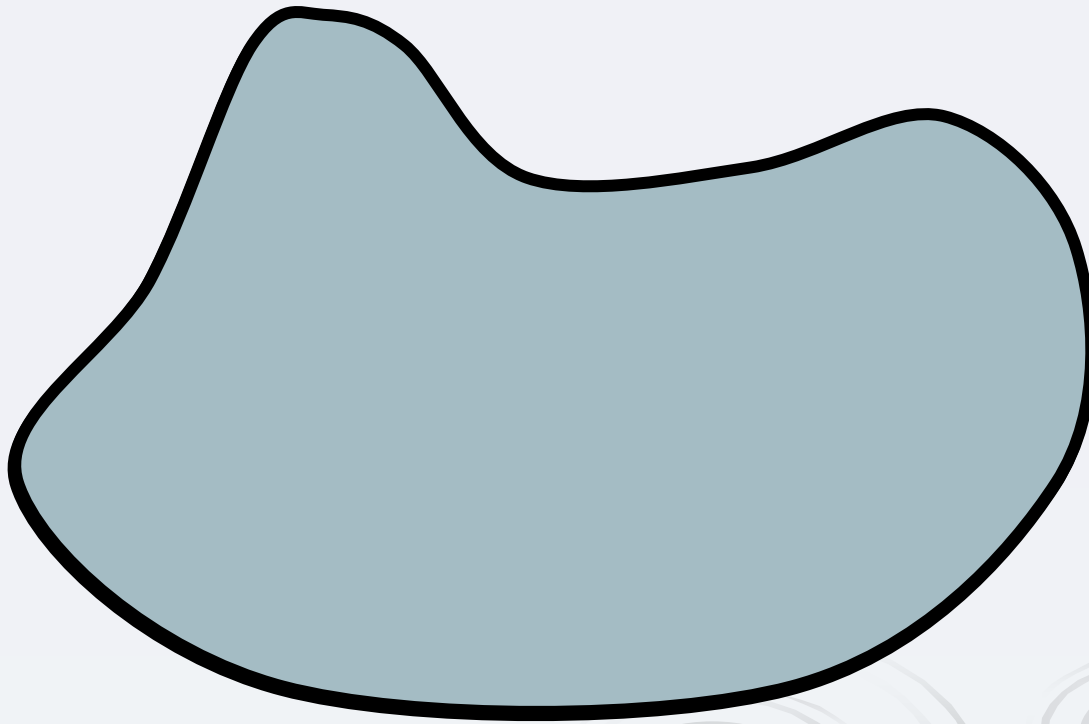# Range Queries

➤ User Supplies a region, and asks for aggregate

We pick a suitable node

And a suitable resolution level to cover the region

# Range queries

➢ Complex regions

# Summary

➢ Fast, efficient, sharp multi-resolution representation

➢ Useful in interpreting importance of data and local decisions

➢ Useful in range queries

➢ Randomization helps efficiency