Lifetime and Coverage Guarantees Through Distributed Coordinate-Free Sensor Activation

Conference：　MobiCom 2009

Authors：　Gaurav S. Kasbekar , Yigal Bejerano , Saswati Sarkar

Presenter：　劉哲維

OUTLINE

- **INTRODUCTION**
- **PRELIMINARY**
- **DLM ALGORITHM**
- **SIMULATION**
- **CONCLUSION**

INTRODUCTION

- **A sensor**
  - Sensing
  - Communication
  - Battery-powered
  - Deployment redundancy
- **We present the first coordinate-free distributed scheme that provides provable approximation guarantees on network lifetime**

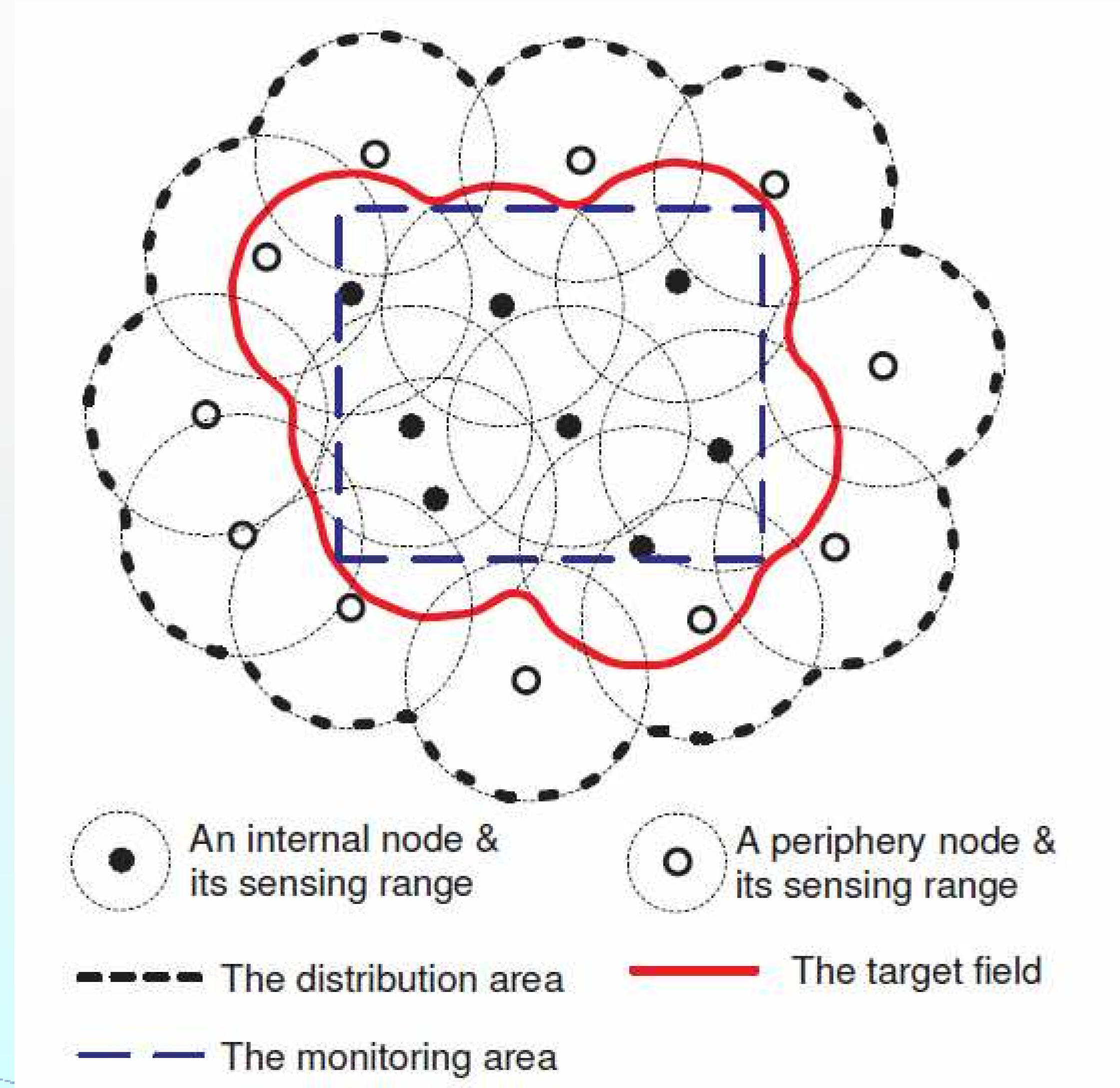
INTRODUCTION

- **Our scheme at each time slot selects subset of sensors for monitoring and ensures k-coverage of the entire target field**
  - Each sensor is assigned a weight based on the energy it has consumed so far
  - The set of sensors that has the minimum total weight is activated
- **The lifetime of the network when this algorithm is used is at least** $\frac{1}{O((\log n)(\log nB))}$ **of the optimal solution**

PRELIMINARY

- **Distribution area**
  - A region obtained by the union of the sensing ranges of all the sensors subsumes the monitoring area
- **Localized distance information -- [8].[9]**
  - r_u – sensing range of node u
  - $d_{u,v}$ and r_v, where node v is a neighbor of u
  - $d_{w,v}$,where w and v are neighbors of each other and are both neighbors of u

PRELIMINARY



PRELIMINARY

- **Sensor Cover**
  - A set C of sensors that k-covers the target field

- **Coverage hole**
  - There does not exist a sensor cover C such that all the nodes in C have non-zero energy
  - We can view this as the WSN is dead

PRELIMINARY

- **The Maximum Network Lifetime Problem**
  - Find an activation schedule which is a sequence of sensor covers that are activated in successive slots to maximizes the network lifetime

- **We assume that**
  - The sensors have **synchronized clocks**
  - $R \geq 2r$, for a coordinate-free algorithm in [10]

DLM ALGORITHM

- **The Distributed Lifetime Maximization (DLM) algorithm consists of an initialization phase and an activation phase**
- **Initialization phase**
  - Executed at the beginning of the network operation
  - For informing each node of the network parameters
- **Activation phase**
  - Every node executes the activation phase at the beginning of each time slot, and decides whether to activate itself in the slot based only on the state information in its neighborhood

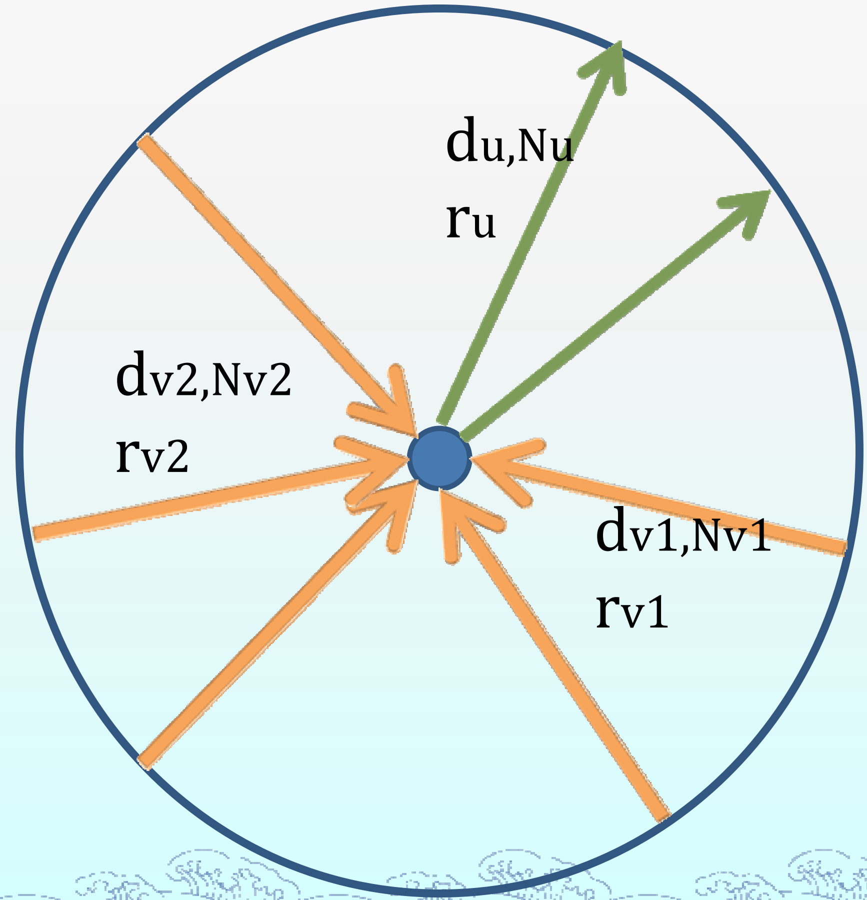
Initialization phase

- **For a node u, we can use localized distance information to get the following**
  - P_u ： Intersection points that u covers
  - T_u ： a node set that share intersection points with u
  - $P_{u,v}$ ： $P_{u,v} = P_u \cap P_v$, for each $v \in T_u$
- **Theorem 1**
  - Consider a set $C \subset S$ of sensors. The set C is a sensor cover if and only if it k-covers every point in the IP set P

Set C is a sensor cover ⇄ Set C k-covers every point in the IP set

Initialization phase

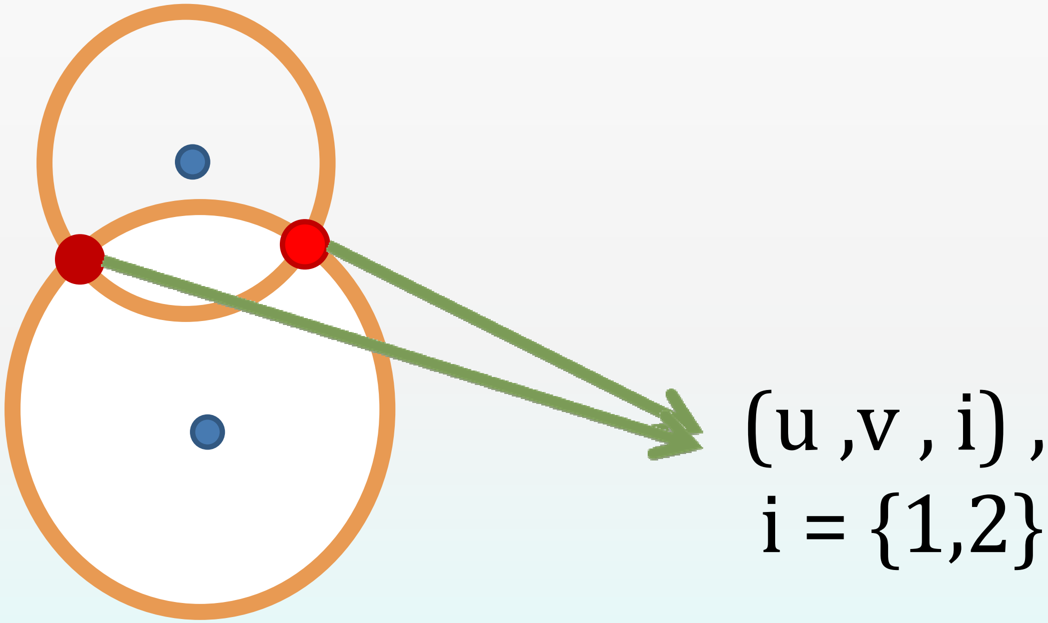
The way we get localized distance information



Initialization phase

- **Property 1 (Intersection Point)**
  - The sensors $v , z \in S$ are intersecting if and only if $d_{v,z} < r_v + r_z$, $d_{v,z} + r_z > r_v$ and $d_{v,z} + r_v > r_z$
  - Any two intersecting sensors v, z are adjacent
- **By using property 1 and Localized distance information , we have Q_u, IP set on border of u**
- **For every intersection point $p \in Q_u$, we find S_p, the set of sensors that cover p.**

Initialization phase

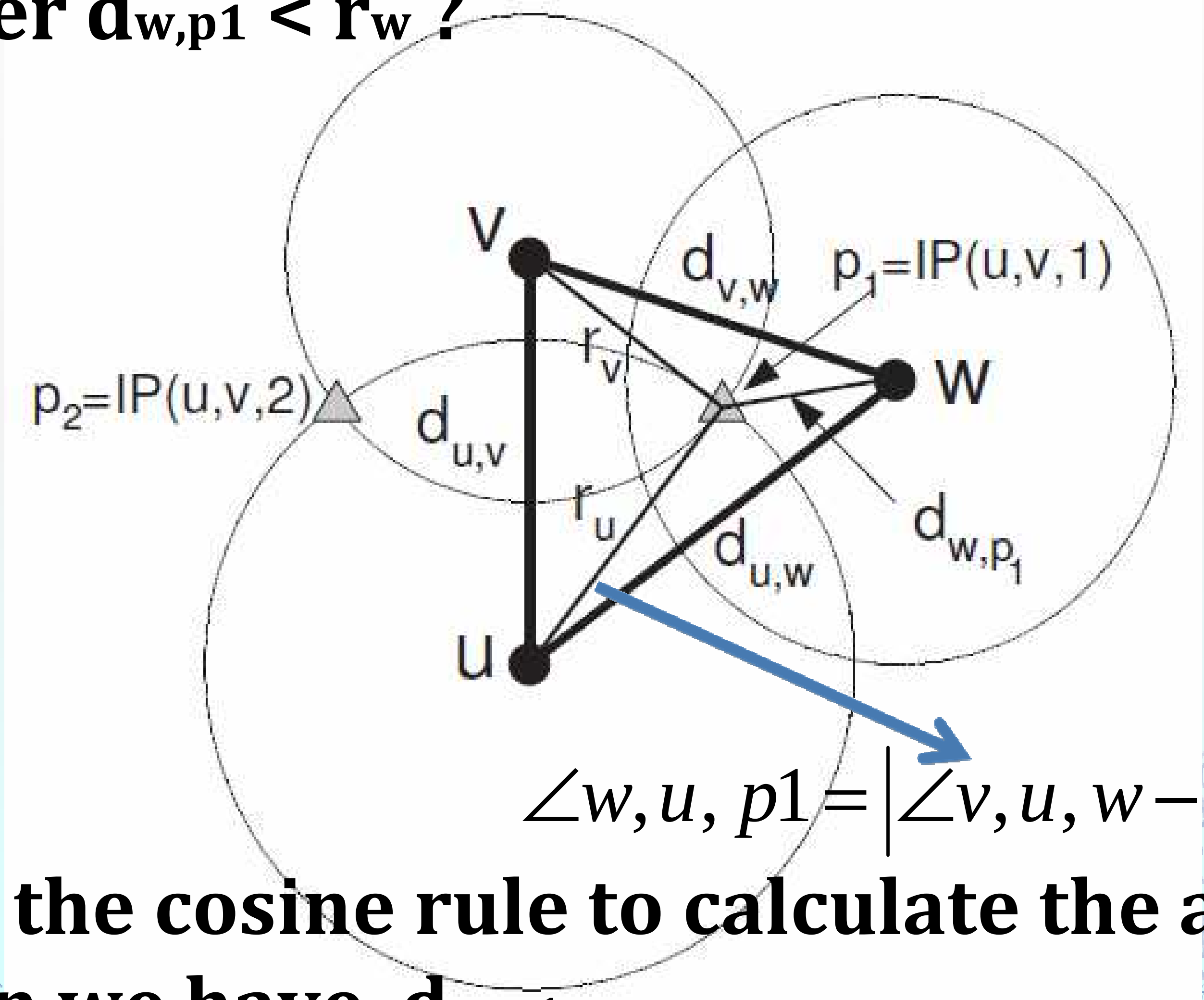


Initialization phase

- **In absence of location information, we rely on**
  - R $\geq$ 2r , so that $S_{pi} \subseteq N_u \cap N_v$
  - Cosine Rule ： $2ac * \cos B = a^2 + c^2 - b^2$
- **Step 1**
  - we partition $N_u \cap N_v$ in three sets: nodes that cover
    - none,
    - only one
    - both of p_1, p_2
- **Step 2**
  - we identify which nodes among the second set cover p1 (p2, respectively)

Initialization phase(Step1)

Whether $d_{w,p1} < r_w$?



$$\angle w,u,p1 = \left|\angle v,u,w - \angle v,u,p1\right|$$

We use the cosine rule to calculate the angle, and then we have $d_{w,p1}$

Initialization phase(Step2)

- **We consider the set Z∈ $N_u \cap N_v$ of sensors that cover only one of the points p1, p2**
- **Property 3**
  - Two sensors w, x∈ Z are located in the same half-plane, defined by the line (u,v), if and only if
    - (1) $\angle w,u,x = \left| \angle v,u,w - \angle v,u,x \right|$
    - (2) $\angle w,u,x + \angle v,u,w + \angle v,u,x < 360^o$
- By using cosine rule, we can have the angles

Activation phase

- **Weight assign**
  - $l_u(j) = \frac{b_u(j)}{B_u}$, consumed fraction of its energy
  - The weight of node u is $W_u(j) = \frac{\mu^{l_u(j)}}{B_u}$

- **Sensor activation by DSC**
  - Distributed Sensor Cover algorithm
  - All the sensors with finite weights are contending for staying active in the slot.

Activation phase

- **Activation preference (ap) of sensor u**
  - $ap_u = < ar_u, ID(u) >$,where $ar_u = \frac{W_u(j)}{|P_u|}$
- **Each contending sensor u communicates its activation preference to the sensors in T_u at**
  - Beginning of the activation phase
  - Each time that its value changes
    - Only when one of u's neighbors in T_u becomes active.
- **Sleep mode**
  - When a node u detect that all Ips in P_u is already k-covered by other activated sensors

- Let $UC_u \subseteq P_u$ be the set of intersection points that have not yet been k-covered by the set of activated sensors.
- Let $CT_u \subseteq T_u$ be the set of contending neighbors of sensor u.

Begin

if $w_u(j) = \infty$ or $P_u = \emptyset$ **then**
    $mode = sleep$
    Return $mode$
else
    $mode = contending$
    $UC_u = P_u$
    $CT_u = T_u$
    $ar_u = \frac{w_u(j)}{|UC_u|}$; $ap_u = < ar_u, ID(u) >$
    Send *My-Init-AP*(ap_u) message to every sensor $w \in T_u$
    Receive *My-Init-AP*(ap_w) message from every sensor $w \in T_u$
        // If *My-Init-AP* message not received from a sensor $w \in T_u$
        // within a given time period, then w is considered inactive
        // and it is removed from CT_u.
    if ($CT_u == \emptyset$ or $ap_u < ap_w$ for every $w \in CT_u$) **then**
        $mode = active$
        Send an *I-am-Active message* to every sensor $w \in CT_u$.
    end if

```
    while mode == contending and upon reception of a message
    M from sensor v ∈ CT_u do
      if the received message M is I-Am-Active then
        CT_u = CT_u − {v}
        // Let NC_u ⊆ UC_u ∩ P_{u,v} be the set of intersection
        // points that are k-covered (after v's activation).
        UC_u = UC_u − NC_u
        if (UC_u == ∅) then
          mode = sleep
          Send an I-Am-Sleeping message to every sensor w ∈
          CT_u.
        else
          old_ap_u = ap_u
          ar_u = w_u(1)/|UC_u|; ap_u =< ar_u, ID(u) >
          if (CT_u == ∅ or ap_u < ap_w for every w ∈ CT_u)
          then
            mode = active
            Send an I-Am-Active message to each sensor w ∈
            CT_u.
          else if (old_ap_u ≠ ap_u) then
            Send a New-AP(ap_u) message to each sensor w ∈
            CT_u.
          end if
        end if
      else if the message M is New-AP(ap_v) then
        Update ap_v
        if (ap_u < ap_w for every w ∈ CT_u) then
          mode = active
          Send an I-am-Active message to each sensor w ∈ CT_u
        end if
      else if the received message M is I-Am-Sleeping then
        CT_u = CT_u − {v}
      end if
    end while
    Return mode
end if
```

DLM ALGORITHM

- **DETECTION OF LIFETIME TERMINATION**
  - For each intersection points p in $P_u \cup Q_u$， sensor u will check whether p is k-covered by the active nodes in $N_u \cup$ u using s_p of p
- **By Lemma 3 and Lemma 4**

$$\frac{2n}{\alpha \log n}(L^* - L) \leq \sum_{u \in S} C_u (L+1) \leq n(2L^* \log(\mu + 1))$$

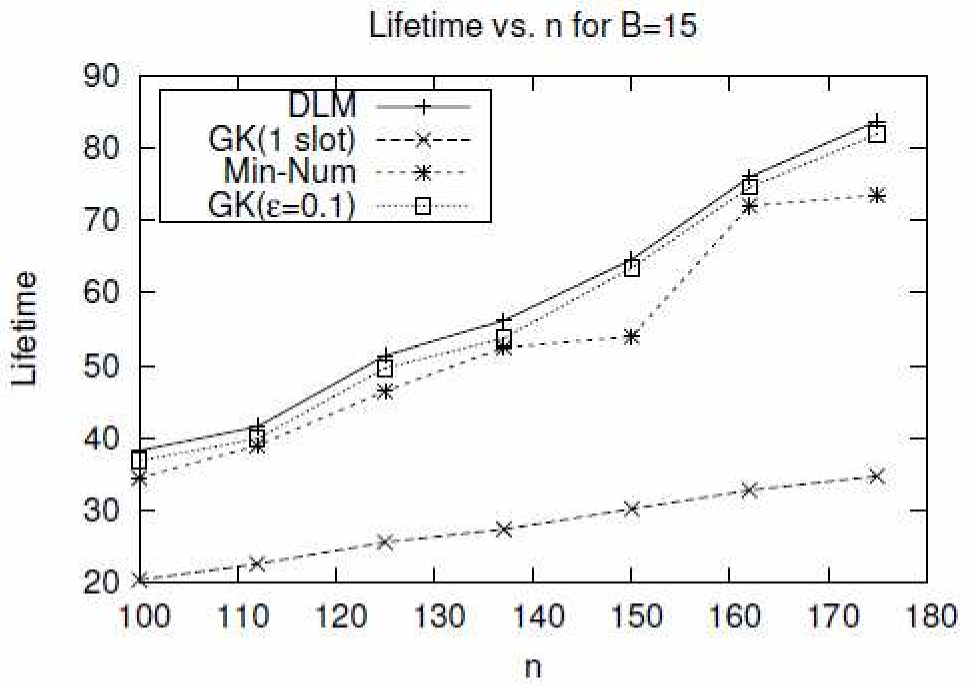
Then we have

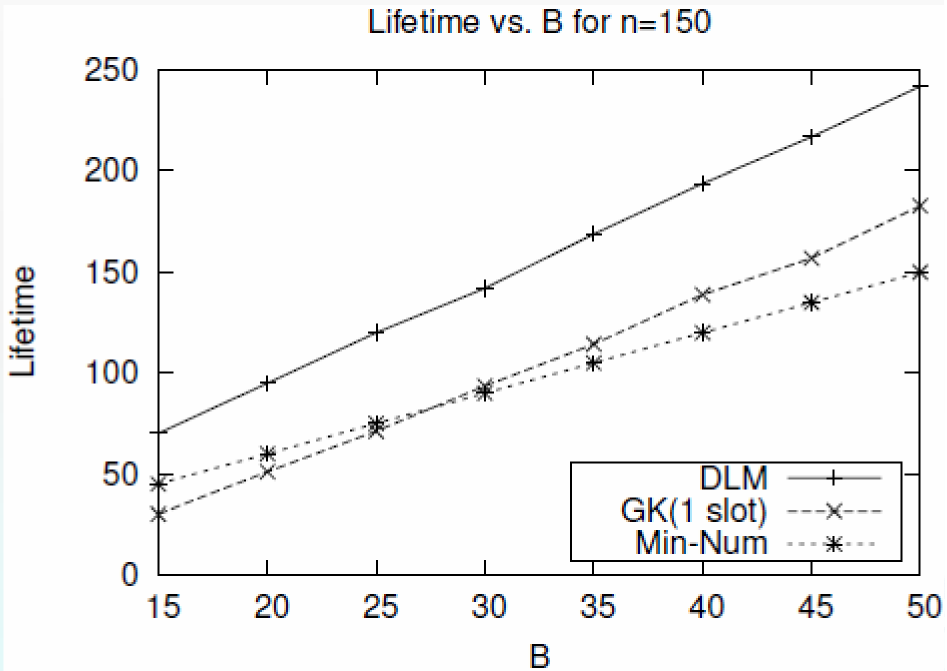
$$L^* \leq L(\alpha(\log n)(\log \mu) + 1) + \frac{\alpha \log n}{2}$$

SIMULATION

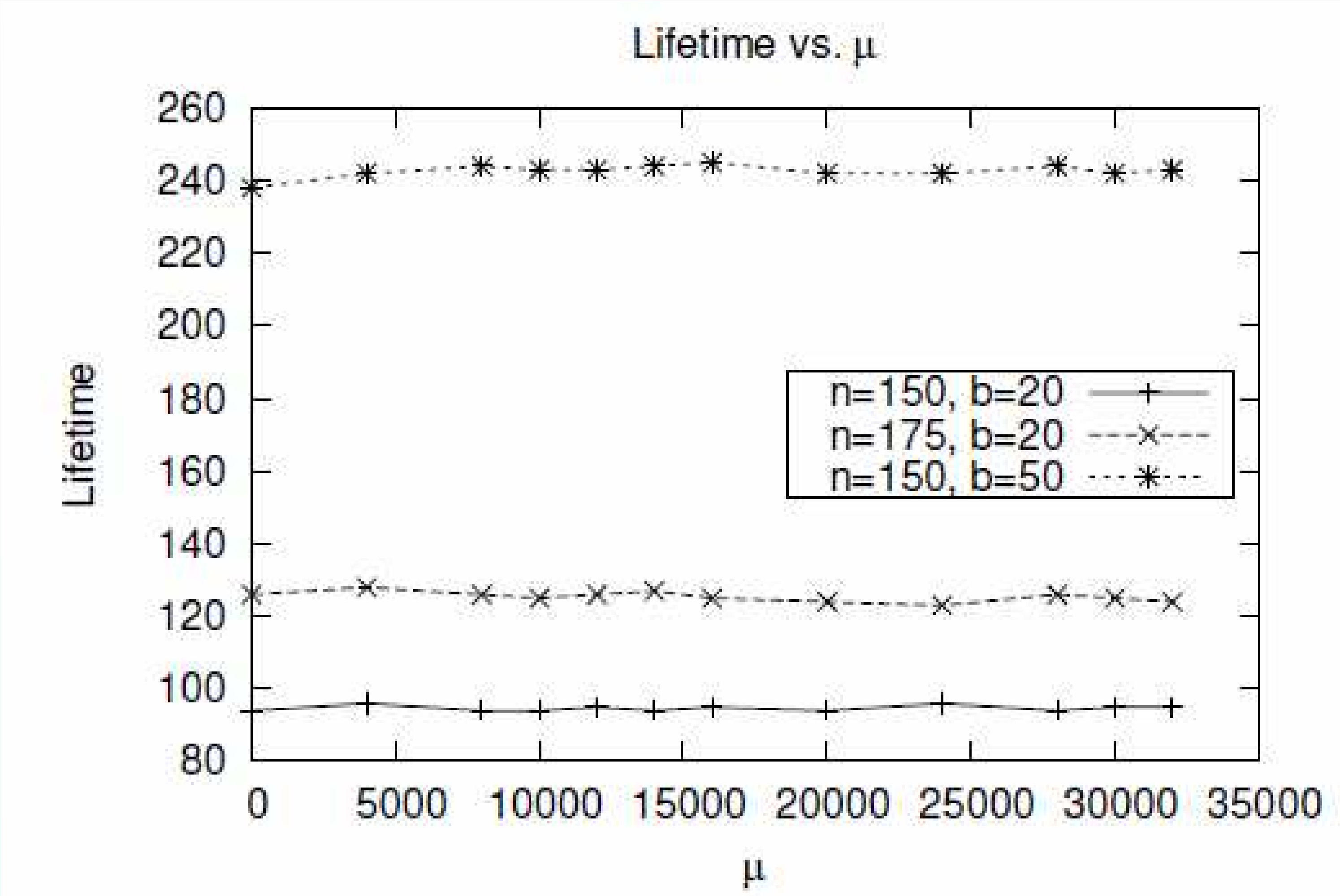
- **We compared the lifetimes of the network under three algorithms:**
  - DLM algorithm
  - Garg-Konemann(GK) algorithm [11]
  - Min-Num proposed in [13, 21]
- **We have sensing and transmission radii of 10 and 22 units respectively, deployed uniformly at random in a 50 **50 units***

SIMULATION


Lifetime vs. n for B=15
Lifetime
n
DLM
GK(1 slot)
Min-Num
GK(ε=0.1)
90
80
70
60
50
40
30
20
100
110
120
130
140
150
160
170
180


Lifetime vs. B for n=150
Lifetime
B
DLM
GK(1 slot)
Min-Num
250
200
150
100
50
0
15
20
25
30
35
40
45
50

SIMULATION



Lifetime vs. μ
Lifetime
260
240
220
200
180
160
140
120
100
80
0
5000
10000
15000
20000
25000
30000
35000
μ
n=150, b=20
n=175, b=20
n=150, b=50

CONCLUSION

- We designed a distributed, coordinate-free algorithm for attaining high lifetimes in WSN, what's more, we also ensure the k-coverage of the target field during the network lifetime

- We proved that the lifetime is at least $\frac{1}{O((\log n)(\log nB))}$ times that of the maximum lifetime of the network.