Obstacle-Free Deployment and Communication Mechanisms for Wireless Sensor Networks

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Outline

- Introduction to Wireless Sensor Networks
- Obstacle-Free Deployment Mechanism
- Obstacle-Free Routing Mechanism
- Conclusions

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- Obstacle-Free Routing Mechanism
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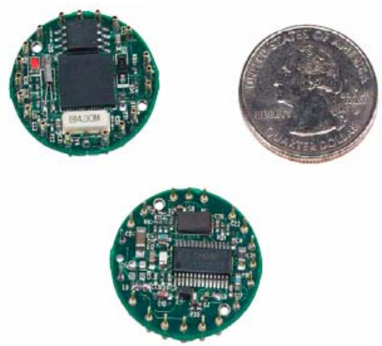
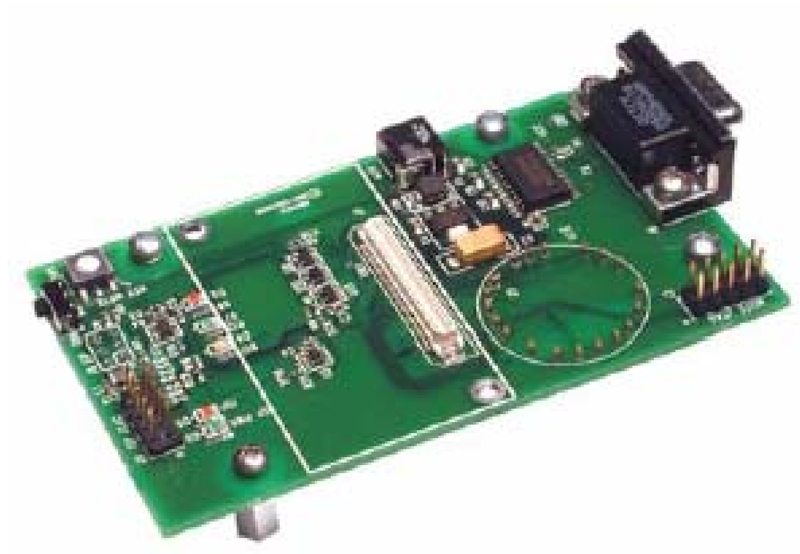
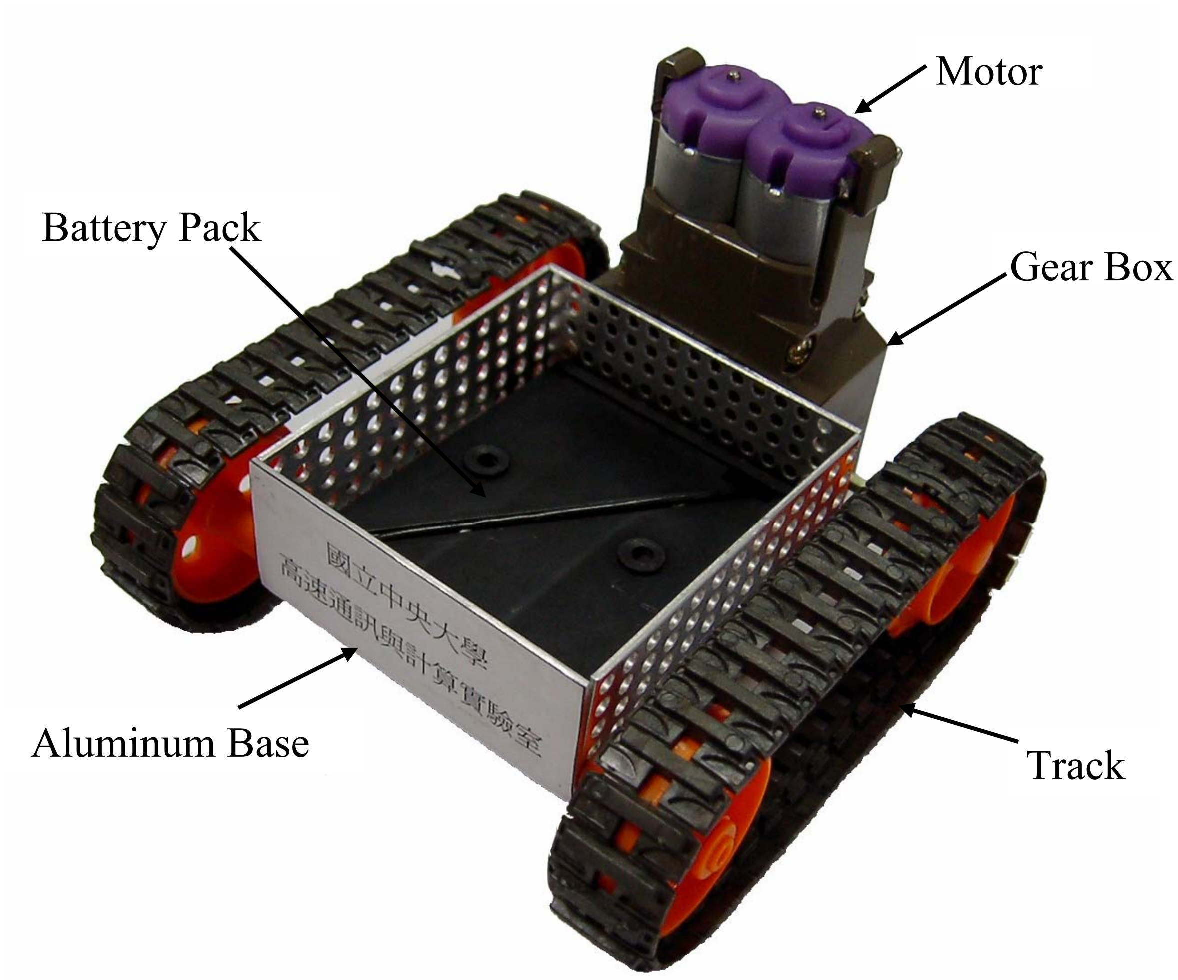
Sensor Networks

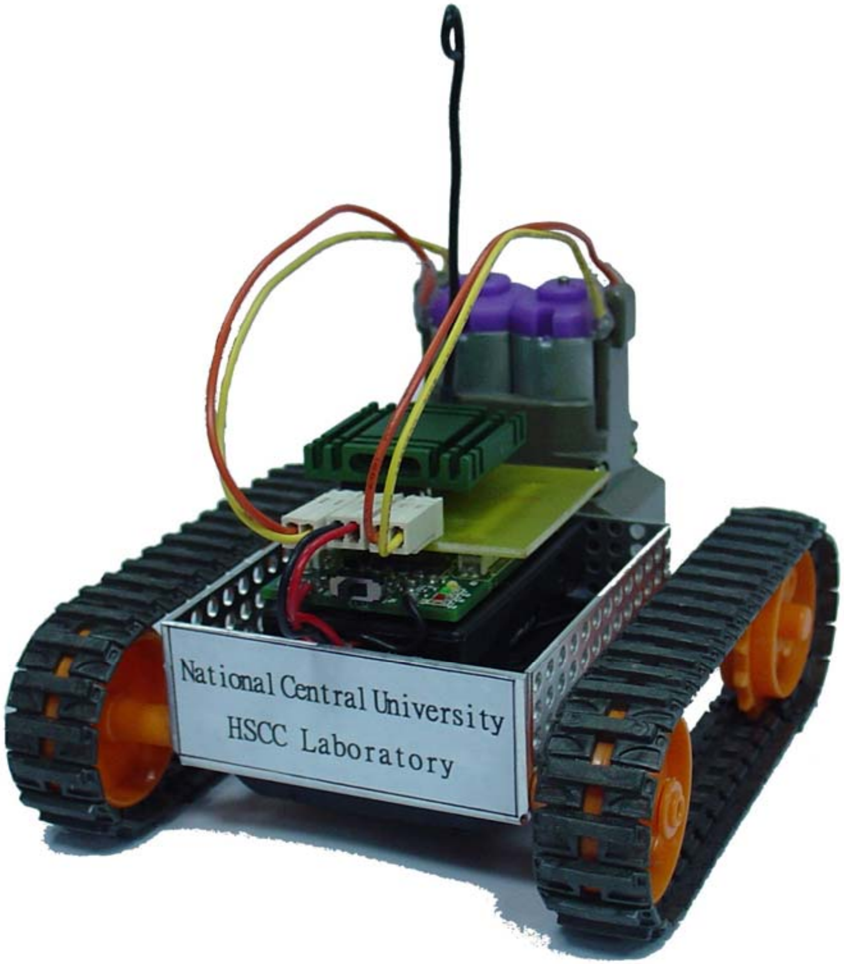
- 光、聲音、振動、壓力、溫度、濕度、 氣體, 加速度, 物體…

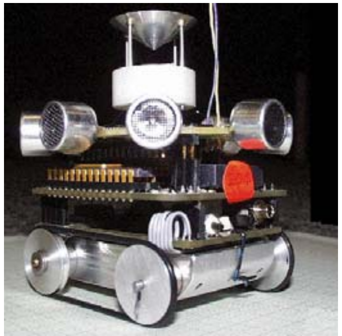
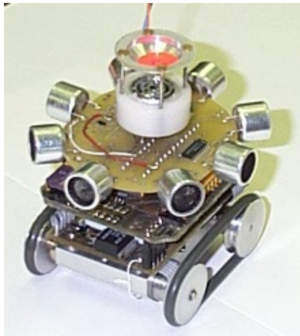
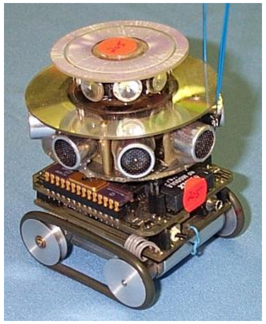
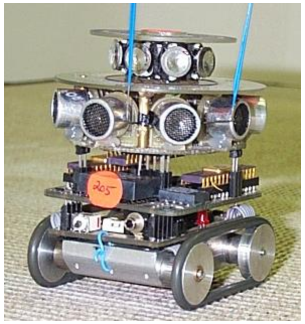
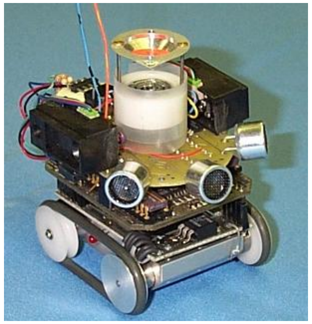
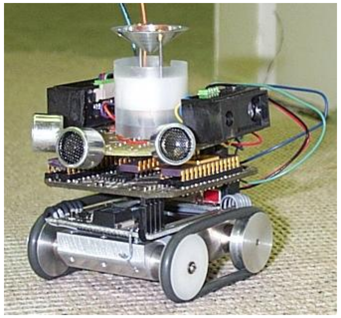
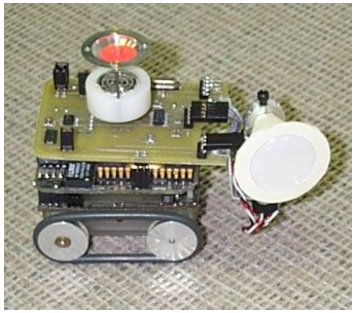
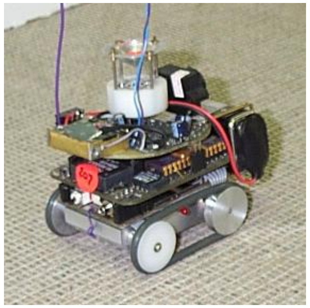
Platform of Mobile Sensor Node

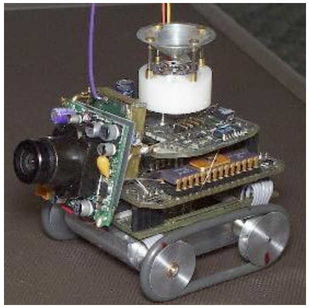


Mobile Sensor Node (Mote)

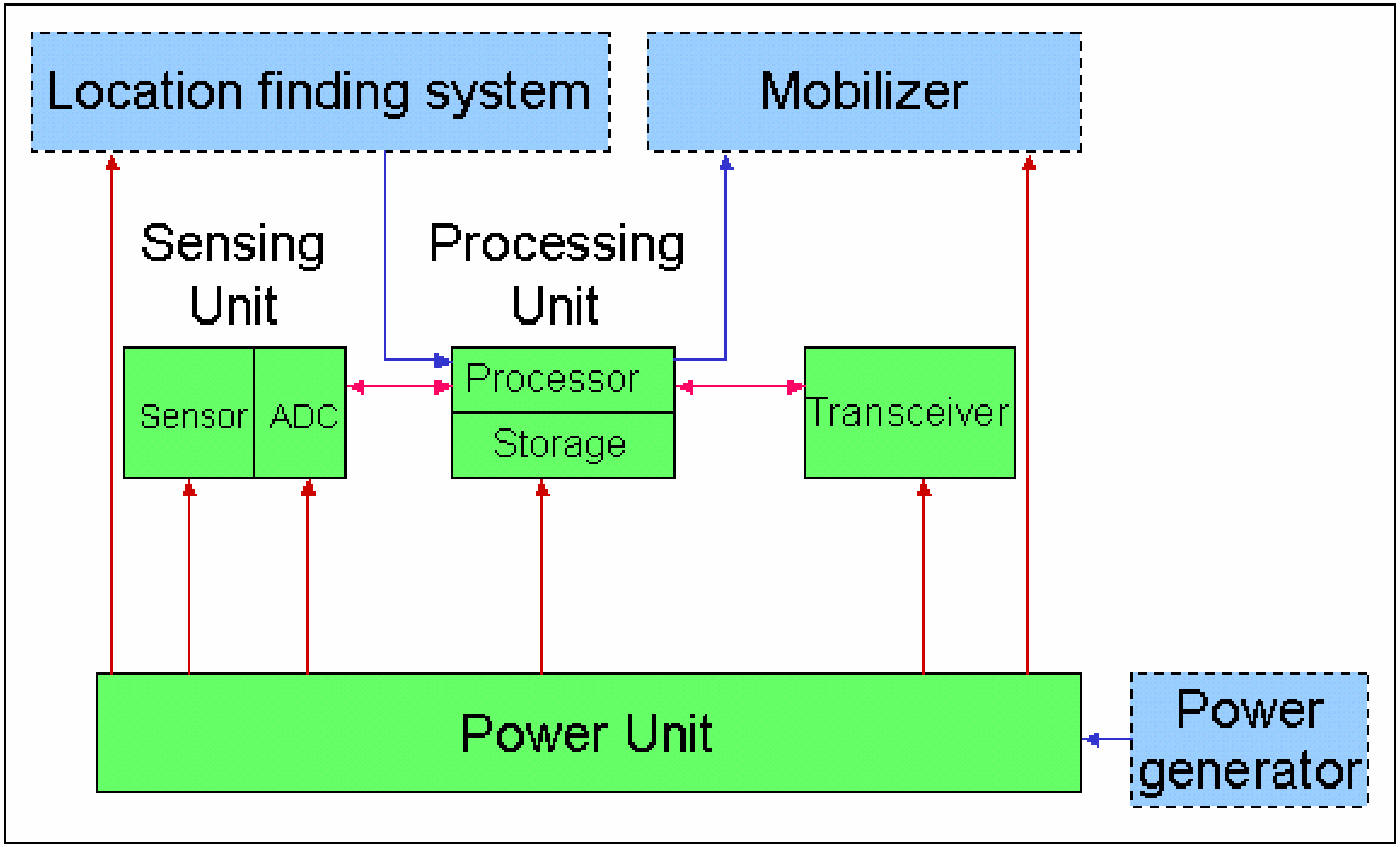


CMU
Millibots



Sensor Hardware (感測器硬體設計)



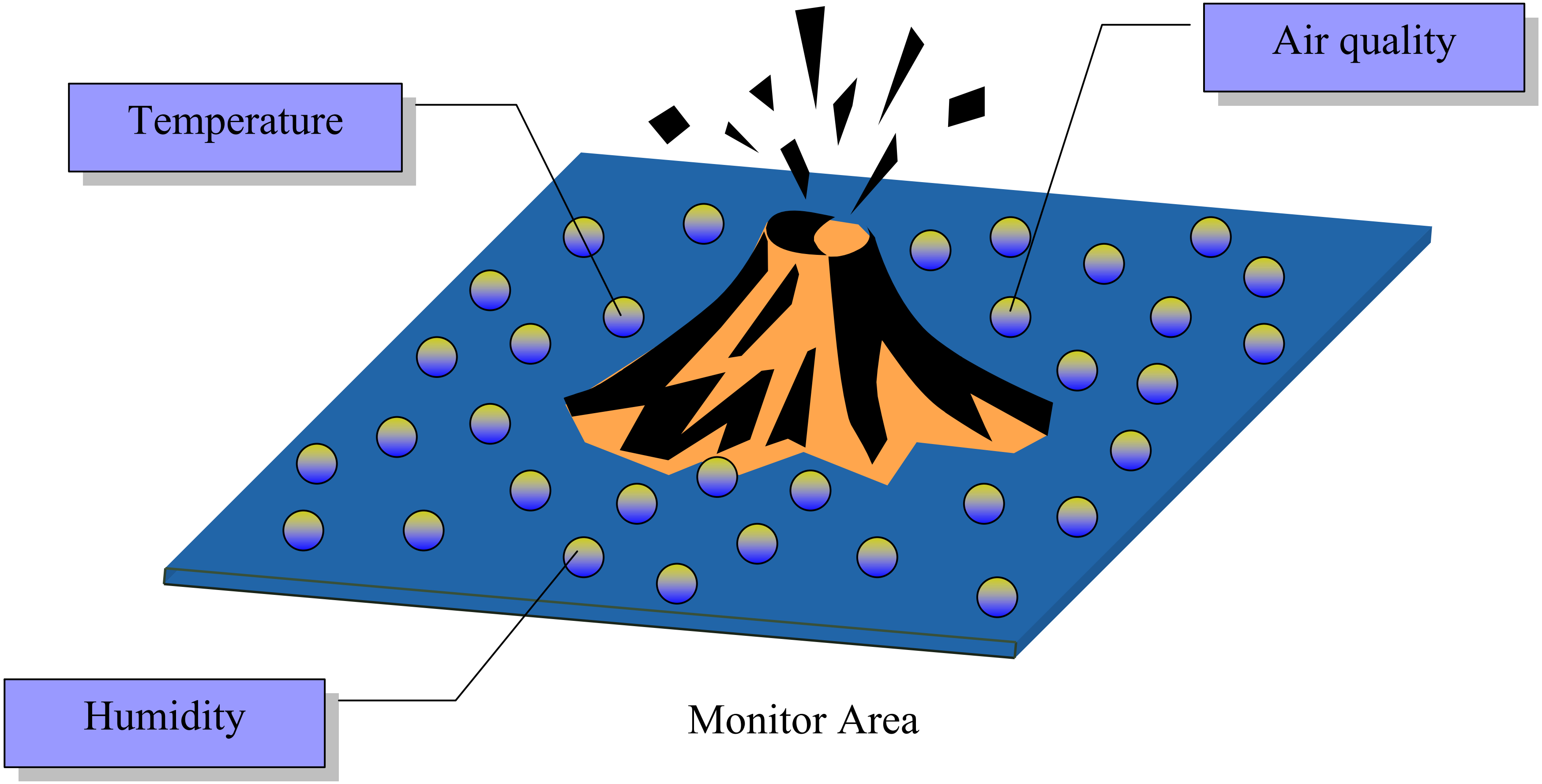
Wireless Sensor Network Applications

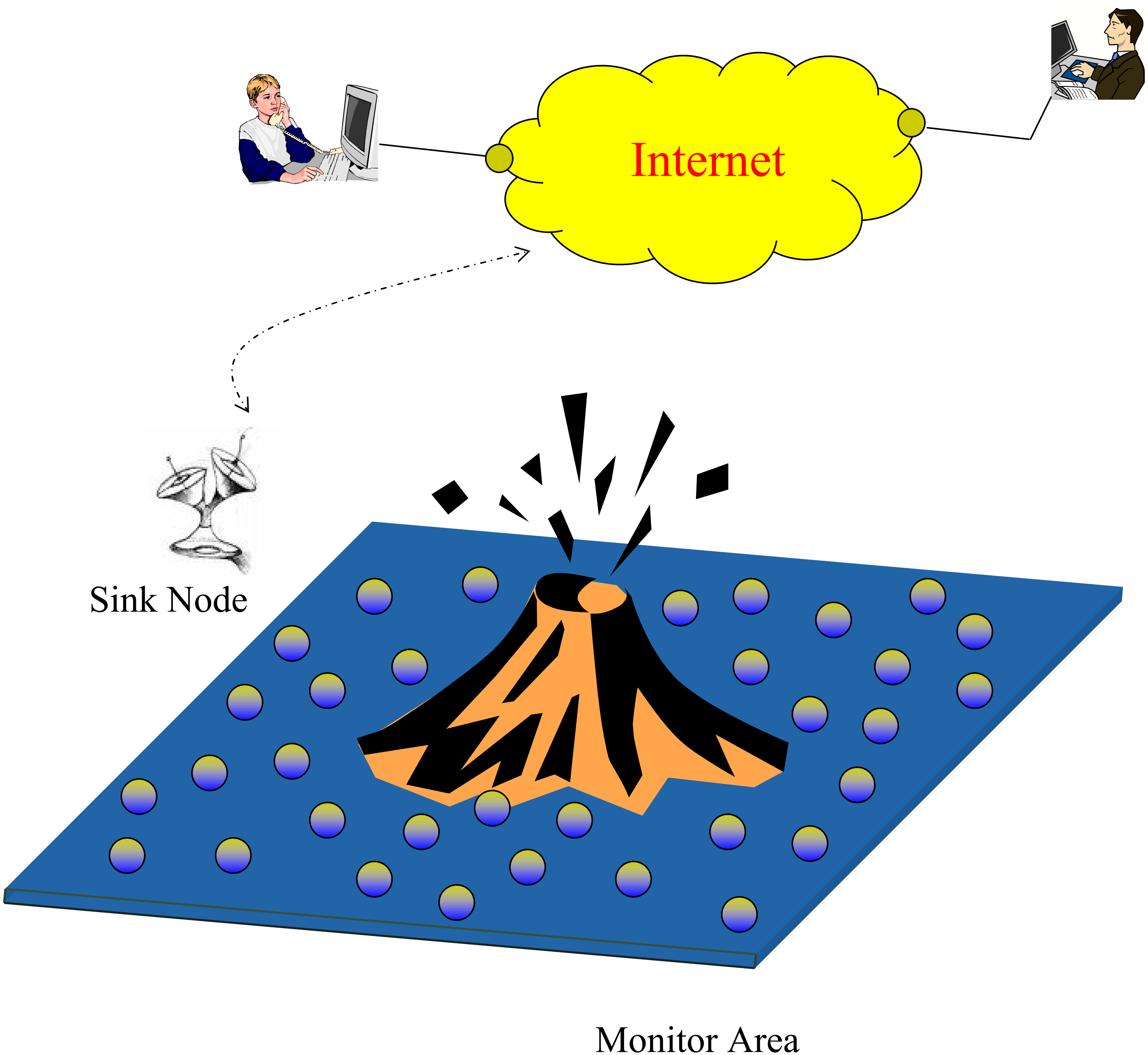
- Environment monitoring
- Habitat monitoring
  - Animal migrate route
- Structural monitoring
  - Buildings and Ships
- Healthy monitoring
- Military applications

Applications in Sensor Networks

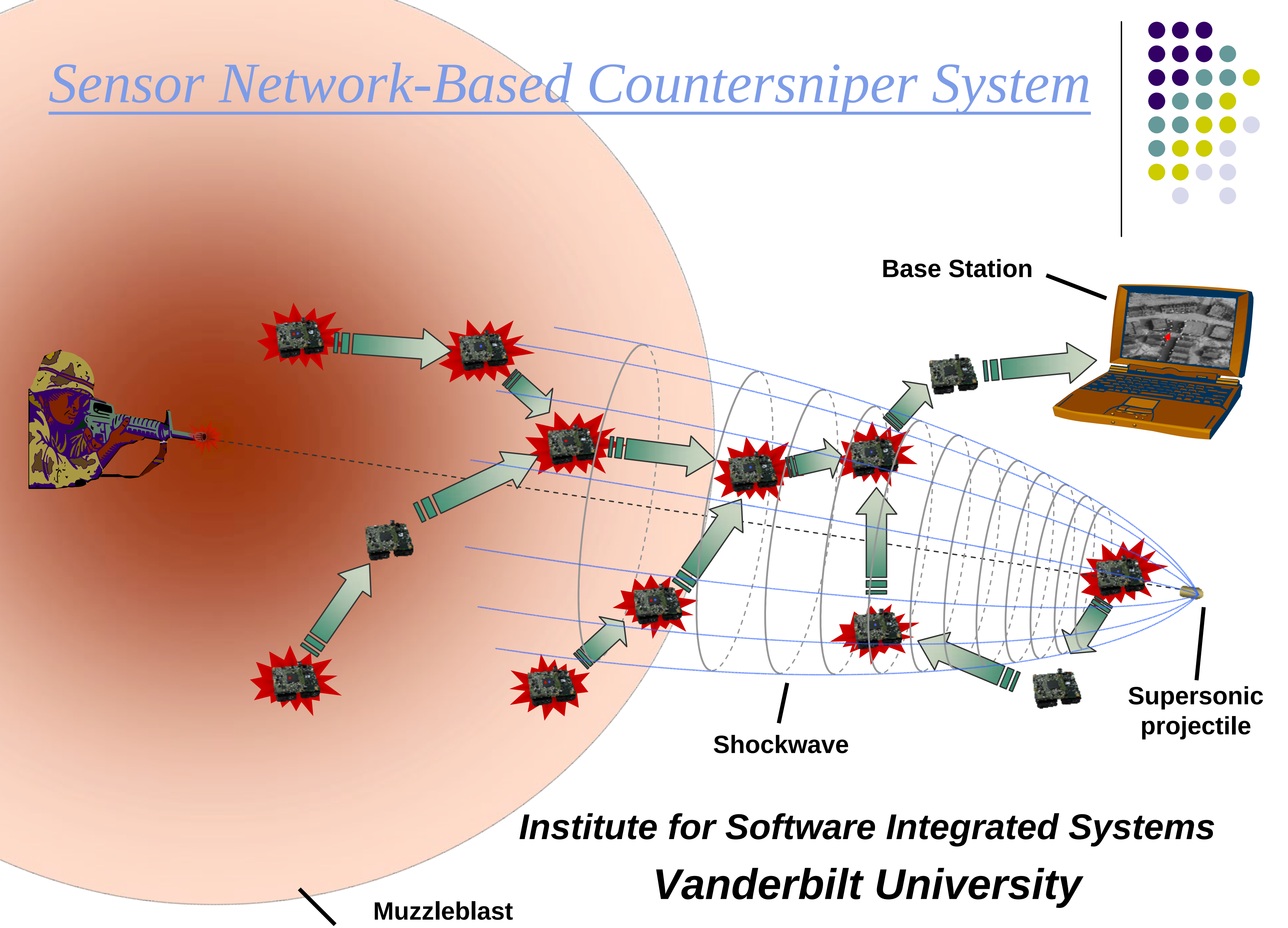
- Monitor and collect interesting information
  - Temperature
  - Pressure
  - Noise level
  - Traffic measurement
- Intruder detection
- Location Tracking

Application—volcanic eruption




Internet
Sink Node
Monitor Area

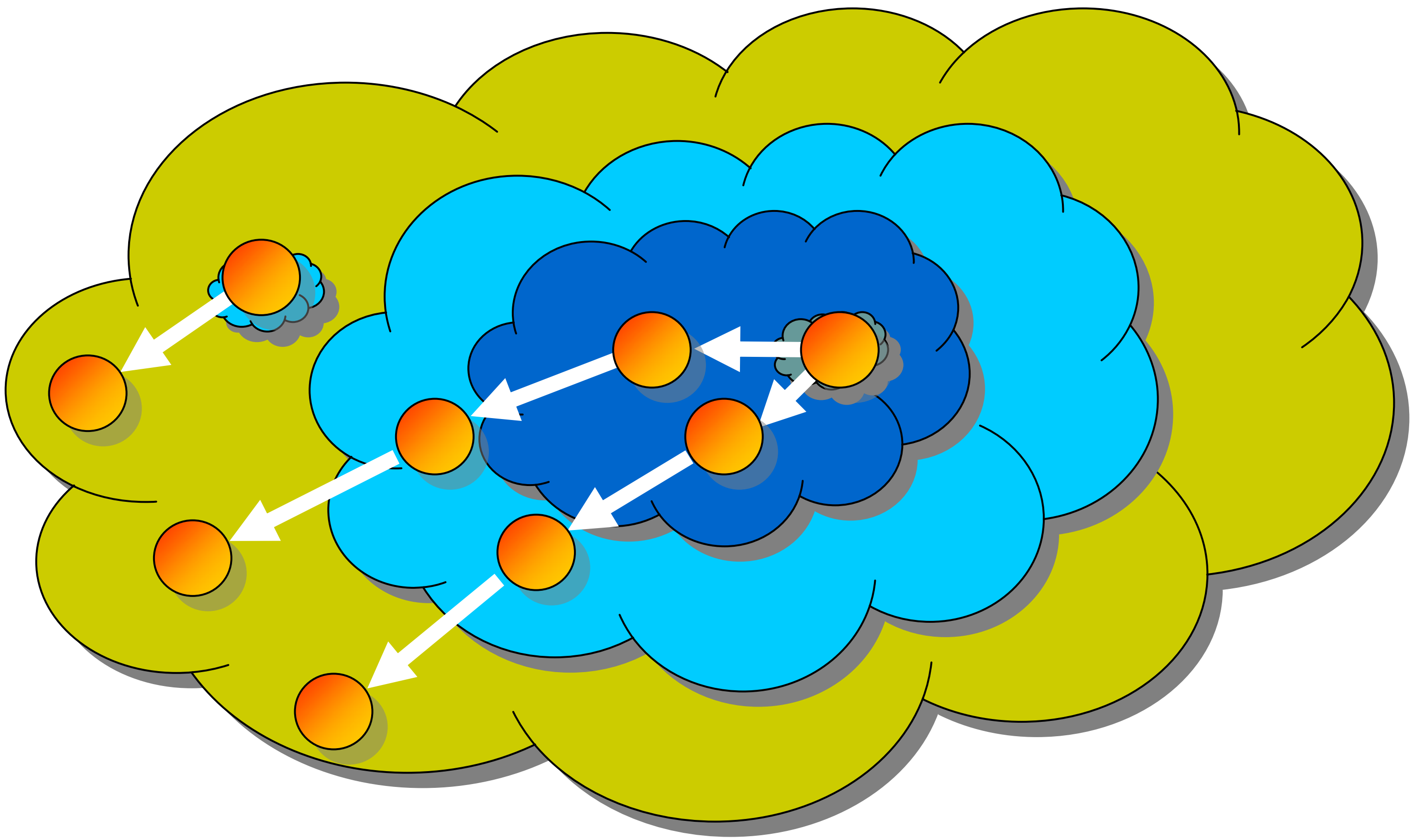
Sensor Network-Based Countersniper System



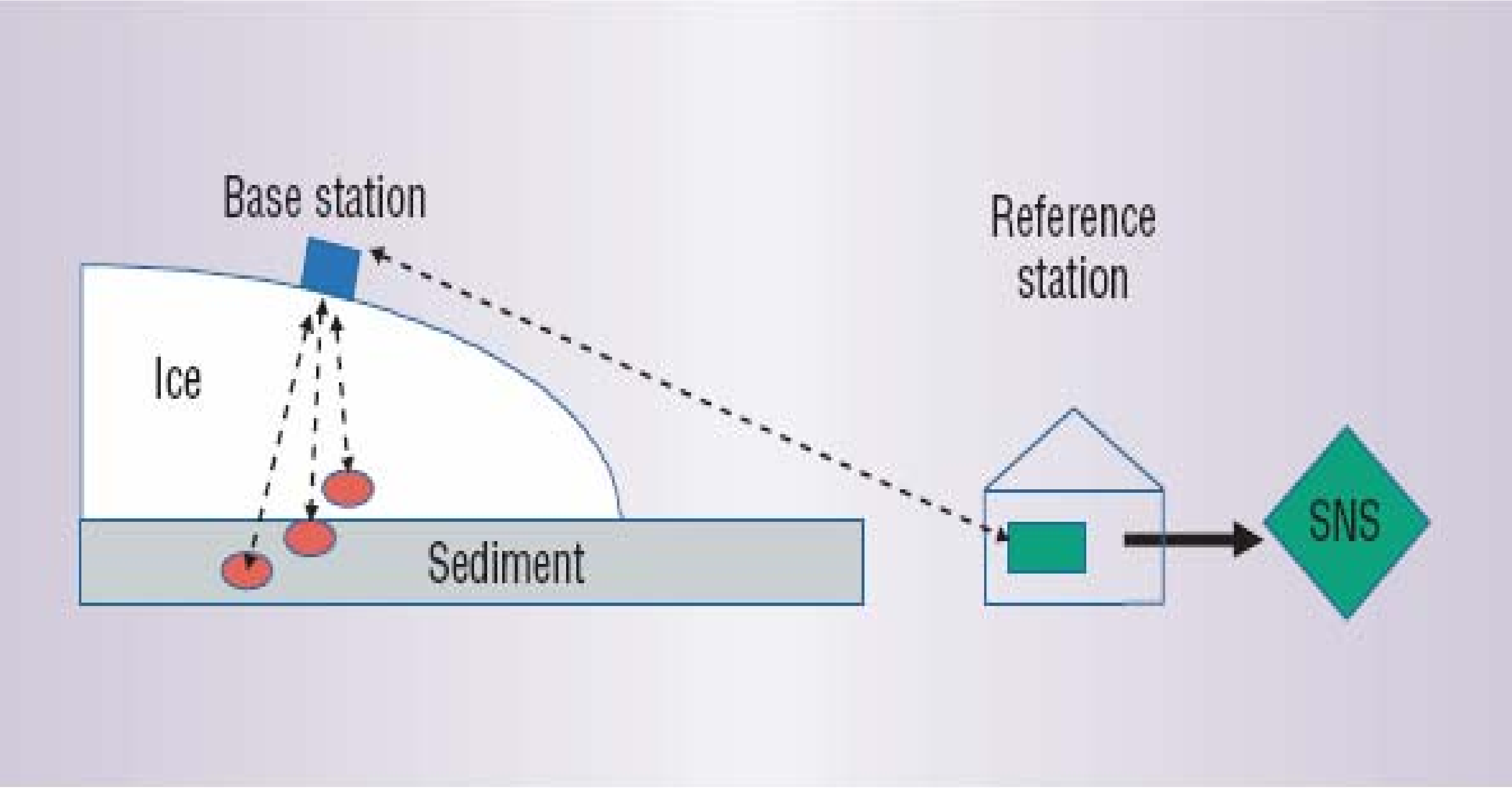
Institute for Software Integrated Systems

Vanderbilt University

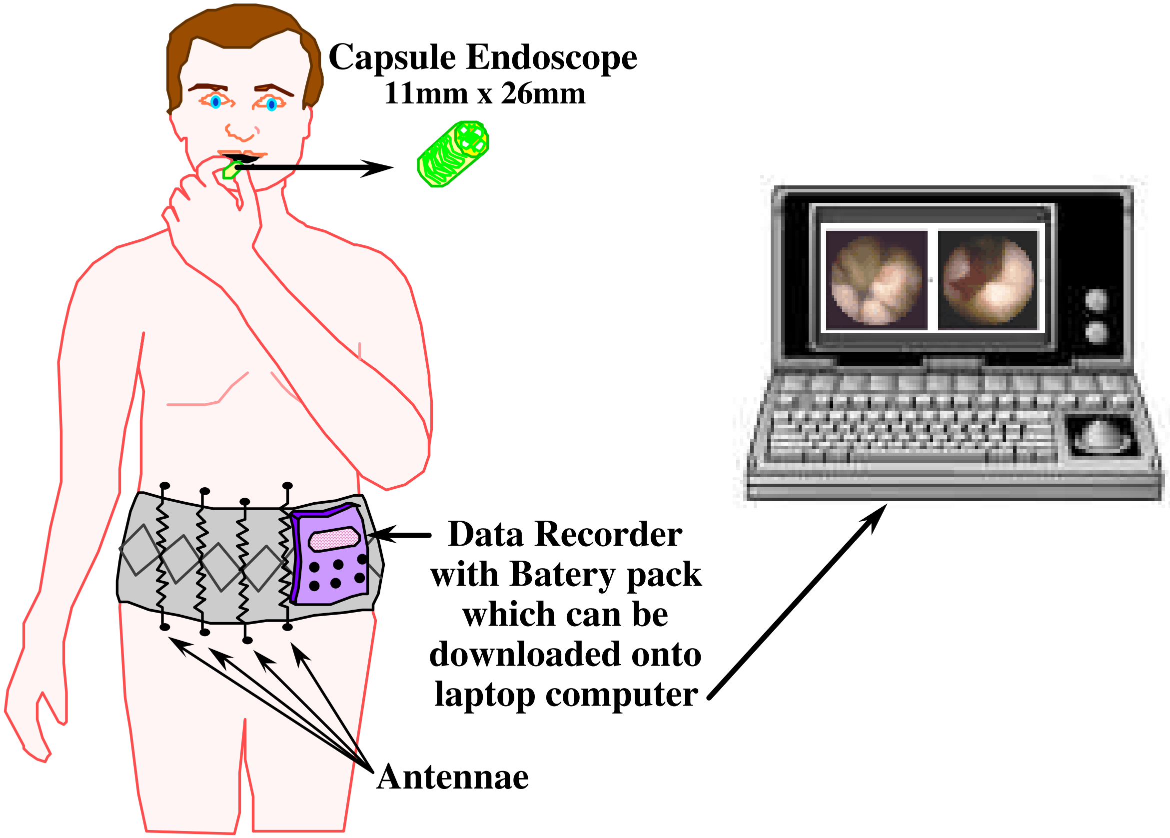
Noxious Gas Detection

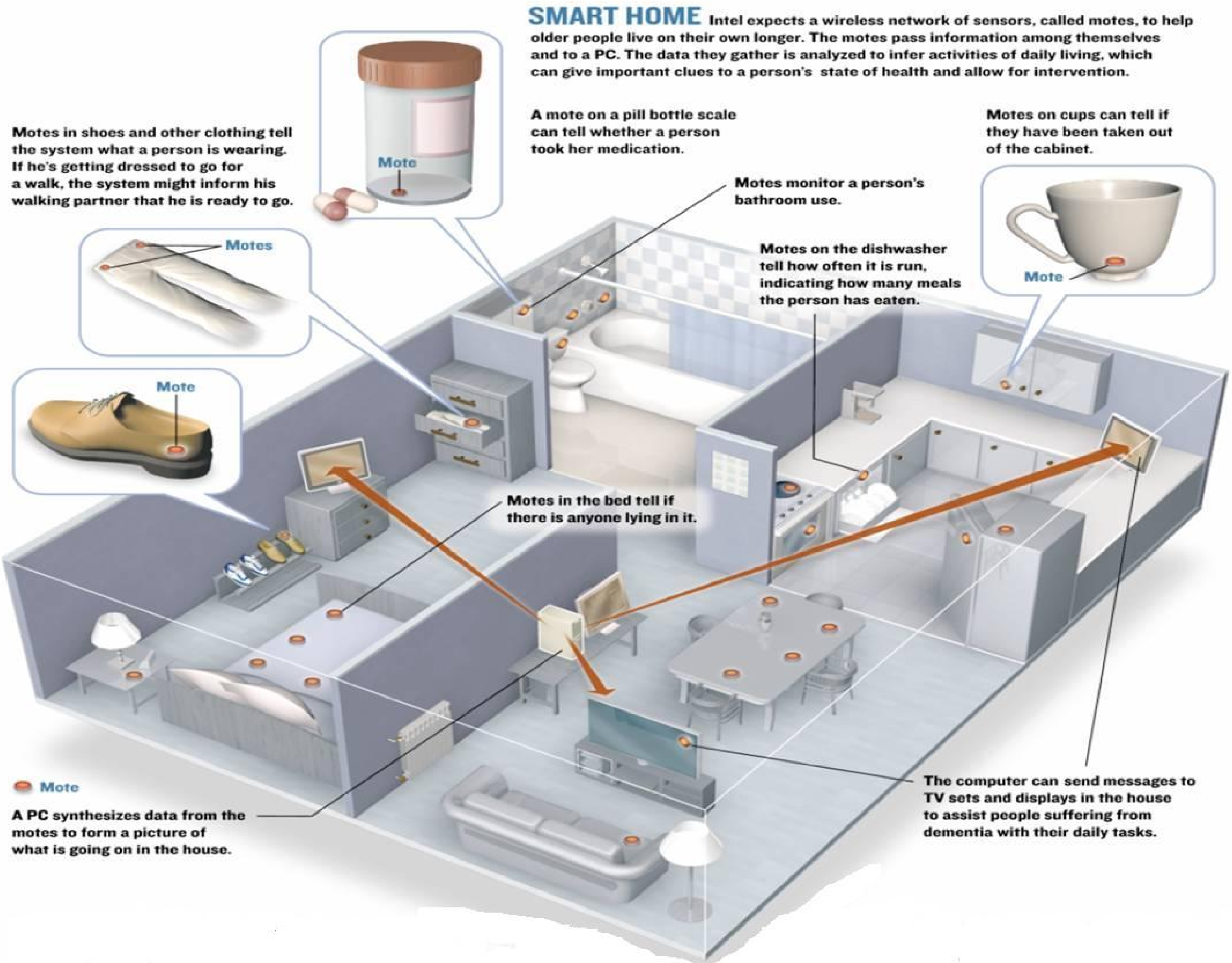


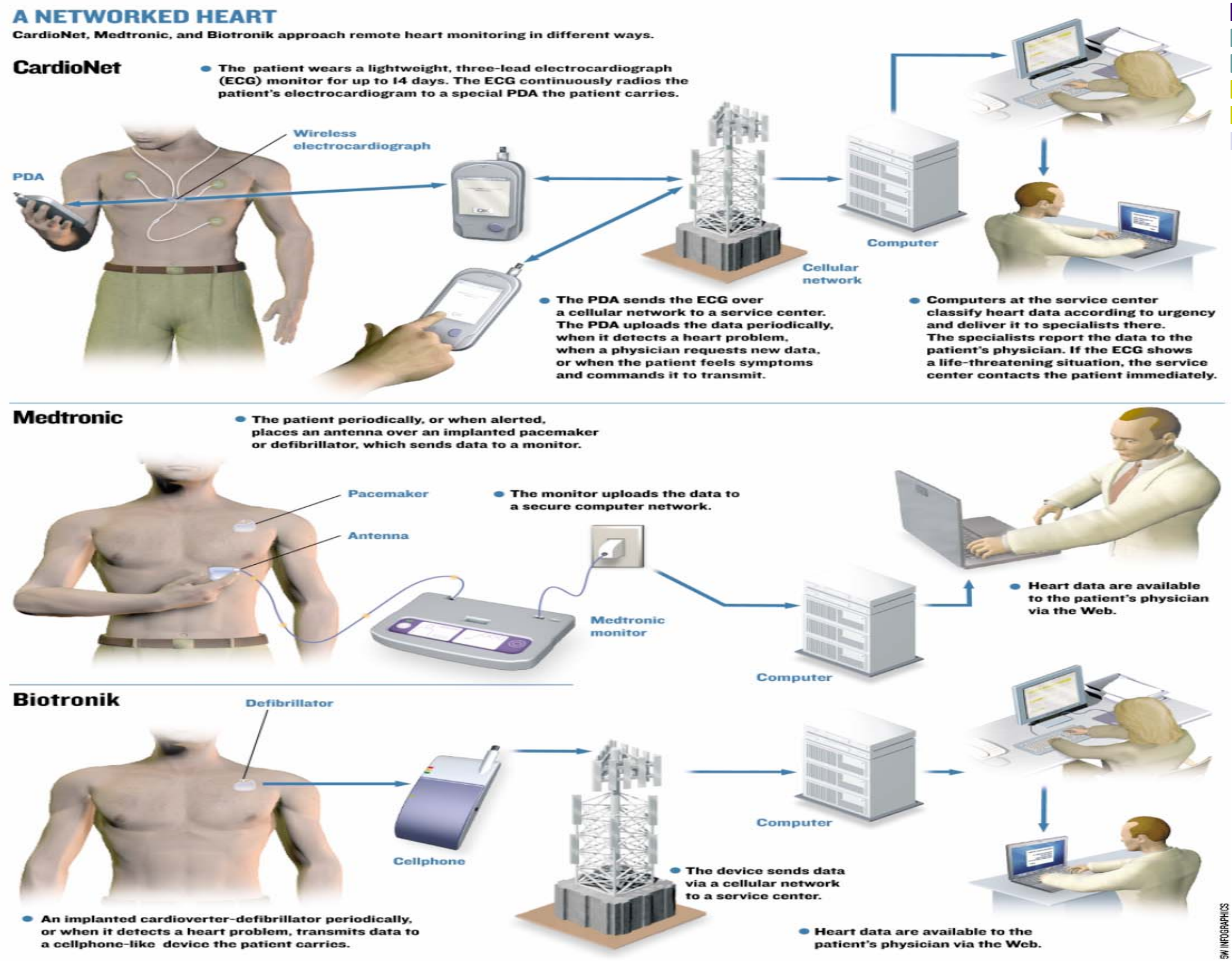
The GlacsWeb Architecture



Sensor Networks

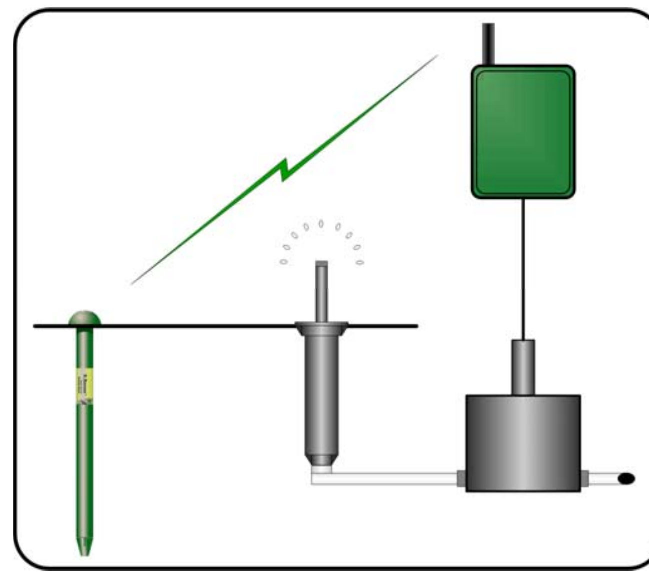



SMART HOME Intel expects a wireless network of sensors, called motes, to help older people live on their own longer. The motes pass information among themselves and to a PC. The data they gather is analyzed to infer activities of daily living, which can give important clues to a person's state of health and allow for intervention.
Motes in shoes and other clothing tell the system what a person is wearing. If he's getting dressed to go for a walk, the system might inform his walking partner that he is ready to go.
A mote on a pill bottle scale can tell whether a person took her medication.
Motes on cups can tell if they have been taken out of the cabinet.
Mote
Motes
Mote
Motes monitor a person's bathroom use.
Motes on the dishwasher tell how often it is run, indicating how many meals the person has eaten.
Mote
Motes in the bed tell if there is anyone lying in it.
Mote
A PC synthesizes data from the motes to form a picture of what is going on in the house.
The computer can send messages to TV sets and displays in the house to assist people suffering from dementia with their daily tasks.


A NETWORKED HEART
CardioNet, Medtronic, and Biotronik approach remote heart monitoring in different ways.
CardioNet
The patient wears a lightweight, three-lead electrocardiograph (ECG) monitor for up to 14 days. The ECG continuously radios the patient's electrocardiogram to a special PDA the patient carries.
Wireless electrocardiograph
PDA
Cellular network
Computer
The PDA sends the ECG over a cellular network to a service center. The PDA uploads the data periodically, when it detects a heart problem, when a physician requests new data, or when the patient feels symptoms and commands it to transmit.
Computers at the service center classify heart data according to urgency and deliver it to specialists there. The specialists report the data to the patient's physician. If the ECG shows a life-threatening situation, the service center contacts the patient immediately.
Medtronic
The patient periodically, or when alerted, places an antenna over an implanted pacemaker or defibrillator, which sends data to a monitor.
Pacemaker
Antenna
The monitor uploads the data to a secure computer network.
Medtronic monitor
Computer
Heart data are available to the patient's physician via the Web.
Biotronik
Defibrillator
Cellphone
Computer
The device sends data via a cellular network to a service center.
An implanted cardioverter-defibrillator periodically, or when it detects a heart problem, transmits data to a cellphone-like device the patient carries.
Heart data are available to the patient's physician via the Web.
5W INFOGRAPHICS

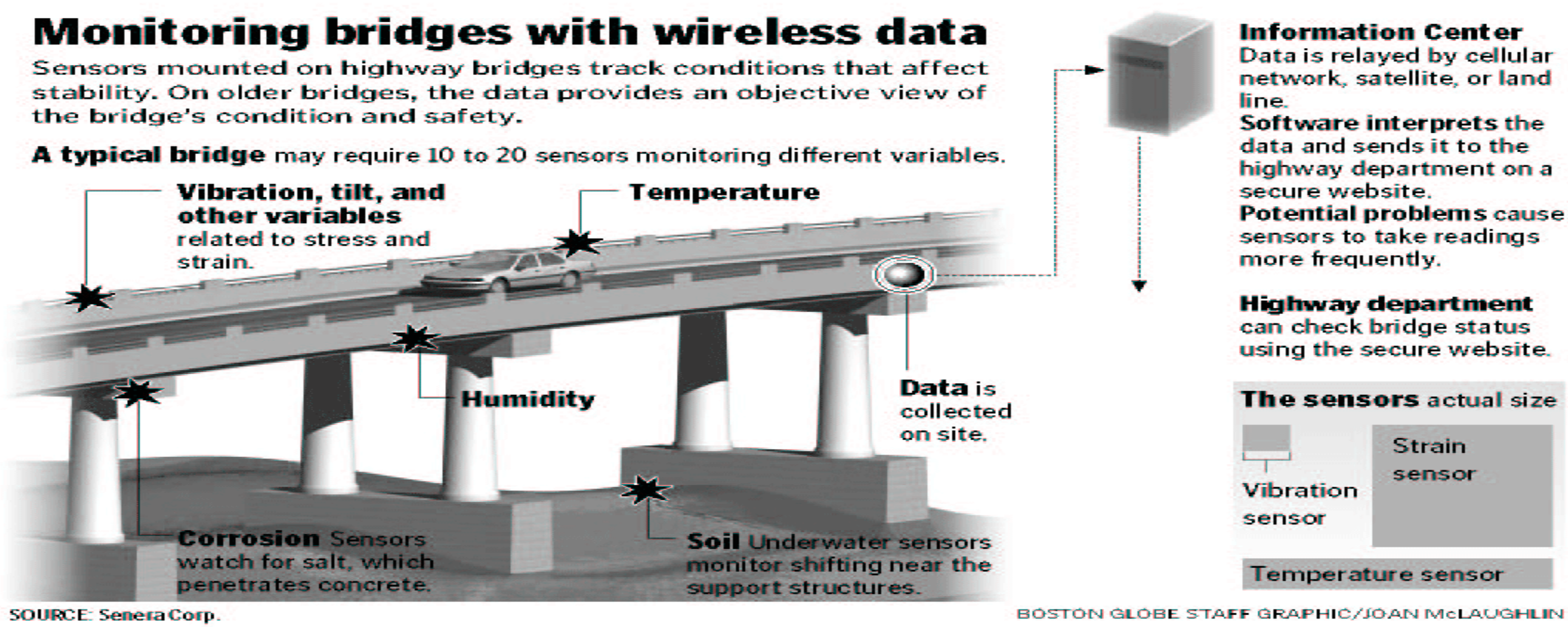
S.Sense Wireless Sensors

- http://www.digitalsun.com/index.html
- Digital Sun, Inc.
- A soil moisture sensor system to keep grass green while saving water



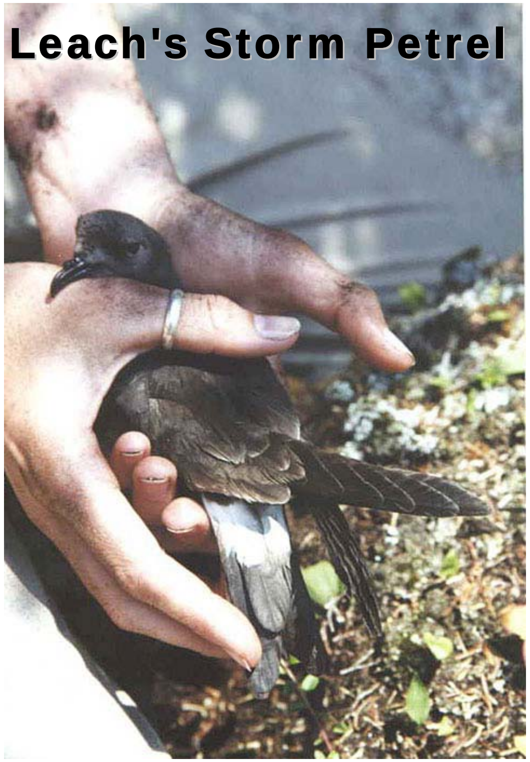
Bridges & Building Monitoring

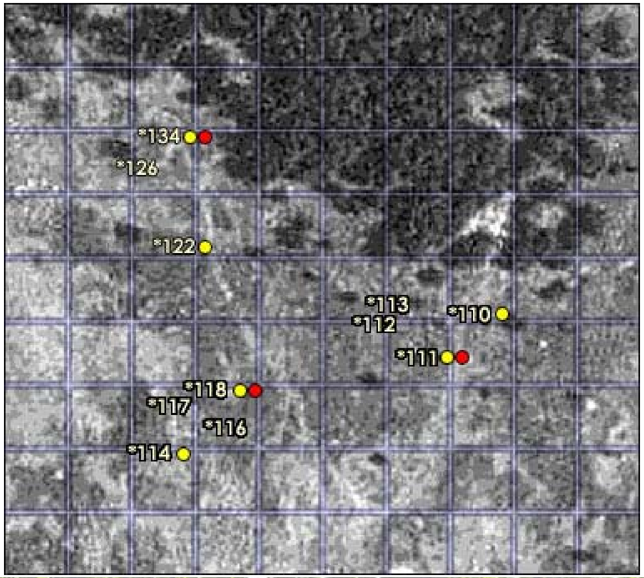
- http://www.senera.com/
- Senera Corp.
- Wireless infrastructure monitoring services for transportation and building infrastructures
- (89. 8.27) 高屏大橋突然斷裂，造成多位民眾受傷



Habitat Monitoring on Great Duck Island

- http://www.greatduckisland.net/
- Intel Research Laboratory at Berkeley
- Temperature, humidity, barometric pressure, mid-range infrared, and image.





Seismic Observing Systems: Field Experiment

- **38 seismometers in 17-story steel-frame Factor Building.**
- **http://crust.ess.ucla.edu:5813/ pass:seismo**

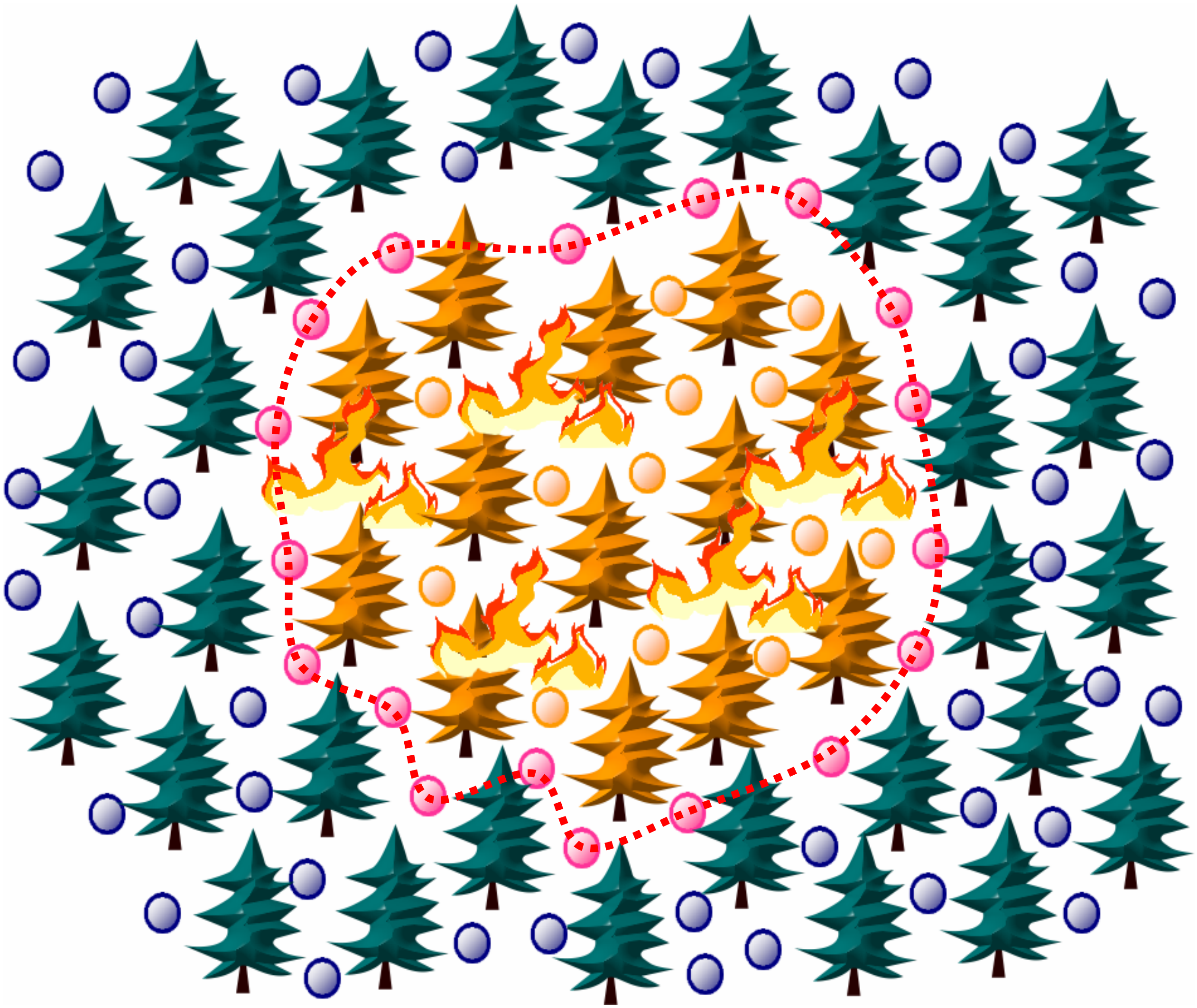
Aquatic Microbial Observing Systems

[CNN]

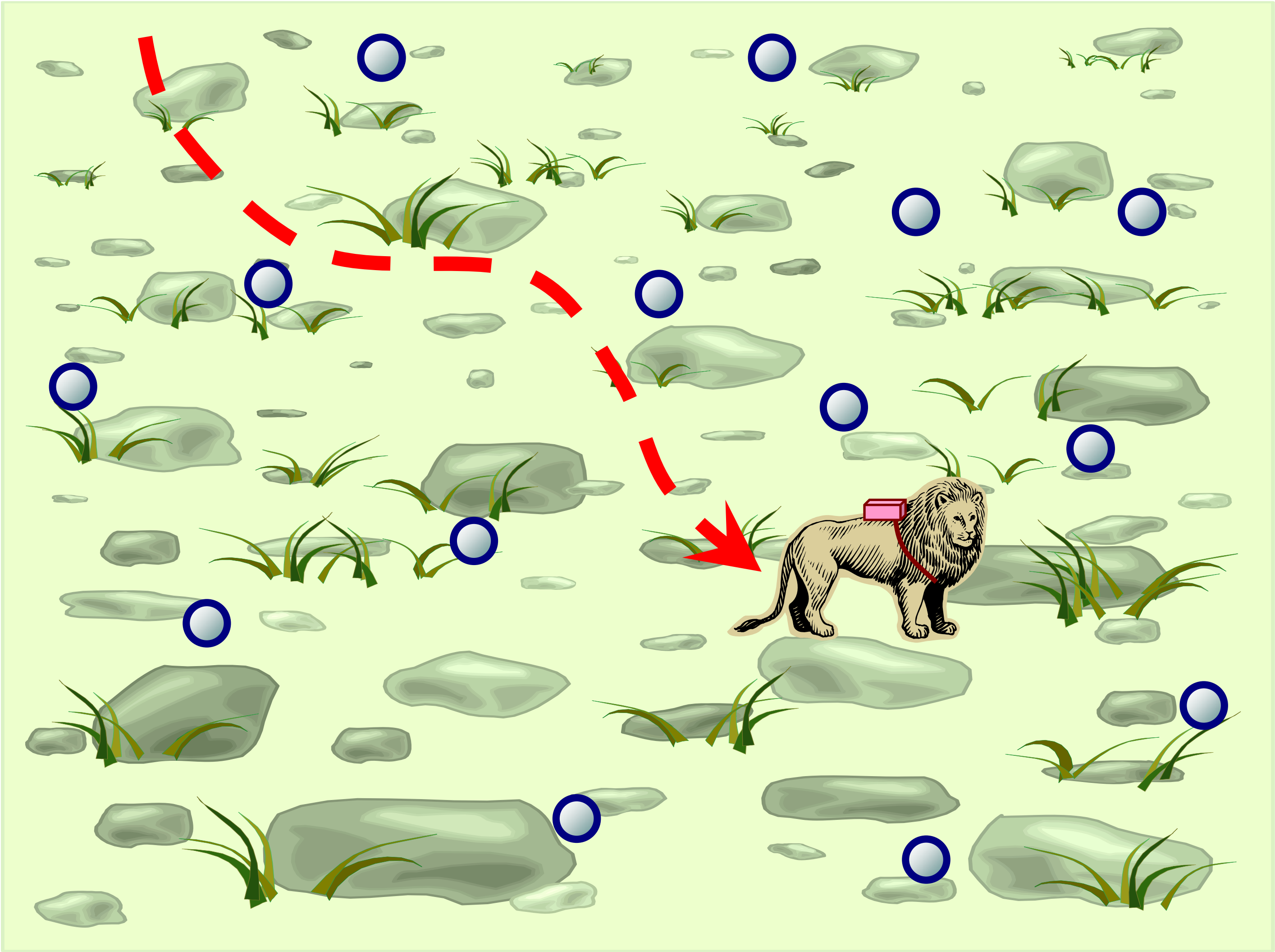
- Marine microorganisms impact:
  - Human health
  - Industries: fisheries and tourism.
- Problem becoming worse with human encroachment in coastal areas.
- Conditions under which aquatic microorganisms develop not understood.

ENS will provide the unprecedented spatial and temporal resolution needed to investigate causal relationships between environmental conditions and microorganisms

森林火警監控

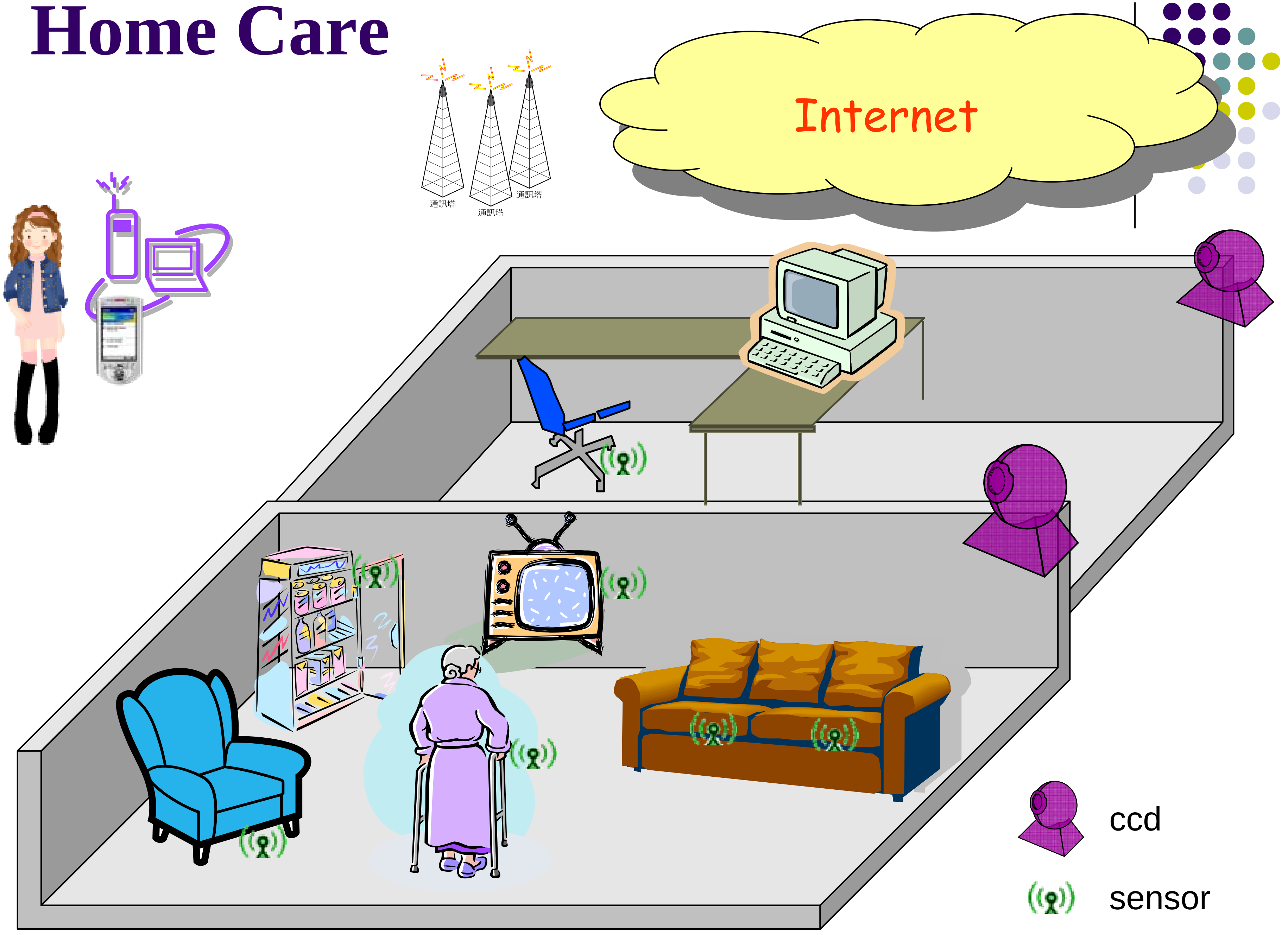


野生動物追蹤

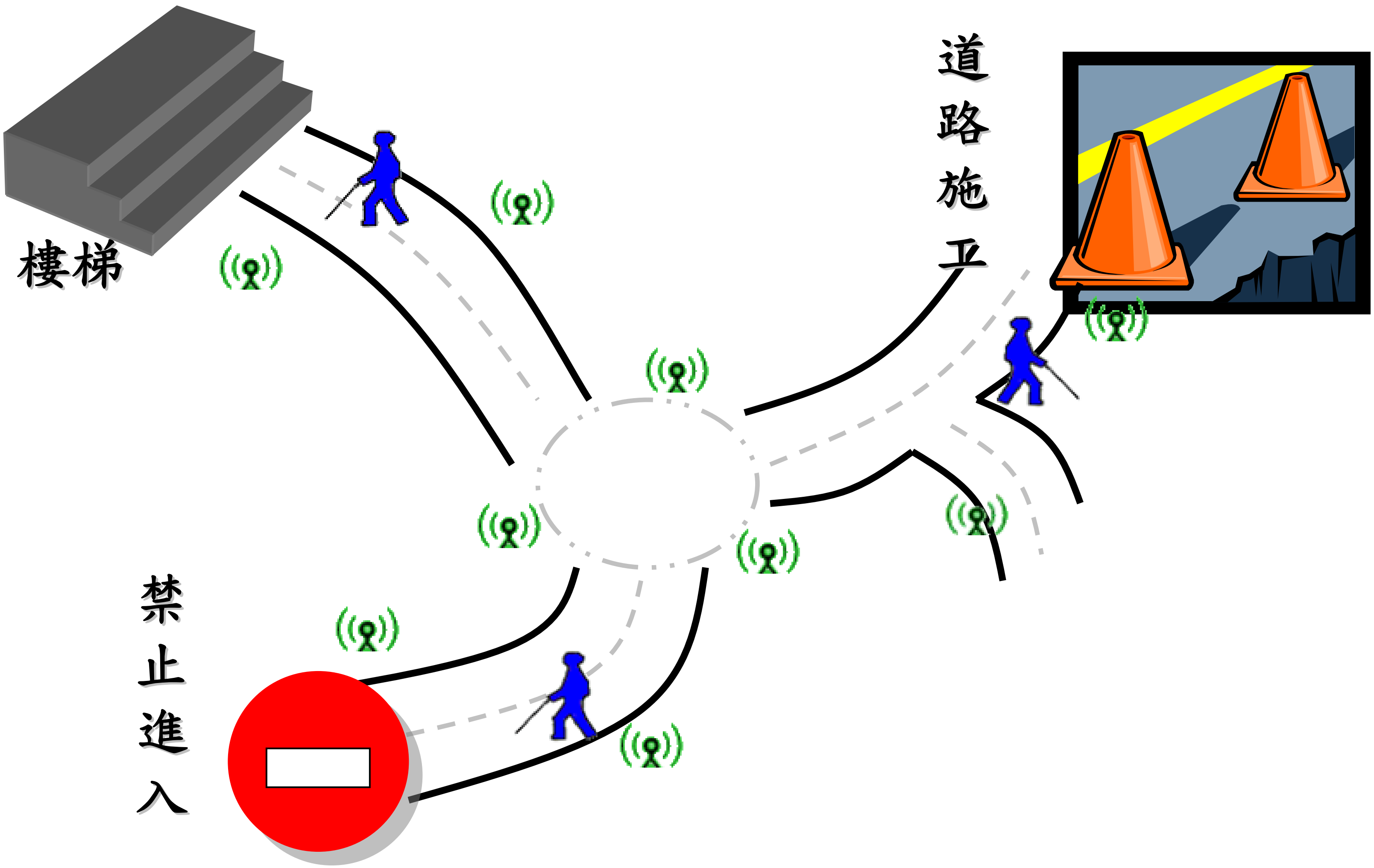


- Wireless sensor networks can replace the barriers

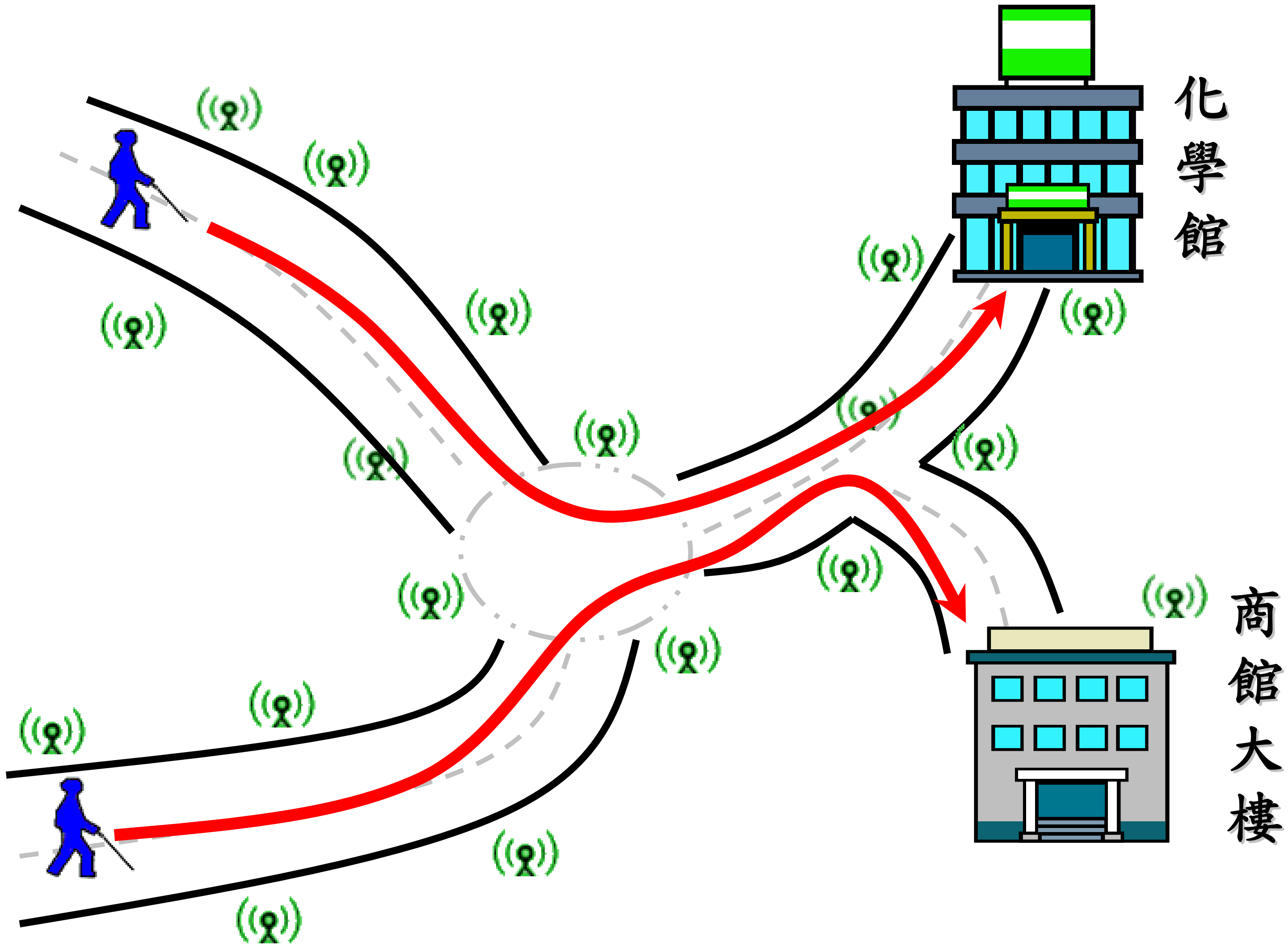
Home Care



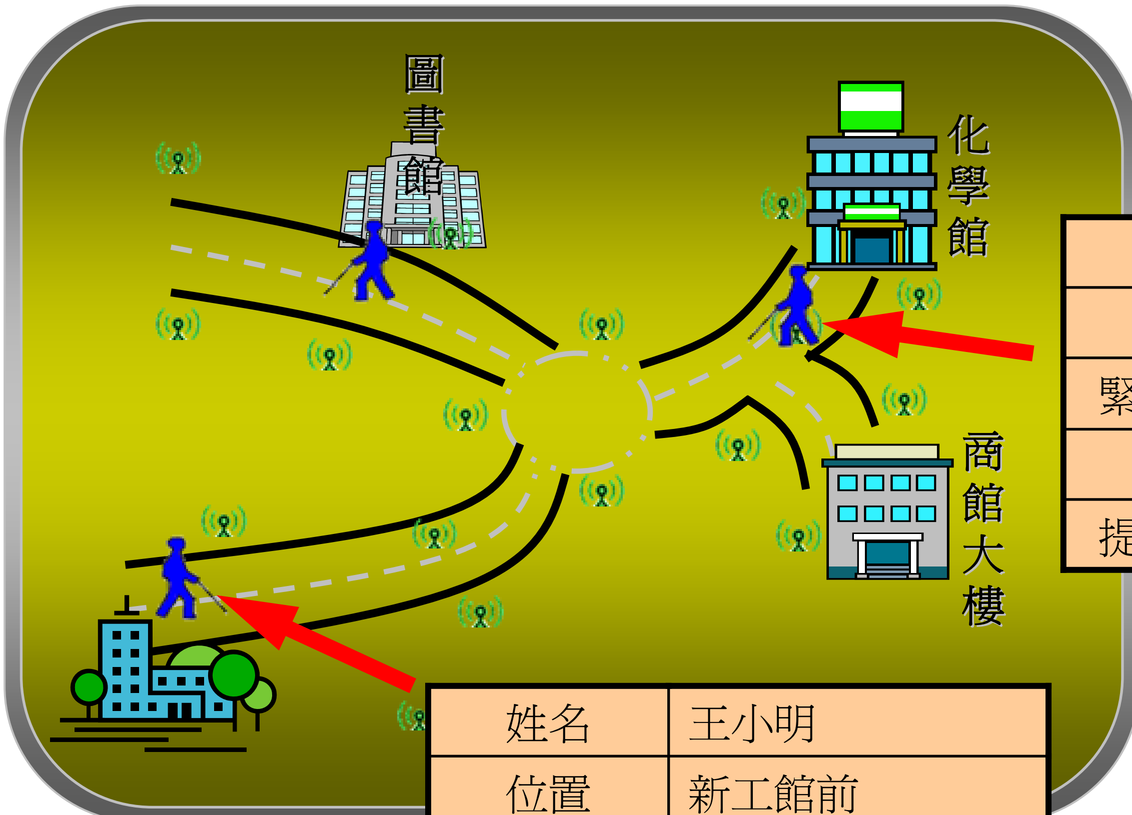
預警系統



導盲系統



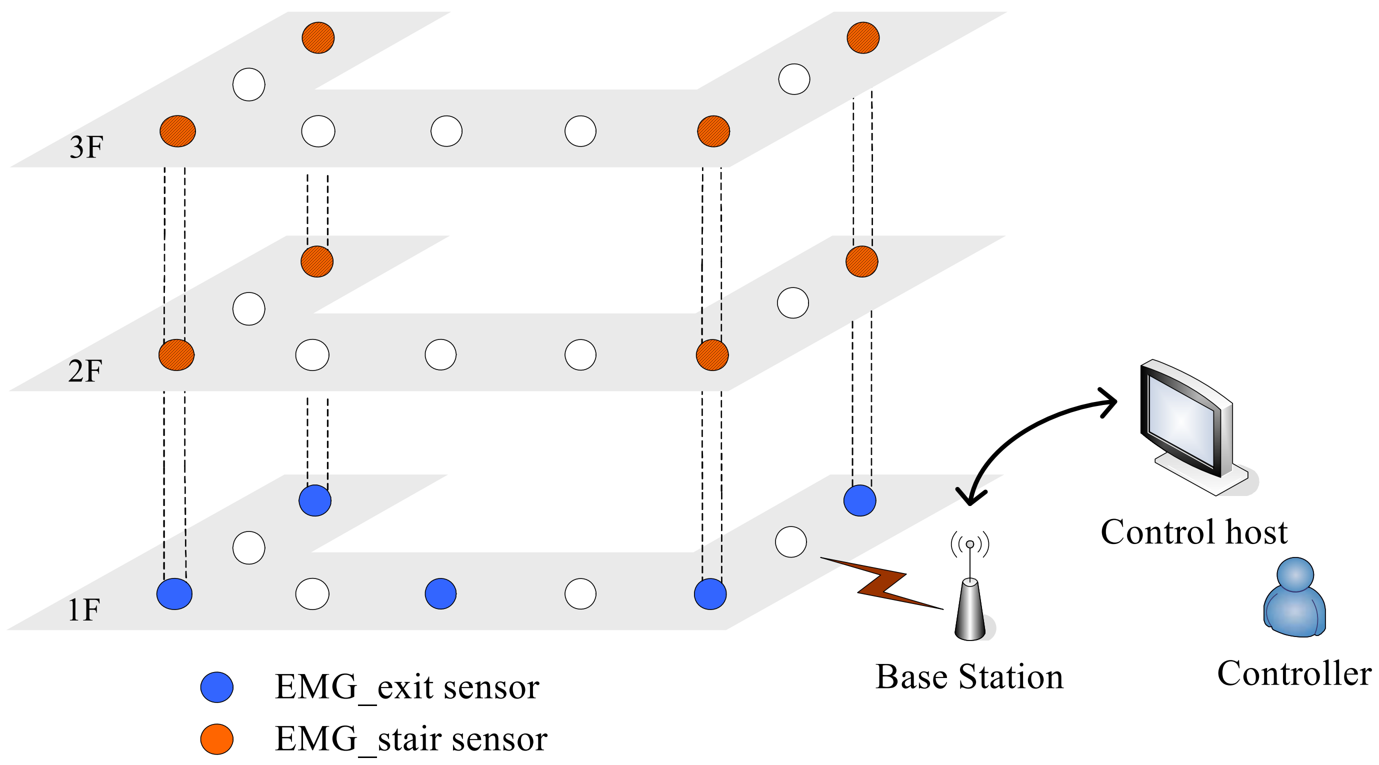
監控系統



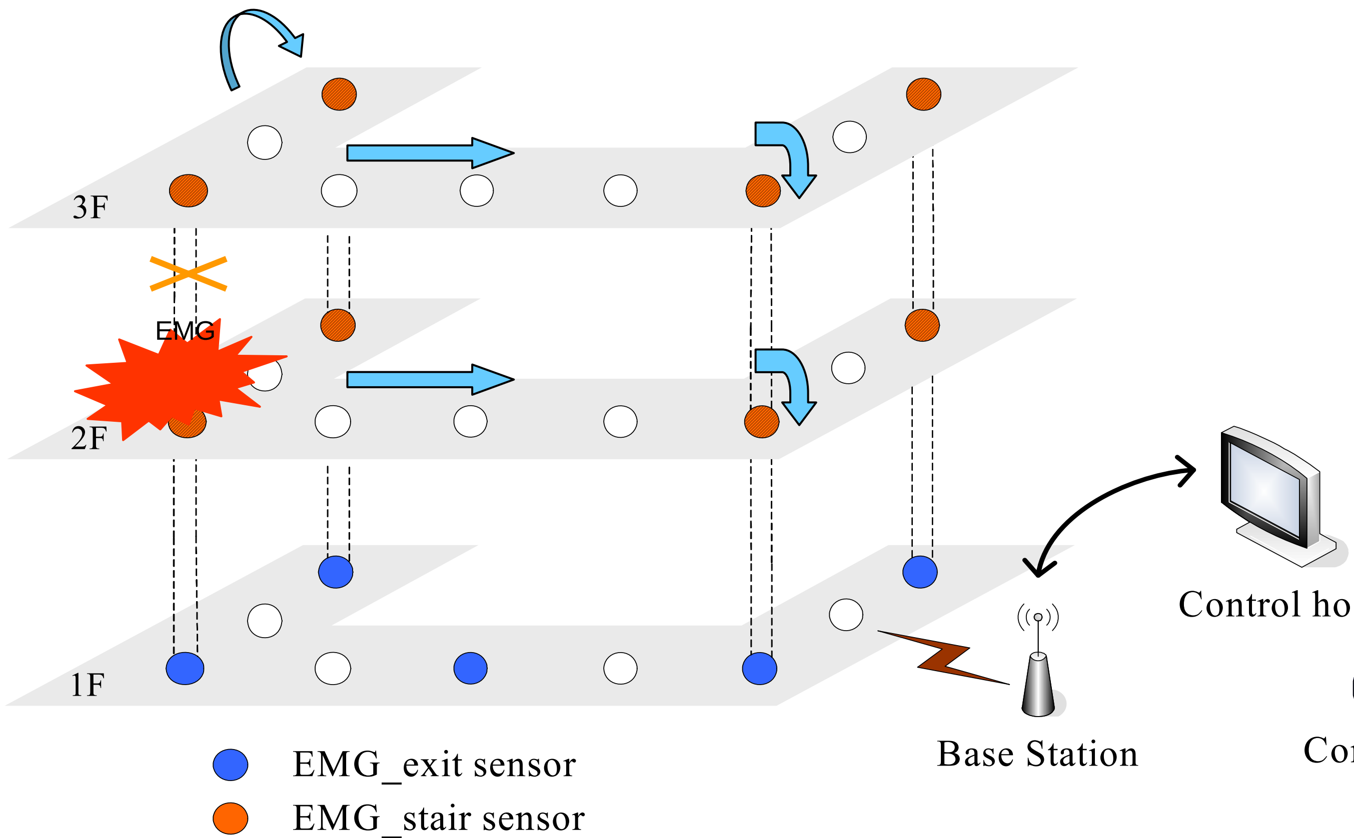
姓名	林阿水
位置	化學館前方100m
緊急連絡	0922-333111
…	
提醒事件	12:10至商館上課

姓名	王小明
位置	新工館前
緊急連絡	0933-111111
…	
提醒事件	12:10至商館上課

室內逃生路線導引


3F
2F
1F
EMG_exit sensor
EMG_stair sensor
Base Station
Control host
Controller

室內逃生路線導引

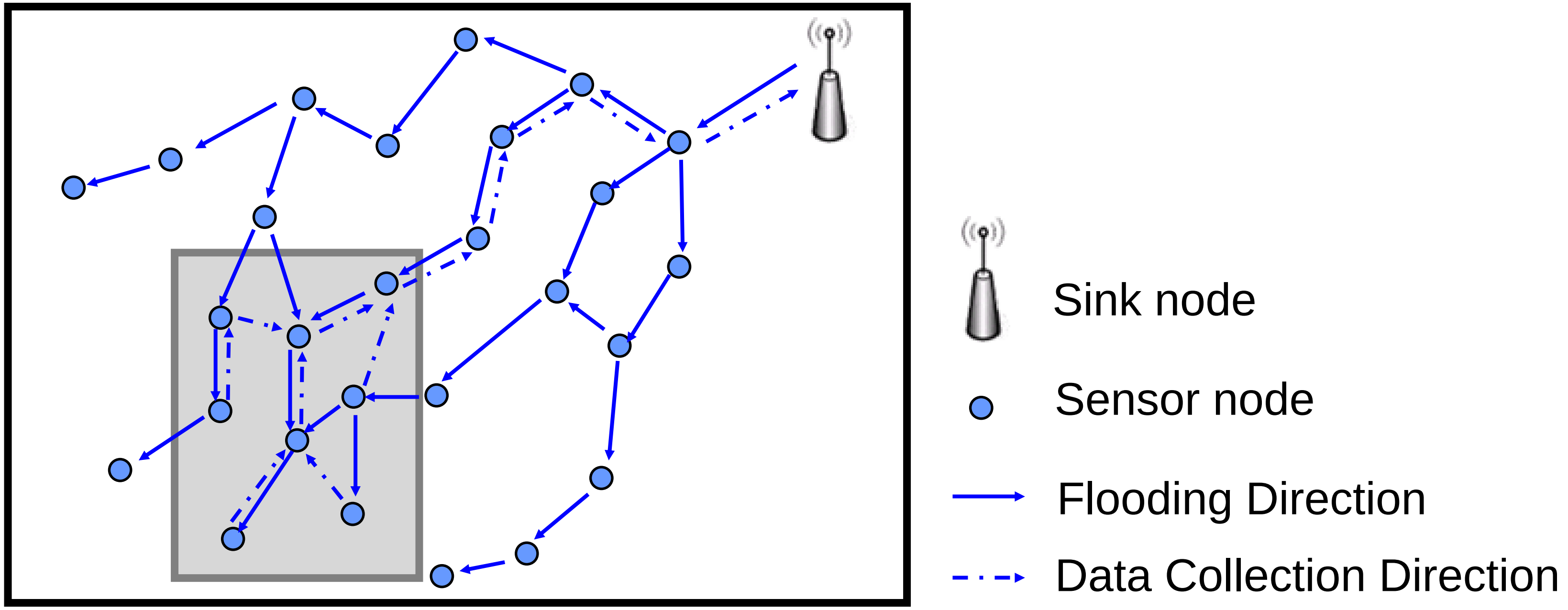

3F
2F
1F
EMG
Control host
Base Station
Controller
EMG_exit sensor
EMG_stair sensor

Wireless sensor networks

- Sensor Network
  - Sensor node: Small cache, low-speed CPU, wireless interface for transmission, battery, possibly with location information
  - Sink node
    - Control center of a sensor network where user can retrieve data gathered from sensor networks

Introduction

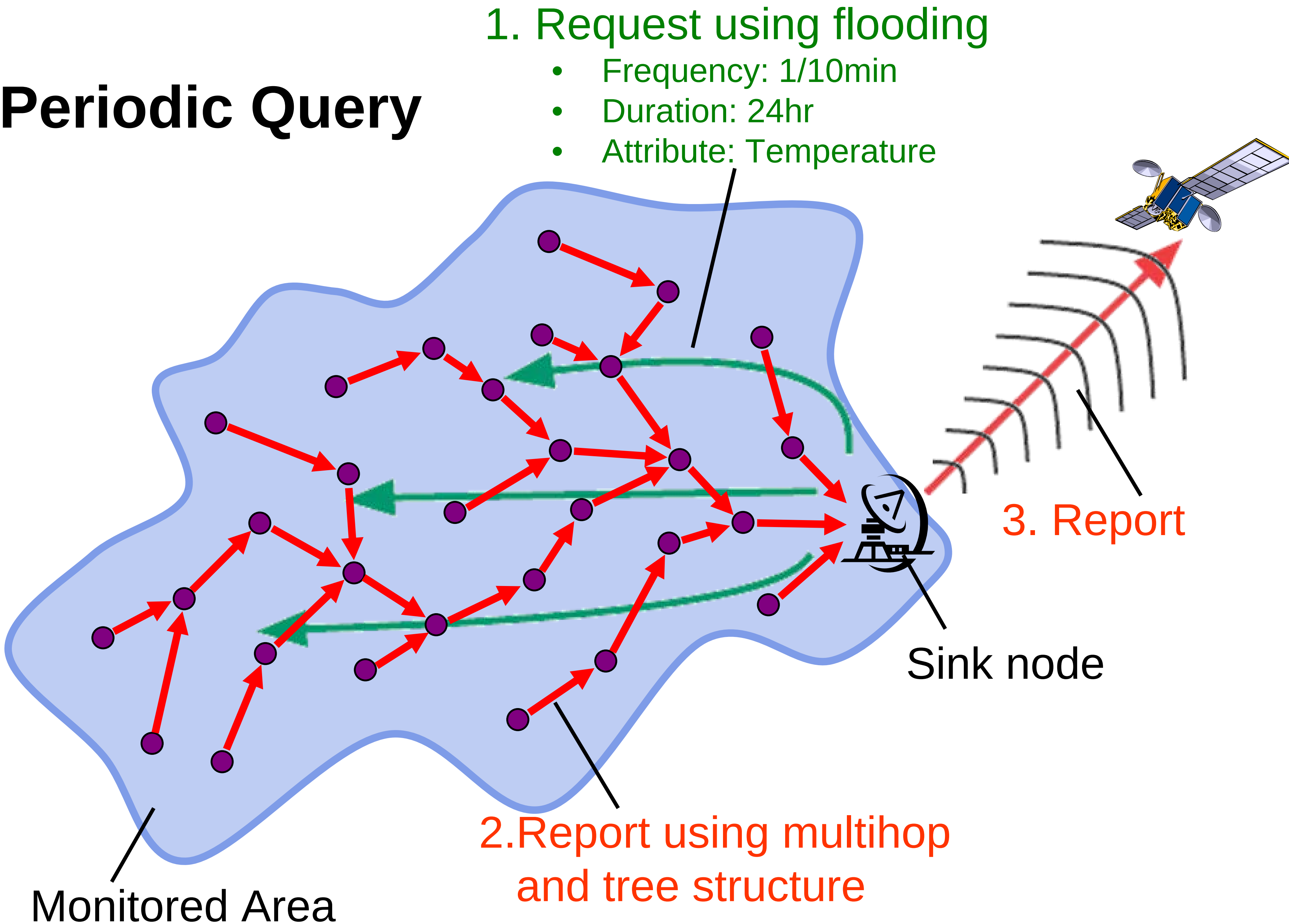
- Wireless Sensor Networks have been widely used in many applications
  - Environmental monitor
  - Military operations



Operating Category

- Periodic Query
  - Frequency: 10/hr
  - Attributes: Temperature/Pressure/Noise level/..
  - Region:(10,10)-(1000,1000)
  - Duration: 1 month
- Event-driven
  - Attributes
  - Region
  - condition

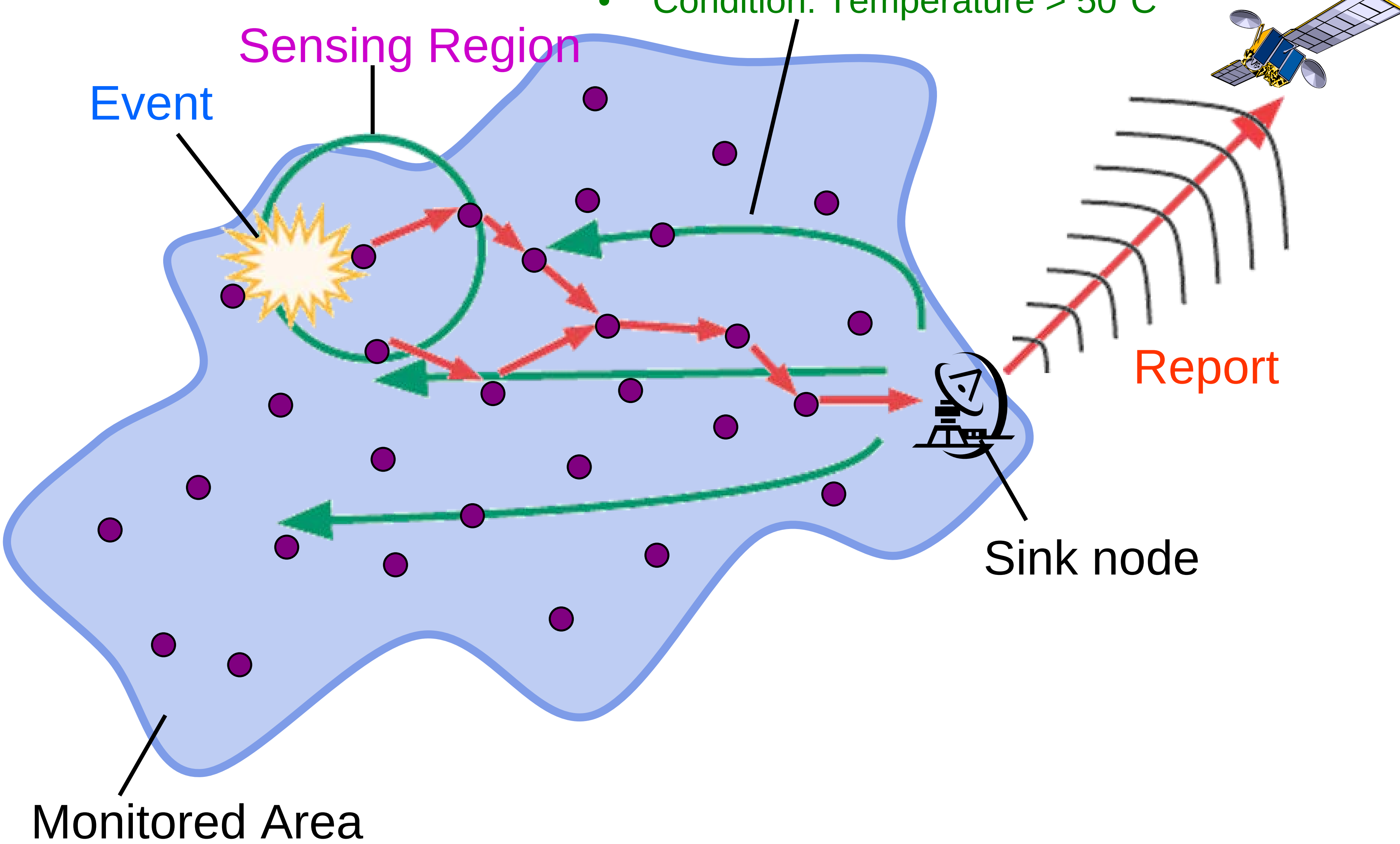
Periodic Query



Event-driven

Request using flooding

- Attribute: Temperature
- Duration: 2 years
- Condition: Temperature > 50^{o}C



Research Issues

- Deployment
  - Static/Mobile sensors
- Localization
- Communication
  - Network Layer Protocol
  - MAC Scheduling
    - Sleep-Wakeup
    - Contention
- Coverage
  - Hole problem/ K-cover
  - Target Coverage
  - Barrier Coverage

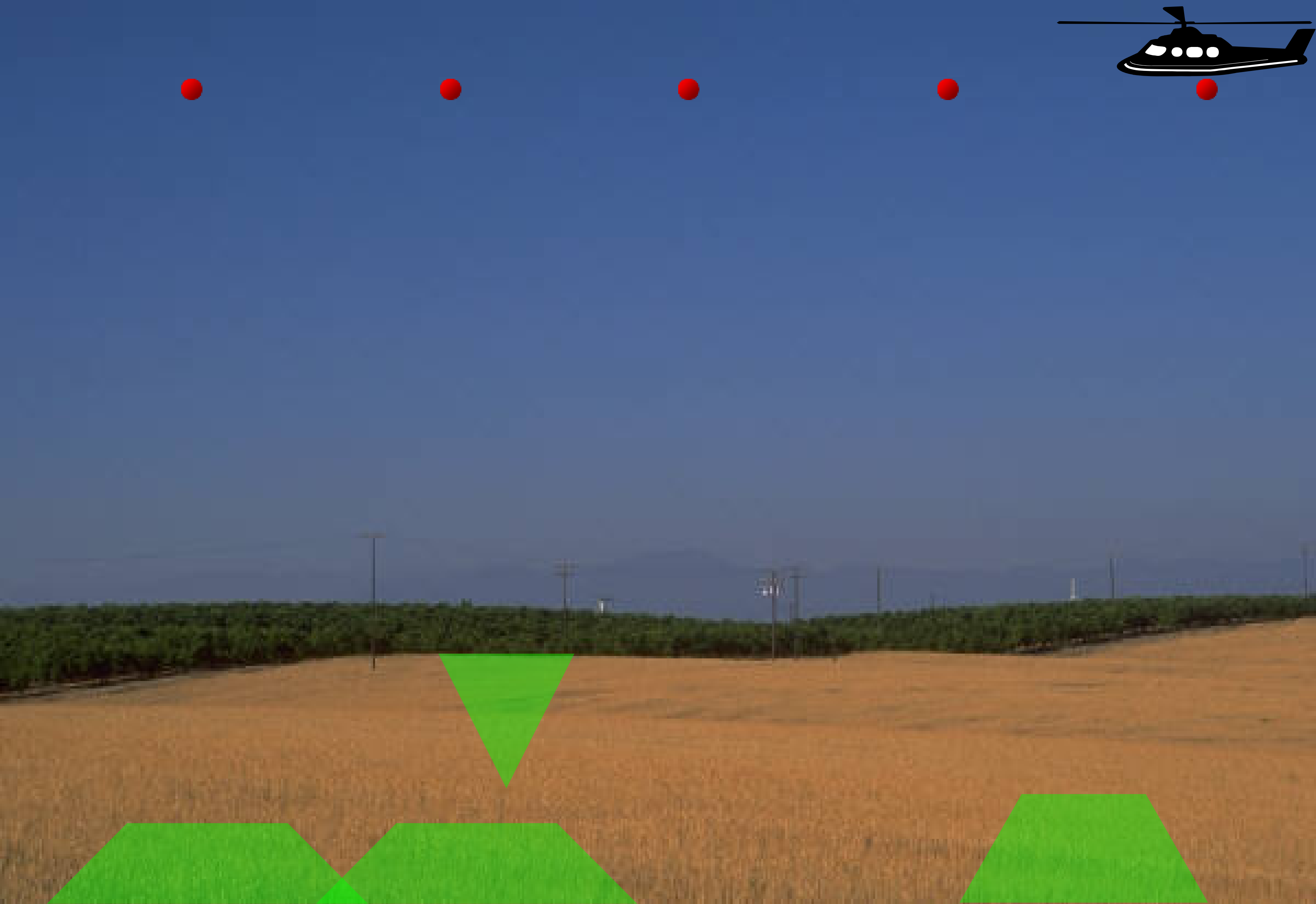
Outline

- Introduction to Wireless Sensor Networks
- Obstacle-Free Deployment Mechanism
- Obstacle-Free Routing Mechanism
- Conclusions

Network Deployment

- The coverage of a sensor network represents the quality of surveillance
- Existing deployment schemes
  - Random deployment
  - Mobile sensor
  - Robot deployment

Random Deployment



Deployment

- Random Deployment
  - Coverage Hole
  - A large number of sensor nodes (hardware cost)
- Mobile Sensors
  - Mobility overcomes hole problem
  - Hardware Cost

Robot Deployment

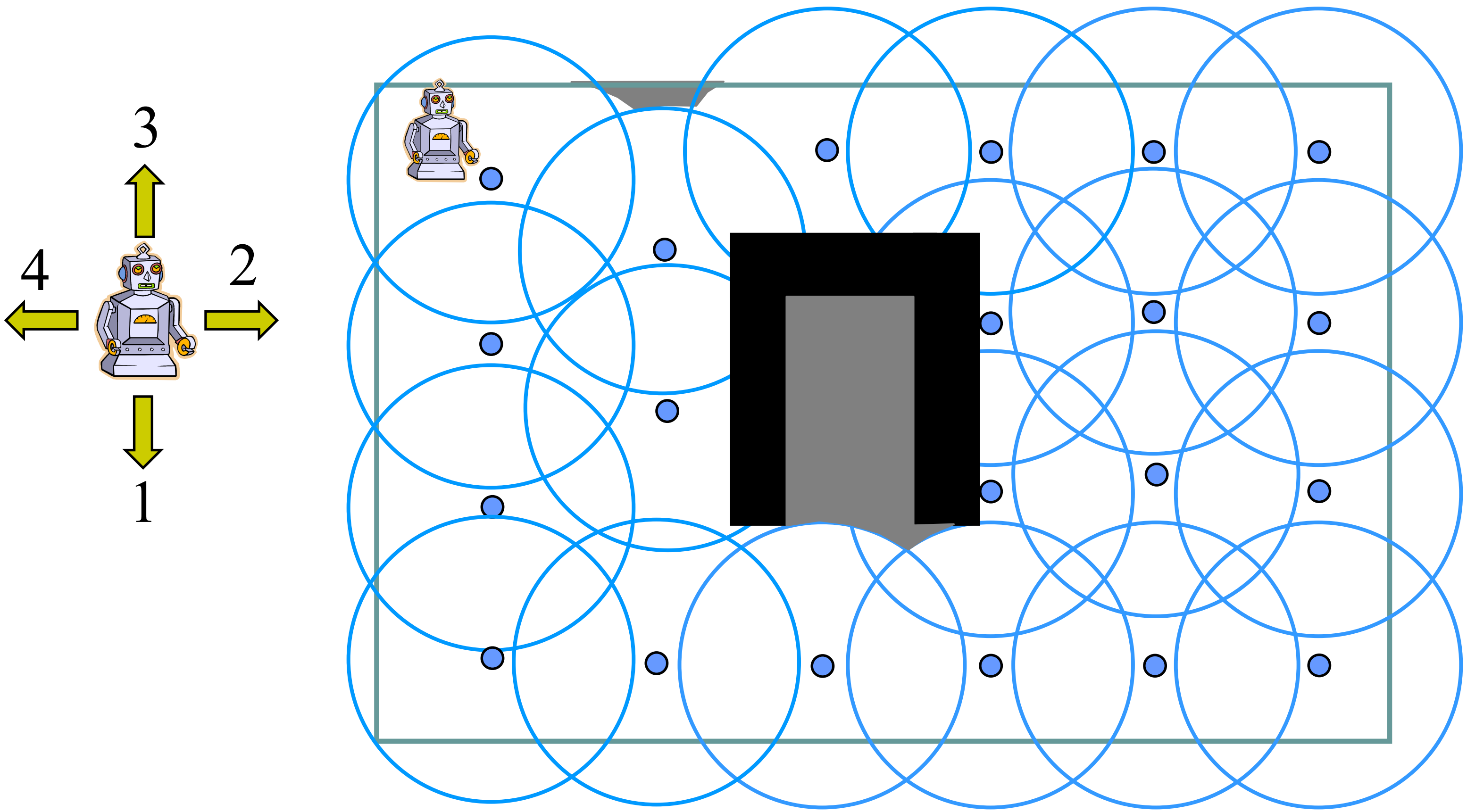
- Regularly deploy static sensor nodes
- Easy to obtain full coverage by using minimal number of static sensors
  - Low hardware cost
  - Easy and Simple

Related Work

- Title: Efficient Exploration Without Localization
- From: *IEEE International Conference on Robotics and Automation* (*ICRA*), May 2003
- Authors: M. A. Batalin and G. S. Sukhatme

- Title: The Design and Analysis of an Efficient Local Algorithm for Coverage and Exploration Based on Sensor Network Deployment
- From: *IEEE Transactions on Robotics*, 23(4):661-675, Aug 2007.

Related Work



Related Work

- Disadvantages
  - Deploy too many sensor nodes
  - Results holes if there exist obstacles

Obstacle-Free Robot Deployment Mechanism

- Published in *IEEE Wireless Communications and Networking Conference* (*IEEE WCNC*), Hongkong, March 2007.
- *Submitted to IEEE Transactions on Vehicular Technology (Minor Revision)*

Goals

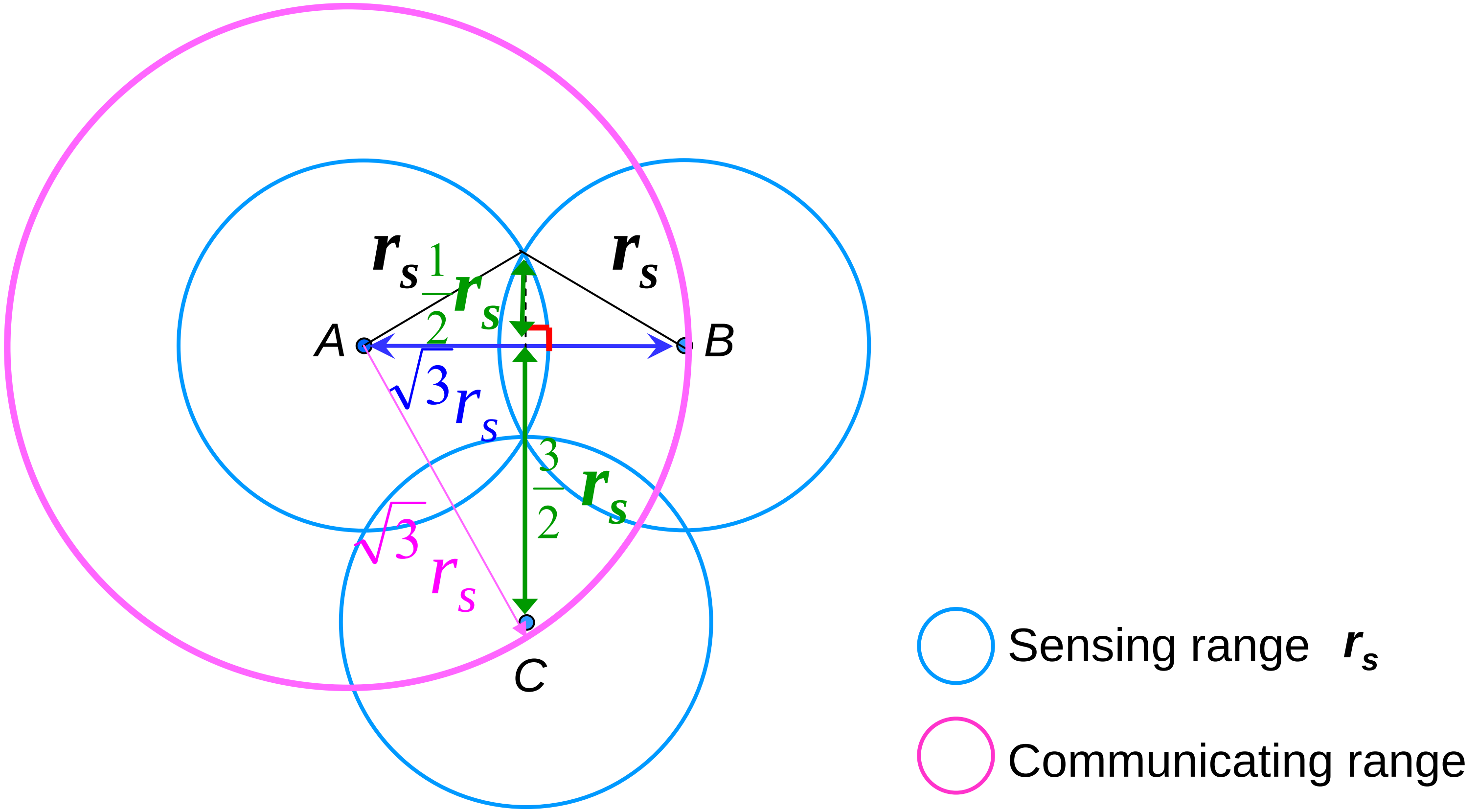
- **Network Deployment**
  - Use the minimal number of sensors
  - Achieve full coverage
  - Resist Obstacle

OFRD Mechanisms

- Environment
  - A single robot
    - limited static sensors
    - Compass
  - Static sensor nodes
    - Without location information
- Assumptions
  - The Robot is arranged in the boundary of WSN region
  - Sensors
    - Communication range $\geq \sqrt{3}$ sensing range

Overview

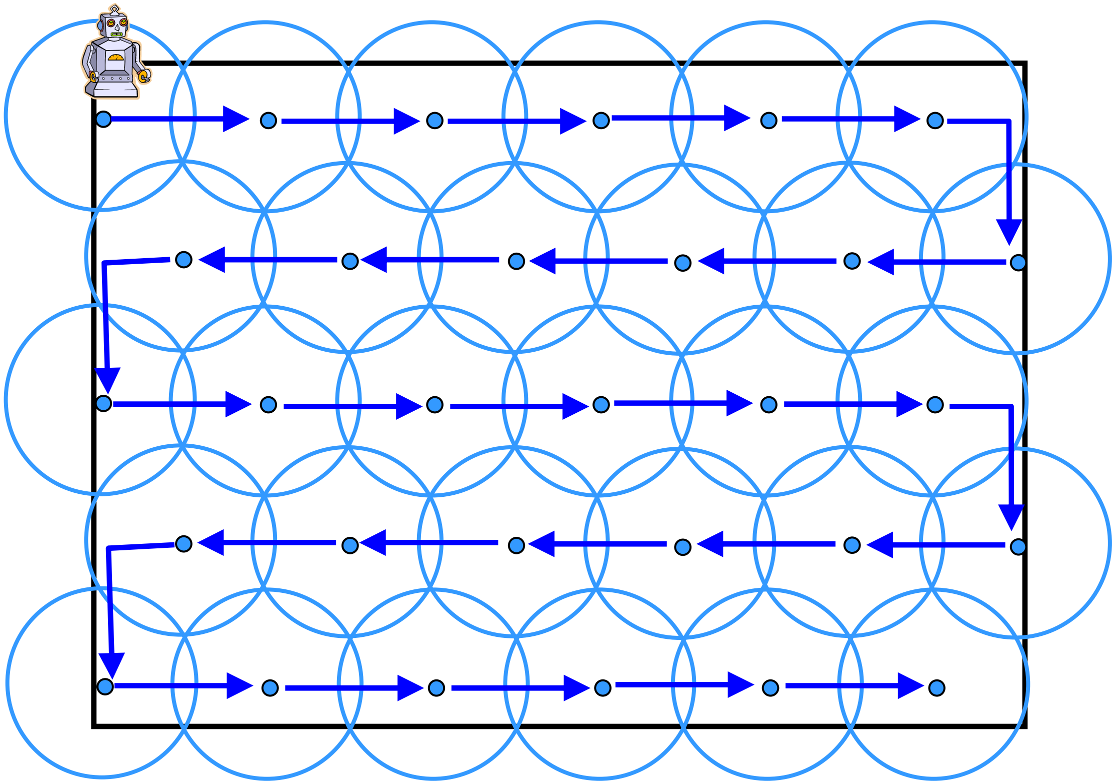
- *Obstacle-free deployment mechanism*



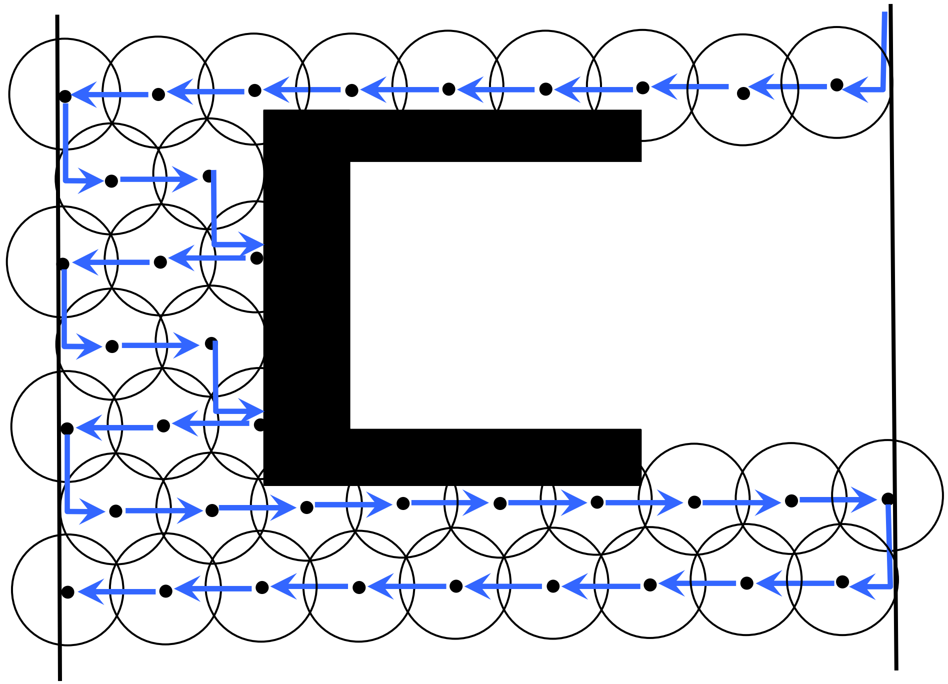
Overview

- OFRD Mechanism -

- *Obstacle-free deployment mechanism*
  - Snake-like deployment

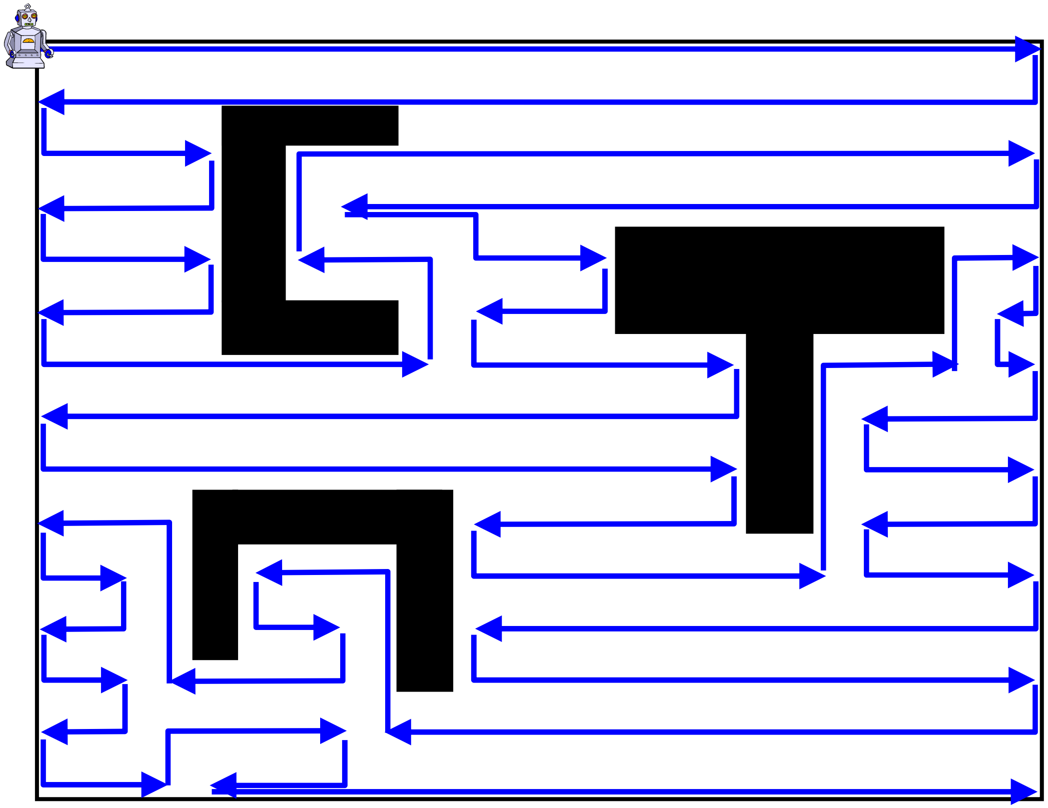


The impact of the existence of obstacles



Overview - OFRD Mechanism -

- *Obstacle-free deployment mechanism*
  - Overcome obstacle environment



The Obstacle-Free Robot Deployment

- Problem Statement
  - Given a region of monitoring area, how to use robot to
    - Deploy minimal number of static sensors
    - Achieve full coverage
    - Overcome obstacle

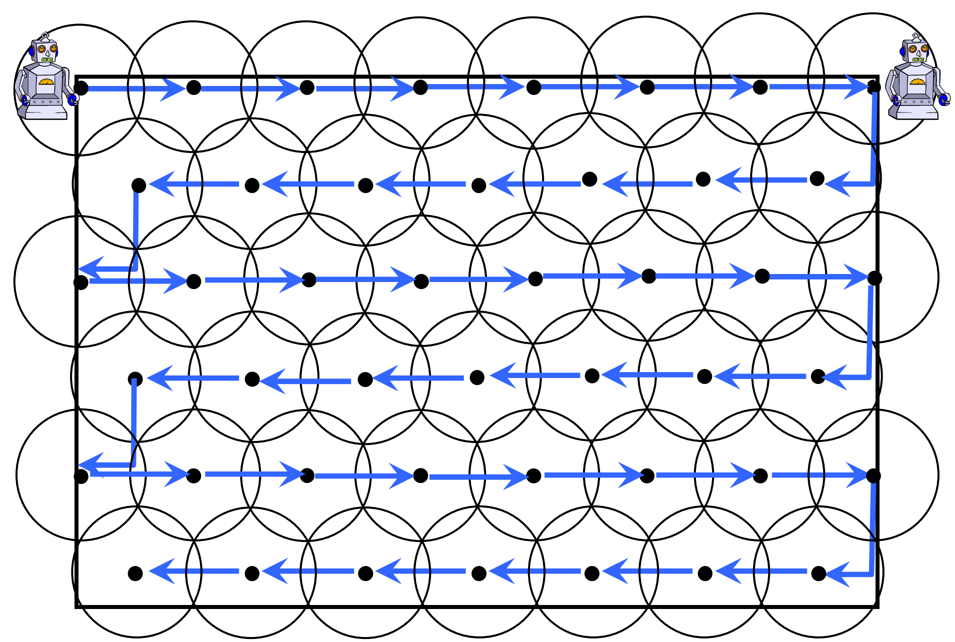
Obstacle-free deployment mechanism

- Snake-like Deployment
  - Prefer Directions for snake-like deployment

Switch state

States	Prefer Direction 1	Prefer Direction 2
East	→	↓
West	←	↓

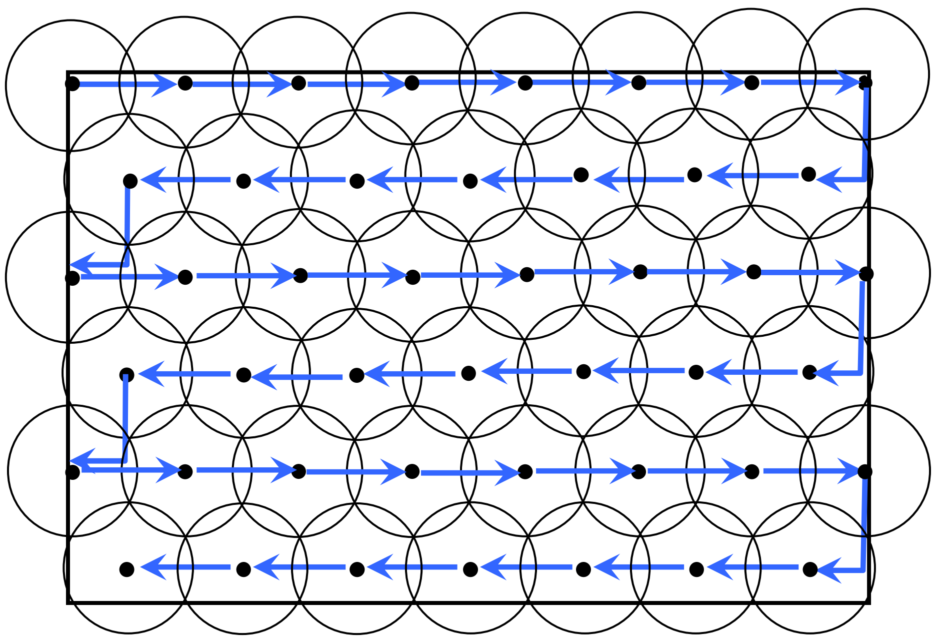
states	Prefer Direction 2	
East	↳	↵
West	↵	↳



Obstacle-free deployment mechanism

- Snake-like Deployment
  - Prefer Directions for snake-like deployment

States	Prefer Direction 1	Prefer Direction 2	
East	→	↳	↵
West	←	↵	↳



Snake-like movement rules

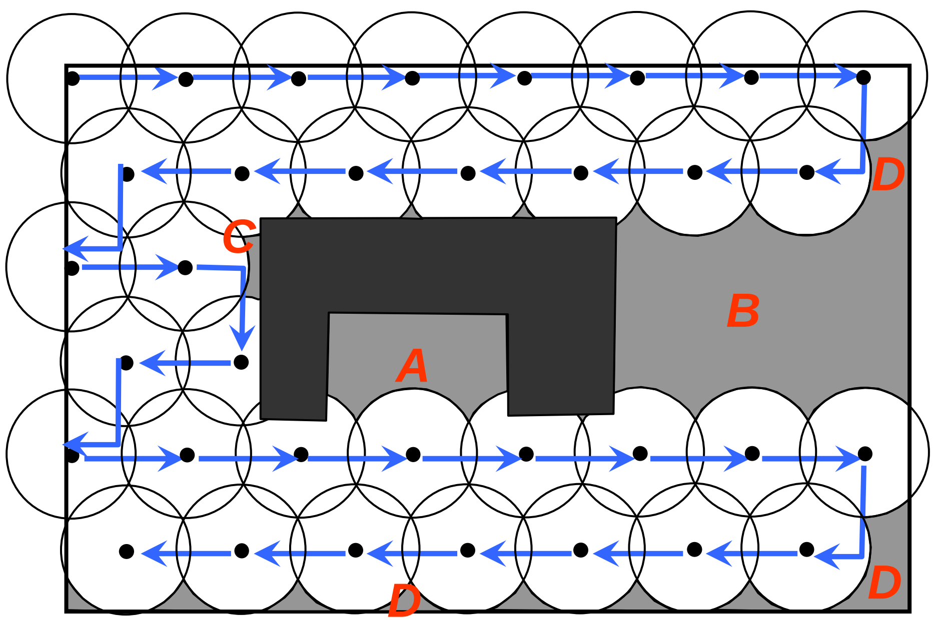
- ***Rule* 1**: The robot checks Prefer Direction 1 for possible movement. If the try in this direction is failure, the robot executes Rule 2. Otherwise, the robot moves toward the Prefer Direction 1 for a distance of $\sqrt{3}r_s$.

- ***Rule* 2:** The robot checks Prefer Direction 2 for possible movement. If the try in this direction is failure and the deployment is not terminated, the robot will go back to the location of previous deployed sensor and checks the four rules again in order. Otherwise, the robot moves toward to the Check Direction 2 for a distance of $\sqrt{3}r_s$.

States	Check Direction	Prefer Direction 1	Prefer Direction 2	
East	↑	→	↳	↵
West	↑	←	↵	↳

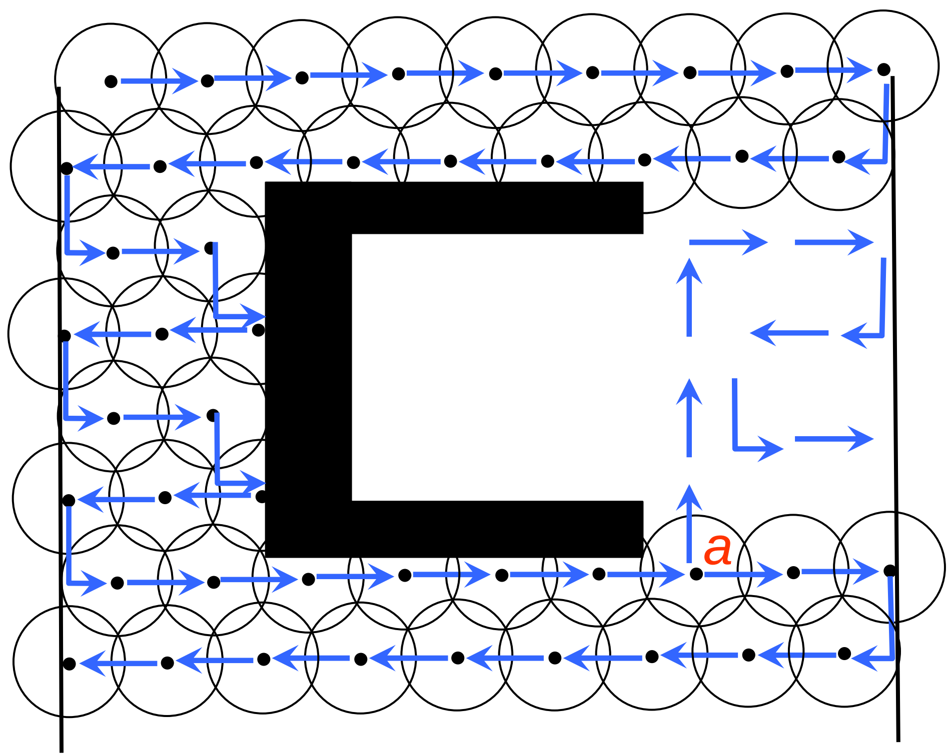
States	Check Direction
East	↑
west	↑

States	Prefer Direction 1	Prefer Direction 2	
East	→	↳	↵
West	←	↵	↳



Obstacle-free deployment mechanism

States	Check Direction	Prefer Direction 1	Prefer Direction 2	
East	↑	→	↳	↵
West	↑	←	↵	↳



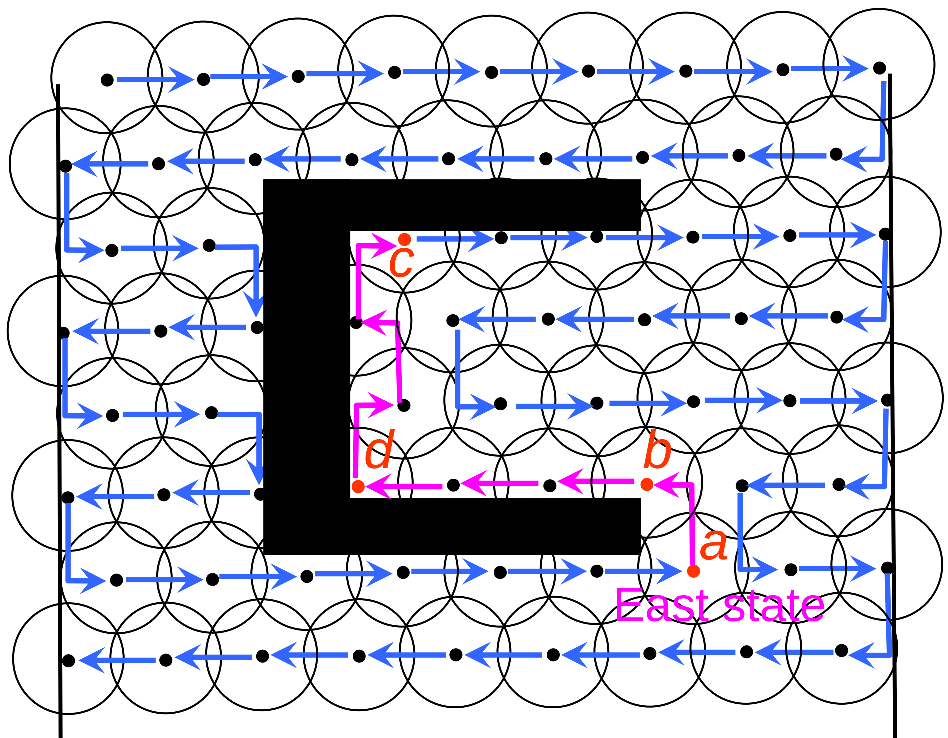
East state

States	Check Direction	Check Direction	Prefer Direction 1	Prefer Direction 2	
East	←	↑	→	↳	↲
West	→	↑	←	↲	↳

States	Check Direction
East	←
west	→

States	Check Direction	Prefer Direction 1	Prefer Direction 2	
East	↑	→	↳	↲
West	↑	←	↲	↳

states	Check Direction 2	
East	↰	↱
West	↱	↰



Obstacle-handling rules

- ***Rule*** **3**: The robot checks Check Direction 1 (which is opposite direction to Prefer Direction 1) for possible movement. If the try in this direction is failure, the robot executes the next rule. Otherwise, the robot will move toward to the Check Direction 1 for a distance of $\sqrt{3}\,r_s$.

- ***Rule*** **4**: The robot tries to move in Check Direction 2. If the try in this direction is failure, the robot checks Rule 2 subsequently. Otherwise, the robot moves toward the Check Direction 2 for a distance of $\sqrt{3}\,r_s$.

Obstacle-free deployment mechanism

- Obstacle-free snake-like movement rule

	For obstacle-free			For snake-like movement		
	Priority 1	Priority 2		Priority 3	Priority 4	
States	Check Direction 1	Check Direction 2		Prefer Direction 1	Prefer Direction 2	
East	←	↰	↱	→	↳	↵
West	→	↱	↰	←	↵	↳

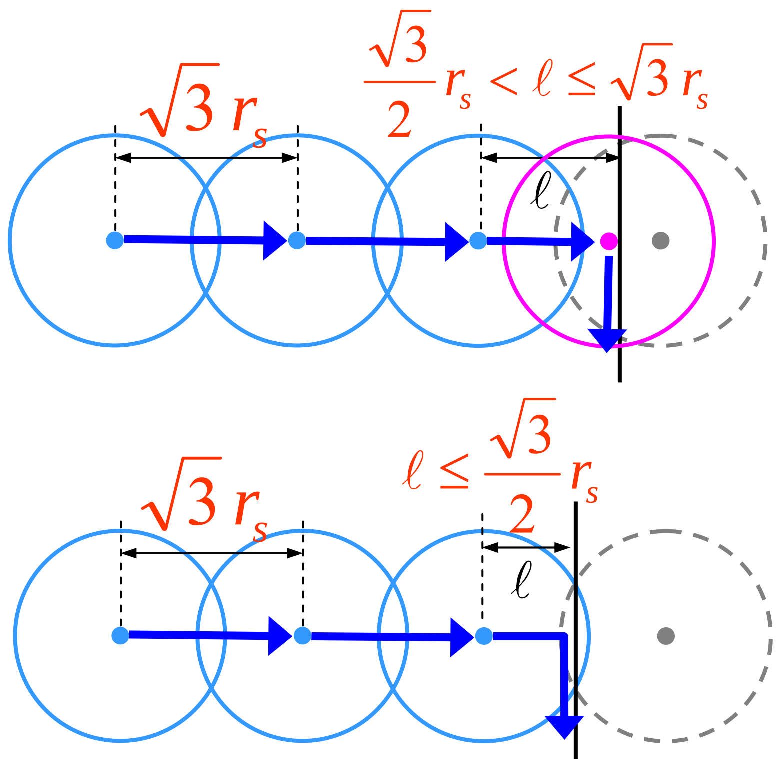
Obstacle-free deployment mechanism

- To achieve full coverage, some boundary problems should be considered

Obstacle-free deployment mechanism

- Boundary Problems
  - Vertical problem
    - East or West

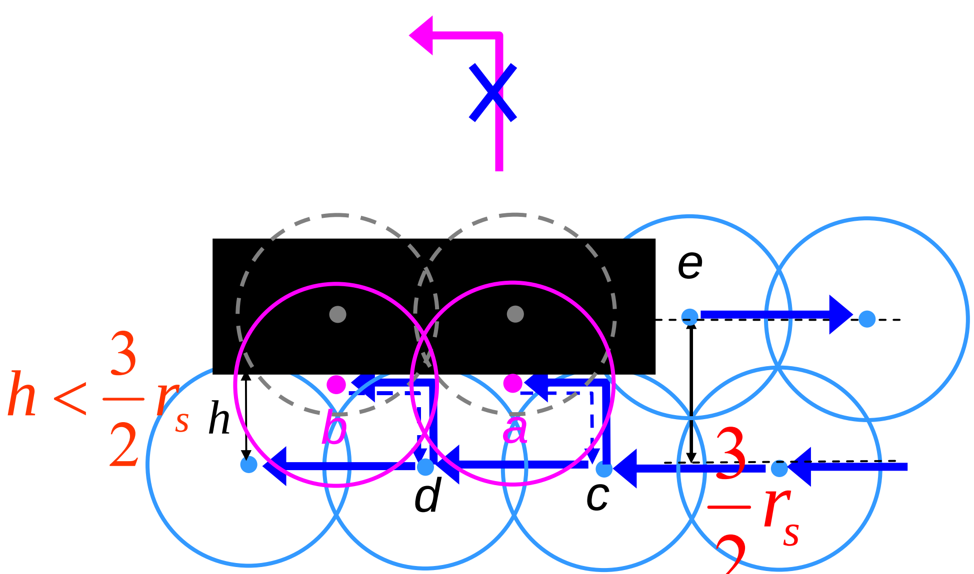
States	Check Direction 1	Check Direction 2		Prefer Direction 1	Prefer Direction 2	
East	←	↰	↱	→	↳	↵
West	→	↱	↰	←	↵	↳

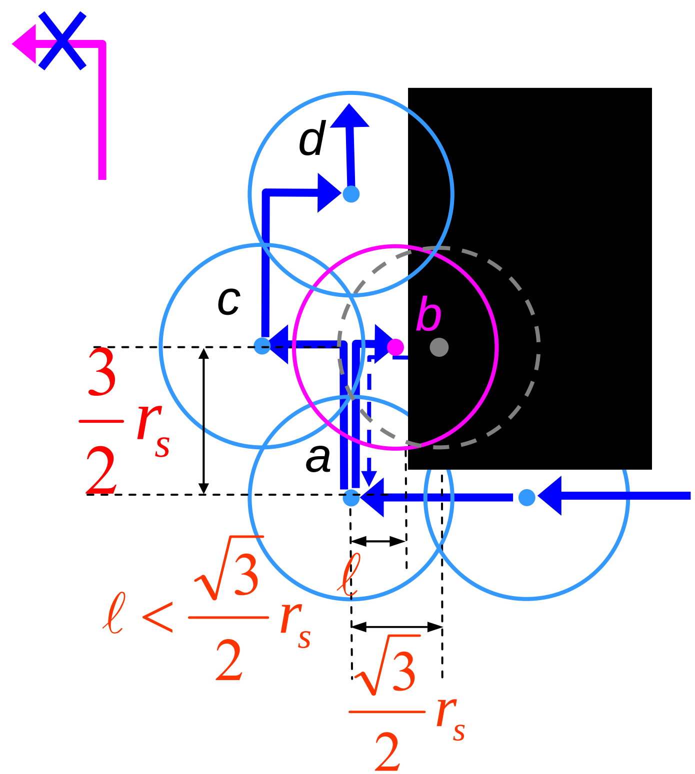


Obstacle-free deployment mechanism

- Boundary Problems
  - Vertical problem
    - North and South

States	Check Direction 1	Check Direction 2		Prefer Direction 1	Prefer Direction 2	
East	←	↰	↱	→	↳	↵
West	→	↱	↰	←	↵	↳





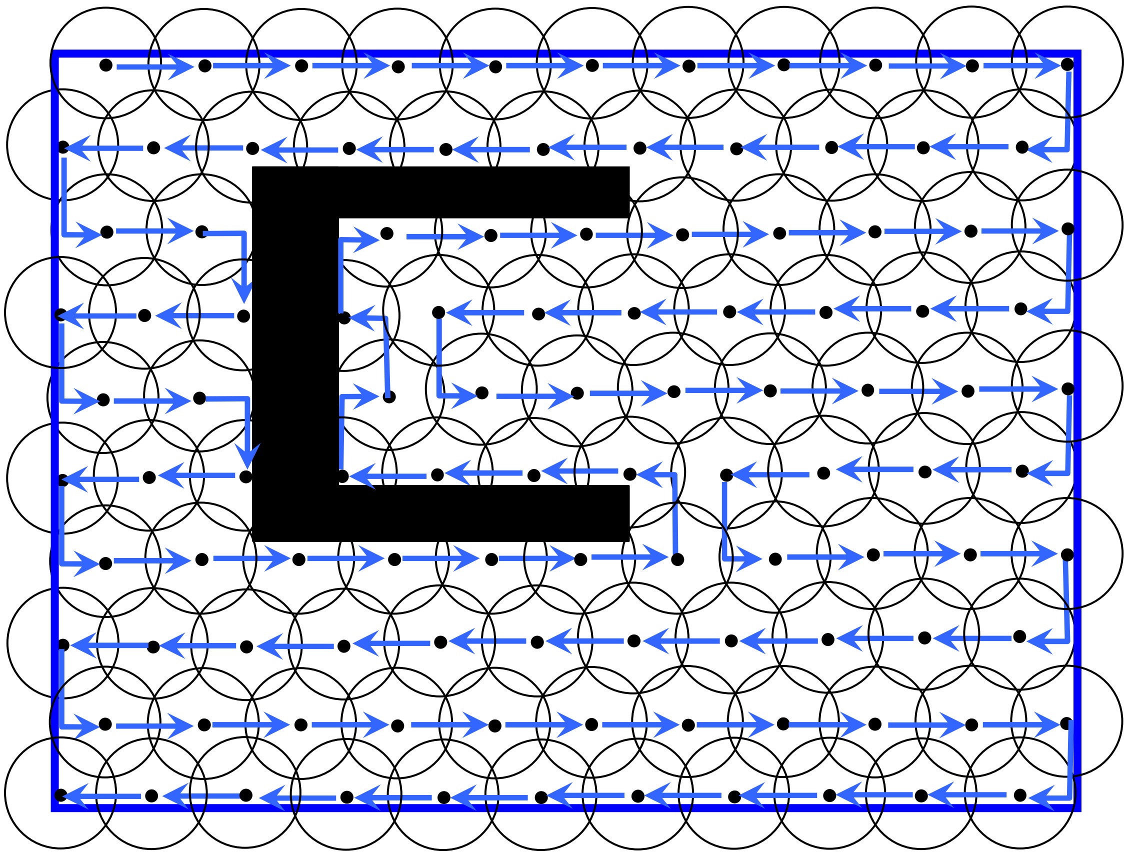
Boundary-handling rules

- ***BRule1***: If $(\sqrt{3}/2)r_s < l < \sqrt{3}r_s$, the robot will deploys a sensor nearby the boundary. Otherwise, the robot is not necessary to deploy a sensor nearby the boundary. The robot then goes back to $s1.loc$.

- ***BRule2***: If $(1/2)r_s < l < (\sqrt{3}/2)r_s$, the robot should deploy a sensor nearby the boundary or obstacle. Otherwise, the robot is not necessary to deploy any sensor. Then the robot goes back to $s1.loc$.

Obstacle-free deployment mechanism

- Final deployment



Algorithm: ***OFRD***

Input: A given monitoring region which might contains obstacles. A robot that carries static sensors is located in the region.

Output: A region that has been deployed with the near minimal number of sensors and has achieved full coverage.

```
while there is an uncovered hole do
    Rule1.execute
        if Rule1.success = false then
            BRule1.execute
            Rule2.execute
            if Rule2.success = false then
                BRule2.excute
                Rule3.execute
                if Rule3.success = false then
                    BRule1.execute
                    Rule4.execute
                    if Rule4.success = false then
                        BRule2.execute
                    Else
                        switch the state
                    end if
                end if
            end if
        end if
end while
```

Obstacle-handling

Snake-like movement

Simulation Results of OFRD Mechanism

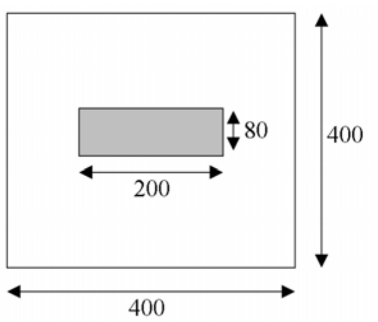
Simulation Parameters

-Refer to [19][20]-

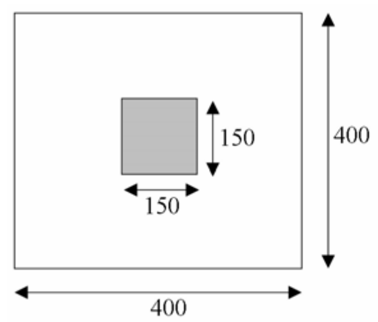
Parameter	value
Total energy of the robot	64800J
The speed of the robot	3m/s
The mobility cost of the robot	8.267J/m
The network size	400*400m^2
Communication range	40m
Sensing range	20m
Packet transmission cost	0.075J/s
Packet reception cost	0.030J/s
Idle cost	0.025J/s
Maximum energy consumption in motes	324J/hr
Total initial energy of sensor	32400J (100hr)

Obstacles with various shapes

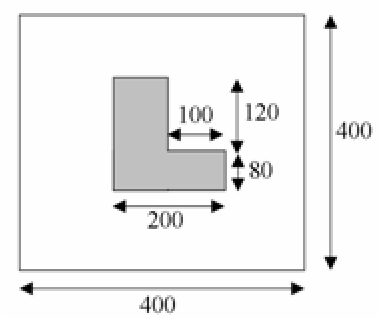
-OFRD mechanism-



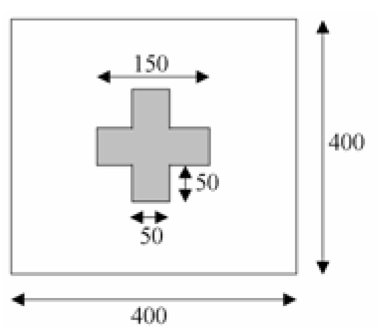
(a) Rectangle obstacle



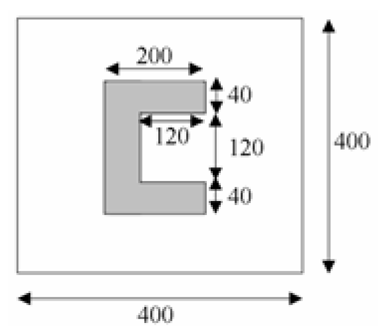
(b) Square obstacle



(c) X-shape obstacle

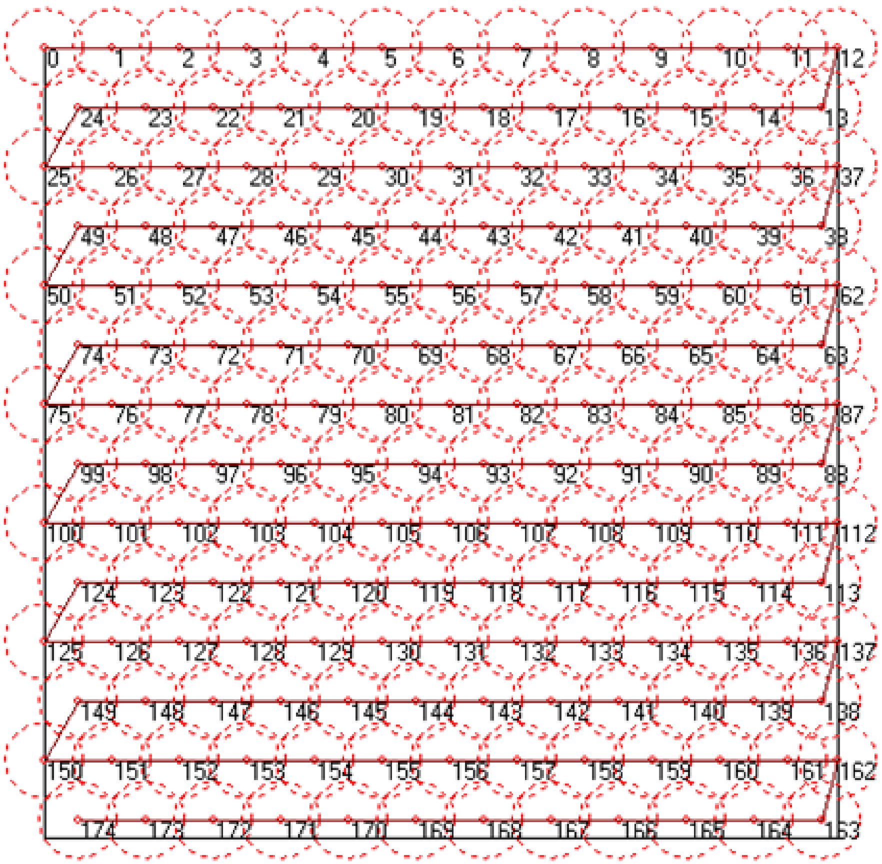


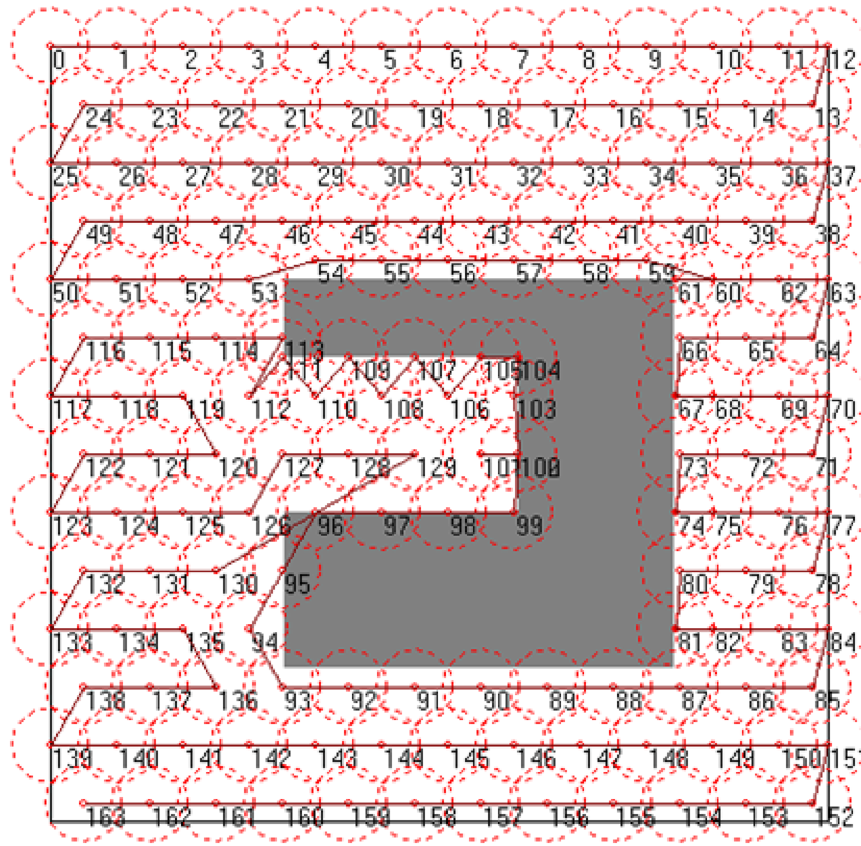
(d) L-shape obstacle



(e) C-shape obstacle

Simulation Results

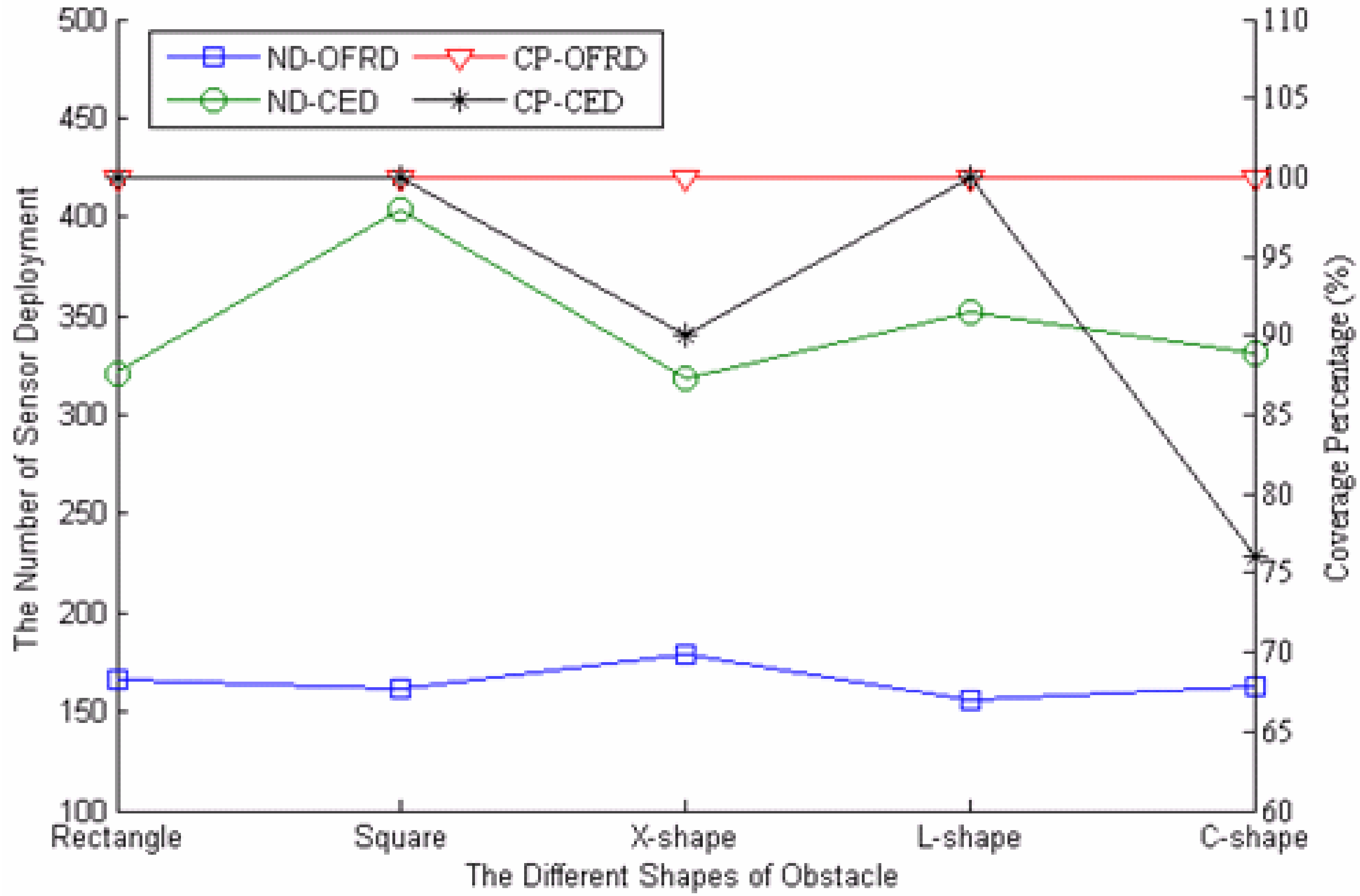




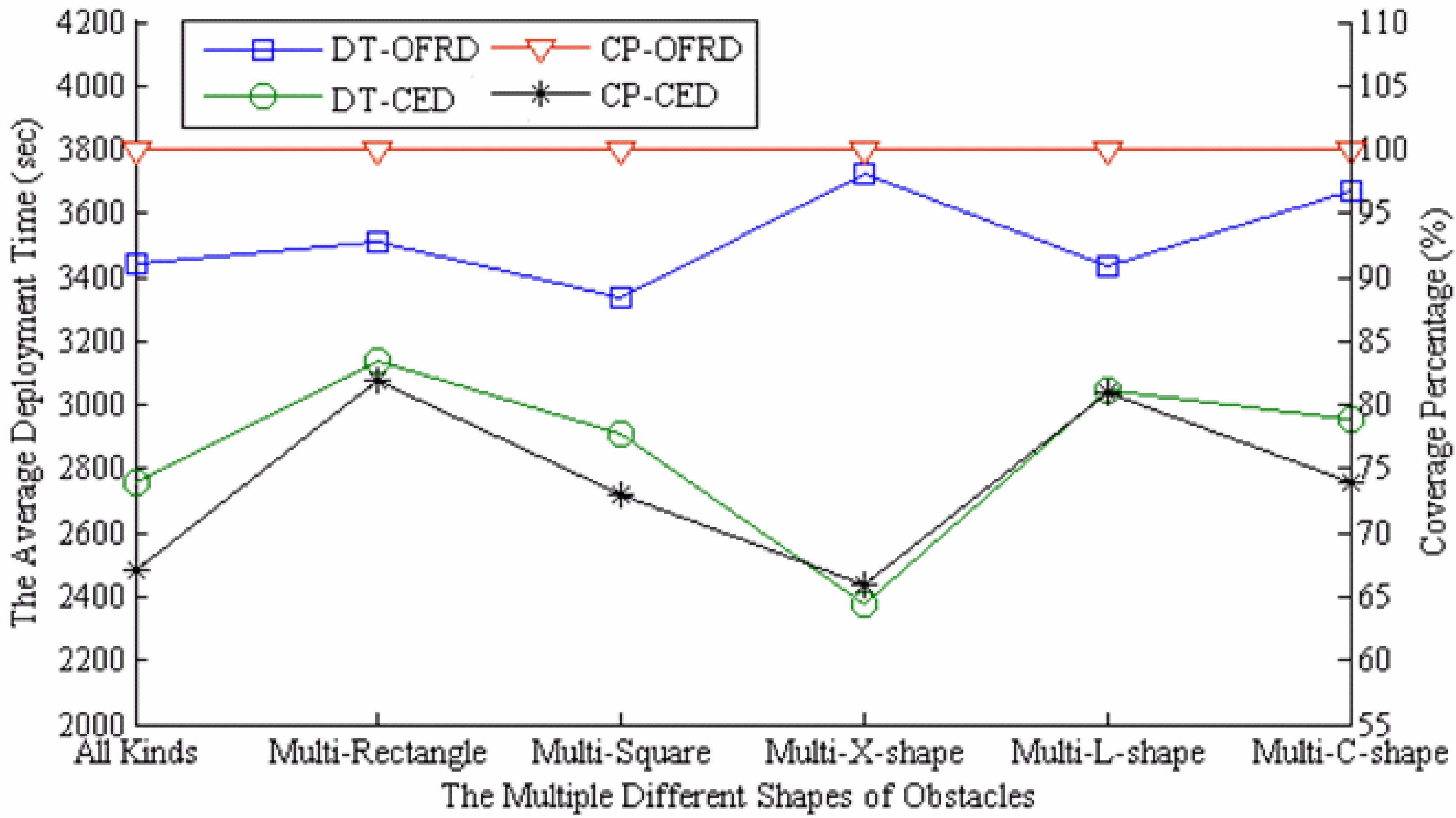
Simulation Results

Number of deployed sensor nodes in different environments						
	No obstacle	**Rectangle obstacle**	**Square obstacle**	**X-shape obstacle**	**L-shape obstacle**	**C-shape obstacle**
OFRD	174	166	162	171	160	163
CED	400	321	404	388	364	370

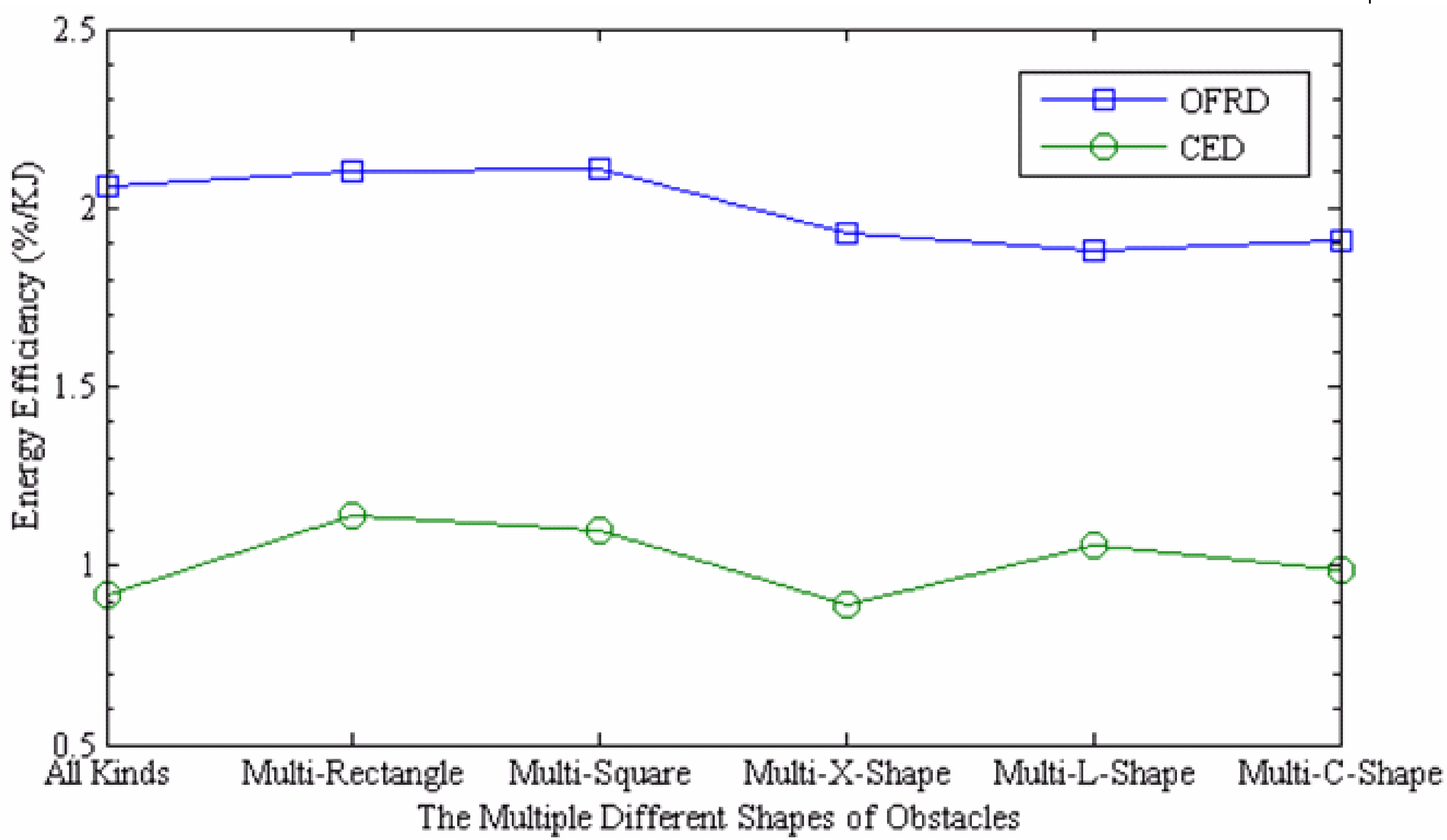
Simulation Results



Simulation Results

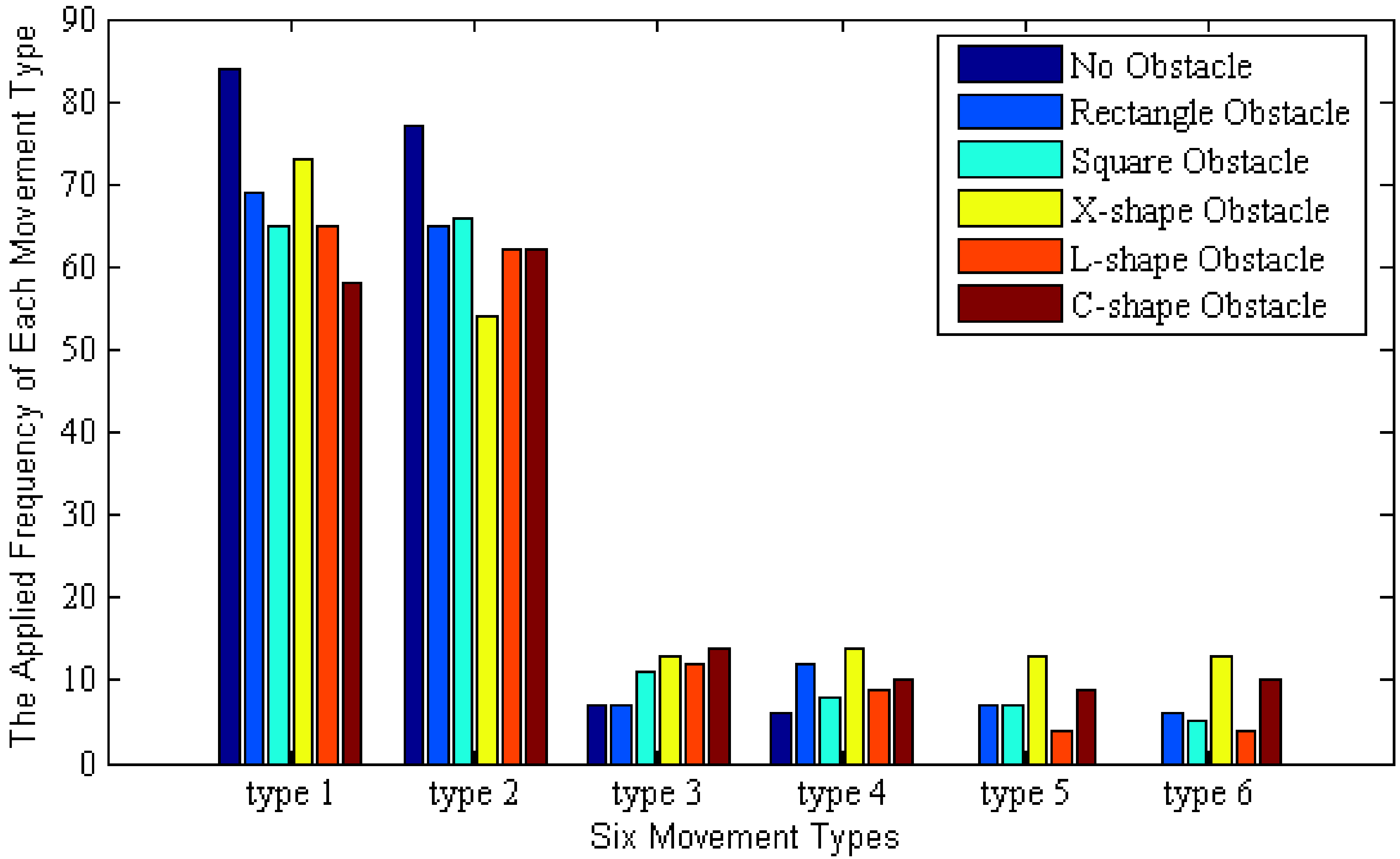


Simulation Results

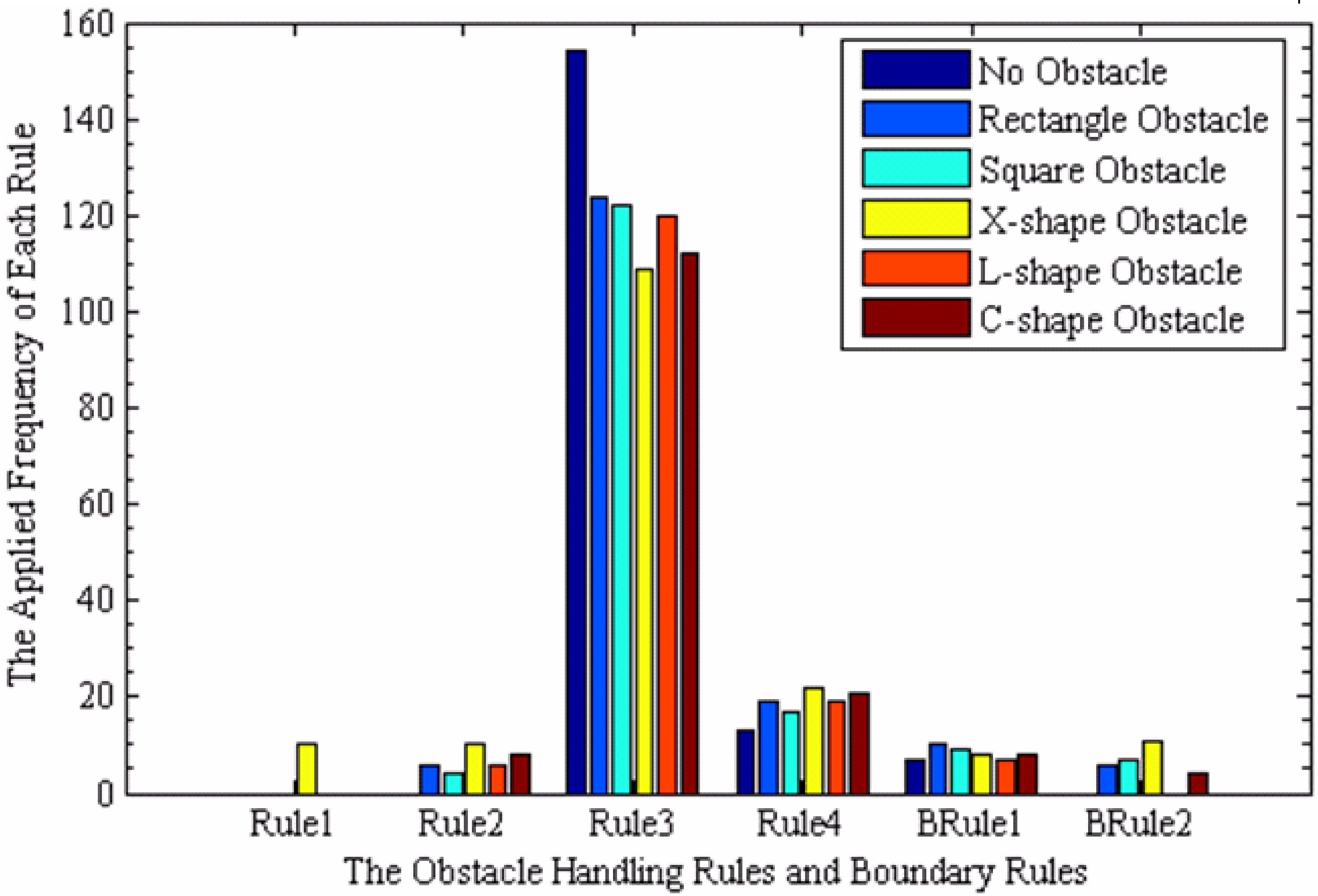


$$Energy\ Efficiency = \frac{the\ final\ coverage\ percentage}{the\ total\ energy\ consumption}$$

Simulation Results



Simulation Results



Outline

- Introduction to Wireless Sensor Networks
- Obstacle-Free Deployment Mechanism
- Obstacle-Free Routing Mechanism
- Conclusions

Current Research:

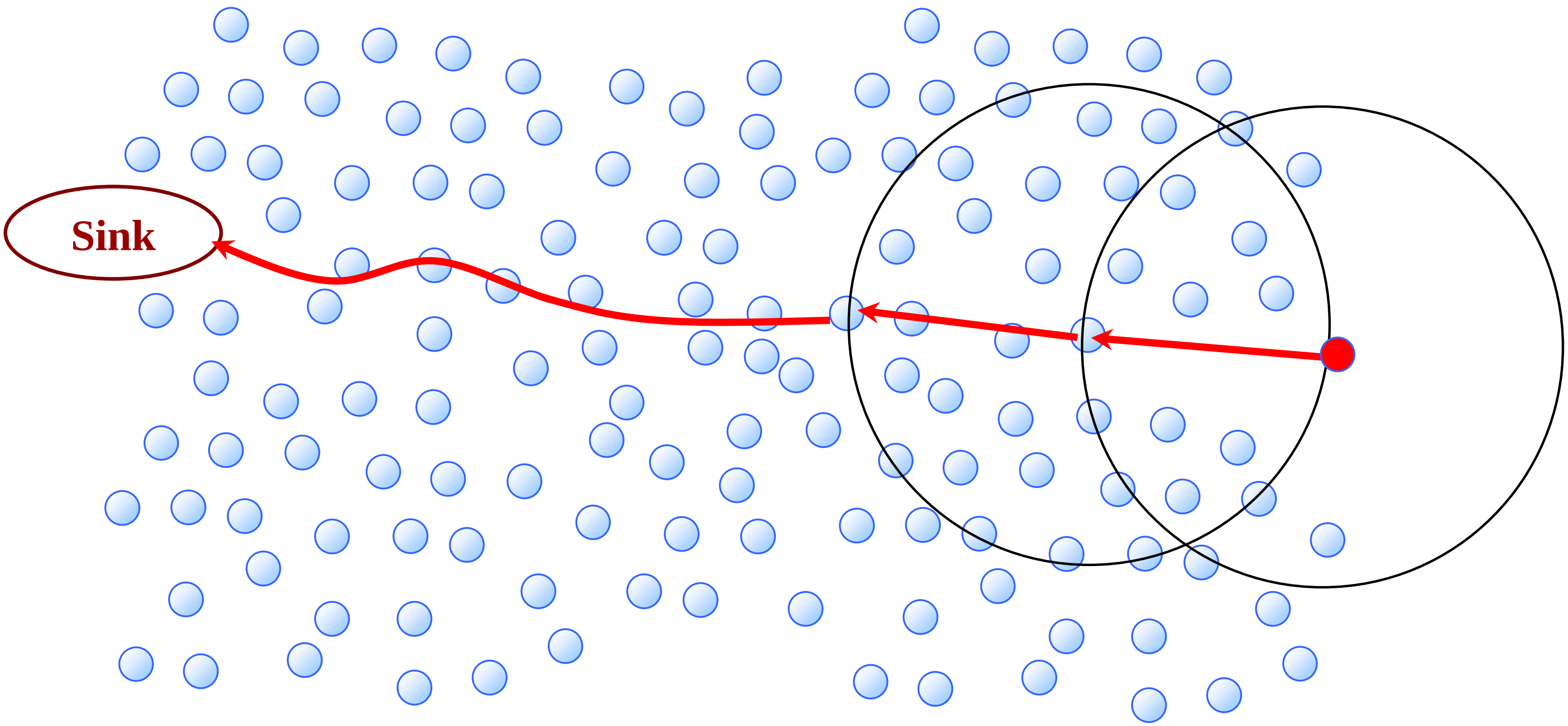
RGP : Active Route Guiding Protocol for WSNs with Obstacles

IEEE MASS 2006

(Accepted rate <25%)

Location Aware Routing

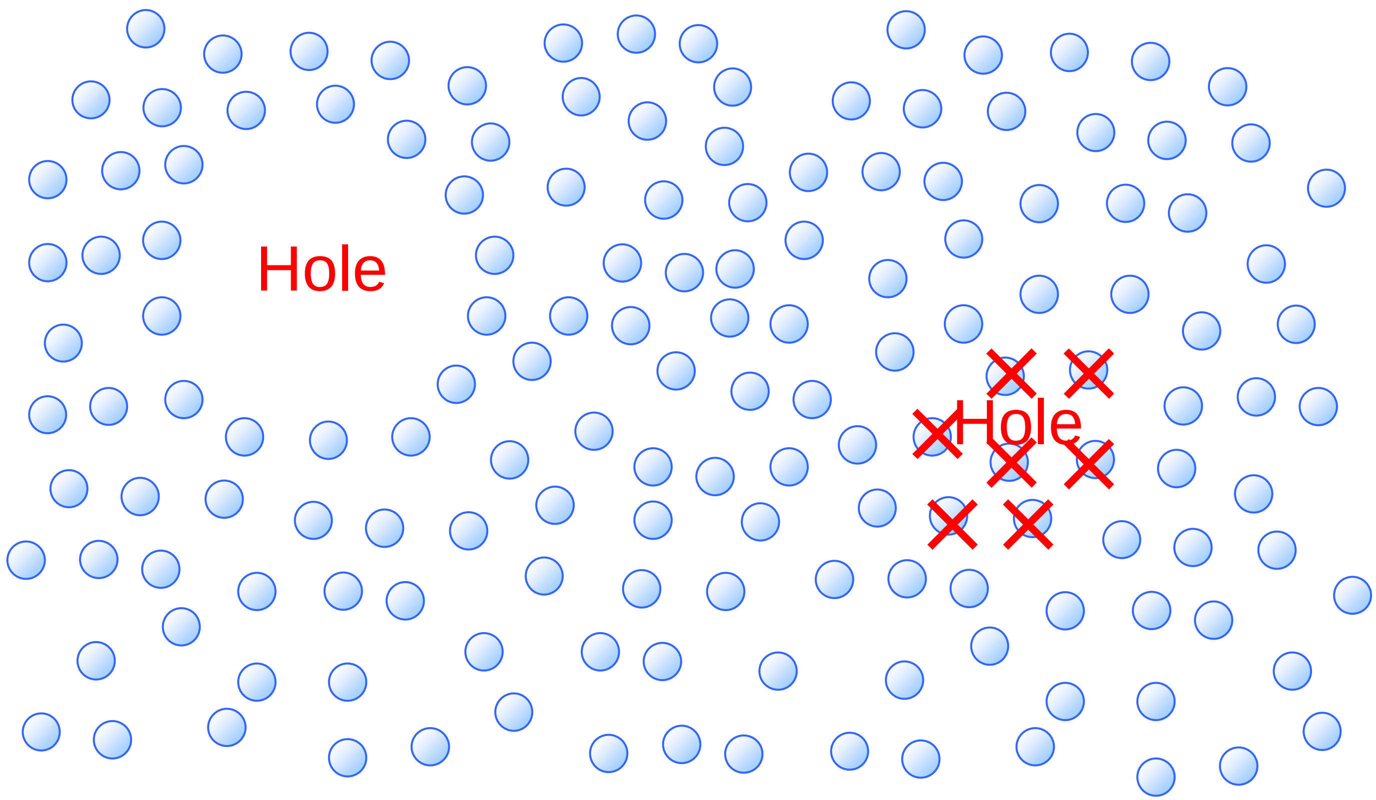
- A sensor node intends to send its reading information to the sink node



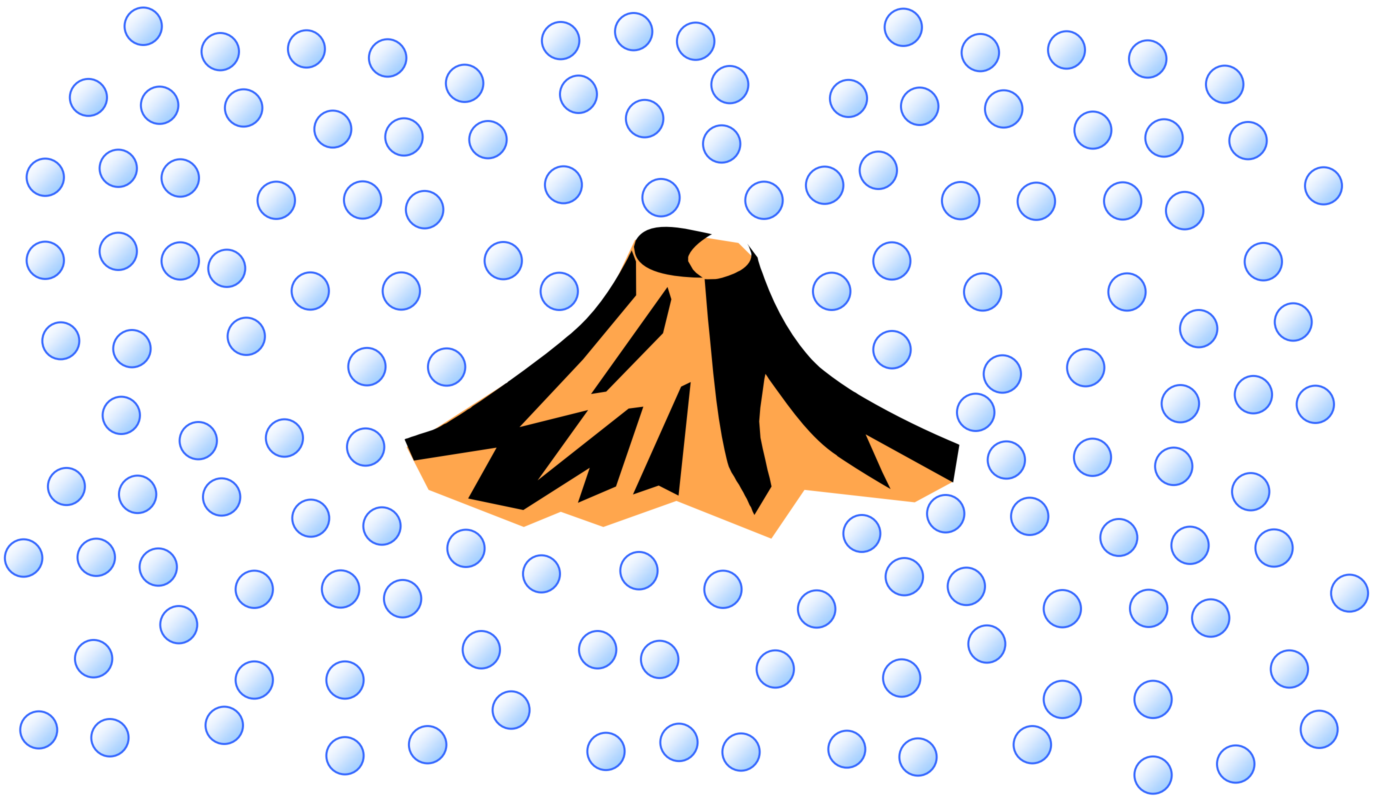
Wireless Sensor Networks

- Obstacles are existed in WSNs
  - Some sensor nodes will be failure after working in networks for a long time
  - Unbalanced deployment of sensor nodes
  - Existing natural objects such as river and mountain also form obstacle regions
  - Animus interference
- Packet transmission will be inefficient or blocked if obstacle is encountered

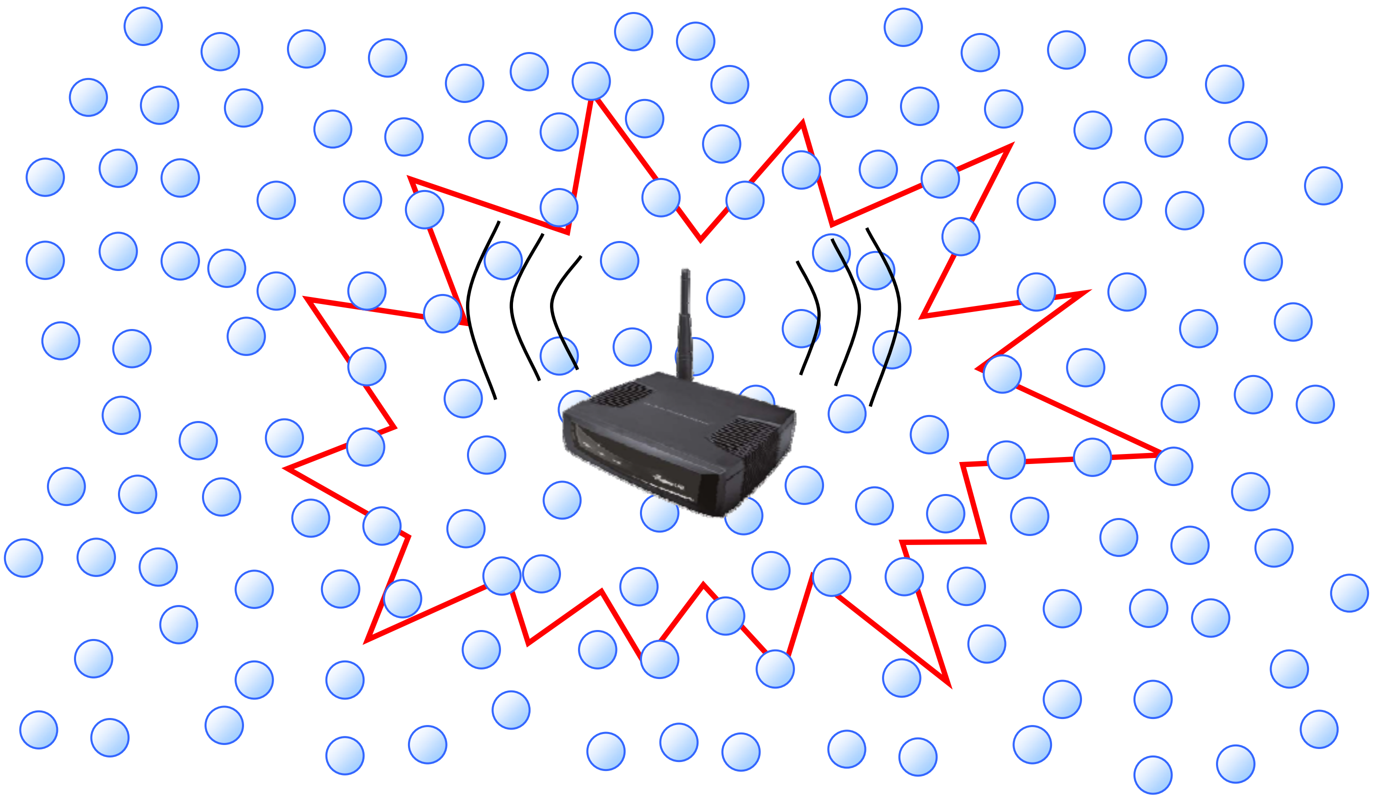
Obstacles exist in WSN



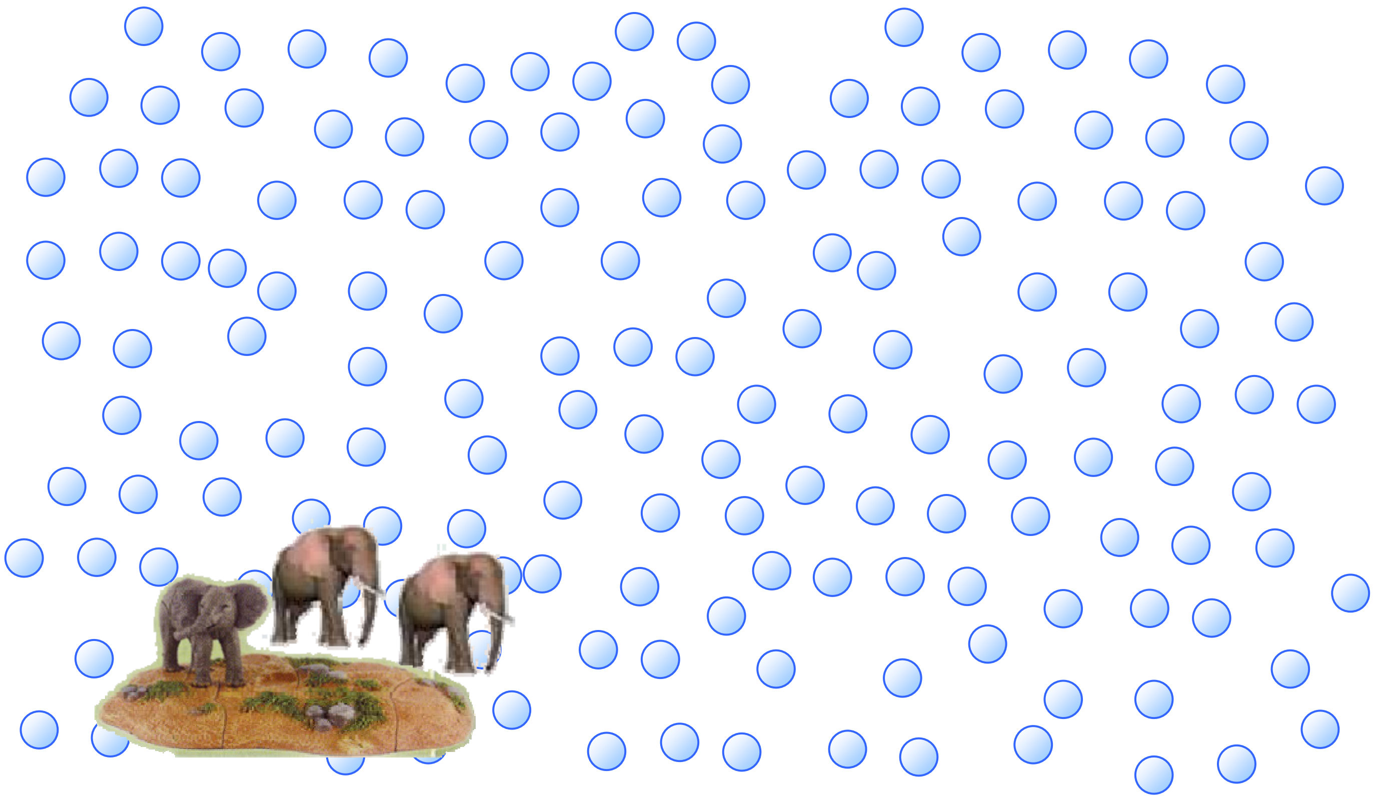
Obstacles exist in WSN



Obstacles exist in WSN



Obstacles exist in WSN



Obstacle Handling Protocols

- Passive Protocols
  - Obstacle handling rules are triggered when data packets encounter the obstacle
- Active Protocols
  - Obstacles are handled actively before packet routings

Class 1:
Passive Geocasting Protocols

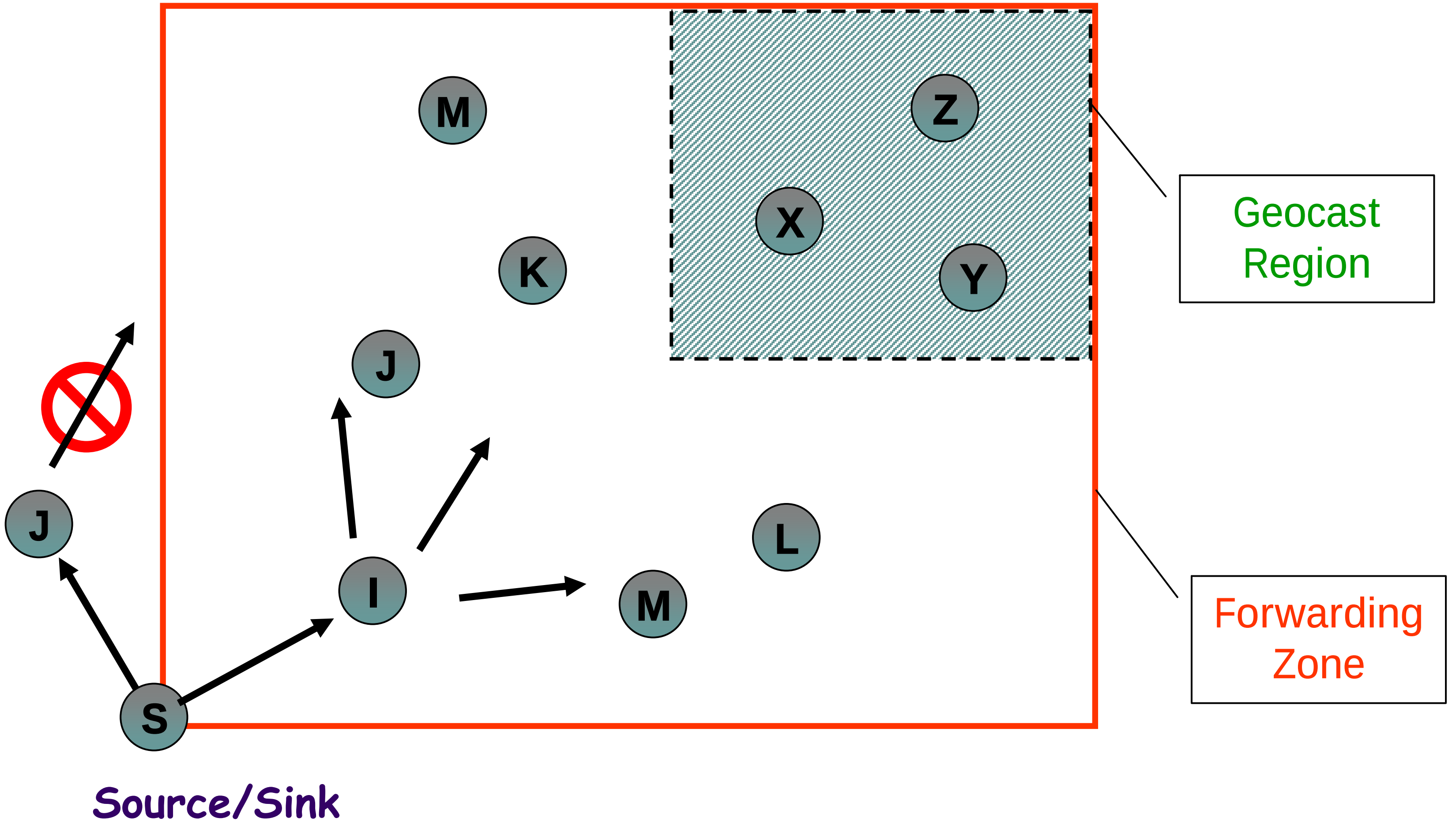
Previous Work

Title: Geocasting in Mobile Ad Hoc Networks: Location-Based Multicast Algorithms

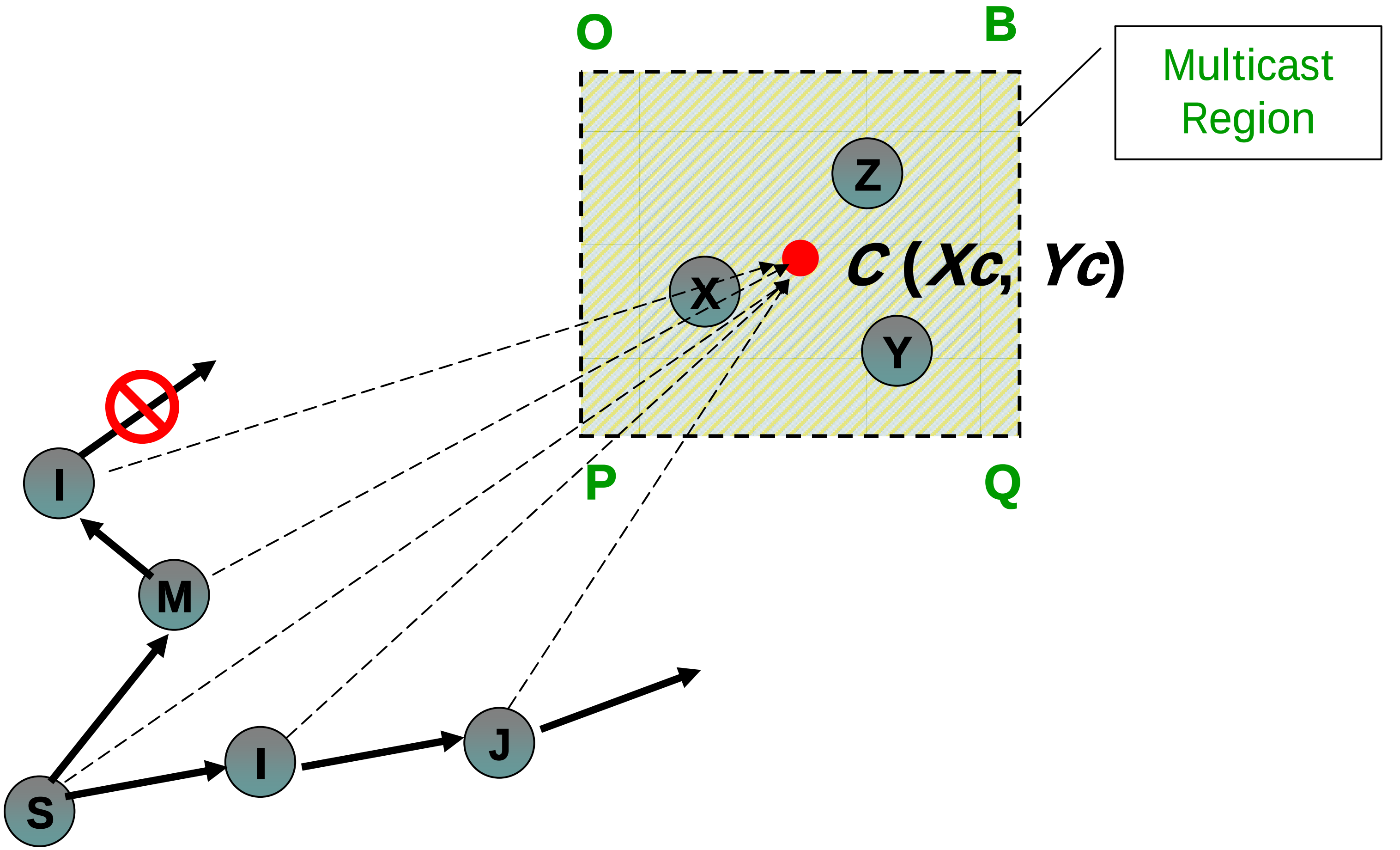
Authors: Young-Bae Ko and Nitin H. Vaidya

From: *Mobile Computing Systems and Applications 1999*

LBM
- Location-Based Multicast Scheme 1



LBM
- Location-Based Multicast Scheme 2



Previous Work

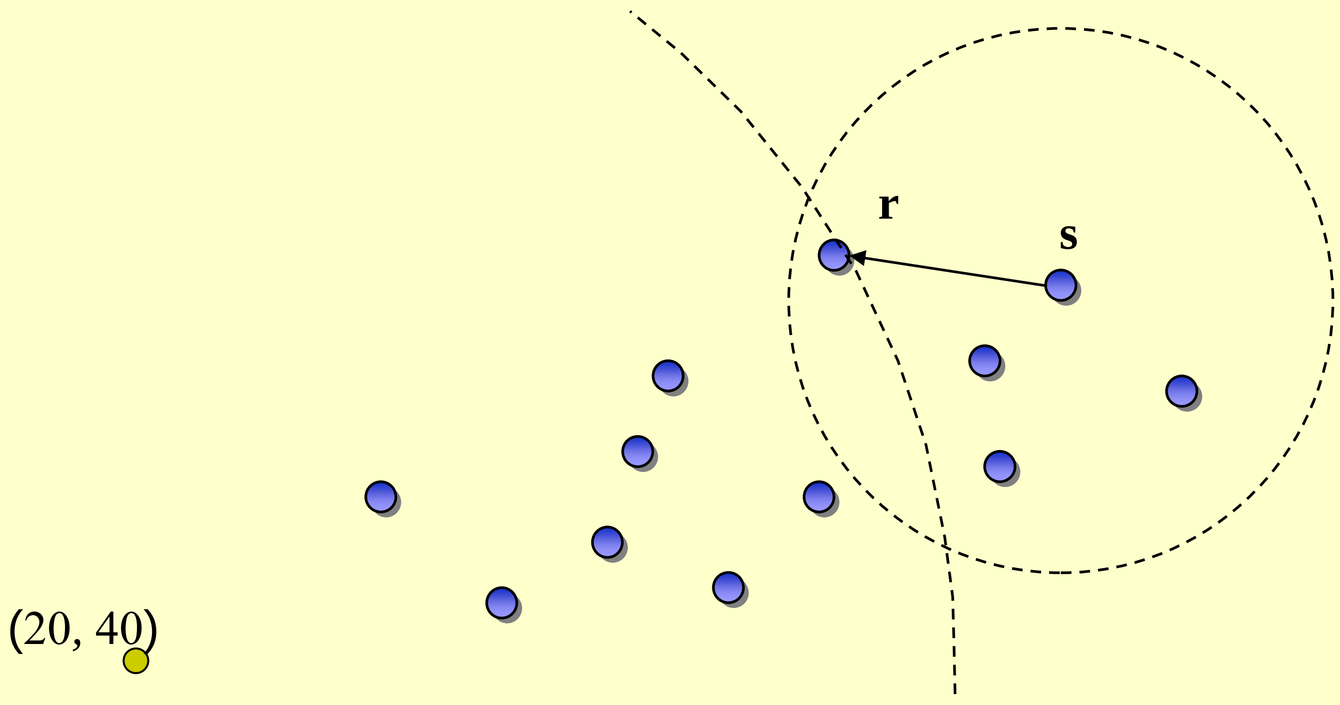
Title: GPSR: Greedy Perimeter Stateless Routing for Wireless Networks

Authors: Brad Karp and H. T. Kung

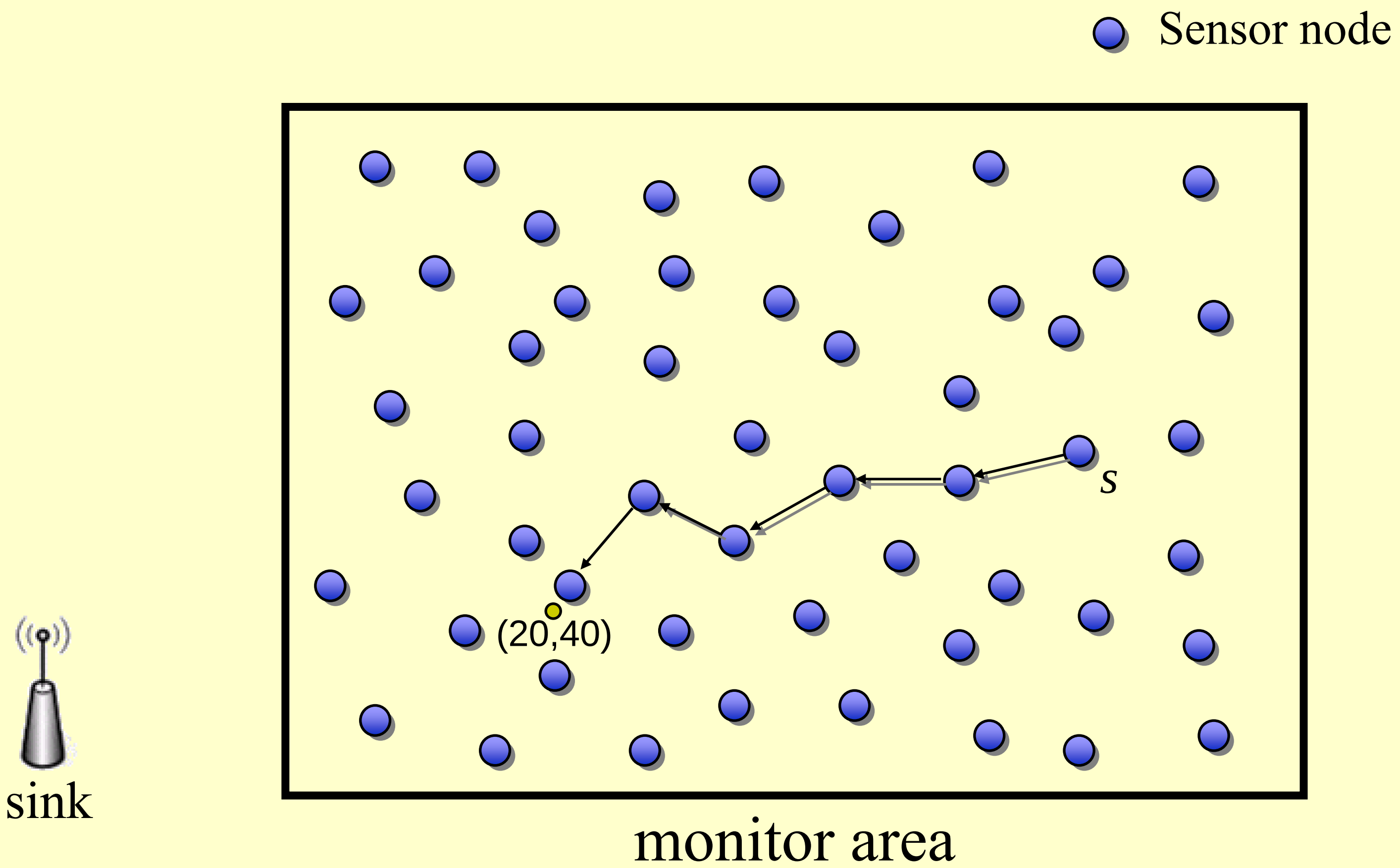
From: *Proceedings of the Annual International Conference on Mobile Computing and Networking 2000*

Example of GPSR

- GPSR—Greedy forwarding algorithm

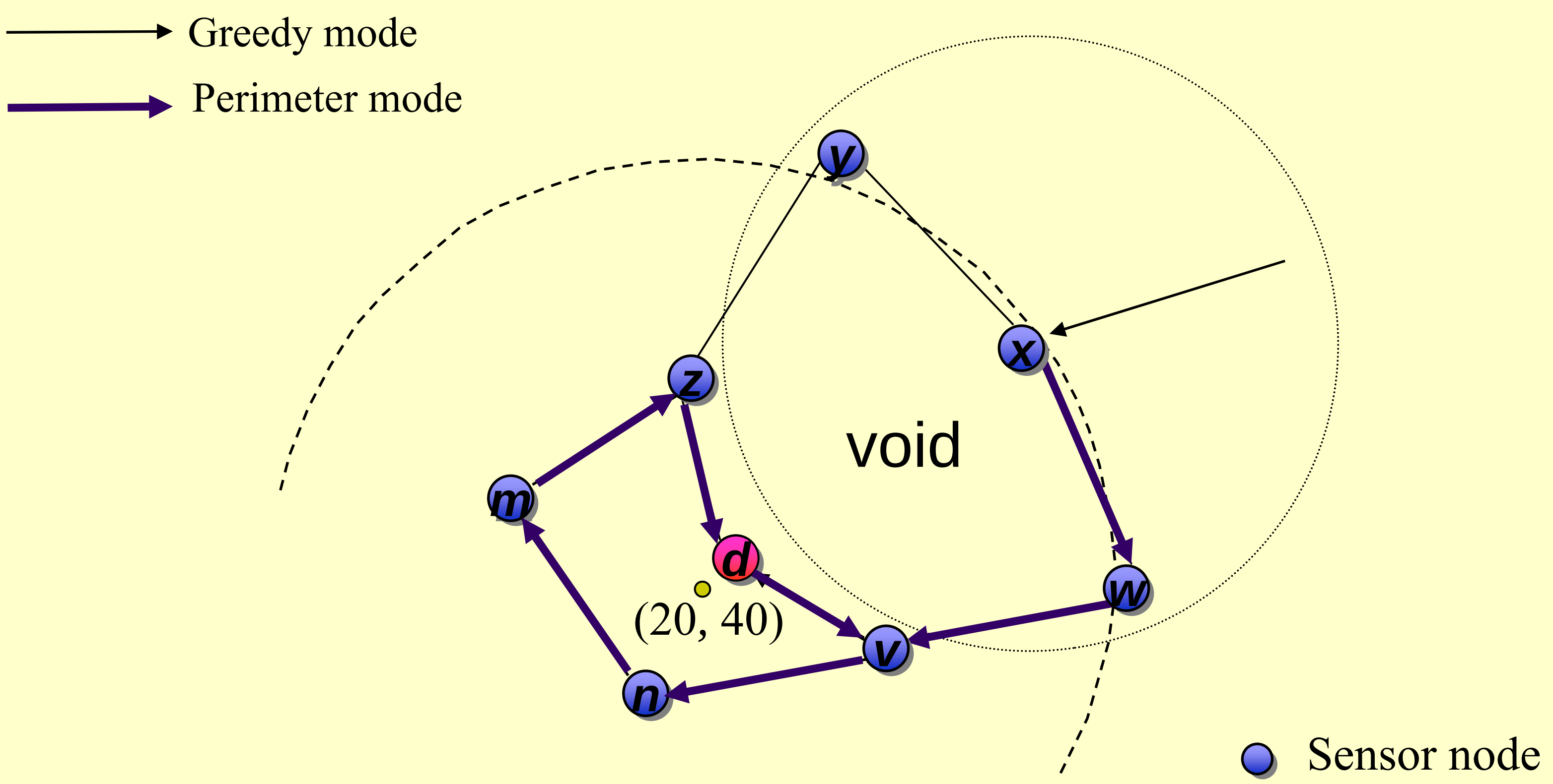


Example of GPSR

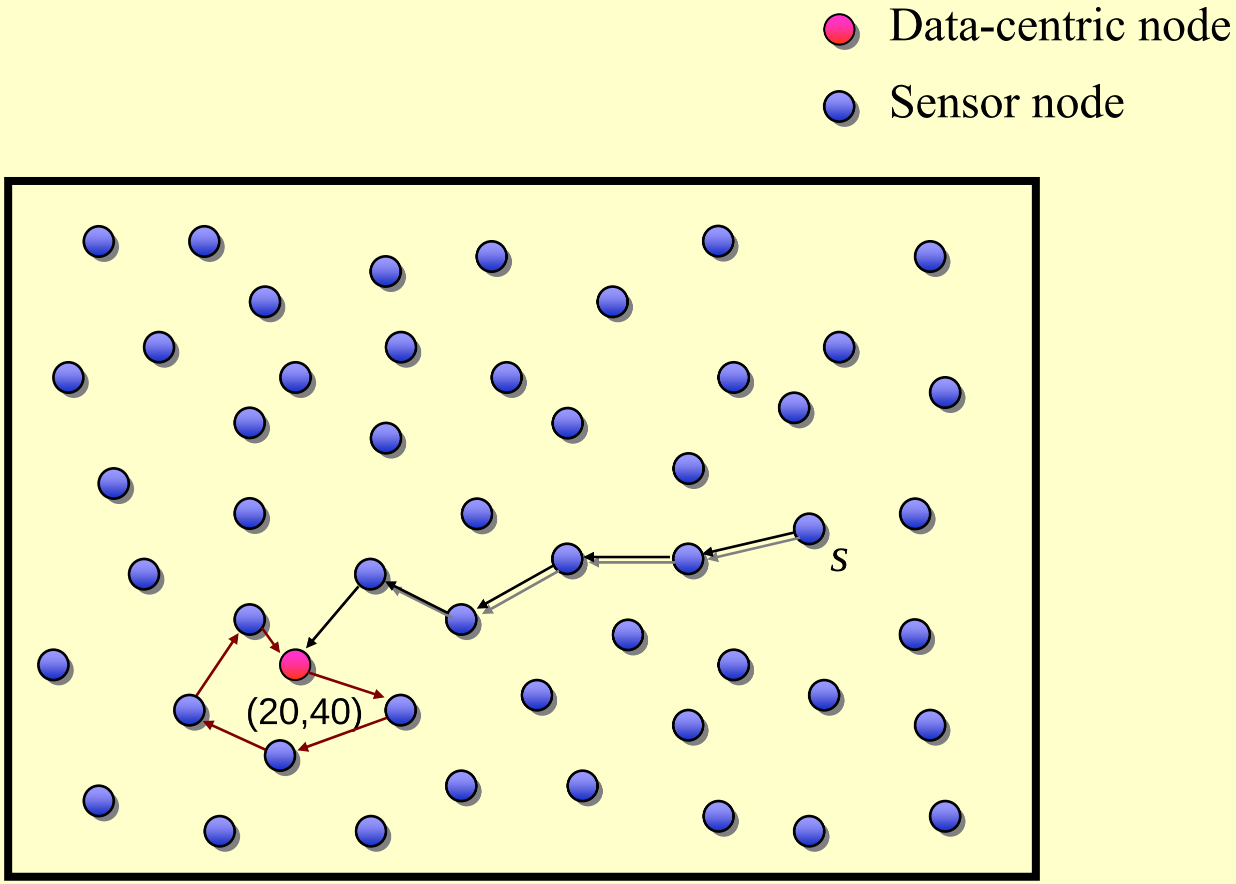


Example of GPSR

- GPSR—Perimeter forwarding algorithm

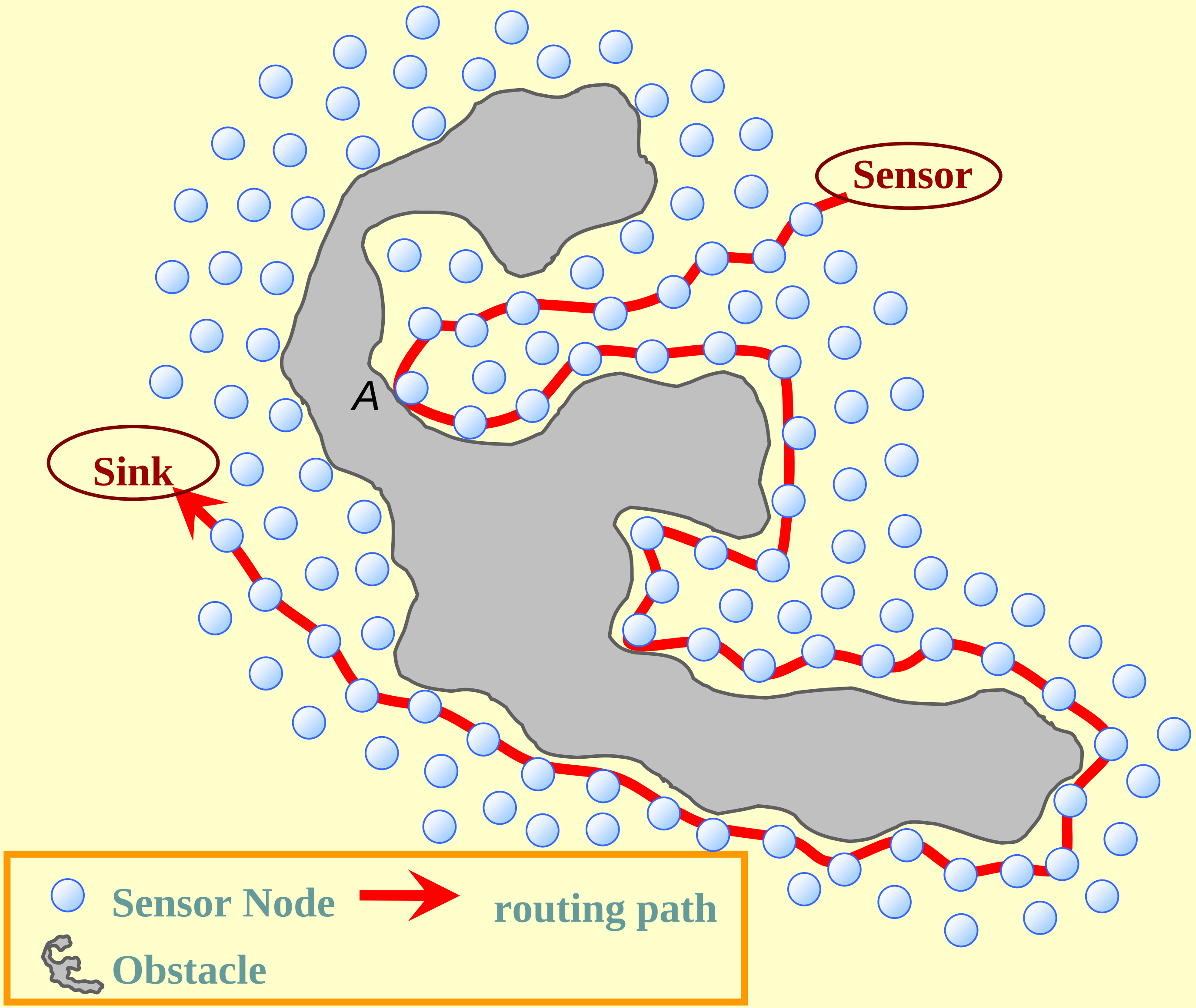


Example of GPSR



monitor area

Obstacle effect of GPSR



Class 2:
Active Geocasting Protocols

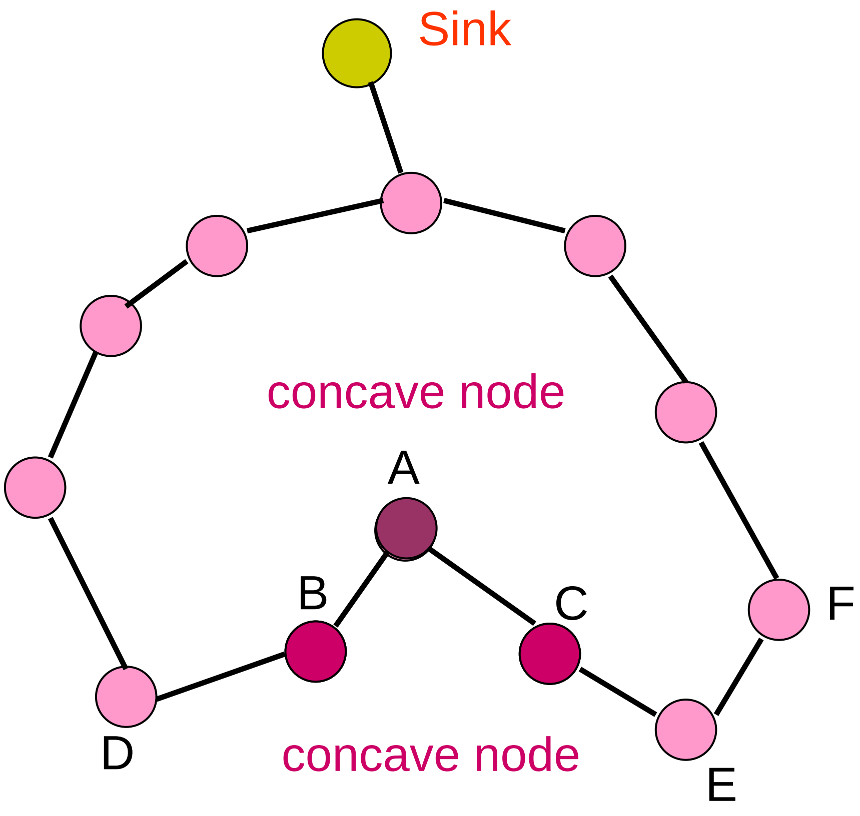
Previous Work

Title: A Distributed Algorithm for the Dead End Problem of Location Based Routing in Sensor Networks

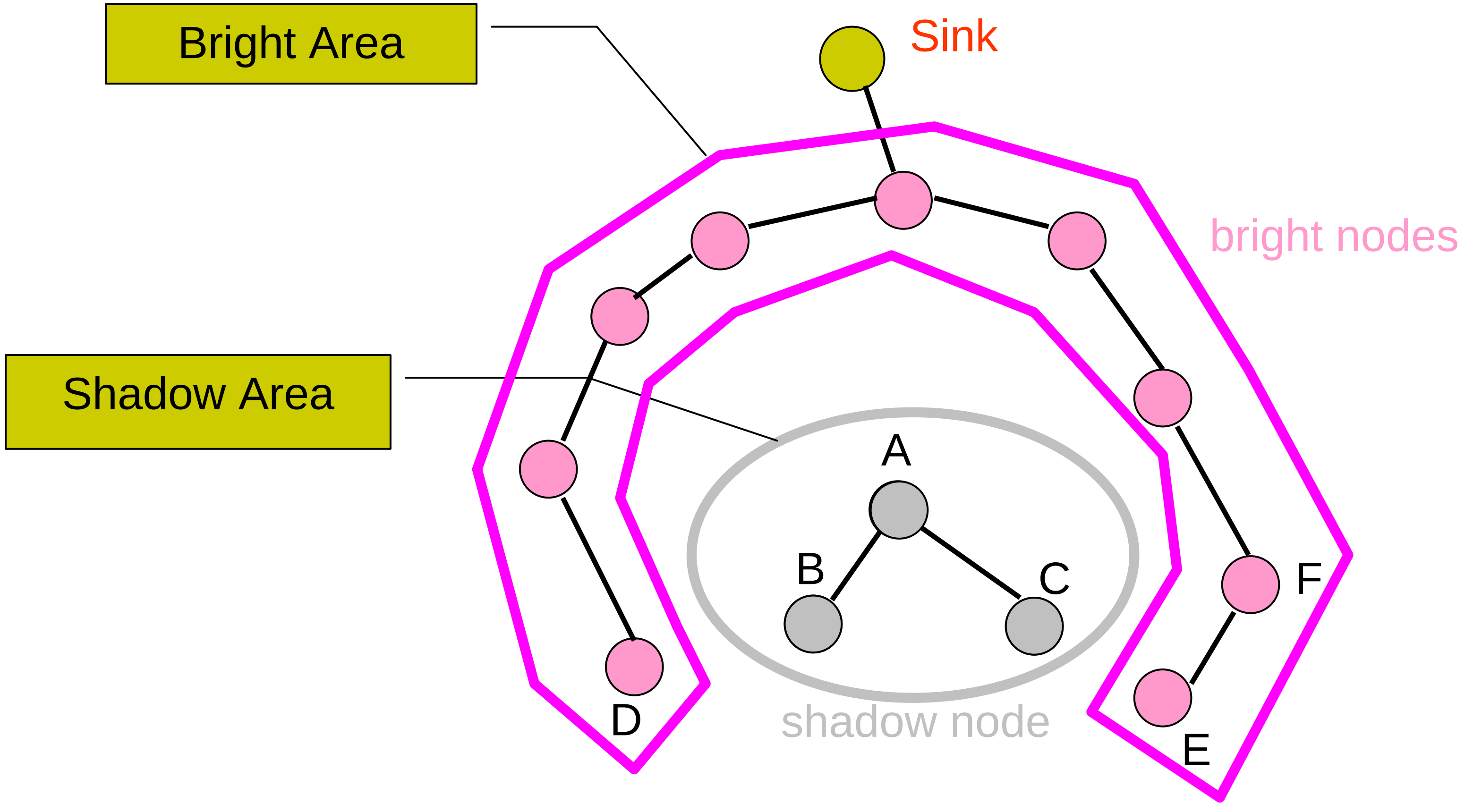
Authors: Le Zou, Mi Lu, Zixiang Xiong

From: *IEEE Transactions* on *Vehicular Technology* 2005

The Shadow Spread Phase

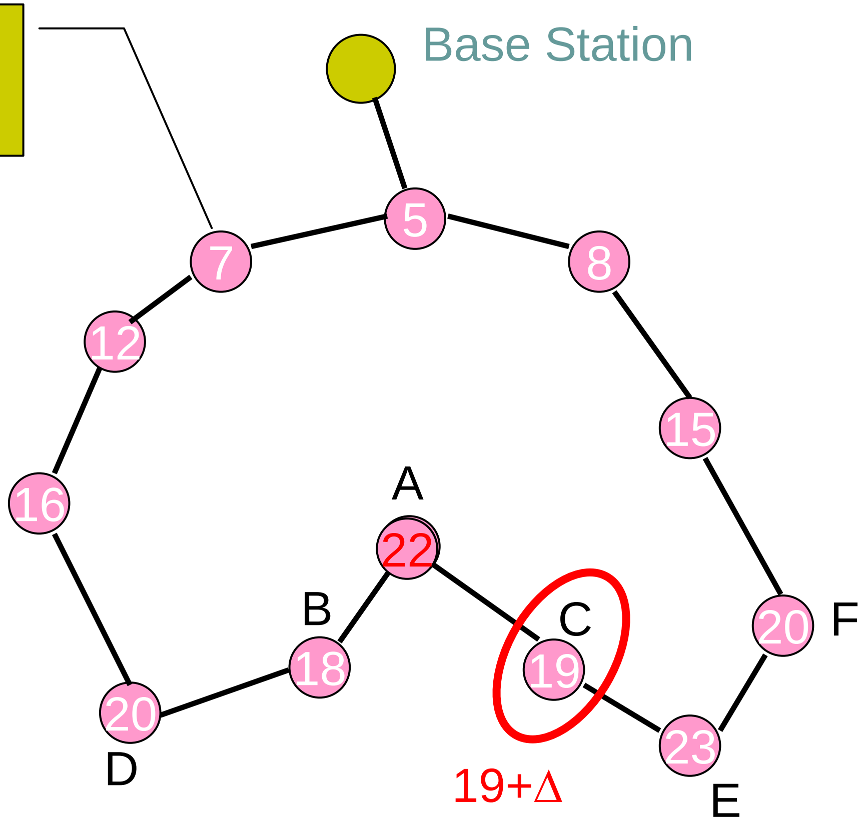


The Shadow Spread Phase



The Cost Spread Phase

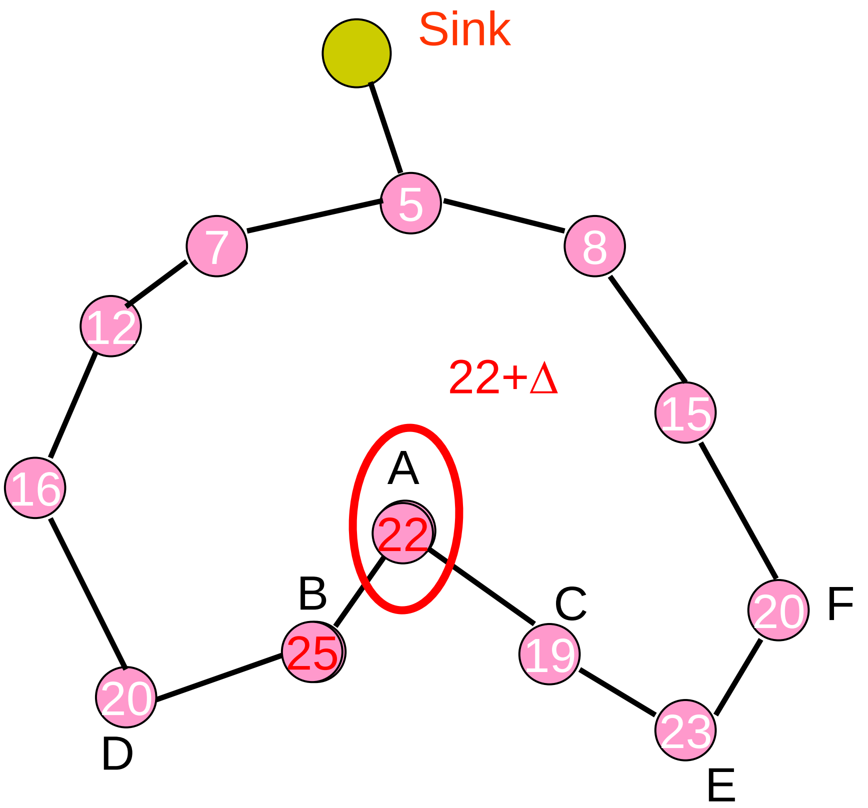
Euclidian distance to the BS



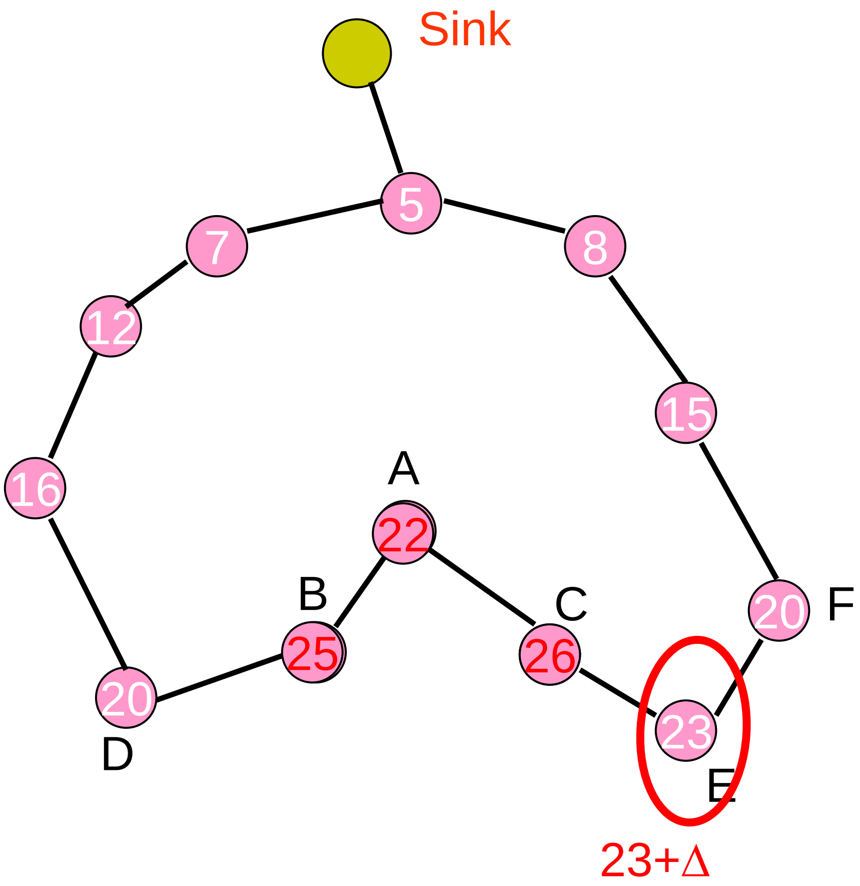
Δ should be set to the average Euclidean distance between neighboring sensor nodes

Δ is set to 3 in this example

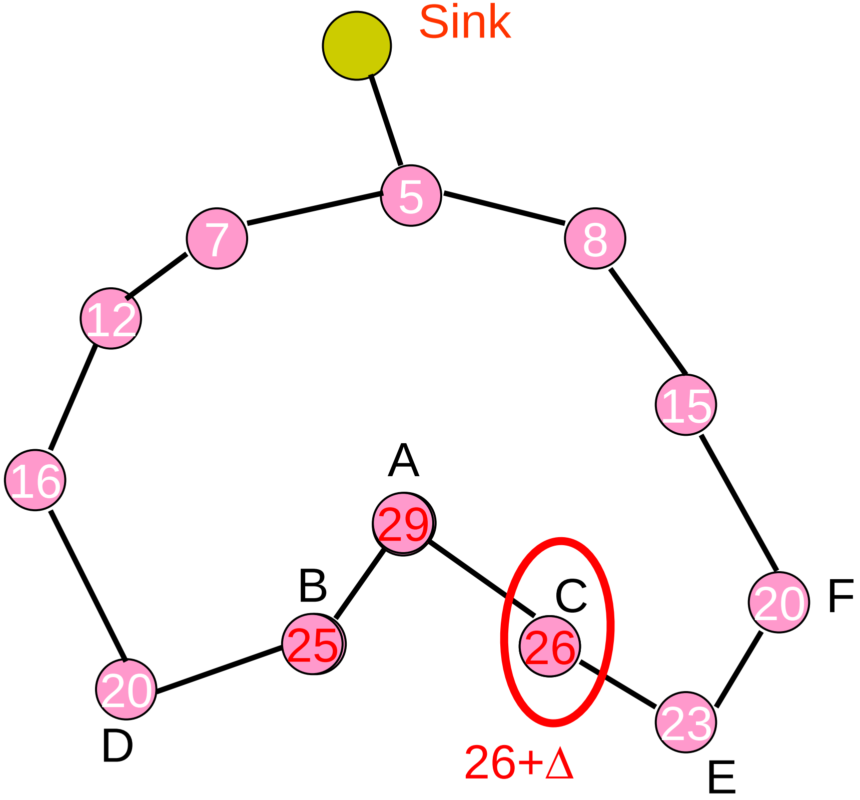
The Cost Spread Phase



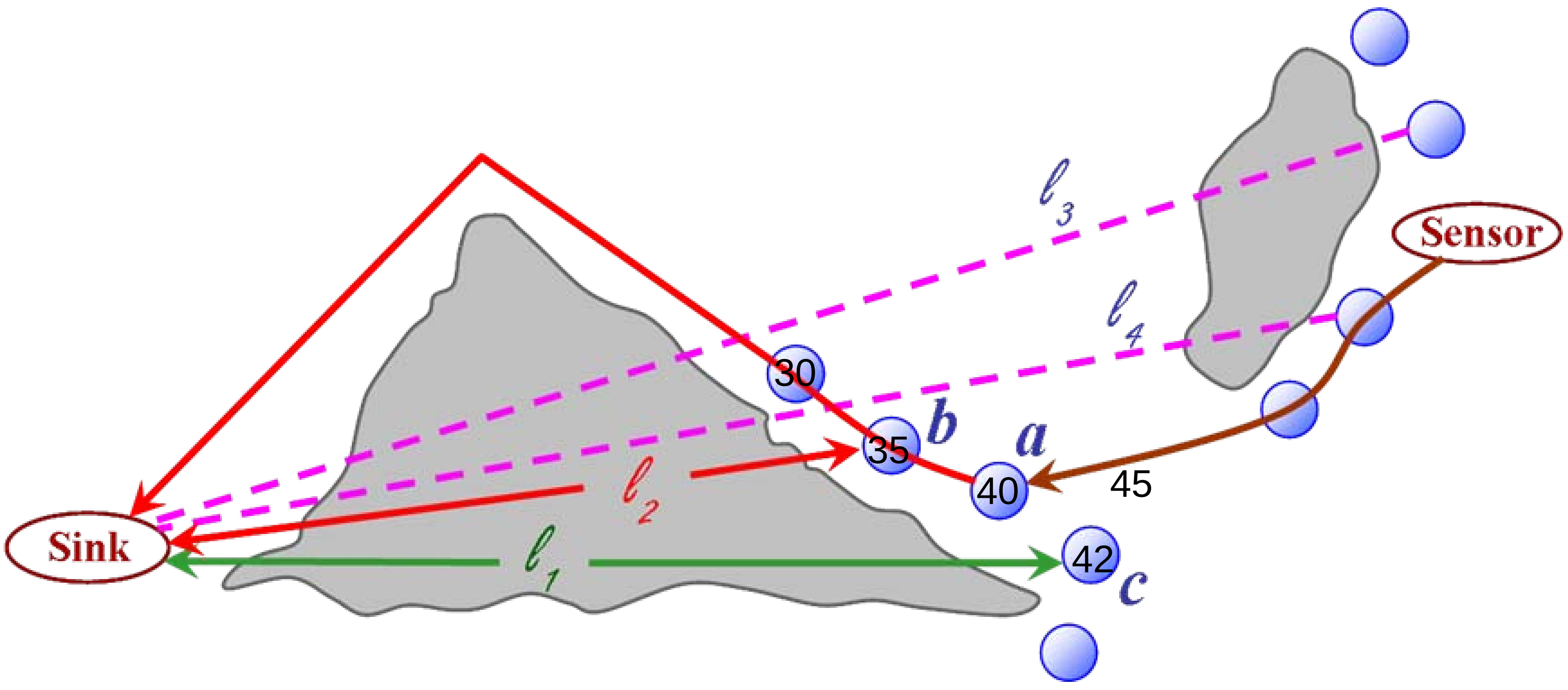
The Cost Spread Phase



The Cost Spread Phase



Obstacle effect of PAGER



Goals

- To handle the obstacle efficiently
  - Detect dynamic obstacles
  - Obstacles Information transparent
  - Packet Guiding for overcoming obstacles
  - Multiple-obstacle consideration

Assumptions

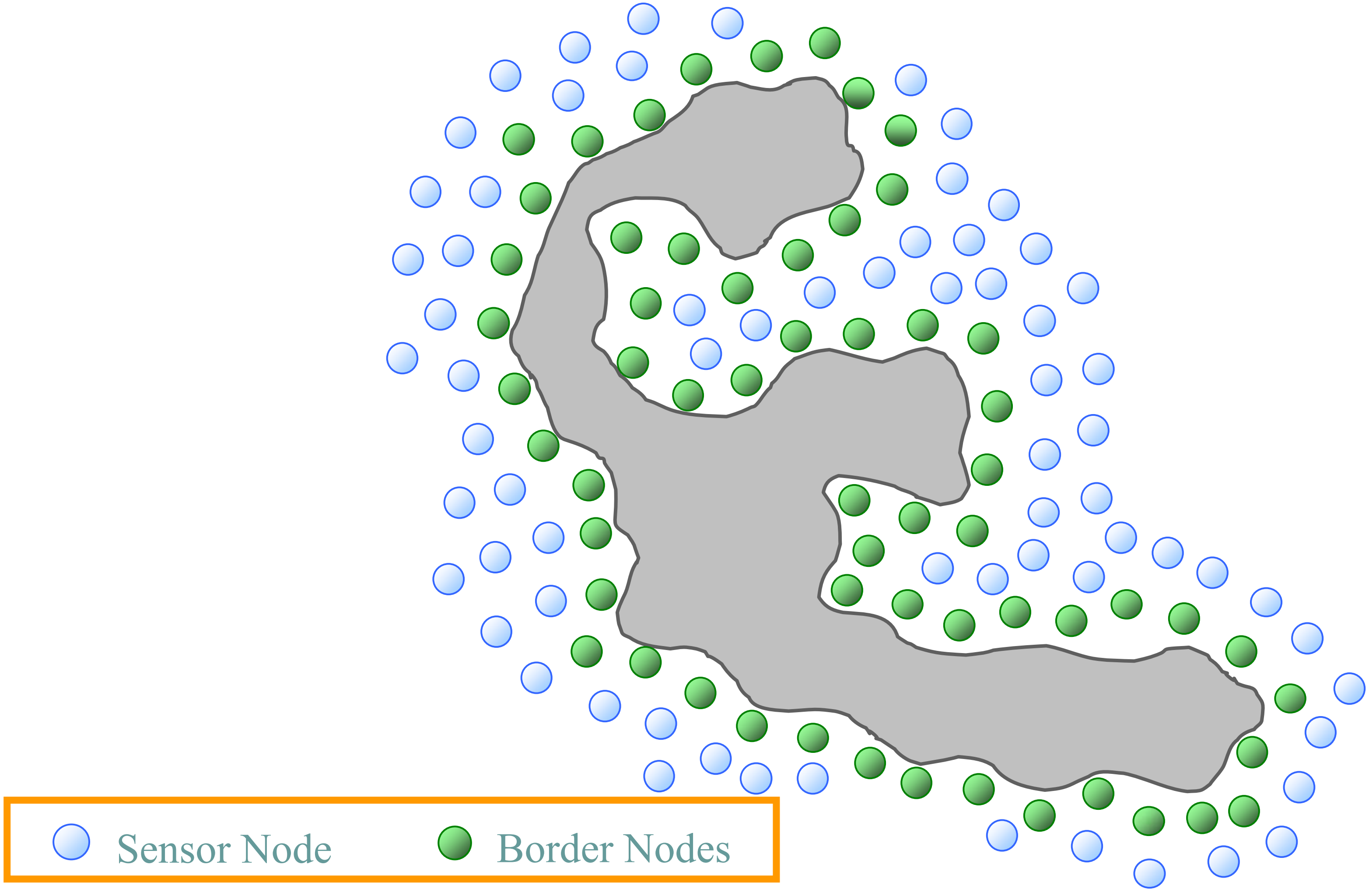
- Assumptions
  - Each node is aware of its location
  - Each sensor node has a unique ID

Overview of RGP

- **Four phases**
  - ***Obstacle Detection Phase***
  - ***Normalization Phase***
  - ***Forbidden Region Construction Phase***
  - ***Packet Guiding Phase***

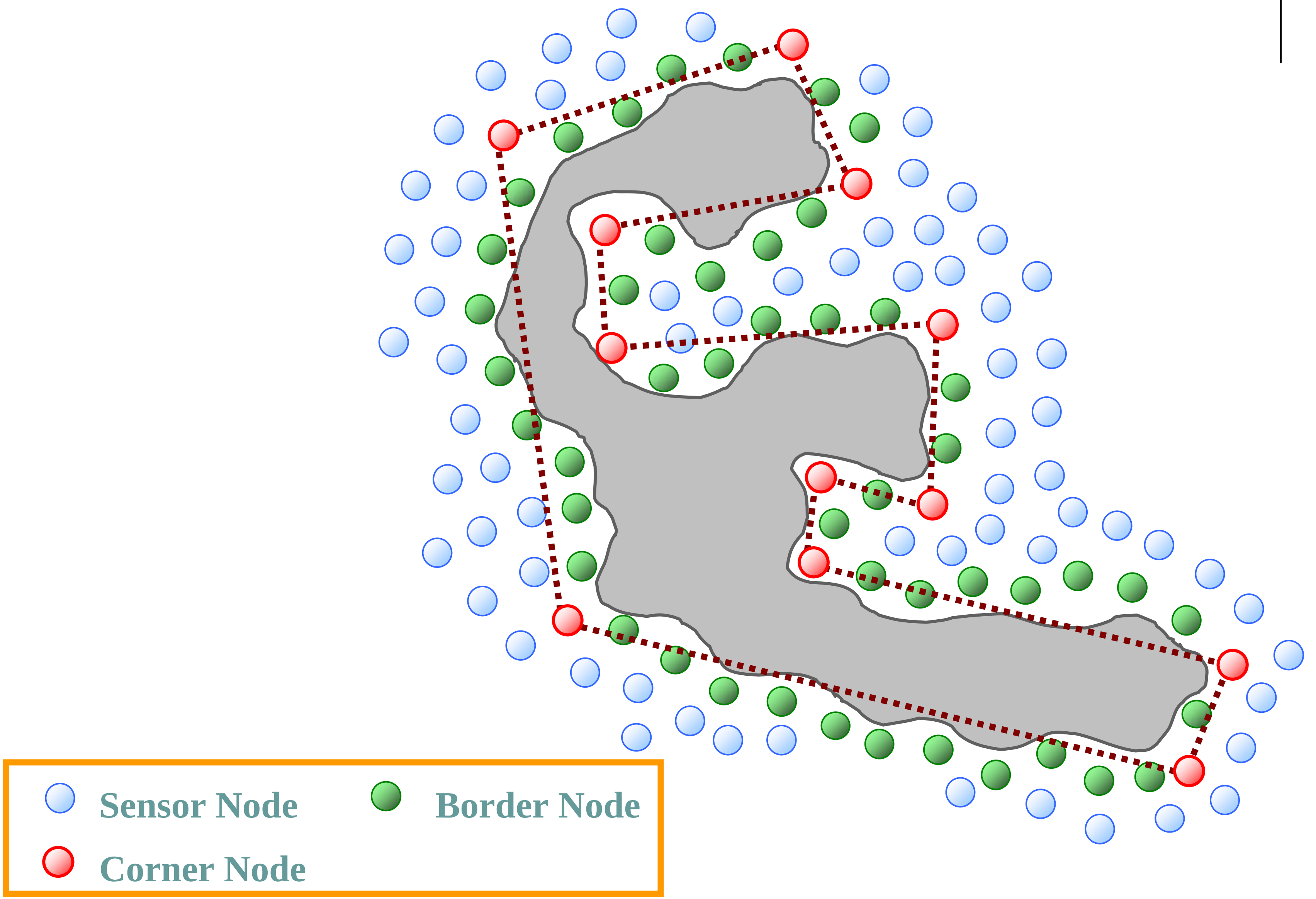
RGP – Obstacle Detection Phase (1st)

Goal: find minimal number of border nodes



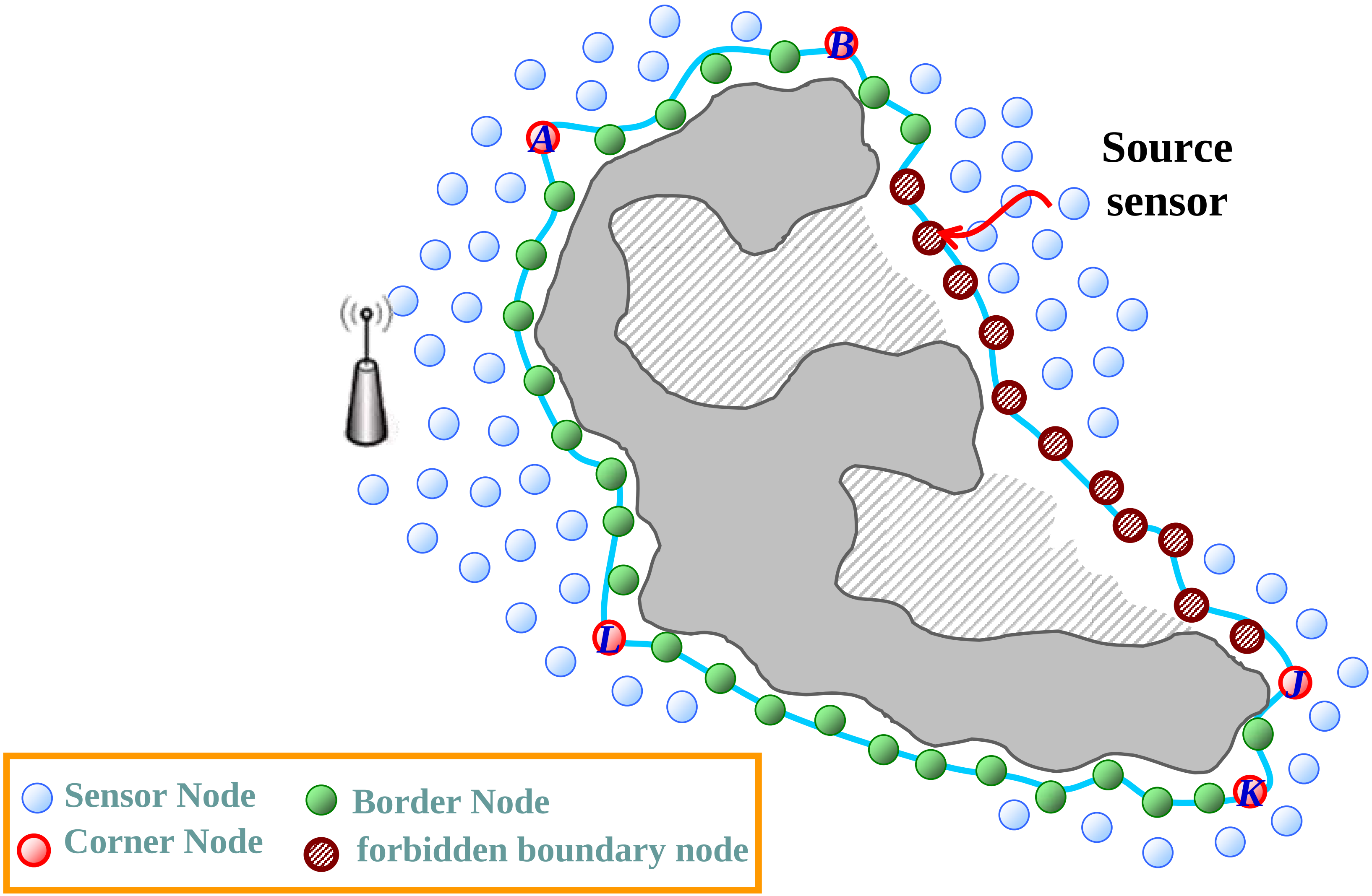
RGP – Normalization Phase(2nd)

Goal: Normalize the obstacle shape



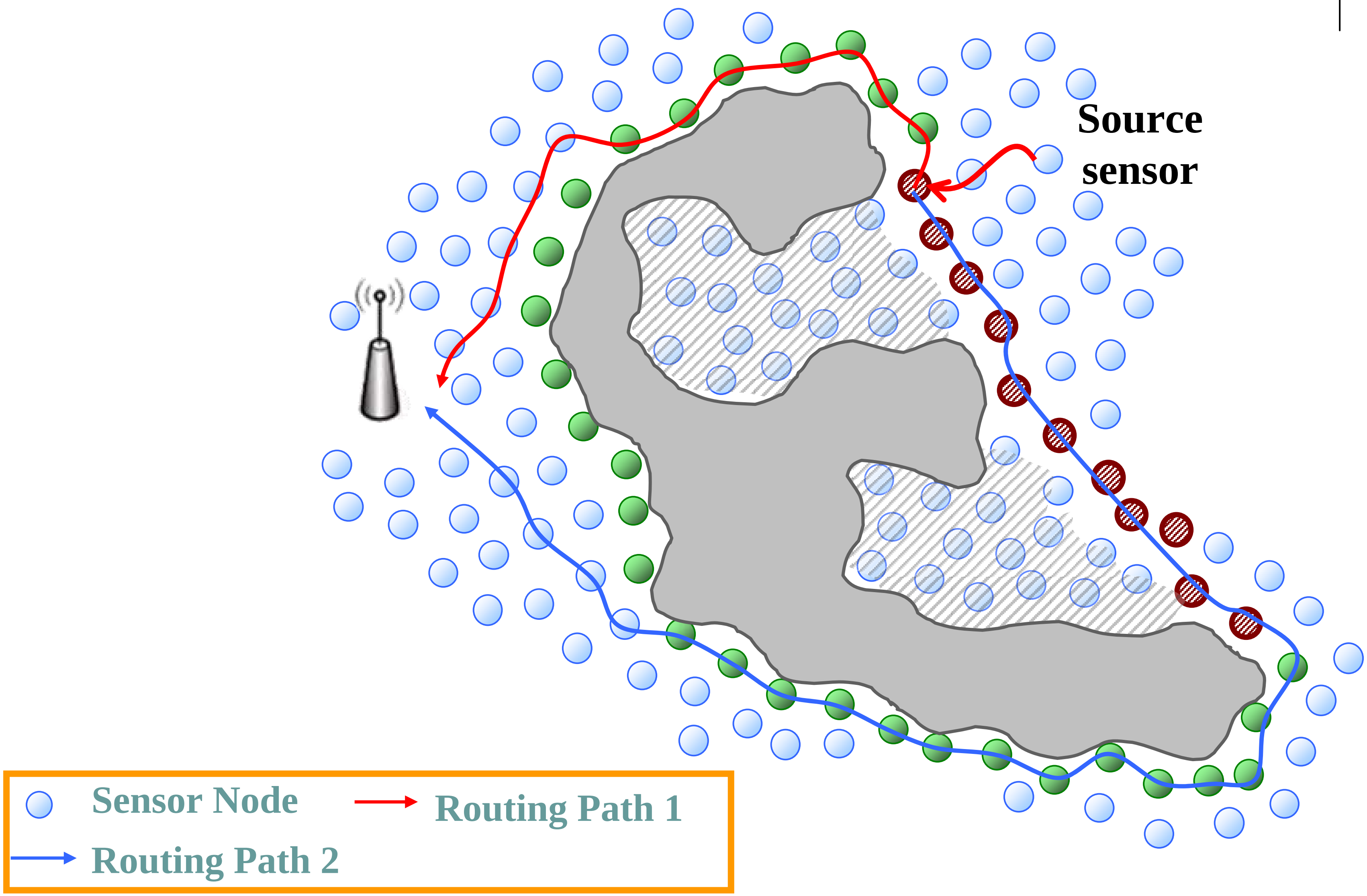
RGP – Forbidden Region Construction Phase(3rd)

Goal: Construct a forbidden region to avoid the packet entering obstacle region.



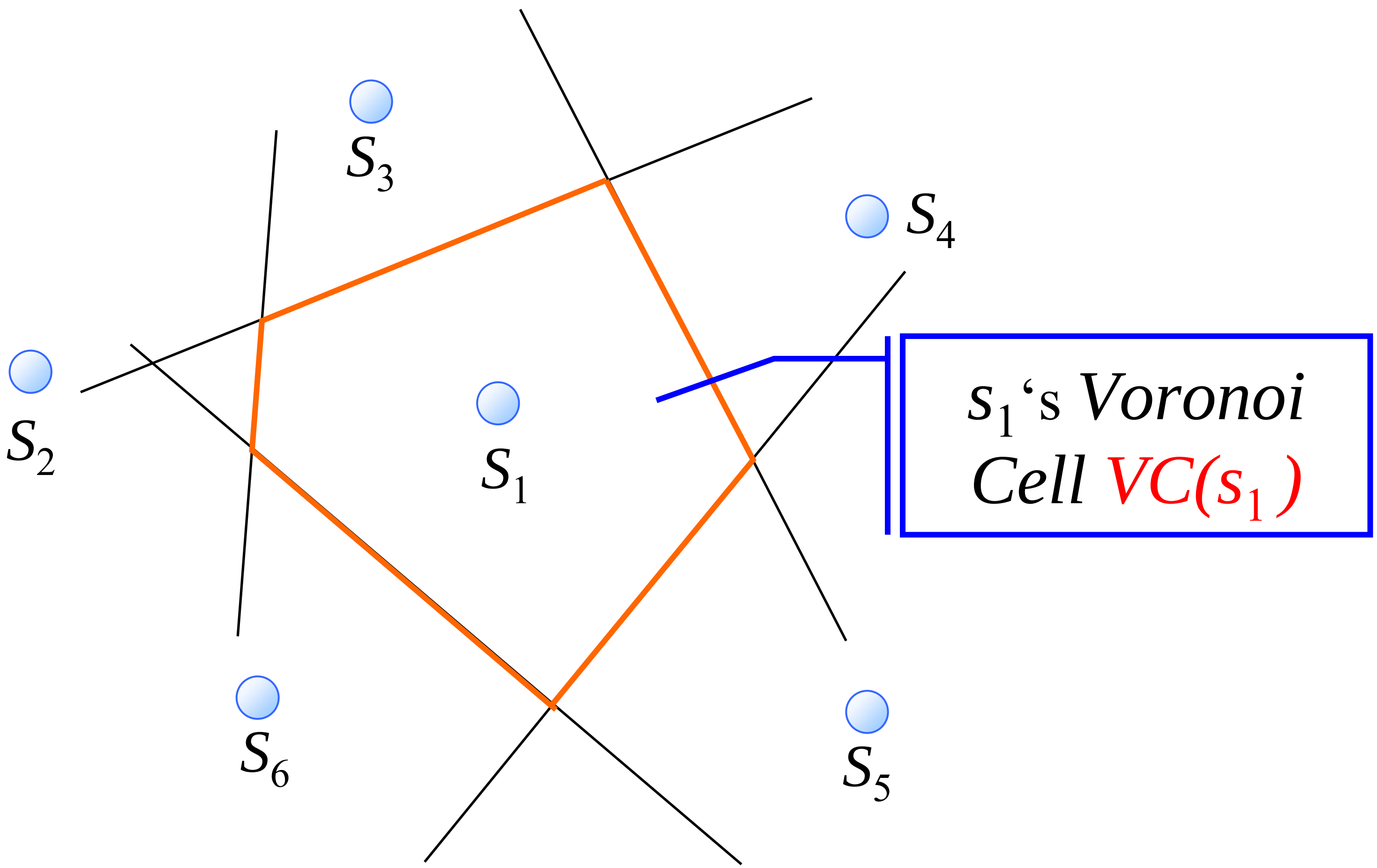
RGP – Packet Guiding Phase(4th)

Goal: Guide the packet to the better route.

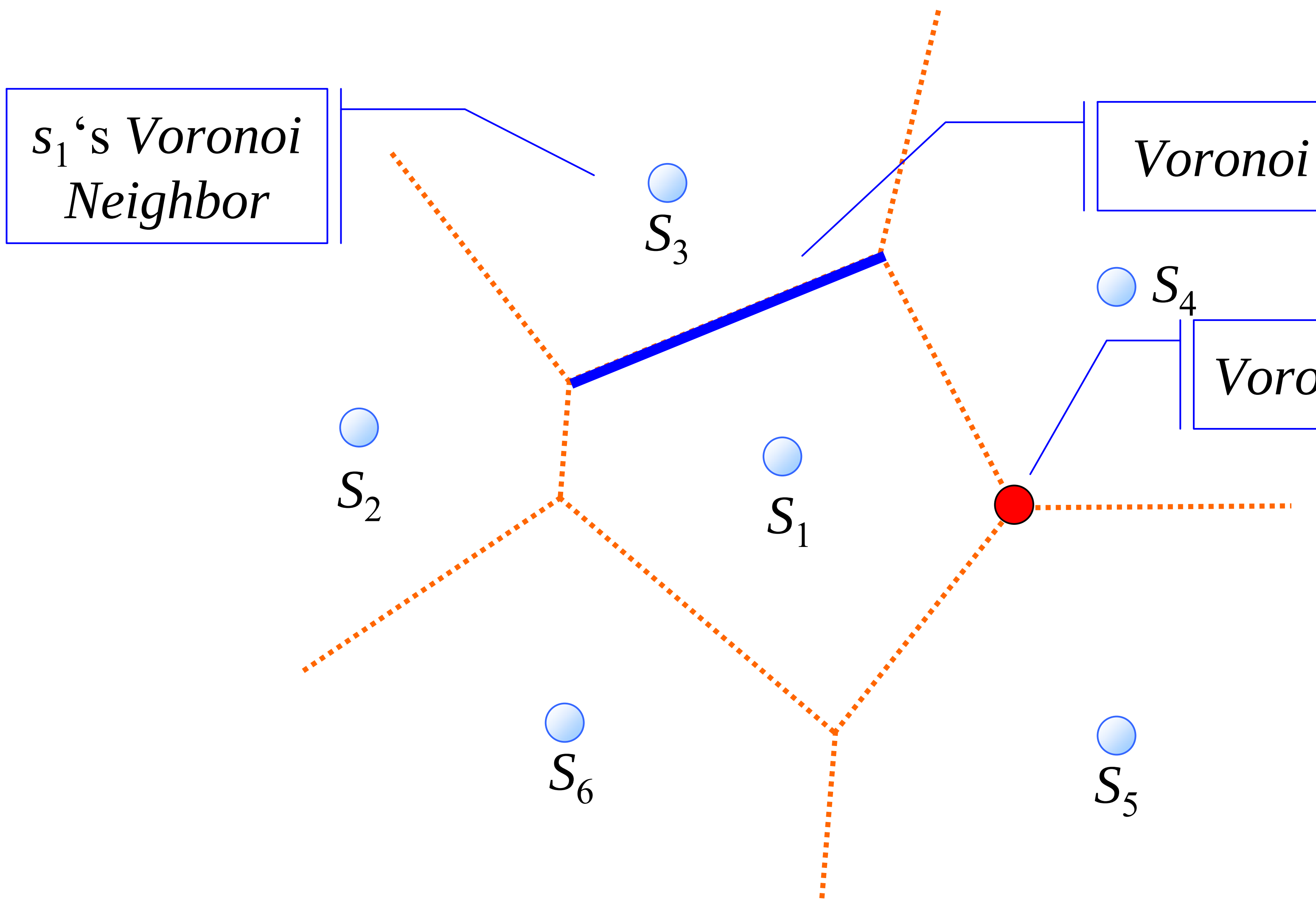


RGP – Obstacle Detection Phase (1st)

- Voronoi Diagram

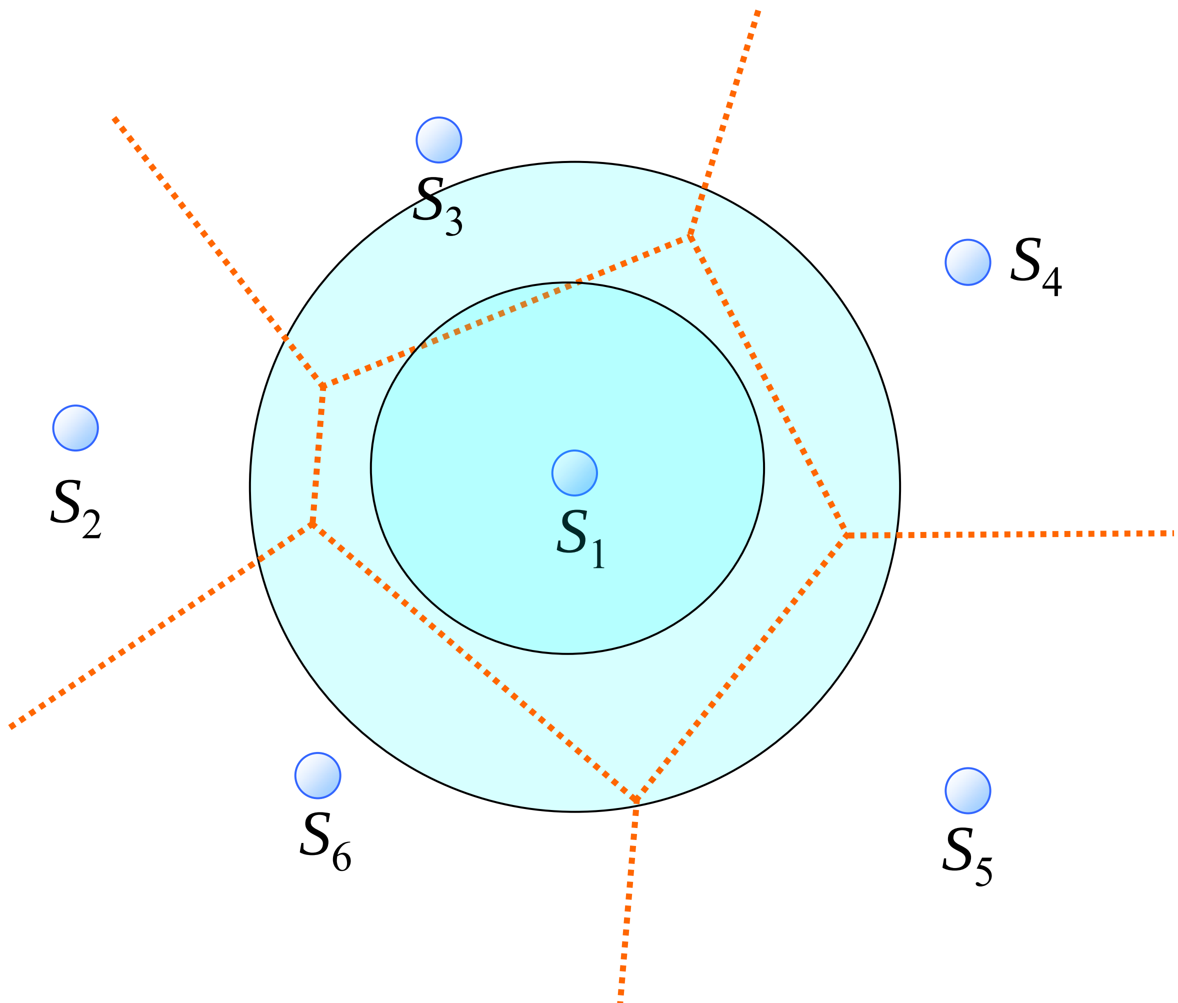


RGP – Obstacle Detection Phase (1st)



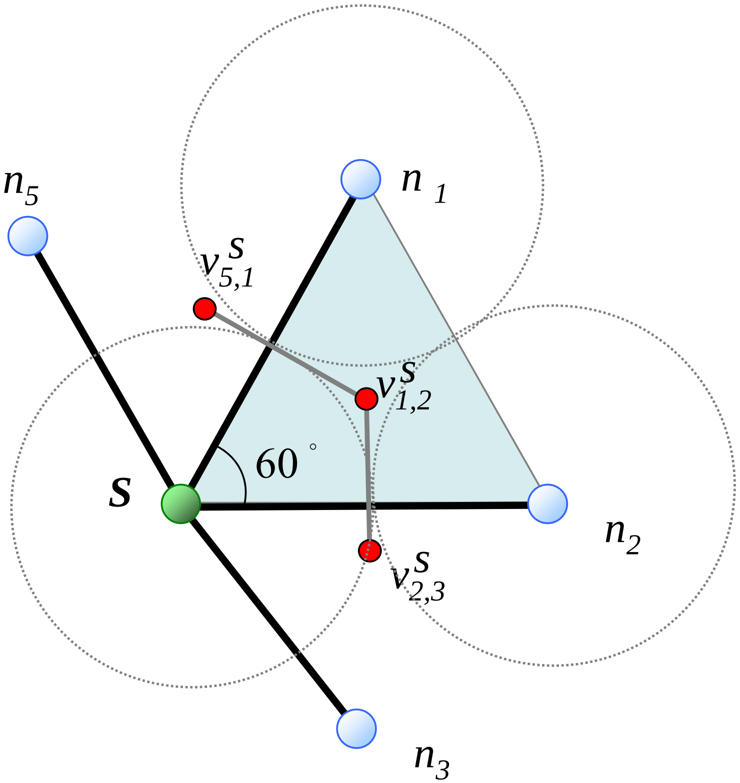
RGP – Obstacle Detection Phase (1st)

- Applying Voronoi Diagram can detect a hole



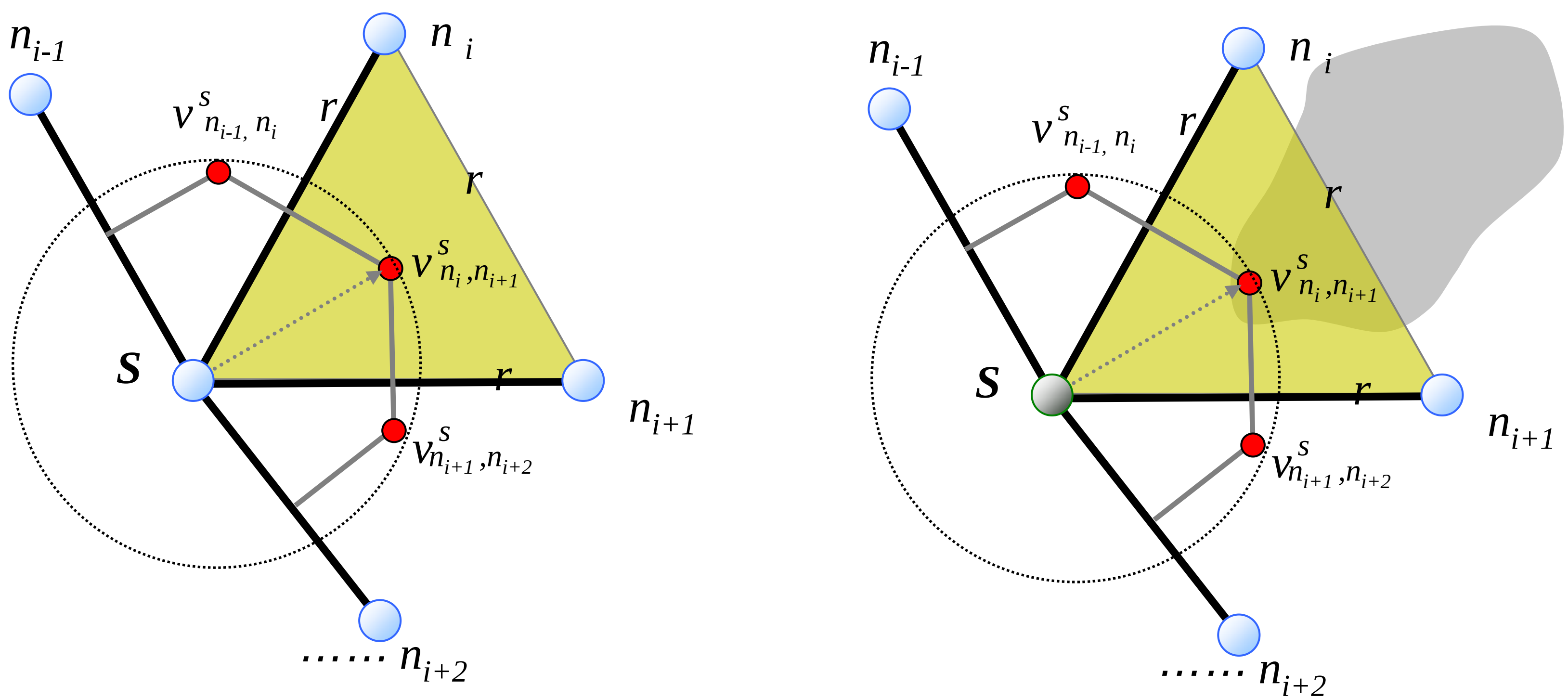
RGP – Obstacle Detection Phase (1st)

An obstacle is different from a hole.
An obstacle might impact the communication but a hole might not.
An example that a hole does not impact the communications of s, n_1 and n_2.



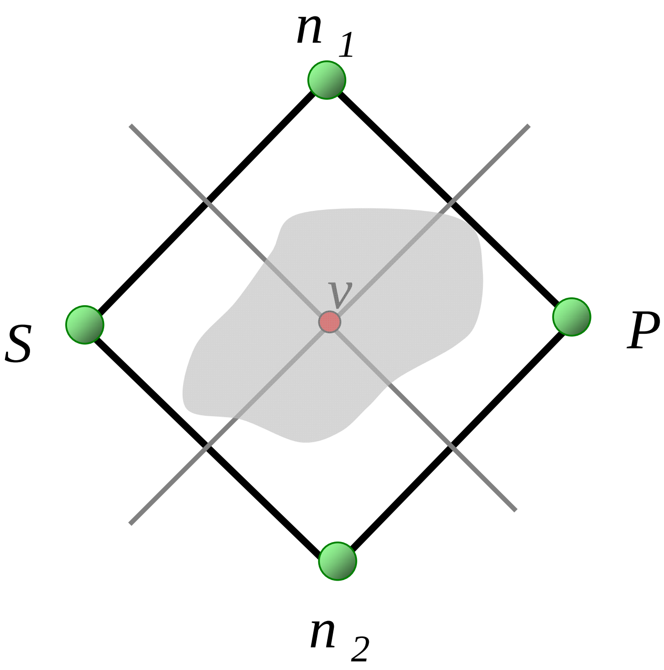
RGP – Obstacle Detection Phase (1st)

Check Rule: For each voronoi vertex $v^{s}_{n_i,n_{i+1}}$ of sensor node s, if $v^{n_i}_{s,n_{i+1}}$ does not belong to n_i or $v^{n_{i+1}}_{n_i,s}$ does not belong to n_{i+1}, then s should serve as a border node



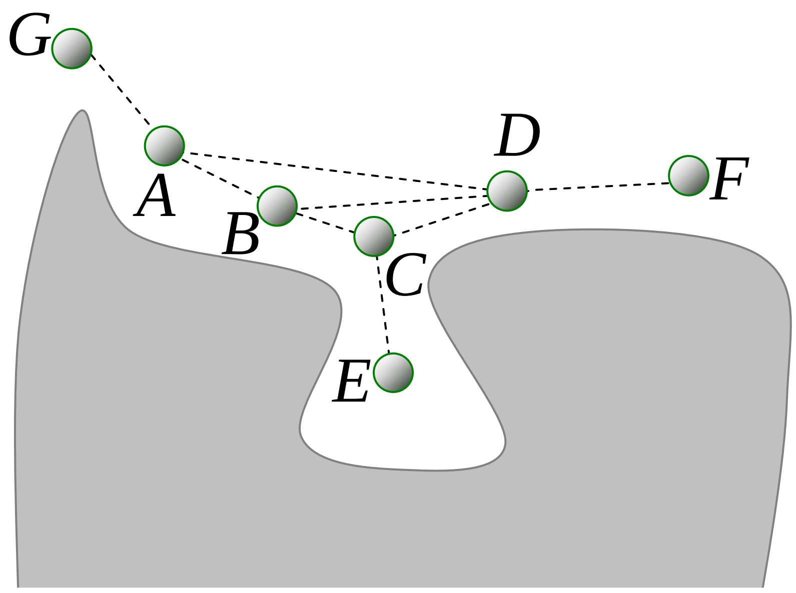
Node s is a border node since the physical obstacle blocks the communication between n_1 and n_2.

Check Rule: For each voronoi vertex $V^{s}_{n_i,n_{i+1}}$ of sensor node s, if $V^{n_i}_{s,n_{i+1}}$ does not belong to n_i or $V^{n_{i+1}}_{n_i,s}$ does not belong to n_{i+1}, then s should serve as a border node



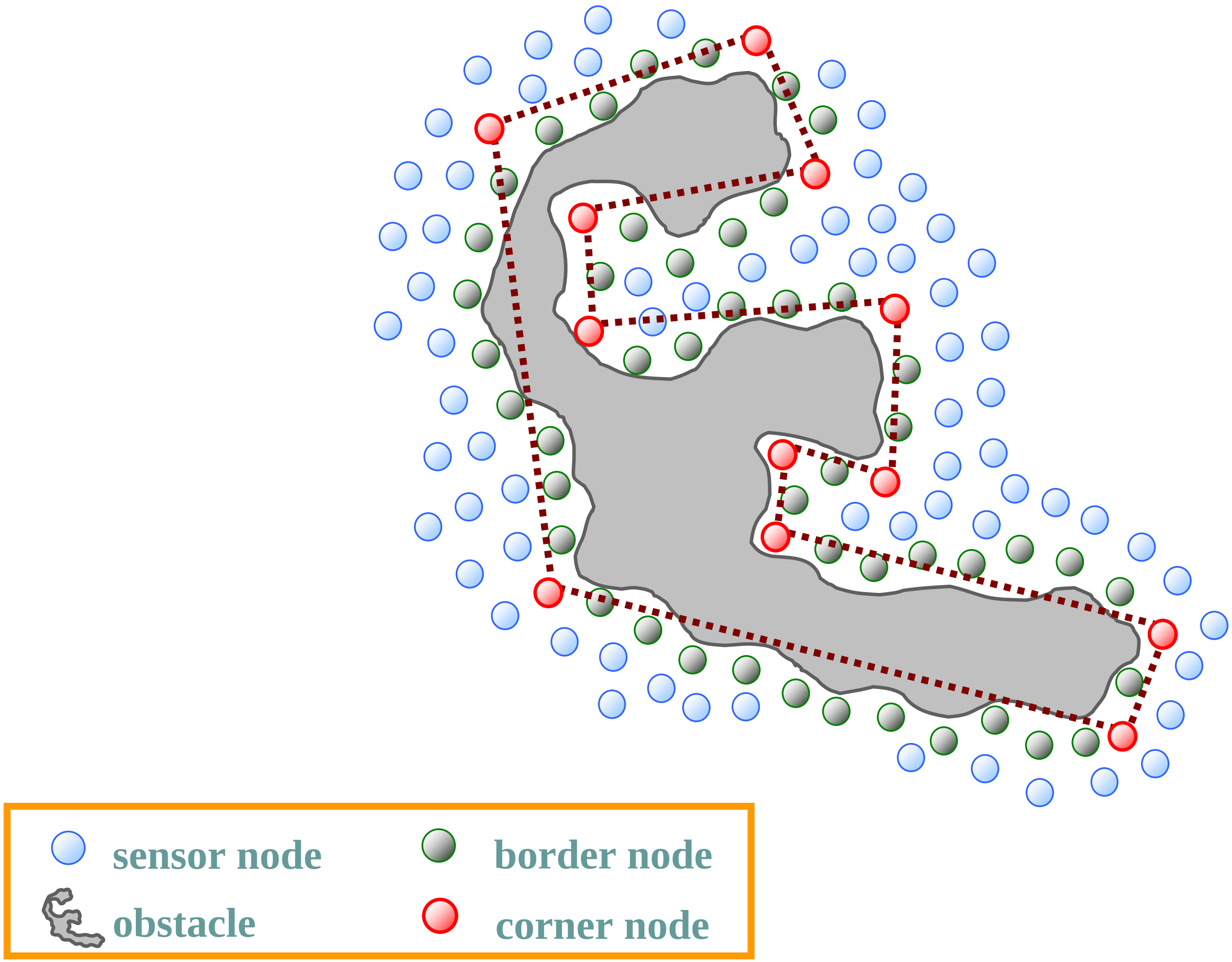
RGP – Obstacle Detection Phase (1st)

- Develop the pruning rule to reduce the number of border node but still guarantee the surrounding property
- Border nodes *C* and *B* abandons to serve as the border node

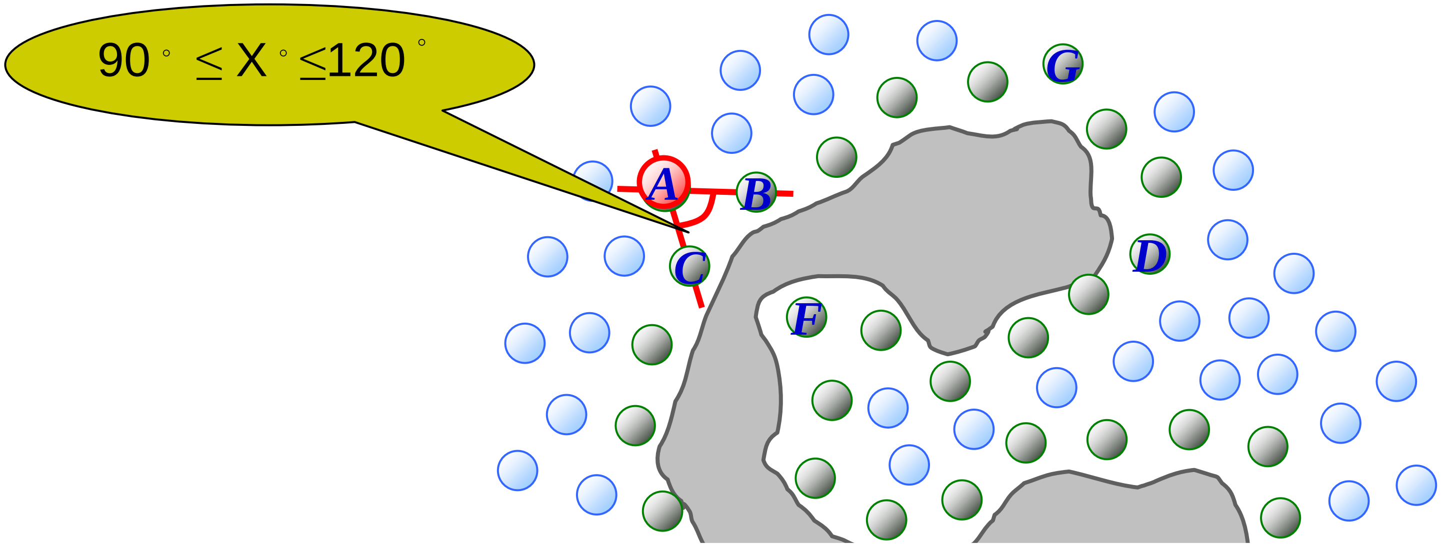


: Border Node

RGP – Normalization Phase (2nd)

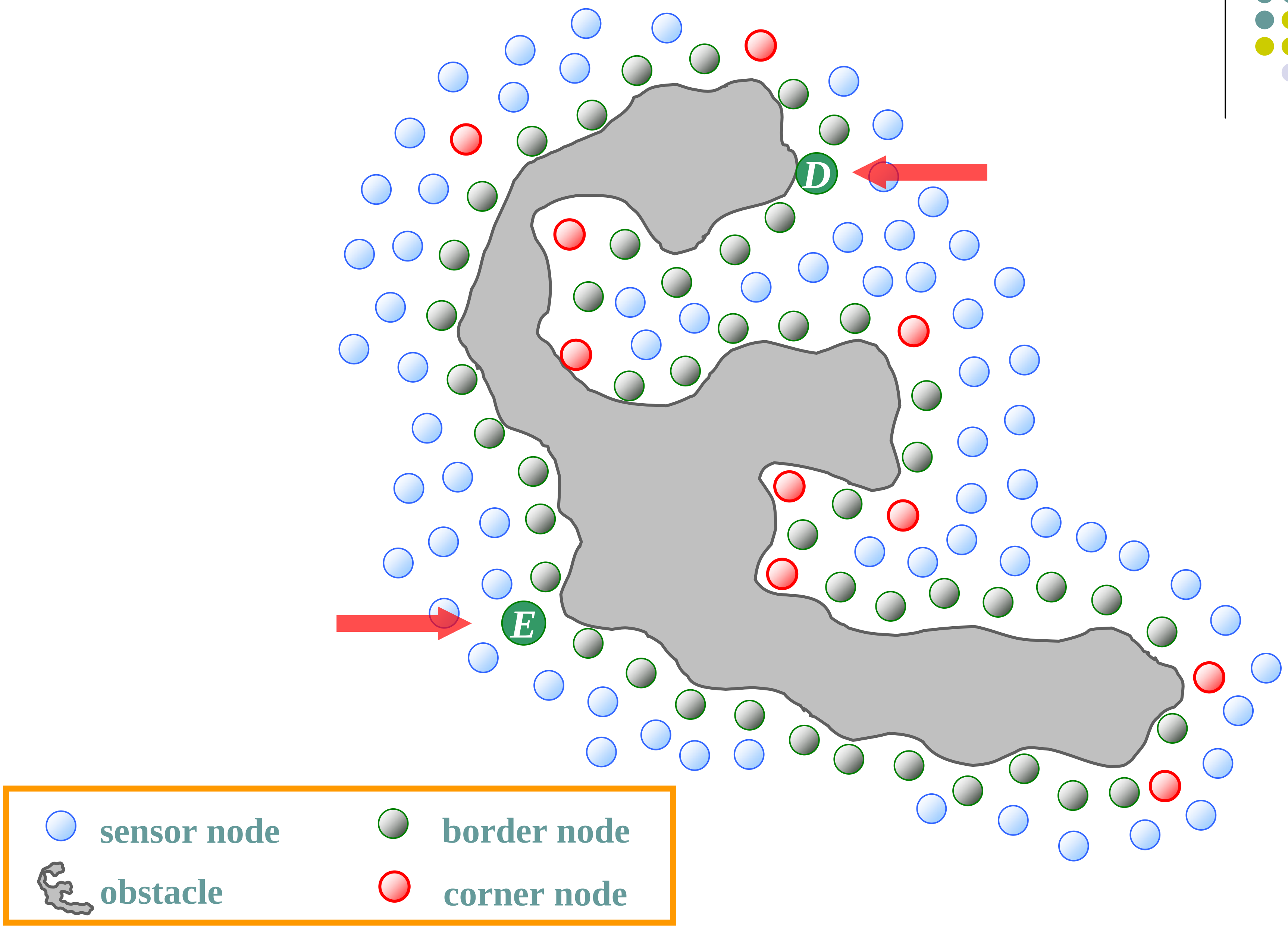


RGP – Normalization Phase (2nd)

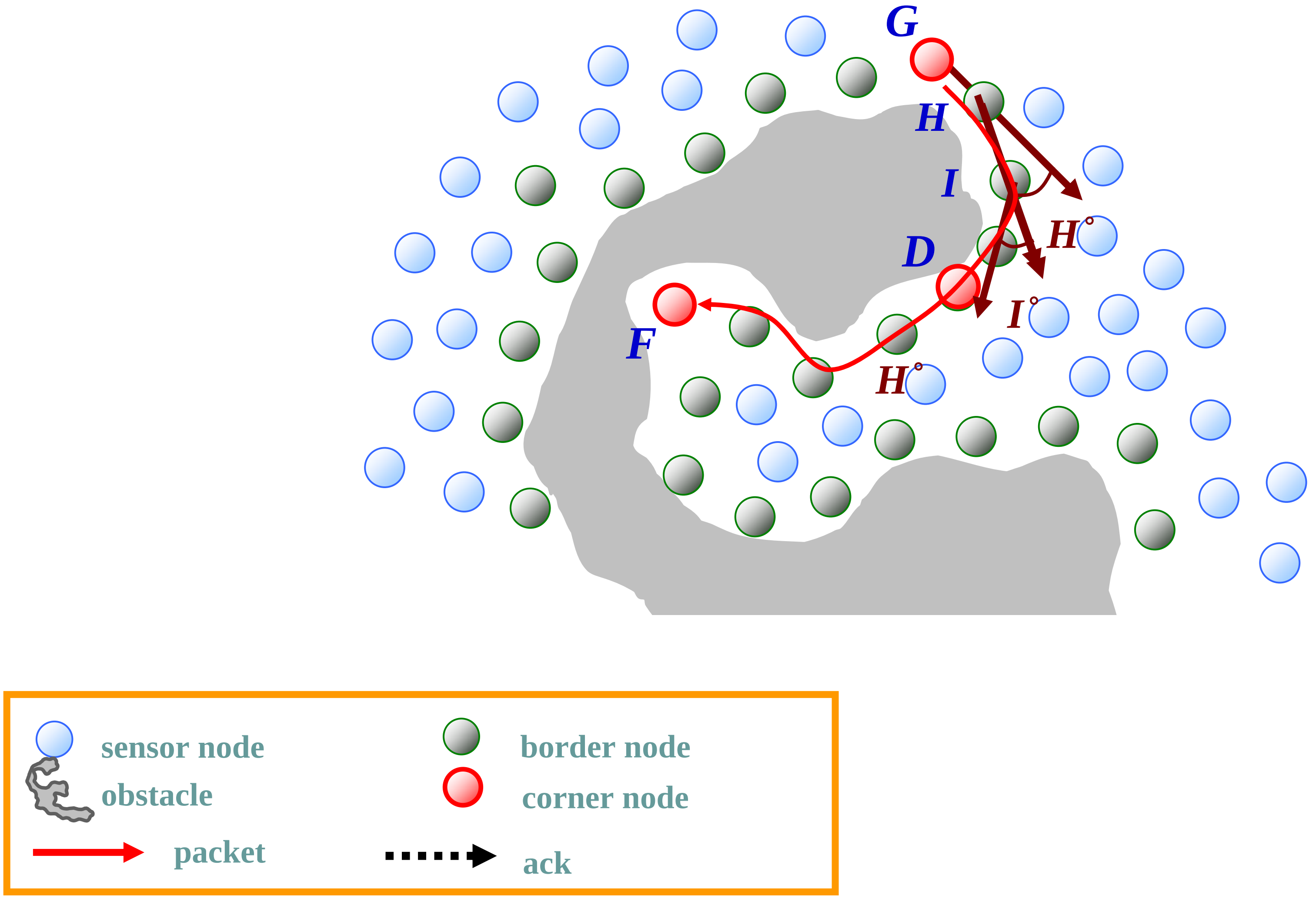


sensor node
border node
obstacle
corner node

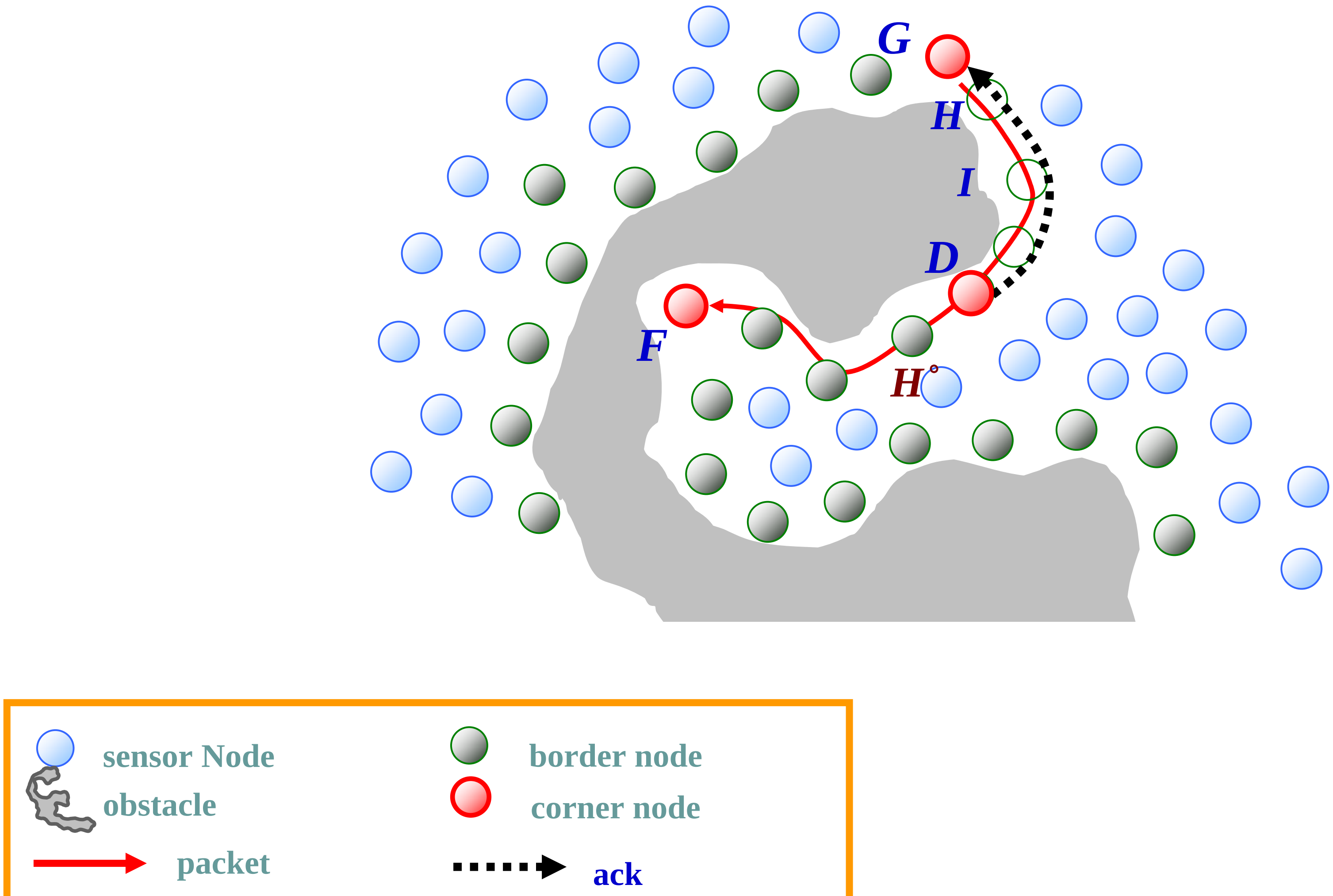
RGP – Normalization Phase (2nd)



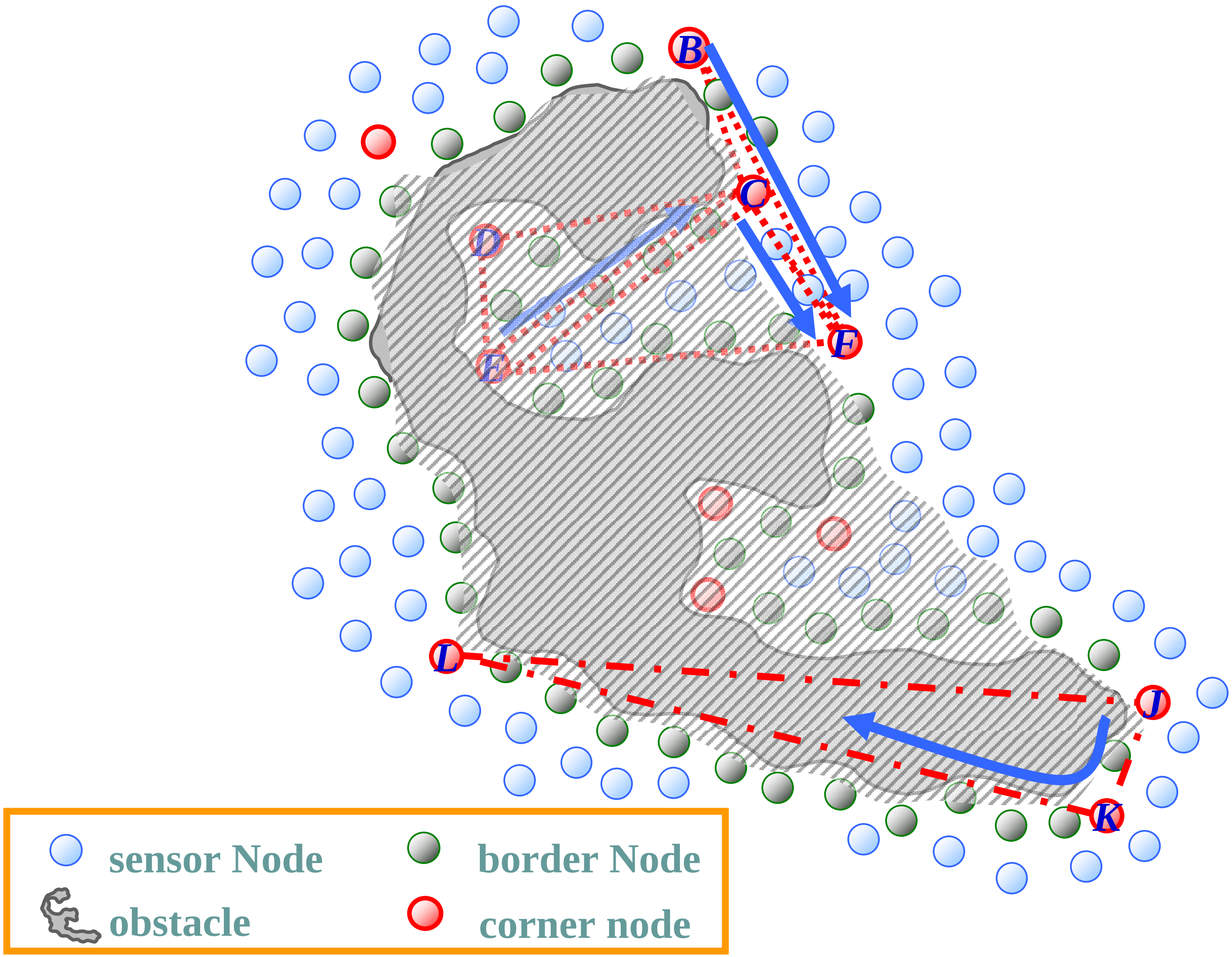
RGP – Normalization Phase (2nd)



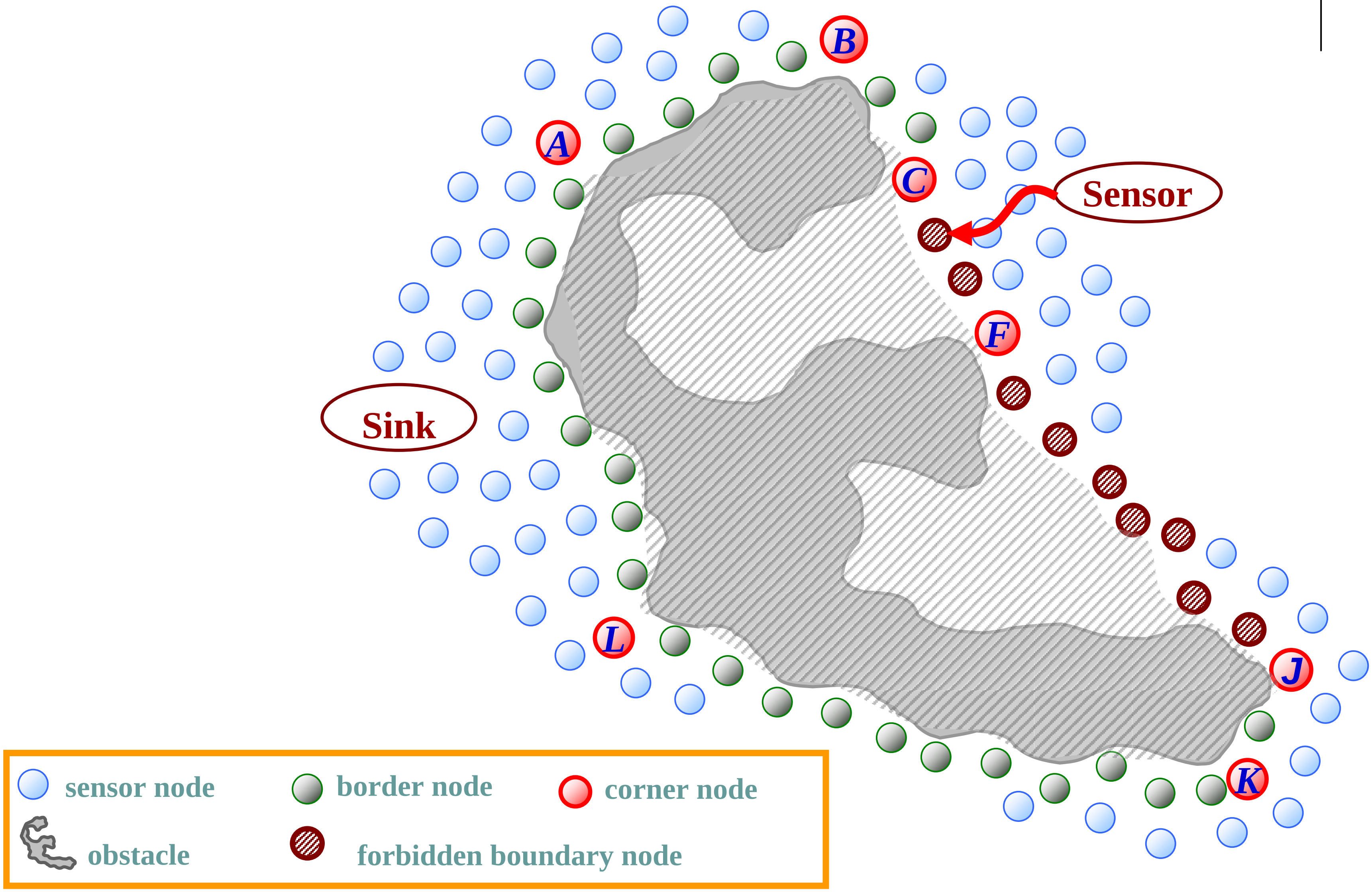
RGP – Normalization Phase (2nd)



RGP – Forbidden Region Construction Phase (3rd)

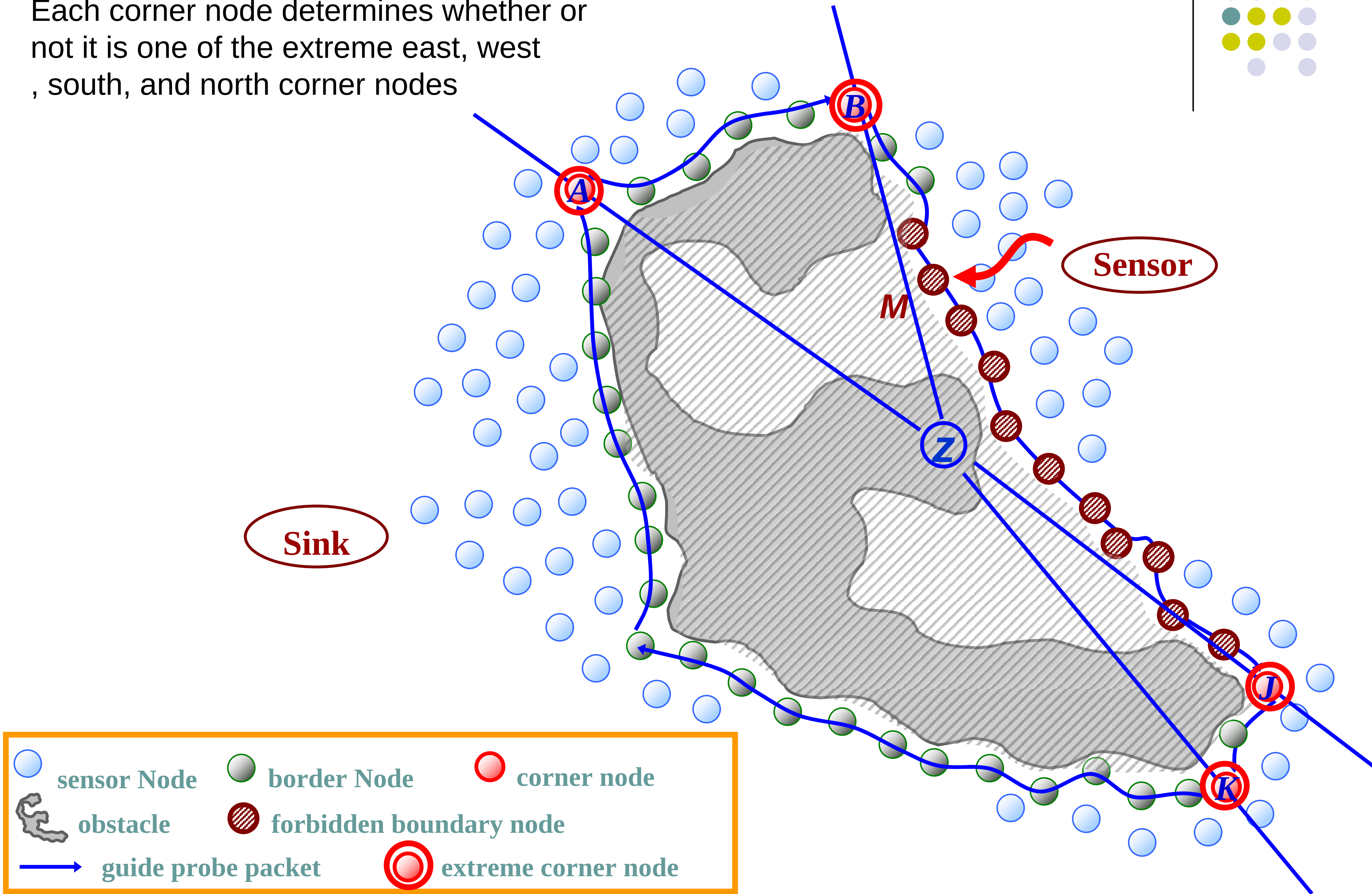


RGP – Forbidden Region Construction Phase (3rd)

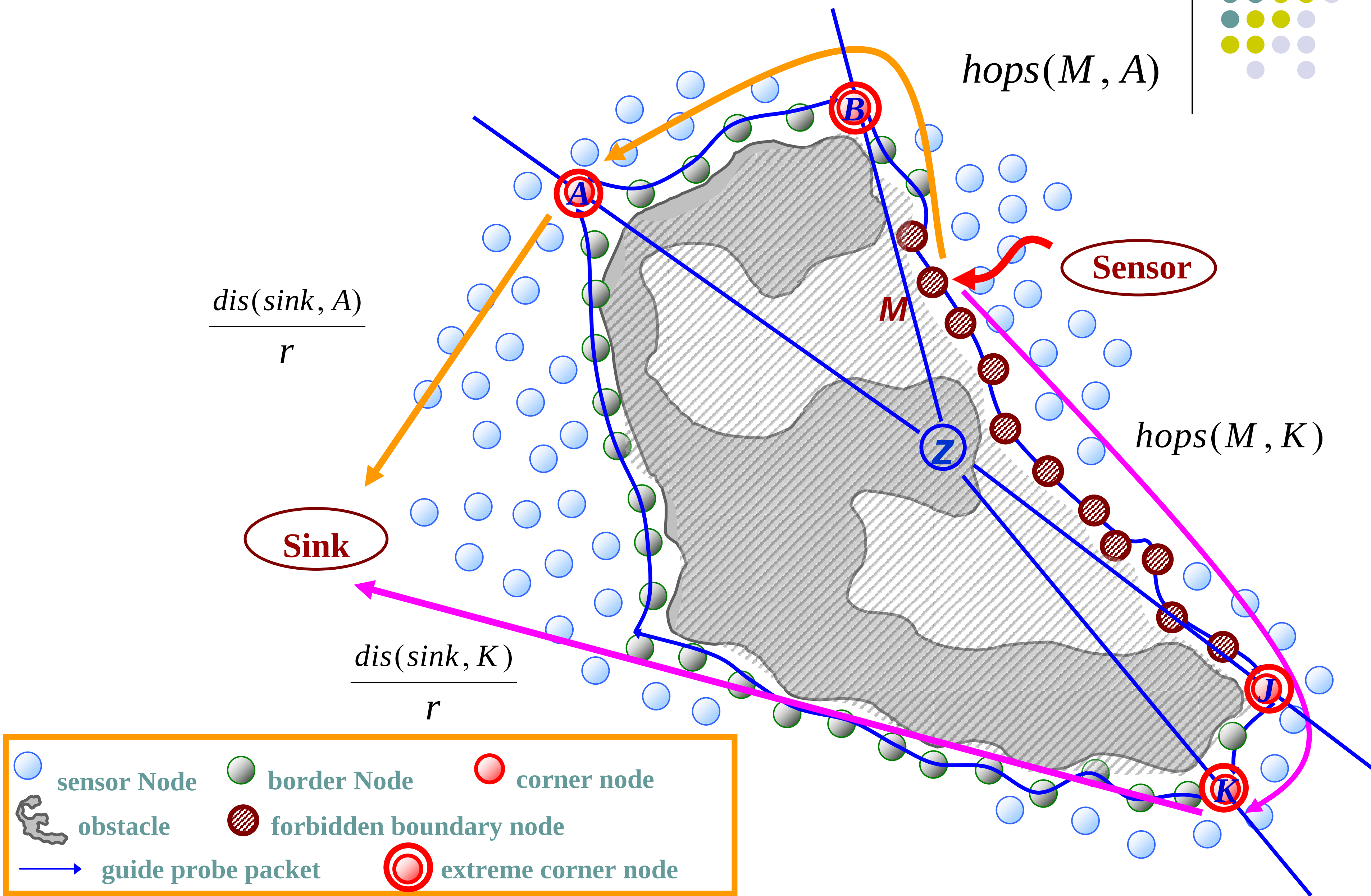


RGP – Packet Guiding Phase (4th)

Each corner node determines whether or not it is one of the extreme east, west , south, and north corner nodes



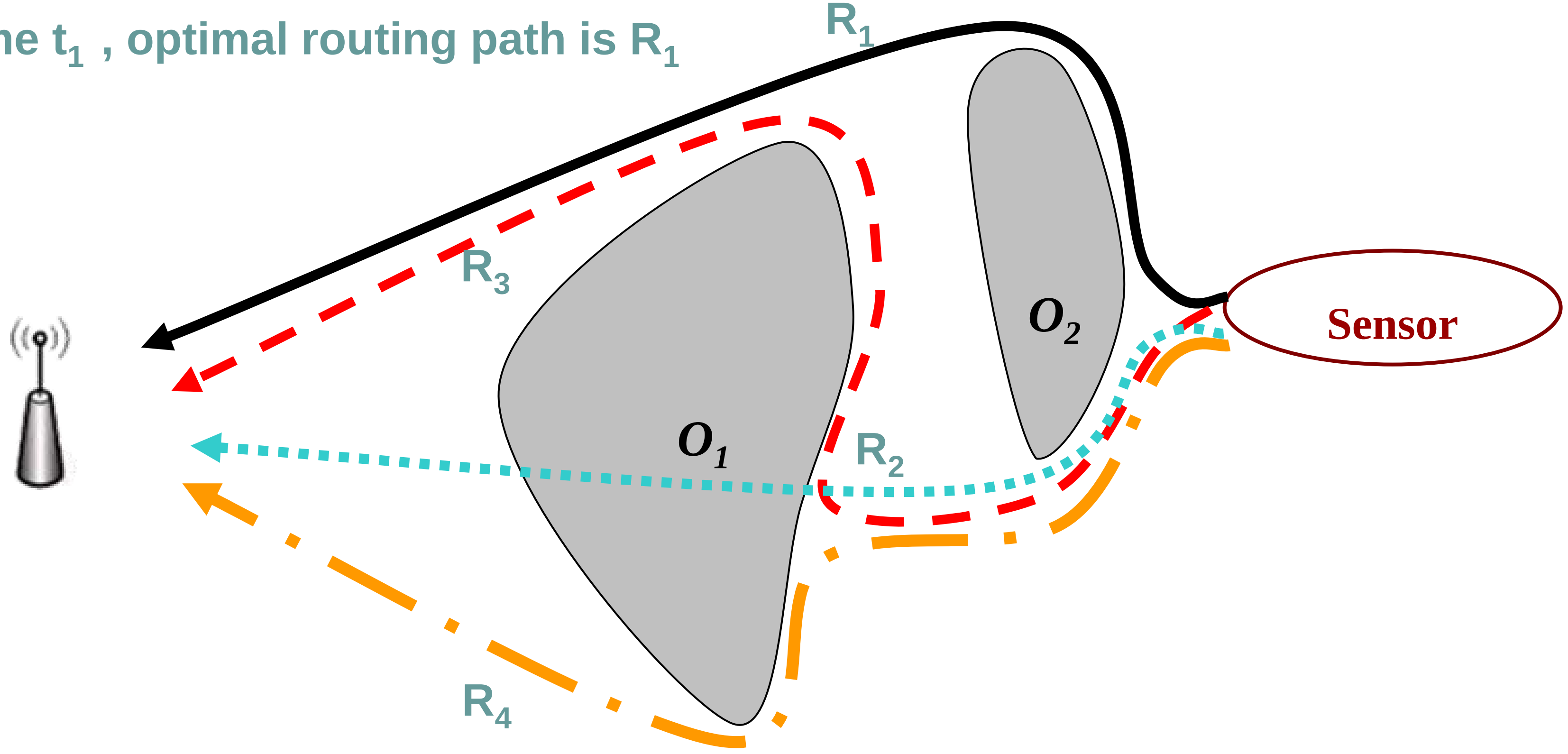
RGP – Packet Guiding Phase (4th)



RGP – Multiple Obstacles

At time t_o , optimal routing path is R_2

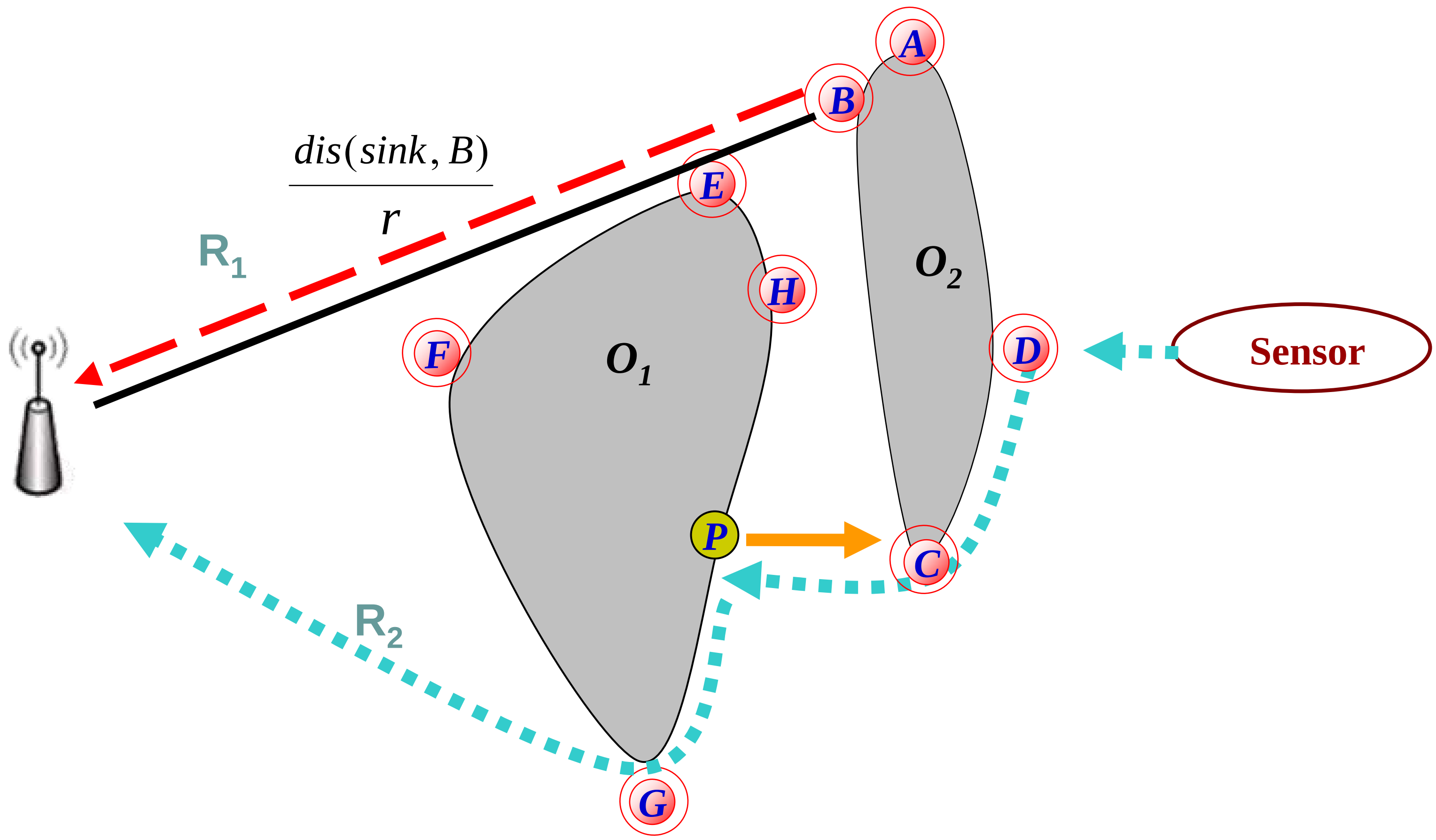
At time t_1 , optimal routing path is R_1



RGP – Multiple Obstacles

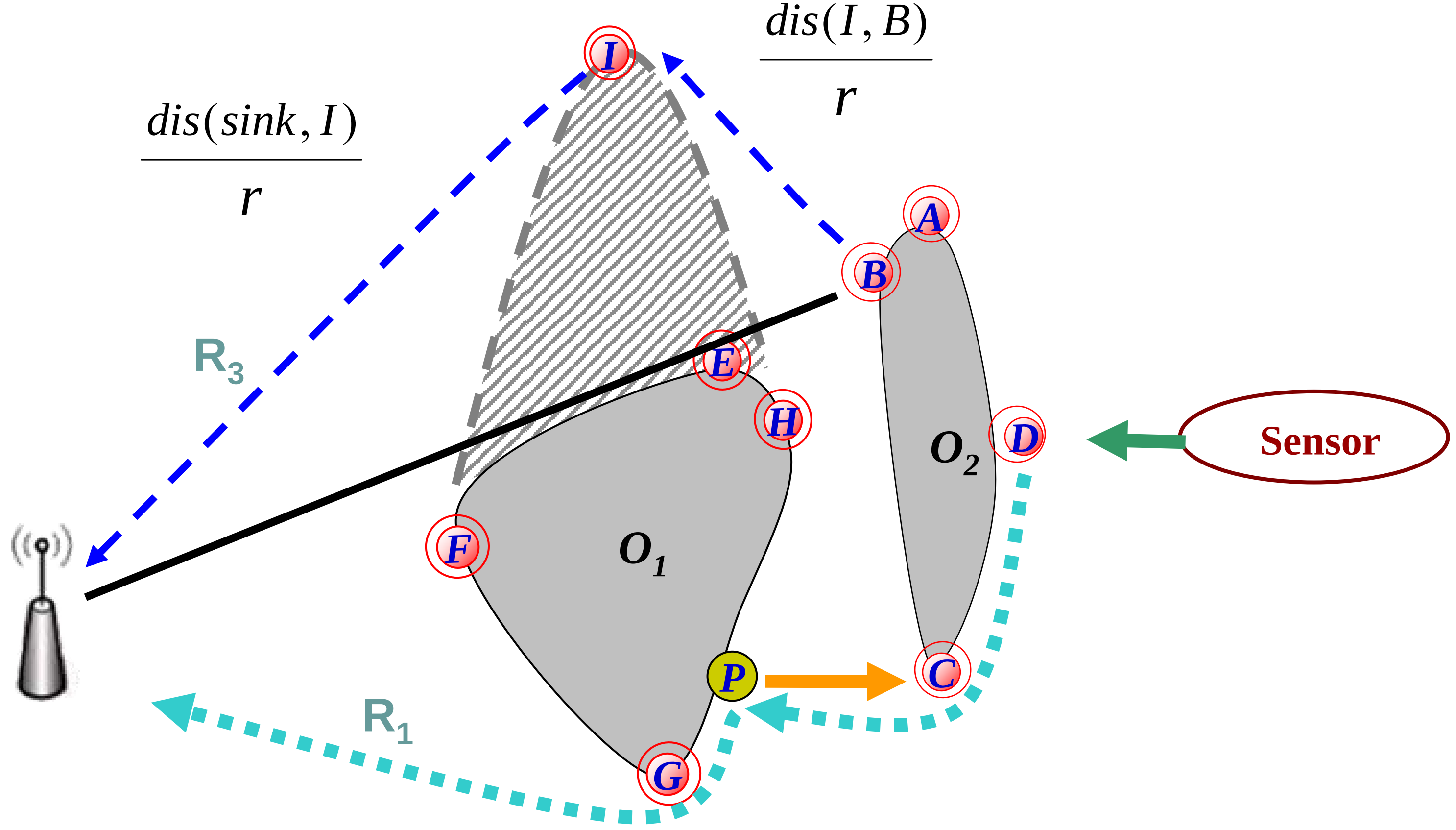
B and *C* are virtual border nodes of O_1

If E, F, G, H are at the same side , the distance between *B* and sink is $\dfrac{dis(sink, B)}{r}$



RGP – Multiple Obstacles

If E, F, G, H are not at the same side

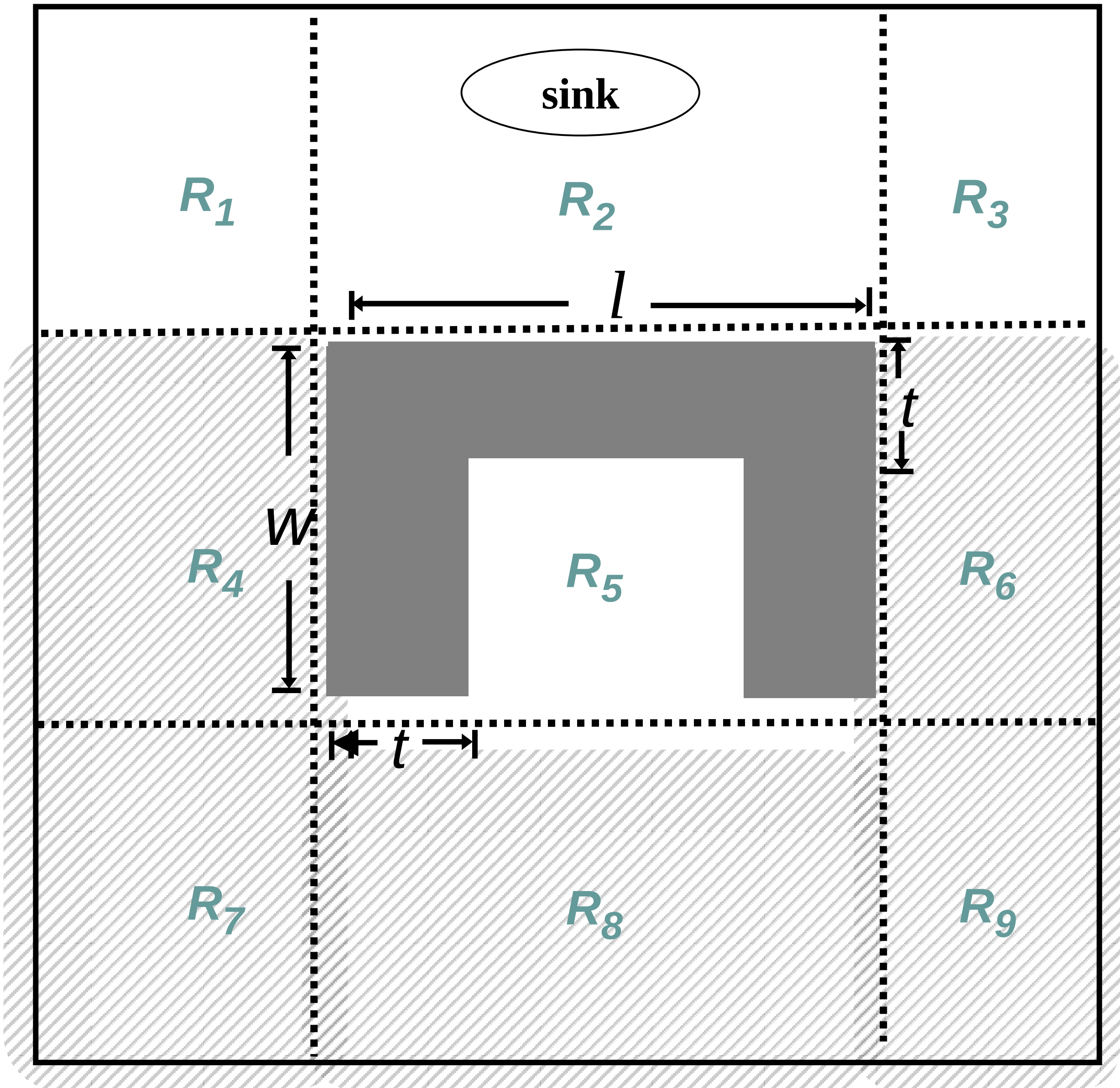


Simulation

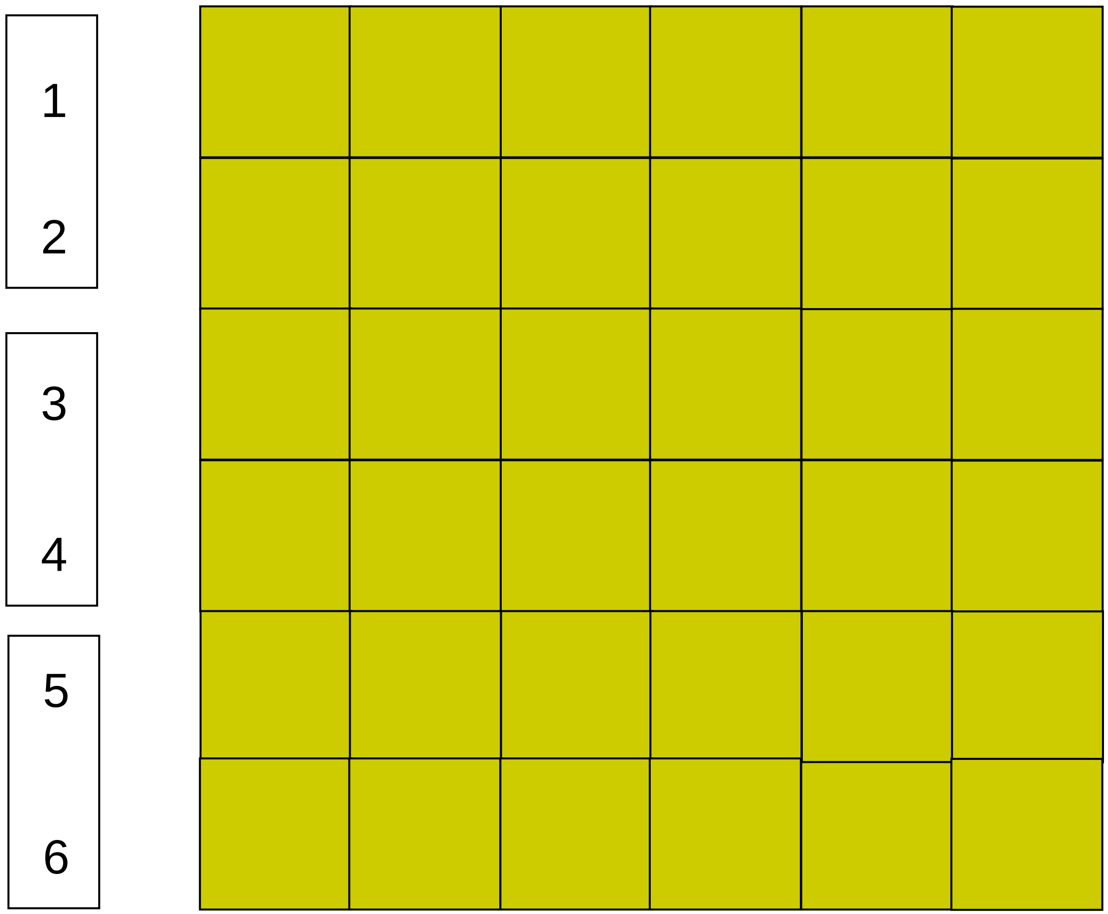
- Simulator : TinyViz
- Network size : 500m * 500m , 2500m * 2500m
- Obstacle size
  - 200mx200m
  - 250mx250m
  - 300mx300m
  - 350mx350m

- Compare with
  - PAGER
  - Flooding
  - GPSR

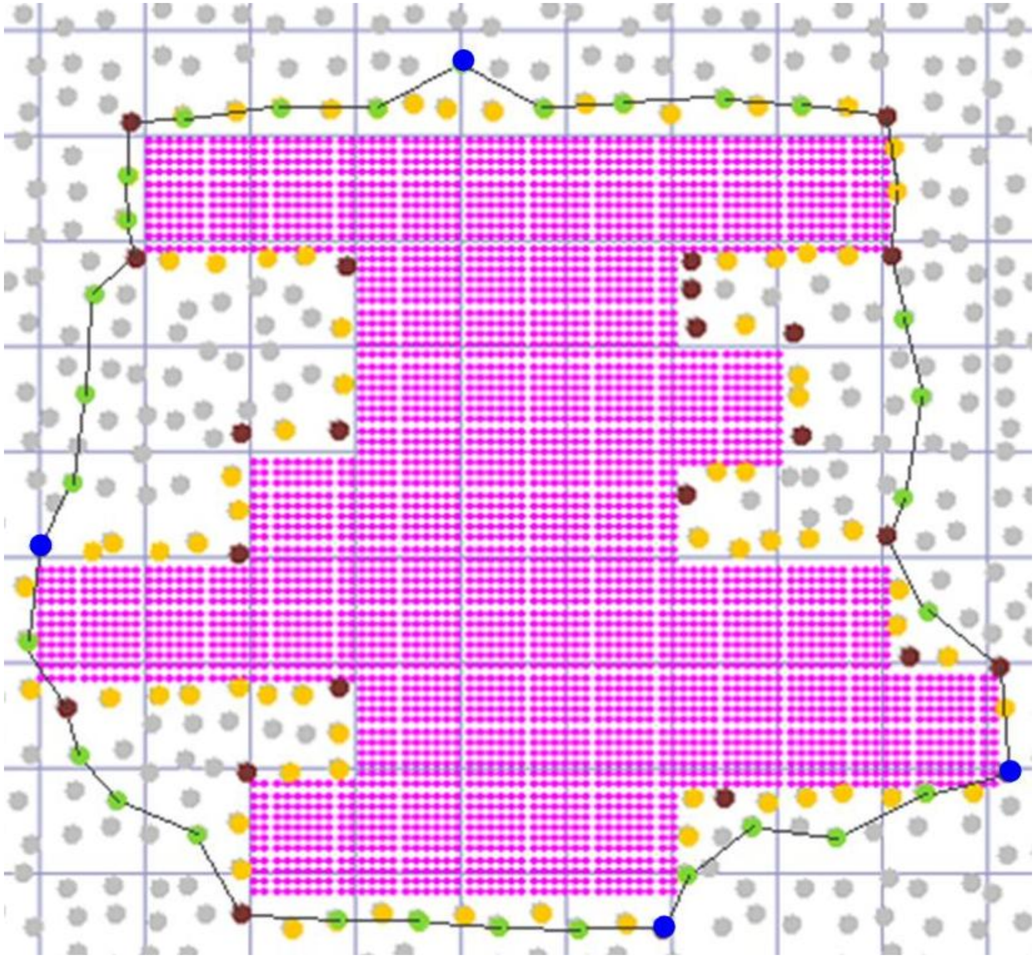
Simulations



Simulations

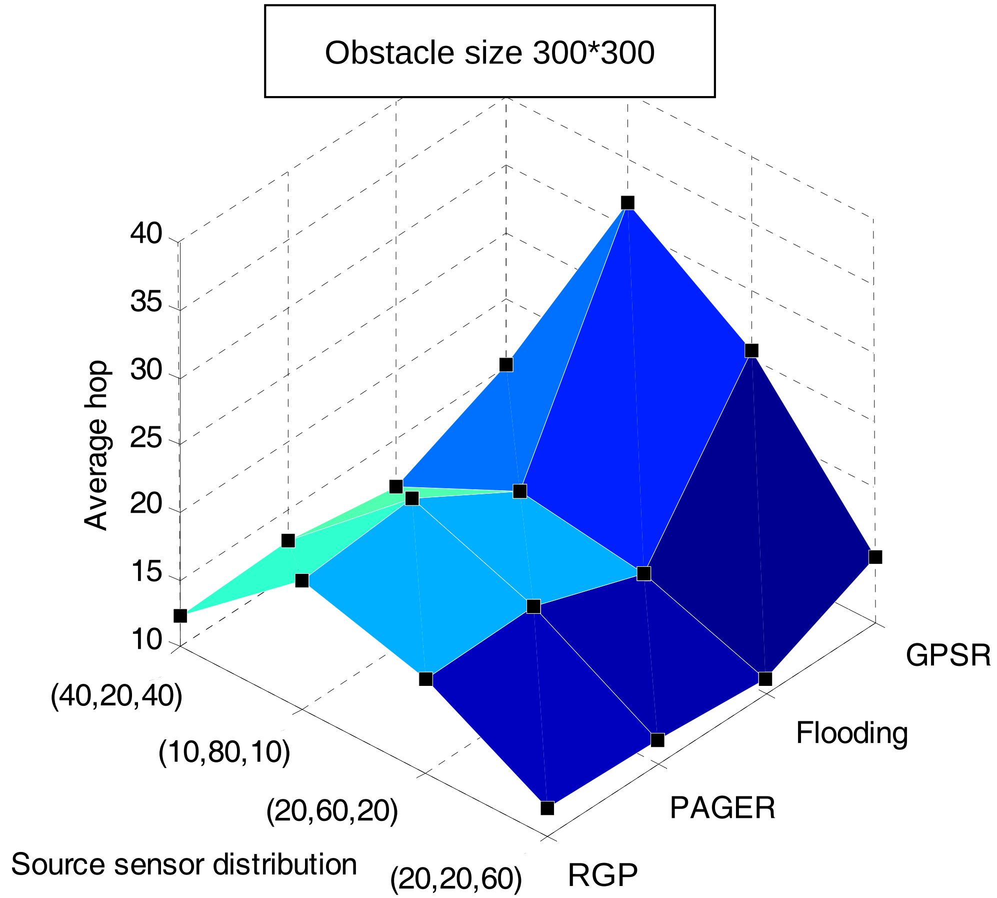


Simulations



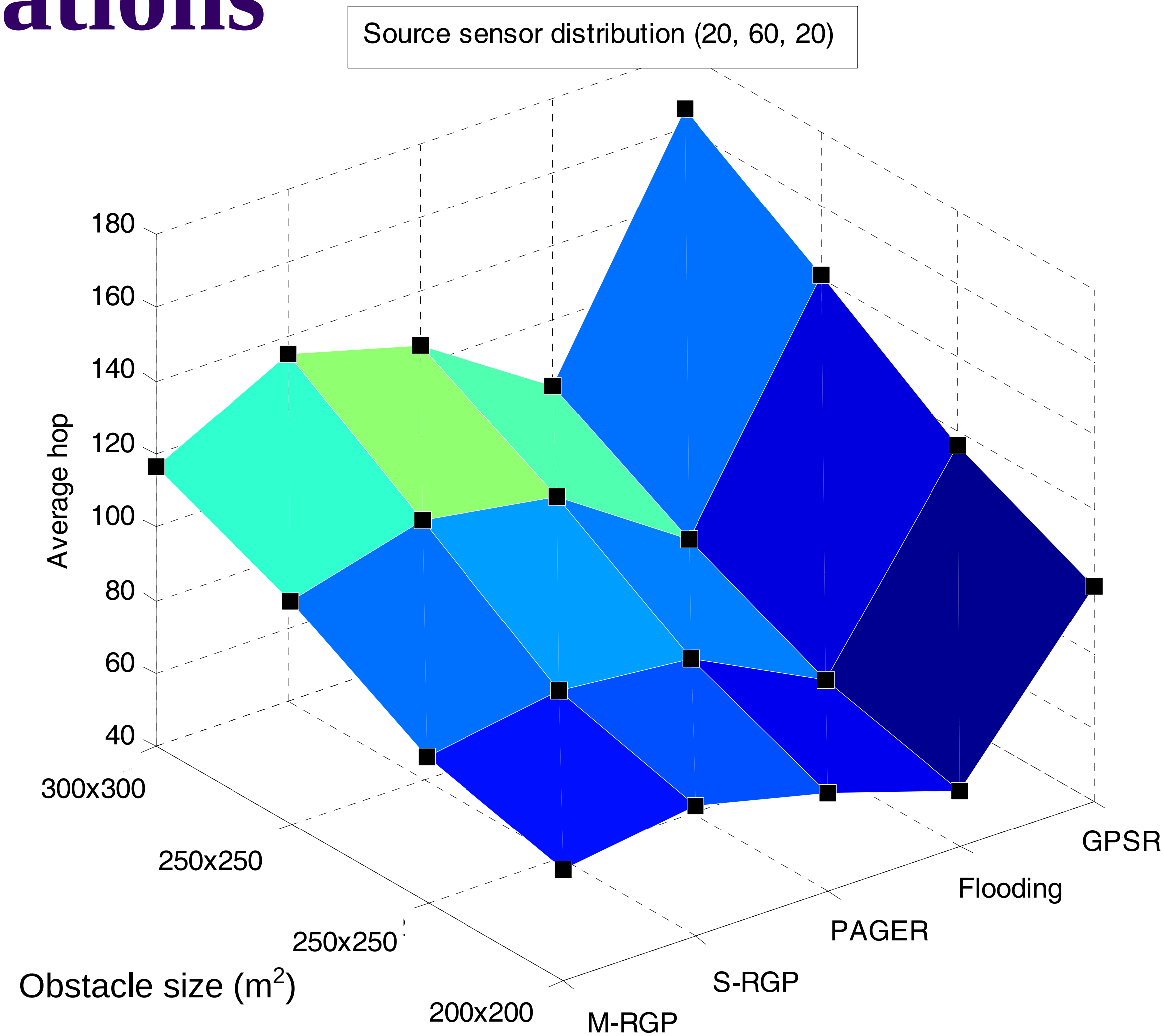
border node
extreme corner node
corner node

Simulations



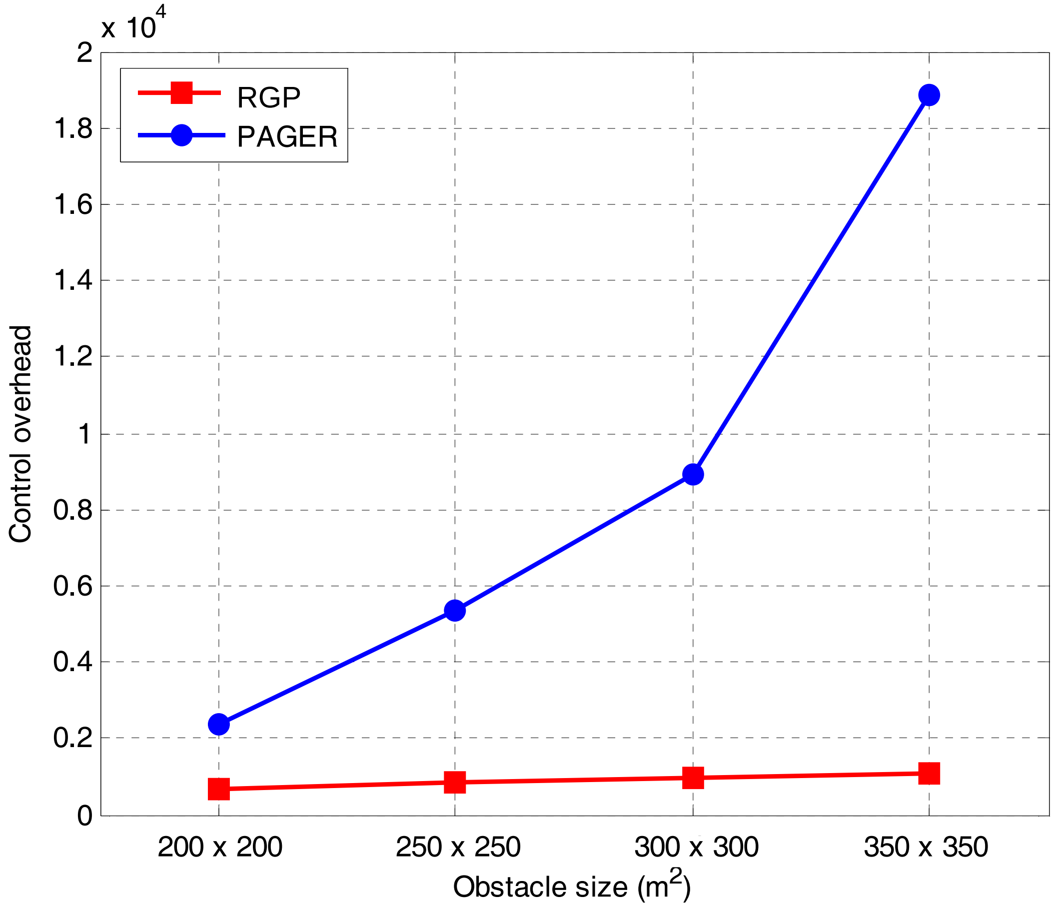
The comparison of RGP, flooding, GPSR, and PAGER mechanisms in terms of average hop count in single-irregular-obstacle environment .

Simulations



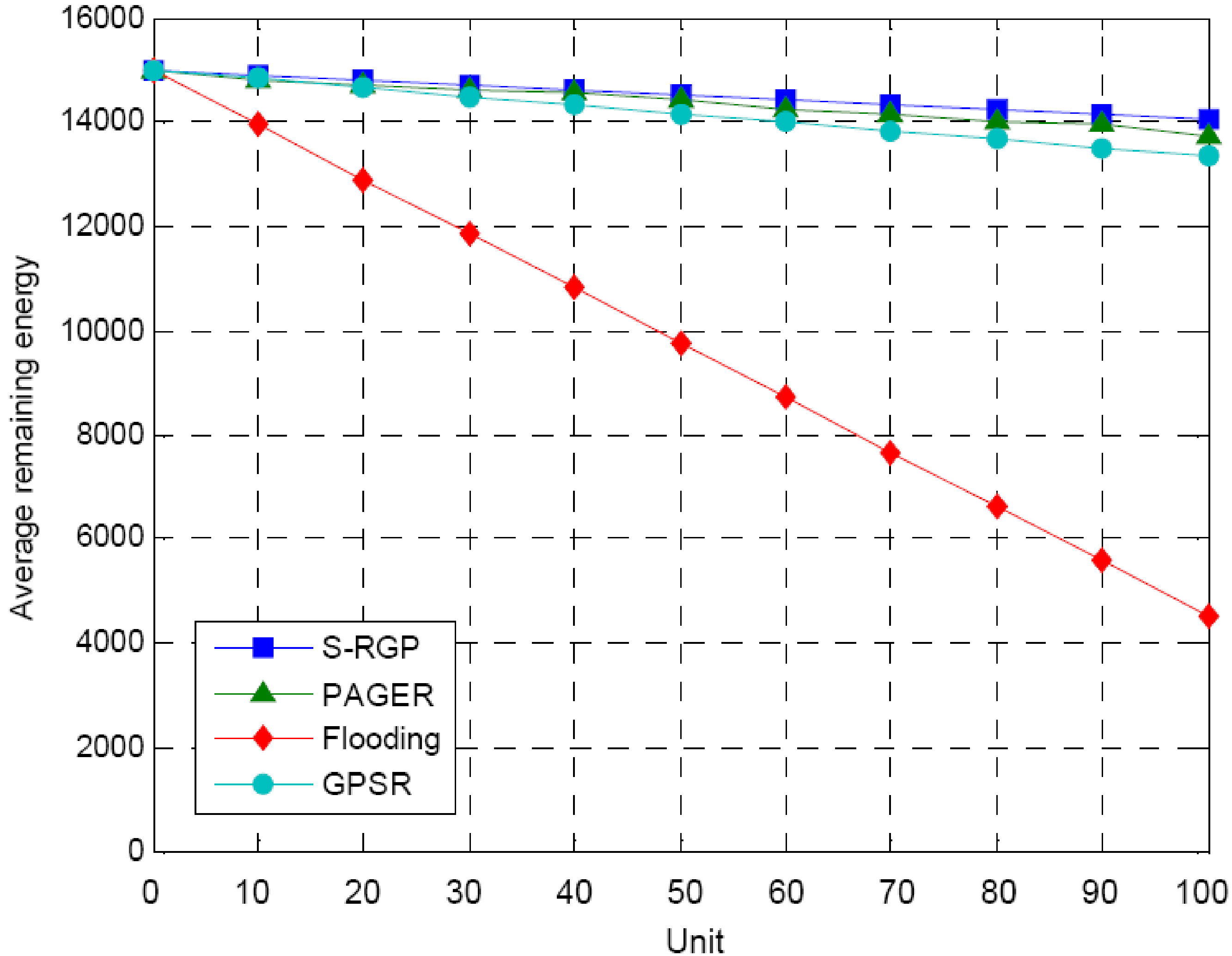
The comparison of Flooding, S-RGP, M-RGP, PAGER, and GPSR in terms of average hop in the multiple-irregular-obstacle environment

Simulations

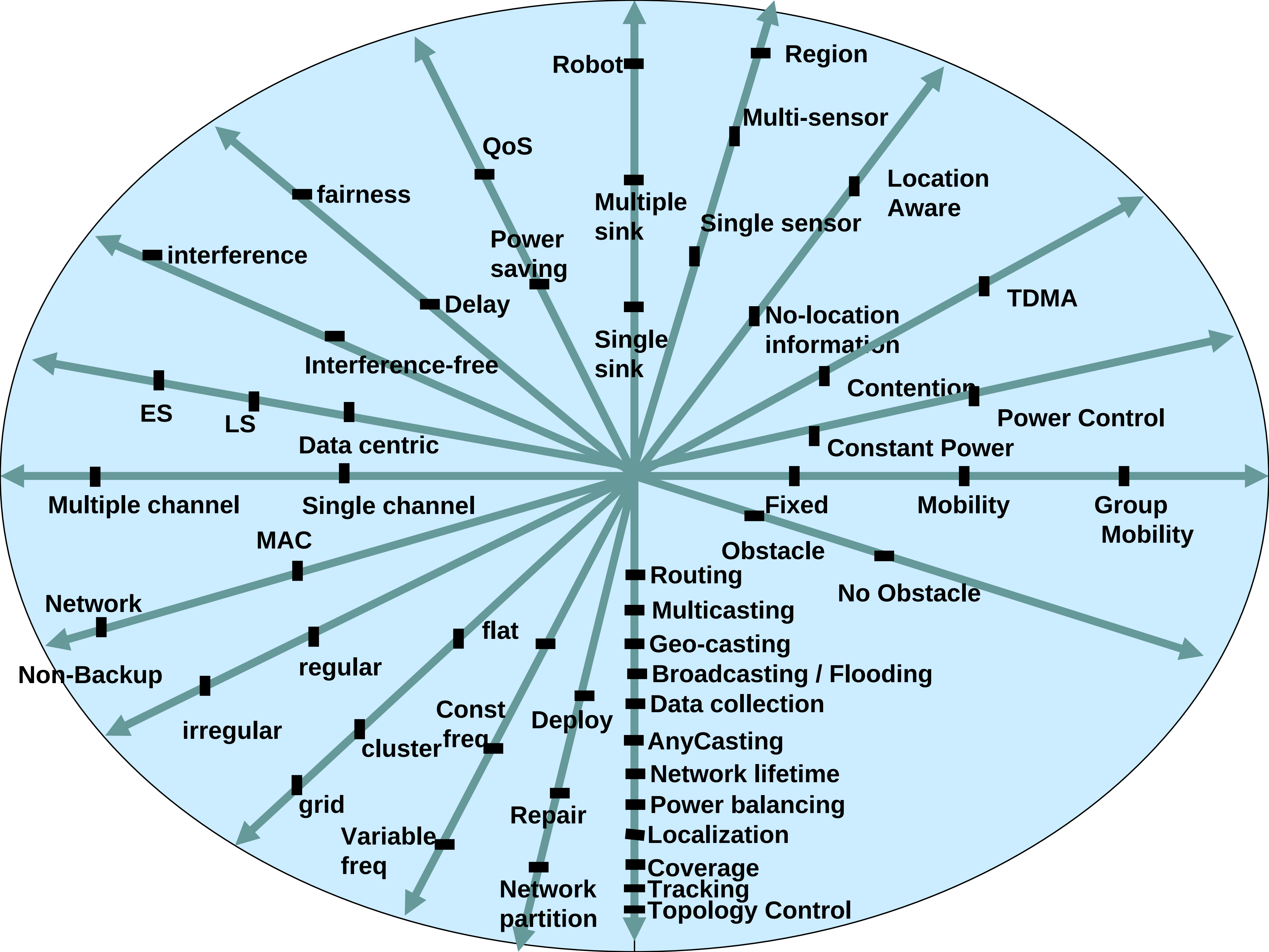


The control overhead of PAGER and RGP in different size of single-regular-obstacle.

Simulations



The comparison of the Flooding, S-RGP, GPSR, PAGER mechanisms in terms of the remaining energy in the single-irregular-obstacle environment.



Robot
Region
Multi-sensor
QoS
fairness
Multiple sink
Single sensor
Location Aware
interference
Power saving
Delay
TDMA
No-location information
Single sink
Interference-free
Contention
Power Control
ES
LS
Data centric
Constant Power
Multiple channel
Single channel
Fixed
Mobility
Group Mobility
MAC
Obstacle
Routing
No Obstacle
Network
Multicasting
flat
Geo-casting
Non-Backup
regular
Broadcasting / Flooding
Data collection
Const freq
Deploy
irregular
AnyCasting
cluster
Network lifetime
grid
Repair
Power balancing
Variable freq
Localization
Coverage
Network partition
Tracking
Topology Control

Research Issue

- Strong Motivation
- Novel Idea
- Significant Contribution