Research Issues

- Protocols Design for Mobile WSNs
- Obstacle Handling Mechanism in WSNs
- Data-Centric Storage Mechanisms in WSNs

Flooding

- Flooding is the most simplest mechanism for delivering a data to a destination in WSN.
Geocasting

- A node intends to send a short message to all nodes in a predefined region
- Each node is aware of its location
Wireless Sensor Networks

- Obstacles are existed in WSNs
  - Some sensor nodes will die 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
  - Interference
  - Animus interference
  - Packet transmission will be inefficient or blocked if obstacle is encountered

Geocasting with obstacles
Obstacle Handling: Paper 1

**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

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**LBM**
- Location-Based Multicast Scheme 1

![Diagram of LBM](image)
LBM
- Location-Based Multicast Scheme 2

Disadvantage of LBM
Conclusion

• Advantage
  – limit the forwarding space for geocast packet
  – lower message overhead
• Disadvantage
  – Not always efficient

Obstacle Handling: Paper 2

Title: GPSR: Greedy Perimeter Stateless Routing for Wireless Networks
Authors: Brad Karp and H. T. Kung
From: ACM MobiCom 2000
Goal

- Data-centric concept
  - The data of sensing sensor should be stored at another sensor which is called data-centric node
  - Hashing function is applied to derive the location of data-centric node
- Given a destination location, how to send a data packet for storing the data at the sensor closest to the location such that the communication overhead can be minimized

Example of GPSR

- GPSR—Greedy forwarding algorithm
Example of GPSR

- **GPSR**—Perimeter forwarding algorithm
Example of GPSR

GPSR

- RHR

Source

Destination
Obstacle effect of GPSR

Conclusion

• Greedy Perimeter Stateless Routing
  – Advantages
    • small routing protocol message complexity
    • Extremely robust packet delivery on densely deployed wireless networks
  – Disadvantage
    • Routing path is not always efficient
Obstacle Handling: Paper 3

**Title:** Worst and Best-Case Coverage in Sensor Networks

**Authors:** Seapahn Megerian, Farinaz Koushanfar, Miodrag Potkonjak, and Mani B. Srivastava

**From:** IEEE TRANSACTIONS ON MOBILE COMPUTING 2005

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**Face Routing**

- Network is partitioned into several faces
Face Routing

Face Routing
Face Routing

Face Routing
Face Routing

Face Routing
Conclusion

• Face routing
  – Advantage
    • Increase the packet arrival rate
  – Disadvantage
    • Routing path is not always efficient

Obstacle Handling: Paper 4

Title: Obstacle-Free Geocasting Protocols for Single/Multi- Destination Short Message Services in Ad Hoc Networks

Authors: Chih-Yung Chang, Chao-Tsun Chang and Shin-Chih Tu

From: ACM Wireless Networks 2003
Goals

• Geocasting Protocol
  – Obstacle free
  – High successful
  – Low flooding overhead

Flooding
Zone-based Management

Zone-based Flooding

- Marker
- Sensor Node
- Collision
Network Environment

- Network has been partitioned into several equal-sized zones
- A manager will be elected for each zone

(a) Manager election
(b) Manager Change
OFSGP protocol (cont.)

• The OFSGP comprises two phases
  – Reaching phase
  – Broadcasting phase

![Diagram of OFSGP protocol]

OFSGP protocol (cont.)

• *Reaching Phase Protocol*
  – Rule 1: Manager $M$ should relay the message to the three promising managers.

$\bigcirc C_d$
OFSGP protocol (cont.)

• Executing the *reaching phase protocol* creates a convergent flooding area

![Diagram showing the reaching phase protocol](image)

OFSGP protocol (cont.)

• *Reaching Phase Protocol* (cont.)
  – Rule 2: If the three promising cellulares are obstacles, manager $M$ should relay the message to the other three neighboring managers.

![Diagram showing the reaching phase protocol](image)
OFSGP protocol (cont.)

• **Reaching Phase Protocol** (cont.)
  – Rule 3: If Rules 1 and 2 fail, the message will be returned to the neighboring manager who sent the short message to manager $M$. 

![Diagram of OFSGP protocol example]
OFSGP protocol (cont.)

• Special case of Line-shape obstacles.

• Broadcasting Phase protocol
OFSGP protocol (cont.)

• Operation of broadcasting phase protocol

![Diagram of OFSGP protocol](image)

OFMGP protocol

• **Multi-Destination Geocasting Protocol**
  - **Without** Considering Obstacles
    • Short path
    • Share path
  - **Consideration of Obstacles**
    • To reduce flooding area
OFMGP protocol (cont.)

• **OFMGP without considering obstacles**
  – Shared path from $C_s$ to $C_{d_1}$ and $C_{d_2}$

![Diagram of OFMGP protocol without considering obstacles]

Hop count = 6

OFMGP protocol (cont.)

• **OFMGP without considering obstacles**
  – Shared path from $C_s$ to $C_{d_1}$ and $C_{d_2}$

![Diagram of OFMGP protocol without considering obstacles]

Hop count = 6
• **OFMGP without considering obstacles**
  – Shared path from $C_s$ to $C_{d1}$ and $C_{d2}$

```
<table>
<thead>
<tr>
<th>Direction</th>
<th>Destination Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$C_{d2}$ $C_{d3}$</td>
</tr>
<tr>
<td>2</td>
<td>$C_{d2}$ $C_{d3}$ $C_{d4}$</td>
</tr>
<tr>
<td>3</td>
<td>$C_{d4}$</td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>$C_{d1}$</td>
</tr>
</tbody>
</table>
```

OFMGP protocol (cont.)

• An example for executing OFMGP without considering obstacles
OFMGP protocol (cont.)

• An example for executing OFMGP without considering obstacles

C₅’s Table

<table>
<thead>
<tr>
<th>Direction</th>
<th>Destination Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td></td>
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<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>C₅₁</td>
</tr>
</tbody>
</table>

Conclusions

• Geocasting protocols
  – OFSGP
    • Obstacle free
    • smaller flooding area
    • higher success rate
  – OFMGP
    • shared path
Obstacle Handling: Paper 5

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 PAGER Algorithm

• The Shadow Spread Phase
  – Divides a connected graph into subgraphs originated from concave nodes

• The Cost Spread Phase
  – Establishes paths on a given subgraph obtained in the first phase
The Shadow Spread Phase

Sink

concave node

A

B C

D E

F

shadow node

The Shadow Spread Phase

Bright Area

Sink

bright nodes

Shadow Area

A

B C

D E

F

shadow node
The Cost Spread Phase

Euclidian distance to the BS

\( \Delta \) should be set to the average Euclidean distance between neighboring sensor nodes

\( \Delta \) is set to 3 in this example

The Cost Spread Phase

Sink

22 + \( \Delta \)

22

22

25

22

22

25

A

B

C

D

E

F
The Cost Spread Phase

Sink

A B C D E F

23+\Delta

26+\Delta

22

23

25

26

29
The shadow spread and cost spread processes begin

A changes its status to “bright”, then sends out beacon message
Obstacle effect of PAGER

Not Always efficient due to the lack of the obstacle information!

Obstacle effect of PAGER

Not Always efficient due to the lack of multiple obstacles information!
Conclusion

• Advantage
  – Active obstacle handling

• Disadvantage
  – Requires a large amount of control packets to update the weight of shadow nodes
  – Without packet guiding

Obstacle Handling: Paper 6

**Title:** RGP: Active Route Guiding Protocol for Wireless Sensor Networks with Obstacles

**Authors:** C. Y. Chang, K. P. Shih, S. C. Lee, and S. W. Chang

**From:** IEEE MASS 2006
No Obstacle

Obstacle Effect
Goals

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

The RGP Mechanism

• Advantages
  – Guide packet to the best route
  – Reduce the delay time of packet transmission
  – Reduce the power consumption
  – Improve bandwidth utilization
Assumptions

- Assumptions
  - The density of sensor nodes is high
  - 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
Goal: Normalize the obstacle shape

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)
RGP – **Obstacle Detection Phase (1st)**

- Use Voronoi Diagram to determine the border node

RGP – **Obstacle Detection Phase (1st)**

- Each Voronoi Vertex is constructed by three sensor nodes
RGP – Obstacle Detection Phase (1st)

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

- 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.

![Diagram showing edge pruning for border nodes.](image)
RGP – Normalization Phase (2nd)
RGP – Normalization Phase (2nd)

RGP – Forbidden Region Construction Phase (3rd)
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)

Dis(sink, A) = \frac{\text{hops}(M, A)}{r}

Dis(sink, K) = \frac{\text{hops}(M, K)}{r}

RGP – Multiple Obstacles

At time \( t_0 \), 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 $O_{i,j}$.

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

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

The comparison of RGP, flooding, GPSR, and PAGER mechanisms in terms of average hop count.
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.
Title: WRGP : Weight-Aware Route Guiding Protocol for Wireless Sensor Networks with Obstacles

Obstacle Effect

- sink
- sensor
- sensor node
- obstacle
- routing path
Goals

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

The WRGP Mechanism

• Advantages
  – Guide packet to the best route
    • Reduce the end-to-end delay
    • Reduce the power consumption
  – Avoid Ping-Pong effect for weight modification
    • Reduce the power consumption
Assumptions

- Each node is aware of its own and its neighbors’ locations

Overview of WRGP

- Four phases
  - Obstacle Detection Phase
  - Normalization Phase
  - Forbidden Region Construction Phase
  - Packet Guiding Phase
**WRGP - Obstacle Detection Phase (1st)**

Goal: find minimal number of border nodes

**WRGP - Concave Region Decision Phase (2nd)**

Goal: identify all the concave regions that block the transmission
WRGP - Weight Modification Phase (3rd)

Goal: reassign the weight value and construct a forbidden region to avoid the packet entering obstacle region

WRGP - Packet Guiding Phase (4th)

Goal: guide the packet to the best route
Phase 1: Obstacle Detection

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

Phase 2: Concave Region Decision

Phase
Phase 3: Weight Modification

\( \triangle \): The length of diagonal of sensing field

\( 2\triangle - w \)

sink
Phase 3: Weight Modification

\[ \triangle: \text{The length of diagonal of sensing field} \]

\[ 2\triangle - w \]

sink
Phase 3: Weight Modification Phase

\[ \triangle: \text{The length of diagonal of sensing field} \]

\[ 2\triangle - w \]

sink

Phase 4: Packet Guiding Phase

\( h_{max} \)

effective border node

critical border node
	sink
Phase 4: Packet Guiding Phase

source

sink

a: 16
b: 26
a: 17
b: 25
a: 18
b: 24
a: 19
b: 23
a: 20
b: 22
a: 21
b: 21
b: 20

2015

source

sink