

CS1E **Chapter 12:** Mobicast **Routing Protocol in Wireless** Sensor Networks

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Outline

- 1. Introduction
- 2. Related works
- 3. Our VE-mobicast routing protocol
 - 1. ACM Wireless Network, 2006
 - 2. IEEE ICC, Korea, 2005
- 4. Our HVE-mobicast routing protocol
 - 1. IEEE WCNC, USA, 2006
- 5. Conclusion







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- 1. Introduction
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- 3. Our VE-mobicast routing protocol
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Mobicast

- In this talk, we consider a new "mobicast" routing protocol in the wireless sensornets
 - A spatiotemporal variant of **multicast** called a "mobicast" were designed to support a **forwarding zone** that moves at a constant velocity, *v*, in sensornets.
 - This spatiotemporal multicast protocol provides sensing applications that need to transfer the multicast message to the "right" place at the "right" time.





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Mobicast applications







Our Mobile-Sink Implementation







Motes

Smart Dust Sensors, Wireless Sensor Networks (http://www.xbow.com/)









Mote Kits













CCUCSIE MTPU, Department of Computer Science and Infor-MICA2DOT Multi-Sensor Module (MTS510)









MICAz - 2.4 GHz IEEE 804.15.4/ZigBeeTM Compliant Mote

New! MICAz





Our Implementation













RIGHT BUR/STOPL R/F 0







多媒體無線行動感測車

















CSIE MEP410CA– Micro Climate Multi-Sensor Node











Gateway & Network Interface Modules

Stargate - XScale Network Interface and Single Board Computer

















CCS1E Mobicast framework













Outline

- 1. Introduction
- 2. Related works
- 3. Our mobicast routing protocol
 - **1.** ACM Wireless Network (accepted)
 - 2. IEEE ICC, Korea, 2005
- 4. Our enhanced mobicast routing protocol
 - **1. IEEE WCNC, USA, 2006**
- 5. Conclusion







Related Works

Multicast

• IEEE INFOCOM (2000), MSWiM (2000), WCNC (2003), IEEE GLOBECOM (2003).

Geocasting

 Ko *et al.*, "Geocasting in Mobile Ad Hoc Networks: Location-Based Multicast Algorithms", WMCSA (IEEE Workshop on Mobile Computing System & Applications), 1999.

Mobicasting

- Huang *et al.*, "Design and Analysis of Spatiotemporal Multicast Protocols", **Telecommunication System**, Aug. 2004.
- Huang *et al.*, "Spatiotemporal Multicast in Sensor Networks," ACM SenSys, Nov, 2003.

Huang *et al.*, "Reliable Mobicast via Face Aware Routing", IEEE INFOCOM, March 2004.



Geocasting: the group consist of the set of all nodes within a specified geographical region





Huang et al., "Design are protocols", Spatiotemporal Multicast Protocols", **Telecommunication System (SCIE)**, Aug. 2004.

- A Spatiotemporal multicast protocols for sensornets
 - A new multicast routing protocol
 - Multicast message be disseminated to the "right-place" at the "right-time"
 - A special class of spatiotemporal multicast
 - Mobicast routing protocol
 - A delivery zone that translates through a 2-D space at some constant velocity
 - Centralized Algorithm





- Hold-and-Forward
 - Only nodes on the path of the delivery zone will participate.
 - Delivery-Zone-constrained (DZC) protocol









A Reliable Mobicat Protocl

- Forward-Zone Constrained (FZC)
 - Only nodes in the path of the forwarding zone will participate in the mobicast forwarding.





Networks," ACM SenSys, Nov, 2003.

- The value of compactness is estimated under a local environment
 - Local compactness
 - Reduce message overhead
 - Distributed algorithm but is un-reliable







Reach reliable mobicast delivery

- Using information form a sensor node's immediate spatial neighborhood
- Forwarding schedule depends on local topology information.
 - Right-hand neighborhood discovery protocol
- Face-Aware Routing (FAR)
 - Greedy Forwarding
 - Forwards a packet in an "as-soon-as-possible"
 - Timed Forwarding
 - Forwarding decision based on the "relative times"











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VE-Mobicast: A Variant-Egg-Based Mobicast Routing Protocol in Sensornets

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Mobicast framework









Motivation

- Existing protocols for a spatiotemporal variant of a multicast system were designed to support a forwarding zone that moves at a constant velocity, v, in sensornets.
- To consider the path of a mobile entity which includes turns, this work mainly develops a new mobicast routing protocol, called the variant-egg-based mobicast (VEmobicast) routing protocol, by utilizing the adaptive variant-egg shape of the forwarding zone to achieve high predictive accuracy.





^{ccu}CS¹E Delivery zone Z[t], Z[t + 1] and forwarding zone F[t]+1] at time *t* and *t*+1

High predictive accuracy

(a)

Application example of the VE-mobicast

System Model

- The node capabilities of all sensor nodes, including the mobile physical entities (or mobile sink node), in our work are assumed to know their location information by using GPS (Global Positioning System) or other location information-aided devices
 - Our approach adaptively determines the forwarding zone based on the location information. Without the location information, the exact forwarding zone cannot be accurately determined.

Cont.

- This paper is assumed that all nodes are synchronized. When nodes are not synchronized, the predictive mechanism of our VE-mobicast protocol cannot be correctly performed.
 - This leads to predict the incorrect size and shape of the forwarding zone, and it causes power to be needlessly consumed.

All sensor nodes are homogeneously and randomly deployed in a monitoring area by a random network. This paper is only concerned with a static and irregular topology, i.e., all sensor node locations are fixed and irregular.

Cont.

The main operation of VE-Mobicast is depended on the control packets to determine the right forwarding zone in a distributed fashion. Therefore, this paper is **not investigated the robust problem** when VE-Mobicast operation losses of control packets.

Contribution

- To simultaneously consider the factors of moving speed an direction
 - This paper mainly investigates a new mobicast routing protocol, called variant-egg-based mobicast (VE-mobicast) routing protocol, by
 - To utilize the variant-egg shape of the forwarding zone to achieve mobicast forwarding with **high predictive accuracy**.

Our basic idea

Our variant-egg-based mobicast routing protocol

- A <u>distributed and adaptive mechanism</u> to provide a dynamic shape of variant-egg
 - Dynamically adjust the shape and size of variant-egg
 - Variant-egg-based scheme offer the result of high predicted accuracy
 - Maintaining the same number of wake-up sensor nodes in the dynamic shape of forwarding zone is the main goal of this work

Dynamic size and shape of $F_{VE}[t+1]$

A Variant-Egg-Based Mobicast Routing Protocol in Sensornets

- Distributed and adaptive scheme to construct an variant-egg forwarding zone
- Two phases
 - Phase I: Egg estimation phase
 - Phase II: Distributed variant-egg-based mobicast phase

Phase I: Egg estimation phase

Phase I: Egg estimation phase

Variant-egg forwarding zone F_{VE}[t+1]
 Based on Cassini Oval

 $[(px)^{2} + (qy)^{2}]^{2} - 2e^{2}[(px)^{2} - (qy)^{2}] = 0$, where $\tan \theta = q/p$ and $p \times q = 1$.

Sensor nodes P in H[t] estimate the shape and size of next variant-egg F_{VE}[t+1]

$$H[t] = F_{VE}[t] [F_{VE}[t+1]$$

Example of phase I

 $P_{VE}(2/4, X, B)t_{2}$

Phase II: **Distributed** variant-eggbased mobicast phase

- Control packet P_{VE} (^h/_H, N₁₁, N₁₂,..., N_{1j})_{t_i}
 ^h/_H is used to limit the number of packet forwarding, where initial value of H is the estimated hop number (from phase I) and initial value of h is 0.
 - If $\frac{h}{H} = 1$, stop the message forwarding
 - N_{11} , N_{12} , ..., N_{1j} denotes the traversed-path history
 - P_{VE} packet is allowed to be re-forwarded at time t_i
 - New P_{VE} packet is forwarded at $t_x = t_y + d + backoff_time$ $Z_{P_{VE}(1/3, Z)t_0}$

• Let
$$\frac{h_{merge}}{H_{merge}} = \frac{\underset{\substack{1 \le i \le m \\ Max = H_i}}{\underset{1 \le i \le m \\ 1 \le i \le m}{Min = h_i}}$$
, if *P* is in region 1
• Let $\frac{h_{merge}}{H_{merge}} = \frac{\underset{\substack{1 \le i \le m \\ 1 \le i \le m}}{\underset{1 \le i \le m}{Min = H_i}}$, if *P* is in region 2
• $\frac{h_{merge}}{H_{merge}} = \frac{\underset{\substack{1 \le i \le m \\ 1 \le i \le m}}{\underset{1 \le i \le m}{Min = H_i}}$, if *P* is in region 3

(b)

 $F_{\rm ve}[t+1]$

Scenario of the no "hole" problem

Scenario of the "hole" problem

Performance analysis

- We provide theoretically proven bounds for the predictive accuracy and energy efficiency of our algorithm, and perform an analysis of our algorithm in terms of the number of messages used and running time.
- The simulation results are then analyzed.

Mathematical analysis

Lemma 1 The low bound of the predictive accuracy, denoted as RA_{low_bound} , is $\frac{2\int_{R_d}^{R_d} |\overline{PP'}| \sqrt{R_d^2 - x^2} dx}{\pi R_d^2}$ for $0 < |\overline{PP'}| = R_d - (|\overline{F_{t+1}Z_{t+1}}| - |\overline{F_{t+1}P}|) < 2R_d$, where P is the intersection point of line $b_1x - a_1y + c_2 = 0$ and $F_{VE}[t+1]$, P' is the intersection point of line $b_1x - a_1y + c_2 = 0$ with Z[t+1], R_d is the radius of the delivery zone Z[t], F_{t+1} is the focus of $F_{VE}[t+1]$, and Z_{t+1} is the point closest to F_{t+1} .

Lemma 2.

Lemma 2 The low bound of energy consumption of the VE-mobicast protocol from time t to t + 1 is $N_{total} \times (P_t + (d-1)P_r + P_{switch})$, where N_{total} is the total number of sensor nodes in $F_{VE}[t+1]$, d is the average degree of all sensor nodes, P_t is the power consumption cost of one data transmission operation, P_r is the power consumption cost of one data reception operation, and P_{switch} is the power consumption cost of a switching operation to switch a sensor node from the sleep mode to the active mode.

Low Bound of Energy Consumption

 $F_{Area} = \int_0^{\sqrt{2}e} (x^2 + y^2)^2 - 2e^2(x^2 - y^2) dxdy$

Lemma 3.

Lemma 3 The total number of mobicast messages of the VE-mobicast protocol from time t to t + 1is $N_{total} \times (d-1)$, where N_{total} is the total number of sensor nodes in $F_{VE}[t+1]$ and d is the average degree of all sensor nodes.

Total Number of Mobicast Messages

Lemma 4.

Lemma 4 The running time of the VE-mobicast protocol from time t to t + 1 is $\frac{\sqrt{2}e}{R_t} - 1$ × $((d - 1)T_r + T_b)$, where $\frac{\sqrt{2}e}{R_t}$ is the diameter of the $F_{VE}[t+1]$, d is the average degree of all sensor nodes, T_r is the time cost of data transmission, and T_b is the random backoff time.

The Running Time

Simulation result

- Our paper presents a variant-egg-based mobicast protocol. To evaluate our VE-mobicast protocol (VE-mobicast), Huang *et al.*'s mobicast protocol (mobicast) [10], and the FAR protocol (FAR) [12],
 - all these protocols are mainly implemented using the NCTUns 2.0 simulator and emulator [28].
- The simulation environment
 - \bullet 1000 x 800 m² area with 800 sensor nodes which are setting by random
 - The communication radius of sensor node is 35 meters
 - The delivery zone is a circular delivery zone
 - velocity is 45 m/sec and radius is 45 meters
 - Consumption of power is denoted as n = W (walt)
 - \square n = 1, sensor node in sleeping mode
 - n = 5, sensor node in active mode
 - \square n = 10, sensor node transmits the message



The initial estimated shape of the variable-egg

The predictive accuracy gap is defined as $GPA(p,q) = PA_{optimal} - PA_{p,q}$, where $PA_{p,q}$ denotes the predictive accuracy (PA) under given values of p and q, where $p \times q = 1$.

 $[(px)^{2} + (qy)^{2}]^{2} - 2e^{2}[(px)^{2} - (qy)^{2}] = 0$, where $\tan \theta = q/p$ and $p \times q = 1$.





CCUCS 1 Performance of the average predictive accuracy gap GPA(p,q) vs. (a) the rotation angle (10% \leq RF \leq 100%), (b) the rotation frequency (6 \leq ND \leq 20 nodes/m2











Performance of the average predictive accuracy gap GPA(p,q) vs. (c) the network density (10% \leq RF \leq 100%).









Performance Metrics

- The *predictive accuracy* (PA) is the percentage of sensor nodes located in both Z[t +1] and F_{VE}[t+1] (or F[t+1]) divided by the total number of sensor nodes in Z[t+1], i.e., PA = 100% if all nodes in Z[t+1] are located in F_{VE}[t+1] (or F[t+1]).
- The *packet overhead ratio* (POR) is the total number of packets that all sensor nodes transmit, including the control and mobicast messages, divided by the minimum number of packets used in our VE-mobicast protocol.





Cont.

- The *throughput* (TP) is the total number of data packets the mobile entity receives from sensor nodes in Z[t+1] per second.
- The *power consumption ratio* (PCR) is the total power consumption of all sensor nodes divided by the minimum power consumption of our VEmobicast protocol.







The *predictive accuracy* (**PA**) is the percentage of sensor nodes located in both Z[t + 1] and $F_{VE}[t+1]$ (or F[t+1]) divided by the total number of sensor nodes in Z[t+1], i.e., PA = 100% if all nodes in Z[t + 1] are located in $F_{VE}[t + 1]$ (or F[t+1]).









Performance of the predicitive accuracy vs. the rotation angle, where (c) the rotation frequency = 100%, and (d) $10\% \leq$ the rotation frequency \leq 100%.







Performance of the predicitive accuracy vs. the rotation frequency, where (c) the network density = 20 nodes/ m^2 , and (d) 6 nodes/ m^2 ≤ the network density ≤ 20 nodes/ m^2 .







CONSTITUTE Performance of the predictive accuracy vs. the network density, when (c) the rotation angle = 50 °, and (d) 5 ° \leq the rotation angle \leq 50 °







The *packet overhead ratio* (POR) is the total number of packets that all sensor nodes transmit, including the control and mobicast messages, divided by the minimum number of packets used in our VE-mobicast protocol.

















The *throughput* (TP) is the total number of data packets the mobile entity receives from sensor nodes in Z[t+1] per second.

















The *power consumption ratio* (PCR) is the total power consumption of all sensor nodes divided by the minimum power consumption of our VEmobicast protocol.

















Conclusion

- In this paper, we present a new "spatiotemporal multicast" protocol for supporting applications which require spatiotemporal coordination in a sensornet.
- To consider the path of a mobile entity which includes turns, in this paper, we develop a new mobicast routing protocol, called the variant egg-based mobicast (VEmobicast) routing protocol, by utilizing an adaptive variant-egg shape for the forwarding zone to achieve high predictive accuracy.







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Extended result

- Yuh-Shyan Chen and Yi-Jiun Liao, "<u>HVE-Mobicast: A</u> <u>Hierarchical-Variant-Egg-Based Mobicast Routing Protocol for</u> <u>Sensornets</u>,"
 - *IEEE Wireless Communications and Networking Conference* (<u>WCNC 2006</u>), Las Vegas, NV, USA, 3-6 April 2006.









HVE-mobicast routing protocl











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Conclusion

This work develops a new mobicast routing protocol for WSN (wireless sensor network)

Future work

• multi-sinks mobicast routing protocol.









Homework #12:

1. What's mobicast routing protocol in WSNs ?



