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Attacks and Defense on Virtual Coordinate Based Routing in Wireless Sensor Networks

Jing Dong, Kurt Ackermann, Brett Bavar, Cristina Nita-Rotaru
Department of Computer Science, Purdue University

Abstract

Recent developments in wireless sensor networks bring about the need for point-to-point routing. Virtual Coordinate System (VCS) based routing presents an alternative to the traditional routing protocols with the following attractive properties:

- Proactive route discovery
- Requires only local interaction
- Requires only local state information

However, little work has been done to protect VCS-based routing. In this poster, we demonstrate several dangerous attacks against VCS-based routing and propose defense techniques.

Virtual Coordinate based Routing

VCS-based routing typically follows a common design:

- **Coordinate Establishment**
  - A set of *reference nodes* are determined by pre-assignment or election
  - The reference nodes flood *coordinate messages*
  - The coordinates of each node are a vector of hop counts to each of the reference nodes and are derived from the hop count field in the coordinate messages
- **Coordinate Lookup**
  - One or more coordinate servers maintain the coordinates of all the nodes and answer coordinate queries
- **Greedy Forwarding**
  - Each node forwards the message to the neighbor closest to the destination

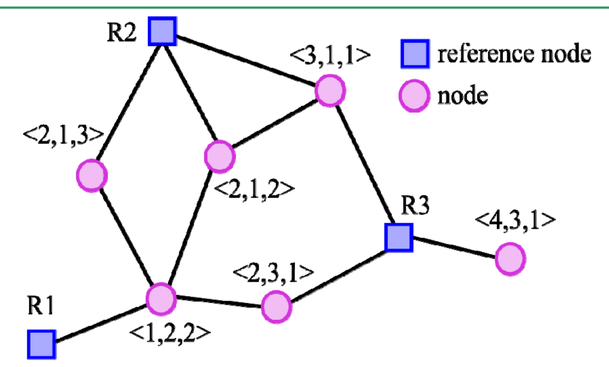
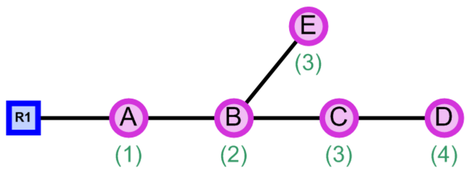


Figure 1
Example of virtual coordinates in a small network

Attacks on Virtual Coordinate Systems

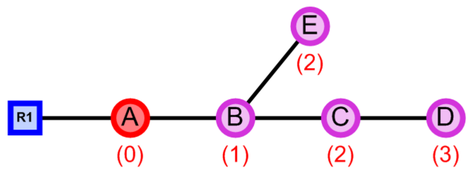
Attacks are epidemic!

Normal Coordinates



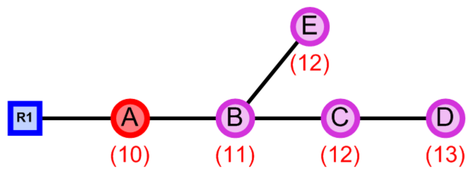
Coordinates of nodes without under attack

Coordinate Deflation Attack



Attacker A claims coordinate 0, causing node B,C,D, E to obtain incorrect small coordinates

Coordinate Inflation Attack



Attacker A claims coordinate 10, causing node B,C,D, E to obtain incorrect large coordinate

Coordinate Oscillation Attack

Attacker nodes alternate between large and small coordinate announcements or announce random coordinates to cause coordinate instability in nearby nodes

Coordinate Pollution Attack

Attacker nodes compromise coordinate servers or spoof coordinate replies to cause incorrect destination coordinates in messages

Defense Mechanisms and Experimental Results

Detect Coordinate Deflation with Statistical Tests

- The epidemic effect of deflation attacks causes a large change in the distribution of coordinates in the network.
- We use Wilcoxon signed rank statistical test to detect the coordinate distribution change and hence the presence of attacks

Prevent Coordinate Deflation with One-way Hash Chain

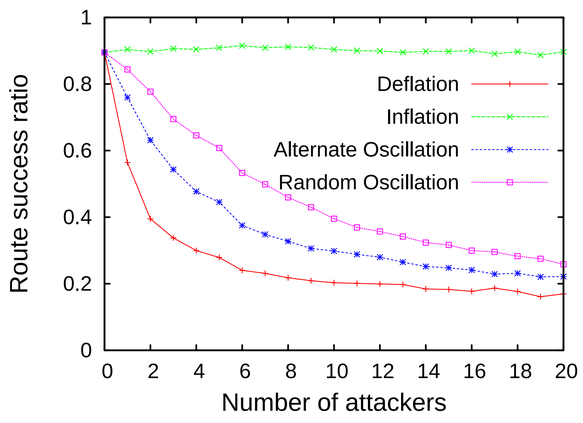
- Hop count is authenticated each hop with one way hash chain, so that intermediate nodes cannot announce coordinate messages with arbitrary small coordinates.

Stabilize Coordinates with PID Controller Technique

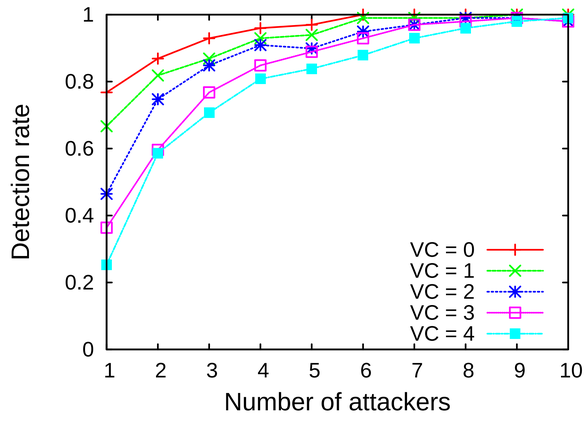
- Evaluate node coordinate stability with the technique of Proportional-Integral-Derivative(PID) controller
- Each node selects neighbors with stable coordinates as its parent for deriving its own coordinate
- Neighbors of the attacker will not select the attacker as their parent, thus attackers will be isolated

Experimental Results

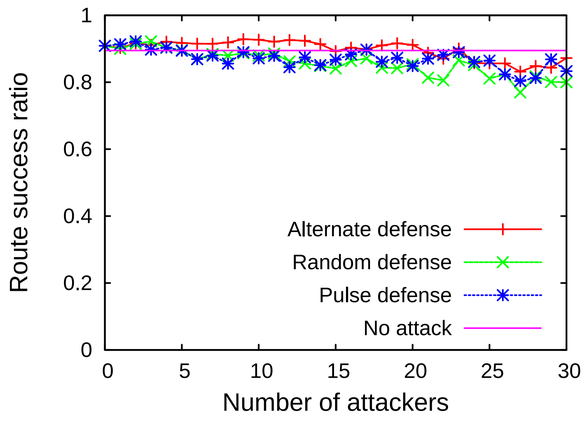
- **Attacks impact routing significantly**



- **Statistical test detects attack with high accuracy**



- **Stabilization technique effectively mitigates oscillation attacks**



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