Simulation of Swarm Intelligence-Based Message Broadcast in Highly Mobile Ad Hoc Networks

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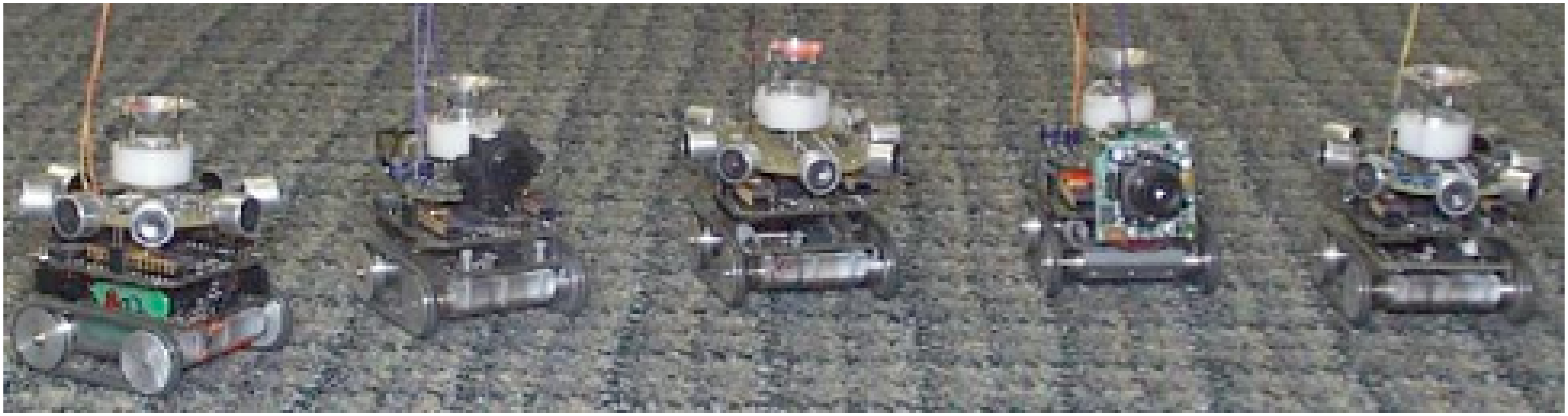
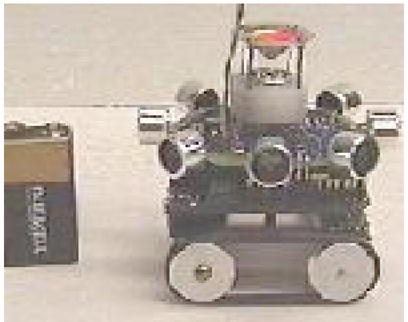
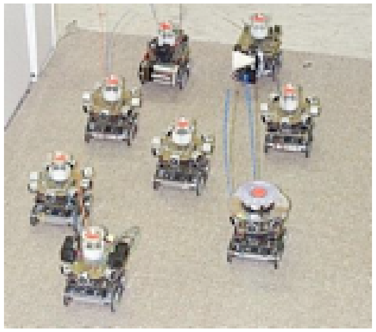
Assumptions

- Highly mobile, ad hoc communication networks
- Route discovery and maintenance futile
- Power management algorithms in use
- Entities may be synchronized and communicate in timed bursts
- Large numbers, low cost, disposable, small entities: robots, sensors, e.g., smart dust
- Size: millimeter to nanometer
- MEMS, Nanofabrication, Molecularly Engineered Systems
- Propulsion may be passive: floating, drifting, sailing, flowing

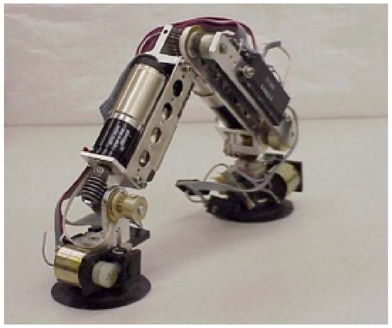




CMU
Millibots



JPL
Lemur



DARPA Microbot
Michigan State

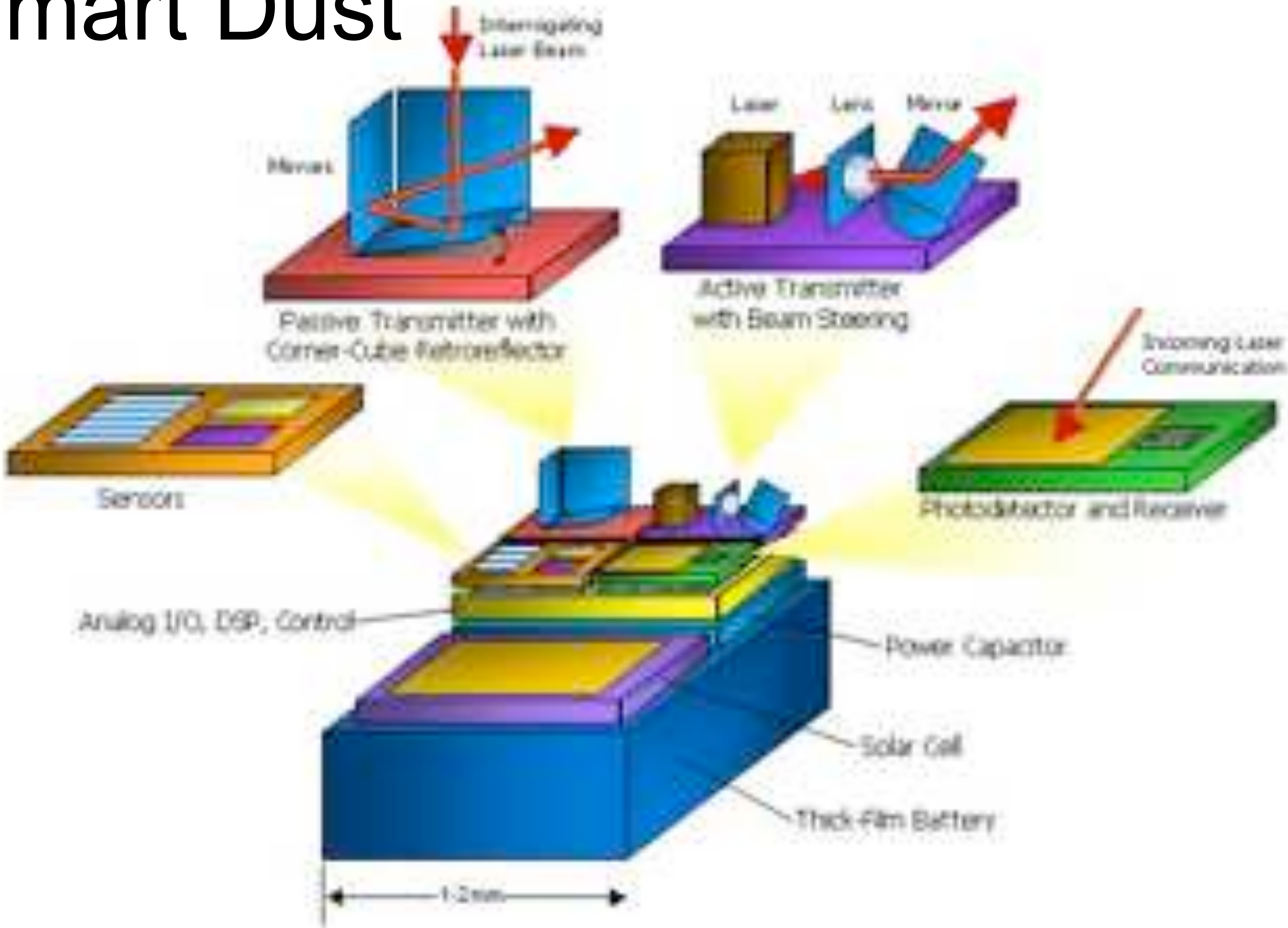
UC Berkeley
Motes
Smart Dust

Smart Dust

The goal of the Smart Dust project is to build a self-contained, millimeter-scale sensing and communication platform for a massively distributed sensor network. This device will be around the size of a grain of sand and will contain sensors, computational ability, bi-directional wireless communications, and a power supply, while being inexpensive enough to deploy by the hundreds. The science and engineering goal of the project is to build a complete, complex system in a tiny volume using state-of-the art technologies (as opposed to futuristic technologies), which will require evolutionary and revolutionary advances in integration, miniaturization, and energy management. Brett Warneke, UC Berkeley

http://www-bsac.eecs.berkeley.edu/~warneke/SmartDust/

Smart Dust


Interrogating Laser Beam
Mirrors
Passive Transmitter with Corner-Cube Retroreflector
Laser
Lens
Mirror
Active Transmitter with Beam Steering
Incoming Laser Communication
Sensors
Photodetector and Receiver
Analog I/O, DSP, Control
Power Capacitor
Solar Cell
Thick-Film Battery
1-2 mm

Applications

- Surveillance
- Sensor networks
  - Weather/Environmental monitoring
  - Chemical/biological monitoring
  - Weapons stockpile monitoring
- Search and rescue
- Bomb squads
- Exploration: “Mars Miromission”
- Maintenance, hazardous environments: nuclear, space, deep sea
- Surgery/Medical procedures
- Product quality monitoring

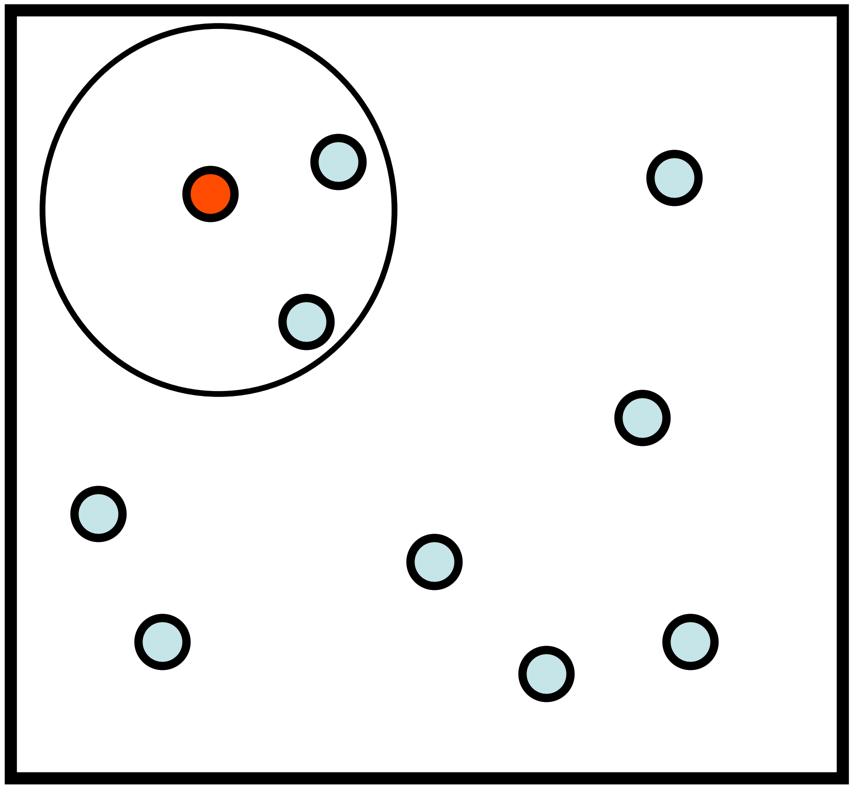
Approach

- Biologically inspired: social insects (honeybees, ants), flock behavior, epidemics, ecology
- Methods inspired by cellular automata, artificial life, artificial intelligence, evolutionary computation, object orientation, discrete event simulation
- Labels include agent-based modeling (ABM), individual-based modeling (IBM), Swarm Intelligence

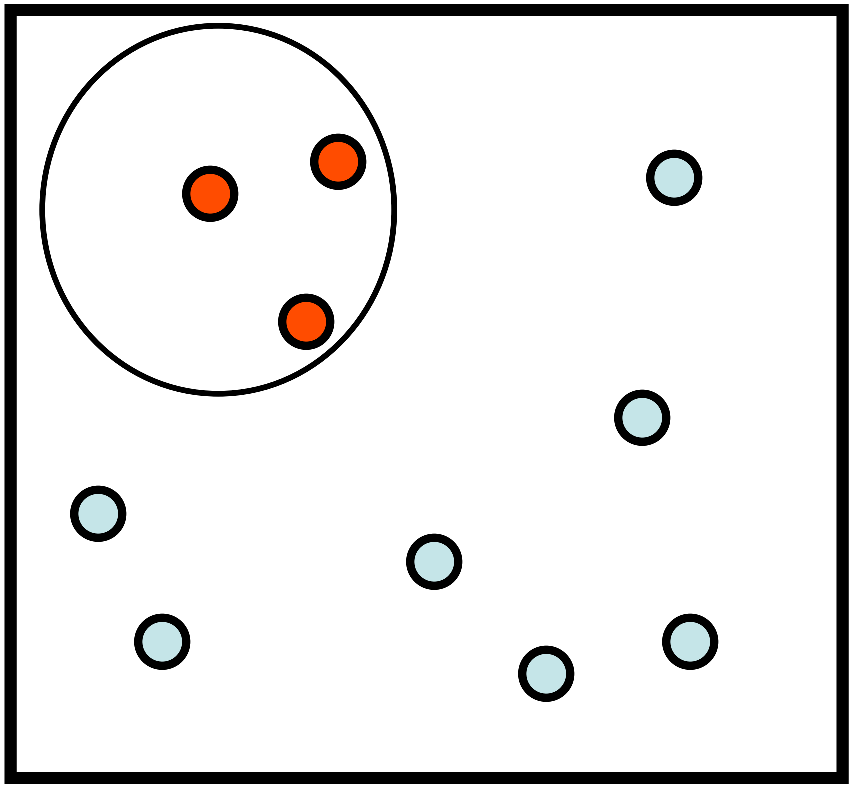
Modeling & Simulation Tools

- Agent-based toolkits/libraries/packages
  - MIT-Media Lab/Northwestern Univ: **Starlogo*,** Netlogo
  - Santa Fe Institute: **Swarm***
  - Argonne/University of Chicago: RePast
  - George Mason: Mason
  - Brookings Institute: Ascape
  - AgentsSheets, and many others
- Your favorite OOP language
  - Agent classes
  - Agents are instantiated objects
- More “spaces” for agents: 2D, 3D, graphs, “well-stirred soup”

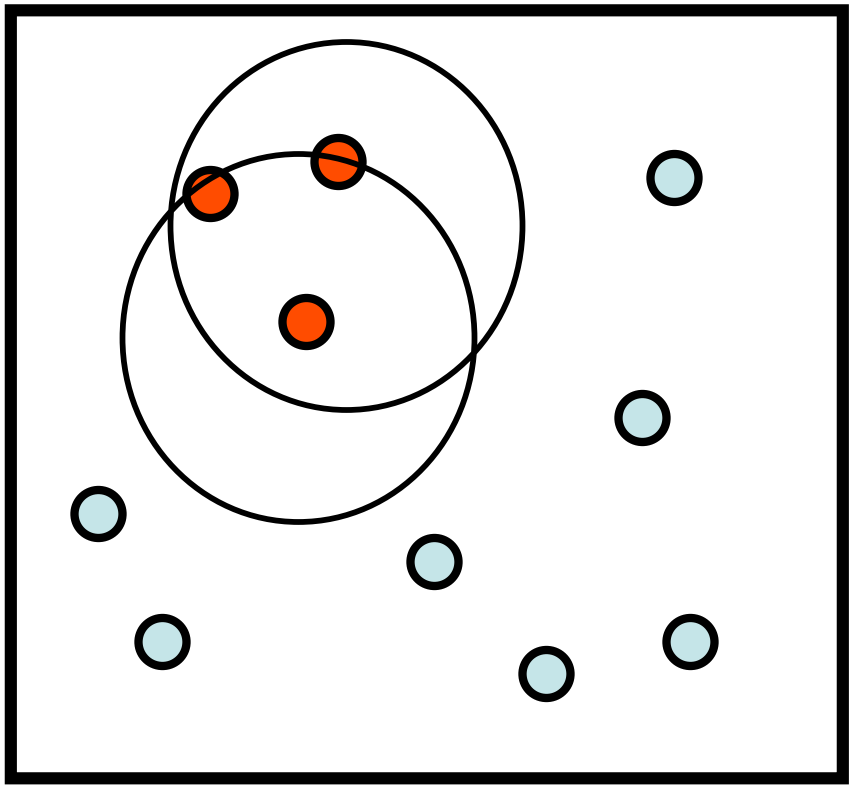
*** Tools we used**



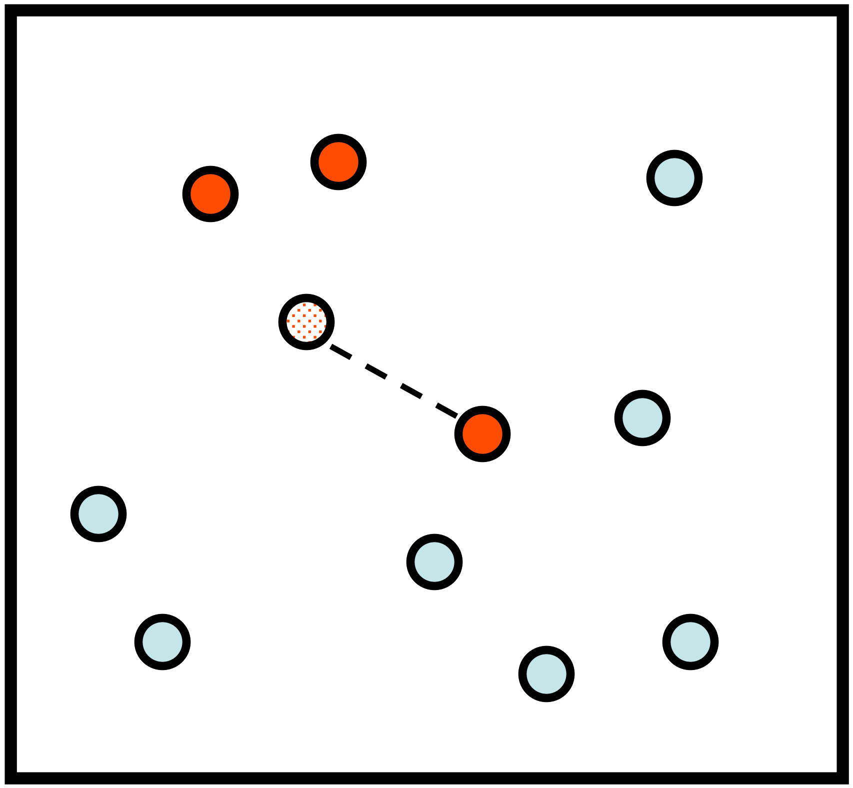
Agent with message is in range of two other agents.



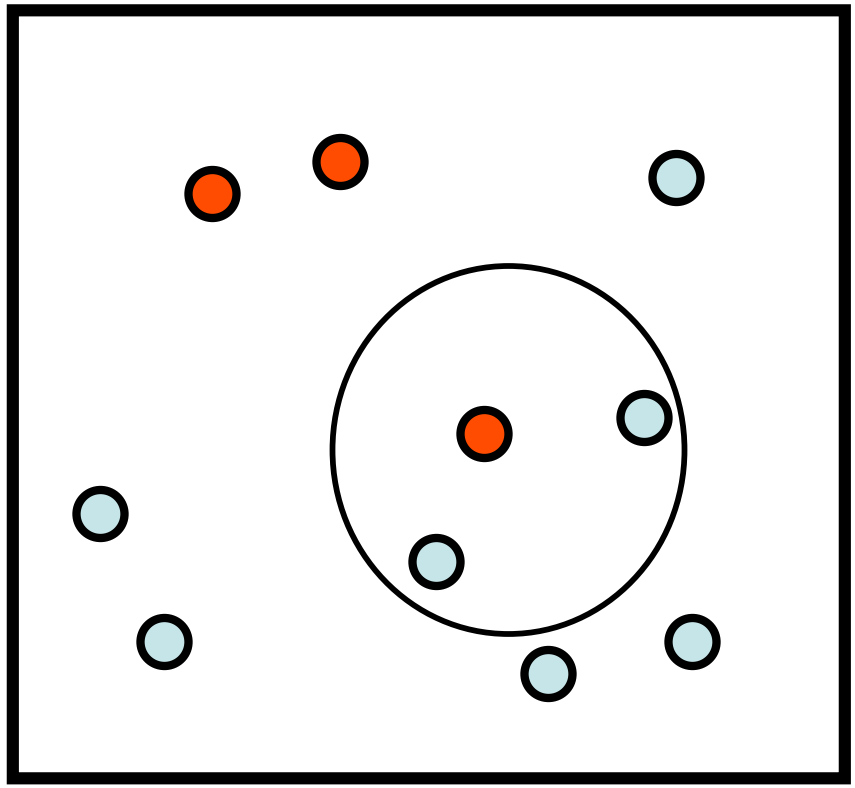
Message is passed to those agents.



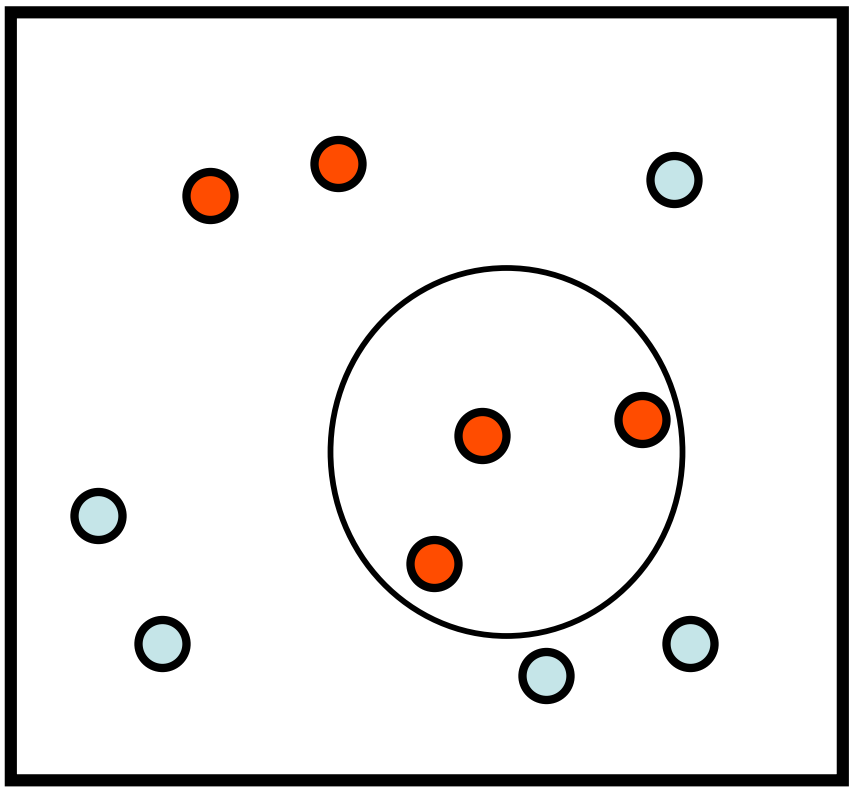
No other agents are now in range of agents with message.



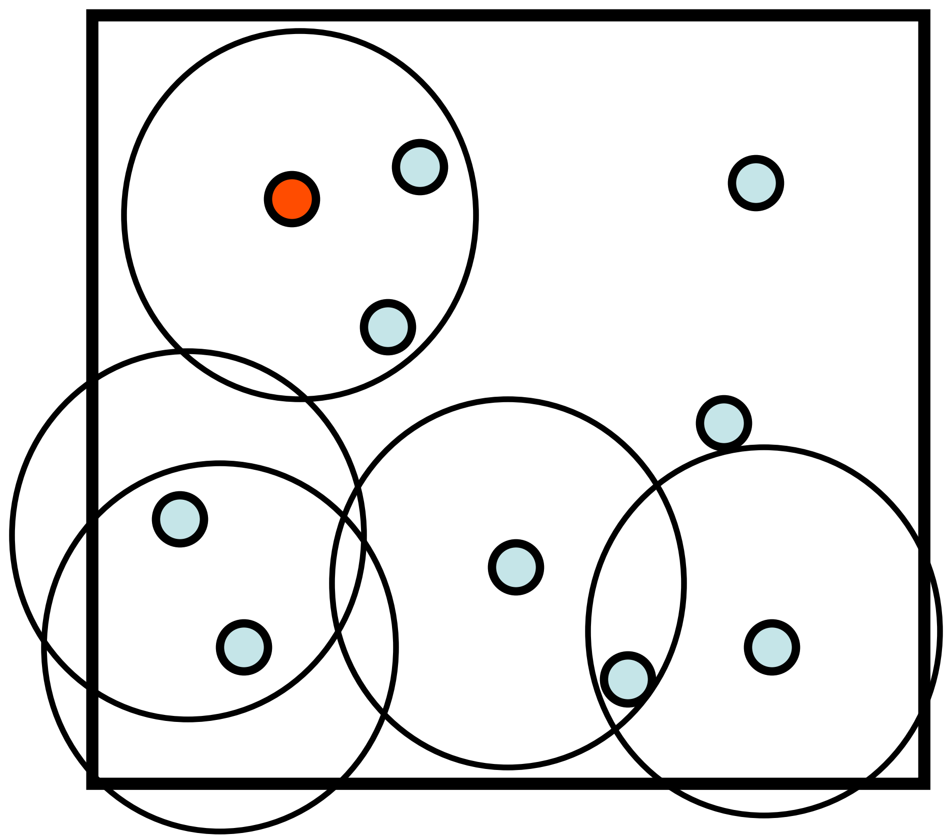
Agent moves.



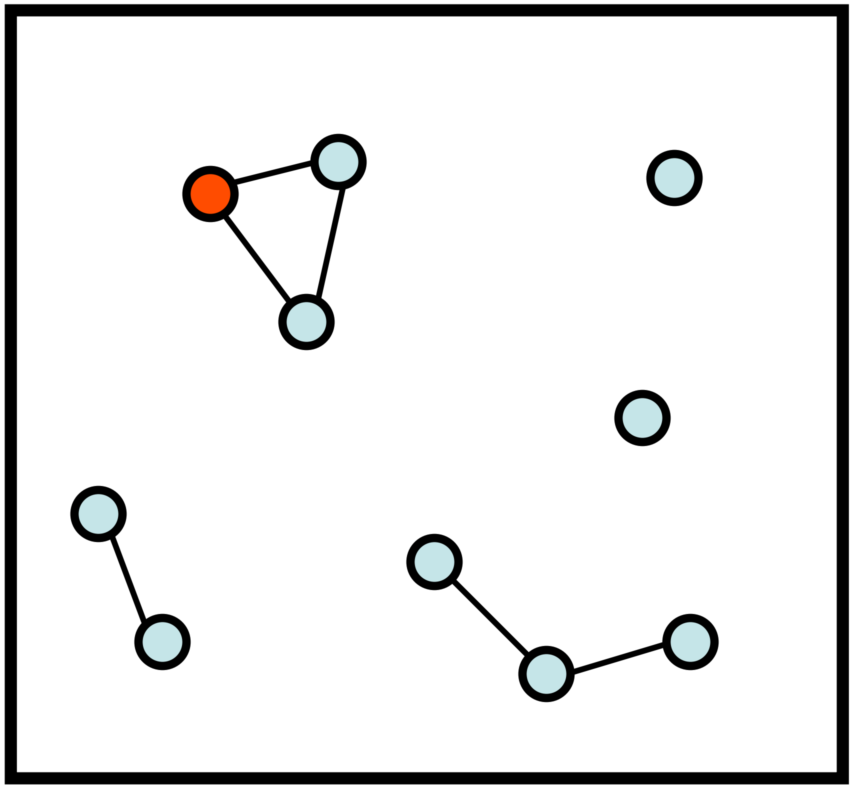
Two more agents are now within range of agent with message.



Message is passed to more agents.



At any given time, agents can communicate with some, but not all of the other agents.



These temporarily connected agents form ad hoc networks while they remain connected.

Problem of Very High Mobility

- Much research has been done into the problem of determining a good path by which to transmit messages in these ad hoc networks.

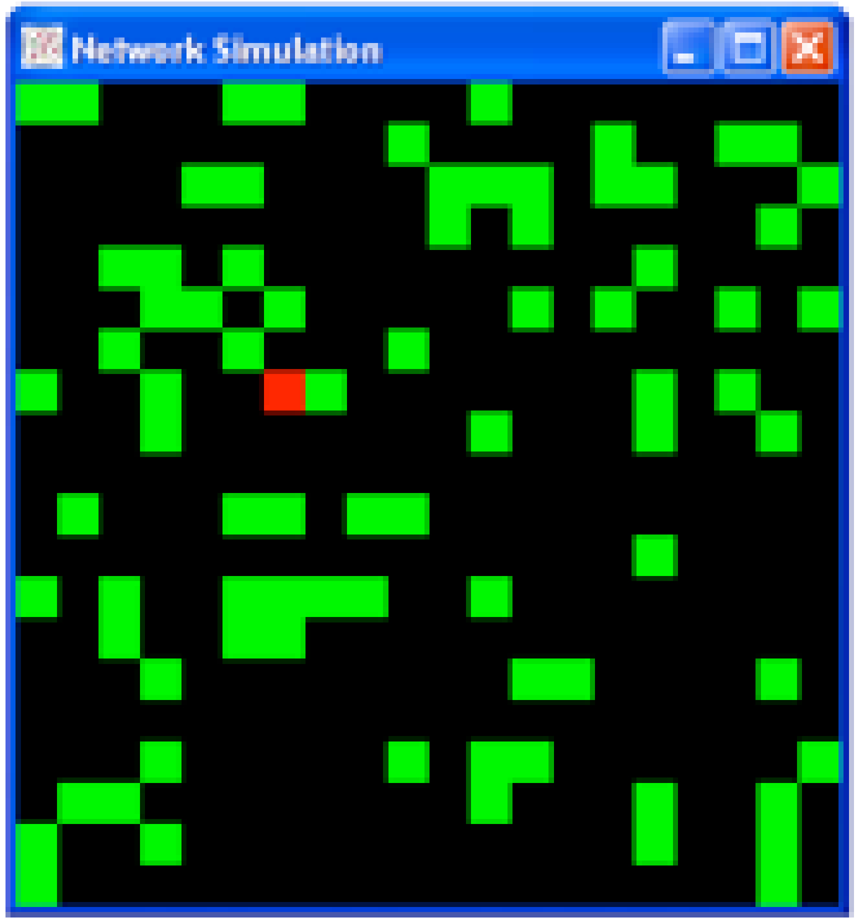
- These methods work well if changes in the network topology are relatively infrequent.

- But, the faster the agents move, the faster the known configuration of the network changes.
- And the harder it becomes to calculate good paths while the information remains valid.
- Another technique is required.

- Many things in nature appear to perform complicated tasks while actually only employing a few simple rules.
- For example, birds flock without any “leader” bird directing their movement.
- Each bird just reacts to those around it.

- Question: If each agent uses a simple set of rules for message passing, can the message be broadcast to all agents efficiently?

- How can we model this in order to investigate it?



Agents are modeled using Swarm agent-based modeling.

- Agents move randomly from cell to cell, representing location at time steps associated with communication bursts

- If an agent has a message in one time step and a neighboring cell has an agent with no message, the message can be passed.

The “simple” rules are:

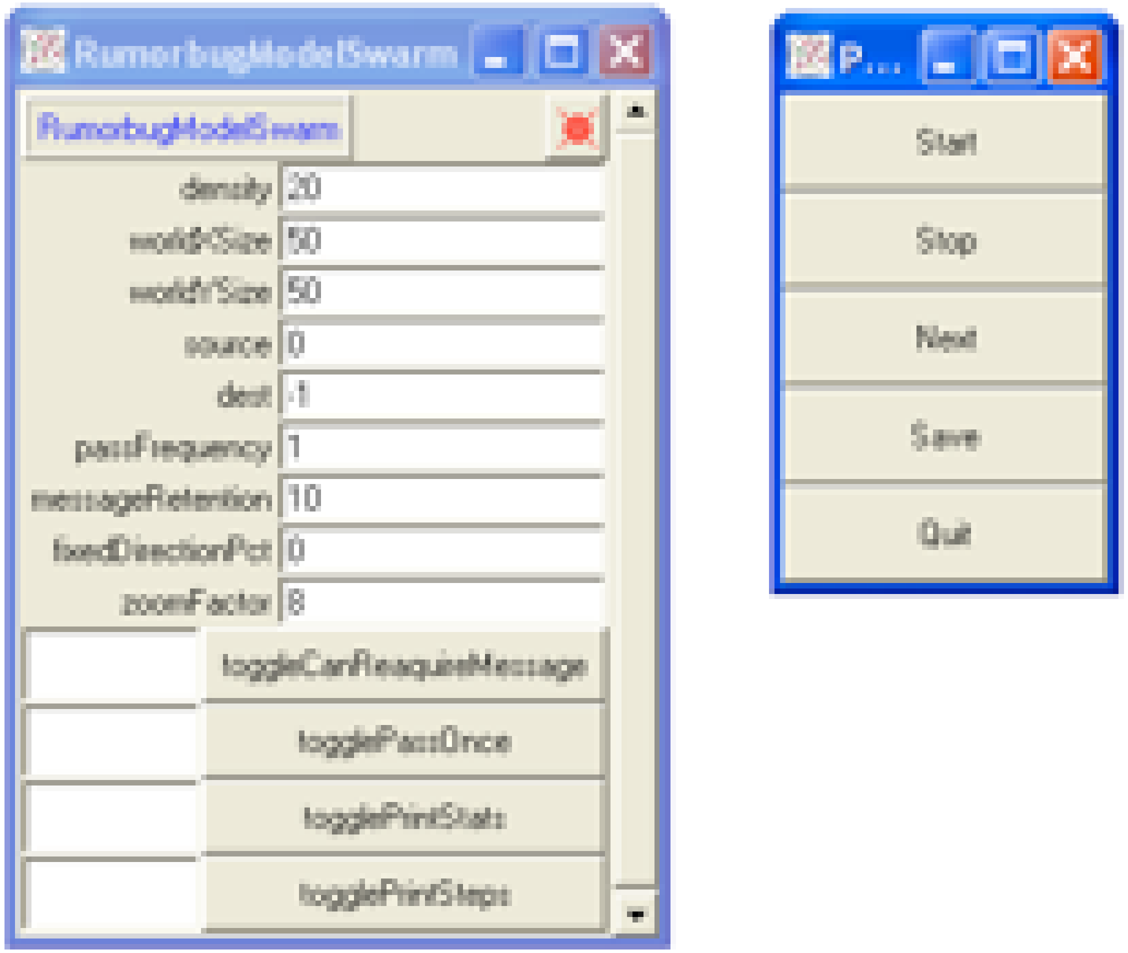
- Agents move “randomly” on their own.
- If an agent has a message, it passes it to other agents it encounters.

Additionally:

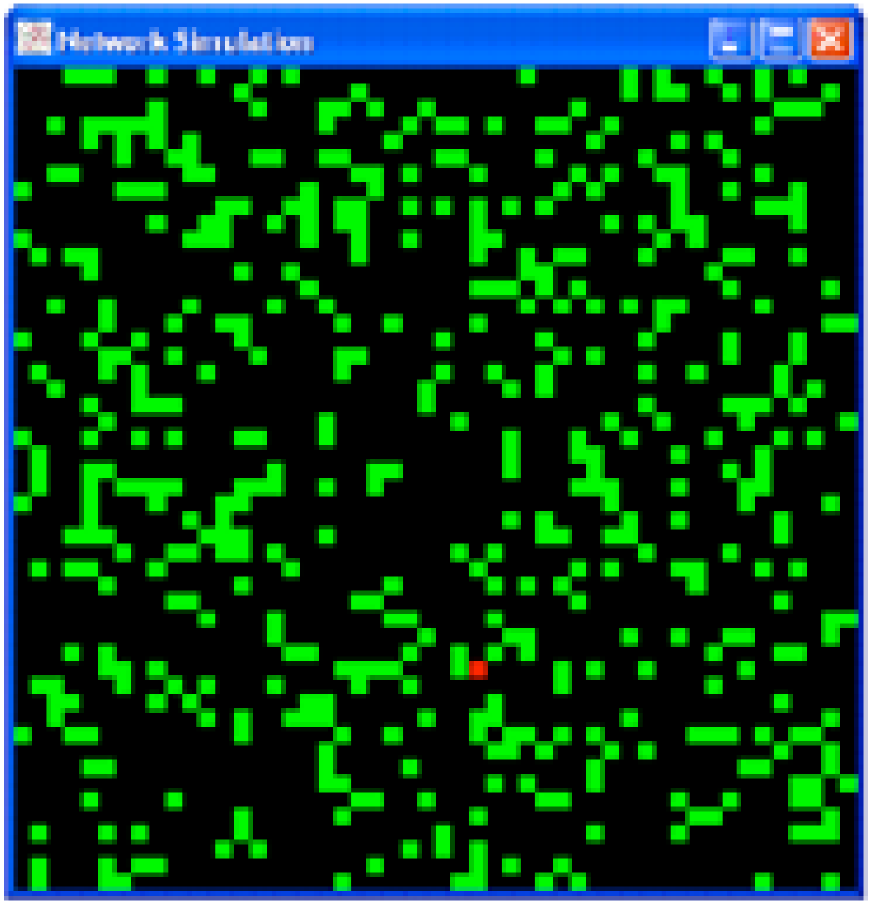
- Agents are only aware of their immediate neighbors.
- The system has no global knowledge of the location of agents or message.

We can vary several simulation parameters:

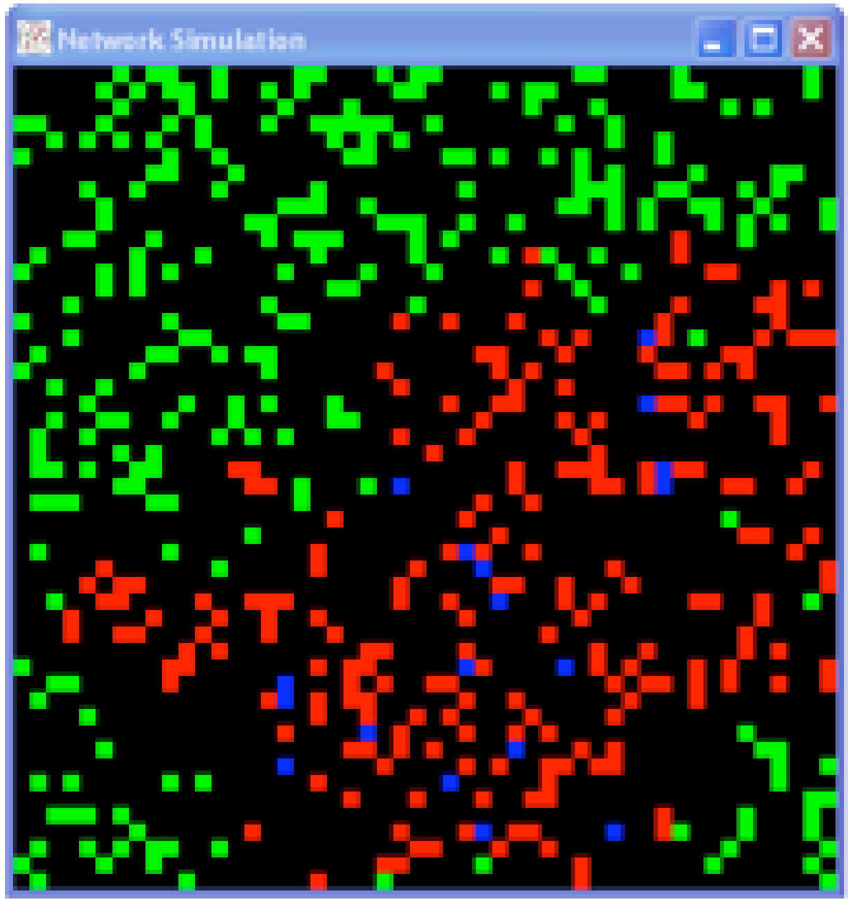
- Size and dimensions of “world”
- Density of agents
- How long an agent retains a message
- Whether an agent can reacquire a message if it is purged



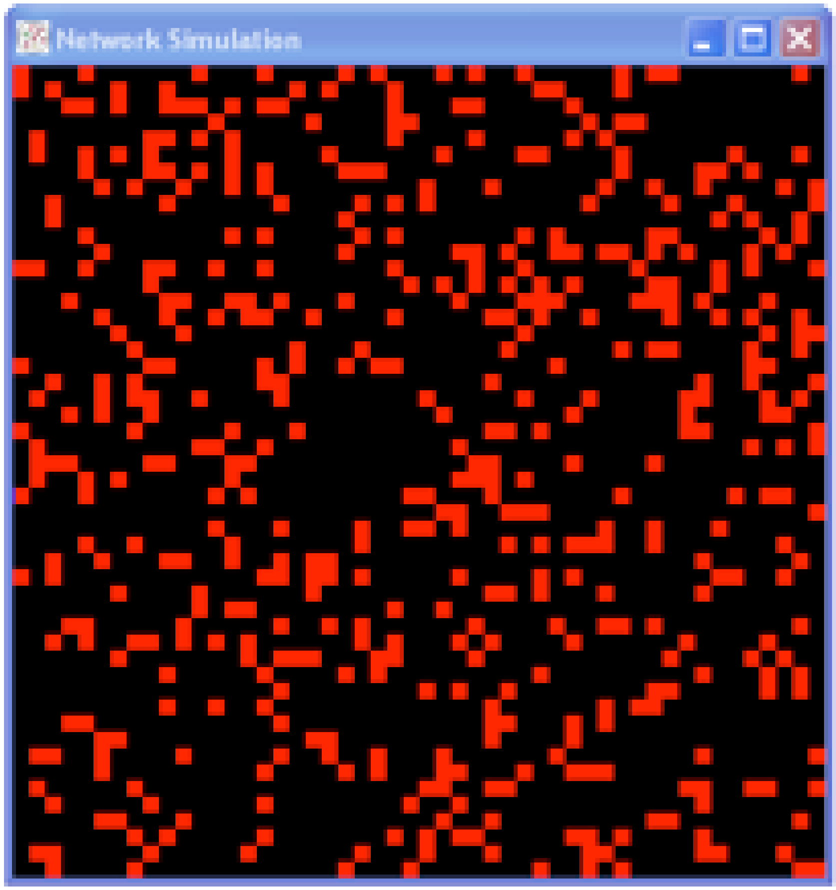
For example, a 50 x 50 world is specified with an agent density of 20% where agents hold a message for 10 time steps before purging it.



The red agent has the message initially.

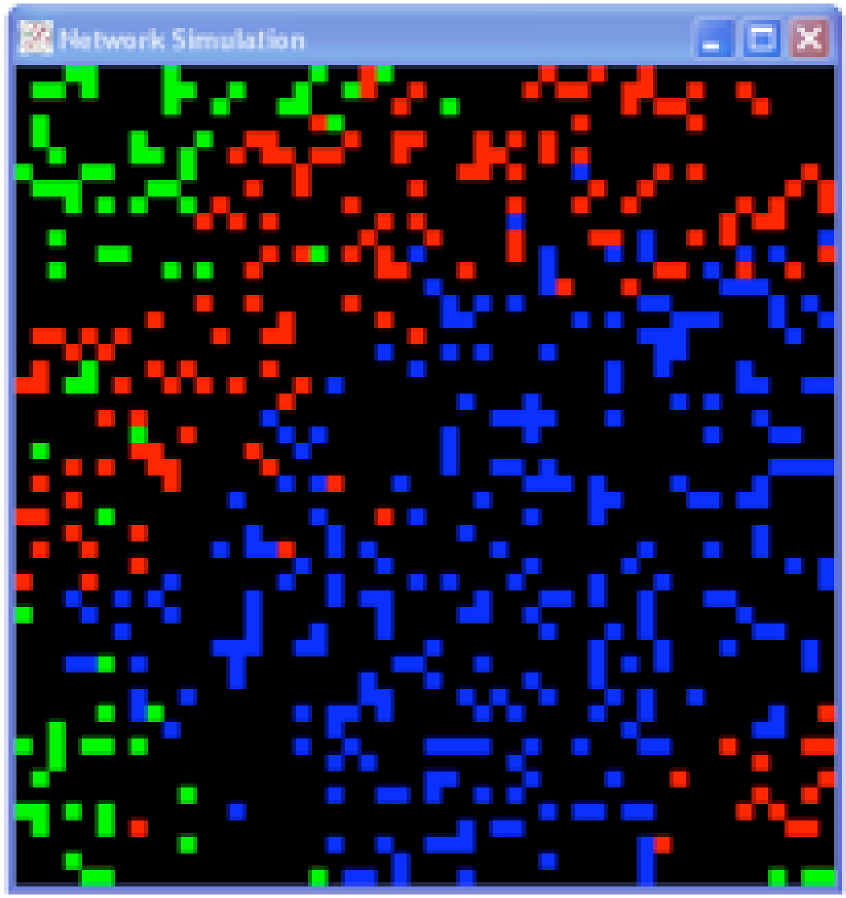


The message is passed to other agents.
Blue agents have received the message, held it for ten time steps and purged it.

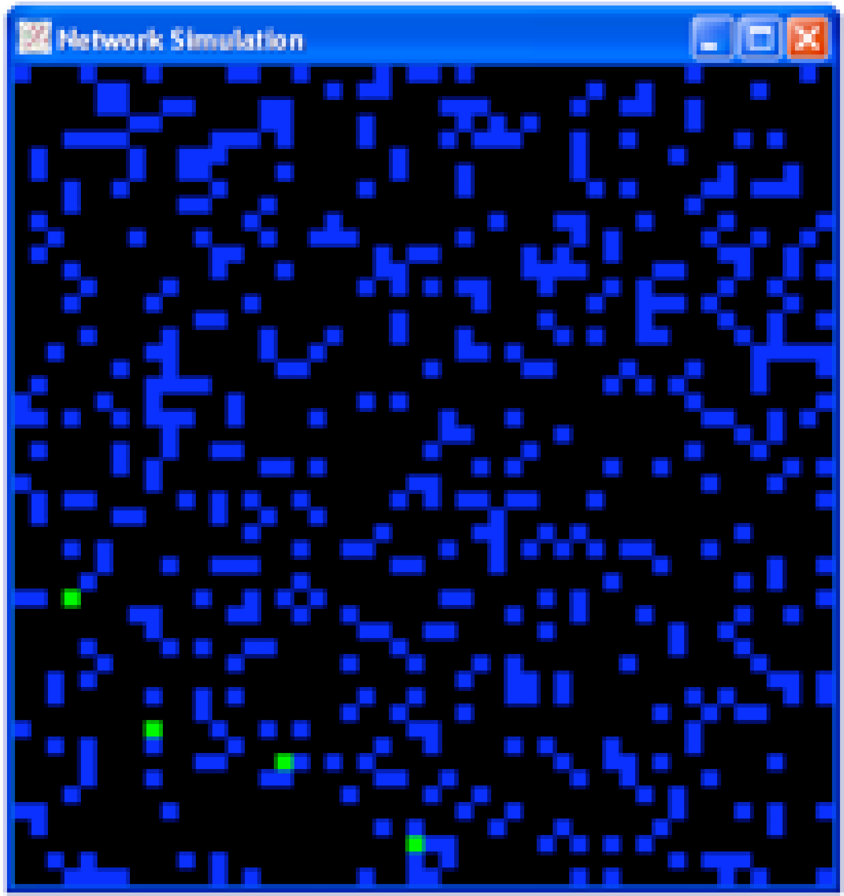


The message is received by all agents in 49 steps.

Saturation percentage per number of time steps.



Even when agents do not reacquire purged messages, the agents holding the message form an "advancing wall" disseminating the message.



The message is delivered to 99.2% of all agents in 59 time steps

Potential Design Support

- Buffer size
- Value of heterogeneous sensors
- Power vs wireless range
- Power vs communication window
- Numbers
- Performance prediction
- Message handling rules
  - Re-accept
  - Ack
  - TTL

Conclusions

- A method of simulating highly mobile ad hoc networks in which messages are broadcast using only a simple set of rules has been presented.
- This simulation technique provides a means of studying the promise of swarm intelligence based approaches to the problem of message broadcasting.