A Biologically Inspired Programming Model for Self-Healing Systems

Selvin George
Computer Science

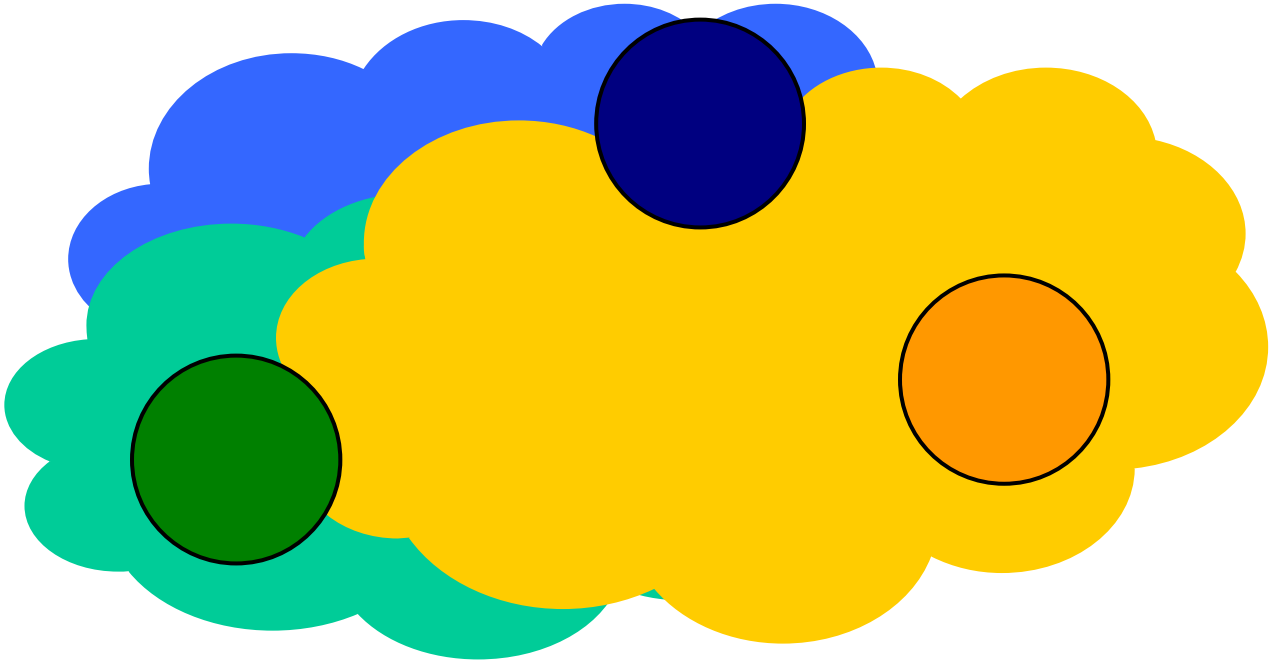
David Evans
Computer Science

Lance Davidson
Biology

UNIVERSITY OF VIRGINIA

Self Healing in Nature

Diffusion – Local Communication



Cells are aware of surroundings by sensing chemicals emitted by other cells

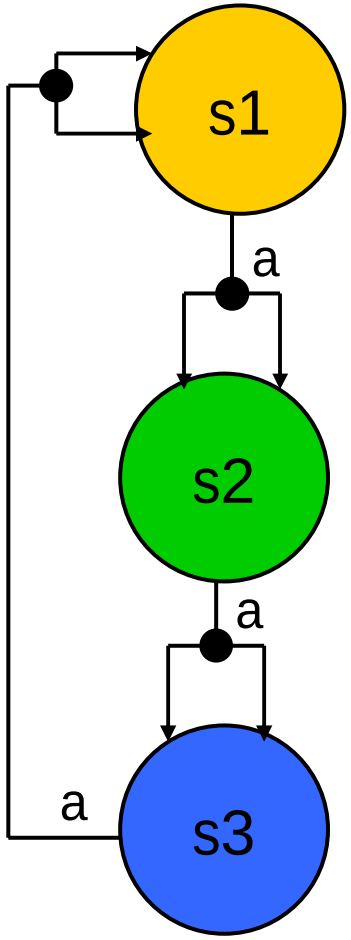
Nature's Programs – Observations

- Aware
  - Of self
  - Of environment
- Redundant
- Decentralized
- Expressive
  - Human program – 3 billion base pairs (~250MB)
  - Two human programs differ by about 0.5MB (< 1% of Windows 2000)

Our Programming Model

- Similar to cellular automata
- Simple chemical diffusion model
- Correspondence to biological cells
  - Genes turn on and off $\Leftrightarrow$ state changes
    - Emit different chemicals depending on state
    - Change state based on sensed chemicals
  - Cells can divide asymmetrically

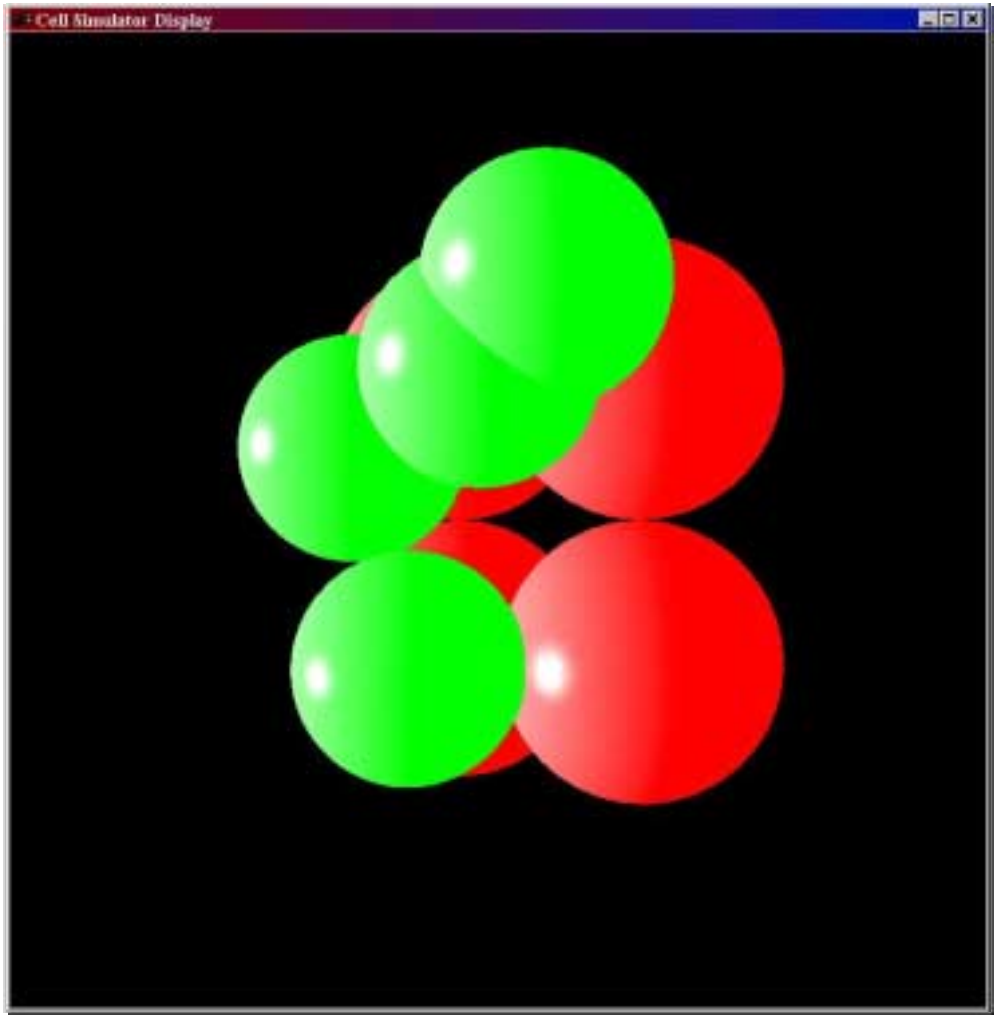
Blastula Program

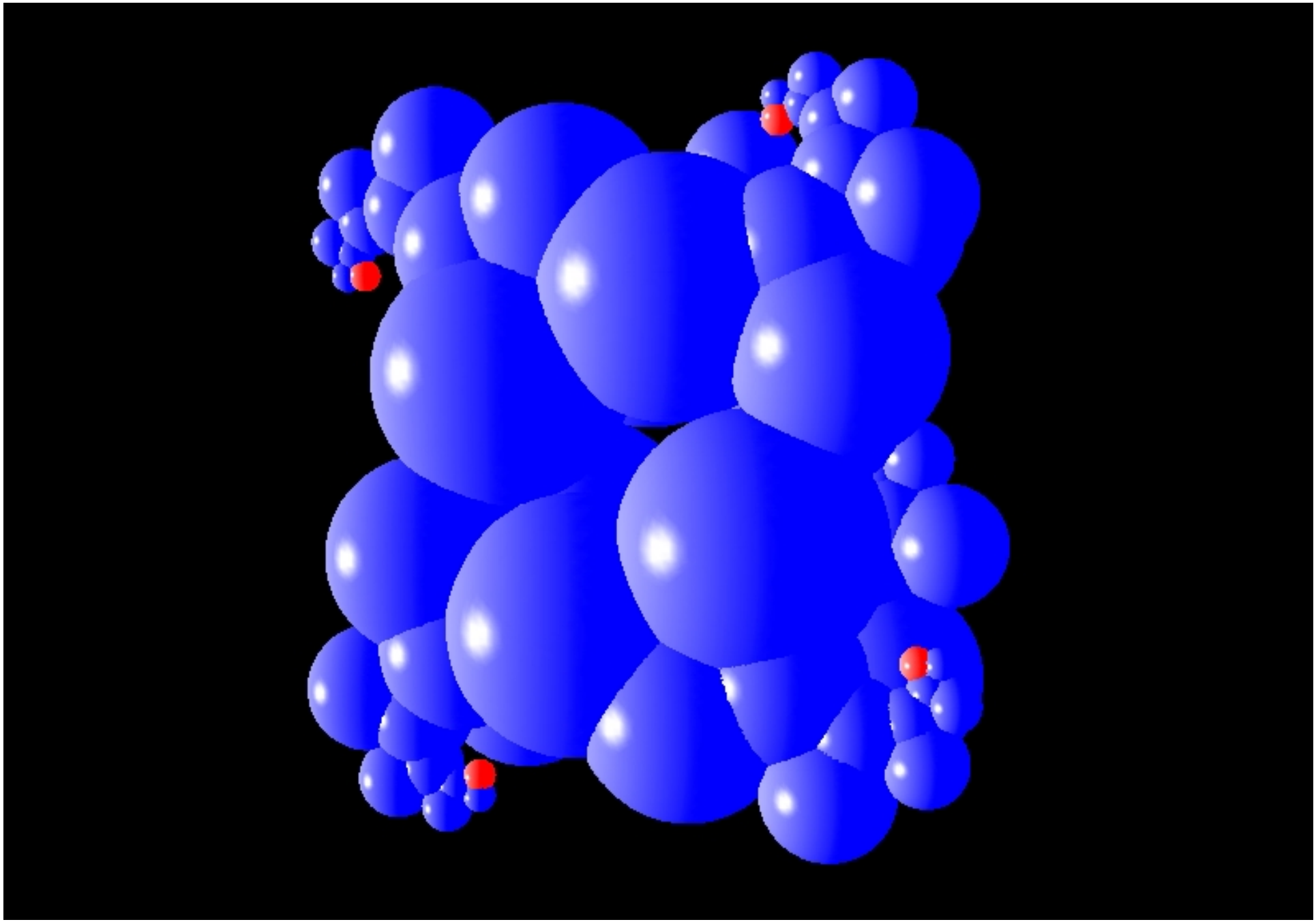



```
state s1 {
    emits (a, 0.1)
    transitions
    (0 <= a <= 0.375) -> (s2, s2) axis;
    -> (s1);
}

state s2 {
    emits (a, 0.1)
    transitions
    (0 <= a <= 0.375) -> (s3, s3) normal-X;
    -> (s2);
}

state s3 {
    emits (a, 0.1)
    transitions
    (0 <= a <= 0.375) -> (s1, s1) normal-Y;
    -> (s3);
}
```

Self-Healing Blastula

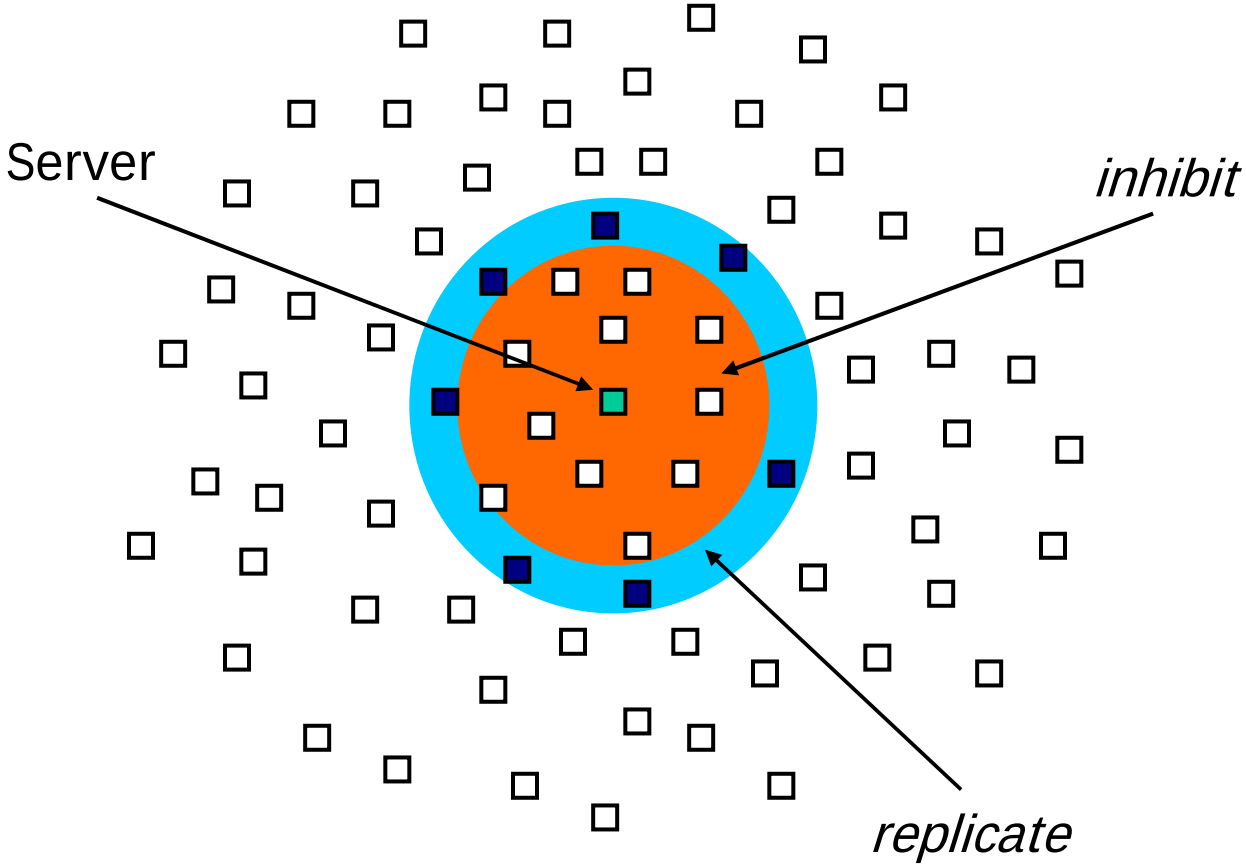
```
state s1 {
    emits (a, 0.1)
    transitions
    (0 <= a <= 0.375)
       -> (s2, s2) axis;
    -> (s1);
}

state s2 {
    emits (a, 0.1)
    transitions
    (0 <= a <= 0.375)
       -> (s3, s3) normal-X;
    -> (s2);
}

state s3 {
    emits (a, 0.1)
    transitions
    (0 <= a <= 0.375)
       -> (s1, s1) normal-Y;
    -> (s3);
}
```





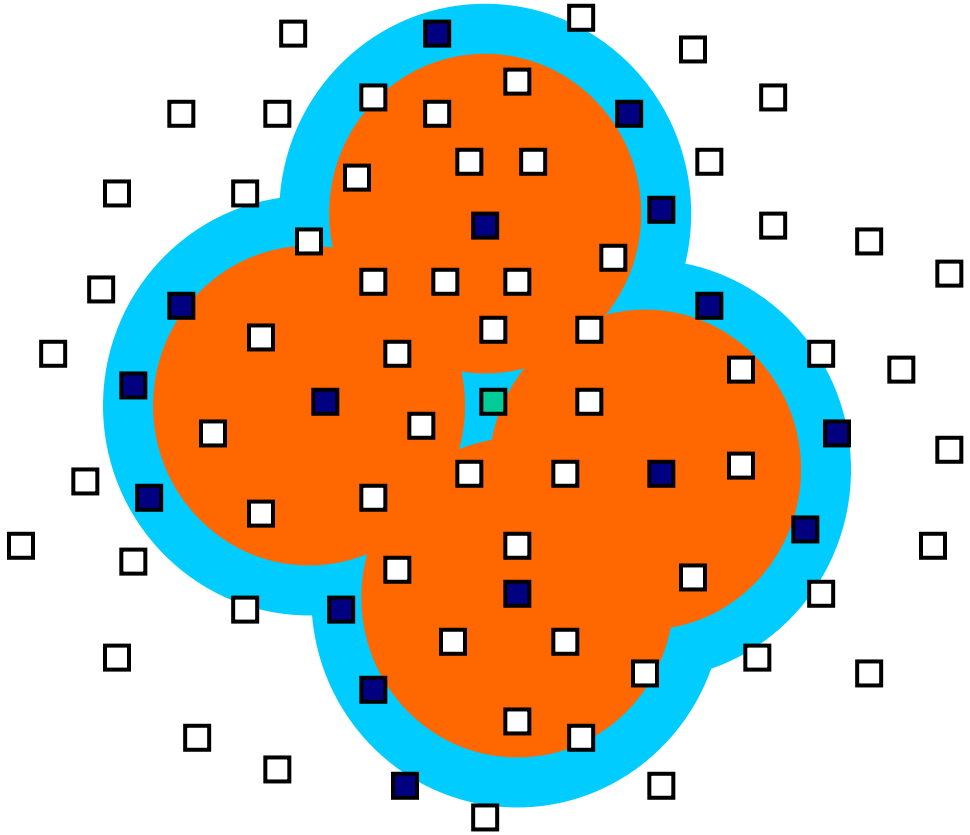
Distributed Wireless File Service

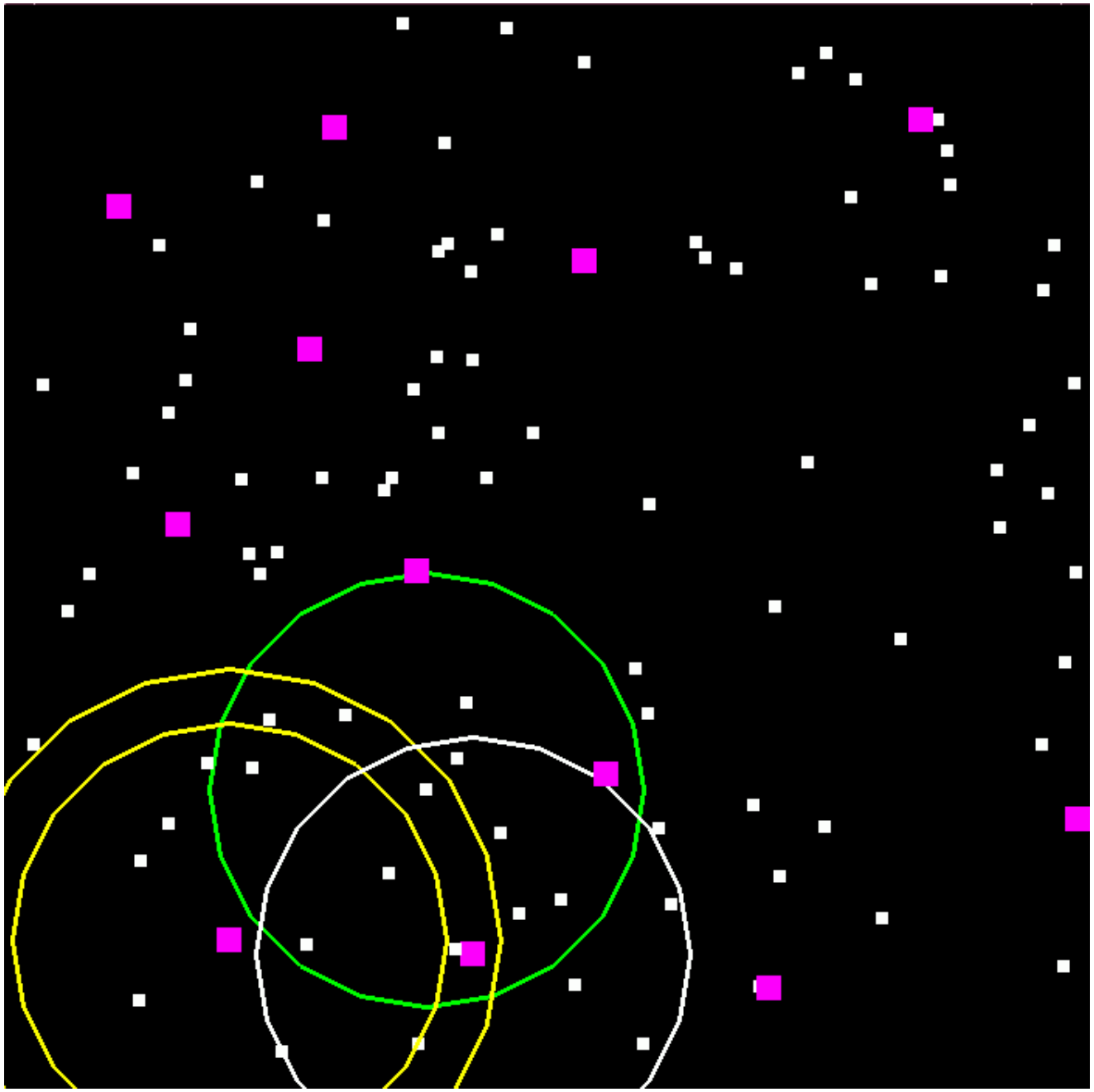
File Distribution and Update



Distributed Wireless File Service

File Distribution and Update





DWFS Simulation

Purple Nodes
– store File 1

Concentric Circles
– Inhibit/Replicate

Green Circle
– File Request

White Circle
– Server Response

Mantra

- Biology has killed trillions of organisms over millions of years to solve complex engineering problems
- Engineers should be able to learn from these solutions

- Simulator available: http://swarm.cs.virginia.edu/cellsim