

Programming an Amorphous Medium

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What am I programming?

Amorphous computer:

Extremely large network, scattered through space, communicating only between nearby neighbors, and made of unreliable parts.

Amorphous medium:

The space approximated by an amorphous computer.

Key idea: Make networking entirely implicit!

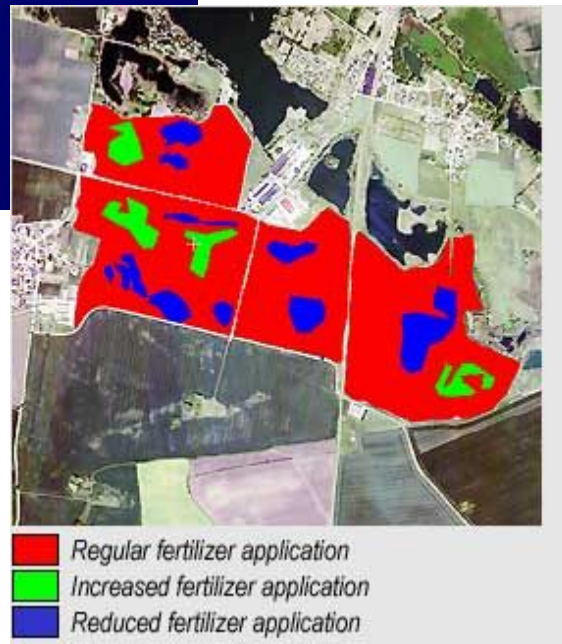
What sort of programs?



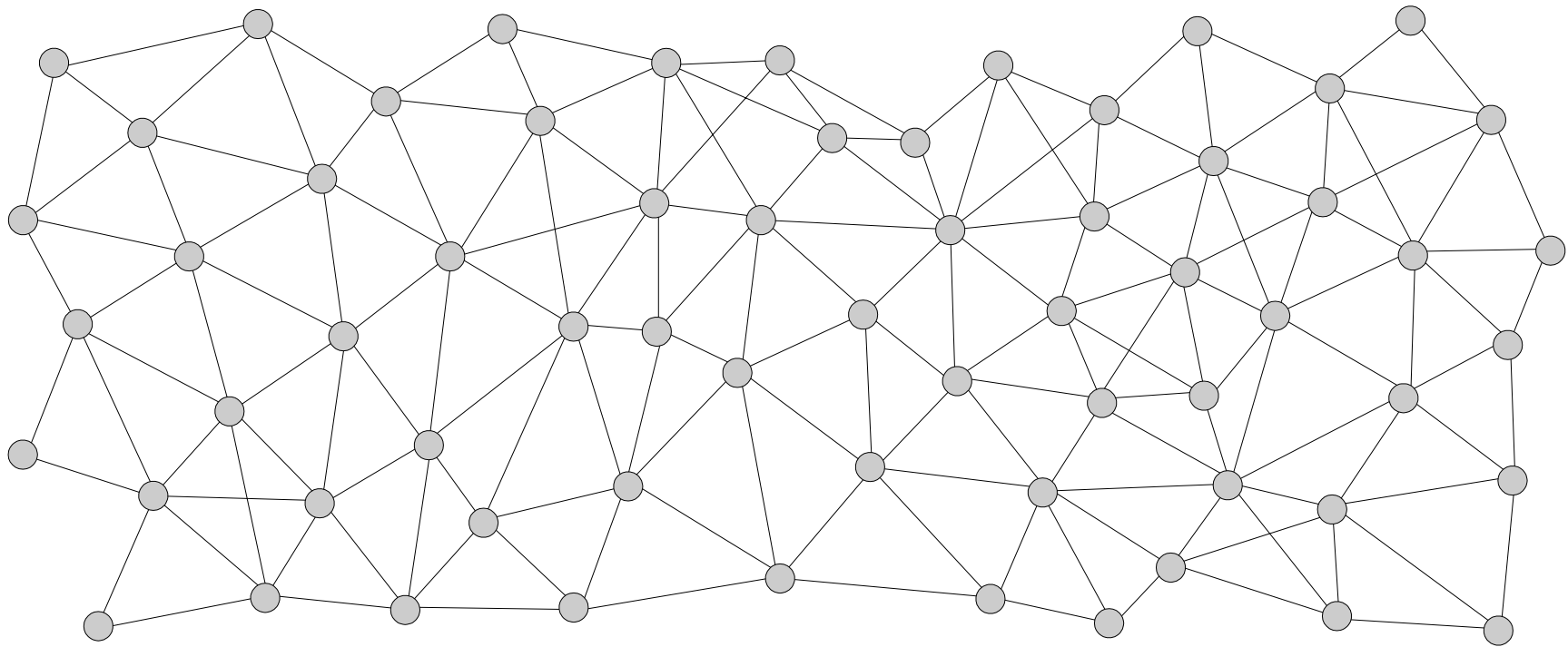
Traffic Control



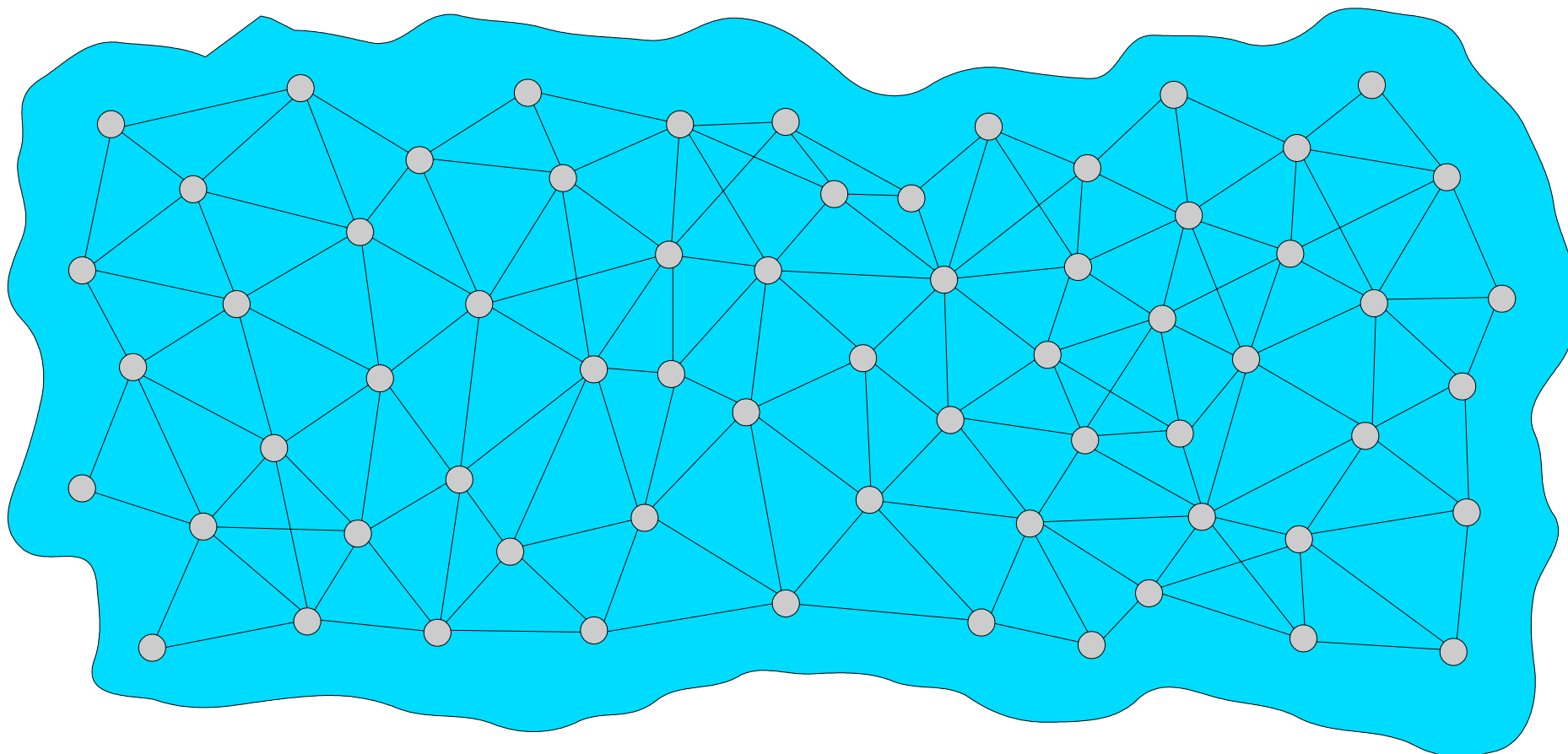
Habitat Monitoring



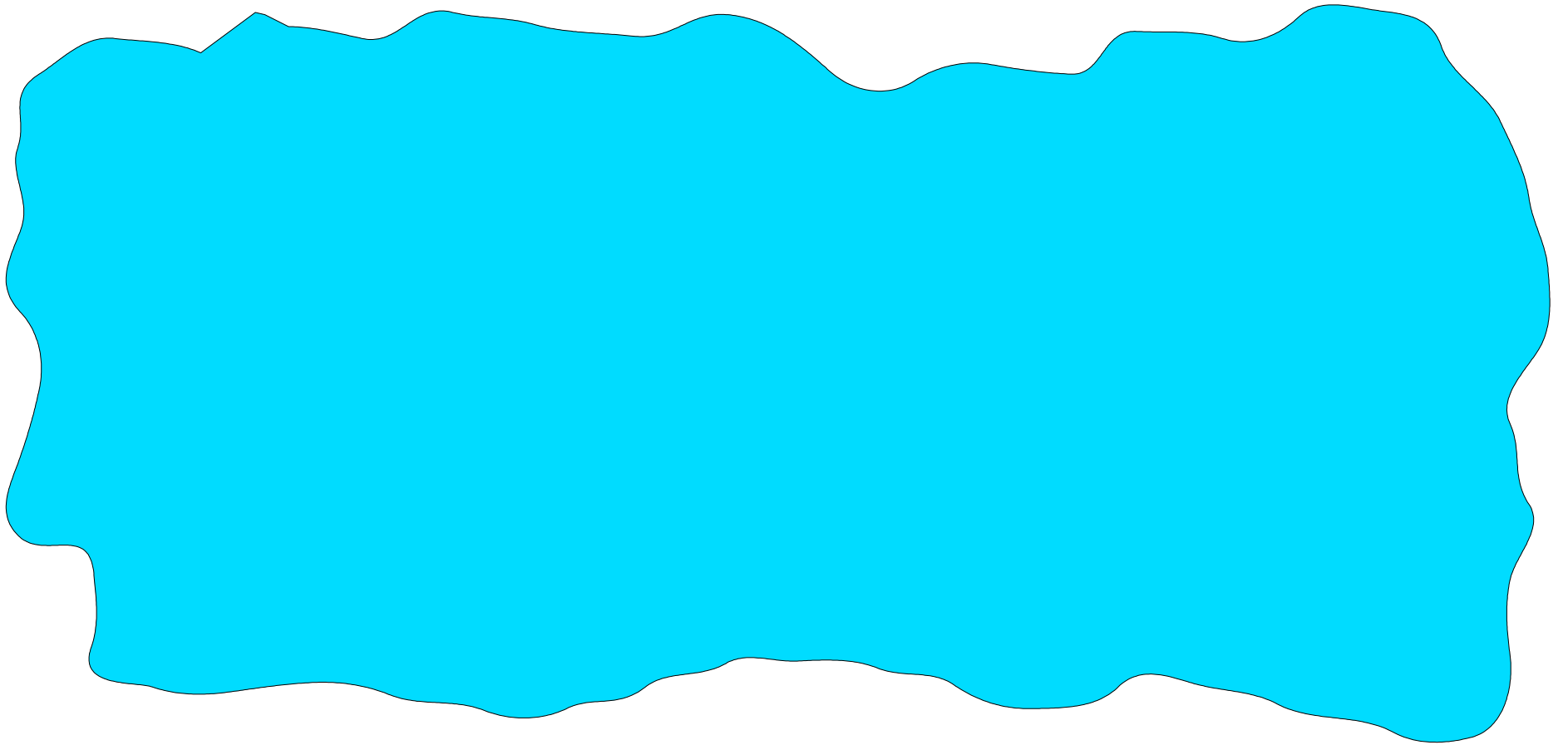
Agricultural Management



A geographically distributed network...



... approximates a region of space ...



... but it's the space I want to program!

Amorphous Design Space

$n > 10^6$ nodes

Plentiful energy, memory and processing

No naming, time or coordinate service

Cost constraints:

Communication density $O(\lg n)$

Time (stabilization, update, etc.) $O(d \lg d)$

Locality of execution

Challenges to Robustness

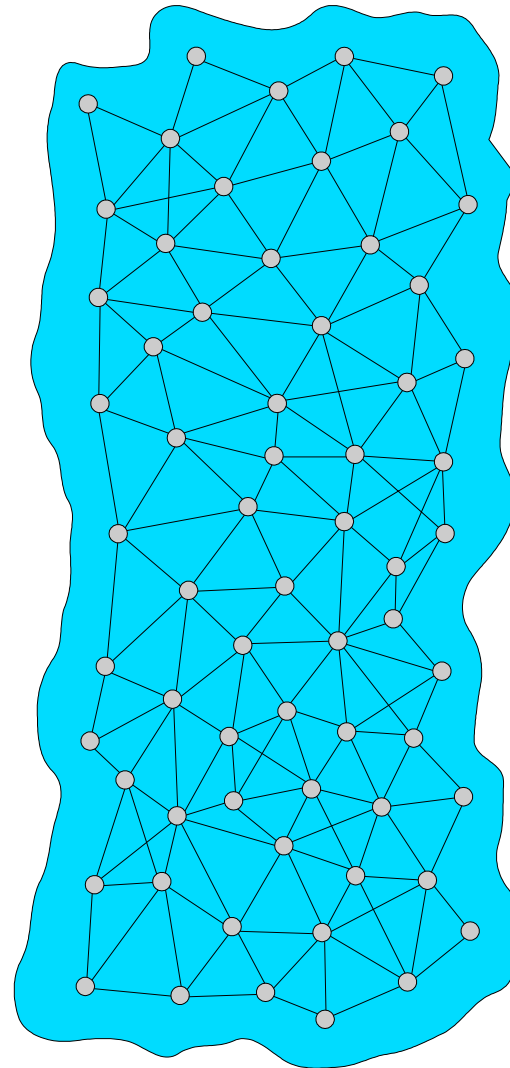
Point failure & rejoin

Node, edge, or micropartition

Continuously occurring

Region failure & rejoin

Cut and paste too?



Challenges to Robustness

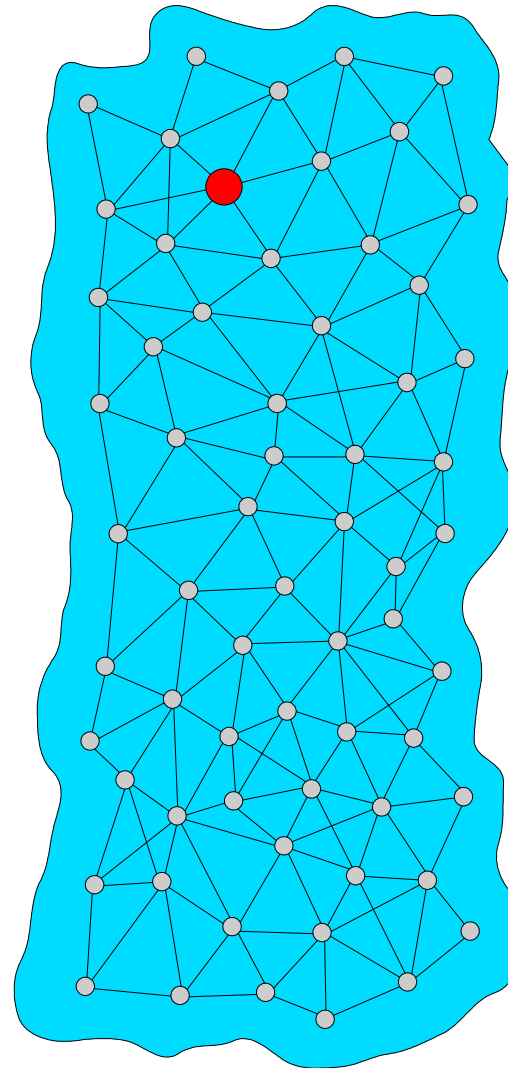
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Challenges to Robustness

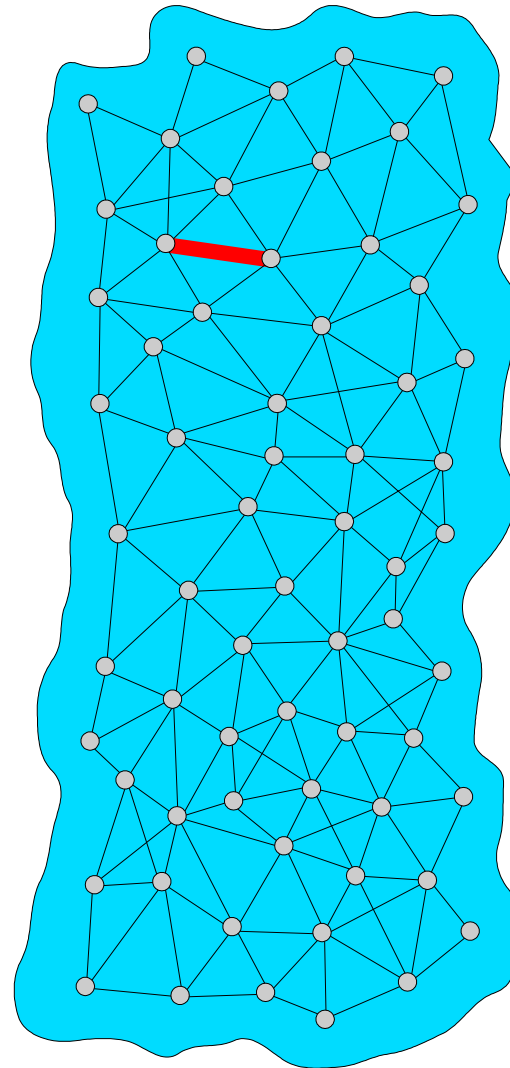
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Challenges to Robustness

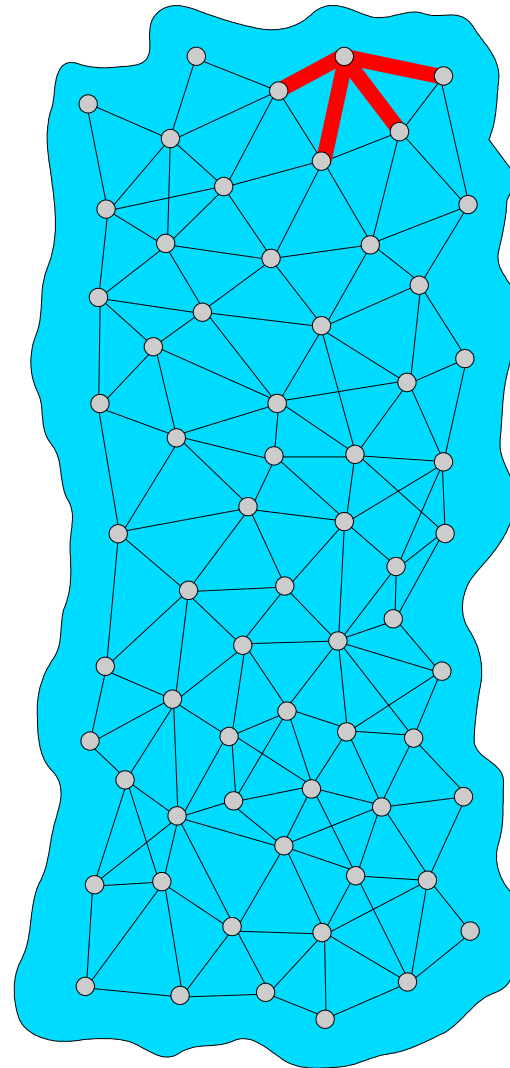
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Challenges to Robustness

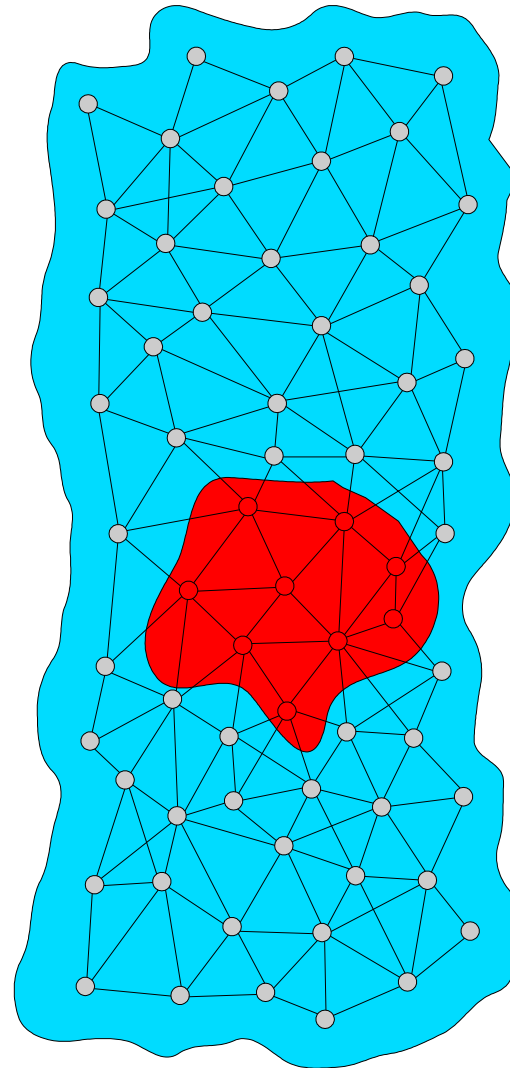
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Node, edge, or micropartition

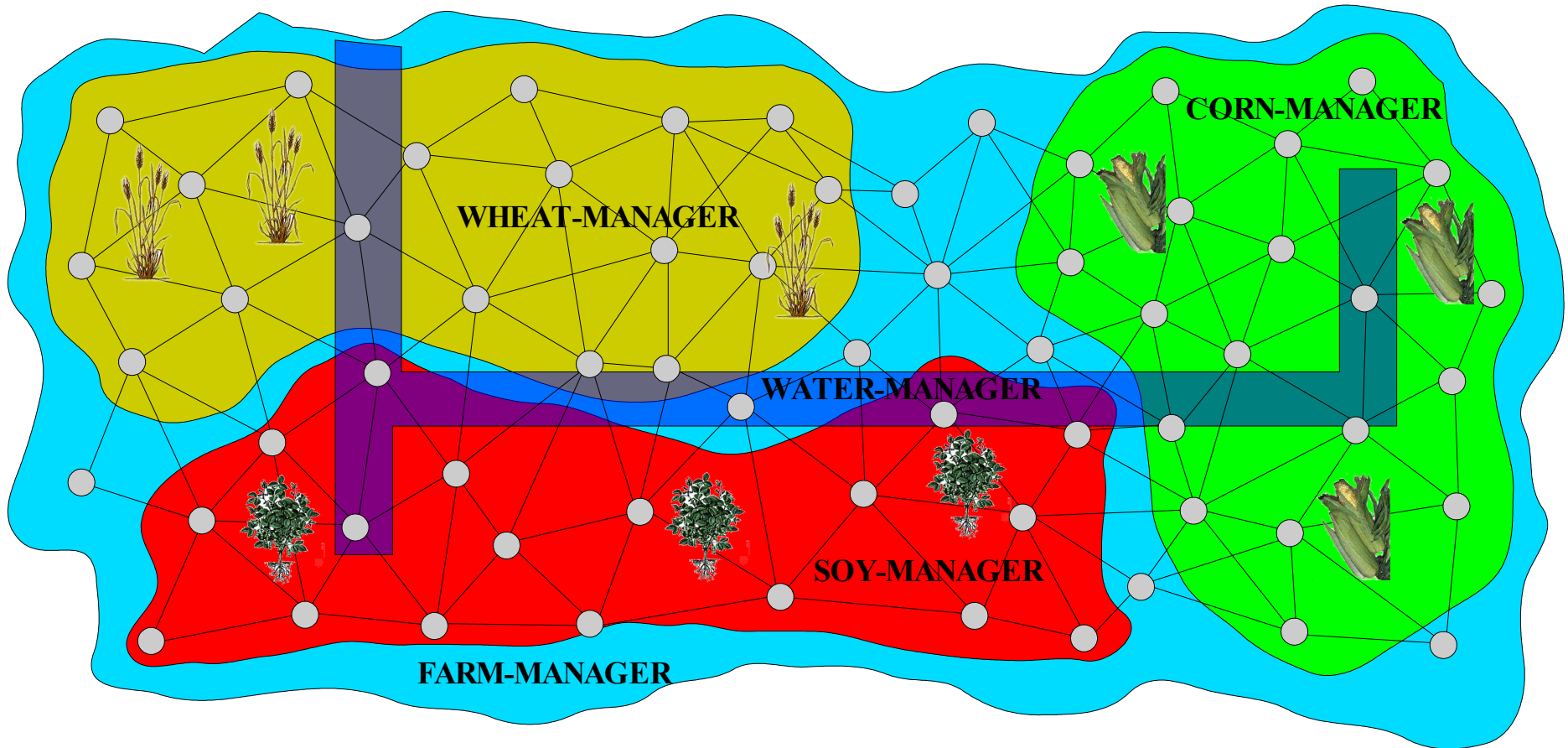
Continuously occurring

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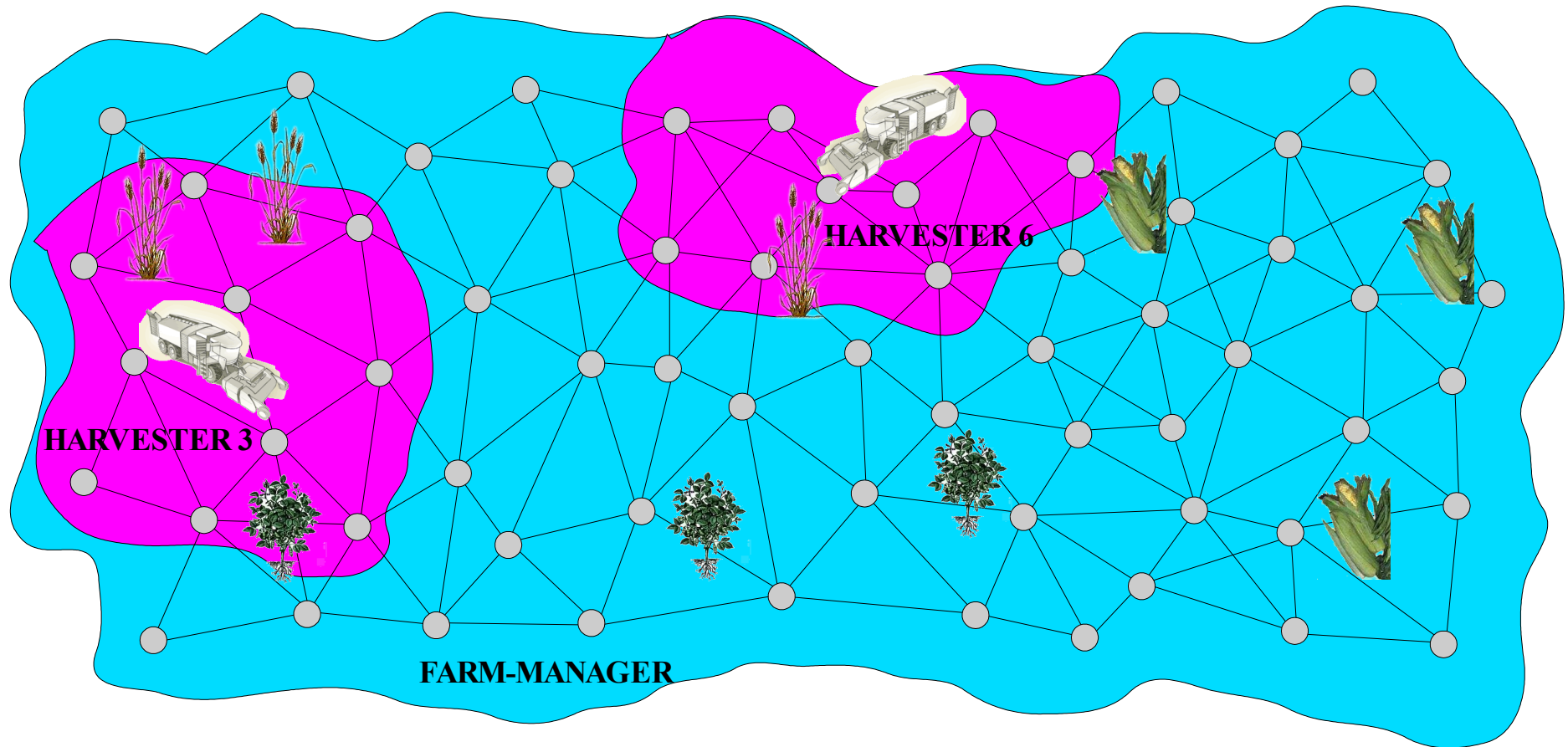
Process = Region



Behavior is specified for a generic point in the region.

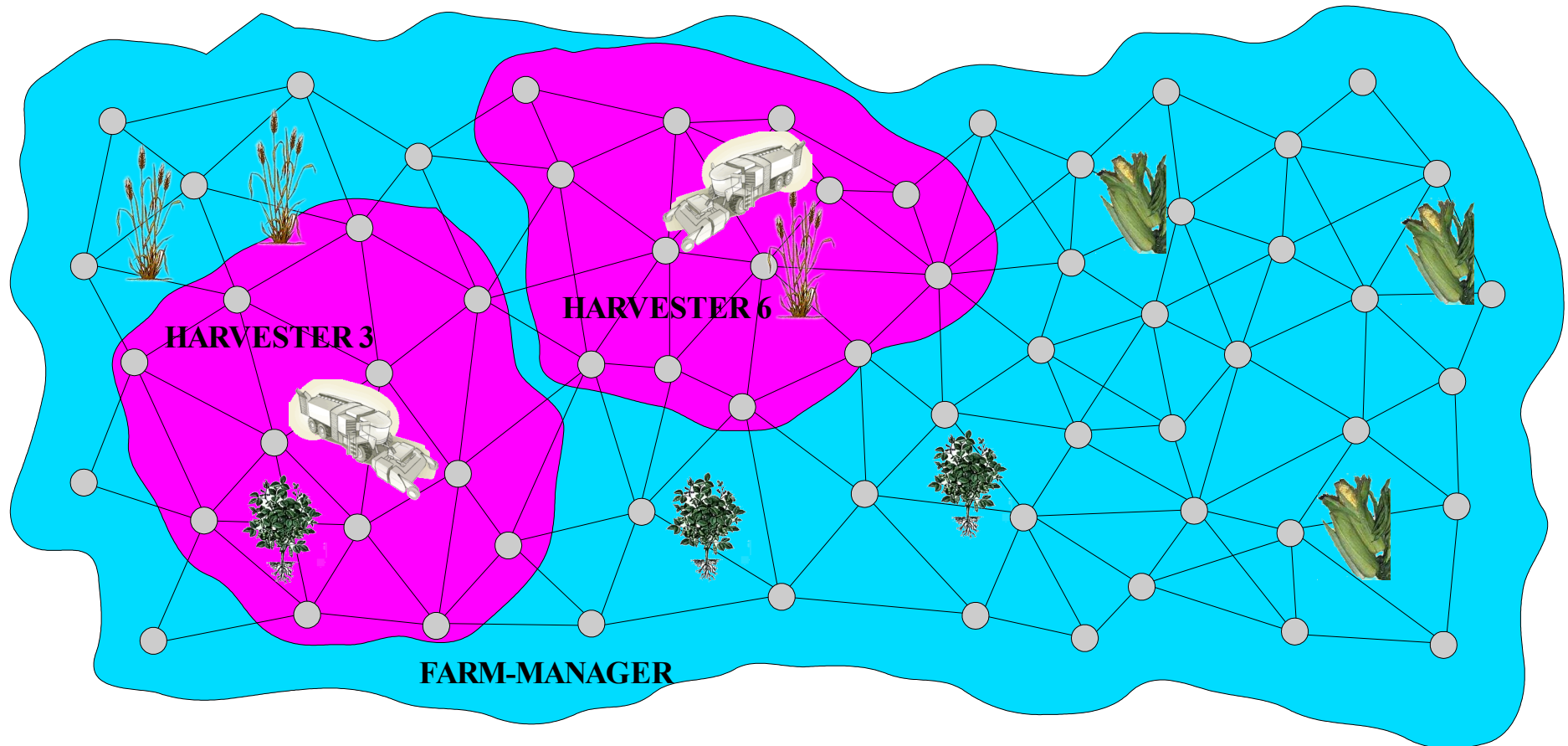
```
(defprocess wheat-manager ...)  
(defprocess corn-manager ...)  
(defprocess soy-manager ...)  
(defprocess water-manager ...)
```

Executing Processes Can Move



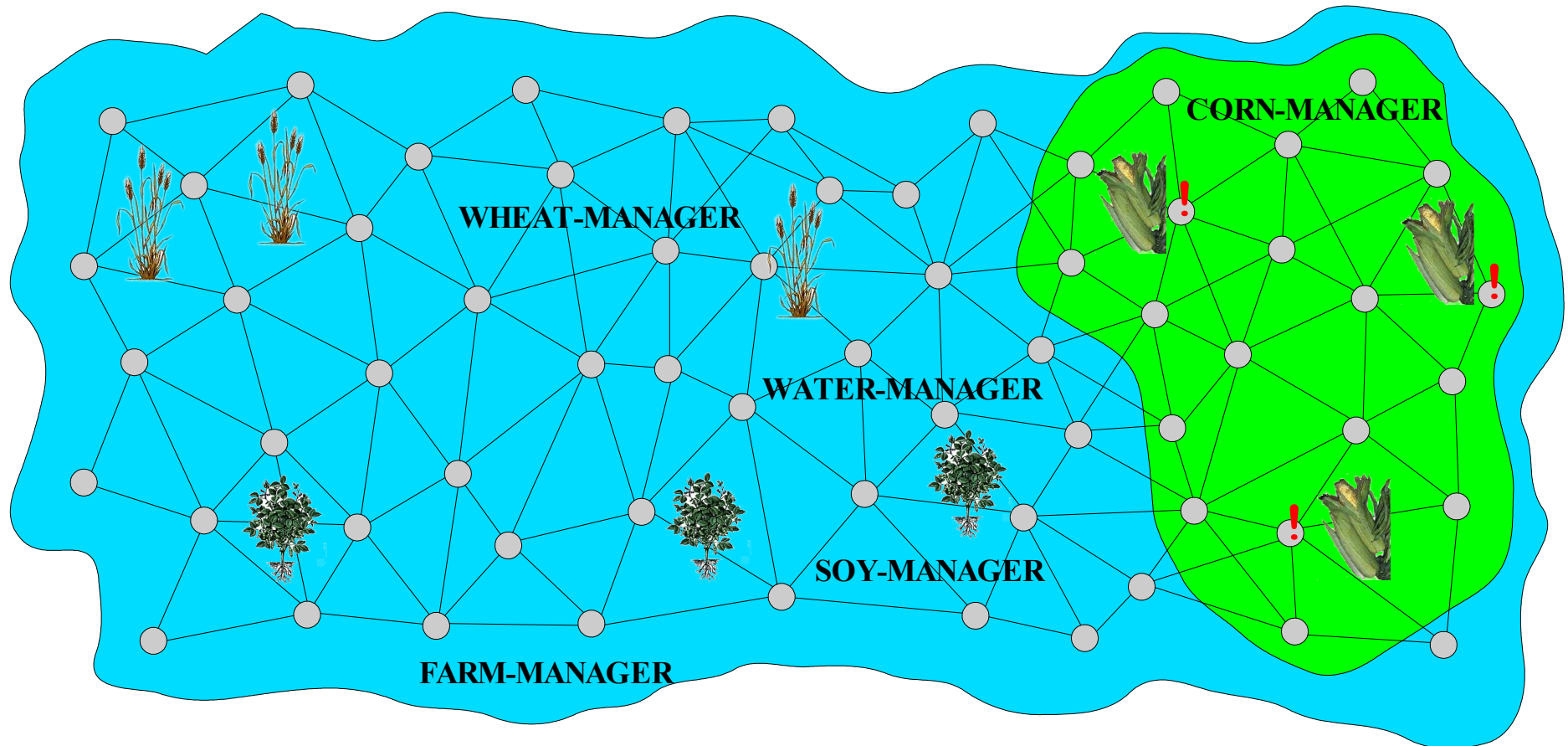
```
(defprocess farm-manager ...  
  (p-assert  
    (h (local harvesters))  
    (subprocess (harvester h) :gradient 2))  
  ...)
```

Executing Processes Can Move



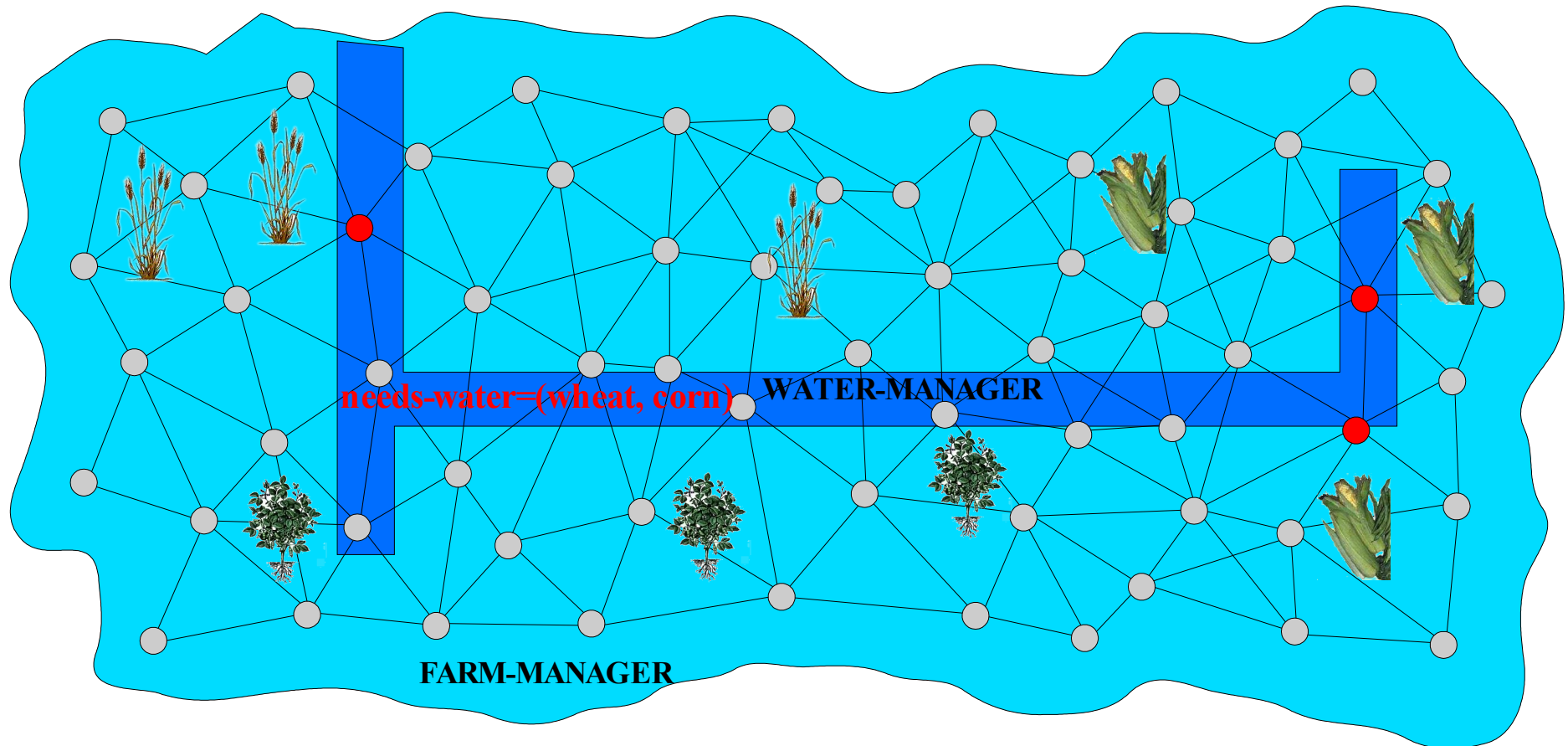
```
(defprocess farm-manager ...  
  (p-assert  
    (h (local harvesters))  
    (subprocess (harvester h) :gradient 2))  
  ...)
```

Action via Invariant & Repair



```
(defprocess corn-manager ...  
  (constraint ; ensure mature ears are picked  
    (or (not (local ears)) ; invariant  
        (not (maturep (local ears))))  
    (assert request-picking 'corn) ; repair  
  ...)
```

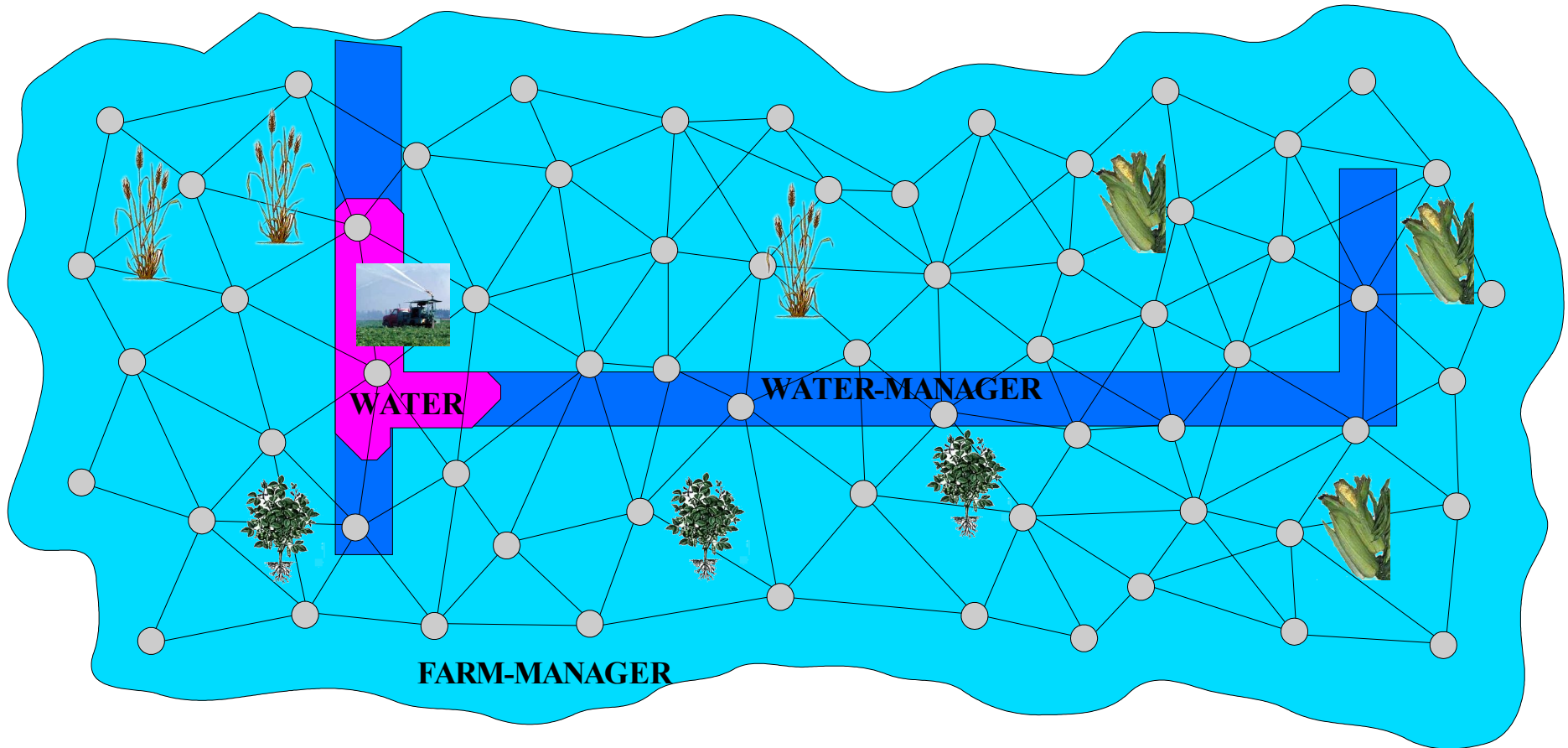

Process Variables Have Aggregate Values



Local: doesn't spread
Gossip: free aggregation
Fold: no point counted twice
Atomic: serializable

```
(defprocess water-manager ...  
  (variable needs-water :gossip :fold push)  
  (p-constraint  
    (c (local crops))  
    (> (local dampness) (damp-pref c))  
    (assert needs-water c))
```

Subprocesses Run In Parent's Region



```
(defprocess water-manager ...  
  (constraint  
    (not needs-water)  
    (subprocess (water) :node 2  
      :move (attract-to (source-of needs-water))  
    ..)  
  ..)
```

Contributions

Network is a discrete sampling of space

Toward a high-level spatial language:

Amorphous computing primitives

Process = Region

Invariant & Repair