Epidemic Algorithms for Replicated Database Maintenance

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EPIDEMIC ALGORITHMS FOR REPLICATED DATABASE MAINTENANCE

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Scott Shenker, Howard Sturgis, Dan Swinehart, and Doug Terry

Epidemic Algorithms For Replicated Database Maintenance

- **Alan Demers** Retired Professor at Cornell University
- **Dan Greene** At Xerox PARC – Vehicle networks
- **Carl Hauser** Associate Professor, Washington State University
- **Wes Irish** Coyote Hill Consulting
- **Scott Shenker** Professor at UCBerkeley
- **Doug Terry** Microsoft Research

John Larson, Howard Sturgis, Dan Swinehart

Summary of the Research

- Database management for distributed systems
  - Consistent data records

- 3 methods
  - Direct Mail
  - Anti-Entropy
  - Rumor Mongering

- CAP Theorem

- Real world applications
  - Vegvisir blockchain
  - Amazon

Research Motivation

- Clearinghouse servers on Xerox Corporate Internet (CIN)
    - Hundreds of ethernets connected by gateways and phone lines
        - Ex Message: Japan -> Europe goes through 14 gateways and 7 phone lines
    - Organized by Hierarchical name (domains)
    - Remailing – Inefficiency during disagreement among participants

Points of Differentiation

- Eventual delivery of repeated messages and do not require data structures at one server to describe information held at other servers
- Algorithm are randomized

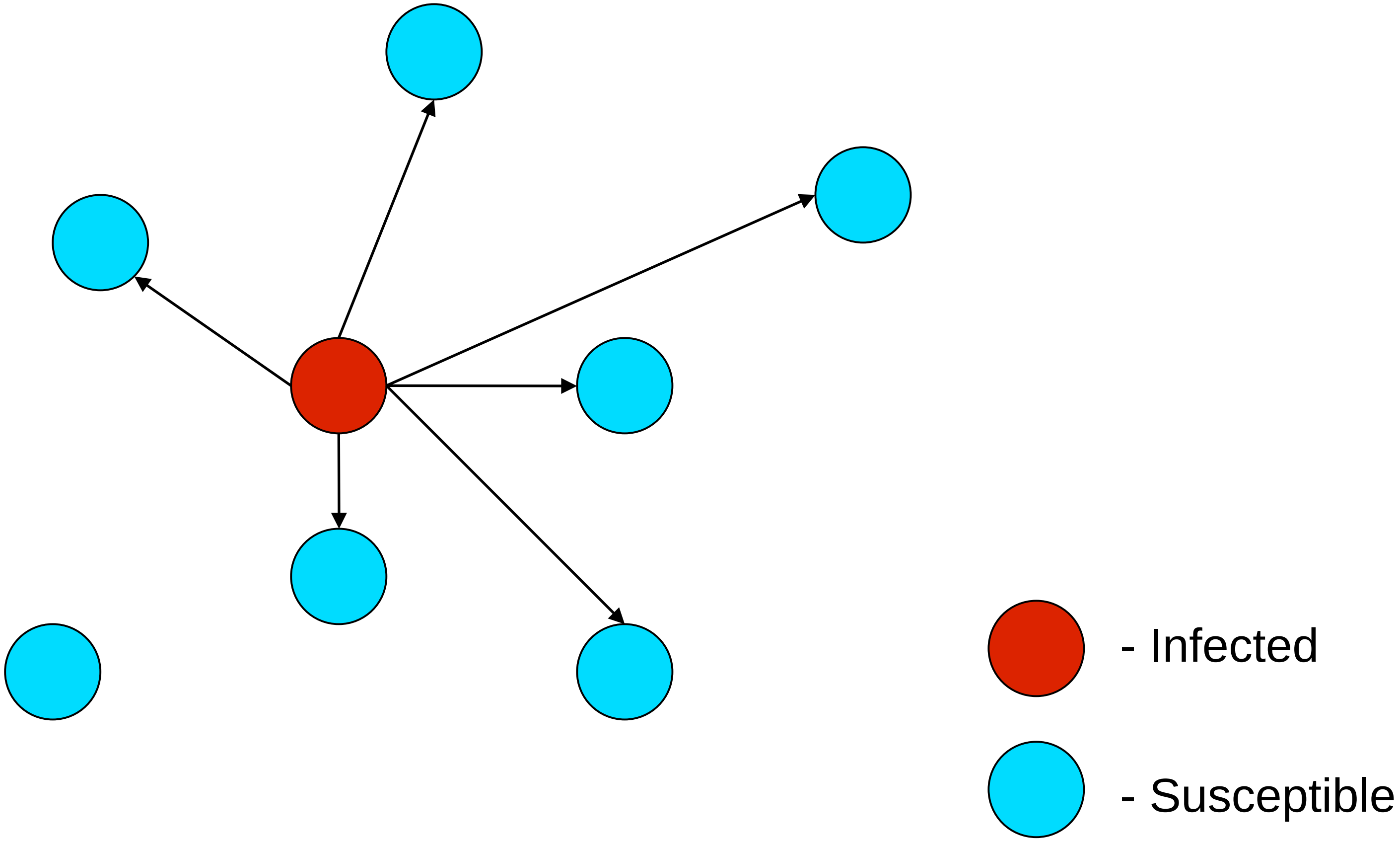
Vocabulary

- **Infected** – Knows the update and *spreads* it
- **Susceptible** – Does not know the update
- **Removed** – Knows the update but *not* able to spread it anymore
- **Push** – Tells an updates to another node
- **Pull** – Asks for an update from another node

Direct Mail

Direct Mail – Sends update to all nodes in the network

- Traffic proportional to the number of sites * average distance between sites



Direct Mail

Failure Modes

- Message discarded for nodes
  - Que overflows
  - Extended period of inaccessibility

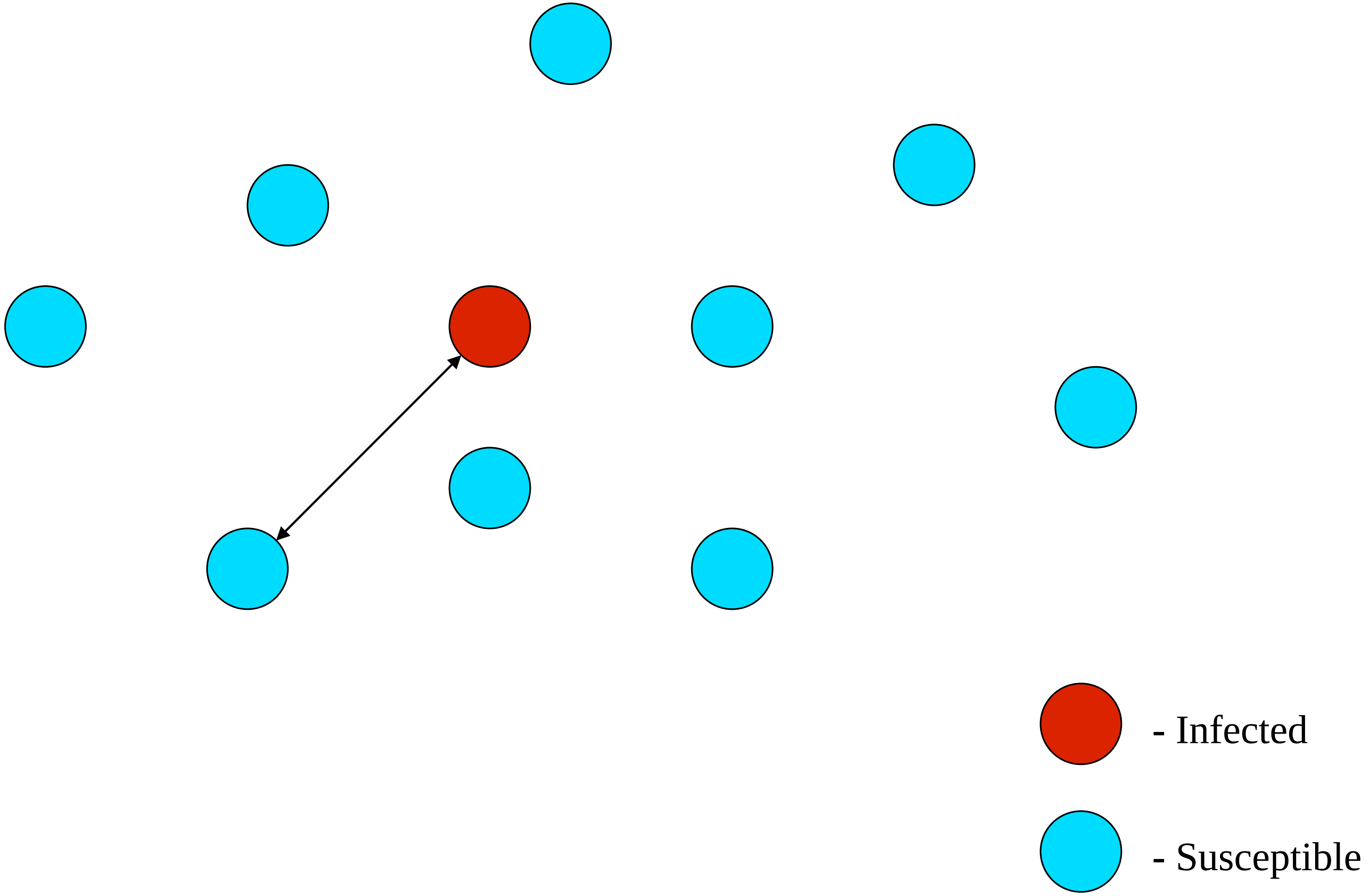
Anti-Entropy

Anti-Entropy – Nodes exchange messages with a random node through the methods below:

- Pull – Grows fast but slows down overtime
- Push – Grows slowly but speeds up overtime
- Push-pull – Most efficient and every node receives the message

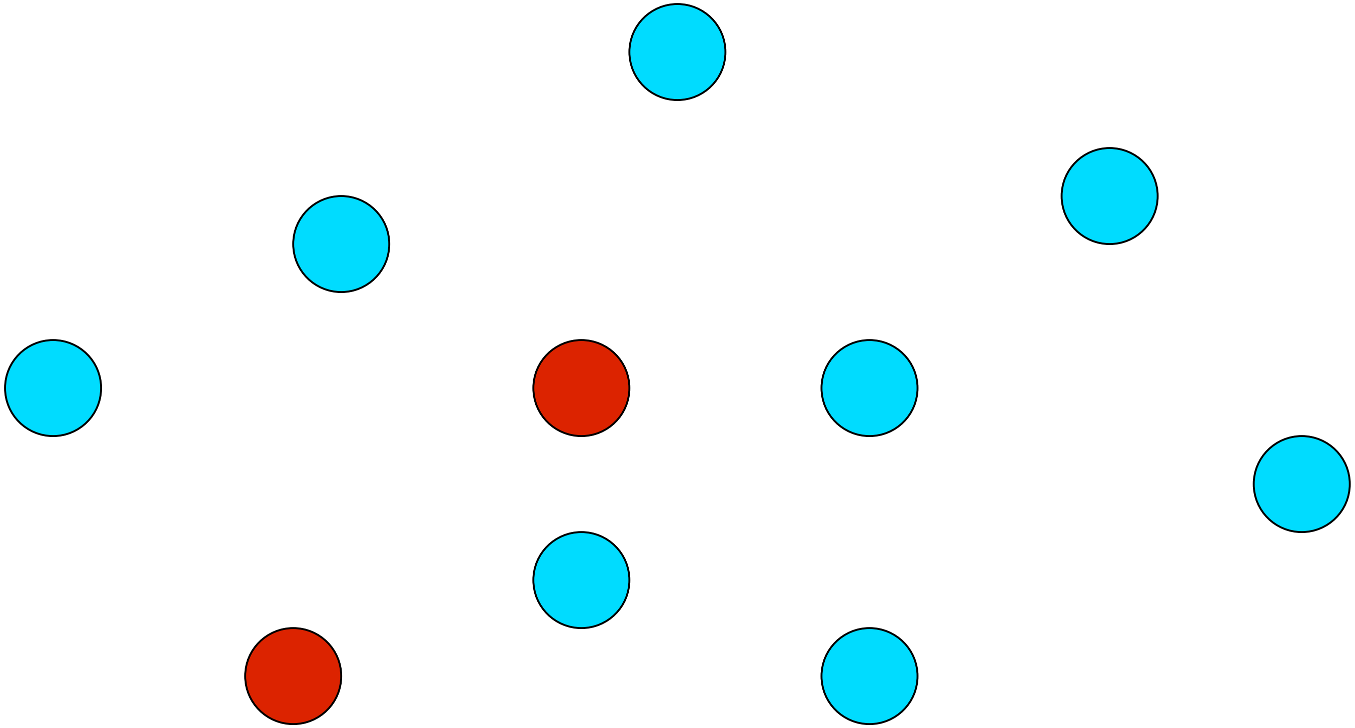
How it works

Anti-Entropy



How it works

Anti-Entropy

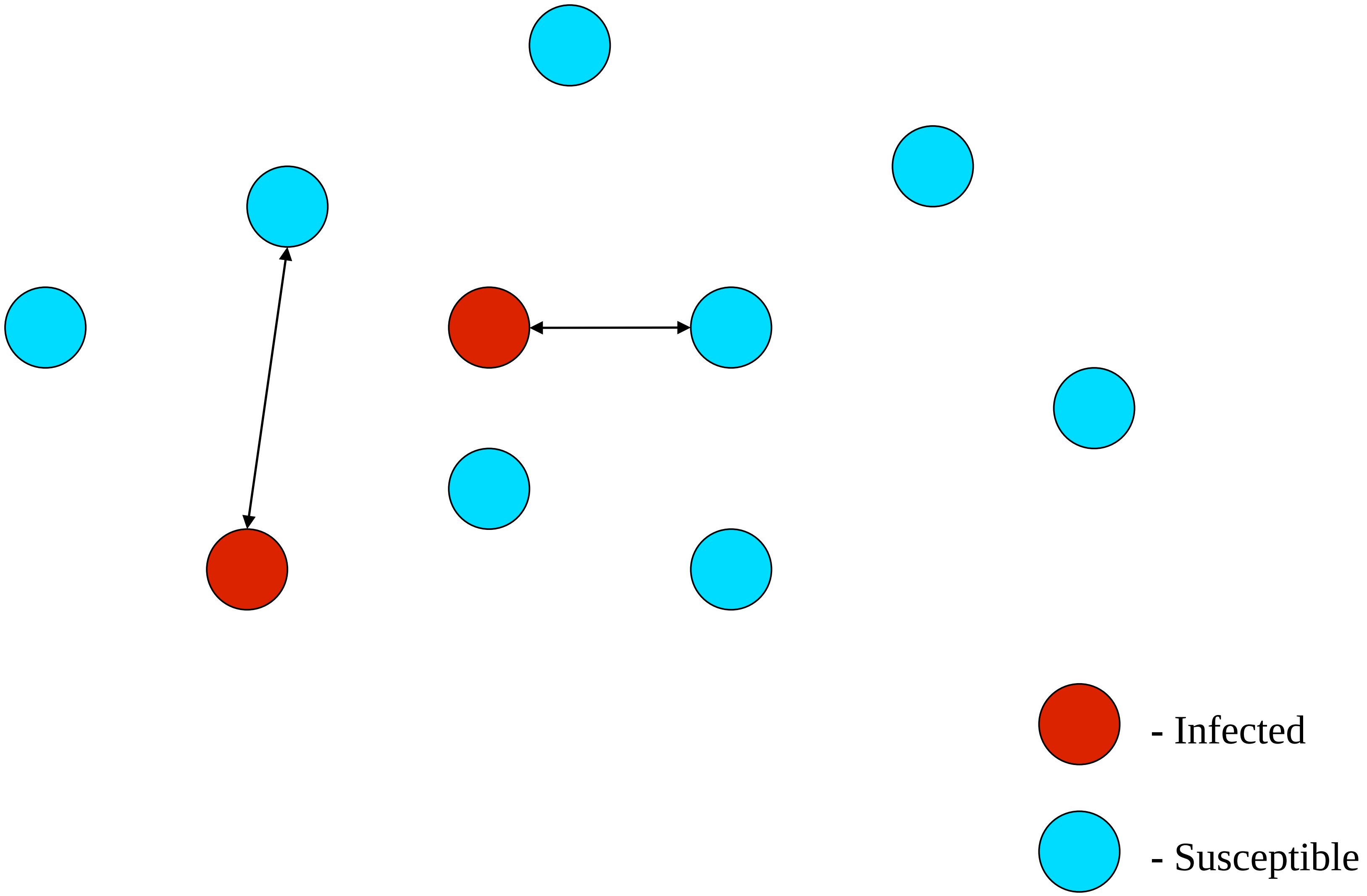


🔴 - Infected

🔵 - Susceptible

How it works

Anti-Entropy



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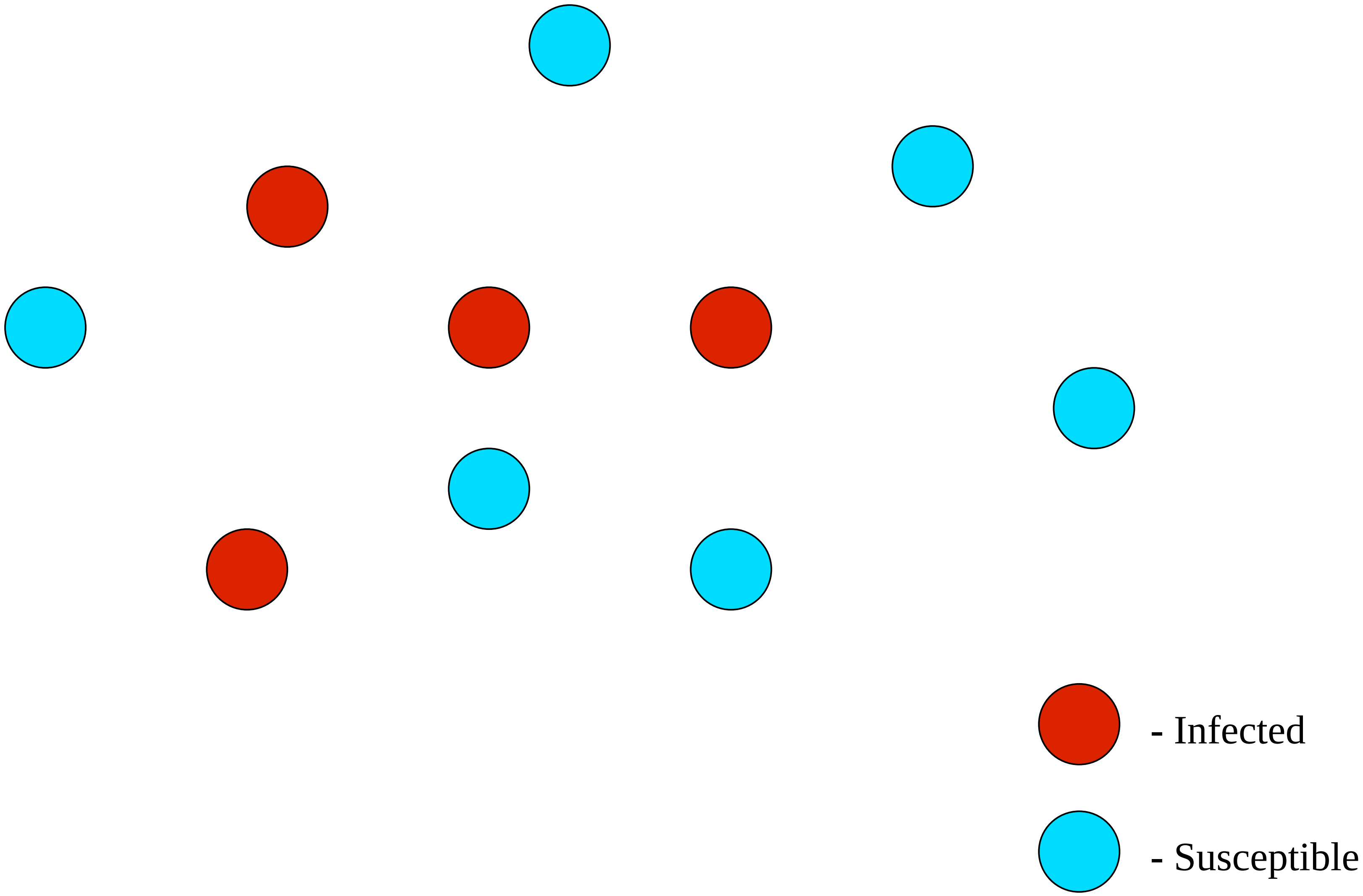
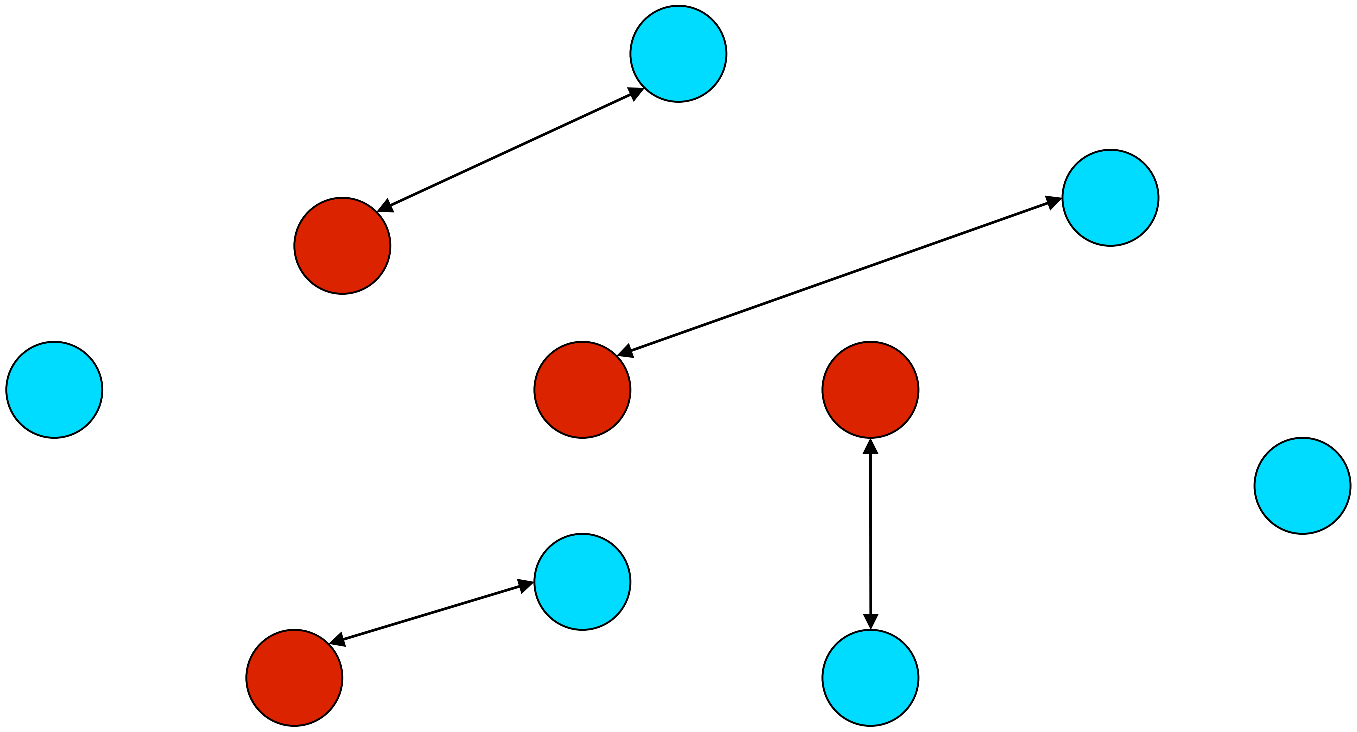
How it works

Anti-Entropy



How it works

Anti-Entropy



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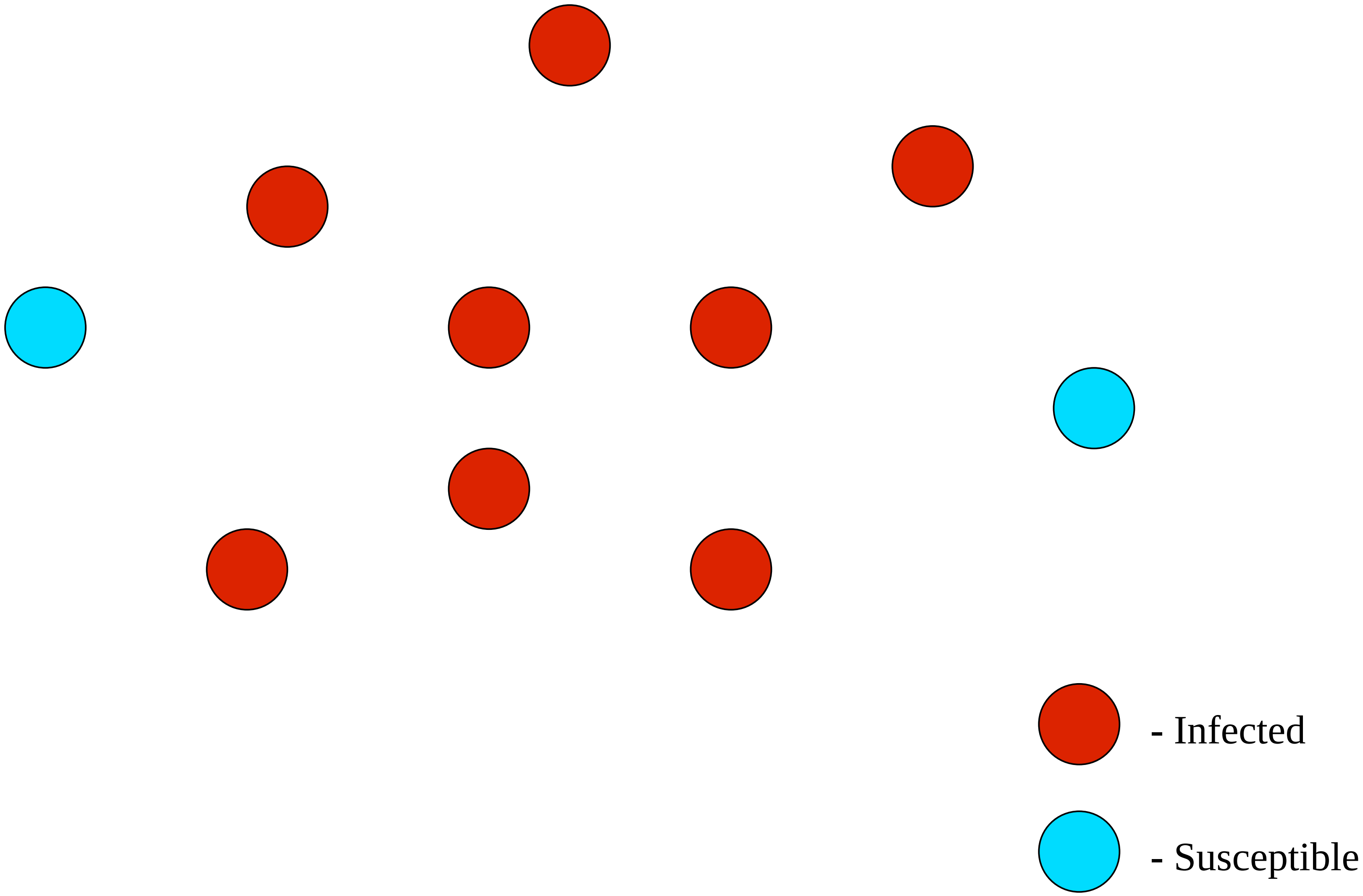
How it works

Anti-Entropy



Anti-Entropy

Pro:

- Eventually everyone receives the message

Con:

- Large overhead due to external requests for updates

Rumor Mongering

Rumor mongering – Optimized algorithm for spreading messages

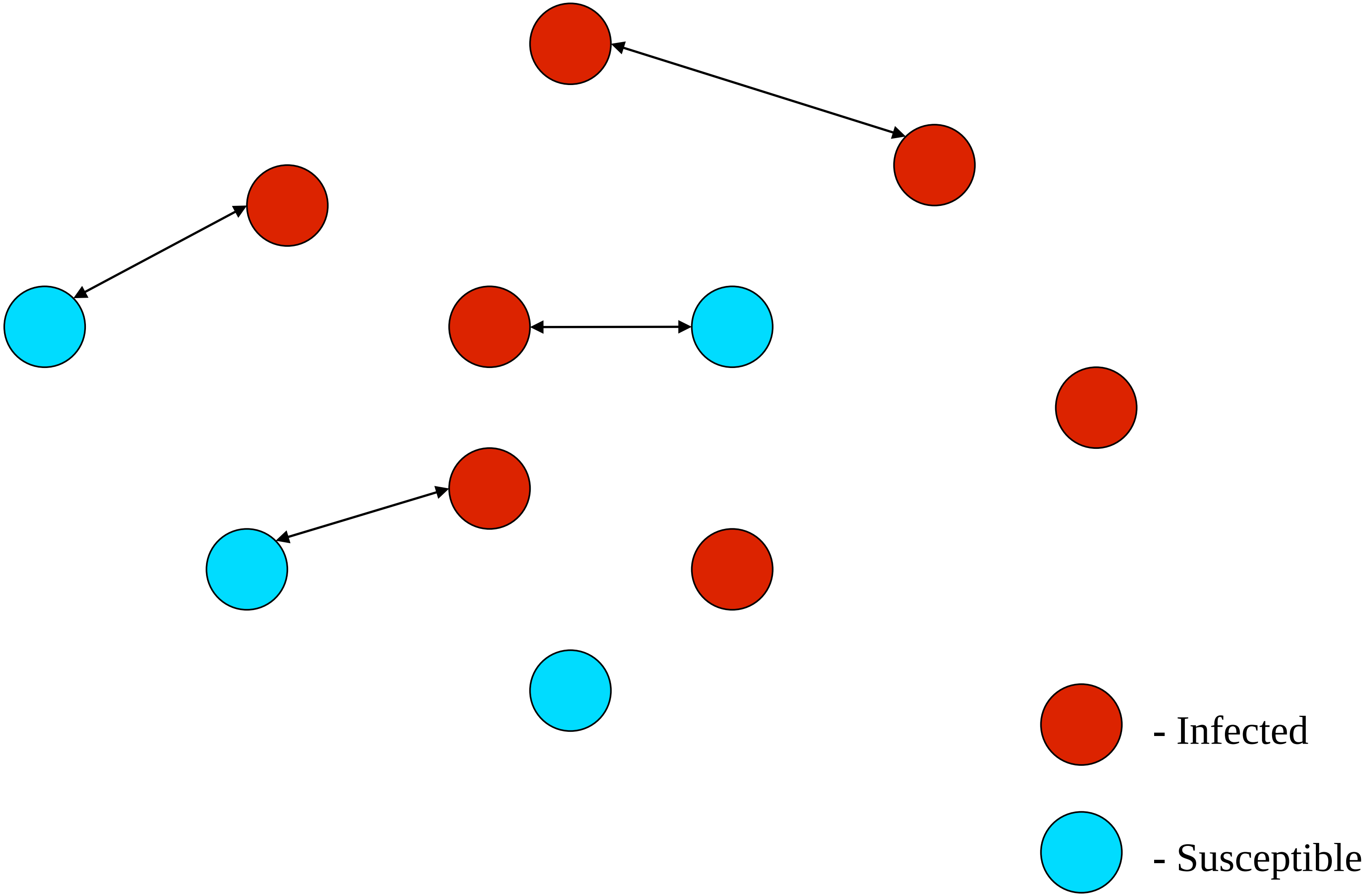
- When a node receives a new update (rumor)
- Periodically choose another site at random to infect other nodes
- When enough nodes have seen the rumor it is removed

Problem of convergence

- Fix with anti-entropy combination

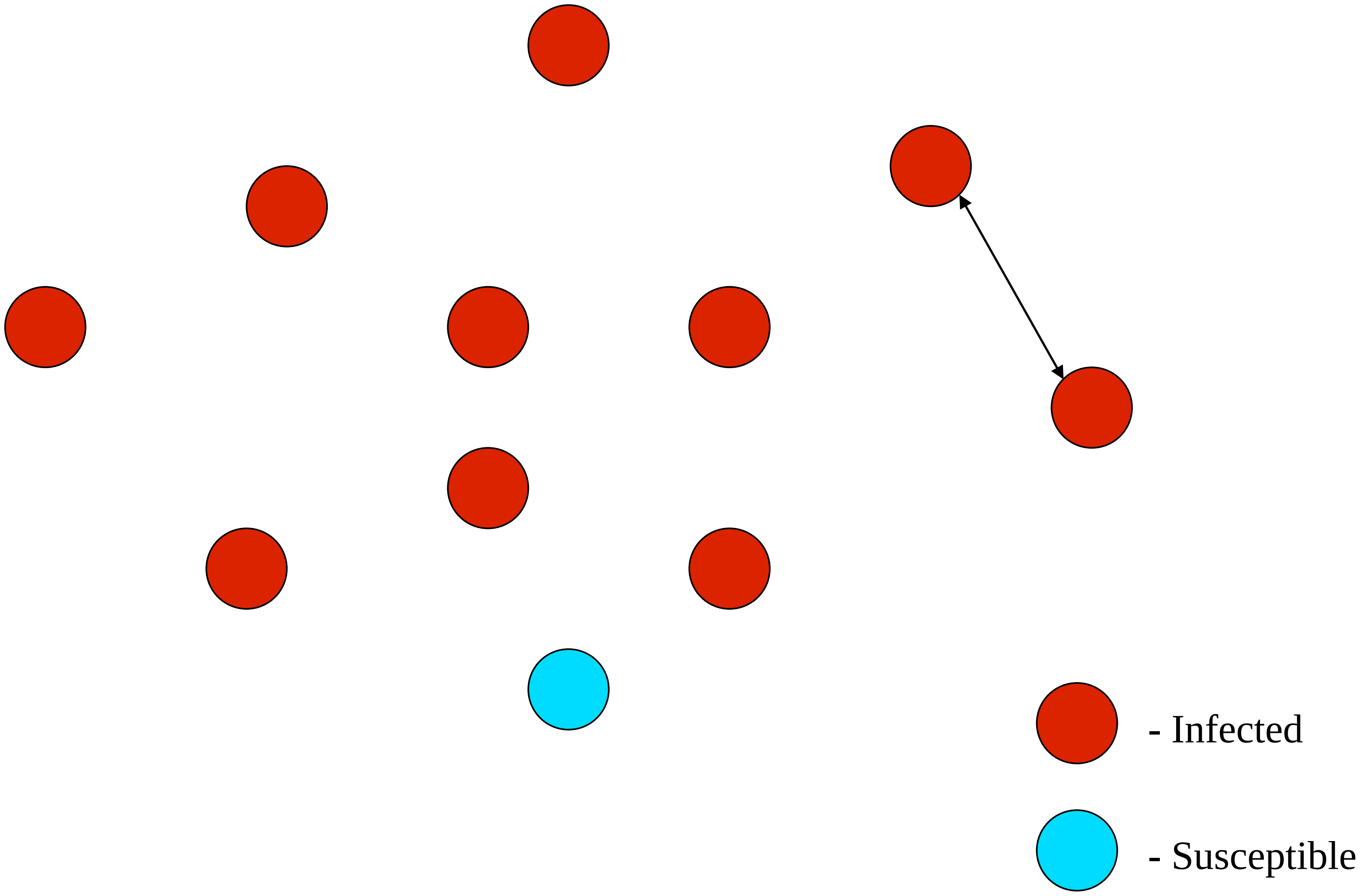
How it works

Rumor mongering



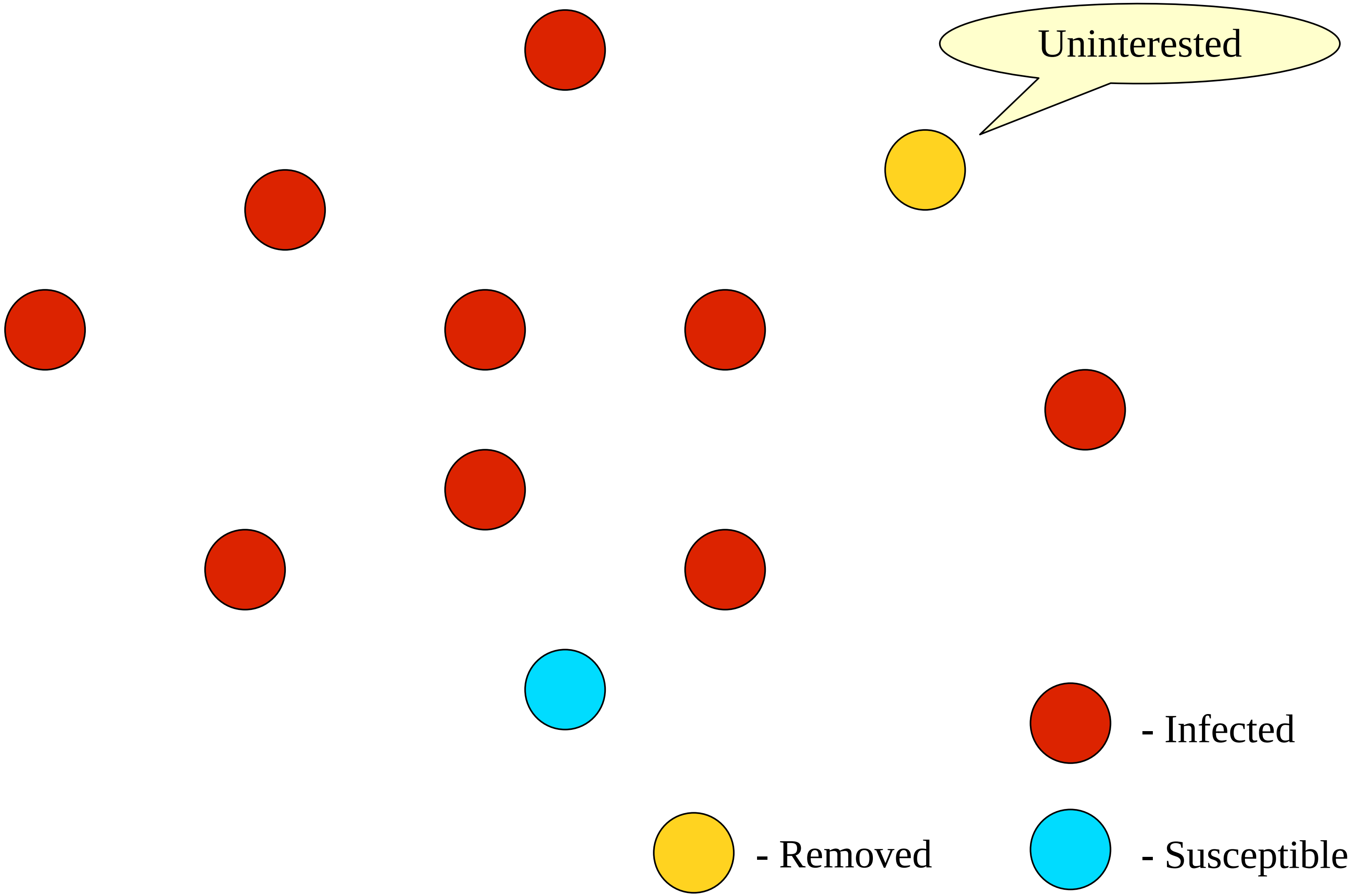
How it works

Rumor mongering



How it works

Rumor mongering



Uninterested

🔴 - Infected

🟡 - Removed

🔵 - Susceptible

Points of differentiation

Death certificates

- Shows when a node is decommissioned
- Verified with a timestamp

Spatial distribution

- Favors sending updates to closest nodes first

Anti-Entropy Results

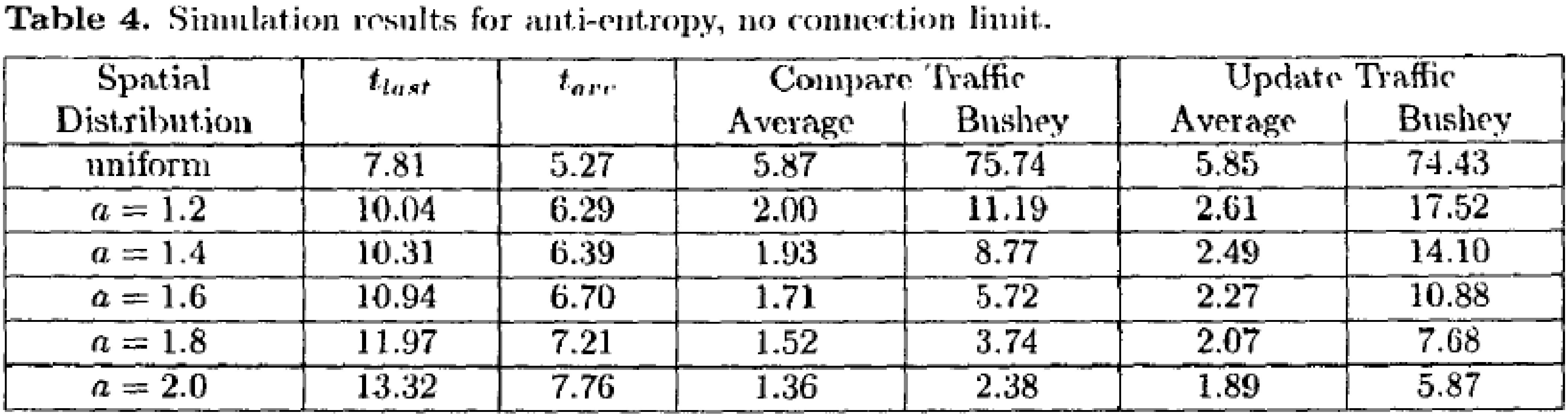


Table 4. Simulation results for anti-entropy, no connection limit.

Spatial Distribution	t_{last}	t_{ave}	Compare Traffic		Update Traffic	
			Average	Bushey	Average	Bushey
uniform	7.81	5.27	5.87	75.74	5.85	74.43
$a = 1.2$	10.04	6.29	2.00	11.19	2.61	17.52
$a = 1.4$	10.31	6.39	1.93	8.77	2.49	14.10
$a = 1.6$	10.94	6.70	1.71	5.72	2.27	10.88
$a = 1.8$	11.97	7.21	1.52	3.74	2.07	7.68
$a = 2.0$	13.32	7.76	1.36	2.38	1.89	5.87

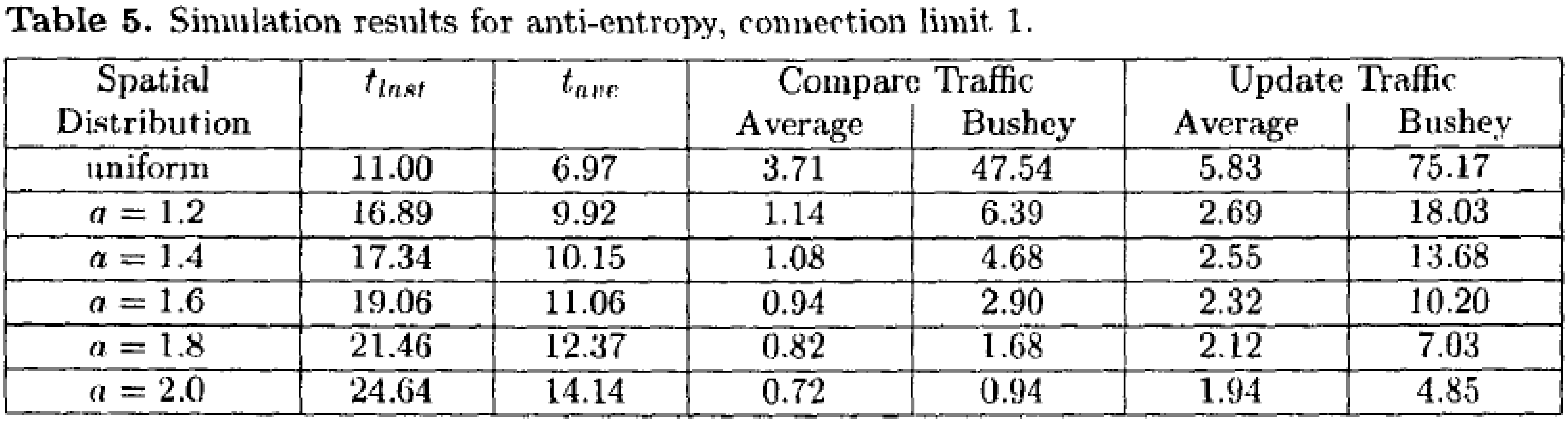


Table 5. Simulation results for anti-entropy, connection limit 1.

Spatial Distribution	t_{last}	t_{ave}	Compare Traffic		Update Traffic	
			Average	Bushey	Average	Bushey
uniform	11.00	6.97	3.71	47.54	5.83	75.17
$a = 1.2$	16.89	9.92	1.14	6.39	2.69	18.03
$a = 1.4$	17.34	10.15	1.08	4.68	2.55	13.68
$a = 1.6$	19.06	11.06	0.94	2.90	2.32	10.20
$a = 1.8$	21.46	12.37	0.82	1.68	2.12	7.03
$a = 2.0$	24.64	14.14	0.72	0.94	1.94	4.85

Rumor Mongering Results

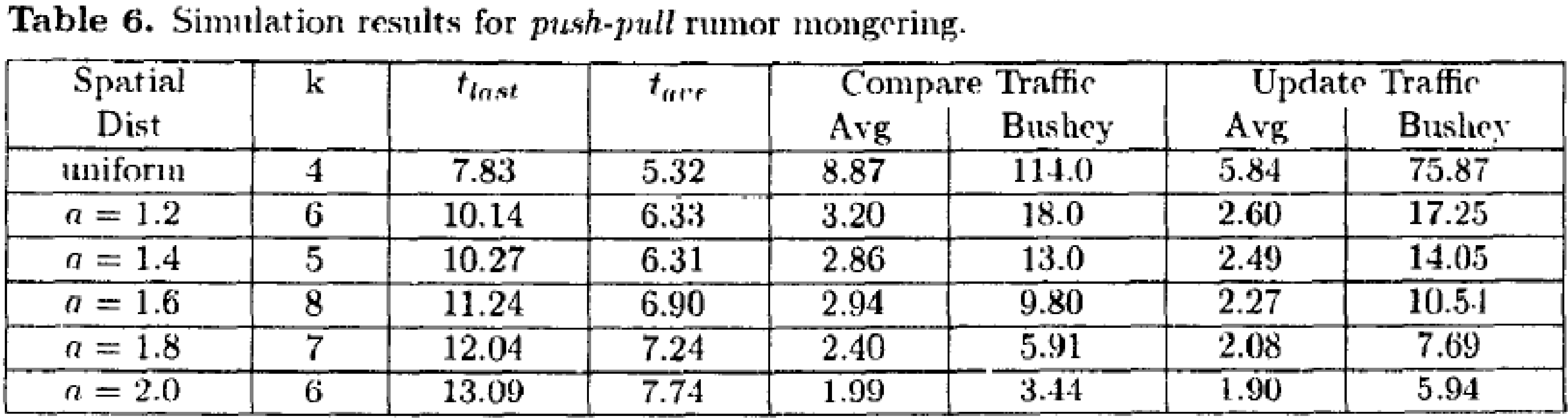


Table 6. Simulation results for *push-pull* rumor mongering.

Spatial Dist	k	t_{last}	t_{ave}	Compare Traffic		Update Traffic	
				Avg	Bushey	Avg	Bushey
uniform	4	7.83	5.32	8.87	114.0	5.84	75.87
$\alpha = 1.2$	6	10.14	6.33	3.20	18.0	2.60	17.25
$\alpha = 1.4$	5	10.27	6.31	2.86	13.0	2.49	14.05
$\alpha = 1.6$	8	11.24	6.90	2.94	9.80	2.27	10.54
$\alpha = 1.8$	7	12.04	7.24	2.40	5.91	2.08	7.69
$\alpha = 2.0$	6	13.09	7.74	1.99	3.44	1.90	5.94

CAP Theorem

Only 2/3 are achievable

- Consistency – Every node has the most recent message
- Accessibility – Every node receives a message but no guarantee that it is the most recent
- Partition Tolerance – System continues to operate even if messages are lost

Applications of the Research

1. Vegvisir – Agriculture specific blockchain that reconciles with random nodes within a specific range
2. Amazon – S3 storage system uses gossip to disseminate information

Questions?