P2P Systems: Gossip Protocols

CS 6410

By Alane Suhr & Danny Adams

Outline

- Timeline
- CAP Theorem
- Epidemic algorithms for replicated database maintenance
- Managing update conflicts in Bayou, a weakly connected replicated storage system
- Conclusion

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Timeline

1978	1982	1985	1987	1990	1995	1998
Lamport	**Lamport**	**FLP**	**Demers**	**Schneider**	**Terry**	**Lamport**
Time, Clocks, and the Ordering of Events in a Distributed System	The Byzantine Generals Problem	Impossibility of Distributed Consensus with One Faulty Process	Epidemic algorithms for replicated database maintenance	Implementing fault-tolerant services using the state machine approach: A tutorial	Managing update conflicts in Bayou, a weakly connected replicated storage system	The part-time parliament

CAP

- Consistency -- all nodes contain the same state
- Availability -- requests are responded to *promptly*
- Partition
  - part of a system completely independent from the rest of the system
  - ideally should maintain itself autonomously
- Partition tolerance -- system can stay online and functional even when message passing fails

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CAP Theorem

Paxos & Gossip

- Paxos: prioritize consistency given a network partition
- Gossip: prioritize availability given a network partition

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Gossip


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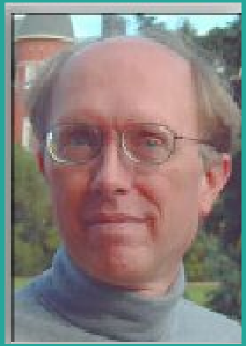
Gossip Overview

- Authors
- Motivations
- Epidemic Models
  - Direct Mail
  - Anti-Entropy
  - Rumor mongering
- Evaluation
- DC’s
- Spatial Distribution

Authors

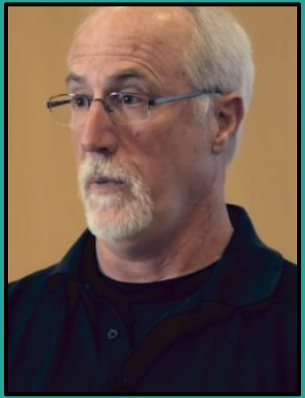
Alan Demers
Cornell University

Dan Greene
PARC Research



Carl Hauser
PhD Cornell
Washington State University

Scott Shenker
EECS Berkeley



Doug Terry
Amazon Web Services

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Motivations

- Unreliable network
- Unreliable nodes
- CAP: *AP*
  - always be able to respond to a (read/write) request
  - eventual consistency

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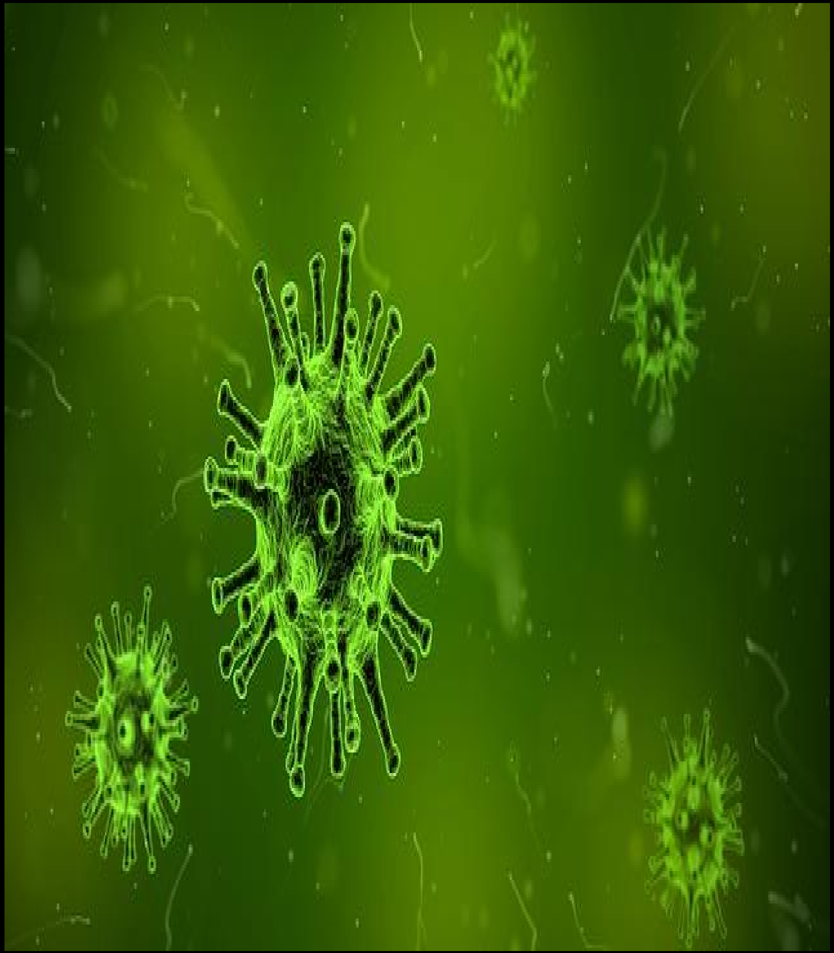
Epidemic Models

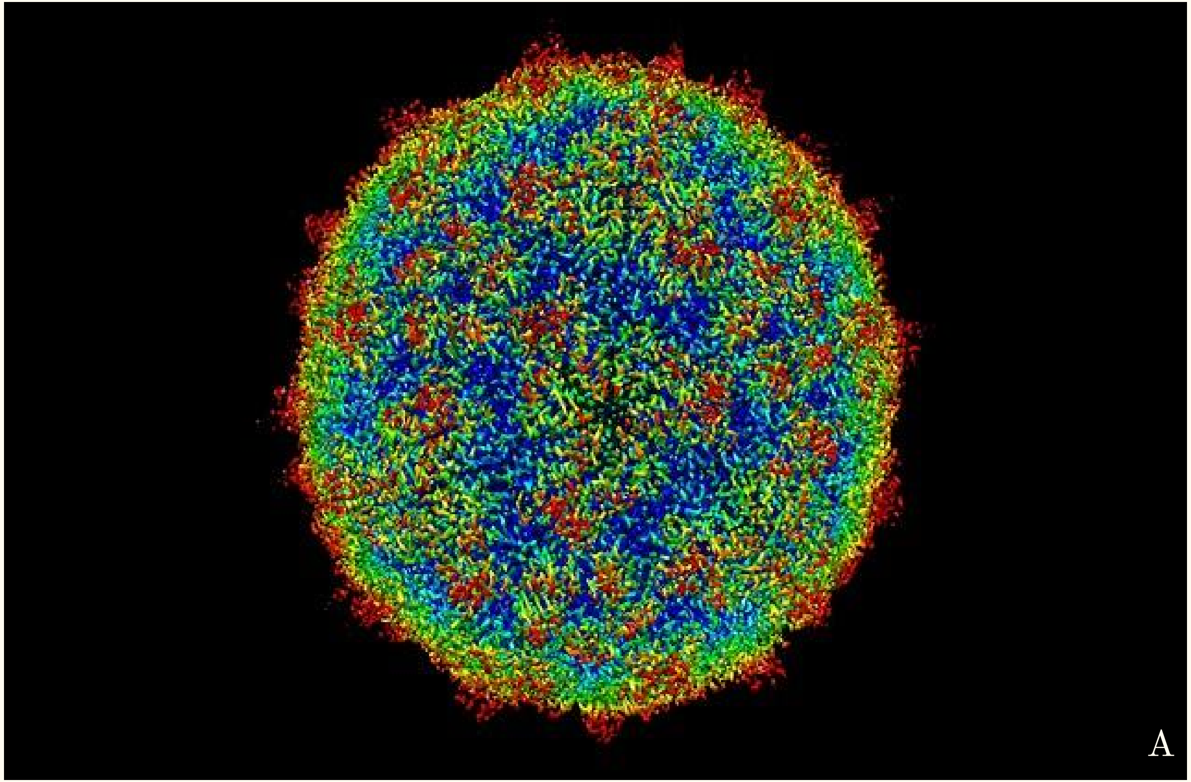


Proposers and Acceptors

- Proposer
  - In Paxos: clients propose an update to the database
  - Epidemic model: a node infects its neighbors
- Acceptor
  - In Paxos: acceptor accepts an update based on one or more proposals
  - Epidemic model: a node is infected by a neighbor

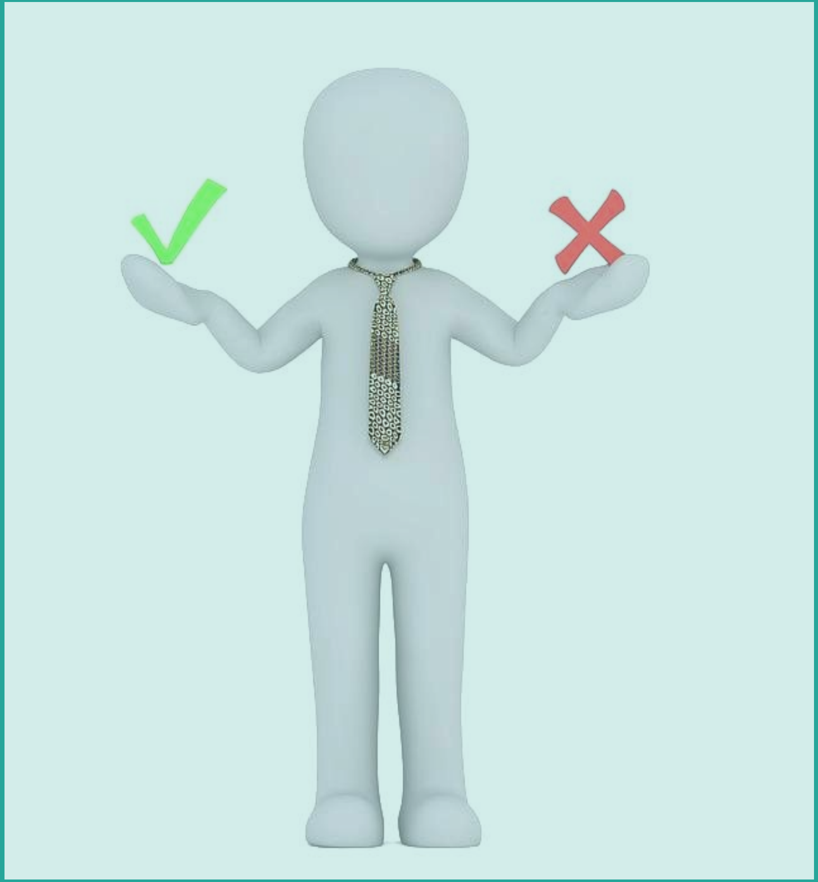
Types of Epidemics

- Direct Mail
- Anti-Entropy
- Rumor Mongering



Advantages

- Simple algorithms
- High Availability
- Fault Tolerant
- Tunable
- Scalable
- Works in Partition



- Notify all neighbors of an update
- Timely and reasonably efficient
- n messages per update

Direct Mail

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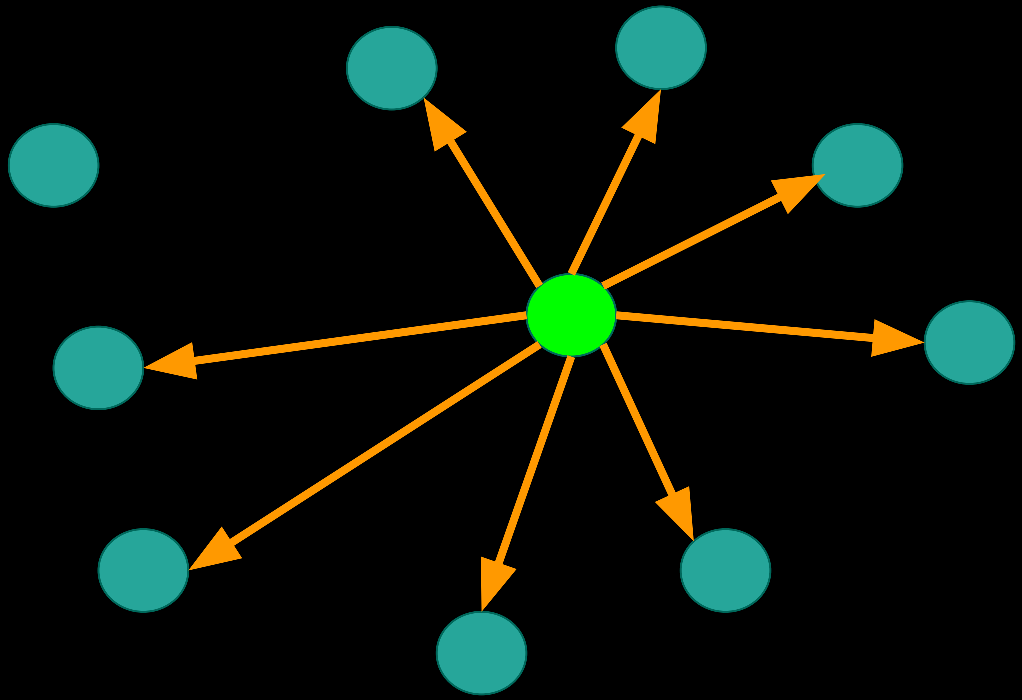
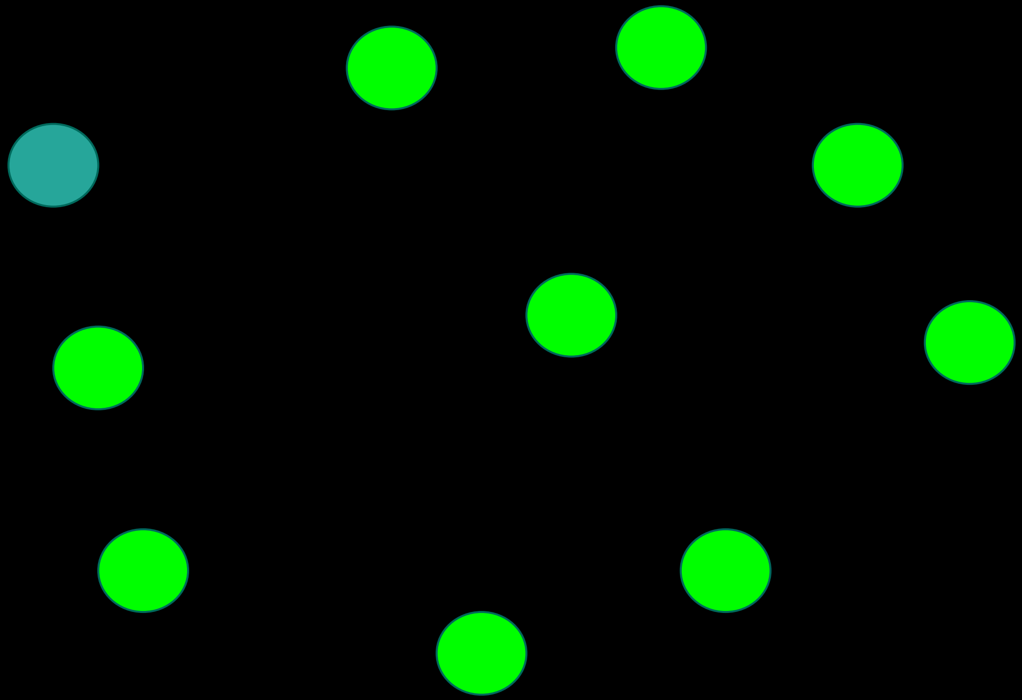
Direct Mail



Direct Mail



Direct Mail

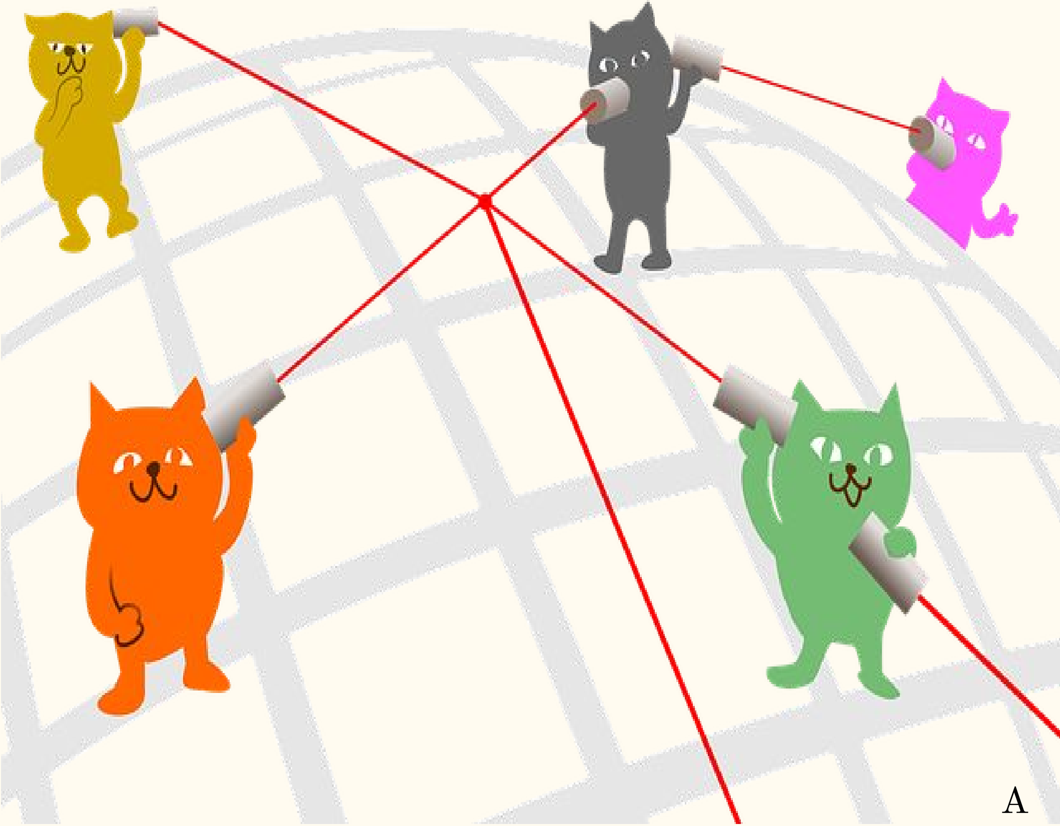
Messages sent: O(n) where n is number of neighbors

Not fault tolerant -- doesn't guarantee eventual consistency

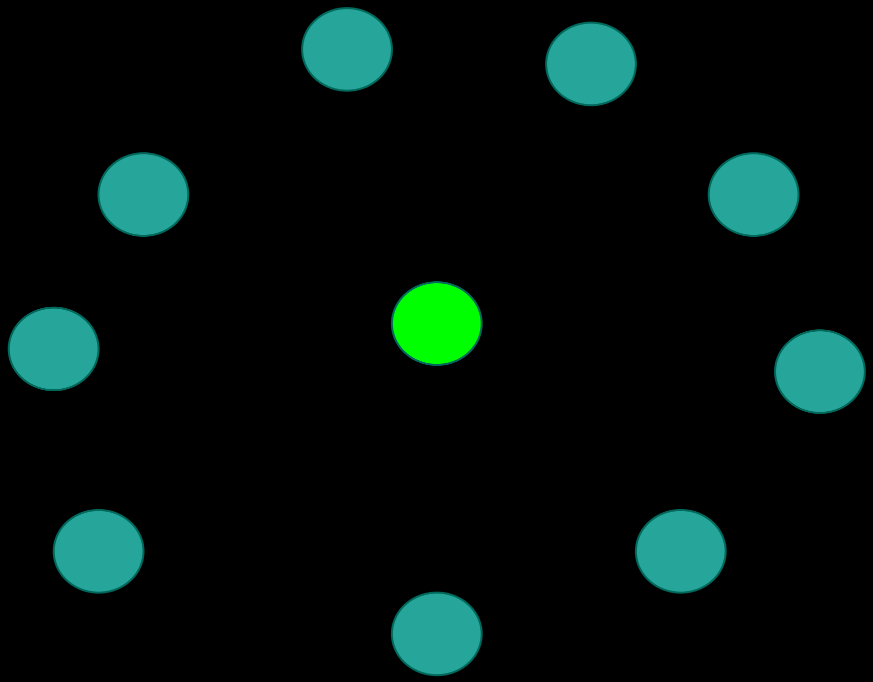
High volume of traffic with site at the epicenter

Anti-Entropy

- Site chooses random partner to share data
- Number of rounds til consistency: O(log n)
- Sites use custom protocols to resolve conflicts
- Fault tolerant



Anti-Entropy



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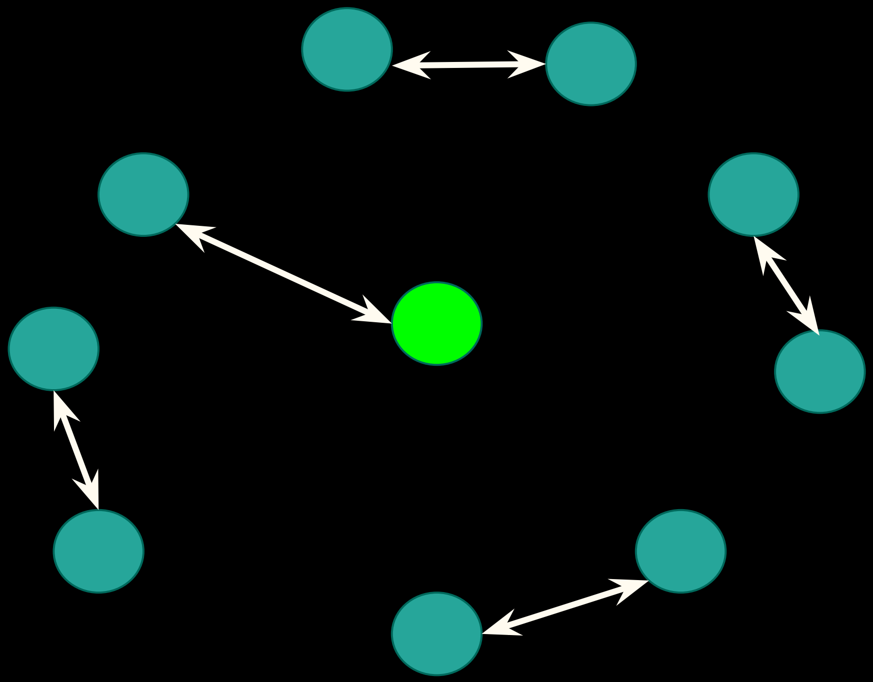

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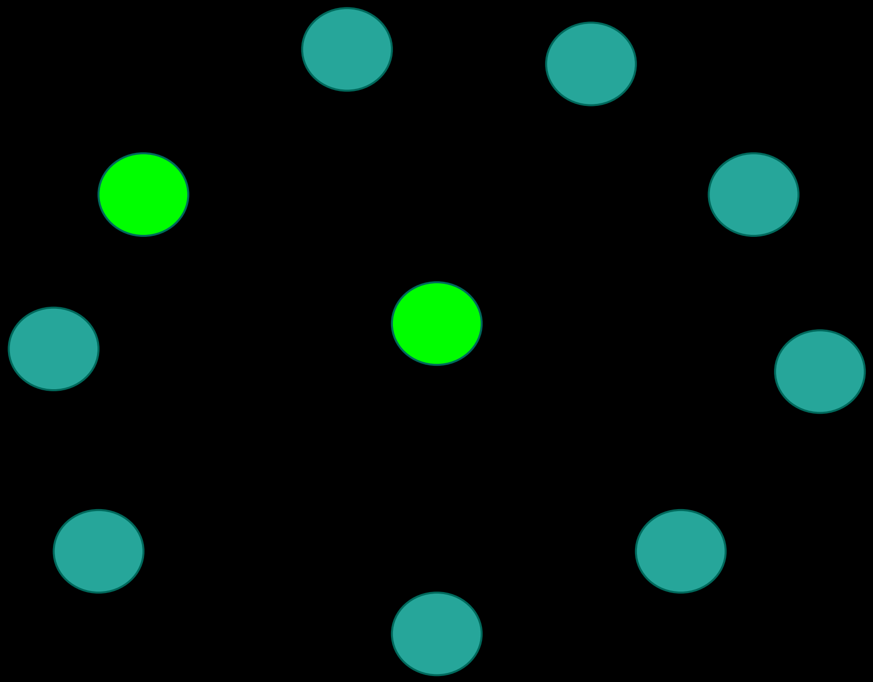
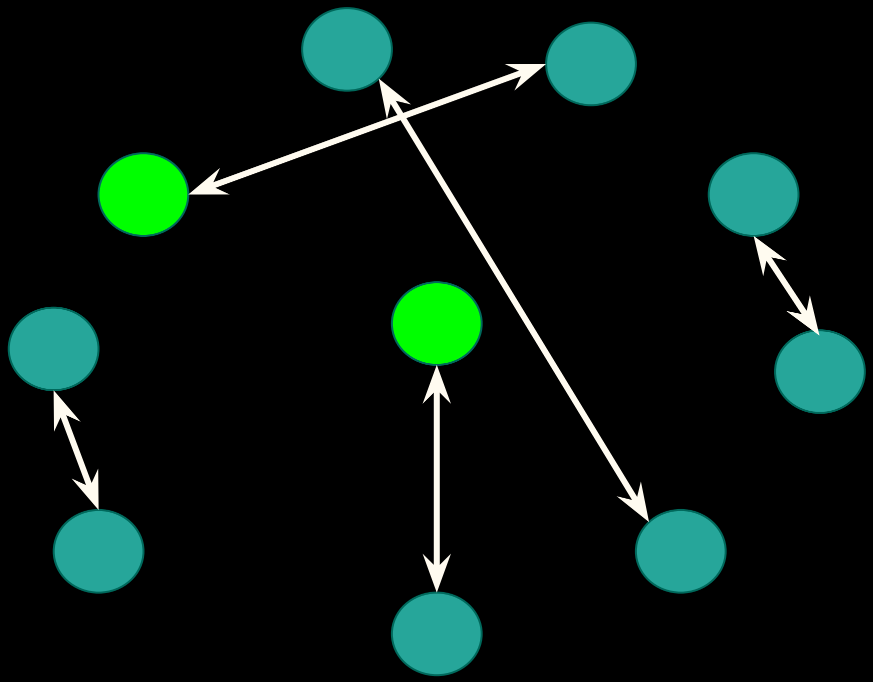
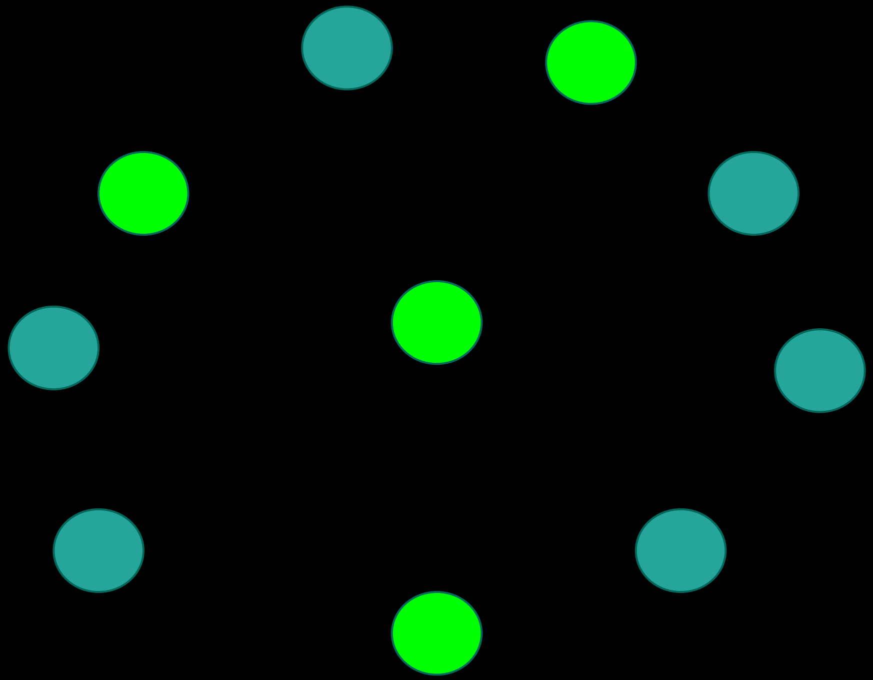
Anti-Entropy



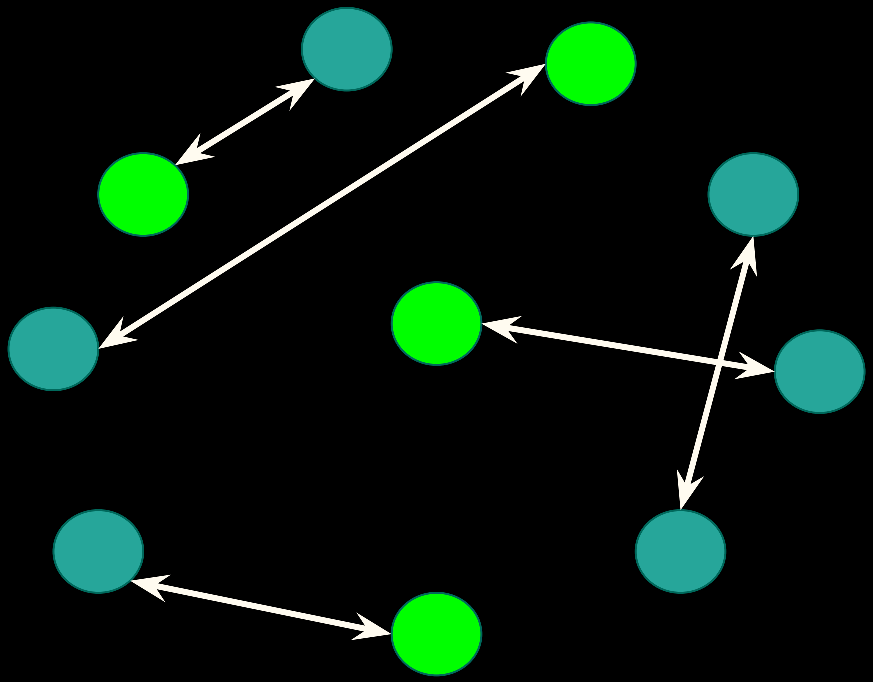
Anti-Entropy



Anti-Entropy



Anti-Entropy



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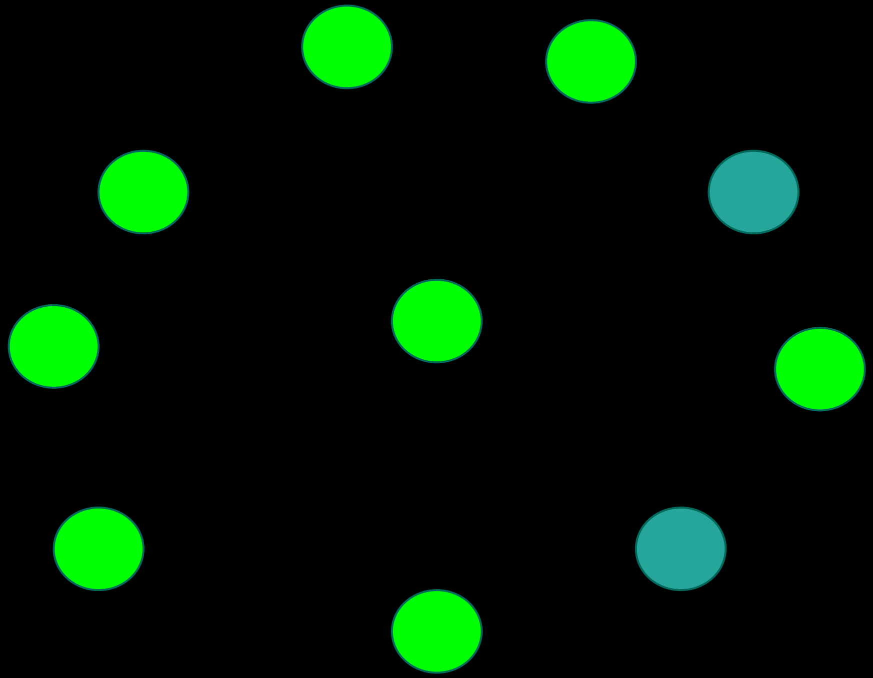

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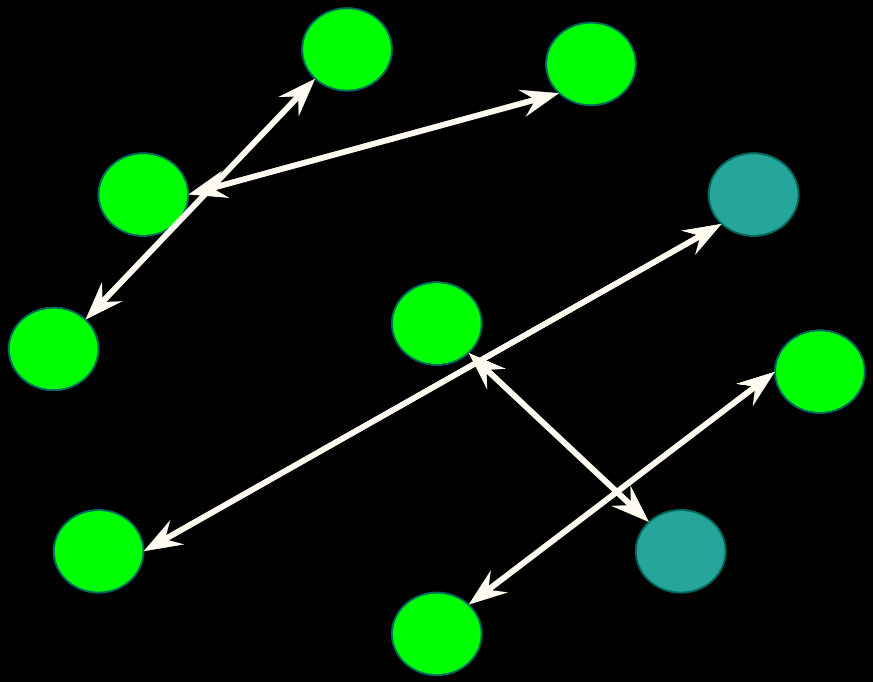
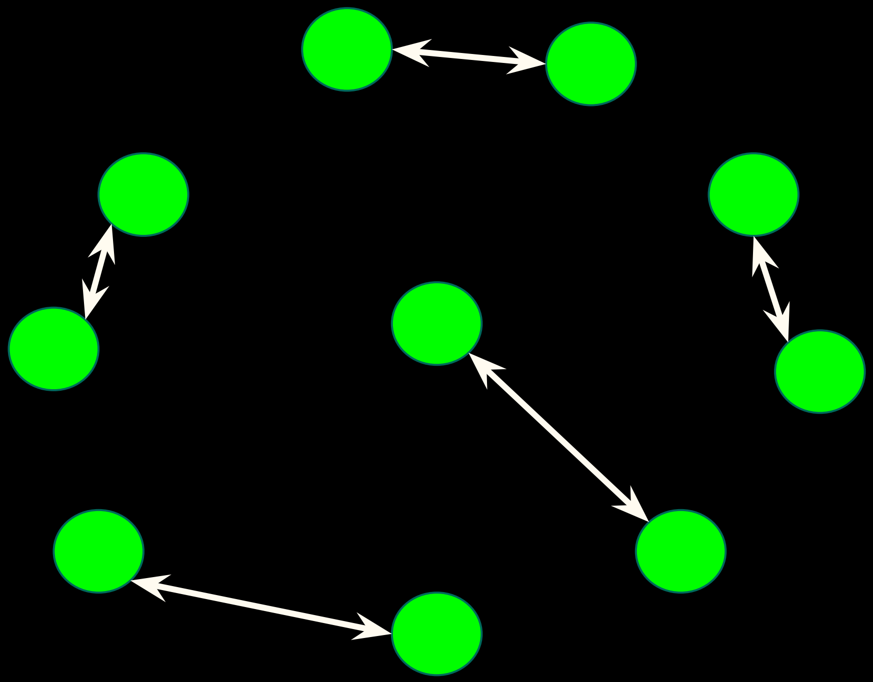


Anti-Entropy



What happens next?

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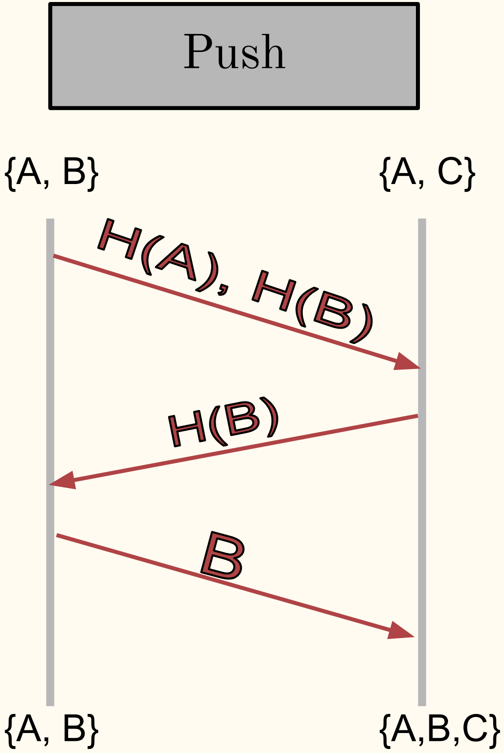
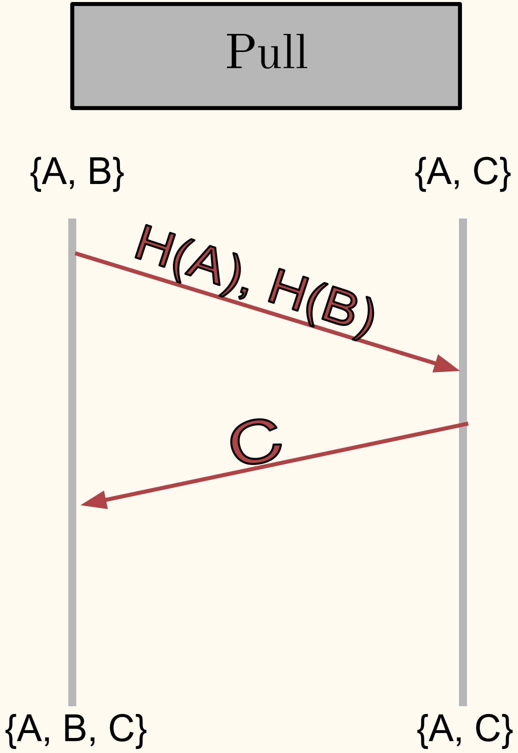
Mechanism: Push & Pull

Push vs. Pull





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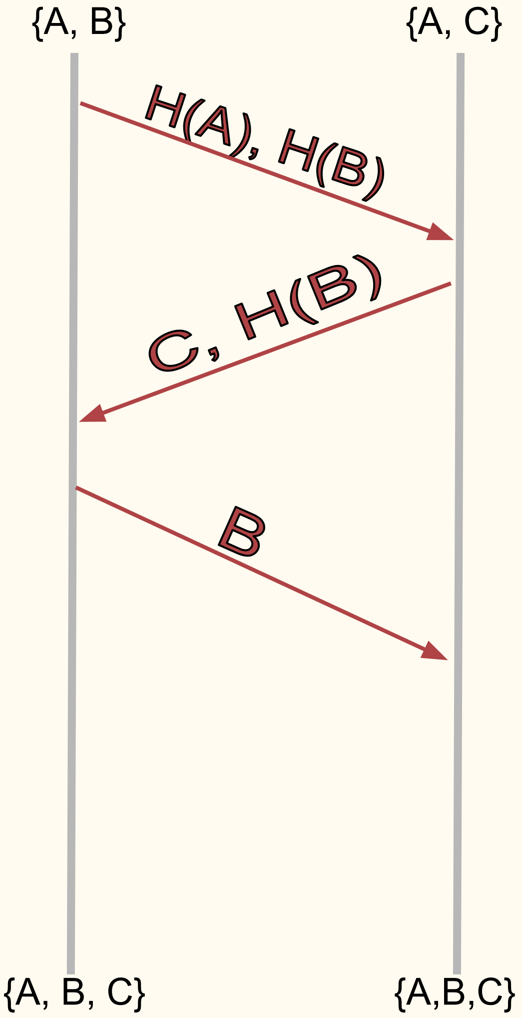
What is Push-Pull?



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Propagation times of Push vs. Pull

Push: $P_{i+1} = P_i e^{-1}$

Pull: $P_{i+1} = P_i^2$

Pull is faster!!

P= Probability node hasn't received update after the i^{th} round

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Rumor Mongering

1. Sites choose a random neighbor to share information with
2. Transmission rate is tuneable
3. **How long new updates are interesting is also tuneable**
4. Can use push or pull mechanisms

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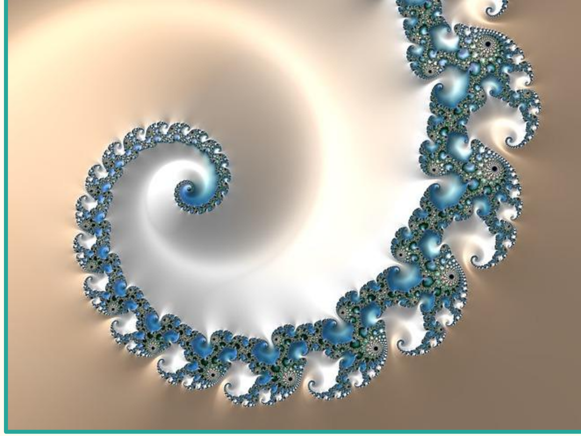
Rumor Mongering Complexity



- O(ln n) rounds leads to consistency *with high probability*
- Push requires O(n ln n) transmissions until consistency
- Further proved lower bound for all push-pull transmissions: O(n ln ln n)

Karp et al 2000. Randomized rumor spreading. In *FOCS*.

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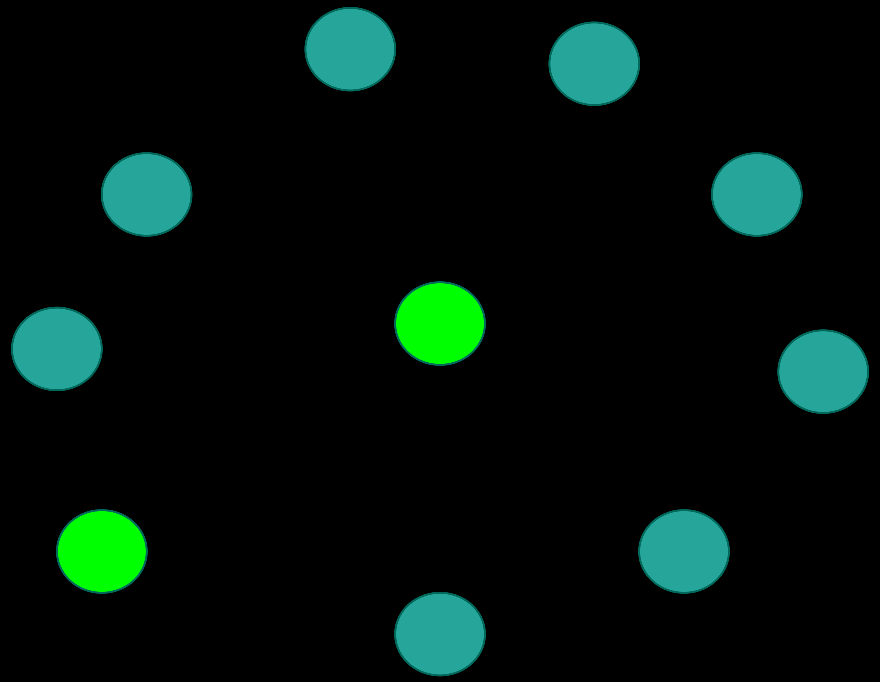
Analogy to epidemiology

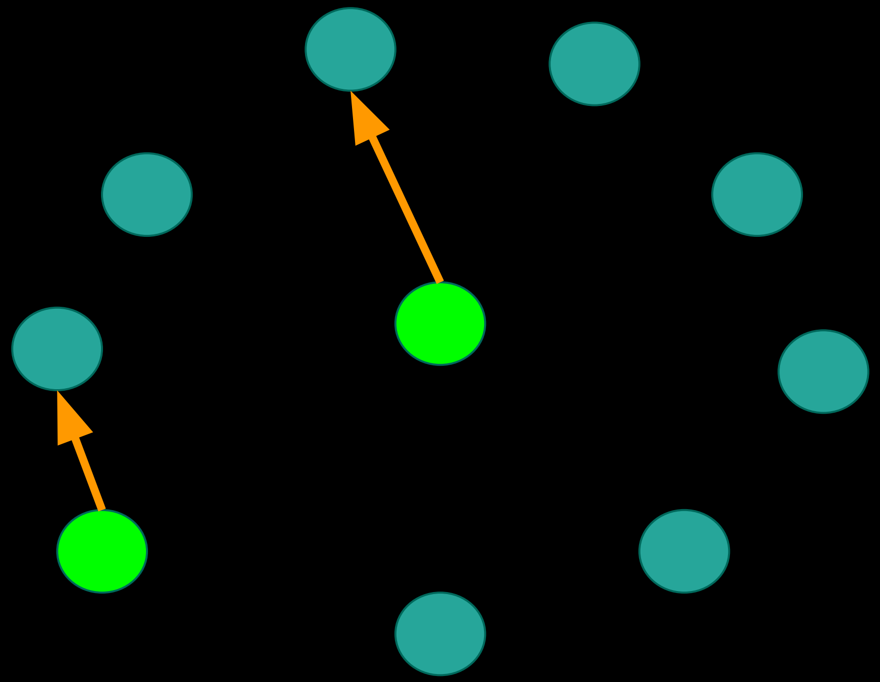
- **Susceptible:** site does not know an update yet
- **Infective:** actively sharing an update
- **Removed:** updated and no longer sharing

Rumor mongering: nodes go from *susceptible* to *infective* and eventually (probabilistically) to *removed*

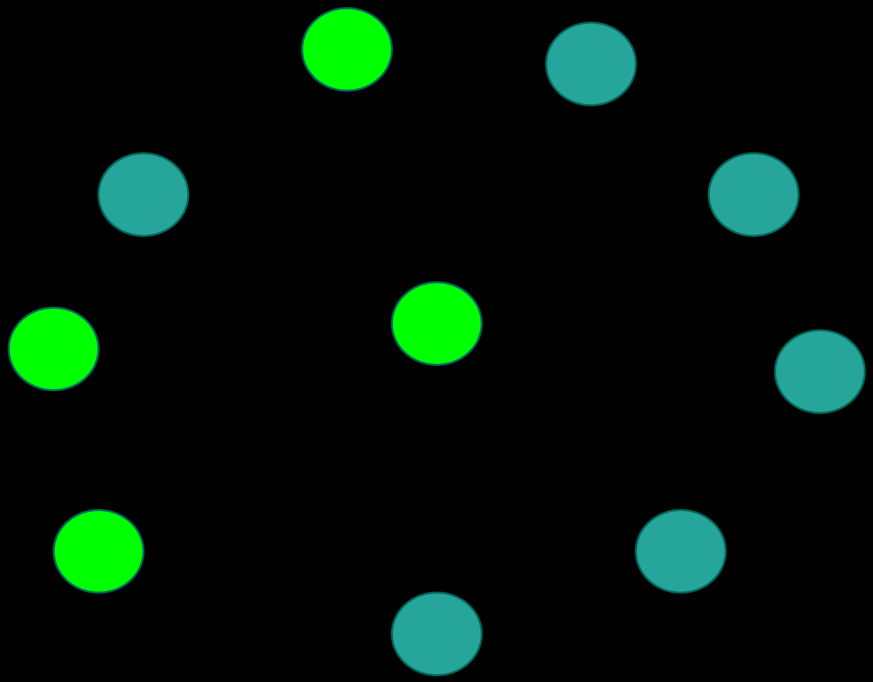
Rumor mongering



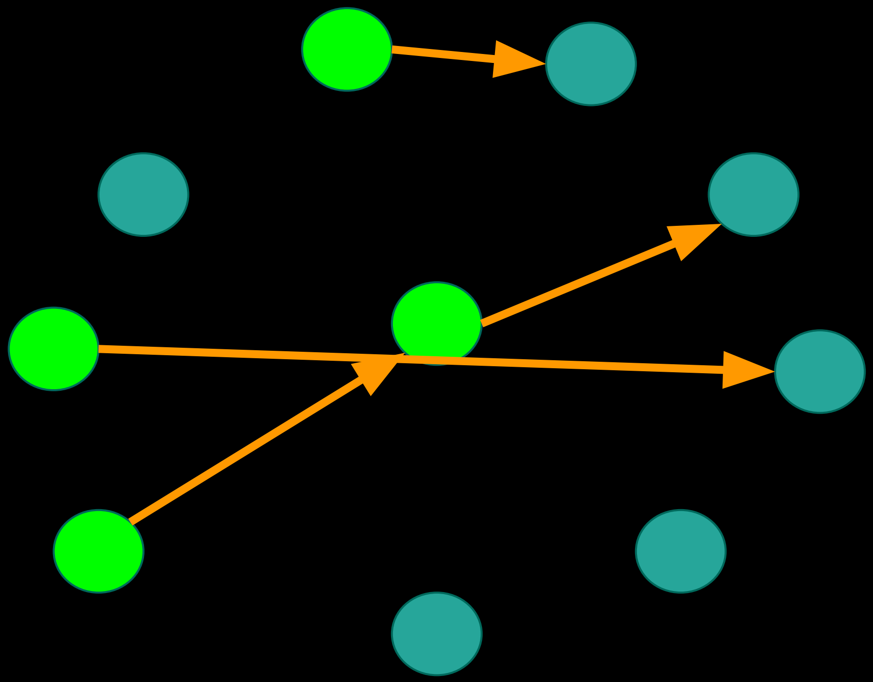
Rumor mongering



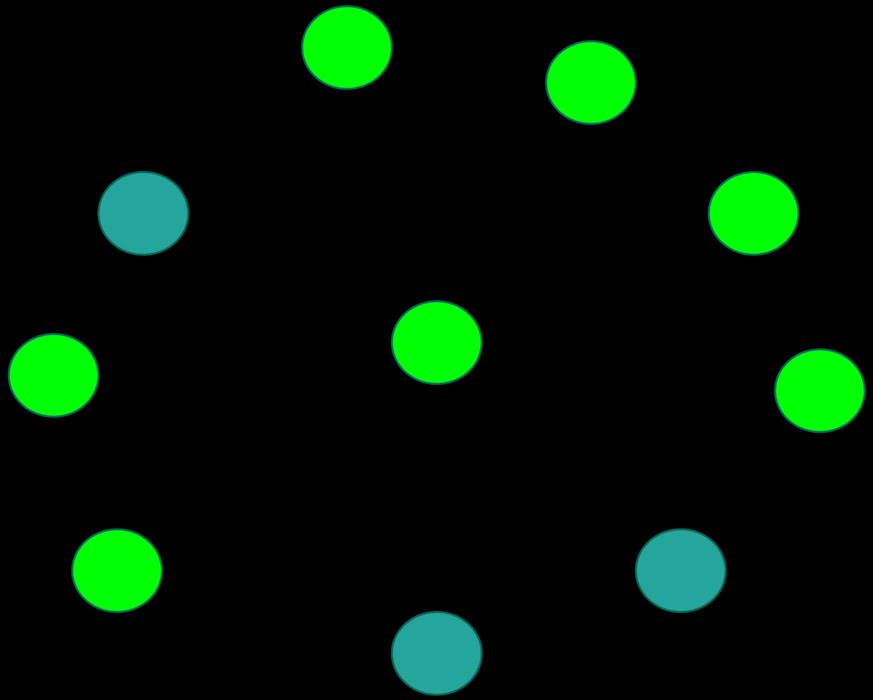
Rumor mongering



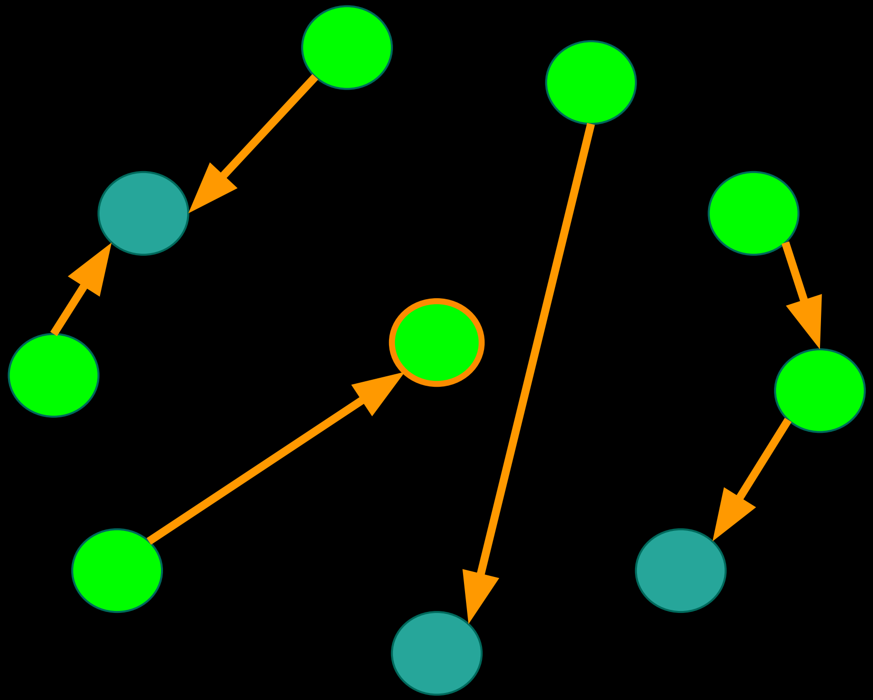
Rumor mongering



Rumor mongering



Rumor mongering



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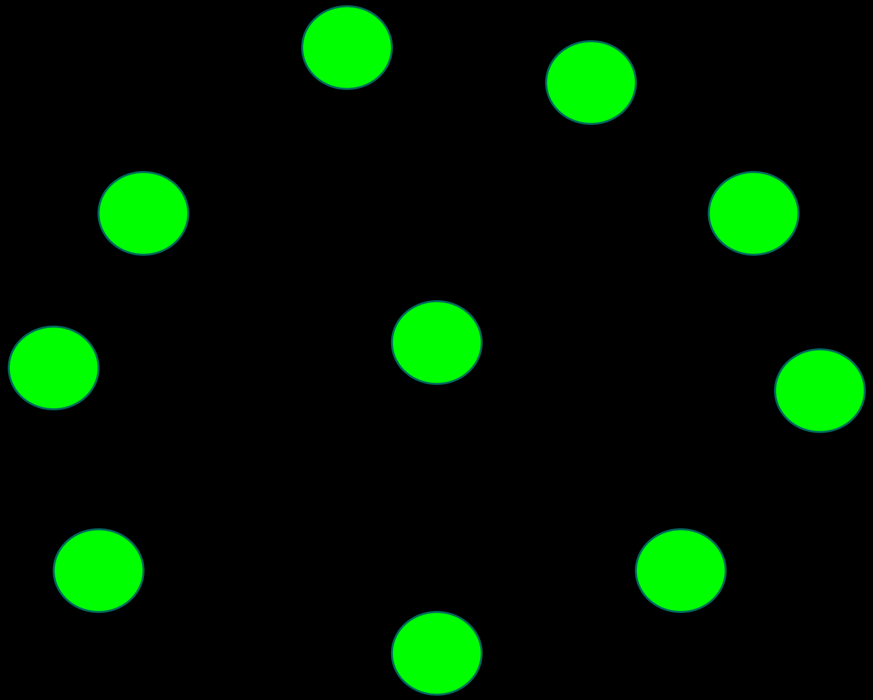

Rumor mongering

Pros:

- Fast
- Low call on resources
- Fault-Tolerant
- Less traffic

Cons:

- A site can potentially miss an update

Backups

- Anti-entropy can be used to “update” the network regularly after direct mail or rumor mongering
- If inconsistency found in anti-entropy, run the original algorithm again

Death Certificates

- How are items deleted using epidemic models?

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System Update

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Death Certificates

- ❖ How to remove items from epidemic model?

- ❖ Drawbacks
  - ➢ Space
  - ➢ Increases traffic
  - ➢ DC Can be lost
- ❖ Dormant death certificates & retention

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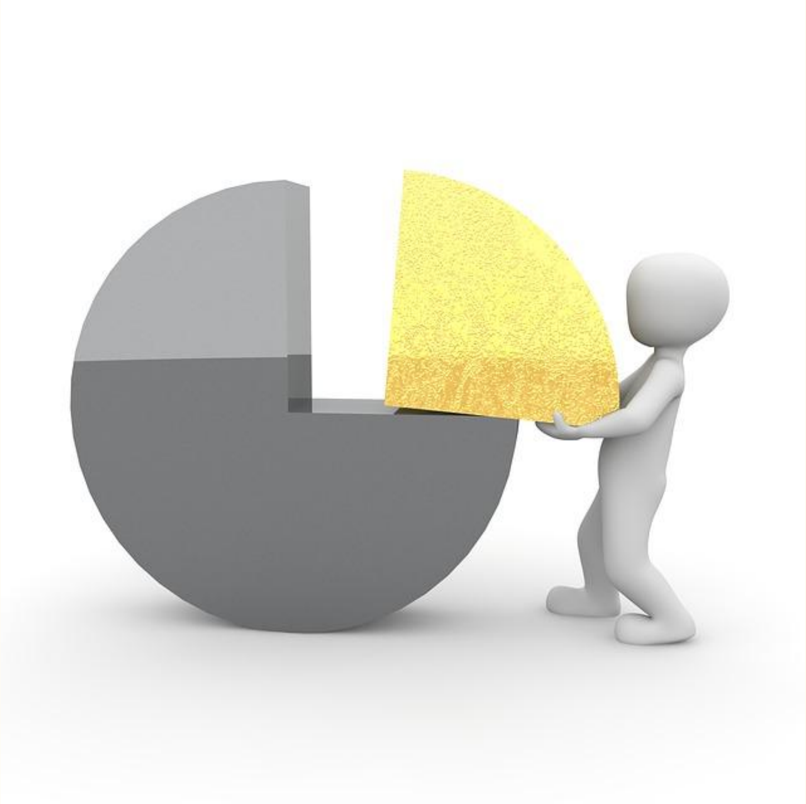
Evaluating Epidemic Models

- **Residue:** remaining susceptibles when epidemic finishes
- **Traffic:** $\frac{update\_traffic}{number\_of\_sites}$

- **Delay:**
  - **T_{avg}**: Average time between start of outbreak and arrival of update @ given site
  - **T_{last}**: Delay until last update



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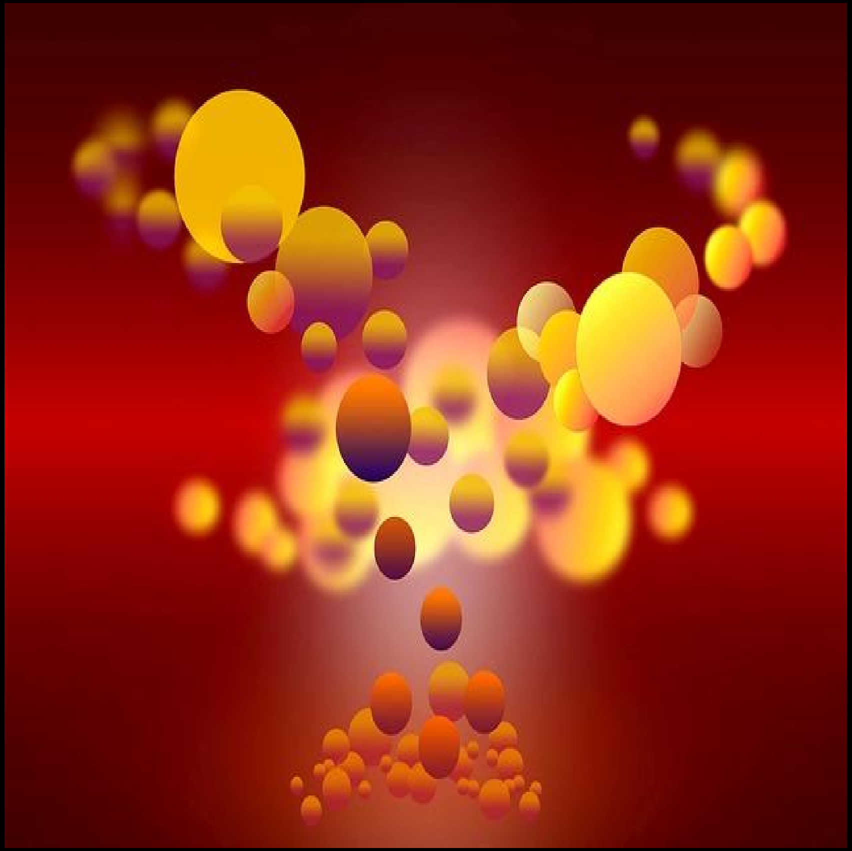
Spatial Distribution

Helping
Or
Hurting



Convergence Times and Traffic

- Linear network: anti entropy
  - **Nearest-neighbors**
    - O(n) convergence
    - O(1) traffic
  - **Random connections**
    - O(log(n)) convergence
    - O(n) traffic

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Optimizations for realistic network distributions

- Select connections from list of neighbors sorted by distance
- Treat network as linear
- Compute probabilities based on position in list

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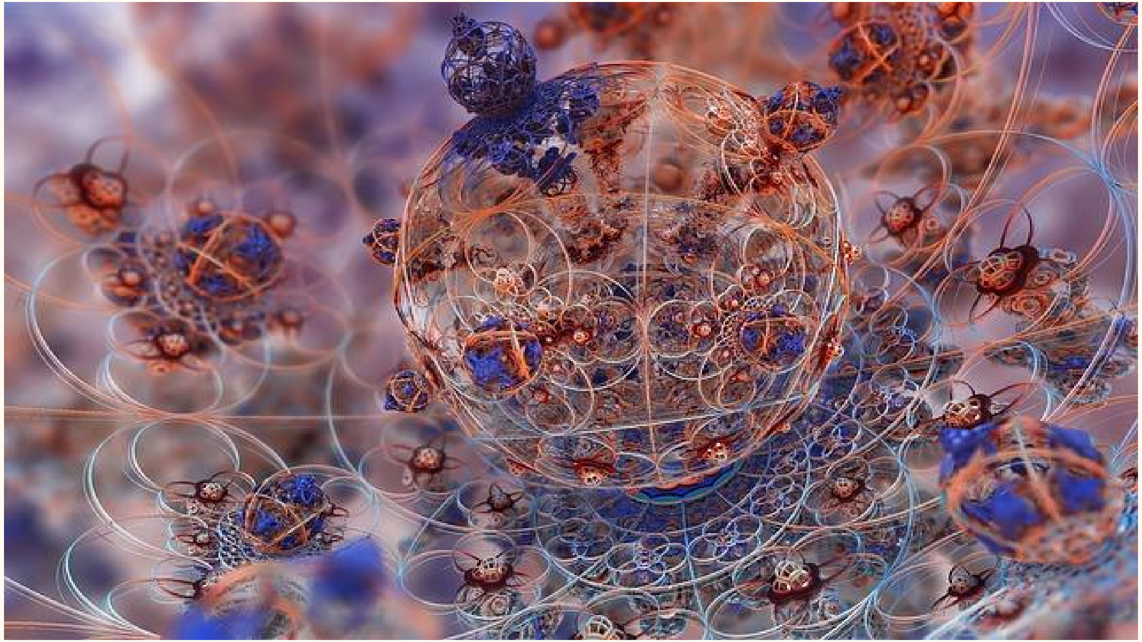
Rumor Mongering Non-Standard Distribution

- Increase k -- number of rounds a rumor is "interesting"
- Use push-pull



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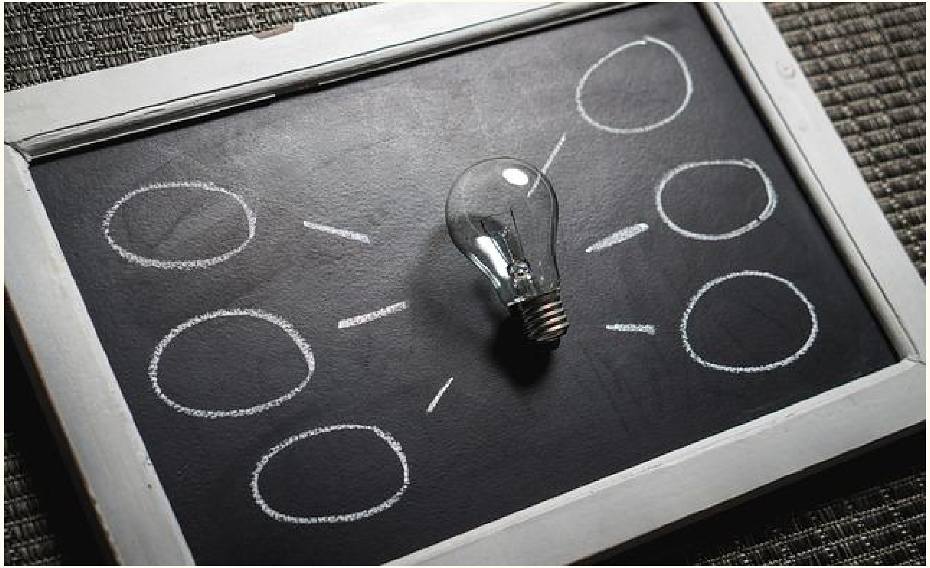
Takeaways

- Availability >> consistency
- Updates can be expensive
- Distribution protocols should be robust
- Network design can hurt overall performance
- Byzantine Behavior not addressed

Questions?



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Additional Reading

Managing update conflicts in Bayou, a weakly connected replicated storage system

1995

- Weak consistency makes unstable network applications possible
- Developing good interfaces allows for complex functions like merging to be interchangeable via the application

Timeline

1978 — **Lamport**

Time, Clocks, and the Ordering of Events in a Distributed System

1982 — **Lamport**

The Byzantine Generals Problem

1985 — **FLP**

Impossibility of Distributed Consensus with One Faulty Process

1987 — **Demers**

Epidemic algorithms for replicated database maintenance

1990 — **Schneider**

Implementing fault-tolerant services using the state machine approach: A tutorial

1995 — **Terry**

Managing update conflicts in Bayou, a weakly connected replicated storage system

1998 — **Lamport**

The part-time parliament

What is Bayou?

- Storage system designed for mobile computing
  - Network is not stable
  - Parts of the network may not be connected all the time
  - **Goal: high availability**
  - Guarantees *weak* consistency

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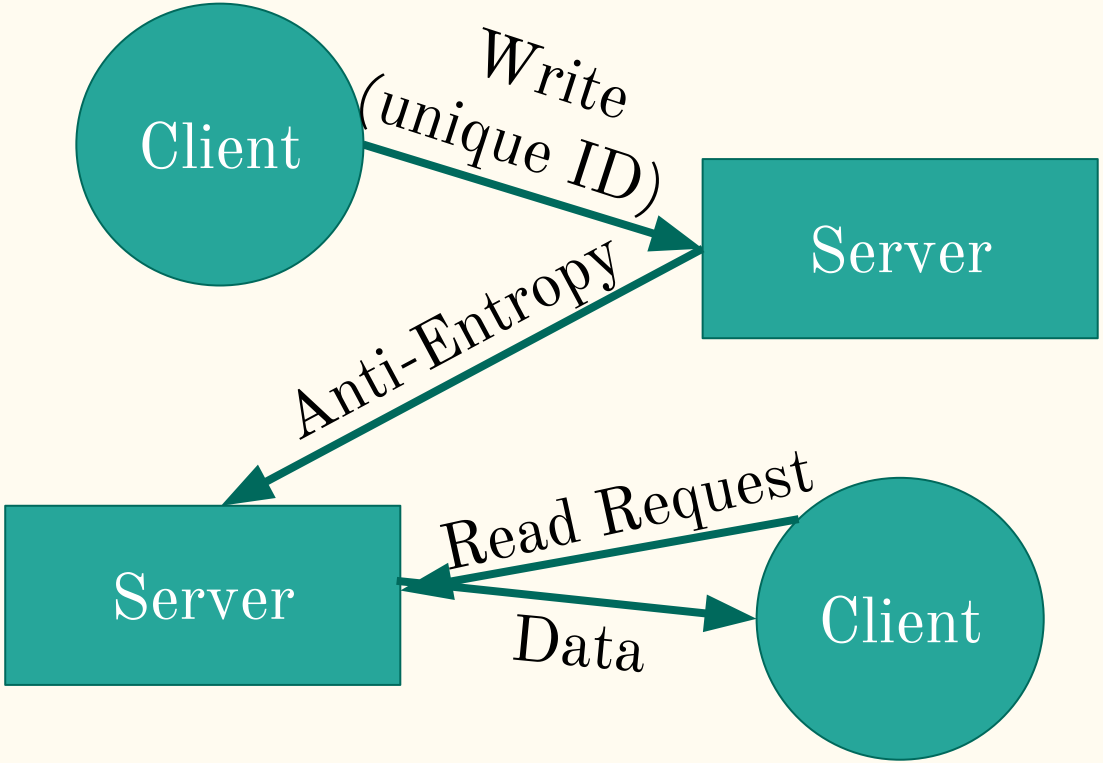

Bayou System Diagram

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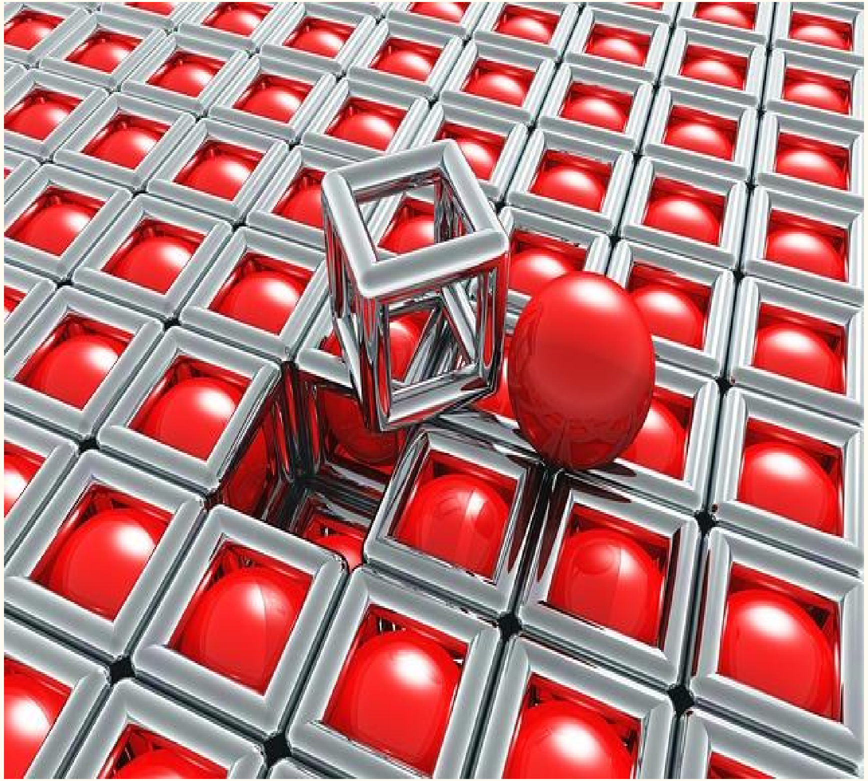
Consistent Replicas

- Writes are first tentative
- Eventually they are committed, ordered by time
- Clients can tell whether writes are stable (committed)
- Primary servers deal with committing updates



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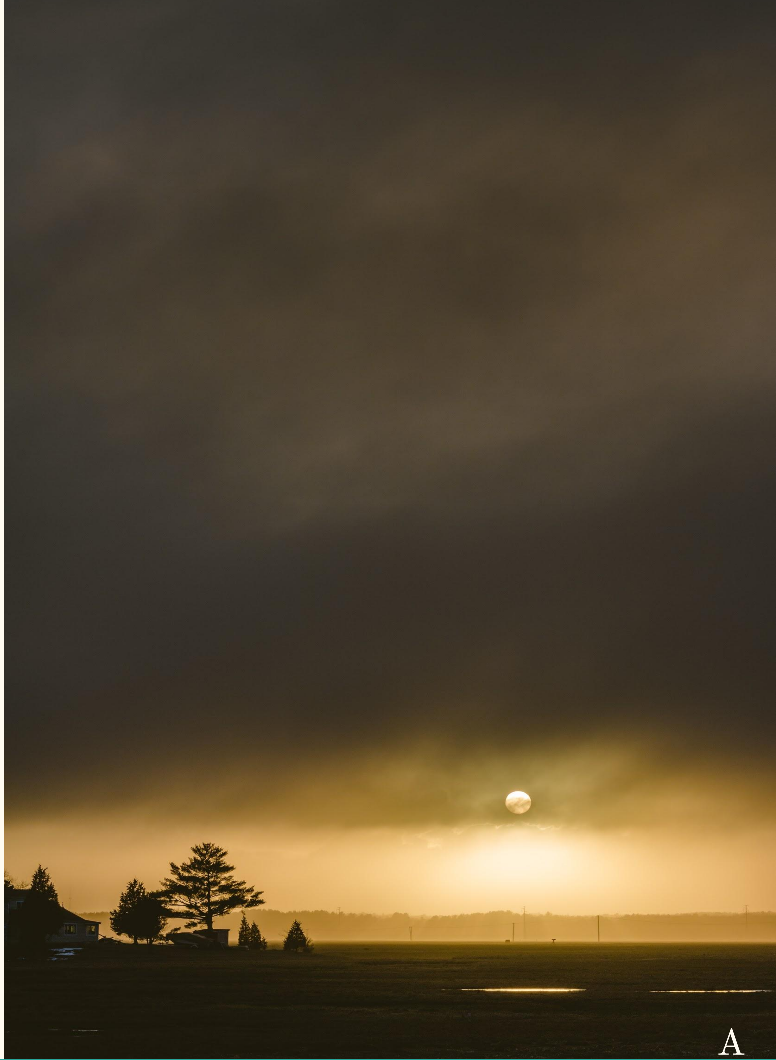
Detecting and Resolving Conflicts

- Dependency checks
- Merge procedures
- Described by the clients, application-dependent

Conclusions

- Distributed systems need a form of consensus
- Effectively choosing the correct consensus model for a system has to be weighed carefully with the attributes of the system



Acknowledgements

Content Inspired by:

Ki Suh Lee: “Epidemic Techniques”[2009]

Eugene Bagdasaryan: “P2P Gossip Protocols” [2016]

Photos

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