Gossip Protocols

CSE 486: Distributed Systems

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Gossip

The multicast protocols we have looked at have common properties:

- Processes must know all other processes
- Message count of $O(|G|)$ for unreliable or $O(|G|^2)$ for reliable transmission
- Messages are either unreliable or always received

Gossip protocols can provide:

- Processes must know a small fraction of other processes
- Typically $O(|G| \log |G|)$ messages per multicast
- Messages are probabilistically received by all correct processes

Origins

Gossip protocols have their origins in epidemiology.

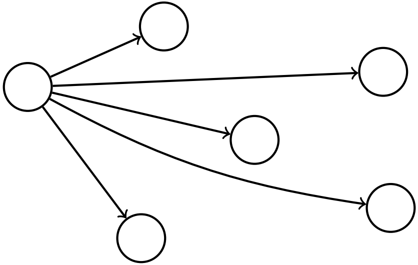
An epidemiology book [1] was noticed by computer scientists [2].

It describes epidemics as proceeding in rounds of infection.

In gossip protocols, as in epidemiology, a process is either:

- Susceptible to infection by a new message
- Infected by a new message and capable of retransmitting it
- Removed from the set of infected processes (and now “immune” to the message)

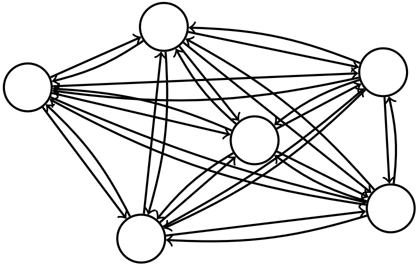
Simple Multicast



$|G|$ processes, $|G|$ messages.

If a message is lost or the sender fails, messages are lost.

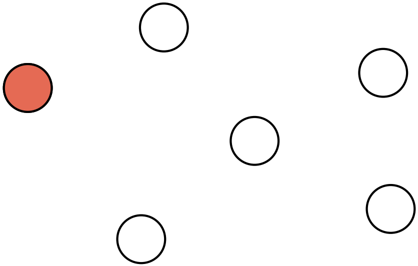
Reliable Multicast



$|G|$ processes, $|G|^2$ messages.

If any correct process receives the message, all correct processes receive the message.

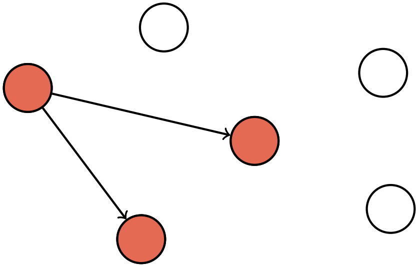
Simple Gossip



Gossip proceeds in rounds.

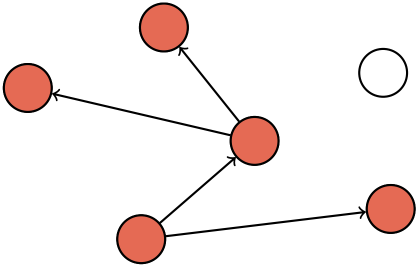
A process decides that it wants to multicast a message *m*.

Simple Gossip



It multicasts it to *k* randomly selected processes.

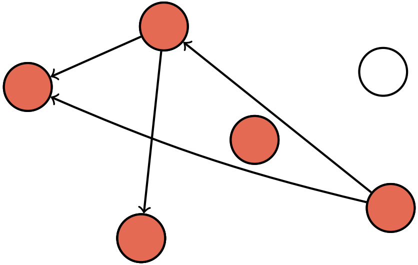
Simple Gossip



If a process hears m for the first time, it re-multicasts.

Each such process chooses k randomly selected processes.

Simple Gossip



This repeats until no new process hears the message.

Some nodes may never hear the message!

The probability of this is exponentially decreasing in k [2].

Benefits of Gossip

Far fewer than $O(|G|^2)$ messages even with $k \gg 1$.
(Bounded above by $k \cdot |G|$.)

Only one process must hear the message to start an epidemic.

Every process receives every message with high probability.

Message loss and process failure are tolerated by raising k.

Disadvantages of Gossip

Some processes may not receive a message even without failure.

Small groups require $k \approx |G|$ anyway.

Delay between first transmission and final infection can be large.

Lightweight Probabilistic Broadcast

Lightweight Probabilistic Broadcast [3] (*lpbcast*) uses gossip for:

- Message distribution
- Group membership

This allows:

- Large groups
- Dynamic membership
- Configurable reliability
- Low message traffic

LPBCast Actions

LPBCast uses publish-subscribe terminology.

In *lpbcast*, processes can:

- Subscribe to a topic (join a group)
- Unsubscribe from a topic (leave a group)
- Send notifications (messages) to a topic (group)

All of these actions are communicated via one message type.

Unlike simple gossip, messages are sent on a heartbeat.

Notifications

A notification in *lpbcast* is a message to be sent.

Every notification has an associated unique ID.

Processes keep track of two notification lists per topic:

- Recently-seen notifications in the variable *events*
- The identifiers of recently-seen notifications in *eventIds*

The rules for keeping track of these are different.

Subscriptions

Processes subscribed to the *lpbcast* topic are group members.

Processes keep track of three subscriber lists per topic:

- Recently subscribed processes in *subs*
- Recently unsubscribed processes in *unSubs*
- Exactly l processes believed to be subscribed in *view*

Messages in *lpbcast*

Each *lpbcast* process sends a message to F processes every T ms.

Every *lpbcast* message contains:

- A list of all new notifications since the last message.
- A list of event IDs for some recent notifications
- A list of some recent subscriptions
- A list of some recent unsubscriptions

The total number of messages sent per T ms is exactly $F \cdot |G|$.

Note that F is like the k from our previous gossip example!

Receiving Messages

Upon receiving a message, a *lpbcast* process will:

1. Update subscriptions:
   - Update *view* and *unSubs* from the recent unsubscriptions
   - Update *view* and *subs* from the recent subscriptions
   - Prune *subs* and *unSubs* until they reach a configurable size
   - Prune *view* until $|view| \leq l$
2. Deliver any new notifications
3. Update event information:
   - Update *events* and *eventIds* with the new notifications
   - Remember event IDs for unknown events from the message
   - Prune *events* and *eventIds* until they reach a configurable size

Probability and Reliability

Items are pruned uniformly at random from each set:
events, *eventIds*, *subs*, *unSubs*, *view*

The set sizes are configured taking into account:

- The expected number of subscribers
- The probability of process failures
- The probability of message loss

Note that:

- notifications are sent only once
- *eventIds* is pruned randomly

Subscriptions

To subscribe to the topic, a process must send a request to any subscribed process.

If it does not start receiving notifications, it tries again.

A subscribed process periodically gossips its subscription.

To unsubscribe from a topic, it gossips its unsubscription.

Failed processes are eventually forgotten.

Partitions

The group may become partitioned.

This is a condition where:

- $\exists G, G', G'' : G' \subset G, G'' \subset G$
- $G' \cap G'' = \varnothing$

Once this happens, G' and G'' will remain disjoint.

l is selected such that the probability of this is extremely low.

Some privileged processes can be kept by all processes to prevent partition.

Benefits of *lpbcast*

LPBCast adds membership management to simple gossip.

It also adds reliability through *events* and *eventIds*.

It uses a relatively constant bandwidth due to T and F.

Each process only has to know l hosts regardless of $|G|$.

Reliability (l, other set sizes), latency (T), and cost (F) are configurable.

Uses of Gossip

The first use of gossip was in distributed database updates.

It was later used for maintaining group membership.

Then, for general multicast as in *lpbcast*.

It can be used for failure detection.

It has been used in sensor networks (“IoT”).

Choosing Gossip

Gossip is appropriate when:

- The occasional lost message can be tolerated
- Simple multicast is not reliable enough
- Reliable multicast is too expensive
- Group membership is unstable

Tuning gossip for the application is critical!

What is $|G|$? What should k (l for *lpbcast*) be?

Gossip for Failure Detection

How might we use gossip for failure detection?

- Is it complete?
- Is it accurate?

What parameters are configurable?

Summary

- Gossip protocols provide probabilistic delivery
- Cost is usually about $c \cdot |G| \log |G|$ per message
- Lightweight Probabilistic Broadcast solves:
  - Changing group membership
  - Process membership knowledge overhead for very large $|G|$

References I

Optional Readings

[1] Norman T. J. Bailey. *The Mathematical Theory of Infections Diseases*. Second. Hafner Press, 1975. ISBN: 9780852642313.

[2] Alan Demers et al. "Epidemic Algorithms for Replicated Database Maintenance". In: *Proceedings of the ACM Symposium on Principles of Distributed Computing*. ACM, Dec. 1987, pp. 1–12. DOI: 10.1145/41840.41841. URL: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.449.8317&rep=rep1&type=pdf.

References II

[3] Patrick T. Eugster et al. "Lightweight Probabilistic Broadcast". In: *Proceedings of the IEEE International Conference on Dependable Systems and Networks*. IEEE, July 2001, pp. 443–452. DOI: 10.1109/dsn.2001.941428. URL: http://se.inf.ethz.ch/people/eugster/papers/lpbcast.pdf.

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