Epidemic and Gossip Broadcast

Algorithmique répartie avancée - ARA
Master2

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Epidemic Broadcast

Diffusion Epidémique

Epidemic Broadcast

- **The broadcast algorithms that we have seen till now are not scalable**
  - They consider a set of processes known by all processes from the beginning.
- **Epidemic algorithms are effective solution for disseminating in large scale and dynamic systems.**
  - They do not provide deterministic broadcast guarantees but just make probabilistic claims about such guarantees.
- **An epidemic broadcast uses a randomized approach where all the participants in the protocol should collaborate in the same manner to disseminate information.**

Epidemic Broadcast

- When a process *p* whishes to send a broadcast message, it selects *k* processes at random and sends the message to them
  - *k* is a typical configuration parameter called *fanout*.
- Upon receiving a message from *p* for the first time, a process *q* repeats the same procedure of *p*'s : *q* selects *k* gossip targets processes and forwards the message to them.
  - If a node receives the message twice, it simply discards the message
    - Each process needs to keep track of which messages it has already seen and delivered. The size of this buffer is also a scalable constraints.
- The step consisting of receiving a message and forwarding it is called a *round*.
  - An epidemic algorithm usually performs a *maximum number of rounds r* for each message.

Epidemic broadcast

- **Epidemic broadcast can only be applied to applications that do not require full reliability.**
  - The cost of full reliability is usually not acceptable in large scale systems.
  - However, it is possible to build scalable randomized epidemic algorithms which provide good reliability guarantees.
  - It exhibit a very stable behavior even in the presence of failures.

Epidemic Broadcast

- **Parameters associated with the configuration of gossip protocols :**
  - ***Fanout (k)***: number of nodes that are selected as gossip targets by a node for each message that is received by the first time.
    - Tradeoff associated between desired reliability level and redundancy level of the protocol.
  - ***Maximum rounds (r):*** maximum number of times a given gossip message is retransmitted by nodes.
    - Each message carries a *round value*, which is increased each time the message is retransmitted.
    - *Modes* :
      - *Unlimited mode:* the parameter maximum round is undefined
      - *Limited mode* : the parameter maximum round is defined with a value greater than 0.
    - Higher value: higher reliability as well as message redundancy.

Epidemic Broadcast

- **Probabilistic Broadcast**
  - **Properties**
    - *Probabilistic validity* : There is a given probability such that for any two correct processes p_i and p_j, every message broadcast by p_i is eventually delivered by p_j with this probability.
    - *No duplication* : No message is delivered more than once by a process
    - *No creation* : If a message *m* is delivered by some process p_j, then *m* was previously broadcast by some process p_i.

Epidemic Broadcast

- **Strategies**
  - ***Eager push approach*** : Nodes send message to selected nodes as soon as they receive them for the first time
  - ***Pull approach*** : Periodically, nodes query random selected nodes for information about recently received messages. When they receive information about a message they did not received yet, they explicitly request the message to their neighbors.
  - ***Lazy push approach*** : When a node receives a message for the first time, it gossips only the message identifier. If a node receives a identifier of a message it has not received, it makes an explicitly pull request.
  - ***Hybrid approach*** : First phase uses a push gossip to disseminate a message in best-effort manner. A second phase of pull gossip is used to recover messages not received in the first phase.

Eager Push Epidemic Broadcast

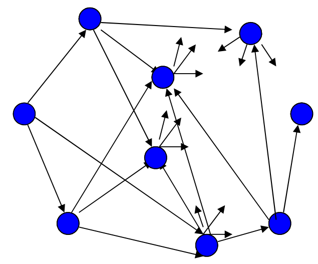
Algorithm

```
Init :
  delivered = ø

Epid_broadcast  (m)
  gossip(self, m, maxrounds);

upon recv (pi, <src,m, r>)
  if (m ∉ delivered)
      delivered = delivered U {m}
      Epid_deliver(src,m)
  if (r > 0)
      gossip(self, m, maxrounds - 1);
```

```
Function chose-targets (ntargets)
  targets = ø
  while ( | targets| < ntargets ) do
      candidate = random (Π)
      if ((candidate ∉ targets) and
        (candidate != self) )
            targets = targets U {candidate};
  return targets

procedure  gossip (src,msg,round)
  for i ϵ chose-targets(fanout) do
        send (i, msg, round);
```


Eager Push Epidemic Broadcast

Execution example



Fanout = 3 ; Maxround = 3

Epidemic Broadcast

- **Ideally, one would like to have each participant to select gossip targets at random from the entire system, as shown in the previous example.**
  - Realistic if it is deployed within a moderate sized cluster.
  - Such approach is not scalable :
    - High memory cost to maintain full membership information.
    - High cost of ensuring the update of such information.
- **Solution:**
  - Gossip-based (epidemic) broadcast protocols rely on *partial view*, instead of full membership information.

Epidemic Broadcast : Partial view

- **Partial view**
  - A process just knows a small subset of the entire system membership, from which it can selects nodes to whom relay gossip messages
  - The membership protocol establishes *neighboring* association among nodes.
    - It must maintain the partial view at each node in face of dynamic changes in the system membership.
      - Joining of new nodes, crashes of nodes, etc.
  - A partial view must be a tradeoff between *scalability* against *reliability*
    - Small views scale better, while large views reduce the probability that processes become isolated or that network partitions occur.
  - ***Overlay***
    - Partial views of all nodes of the system define a graph

Epidemic Broadcast : Partial view

- **Partial View Properties : related to the graph properties of the overlay defined by the partial view of all nodes**
  - *Connectivity* : the overlay should be connected : there should be at least one path from each node to all other nodes.
  - *Degree Distribution* : number of edges of the node.
    - *In-degree* of node *n* : number of nodes that have *n* in their partial view. It provides a measure of *reachability*.
    - *Out-degree* of node *n* : number of nodes in *n*'s view: measure of the importance of that node to maintain the overlay.
  - *Average Path Length* : the average of all shortest paths between all pair of nodes in the overlay.

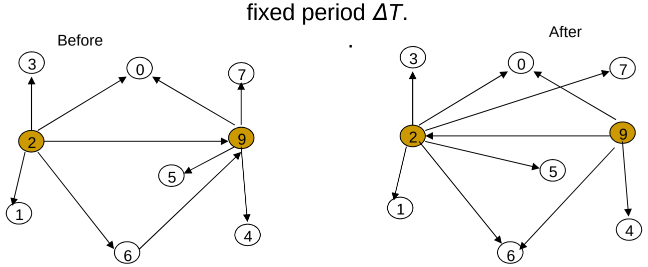
Epidemic Broadcast : Partial view

- **Strategies to maintain partial view**
  - *Reactive strategy* : a partial view only changes in response to some external event such as a joining of a node, a crash of a node, etc.
  - *Cyclic strategy* : A partial view is update every ΔT units of time, as a result of some periodic process that usually involves the exchange of information with one or more neighbors.
  - *Mixing strategy* : the partial view membership is included in the epidemic broadcast protocol
    - Whenever a process forwards a message, it also includes in it a set of processes it knows. Process that receives this message can update its own list of known processes.
    - It does not introduce extra communication to maintain membership.

Epidemic Broadcast : Partial view

CYCLON: Cyclic strategy

exchange of view periodically among neighbors (*shuffling operation*), at a fixed period *ΔT*.



Partial View 2 = {0,1,3,6,9}
Partial View 9 = {0,4,5,7}

Exchange :
2 -> 9 : {2,0,6}
9->2 : {0,5,7}

Partial View 2 = {0,1,3,5,7}
Partial View 9 = {0,2,4,6}

Gossip protocol in ad hoc Networks

- **An ad hoc network is a multi-hop wireless network with no fixed infrastructure**
  - Node broadcasts a message which is received by all nodes within one hop (neighbors)
- **Gossiping protocol Gossip(p)[HHL06]**
  - A source node sends the message *m* with probability 1.
  - Upon reception of *m*
    - first time,
      - it broadcasts *m* with probability *p*
      - it discards *m with* probability *1-p*
    - Otherwise it discards *m*

Gossip protocol in ad hoc Networks

- **If the source has few neighbors, chance that none of them will gossip and the algorithm dies.**
  - Solution : Gossip (p,k)
    - Gossip with probability 1 for the *k* hops before continuing to gossip with probability *p*.
      - Gossip (1,1) is equivalent to flooding.
      - Gossip (p,0) : even the source gossips with probability *p*.

Bibliographie

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