Bio-Inspired Event Dissemination in Dynamic and Decentralized Networks

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ABSTRACT

This work presents a strategy based on *swarm intelligence* for spreading events in dynamic and decentralized networks. An event is defined as a state transition of a node or link. Ants, which correspond to mobile agents, spread event information throughout the network. A node which detects an event in its neighborhood starts disseminating the new information. Pheromones are used to both control the ant population and help to define the paths that the agents take. An empirical study was performed, in which the proposed strategy was compared with *flooding* and *gossip* algorithms. Obtained results show that the proposed strategy presents a good trade-off between the time required to disseminate information and the overhead in terms of the number of messages.

Categories and Subject Descriptors

C [**Computers Systems Organization**]: Miscellaneous; C.4 [**Performance of Systems**]: [fault tolerance]

General Terms

Experiment

Keywords

Event-based, *swarm intelligence*, information spreading

1. INTRODUCTION

In highly dynamic networks, decisions cannot be taken in advance due to the so called churn: nodes may join and leave the system with a high frequency [1]. Furthermore, in these networks there is no single central manager in charge of network monitoring and control. In these cases, network management tasks must be performed in a distributed way, involving all active nodes. In order to take decisions that depend on the network topology, it is important to guarantee that all nodes become quickly aware of topology changes. Thus, event dissemination is a challenge in dynamic networks, such as mobile *ad hoc* and *peer-to-peer* networks. Although deterministic event dissemination strategies can be successfully used to spread events in centralized and nearly static networks, in dynamic networks it is necessary to employ a decentralized and adaptive strategy that is able to succeed even under a highly number of unexpected topology events.

In this work, *swarm intelligence* approach [2] is proposed to solve this problem. Swarm intelligence is the emergent collective intelligence of groups of simple agents, like ant colonies and bee swarms, in which each agent is independent and able to do simple tasks. The interactions between such agents lead to a collective intelligent behavior.

The *EvAnt* algorithm is the basis of the strategy presented in this work. By means of *swarm intelligence*, the algorithm spreads event information in dynamic and decentralized networks. *Swarm Intelligence* algorithm is requested only when new information is detected and is supposed to be spread throughout the network.

Besides describing and specifying the approach, an empirical study was performed in order to evaluate the efficiency and effectiveness. The solution was compared to *flooding* and *gossip* algorithms. Metrics included the event detection latency and the overhead imposed on the network.

EvAnt and *flooding* were able to guarantee that every node would be eventually aware of all events. This happened for all network sizes and topologies. *Flooding* spreads information reliably and always completes only after the whole network is aware of all events. Since the *awareness rate* of both *flooding* and *EvAnt* are the same, we can conclude that *EvAnt* algorithm was also able to guarantee that every node would be eventually aware of all events. On the other hand, *gossip* was not able to give the same guarantee in any simulation execution. Overall we can conclude that results show an advantage of employing the *EvAnt* algorithm, since it is able to spread events effectively and with a lower number of messages.

2. EVANT

The *EvAnt* algorithm uses stigmergy in order to effectively spread information across the network. This "intelligent" approach for information dissemination works as follows: each node has a local pheromone deposit for each link. When an ant goes from node i to a neighbor j, the pheromone concentration $C_{ij}(t)$ related to that link is increased by 1, according to expression 1.

$$C_{ij}(t) = C_{ij}(t) + 1 \quad (1)$$

Pheromones also help ants choose their next destination.

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This choice is probabilistic: a lower pheromone concentration means a higher probability that the associated link is chosen. Given $|e_{it}|$ the neighborhood size of node i, $E_{it}(k)$ the k-th neighbor of i at time t, the probability $P_{ij}(t)$ that an ant migrates from node i to a neighbor j on time t is defined according to expression 2. $\alpha > 0$ is a constant which expresses the pheromone strength: a higher α means higher pheromone weight. Thus our pheromones have the effect of spreading the ants: the higher the pheromone associated with a given link, the higher the probability that the link is not chosen. Our ants thus "flee" from each other, carrying information that is distributed across the network.

$$P_{ij}(t) = \frac{\left(C_{ij}(t) + 1\right)^{-\alpha}}{\sum_{k=1}^{|e_{it}|}\left(C_{iE_{it}(k)}(t) + 1\right)^{-\alpha}} \tag{2}$$

Pheromones evaporate with time. The pheromone concentration at time t is given as function of a previous pheromone value at time $t_0 < t$ and the evaporation rate $0 \leq \rho < 1$. The higher the value of ρ is, the faster the pheromone evaporates. The pheromone evaporation is given by expression 3.

$$C_{ij}(t) = C_{ij}(t_0) \cdot (1 - \rho)^{(t-t_0)} \tag{3}$$

The number of ants in the network has an impact on the performance of the algorithm. A large number of agents means that the same information is being repeatedly received by several nodes. On the other hand, a low number of agents is not able to guarantee that new information is spread across the whole network. In order to solve this problem the ant population size is dynamically adapted. The algorithm also employs pheromones for managing the number of ants in the system. The decisions of creating and destroying agents are taken individually by each node considering only local information.

The total pheromone concentration $C_i(t)$ at node i is defined as the sum of all pheromone values for all links adjacent to i. Let $|e_{it}|$ be the size of the neighborhood of node i, $E_{it}(k)$ the k-th neighbor of i at time t, and $C_{iE_{it}(k)}(t)$ the pheromone concentration of link (i, k) at time t, the total pheromone concentration is shown in expression 4.

$$C_i(t) = \sum_{k=1}^{|e_{it}|} C_{iE_{it}(k)}(t) \tag{4}$$

$C_i(t)$ is compared to minimum $\left(L_{min}(t)\right)$ and maximum $\left(L_{max}(t)\right)$ thresholds, defined by expressions 5 and 6, respectively. δ is a constant, $\delta \geq 0$, that defines the role of the neighborhood size. A higher δ value means that the same number of neighbors results in a higher values for thresholds $L_{min}(t)$ and $L_{max}(t)$ values. The other two constants must be $\gamma_{min} > 0$ and $\gamma_{max} > \gamma_{min}$.

$$L_{min}(t) = \gamma_{min} \cdot |e_{it}|^{\delta} \tag{5}$$

$$L_{max}(t) = \gamma_{max} \cdot |e_{it}|^{\delta} \tag{6}$$

If $C_i(t)$ is higher or equal than $L_{max}(t)$, then a large number of ants have already passed through node i. Node i has spread its local information with a high probability, and all agents located at this node are destroyed. On the other hand, if $C_i(t)$ reaches an equal or lower value than $L_{min}(t)$, then it is possible to conclude that a very low number of ants have passed through node i and, consequently, its information has not been well spread. In order to solve this problem, a new ant is created at node i. This ant initially carries the same information owned by that node.

The proposed strategy consists of two main procedures: the first, presented in algorithm 1 (*EvAnt*: node cycle), is executed by a node i. Algorithm 2 (*EvAnt*: ant cycle) is executed by ant a. Initially, in algorithm 1, all nodes that detected a new event start creating ants, which will spread new information throughout the network. Nodes which receive messages then create ants periodically while condition $C_i(t) \leq L_{min}(t)$ remains true. When the local pheromone concentration $C_i(t)$ is equal or higher than the upper limit $L_{max}(t)$, all ants at node i are destroyed. The ants' cycle, presented in algorithm 2, consists of 5 steps. First, ant a goes from node i to node j, increasing the pheromone value of link (i, j). Then, a updates node j with any new information it might carry. After staying inactive for a period of time, defined as parameter, agent a updates itself with any new information that the node has. Finally, a chooses a new destination and departs. The choice is made according to expression 2.

Algorithm 1 *EvAnt*: node i cycle

```
while true do
  evaporate pheromones → C_ij(t) = C_ij(t_0) · (1 − ρ)^(t−t_0)
  if C_i(t) ≤ L_min(t) and (i has detected an event or i
  has received ant carrying new information ) then
    create a new ant
    schedule cycle for the new ant (Algorithm 2)
  else if C_i(t) ≥ L_max(t) then
    destroy all ants located at node i
  end if
end while
```

Algorithm 2 *EvAnt*: ant a cycle

```
while true do
  ant goes from node i to j → C_ij(t) = C_ij(t) + 1
  ant updates node topology
  ant stays idle in the node for a period of time
  ant updates itself with node info
  ant chooses its next destination → P_ij(t) =
  (C_ij(t)+1)^(−α) / Σ_{k=1}^{|e_it|} (C_iE_it(k)(t)+1)^(−α)
end while
```

3. REFERENCES

[1] A. Ahmed and B. Far. Performance of mobile agent based network topology discovery. In *Electrical and Computer Engineering, 2007. CCECE 2007. Canadian Conference on*, pages 66–69, 2007.

[2] E. Bonabeau, M. Dorigo, and G. Theraulaz. *Swarm intelligence: from natural to artificial systems.* Oxford University Press, USA, 1999.