“On the self-reshaping of a graph based on local rules to achieve new topological properties”

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Abstract

In this study, a given planar graph (with grid or ring topology) is regarded as a distributed system, where nodes are the active entities that process information and links are channels through which nodes exchange information. Next, the graph is embedded in an euclidean space. Then, using a distributed exploration algorithm, each node is able to reconnect or rewire some of its links, to set shortcuts that allow it to reach distant regions of the system. The overall result shows that the underlying graph changes its topological properties (diameter, average path length, average clustering coefficient) up to the point where it reaches a stable condition. Nevertheless, different topologies arise depending on the exploration technique and the selection or appointment criteria that guide each node to choose its new neighbors. This work shows that based on local rules and distributed decisions, it is possible to reshape the overall system to achieve a strong resemblance with different types of complex networks.

Methodology

Consider a 2D-grid or a ring, where each node has two types of links, fixed and dynamic (rewirable).

The experiment is based on cycles, each of which is divided into three phases:

- ✓ **Exploration:** Each node selects 20 random destinations to which it will send an explorer packet. The packet travels with the help of a routing algorithm until it reaches the destination. Once it arrives, it responds with an ACK that contains the path followed by the packet. When the packet returns to the source node, it will be able to know the nodes through which all its explorer packets traveled and the usefulness of its dynamic links.

- ✓ **Negotiation:** Each node negotiates a connection or reconnection of its dynamic links looking for possible shortcuts to regions far from its local environment. In this phase only the negotiation is performed, while in a later phase the connection of these links will be performed.

  Three local rewiring rules are defined for this phase:

  - **R1**: A node selects as candidate the most visited node in the exploration phase.
  - **R2**: A node selects as candidate the first node at distance 2 of which it is aware.
  - **R3**: A node selects another node as a candidate, based on a probability proportional to the frequency of visit of the explorer packets of each of the nodes of which it is aware.

- ✓ **Cabling-Rewiring of dynamic links:** The nodes carry out the connection-reconnection of the dynamic links as agreed in the negotiation phase.

Results

The changes emerging in the networks are:

- The diameter and average path length are significantly reduced to $O(log\ n)$, where n is the grid order.
- The average clustering coefficient increases.
- The degree´s distribution is modified.

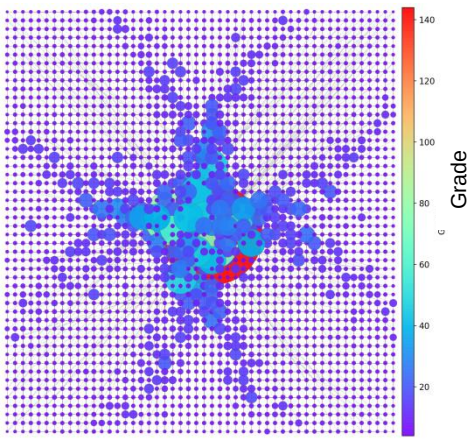

Figure 1: Final structure of the 2500-node grid network with R1

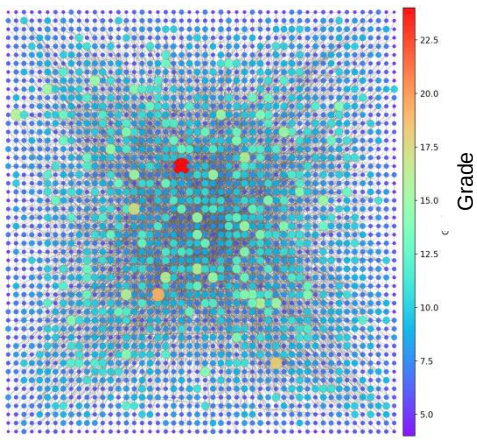

Figure 2: Final structure of the 2500-node grid network with R2

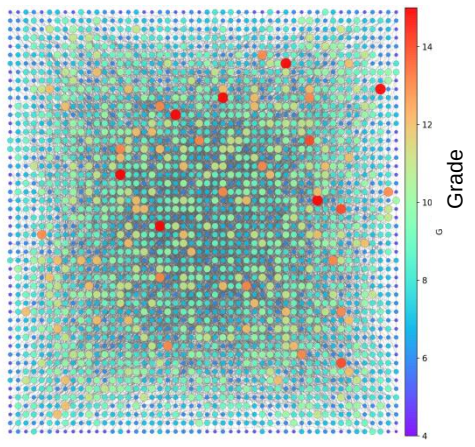

Figure 3: Final structure of the 2500-node grid network with R3

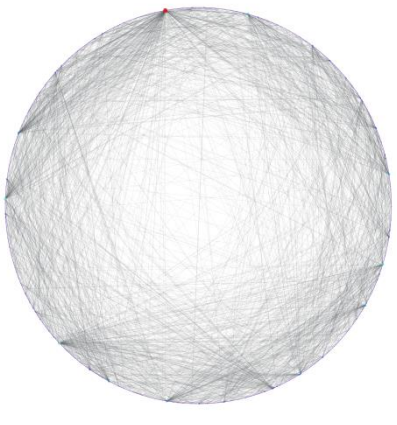

Figure 4: Final structure of the 1500-node ring network with R1

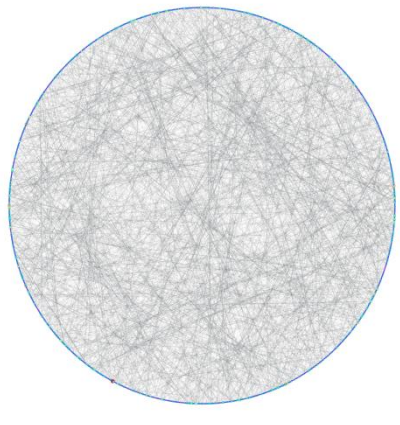

Figure 5: Final structure of the 1500-node ring network with R2

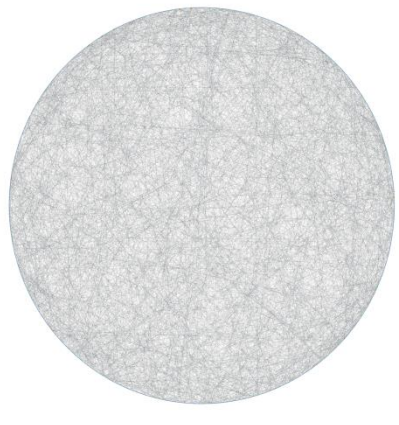

Figure 6: Final structure of the 1500-node ring network with R3