Research Proposal

Title: Network Monitoring Through Topological Data Analysis

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Background and Aim

Communication networks serve as a vital infrastructure in modern societies. The monitoring of these networks is crucial for network administrators as it enables the detection of performance issues and security breaches. Nevertheless, these networks are complex dynamic systems with multiple abstraction layers and continually evolving use cases. This complexity poses challenges in accurately characterizing and studying them. To address these challenges, our approach involves leveraging mathematical models drawn from the field of Topological Data Analysis (TDA). By employing these models, we can effectively represent networks comprising numerous nodes and links, each endowed with specific properties such as traffic rate and latency. Our objective is to create comprehensive models that encapsulate the intricacies of the network's structure and functionality. The resulting models play a pivotal role in characterizing the network's current state, providing valuable insights into its behavior. This deeper understanding facilitates more efficient and effective network monitoring. By employing Topological Data Analysis, we not only enhance the accuracy of our characterizations but also contribute to a more robust and insightful monitoring system for dynamic communication networks.

Method

We consider a network modeled with a directed graph $G = (\mathcal{N}, \mathcal{E})$, where $\mathcal{N}$ and $\mathcal{E}$ are the set of nodes and edges, respectively.

Suppose an interconnection network with n nodes where the dynamically changing functional node data is decoded by a vector as scatter points in $\mathbb{R}^n$. We assign a weighted network to the data of node in each epoch $t_0, \cdots, t_m$ based on the Euclident distances between the corresponding scatter points. Then we build graph filtration to obtain the dynamically changing $0D$ and $1D$ bar-codes. Finally, by experimental results we will show that our methods improve over the prior work on the same standard benchmark datasets, complementing our theoretical results. For instance, when measuring performance using TDA, our algorithm is with high probability over the different datasets.

Mathematical Tools

This data is shown as point collections in Euclidean space as a metric space. Topology and geometry provide a powerful approach to analyzing data samples for prediction even with high probability. Topological and geometric tools are usually associated with continuous concepts while a data sample is a finite space. a natural way to overcome this discrepancy is to highlight some topological structures out of data by using the distance between them. So TDA consider data sample as metric spaces. To compare two sets of data, we need *Hausdroff distance* and *Gromov-Hausdroff distance* and to compare different bar-codes, *Wasserstein distance* is useful. These tools are applied for exploratory topological data analysis. Moreover, in order to extract topological or geometric information from the structures built on top of the data, we need specific methods in algebraic topology such as persistent homology.