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A Visualization and Modeling Tool for Fault-Tolerant Gossip Graphs

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Abstract

The gossip problem (telephone problem) is an information dissemination problem where each of n nodes of a communication network has a unique message that should be transmitted to all the other nodes using two-way communications (telephone calls) between the pairs of nodes. During a call between the two given nodes, they exchange all the information known to them at that moment.

In this paper, a visualization and modeling tool for constructing and analyzing gossip graphs is presented. The tool features an interactive interface and automated algorithms for generating arbitrary graphs and evaluating their gossiping properties. Among the supported features are k-fault-tolerance analysis, simulation of Messy broadcast models, exploration of the NOHO (No One Hears one's Own information) schemes, detection of information flow folded paths, and identification of non-optimal communication patterns (i.e., repeated message arrivals).

Keywords: Gossip problem, Knödel graphs, Fault-tolerant gossip schemes.

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1. Introduction

Gossiping is one of the basic problems of information dissemination in communication networks. The gossip problem (also known as a telephone problem) is attributed to A. Boyd (see ex. [1] for review), although, to the best knowledge of the reviewers, it was first formulated by R. Chesters and S. Silverman (Univ. of Witwatersrand, unpublished, 1970). Consider a set of n persons (nodes), each of which initially knows some unique message that is unknown to the others, and they can make a sequence of telephone calls to spread the information. During a call between the two given nodes, they exchange all the information known to them at that moment. The problem is to find a sequence of calls with minimum length (minimal gossip scheme), by which all the nodes will obtain all messages (complete gossiping). It has been shown in numerous works [1, 2, 3, 4] that the minimal number of calls is $2n - 4$ when

$n \geq 4$ and $1, 3$ for $n = 2, 3$, respectively. Since then, many variations of the gossip problem have been introduced and investigated [5, 6, 7, 8, 9, 10].

The k-fault-tolerant gossip problem is a generalization of the gossip problem, where at most k arbitrary faults of calls are allowed.

Another variant of the Gossip problem can be formulated by considering the minimum amount of time required to complete gossiping among n persons, where the calls between non-overlapping pairs of nodes can take place simultaneously and each call requires one unit of time [11, 12]. For a detailed reviews on the various gossip problems and related open questions, see the works [13, 14, 15, 16, 17, 18, 19, 20]

In our studies, we implemented a Graph Plotter software tool. The main purpose of the tool is to check for a given input graph whether it satisfies the given level of fault-tolerance [21, 22, 23]. The tool also allows one to check whether the input graph is a NOHO (No One Hears one's Own information) [6] or a NODUP (No Duplicates) [19] graph. The NOHO graphs are graphs that do not contain any node that listens to its own information, or equivalently, do not contain a cycle. The NODUP graphs are defined as the graphs the nodes of which listen to each message exactly once. It means that there is exactly one increasing path between two arbitrary vertices.

In addition, the software tool offers a convenient interface for working with graphs. For example, it supports automatic numbering of vertices and edges, visual highlighting of paths between two vertices using customizable vertex and edge coloring, and the ability to add new edges with specified weights. It also allows sorting of all edge weights by converting them into increasing subsequent integers (discrete moments of calls, or tacts).

Moreover, the system enables modification of the positions of vertices adjacent to a selected edge, as well as the permutation of all adjacent edges with greater (or smaller) weights. The rationale behind this functionality is that if a call occurs between two arbitrary vertices at time t, both vertices will subsequently possess identical information. Therefore, any future calls from other nodes to these two vertices can be redirected to either one without affecting the information flow. This feature is particularly useful in scenarios where edges need to be merged into or dispersed from a single communication channel, especially in certain variants of the gossip problem where the number of edges per channel is constrained. Prior to this, exclusively a mathematical approach was used in solving problems of gossiping, and the hardware model of calculations was not used. See also [24, 25, 26] for the applications of local interchange operation to obtain minimum time gossip graphs.

Graph Plotter is an easily extensible tool. Since "Gossip test", "NOHO" and "NODUP" modules are written in C++ language and are separate processes in relation to the main process, the new modules can be integrated with this software tool easily.

The capabilities of the tool and its user interface are outlined below.

2. Graph Plotter GUI Overview

The Graph Plotter GUI is a dedicated visualization and analysis tool designed to interactively model, manipulate, and evaluate properties of fault-tolerant gossip graphs. This interface is especially suitable for research on edge-weighted graphs with custom vertex properties and dynamic structural operations.

The main visualization panel (See Fig. 1) provides an interactive interface to draw gossip graph schemes where vertices are displayed as labeled circular nodes and edges are colored and weighted according to user settings. The colors visually encode selected properties (e.g., active or test path edges). The edge weights represent sequences of integer or real-valued time steps, corresponding to moments of calls between adjacent vertices. In particular, a selected edge labeled with $\{2,\ 5\}$ is highlighted in red, while the other edges are in green. The interface allows one to color the subsets of vertices or edges to emphasize structural properties (e.g., increasing paths from one vertex to another, or a subset of vertices that violate the gossiping property). Vertex labels are positioned for clarity, and the entire graph layout supports symmetric positioning for readability.

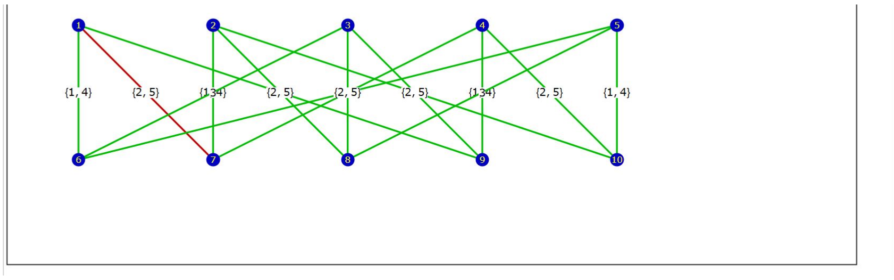

Fig. 1. Graph visualization interface with vertex labels and weighted edges.

Fig. 2 shows the edge parameter editor, where the user can modify edge weights, change colors, and permute vertex or edge orderings. The "permute higher/lower" buttons allow rearranging neighboring edges with weight-based filtering. Users can also collapse an edge or reset and sort edge weights using dedicated controls. The central control block computes key structural properties such as vertex and edge counts and theoretical bounds derived from gossip graph fault-tolerance parameters.

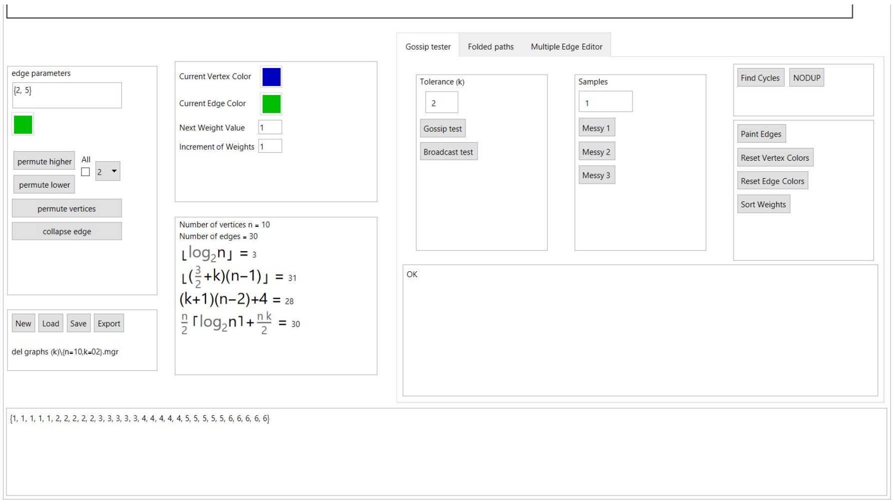

Fig. 2. Edge parameter editor and graph configuration panel.

The Messy broadcasting module in the GUI is dedicated to generating and analyzing Messy broadcast schemes on a given graph structure. The purpose of these tools is to simulate randomized edge colorings that conform to specific Messy models (M_1, M_2, M_3). Each model reflects a different level or type of communication disorder, allowing the user to evaluate robustness under various conditions. By generating a large number of such randomized samples, the tool enables estimation of an upper bound on the minimum achievable Messy broadcasting time for a given number of vertices. The Messy broadcasting module includes preset buttons labeled “Messy 1”, “Messy 2”, and “Messy 3”, corresponding to each of the Messy models. When activated, each button triggers a randomized coloring of the edges according to the constraints of the selected model. The generated configurations can then be evaluated through the gossip or broadcast test buttons to assess their effectiveness and timing. This experimental approach provides insight into the structural and probabilistic limits of information spread under uncertainty.

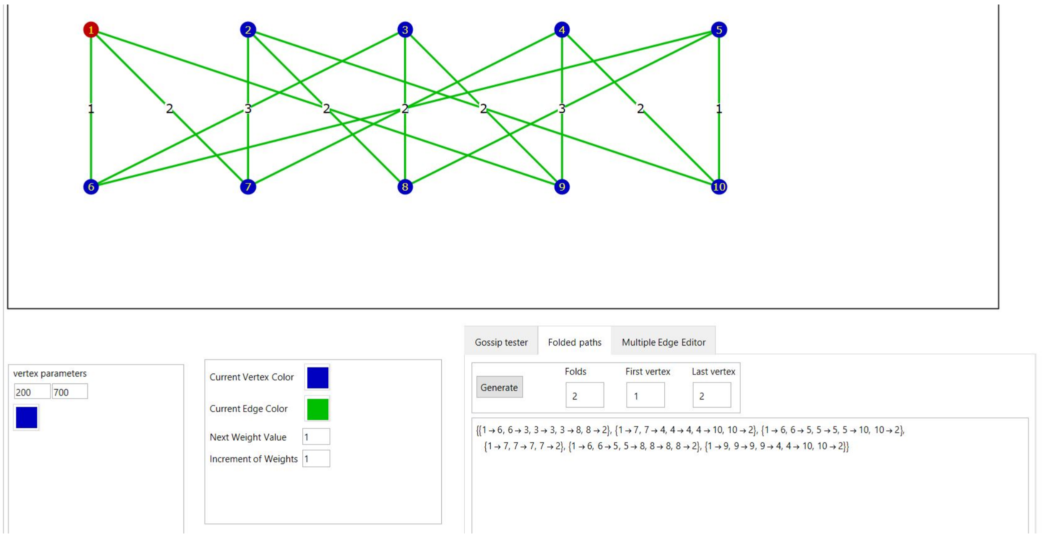

Fig. 3. Folded path generator for evaluating multi-step vertex connections.

The “Folded paths” tab enables the generation of folded paths from a given source to a destination vertex. As shown in Fig. 3, the user can specify the number of folds, and the system produces candidate folded paths following the allowed edge weight constraints. This is particularly useful for analyzing communication protocols with redundancy and delay bounds.

The “Multiple Edge Editor” tab, illustrated in Fig. 4, provides an interface to filter, append, delete, or collapse edges based on their weights. This helps batch process the graph’s edges for weight tuning or visualization simplification. For example, all edges with weight $\{2, 5\}$ can be quickly listed and manipulated collectively.

The GUI supports gossip and broadcast tests under a specified fault-tolerance parameter k, cycle detection, edge painting, and edge color reset. These operations are crucial in evaluating the robustness and communication capabilities of the modeled network, particularly in the context of fault-tolerant information dissemination.

This tool has significantly enhanced our ability to explore and verify the properties of fault-tolerant gossip graphs. By combining interactive visualization with built-in simulation and testing modules, it enabled us to intuitively model communication processes, validate theoretical assumptions, and conduct practical experiments. The ability to dynamically adjust edge weights, visualize folded paths, and perform automated gossip and broadcast tests made it possible to investigate complex scenarios with precision and efficiency. As a result, the tool proved to be an indispensable aid in both theoretical analysis and applied research.

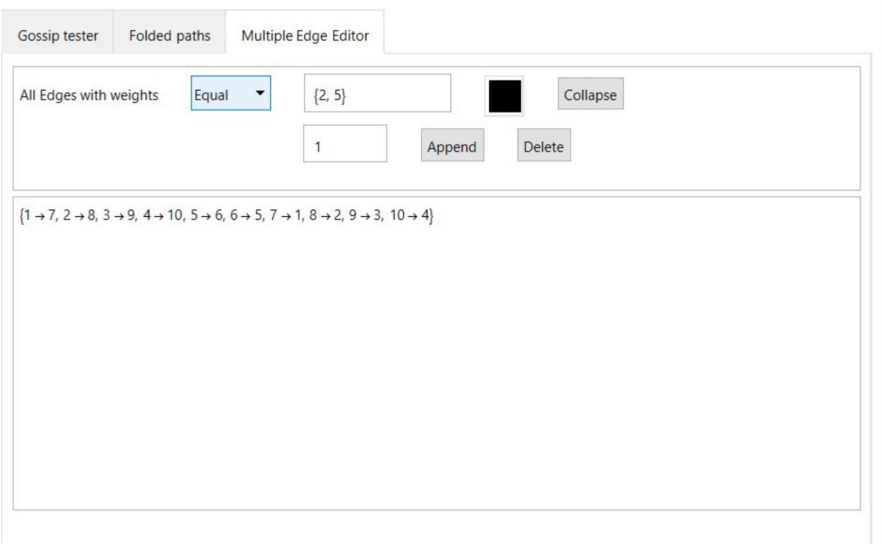

Fig. 4. Multiple edge editor for collective edge operations based on weights.

Overall, the Graph Plotter GUI is a flexible and powerful tool for researchers analyzing gossip graph structures and their resilience properties.

3. Conclusion

The visualization and modeling tool presented here offers an effective and user-friendly environment for studying fault-tolerant gossip schemes. Through its interactive interface and automated analysis capabilities, it enables detailed exploration of how information propagates under various assumptions and constraints. The tool thus provides researchers with a versatile instrument for both theoretical investigation and practical evaluation of gossip protocols.

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Անխափան գոսսիպ գրաֆերի մոդելավորման և վիզուալիզացիայի գործիք

Վահագն Ս. Պողոսյան

ՀՀ ԳԱԱ Ինֆորմատիկայի և ավտոմատացման պրոբլեմների ինստիտուտ, Երևան, Հայաստան
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Ամփոփում

Գոսսիպ խնդիրը (հեռախոսային խնդիրը) ինֆորմացիայի տարածման դասական խնդիր է, որտեղ հաղորդակցային ցանցի n հանգույցներից յուրաքանչյուրն ունի եզակի հաղորդագրություն, որը պետք է փոխանցվի բոլոր մյուս հանգույցներին՝ օգտագործելով հանգույցներով կազմված զույգերի միջև իրականացվող երկկողմ կապեր (հեռախոսազանգեր): Զանգի ընթացքում տվյալ երկու հանգույցները փոխանակում են իրենց տվյալ պահին ունեցած ամբողջ ինֆորմացիան:

Այս աշխատությունում ներկայացվում է գոսսիպ գրաֆերի կառուցման և վերլուծության համար նախատեսված վիզուալիզացիայի և մոդելավորման գործիք: ործիքը տրամադրում է ինտերակտիվ միջավայր, ինչպես նաև ավտոմատացված ալգորիթմներ՝ կամայական գրաֆեր գեներացնելու և դրանց գոսսիպի հատկությունները գնահատելու համար:

Ֆունկցիոնալ հնարավորությունների թվում են k-վթարակայունության (fault-tolerance) վերլուծությունը, Messy լայնարձակ հաղորդումների մոդելավորումը, NOHO (No One Hears One’s Own information) սխեմաների ուսումնասիրությունը, ինֆորմացիոն հոսքերի կոտրատված ուղիների (folded paths) հայտնաբերումը, ինչպես նաև ոչ օպտիմալ հաղորդակցման օրինակների (օր. կրկնվող հաղորդագրությունների) բացահայտումը:

Բանալի բառեր՝ գոսսիպի խնդիր, Knodel գրաֆեր, անխափան գոսսիպի սխեմաներ:

Инструмент визуализации и моделирования отказоустойчивых gossip графов

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Аннотация

Задача gossip (телефонная задача) представляет собой классическую задачу распространения информации, в которой каждый из n узлов коммуникационной сети изначально обладает уникальным сообщением, которое должно быть передано всем остальным узлам посредством двусторонних соединений (телефонных звонков). Во время каждого звонка два участвующих узла обмениваются всей имеющейся у них на данный момент информацией.

В данной работе представлен инструмент для визуализации и моделирования gossip графов, предназначенный для их построения и анализа. Инструмент включает интерактивный интерфейс и автоматизированные алгоритмы для

генерации произвольных графов и оценки их свойств в контексте распространения информации. Поддерживаемые возможности включают анализ.

k-отказоустойчивости, моделирование Messy-broadcast моделей, изучение NOHO схем (No One Hears One's Own information), обнаружение изломанных путей информационного потока, а также выявление неоптимальных коммуникационных паттернов, таких как повторные поступления сообщений.

Ключевые слова: задача gossip, графы Кнёделя, отказоустойчивые gossip-схемы.