様　式　Ｆ－１９－２

科学研究費助成事業　　研究成果報告書

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研究課題名（和文）Bridging the gap between theory and practice for distributed graph algorithms

研究課題名（英文）Bridging the gap between theory and practice for distributed graph algorithms

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交付決定額（研究期間全体）：（直接経費）　　8,100,000円
渡航期間：　　８ヶ月

研究成果の概要（和文）：本研究中、私たちは分散グラフアルゴリズムの分野から理論的ツールを使用して、ネットワーキングで使用されるプリミティブの速度を上げることに成功した。理論的ツールを使用して、故障からの迅速な回復時間を持つネットワーキングアルゴリズムを作成する方法を示した。本結果は、マルチキャストや時計同期といった問題に適用される。

また、アルゴリズムが使用するメモリを制限する新しい理論モデルを分散グラフアルゴリズムに導入しました。これは、理論アルゴリズムを実践へと滑らかに移行させるために重要であり、メモリはデータセンターにおける主要なボトルネックである。

研究成果の学術的意義や社会的意義
Data centers are a critical infrastructure in today's society. They are used by all major companies such as Google, Amazon, etc...
Speeding up the algorithms used in these data centers can lead to a huge financial and societal impact (e.g., faster cloud computing).

研究成果の概要（英文）：During the duration of this research project we managed to used theoretical tools from the field of distributed graph algorithms to speed up primitives used in networking. Specifically, we show how to use theoretical tools such as graph spanners to create networking algorithms with a fast recovery time from failures. Our results apply to fundamental problems such as multicast and clock synchronization.

We also introduced a new theoretical model for distributed graph algorithms that limits the amount of space used by the algorithms. This is critical to allow for a smoothed transition of theory algorithms to practice, as space is a major bottleneck in data centers. We currently have 2 papers in submission.

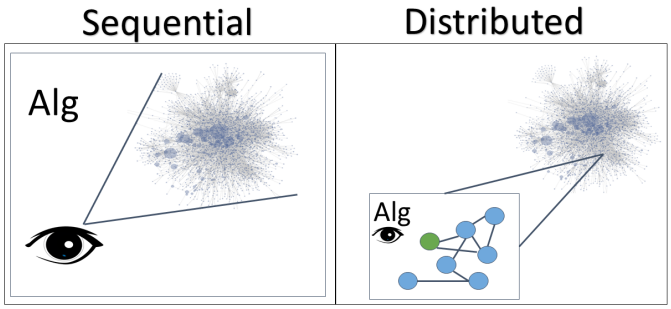
研究分野：distributed computing

キーワード：distributed computing　networking　graph algorithms

１．研究開始当初の背景

Before this project, there was no application of tools from the field of distributed graph algorithms in P4 switches. The potential for leveraging these advanced algorithms to enhance network performance was largely unexplored, leaving a gap between theoretical advancements and practical implementations in data center networks.

The Barefoot Tofino P4 switch



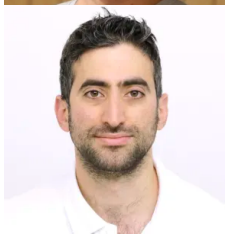
２．研究の目的

Our goal was to bridge the gap between theory and practice by using tools from distributed graph algorithms to speed up networking algorithms running on real-world data centers. We aimed to demonstrate the practical utility of these theoretical tools and introduce better models that accurately reflect real-world systems. This initiative sought to enhance the efficiency and reliability of networking protocols by applying cutting-edge theoretical insights.

３．研究の方法

This project was a collaboration between experts in networking and theoretical computer science. The main collaborators were Ran Ben Basat from University College London and Ami Paz from CNRS/ University Paris Saclay. Over about eight months, I worked closely with them in both France and the UK.

Ami is a leading expert in distributed graph algorithms, with a specific focus on smoothed analysis. He is a long time collaborator, and together we have co-authored many papers on dynamic graphs algorithms and smoothed analysis. His achievements include the best student paper award at PODC, and best paper and best student paper awards at SODA. Not only is Ami a world-class theoretical researcher, he also publishes in networking venues such as INFOCOM.



Ran is a leading expert in networking algorithms, currently working on P4 switches. Before coming to UCL he held a postdoc position at Harvard working with Minlan Yu and Michael Mitzenmacher. He has published more than 50 academic papers, and regularly publishes in leading networking conferences such as SIGCOMM and INFOCOM.

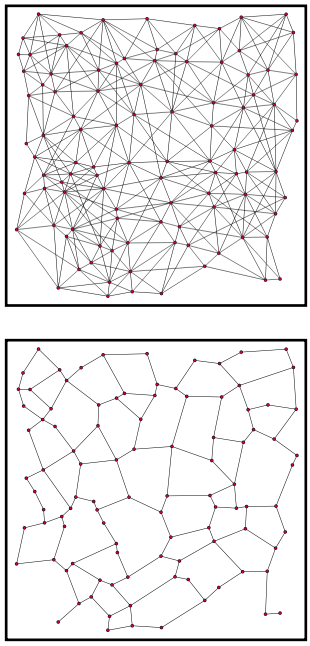
Our joint research involved identifying which algorithms from the extensive literature on distributed graph algorithms were most promising for practical application. We conducted a series of experiments to test these algorithms, verifying that they could indeed surpass the current state-of-the-art solutions. Based on our findings, we also developed a new theoretical model tailored to the specific needs of networking environments.

４．研究成果

During the course of this research project, we successfully used theoretical tools from the field of

distributed graph algorithms to accelerate key networking primitives. Specifically, we demonstrated how to use concepts such as graph spanners to develop networking algorithms with fast recovery times from failures. Our results have significant implications for fundamental problems such as multicast and clock synchronization.

Furthermore, we introduced a new theoretical model for distributed graph algorithms that constrains the amount of space used by these algorithms. This development is crucial for facilitating a smooth transition from theoretical algorithms to practical applications, as space limitations are a major concern in data centers. We have two papers currently under submission that detail our findings and contributions.



Top: original graph
Bottom: 2-spanner

５．主な発表論文等

〔雑誌論文〕　計0件

〔学会発表〕　計2件（うち招待講演　0件／うち国際学会　2件）

１．発表者名 Gregory Schwartzman
２．発表標題 Mini-batch k-means terminates within O(d/ε) iterations
３．学会等名 ICLR 2023（国際学会）
４．発表年 2023年

１．発表者名 Taisuke izumi
２．発表標題 Fully Polynomial-Time Distributed Computation in Low-Treewidth Graphs
３．学会等名 SPAA 2022（国際学会）
４．発表年 2022年

〔図書〕　計0件

〔産業財産権〕

〔その他〕

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６．研究組織

	氏名 （ローマ字氏名） （研究者番号）	所属研究機関・部局・職 （機関番号）	備考
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6．研究組織（つづき）

	氏名 （ローマ字氏名） （研究者番号）	所属研究機関・部局・職 （機関番号）	備考
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7．科研費を使用して開催した国際研究集会

〔国際研究集会〕　計0件

8．本研究に関連して実施した国際共同研究の実施状況

共同研究相手国	相手方研究機関			
フランス	University Paris Saclay			
英国	University college london			