Fast top-k frequent itemset mining under Local Differential Privacy*

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***Abstract*—This is the abstract.**

***Index Terms*—This is the keywords**

I. Introduction

Differential privacy(DP) [7] was named one of the world's top 10 breakthrough technologies in 2020 by the MIT technology review. DP is a means in cryptography that aims to provide a way to maximize the accuracy of data queries when querying from statistical databases while minimizing the chances of identifying their records. As a mathematical technique, it can add noise to the data while quantifying the extent of the increase in privacy, thus making the process of adding "noise" more rigorous.

Due to its unique advantages, DP has been widely studied by the academia and industry. For example, Google, Microsoft, apple and other companies use this technology to protect users' privacy, and at the same time, mobile phones aggregate data, so as to improve service quality. And the U.S. government is to complete a census of 330 million U.S. residents by 2020, keeping their identities secret, in what would be the largest census ever.

There are two types of differential privacy - Centralized differential privacy(CDP) and Local differential privacy(LDP). Compared with CDP, the LDP does not require the assumptions of a trusted third party and provides stronger privacy guarantees. DP's research has involved many aspects, in recent years, the work in data mining(DM) has attracted the attention. A lot of work [3]–[6] has been done to solve DM problems in CDP. However, since the analyst holds the user's raw data in CDP setting, its main job is to add noise to the results to satisfy the DP definition.

The LDP, by contrast, has no reliance on third party assumptions. The main challenge with a DM task is that the data analyst does not hold the user's original sensitive information, so it is quite difficult to mine useful information with noise data.Qin et al. [1] proposed LDPMiner protocol for heavy hitter estimation over set-valued data and left data mining as an open problem. Wang et al. [2] solved the $top-k$ frequent itemset mining(FIM) task for the first time with **padding-and-sampling-based frequency oracle**(PSFO). In [2], the Set-Value Item Mining(SVIM) protocol had been proposed to handles set values under the LDP setting, with the purpose of finding the k most frequent items and their frequencies. To mine frequent itemsets , a core technique is "Guessing Frequency(GF)". That is, the analyst first calculated the frequency of a given itemset X for all candidate itemsets by (1),

$$\varphi(X) = \prod_{x \in X} \mu(x), \mu(x) = \frac{0.9 \times \tilde{\theta}(x)}{\max\limits_{x \in S'} \tilde{\theta}(x)} \tag{1}$$

where $\varphi(X)$ represents the speculative frequency of itemset X, S' and $\tilde{\theta}(x)$ are denoted separately the $top-k$ frequent items set and the frequency of a given item x. Then $2k$ itemsets with highest guessing frequencies are selected to construct candidate set IS. Finally, reference [2] utilized SVIM protocol again with the domain IS to mine $top-k$ itemsets.

In [2], the SVSM protocol first selected $2k$ itemsets with highest guessing frequencies to construct candidate set IS, then utilized SVIM protocol again with the domain IS to mine $top-k$ itemsets.We observe that, the size of candidate set to construct IS increase significantly with k. As a result, it is computationally expensive when k is large(e.g., $k = 100$).

Inspiringly, we propose minefp protocol, which aims at finding $top-k$ itemsets under the LDP setting and provides similar accuracy while providing lower overhead than existing protocol(SVSM) within the same privacy constraints. First, the SVIM protocol is used to estimate the k most frequent items and their frequencies. Second, users report the number of frequent items they have; the analyst estimates the distribution user reported and figure out the right M as the maximum iteration of the tree. Third, users interact with the analyst to build effectively the FP-tree [**?**]. Fourth, the analyst optimizes and mines the FP-tree(post-processing). Fifth, the analyst publishes $top-k$ itemsets.Experimental results how that minefp outperforms SVSM in that it identifies quickly frequent itemsets as well as estimates the frequencies more accurately.

Identify applicable funding agency here. If none, delete this.

Roadmap.

II. Background

A. Local Differential Privacy(LDP)

B. FP-growth

III. Ease of Use

A. Maintaining the Integrity of the Specifications

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Before you begin to format your paper, first write and save the content as a separate text file. Complete all content and organizational editing before formatting. Please note sections IV-A–IV-E below for more information on proofreading, spelling and grammar.

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A. Abbreviations and Acronyms

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, ac, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

B. Units

- Use either SI (MKS) or CGS as primary units. (SI units are encouraged.) English units may be used as secondary units (in parentheses). An exception would be the use of English units as identifiers in trade, such as "3.5-inch disk drive".
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C. Equations

Number equations consecutively. To make your equations more compact, you may use the solidus (/), the exp function, or appropriate exponents. Italicize Roman symbols for quantities and variables, but not Greek symbols. Use a long dash rather than a hyphen for a minus sign. Punctuate equations with commas or periods when they are part of a sentence, as in:

$$a + b = \gamma \tag{2}$$

Be sure that the symbols in your equation have been defined before or immediately following the equation. Use "(2)", not "Eq. (2)" or "equation (2)", except at the beginning of a sentence: "Equation (2) is . . ."

D. LaTeX-Specific Advice

Please use "soft" (e.g., `\eqref{Eq}`) cross references instead of "hard" references (e.g., `(1)`). That will make it possible to combine sections, add equations, or change the order of figures or citations without having to go through the file line by line.

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E. Some Common Mistakes

- The word "data" is plural, not singular.
- The subscript for the permeability of vacuum μ_0, and other common scientific constants, is zero with subscript formatting, not a lowercase letter "o".
- In American English, commas, semicolons, periods, question and exclamation marks are located within quotation marks only when a complete thought or name is cited,

such as a title or full quotation. When quotation marks are used, instead of a bold or italic typeface, to highlight a word or phrase, punctuation should appear outside of the quotation marks. A parenthetical phrase or statement at the end of a sentence is punctuated outside of the closing parenthesis (like this). (A parenthetical sentence is punctuated within the parentheses.)
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- Do not confuse "imply" and "infer".
- The prefix "non" is not a word; it should be joined to the word it modifies, usually without a hyphen.
- There is no period after the "et" in the Latin abbreviation "et al.".
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An excellent style manual for science writers is [14].

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The class file is designed for, but not limited to, six authors. A minimum of one author is required for all conference articles. Author names should be listed starting from left to right and then moving down to the next line. This is the author sequence that will be used in future citations and by indexing services. Names should not be listed in columns nor group by affiliation. Please keep your affiliations as succinct as possible (for example, do not differentiate among departments of the same organization).

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Headings, or heads, are organizational devices that guide the reader through your paper. There are two types: component heads and text heads.

Component heads identify the different components of your paper and are not topically subordinate to each other. Examples include Acknowledgments and References and, for these, the correct style to use is "Heading 5". Use "figure caption" for your Figure captions, and "table head" for your table title. Run-in heads, such as "Abstract", will require you to apply a style (in this case, italic) in addition to the style provided by the drop down menu to differentiate the head from the text.

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a) Positioning Figures and Tables: Place figures and tables at the top and bottom of columns. Avoid placing them in the middle of columns. Large figures and tables may span across both columns. Figure captions should be below the figures; table heads should appear above the tables. Insert figures and tables after they are cited in the text. Use the abbreviation "Fig. 1", even at the beginning of a sentence.

TABLE I
TABLE TYPE STYLES

Table Head	**Table Column Head**		
	Table column subhead	***Subhead***	***Subhead***
copy	More table copy[a]		

[a]Sample of a Table footnote.

Fig. 1. Example of a figure caption.

Figure Labels: Use 8 point Times New Roman for Figure labels. Use words rather than symbols or abbreviations when writing Figure axis labels to avoid confusing the reader. As an example, write the quantity "Magnetization", or "Magnetization, M", not just "M". If including units in the label, present them within parentheses. Do not label axes only with units. In the example, write "Magnetization (A/m)" or "Magnetization $\{A[m(1)]\}$", not just "A/m". Do not label axes with a ratio of quantities and units. For example, write "Temperature (K)", not "Temperature/K".

ACKNOWLEDGMENT

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REFERENCES

Please number citations consecutively within brackets [8]. The sentence punctuation follows the bracket [9]. Refer simply to the reference number, as in [10]—do not use "Ref. [10]" or "reference [10]" except at the beginning of a sentence: "Reference [10] was the first ..."

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For papers published in translation journals, please give the English citation first, followed by the original foreign-language citation [13].

References

[1] Qin, Zhan, et al. "Heavy Hitter Estimation over Set-Valued Data with Local Differential Privacy." computer and communications security (2016): 192-203.

[2] Wang, Tianhao, Ninghui Li, and Somesh Jha. "Locally Differentially Private Frequent Itemset Mining." ieee symposium on security and privacy (2018): 127-143.

[3] Bhaskar, Raghav, et al. "Discovering frequent patterns in sensitive data." knowledge discovery and data mining (2010): 503-512.

[4] Li, Ninghui, et al. "PrivBasis: frequent itemset mining with differential privacy." very large data bases (2012): 1340-1351.

[5] Lee, Jaewoo, and Chris Clifton. "Top-k frequent itemsets via differentially private FP-trees." knowledge discovery and data mining (2014): 931-940.

[6] Zeng, Chen, Jeffrey F. Naughton, and Jinyi Cai. "On differentially private frequent itemset mining." very large data bases (2012): 25-36.

[7] C. Dwork. Differential privacy. In ICALP, pages 1–12, 2006.

[8] G. Eason, B. Noble, and I. N. Sneddon, "On certain integrals of Lipschitz-Hankel type involving products of Bessel functions," Phil. Trans. Roy. Soc. London, vol. A247, pp. 529–551, April 1955.

[9] J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.

[10] I. S. Jacobs and C. P. Bean, "Fine particles, thin films and exchange anisotropy," in Magnetism, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271–350.

[11] K. Elissa, "Title of paper if known," unpublished.

[12] R. Nicole, "Title of paper with only first word capitalized," J. Name Stand. Abbrev., in press.

[13] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, "Electron spectroscopy studies on magneto-optical media and plastic substrate interface," IEEE Transl. J. Magn. Japan, vol. 2, pp. 740–741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].

[14] M. Young, The Technical Writer's Handbook. Mill Valley, CA: University Science, 1989.

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