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Machine Learning-Enhanced Probabilistic Validation Techniques with Minimal Data Exposure in Distributed Systems

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Abstract: *This article studies the distributed state estimation issue for complex networks with nonlinear uncertainty. The extended state approach is used to deal with the nonlinear uncertainty. The distributed state predictor is designed based on the extended state system model, and the distributed state estimator is designed by using the measurement of the corresponding node. The prediction error and the estimation error are derived. The prediction error covariance (PEC) is obtained in terms of the recursive Riccati equation, and the upper bound of the PEC is minimized by designing an optimal estimator gain. With the vectorization approach, a sufficient condition concerning stability of the upper bound is developed. Finally, a numerical example is presented to illustrate the effectiveness of the designed extended state estimator.*

Keywords: Complex networks (CNs), distributed extended state estimator, nonlinear uncertainty

I. INTRODUCTION

COMPLEX networks (CNs) provide a practical way to model many actual systems, which are composed of network nodes and connections. Due to connections among nodes, CNs possess some important properties such as self-organization and self-similarity , which makes it have important applications in different fields, for example, electric power networks , transportation networks , computer networks , biological networks , and social networks . So far, many scholars paid attention to the dynamic analysis of CNs, and a lot of efforts have been devoted to stability , synchronization , consistency , impulse control , pinning control , and state estimation . Although CNs have become an increasingly important research topic in the engineering field, there are still many issues concerning CNs that need further study Due to the limited capacity of sensors, only part of system states can be measured . Therefore, it is important to research state estimation problem for CNs with available measurements in order to effectively study the dynamic behaviors of CNs, and this problem has attracted attentions from many scholars . Because of the nonlinear term in CN system model, in most of the existing works, the extended Kalman filter approach (proposed under the framework of classical Kalman filter theory) is used to estimate states of CNs, and the nonlinear term is linearized by using the Taylor series expansion formula and ignoring the influence of higher-order terms. For instance, in , state estimation for discrete stochastic CNs with time-varying parameters was investigated, where the measurements are missed with certain probability. Since the dynamic fluctuations of networks and the disturbances from the external environment are inevitable, it is difficult to get the accurate nonlinear model for CNs. In these cases, the extended Kalman filter approach is not applicable any more. Therefore, new methods should be proposed to address the state estimation issue for CNs with nonlinear uncertainty. In , the extended state Kalman filter was designed for the stochastic nonlinear uncertain systems, where the uncertain nonlinearity is defined as an unknown extended state and it is estimated by the extended state estimator

II. LITERATURE SURVEY

[1] S. Tan and Y. Wang, “Graphical Nash equilibria and replicator dynamics on complex networks,” IEEE Trans. Neural Netw. Learn. Syst., vol. 31, no. 6, pp. 1831–1842, Jun. 2020.

Graphical Nash Equilibria and Replicator Dynamics on Complex Networks," was published in the IEEE Transactions on Neural Networks and Learning Systems in June 2020.

In this paper, it's likely that the authors explore the concepts of Nash equilibria and replicator dynamics within the context of complex networks. Nash equilibria are solutions in game theory where each player's strategy is optimal given the strategies of the other players. Replicator dynamics, on the other hand, is a concept used to study the evolution of strategies in a population of agents over time.

The authors probably investigate how these concepts apply to complex networks, which are networks characterized by non-trivial topological features such as small-world properties, scale-freeness, or community structures.

They may analyze how the structure of complex networks affects the existence and stability of Nash equilibria, as well as how replicator dynamics unfold within such networks. This research could have implications for understanding the behavior of interconnected systems, such as biological networks, social networks, or economic networks.

[2]. S. Zhu, J. Zhou, G. Chen, and J.-A. Lu, “A new method for topology identification of complex dynamical networks,” IEEE Trans. Cybern., vol. 51, no. 4, pp. 2224–2231, Apr. 2021.

A New Method for Topology Identification of Complex Dynamical Networks," was published in the IEEE Transactions on Cybernetics in April 2021.In this paper, it's likely that the authors propose a novel approach for identifying the topology of complex dynamical networks. Complex dynamical networks are systems composed of interconnected elements whose states evolve over time according to certain rules or dynamics. Examples include social networks, biological networks, and communication networks.

Topology identification refers to the task of inferring the underlying structure or connectivity pattern of the network based on observed data, such as time-series measurements of node states or interactions.The authors likely introduce a new method or algorithm that utilizes data-driven techniques to infer the topology of such networks. This method may leverage concepts from machine learning, signal processing, or network science to analyze the dynamics of the system and extract information about its underlying structure.

III. METHODOLOGY SECTION

Our proposed system aims to revolutionize data security and confidentiality in Business Process Outsourcing by integrating Zero-Knowledge Proofs (ZKPs) into the authentication and verification processes. This system focuses on enhancing the efficiency, security, and confidentiality of data handling during outsourced operations. The key feature of this proposed system involves implementing ZKPs to enable secure data verification without the exchange of sensitive information. By leveraging ZKPs, it securely transmit data and the received data undergoes meticulous processing. All data interactions within this framework strictly adhere to the ZKP protocol, allowing for seamless verification of the data's authenticity without revealing the actual content. Furthermore, the integration of Zero-Knowledge Proofs within this proposed system is rooted in enhancing data integrity and protection. The system prioritizes stringent security measures to safeguard sensitive information during verification processes. By employing cryptographic protocols as ZKPs, This strategic implementation aims to fortify data security, mitigate the risks of data breaches, and maintain client confidentiality throughout the data exchange and processing stages. The proposed system emphasizes immediate interaction and collaboration between BPO teams upon the completion of each process. This seamless interaction facilitates swift progression to subsequent tasks, ensuring a timely and coordinated workflow across different departments. It promotes efficient division of work responsibilities, enabling smoother operations and timely delivery of services..

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ADMIN:

Administrators must first log in using their authorized credentials. Upon successful authentication, one of the crucial sections within the admin module is the approval section, where administrators play a pivotal role in ensuring the integrity of the platform by reviewing and approving outsourcing company, service provider, outsourcees and ZKP protocol. Administrators comprises meticulously designed sections tailored to proficiently manage and oversee the operations related to Zero Knowledge Proof (ZKP) protocols within the platform. They meticulously review and approve ZKP protocol, ensuring compliance and security among involved entities—outsourcing companies, service providers, and outsourcees. The ZKP protocol verification process initiates with the formulation of comprehensive reports by specialized teams. Admins facilitate and approve contracts between service providers and outsourcing companies within the platform, ensuring that negotiated ZKP protocols are incorporated into these agreements. They meticulously review contract terms, emphasizing ZKP compliance and security requisites. Administrators actively engage in analyzing complaint data submitted by outsourcees, investigating reported issues, and providing swift and effective solutions. Their prompt responses and solutions contribute to maintaining trust and ensuring a secure data environment for all participants. The Admin module encompasses features facilitating continual oversight of ZKP compliance and security measures. Admins conduct periodic reviews, audits, and assessments, fostering continual improvement strategies for enhancing ZKP protocols and reinforcing data security measures.

CLIENT:

This module gives the registration process with the outsourcees details of name company name, contact person, email id, contact number, and password. Once admin approves the outsourcees, then he can able to login to the outsourcees page. Outsourcees securely share sensitive data with authorized outsourcing companies, ensuring robust confidentiality and adherence to data security protocols. They oversee and manage the transmission of sensitive project information, documents, and specifications securely to designated outsourcing companies. Outsources have visibility into the ZKP negotiation process between outsourcing companies and their service providers. They monitor and oversee the agreement and negotiation stages concerning ZKP protocols, ensuring the establishment of secure data handling protocols throughout the outsourcing process. Upon the completion of ZKP negotiation, Outsources receive processed data from the designated service providers. They verify and ensure the accuracy and security of the received data before proceeding with further stages of their operational or business processes. In the event of any data leakage or breach by the service providers, Outsources have the functionality to lodge complaints through the platform.

IV. EXPERIMENTAL RESULTS

In this section, we provide a comprehensive experimental study of our approaches. A. Experimental Settings Competitors. We evaluate our solution by comparing it with the following methods: PrivTree. PrivTree is proposed to publish sequential data in the centralized setting. In PrivTree, we first put all the local datasets D1, D2,...,DK together (where K denotes the number of parties), and get a global dataset D = K k=1 Dk. Then, we construct a prediction suffix tree T based on the global dataset D under differential privacy. Next, we generate a synthetic dataset D from the global tree T . Our DPST approach (without the prefixbased pre-pruning method) replaces the computation in the centralized PrivTree approach with corresponding secure multi-party computation (MPC) implementation, that is, they compute the same things with different methods. In, we also formally prove that the scale of noise injected in our DPST approach (without the prefix-based pre-pruning method) is the same as that injected in the centralized PrivTree approach. Therefore, their utility is always the same, and we no longer compare our DPST approach (without the prefix-based pre-pruning method) with the centralized PrivTree approach in terms of utility in our experiments. Independent. In Independent, each party Pk first locally constructs a prediction suffix tree Tk based on the local dataset Dk under differential privacy, and then generates a synthetic dataset Dk from the tree Tk. Next, the parties put all the local synthetic datasets D1, D 2,...,DK together, and get a global synthetic dataset D = K k=1 D k. Noprivacy. Moreover, we consider a non-private approach called Noprivacy to evaluate the utility

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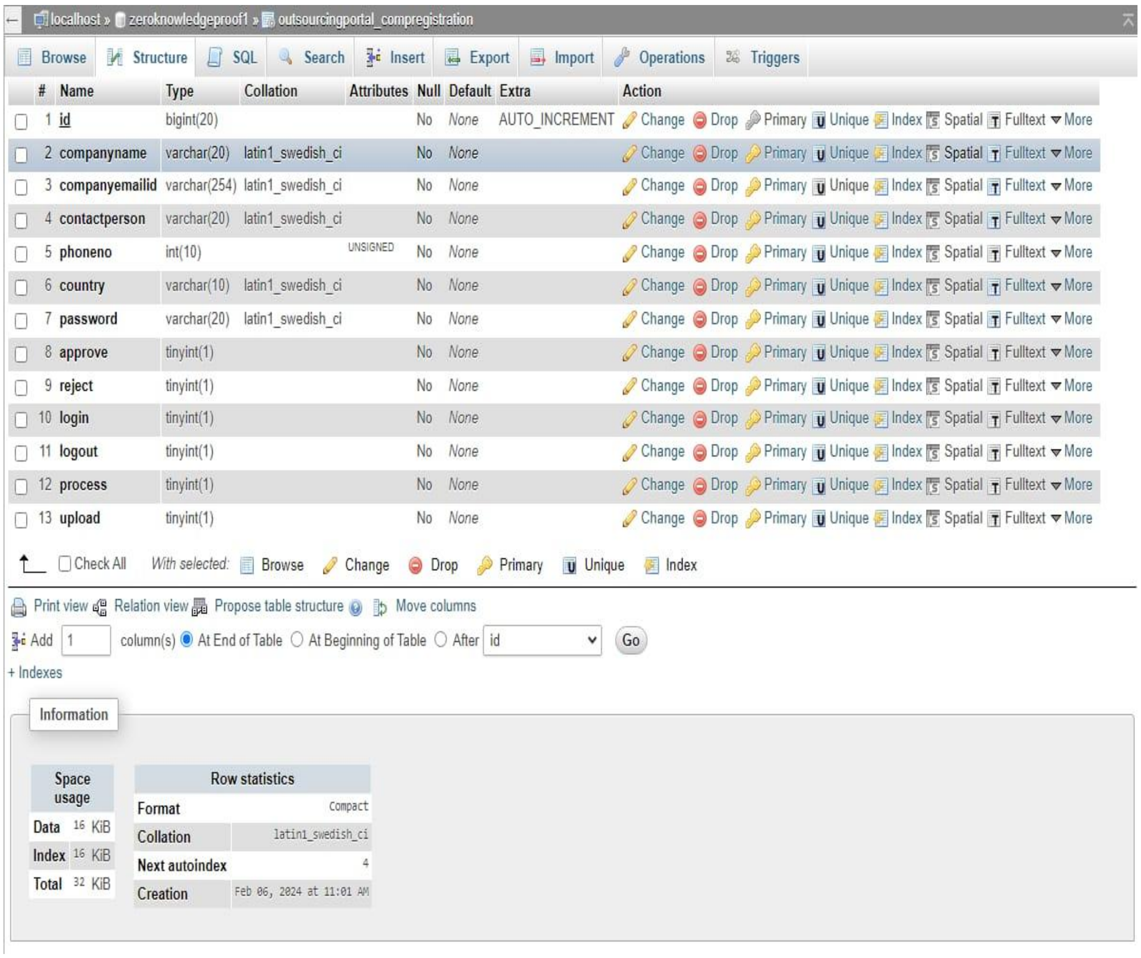
cost due to privacy requirements. This approach directly learns a prediction suffix tree from all data and utilizes the learned tree to generate a synthetic dataset without any privacy protection

V. INPUT/OUTPUT SCREENS



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3	companyemailid	varchar(254)	latin1_swedish_ci		No	None		Change Drop Primary Unique Index Spatial Fulltext More
4	contactperson	varchar(20)	latin1_swedish_ci		No	None		Change Drop Primary Unique Index Spatial Fulltext More
5	phoneno	int(10)		UNSIGNED	No	None		Change Drop Primary Unique Index Spatial Fulltext More
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7	password	varchar(20)	latin1_swedish_ci		No	None		Change Drop Primary Unique Index Spatial Fulltext More
8	approve	tinyint(1)			No	None		Change Drop Primary Unique Index Spatial Fulltext More
9	reject	tinyint(1)			No	None		Change Drop Primary Unique Index Spatial Fulltext More
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+ Indexes

Information

Space usage		
Data	16	KiB
Index	16	KiB
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Row statistics	
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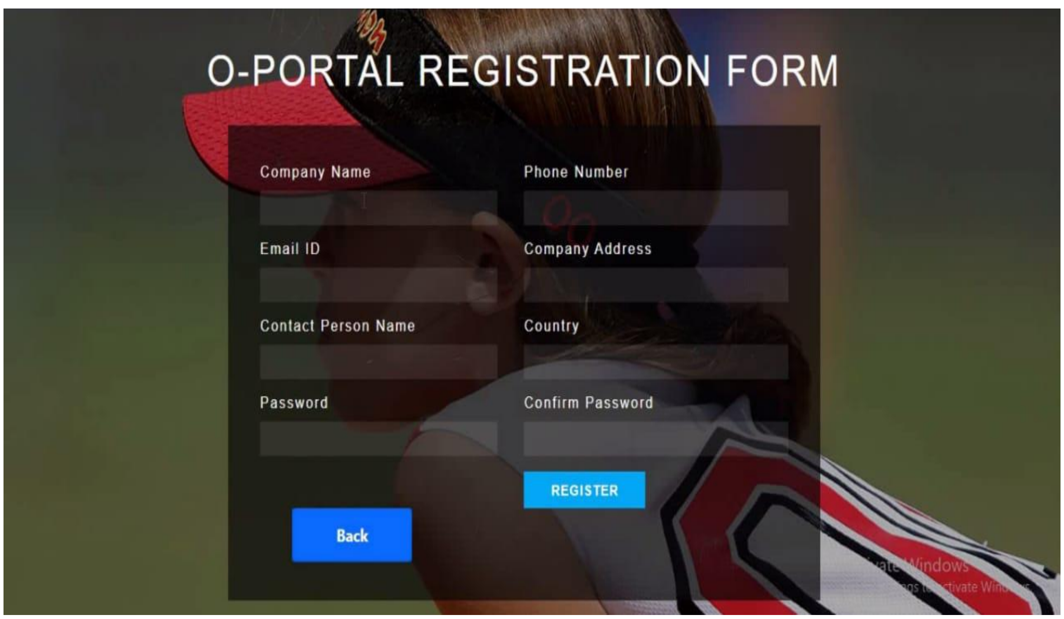

VI. CONCLUSION

The distributed state estimation problem for CNs has been addressed. Nonlinear uncertainty has been considered for each node, which has been handled by using the extended state approach. The distributed state predictor and the distributed state estimator have been designed based on the extended state model and the measurement, respectively. The upper bound of the PEC has been obtained, which has been optimized by designing the optimal estimator gain. A sufficient condition guaranteeing the stability of the upper bound has been derived by the vectorization method. Finally, the effectiveness of the proposed extended state estimation method has been illustrated by a numerical example. Based on the work of this article, our future work will include state estimation for CNs by set-membership filter and moving horizon filter.

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