Federated Routing Scheme for Large-scale Cross Domain Network

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***Abstract*—With the development of multi-network integration, how to ensure interconnections among multiple independent network domains is becoming a key problem. Traditional inter-domain routing protocol such as BGP (Border Gateway Protocol) or SR (Segment Routing) fails due to the limitation of information island (data privacy), where each autonomous network domain does not share any specific intra-domain information.**

In this poster, we propose a federated routing scheme *FRP*, which realizes global routing without any intra-domain data. Each domain only needs to exchange the very lightweight cumulative gradients of overlapped parameters to build the federated routing model. With *FRP*, flows between any pair of nodes can get global optimal routing results no matter which domain the source and destination nodes locate.

***Index Terms*—Federated Routing, Network Integration, Information Island.**

I. Introduction

As cloud computing has become mature and popularized, more and more autonomous networks are emerging. In order to ensure the network interconnections, multi-network integration naturally becomes a promising solution [1] [2]. But how to route under such a multi-network integration scenario is still facing two contradictory challenges.

- **Information Island**. Due to data privacy, autonomous networks usually do not share any specific information to each other. For example among different enterprise networks (or among different metropolitan area networks). Such isolation brings information barriers and finally results in information islands between cross domain networks.
- **Excessive Communication**. A good routing strategy requires global information from all the involved networks, and thus need heavy real-time data exchange, in other words, it needs additional data transmission and high communication efficiency.

The traditional inter-domain routing algorithms such as BGP and SR work well when all the involved ASs (Autonomous Systems) can exchange routing information such as path accessibility. But BGP heavily depends on AS routing information and fails when ASs refuse to provide detailed data. As an emerging routing architecture, SR has been regarded as a revolutionary routing technology, however its performance in privacy preservation is barely satisfactory. Moreover, SR must be globally enabled on the chassis before enabling it on the IGPs (Interior Gateway Protocols), which introduces extra overhead [3]. Therefore, how to design a global optimal routing scheme becomes a key question for large-scale cross domain network, such scheme should meet the following two requirements: First, it can obtain the global optimal routing results when facing information island problem. Second, it should not require for much information exchange among the involved networks.

Inspired by the success of federated learning in user privacy protection [4], [5], wireless communication scenarios [6] and Vehicular Social Networks [7], in this poster, we propose a novel federated routing protocol named *FRP*, which requires no specific information from autonomous networks at all, and only needs very lightweight parameter values exchange (at KB level).

The contributions of this poster is as follows:

- We point out the information island problem and heavy communication problem in cross domain routing under network integration.
- We propose a novel federated routing scheme called *FRP*, which successfully addresses the above challenges.

II. Framework of Federated Routing

The goal of *FRP* is to carry out a global routing scheme across multiple domains without detailed data of much communications of those networks.

The framework of *FRP* is shown in Figure 1. Each big circle represents a domain, and small circles represent routers. The border routers from network domains communicate with the controller, so as to co-construct the federated routing model. With this global routing model, flows between any pair of nodes (source and destination, represented by yellow boxes) can be routed efficiently.

III. Algorithm of Federated Routing

In this section, we give a brief introduction on the federated routing algorithm. The roadmap is shown in Figure 2.

Step 1: Cross domain feature alignment.

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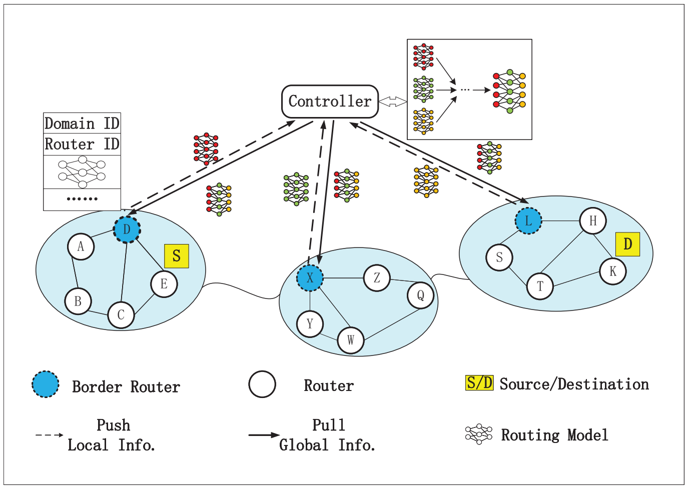

Fig. 1: Framework of federated routing scheme.

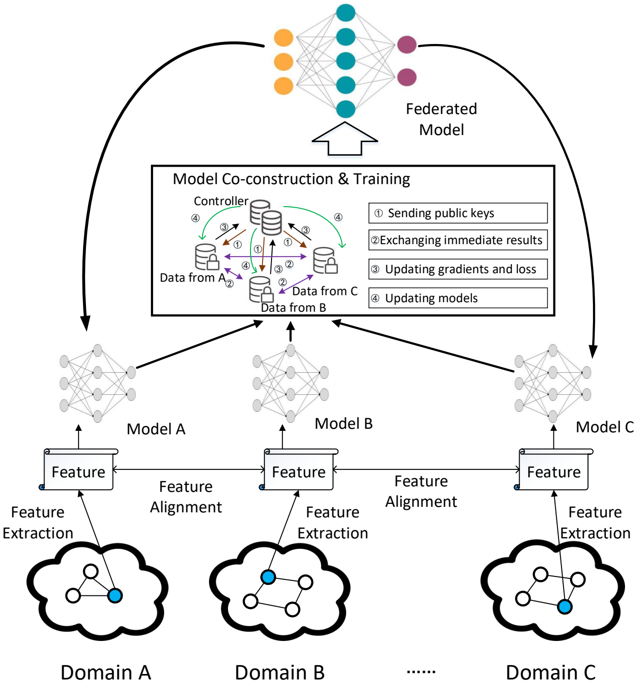

Fig. 2: Federated routing algorithm.

As the structures of the involved networks are possibly not coincident, *FRP* uses encryption based data extraction technology to get a consistent model architecture. Such globally consistent model contains the overlapped data features (such as link utilization and node state). Any party does not need to expose its detailed local data (such as specific topology or device configuration), but only reaches an agreement on the structure of the co-construction model.

Step 2: Federated routing model training.

2.1 Push local information.

With each independent domain, a border router calculates the gradient of loss function of that global model with its local data, then reports the cumulative gradients to the controller.

2.2 Federated model update.

TABLE I: Comparison between routing schemes.

Schemes	Privacy Preservation	Exchanged Information	Convergence Rate	Stability
BGP	×	more	×	×
SR	×	mediate	✓	✓
FRP	✓	less	✓	✓

Once receiving a "push" from domains, the controller updates the overlapped parameter values in the global federated routing model. These domains do not interfere with each other by running independently and asynchronously.

2.3 Pull global information.

After the global federated model is updated, the domain which push its local information updates its local model to the latest global federated model. The above steps are iterated continuously until loss function converges, and thus completes the training process of the federated routing algorithm.

FRP successfully solves the contradictory challenges mentioned in Section I. First, *FRP* generates a global routing model without the specific data from local domains (addresses information island). Second, in the model training process, the only data need to be transmitted is the cumulative gradients of overlapped parameters, greatly reduces cross network communication (addresses communication problem).

We summarize the properties of different routing schemes and show the comparison results in Table I, which reveals the advantages of *FRP*.

IV. Conclusion

Being limited to data privacy and information isolation, traditional inter-domain routing schemes fails in the coming cross domain network integration scenario. So in this poster, we propose a novel federated routing scheme *FRP*, which achieves global routing in large-scale cross domain network, while the co-construction of the global routing model only needs the cumulative parameter gradients instead of specific data from local domain, so each domain can run independently and privately.

References

[1] Z. N. Abdullah, I. Ahmad, and I. Hussain, "Segment routing in software defined networks: A survey," *IEEE Communications Surveys & Tutorials*, vol. 21, no. 1, pp. 464–486, 2018.

[2] Q. Chen, S. Shi, X. Li, C. Qian, and S. Zhong, "Sdn-based privacy preserving cross domain routing," *IEEE Transactions on Dependable and Secure Computing*, vol. 16, no. 6, pp. 930–943, 2018.

[3] A. Cianfrani, M. Listanti, and M. Polverini, "Incremental deployment of segment routing into an isp network: A traffic engineering perspective," *IEEE/ACM Transactions on Networking*, vol. 25, no. 5, pp. 3146–3160, 2017.

[4] Q. Yang, Y. Liu, T. Chen, and Y. Tong, "Federated machine learning: Concept and applications," *ACM Transactions on Intelligent Systems and Technology (TIST)*, vol. 10, no. 2, pp. 1–19, 2019.

[5] Z. Zhang, K. Xu, Q. Li, X. Liu, L. Li, B. Wu, and Y. Guo, "Seccl: Securing collaborative learning systems via trusted bulletin boards," *IEEE Communications Magazine*, vol. 58, no. 1, pp. 47–53, 2020.

[6] J. Mills, J. Hu, and G. Min, "Communication-efficient federated learning for wireless edge intelligence in iot," *IEEE Internet of Things Journal*, 2019.

[7] M. Shen, J. Zhang, L. Zhu, K. Xu, and X. Tang, "Secure svm training over vertically-partitioned datasets using consortium blockchain for vehicular social networks," *IEEE Transactions on Vehicular Technology*, 2019.