

## I PATH: I PATH INFERENCE IN WIRELESS SENSOR NETWORKS

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**ABSTRACT:** Recent wireless sensor networks (WSNs) are becoming increasingly complex with the growing network scale and the dynamic nature of wireless communications. Many measurement and diagnostic approaches depend on per-packet routing paths for accurate and fine-grained analysis of the complex network behaviours. In this paper, we propose iPath, a novel path inference approach to reconstructing the per-packet routing paths in dynamic and large-scale networks. The basic idea of iPath is to exploit high path similarity to iteratively infer long paths from short ones. iPath starts with an initial known set of paths and performs path inference iteratively. iPath includes a novel design of a lightweight hash function for verification of the inferred paths. In order to further improve the inference capability as well as the execution efficiency, iPath includes a fast bootstrapping algorithm to reconstruct the initial set of paths. We also implement iPath and evaluate its performance using traces from large-scale WSN deployments as well as extensive simulations. Results show that iPath achieves much higher reconstruction ratios under different network settings compared to other state-of-the-art approaches.

**KEYWORDS:** Measurement, path reconstruction, wireless sensor networks

### INTRODUCTION

WIRELESS sensor networks (WSNs) can be applied in many application scenarios, e.g., structural protection [1], ecosystem management [2], and urban CO monitoring [3]. In a typical WSN, a number of self-organized sensor nodes report the sensing data periodically to a central sink via multihop wireless. Recent years have witnessed a rapid growth of sensor network scale. Some sensor networks include hundreds even thousands of sensor nodes [2], [3]. These networks often employ dynamic routing protocols [4][5][6] to achieve fast adaptation to the dynamic wireless channel conditions. The growing network scale and the dynamic nature of wireless channel make WSNs become increasingly complex and hard to manage.

Reconstructing the routing path of each received packet at the sink side is an effective way to understand the network's complex internal behaviours [7], [8]. With the routing path of each packet, many measurement and diagnostic approaches [9]–[13] are able to conduct effective management and protocol optimizations for deployed WSNs consisting of a large number of unattended sensor nodes. For example, PAD [10] depends on the routing path information to build a Bayesian network for inferring the root causes of abnormal phenomena. Path information is also important for a network manager to effectively manage a sensor network. For example, given the per-packet path information, a network manager can easily find out the nodes with a lot of packets forwarded by them, i.e., network hop spots. Then, the manager can take

actions to deal with that problem, such as deploying more nodes to that area and modifying the routing layer protocols. Furthermore, per-packet path information is essential to monitor the fine-grained per-link metrics. For example, most existing delay and loss measurement approaches [11][12] assume that the routing topology is given a priori. The time-varying routing topology can be effectively obtained by per-packet routing path, significantly improving the values of existing WSN delay and loss tomography approaches.

A straightforward approach is to attach the entire routing path in each packet. The problem of this approach is that its message overhead can be large for packets with long routing paths. Considering the limited communication resources of WSNs, this approach is usually not desirable in practice.

In this paper, we propose iPath, a novel path inference approach to reconstruct routing paths at the sink side [13]. Based on a real-world complex urban sensing network with all node generating local packets, we find a key observation: It is highly probable that a packet from node and one of the packets from 's'.

The contributions of this work are the following.

- We observe high path similarity in a real-world sensor network. Based on this observation, we propose an iterative boosting algorithm for efficient path inference. We propose a lightweight hash function for efficient verification within iPath. We further propose a fast bootstrapping algorithm to improve the inference capability as well as its execution efficiency [14].
- We propose an analytical model to calculate the successful reconstruction probability in various network conditions such as network scale, routing dynamics, packet losses, and node density.
- We implement iPath and evaluate its performance using traces from large-scale WSN deployments as well as extensive simulations. iPath achieves higher reconstruction ratio under different network settings compared to states of the art.

The rest of this paper is organized as follows. Section II discusses the related works. Section III gives the results of a measurement study on two deployed networks. Section IV describes the network model and assumptions made in this paper. Section V describes the design of iPath. Section VI formally analyses the reconstruction performance of iPath and two related works. Section VII evaluates iPath's performance compared to existing works in a trace-driven study. Section VIII reveals more system insights by extensive simulations, and Section IX concludes this paper.

## I. EXISTING SYSTEM

- With the routing path of each packet, many measurement and diagnostic approaches are able to conduct effective management and protocol optimizations for deployed WSNs consisting of a large number of unattended sensor nodes. For example, PAD depends on the routing path information to build a Bayesian network for inferring the root causes of abnormal

phenomena[15].

- Path information is also important for a network manager to effectively manage a sensor network. For example, given the per- packet path information, a network manager can easily find out the nodes with a lot of packets forwarded by them, i.e., network hop spots. Then, the manager can take actions to deal with that problem, such as deploying more nodes to that area and modifying the routing layer protocols.

- Furthermore, per-packet path information is essential to monitor the fine-grained per-link metrics. For example, most existing delay and loss measurement approaches assume that the routing topology is given as a priori.

The time-varying routing topology can be effectively obtained by per-packet routing path, significantly improving the values of existing WSN delay and loss tomography approaches.

## II. PROPOSED SYSTEM

- In this paper, we propose iPath, a novel path inference approach to reconstruct routing paths at the sink side. Based on a real-world complex urban sensing network with all node generating local packets, we find a key observation: It is highly probable that a packet from node and one of the packets from its parent will follow the same path starting from its parent toward the sink. We refer to this observation as high path similarity.
- The basic idea of iPath is to exploit high path similarity to iteratively infer long paths from short ones. iPath starts with a known set of paths (e.g., the one-hop paths are already known) and performs path inference iteratively[16]. During each iteration, it tries to infer paths one hop longer until no paths can be inferred.
- In order to ensure correct inference, iPath needs to verify whether a short path can be used for inferring a long path. For this purpose, iPath includes a novel design of a lightweight hash function. Each data packet attaches a hash value that is updated hop by hop. This recorded hash value is compared against the calculated hash value of an inferred path. If these two values match, the path is correctly inferred with a very high probability
- In order to further improve the inference capability as well as its execution efficiency, iPath includes a fast bootstrapping algorithm to reconstruct a known set of paths.

### ADVANTAGES OF PROPOSED SYSTEM:

- We observe high path similarity in a real-world sensor network.
- It's an iterative boosting algorithm for efficient path inference.
- It's a lightweight hash function for efficient verification within iPath.
- The proposed systems further propose a fast bootstrapping algorithm to improve the inference capability as well as its execution efficiency [17]. iPath achieves higher reconstruction ratio under different network settings compared to states of the art.

### IMPLEMENT:-

#### ION Network Mode

In this module we design the network model. We assume a multi hop WSN with a number of

sensor nodes

### **Iterative Boosting**

IPath reconstructs unknown long paths from known short paths iteratively. By comparing the recorded hash value and the calculated hash value, the sink can verify whether a long path and a short path share the same path after the short path's original node.

When the sink finds a match, the long path can be reconstructed by combining its original node and the short path.

### **PSP-Hashing**

- As mentioned in the iterative boosting algorithm, the PSPHashing (i.e., path similarity preserving) plays a key role to make the sink be able to verify whether a short path is similar with another long path.
- There are three requirements of the hash function. The hash function should be lightweight and efficient enough since it needs to be run on resource-constrained sensor nodes
- The hash function should be order-sensitive. That is, hash (A, B) and hash (B, A) should not be the same. The collision probability should be sufficiently low to increase the reconstruction accuracy.
- Traditional hash functions like SHA-1 are order-sensitive. However, they are not desirable due to their high computational and memory overhead.
- For example, an implementation of SHA-1 on a typical sensor node TelosB takes more than 4 kB program flash and longer than 5 ms to hash 20 B of data. Note that this memory overhead is about 10% of the total program flash of a TelosB node, and 5 ms computational overhead nearly doubles the forwarding delay in a typical routing protocol.

In order to design an efficient and lightweight hash function, efficient operations, such as bitwise XOR operation, are preferred. Since XOR operation is not order-sensitive, the order information should be explicitly hashed into the hash value. We propose PSP-Hashing, a lightweight path similarity preserving hash function to hash the routing path of each packet. PSP-Hashing takes a sequence of node ids as input and outputs a hash value. Each node along the routing path calculates a hash value by three pieces of data. One is the hash value in the packet that is the hash result of the subpath before the current node. The other two are the current node id and the previous node id. The previous node id in the routing path can be easily obtained from the packet

header. Shows this chained hash function along the routing path

### **Fast Bootstrapping**

- The iterative boosting algorithm needs an initial set of reconstructed paths.
- In addition to the one/two-hop paths, the fast bootstrapping algorithm further provides more initial reconstructed paths for the iterative boosting algorithm.
- These initial reconstructed paths reduce the number of iterations needed and speed up the iterative boosting algorithm.

- The fast bootstrapping algorithm needs two additional data fields in each packet, parent change counter and global packet generation time.

The parent change counter records the accumulated number of parent changes, and the global packet generation time can be estimated by attaching an accumulated delay in each packet.

## CONCLUSION

In this paper, we propose iPath, a novel path inference approach to reconstructing the routing path for each received packet. iPath exploits the path similarity and uses the iterative boosting algorithm to reconstruct the routing path effectively. Furthermore, the fast bootstrapping algorithm provides an initial set of paths for the iterative algorithm. We formally analyse the reconstruction performance of iPath as well as two related approaches. The analysis results show that iPath achieves higher reconstruction ratio when the network setting varies. We also implement iPath and evaluate its performance by a trace-driven study and extensive simulations. Compared to states of the art, iPath achieves much higher reconstruction ratio under different network settings.

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