

# Privacy Preserving Distributed Hash Table [DRAFT]

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## Abstract

**Distributed Hash Tables (DHT) are overlay networks that allow peers to store and lookup data in a decentralized network. Peers are responsible for routing requests and storing data without the need for external control. DHTs are an important building block for the decentralized web and many P2P systems. However, its decentralized nature introduces privacy vulnerabilities to the services built on top of it. We discuss privacy threat model of DHTs, define the requirements for a privacy preserving DHT and review the literature for mechanisms and protocols to achieve it. We also outline open problems and directions for future research.**

## Introduction

Distributed Hash Tables (DHT) are an important building block for the decentralized web and P2P systems. DHTs are overlay networks that allow peers to store and lookup information stored in a decentralized network, where participant nodes are responsible for routing requests and storing data.

As a result of its P2P nature, naive design and implementation of DHTs leak user behavior information to other participants. Questions such as “who is participating in the network?”; “who is requesting a particular set of data?”; and “who is storing and providing a particular set of data?” can be answered by anyone with relatively low resources. The data leaked

by DHTs can be used to target and censor individuals, communities and services.

Privacy preserving networks are designed and implemented in such ways that user privacy is protected against targeted and mass surveillance and censorship. We argue that 1) the comeback of decentralized networks is a crucial opportunity for building privacy preserving networks from the ground-up and; 2) that DHTs are an important primitive in the decentralization landscape and thus implementations of the DHTs should take user privacy in consideration.

This work aims at building the foundations to research and implement privacy preserving DHTs. We review protocols and techniques used to design and build secure and privacy preserving DHTs and their current implementations. We also discuss future directions for design and implementation of privacy preserving DHTs, taking into considerations how it impacts properties such as decentralization, scalability and performance of the network. We conclude that ...

The remaining paper is structured as follows. First, we review literature on privacy preserving protocols and techniques on P2P networks. Secondly, we describe how a general purpose DHT works and outline the most popular protocols used nowadays and their respective applications. Thirdly, we describe the threat model of DHTs from a security and privacy perspectives. We then proceed with by reviewing protocols and techniques that aim at preserving complete or a subset of privacy properties in DHTs. Finally, we outline open questions and future research directions.

## Literature Review

Octopus (Wang and Borisov 2012) is a DHT lookup mechanism that aims at providing security and anonymous lookups. The threat model assumes partial adversaries that control up to a fraction of the network (max. 20%) and discards the possibility of global adversaries with the ability to monitor all the traffic in the network. (Wang and Borisov 2012) remarks that anonymity in DHTs as defined by (Pfitzmann and Hansen 2009) can only be achieved if the DHT is secure against active attacks. An adversary can use its influence in the network to perform lookup bias attack, lookup misdirection attack and finger pollution attack to de-anonymize a lookup initiator. Thus, (Wang and Borisov 2012) starts by describing how active attacks can be identified and flagged. Since all the active attacks are performed by manipulating adversary finger tables, the strategy to flag those attacks consists of honest nodes checking the correctness of other node's routing tables coupled to a reputation system. For this purpose, Octopus defines another overlay network for peers to check the correctness of its neighbor's routing table. To punish malicious peers, a Certificate Authority (CA) is used to revoke rights for identified malicious nodes to participate in the network. Once the active attacks are identified and flagged, Octopus ensures anonymity by using an anonymous path to send lookup requests without revealing who is the initiator. Moreover, it splits queries into multiple paths and introduces dummy queries to achieve lookup anonymity. (Wang and Borisov 2012) showed that Octopus "has reasonable lookup latency and communication overhead".

## Distributed Hash Tables

- any peer can participate in the network
- constrained overlay vs non-constrained

## Threat model

We assume that an attacker can control up to a fraction  $f$  of the network nodes, and suggest that  $f$  should be 0.2. We assume the worst case in which the adversary nodes can passively and actively attack the network and may cooperate. Adversaries that can control more than a relatively small fraction of the network and monitor the whole network activity are not considered. (Mittal and Borisov 2009), (Wang and Borisov 2012), (Panchenko, Richter, and Rache 2009) claim that such adversary is unlikely to exist in large P2P networks.

We consider a DHT to be fully privacy preserving if a lookup initiator is anonymous. Based on (Pfitzmann and Hansen 2009) definition, a lookup initiator peer is anonymous if honest or adversary peers can not tell from the set of possible lookup initiators - all nodes in the DHT - who initiated a particular lookup. Additionally, given a lookup initiator, a network peer should not be able to determine what is the lookup target.

We also consider message unlinkability (Pfitzmann and Hansen 2009) as a requirement for a privacy preserving DHT. An adversary must not be able to link multiple messages as belonging to an anonymous initiator.

## Attacks on DHT

Given its decentralized nature, naive DHTs are vulnerable to multiple attacks that can directly affect privacy. The underlying cause of the attacks are when malicious nodes cooperatively deceive honest nodes about their routing tables. Most of the privacy preserving mechanisms and protocols [shadowwalker], (Wang and Borisov 2012), ... need ways to enforce security in DHT before providing privacy. According to (Wang and Borisov 2012) DHTs are vulnerable to the following attacks:

- *Lookup Bias Attack*::
- *Lookup Misdirection Attack*: malicious nodes may

provide manipulated finger tables so that the lookup initiator only uses malicious nodes as part of the lookup path. This attack potentially de-anonymises the lookup initiator since the attacker acquires a lot of information about the lookup along the path.

- *Finger Pollution Attack*: when honest nodes attempt to update its finger table by requesting other peer's routing tables, malicious node may attempt to pollute its routing table with malicious nodes in order to perform lookup bias attacks and lookup misdirection attacks.

Thus, we conclude that in order to achieve a privacy preserving DHTs, we need to ensure that malicious nodes cannot deceit honest nodes with manipulated finger tables. This is a hard precondition to our goal of achieving privacy preserving DHTs.

## Approaches for privacy preserving DHTs

### Friend to friend restricted network topology

*as in Freenet "darknet"*

### In-DHT garlic routing

*as in I2P*

### In-DHT onion routing

Onion routing [(Goldschlag, Reed, and Syverson 1999), (Reed, Syverson, and Goldschlag 2006)] has been researched and used (Dingledine, Mathewson, and Syverson 2004) to protect network level metadata leakage

## Open questions and future research

**scalable and decentralized secure DHT**: malicious peers that control a fraction of the network are able to perform

**measuring anonymity**: reference to 'why I'm not an entropist'

## Conclusion

## References

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