The Sybil Attack - Theory and Practice

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Abstract

1 Introduction

Electronic commerce and online social networks are common phenomenons at the present time. They allow us to orchestrate many aspects of our lives in the comfort of our homes, behind the monitors of our devices. An online identity is often required to use such services, for examples we must create an account to Tweet[1] our friend, who must also have an account. In this scenario, users can choose to remain psudonymous if they are careful, where their real-life identity is uncorrelated with their online identity.

While creating pseudonyms is useful for protecting users' privacy, it also opens an alleyway for attackers. The Sybil attack, first described by Douceur[16], is an attack where an entity can assume multiple identities or Sybils, and then attack either another entity or undermine the whole system. For example, a malicious Twitter user can create many fake identities and have the fake identities follow his real identity, thus creating a false reputation. It is one of the most important attacks because it leads to a large number of consequences including but not limited to spreading false information, identity theift[7] and ballot stuffing[6]. Furthermore, to the best of our knowledge, there is no general solution for preventing the Sybil attack.

In this work, we survey various aspects of the Sybil attack. But in contrast with previous surveys, we include both the theoretical and practical aspects. First, we describe the Sybil attack in more detail and and illustrate

[1] A message sent using Twitter is a Tweet.

its importance by looking at how researchers and black-hat hackers mounted the attack on real-world e-commerce and online social network systems in section 2. Since there is a large variety of Sybil attack defence mechanisms, from using trusted-third-party to exploiting the graph characteristics in online social networks, thus we classify these mechanisms by their "main idea" in section 3. Finally we present the related work and conclude in section 4 and section 5.

2 The Sybil Attack

The Sybil attack is coined by Douceur[16] in 2002 in the context of peer-to-peer systems. In this section, we first introduce the Sybil attack using Douceur's original definition and outline the key (discouraging) theoretical results. Next, we review practical attacks in three types of systems (1) MANET (mobile ad-hoc networks) such as sensor networks, (2) reputation systems such as PageRank[43] but also include e-commerce systems such as eBay and (3) OSN (online social networks) such as Twitter and Facebook. We hope our review illuminates the alarming consequences of the Sybil attack.

2.1 Theoretical Results

Douceur defined the Sybil attack as forging multiple identities under the same entity[16]. An entity can be for example a physical user of the system and identities are how entities present themselves to the system. Thus a local entity has no direct knowledge of remote entities, only their identities. We use these terms in the remainder of the survey. The author modelled the system as a general distributed computing environment where there is no constraint on the topology, every node has limited computational resources and messages are guaranteed to be delivered. Under this model, the author proved that the Sybil attack is always possible without a central, trusted authority.

Cheng and Friedman proved an important result regarding the Sybil attack in reputation systems[9]. Reputation systems are commonly used in MANET, e-commerce and the internet in general, where entities are rewarded by their good behaviour and penalised otherwise. Google's PageRank[43] is an example of a reputation system, where a large number of links to a website

makes it more reputable. Cheng and Friedman classified reputation systems into two categories,

1. symmetric reputation systems where the reputation score only depends on the network topology, popular reputation mechanisms such as PageRank[43] and EigenTrust[29] are examples of symmetric reputation systems, and

2. asymmetric reputation systems where there some nodes are trusted and reputation scores are propogated through the trusted nodes, most OSN are examples of asymmetric reputation systems.

The authors formally proved that symmetric reputation systems are vulnerable to the Sybil attack. But in the asymmetric case, it is possible to construct a Sybil-proof reputation system.

2.2 The Sybil Attack in MANET

2.3 The Sybil Attack in Reputation Systems

2.3.1 Reputation Systems

2.3.2 Attacks

2.4 The Sybil Attack in Online Social Networks

2.4.1 Online Social Networks

2.4.2 Attacks

2.5 TODO

a test bed for sybil attacks[25]
Quantifying Sybil attack[37]

3 Defences

In this section we categorise various defence techniques against the sybil-attack in reputation systems.

3.1 Trusted Third Party

One of the earliest and best known reputation system is eBay[46]. The buyers and sellers rely on a trusted third party, in this case eBay, to gather and distribute feedbacks after every transaction. Even when there are no incentives to provide feedback, Resnick and Zeckhauser observed that feedback was provided more than half of the time[46], making eBay one of the most well-known online marketplaces.

In general, trusted third parties manage the issurance and verification of identities. Thus they can apply a fee on the peer for creating a new identity[45] or rate-limit the creation of new identities[16], making sybil-attacks more difficult. Furthermore, trusted third parties often have the ability to manipulate the identities. For example they could punish the attackers by disabling all of their identity when caught, making the sybil-attack much riskier especially when identities are costly.

Trusted third party is likely the most widely used technique in practice. Marketplaces such as Amazon or eBay, online forums such as Stackoverflow or Reddit, all use a form of trusted third party.

Unfortunately, a trusted third party is often a single point of failure. Moreover, being a centralised system, it is difficult to scale up to suit increasing user demands. In the remainder of this section, we focus on distributed techniques for preventing the sybil-attack.

Credence 06[64] - uses central authority to sign key

3.2 Costly Identity Creation

3.2.1 IP Address

3.2.2 Low reputation for new users

Feldman 04[17] - adaptive stranger, low score on entry

3.3 Indirect Information

EigenTrust[29] - doesn't prevent sybils, suggests to add cost in ID creation
R2Trust[59] - credibility, tackles colluders, time decay factor

3.4 Graph Techniques

Theory[52] Gal-Oz et al. [18] communities are collection of knots, sybils can form a knot? Regret[47, 48] - information from multiple dimensions Guha 04[19] - no mention of sybil attacks or attacks in general

3.4.1 Flow Based

BarterCast[40] SybilRes[13]

3.4.2 Topology

SybilGuard[71] SybilLimit[70] SybilInfer[12] SybilShield[53] - assuming sybils have bad connectedness SumUp[60] GateKeeper[61] - based on SumUp Social-network[62] - community detection

Distributed Sparse Cut Monitoring[32]

Other systems are built on top: ReDS[2] suggests to use sybilimit or sybilinfer SybilProof-DHT[34]

3.5 Reputation Transfer

Trust-transfer[50]

3.6 Self Registration

P-GRID 01[1] Self-registration[15] - distributed registration based on IP address

3.7 Cryptography Based Techniques?

Secure-Overlay[36] - ID crypto and SSS Privacy-preserving[49] - blockchain? Proof-of-stake[14] SybilConf[57]

3.8 Content Driven

[8]

3.9 Other

Parental control[58] - uses parents to "observe" find suspects, only for detection, requires a sybil-proof reputation scheme DSybil[69] - recommendation system, need historical data Symon[28] - pair peers together, likelihood for both to be sybils is low, the pair monitor each other to prevent attacks XRep 02[11] IP check, and checks digest, uses existing P2P systems like Gnutella

3.10 Unsorted?

Beth and PGP limits Sybil attack to some extent by using social graphs Beth 94[5] PGP (Zimmermann) 95[75]

Yu 00[68] Lee 03[33] - uses flooding, might not be scalable, only talks about DoS Marti 04[39] ARA 05[22] - no mention of sybil, prevents freeriding, prevents short-term abuse because reputation increases gradually FuzzyTrust Song 05[55] - uses fuzzy logic P2PRep/Fuzzy 06[4] - also fuzzy, does not prevent generation of false rumors Xiong 05[66] - no mention of sybil, but tries to mitigate false information PowerTrust 06[74] - uses "power nodes" (from power-law), no mention of sybil, some defence against colluders

Histos and Sopras[72], doesn't really have structure? Beta[26] Gupta et al.[21]

PeerTrust[65] - DHT, used P-GRID source code, has credibility rating

PerContRep[67]

3.11 Does not handle Sybil-attack?

TrustMe[54] is a reputation that focuses on anonymity, no mention of sybil attack

H-Trust[73] does not mention sybil

Coner et al.[10] assumes clients cannot perform sybil attack

TrustGuard 05[56] - assumes it is built on secure overlay networks (sybil-proof networks)

Scrivener 05[42] - assumes ID cannot be created and discarded

4 Related Work

Reputation Surveys: [38] [27] ? [24] [31] [51] ? [23]

Sybil Surveys: [35] [41] [44] [20] [30] Sok[3] but also some contribution

Other: [63]

5 Summary

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