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Honey Onions: Exposing Snooping Tor HSDir Relays

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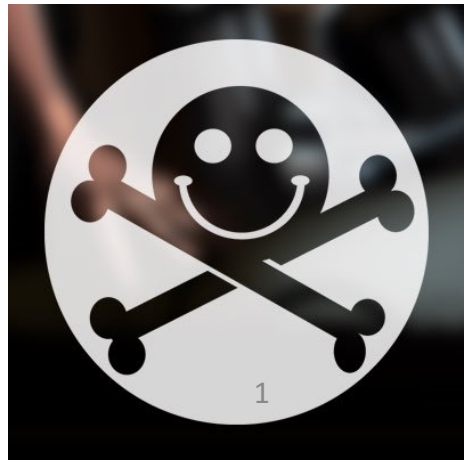


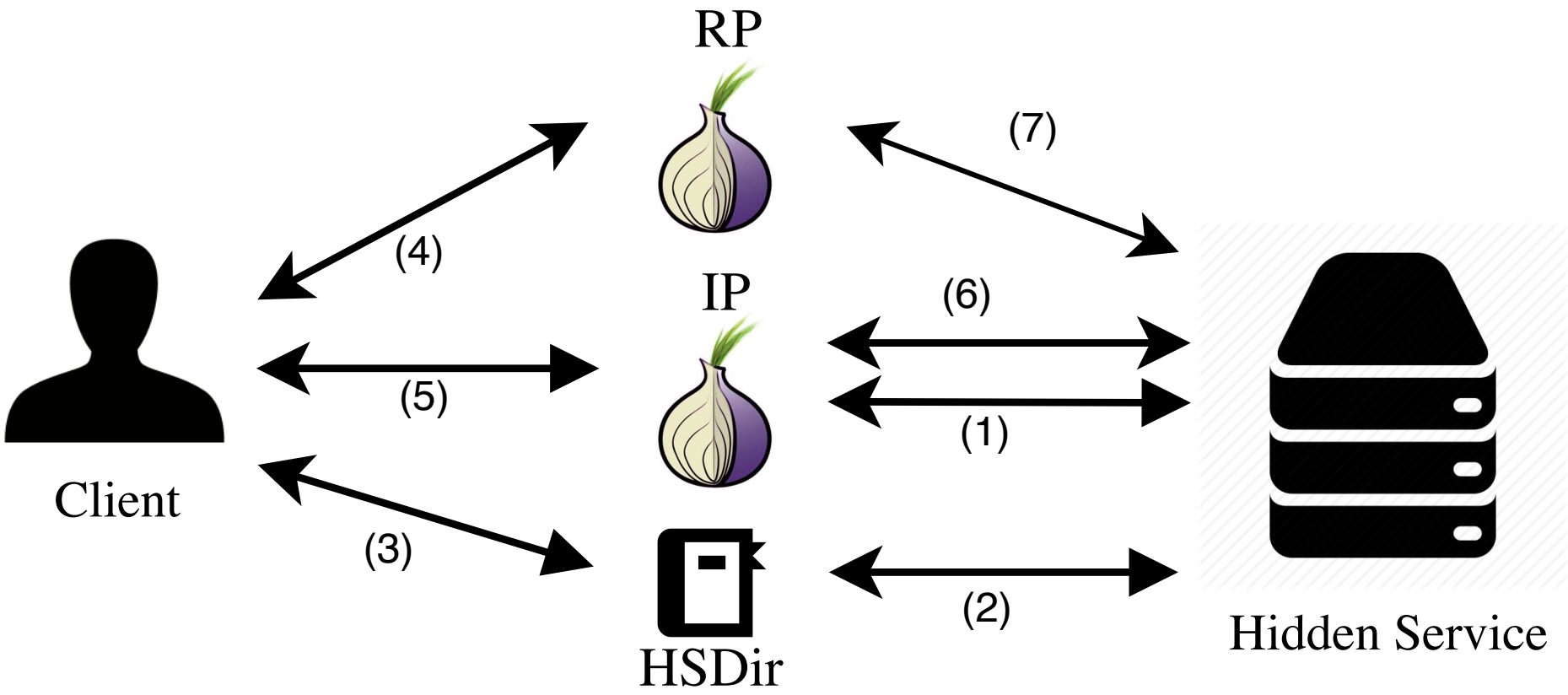
Motivations

- Previous research studied the maliciousness of the relays
- Known bad Exit nodes
- Other work looked at the nature of hidden services content
- No prior work on the Hidden Service Directories (HSDirs)
- Indexing hidden services requires modification to Tor, which can be an indicator of some effort and potentially more malicious activities

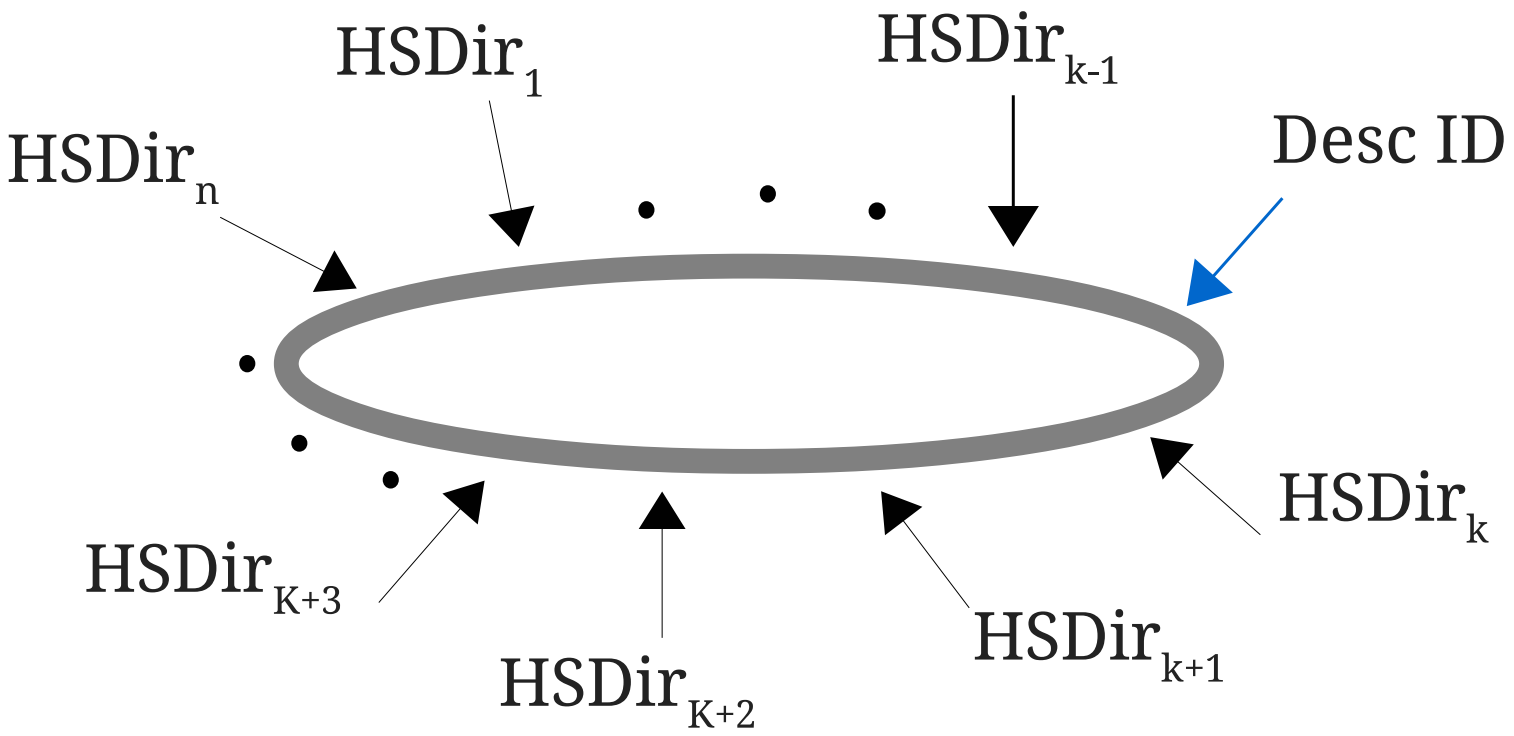
Tor & Hidden Services

- A widely used practical anonymity infrastructure
- Provides anonymity for both the clients and the server through hidden services
- Depends on the honest behavior of the volunteering relays
- It is known that some relays are misbehaving (Bad Exit nodes)
- Some Exit nodes actively try to perform Man in the Middle Attack (MITM)
- Not much is known about the HSDirs or Hidden Services in general

Hidden Service Directories (HSDir)



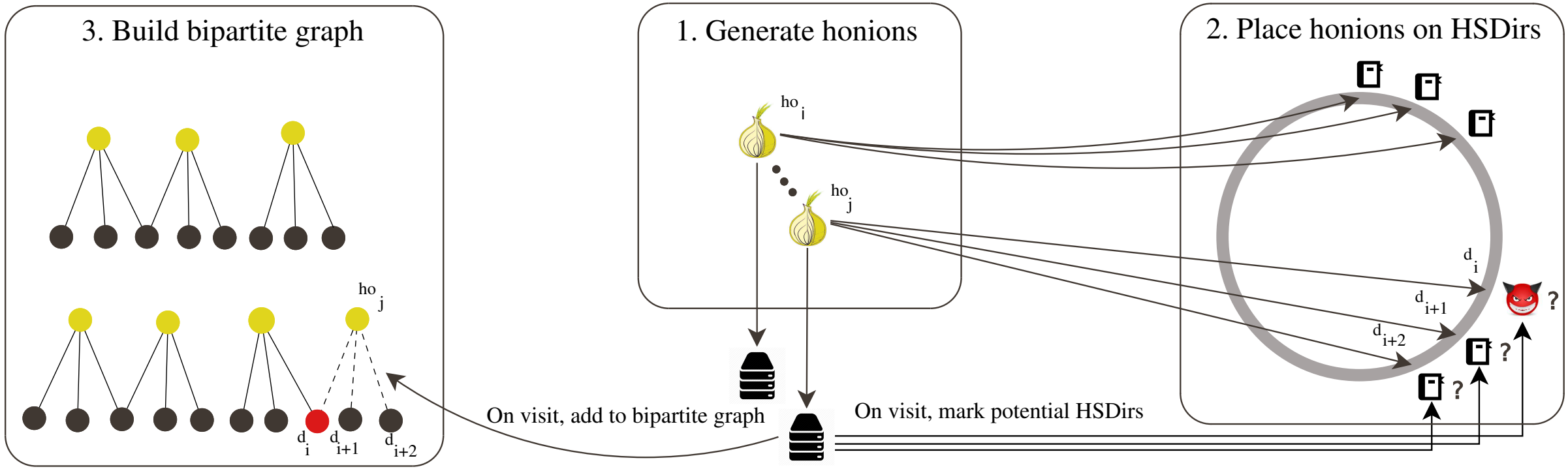
Ring of Responsible HSDirs



Honey Onions (HOnions)

- Each HOnion corresponds to a server/process
- Run on local IP address (Hidden Service)
- Accessible only through Tor and not shared anywhere
- Three schedules
  - Daily
  - Weekly
  - Monthly
- Log the requests for further investigation

HOnions Architecture



Set Cover Problem

- $HSD = \{\, d_i : Tor\ relays\ with\ HSDir\ flag \,\}$
- $HO = \{ho_j : HOnion\ that\ was\ visited\}$
- $V = \{HSD \cup HO\}$
- $E = \{(ho_j, d_j) \in HO \times HSD \mid ho_j\ was\ placed\ on\ d_i\ and\ was\ visited\}$
- $\underset{S \subseteq HSD}{argmin} \mid S\colon \forall\, (ho_j, d_i) \in E,\ \exists d'_i \in S \ \wedge (ho_j, d'_i) \in E \mid$

- The set cover is an NP-complete problem
- Can be calculated using approximation algorithms
- Set cover gives the lower bound on the number of snooping HSDirs

Heuristic Approach

- **Input**: *G(V, E)*: Bipartitie graph of HOnions to HSDirs
- **Output**: S: Set explaining visits

- $S \longleftarrow \emptyset$
- **while** $V \cap HO \neq \emptyset$ **do**
  - Pick $d \in V \cap HSD$: $with\ highest$ degree
  - $V \leftarrow V \setminus \{d\ and\ its\ HOnion\ neighbors\}$
- **end**

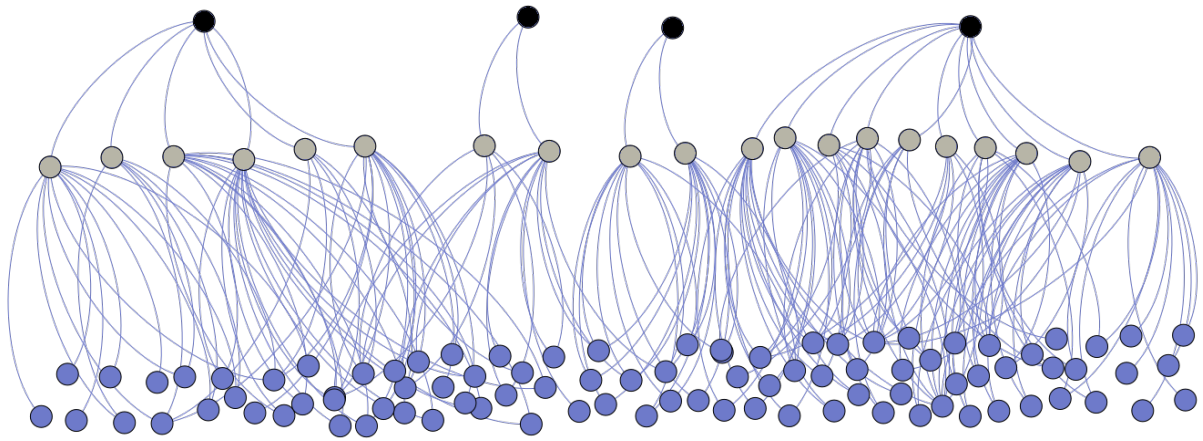
Integer Linear Programming (ILP)

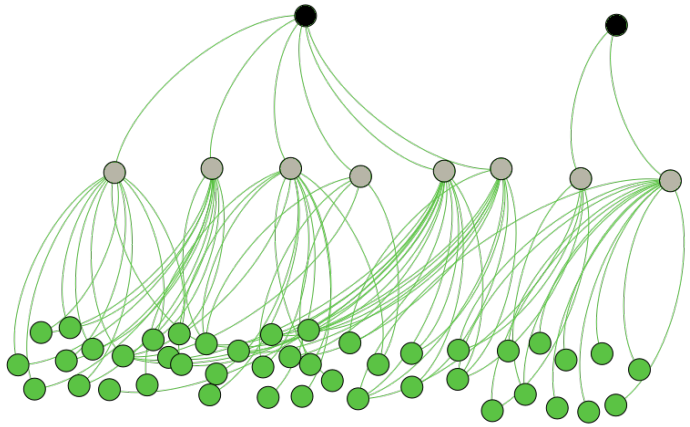
- $\min\ (x_1, \ldots, x_{HSD})$ $\quad \sum_{j=1}^{|HSD|} x_j$

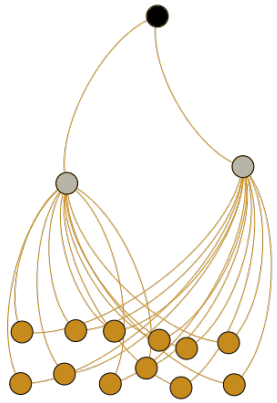
  subject to $\forall\ ho_i \in HO$ $\quad \sum_{\forall\ j:(ho_i,d_j)\in E} x_j \geq 1$

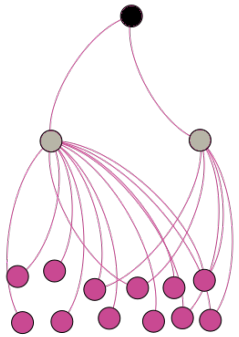
- Provides a lower bound on the number of snooping HSDirs to explain the visits

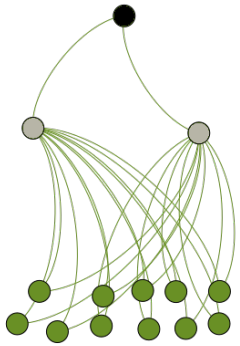
Connectivity Graph

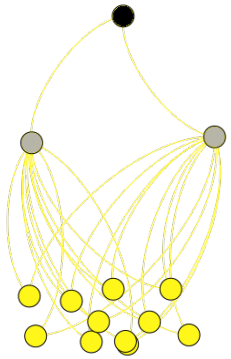


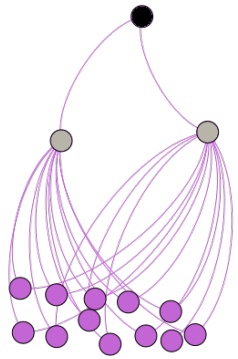


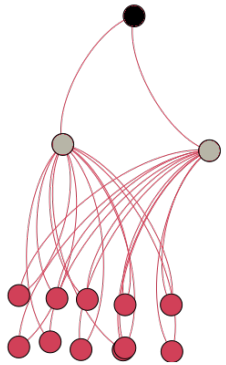


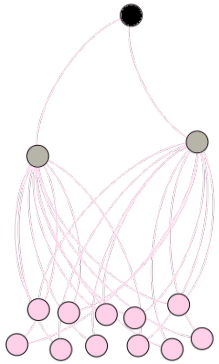


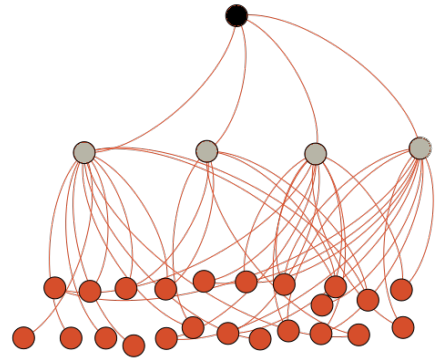












Snooping Behavior

- Wide variety of behavior
- Automated vs manual probing
- Aggressive, periodic probing
- Attempts to find vulnerabilities
  - SQL Injection
  - XSS
  - Path traversal
  - PHP Easter Eggs
  - Targeting Drupal and Ruby on Rails

Snoopers' Most Likely Geolocation

Snoopers' Identity

- Hard to identify the real entity behind the relays
- More than half of the HSDirs are hosted on cloud platform
- The geolocations correspond to the location of the hosting platform and not necessarily the entity running them
- Number of cloud platforms are located in countries with stronger privacy protection for costumers
- Some cloud platform accept payments over bitcoin, making it even harder to identify the real actors

Conclusion

- Honey Onions (HOnions) is a framework to detect snooping HSDirs
- Provides a lower bound on such relays
- Tor relies on the honest behavior of the volunteering relays
- The detection, identification and mitigation of misbehaving relays helps to improve the privacy and security of Tor
- This work is an addition to the previous body of work focusing on detection of misbehaving Tor relays