Combinatorial Methods and Models for Privacy

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Combinatorial Methods in the Context of Privacy

Combinatorial Browser Fingerprinting

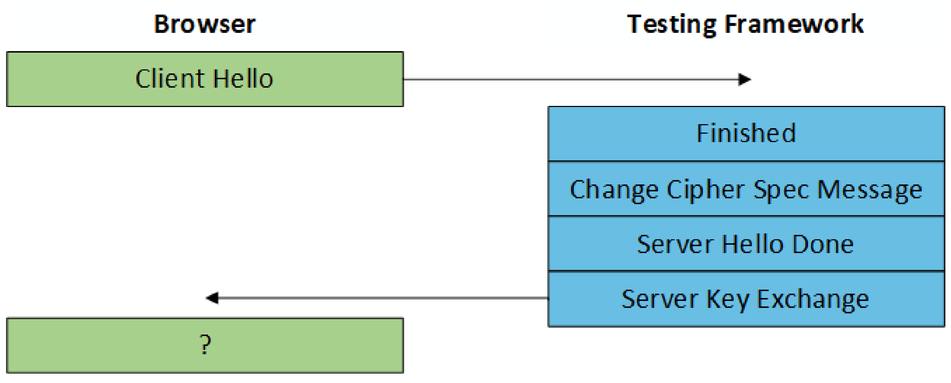
- Distinguish between Browsers using TLS-Handshake messages.
- Novel approach that does not need JavaScript.

Anonymity Networks

- Combinatorial design structures for analysis and as building blocks.
- Analysis of anonymity networks with Design of Experiments.

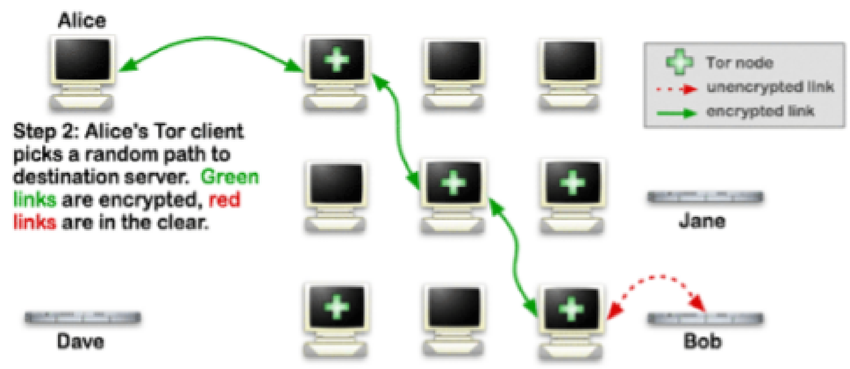
Browser Fingerprinting

- Browsers are widely used to consume services over the Internet.
- Transport Layer Security (TLS) is used to keep connection secure.
- Different TLS-Implementations expose different behaviour, especially when exposed to manipulated Handshakes.
- This allows distinction between browsers.



Anonymity Networks

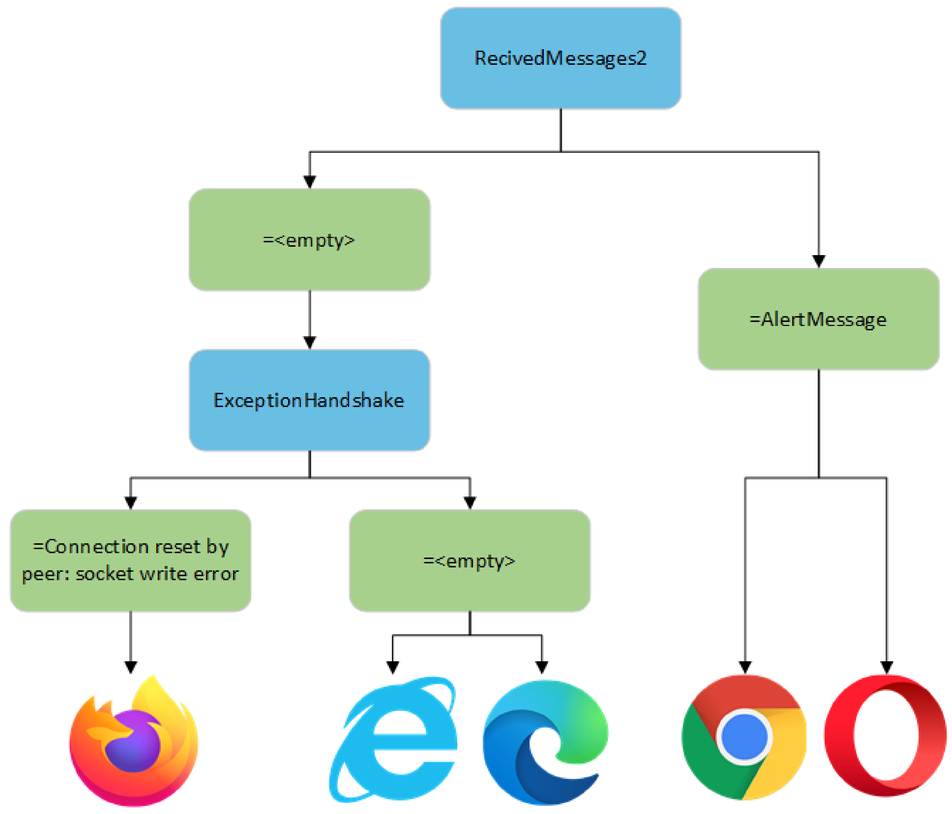
- Analysis of low-latency anonymity overlay networks.
- **T**he **O**nion **R**outer (Tor) de-facto standard for online anonymity.
- Hides IP addresses of hundreds of thousands of users every day.
- Combine flow-networks and block designs for new attacks.



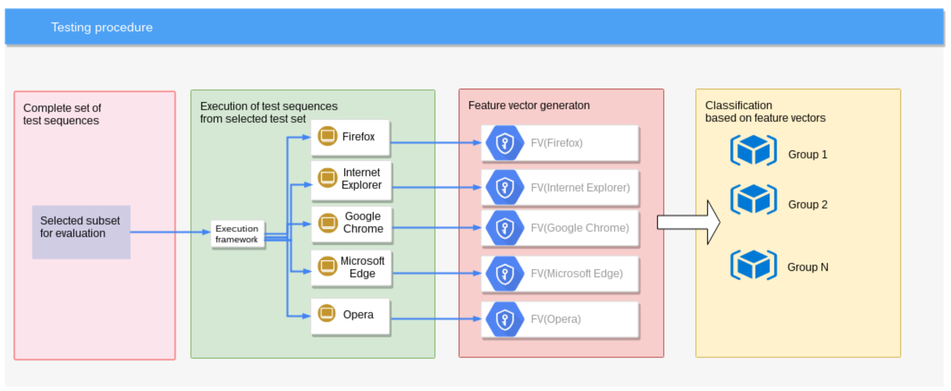
Sequences

- The six server-side TLS handshake messages are regarded as a set of six abstract events $\mathcal{M}$.
- $\mathcal{M}$ = {*ServerHello*, *Cert*, *ServerKeyExchange*, *ServerHelloDone*, *ChangeCipherSpec*, *Finished*}.
- All permutations of any non-empty subset ***E*** of $\mathcal{M}$ are tested, therefore all SCAs defined over the elements ***E*** are included.
- A row in a SCA created in such a way is a test sequence that can be transformed to a sequence of actual TLS handshake messages.
- Example: $\{0, 3, 2, 1\}$ translates to {*ServerHello*, *ServerHelloDone*, *ServerKeyExchange*, *Cert*}.

Decision Tree Based on a Single Test



Testing Methodology



Testing Framework:

- Java-based software that automatically records behaviour of Browsers
- Uses TLS-Attacker to execute manipulated TLS Handshakes
- Only the sequence of the six server-side TLS messages is altered
- All possible $\sum_{i=1}^{6} \binom{6}{i} \cdot i! = 1956$ permutations were tested

Evaluation

- Five Browsers were tested (Chrome, IE, Edge, Firefox and Opera).
- The best possible splitting was based on the browser families: {Chrome, Opera} {IE, Edge} {Firefox}.
- Distinguished by pairwise comparison of their feature vector.
- The best possible distinction was achieved even using sequences of length 2 (higher-strength sequences also yielded this outcome).

Bernhard Garn, Dimitris E. Simos, Stefan Zauner, Rick Kuhn, and Raghu Kacker. Browser fingerprinting using combinatorial sequence testing. In *Proceedings of the 6th Annual Symposium on Hot Topics in the Science of Security*, HotSoS '19, New York, NY, USA, 2019. Association for Computing Machinery.

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