On the Applicability of Traffic-splitting Strategies as a Protection Shield against End-to-end Traffic Correlation Attacks in Tor

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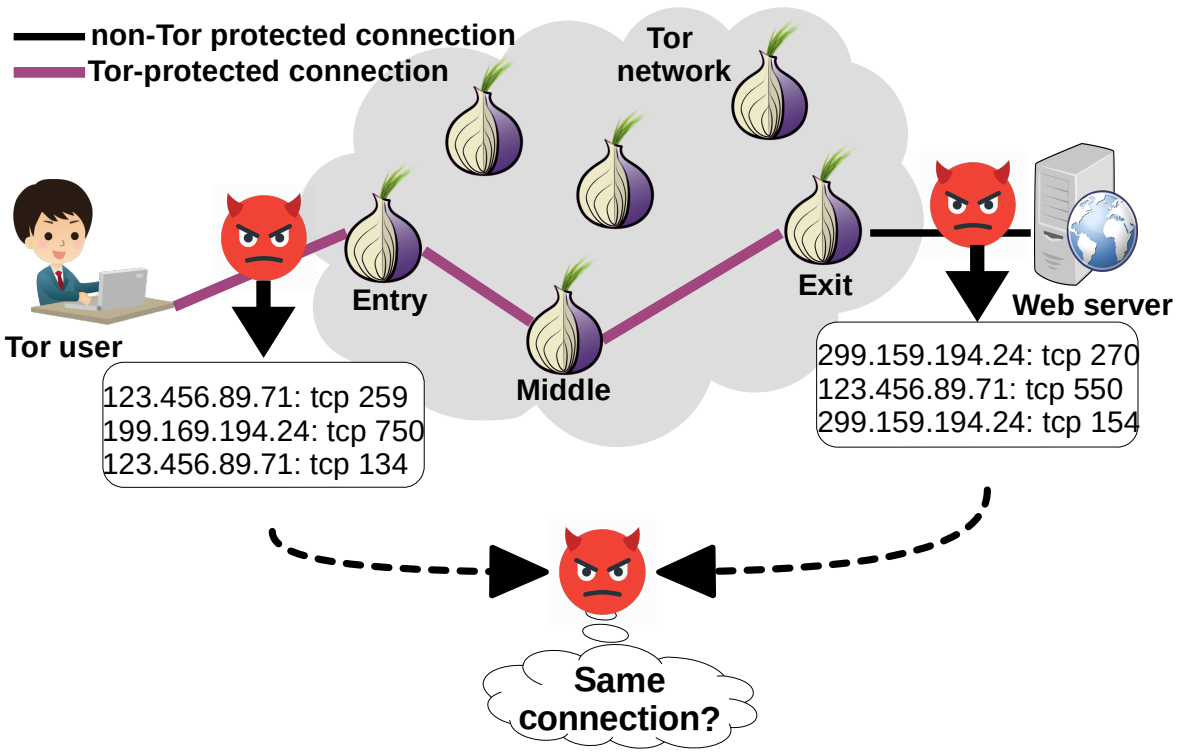
- **Tor – most popular low-latency anonymization network**
  - Hides the relationship between users and websites visited by them
- ***Problem:* Tor does not hide packet number, direction, timing**
  - Vulnerable to *end-to-end (E2E) traffic correlation* attacks



The Scope of This Work

- **E2E traffic correlation was considered impractical in real world**
  - Significant differences between the ingress and egress Tor traffic
  - Requires more computational resources to compare all traffic pairs
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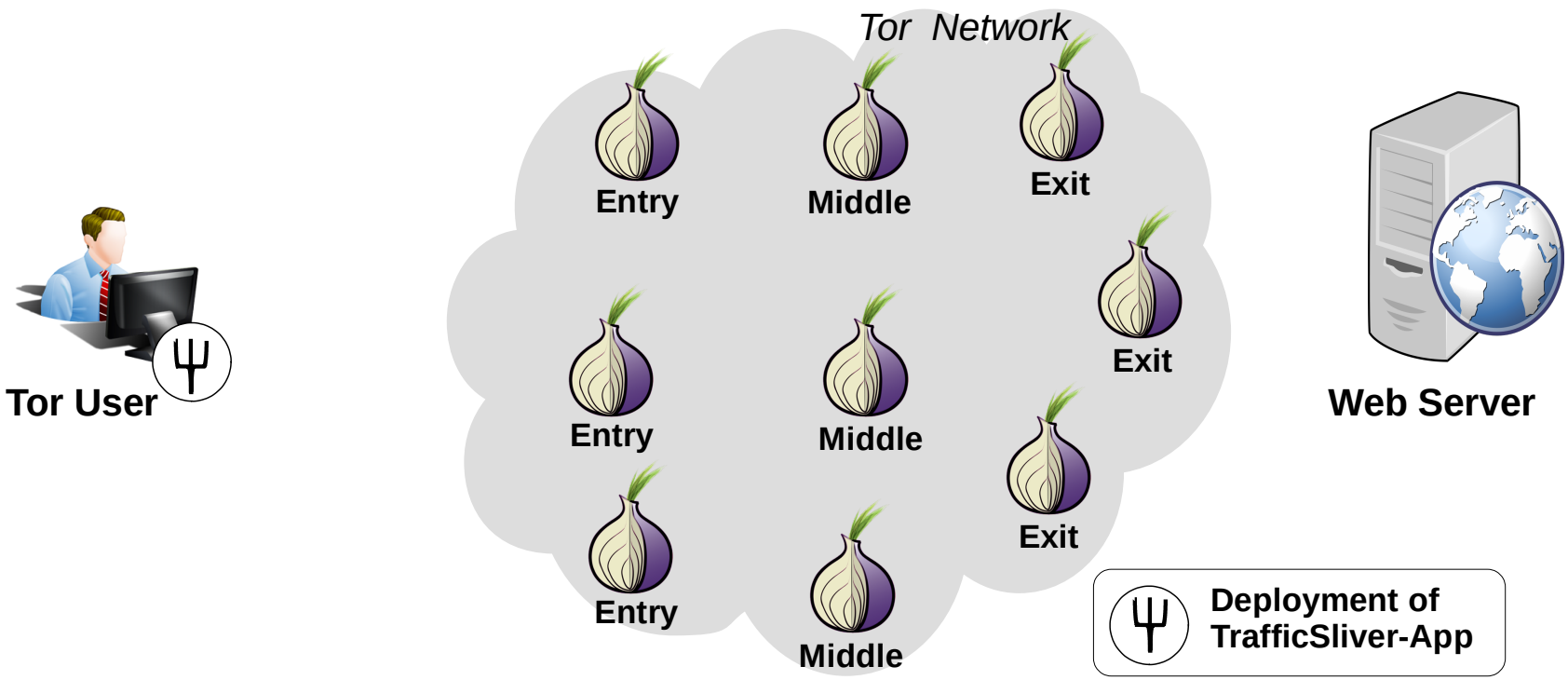
- **Our contributions**
  - Bridge the gap between E2E traffic correlation and website fingerprinting (WFP) communities
  - Identify defense protecting against both traffic analysis attacks
  - Assess the effectiveness of two state-of-the-art, traffic-splitting-based WFP defenses against E2E traffic correlation

Splitting-based Traffic Analysis Defenses (1/2)

- **TrafficSliver-App: Traffic splitting at the application layer**
  - Published at *ACM CCS '20*
  - Independent of the Tor network, minimal overhead
  - Send *single*, *full* HTTP requests via different entry nodes



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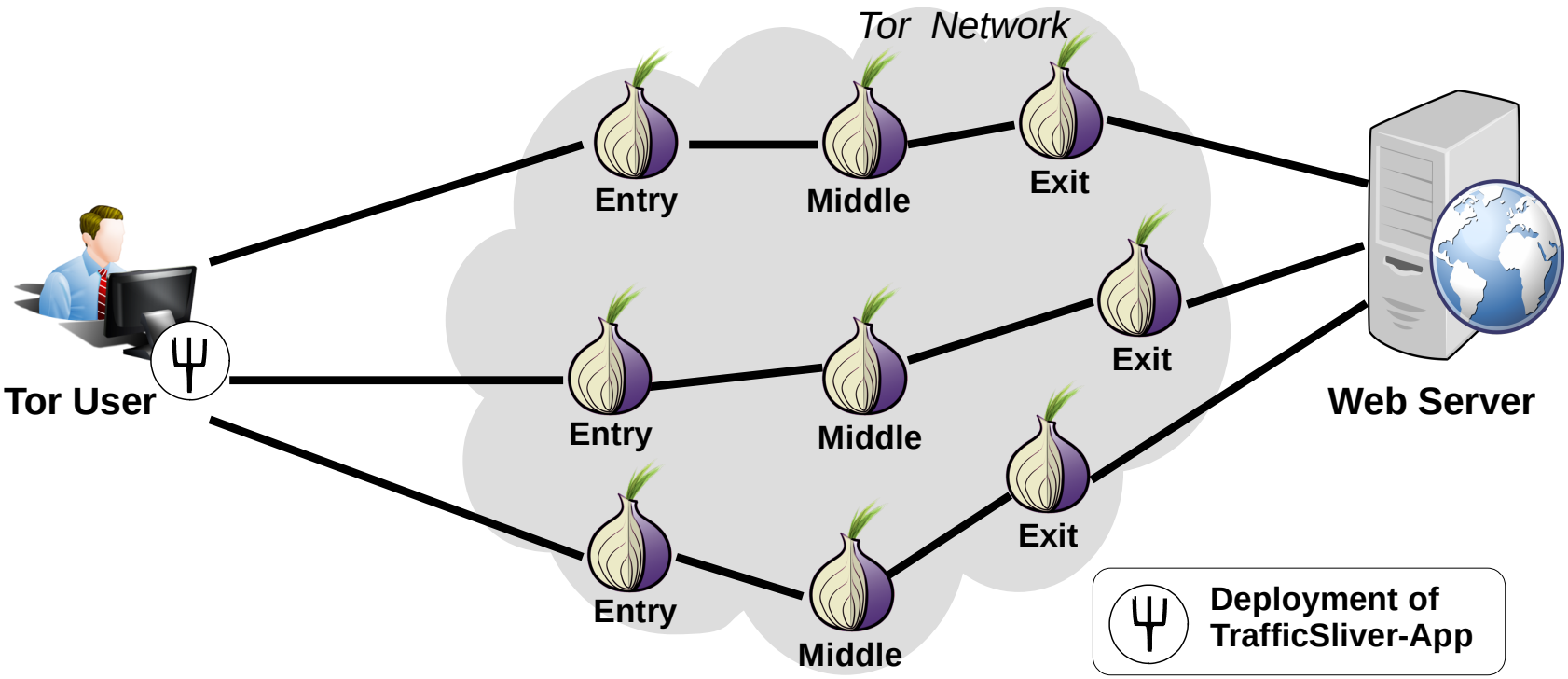

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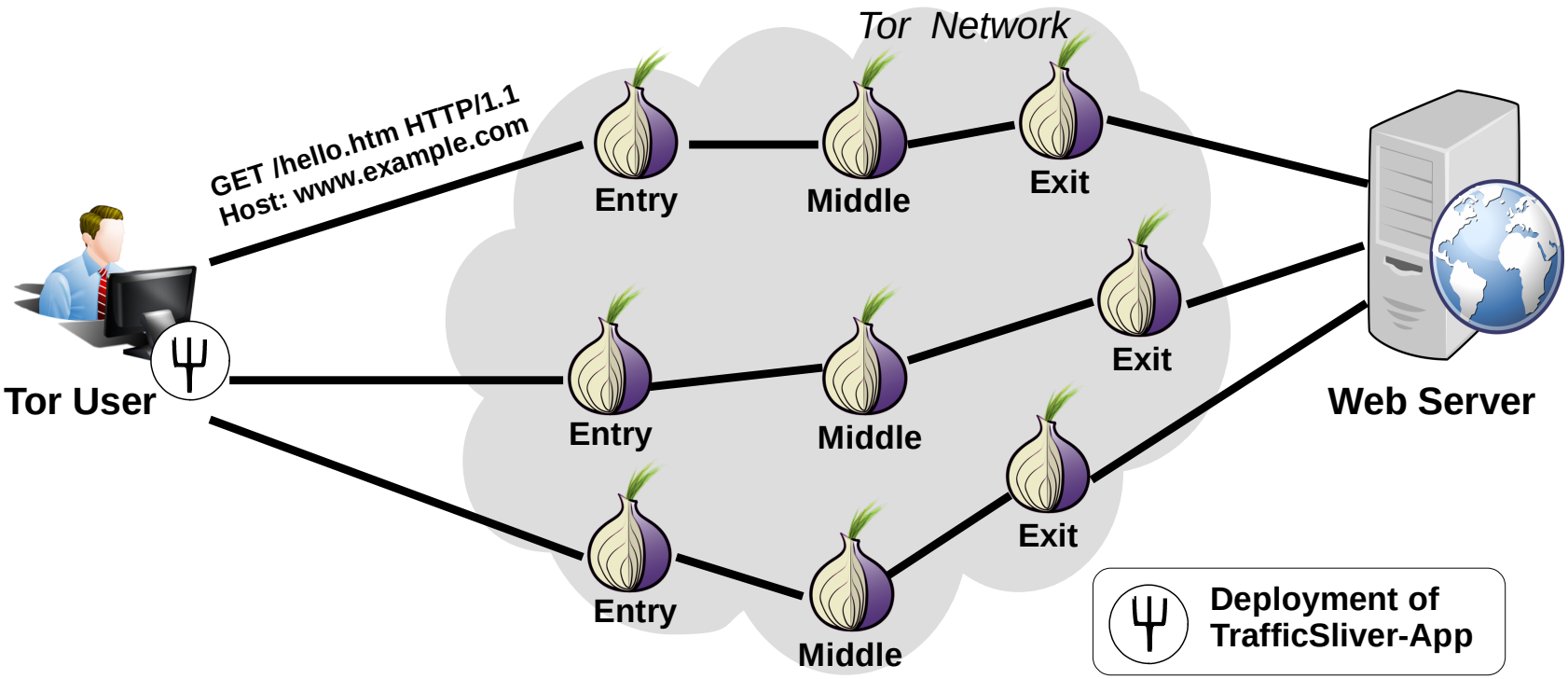

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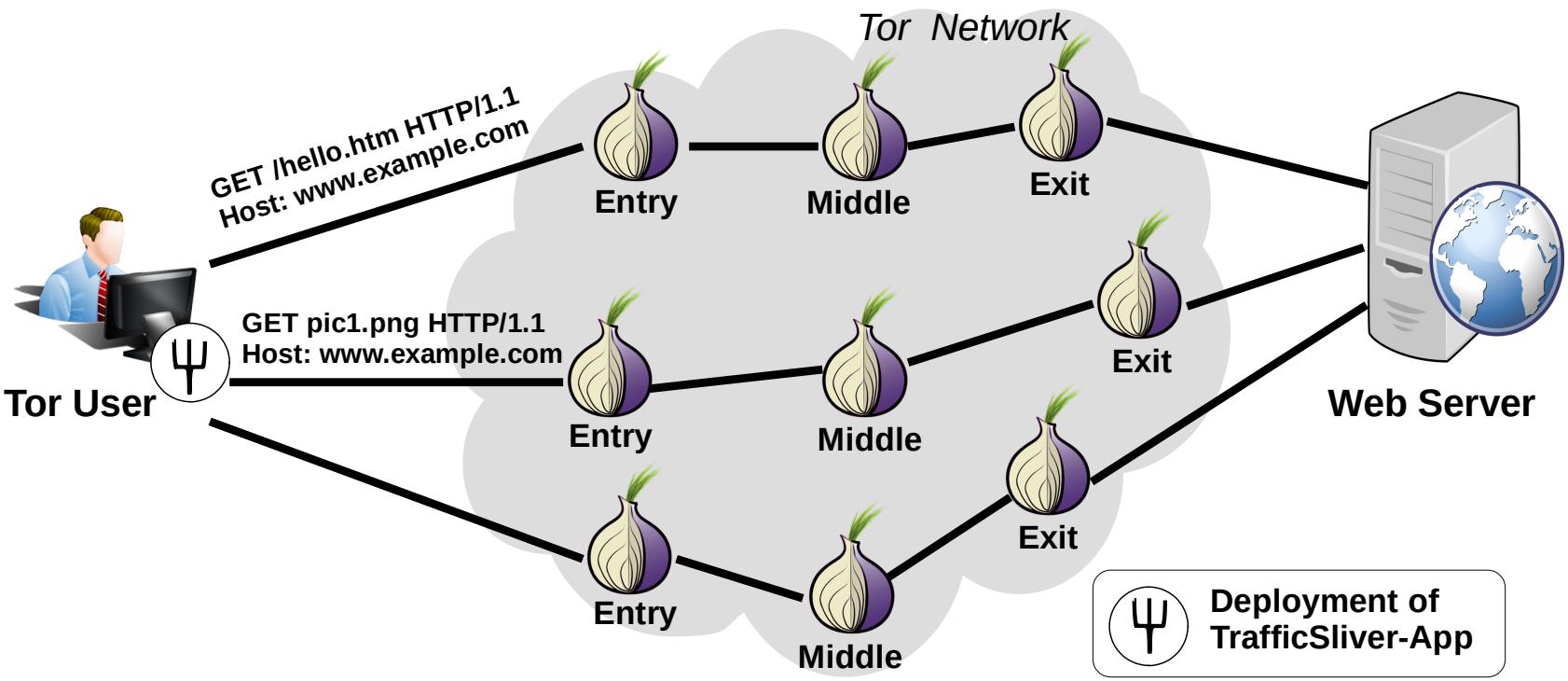

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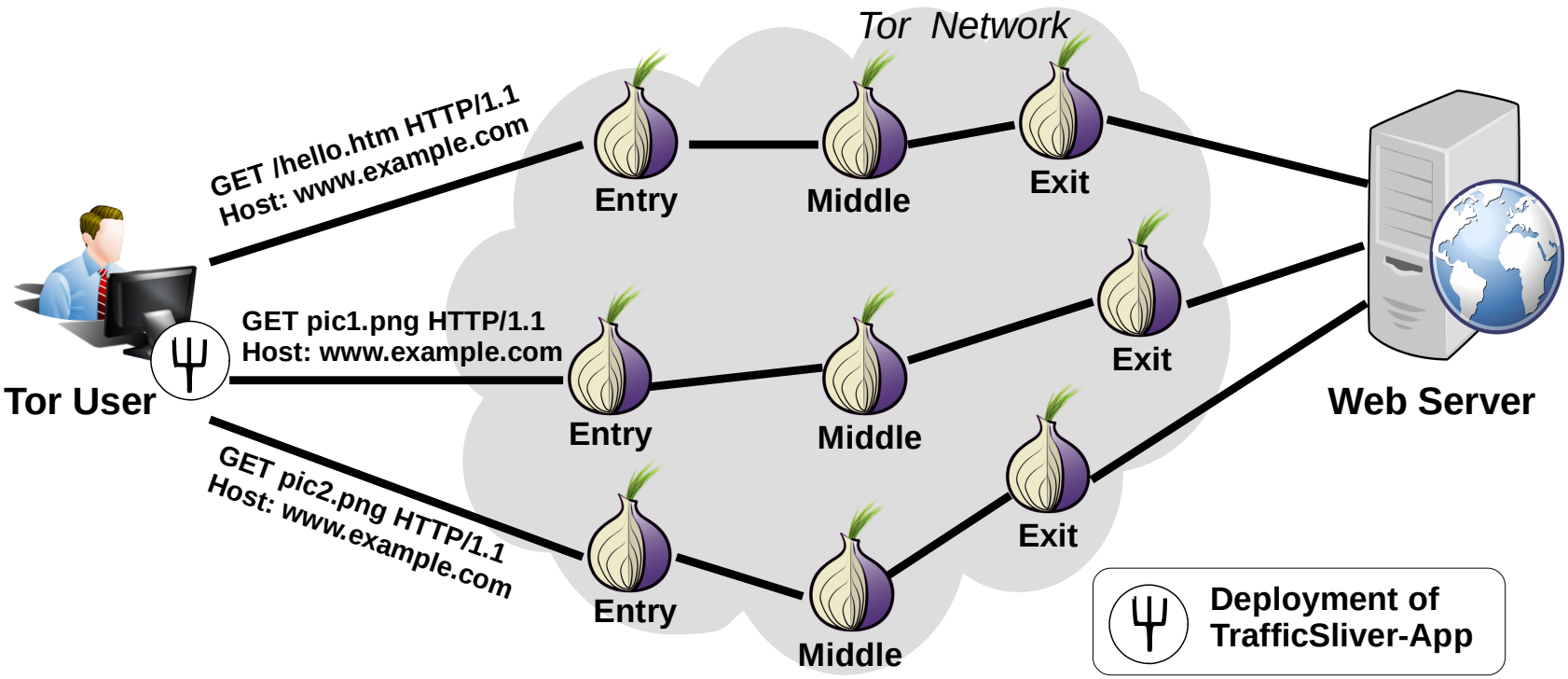

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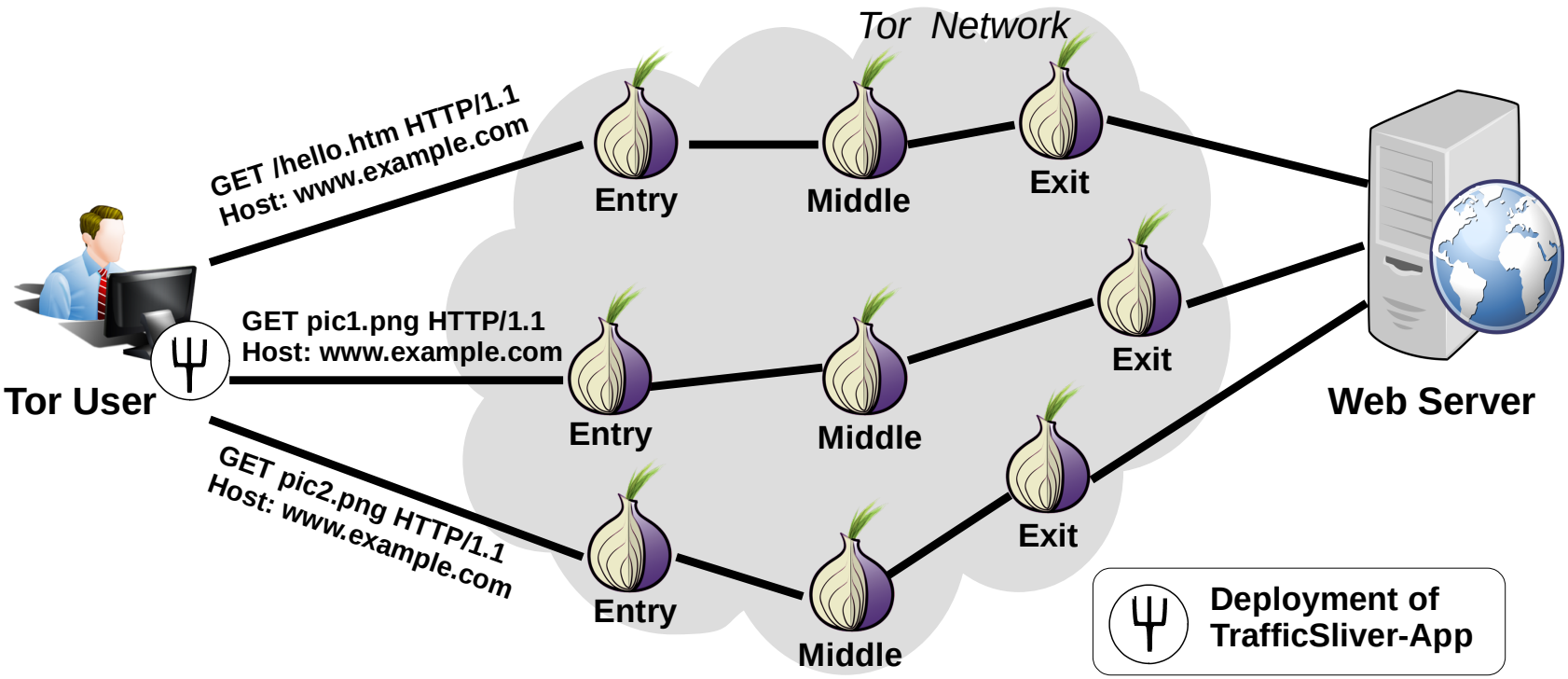
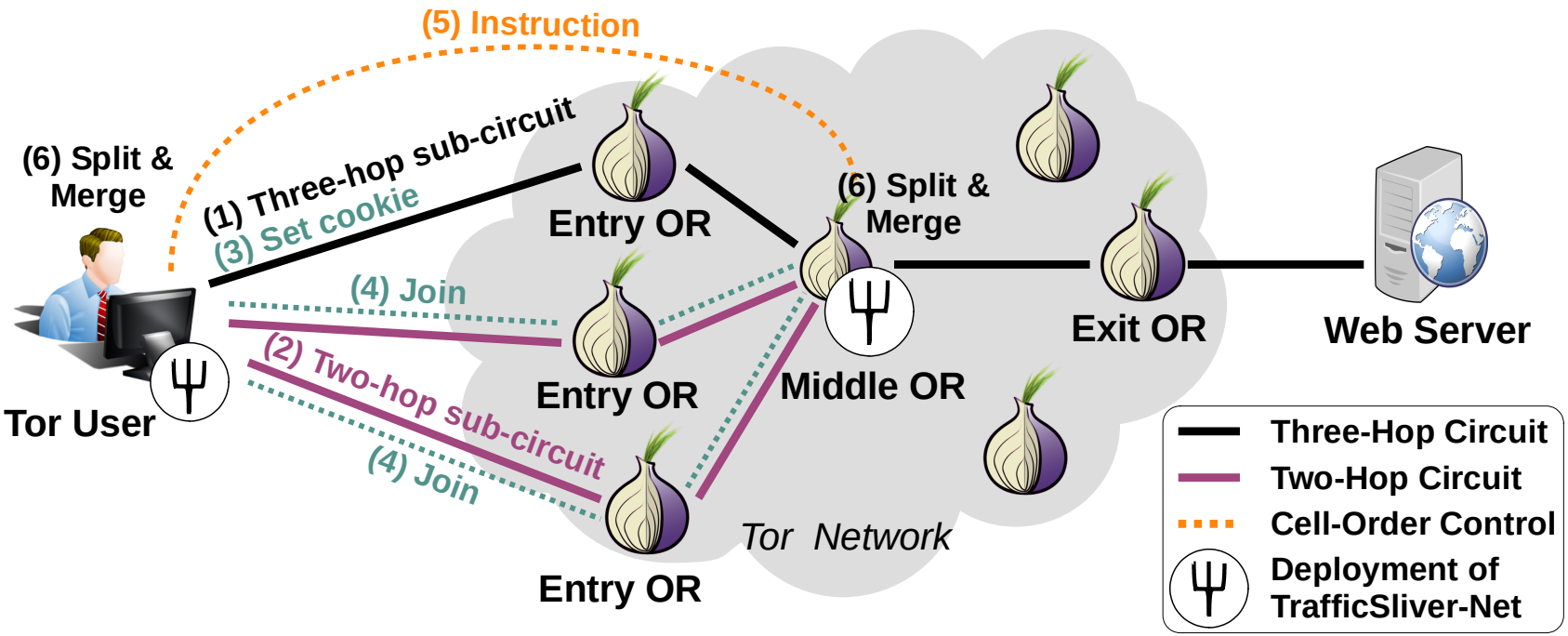
- ***Our extension*** **of the operational scope of TrafficSliver-App**
  - Different exit nodes for each sub-path of the multi-path connection
  - Single exit node for all sub-paths of the multi-path connection



Splitting-based Traffic Analysis Defenses (2/2)

- **TrafficSliver-Net: Traffic splitting at the network layer**
  - Published at *ACM CCS '20*
  - Modify Tor to distribute separate packets through different entry nodes
  - Splitting scheme: *Batched weighted random with five entry nodes*
    - Using a probabilistic distribution
    - Variable-sized batches of packets over multiple entry nodes



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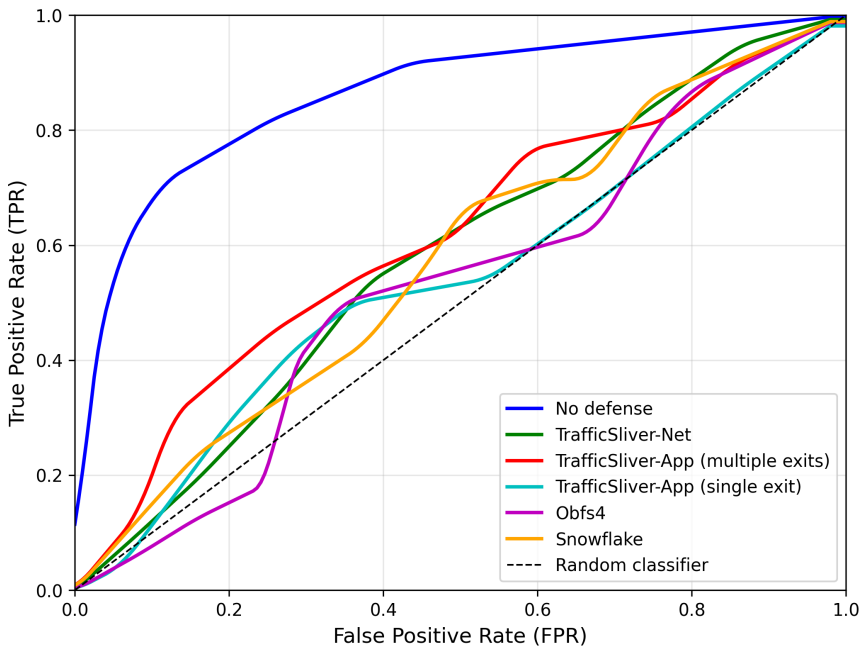
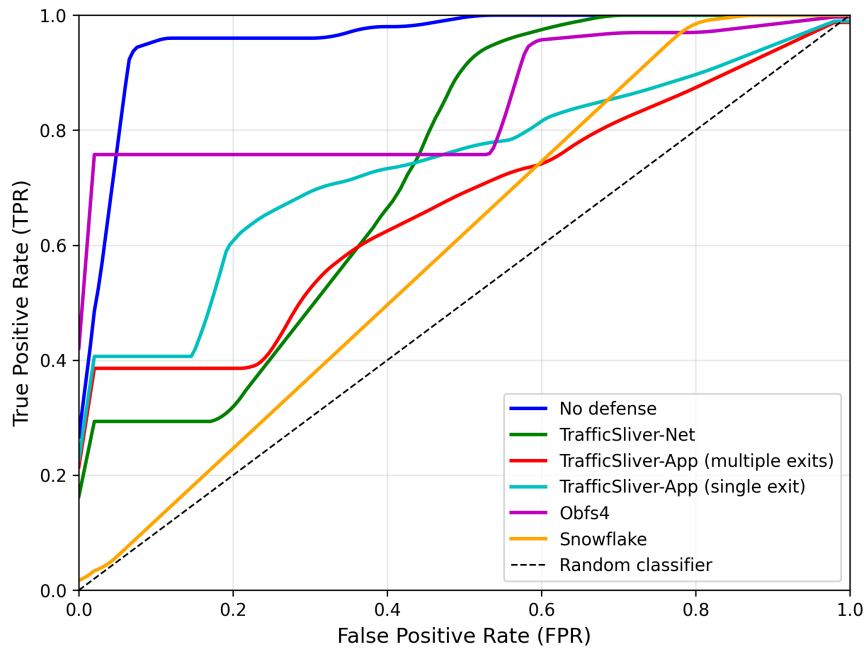
- **Classifiers and evaluation setup**
  - Two state-of-the-art E2E traffic correlation classifiers
    - DeepCorr (*ACM CCS '18*) and DeepCoFFEA (*IEEE S&P '22*)
  - Evaluated metrics
    - True positive rate (TPR): fraction of detected, correctly correlated pairs
    - False positive rate (FPR): fraction of pairs that were falsely identified as correlated

Evaluation (1/2)

- **TrafficSliver defenses against E2E traffic correlation**
  - Significant drop in classifiers' detection rate for both defenses
  - Higher detection rate for TrafficSliver-App with multiple exit nodes
    - Possibly due to isolation of unique web objects over single sub-paths
  - Effective attacks in vanilla settings do not necessarily imply superiority in case of defenses



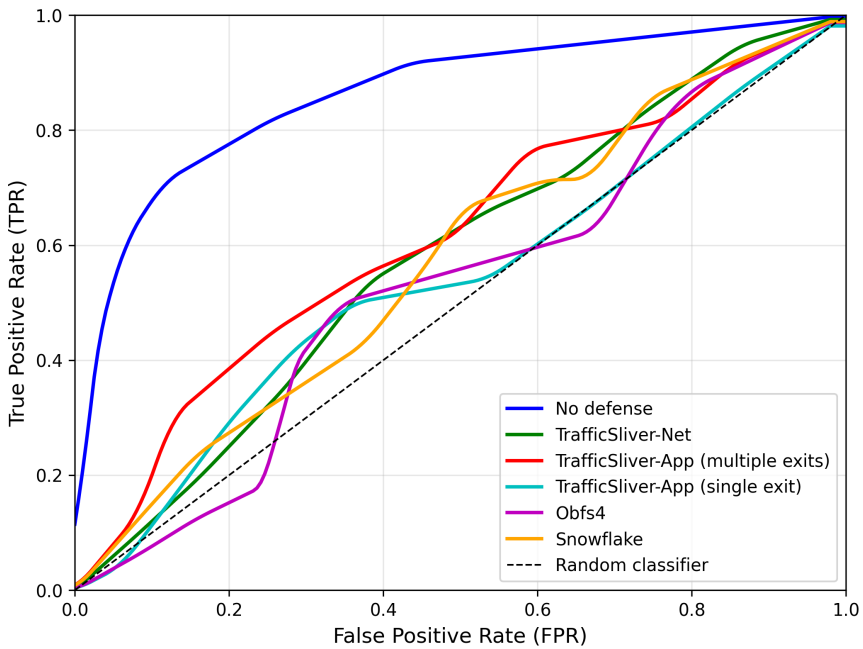
(a) DeepCorr



(b) DeepCoFFEA

Evaluation (2/2)

- **Comparison with Tor pluggable transports**
  - Obfs4's protection level is lower than TrafficSliver's for DeepCoFFEA
  - Snowflake provides higher level of protection than TrafficSliver defenses
  - *However,* pluggable transports are *not suitable* for all Tor users
    - Depend on the cooperation of Content Delivery Networks
    - Require Tor bridges, and have higher latency and bandwidth overhead



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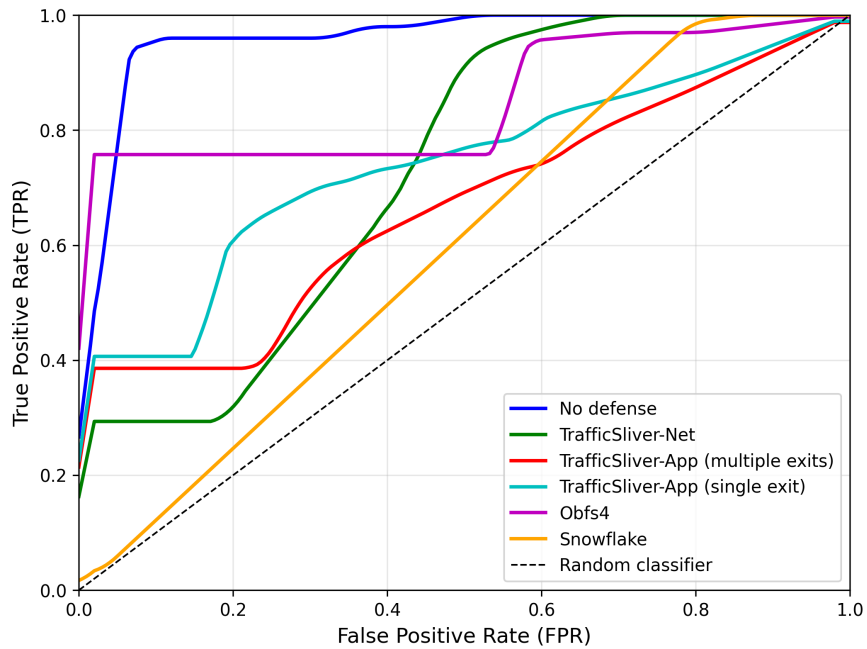

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  - Significant reduction of detection rates of modern E2E traffic correlation classifiers

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Thank you for your attention!