DISTDET: A Cost-Effective Distributed Cyber Threat Detection System

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Advanced Persistent Threat (APT) Attack

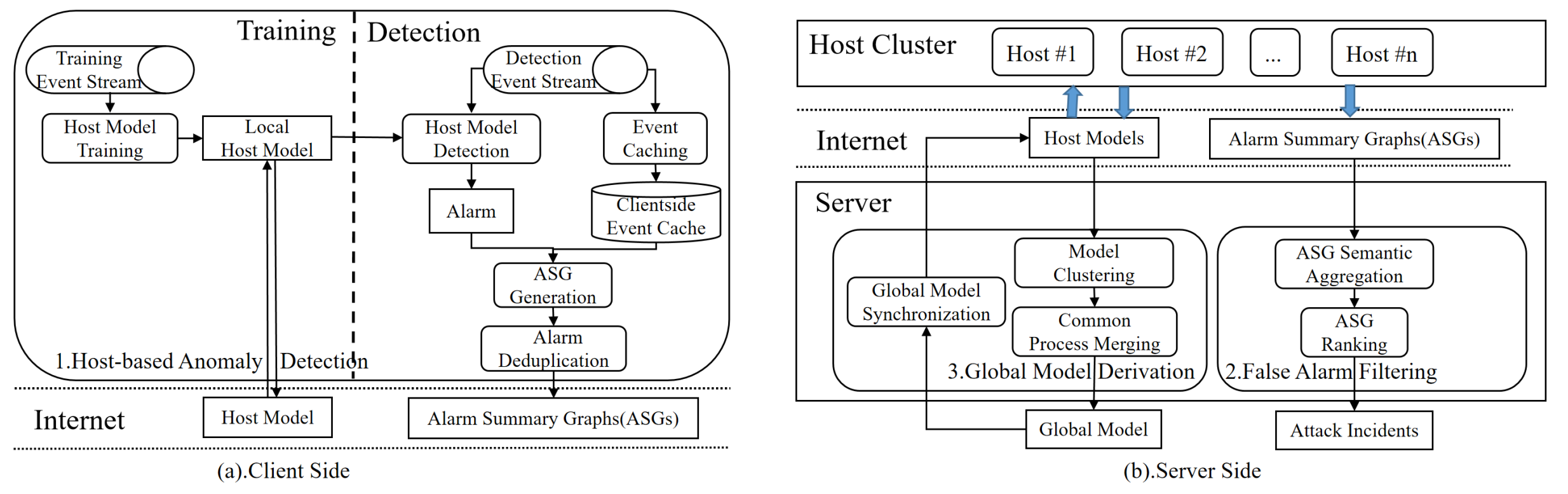
APT attacks have plagued many well-protected businesses

CYBERATTACK
PERSONAL INFORMATION EXPOSED
EQUIFAX
AS MANY AS 143 MILLION CUSTOMERS

- **Advanced**: **sophisticated** techniques exploiting multiple vulnerabilities
- **Persistent**: **continuously** monitoring and stealing data from target
- **Threat**: **strong** economical or political motives

DISTDET System

The first cost-effective detection system that synergistically combines **distributed computing**, **anomaly detection**, and **false alarm filtering** techniques for detecting and investigating advanced cyber attacks



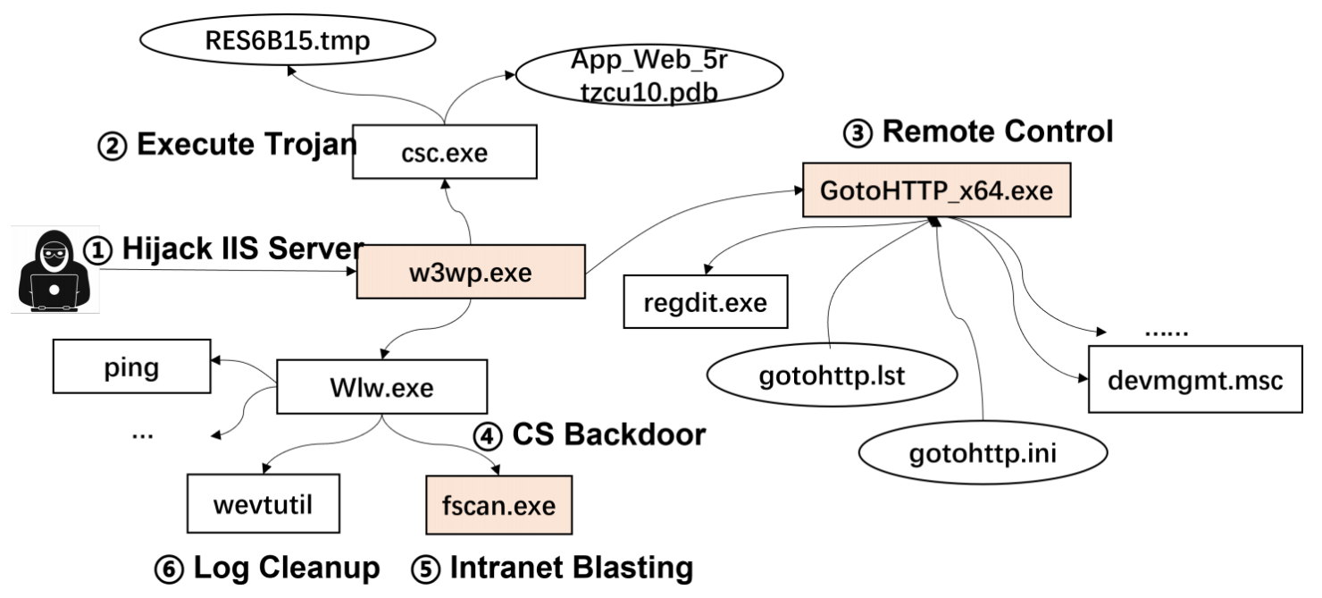
DISTDET Overview

- **Lightweight Client-Side Detection**
  - Shift part of the attack detection to the clients and transmit only summary graphs that represent potential attacks to the server.
- **Unique Properties of False Alarms**
  - False alarms typically possess some unique properties: (1) the alarms representing the same behaviors will be repetitively reported over a period of time; (2) many false alarms are related to the benign behaviors triggered by semantically similar commands; (3) the contexts for these alarms are generally known to represent benign behaviors.
- **Global View of Service Behaviors**
  - A global model built in the server can observe the behaviors in all the phases and can complement the missing observations in the local models.

Ubiquitous System Monitoring

- Build a **provenance graph** based on system events collected from system kernels, describing operations of system entities (e.g., process read/write files).
- **Contextual information** in the provenance graph is effective in revealing advanced attack tactics.

Entity↔Entity	Operation Types
Process→File	read, write, create, chmod, rename
Process↔Process	fork, clone, execve, pipe
Process→IP	sendto, recvfrom, recvmsg, sendmsg

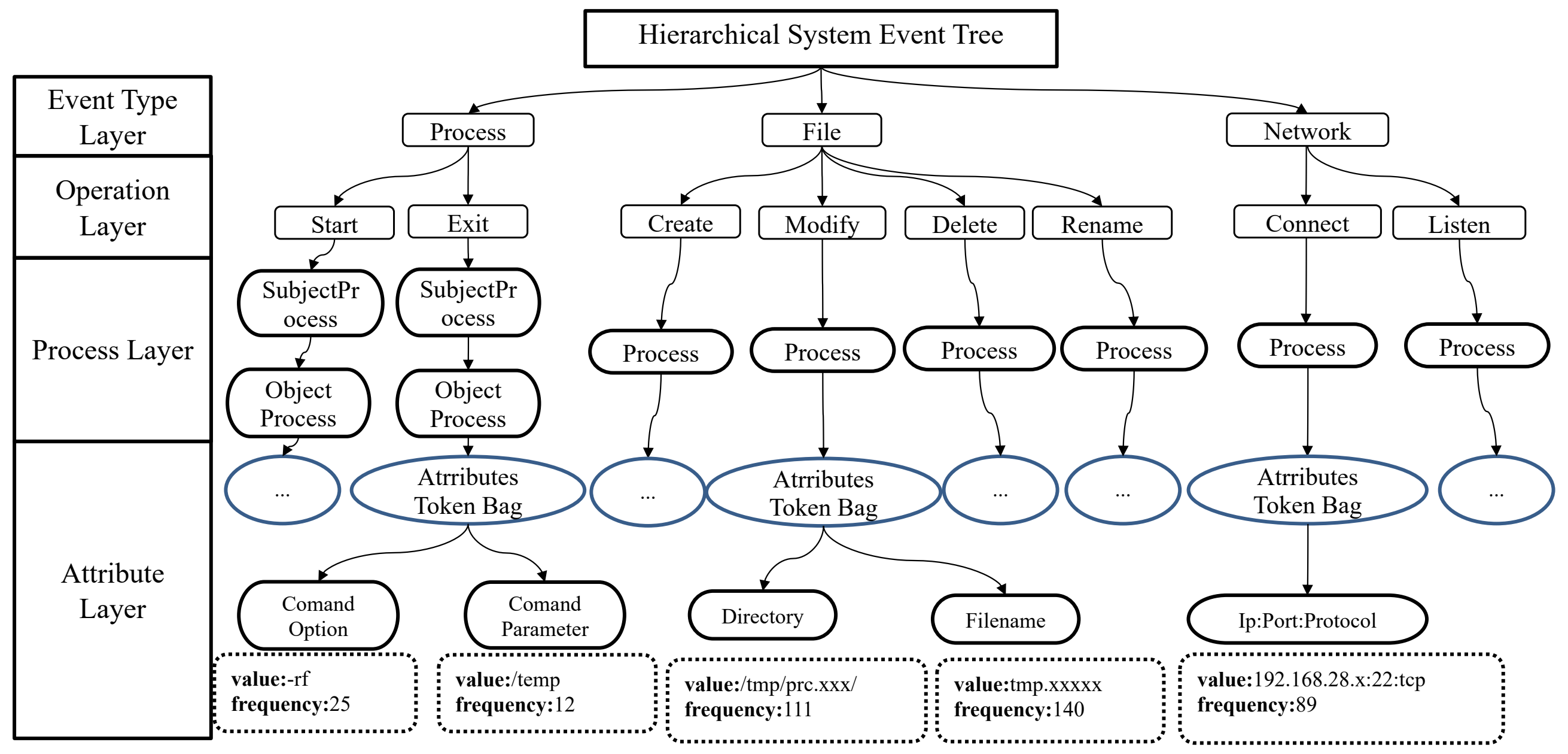


Fundamental limitations in efficient attack investigation

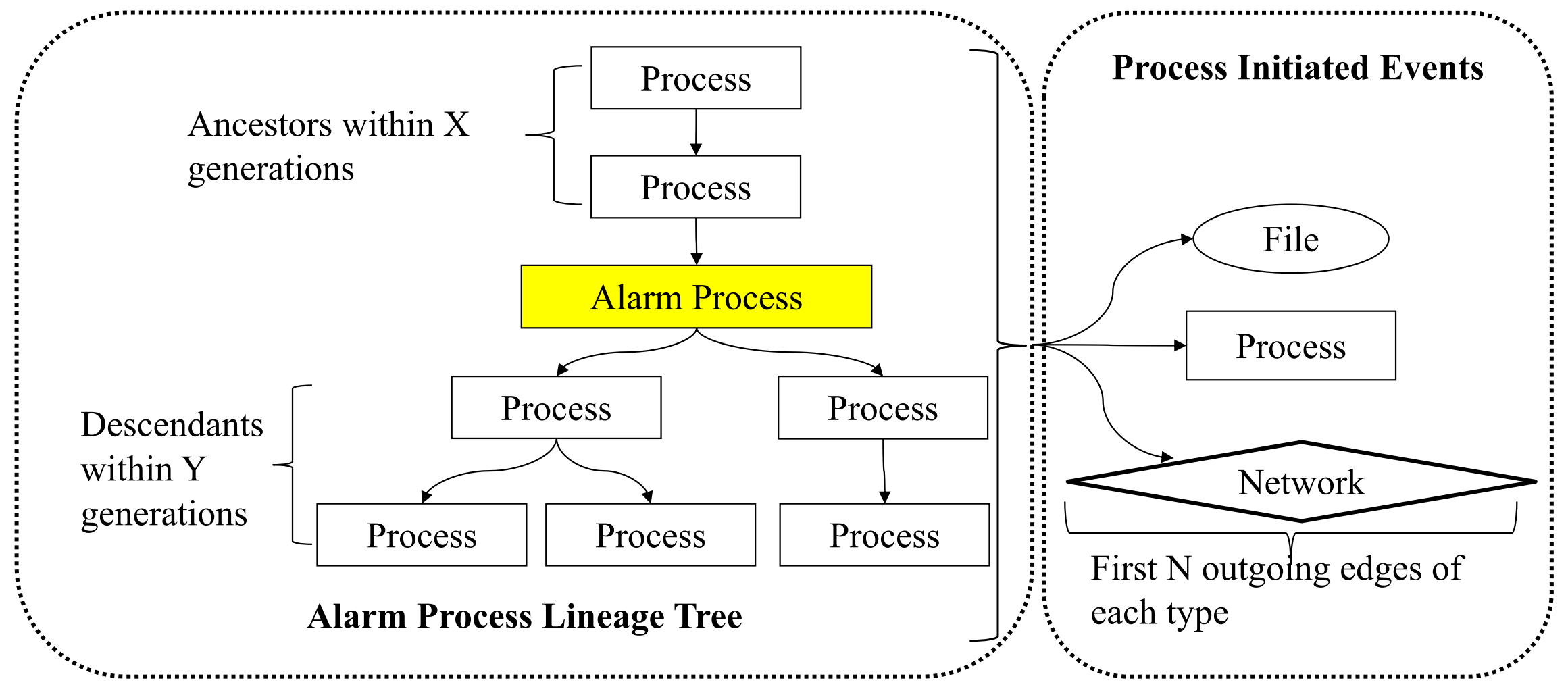
- **Intolerable computational overheads**: constructing provenance graphs consumes significant computing resources.
- **Poor balance in precision and recall for detection**: it is difficult to achieve a balance of precision and recall in detection.

Host-based Anomaly Detection – HST and ASG

- Hierarchical System Event Tree (HST) is a compact index that categorizes auditing events based on their properties using a multi-layer tree. It is built based on training events. Any event not observed in the built HST will generate an alarm.
- An Alarm Summary Graph (ASG) is a summary graph that includes the process p that initiates the suspicious behavior reported in an alarm, and the events initiated by p's ancestor processes and descendent processes.



Hierarchical System Event Tree (HST)


Ancestors within X generations
Process
Process
Alarm Process
Descendants within Y generations
Process
Process
Process
Process
Process
Alarm Process Lineage Tree
Process Initiated Events
File
Process
Network
First N outgoing edges of each type

Alarm Summary Graphs (ASG)

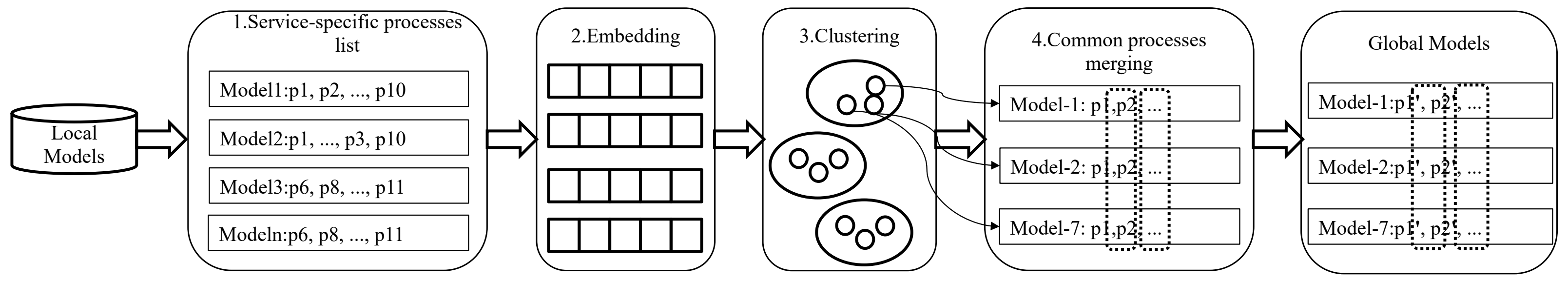
False Alarm Filtering

- **Observation**: "*the alarms representing the same behaviors will be repetitively reported over a period of time*"
  - **Alarm Deduplication**: Alarms with the same events in a time window are aggregated into one alarm
- **Observation**: "*many false alarms are related to the benign behaviors triggered by semantically similar commands*"
  - **ASG Semantic Aggregation:** ASGs with similar commands are aggregated into one ASG
- **Observation**: "*the contexts for these alarms are generally known to represent benign behaviors*"
  - **ASG Prioritization: C**ompute anomaly scores of aggregated ASGs based on rareness (frequency) and filter those with low anomaly scores

Global Model Derivation

Observation: "*local models can easily lead to false alarms in detection*"

- Cluster the host models based on the services provided by the hosts
  - Extract the list of service-specific processes from each host model
  - Compute the word embeddings of the extracted processes' names
  - Use k-means algorithm to cluster the host models
- Merge the behaviors of the common processes in the same cluster



Evaluation Summary

- Reduce the host cost (the expense of securing a single host) from 3.4 USD to 0.061 USD (56× reduction)
- Outperform the state-of-the-art approaches
  - Achieve a F1 of 0.98 for the industry arena and DARPA TC datasets
  - Achieve a F1 of 0.89 for the public arena dataset
- DISTDET reduces the false alarms from 230 alarms/host/day to 0.71 alarms/host/day, saving 99.69% of the required inspection efforts.
- DISTDET found 900+ real attacks during roughly 6 months and achieved better performance than other existing EDRs.

Feng Dong, Liu Wang, Xu Nie, Fei Shao, Haoyu Wang, Ding Li, Xiapu Luo, and Xusheng Xiao. **DISTDET: A Cost-Effective Distributed Cyber Threat Detection System**. In *Proceedings of the USENIX Security Symposium (USENIX Security 2023)*, Anaheim, CA, USA, May 2023.