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FLAME:
A Flow-level Anomaly Modeling Engine

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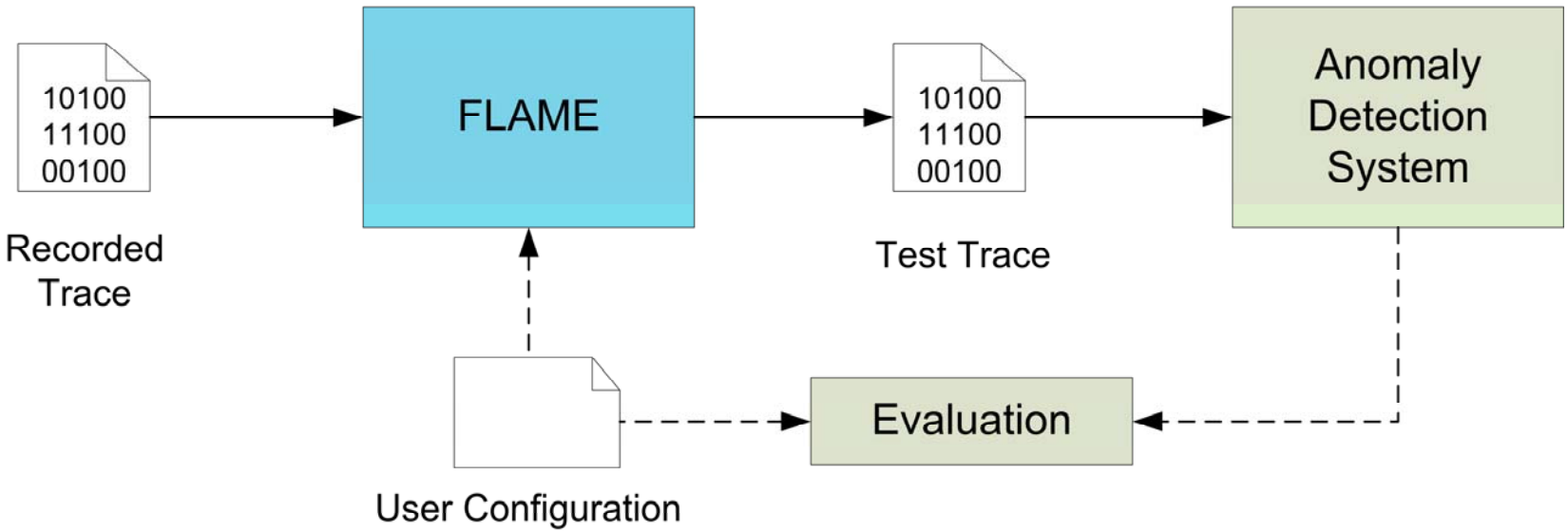
Motivation

- Many approaches for NetFlow-based anomaly detection developed in recent years
  - PCA, Kalman/bloom filter, clustering, wavelets, SOMs, sketches,...
- Evaluation of approaches is difficult since appropriate evaluation traces are not available
  - Appropriate means labeled, versatile, representative, and of sufficient size and length

Available Evaluation Methods

- Trace Merging
  - Merge captured trace with attack traffic e.g., output from nmap scanner → generate flows
  - Drawbacks: too simplistic, network characteristics might not match
- Shape injection
  - Inject anomaly of certain shape, e.g., rectangle, directly into metric used by detector
  - Drawbacks: too specific, required for each metric, unrealistic
- Simulation/Emulation
  - Emulate network nodes and generate traffic synthetically
  - Drawbacks: limited size of experiments, generation of background traffic is difficult

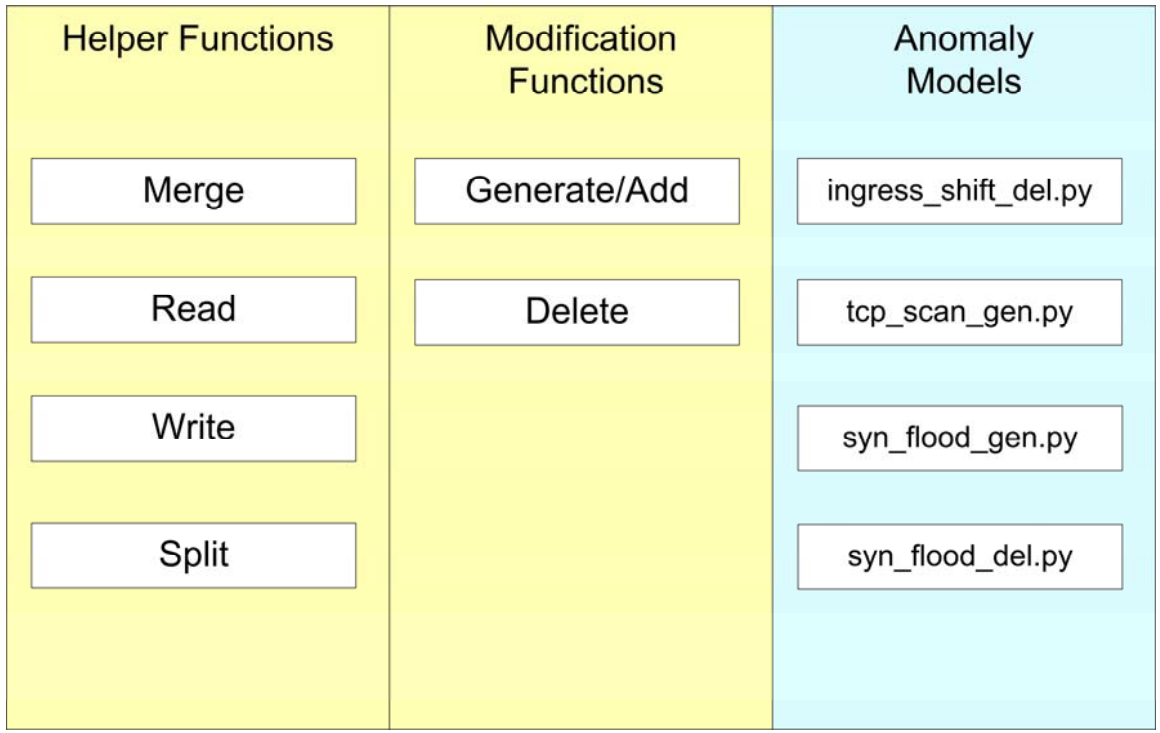
Anomaly Injection for ADS Testing



Anomaly Injection by Trace Modification

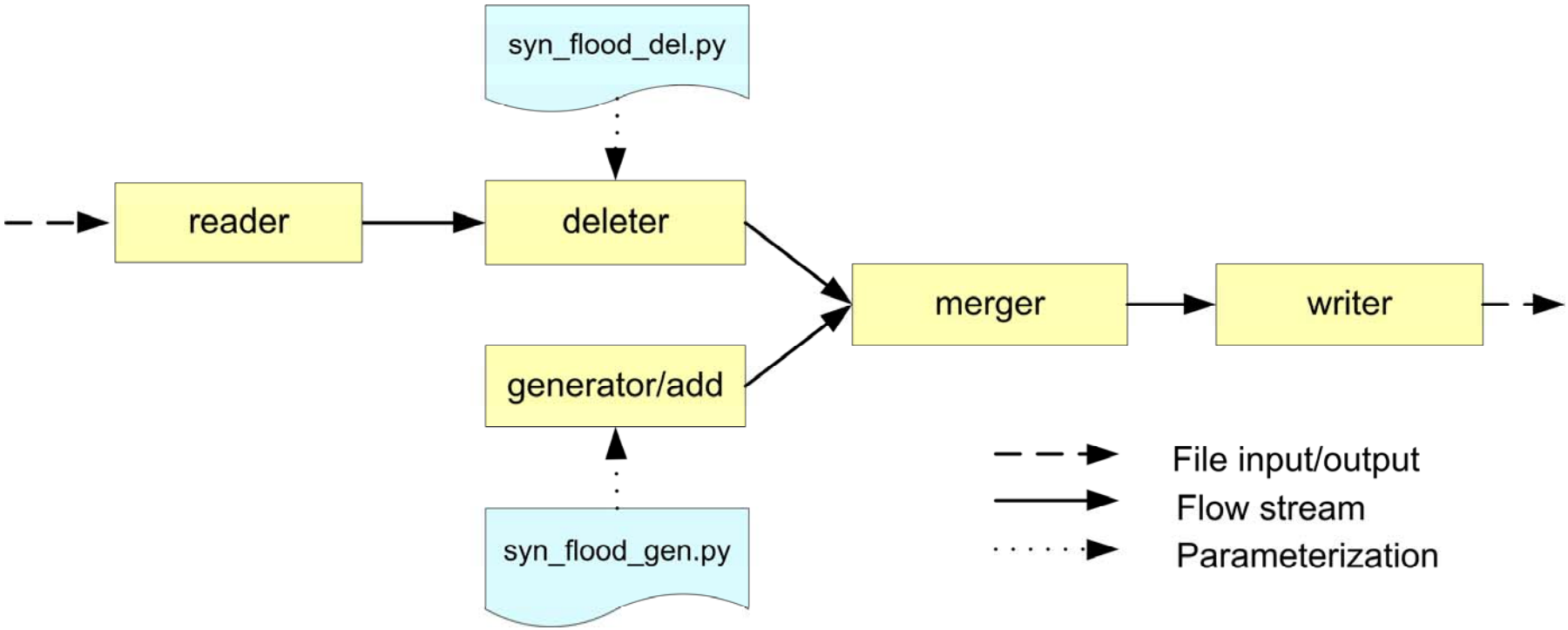
- Advantages
  - High reproducability
  - Applicable to different data sets
  - Fine-grained anomaly parameterization possible
  - Generic with respect to detector since it modifies traffic directly (not derived metrics)
- Disadvantages
  - Interaction with background traffic must be accounted for by the anomaly model
  - Attack mitigation approaches cannot be evaluated
  - Manual labeling of background traffic still necessary

FLAME: An experimentation framework



FLAME is flexible, easily extensible, and available (so far upon request)

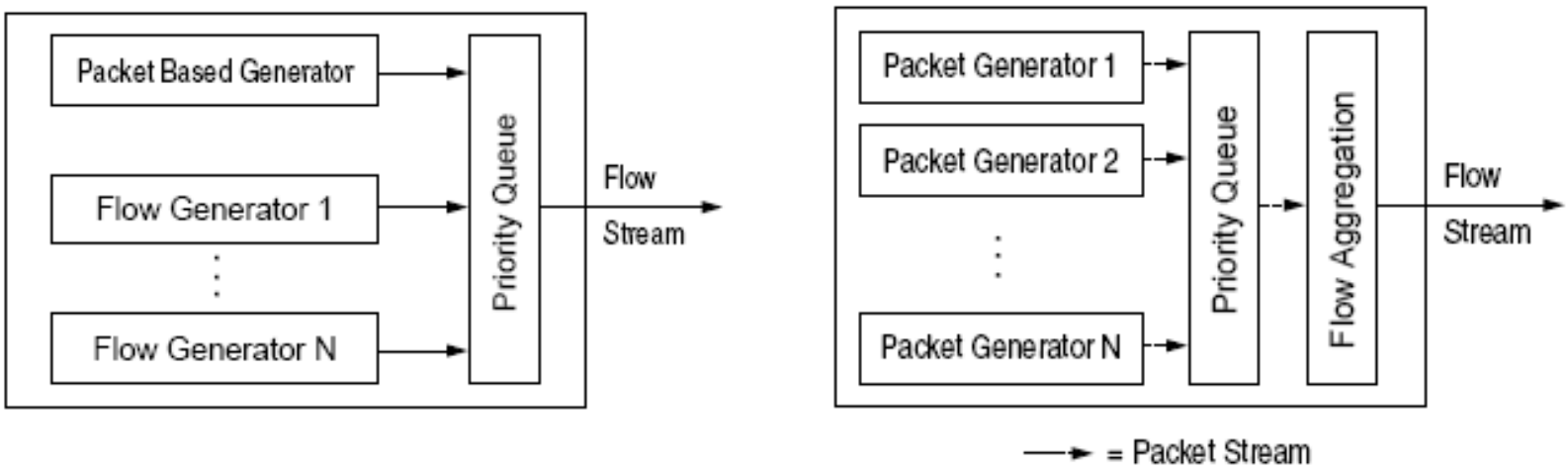
Setup Example



Flow vs Packet Generation

- Packet-level traffic generation has advantage that flow export settings (timeouts, sampling rates) can be adapted to the underlying trace → less injection artifacts
- Packet-level models might not be available for all attacks (especially if models are extracted from flow traces), potentially more expensive
- FLAME supports packet-level and flow-level traffic generation

Generator/Add Component



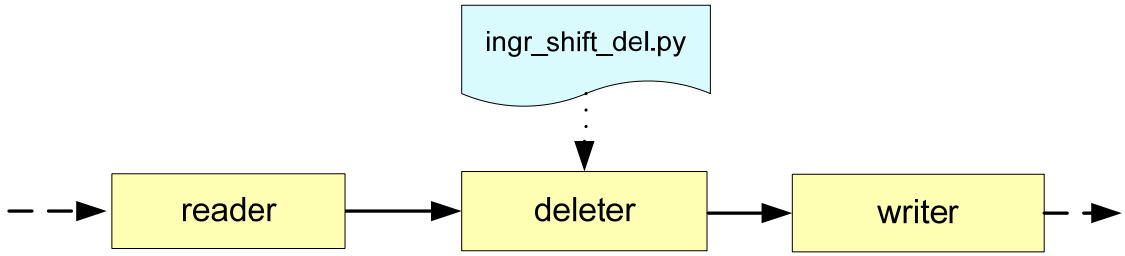
Implementation Summary

- Communication between components via named pipes
- Producer-consumer synchronization with bounded buffer size (consumer waits for input from producer)
- Generic flow forwarder interface between core components (based on NetFlow v5)
- Configuration for deleter and packet generator via embedded Python (plug-ins)
- Performance: 140‘000 flow records per second (4-way Linux, dual-core CPUs, 2.2 GHz, 8 GB RAM)

Types of Anomalies

- Subtractive Anomalies
  - **Delete** flows with defined characteristics from existing traffic
  - Examples are outage events, ingress shifts
- Additive Anomalies
  - **Add** flows with defined characteristics to existing traffic
  - Examples are alpha flows, scans, bots
- Interactive Anomalies
  - **Delete** exisiting flows, and **add** new flows
  - Examples are denial of service attacks

Example 1: Ingress Shift



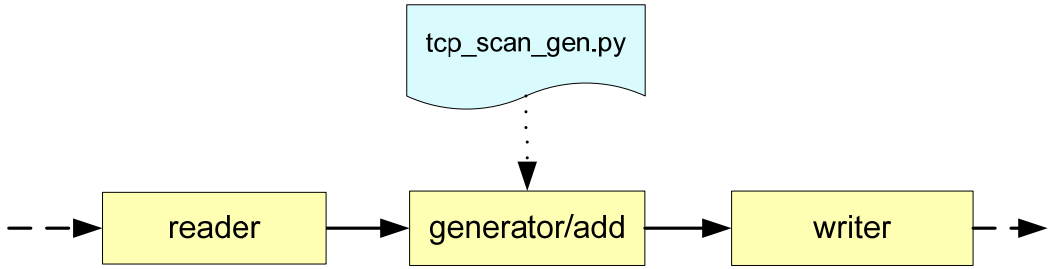
- **Deleter Model (python pseudo code):**

```
if (start < time < end) {
        if (source or destination IP address within range){
                delete flow;
        }
}
```

- **Deleter Parameters:**

  start, end, shifted IP address range

Example 2: Constant Rate TCP SYN Scan



- **Generator Model on packet level (python pseudo code):**

  while (start < time < end) {

  generate TCP SYN packet header

  generate reply with constant delay plus random offset, reply is either nothing, TCP RST, TCP SYN/ACK, or ICMP dest unreachable (source is router)

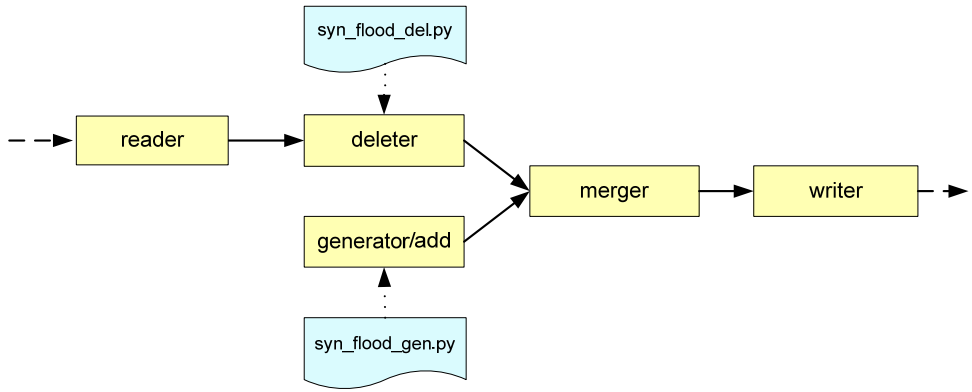
  advance time by 1 / scan rate

  }

- **Generator Parameters:**

  start, end, scan rate, scanned IP address range, scanner‘s source IP address, probability for each reply type, source/destination port

Example 3: Constant Rate SYN flooding

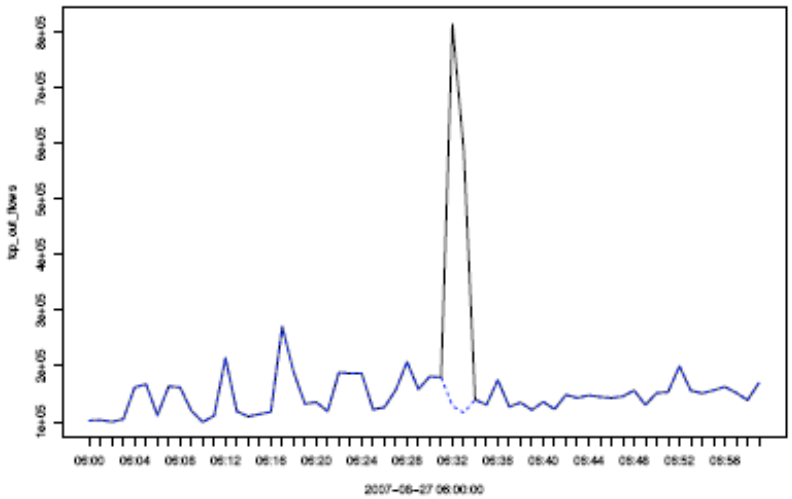


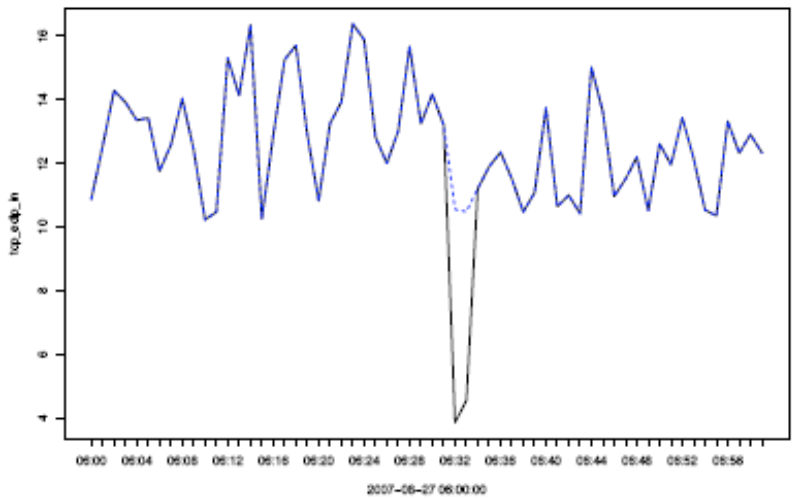
- **Generator Model and Parameters:**
  - Generate TCP SYN packet at flooding rate, generate reply with certain probability and constant delay plus random offset
  - start, end, flooding rate, reply probability, victim IP address

- **Deleter Model (accounts for loss of replies) and Parameters:**
  - Delete each flow with certain probability if source is victim
  - start, end, IP address of victim, probability for a loss

Plots: Injection of TCP SYN Scan

- Injection in flow trace captured from border router of Swiss educational backbone network (SWITCH AS 559)
- Scanning source internal, scanned destinations external
- Impact on common detection metrics (outgoing traffic):
  - Left: number of flows, right: destination IP address entropy





Conclusion

- Contributions
  - Flexible tool for anomaly injection (scripted model plugins)
  - Extensibility: components can be easily added
  - Three example anomalies (ingress shift, ddos, network scan)
- Future work
  - Concentrate on model development
  - Evaluate the model accuracy with flow traces

Questions

FLAME is available from

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