High-Speed Parallel Processing of Protocol-Aware Signatures

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Problem Definition and Previous Work

- **Why: Intelligent signature matching and protocol parsing are key functions of intrusion detection systems that need to keep up with line rates (100 Gbps)**
  - There exists a **trade off** between complexity of the signatures and processing speed.
  - Trend: cyber attacks become smarter, so **need to handle complex signatures.**
  - Trend: network trunks become faster, so **need to handle high speed**.
- **Problem: How to process large number of protocol signatures at high speed?**
  - Need to be able to process large number of signatures in parallel.
  - Need to minimize processing overhead on core processors.
- **How: Use SAT tools, binary decision diagrams (BDD) and deterministic finite automatons (DFA)**
  - Use SALT™ (converts Boolean functions into simplified Conjunctive Normal Form).
  - Compose OR signature, obtain its CNF form and calculate optimal BDD cuts.
  - Offload the resulting BDDs onto hardware accelerated DFA engines.
- **Result: Capability to process large number of signatures at high speed onto hardware DFA engines**
  - Currently building prototype on a heterogeneous 16-core processor/accelerator NPU (Cavium Octeon Plus) and looking at running this on the Octeon II and Tilera TILE64.
  - Experimental results presented in our abstract and poster.

How it Works Through a Low-Scale Example

Ghttpdlog signature expressed in salt:

```
;;;
;;; Ghttpdlog Salt
;;;

$bit1 expr =?
$bit2 expr =?
$bit3 expr =?
$bit4 expr =?
$bit5 expr =?
$conjunction1 and ~$bit1 $bit2 =
$conjunction2 and $bit1 ~$bit3
$bit4 =
$conjunction3 and $bit1 $bit3 $bit5
=
$disjunction or $conjunction1
$conjunction2 $conjunction3 =
$_ eval $disjunction + ; assert
return value true

#done
```

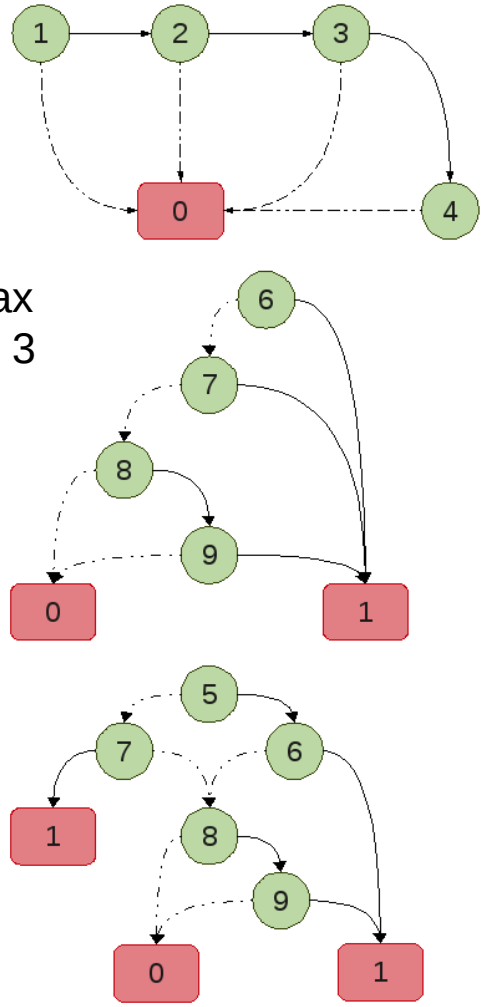
CNF:

```
2 4 5 0
2 1 4 0
2 3 4 0
2 -3 5 0
2 1 -3 0
2 1 5 0
2 1 0
2 1 3 0
-1 4 5 0
-1 3 4 0
-1 -3 5 0
6 0
-7 0
```

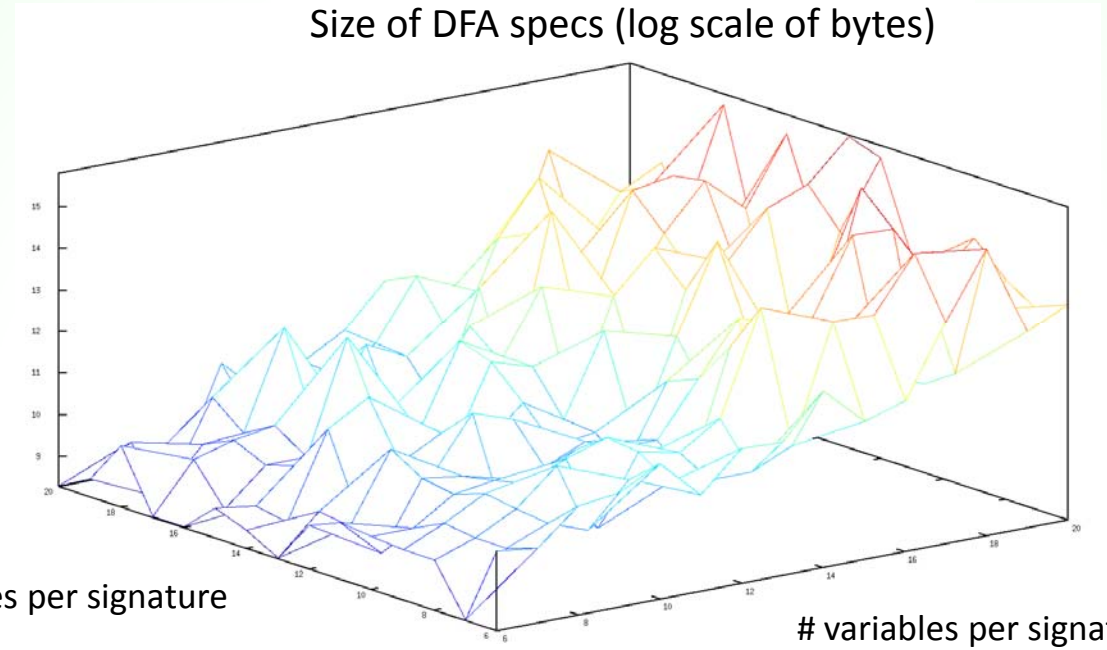
SALT™

$$(b2 \cap b4 \cap b5) \cup (b2 \cap b1 \cap b4) \cup (b2 \cap b3 \cap b4) \cup (b2 \cap \overline{b3} \cap b5) \cup (b2 \cap b1 \cap \overline{b3}) \cup (b2 \cap b1 \cap b5) \cup (b2 \cap b1) \cup (b2 \cap b1 \cap b3) \cup (\overline{b1} \cap b4 \cap b5) \cup (\overline{b1} \cap b3 \cap b4) \cup (\overline{b1} \cap \overline{b3} \cap b5)$$

Optimal min-max cut mapping on 3 DFA engines



Results and Preliminary Conclusions



- **Average case analysis. Using a random signature generator and taking average cases:**
  - Emitting DFA specs for signatures from 6 to 20 variables and from 6 to 20 clauses per signature, the average DFA size obtained is **410340 bytes**.
  - That yields **2.43 signatures per megabyte.**
  - On a DFA with 256MB of memory, we can fit in average about **600 signatures**.
  - Each signature can involve 100s of CPU cycles per connection offloaded from the core processor.
- **Real examples. Examples using real signatures are shown in the poster.**

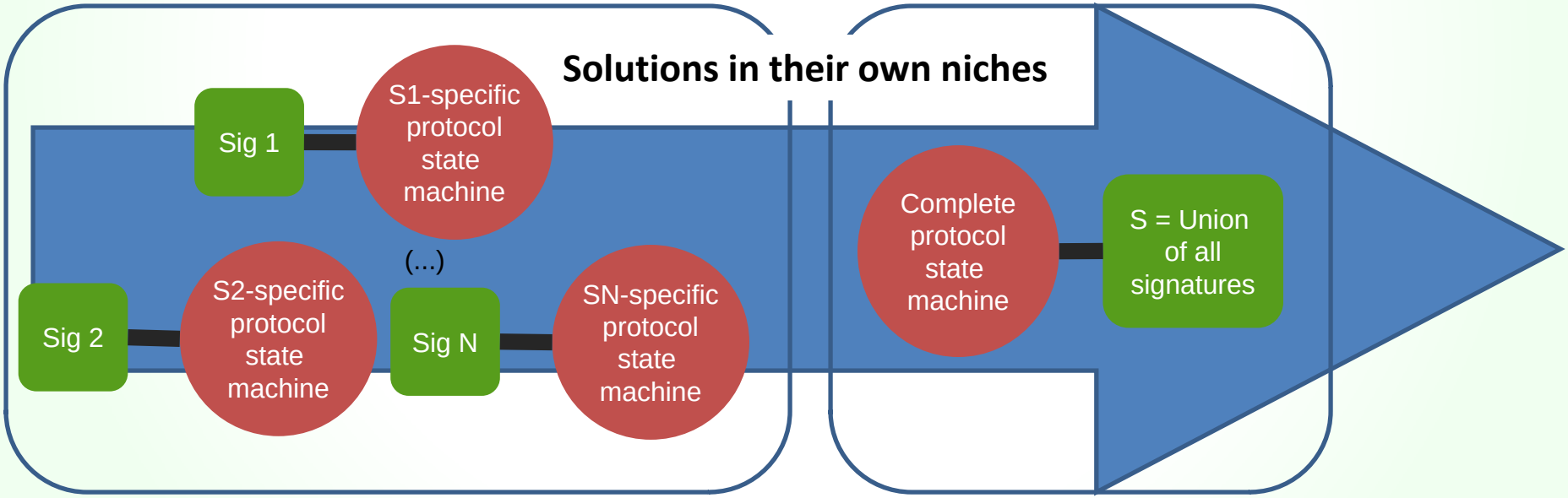
Relationship with Previous Work

Schear's Approach:

- A single signature only uses a small portion of the protocol state machine.
- By customizing the state machine to each signature (removing those elements in the state machine that are irrelevant to the signature), each signature can run much faster .

Our Approach:

- If N is large enough, then the union of Schear's specialized state machines add up to the complete protocol state machine.
- In this case, it pays off to implement one single complete protocol state machine and have all signatures leverage the same machine



Small number of signatures

Large number of signatures