Deep Packet Inspection over Encrypted Traffic

Divyanshu, Romir, Mrittika

August 1, 2025

Privacy vs. Security

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How to achieve both privacy and security?

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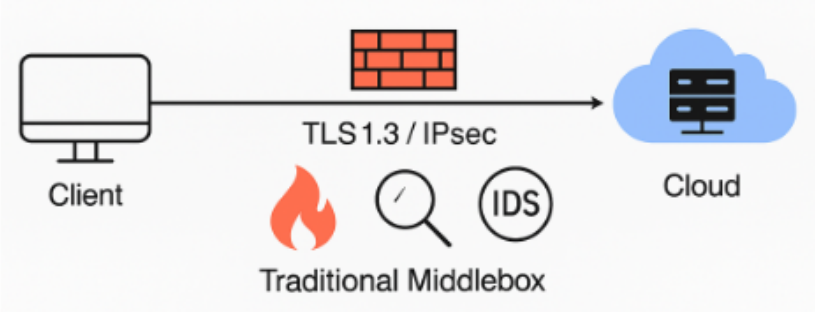

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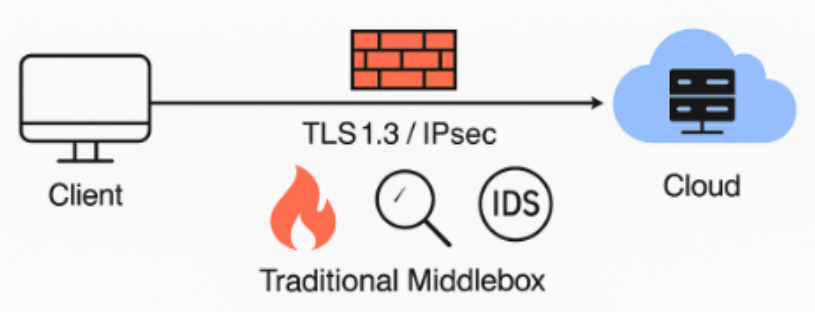

- **Challenge:** Traditional middleboxes (firewalls, IDS/IPS) cannot inspect such encrypted payloads sent over a secure HTTPS/TLS connection.
- **Solution:** Inspect encrypted traffic **without decrypting it**, preserving both ***security*** and ***user privacy***.

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- Such a system enables **selective traffic inspection** over encrypted traffic using **searchable encryption.**
- Searchable Encryption(SE) supports search with keywords over encrypted traffic.

What is DPI?

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- DPI is performed by network middleboxes.
- It provides a wide range of services including IDS,IPS ,etc.
- **DPI over encrypted traffic** enables deep packet inspection over an encrypted payload.

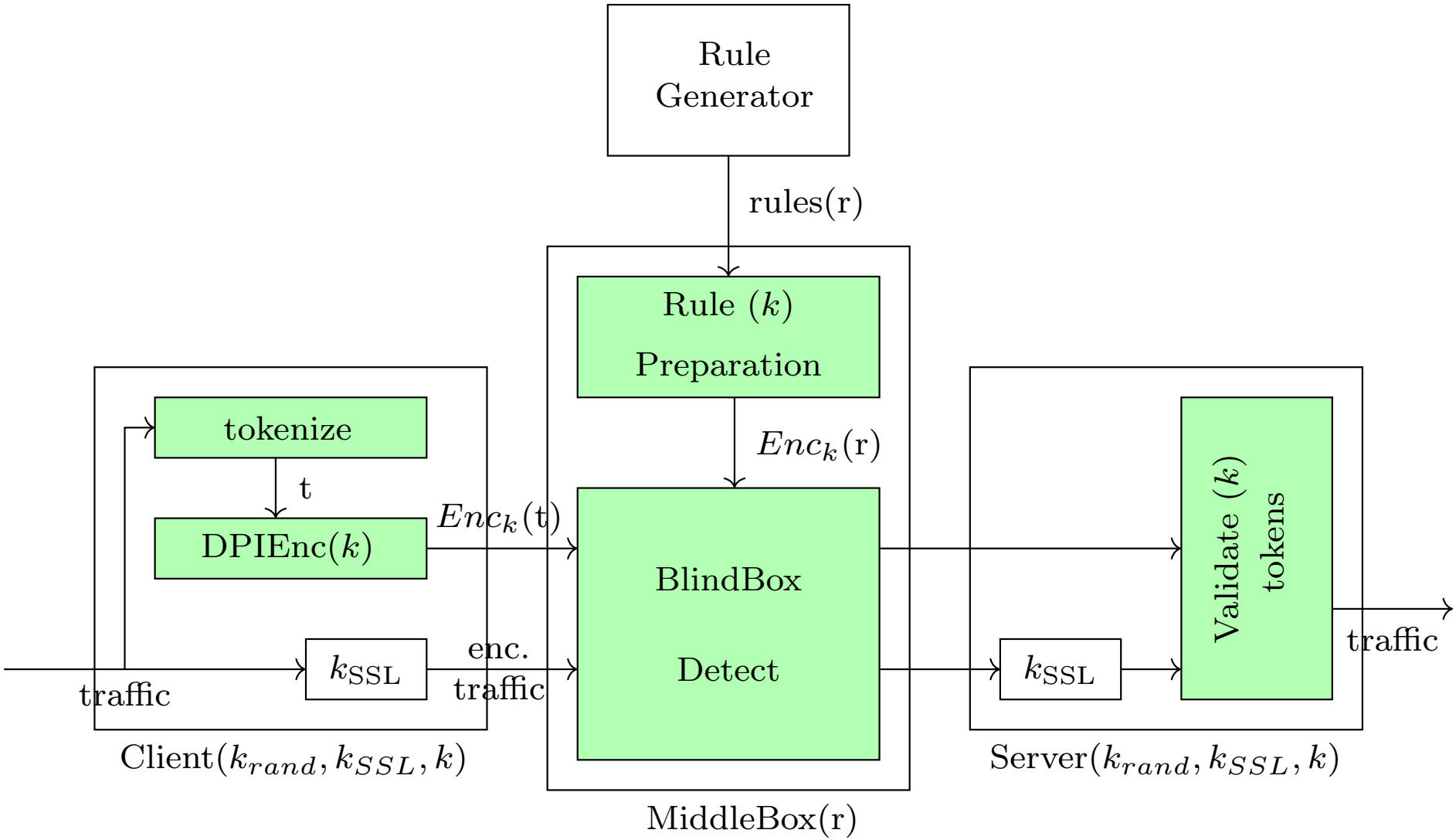
Acknowledgment

This presentation is primarily based on the work:

Sherry et al., *BlindBox: Deep Packet Inspection over Encrypted Traffic*, ACM, 2015.

All technical details and notations closely follow the above.

System Architecture



Protocol I

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1. Tokenization
2. DPIEnc encryption scheme
3. BlindBox Detect
4. Rule Preparation
5. Validate Tokens

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→ Window-based tokenization

t_2

hello everyone (token length=8 bytes)

t_1

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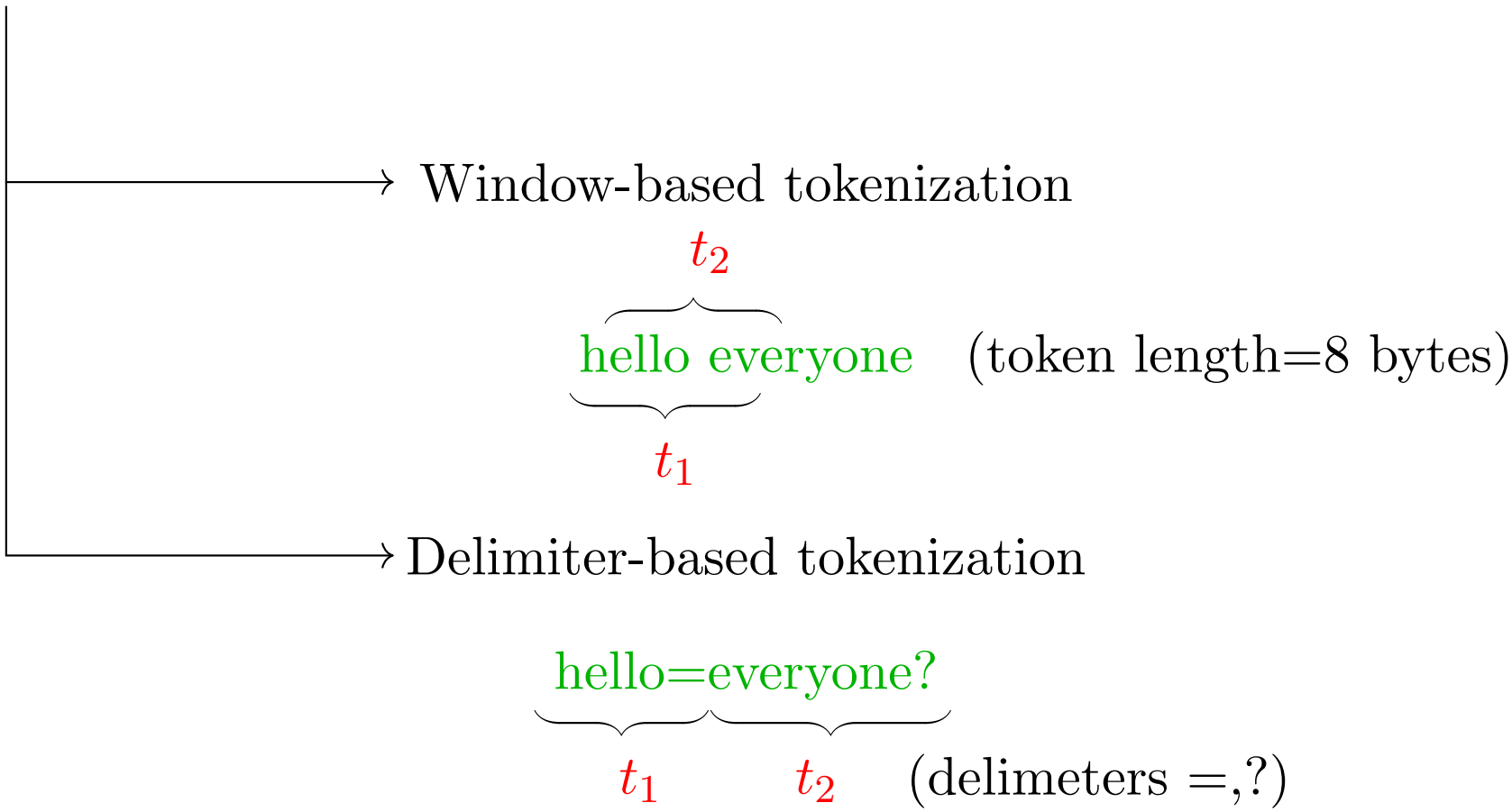
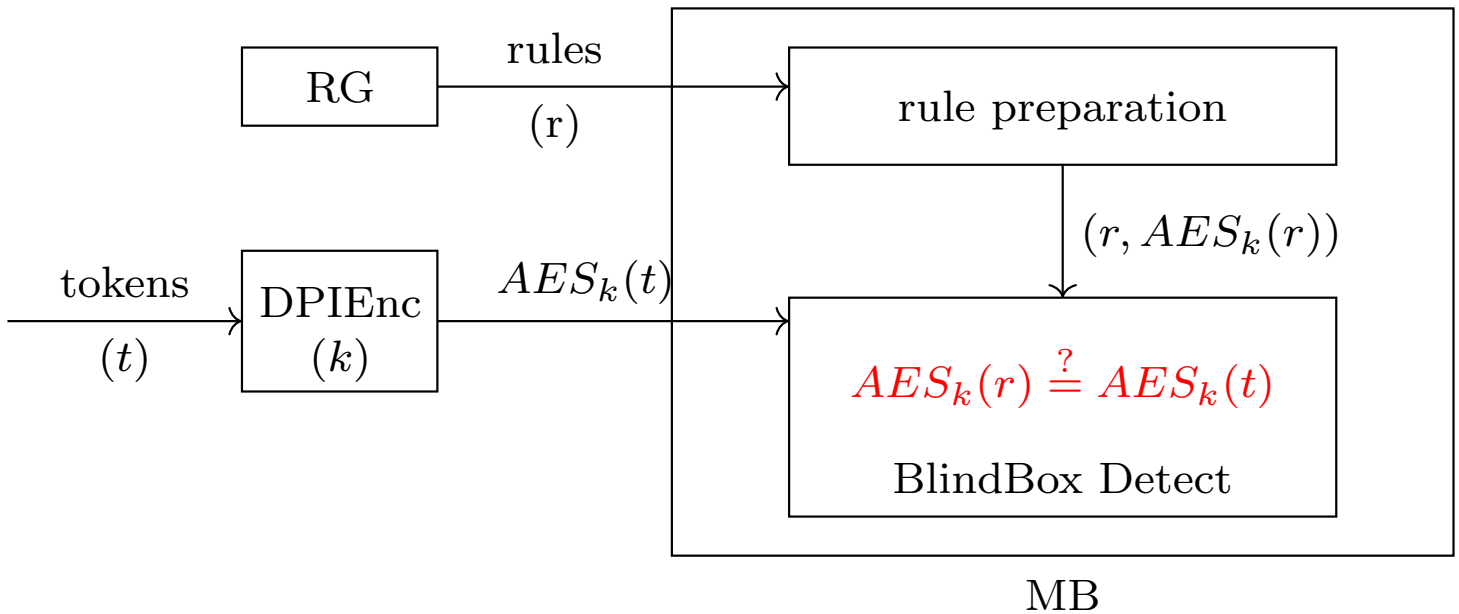


DPIEnc encryption scheme

For now , lets assume that MB has the key k, so it computes the encrypted rule $AES_k(r)$ for each rule r.



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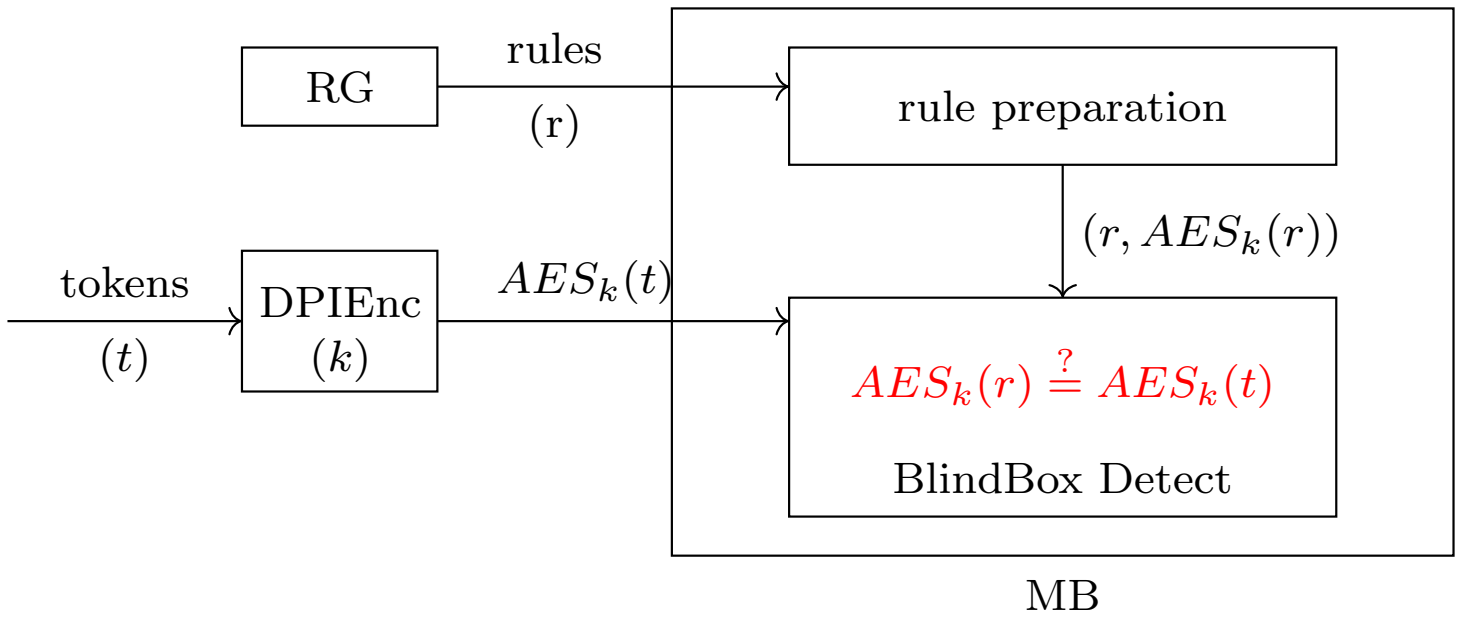

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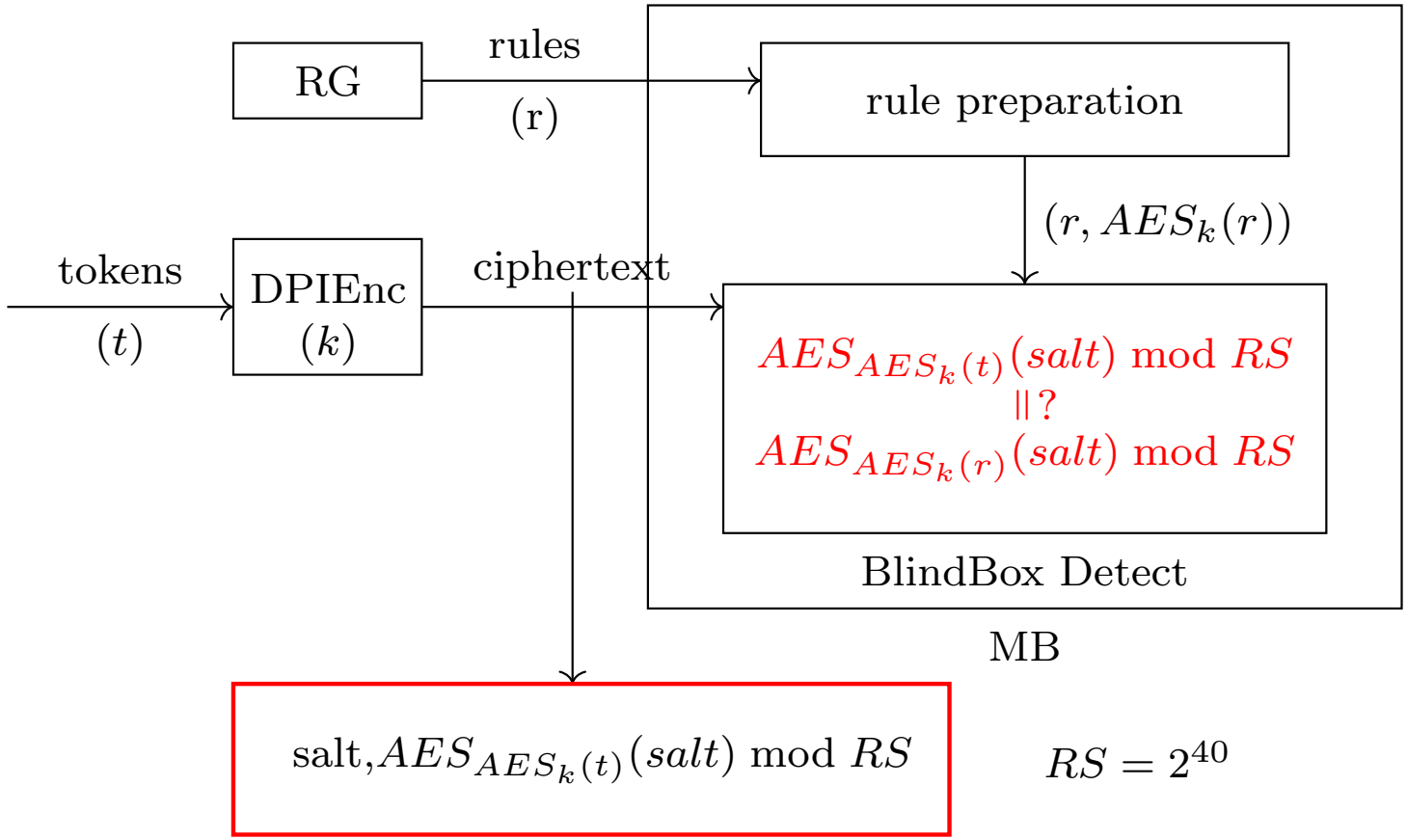

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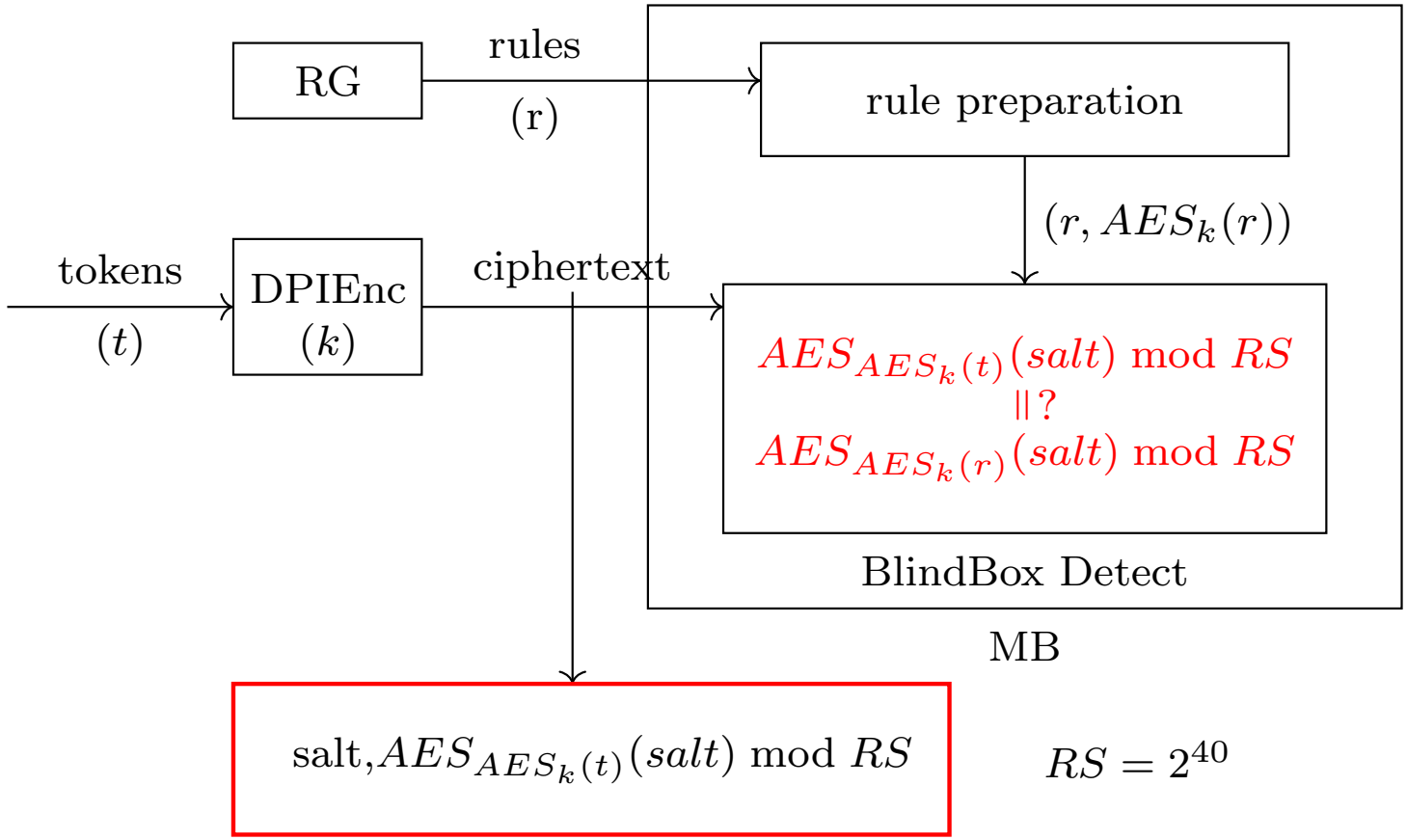

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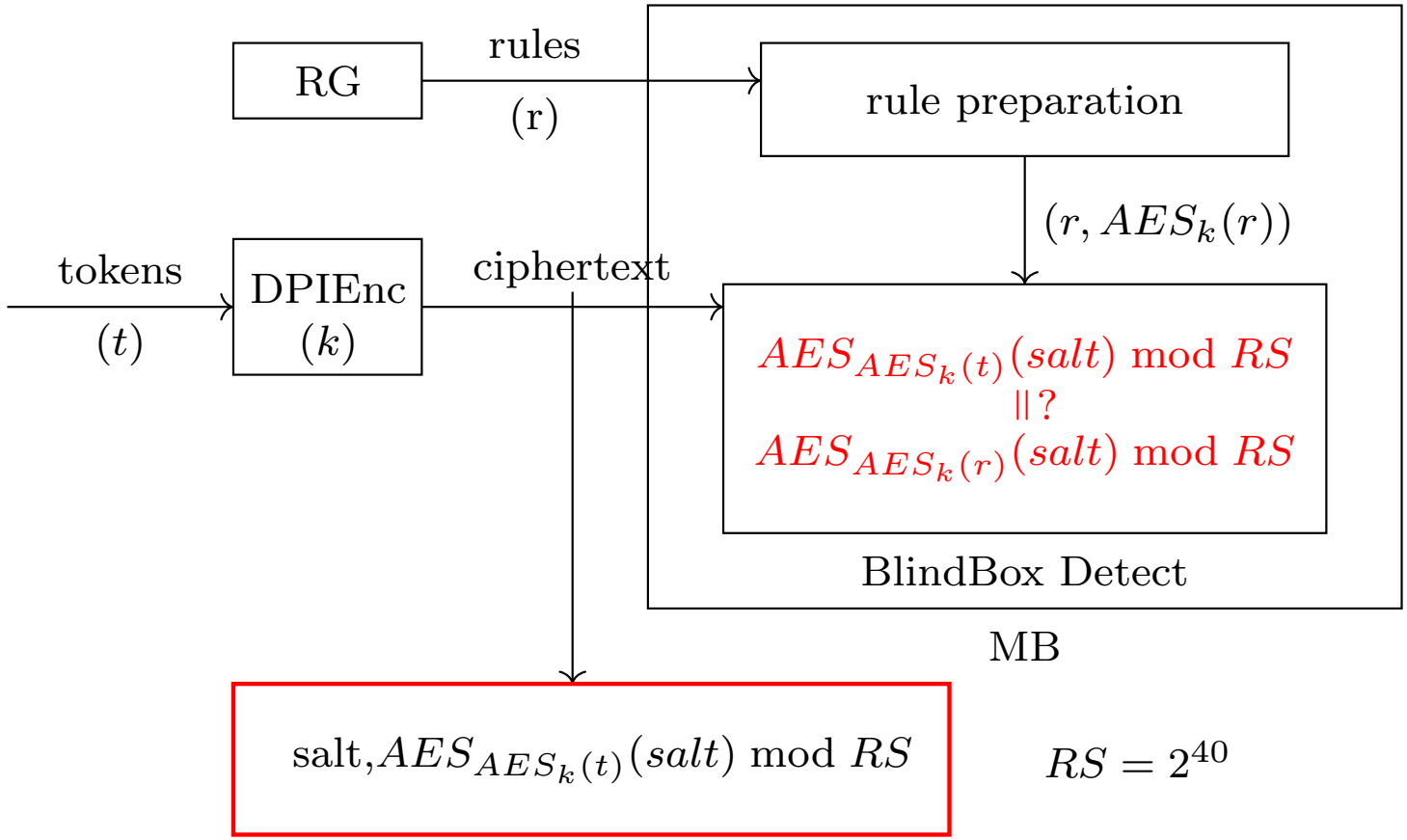

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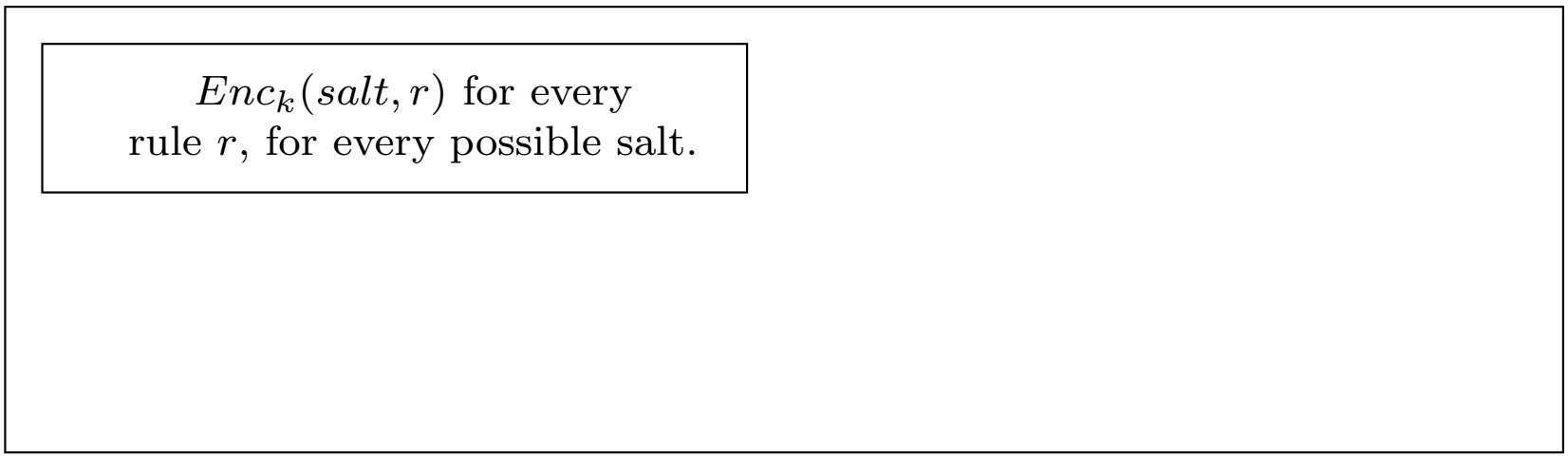

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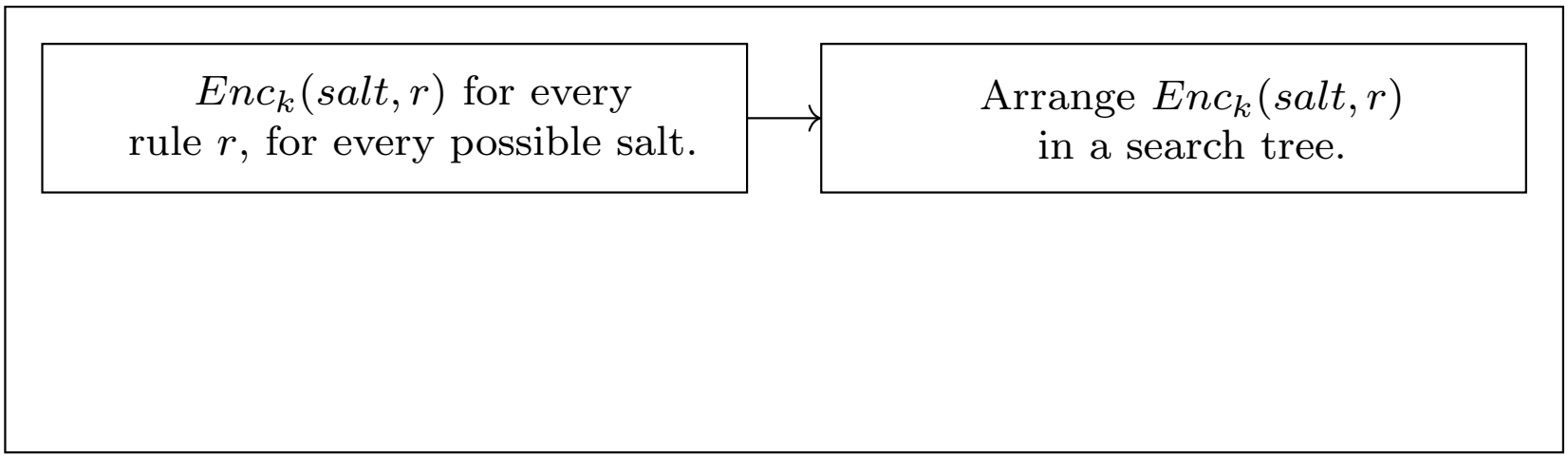

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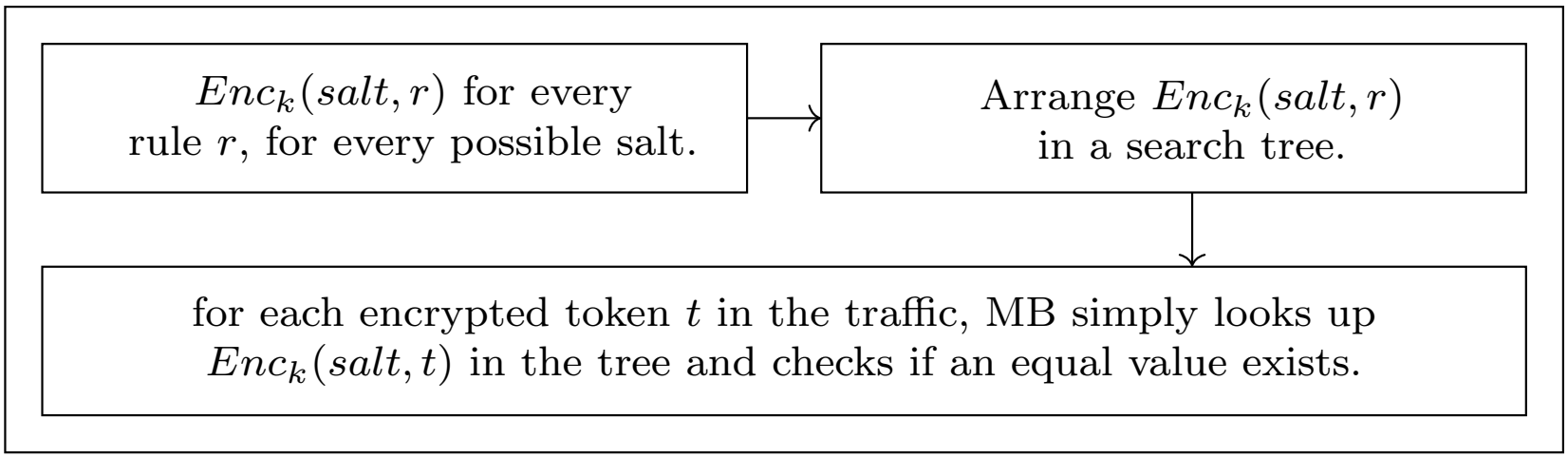

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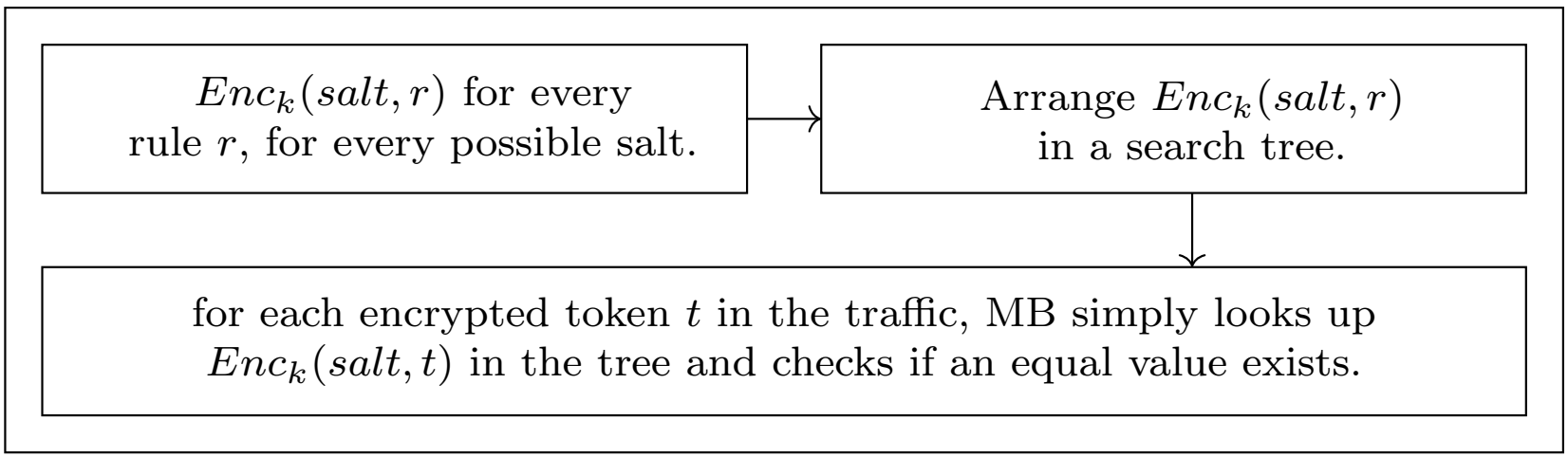

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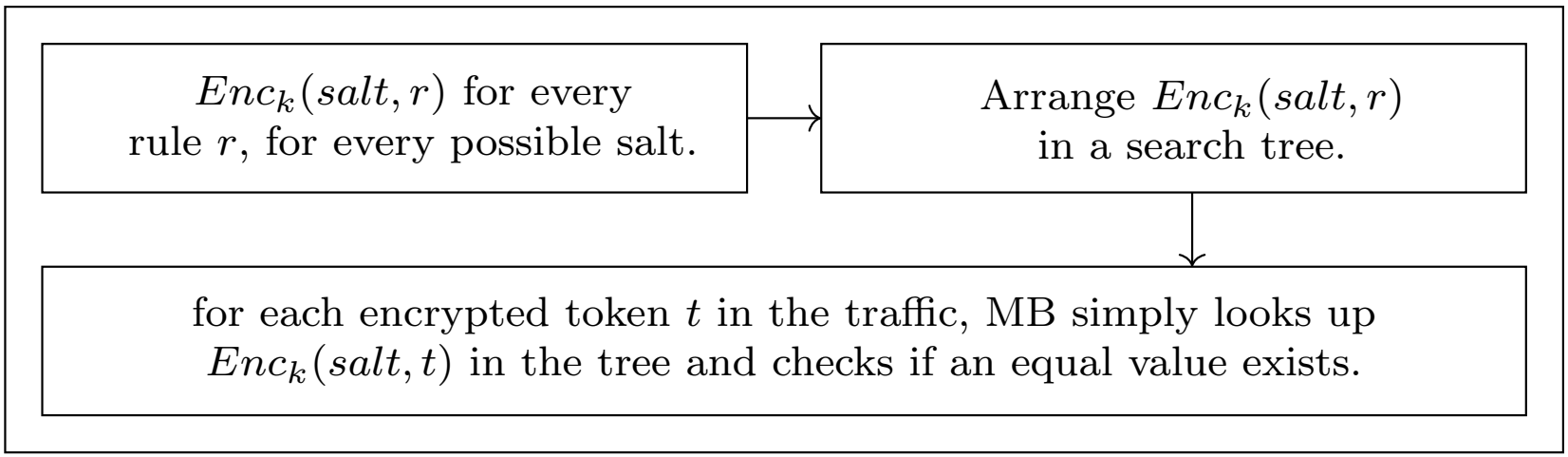

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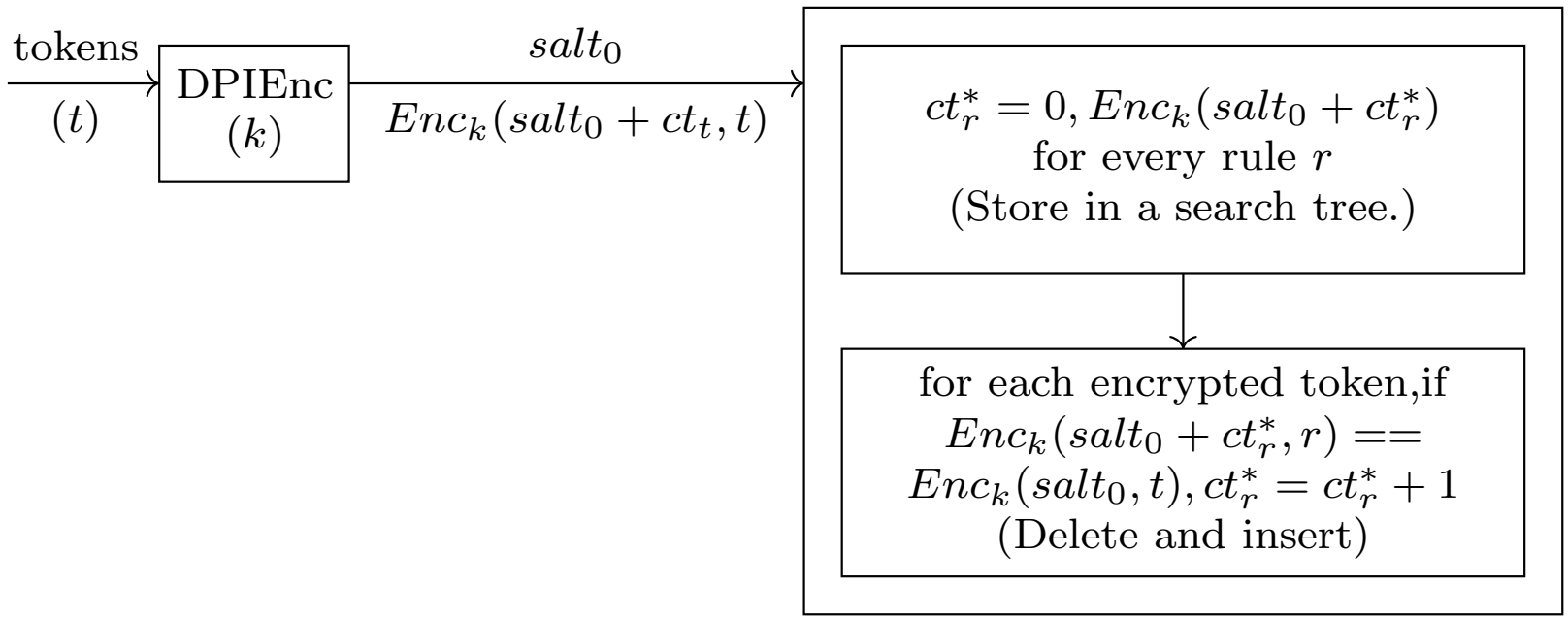

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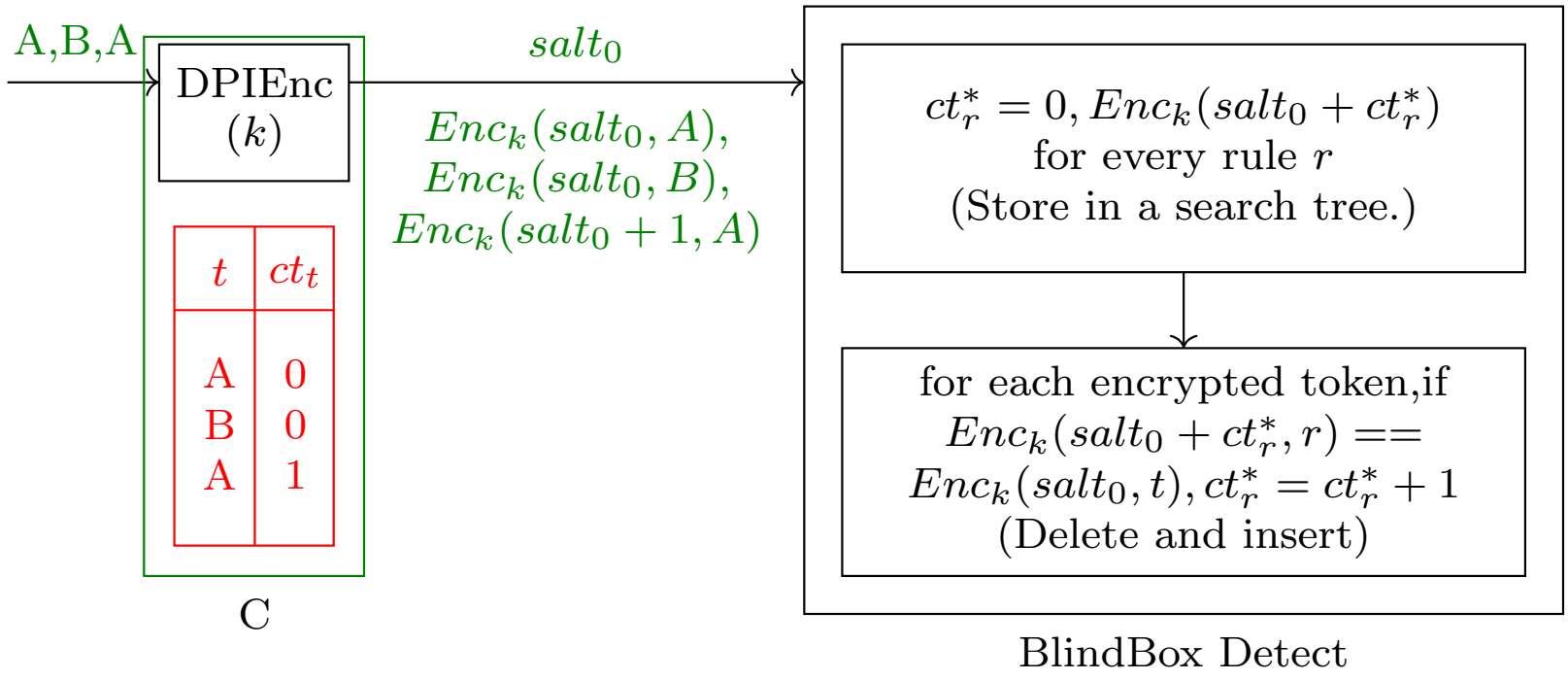

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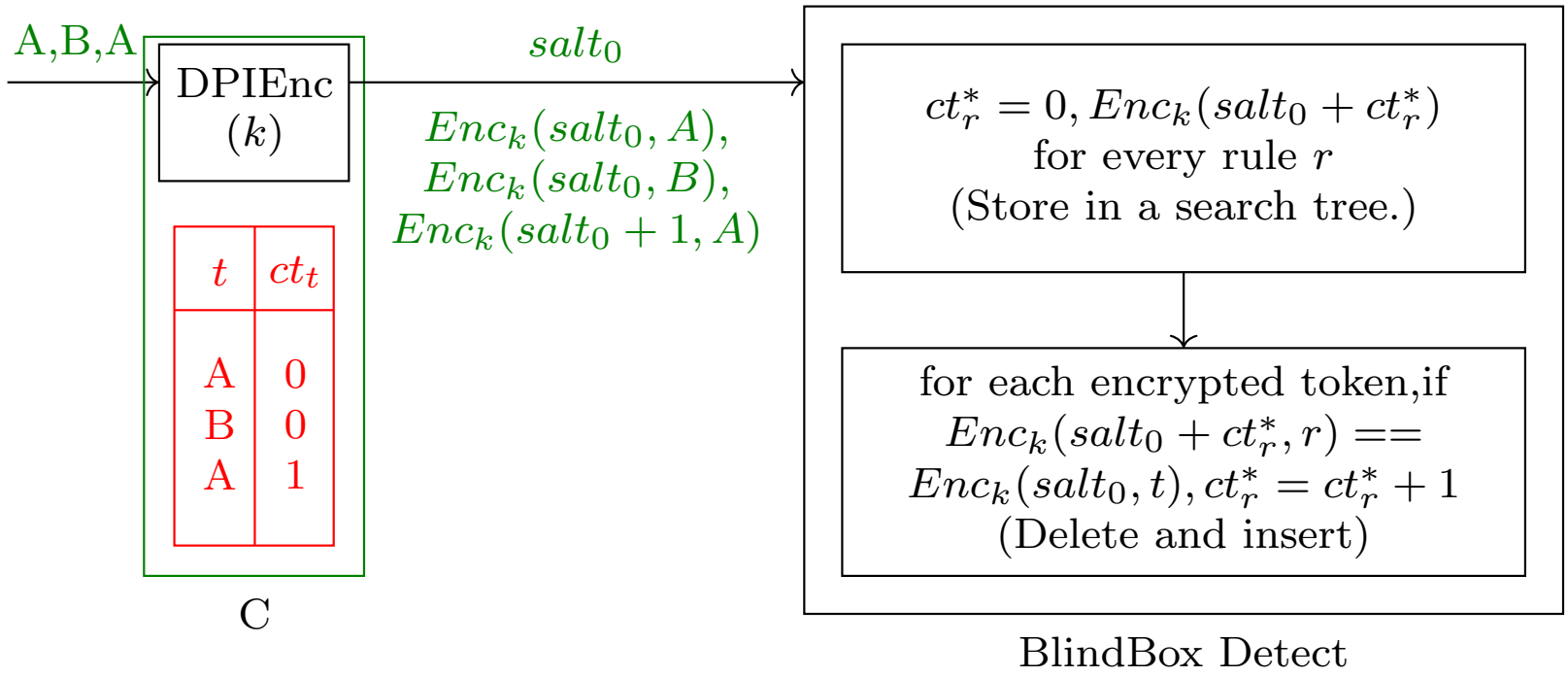

For every token t, MB performs a simple tree lookup, which is logarithmic in the number of rules.

Rule Preparation

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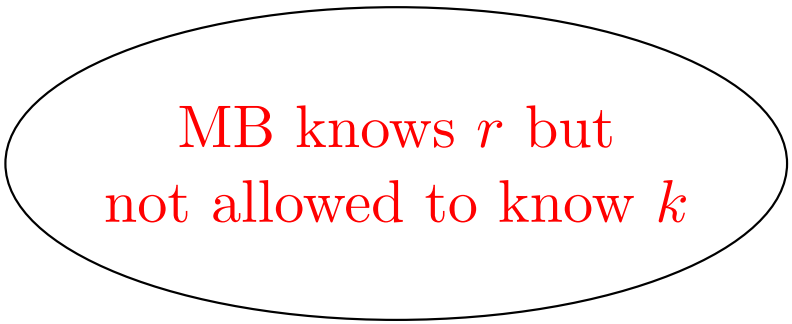

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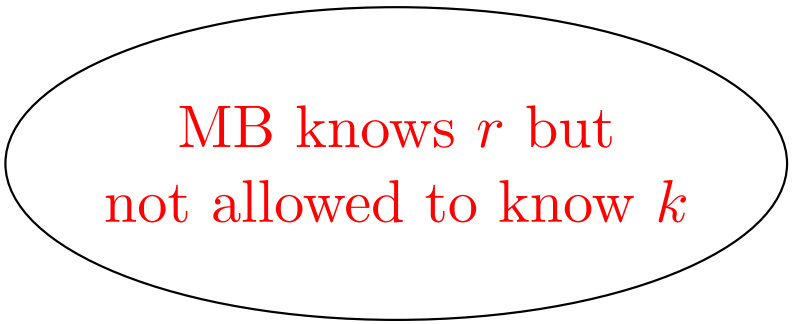

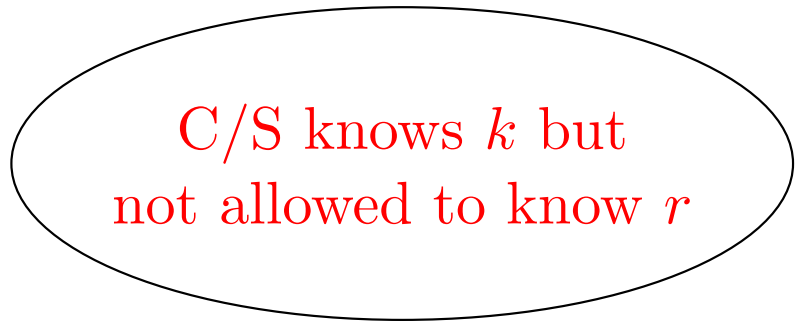

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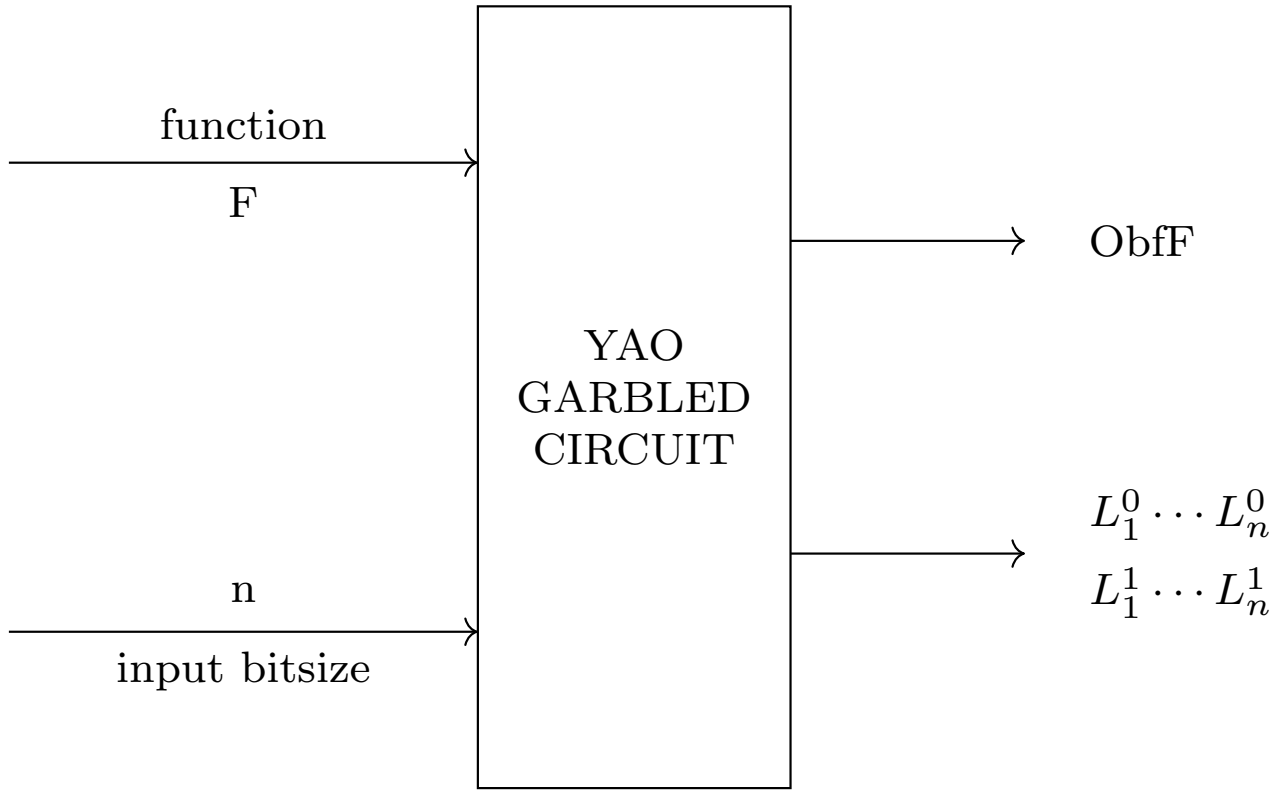
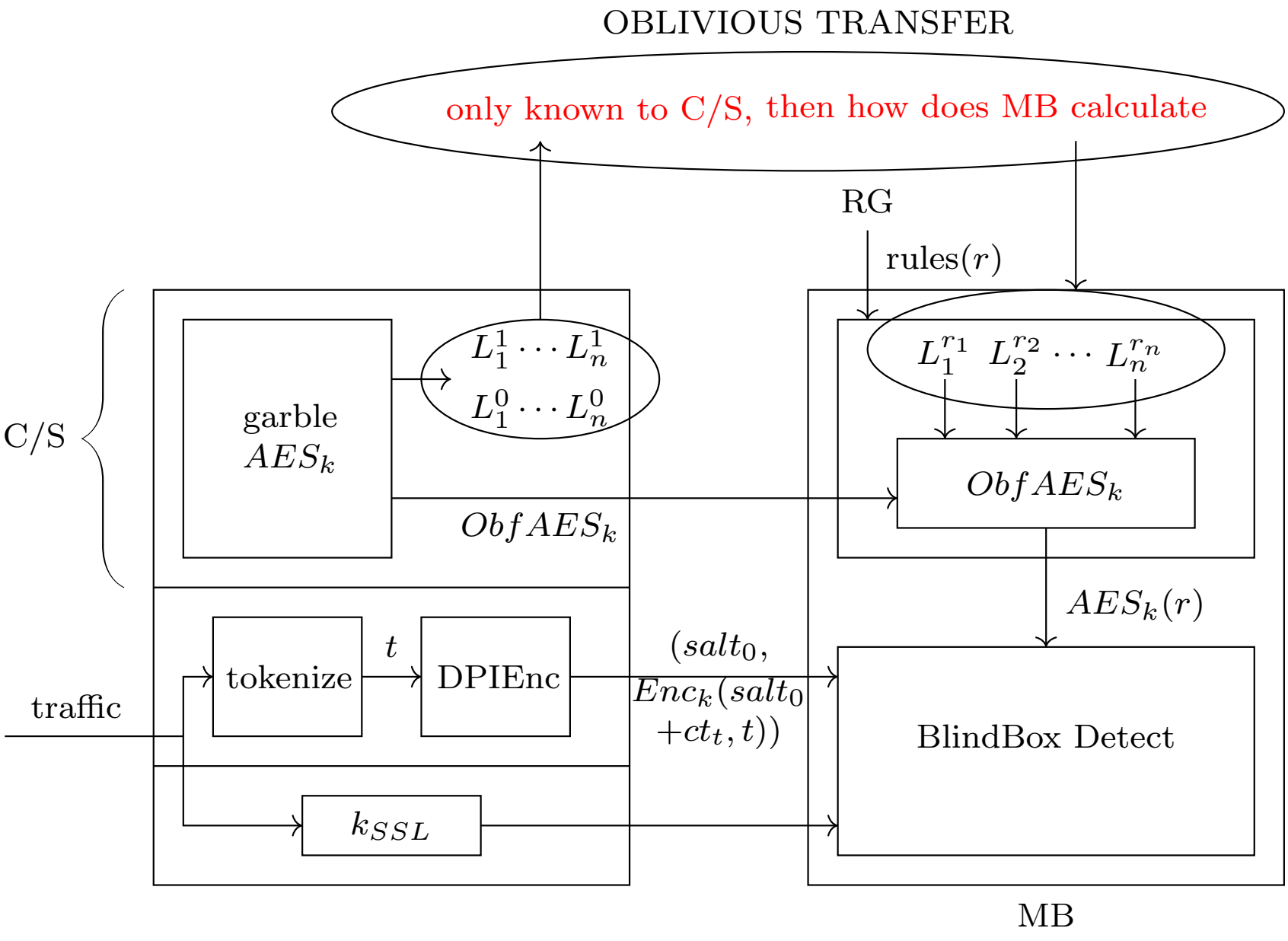
The sender provides the MB with an obfuscation of the function AES with key k hardcoded in it.

Obfuscated Rule Encryption



$\text{ObfF}(L_1^{x_1}, L_2^{x_2}, \ldots, L_n^{x_n})=\text{F(x)}$, $x = x_1 x_2 \ldots x_n$ (bits)


OBLIVIOUS TRANSFER
only known to C/S, then how does MB calculate
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BlindBox Detect
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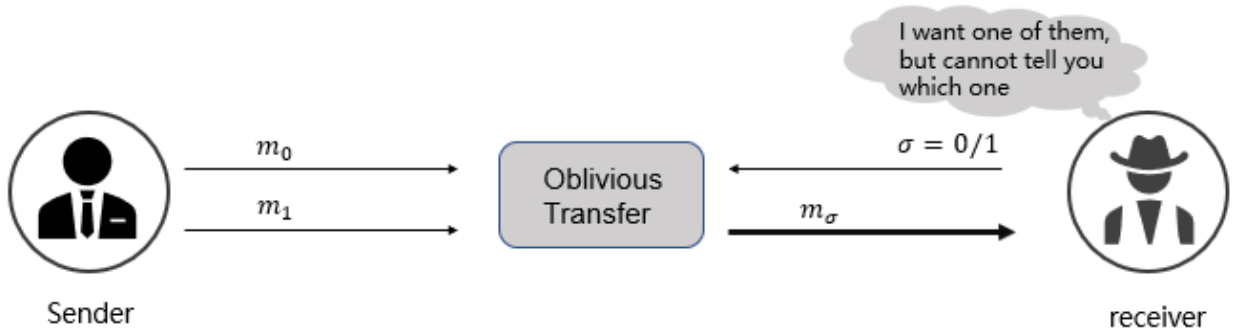
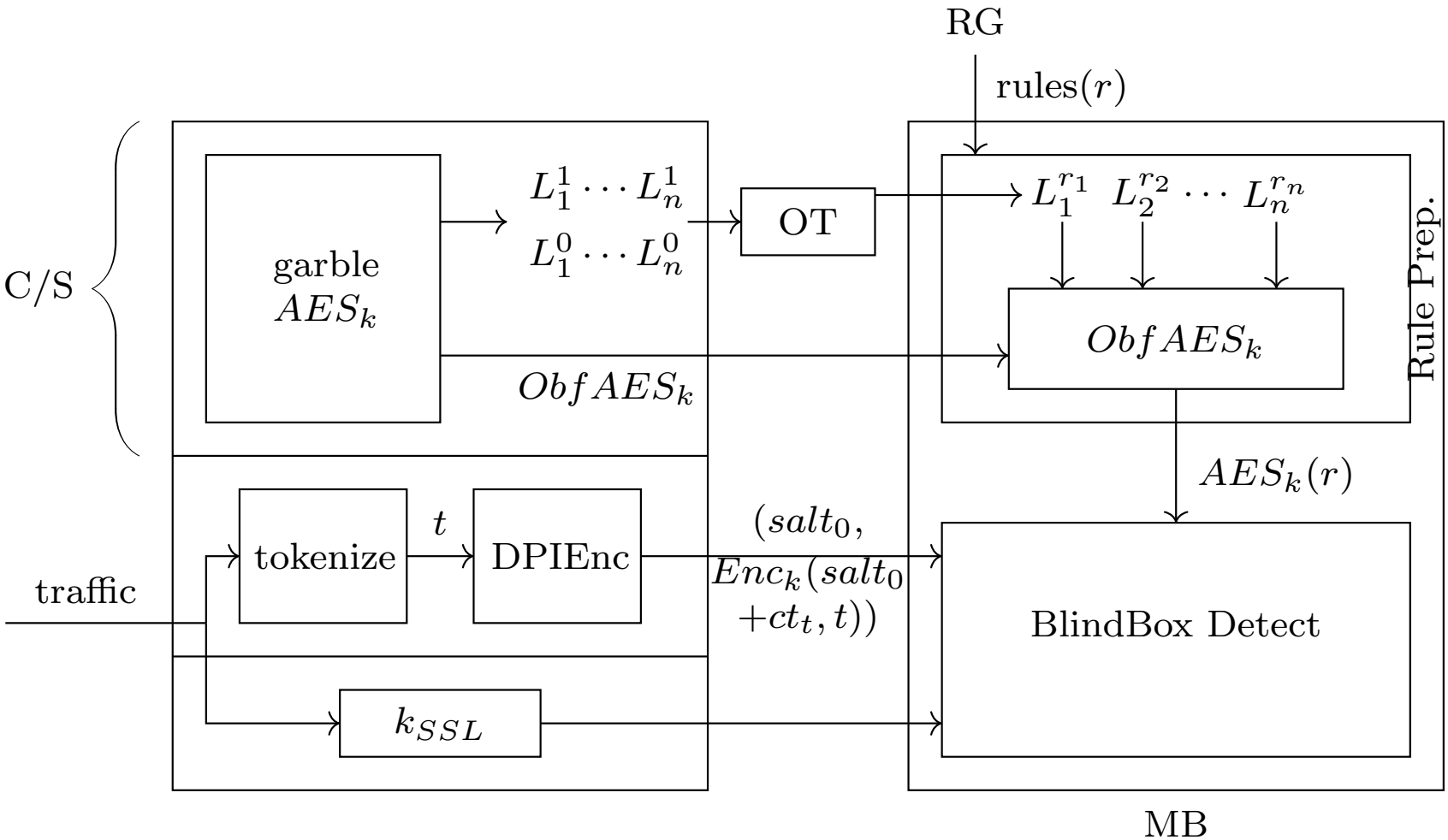
Oblivious transfer: B chooses $b \in 0, 1$. A has L^0, L^1. B can obtain L^b without learning L^{1-b} and A does not learn b.

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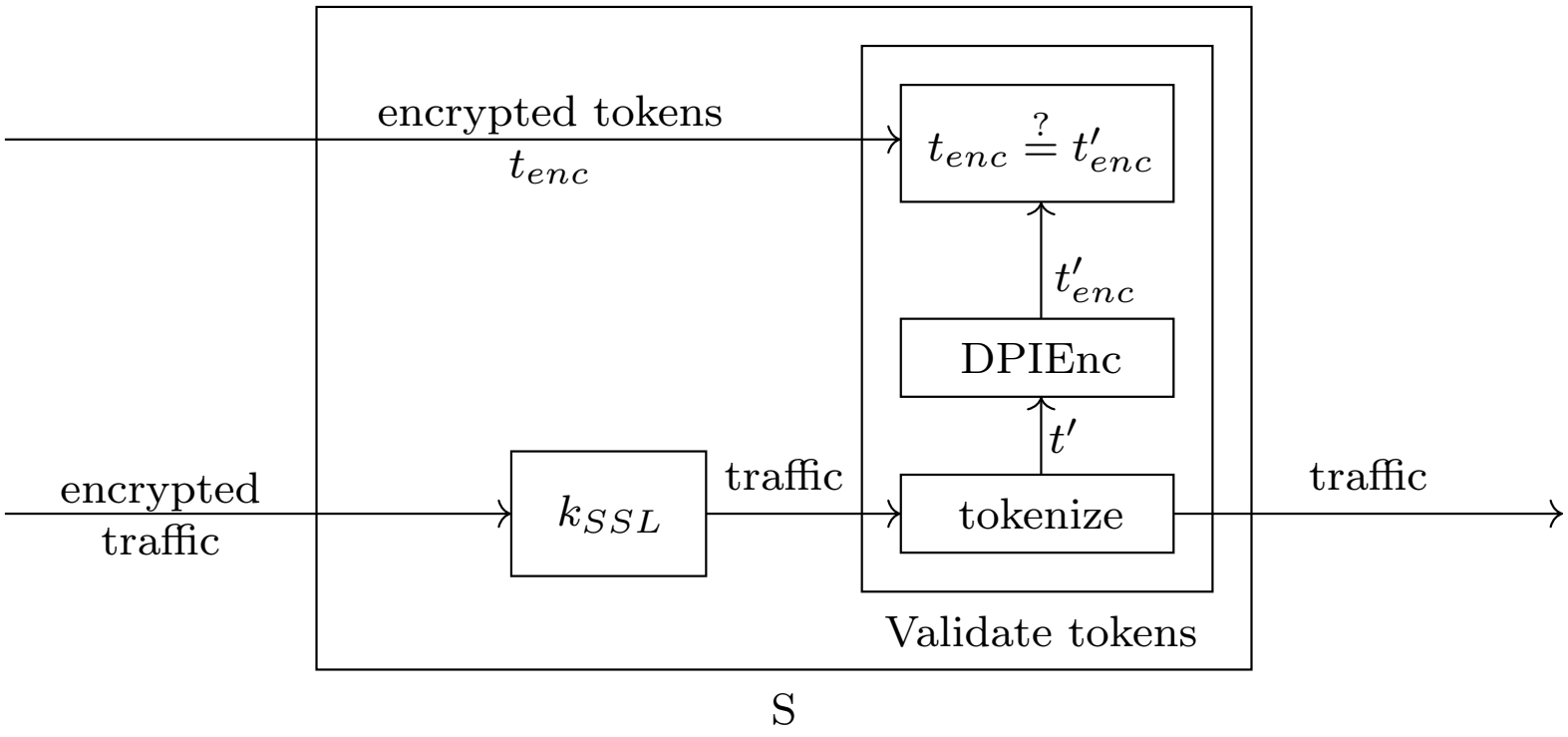

Checks malicious endpoints.

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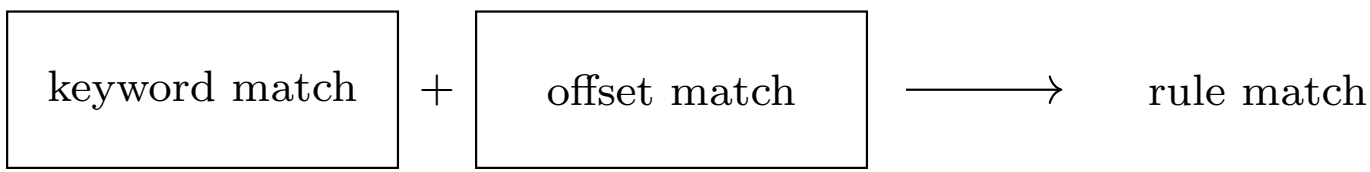

Protocol III

- Protocol III enables full IDS functionality.
- Compared to first approach, it ensures additional functionalities:
  1. If a keyword from a rule (a suspicious keyword) matches a stream of traffic, MB should be able to decrypt the traffic.
  2. If there is **no such match**, MB **cannot decrypt** the traffic.

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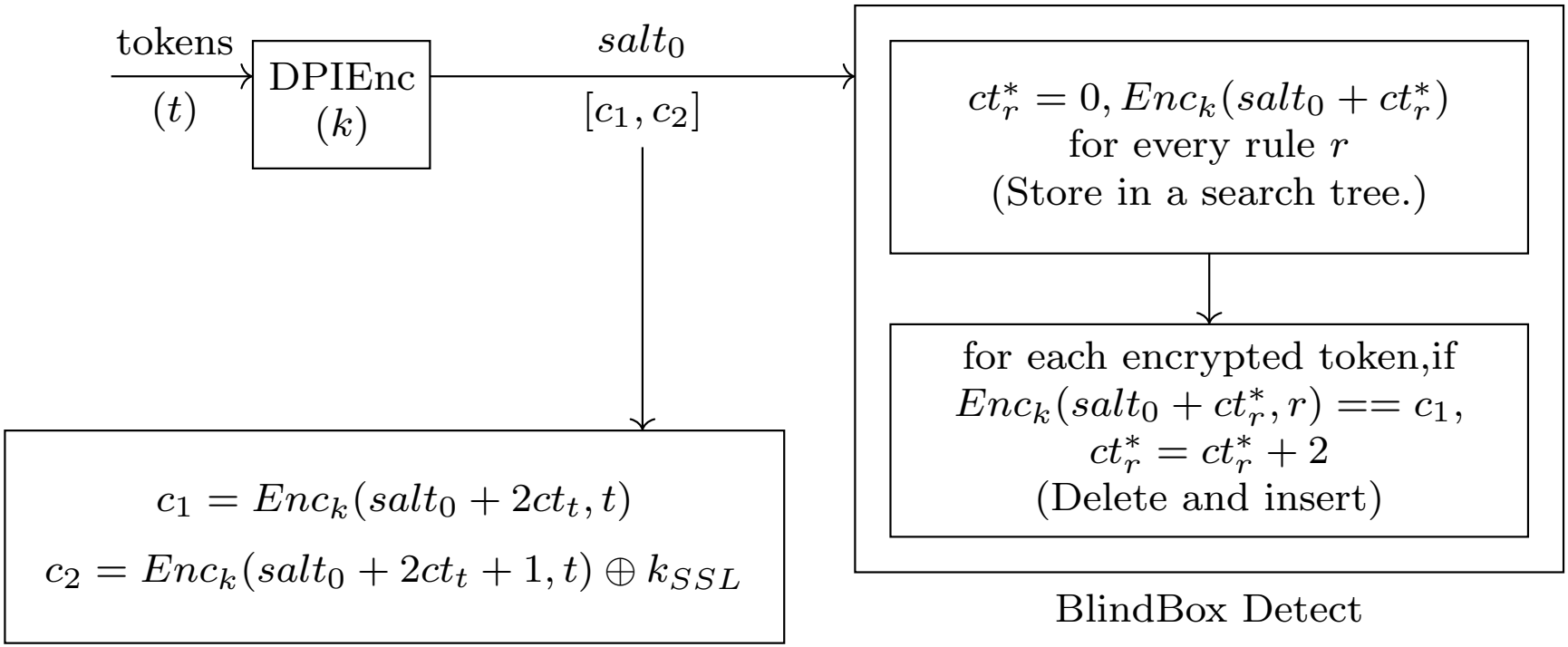

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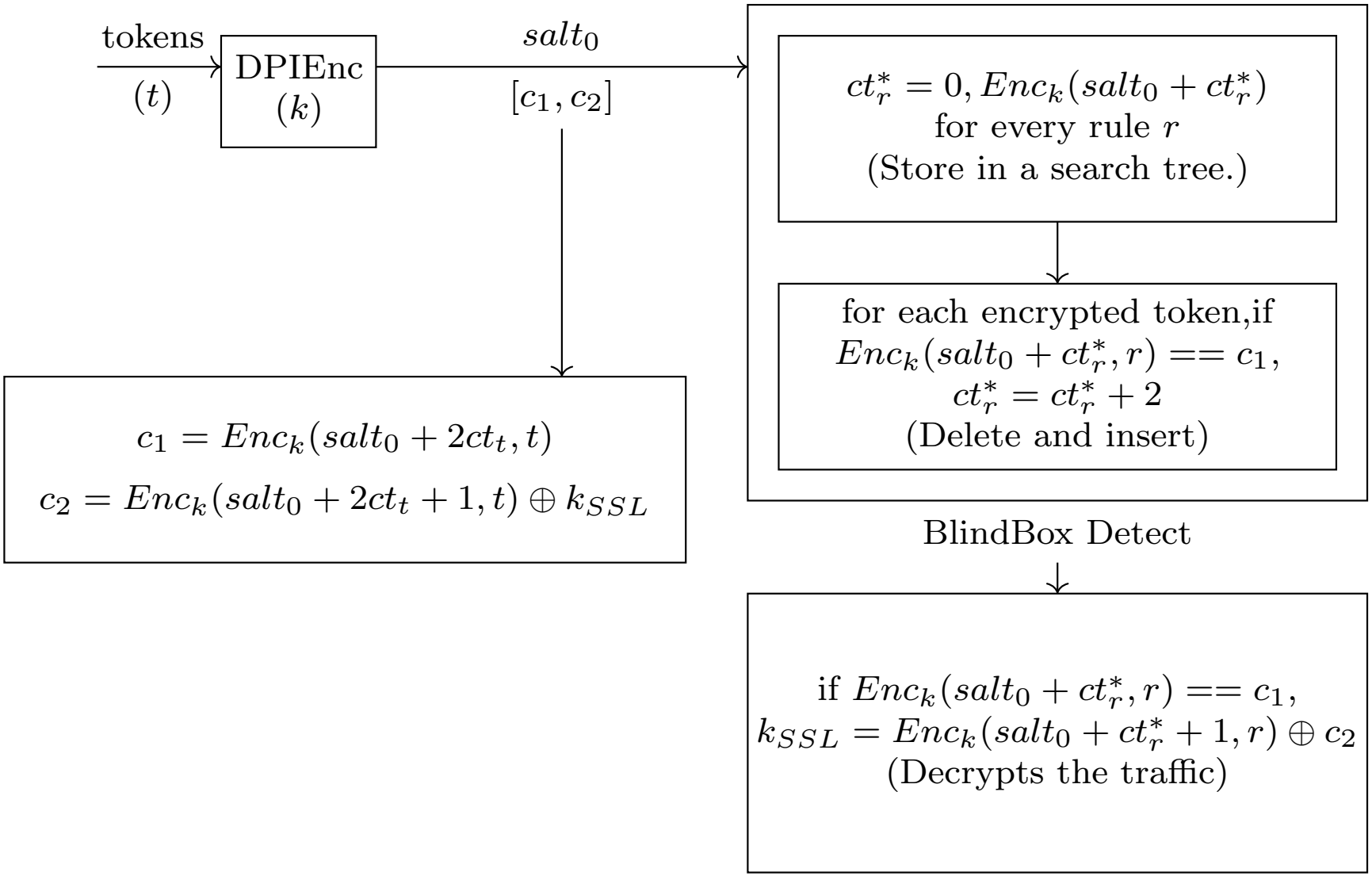

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Optimization Focus: Parallel token encryption, hardware acceleration (AES-NI).

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Detection Throughput:

- 166–186 Mbps/core (middlebox), similar to or faster than Snort.

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- 1,000 rules: 9.5s; 10,000 rules: 97s ($\sim$100 rules/sec).
- Significant bottleneck for large rulesets.

Tokenization:

- Qualitatively fast; negligible overhead claimed (no rate given).

Encryption Overhead:

- 128-bit block: 69ns (BlindBox) vs 13ns (HTTPS).
- 1,400-byte packet: 90μs (BlindBox) vs 3μs (HTTPS).

Detection Throughput:

- 166–186 Mbps/core (middlebox), similar to or faster than Snort.

Network Overhead:

- Delimiter tokenization: 2.5$\times$ increase; window: up to 4$\times$.

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Optimization Focus: Cryptographic optimization, reducing setup, parallelism.

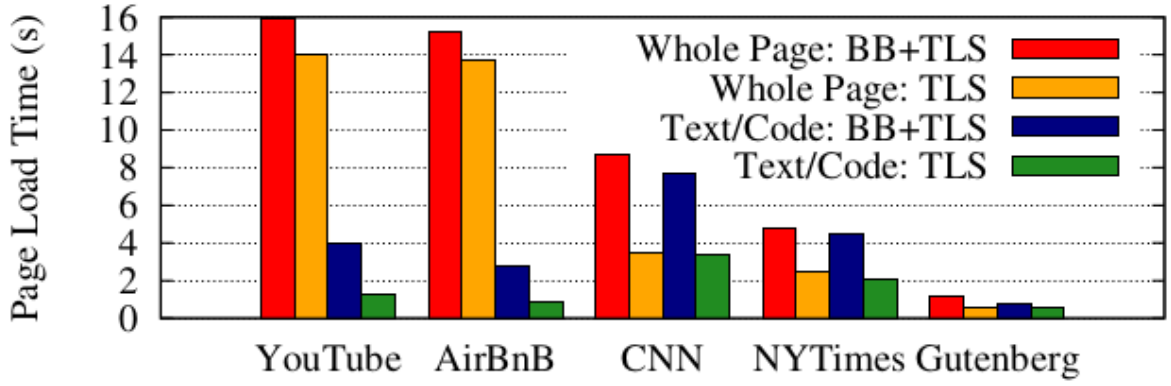

Figure 4: Download time for TLS and BlindBox (BB) + TLS at 20Mbps×10ms.

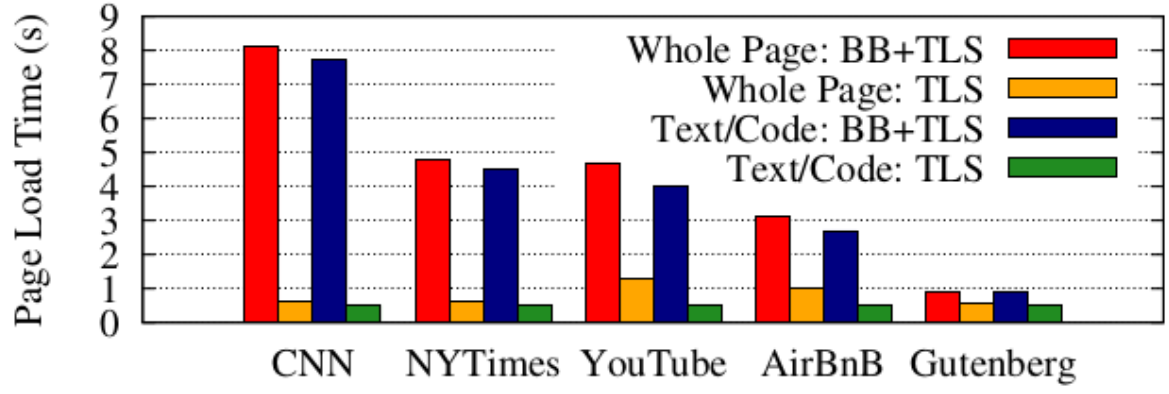

Figure 5: Download time for TLS and BlindBox (BB) + TLS at 1Gbps×10ms.

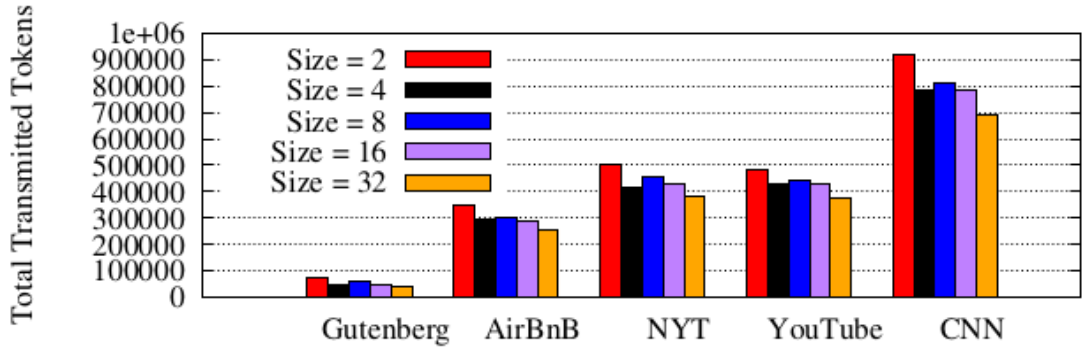

Figure 7: Tokens generated for each of six popular websites using delimiter-based tokenization and a minimum token size between 1-32 bytes.

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- Hardware acceleration (AES-NI)
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Rule encryption (already efficient)

- 4,939 rules encrypt in 1.33 seconds
- Suitable for production use

Thank You!

Appendix

```
alert tcp $EXTERNAL_NET $HTTP_PORTS
                                    -> $HOME_NET 1025:5000 (
  flow: established,from_server;
  content: "Server|3a| nginx/0.";
  offset: 17; depth: 19;
  content: "Content-Type|3a| text/html";
  content: "|3a|80|3b|255.255.255.255"; )
```

- This rule is triggered if :
  1. the flow is from the server
  2. first keyword at an offset between 17 and 19.
  3. second and third keywords.
- If all the fields of the relevant rule are satisfied, MB takes the action indicated by the rule.