Trellis: Privilege Separation for Multi-User Applications Made Easy

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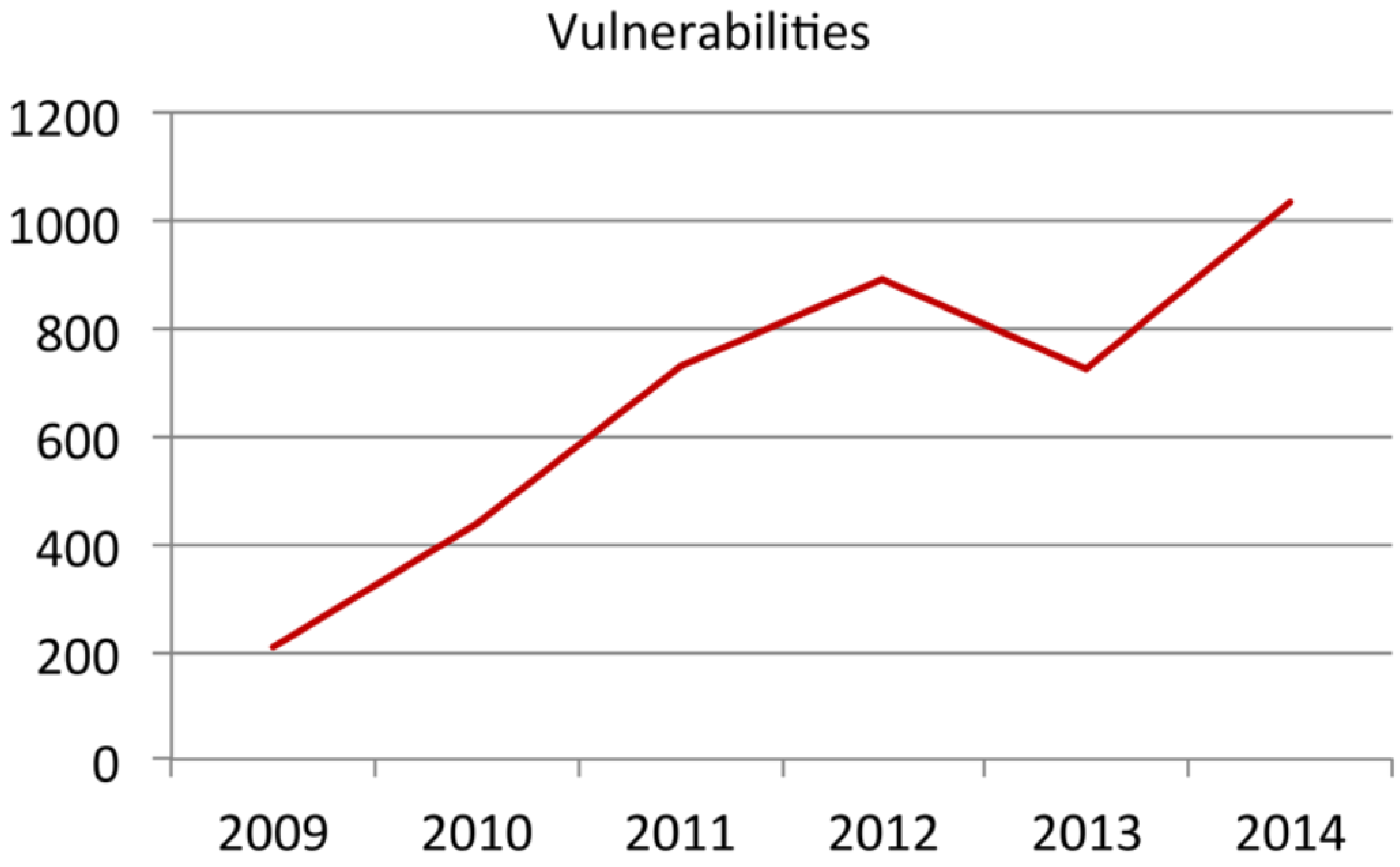
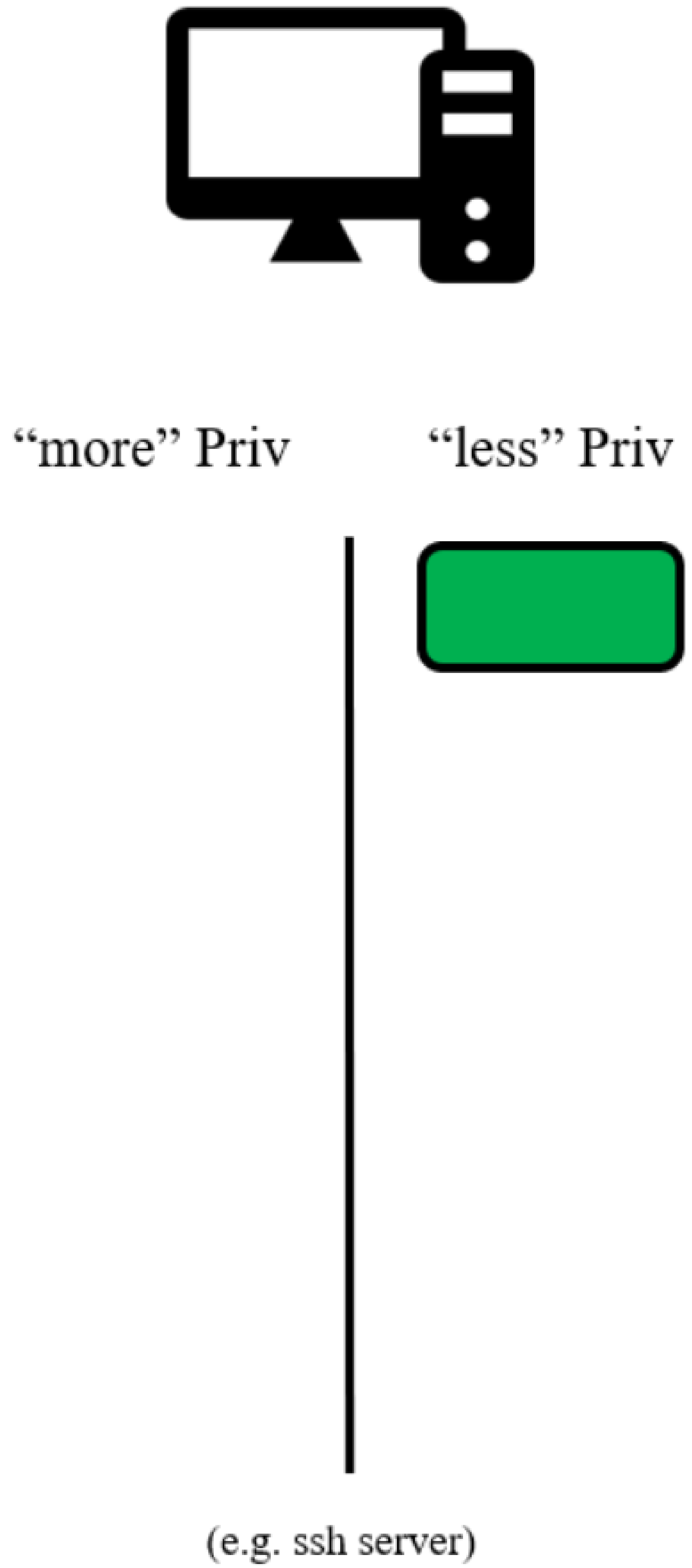
Unsolved Problem?



Secunia review 2015 – Vulnerabilities in the 5 Most Popular Browser

Privilege Escalation



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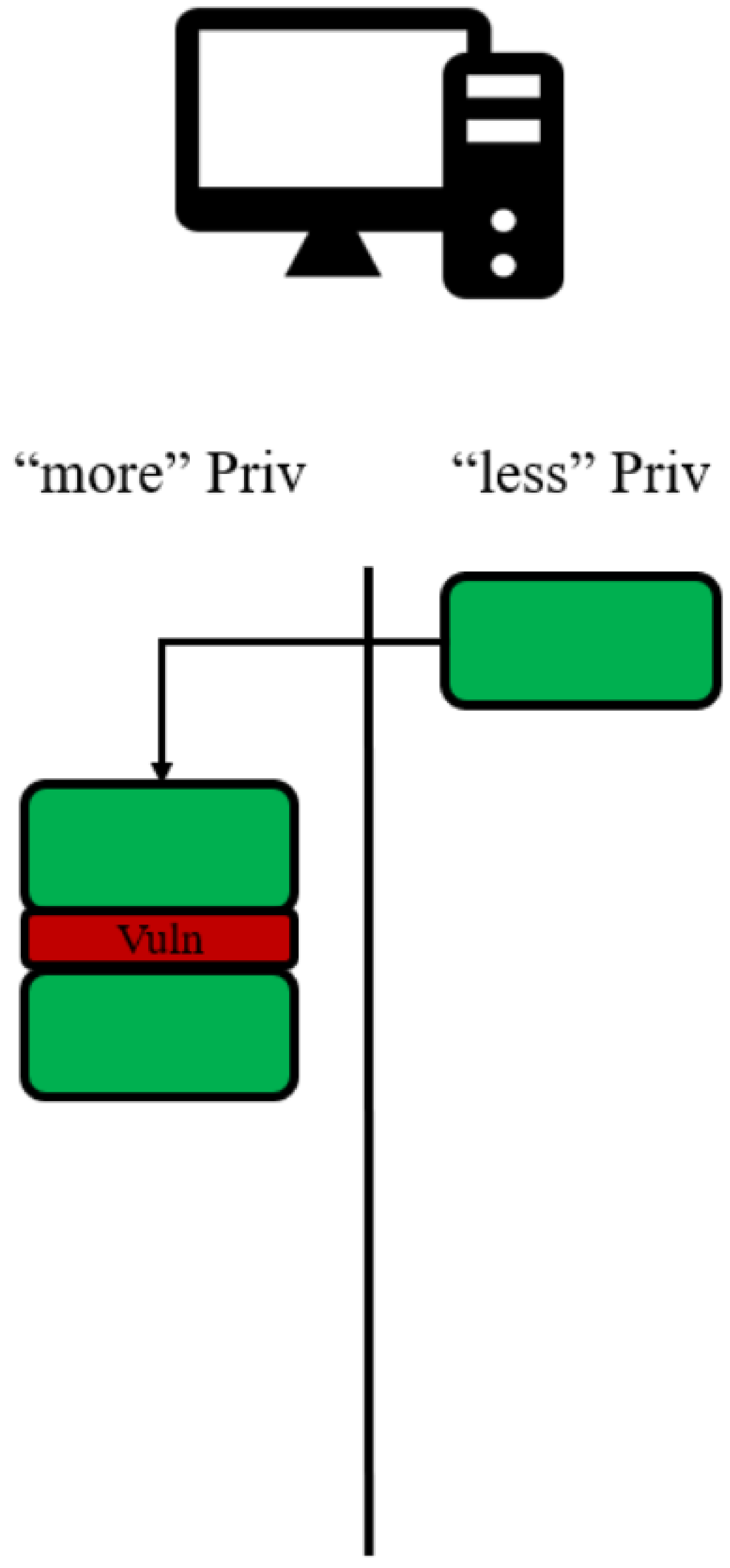

(e.g. ssh server)

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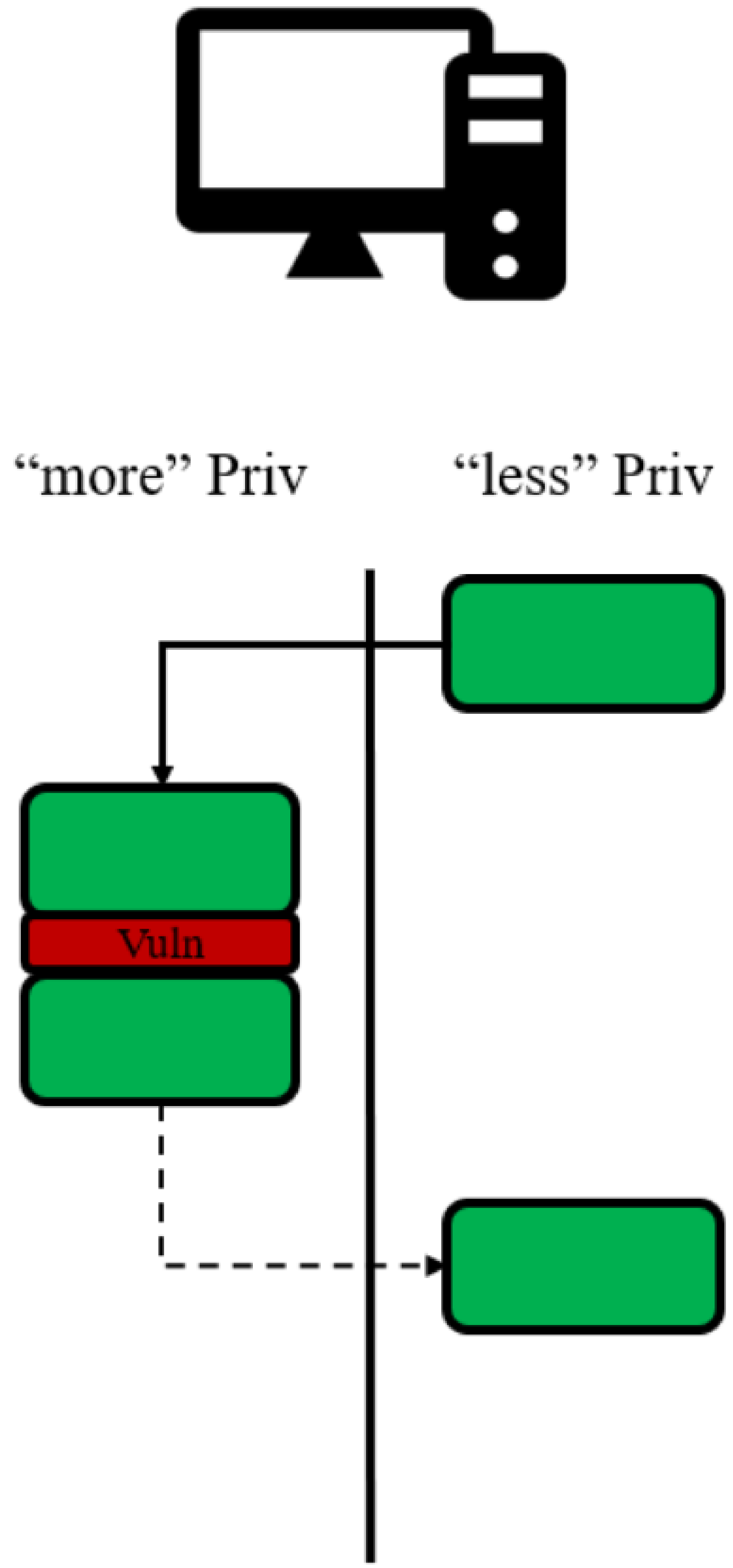

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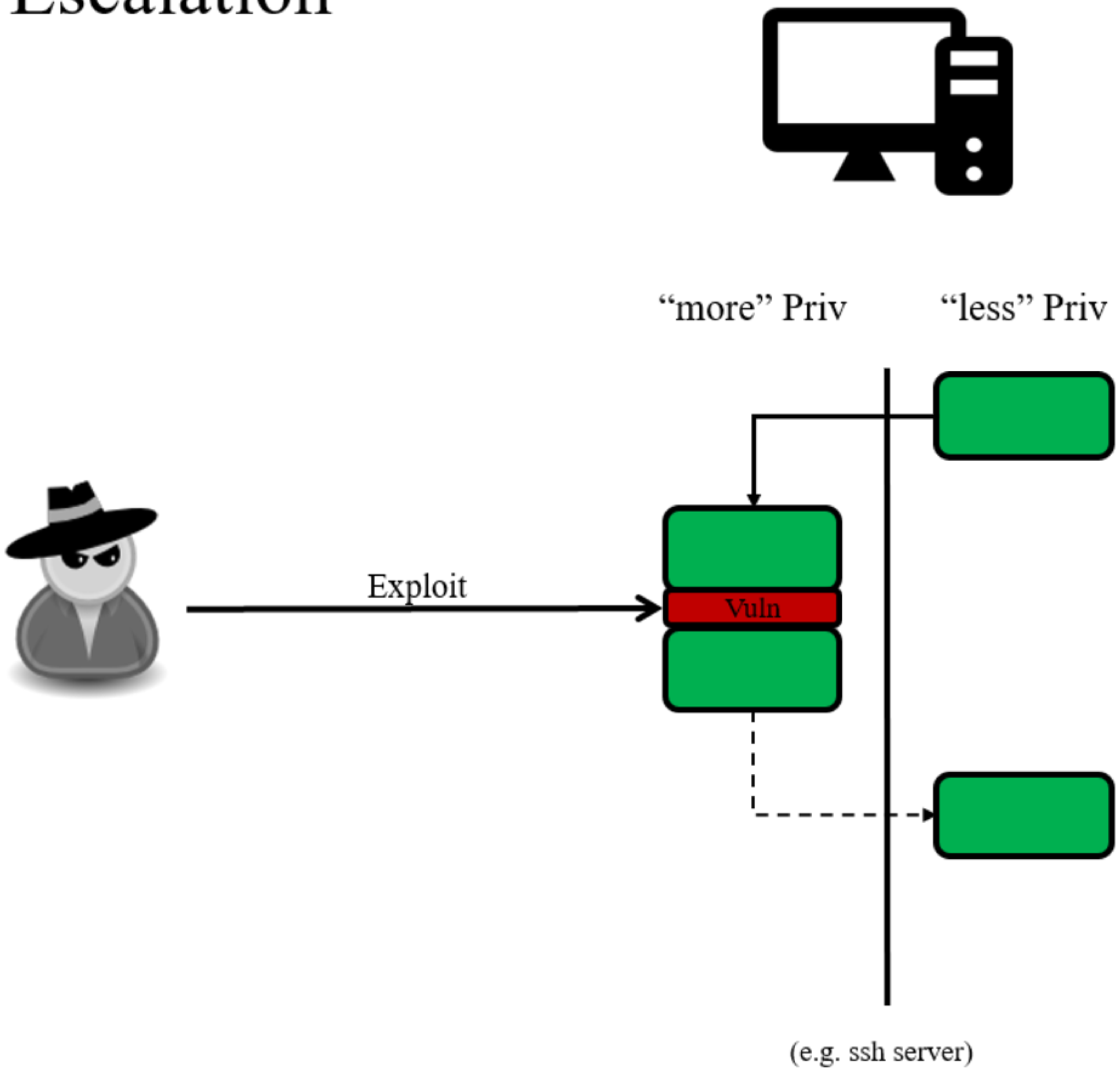
Privilege Escalation



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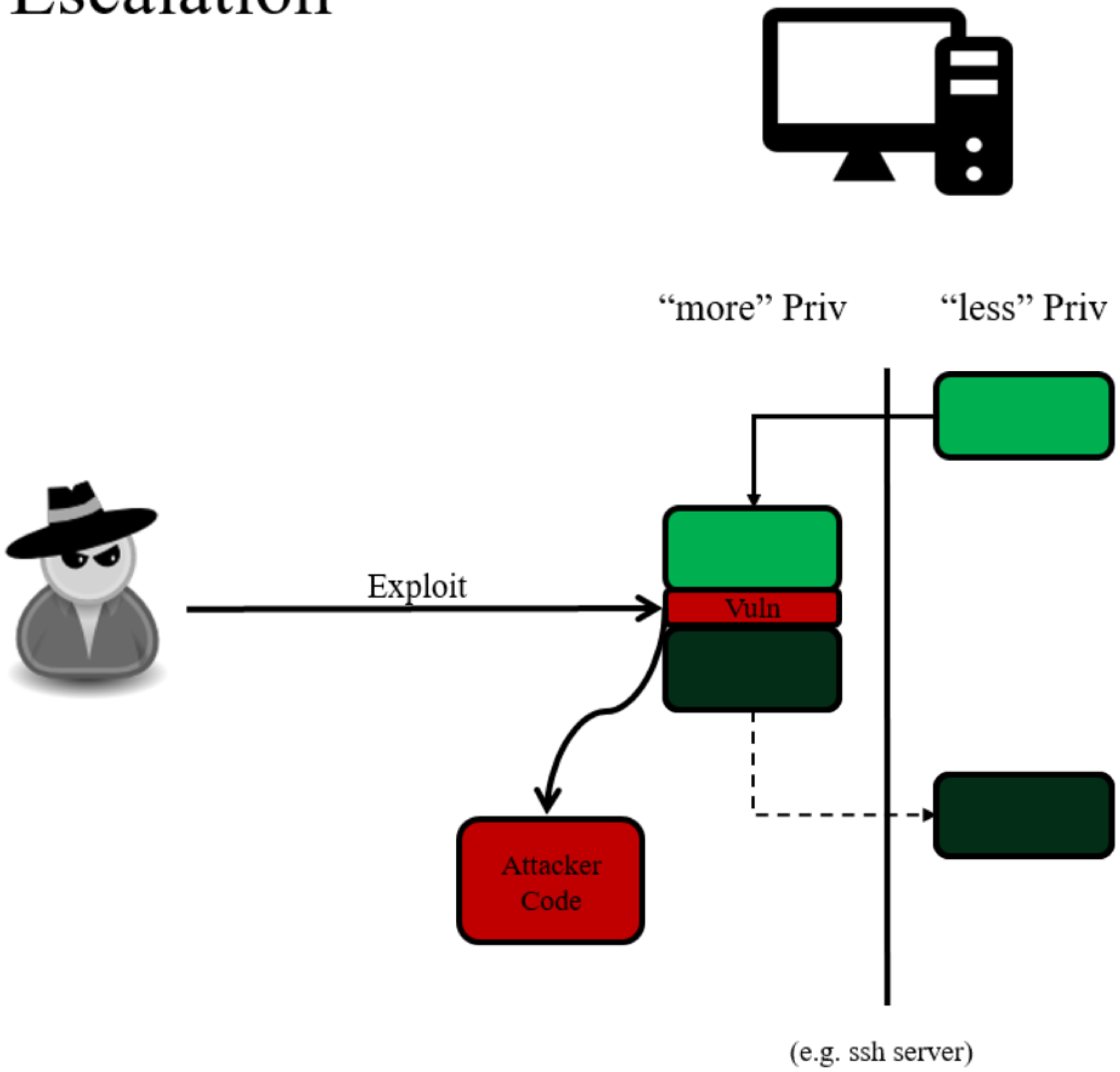

Current Mitigations

GEM [Mulliner(2014)]

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Multi-User Applications?

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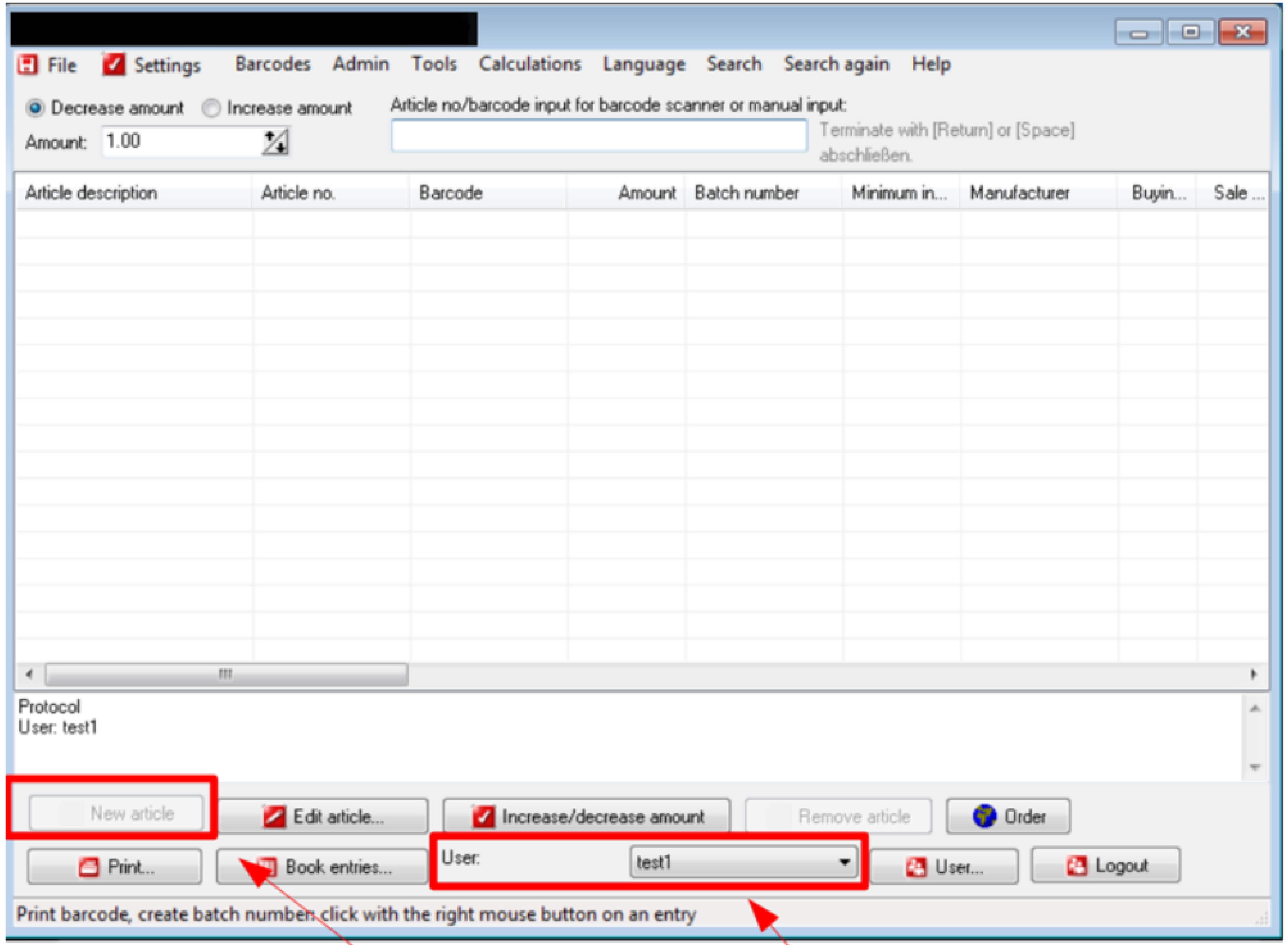


[redacted]

● Decrease amount ○ Increase amount

Amount: 1.00

Article no/barcode input for barcode scanner or manual input:

Terminate with [Return] or [Space] abschließen.

Article description	Article no.	Barcode	Amount	Batch number	Minimum in...	Manufacturer	Buyin...	Sale ...

Protocol
User: test1

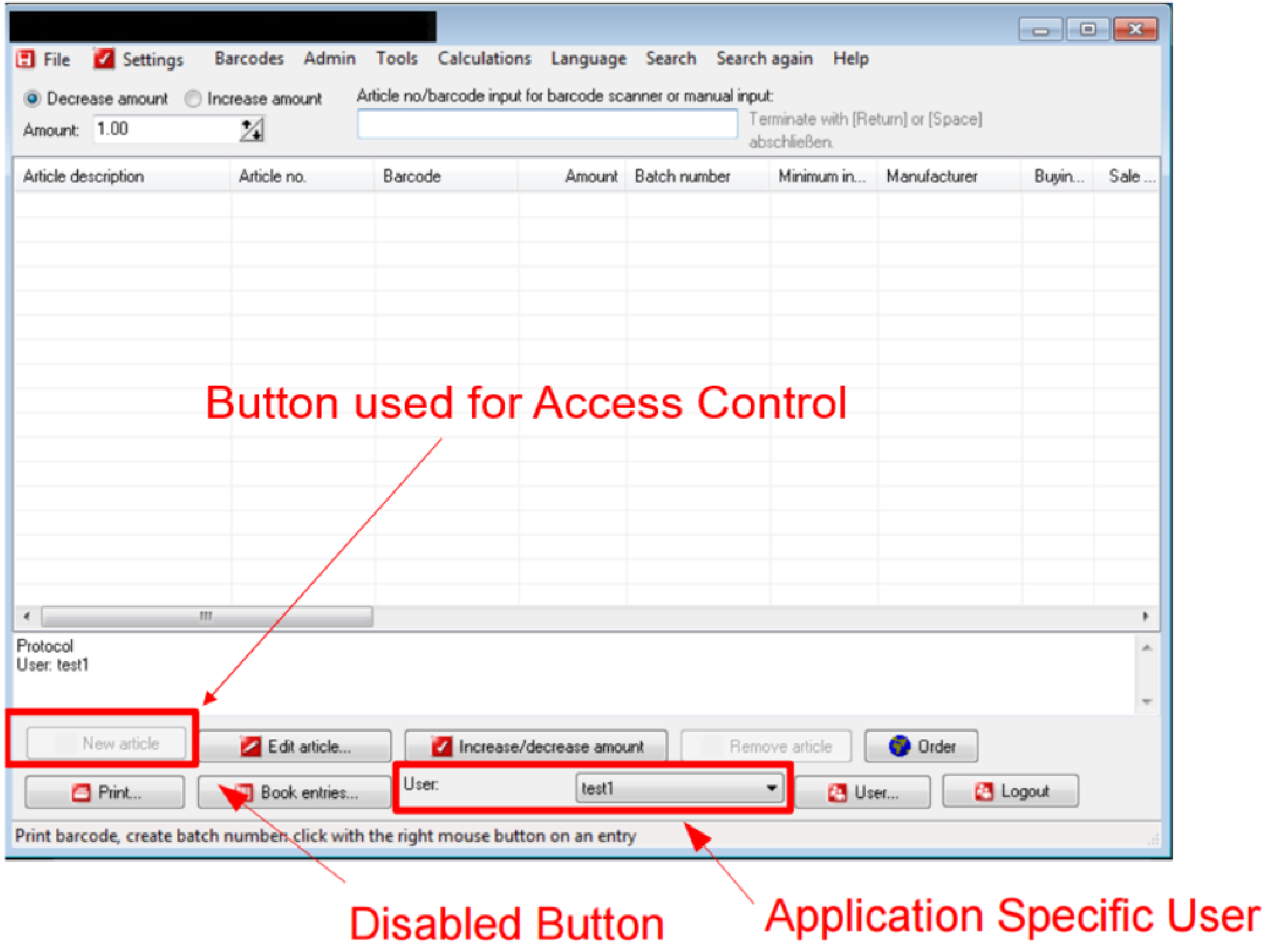
User: test1

Print barcode, create batch number: click with the right mouse button on an entry

Disabled Button

Application Specific User

GEM [Mulliner(2014)]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Button used for Access Control

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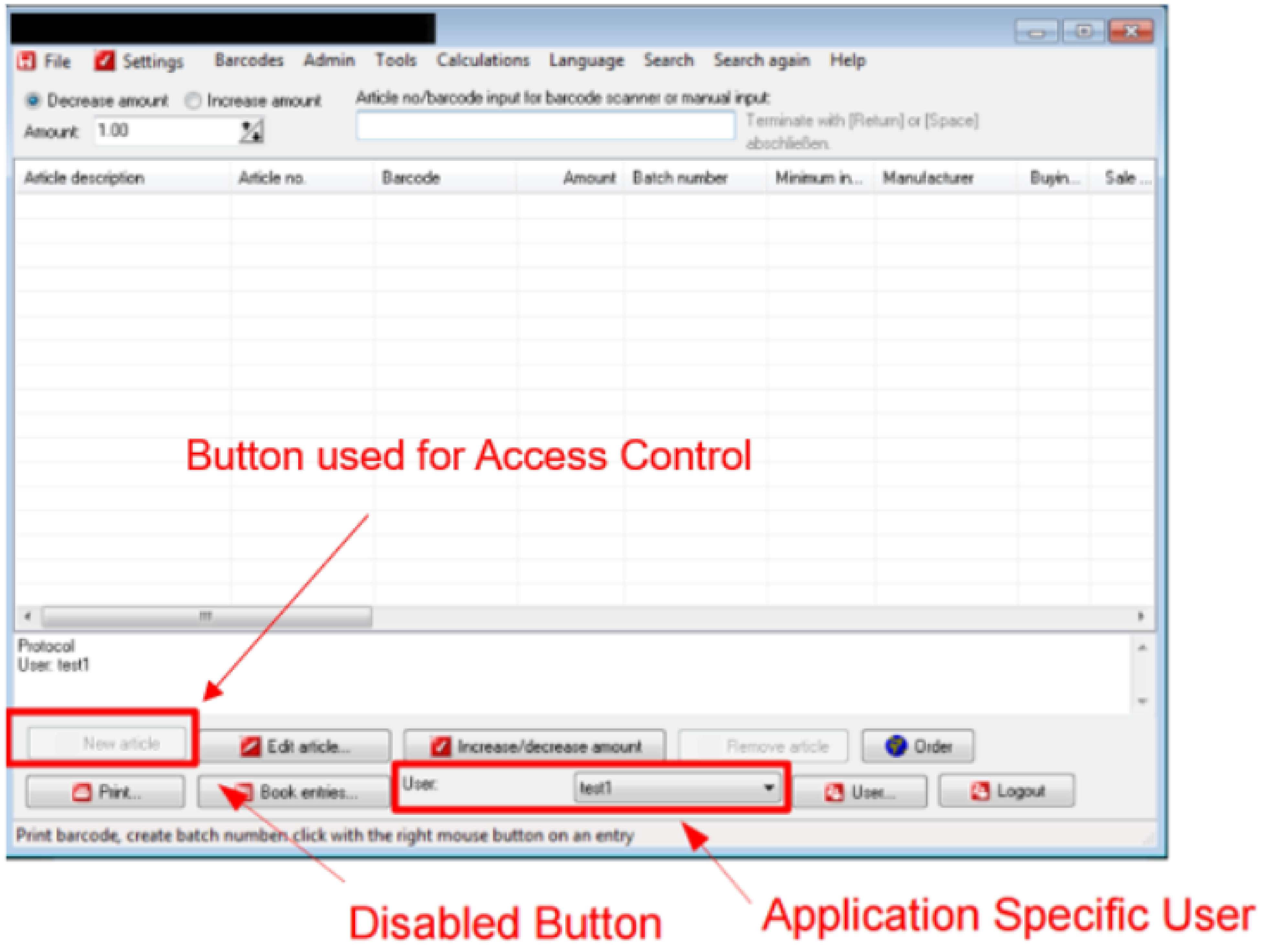

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Button used for Access Control

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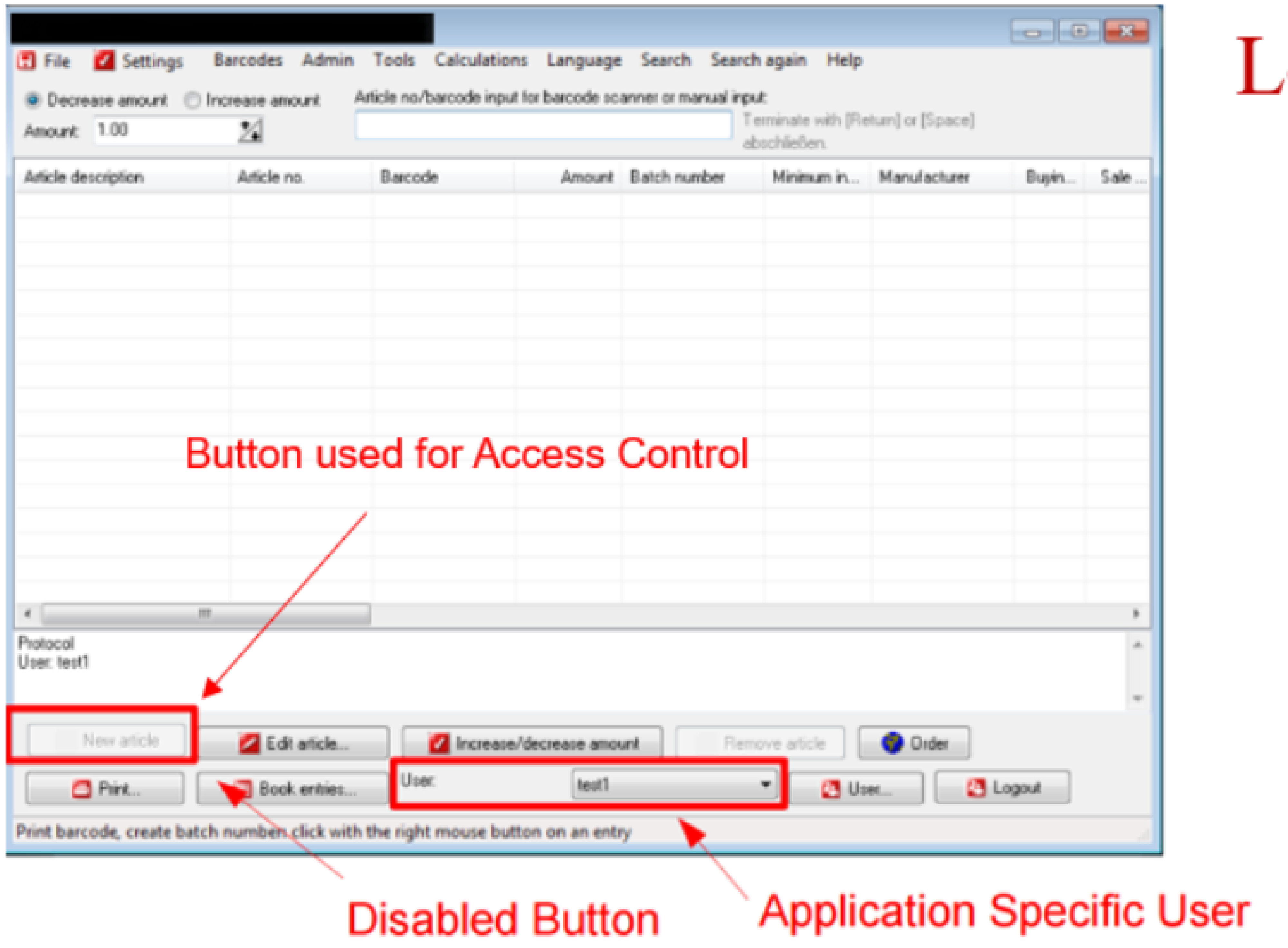
Application Specific User

Behind the scenes

```
void new_article() {
    /* Not for test1 user */
    article = gettext();
    record(article);
}
```

Threat Model



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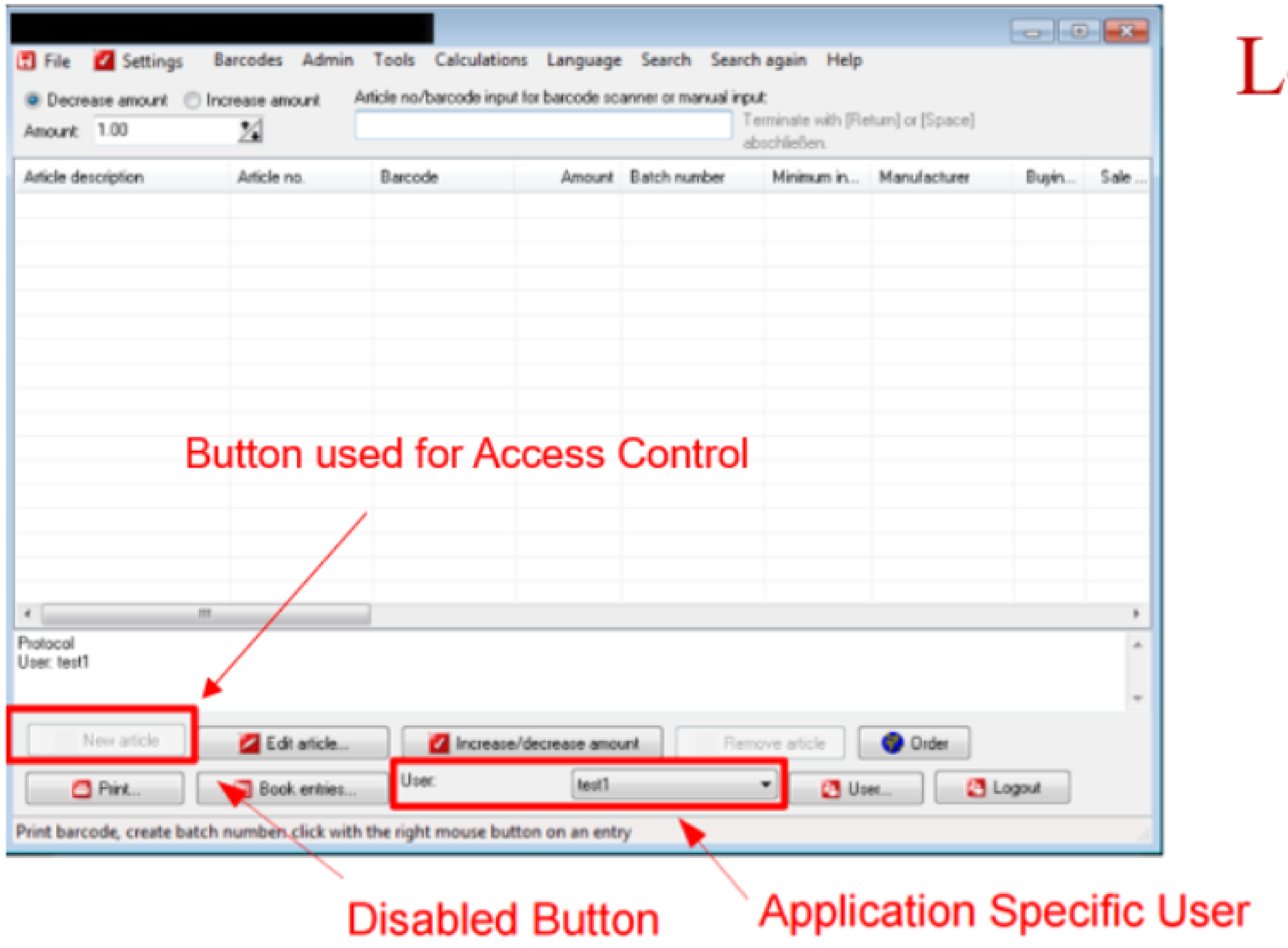
Application Specific User

Logic vulnerability

Threat Model



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Button used for Access Control

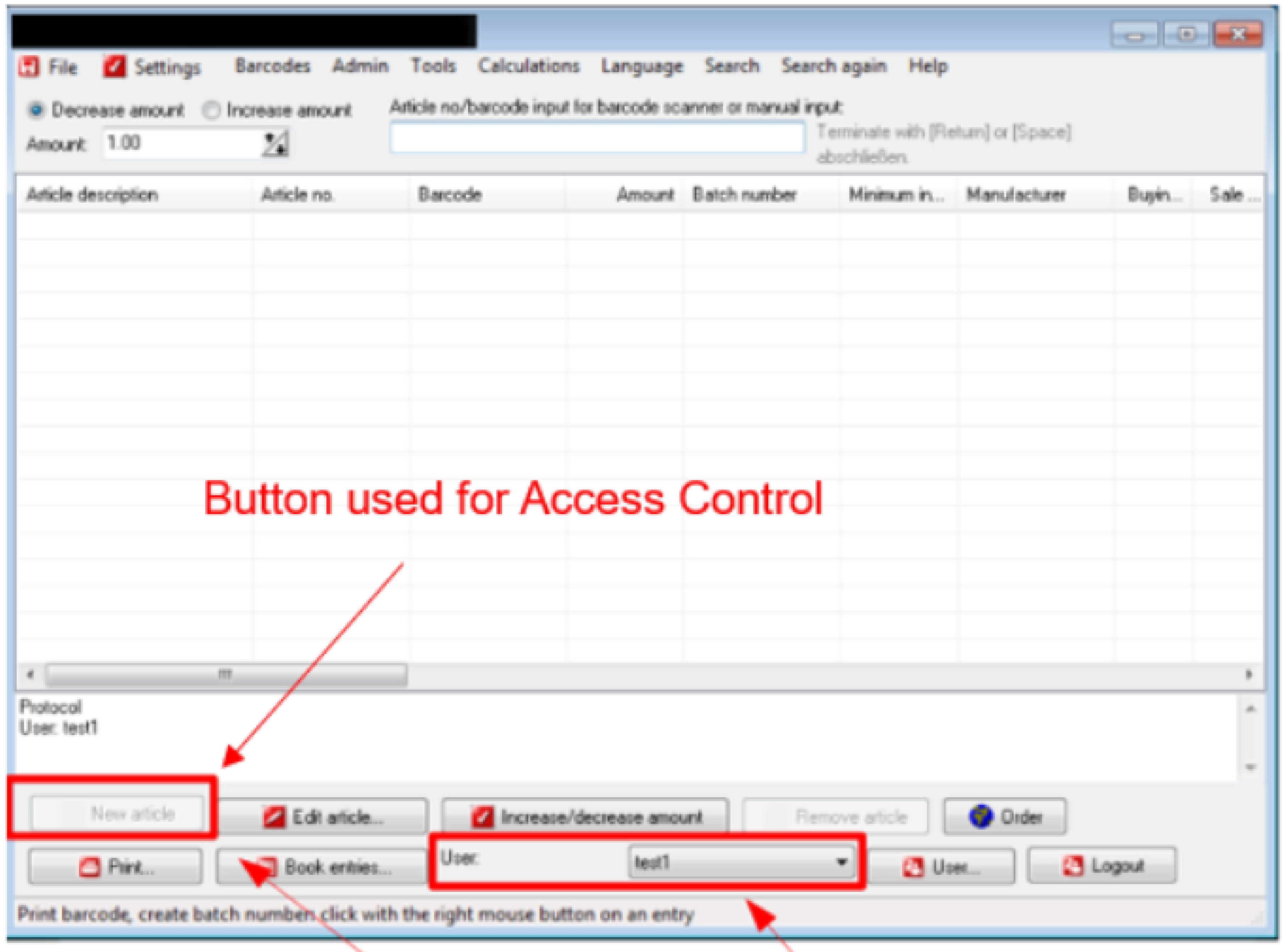
Disabled Button

Application Specific User

Logic vulnerability

- Enforcing the access to **new_article()** using the GUI (e.g., disabling the button)

Threat Model



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Button used for Access Control

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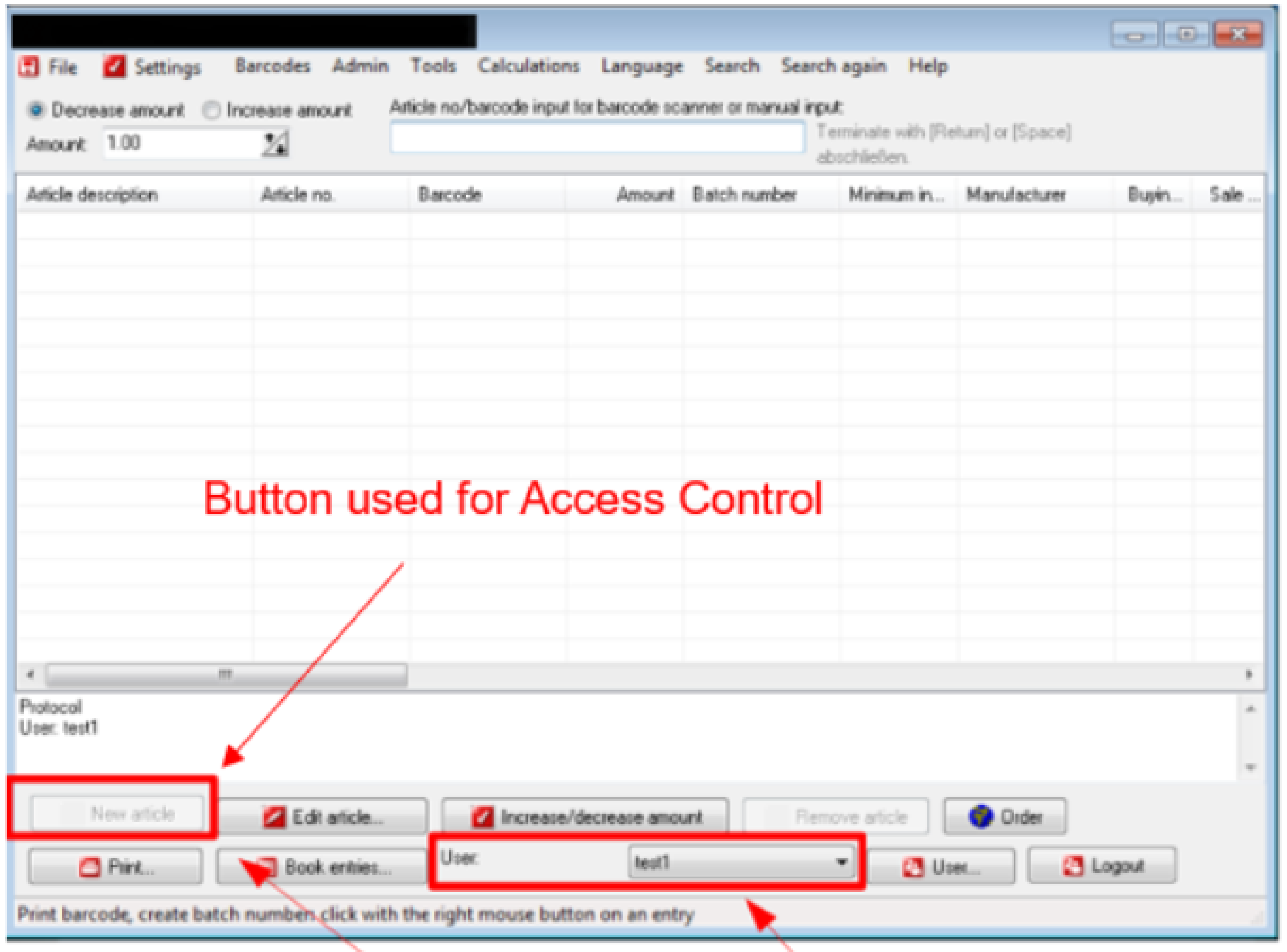
Application Specific User

Logic vulnerability

- Enforcing the access to **new_article()** using the GUI (e.g., disabling the button)

Memory corruption vulnerability

Threat Model



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Button used for Access Control

Disabled Button

Application Specific User

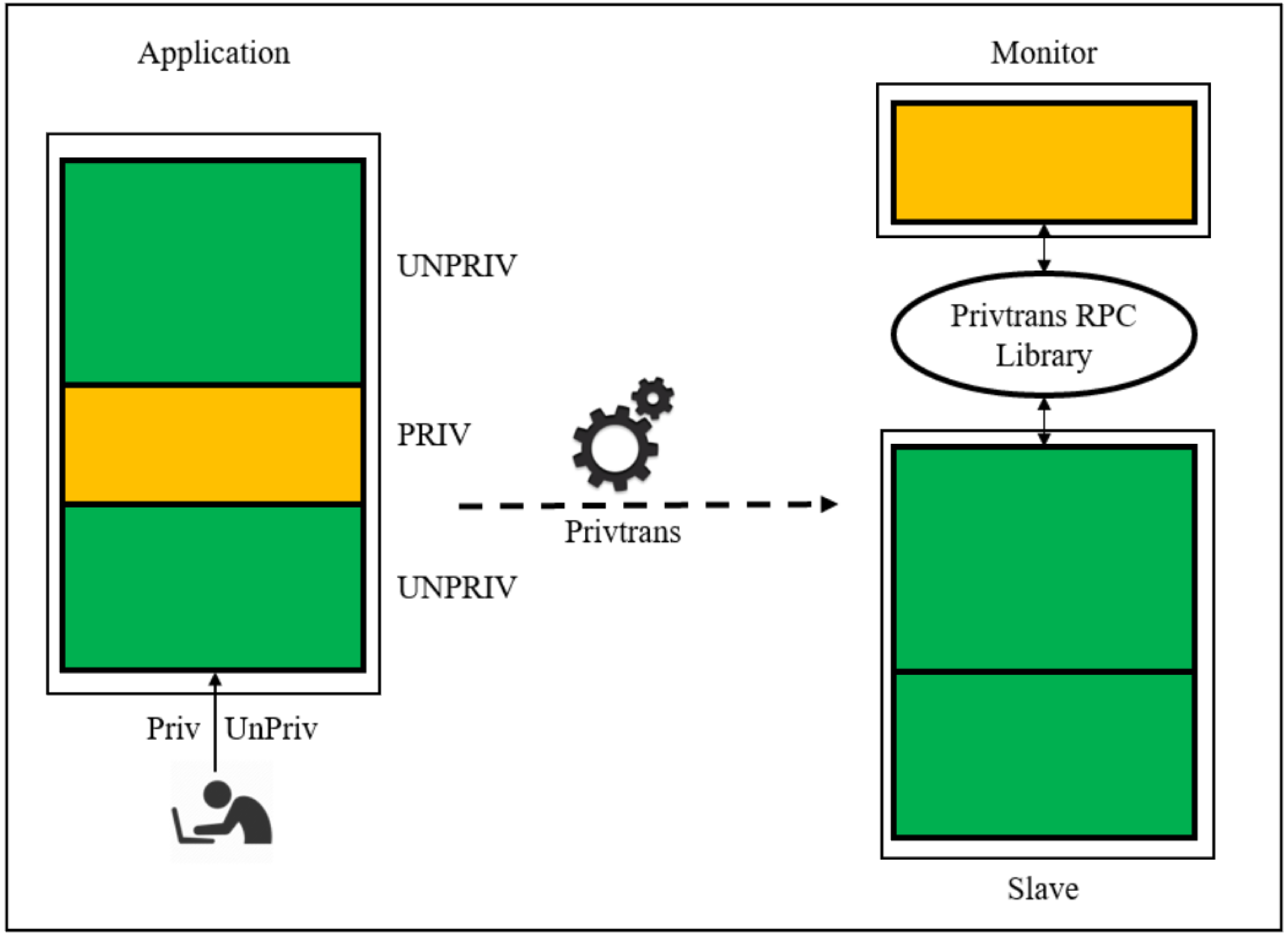
Logic vulnerability

- Enforcing the access to **new_article()** using the GUI (e.g., disabling the button)

Memory corruption vulnerability

- Exploit “test1” available functions and hijack the control flow to **new_article()**

Previous Work - Privtrans



D. Brumley, and D. Song. *USENIX Security ’04*

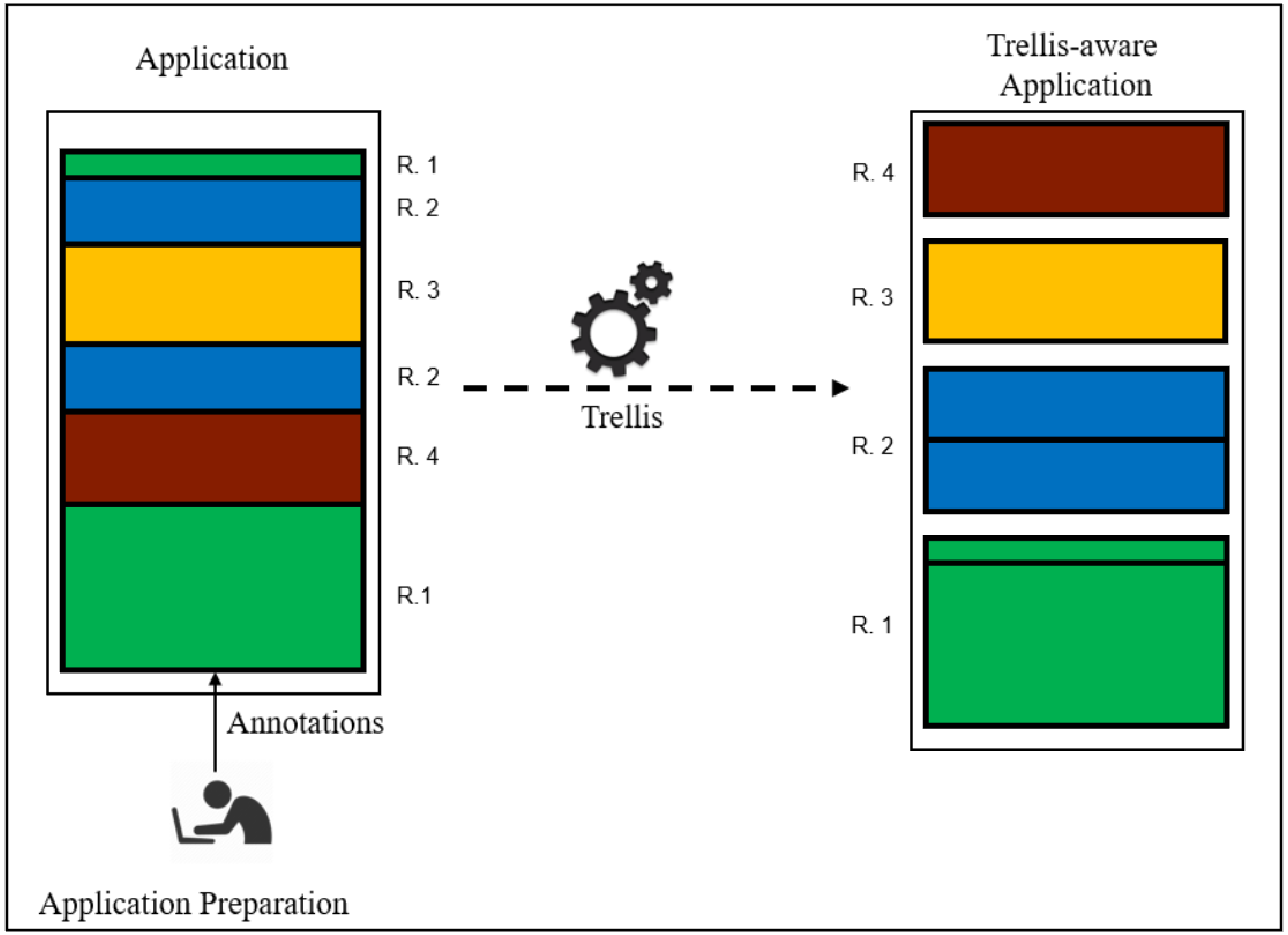
Previous Work - Limitations

Does not support multiple roles

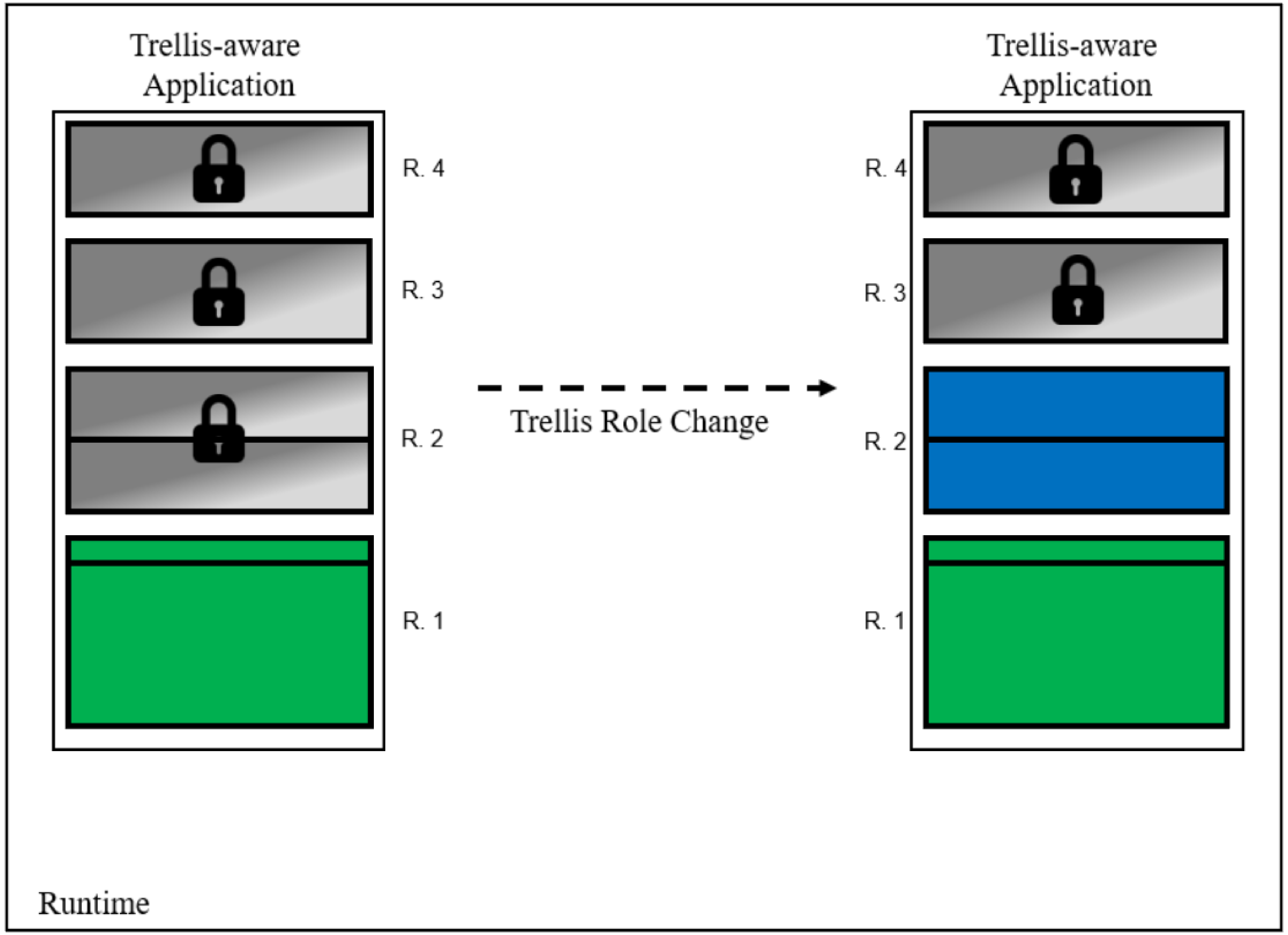
Physical application partitioning

IPC overhead

Trellis Approach



Trellis Approach



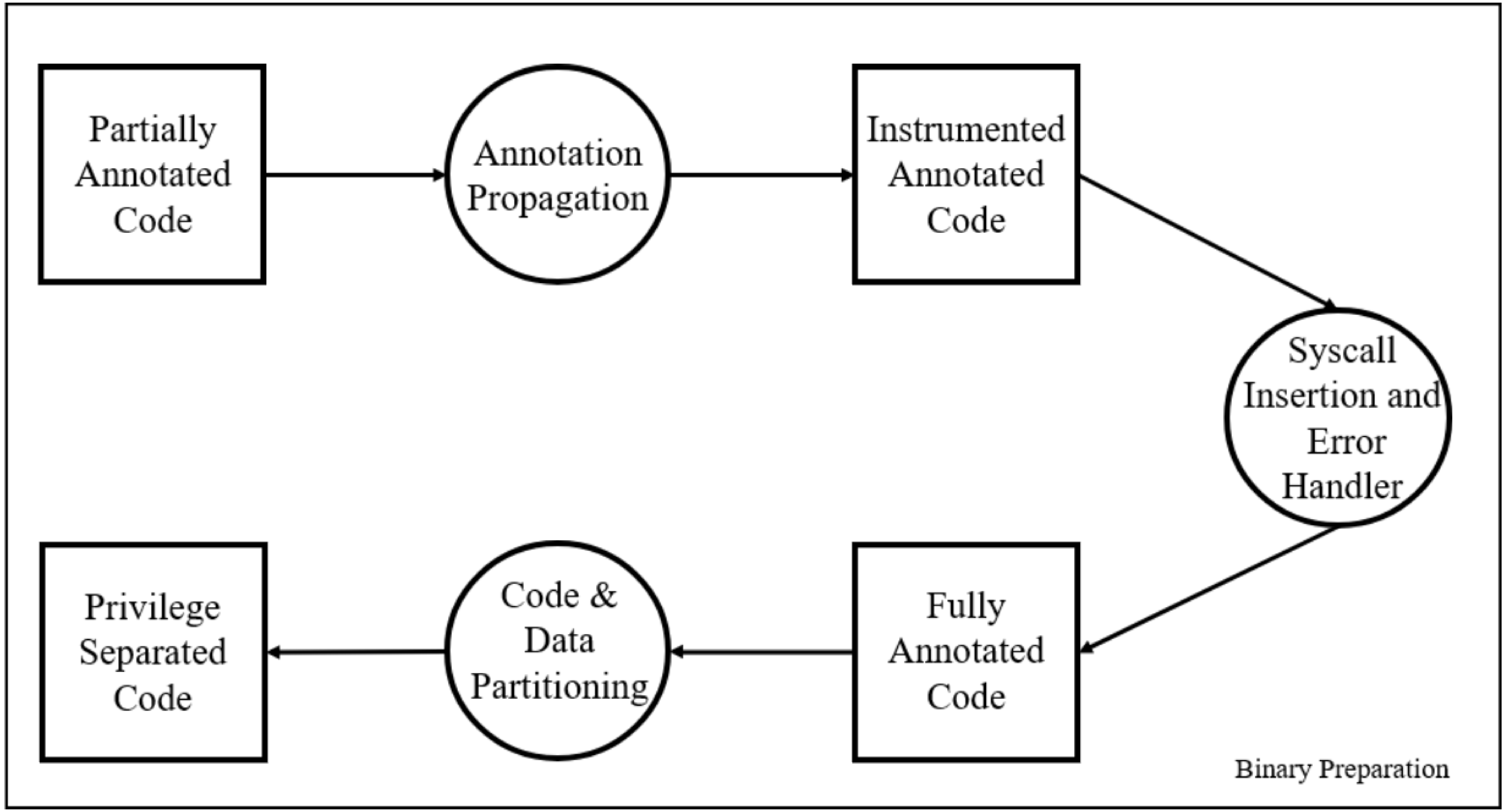
Trellis Contributions

OS-based application development framework for multi-user application to enforce Hierarchical-Base Access Control policies (HBAC)

Prototype implementation based on LLVM/Clang, GNU C Library, and the Linux Kernel

Real-world application evaluation

Implementation



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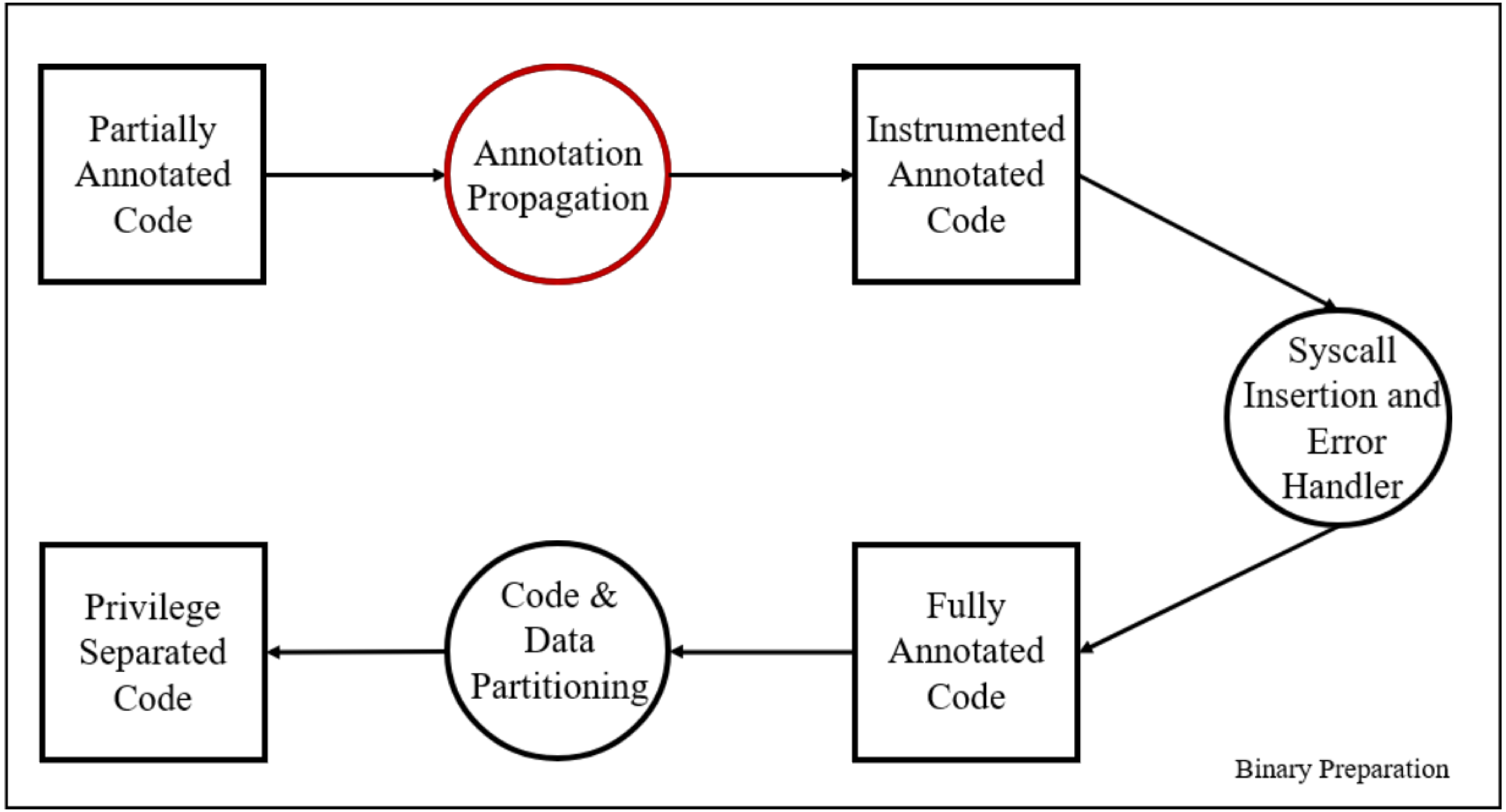

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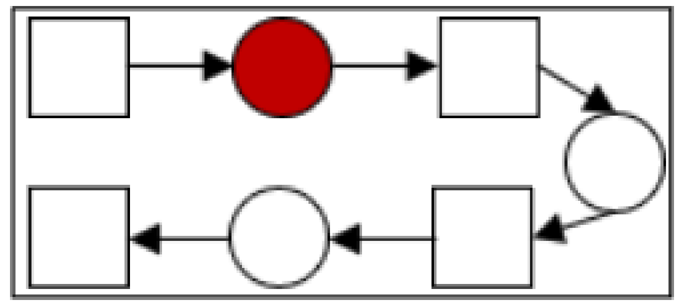

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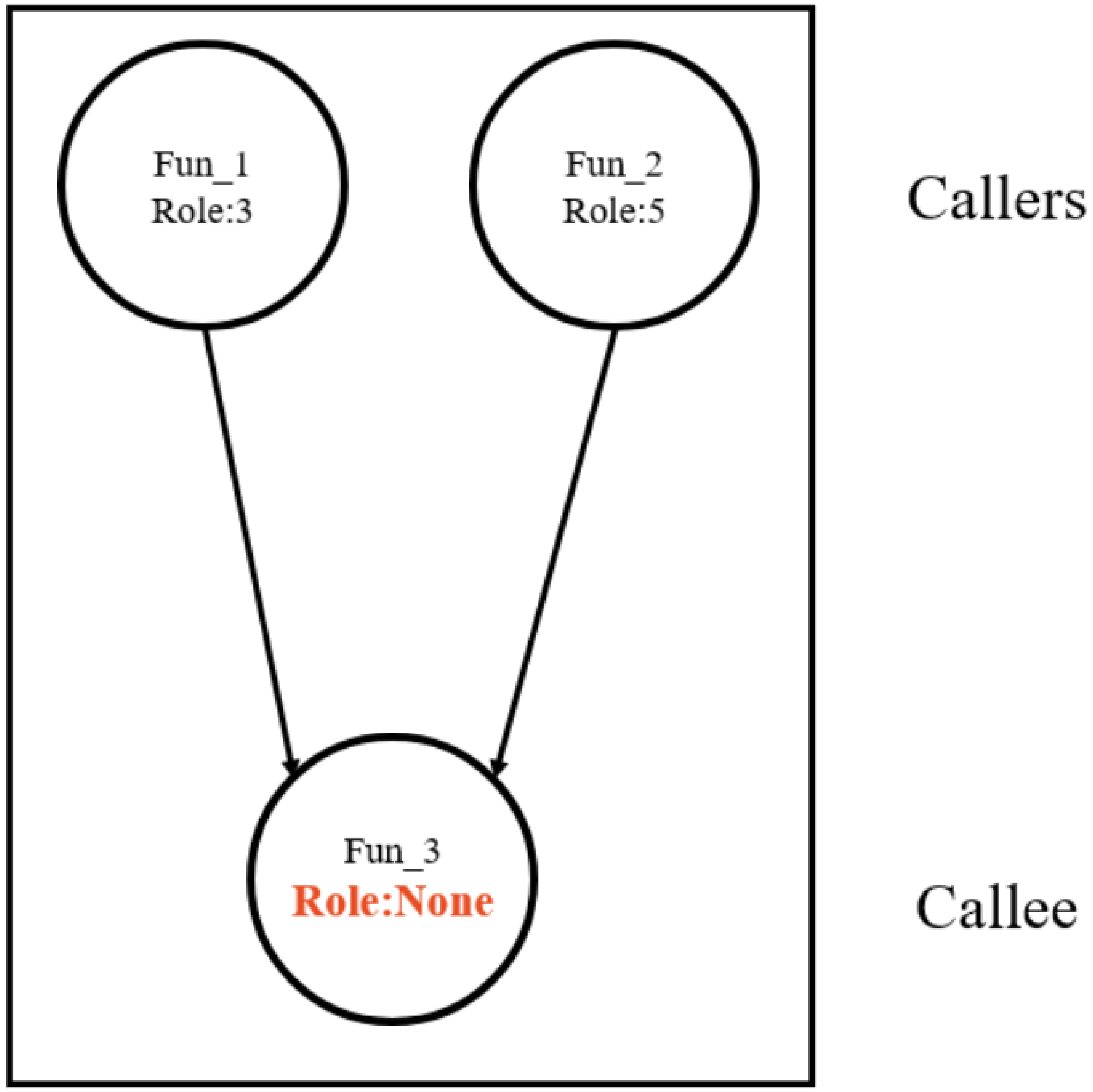
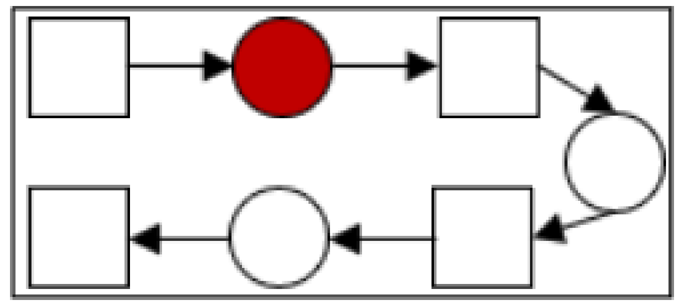
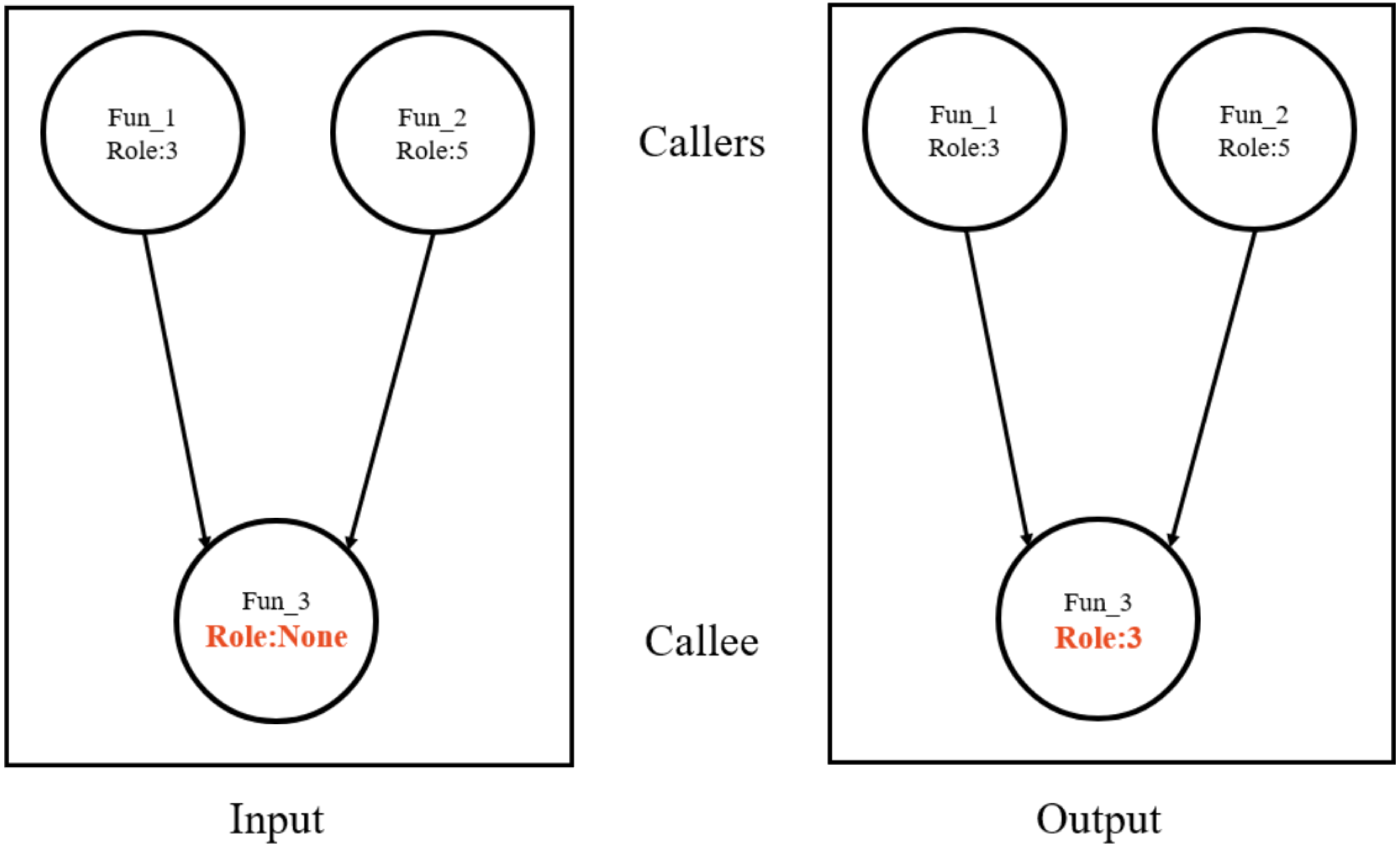


Input

Implementation





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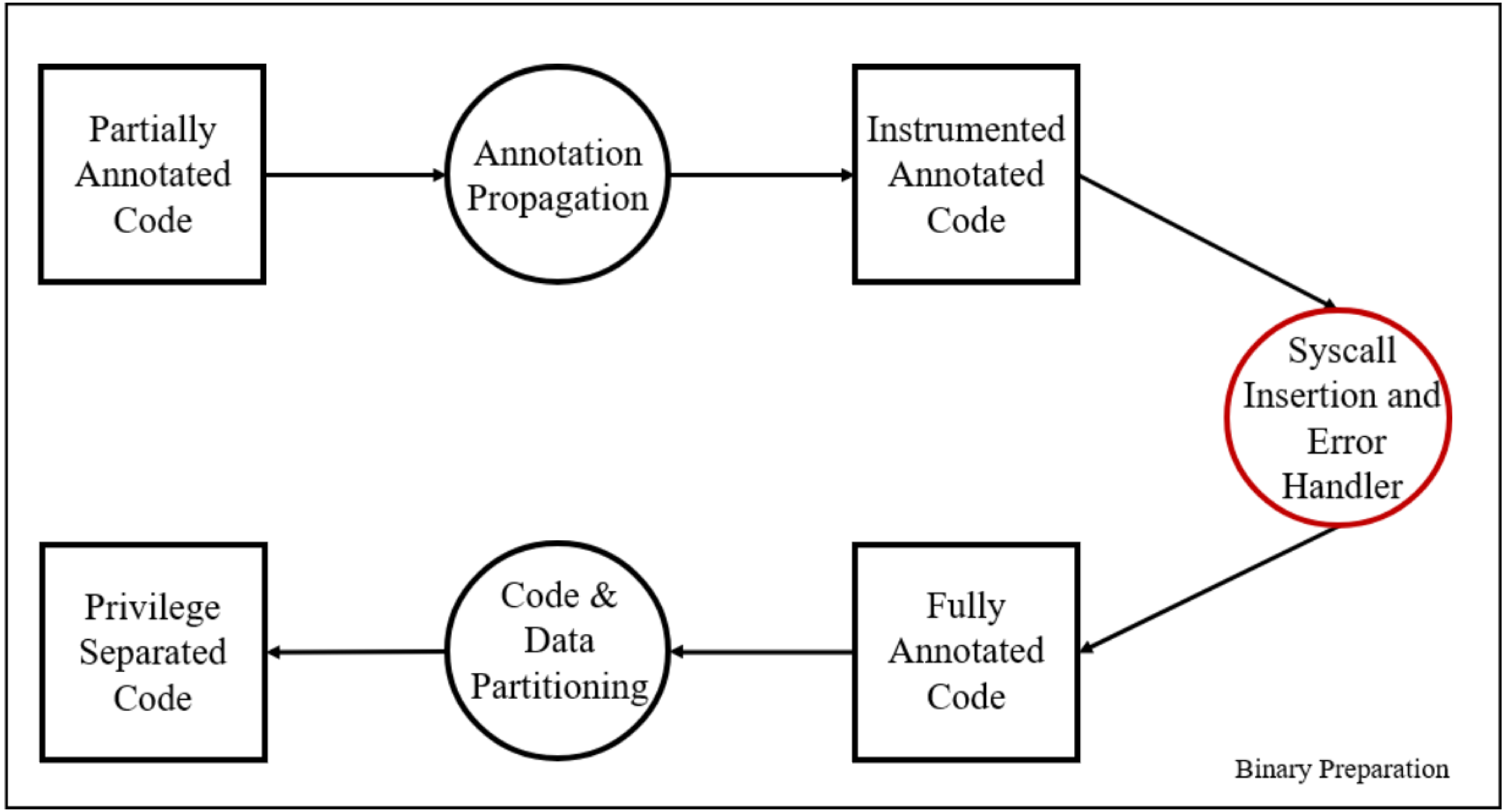

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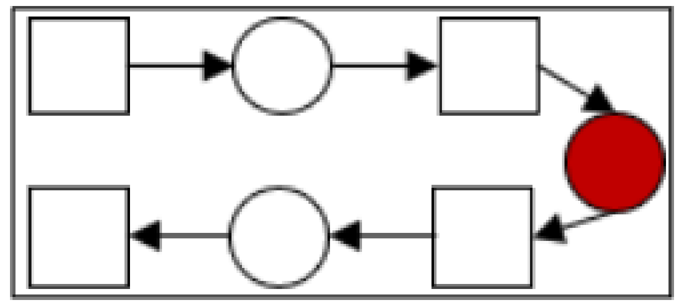

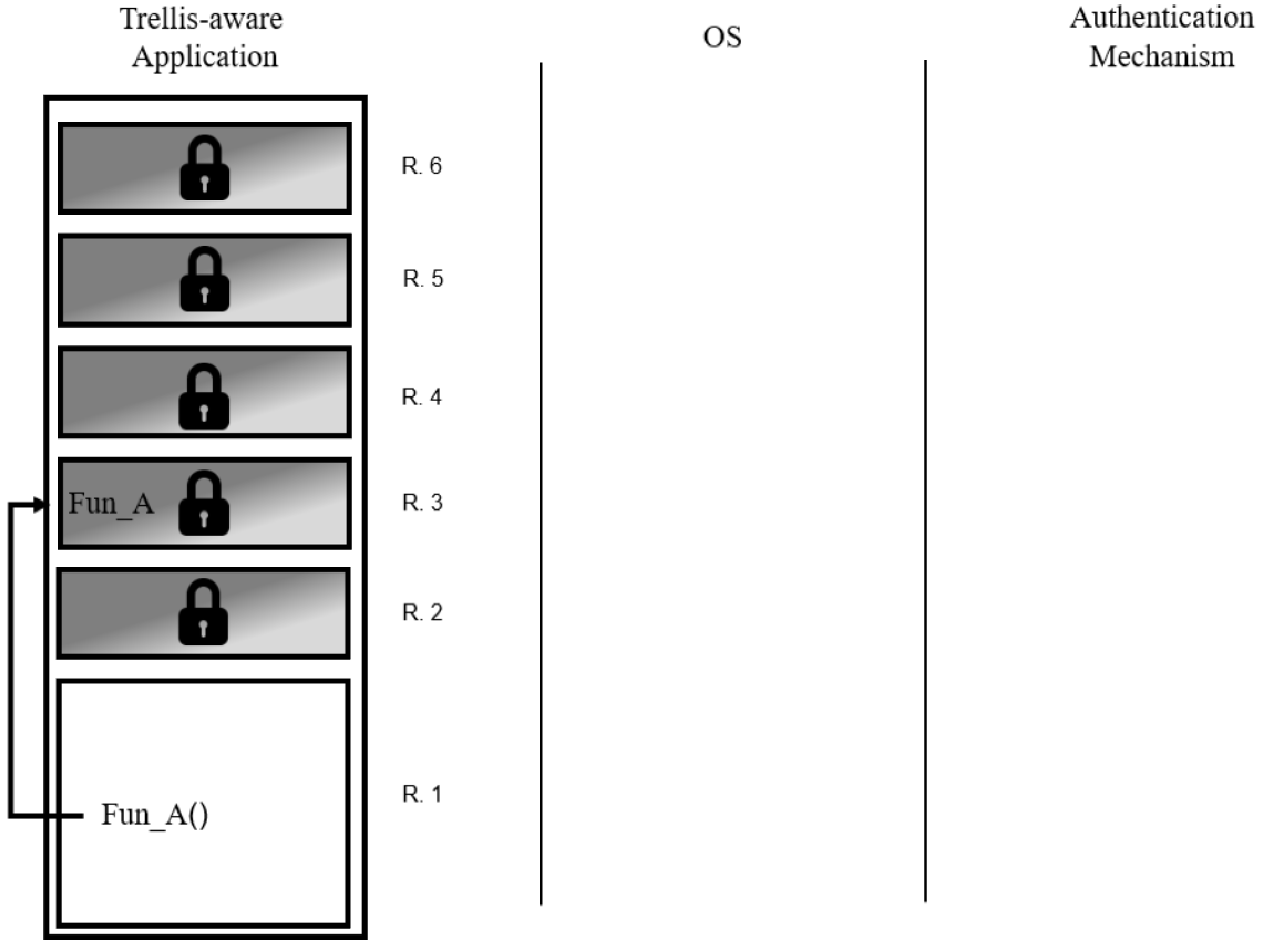

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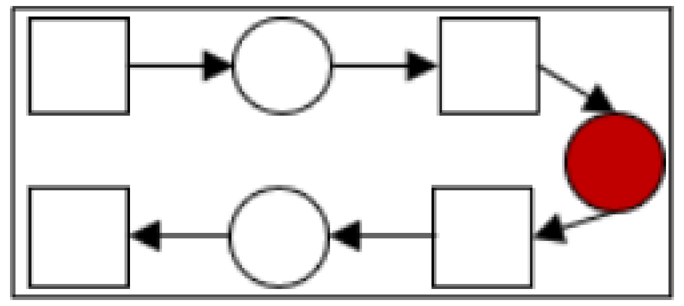
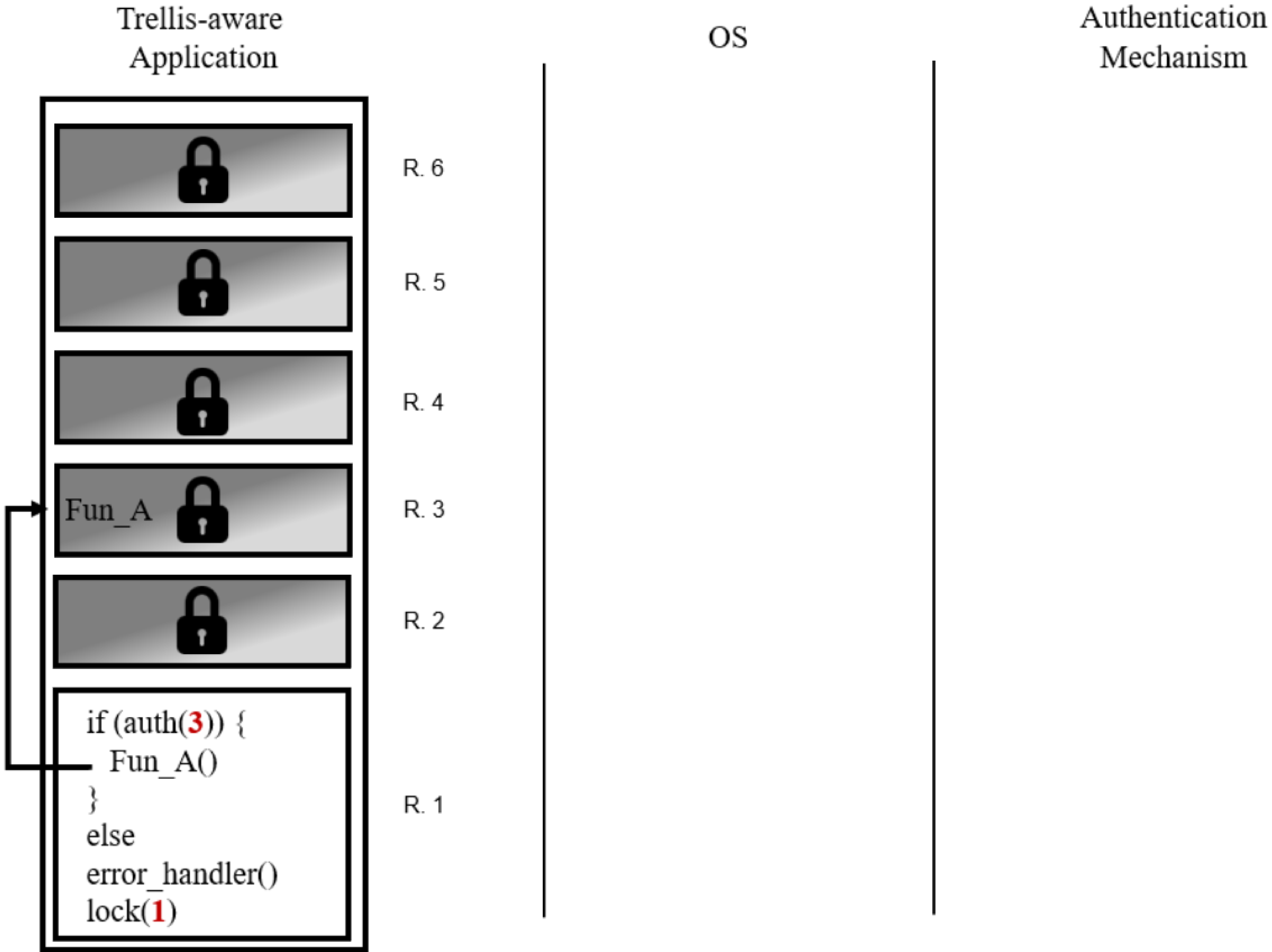
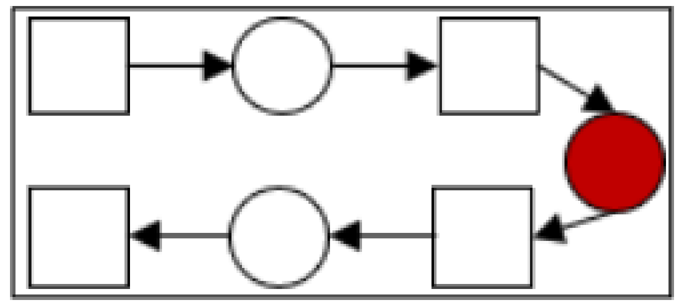
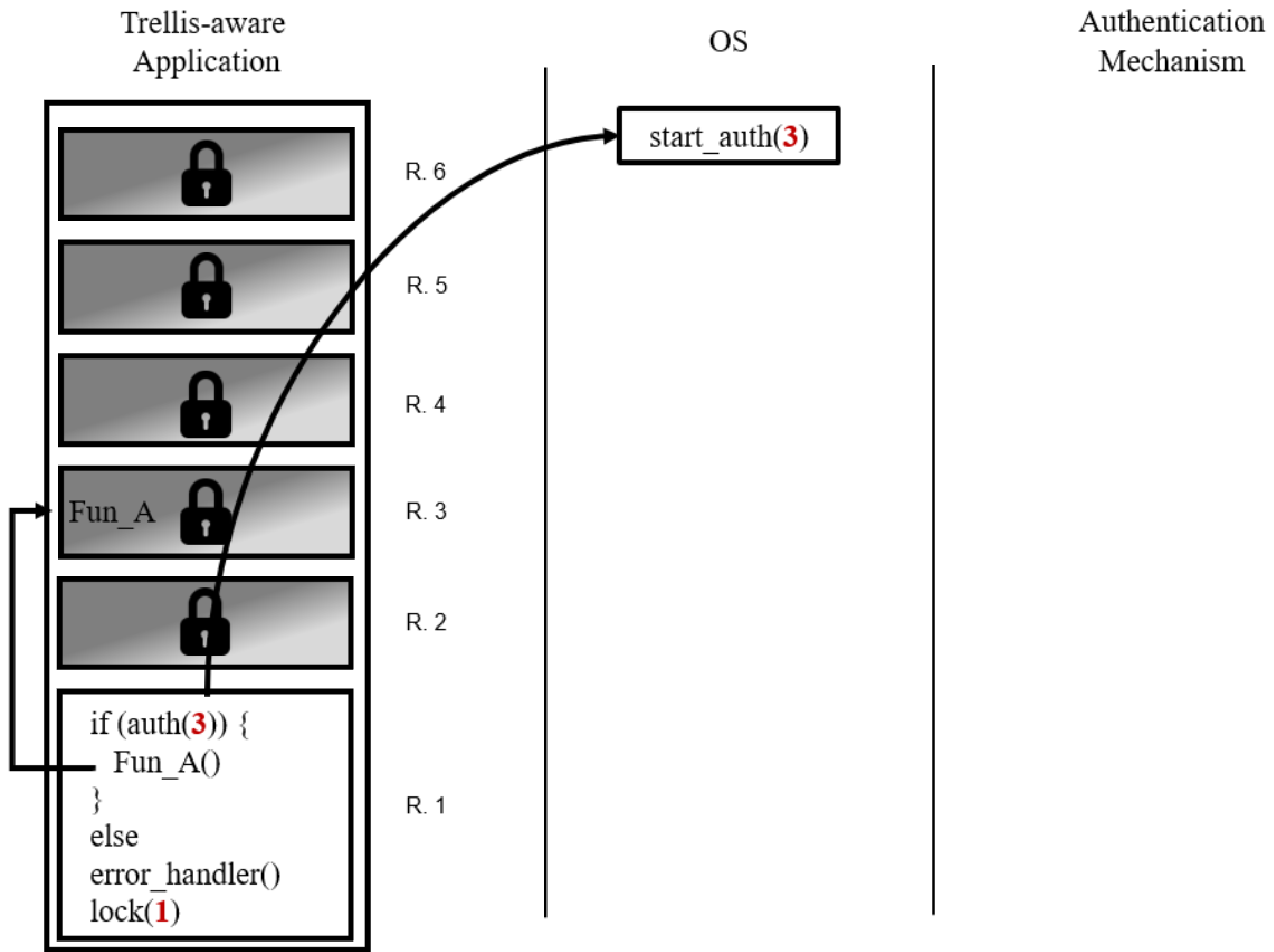




```
if (auth(3)) {
  Fun_A()
}
else
error_handler()
lock(1)
```

Implementation





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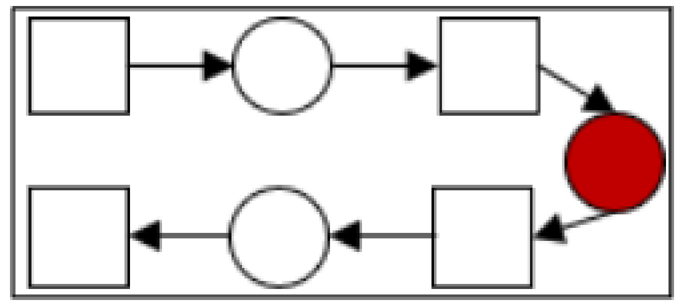

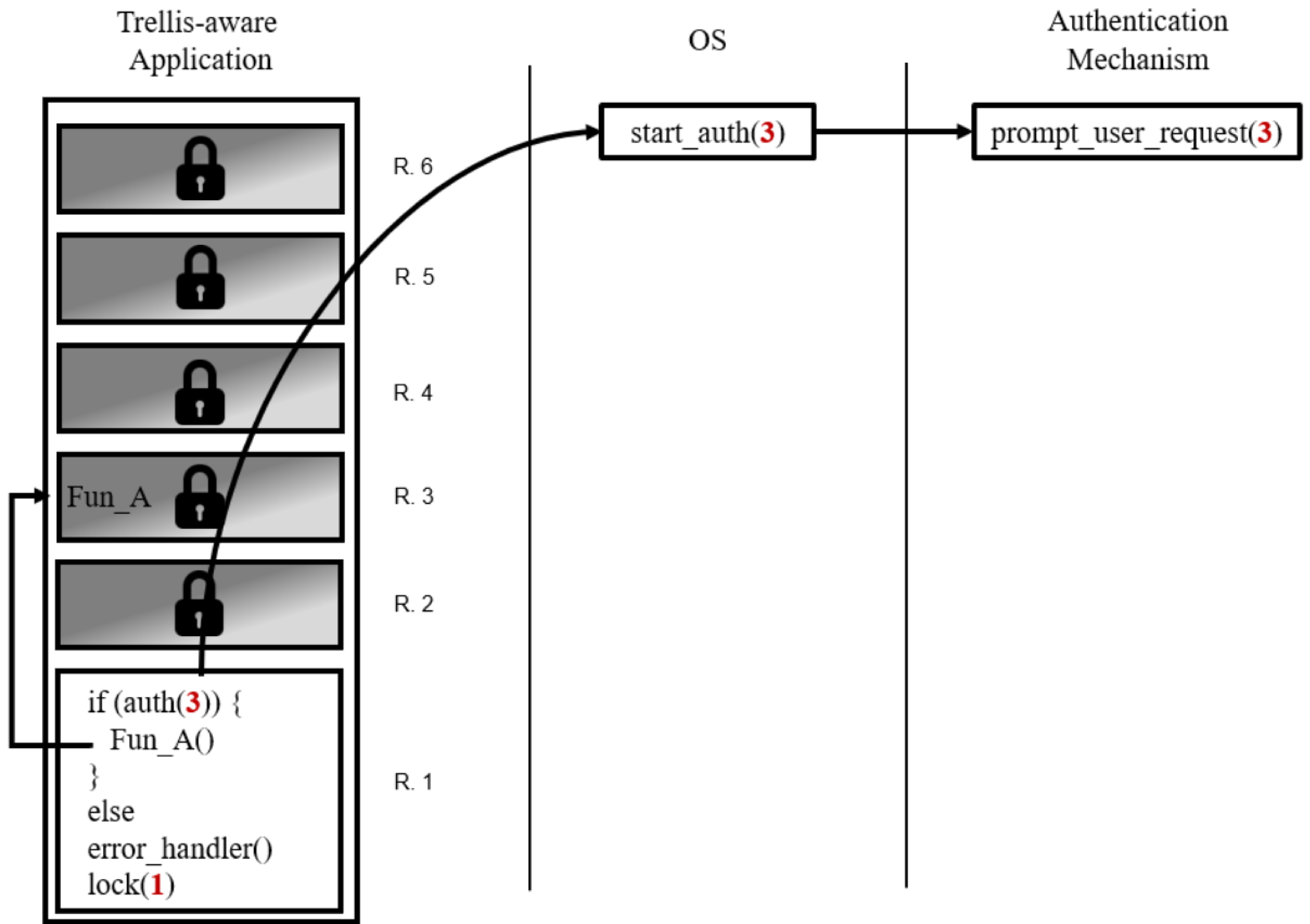

Trellis-aware Application

OS

Authentication Mechanism

start_auth(3)

prompt_user_request(3)

R. 6

R. 5

R. 4

R. 3

R. 2

R. 1

Fun_A

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if (auth(3)) {
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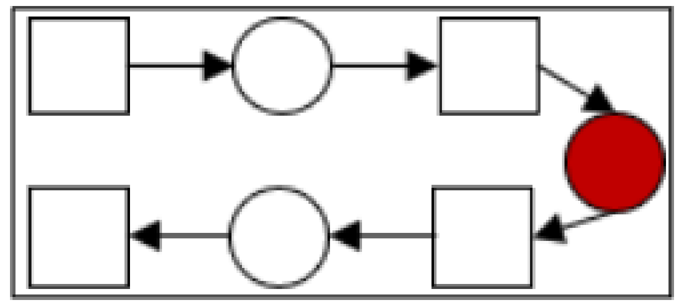
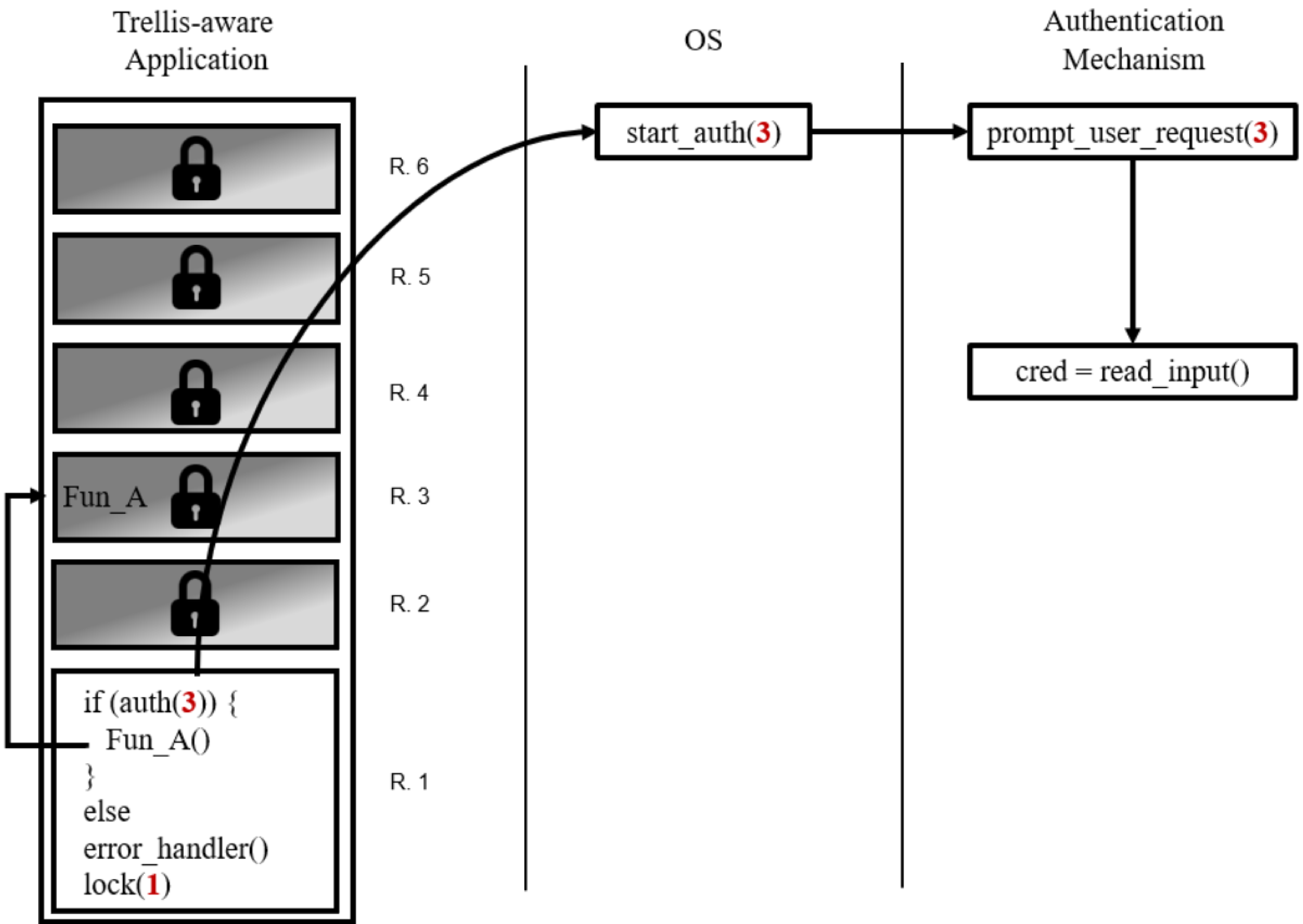
Implementation





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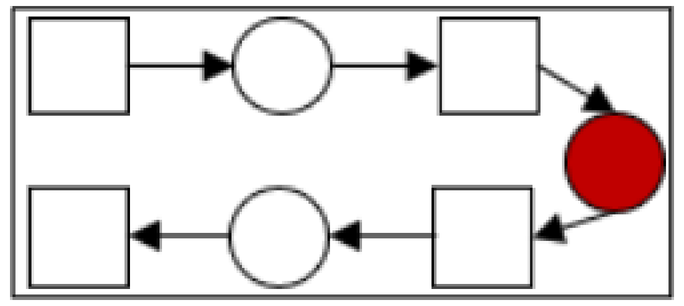

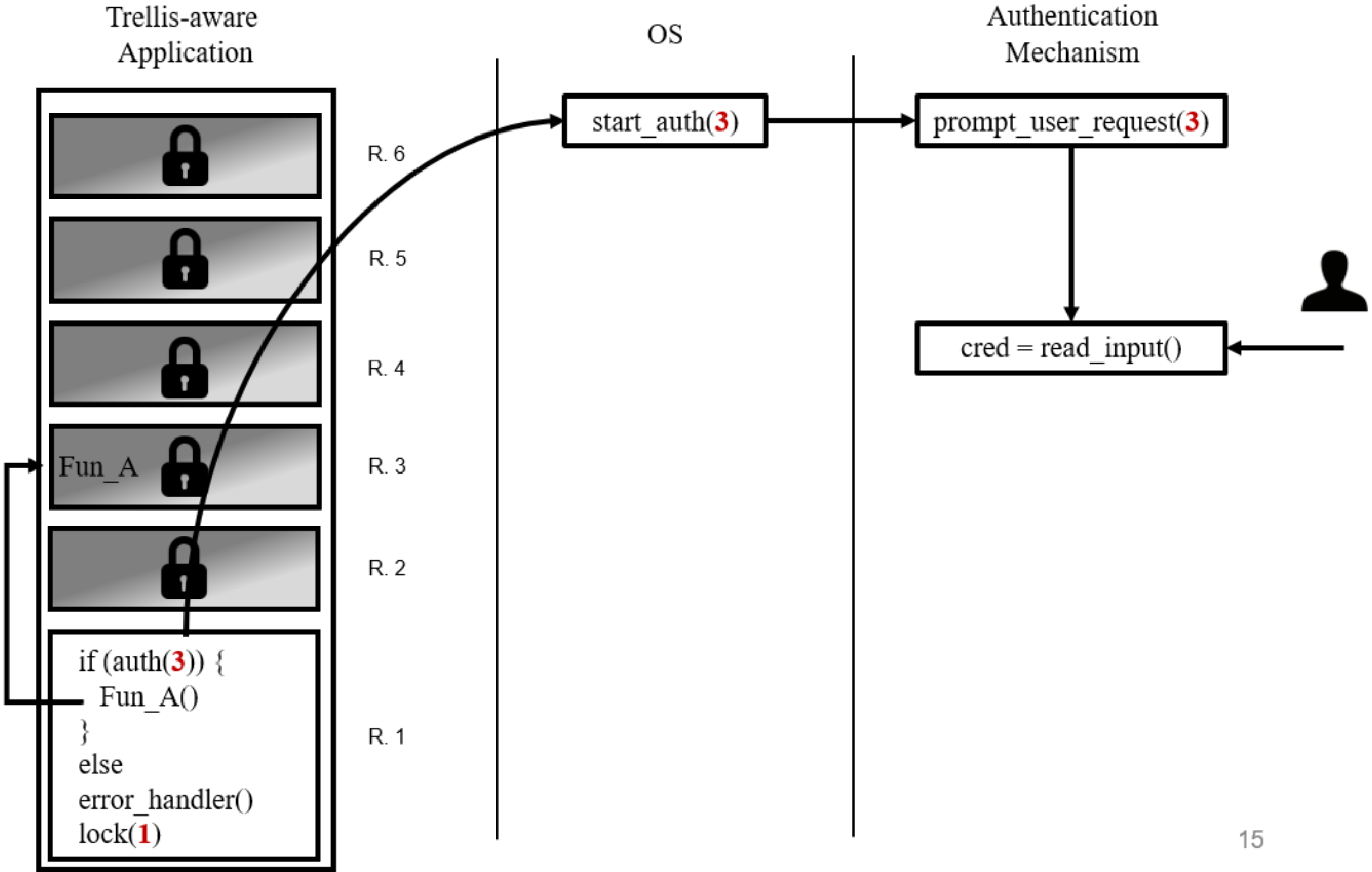

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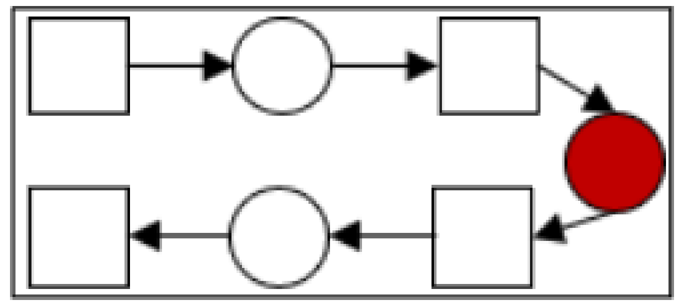

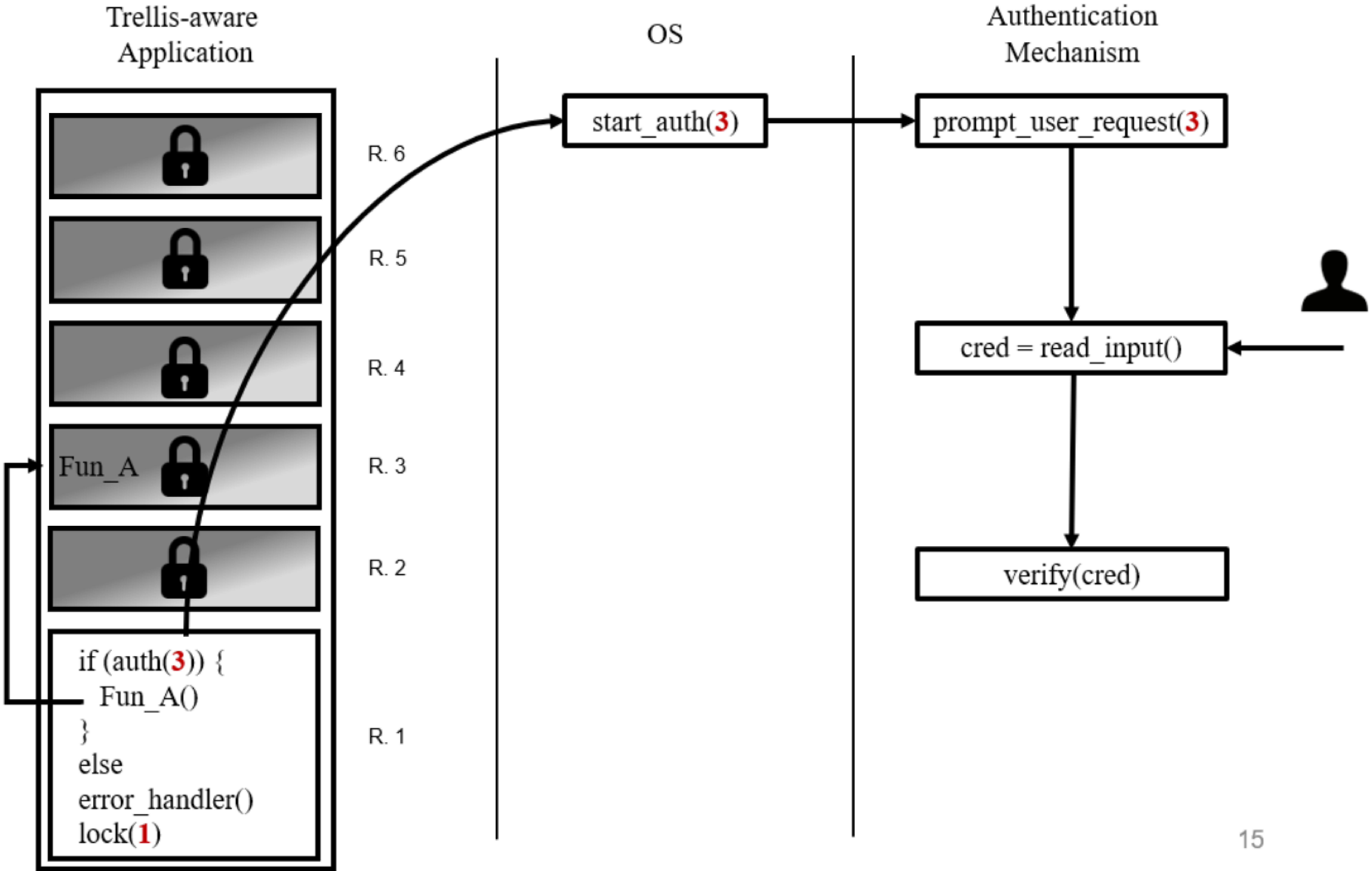

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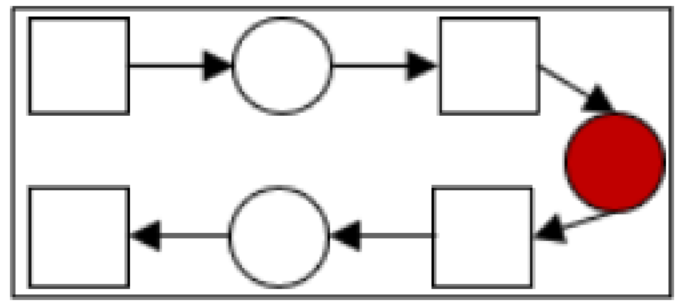

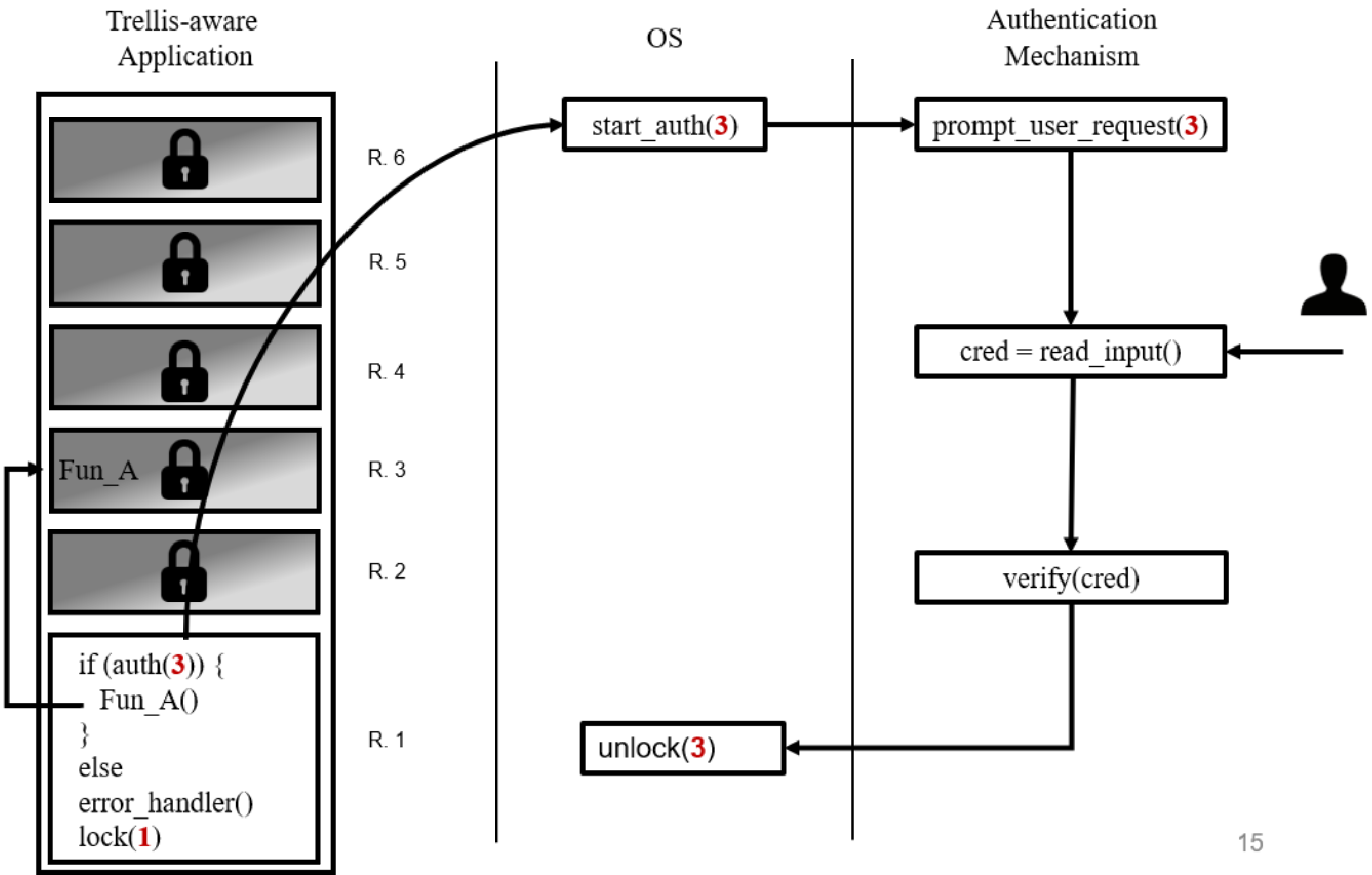

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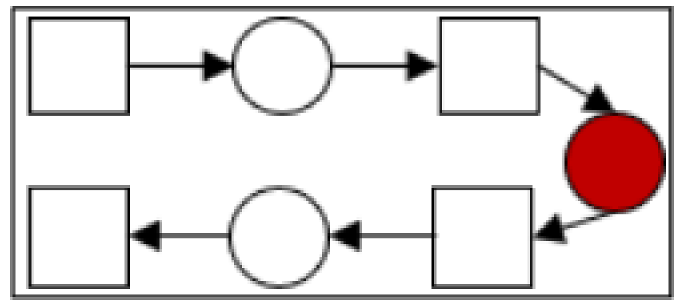

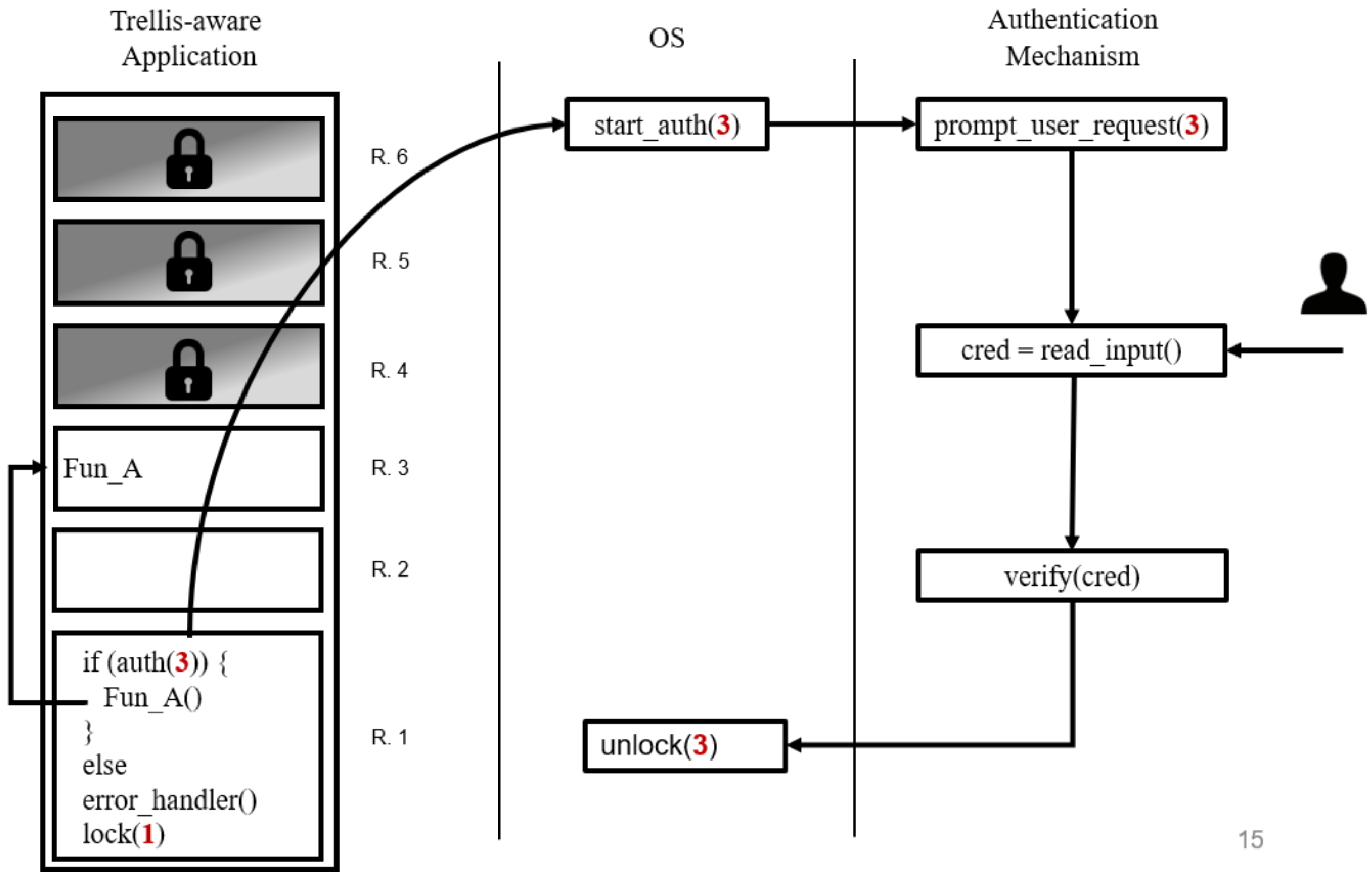

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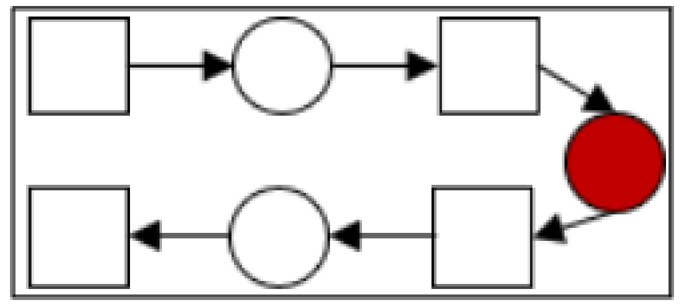

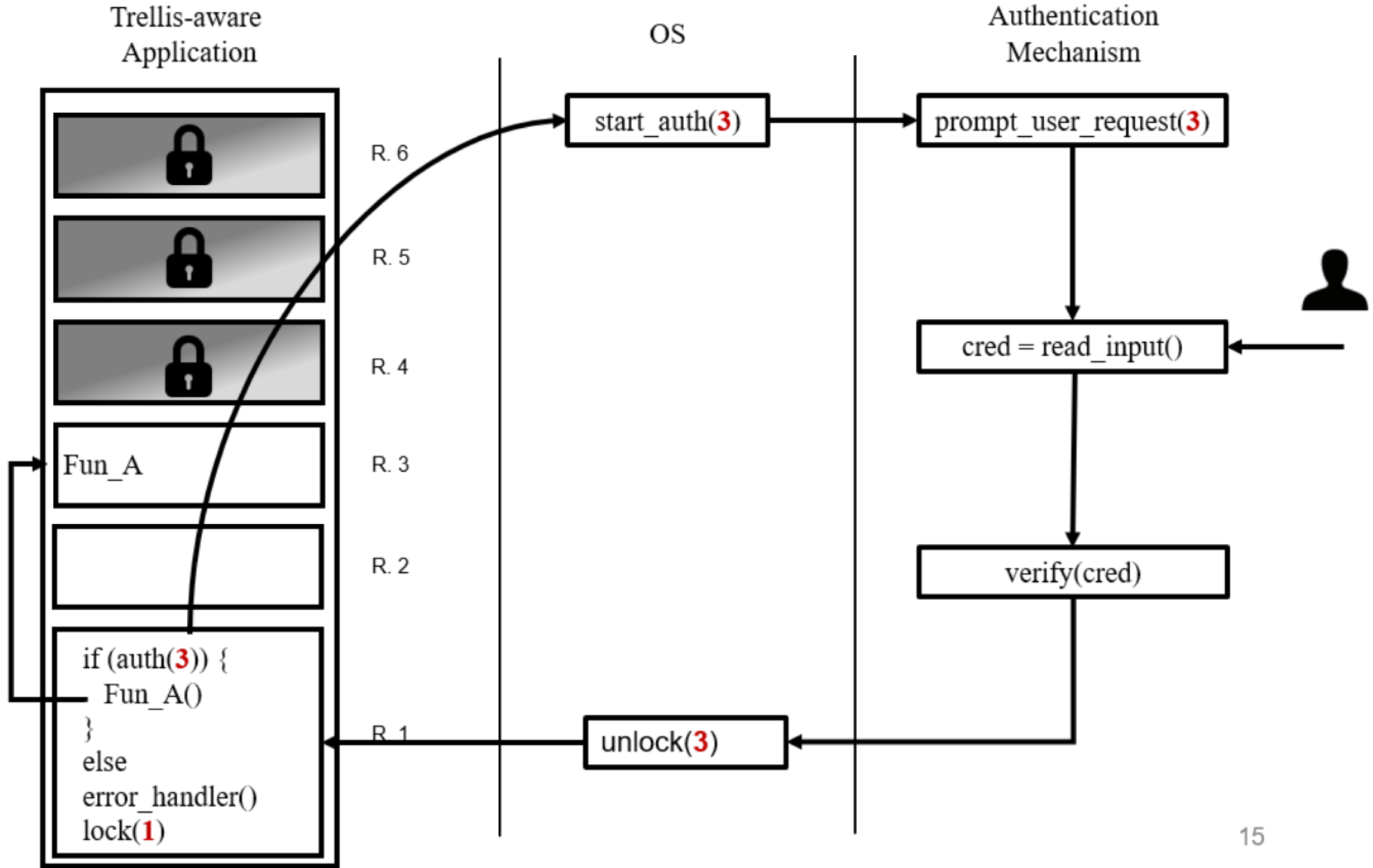

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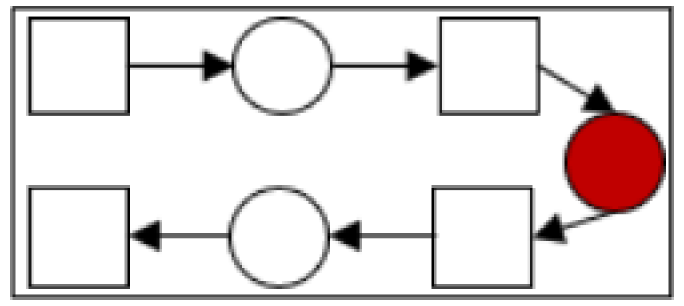

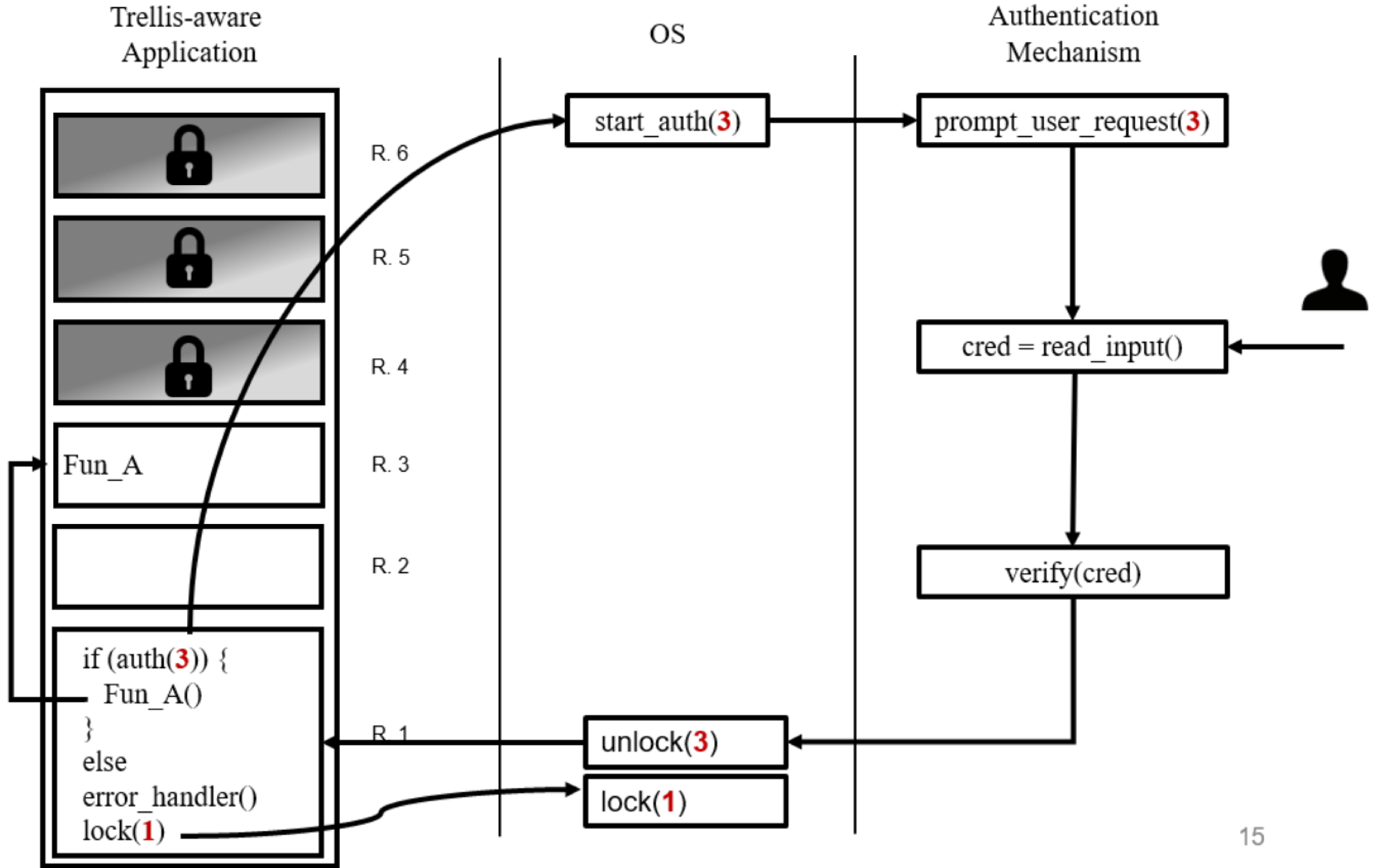

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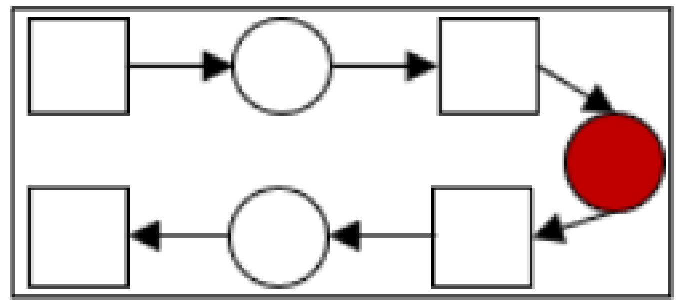
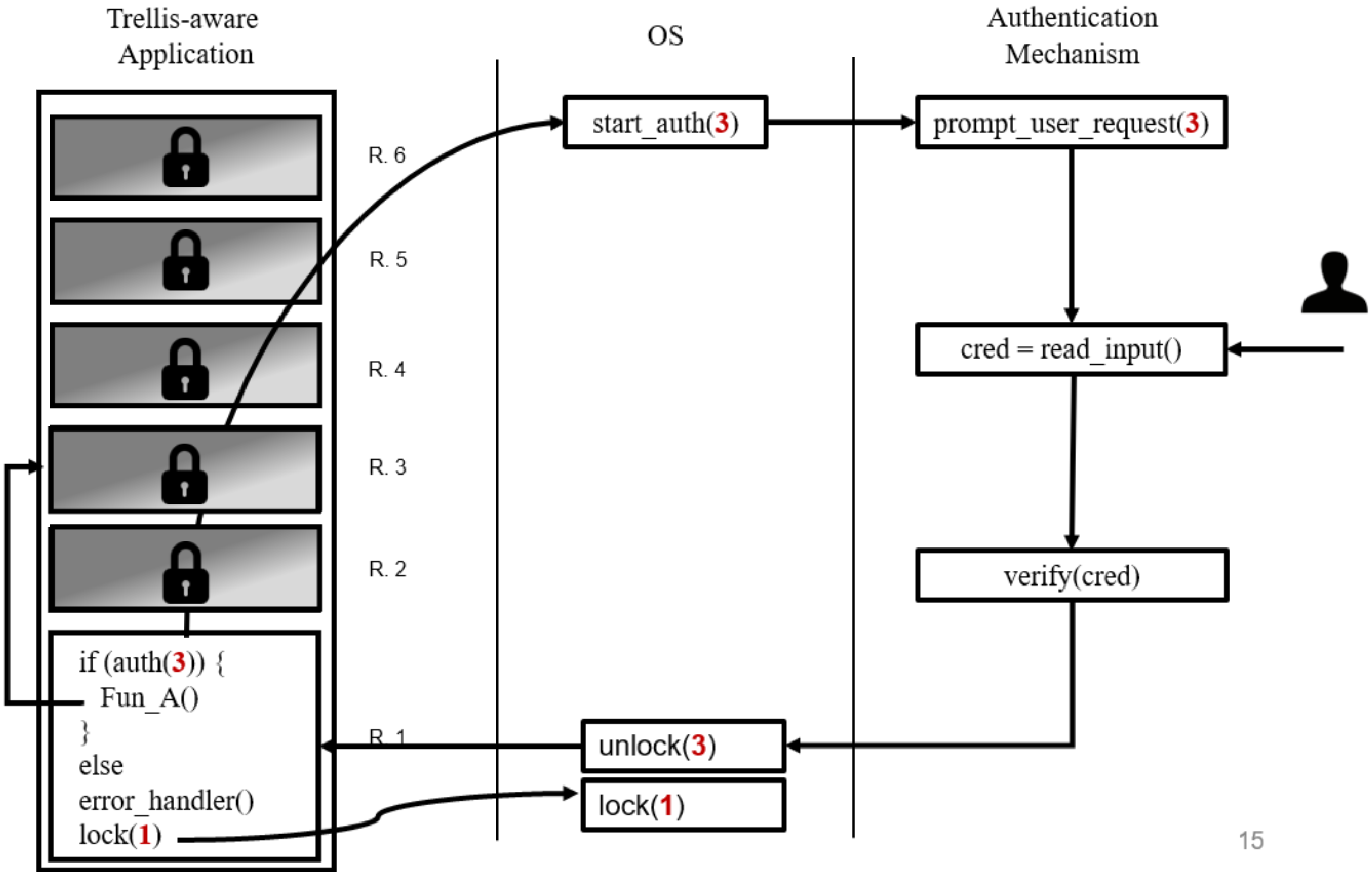




Trellis-aware Application

OS

Authentication Mechanism

R. 6

R. 5

R. 4

R. 3

R. 2

R. 1

```
if (auth(3)) {
  Fun_A()
}
else
error_handler()
lock(1)
```

start_auth(3)

prompt_user_request(3)

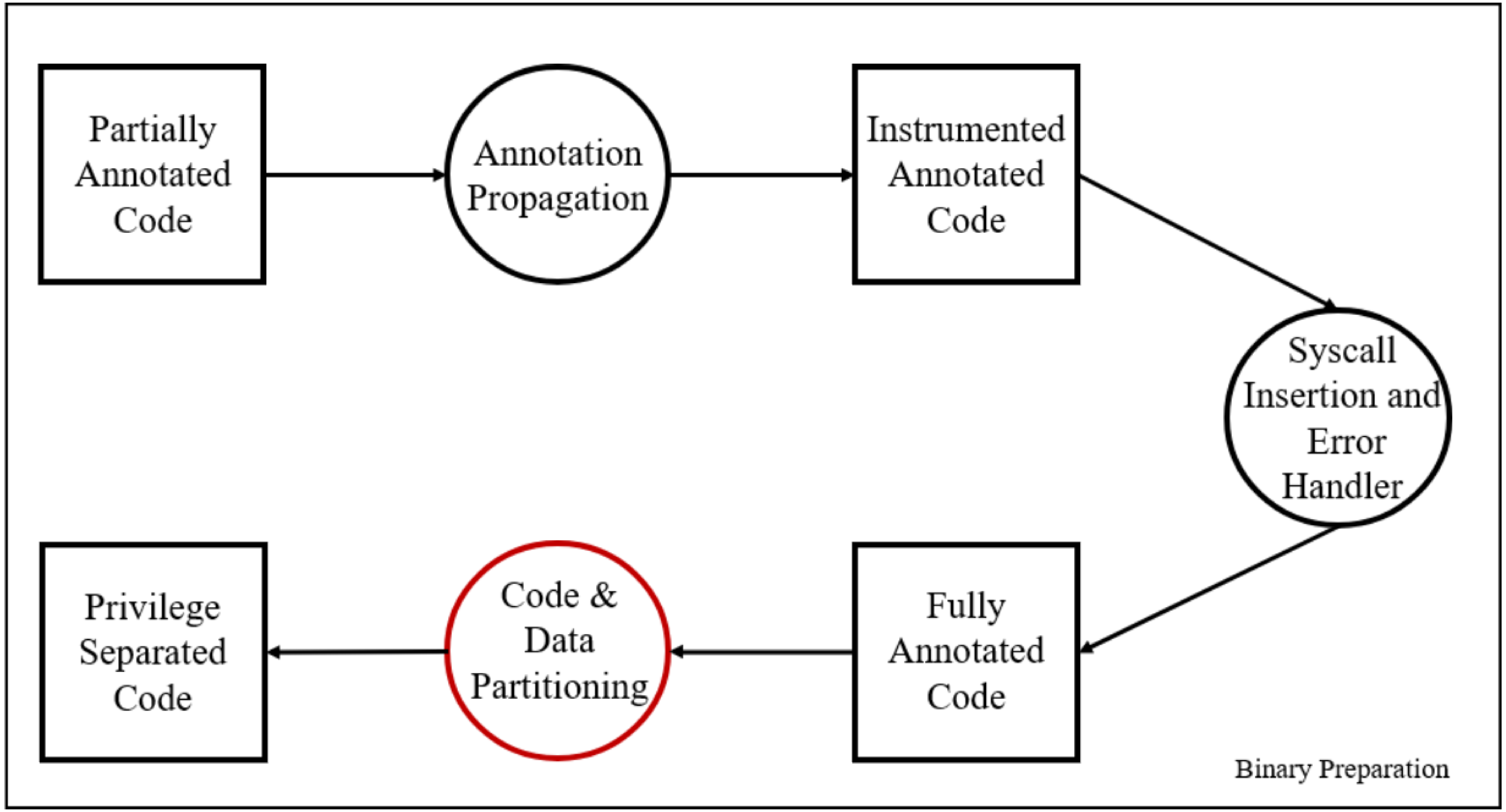
cred = read_input()

verify(cred)

unlock(3)

lock(1)

Implementation



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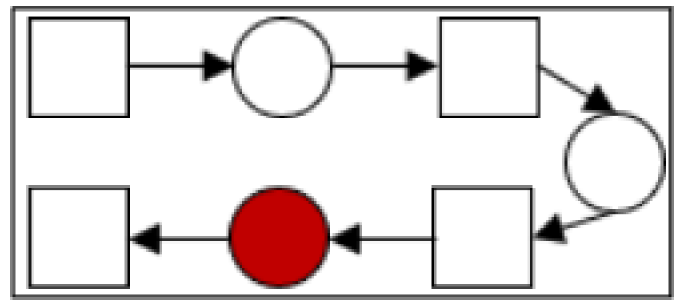


Trellis-aware
App on disk

fun_1 : role 1

fun_2 : role 1

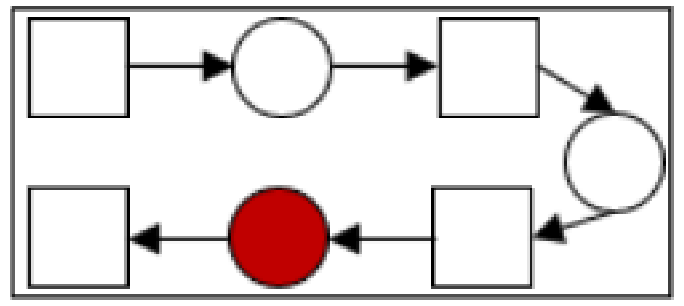
gv_1 : role 1

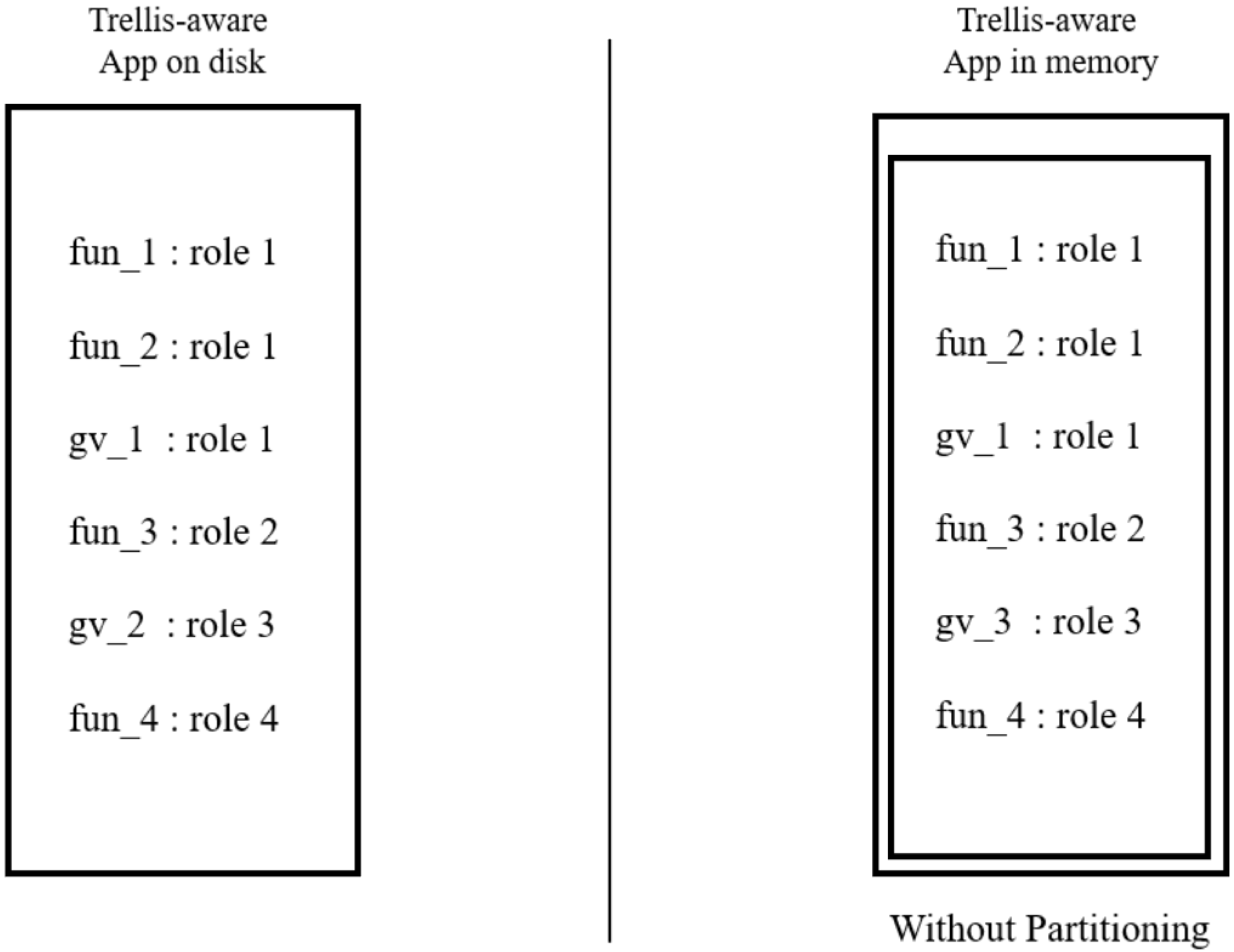
fun_3 : role 2

gv_2 : role 3

fun_4 : role 4

Implementation





Trellis-aware
App on disk

fun_1 : role 1

fun_2 : role 1

gv_1 : role 1

fun_3 : role 2

gv_2 : role 3

fun_4 : role 4

Trellis-aware
App in memory

fun_1 : role 1

fun_2 : role 1

gv_1 : role 1

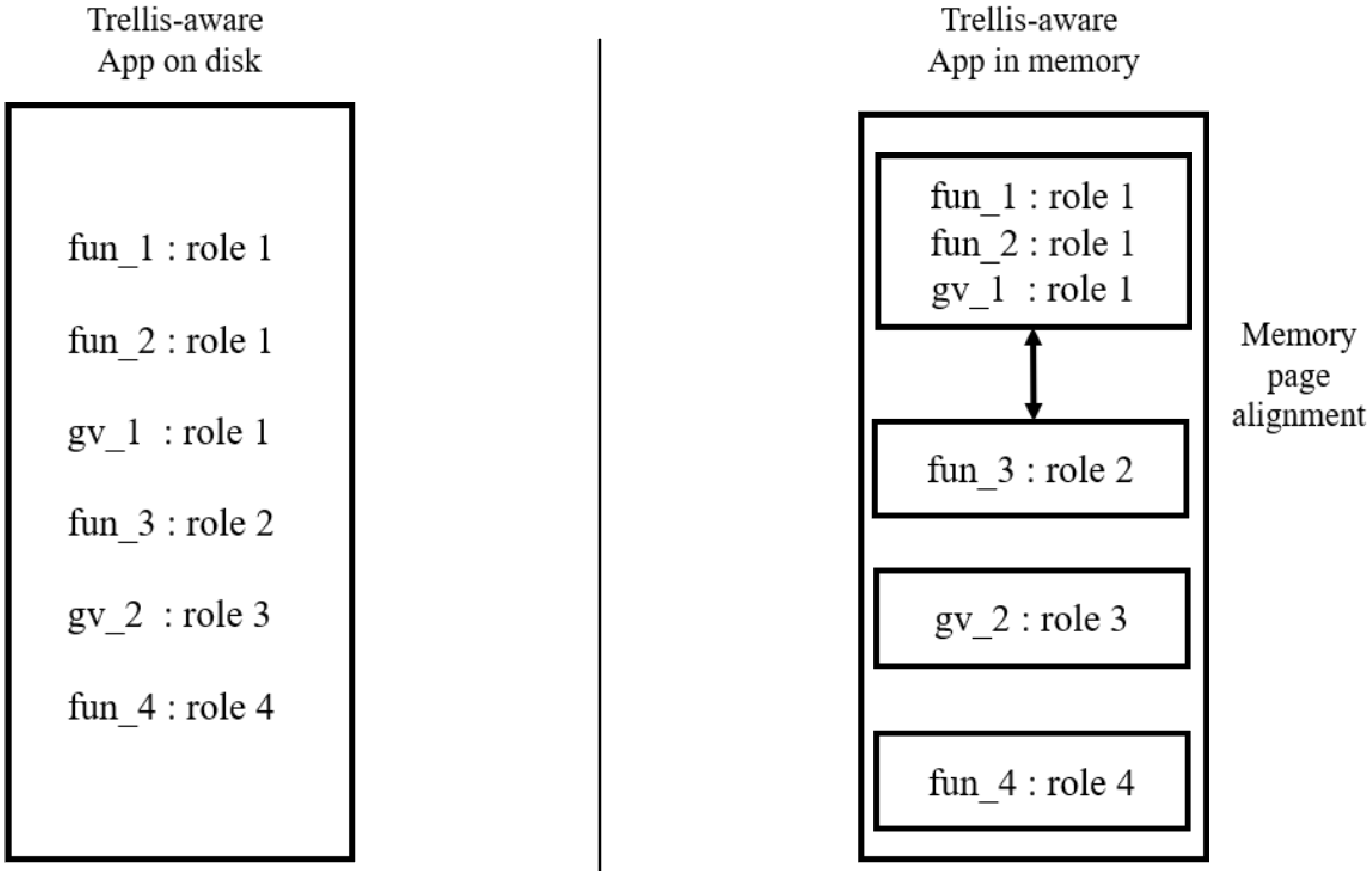
fun_3 : role 2

gv_3 : role 3

fun_4 : role 4

Without Partitioning

Implementation



Trellis-aware
App on disk

fun_1 : role 1

fun_2 : role 1

gv_1 : role 1

fun_3 : role 2

gv_2 : role 3

fun_4 : role 4

Trellis-aware
App in memory

fun_1 : role 1
fun_2 : role 1
gv_1 : role 1

fun_3 : role 2

gv_2 : role 3

fun_4 : role 4

Memory
page
alignment

With Partitioning

Implementation - Runtime

Remove access privileges for memory segments containing non-accessible roles

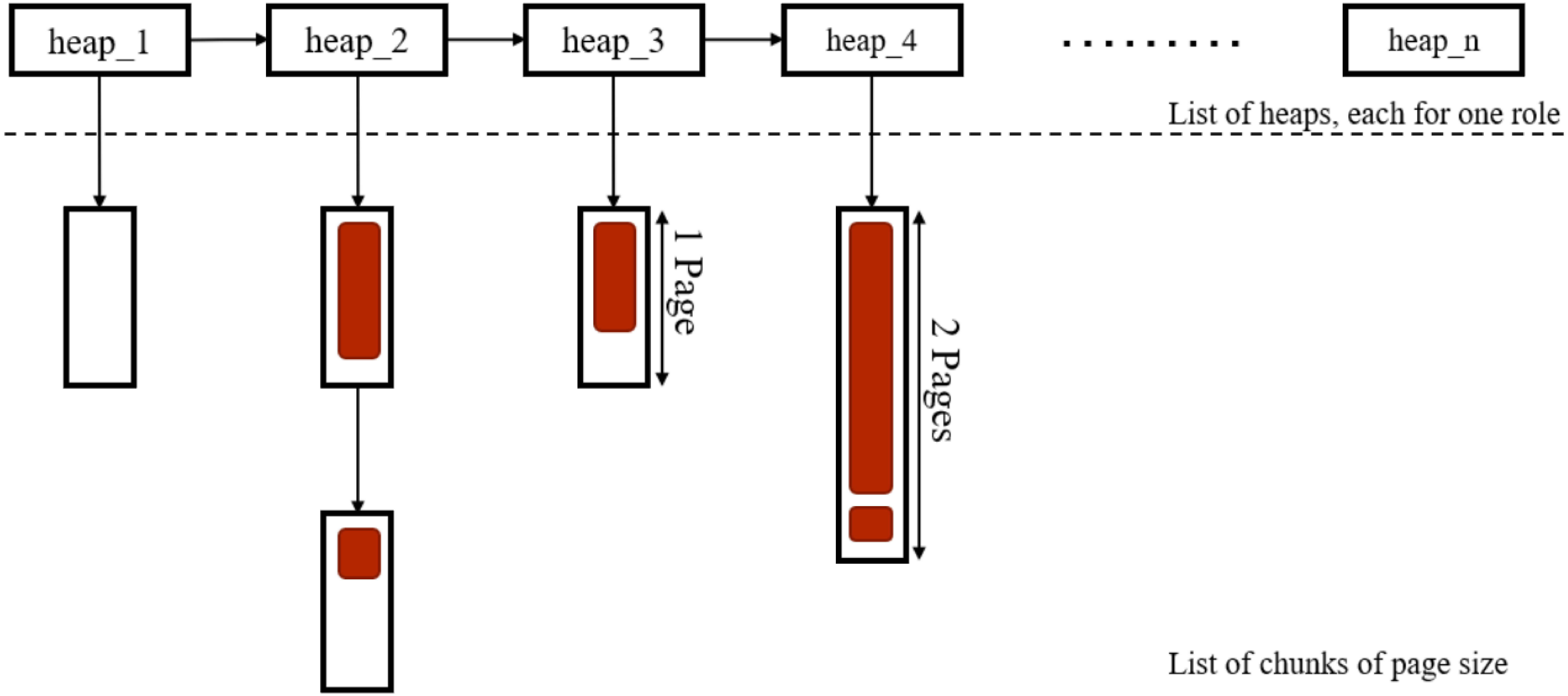
PAM-based Authentication during application role switching

Custom program loader to initialize the metadata in kernel-space

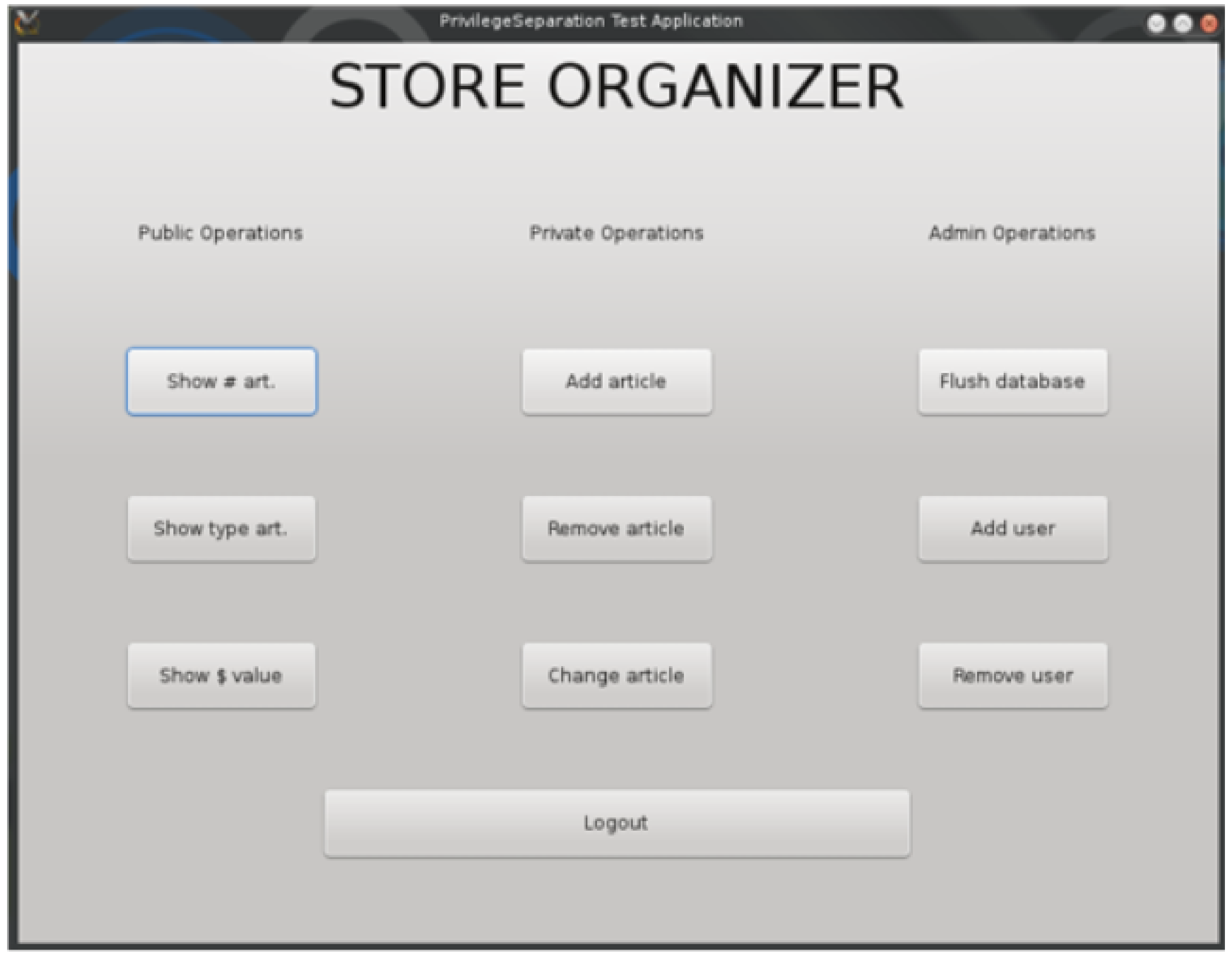
Multi-heap page-based Allocator for protecting dynamic allocated data

Implementation

trellis_alloc(size,role)



Evaluation


PrivilegeSeparation Test Application
STORE ORGANIZER
Public Operations
Private Operations
Admin Operations
Show # art.
Add article
Flush database
Show type art.
Remove article
Add user
Show $ value
Change article
Remove user
Logout

HomeBank
Free, easy, personal accounting for everyone.

Evaluation

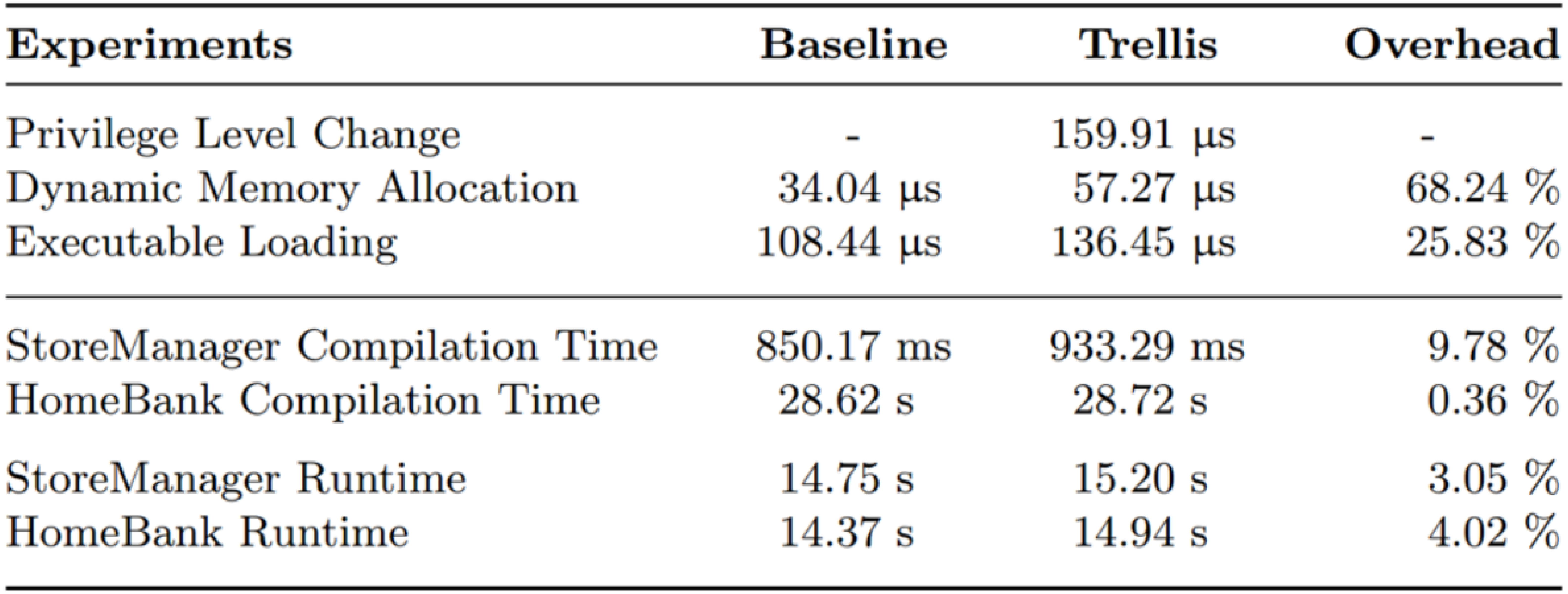
Micro-Benchmarks

End-to-end Performance

Developer Effort

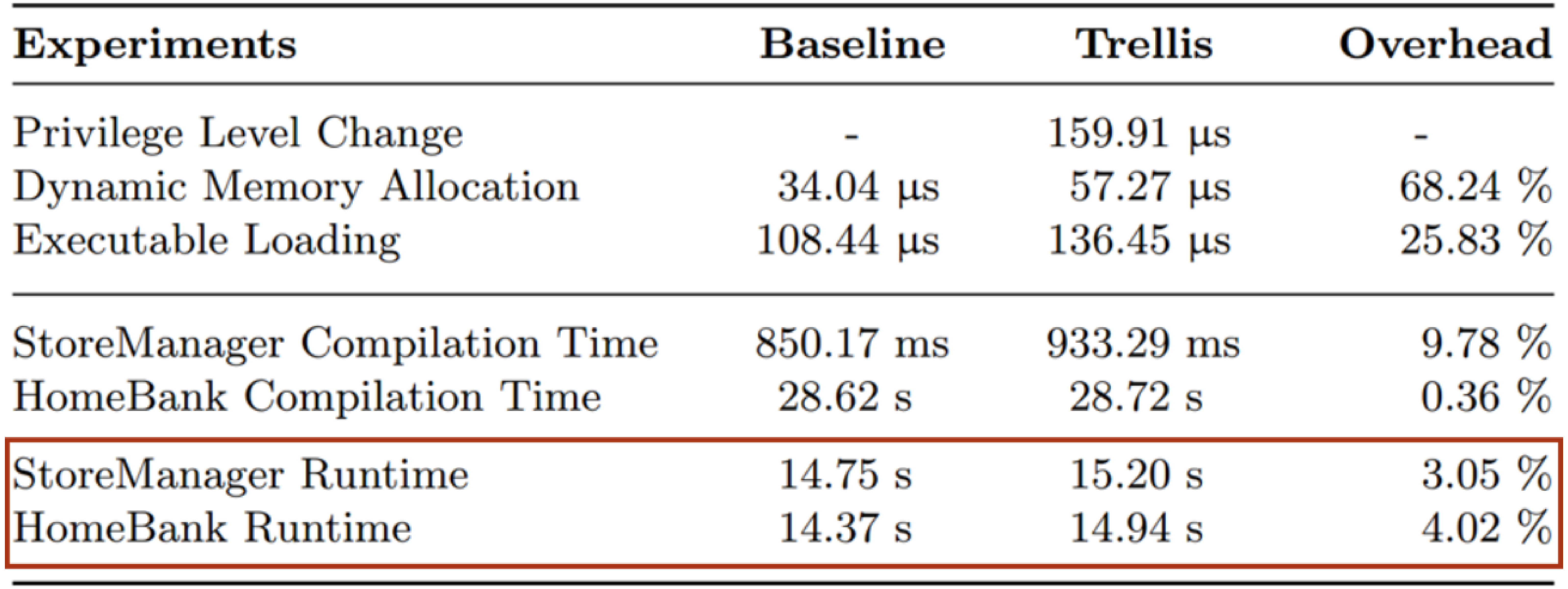
Security Experiments

Evaluation



Experiments	**Baseline**	**Trellis**	**Overhead**
Privilege Level Change	-	159.91 µs	-
Dynamic Memory Allocation	34.04 µs	57.27 µs	68.24 %
Executable Loading	108.44 µs	136.45 µs	25.83 %
StoreManager Compilation Time	850.17 ms	933.29 ms	9.78 %
HomeBank Compilation Time	28.62 s	28.72 s	0.36 %
StoreManager Runtime	14.75 s	15.20 s	3.05 %
HomeBank Runtime	14.37 s	14.94 s	4.02 %

Evaluation



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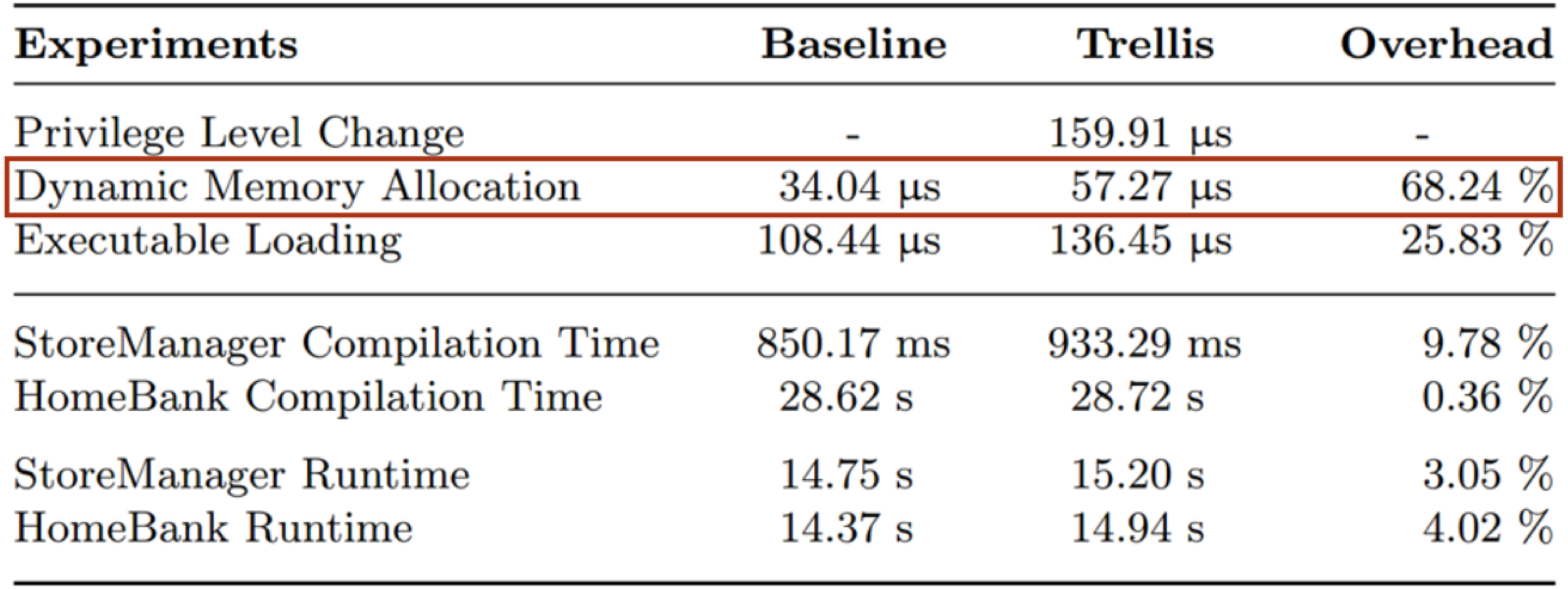

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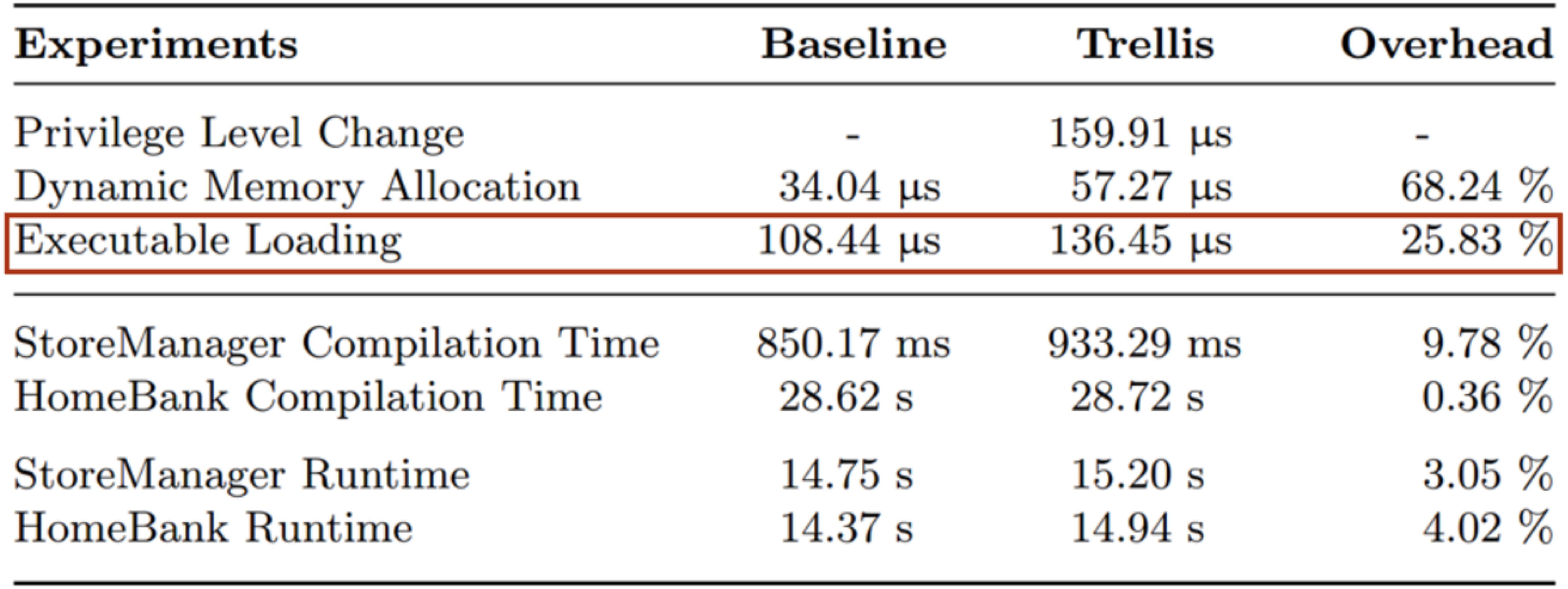

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Discussion and Future works

Binary privilege separation

Just-in-time compiler support

Indirect function call analysis integration

Data declassification

Conclusions

OS-based application development framework for multi-user application to enforce Hierarchical-Base Access Control policies (HBAC)

Prototype implementation based on LLVM/Clang, GNU C Library, and the Linux Kernel

Real-world application evaluation

Trellis is now open-source and available at https://github.com/m4mbr3/trellis.git

Questions?