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SCHOOL OF COMPUTER SCIENCE

SECURE IDENTIFICATION of ACTIVELY EXECUTED CODE on a GENERIC TRUSTED COMPONENT

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Trusted Executions: trends & tradeoffs

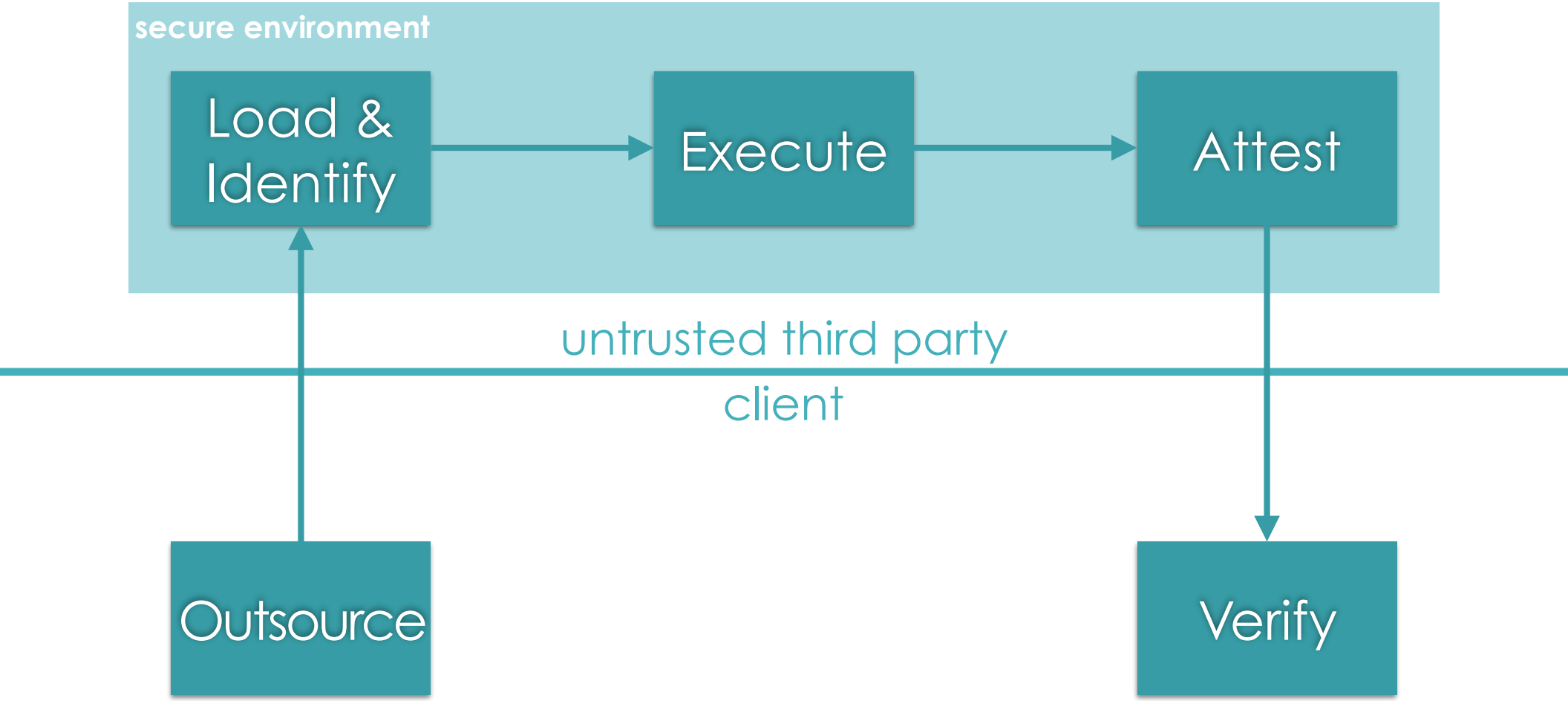
Anatomy of a Trusted Execution

untrusted third party

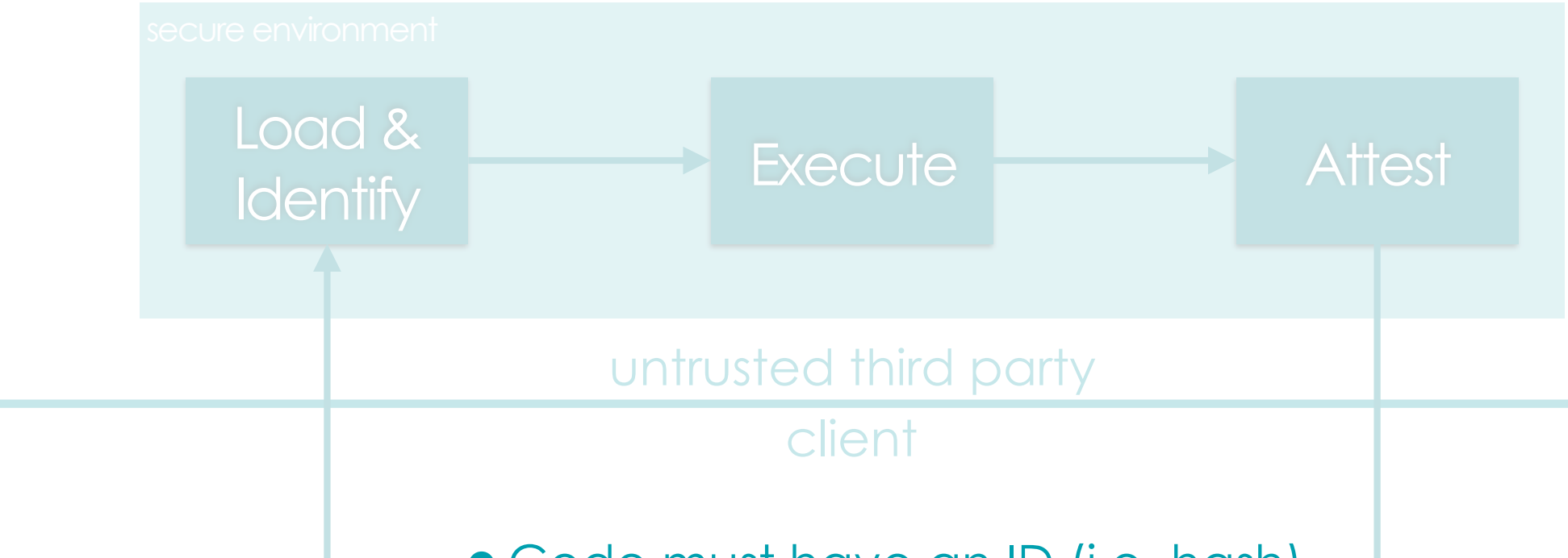
client

Execute

Anatomy of a Trusted Execution



Anatomy of a Trusted Execution



- Code must have an ID (i.e. hash)
- Trusted hardware computes ID
- Hardware attests the ID
- Client trusts hardware & ID

Generic TCC Interface

UTP-side

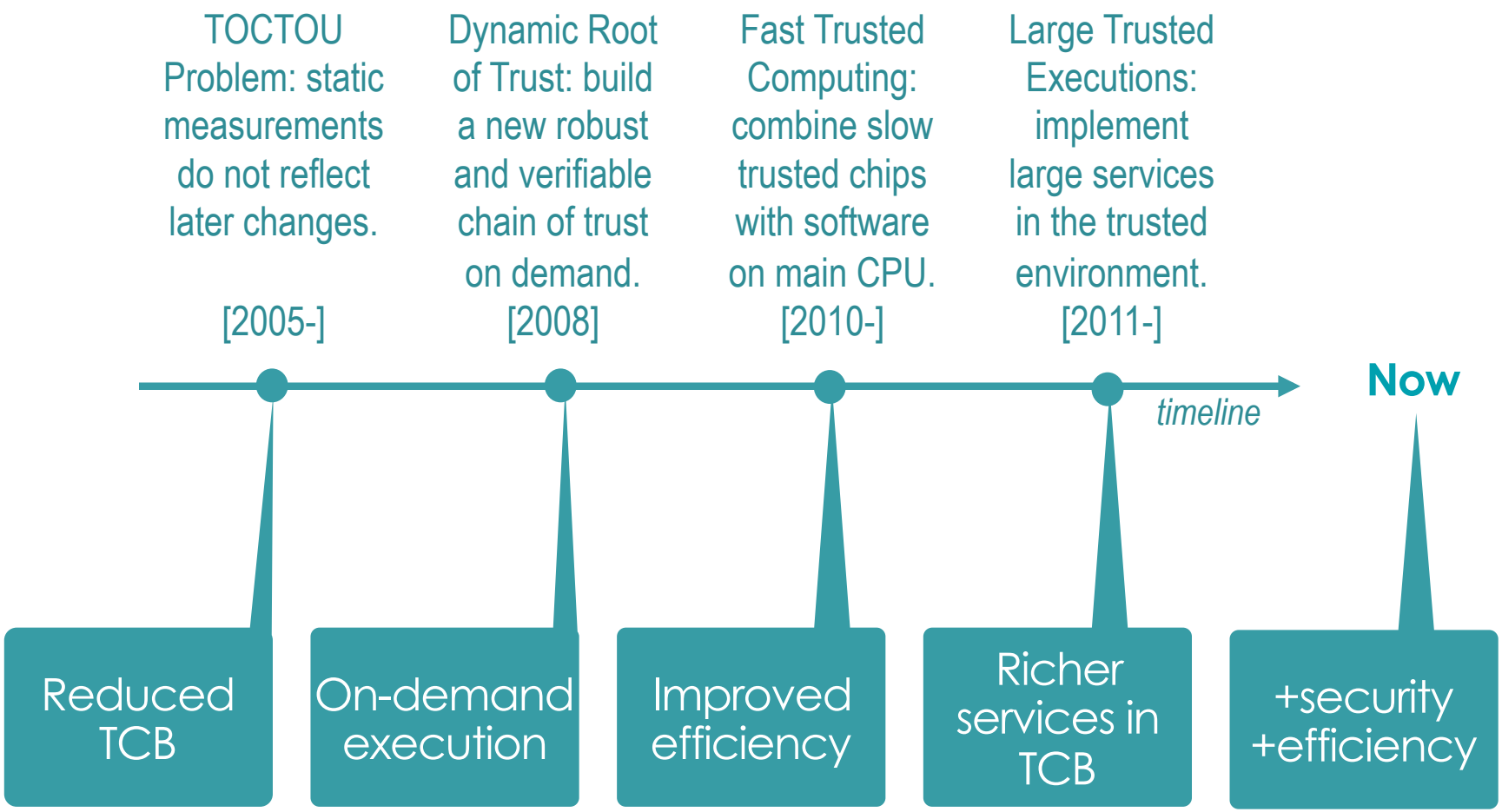
- **execute**
  - code loading + identification + isolated execution
- **attest**
  - TCC-signed code identity and I/O data

client-side

- **verify**

Implementable with:
- **Intel TXT + TPM**
- **Hypervisor-based TCC**
- **Intel SGX**
- **…**

Trends


TOCTOU Problem: static measurements do not reflect later changes.
[2005-]
Dynamic Root of Trust: build a new robust and verifiable chain of trust on demand.
[2008]
Fast Trusted Computing: combine slow trusted chips with software on main CPU.
[2010-]
Large Trusted Executions: implement large services in the trusted environment.
[2011-]
timeline
Now
Reduced TCB
On-demand execution
Improved efficiency
Richer services in TCB
+security +efficiency

Security/Efficiency Tradeoff for Large-Scale Services

Problem definition

Code Identity

```
/* SQLite code */
int main () {
 switch(op) {
  case SELECT:
   do_select();

  case DELETE:
   do_delete();

  case INSERT:
   do_insert();
  .
  .
  case FOOBAR:
  do_foobar();
}
```

source code

COMPILE

1	0	1	0	1	0	1	1	1	0	1	0	0	1	0	0	1	0	1	1
1	0	1	0	1	1	1	0	1	0	0	1	0	0	0	1	1	0	1	0
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0	1	1	0	1	0	1	1	1	0	1	0	0	1	0	0	0	1	1	1

binary

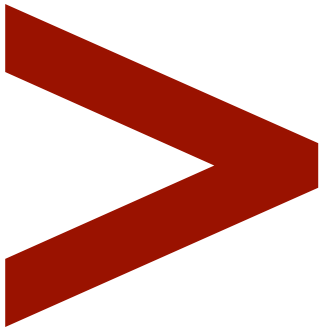
IDENTIFY

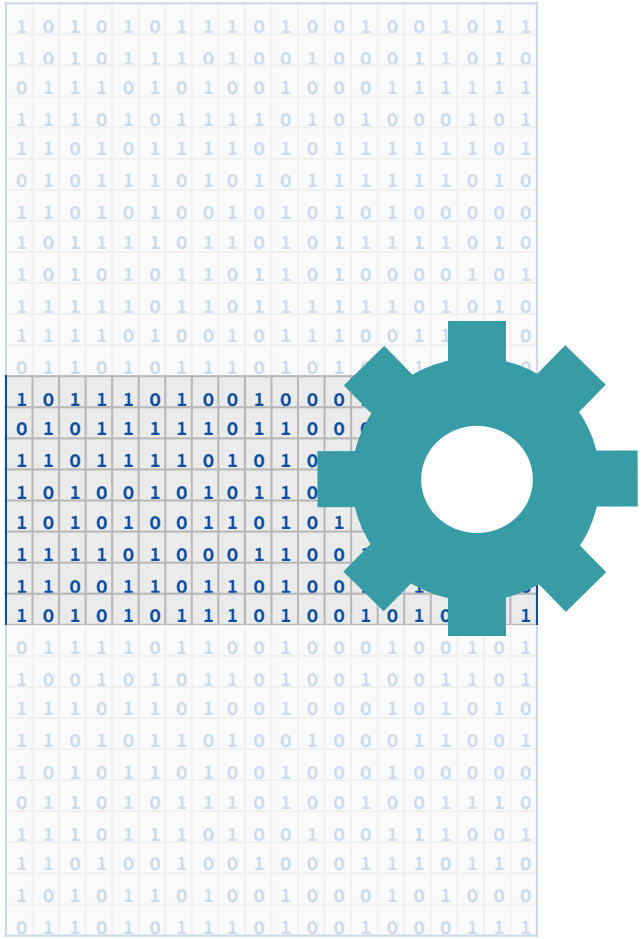
code identity

Execution Verification

Identified ≠ Executed

identified
binary code





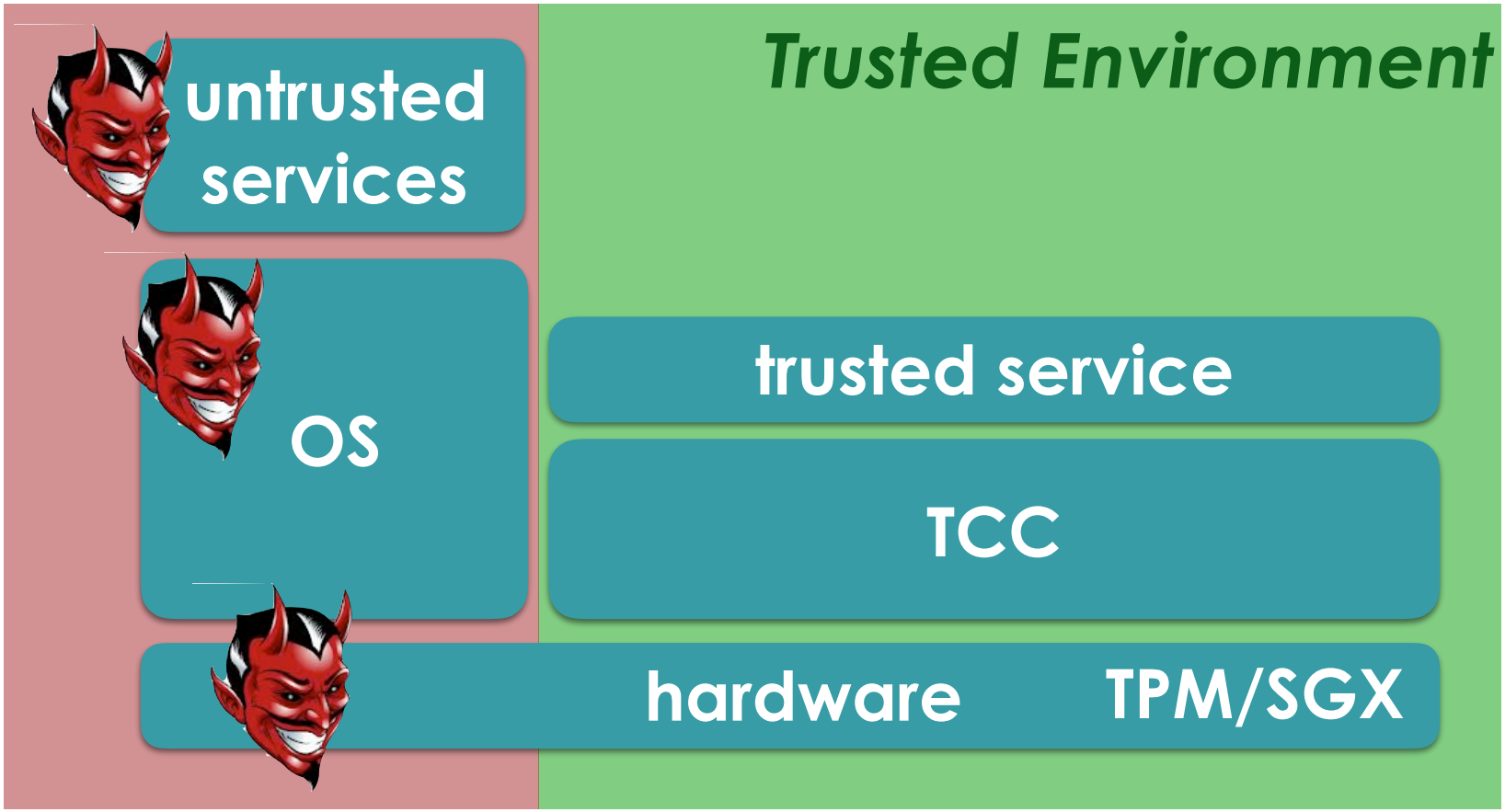
actually executed
binary code

Desirable Properties

- Identifying what is “actually” executed
- TCC agnostic execution
- Keeping efficient client-side verification

Identifying Actively Executed Code

Model



- OS and services are untrusted
- Client knows service identity and TCC certificate

Enriching the Interface

UTP-side

- **execute**
  - code loading + identification + isolated execution
- **attest**
  - TCC-signed code identity and I/O data
- **auth-put**
  - secure storage for a specific recipient (TCC authenticates the sender)
- **auth-get**
  - secure storage from a specific sender (TCC authenticates the recipient)

client-side

- **verify**

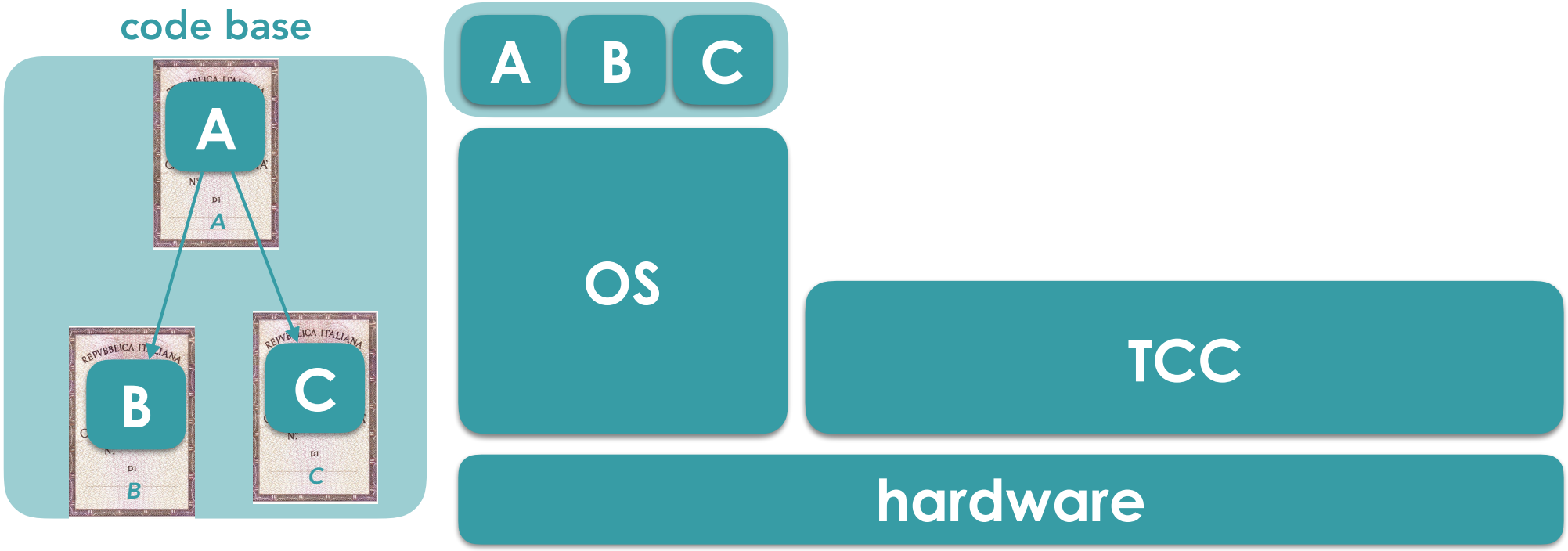
Implementable with:

- **Intel TXT + TPM**
- **Hypervisor-based TCC**
- **Intel SGX**
- **…**

One ID Per Code Module

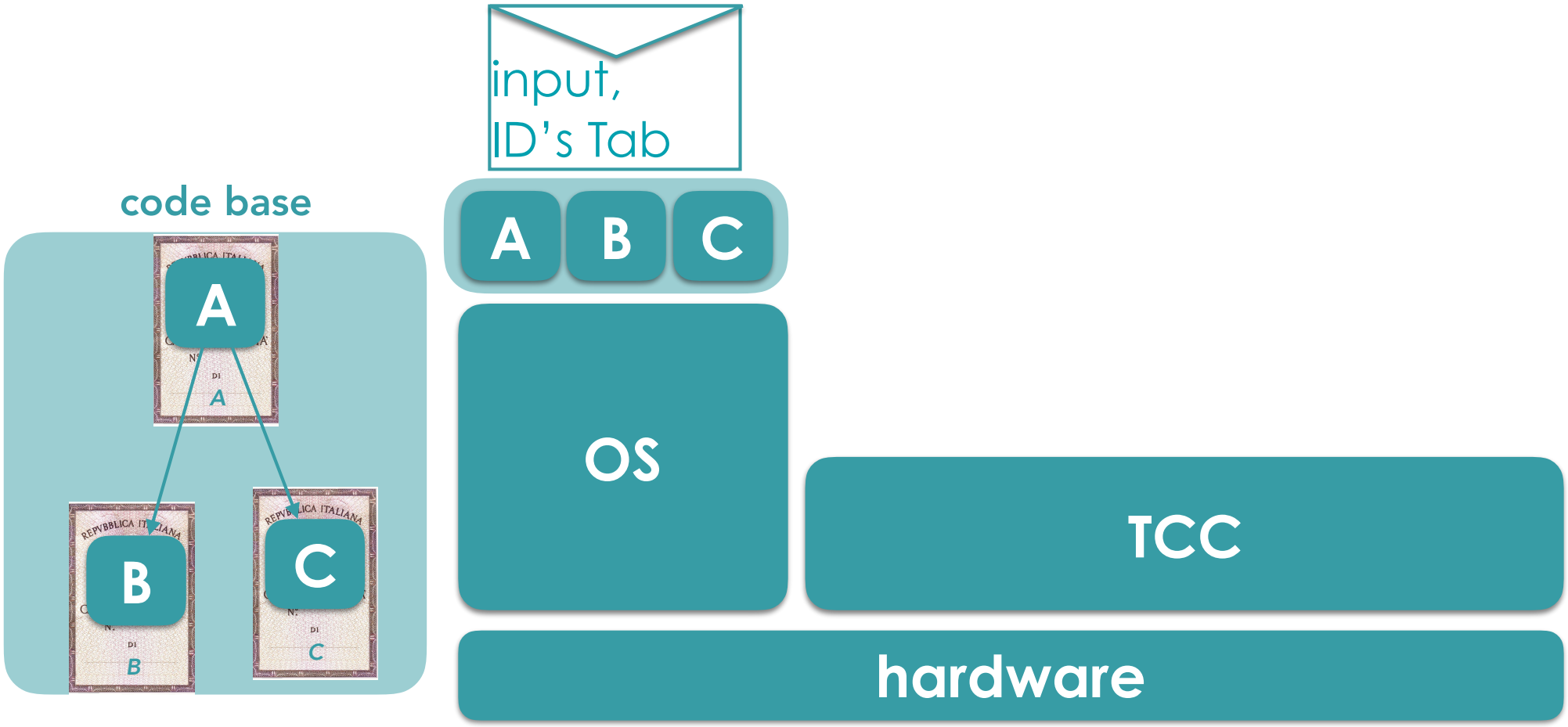
```
/* SQLite code */
int main () {
 switch(op) {
   case SELECT:
    do_select();

   case DELETE:
    do_delete();

   case INSERT:
    do_insert();
    .
    .
   case FOOBAR:
   do_foobar();
}
```

Execution Protocol

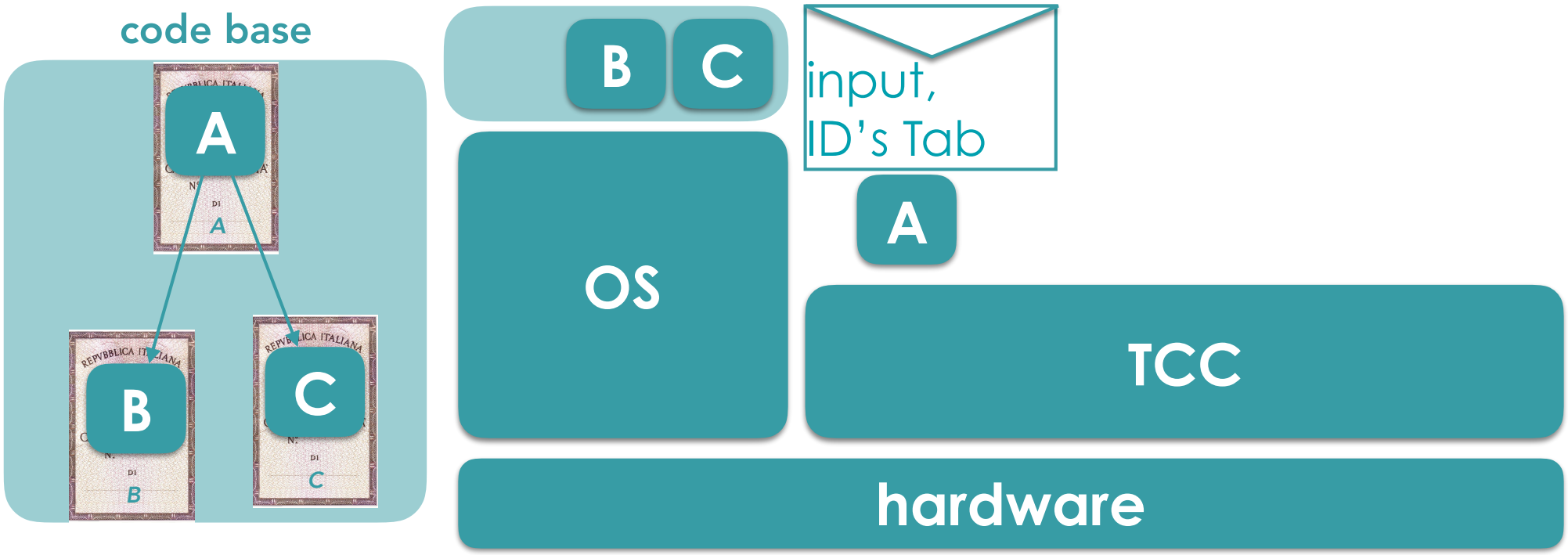


- Execution flows: A-to-B, A-to-C
- If C must be executed, then B is not loaded

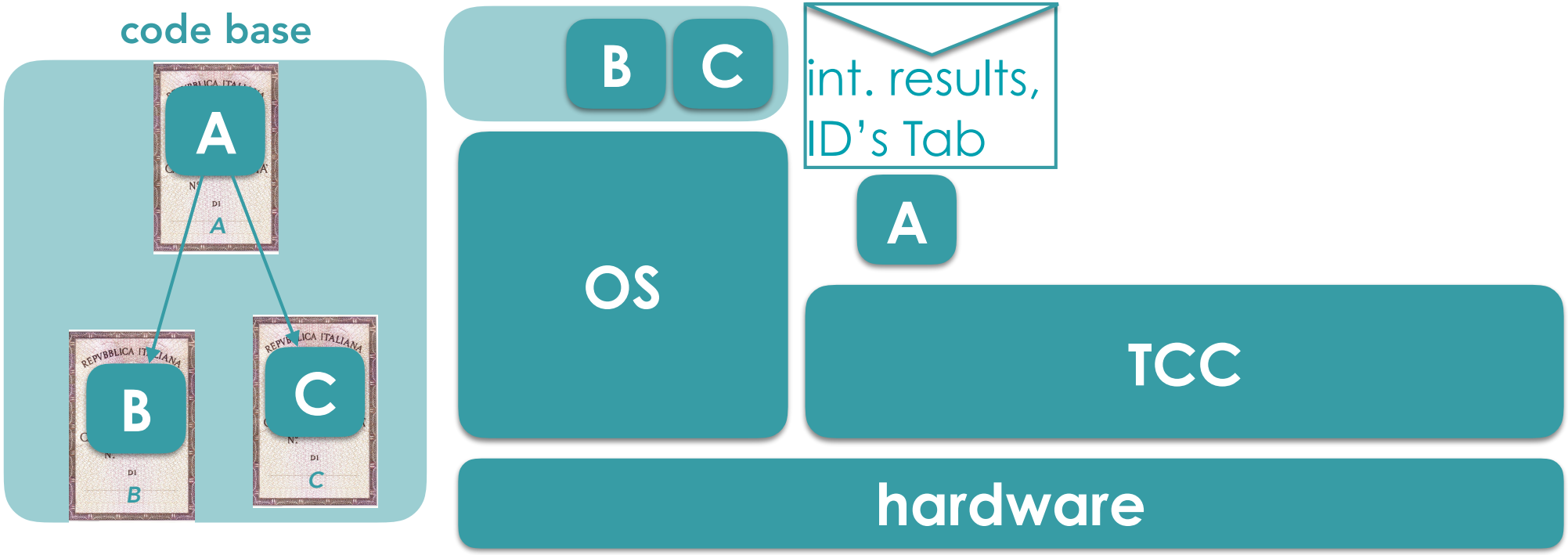
Execution Protocol



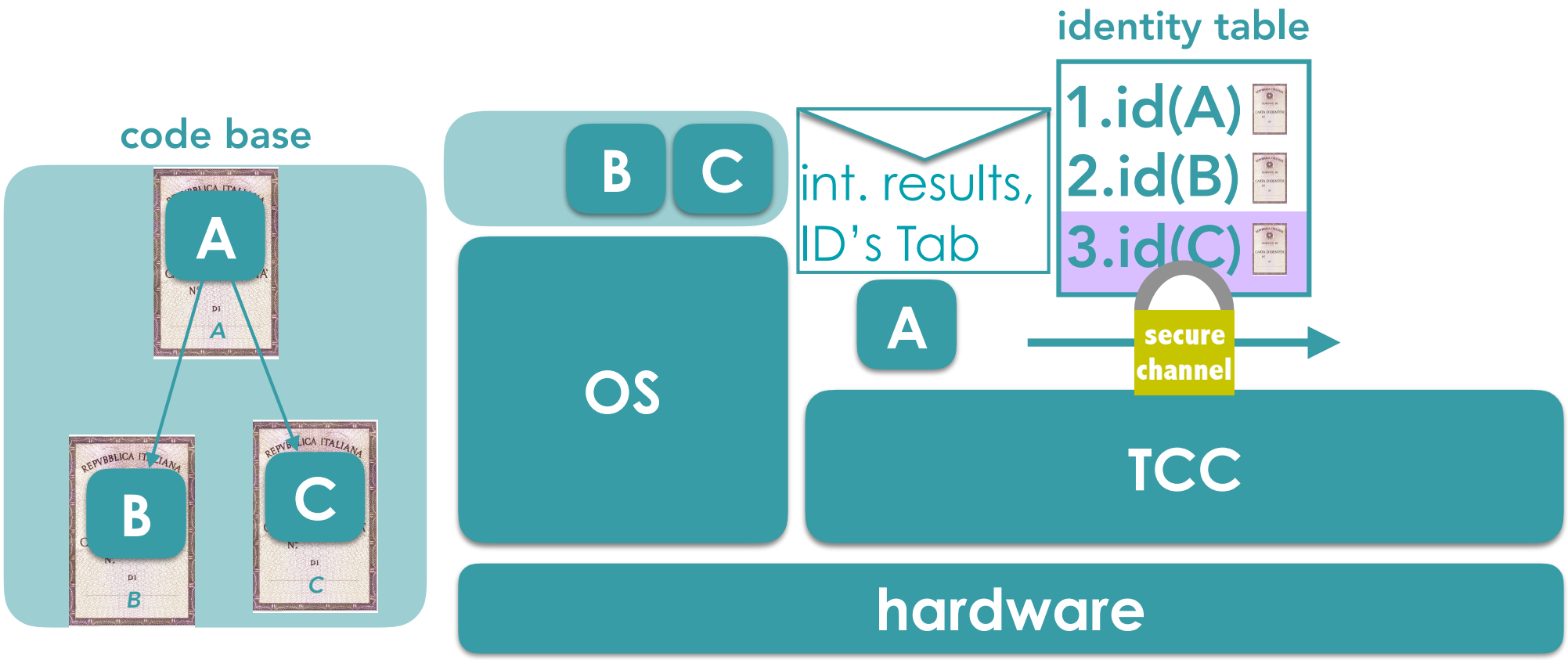
Execution Protocol



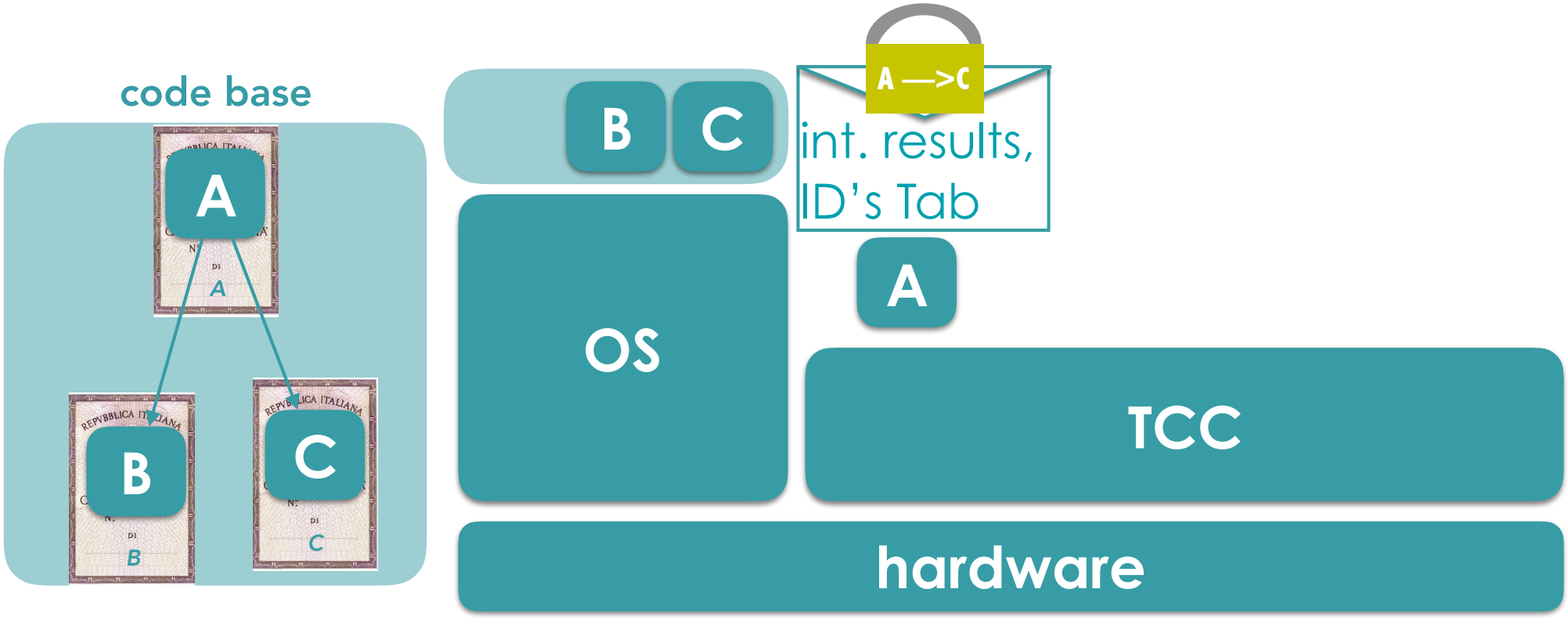
Execution Protocol



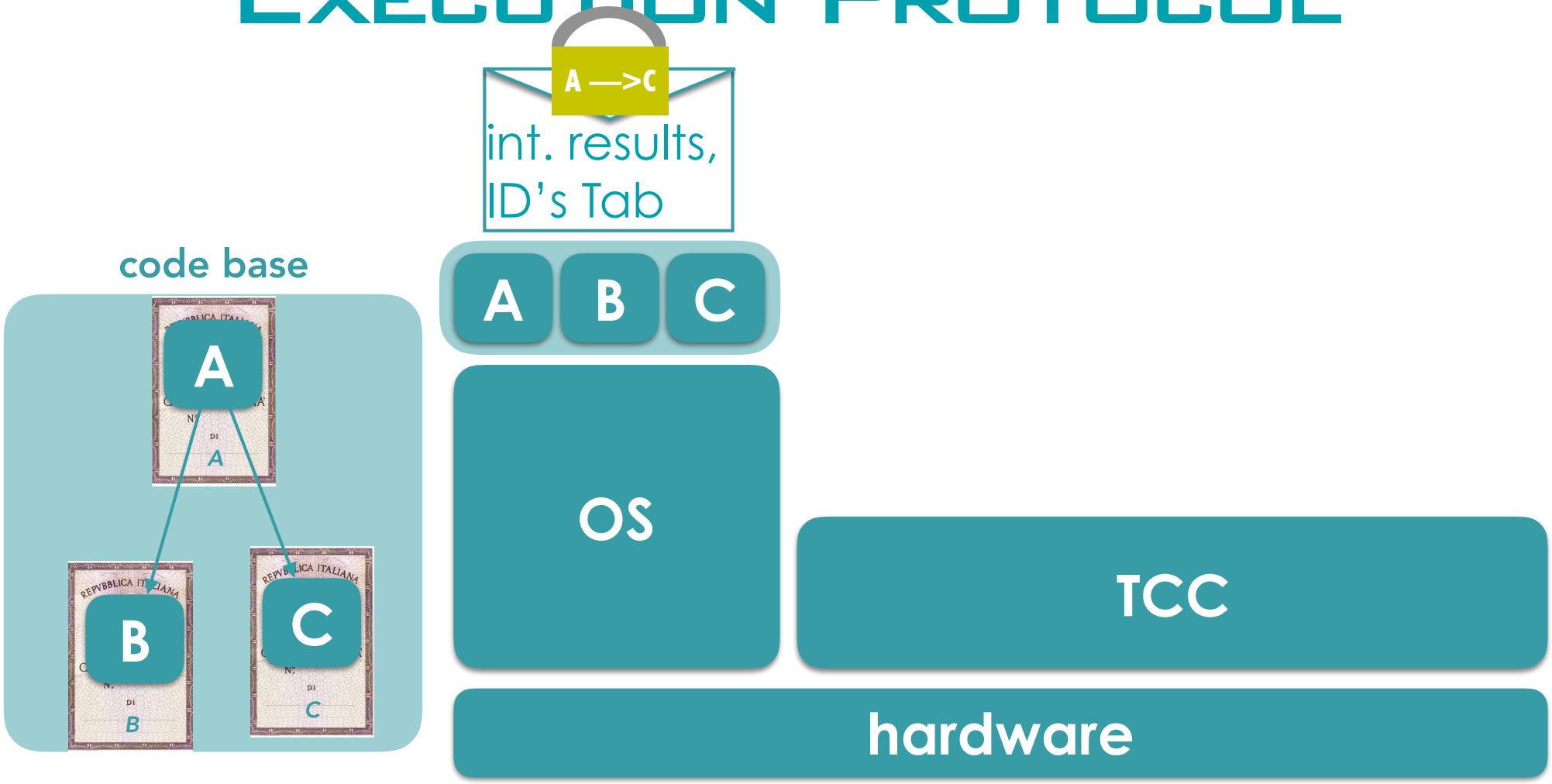
Execution Protocol



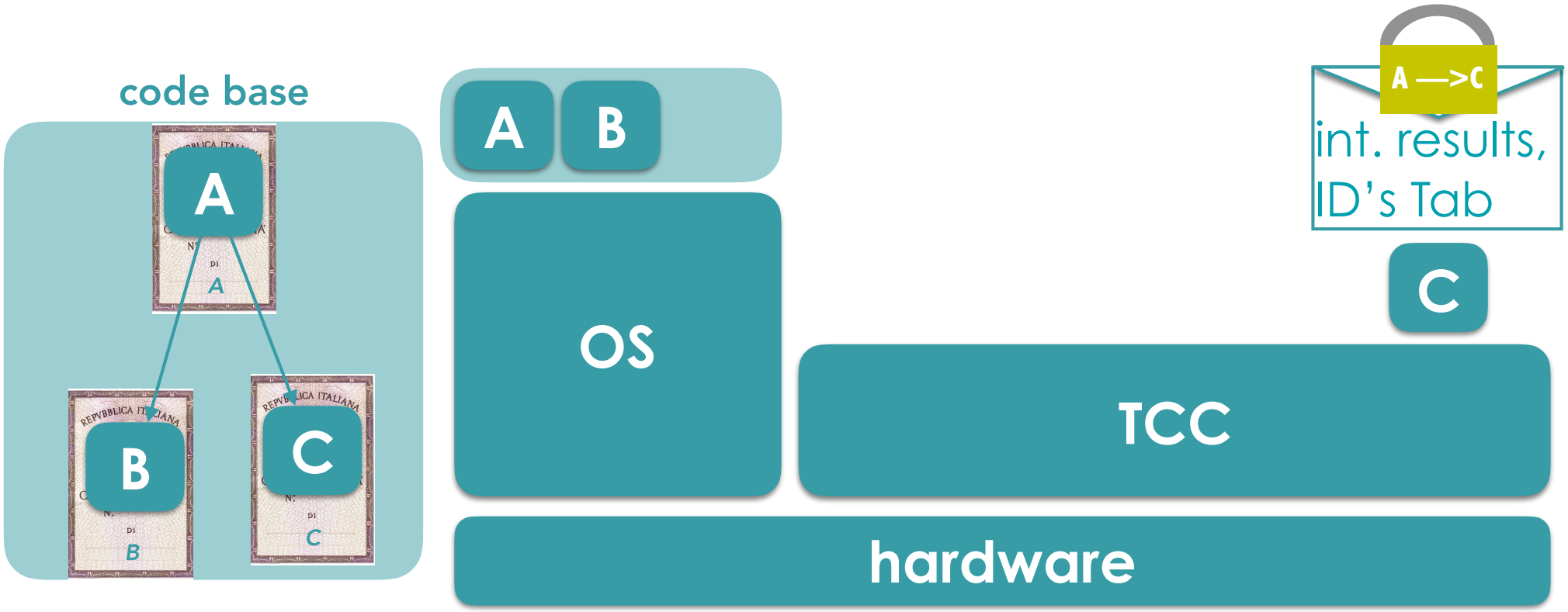
Execution Protocol



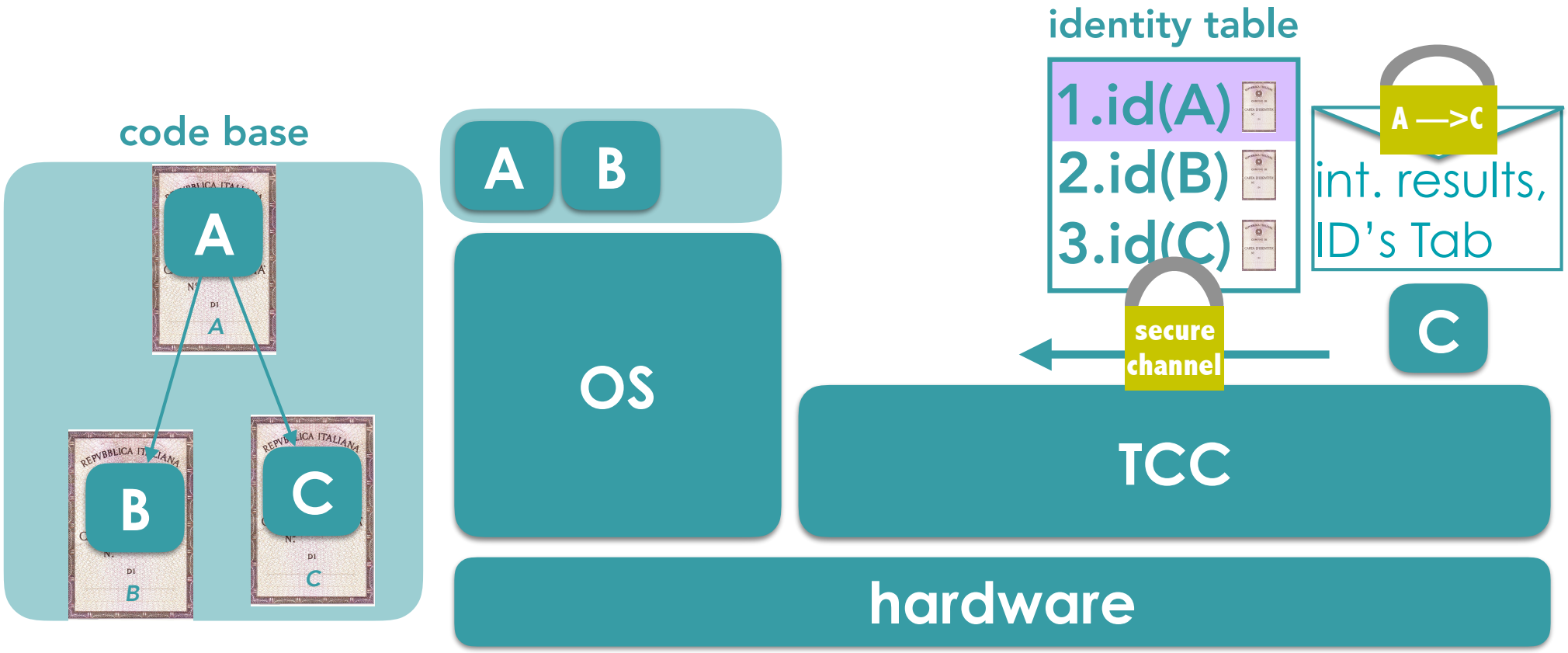
Execution Protocol



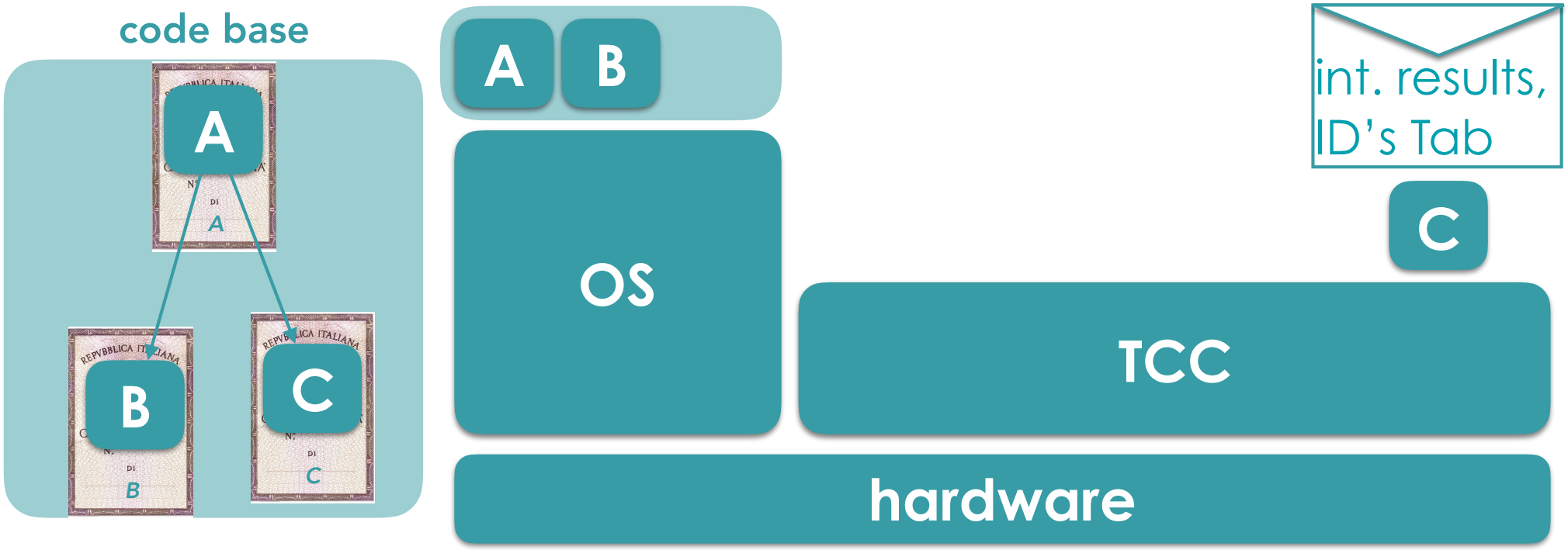
Execution Protocol



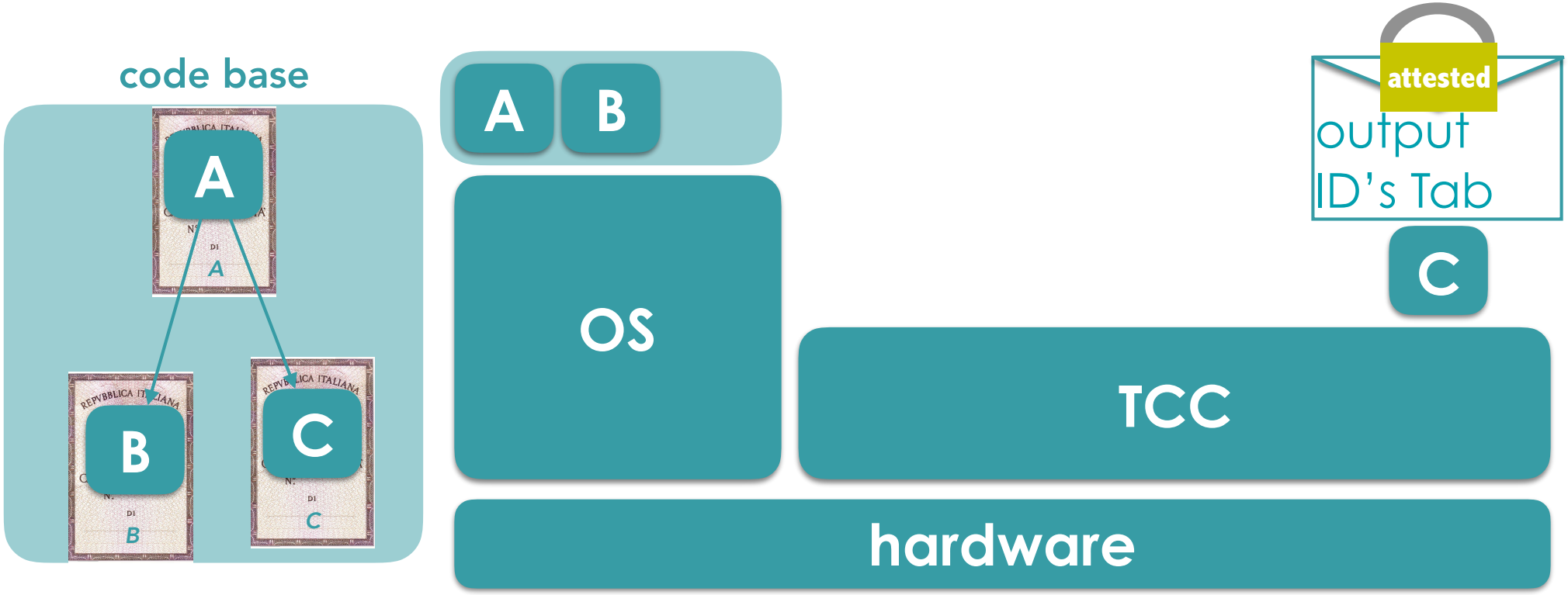
Execution Protocol



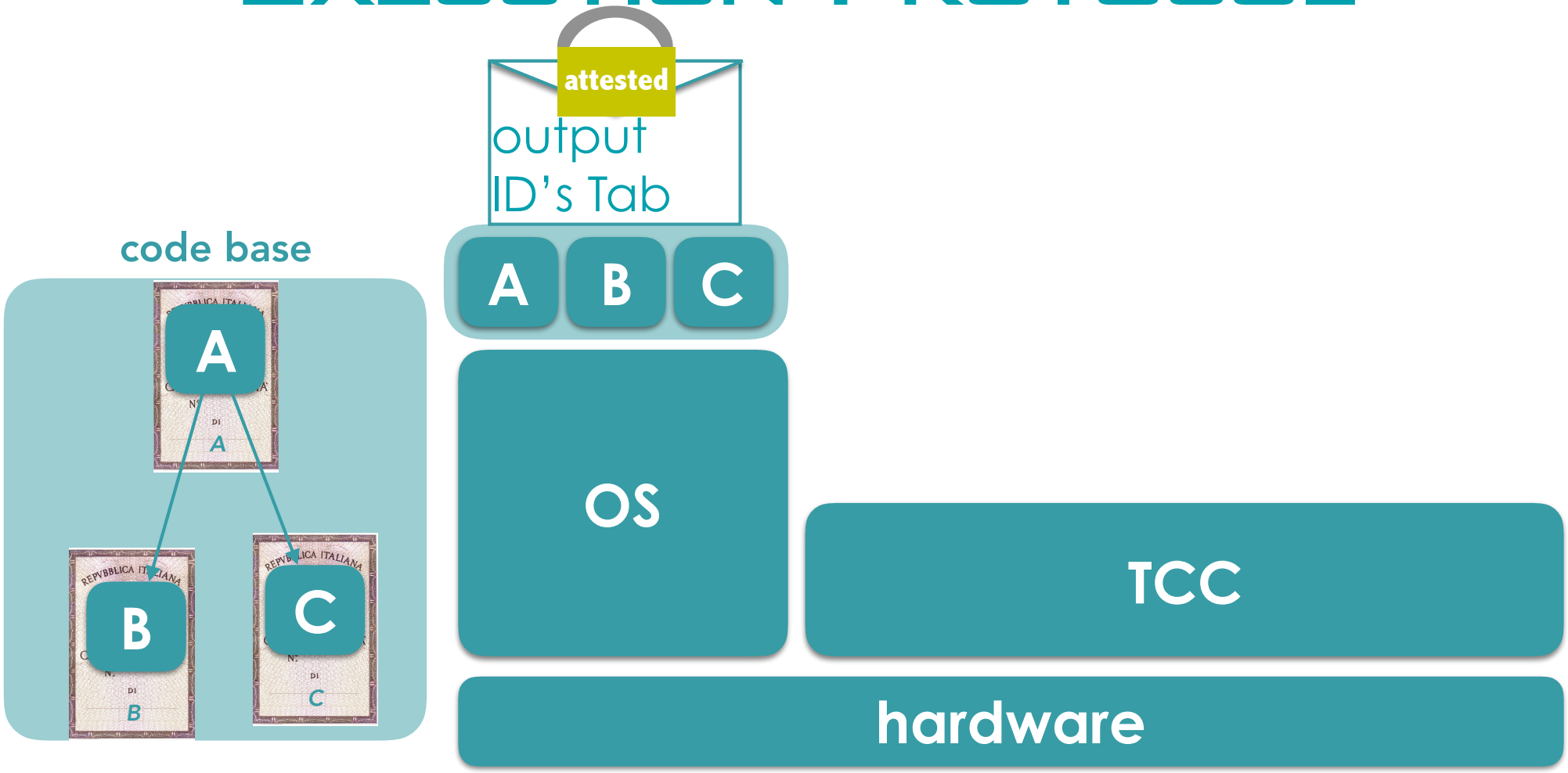
Execution Protocol



Execution Protocol



Execution Protocol



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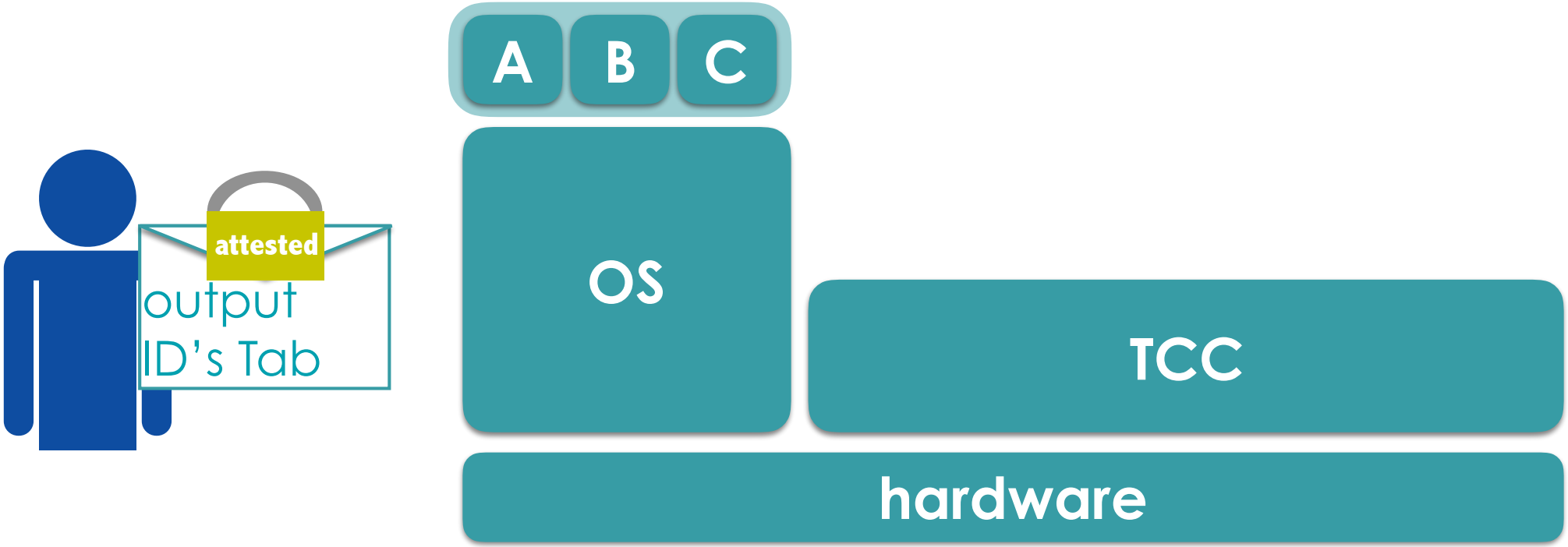
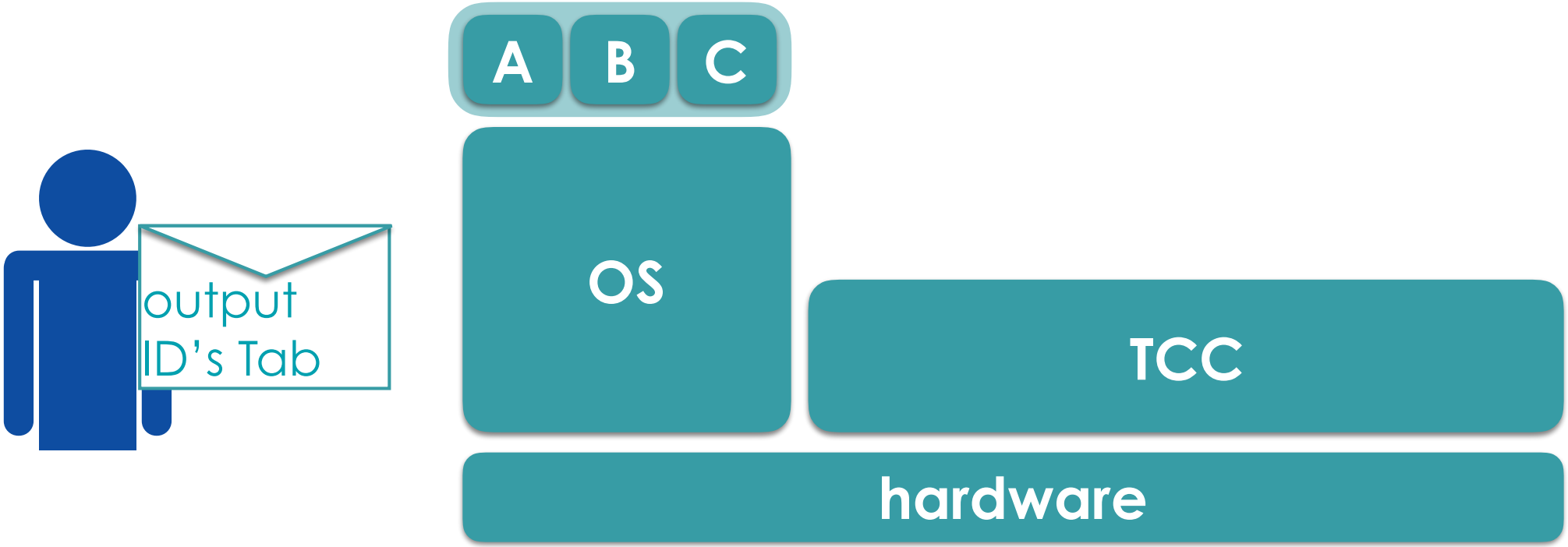


Execution Protocol

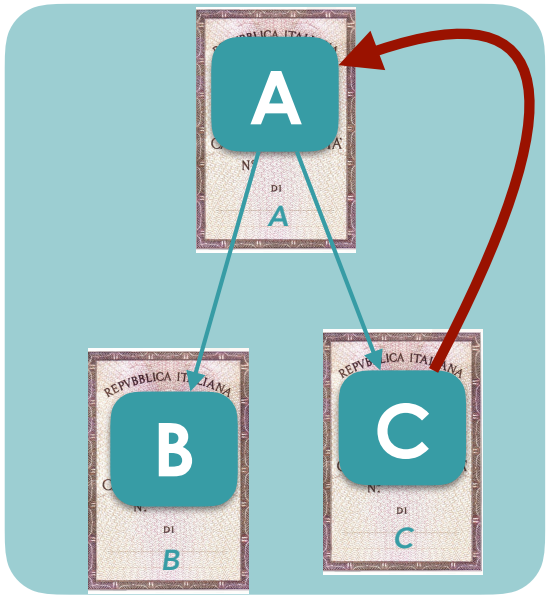


Solved Challenges for General Executions

1. Client/Verifier does not verify intermediate results
   - Results are secured locally
2. Client does not verify execution flow
   - Verification of last module & ID's Table implies correct execution flow
3. Build mutually authenticated secure channels
   - Using TCC-based secure storage
4. Fast (zero round) identity-based key sharing
   - Construction: 1 hash using sender-receiver identity pairs (see paper for details)
5. Avoid hash loops in general executions
   - Detach identity from code module using the ID's Table

5. Avoiding Hash Loops

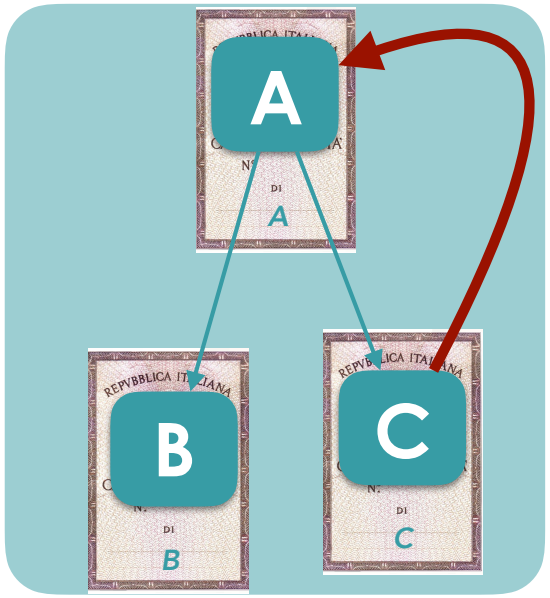
- General execution may have loops



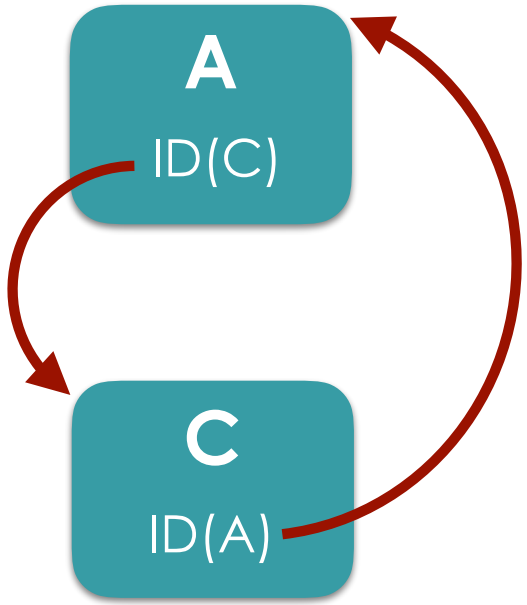
code base

5. Avoiding Hash Loops

- General execution may have loops



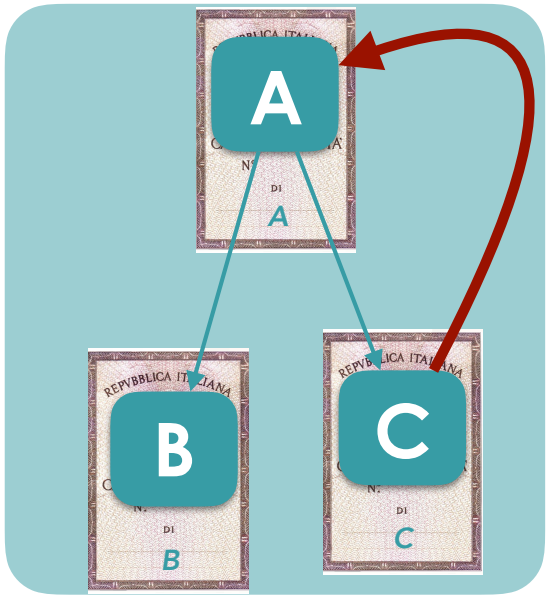
code base



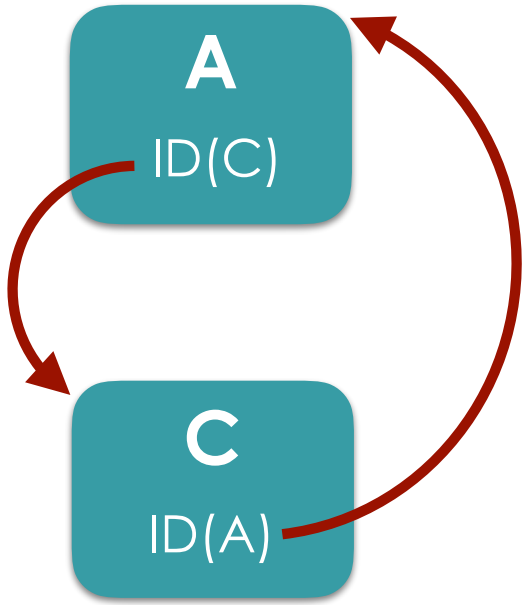
problem
(hash loop)

5. Avoiding Hash Loops

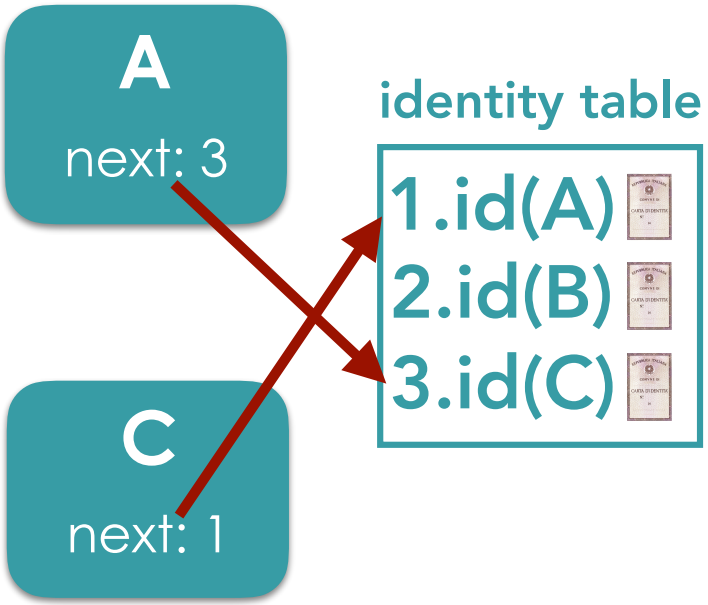
- General execution may have loops



code base



problem
(hash loop)



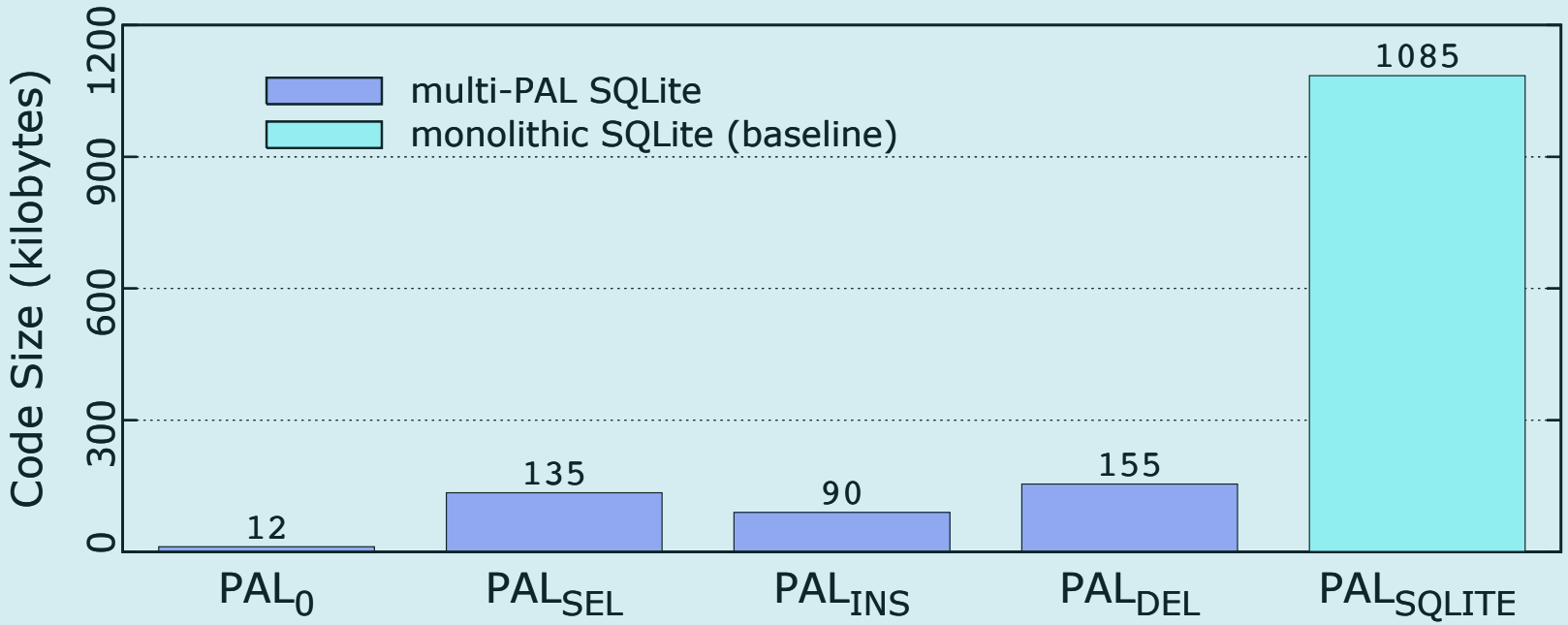
solution
(ID's in input table)

Practical Analysis

Practical Analysis

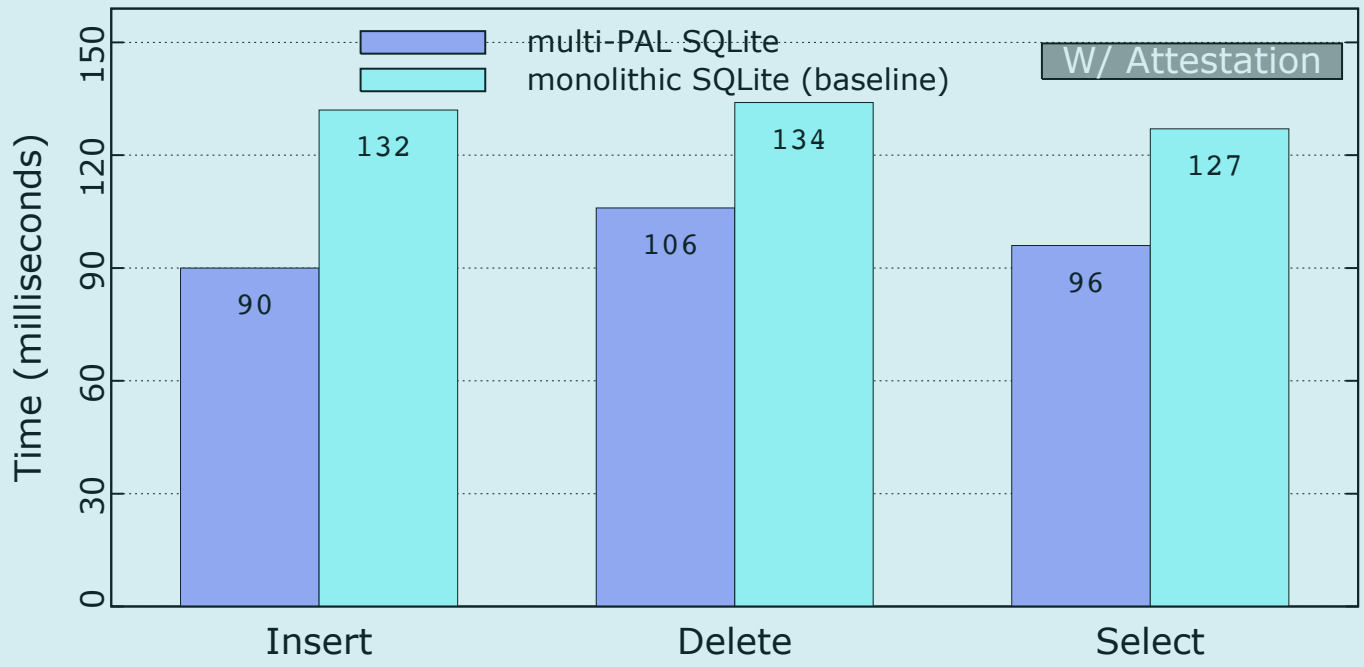
- Hypervisor-based TCC Implementation
- Protocol applied to a real-world service (SQLite)
- End-To-End experiments on server cluster

Code Size



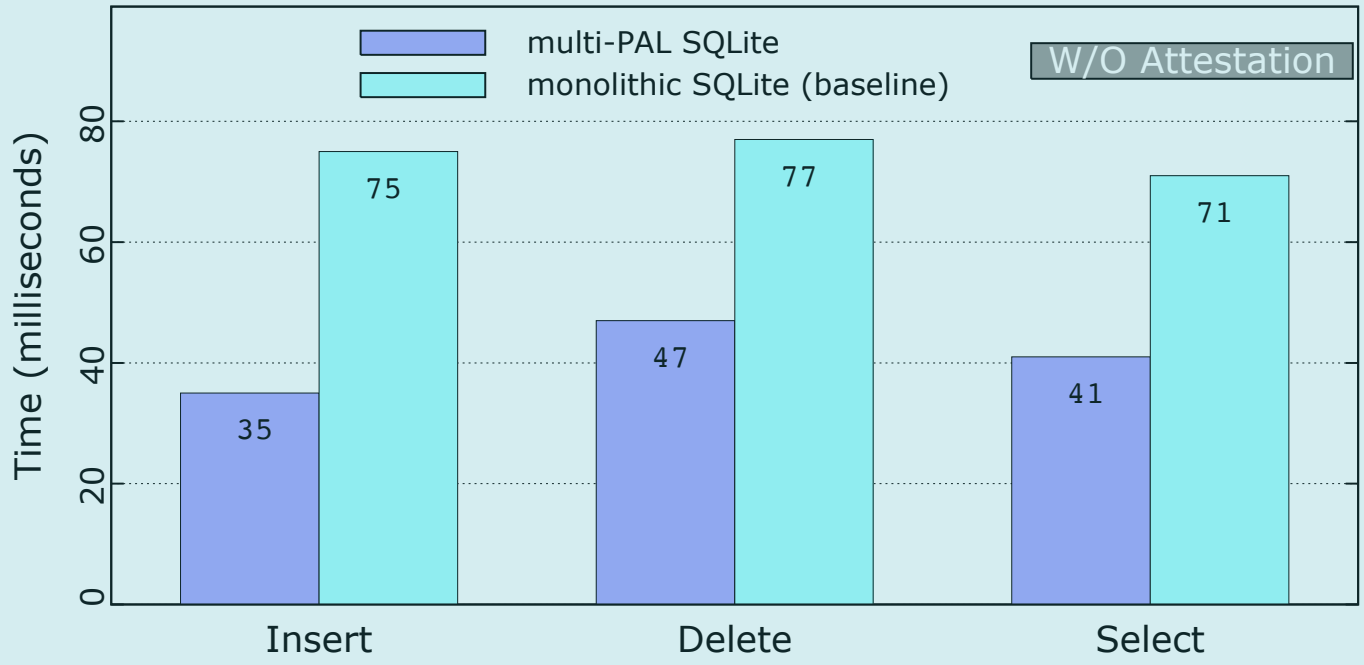
- SQLite (full implementation) is ~1MB
- 5-10x reduction of used code for single operation (PAL = Piece of Application Logic)

End-to-End Evaluation



- Same critical path, different code identification
- Monolithic SQLite is up 46% slower (w/ attestation)

End-to-End Evaluation



- Multi-PAL SQLite up to 2x faster (w/o attestation)

Conclusions

Conclusions

- **Code identification** has security/efficiency **tradeoffs**
- **Identification** of just **actively executed** code can:
  - provide **fresher integrity guarantees**
  - **improved resource usage** & **performance**
  - be done **retrofitting existing trusted components**

Real-World Service

Our Solution

Generic Trusted Component

Ciências ULisboa

Carnegie Mellon
SCHOOL OF COMPUTER SCIENCE

THANKS

BRUNO VAVALA
CMU/UL

Nuno Neves
UL

Peter Steenkiste
CMU

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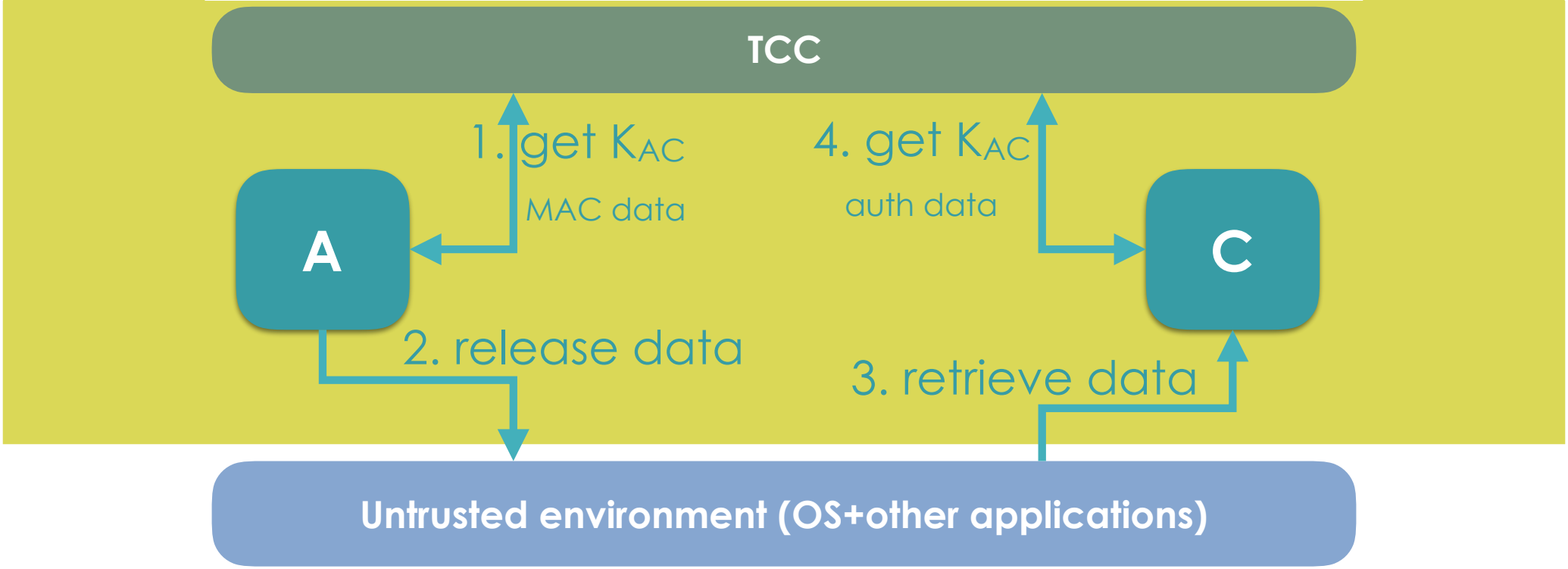
BACKUP SLIDES

Efficient Mutually-Authenticated Channels



- Identity Dependent keys
  - Sender specifies recipient's identity to TCC
  - Recipient specifies sender's identity to TCC
- Very efficient construction (one hash per-key)