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Security Type Checking for MILS-AADL Specifications

Kevin van der Pol, Thomas Noll

MILS Workshop Amsterdam – January 20, 2015

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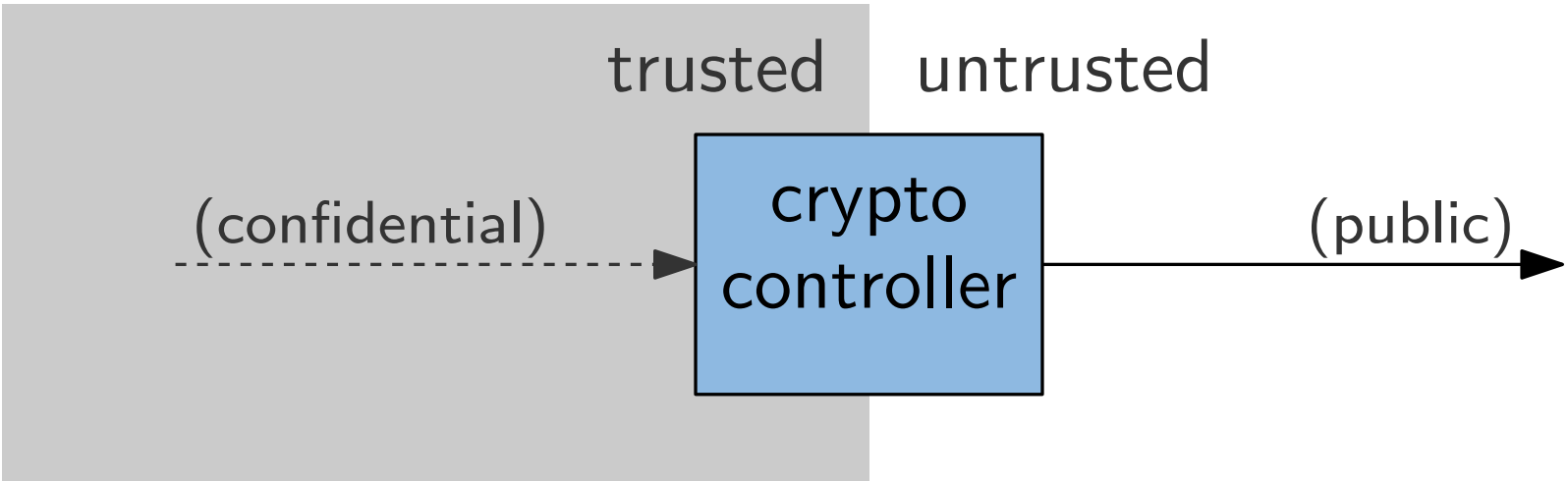
Motivation



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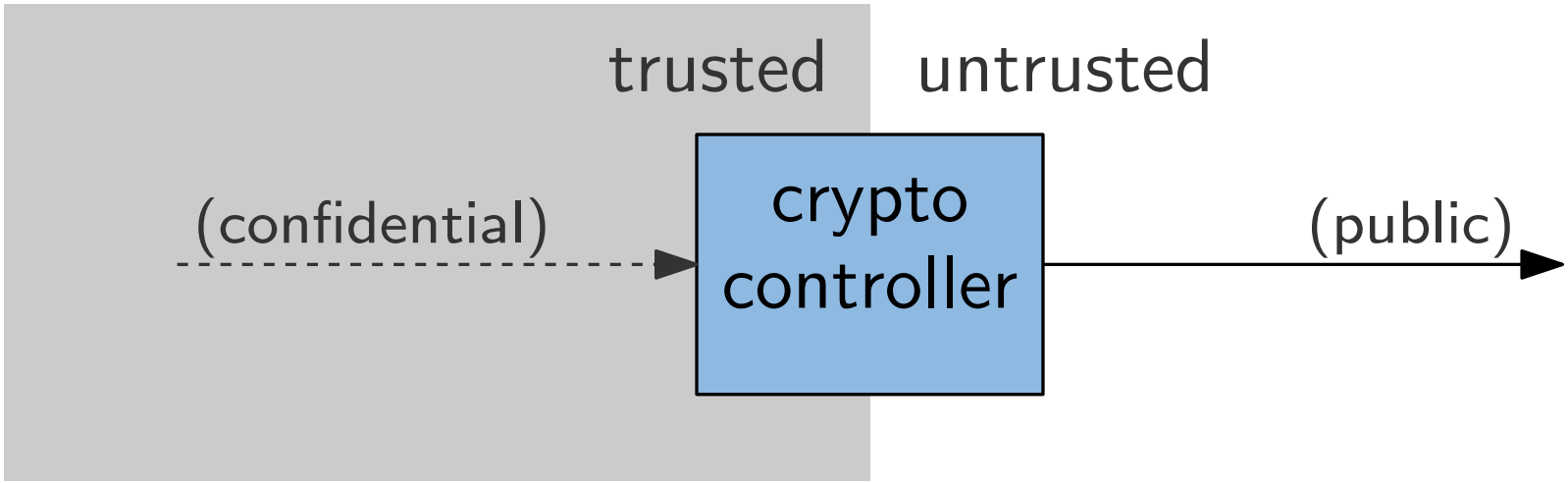

- Cryptographic controller [Rus92]

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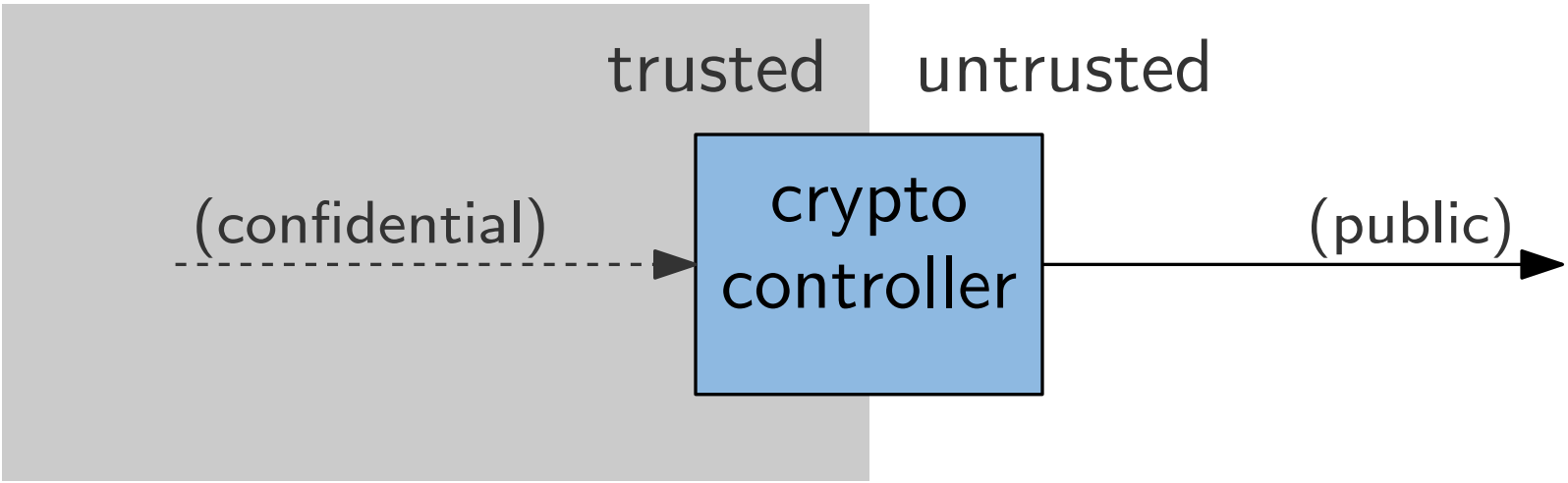

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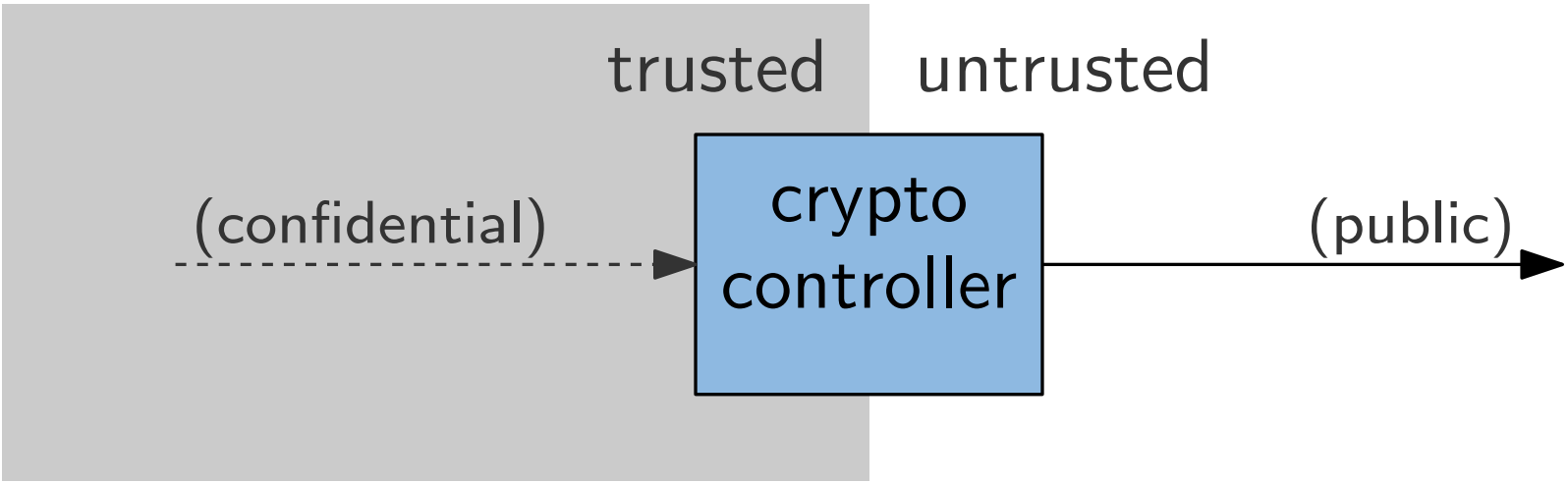

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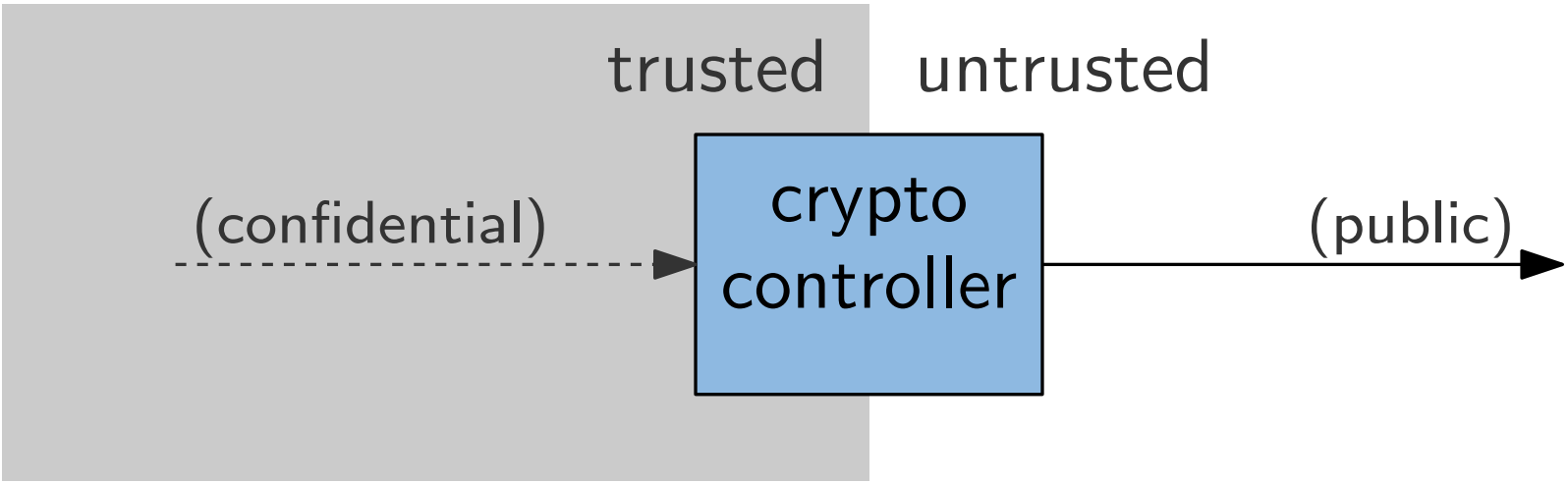

- Cryptographic controller [Rus92]
- Placed between trusted system and untrusted network
- Declassifies confidential information
- Goal: verify its security

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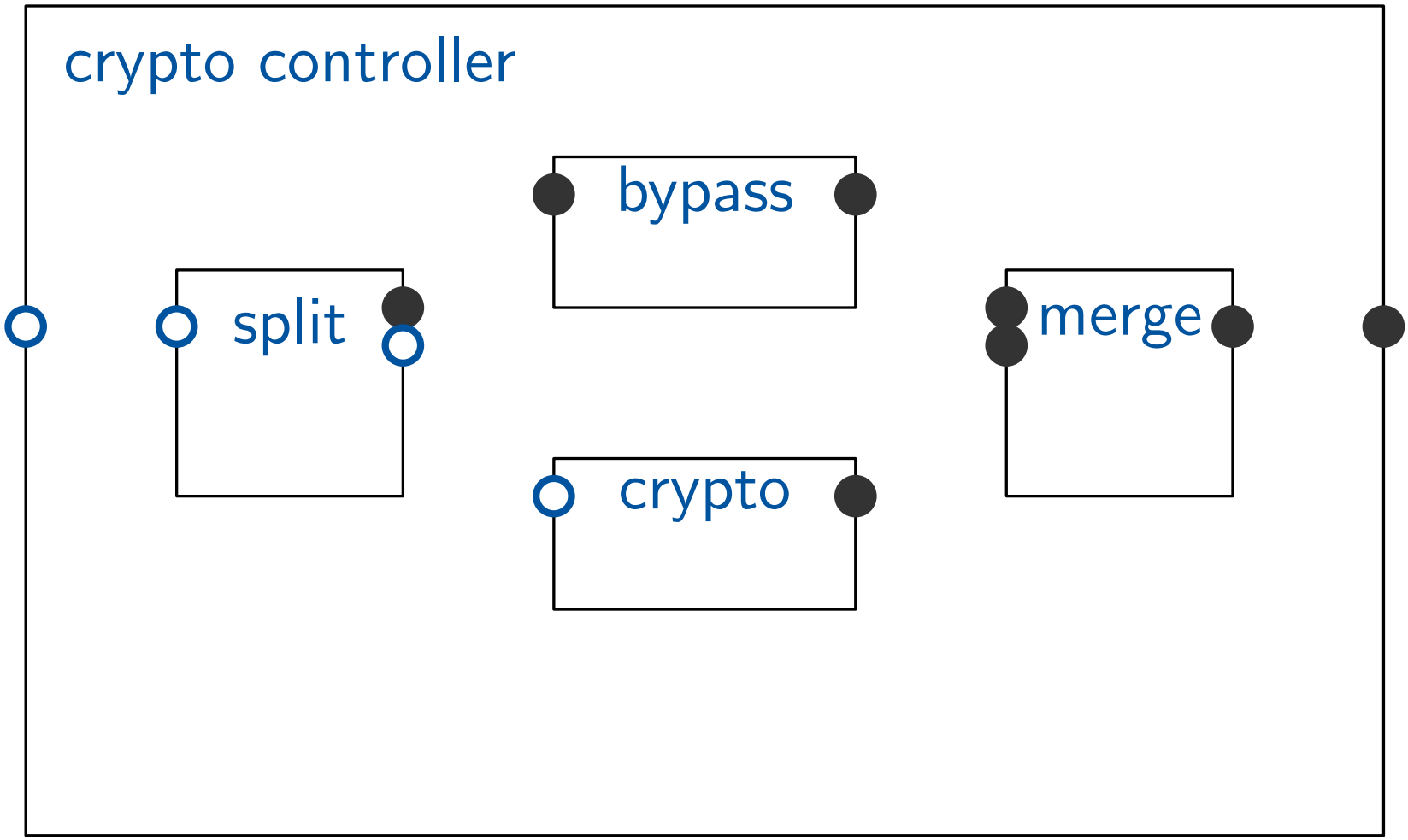

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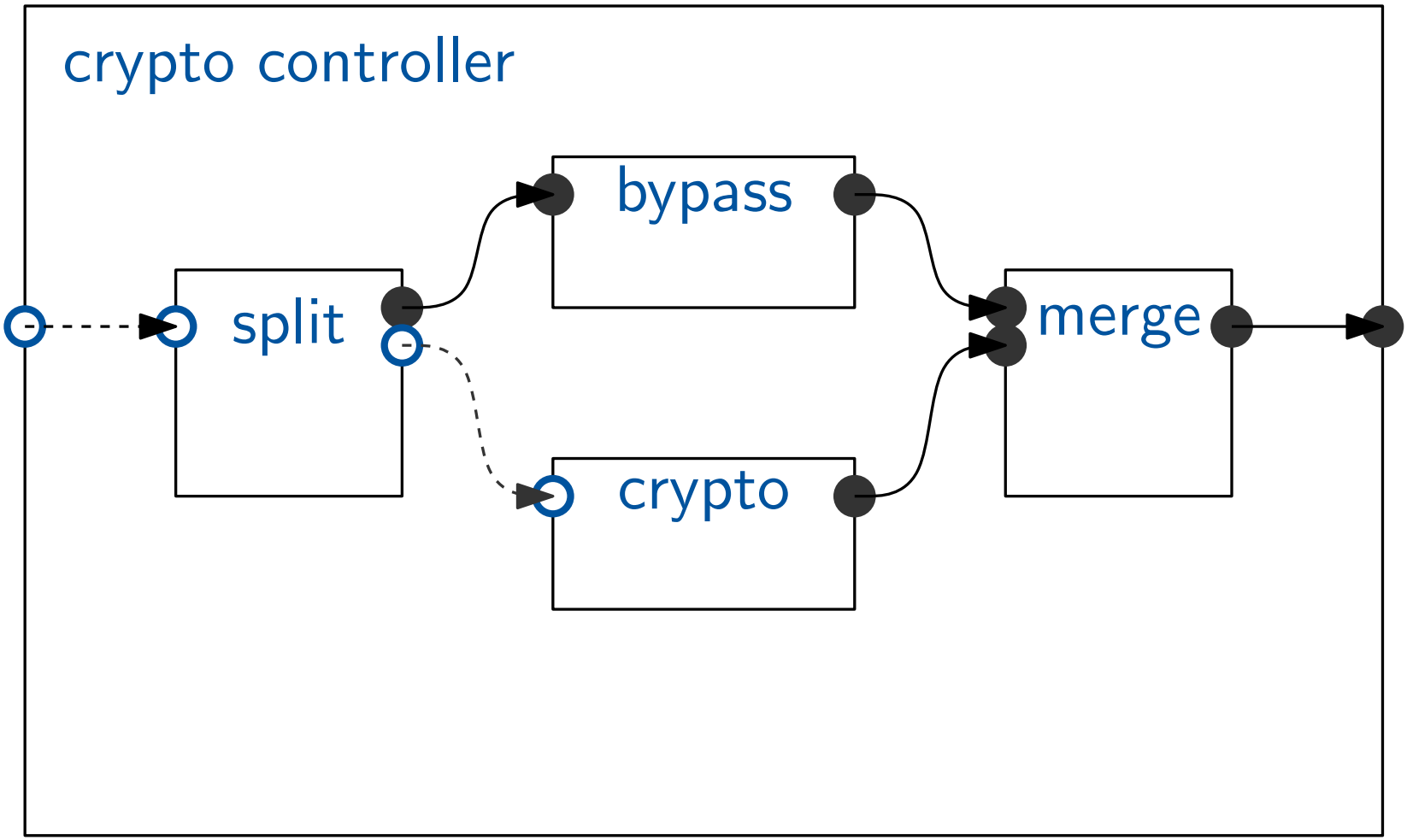

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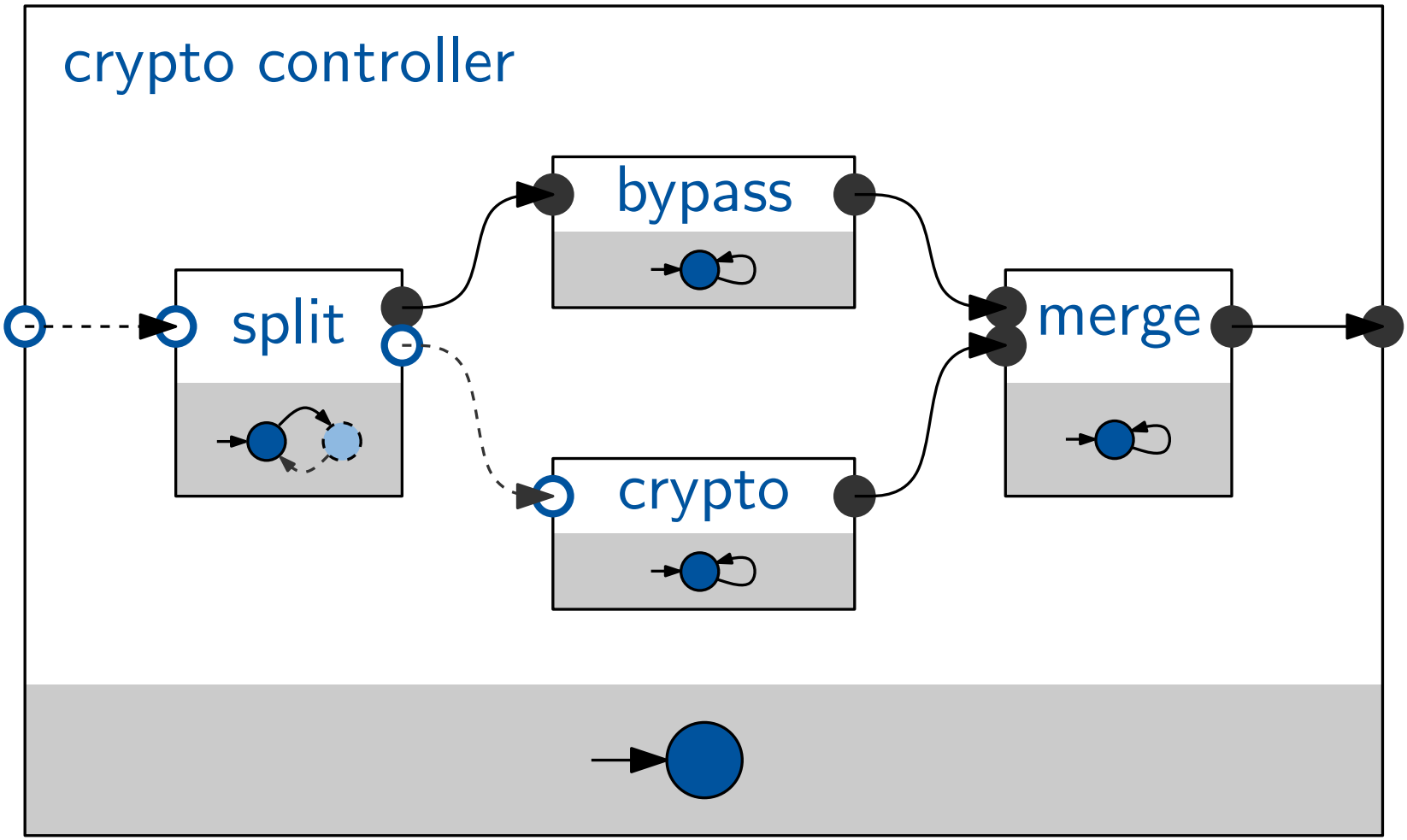

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Syntax

system cryptocontroller(

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system cryptocontroller(
   inframe: in (int L, int H) (0,0)
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system cryptocontroller(
   inframe: in (int L, int H) (0,0)
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   system split(...)
   system bypass(...)
   system merge(...)
   system crypto(
      inpayload: in int H 0
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      k: key L k0


   )



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      inpayload: in int H 0
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      k: key L k0
      m: initial mode L
      m-[then outpayload:=encrypt(inpayload,k)]->m
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```

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Case	Grammar
Level	$\sigma ::= \texttt{H} \mid \texttt{L}$
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Mode	$M ::= m : [\texttt{initial}]\ \texttt{mode}\ \sigma$
Transition	$T ::= m\ \texttt{-[}\ [p]\ [\texttt{when}\ e]\ [\texttt{then}\ x := e]\ \texttt{]->}\ m'$

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Non-interference

- Lattice of confidentiality levels

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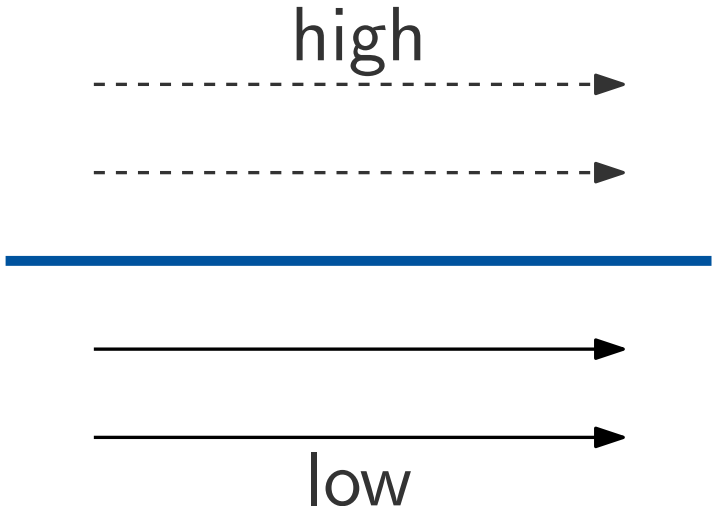

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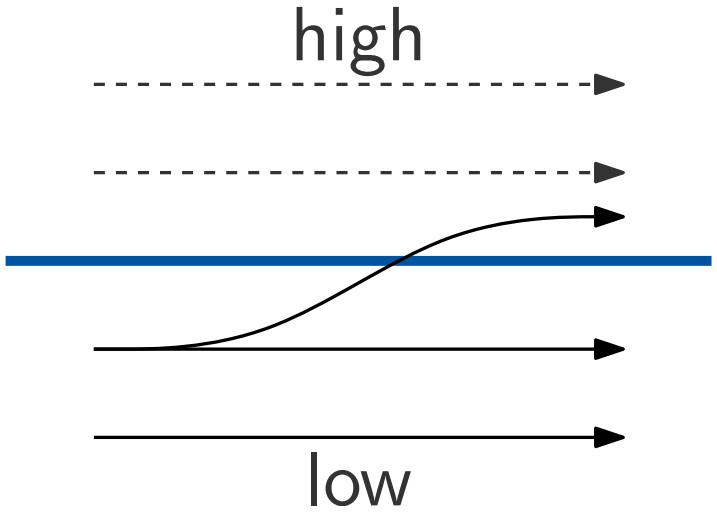

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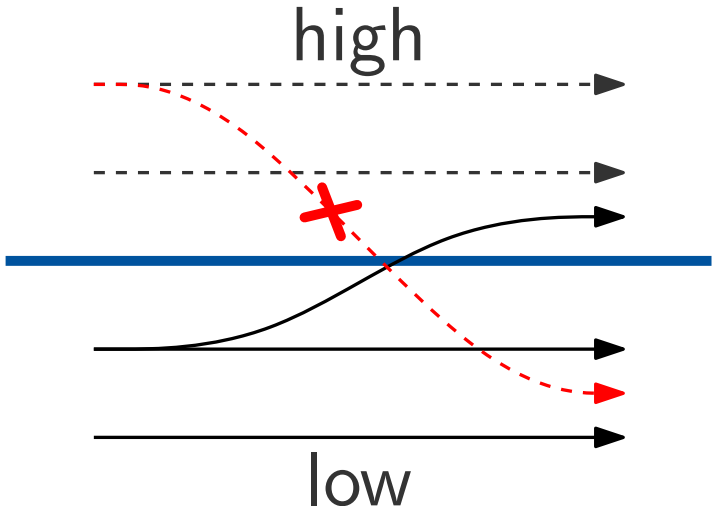

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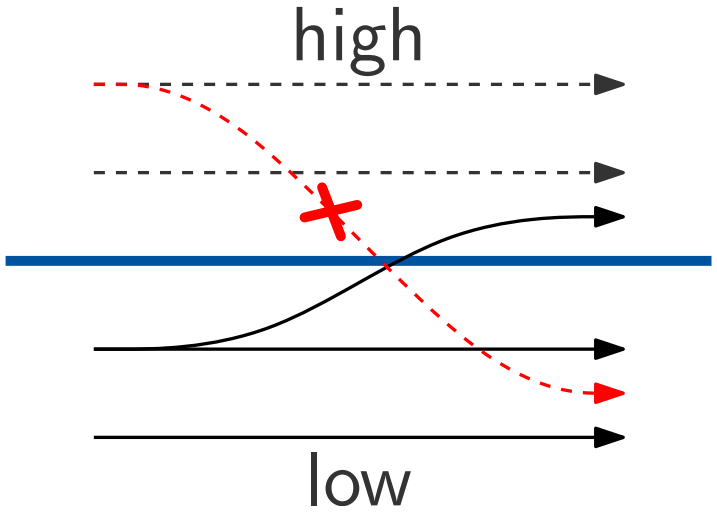

- When varying secret variables and ports, reachable values of public variables and ports are indistinguishable

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Unwanted data flows

- Explicit data flow

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  - low := high
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  - data leak through control flow
  - `if` high `then` low := 1 `else` low := 2 `endif`

Possibilistic non-interference

- Abstract encryption function

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  - low1 := encrypt(v,k); low2 := low1

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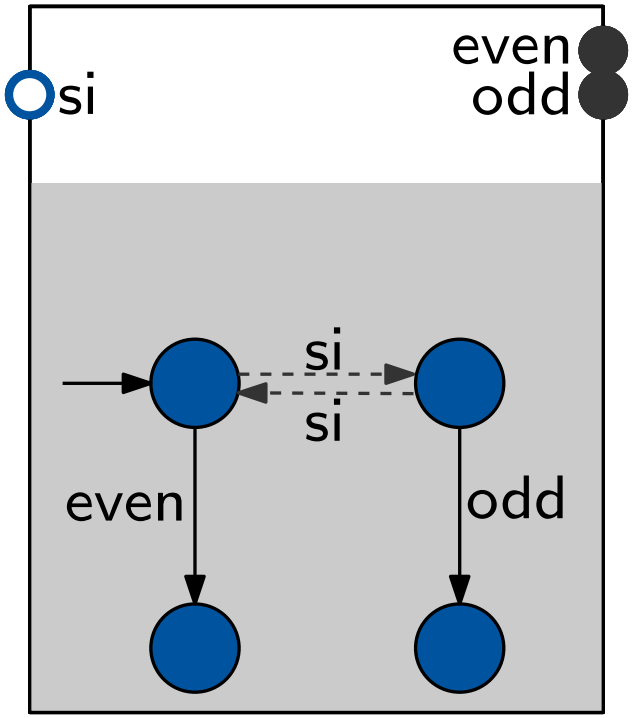

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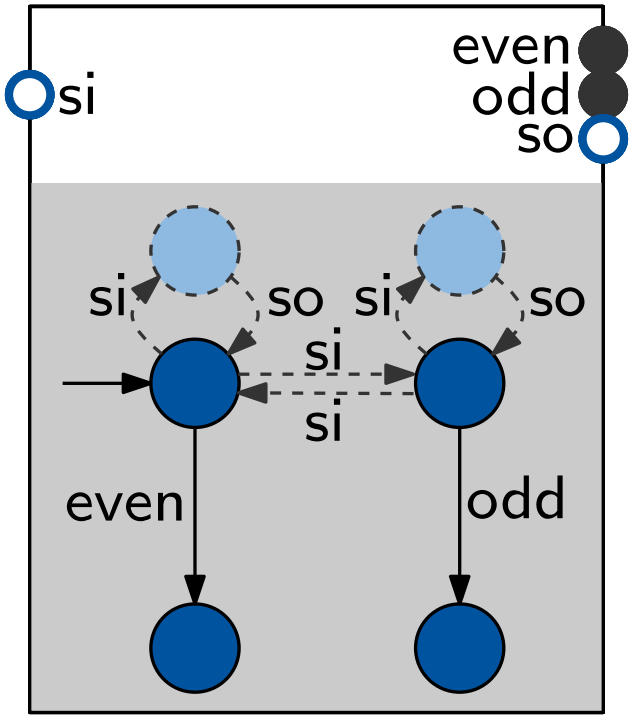

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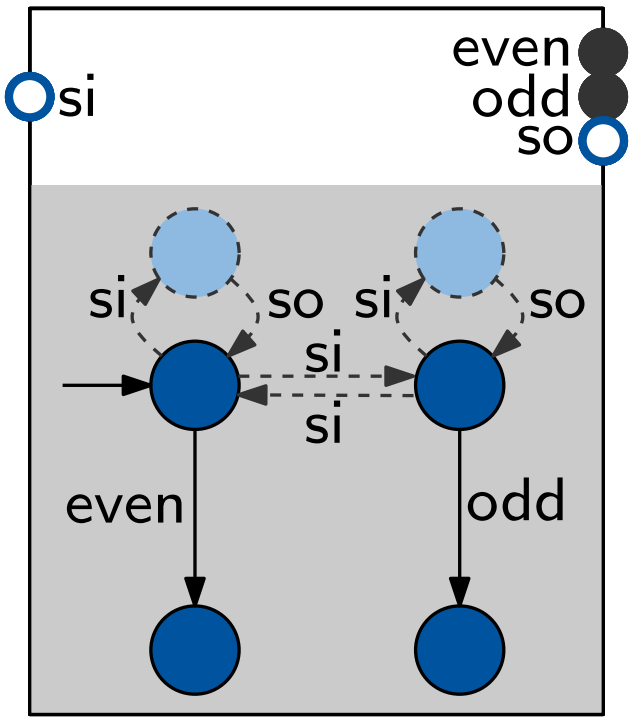

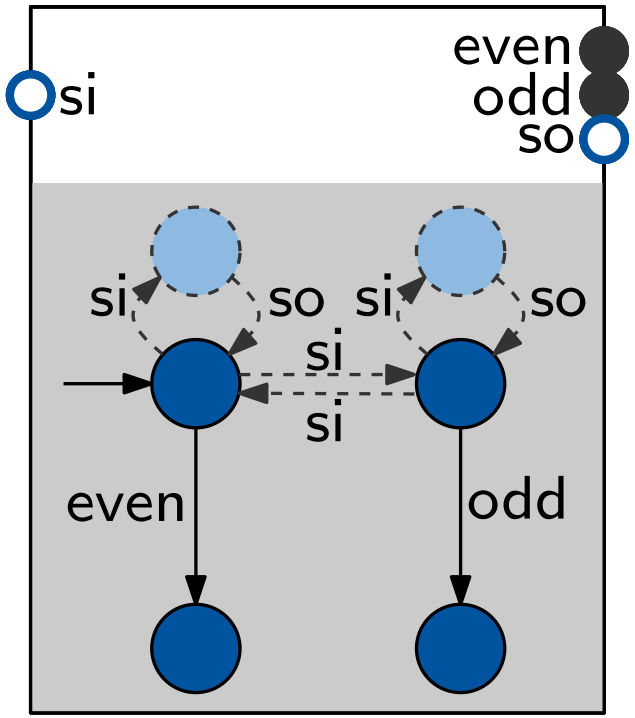

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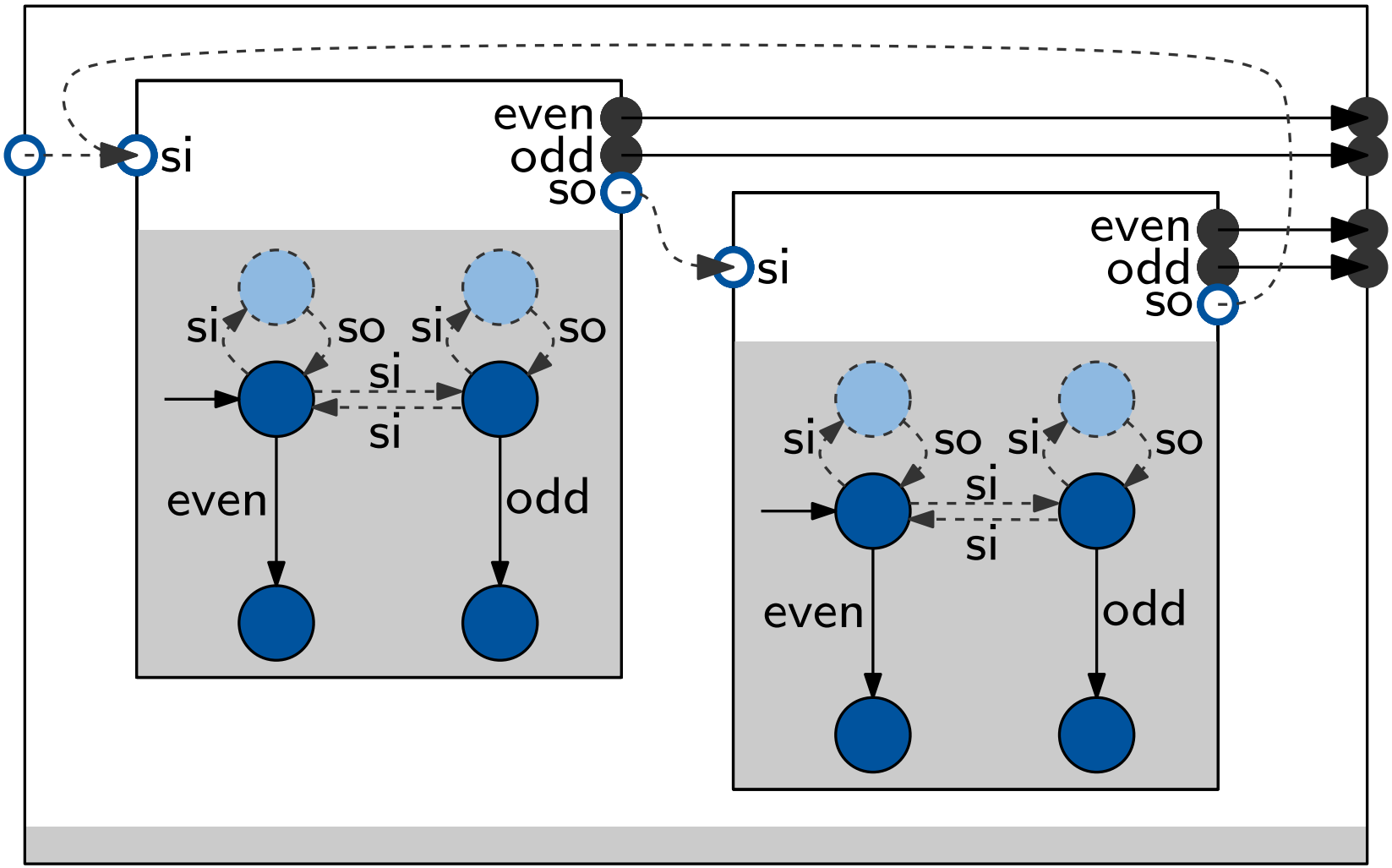
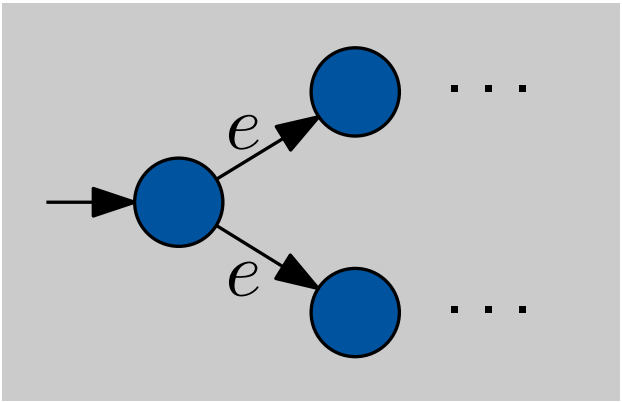


Restrictions



non-determinism

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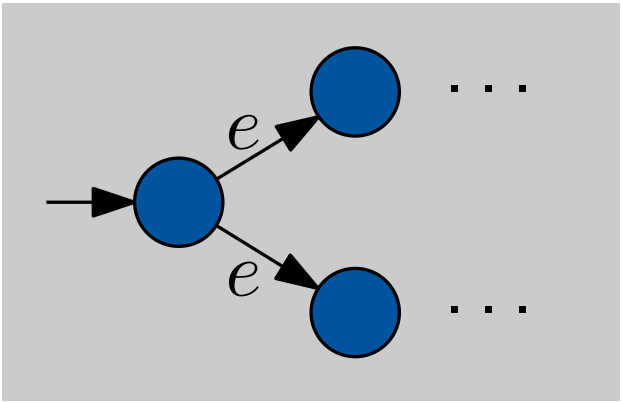

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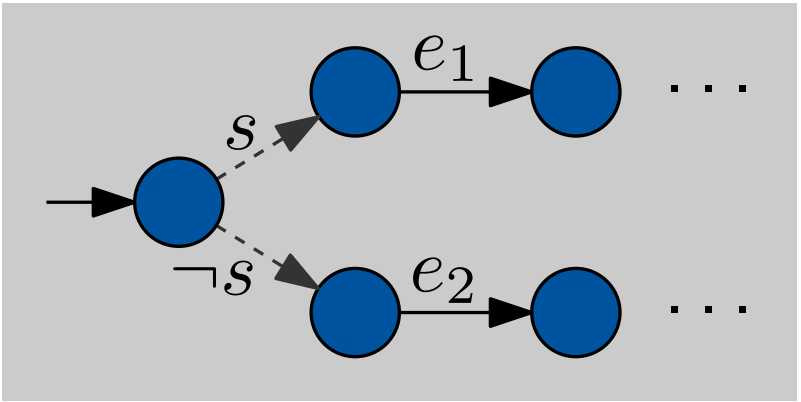

branching on secrets

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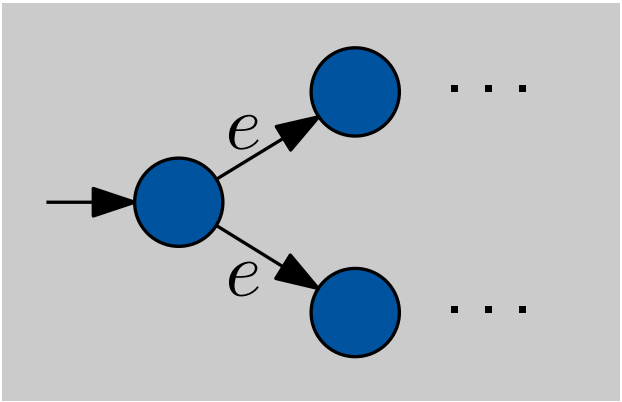

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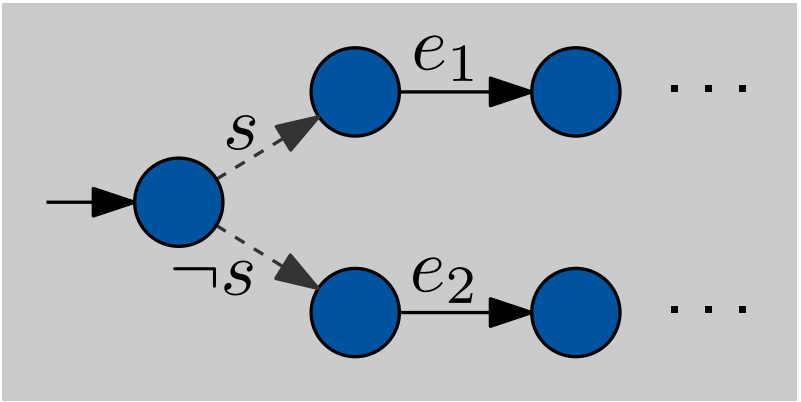

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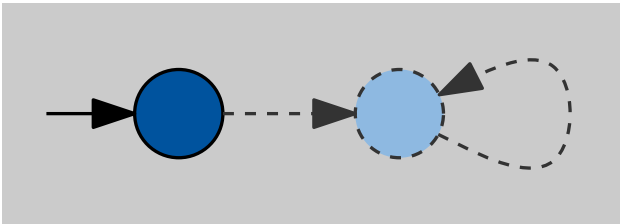

secret-Zeno

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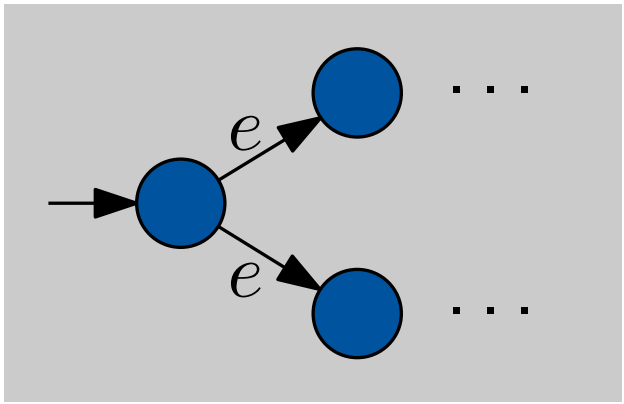

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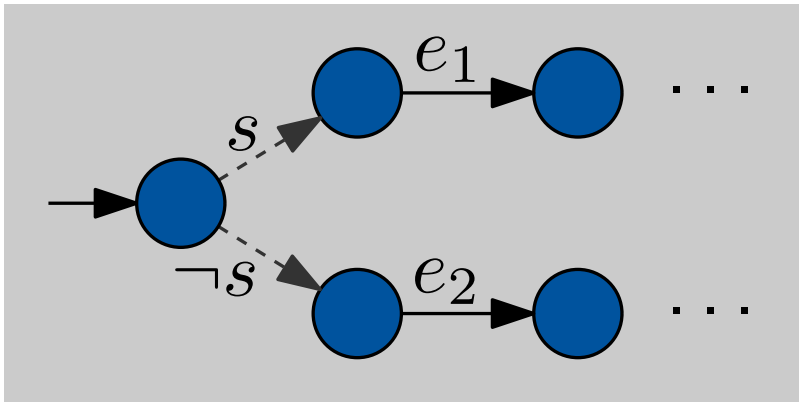

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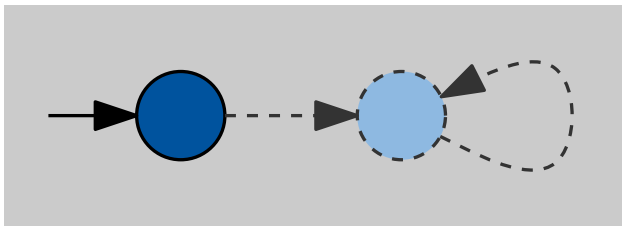

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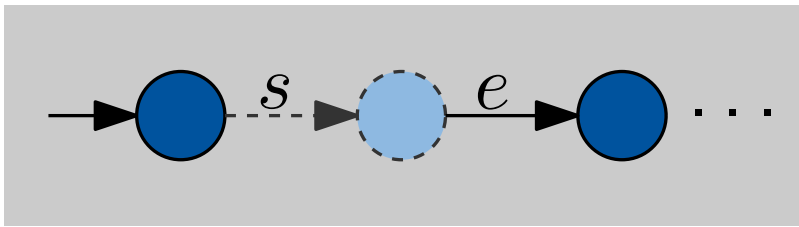

public output from secret region

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Theorem

If the system is typable, it is non-interfering

Types of expressions

Case	Type rule
Basic types	$\dfrac{}{T \vdash n : \texttt{int L}} \qquad \dfrac{}{T \vdash b : \texttt{bool L}}$
Variable	$\dfrac{T(x) = \tau}{T \vdash x : \tau}$
Operator	$\dfrac{T \vdash e_1 : t_1\ \sigma_1 \quad T \vdash e_2 : t_2\ \sigma_2 \quad \oplus : t_1 \times t_2 \to t}{T \vdash e_1 \oplus e_2 : t\ (\sigma_1 \sqcup \sigma_2)}$
Encryption	$\dfrac{T \vdash e_1 : \tau \quad T \vdash e_2 : \texttt{key L}}{T \vdash \texttt{encrypt}(e_1, e_2) : \texttt{enc}\ \tau\ \texttt{L}}$
Decryption	$\dfrac{T \vdash e_1 : \texttt{enc}\ \tau\ \sigma \quad T \vdash e_2 : \texttt{key H}}{T \vdash \texttt{decrypt}(e_1, e_2) : \tau^{\sigma}}$

Types of expressions

```
system crypto(
    inpayload: int H 0
    outpayload: out enc int H L encrypt(0, k0)
    k: key L k0
    m: initial mode L
    m-[then outpayload:=encrypt(inpayload,k)]->m
)
```

- Type of `encrypt(inpayload,k)`?

$$\frac{\dfrac{T(\texttt{inpayload}) = \texttt{int H}}{T \vdash \texttt{inpayload} : \texttt{int H}} \quad \dfrac{T(\texttt{k}) = \texttt{key L}}{T \vdash \texttt{k} : \texttt{key L}}}{T \vdash \texttt{encrypt(inpayload,k)} : \texttt{enc int H L}}$$

Subtyping

- If $\tau_e <: \tau_x$, assignment $x := e$ is valid
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  - Confidentiality restriction

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Case	Subtype rule
Basic types	$\dfrac{\sigma \sqsubseteq \sigma'}{\texttt{int}\ \sigma <: \texttt{int}\ \sigma'}$ $\dfrac{\sigma \sqsubseteq \sigma'}{\texttt{bool}\ \sigma <: \texttt{bool}\ \sigma'}$ $\dfrac{}{\texttt{key}\ \sigma <: \texttt{key}\ \sigma}$

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Encryption	$\dfrac{\tau <: \tau' \quad \sigma \sqsubseteq \sigma'}{\texttt{enc}\ \tau\ \sigma <: \texttt{enc}\ \tau'\ \sigma'}$

Subtyping

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    inpayload: int H 0
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Type of transitions

Case	Type rule
Transition	$$\frac{\begin{array}{lll} T \vdash p : \tau_p & & \\ T \vdash g : \tau_g & \tau_x <: \tau_e & lvl(\tau_x) \sqsubseteq \sigma \\ T \vdash x : \tau_x & lvl(m) \sqsubseteq lvl(\tau_p) & \sigma \sqsubseteq lvl(\tau_p) \\ T \vdash e : \tau_e & lvl(m) \sqsubseteq lvl(\tau_x) & \sigma \sqsubseteq lvl(\tau_g) \end{array}}{T \vdash m \texttt{-[}\, p \ \texttt{when}\ g\ \texttt{then}\ x := e \,\texttt{]->}\, m' : \sigma}$$

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- `crypto` system is non-interfering □

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Conclusion

- AADL variant with cryptographic primitives
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- Future work: soundness proof, implementation, type inference

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Bibliography

Aslan Askarov, Daniel Hedin, and Andrei Sabelfeld, *Cryptographically-masked flows*, Theor. Comput. Sci. **402** (2008), no. 2-3, 82–101.

Peeter Laud, *On the computational soundness of cryptographically masked flows*, Proceedings of the 35th ACM SIGPLAN-SIGACT Symposium on Principles of Programming Languages, POPL 2008, San Francisco, California, USA, January 7-12, 2008, 2008, pp. 337–348.

John Rushby, *Noninterference, transitivity, and channel-control security policies*, Tech. Report SRI-CSL-92-2, Computer Science Laboratory, SRI International, Menlo Park, CA, December 1992.