Robust MPC: Asynchronous Responsiveness yet Synchronous Security

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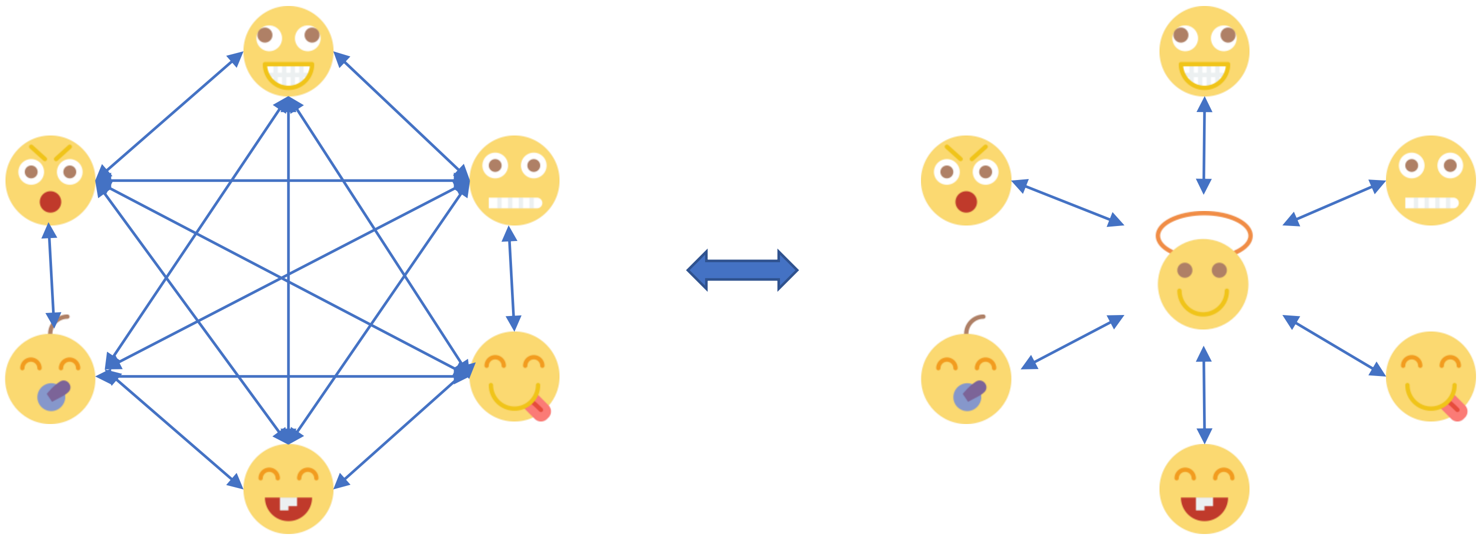
Tal Moran — IDC Herzliya

Daniel Tschudi — Aarhus University

Multiparty Computation



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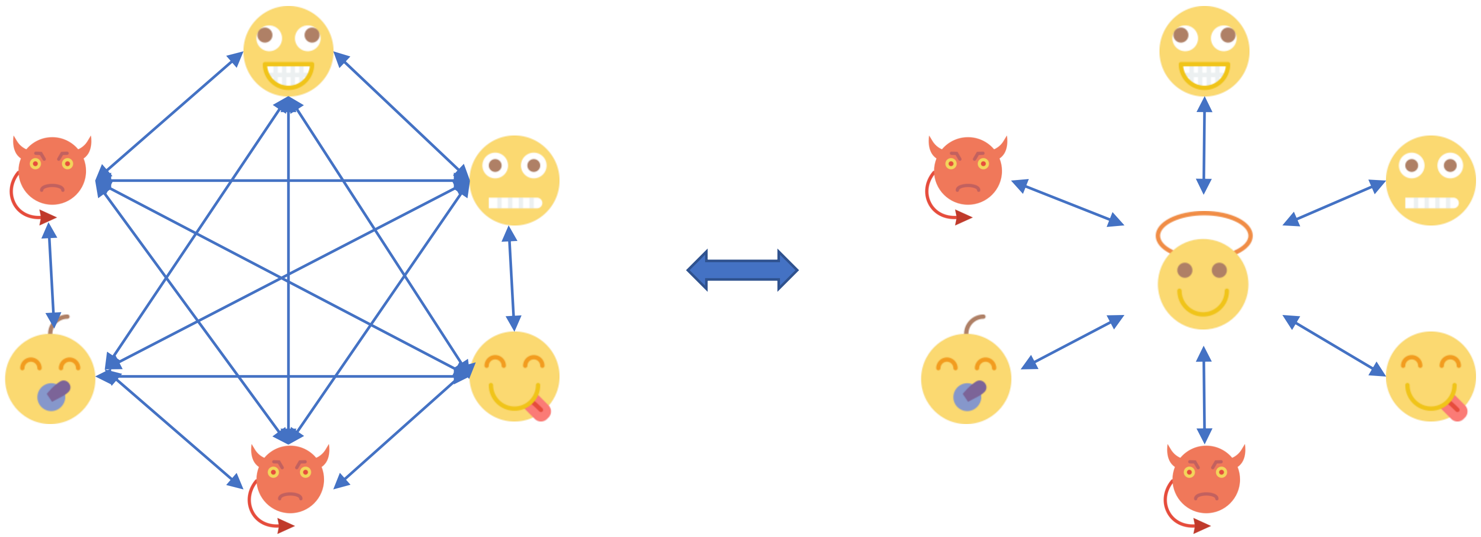

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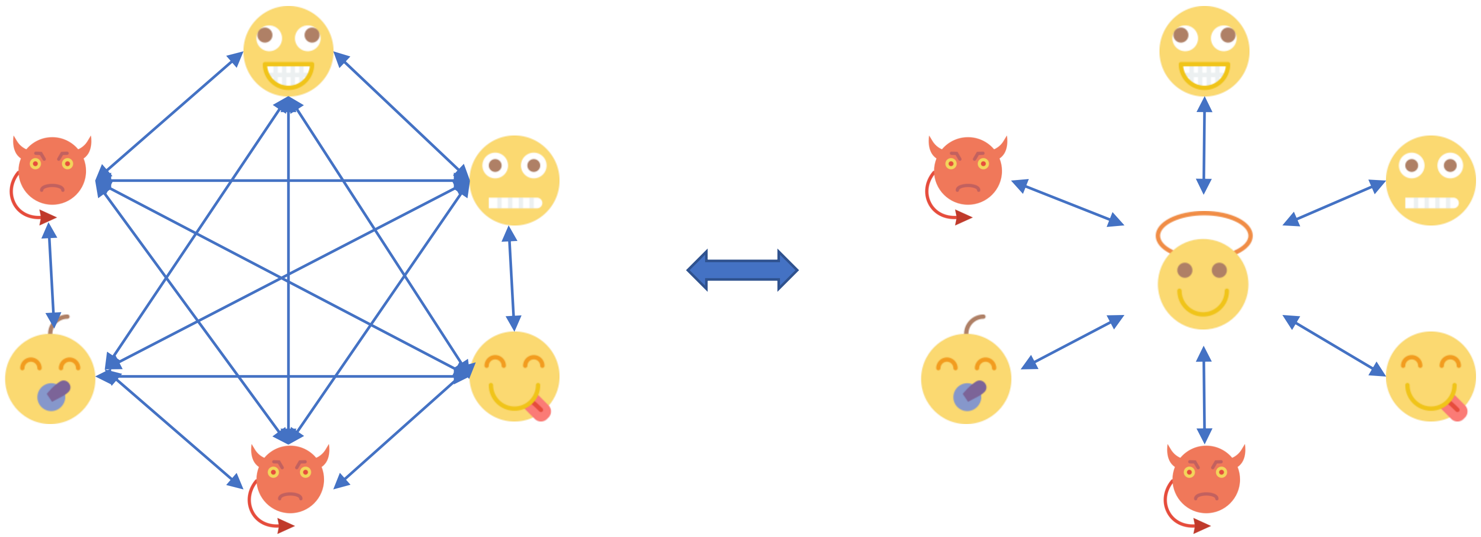

Correctness: Output is correct
Privacy: Inputs remain private
Termination: Parties obtain output

Synchronous Model

Round structure:

- Each P_i knows the current round
- Round r: P_i reads round r-1 messages
  P_i computes/sends round r messages
- **Round r messages are guaranteed to be delivered by round r+1**

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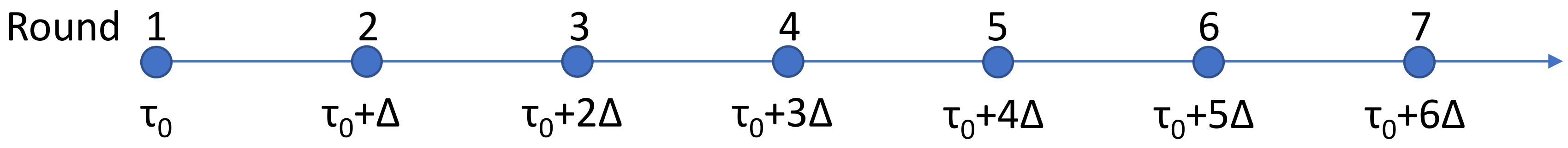
Can be achieved with synchronized clocks and channels with known delay upper bound Δ



Synchronous Protocols

$t < \frac{n}{2}$

Input completeness

Synchronous Protocols

$t < \frac{n}{2}$

Input completeness

Time: T(Δ)

$\Delta \gg \delta$, for network delay δ

Asynchronous Protocols

Greedy approach: P_i continues as soon as it gets enough messages

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Time: T(δ)

δ network delay

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δ network delay

$t < \frac{n}{3}$

Take into account $n - t$ inputs

Synchronous vs Asynchronous

	Correctness	Privacy	Termination		Number of Inputs
			Slow Output T(Δ)	Fast Output T(δ)	
Synchronous	$n/2$	$n/2$	n	-	n
Asynchronous	$n/3$	$n/3$	-	$n/3$	$2n/3$

Synchronous vs Asynchronous

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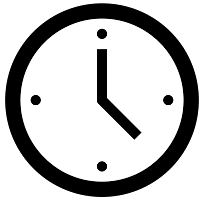
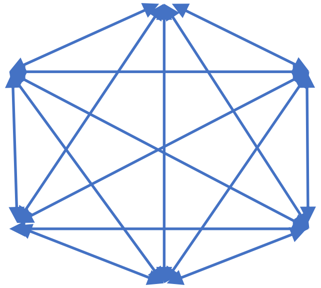
Our work	$n/2$	$n/2$	n	$n/4$	n or $3n/4$

Model



Global clock
[KMTZ13]



Network
unknown delay δ

Time out

Corrupt up to t parties arbitrarily
Schedule messages arbitrarily within δ clock ticks

Protocols can use $\Delta \gg \delta$

Synchronous over δ-network

Each P_i appends to each message its round number
Upon receiving all messages from round r:

- Send messages for round r+1
- Notify every party with round r

Upon receiving notifications from all parties for round r, continue with round r+1

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Single corruption prevents Fast outputs!

Guarantees

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Correctness and Privacy
$^{n}/_{2}$

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Output guarantees depend on 

Guarantees

Correctness and Privacy
$n/2$

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Fast network &
$t \le \frac{n}{4}$

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Slow network or
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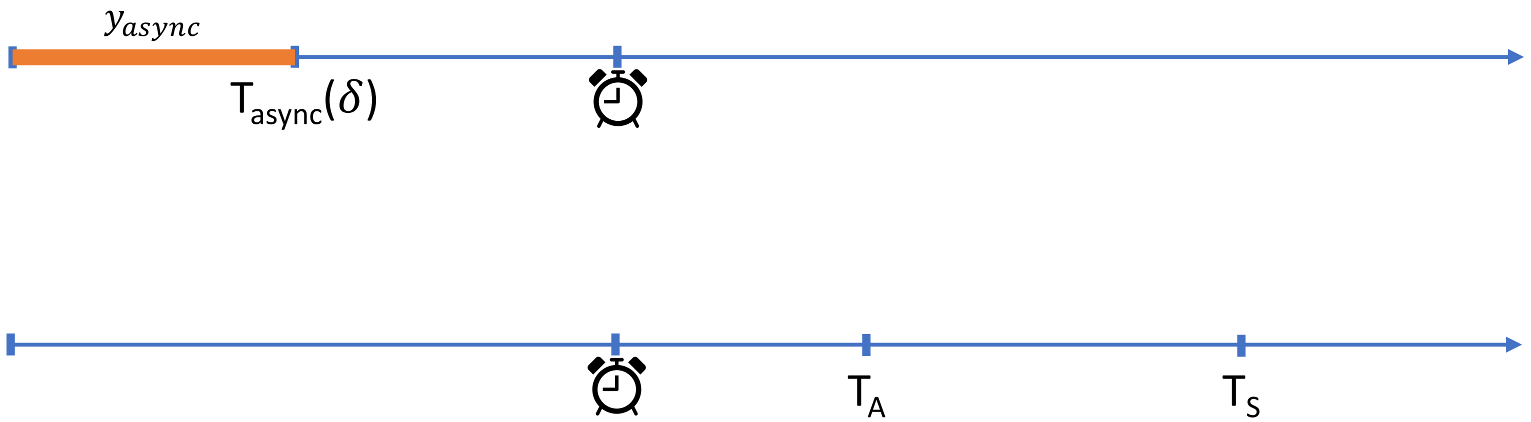

Slow network or
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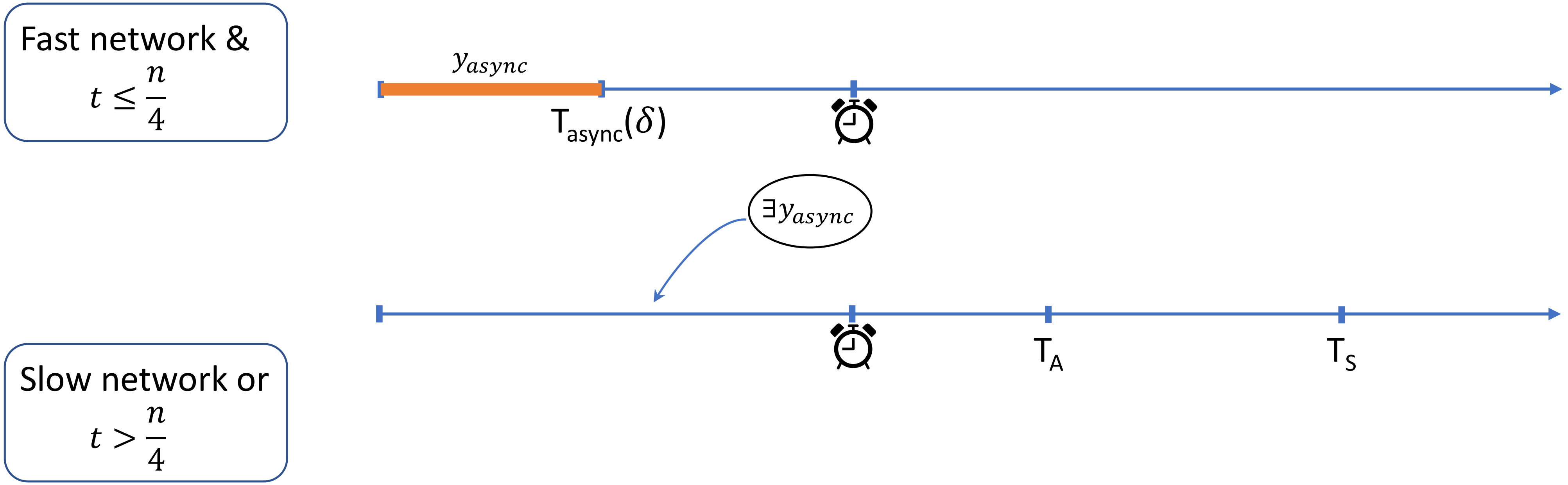

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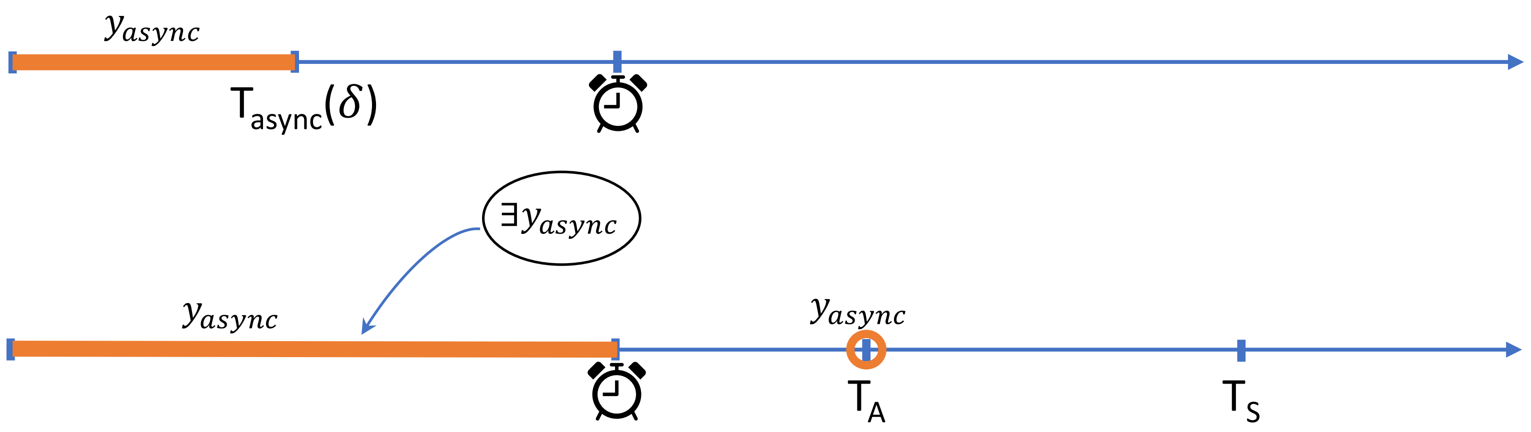

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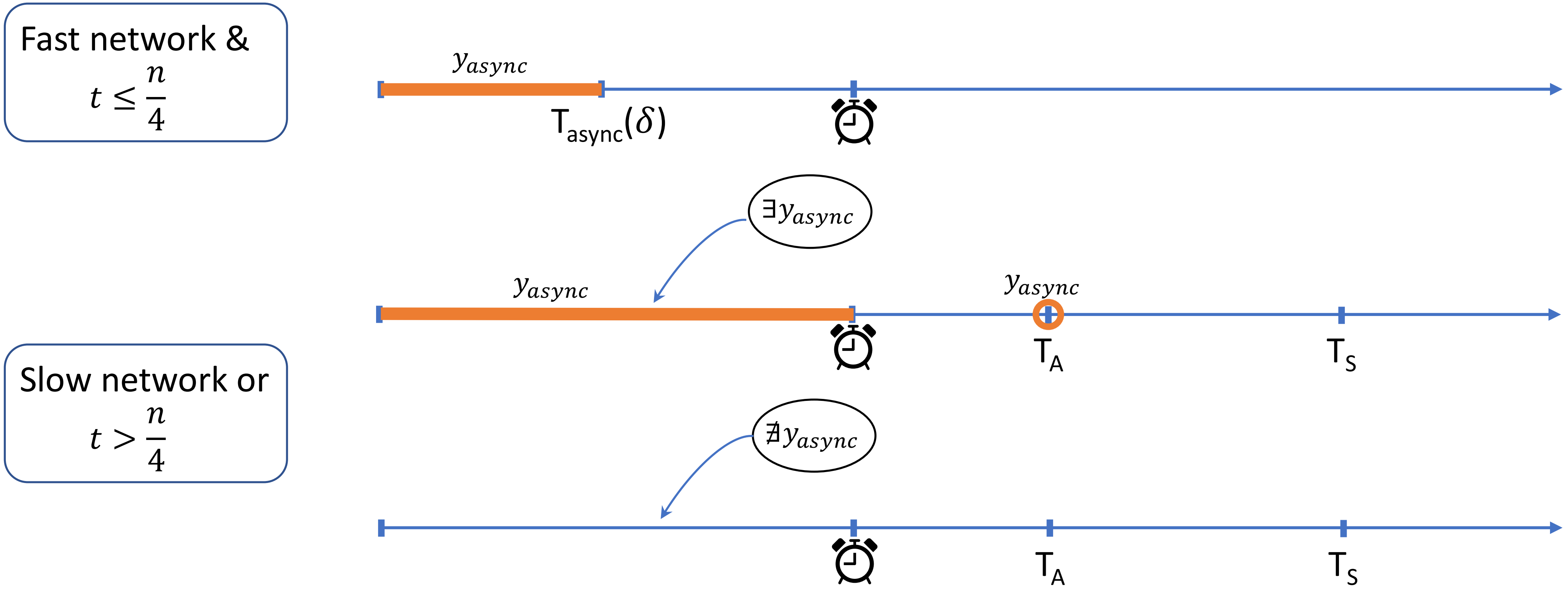

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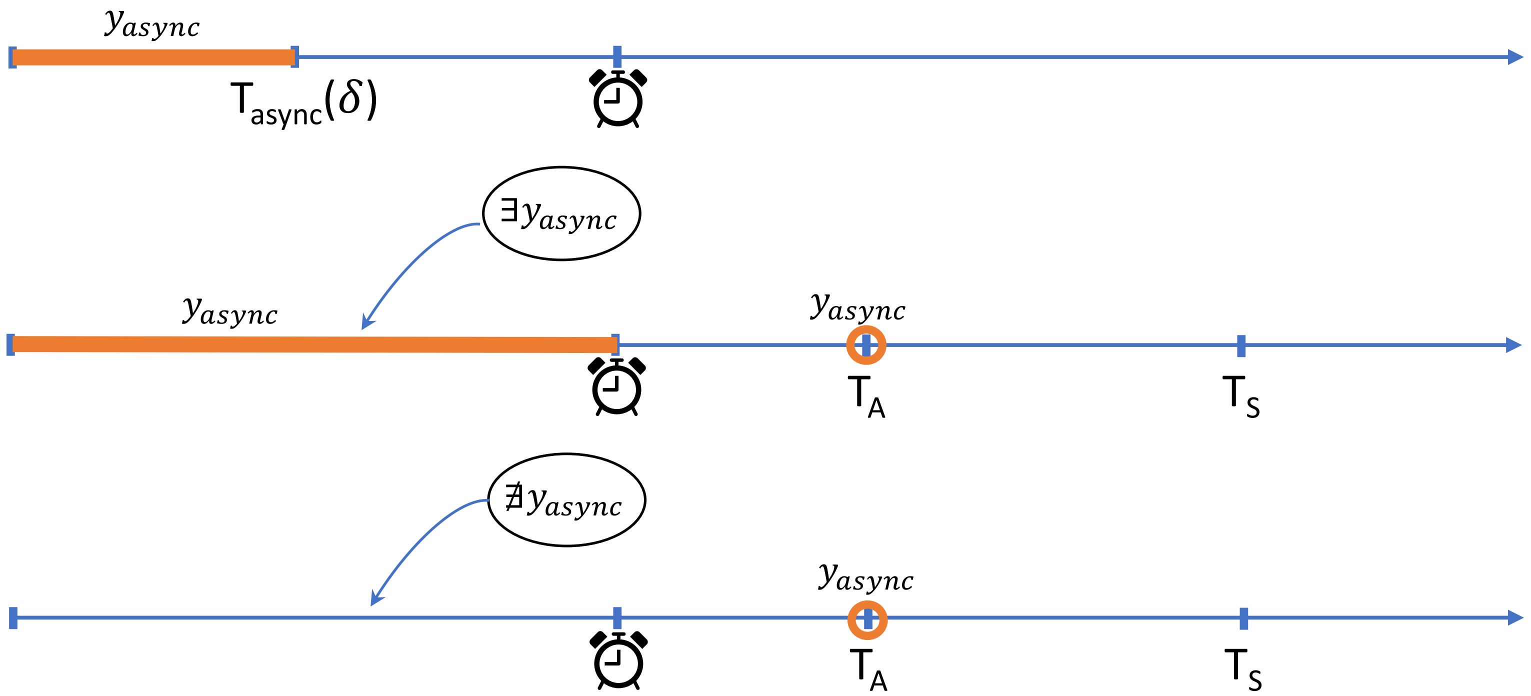

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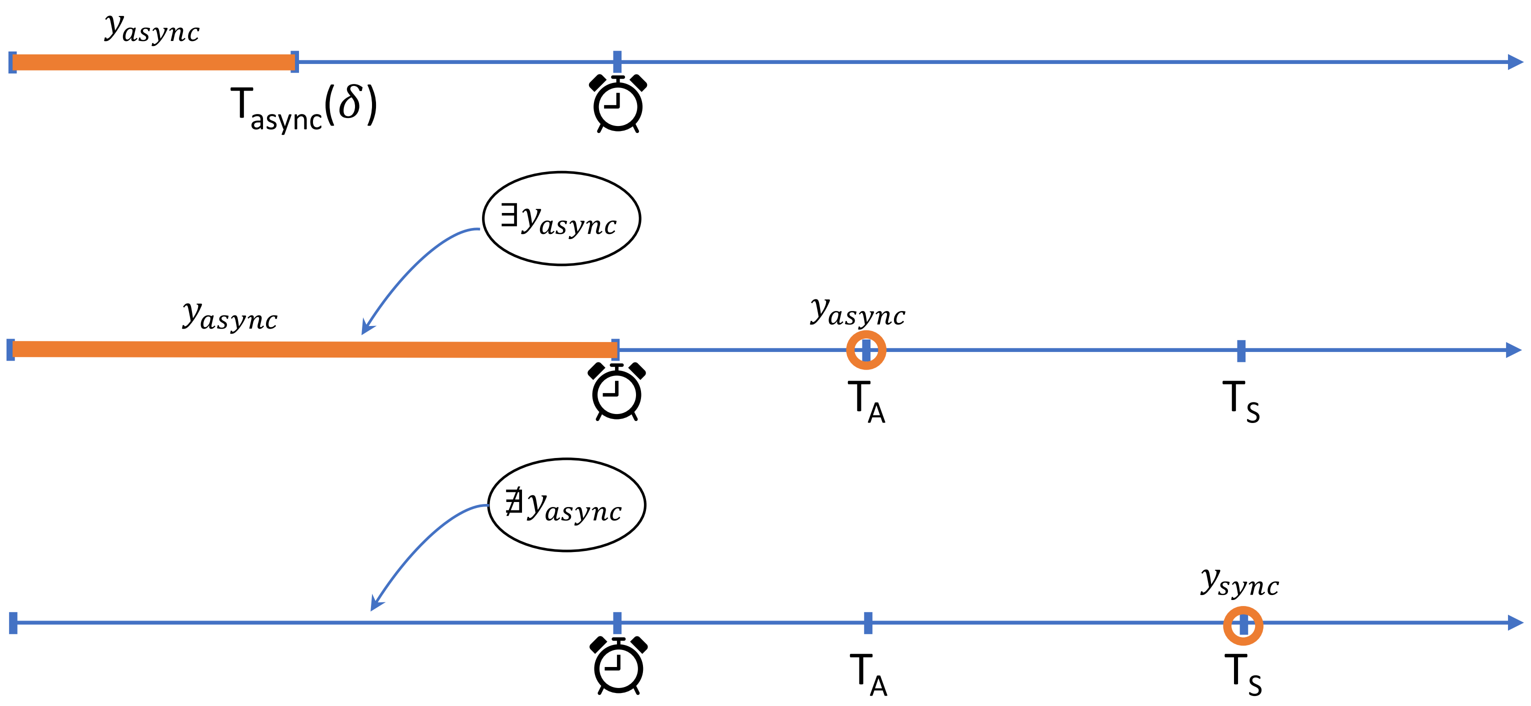

Road map

Π_{ASYNC}

Correctness/Privacy: $\frac{n}{2}$

Fast Output: $\frac{n}{4}$

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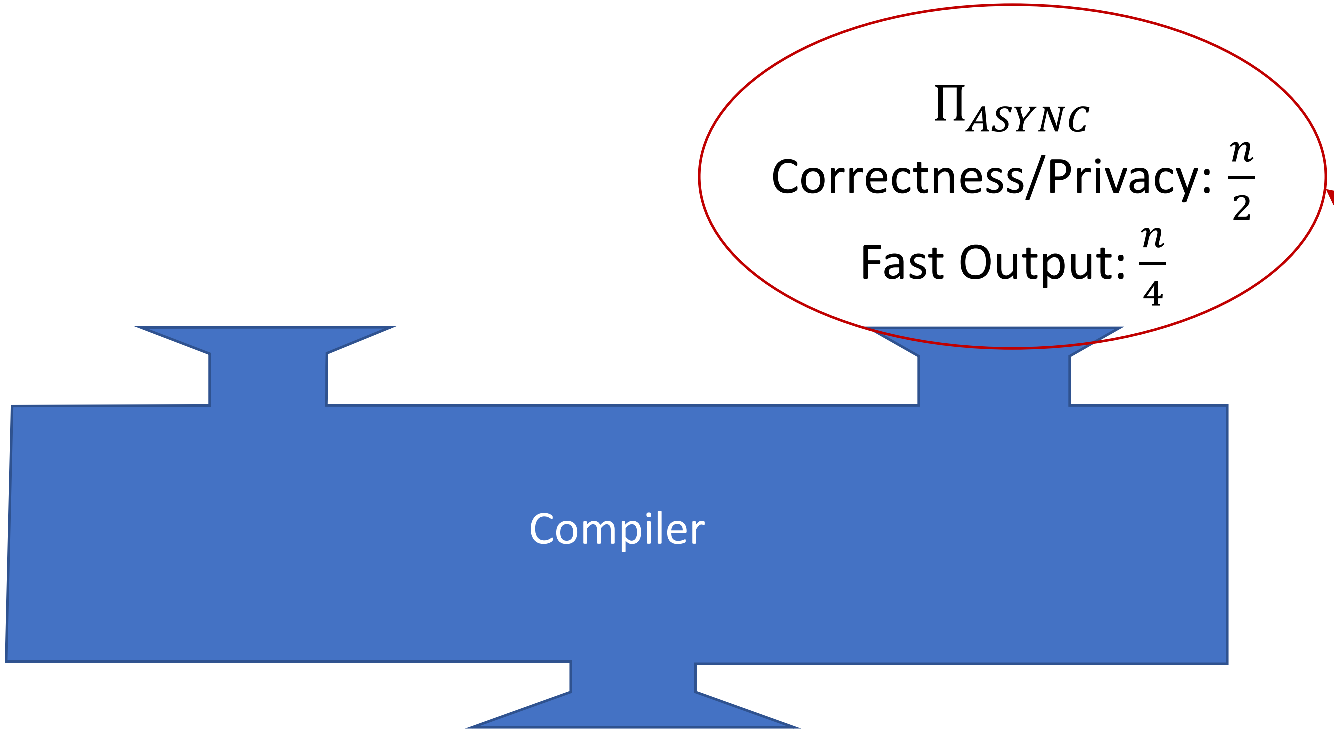
Modify the protocol
by [Coh16], using BA
with increased validity and
consistency, but lower
termination [LosMor17]

Road map



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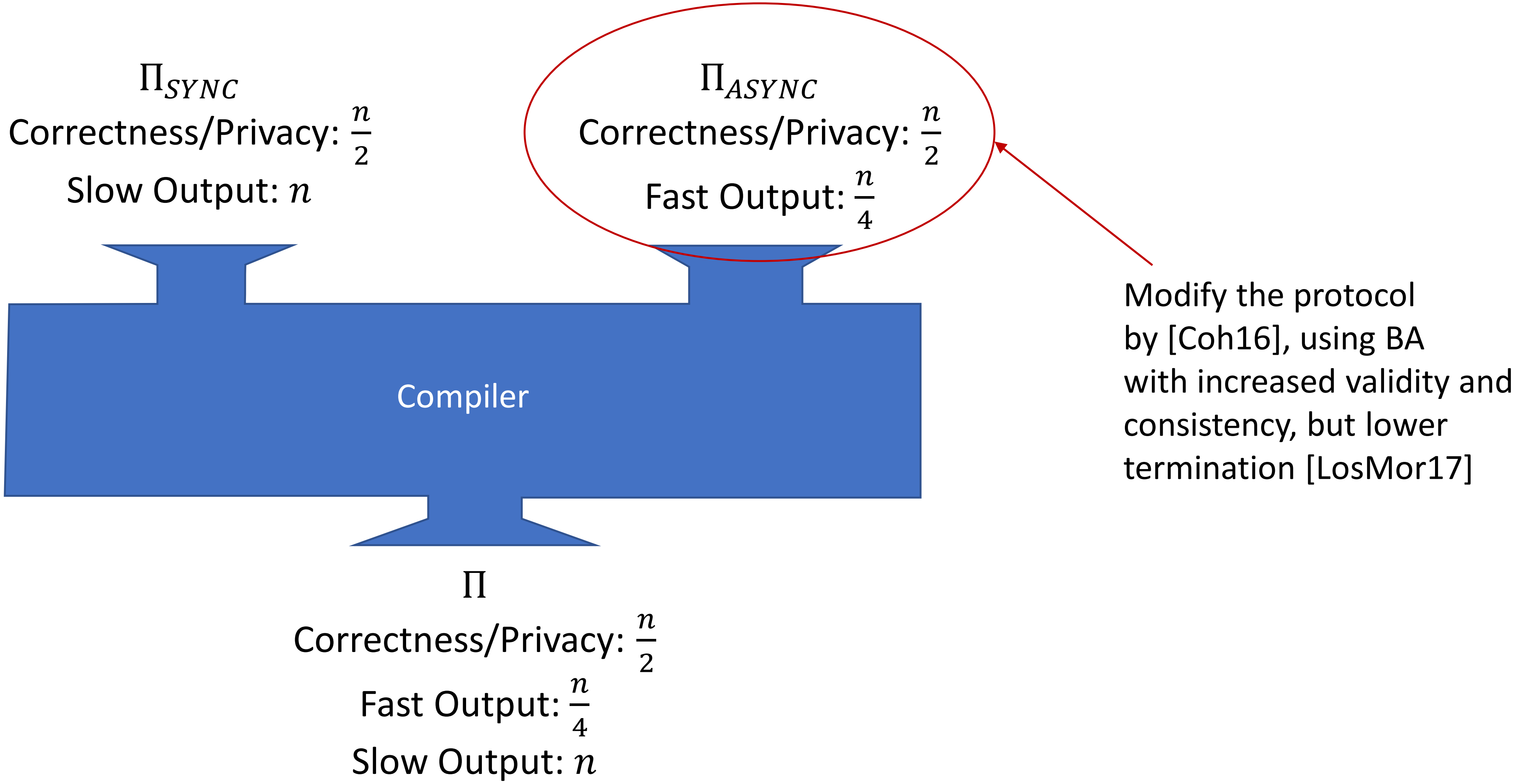
Π_{SYNC}
Correctness/Privacy: $\frac{n}{2}$
Slow Output: n
Π_{ASYNC}
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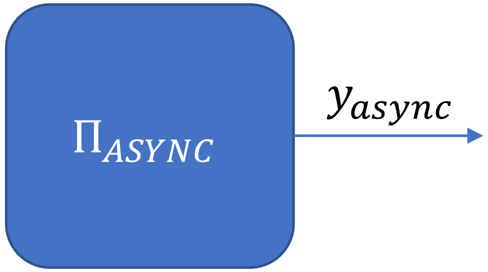
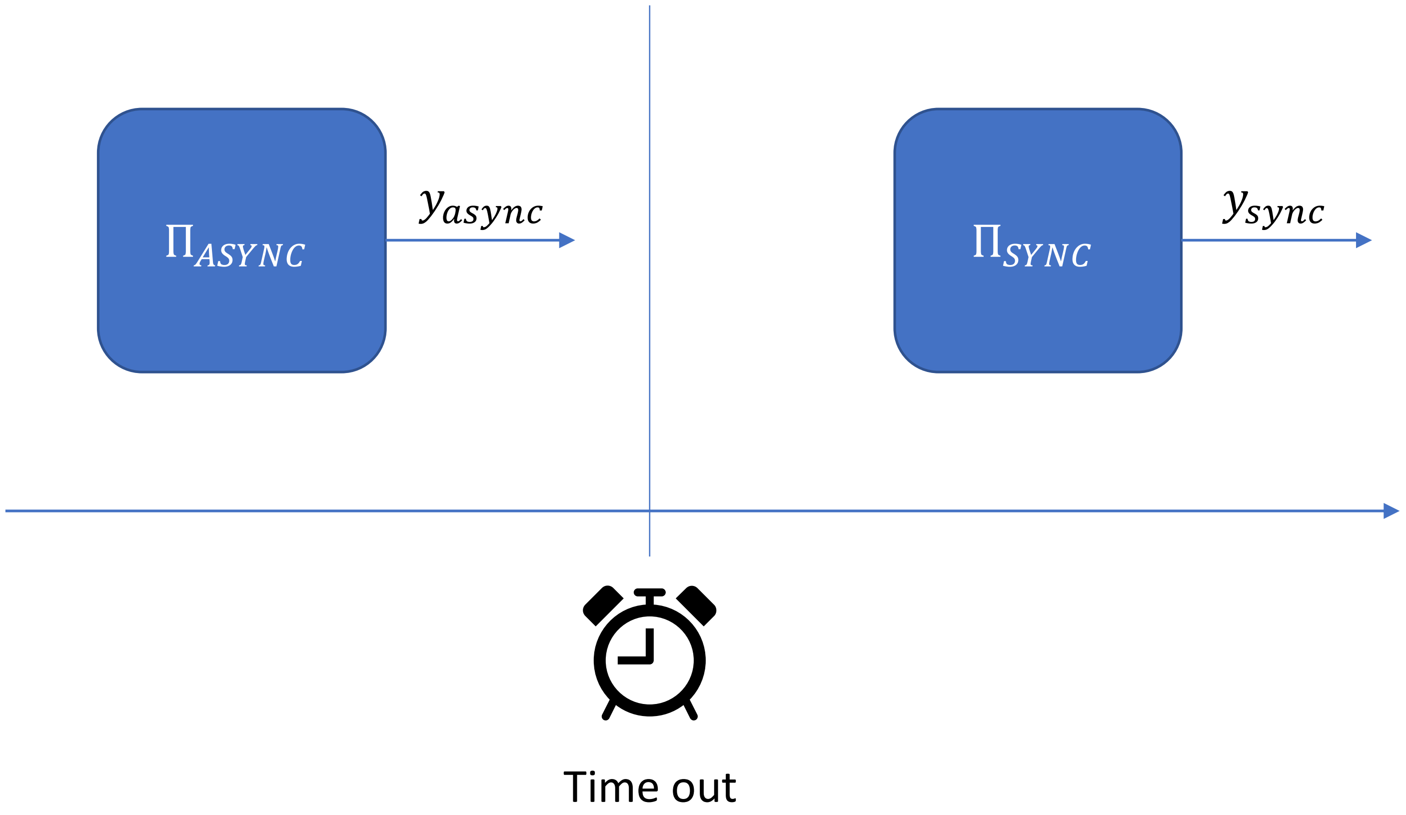
Compiler
Modify the protocol by [Coh16], using BA with increased validity and consistency, but lower termination [LosMor17]
Π
Correctness/Privacy: $\frac{n}{2}$
Fast Output: $\frac{n}{4}$
Slow Output: n

Compiler



Compiler

Use an asynchronous protocol and a synchronous protocol as fall back*



*[PasShi17,LosMor17,GPS19]

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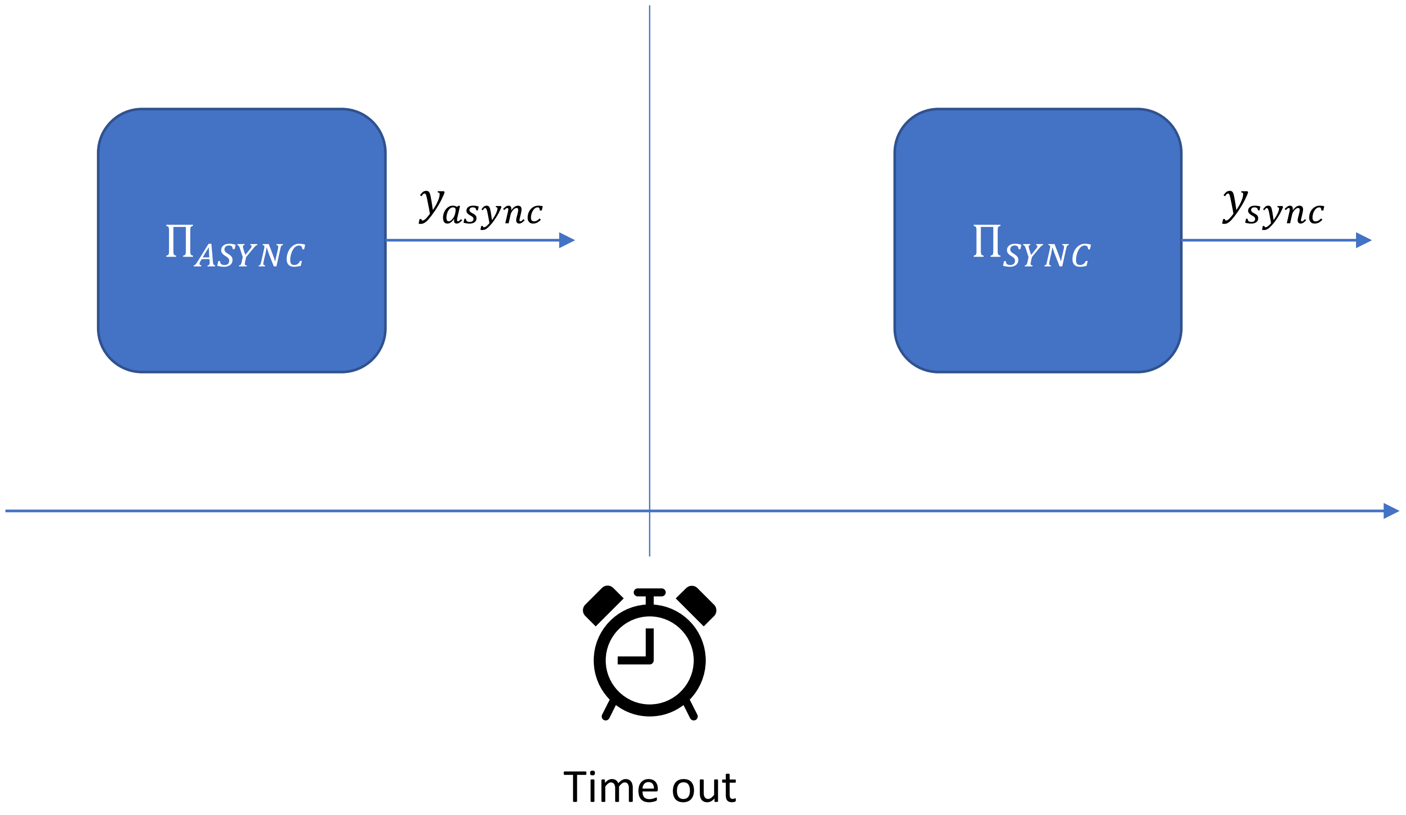
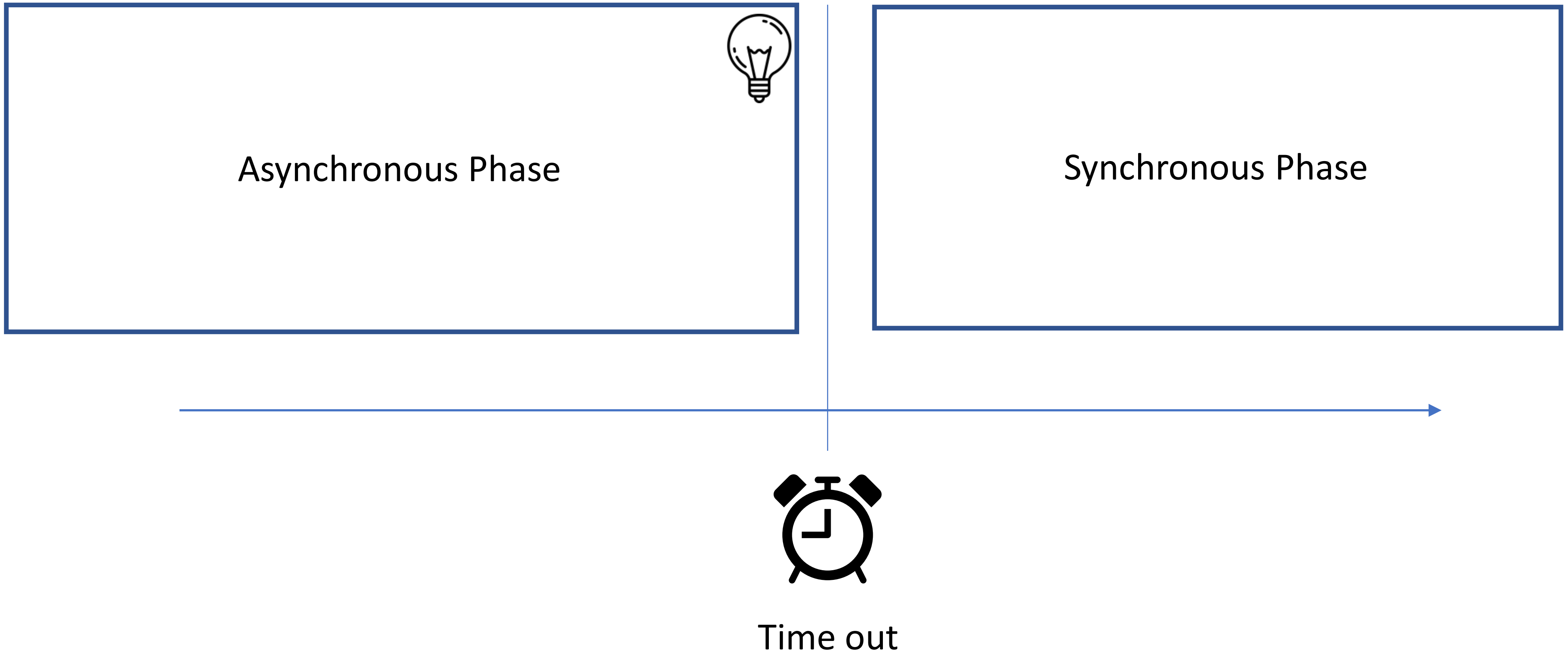


Problem:
Adversary can learn two outputs, y_{async} and y_{sync}!

*[PasShi17,LosMor17,GPS19]

Compiler



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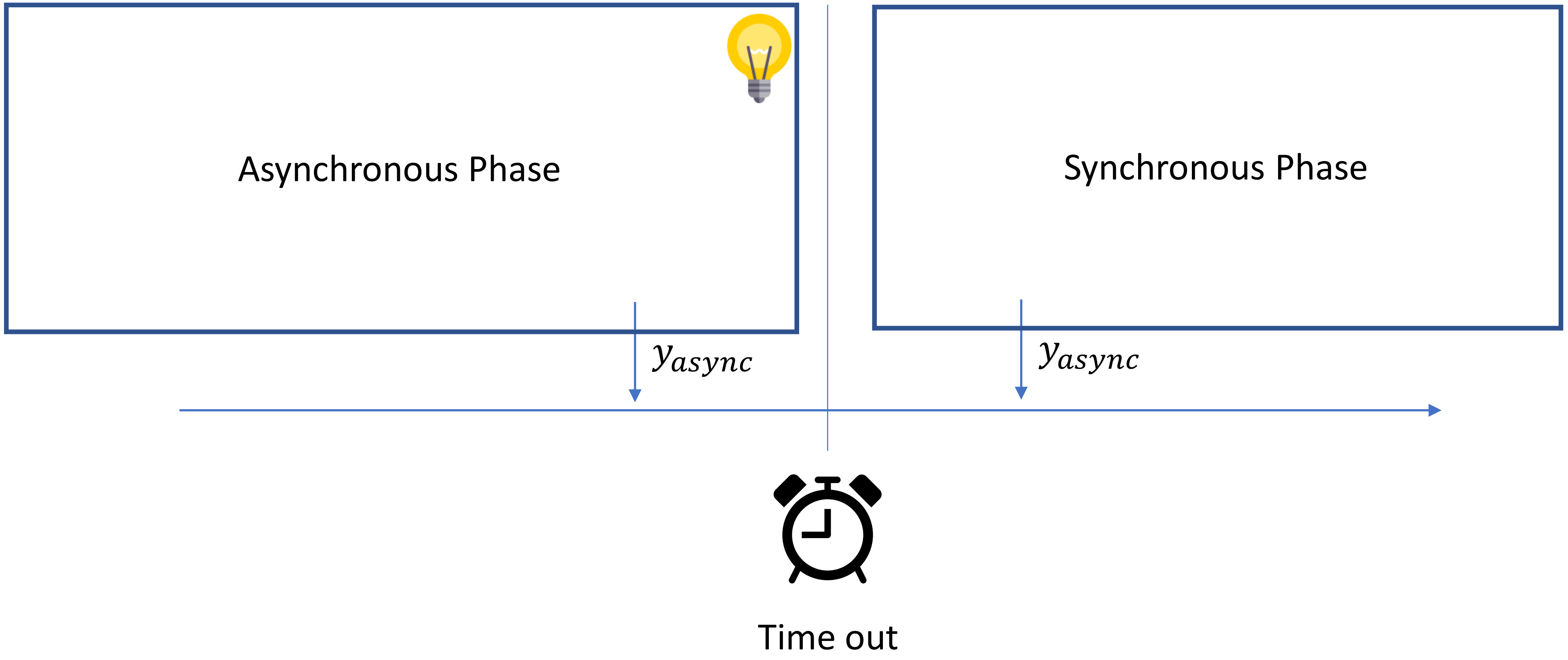
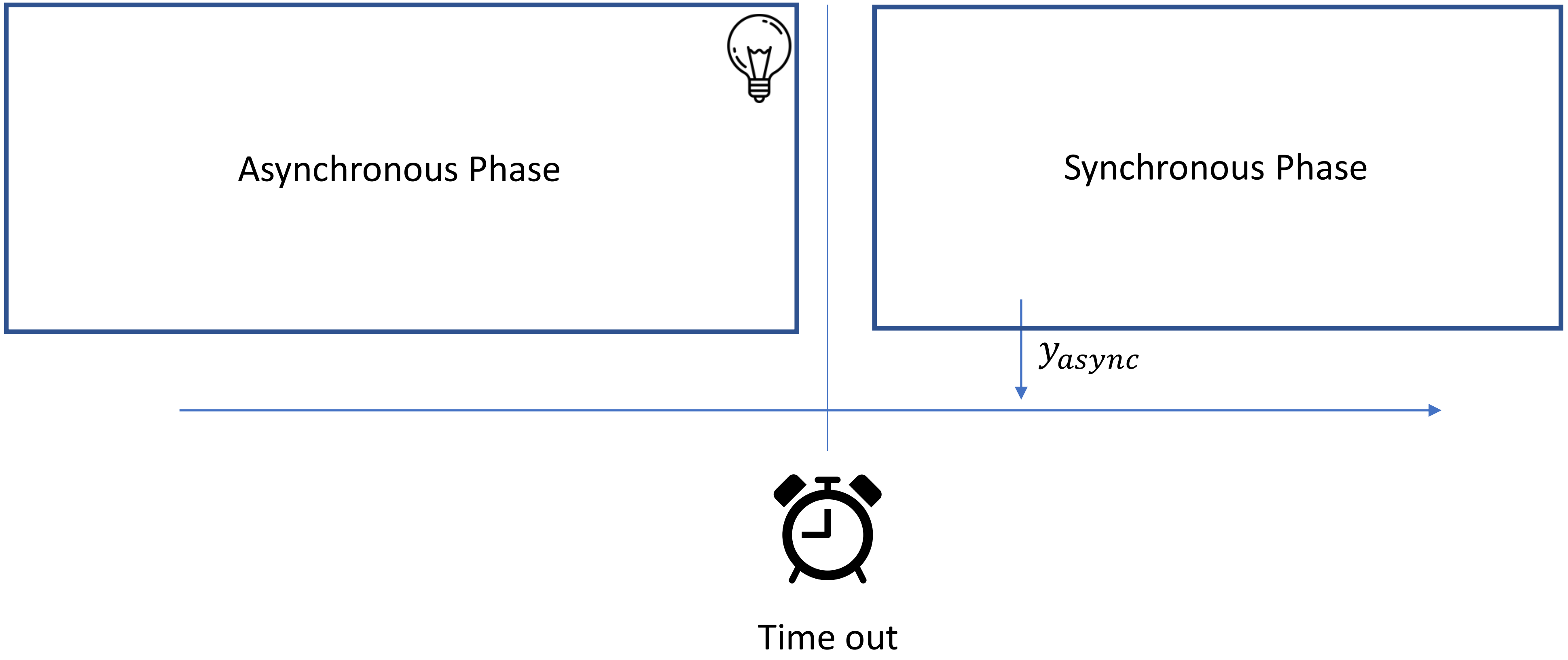

Asynchronous Phase
Synchronous Phase
y_{async}
y_{async}
Time out

Compiler



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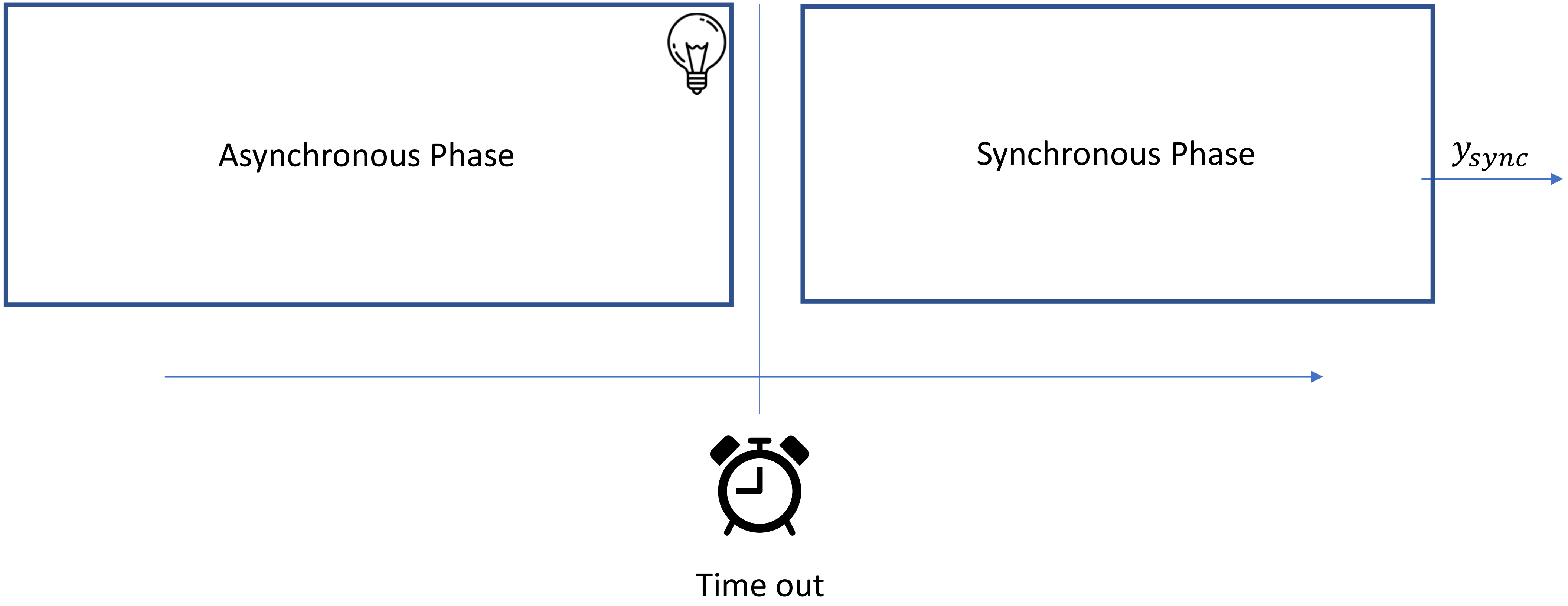

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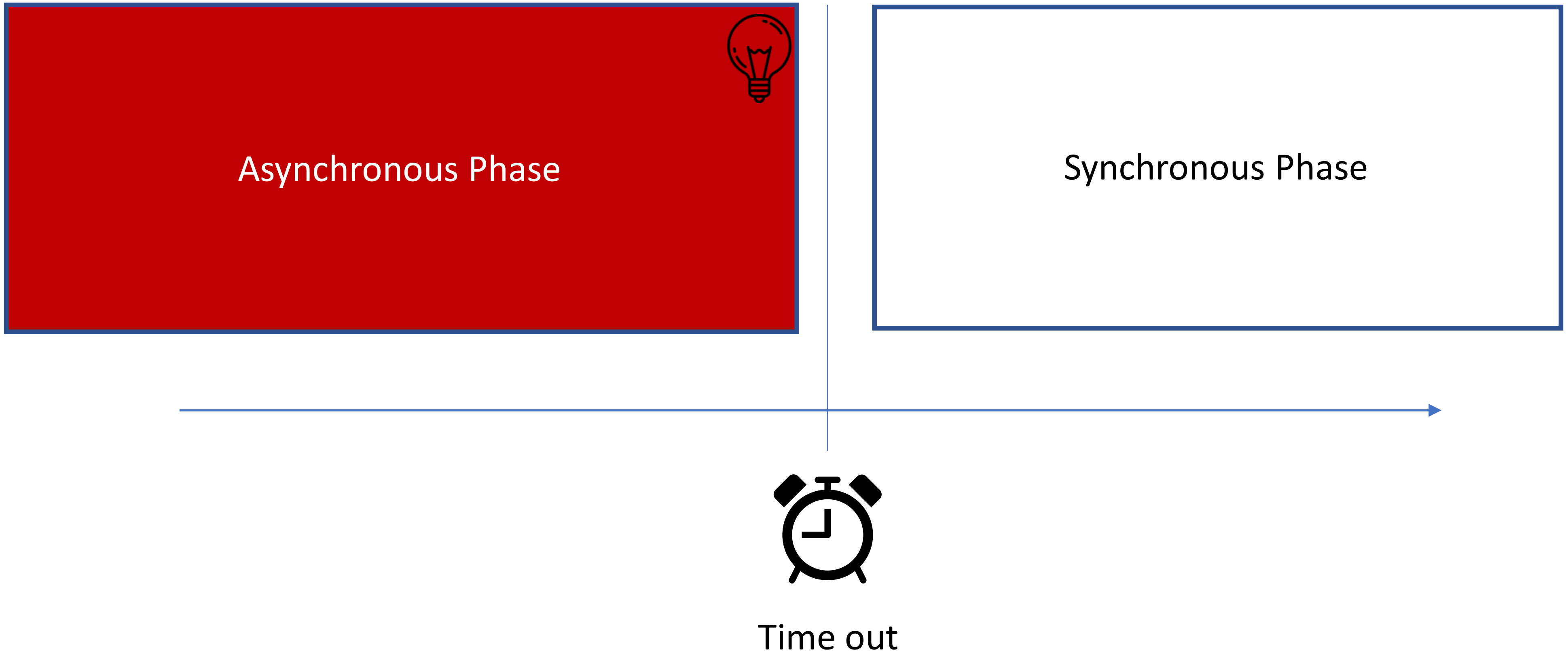
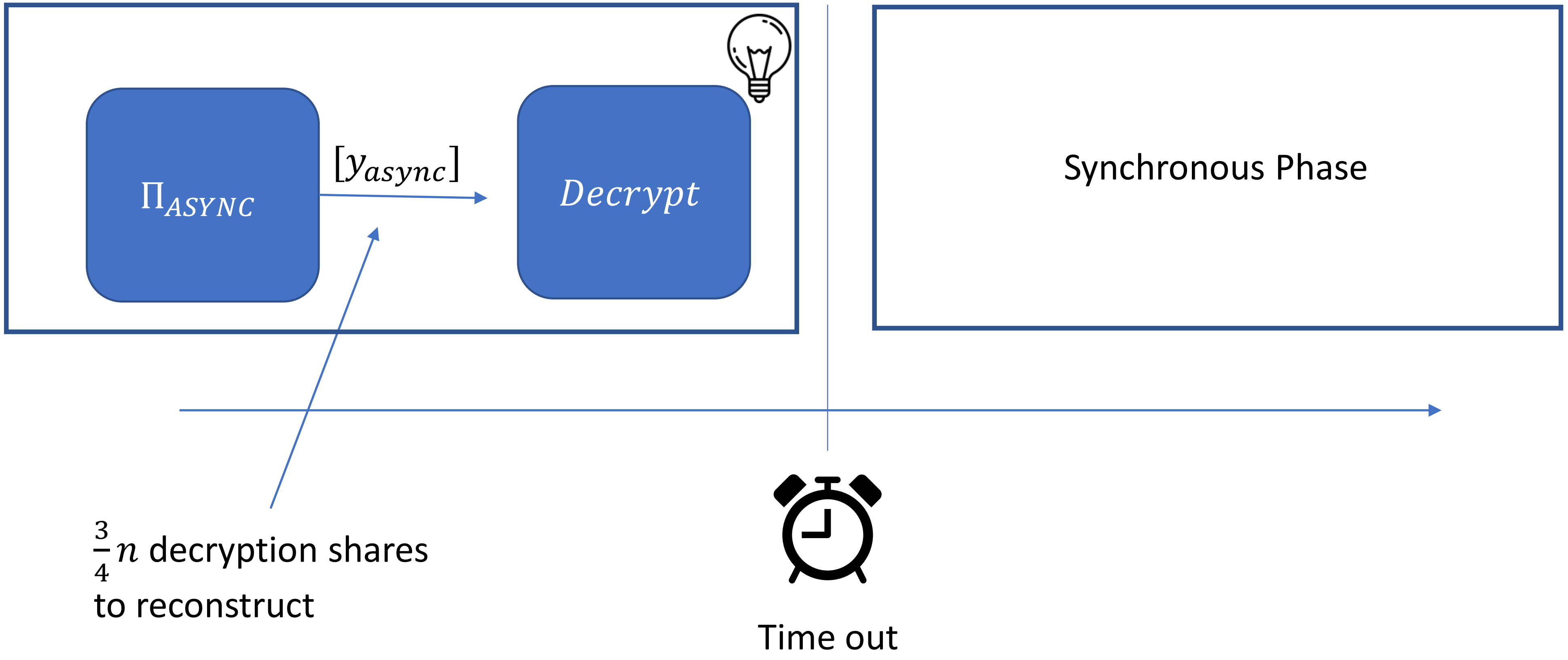


Compiler

Setup: Threshold encryption and digital signatures



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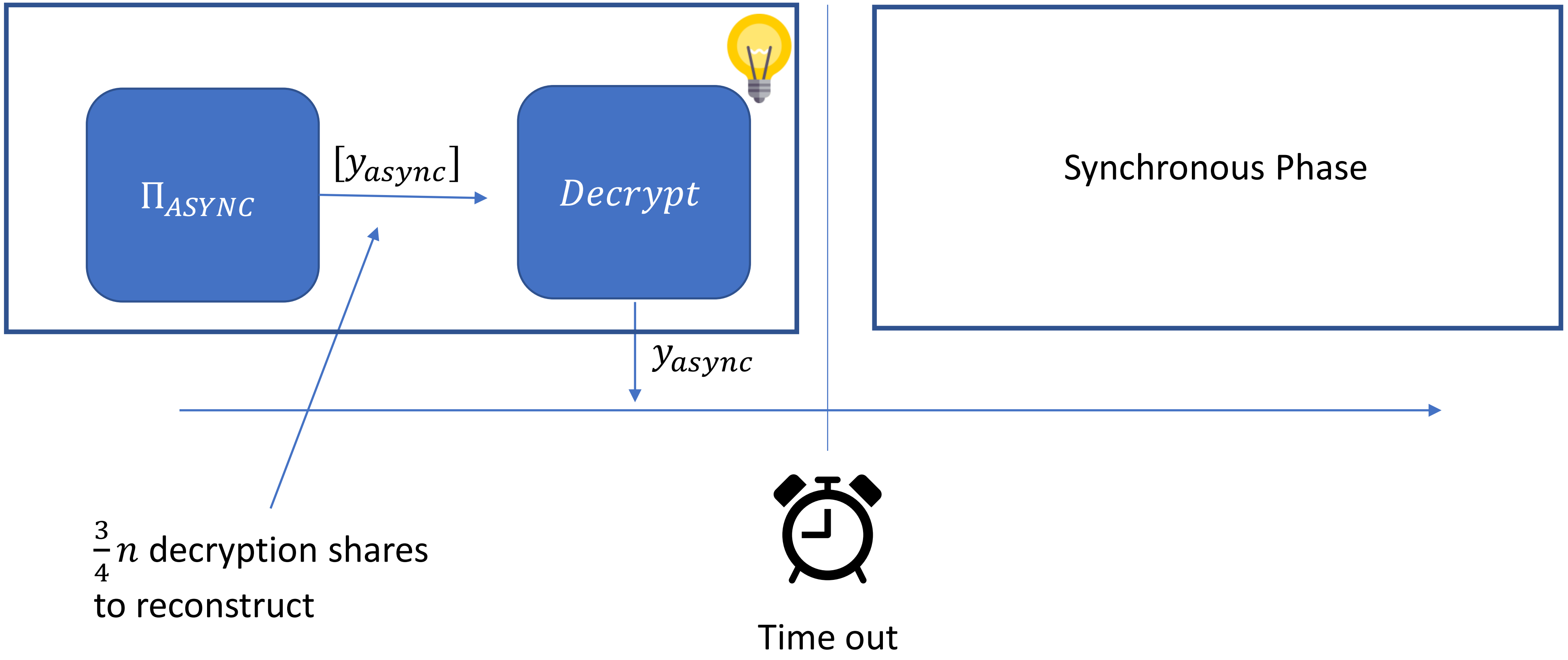

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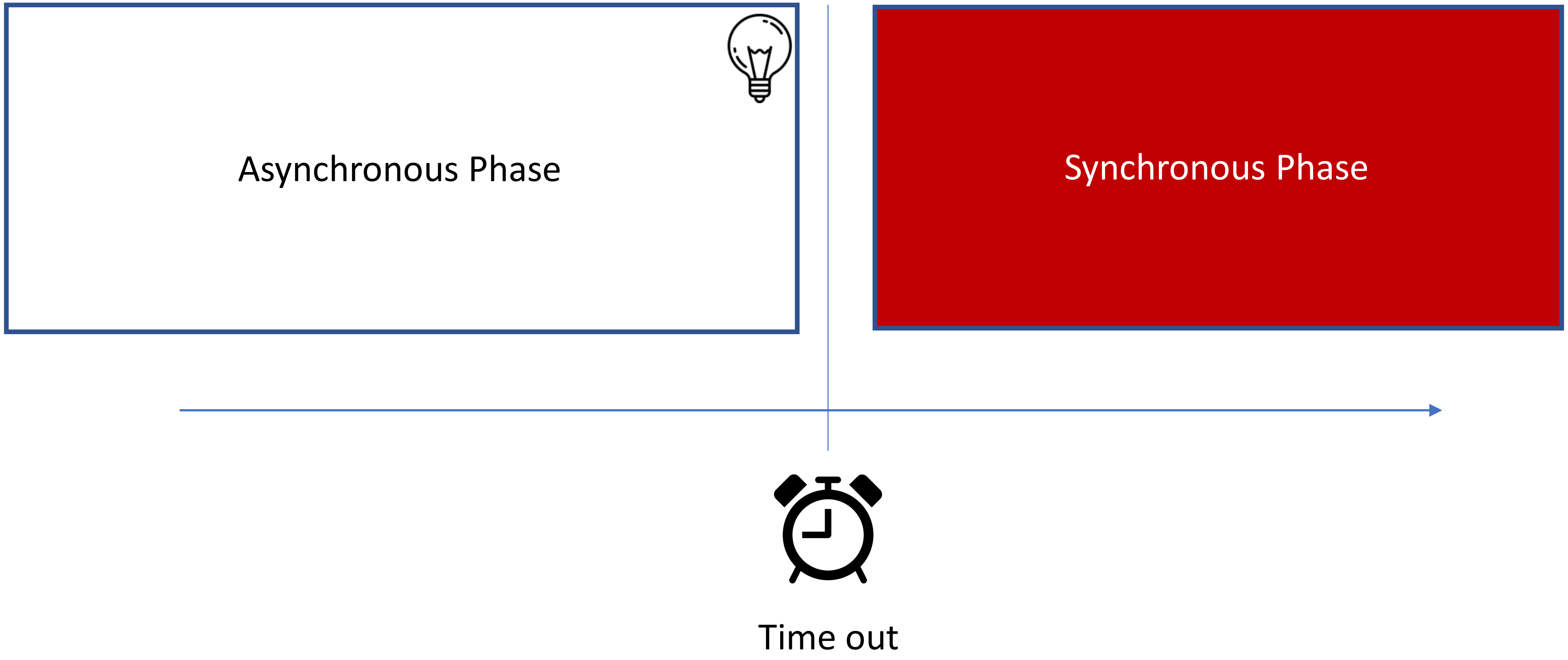

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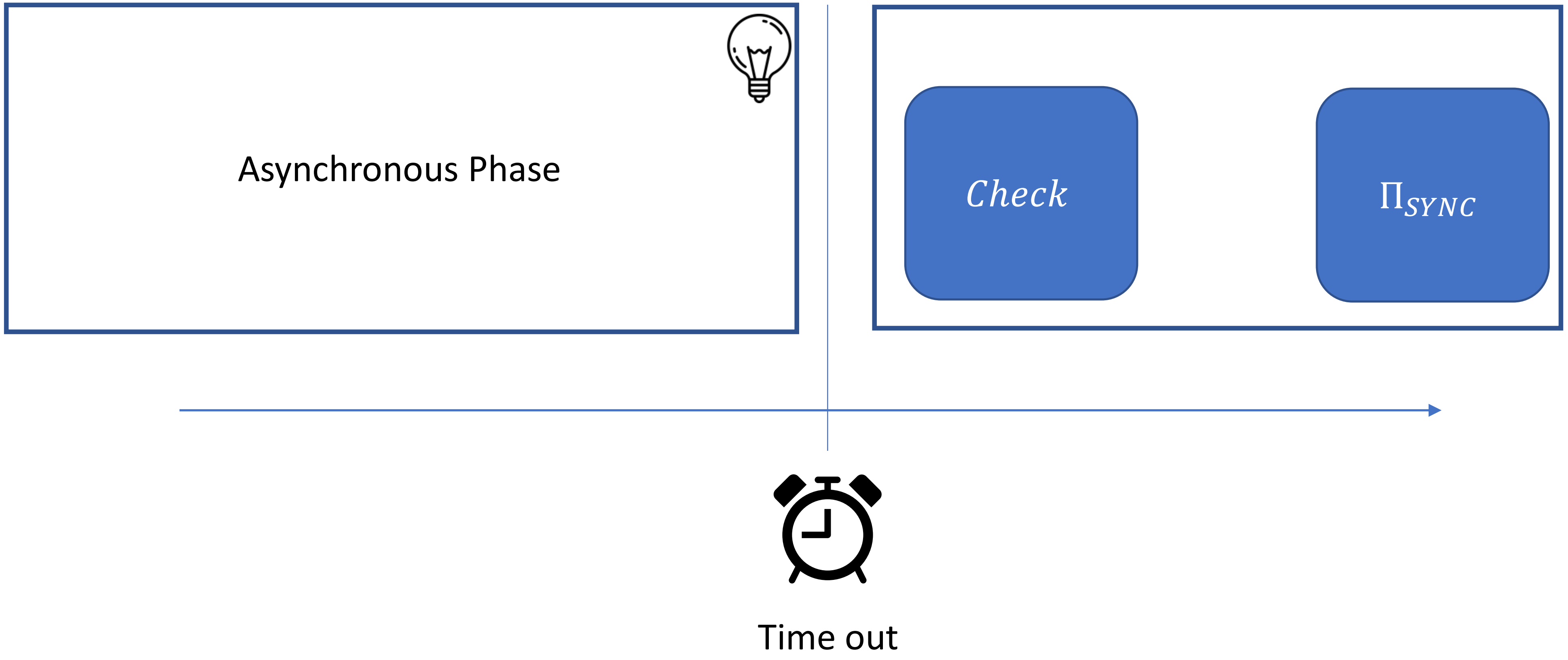

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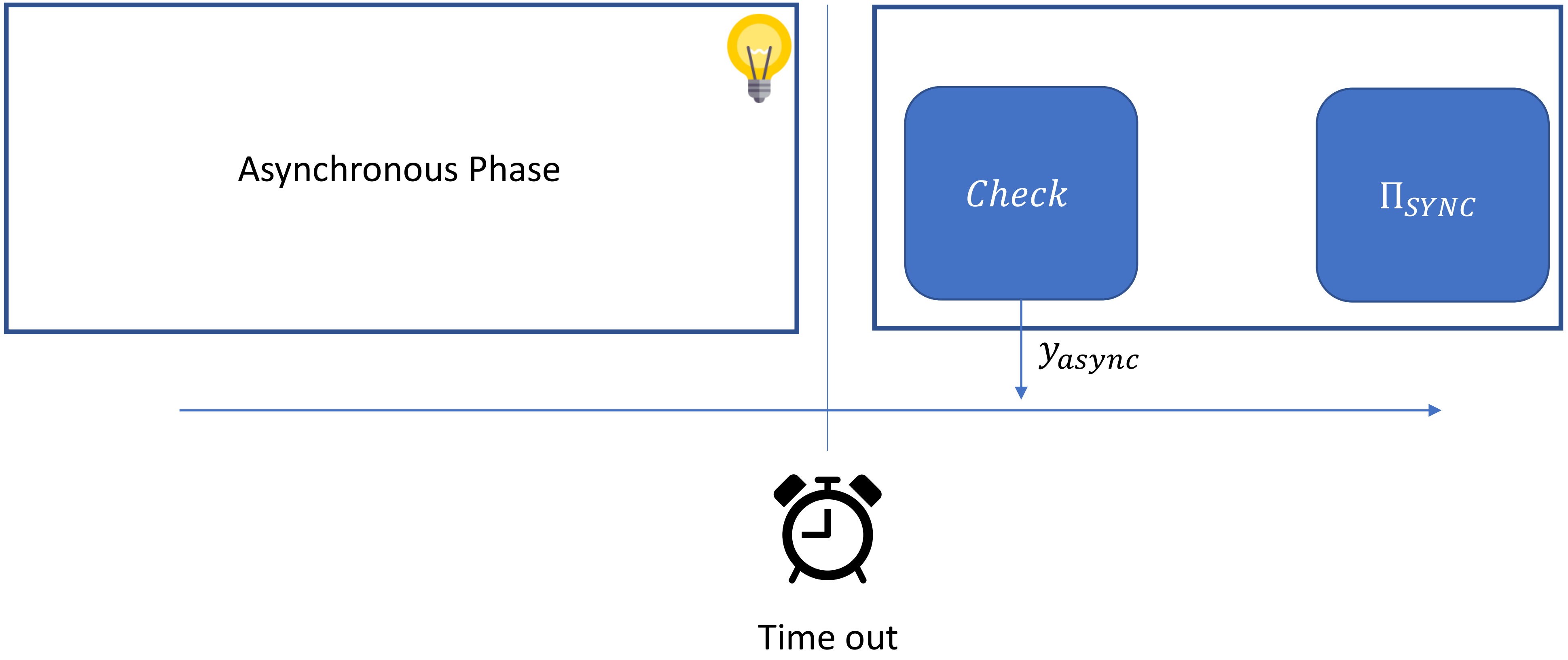

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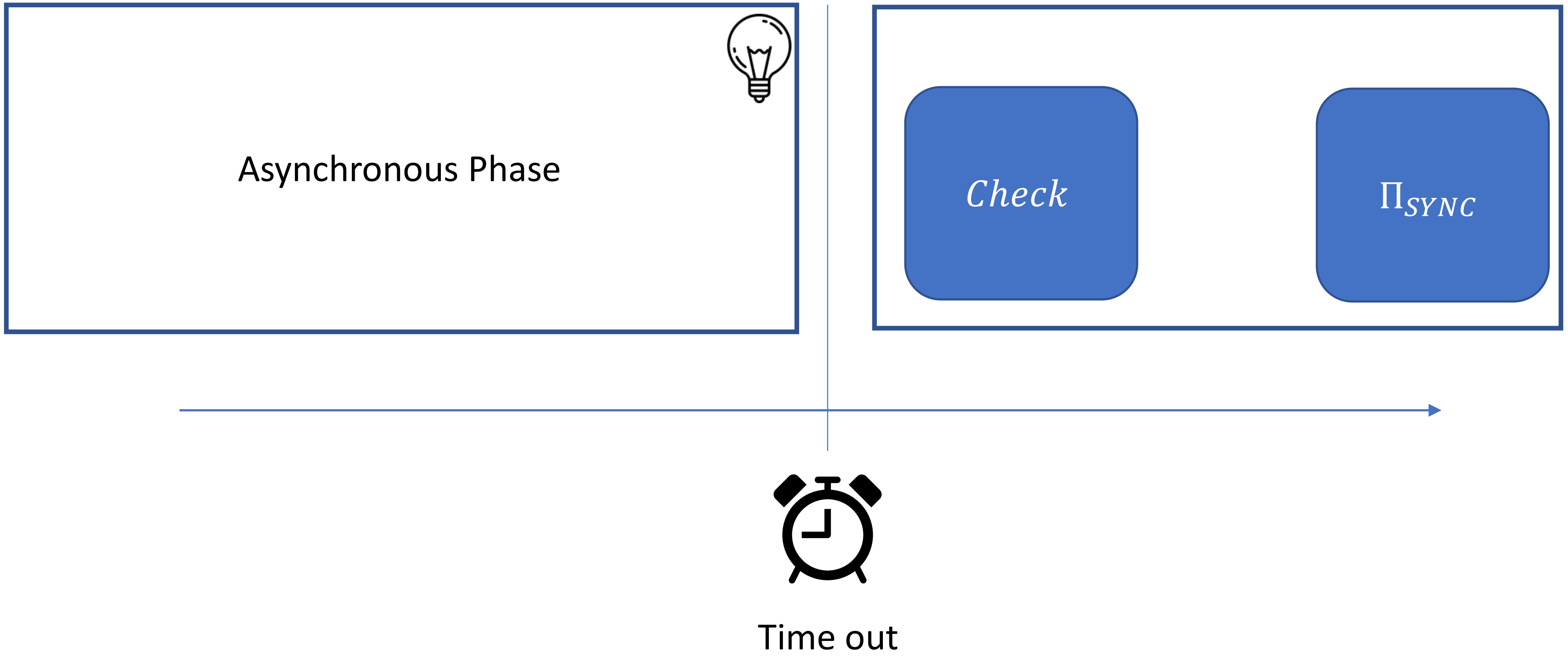

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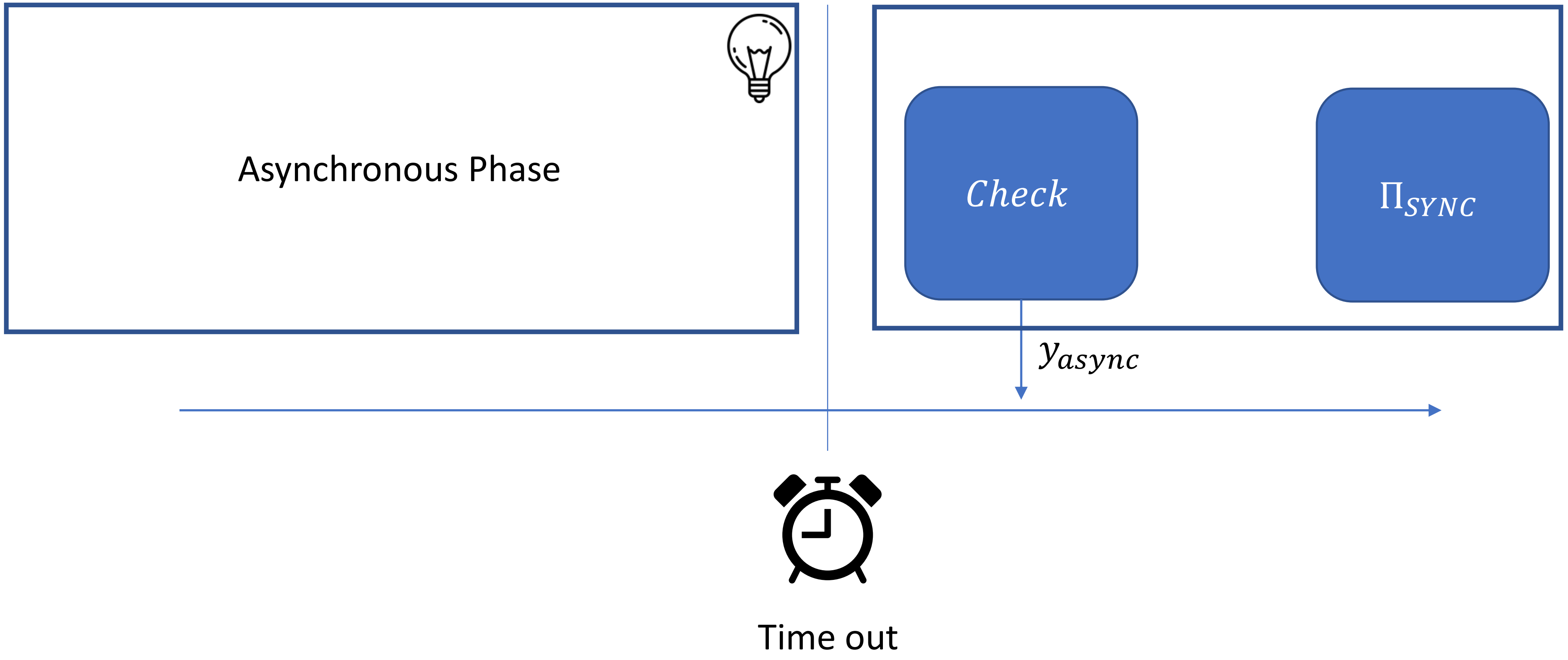

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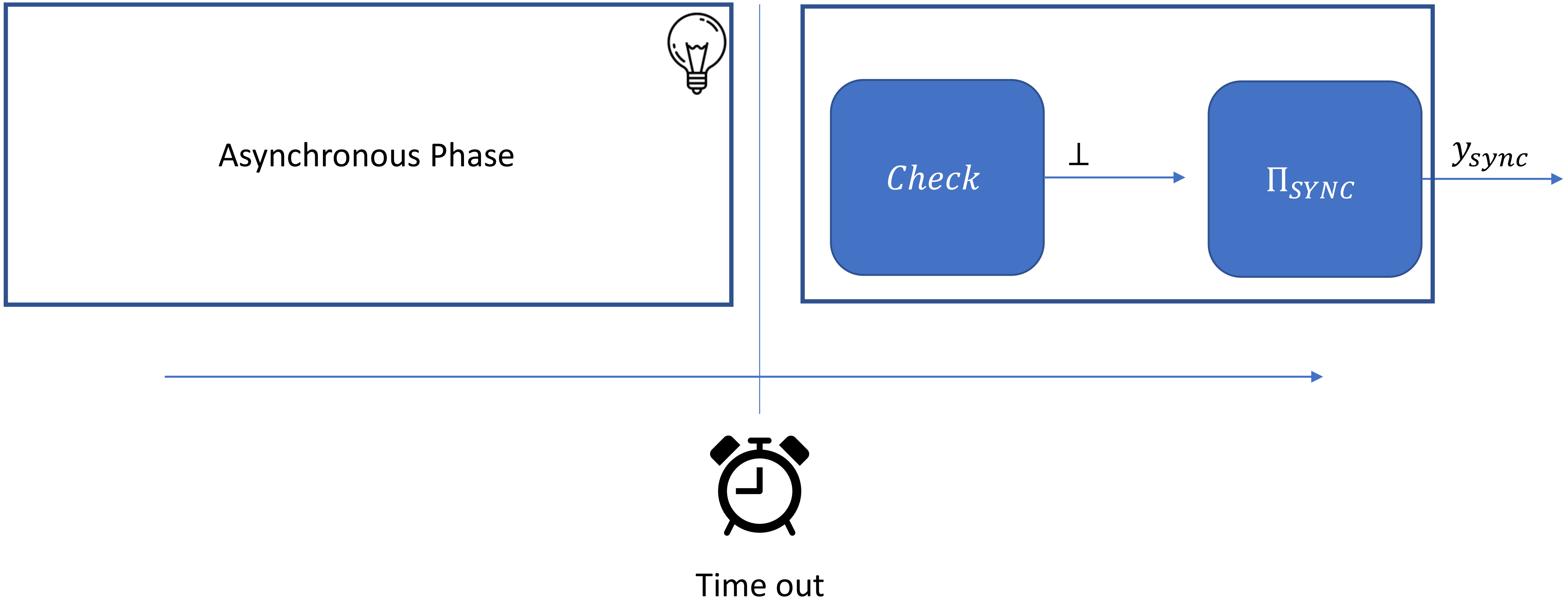

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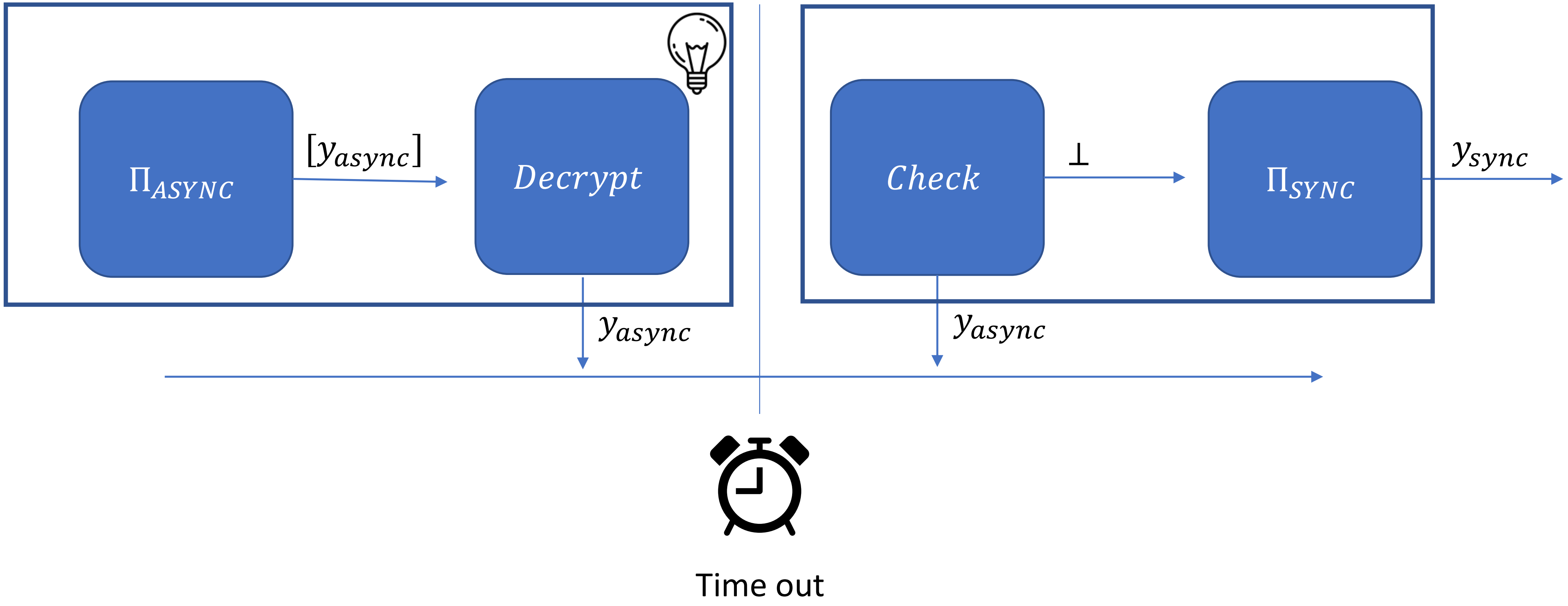

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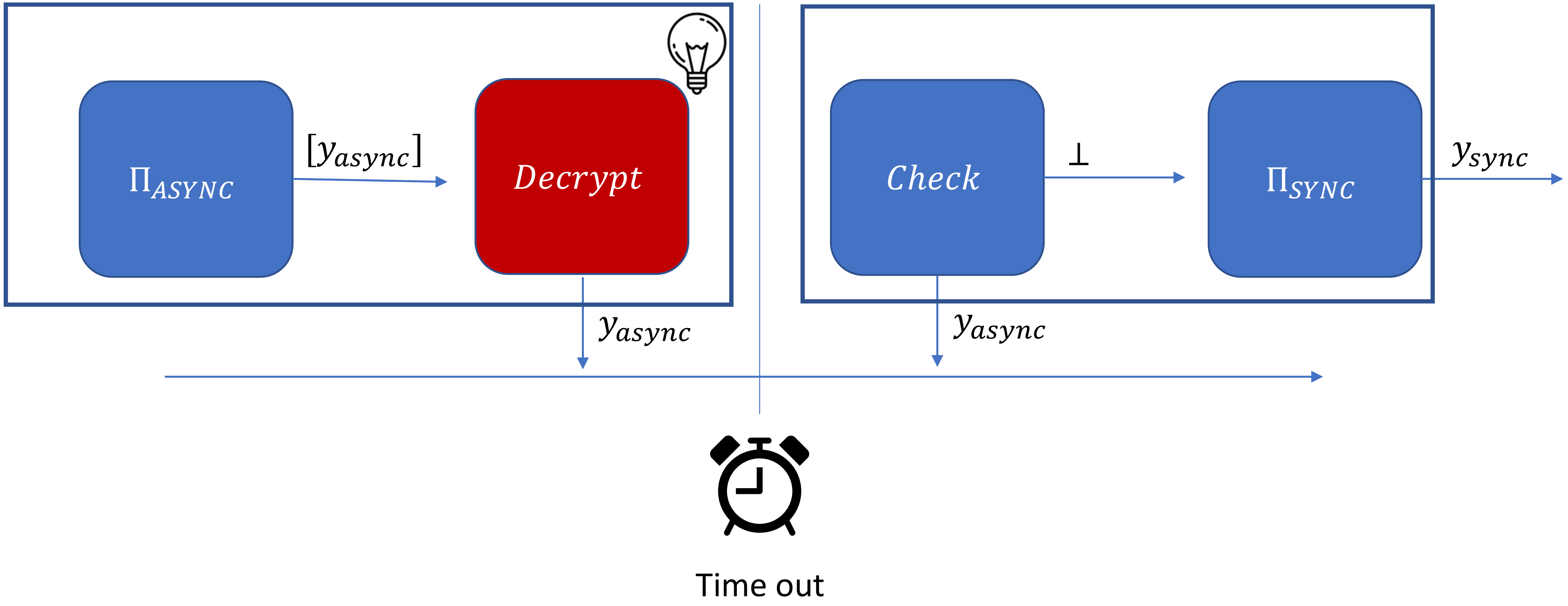

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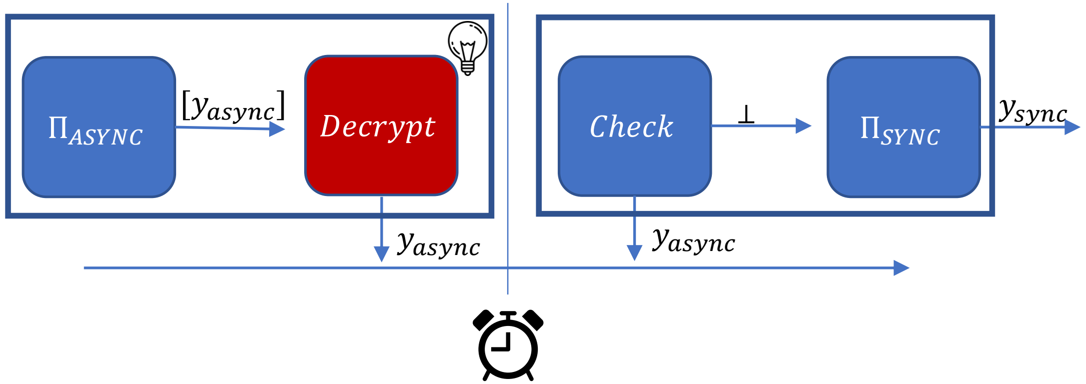
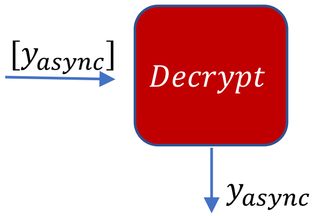
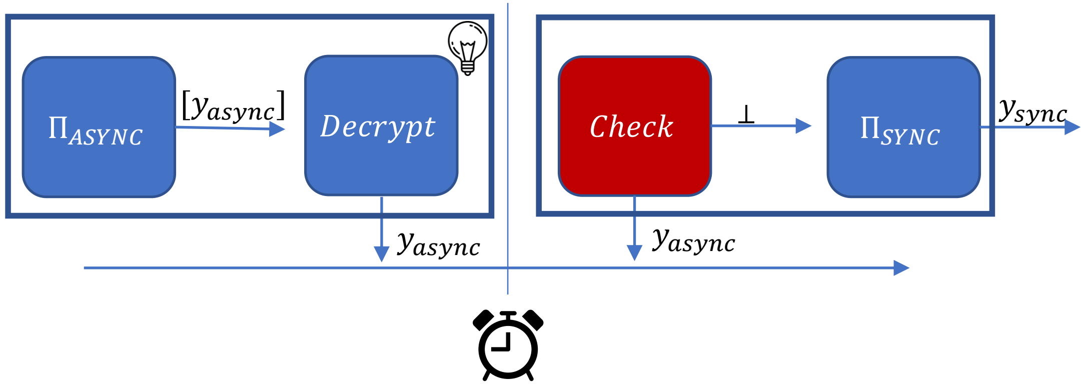
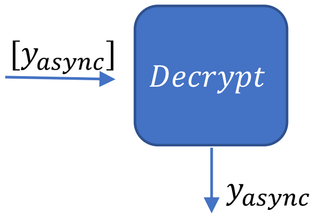




1. Sign $[y_{async}]$ and send it to each P_j
2. Once collected list L of $\frac{3}{4}n$ signatures on c, send decryption share $d_i = Dec_{dki}(c)$
3. Once received $\frac{3}{4}n$ shares, reconstruct the output y_{async}

Compiler





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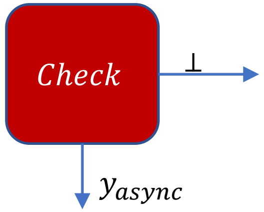
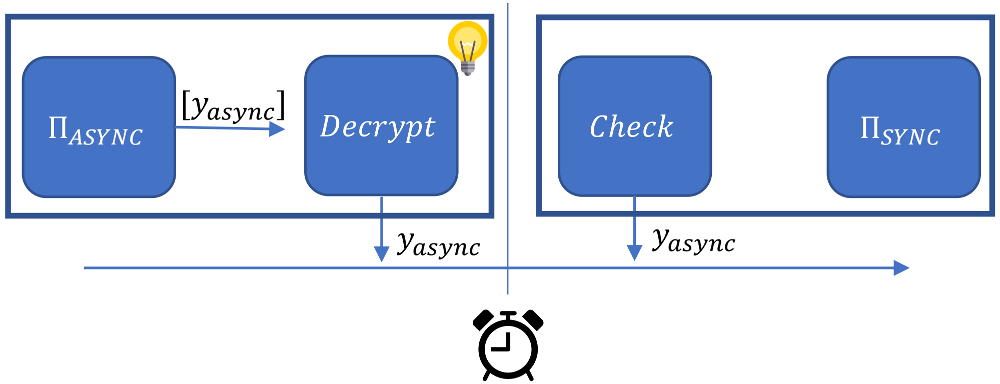


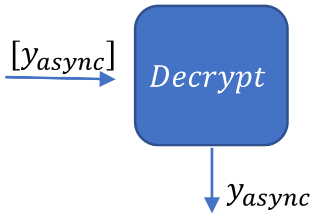
⏰ : Synchronously BC (L,c), if received from Step 2.

After BC: If any (L,c) received, send d_i and reconstruct y_{async}

Otherwise, output ⊥

Compiler





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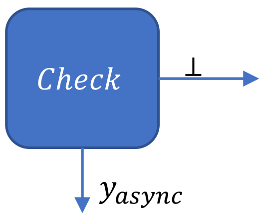

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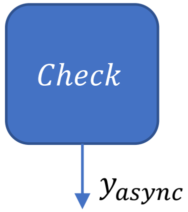
⟹ ∃honest P_i collected list L ⟹



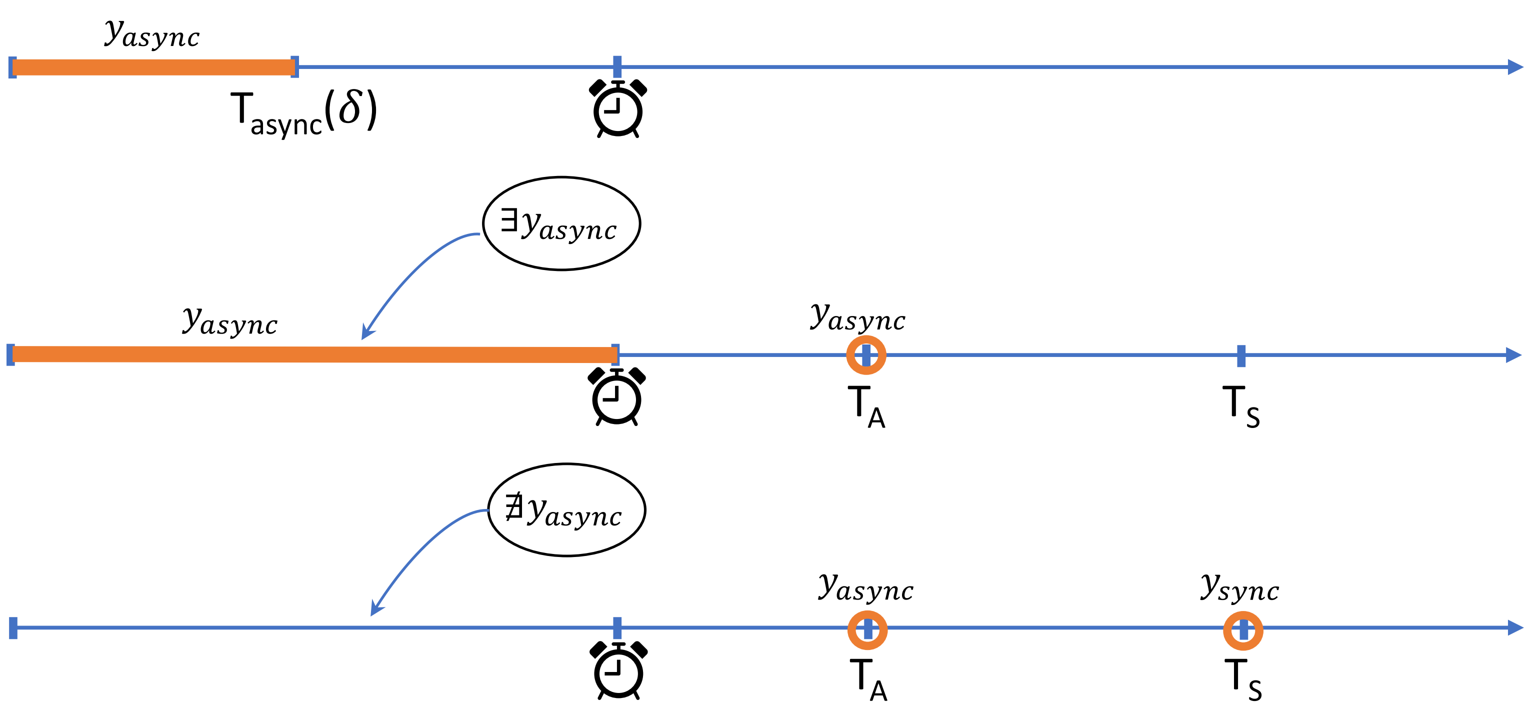
Guarantees

Correctness and Privacy
$^{n}/_{2}$

Output guarantees depend on ⏰

Fast network & $t \le \frac{n}{4}$

Slow network or $t > \frac{n}{4}$



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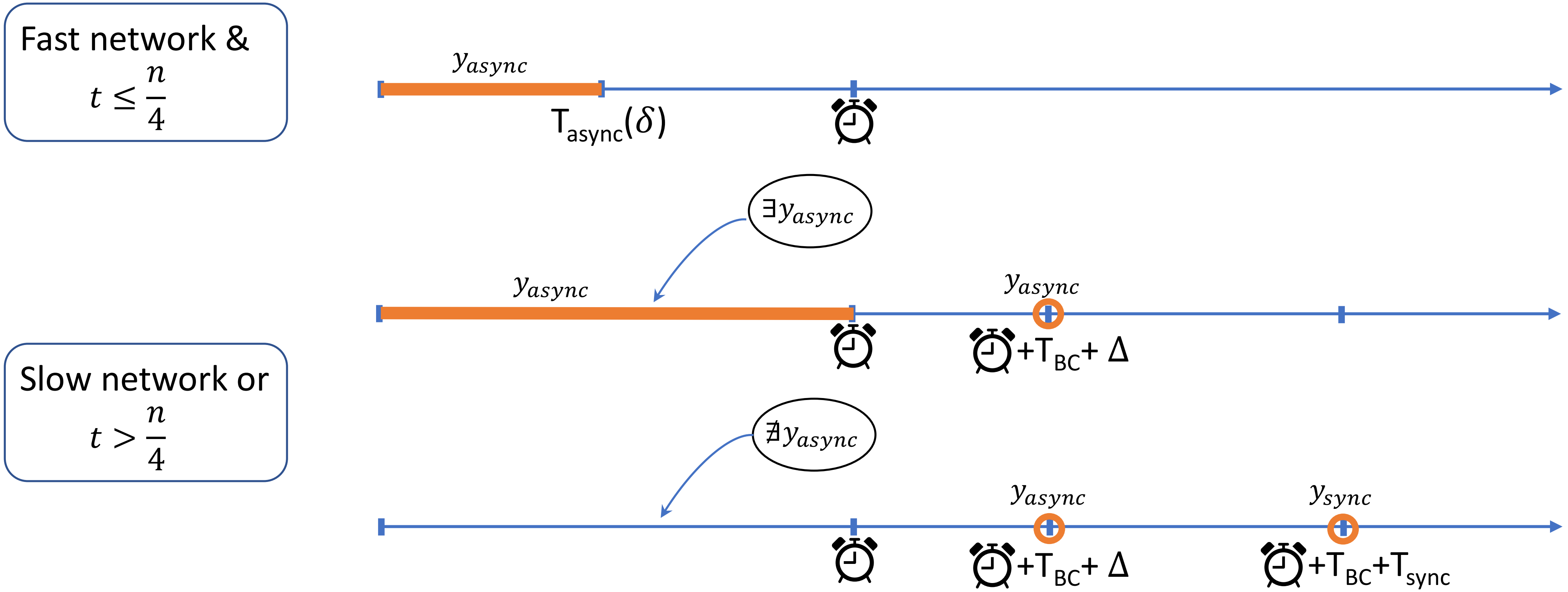

References and Credits

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References:

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Credits:

Icons: https://www.flaticon.com/