Always Have a Backup Plan: Fully Secure Synchronous MPC with Asynchronous Fallback

Erica Blum

U. Maryland

Chen-Da Liu-Zhang

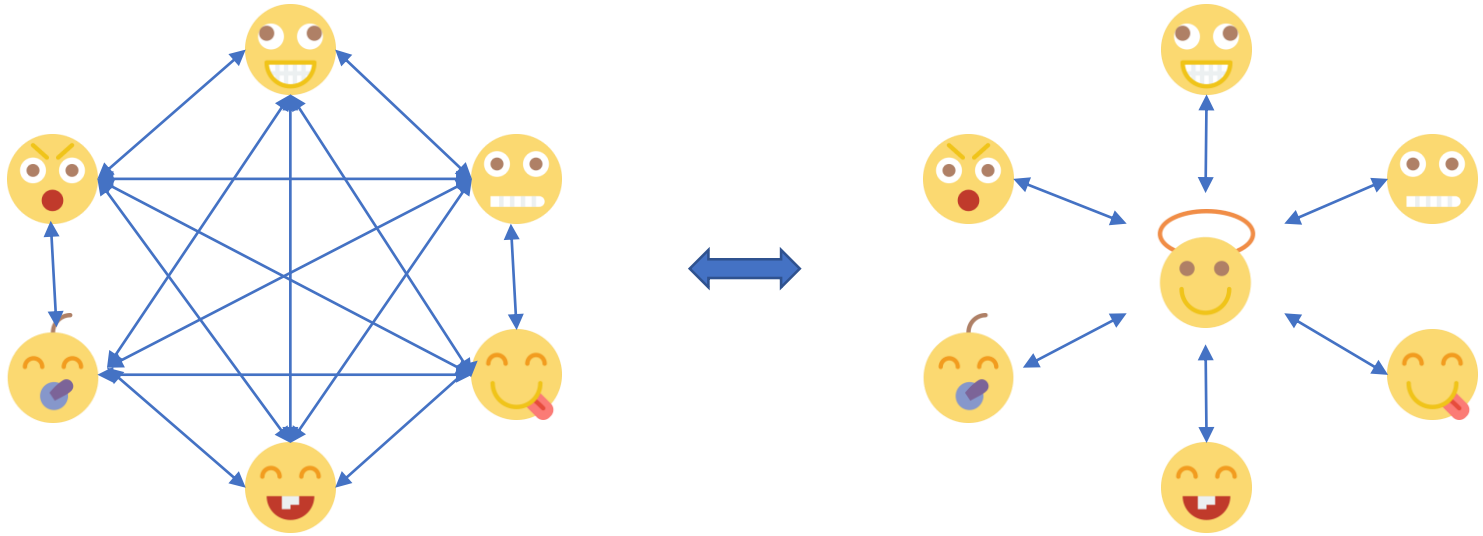
ETH Zurich

Julian Loss

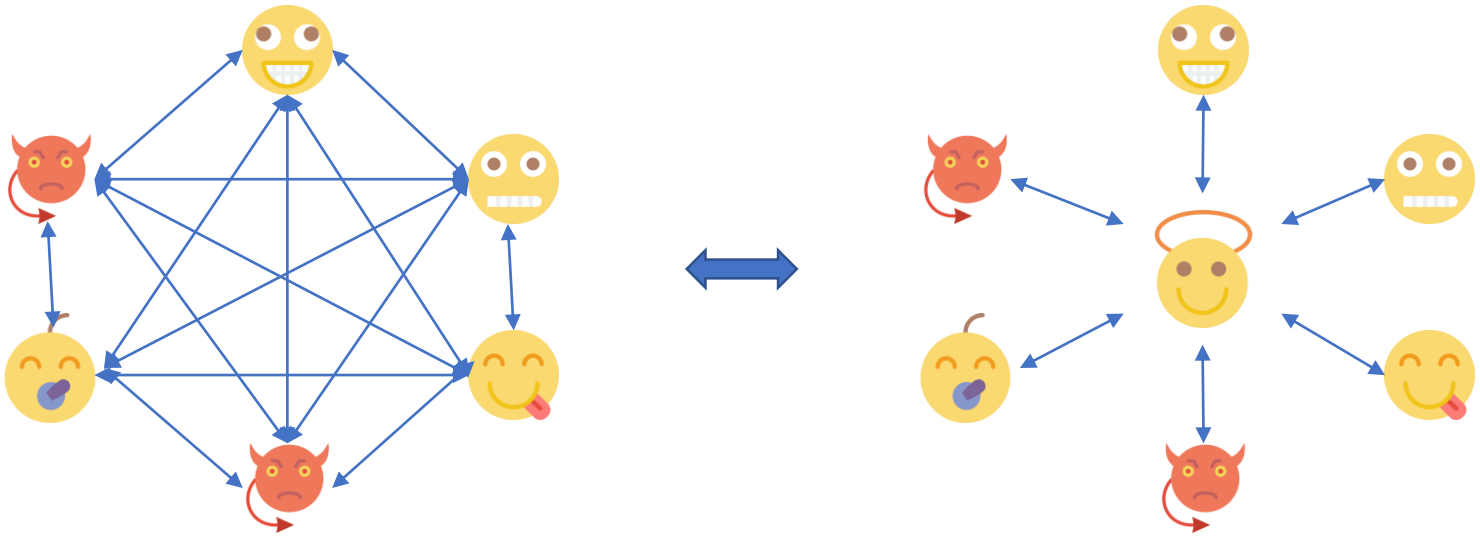
U. Maryland

CRYPTO 2020

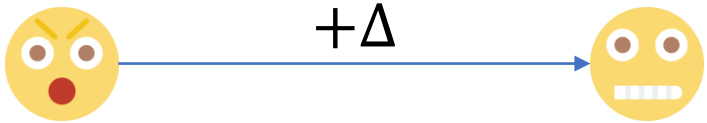
Multiparty Computation



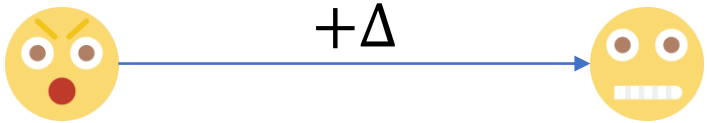
Multiparty Computation



Synchronous

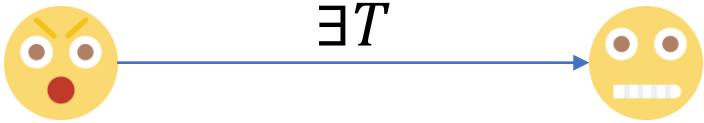


Synchronous



Asynchronous

-



Synchronous

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

Input completeness

$f(x_1, \ldots, x_n)$

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Asynchronous

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

Up to t inputs are ignored

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Asynchronous

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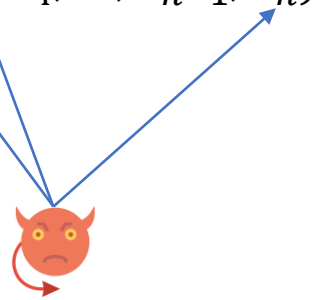
$f(x_1, x_2, x_3, x_4, \dots, x_{n-1}, x_n)$



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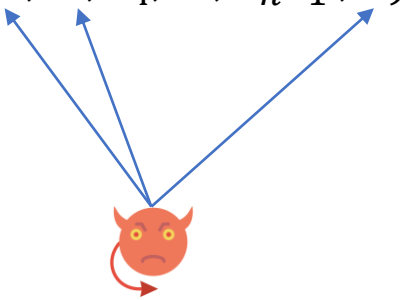
$f(x_1, \perp, \perp, x_4, \ldots, x_{n-1}, \perp)$



Is there an MPC that achieves guarantees in both regimes?

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Synchronous

$^{n}/_{3} \leq t_s < {}^{n}/_{2}$

Input completeness

Asynchronous

$t_a < {}^{n}/_{3}$

Up to L inputs are ignored

Is there an MPC that achieves guarantees in both regimes?

Synchronous

$n/3 \leq t_s < n/2$

Input completeness

Asynchronous

$t_a < n/3$

Up to L inputs are ignored

YES! If and only if $t_a + 2t_s < n$ and $L \geq t_s$

Related Work

[BKL19],[BKL20]: Trade-offs for Consensus primitives.

t_s-secure (resp. t_a) under a synchronous (resp. asynch.) network for any $t_a + 2t_s < n$

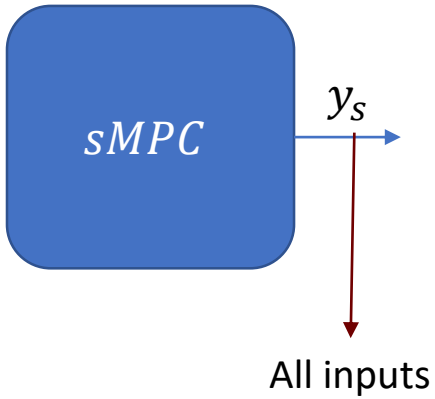
[HNP05]: Asynchronous MPC for $t < \frac{n}{3}$ with input completeness when the network is synchronous

Feasibility

Feasibility

Core Primitive

Synchronous



Feasibility

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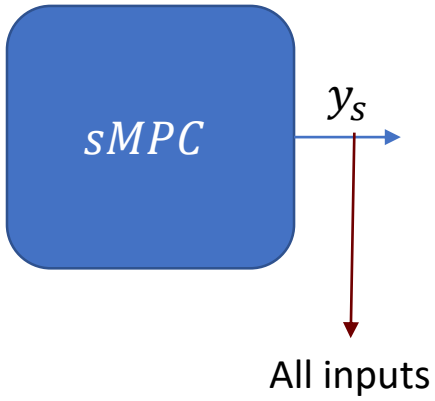
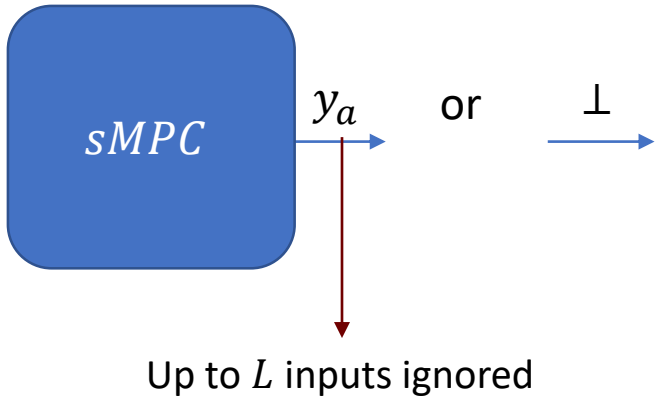
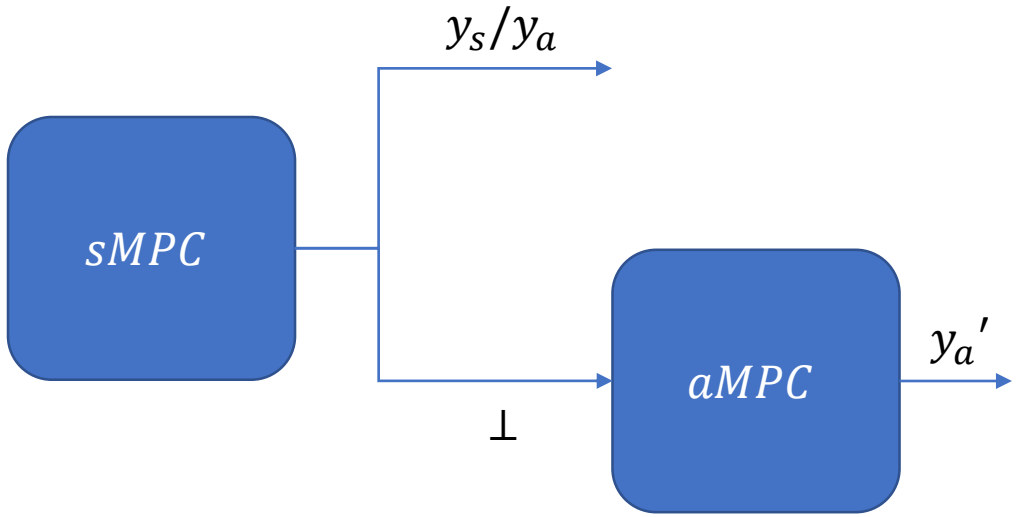


Asynchronous



Feasibility

Compiler



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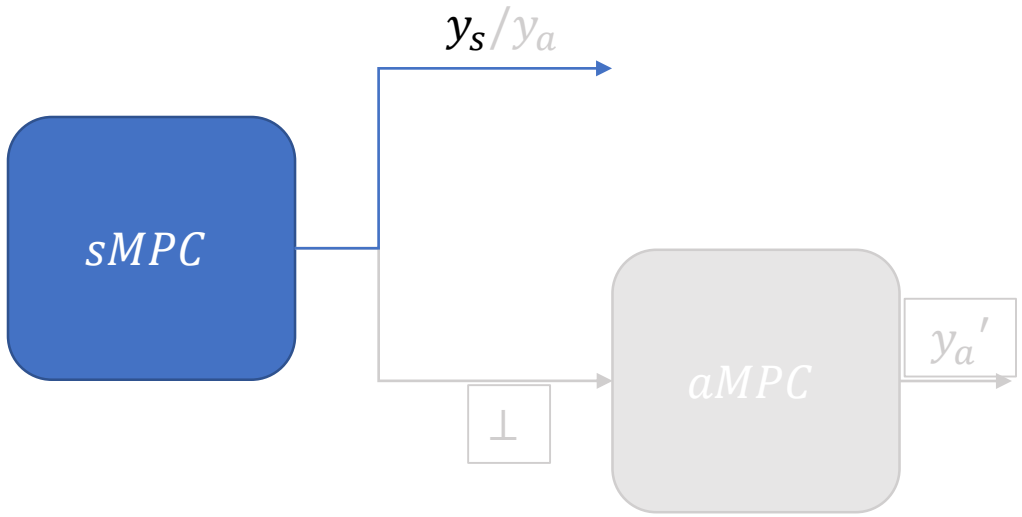

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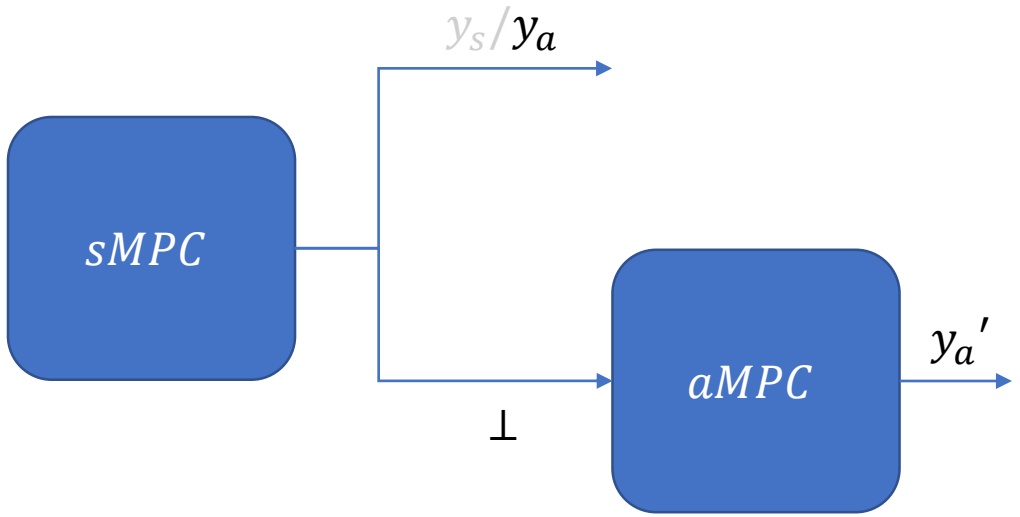
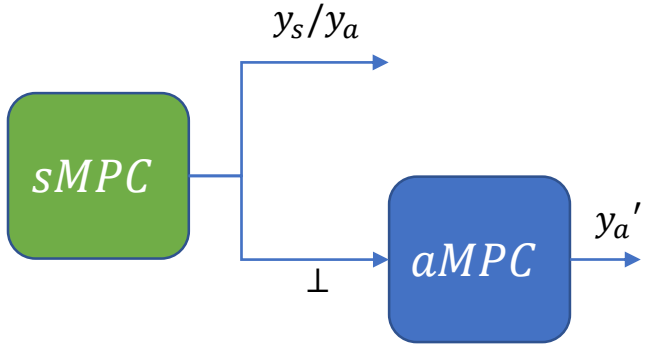


Feasibility

Threshold-Homomorphic Encryption



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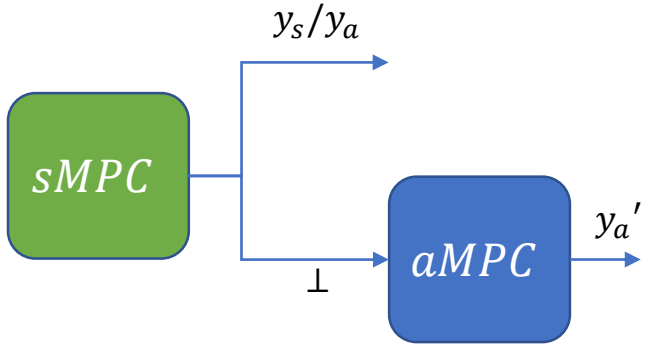
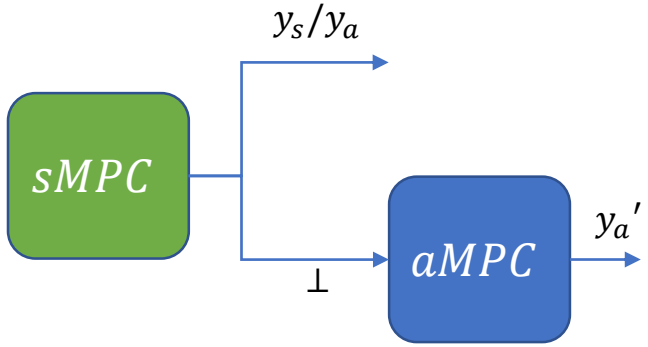


Threshold-Homomorphic Encryption

Public key ek
Secret key $dk = (dk_1, dk_2, \ldots, dk_i, \ldots dk_n)$

P_i

Feasibility



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$$[x_i] = Enc_{ek}(x_i)$$

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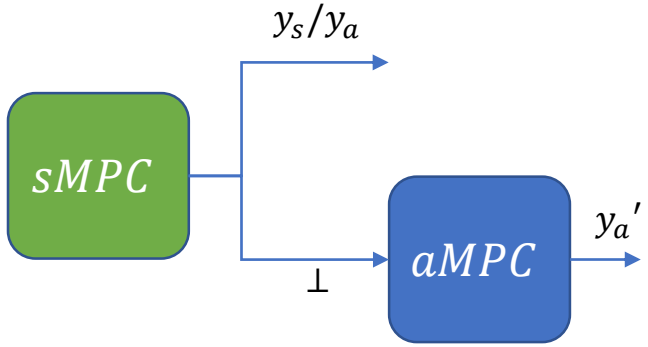

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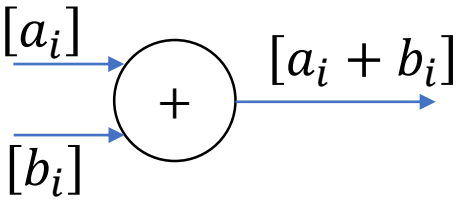
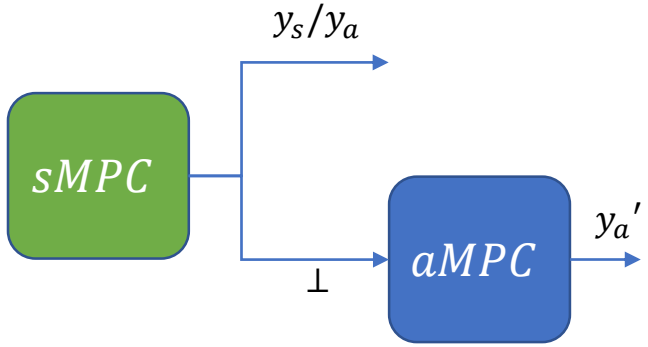


Feasibility



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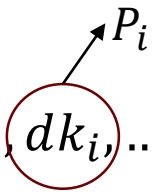

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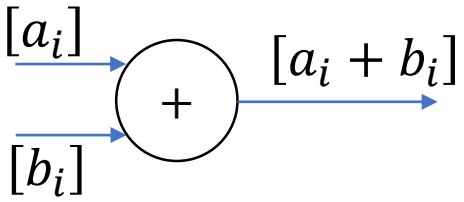
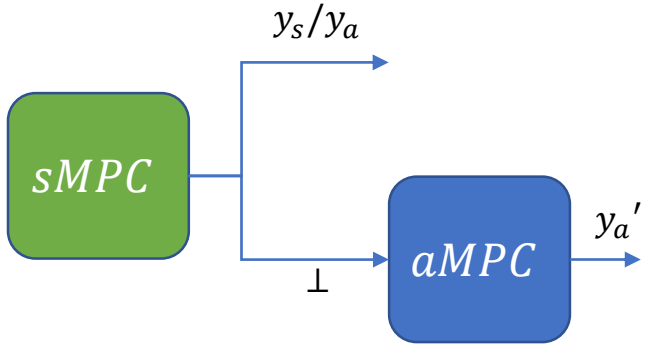


$$d_i = DecShare_{dk_i}([x_i])$$

Feasibility



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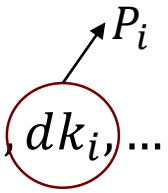

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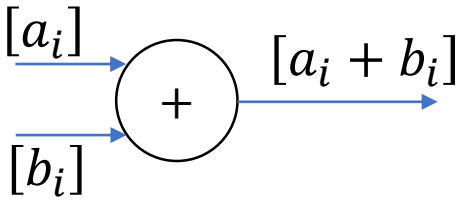


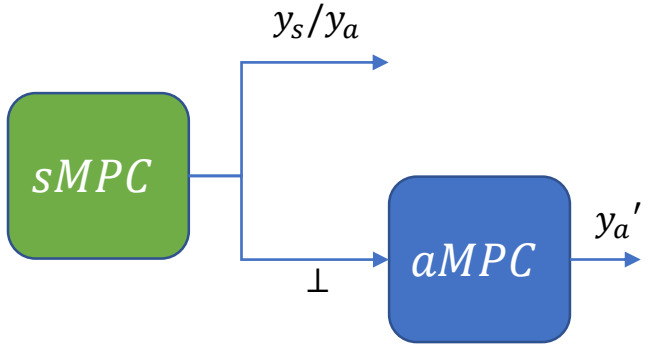
$$d_i = DecShare_{dk_i}([x_i])$$

$$x_i = Rec(\{d_j\})$$

$t_s + 1$ shares

Feasibility

[CDN'01] approach



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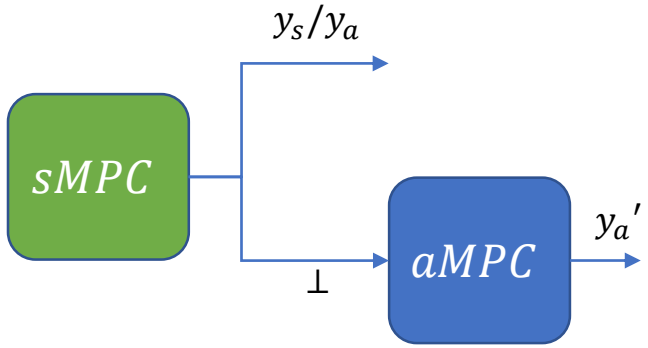

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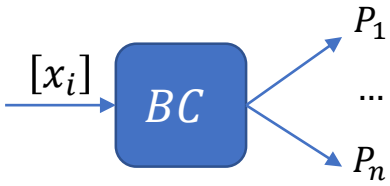
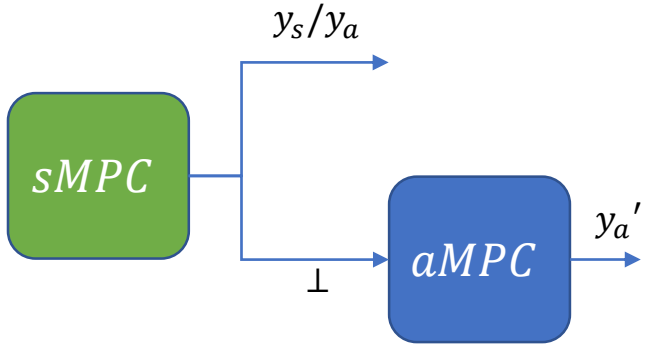


Input Distribution

Feasibility



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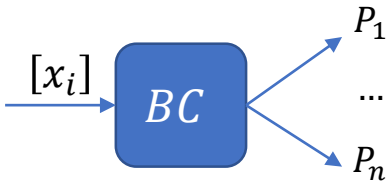

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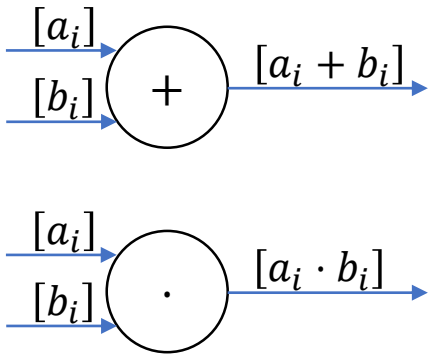
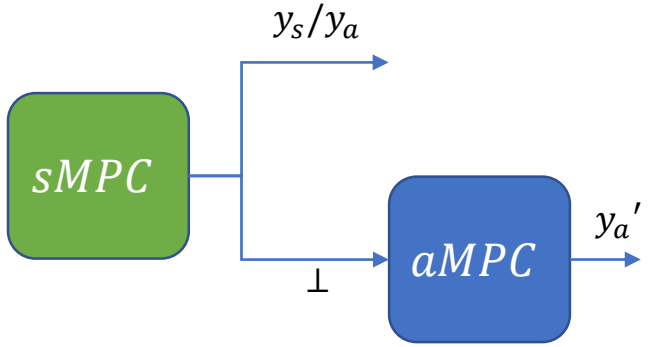


Circuit Evaluation

Feasibility



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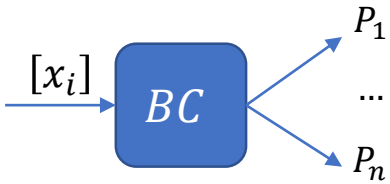

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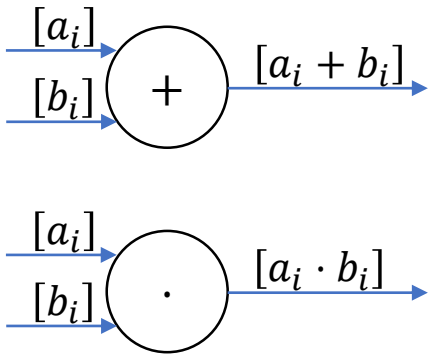

Circuit Evaluation

c output ciphertext

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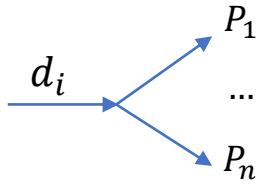
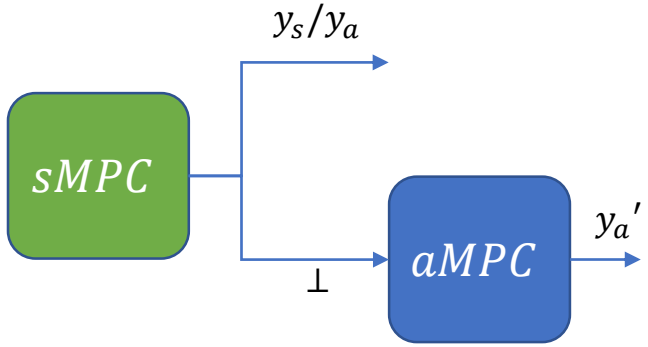


$y_i = Rec(\{d_j\})$

Threshold Decryption

Feasibility

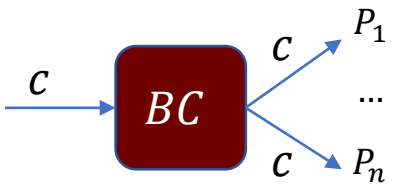


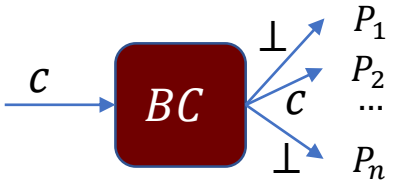
Synchronous

Asynchronous

BC

[DS83]





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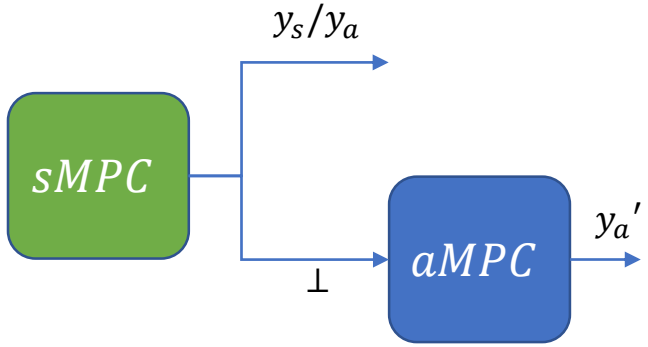

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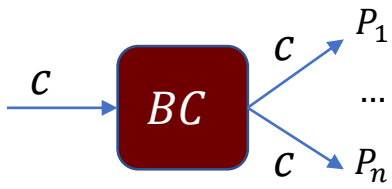
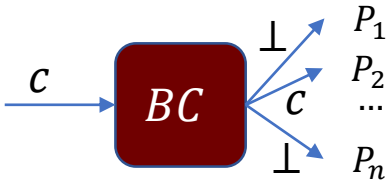
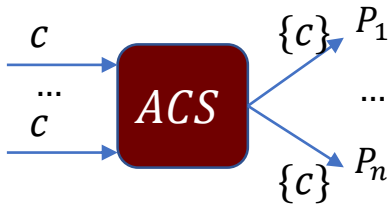
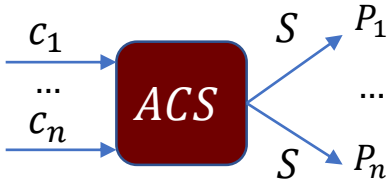




ACS

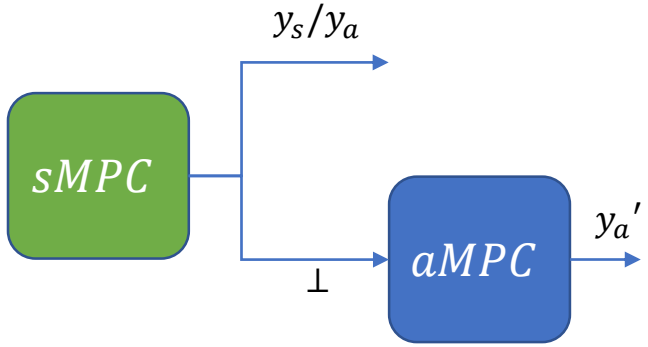
[BKR94,BKL20]





S includes an honest P_i's input

Feasibility



[CDN'01] approach

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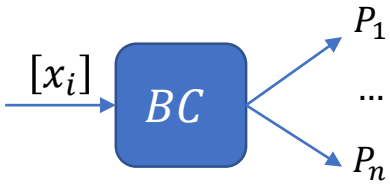

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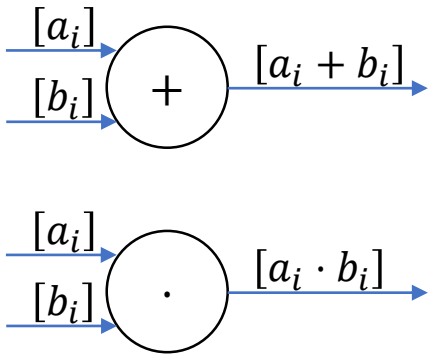

Circuit Evaluation

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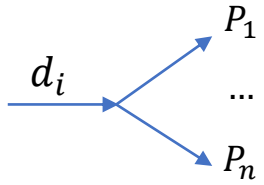

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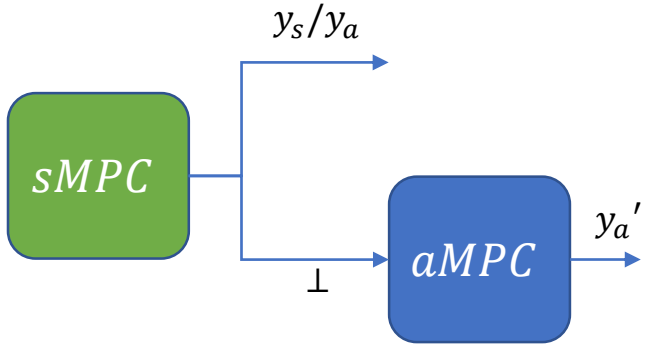
Threshold Decryption

Feasibility



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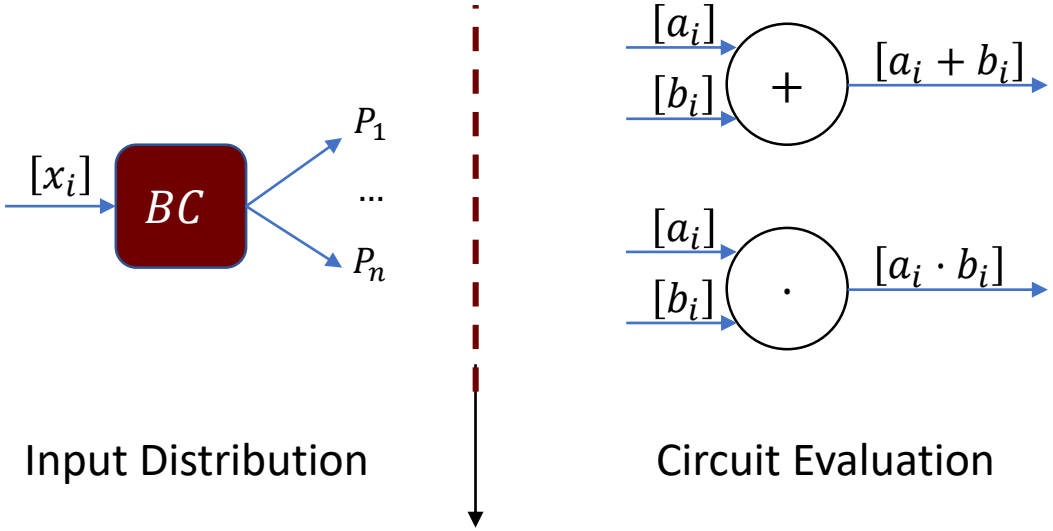

Input Distribution

Circuit Evaluation

Wait for T time
Check if there are
$n - t_s$ inputs

c output ciphertext

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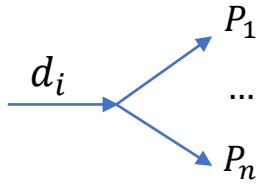

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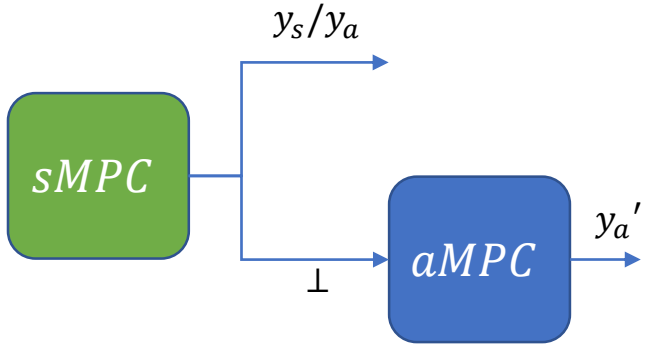

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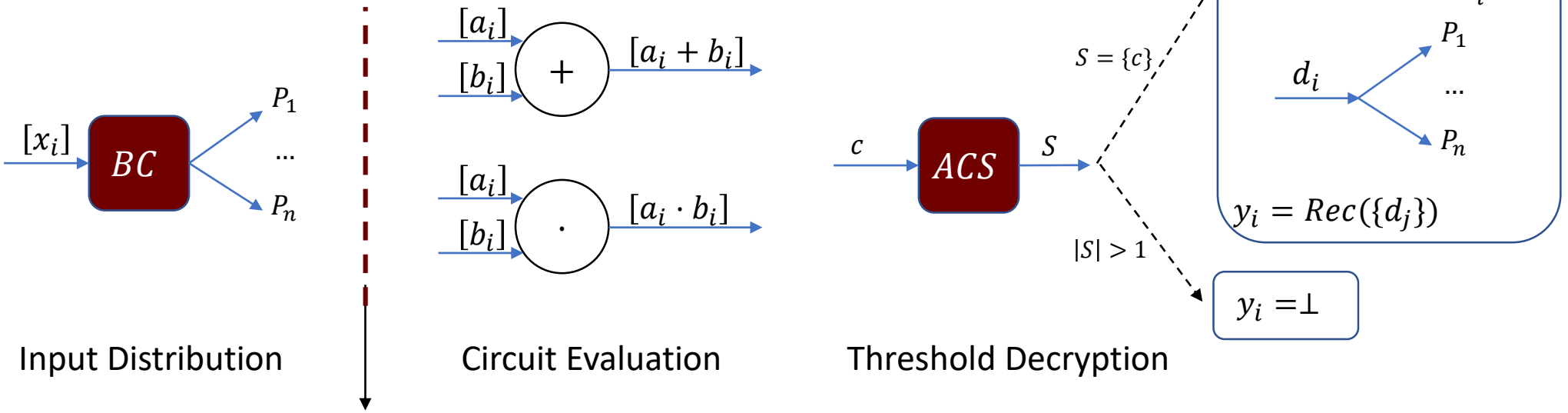
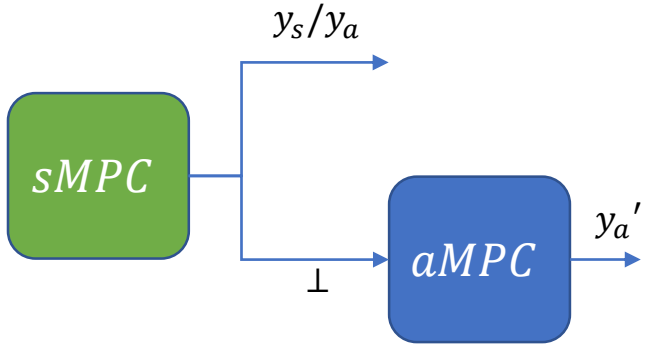


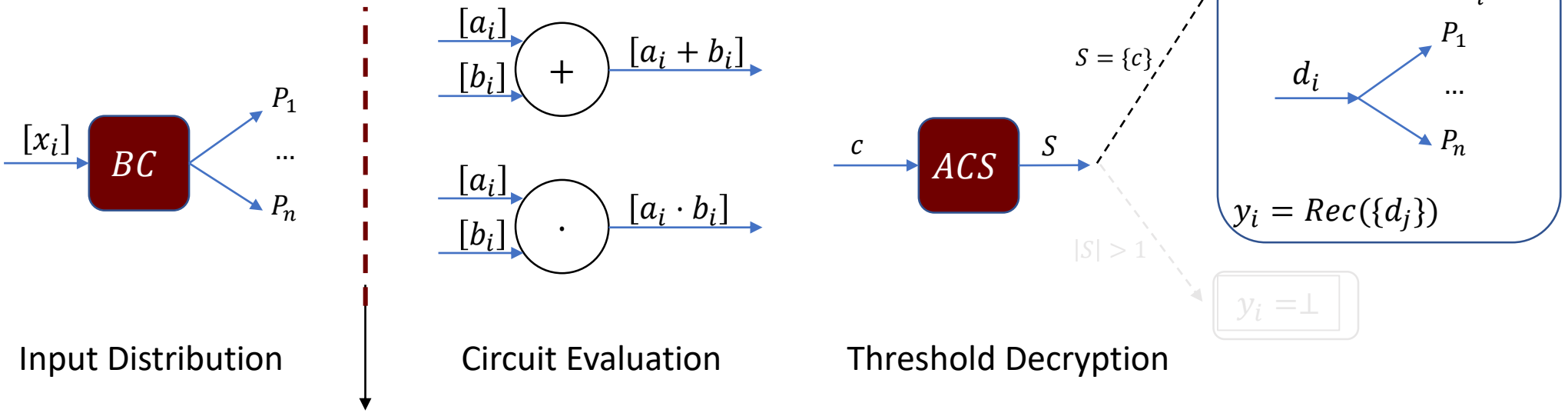
Feasibility



[CDN'01] approach

P_i:

$[x_i] = Enc_{ek}(x_i)$



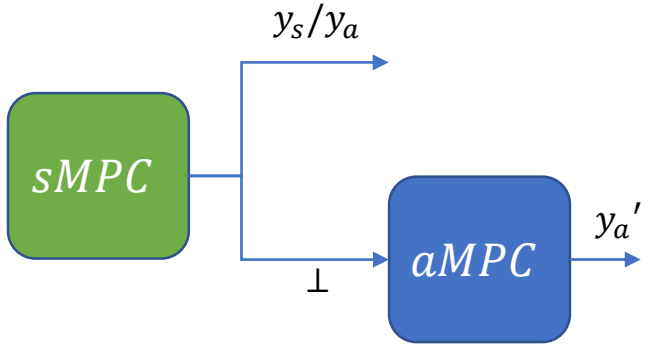
Input Distribution

Circuit Evaluation

Threshold Decryption

Wait for T time
Check if there are
$n - t_s$ inputs

Feasibility



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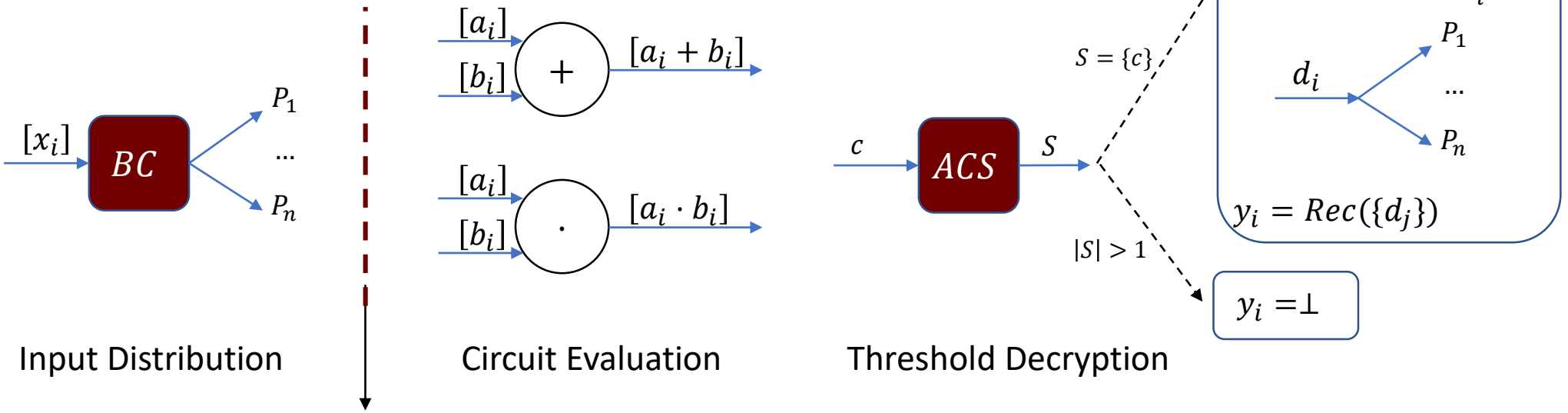

Is there an MPC that achieves guarantees in both regimes?

Synchronous

$n/3 \leq t_s < n/2$

Input completeness

Asynchronous

$t_a < n/3$

Up to L inputs are ignored

YES! If and only if $t_a + 2t_s < n$ and $L \geq t_s$

Impossibility

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$L < t_s$ is impossible: t_s-security implies $L \geq t_s$

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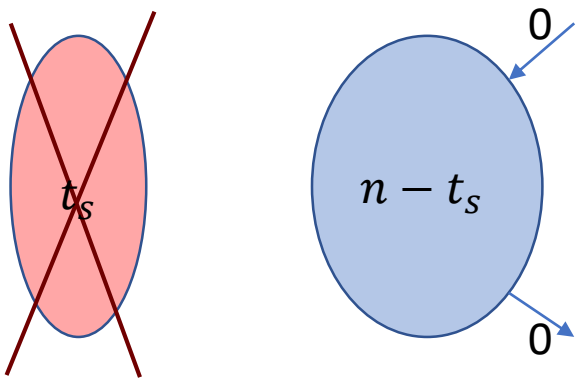
OR function



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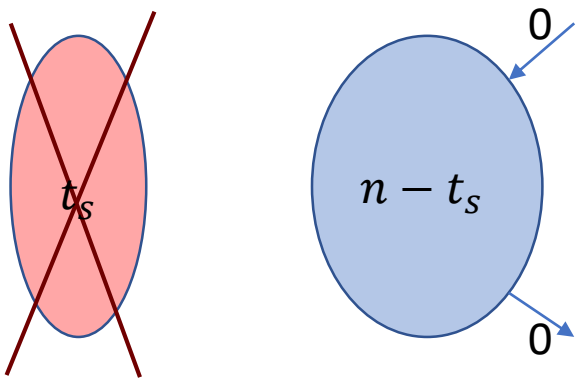
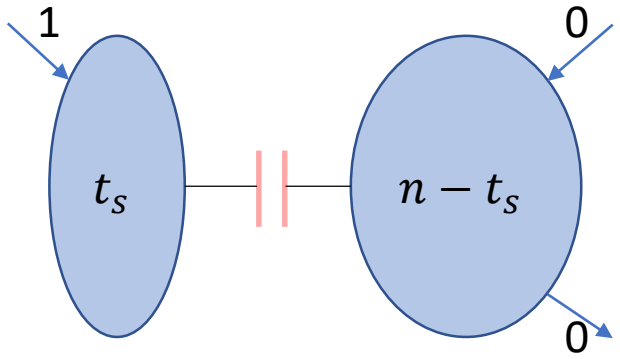


Synchronous



Asynchronous

Impossibility

YES! If and only if $t_a + 2t_s < n$ and $L \geq t_s$

$t_a + 2t_s \geq n$ is impossible (even when all inputs are ignored) [BKL19]

Impossibility

YES! If and only if $t_a + 2t_s < n$ and $L \geq t_s$

$t_a + 2t_s \geq n$ is impossible (even when all inputs are ignored) [BKL19]

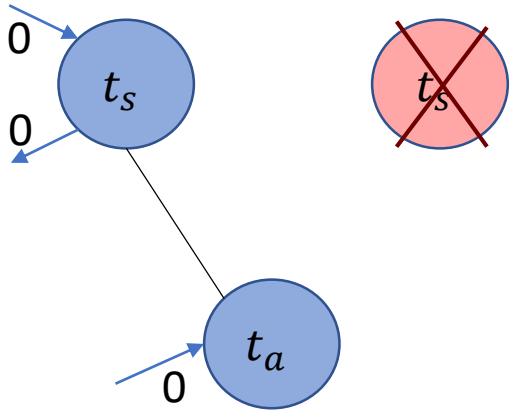
Majority function

Impossibility

YES! If and only if $t_a + 2t_s < n$ and $L \geq t_s$

$t_a + 2t_s \geq n$ is impossible (even when all inputs are ignored) [BKL19]

Majority function



Synchronous

Impossibility

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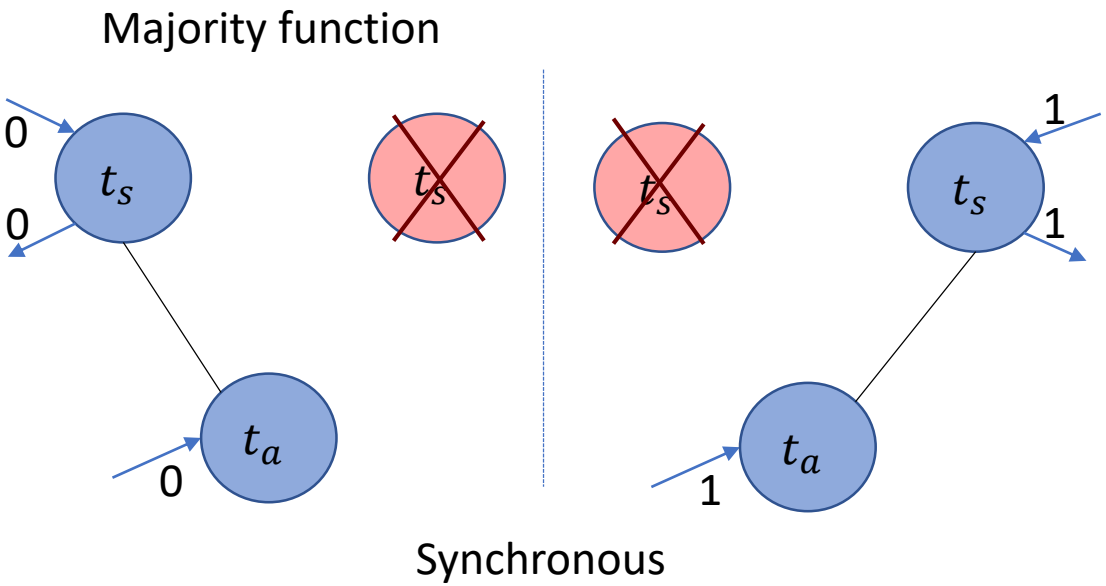

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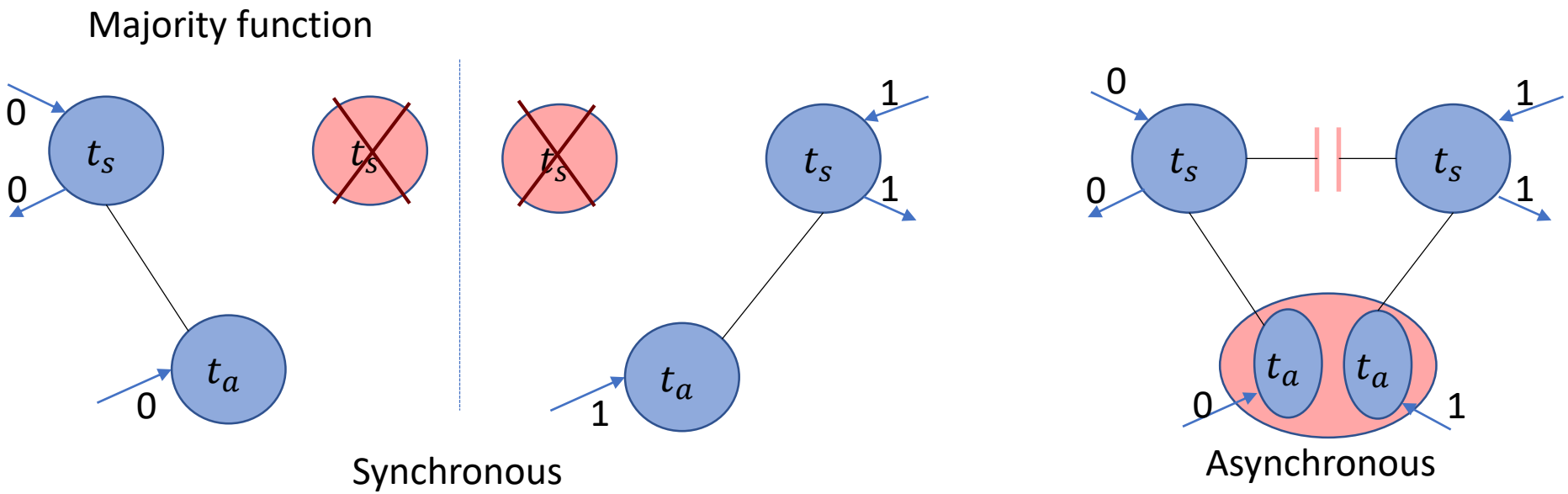

References and Credits

ETH Zurich, Department of Computer Science
lichen@inf.ethz.ch

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Credits:

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