Adaptive Security of Multi-Party Protocols, Revisited

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NTT Research

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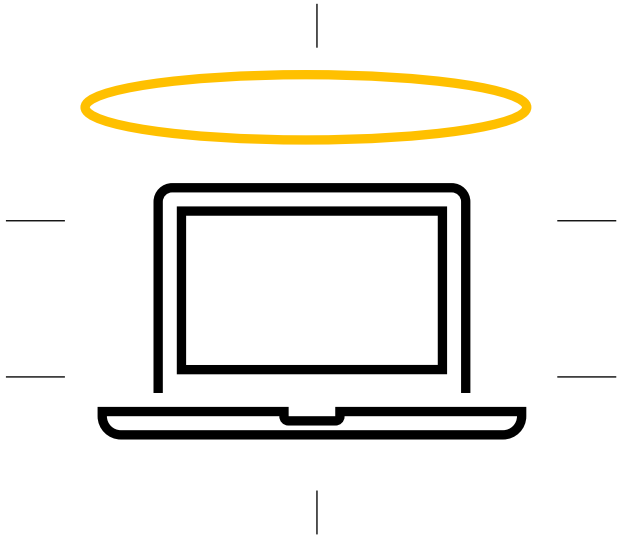
Security Definitions



Simple

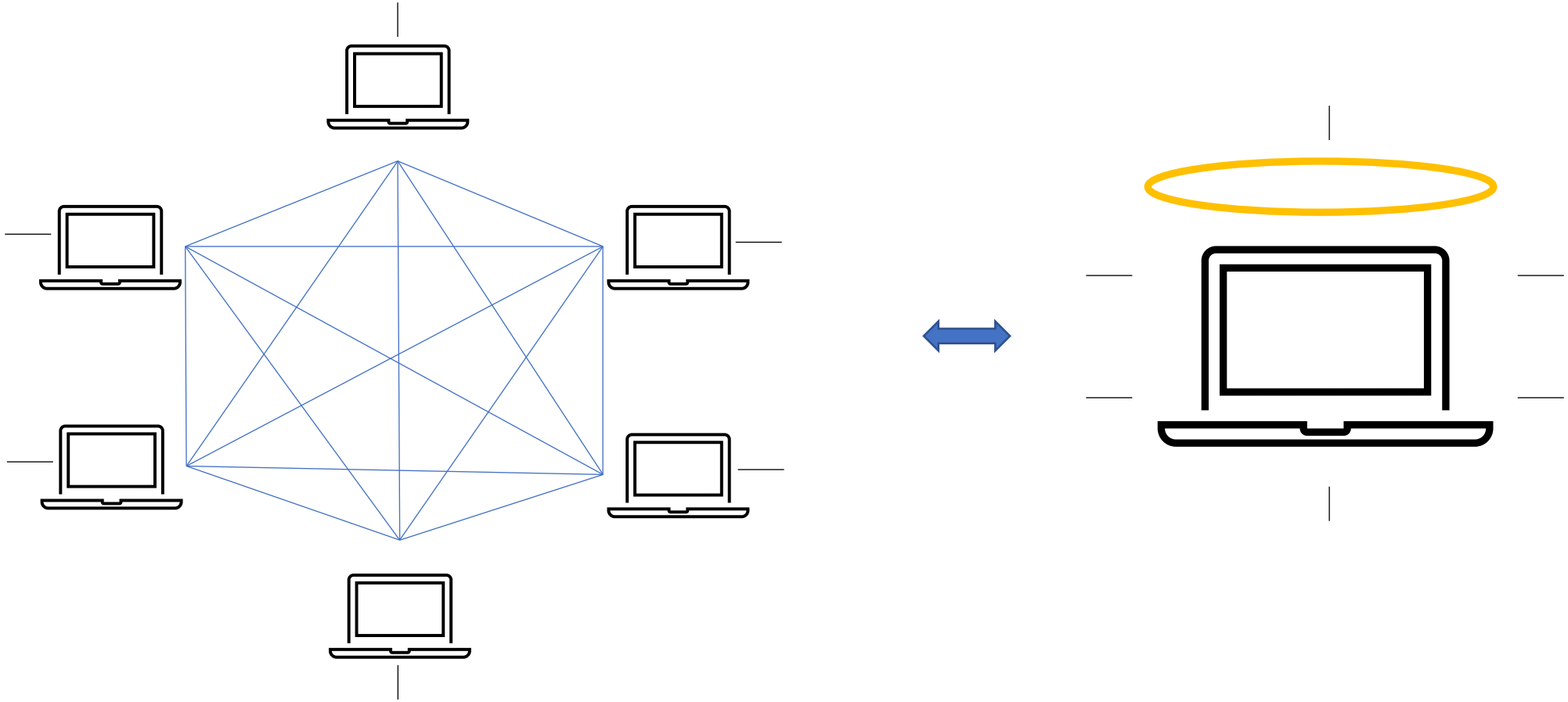
Consistent

Composable

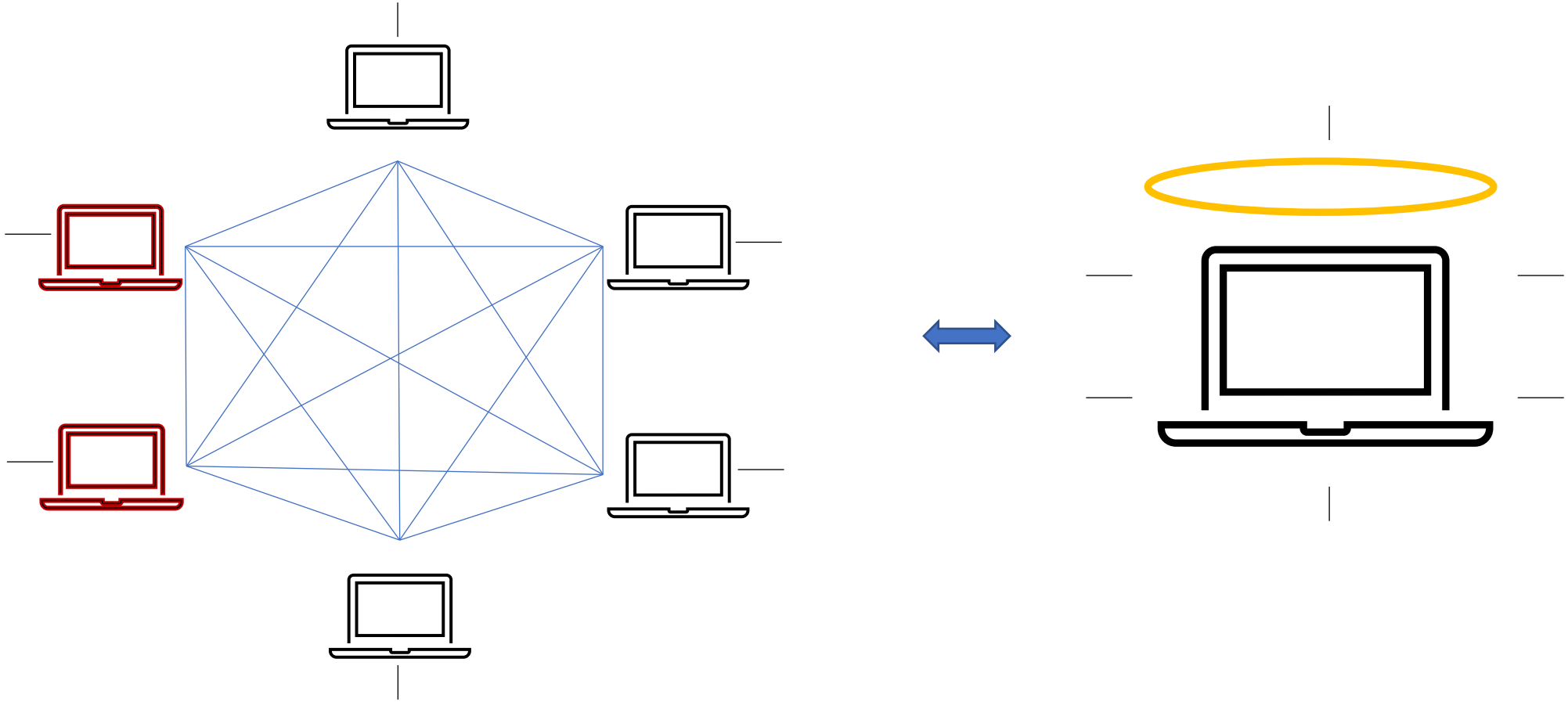
Complete

Sound

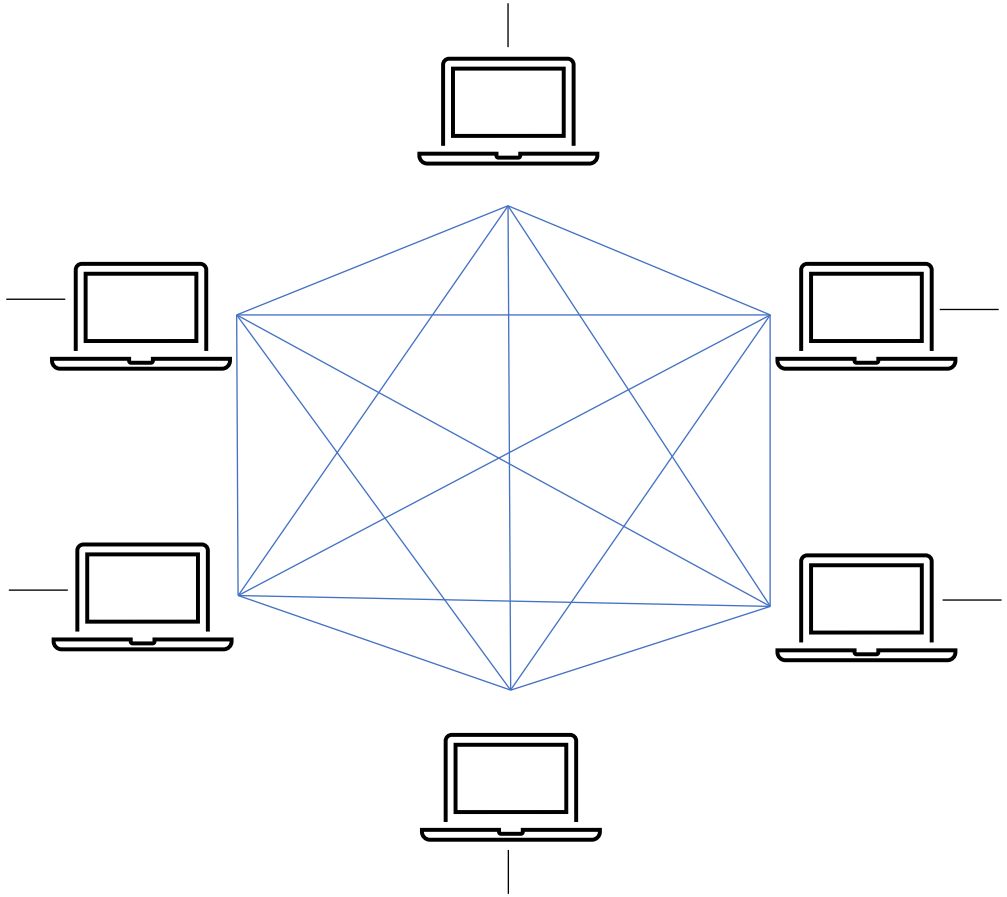
Multiparty Computation



Multiparty Computation



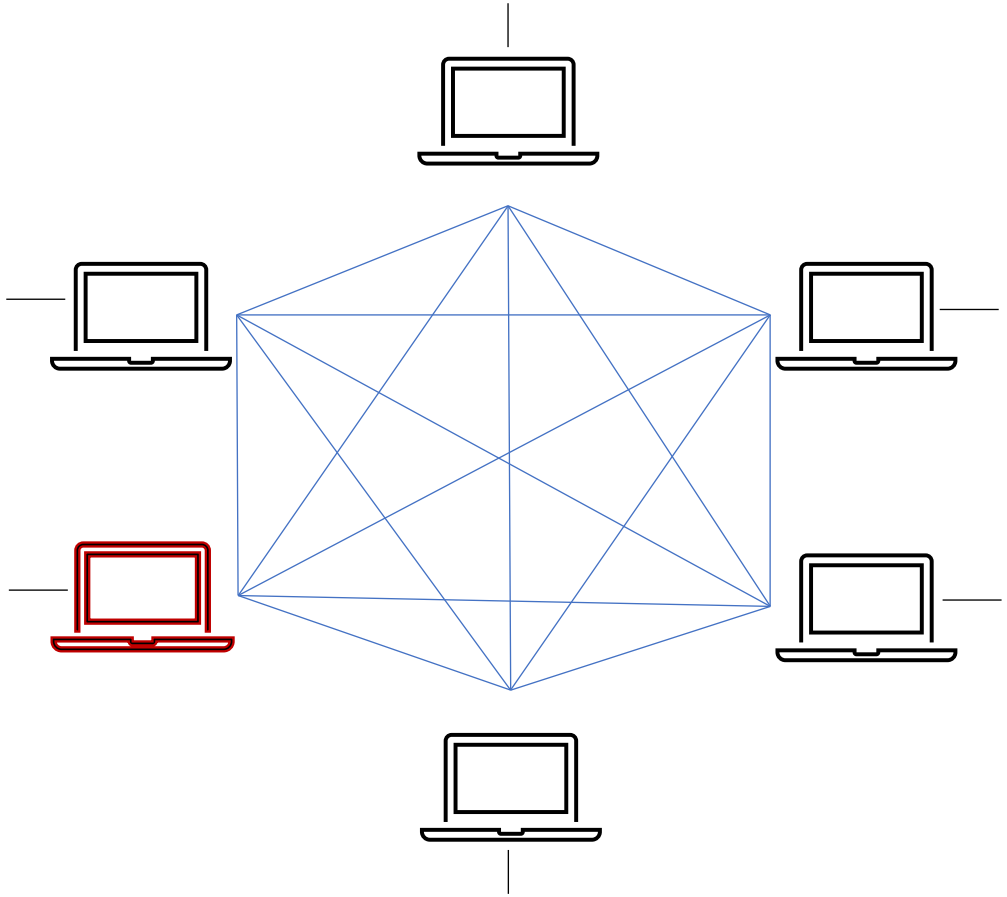
Adaptive Corruption



Network information

Internal state information

Adaptive Corruption



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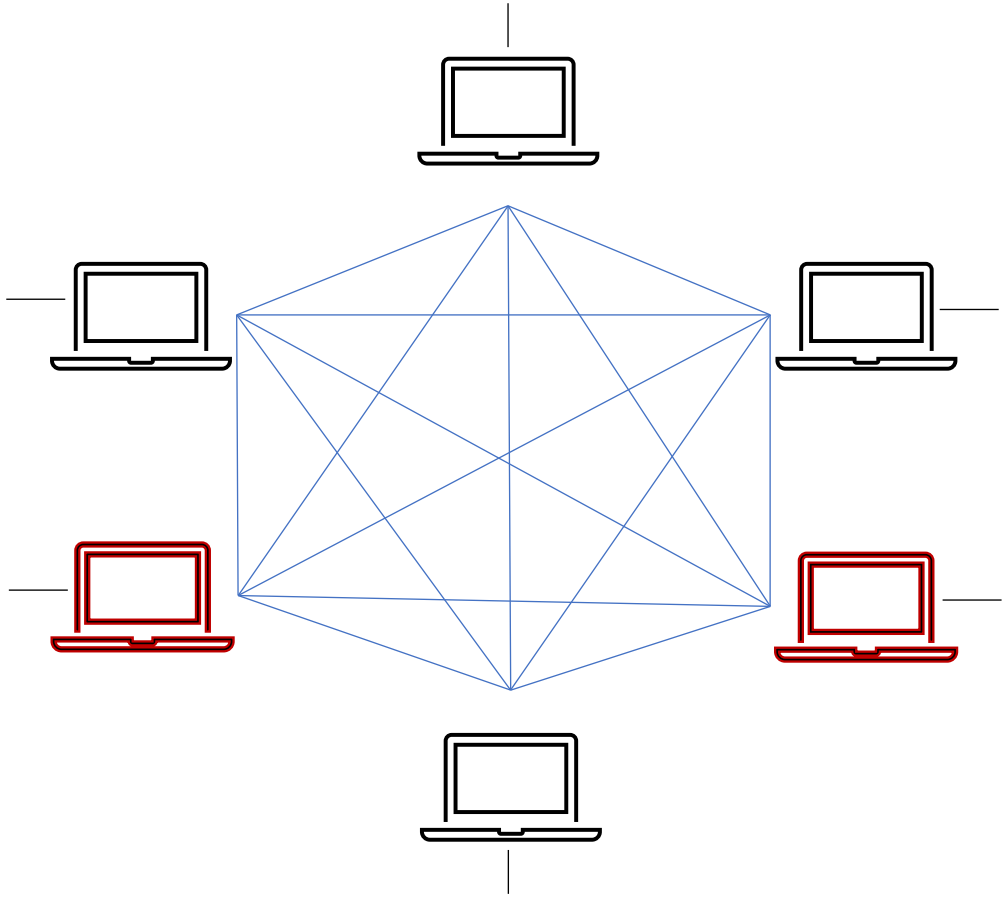

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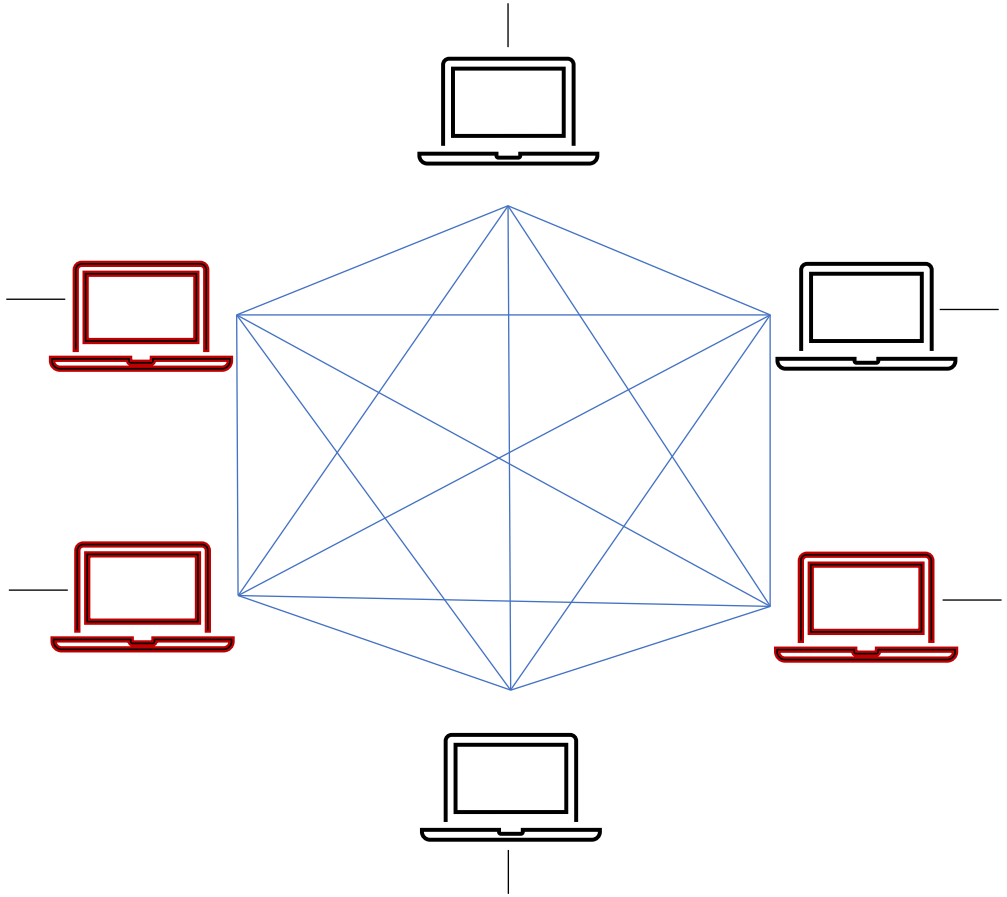

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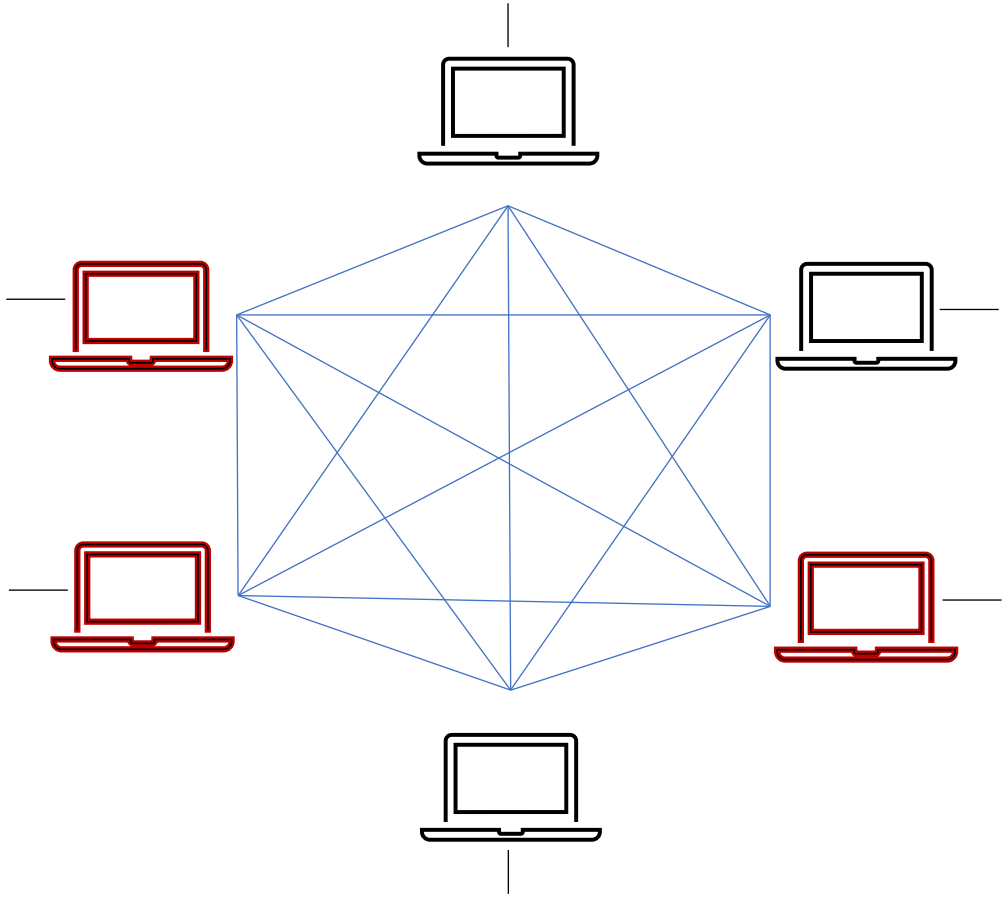
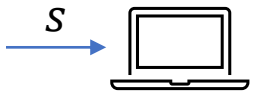
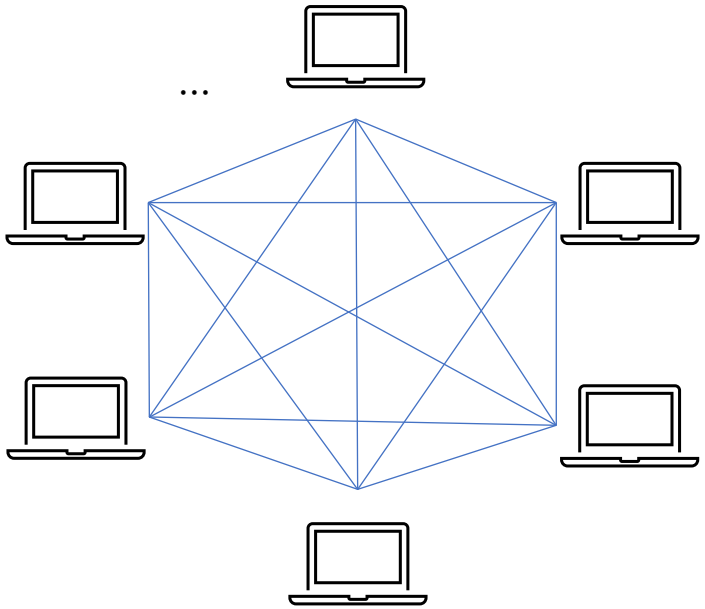


A Simple Example





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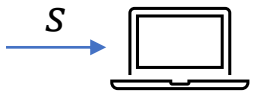
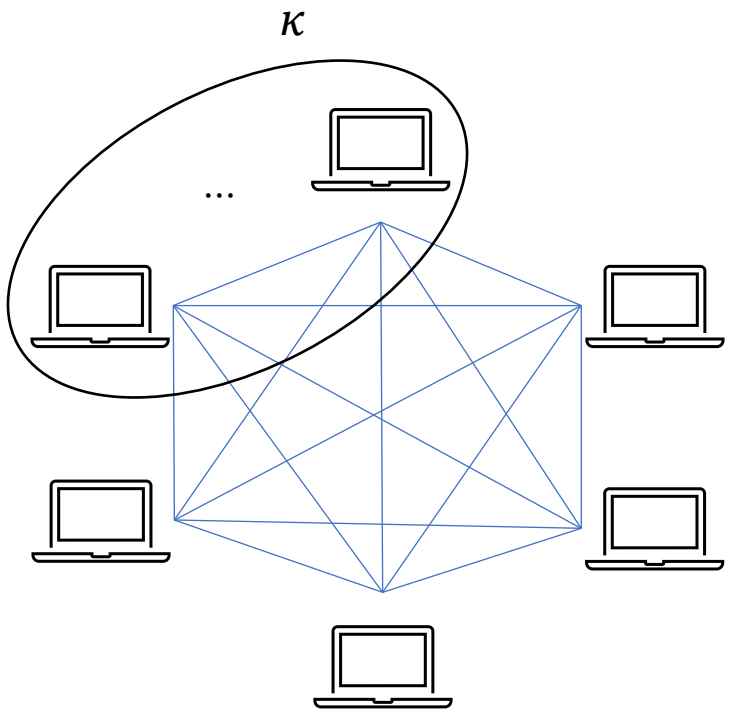
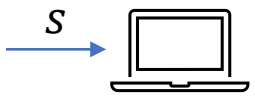
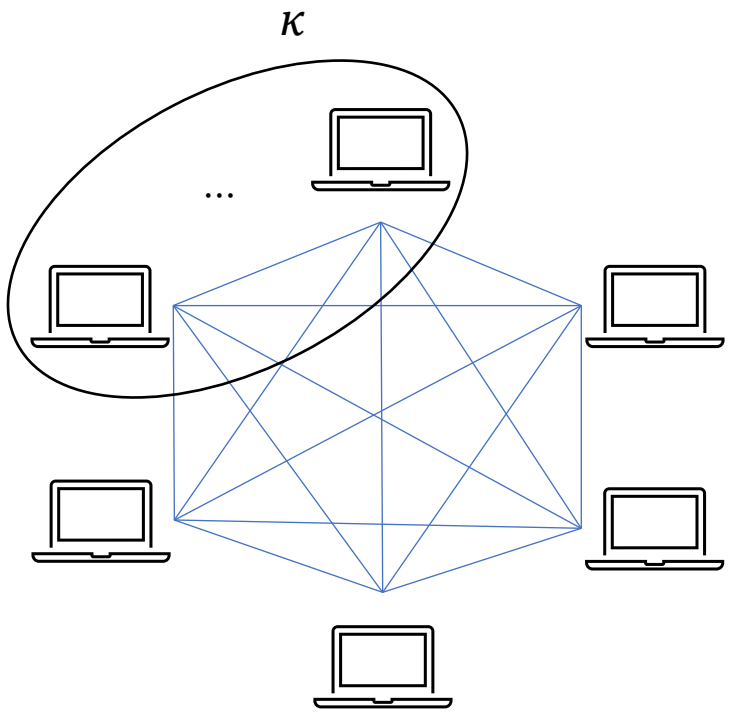




A Simple Example



$$s = s_1 + \cdots + s_k$$



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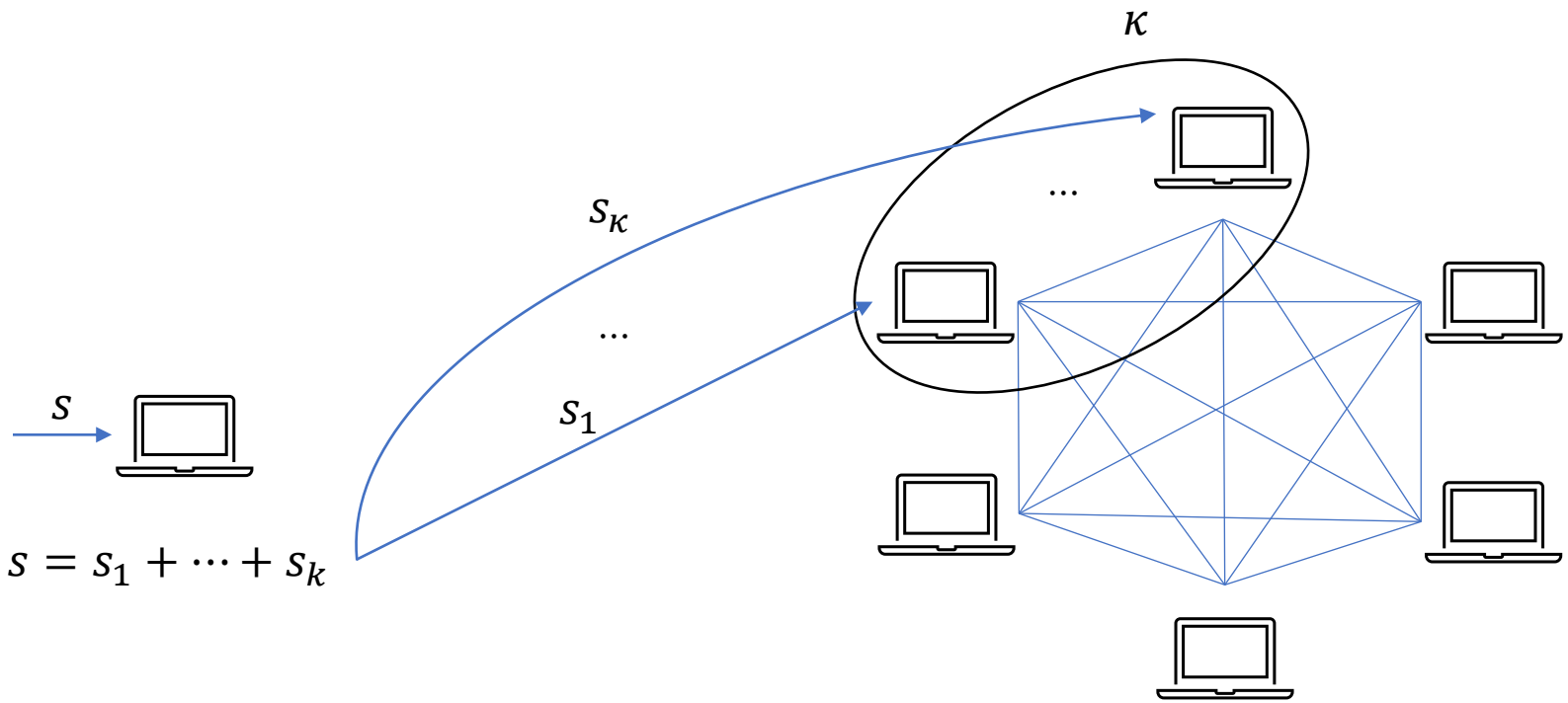

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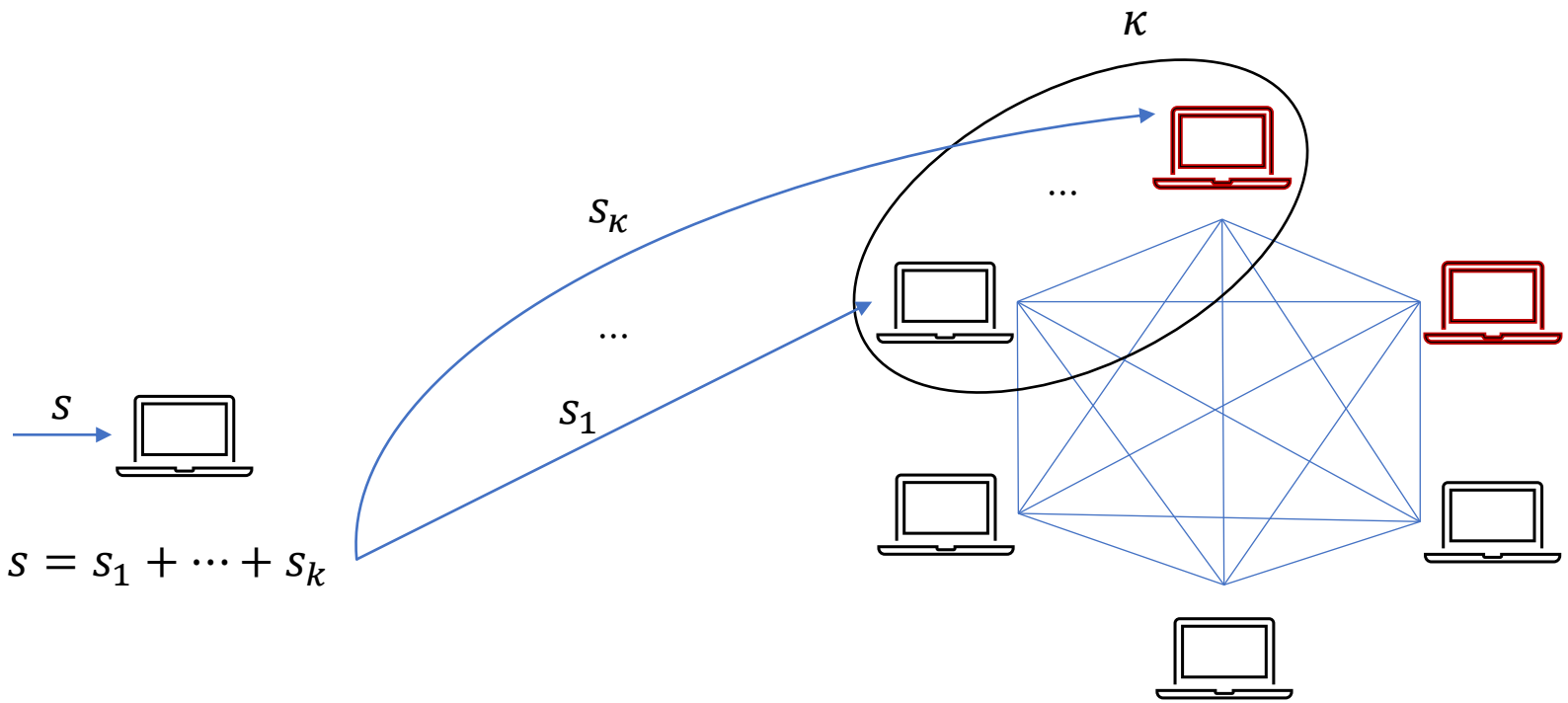
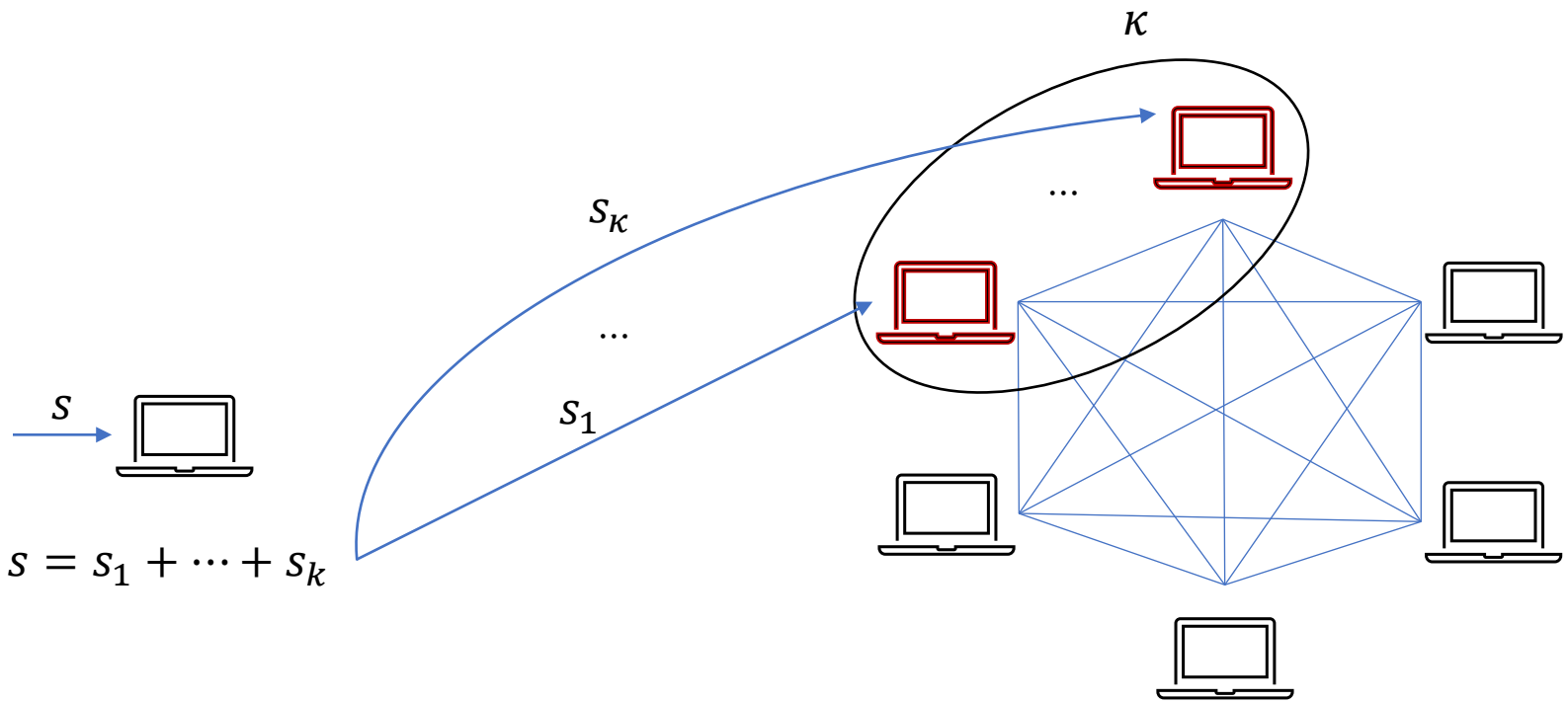


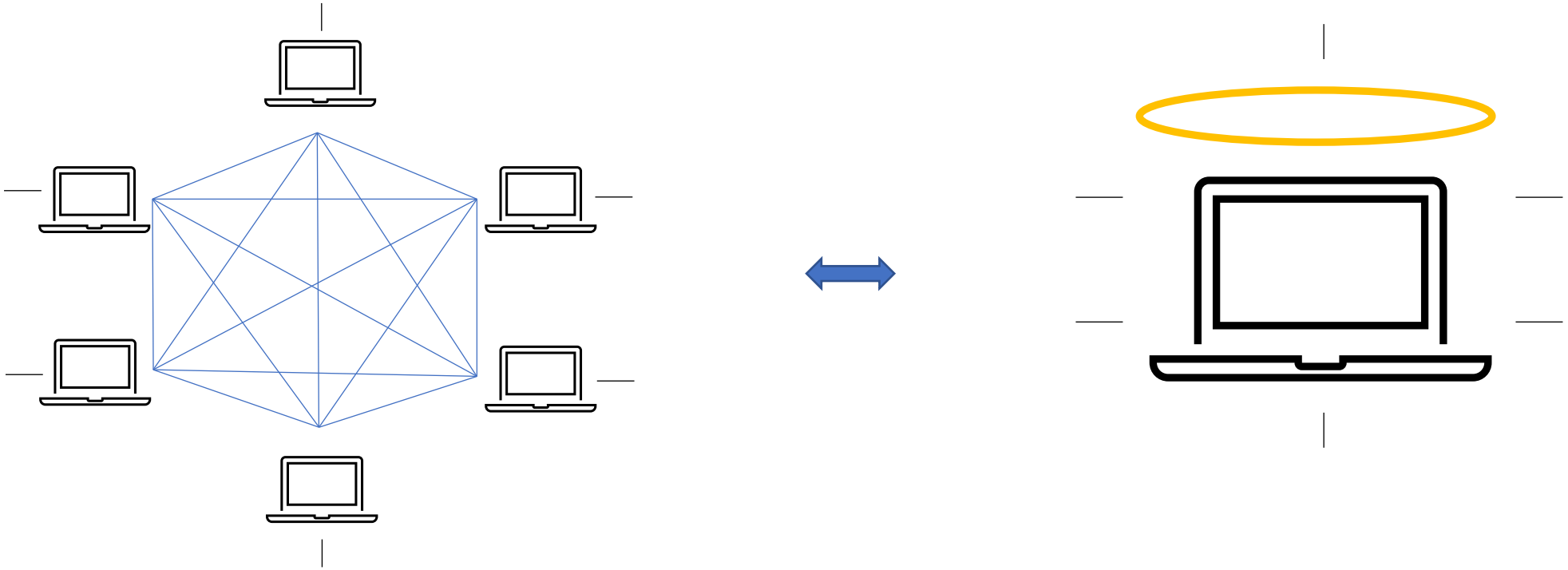
A static adversary corrupting κ parties only learns s with small probability

A Simple Example



An adaptive adversary corrupting κ parties can always learn s

Standard Adaptive Security



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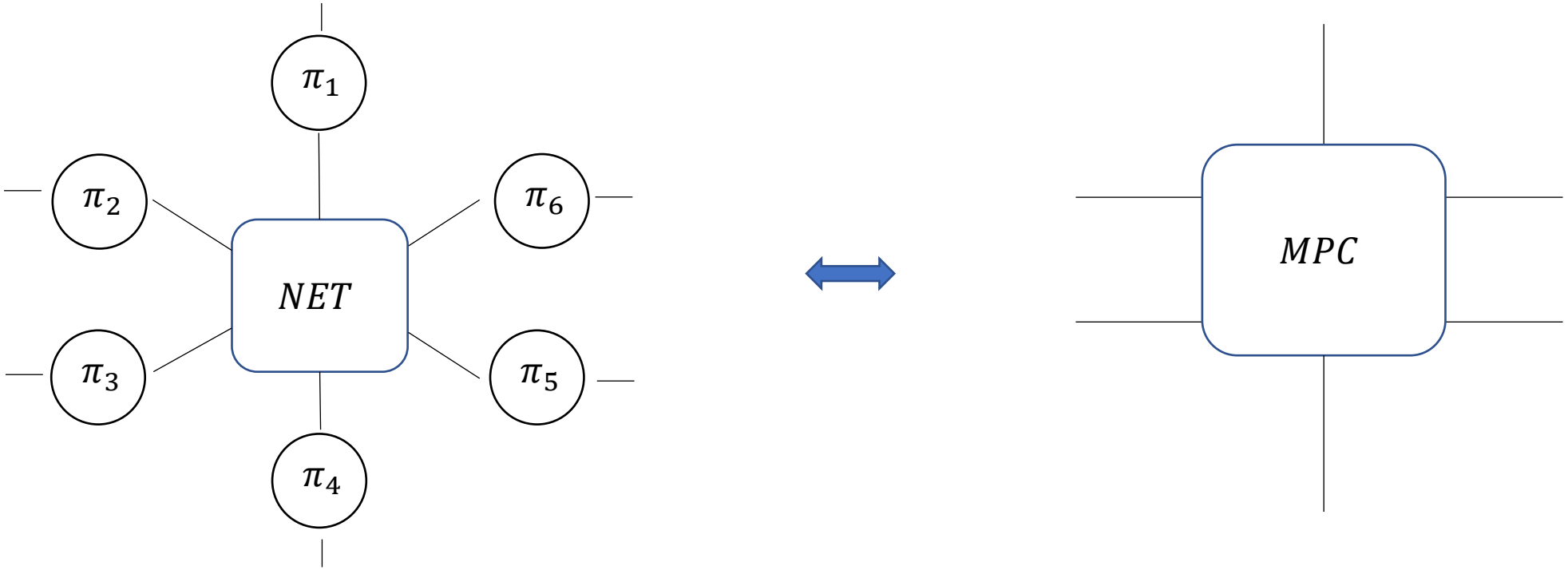

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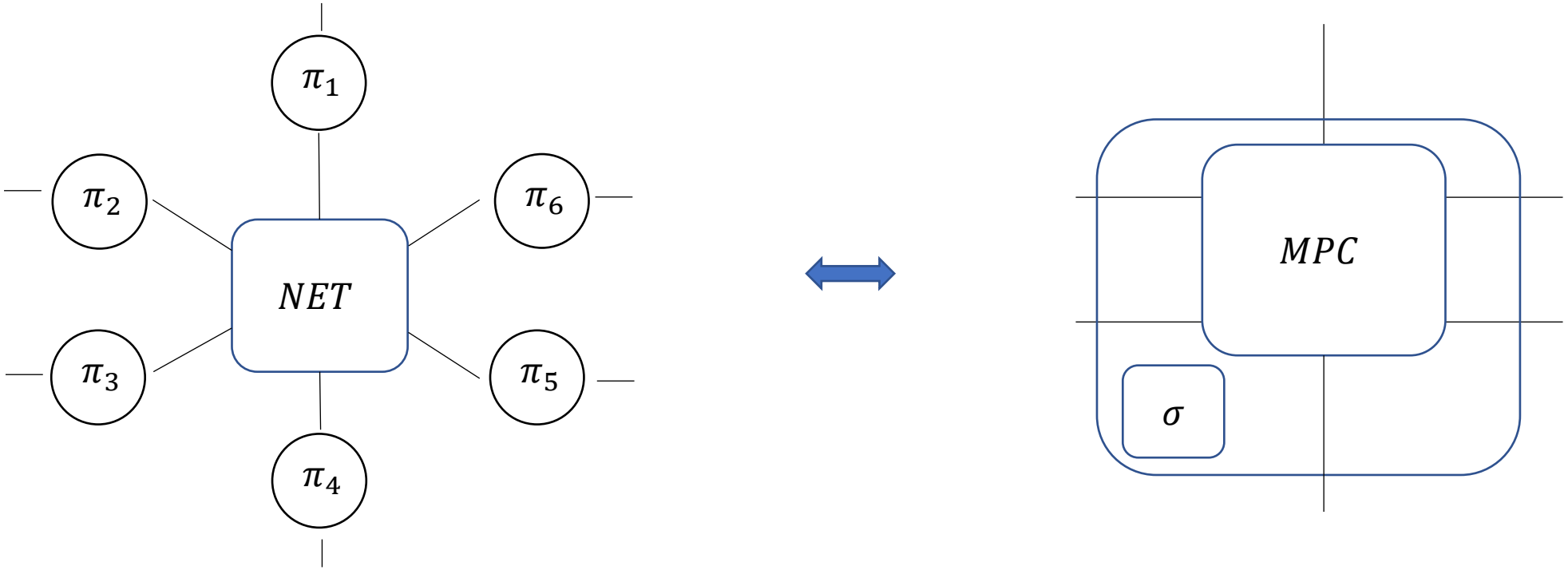

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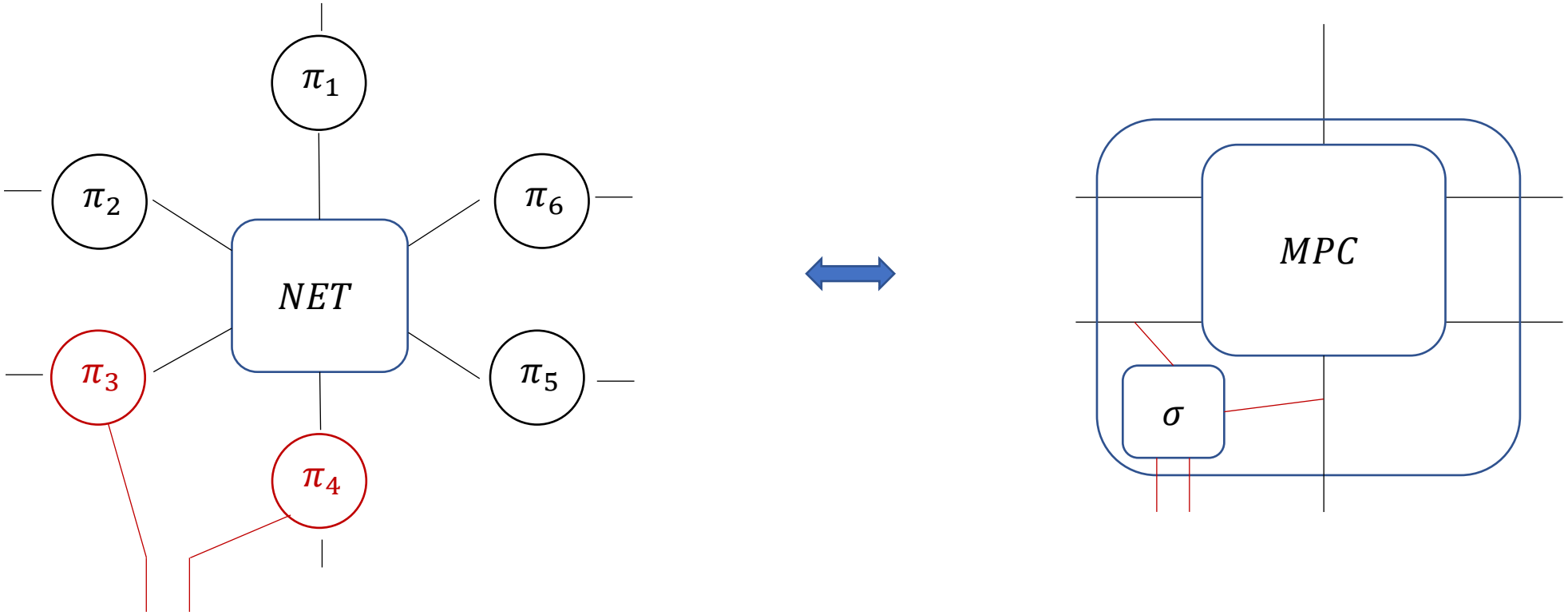

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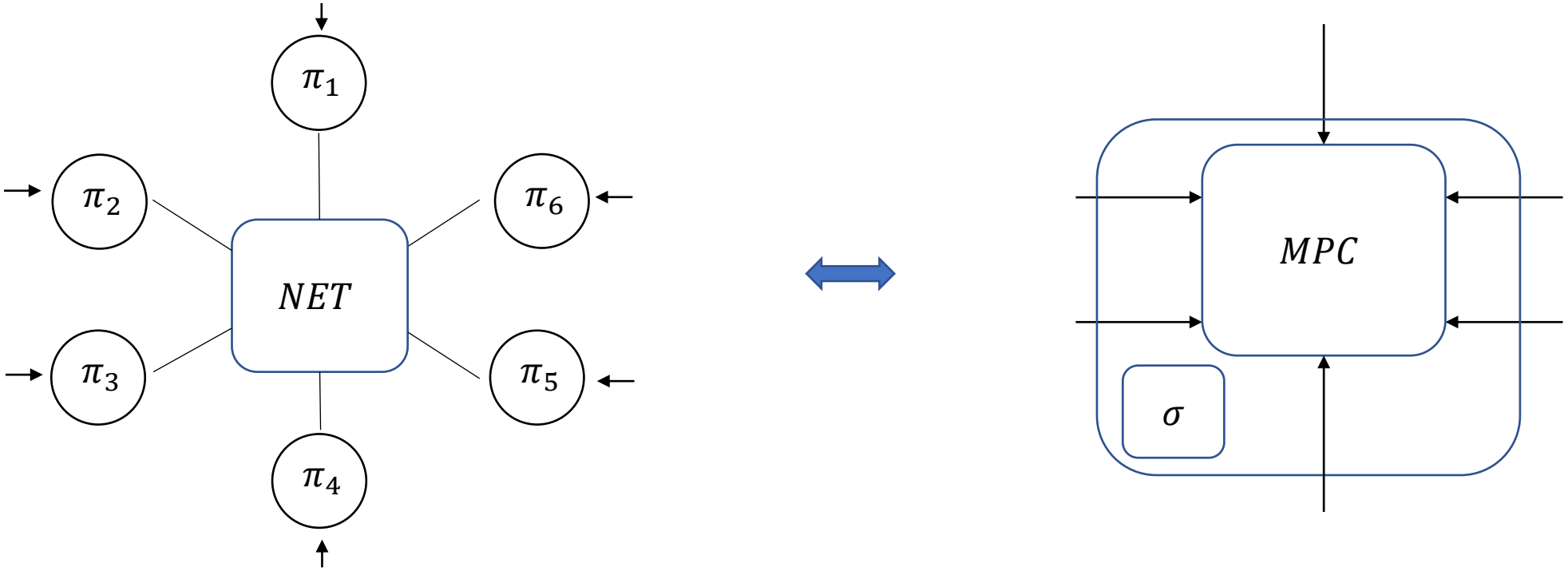

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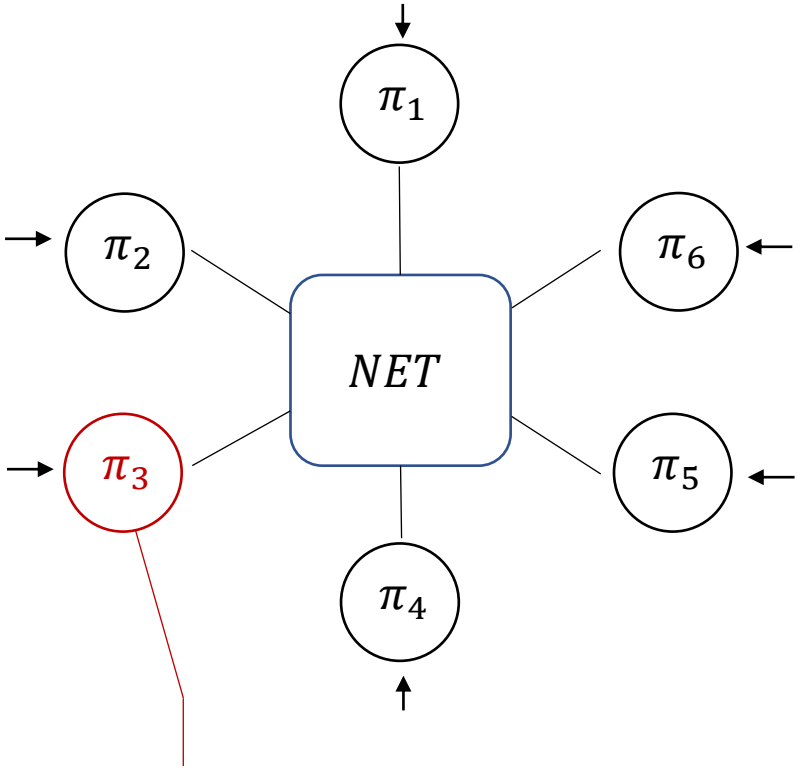

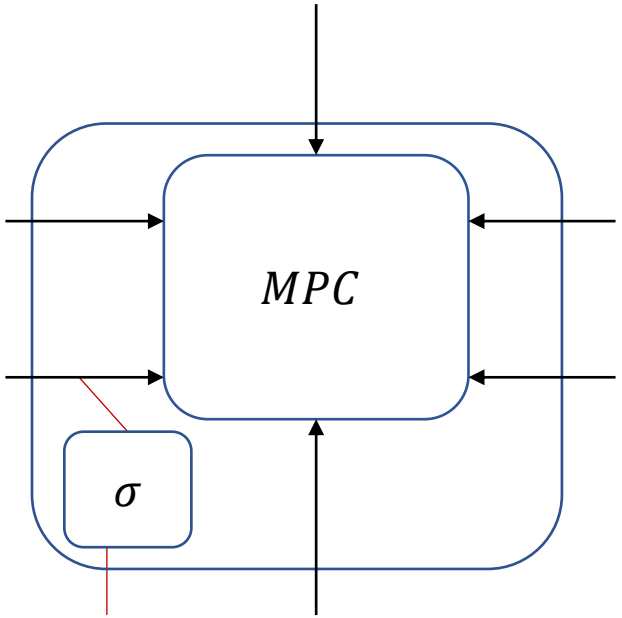

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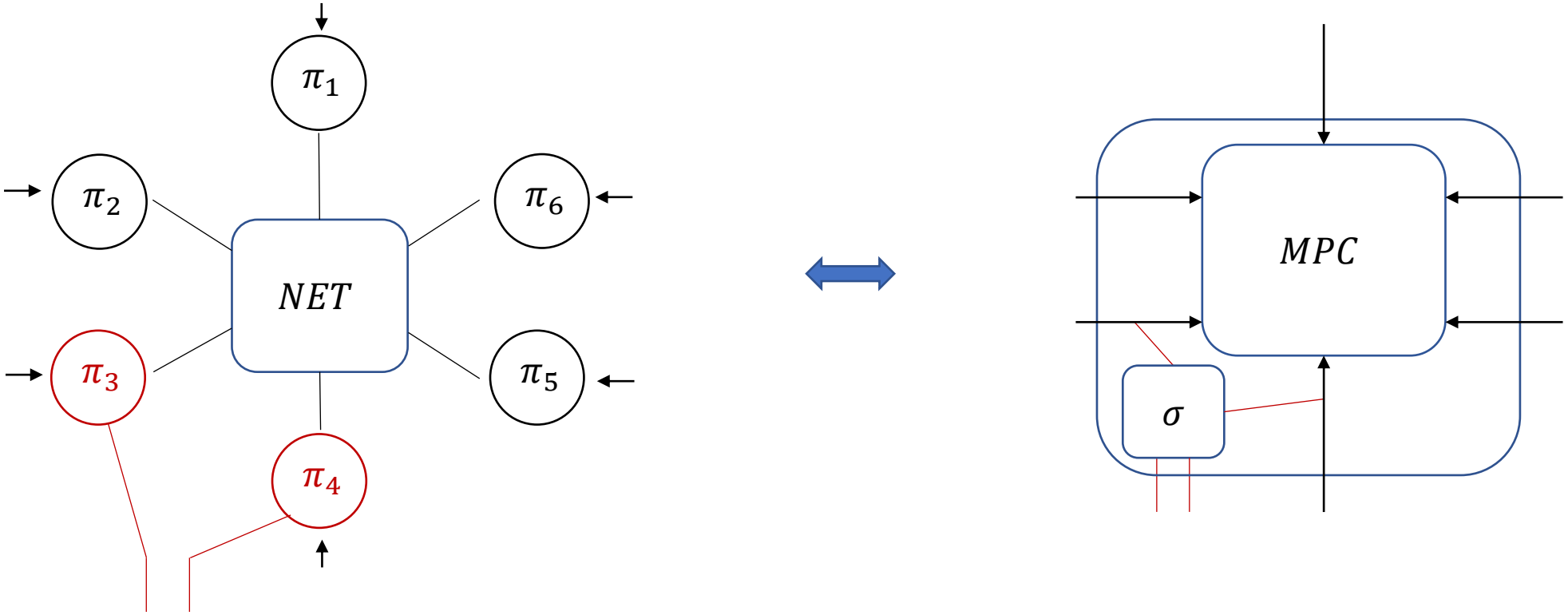

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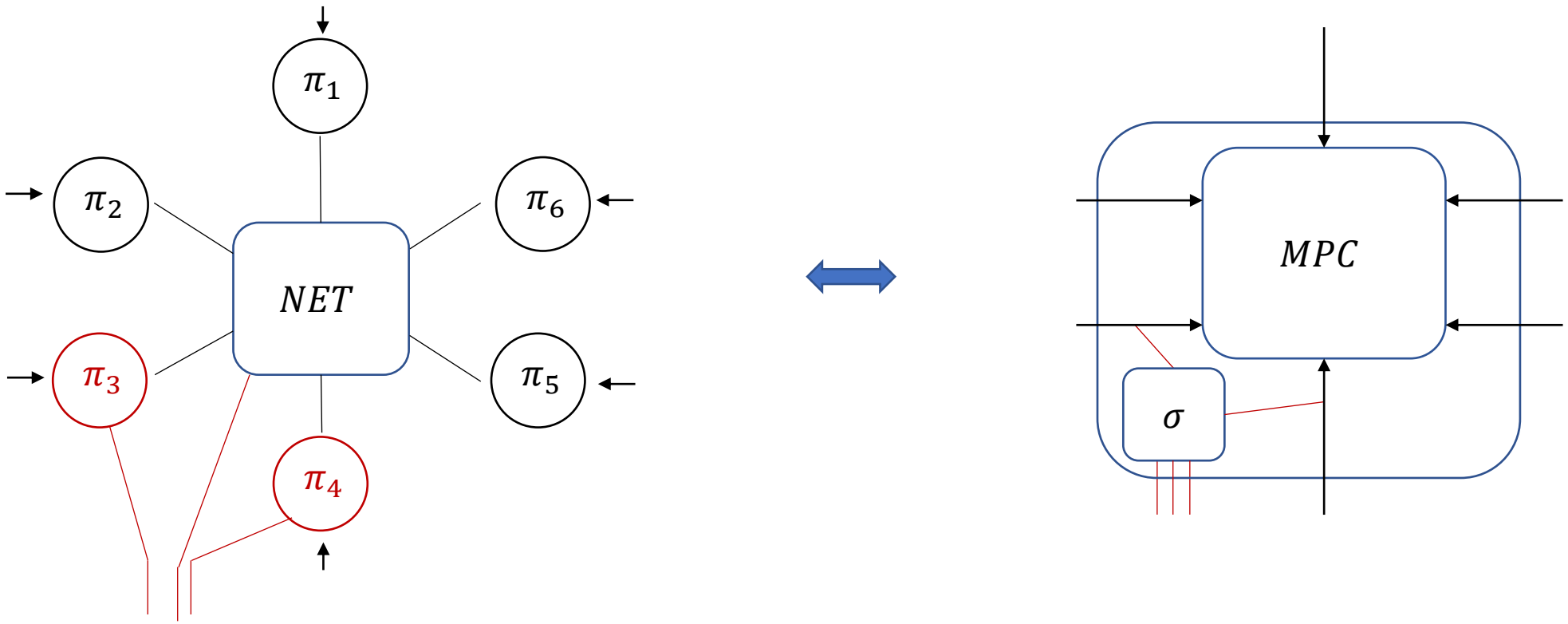

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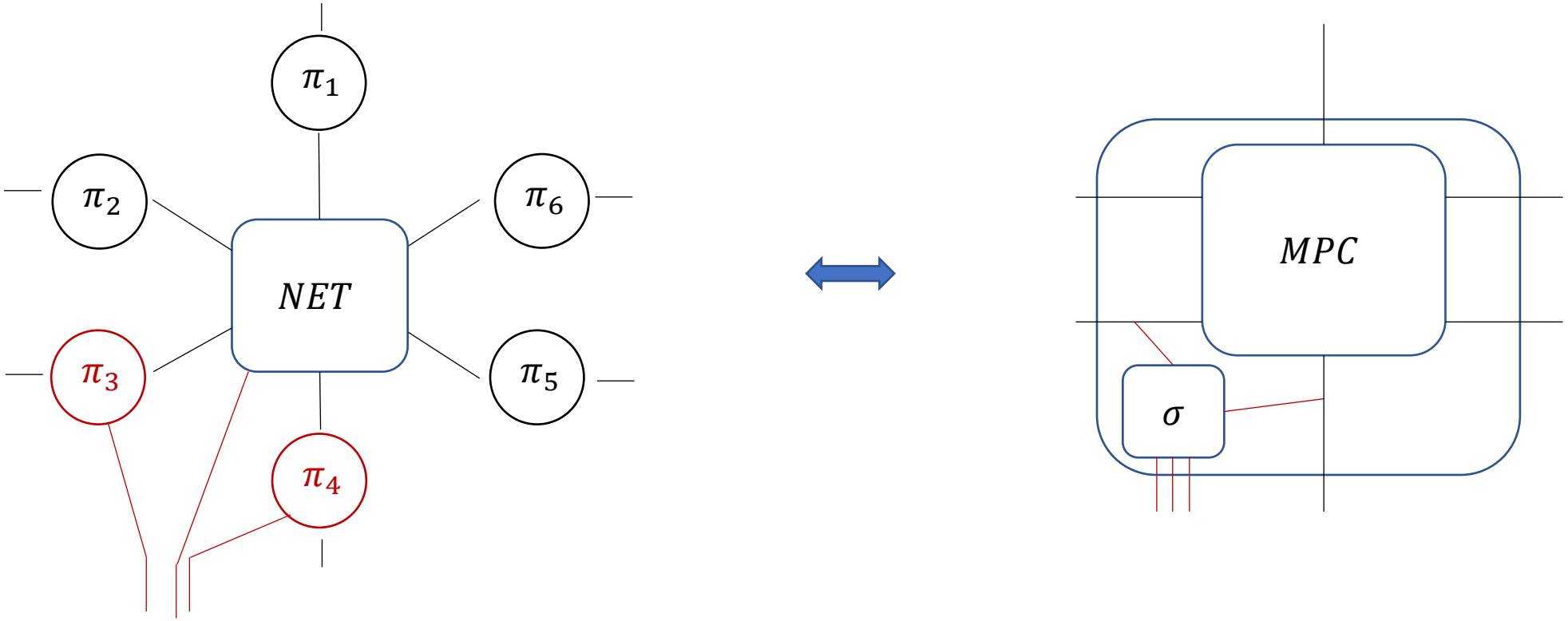

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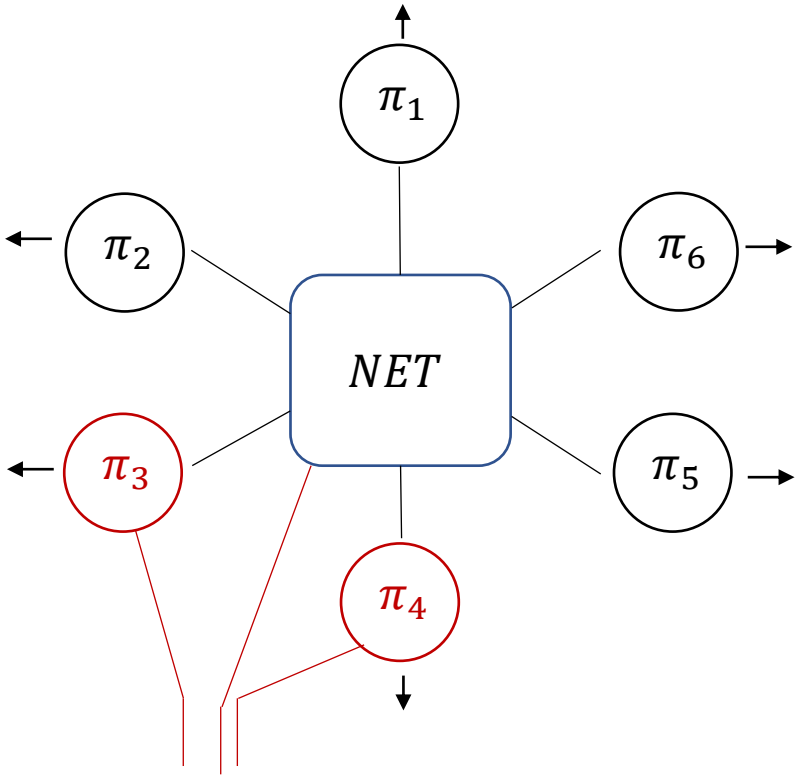

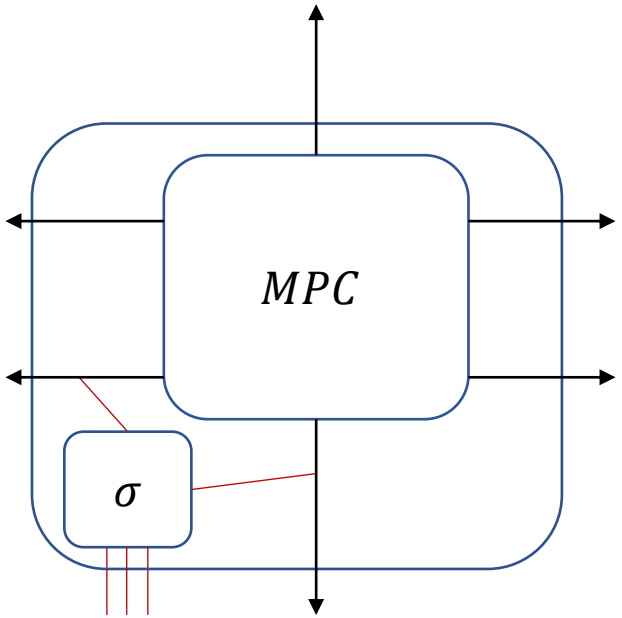

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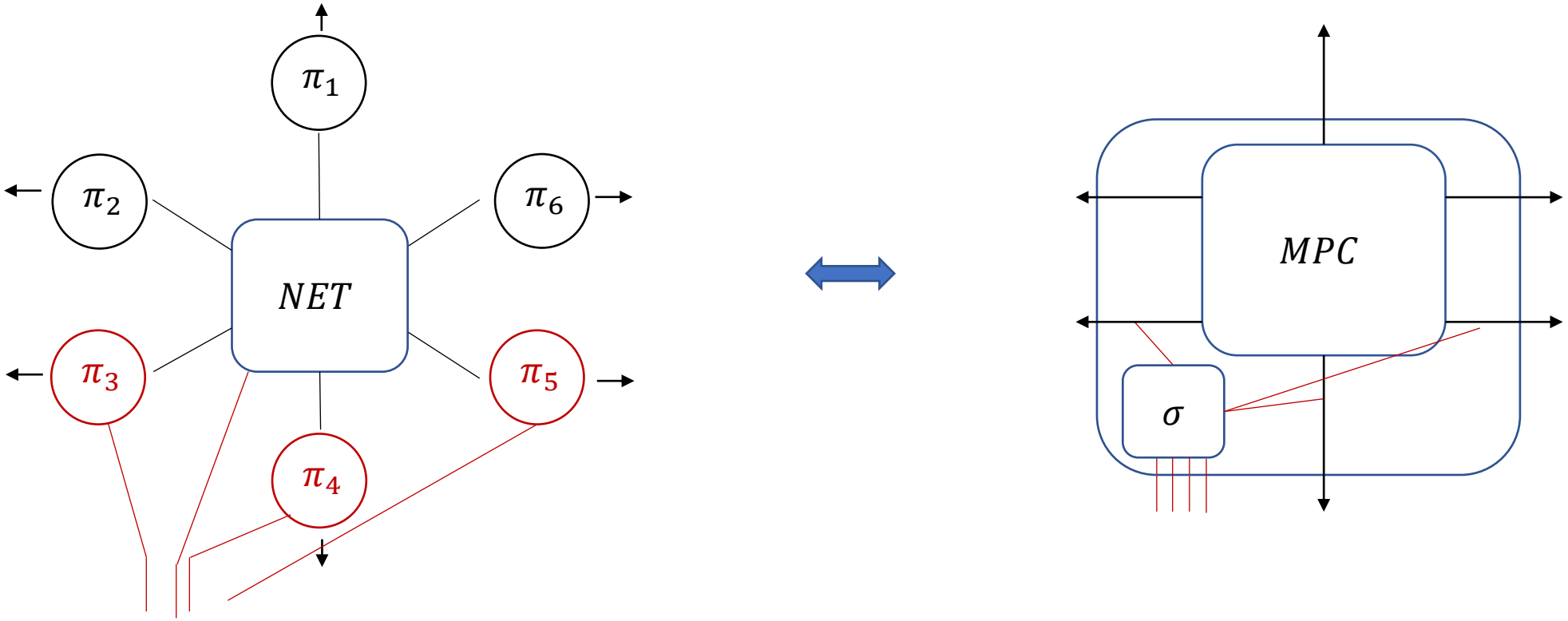
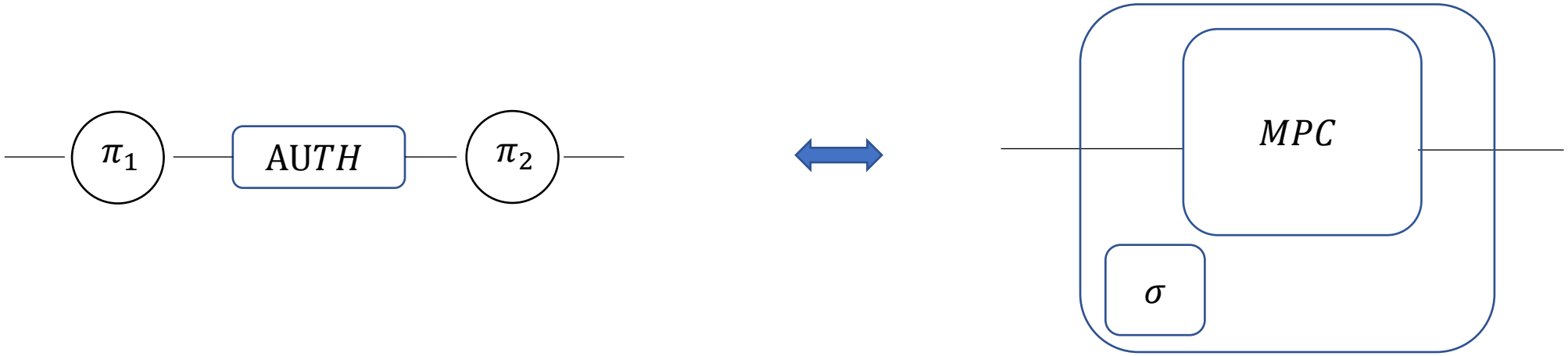


Commitment Problem



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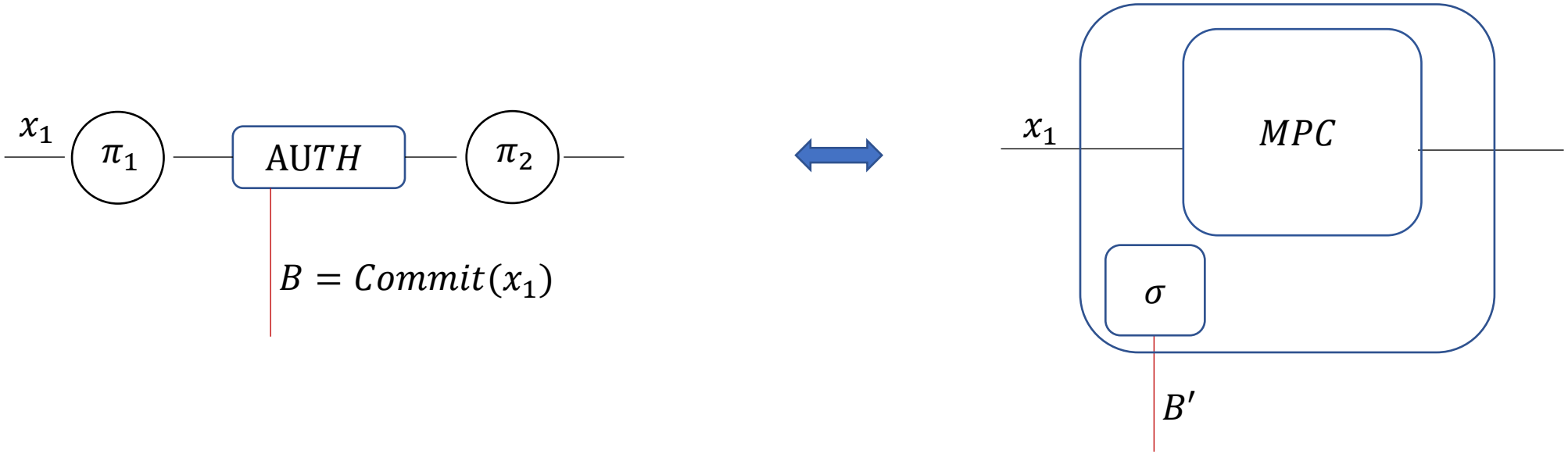

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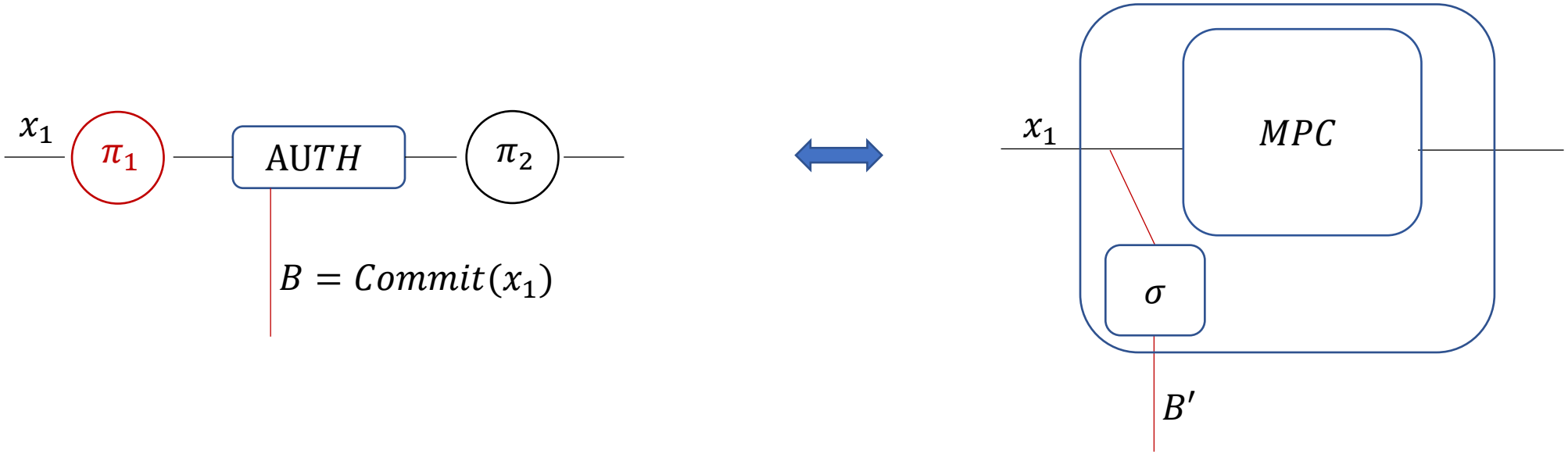

σ cannot open B' to x_1

Commitment Problem

Super-Secure Protocol

1. Receive input x_1
2.
3.
4.
…

Commitment Problem

Random Stuff

1. Receive input x_1
2. $B = Commit(x_1)$
3. Publish B

Super-Secure Protocol

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Random Stuff

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Super-Secure Protocol

1. Receive input x_1
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3.
4.
…

Secure Erasures

Non-committing primitives

Is there a natural definition for adaptive security that is not subject to the commitment problem?

Our Solution

$\forall X \subseteq \mathcal{P}$ as long as X is honest: $Guarantee(X)$ holds

$\emptyset$
$\{P_1\}$
$\{P_2\}$
$\{P_3\}$
$\{P_1, P_2\}$
$\{P_1, P_3\}$
$\{P_2, P_3\}$
$\{P_1, P_2, P_3\}$

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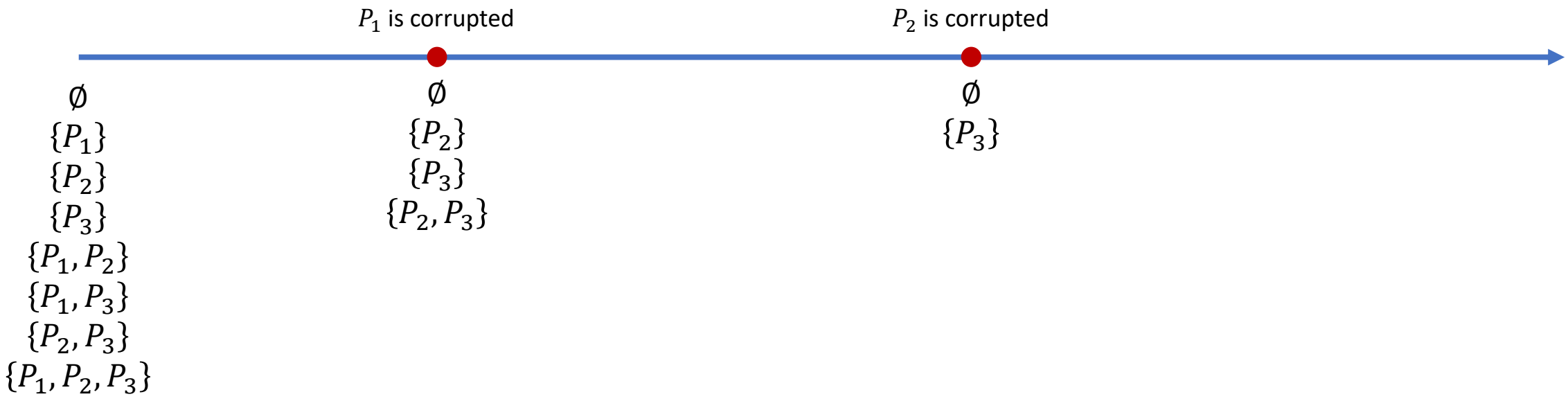

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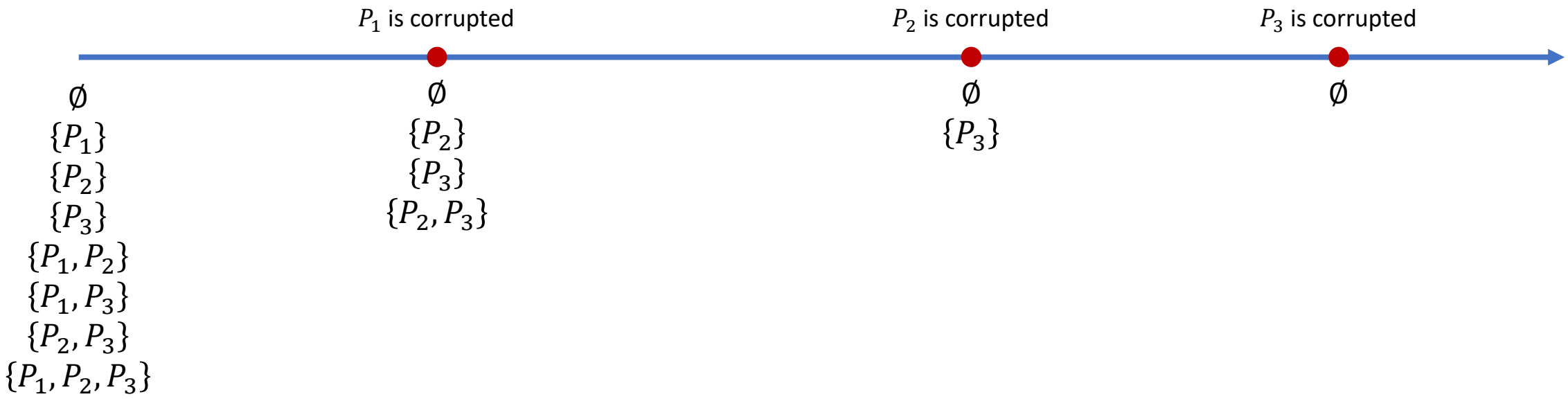

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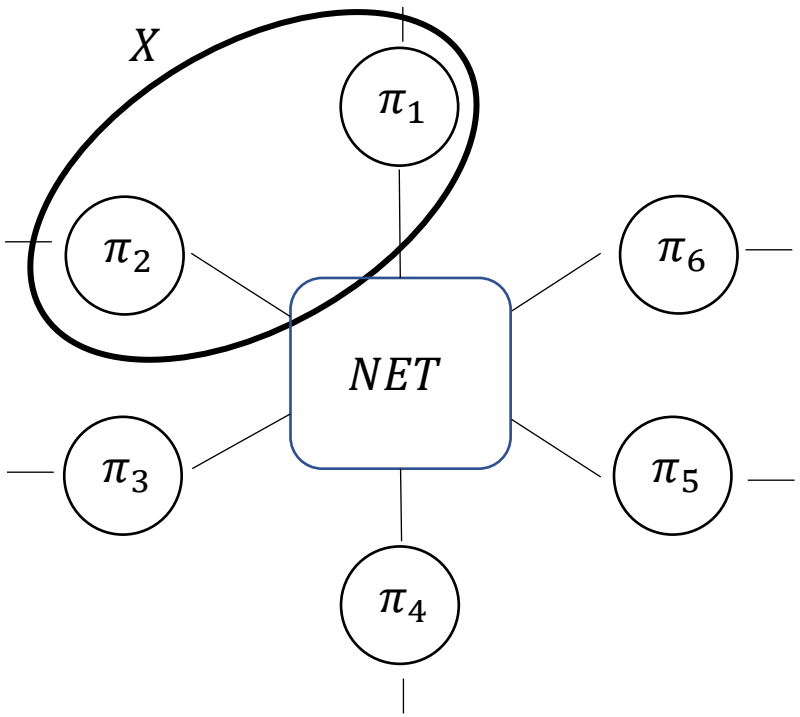
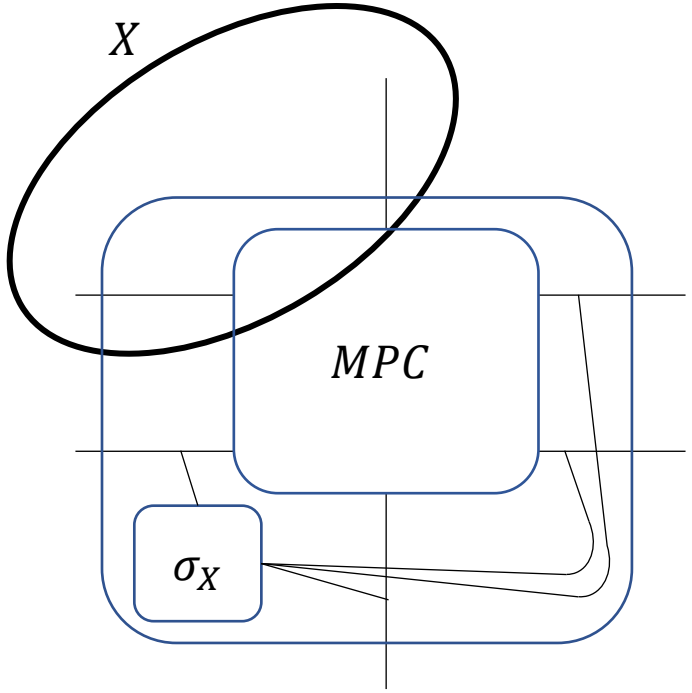
$Guarantee(X)$:

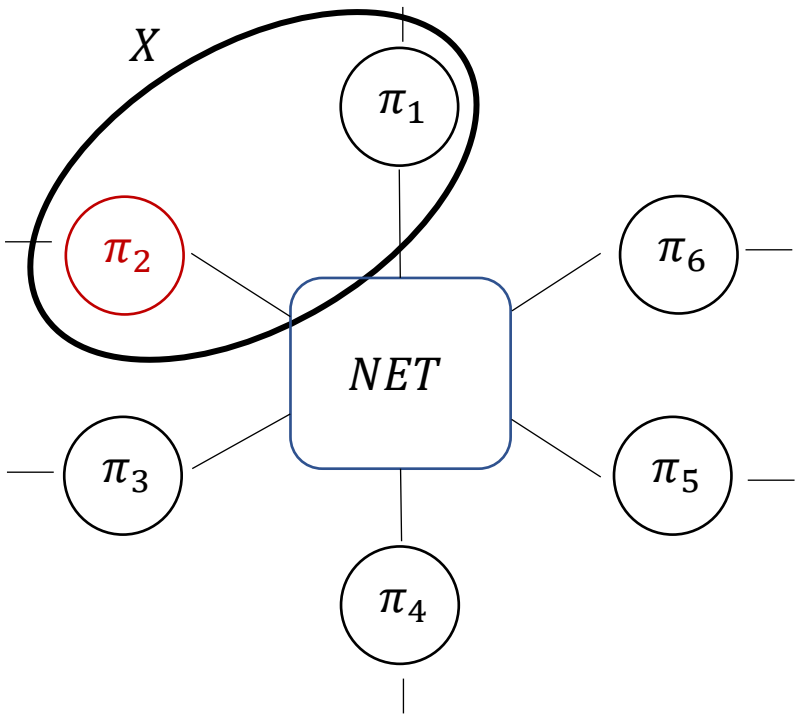


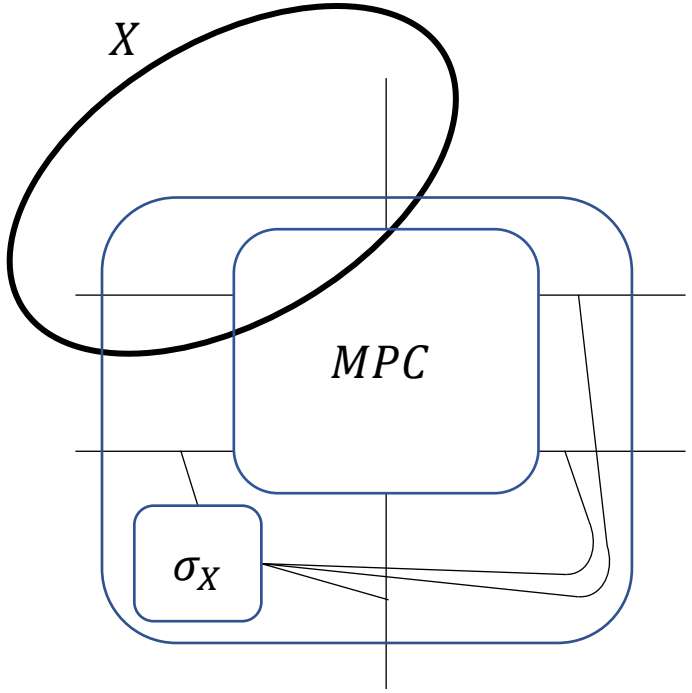


σ_X can read inputs from $\mathcal{P} \setminus X$

Our Solution

$Guarantee(X)$:



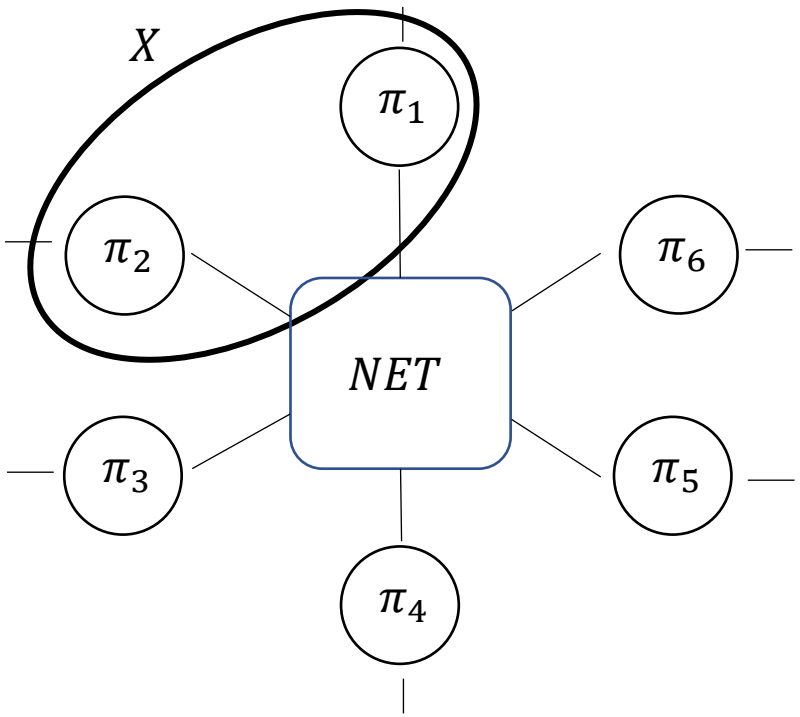


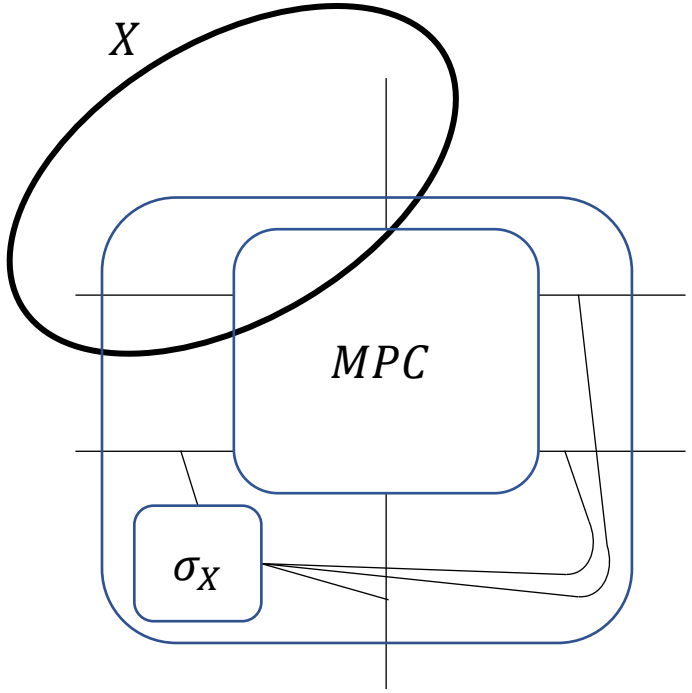
σ_X can read inputs from $\mathcal{P} \setminus X$

If any party in X is corrupted, the guarantee is dropped

Our Solution

$Guarantee(X)$:





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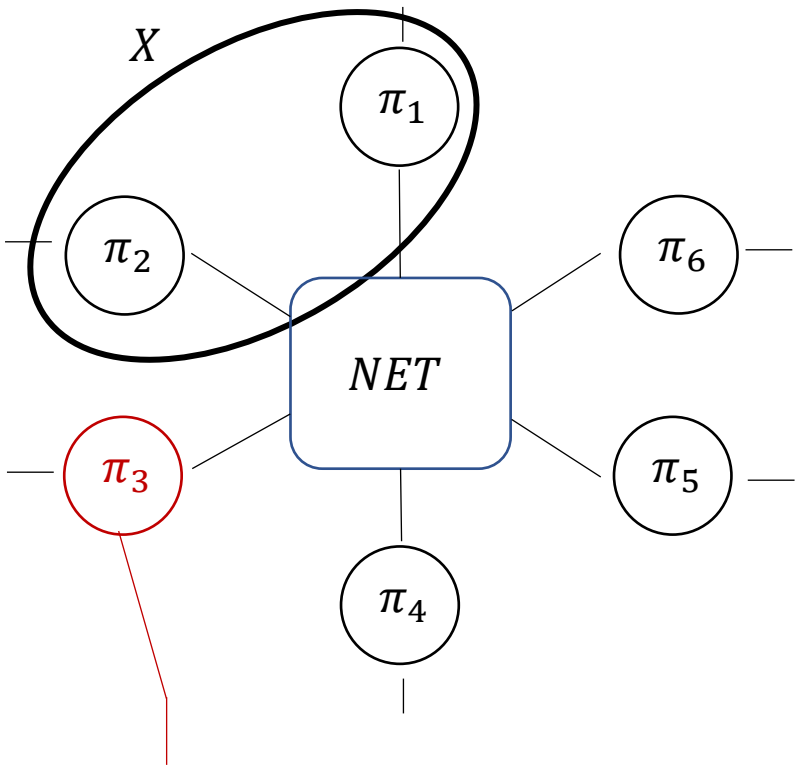
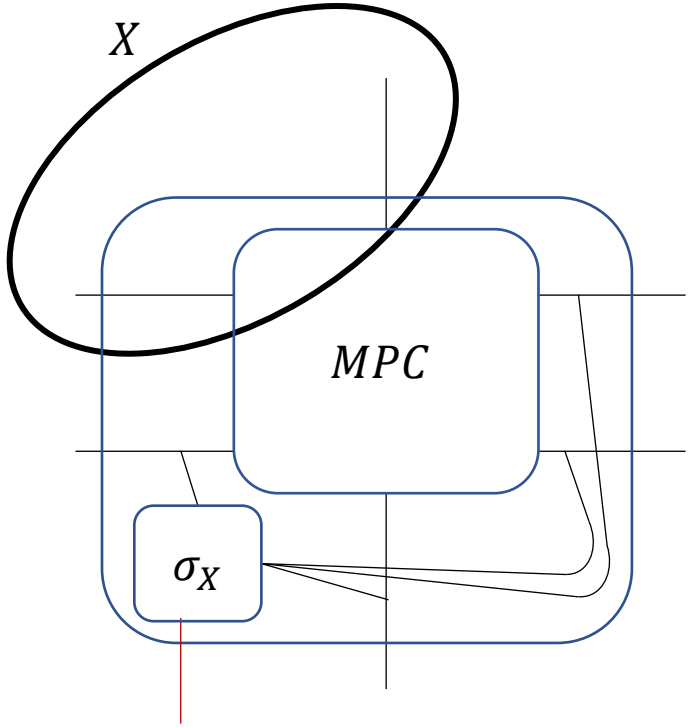
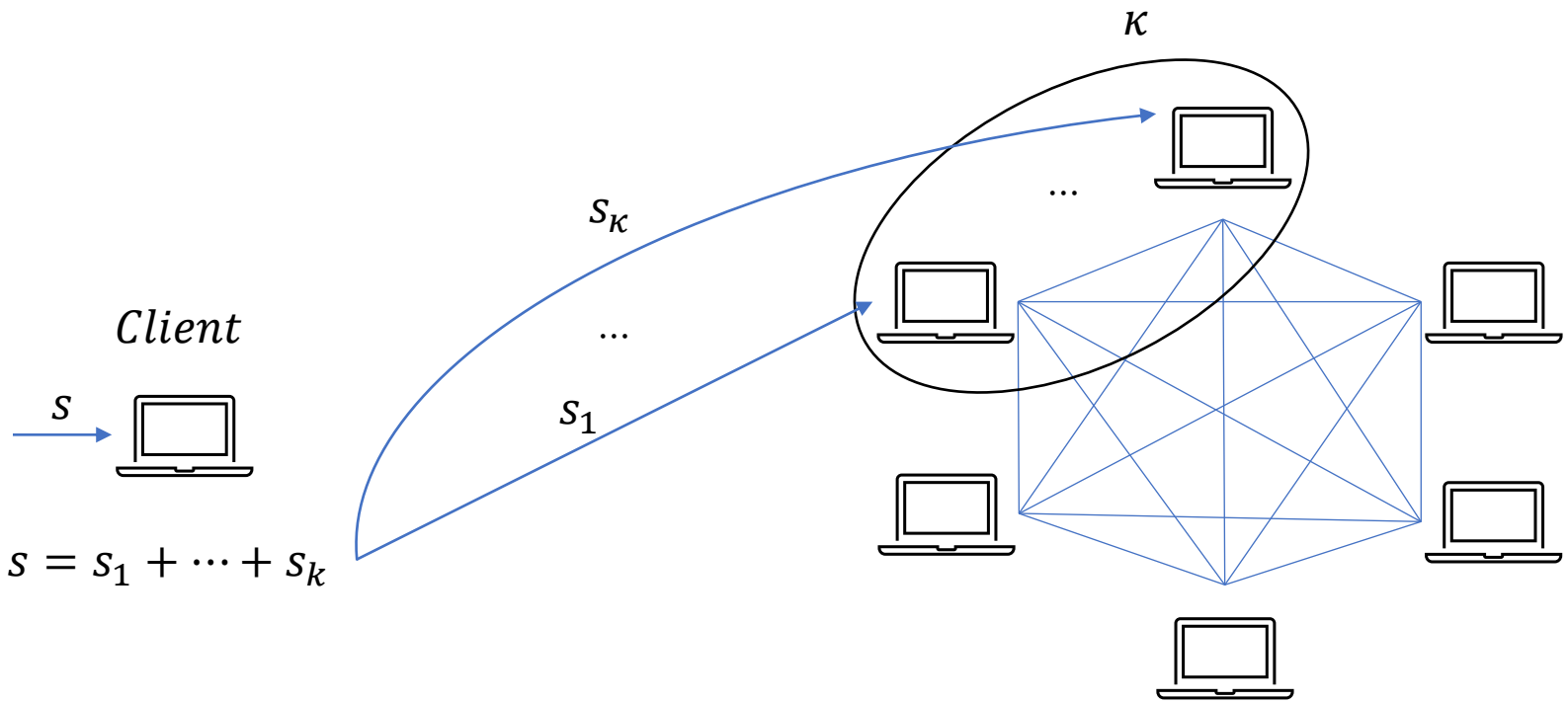




σ_X can read inputs from $\mathcal{P} \setminus X$

σ_X can explain the state of parties in $\mathcal{P} \setminus X$

A Simple Example



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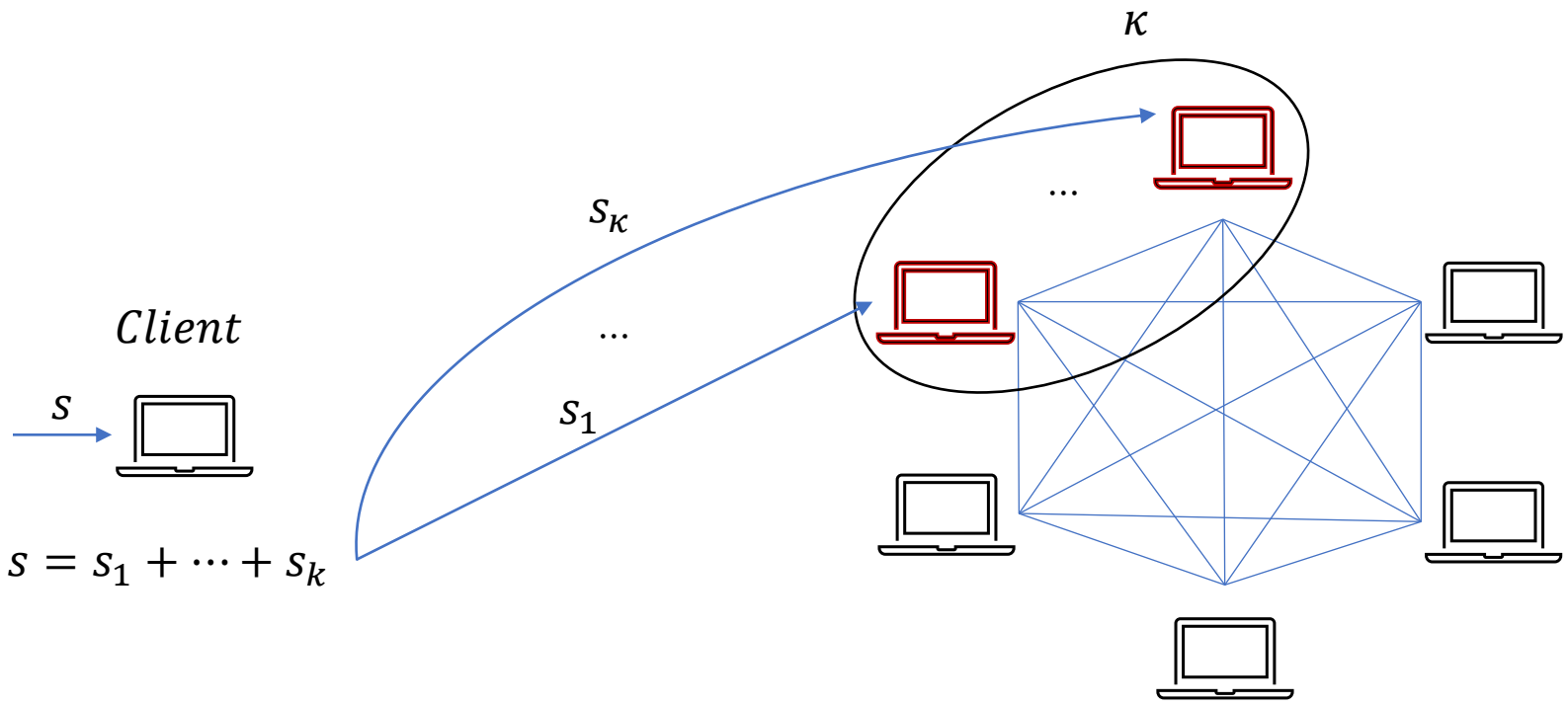


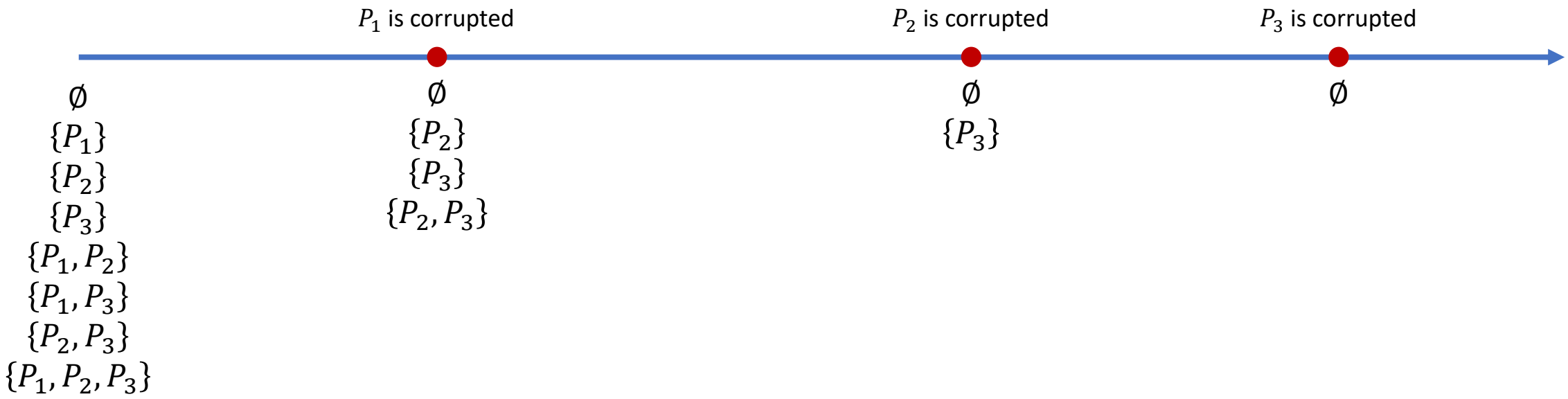
$X = \{Client\}$

$Guarantee(X)$ holds as long as $Client$ is honest

The adversary can adaptively corrupt the small set and learn the secret, which the simulator cannot output

Our Solution

$\forall X \subseteq \mathcal{P}$ as long as X is honest: $Guarantee(X)$ holds



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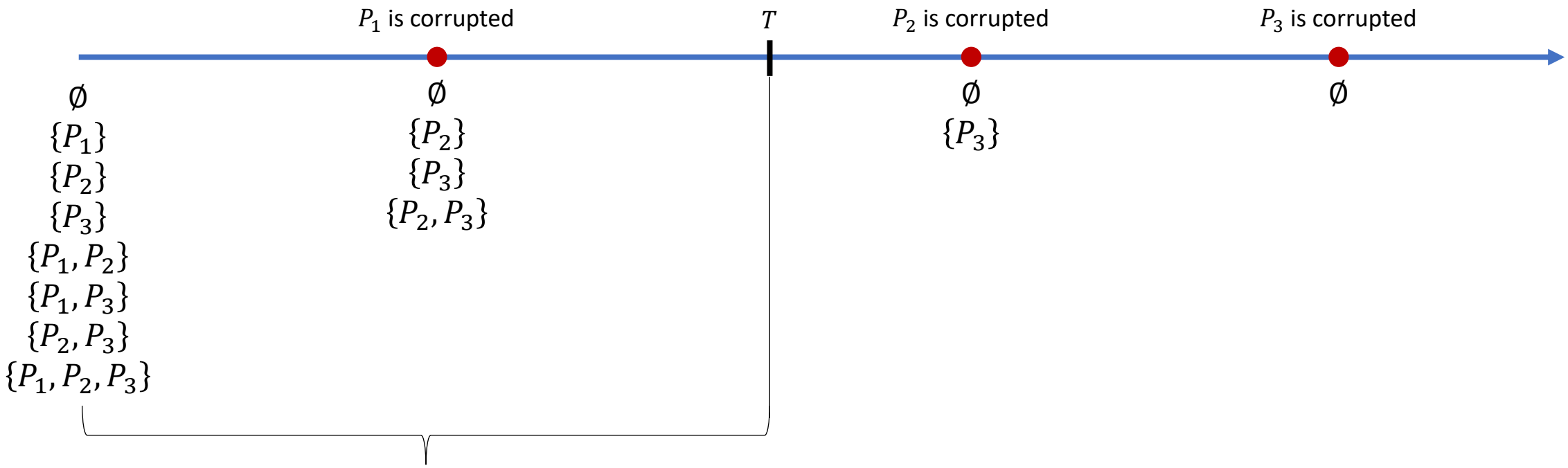
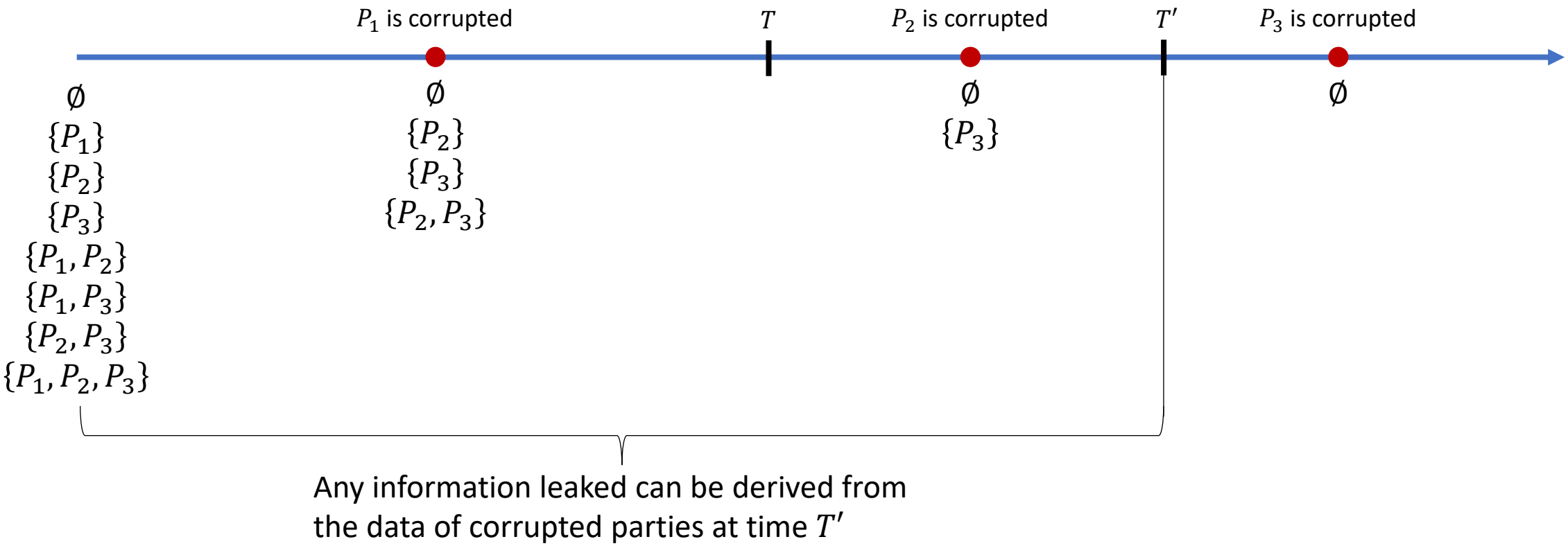


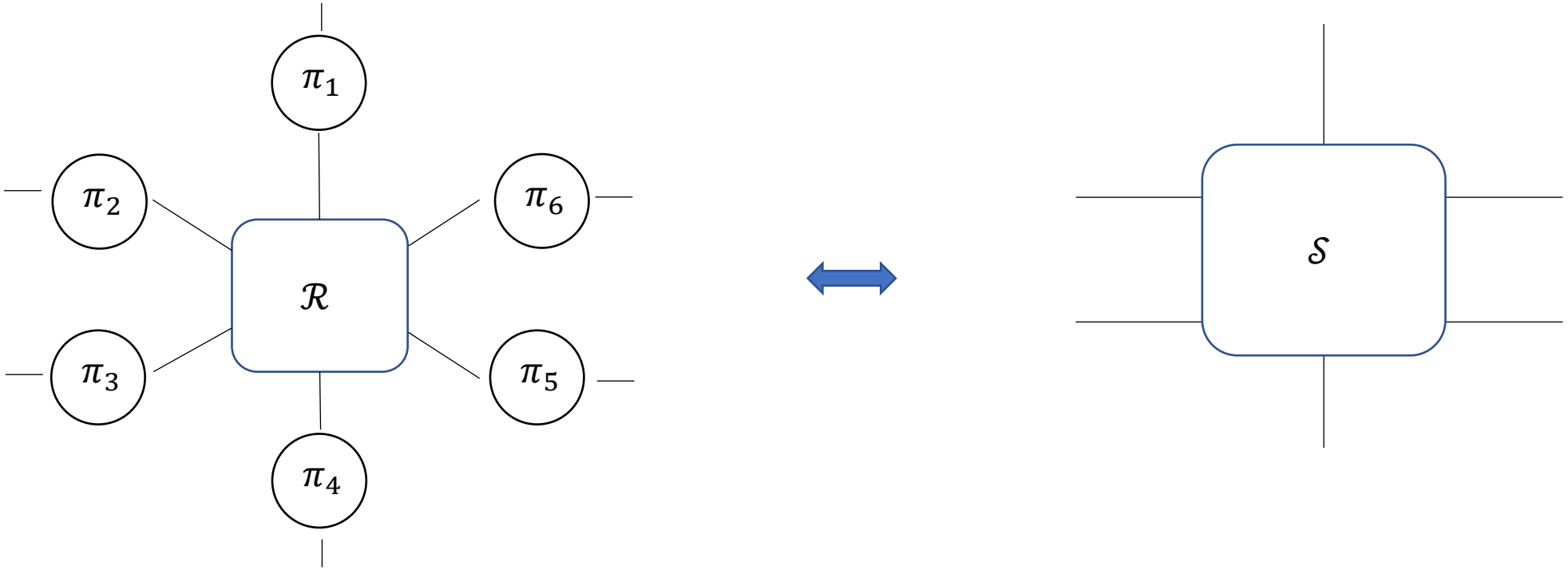
Any information leaked can be derived from the data of corrupted parties at time T

Our Solution

$\forall X \subseteq \mathcal{P}$ as long as X is honest: $Guarantee(X)$ holds



Constructive Cryptography



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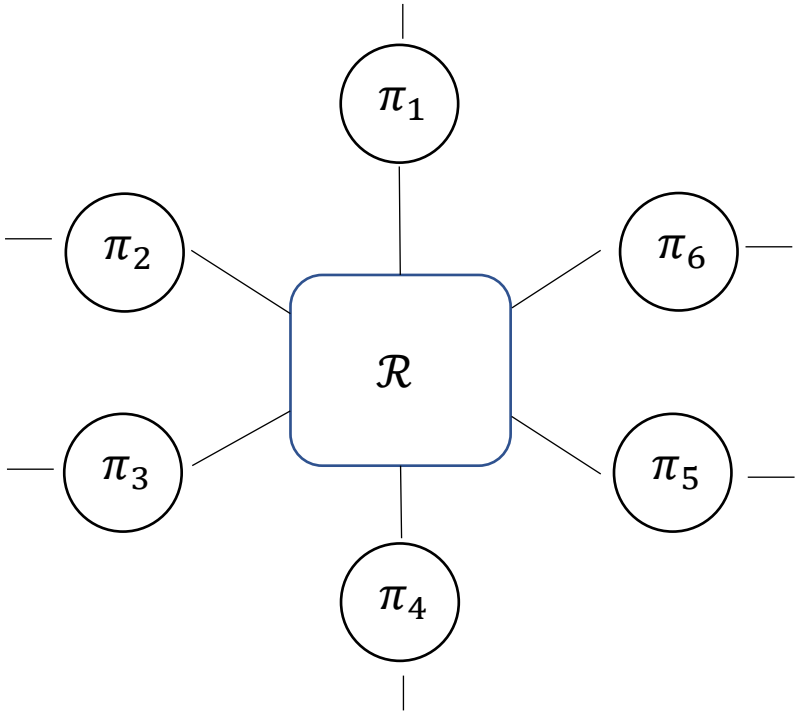
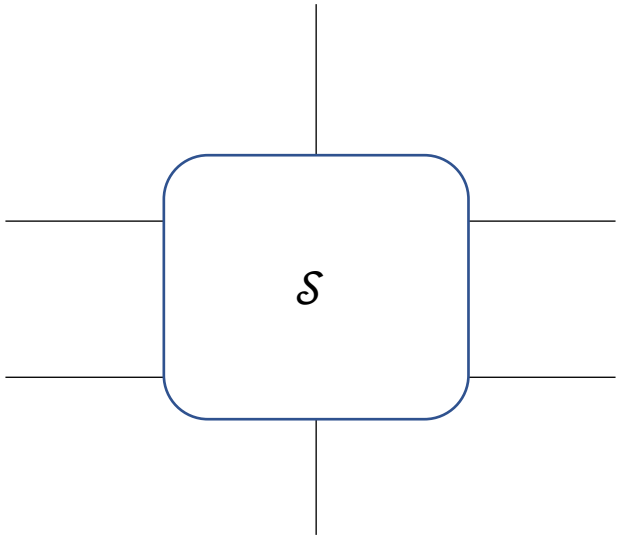


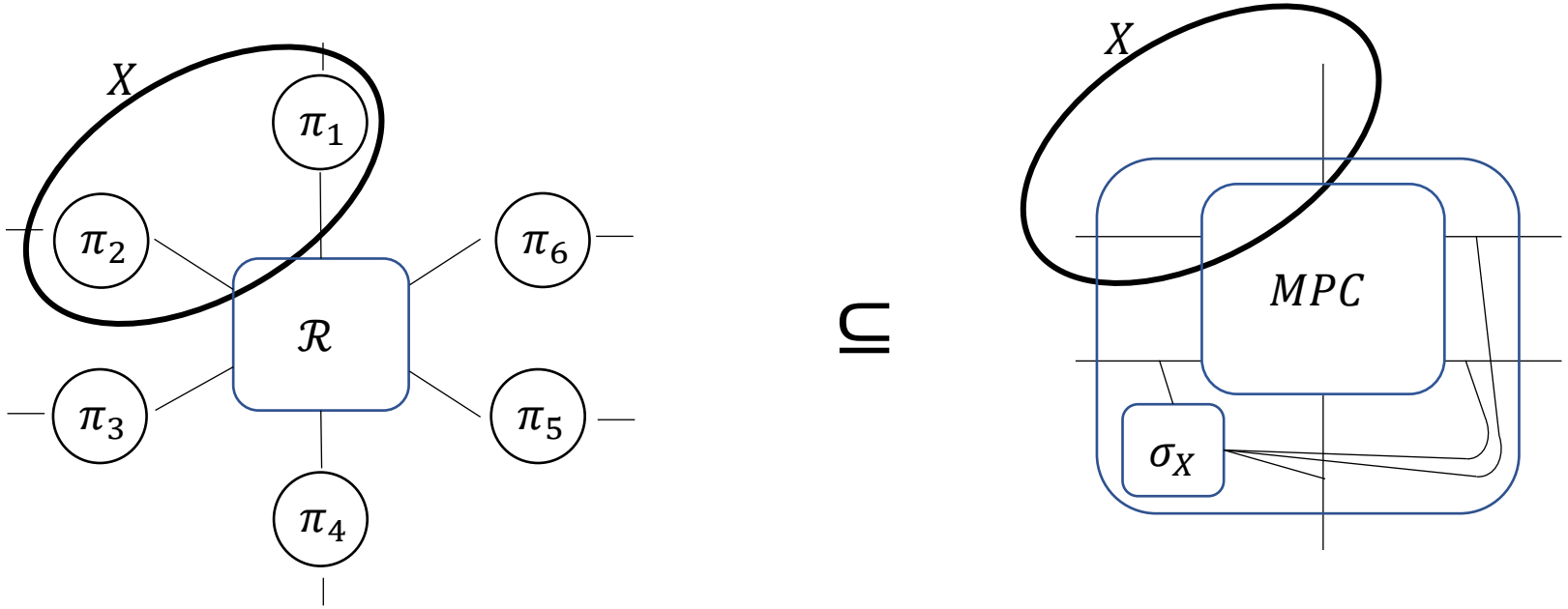
$\subseteq$



$$\pi\mathcal{R} \subseteq \mathcal{S}$$

Constructive Cryptography

$Guarantee(X)$ holds until any party in X is corrupted



$$\forall X \subseteq \mathcal{P}\colon \pi\mathcal{R} \subseteq \mathcal{S}_X \coloneqq (\sigma_X MPC)^{\mathcal{E}_X}$$

$$\Leftrightarrow \pi\mathcal{R} \subseteq \mathcal{S} \coloneqq \bigcap_{X \subseteq \mathcal{P}} \mathcal{S}_X$$

Set of all systems that behave like $\sigma_X MPC$
until event $\mathcal{E}_X$ happens (any party in X is corrupted)

Some Lemmas

Standard Adaptive $\rightleftarrows$ New Notion $\rightleftarrows$ Static

New notion overcomes the commitment problem

Many protocols ‘believed’ to be adaptively secure in practice but not secure under current adaptive security notion satisfy the new notion: CDN, CLOS

Strong adaptive security guarantees

Typical examples separating static from adaptive security also separate static from the new notion

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Paper:
eprint.iacr.org/2021/1175