BLAZE: BLAZING FAST PRIVACY-PRESERVING MACHINE LEARNING

ARPITA PATRA AND **AJITH SURESH**

Ajith Suresh
CrIS Lab, IISc
https://www.csa.iisc.ac.in/~cris

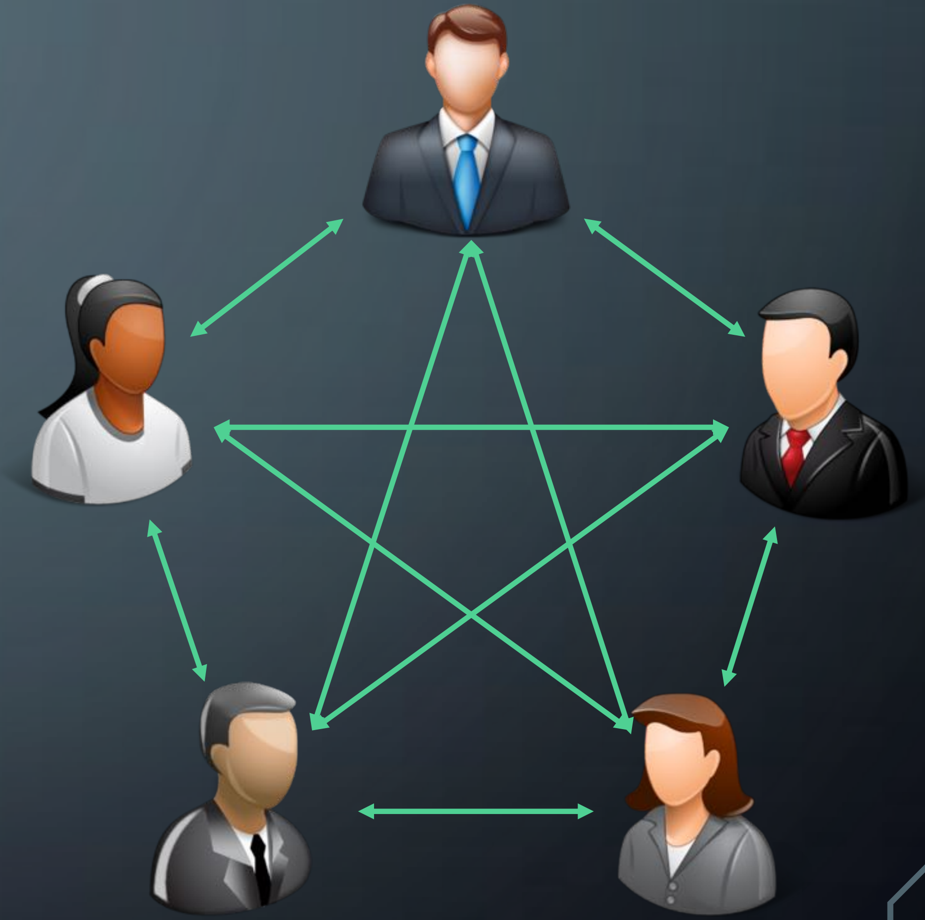
Outline

- Secure Multi-party Computation (MPC)
- MPC for small number of parties (3PC)
- Our Efficient BLAZE Protocol (Results)
- Privacy Preserving Machine Learning (PPML)

Secure Multi-party Computation (MPC) [Yao'82]

- ✓ A set of parties with private inputs wish to compute some joint function of their inputs.

- ✓ Goals of MPC:
  - **Correctness** – Parties should correctly evaluate the function output.
  - **Privacy** – Nothing more than the function output should be revealed



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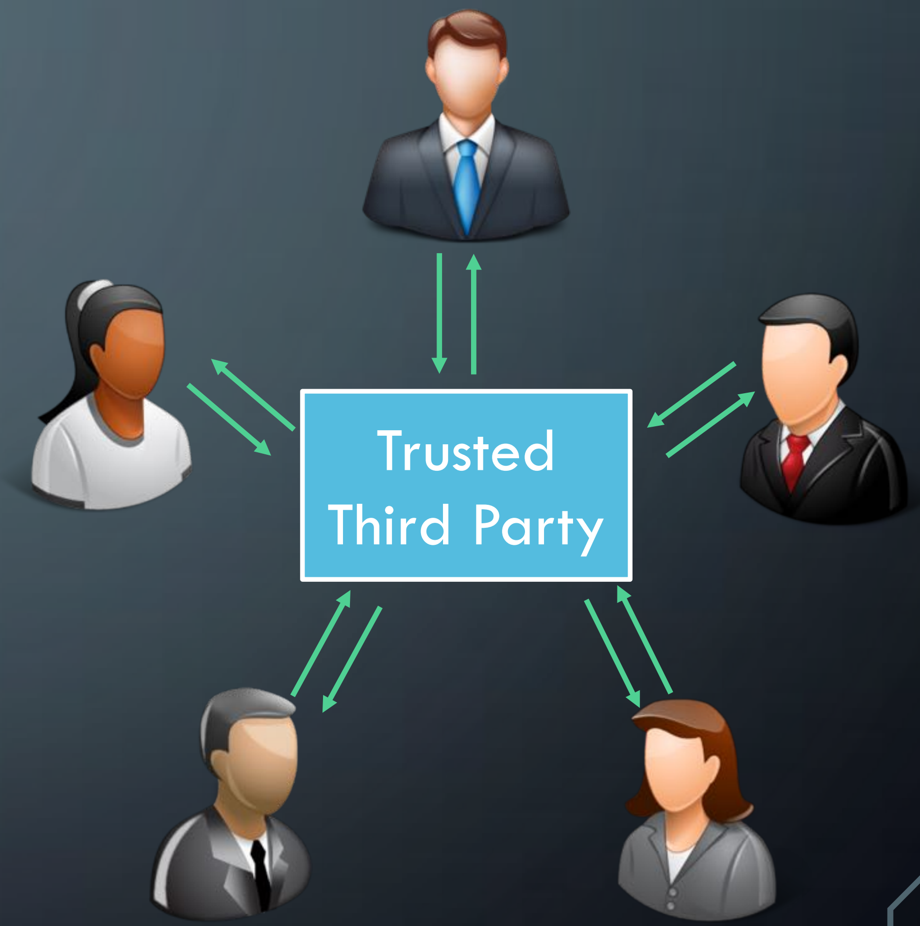

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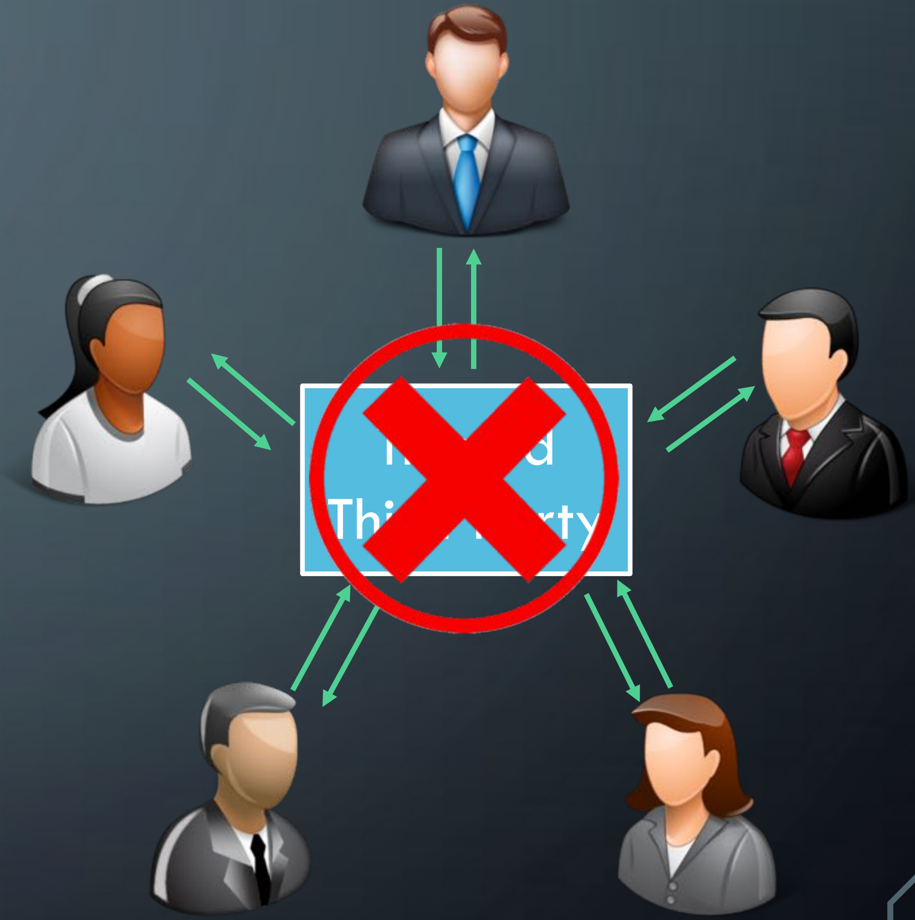

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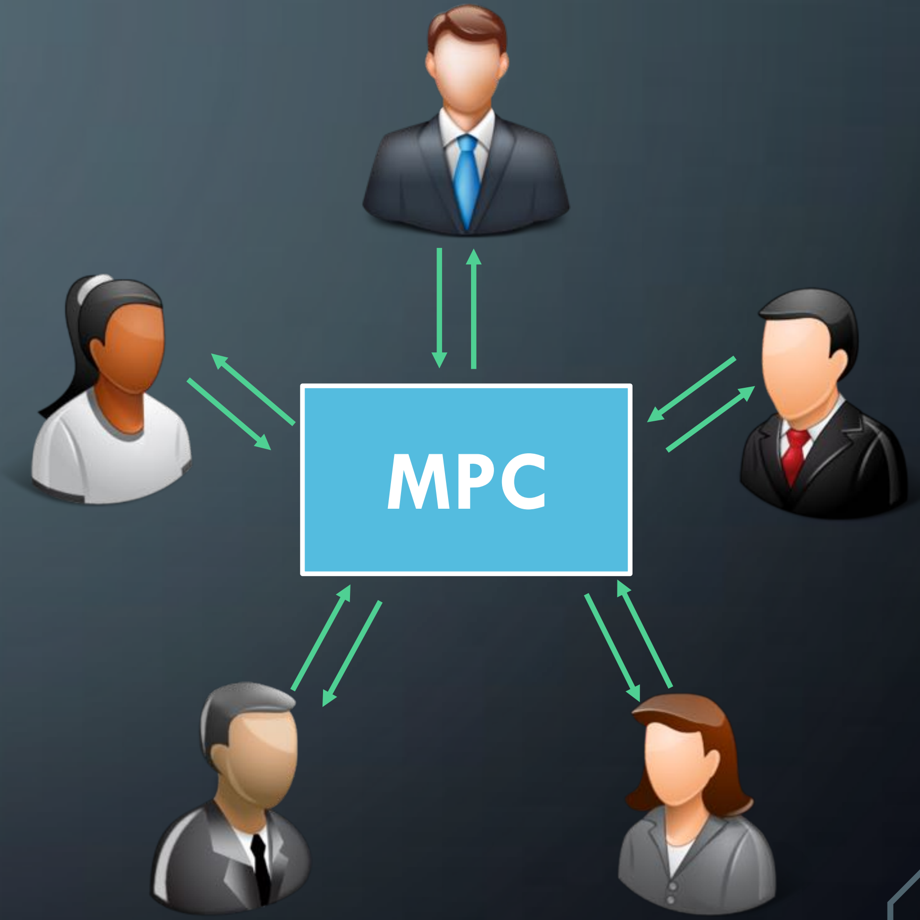
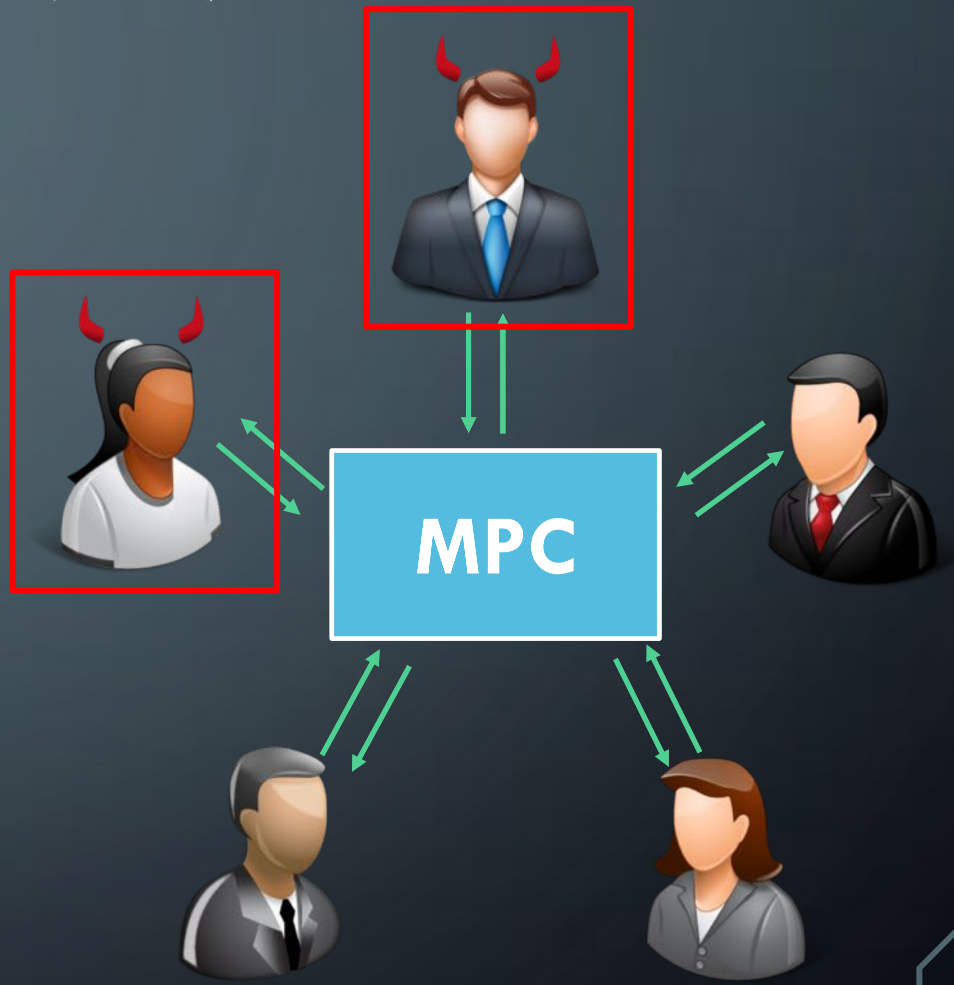


Secure Multi-party Computation (MPC) [Yao'82]

ADVERSARY

- Semi – honest:
  - Follows the protocol but tries to learn more
- Malicious:
  - Can arbitrarily deviate from the protocol



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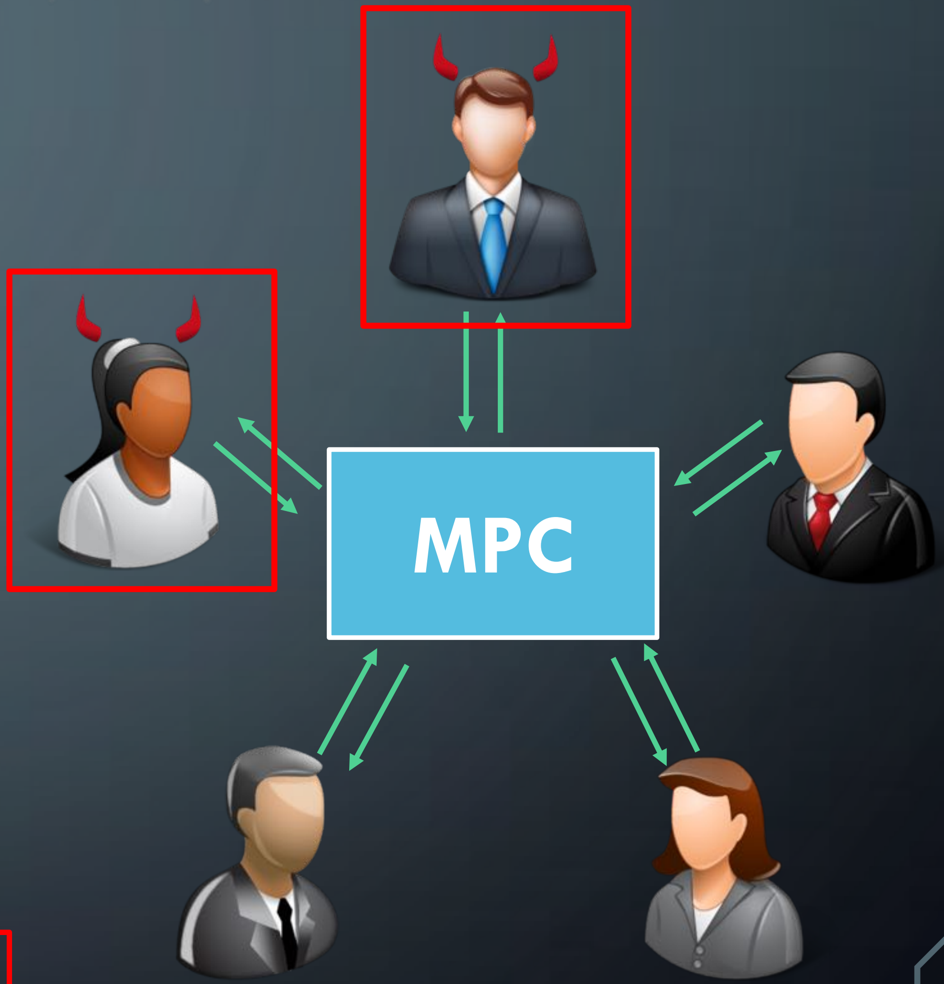


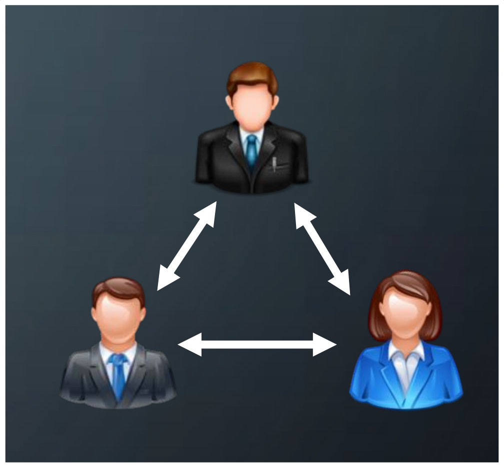
Malicious Corruption

MPC for small number of parties

- Efficiency and Simplicity [MRZ15,AFLNO16,FLNW17,CGMV17]

MPC for small number of parties

- **Efficiency** and **Simplicity** [MRZ15,AFLNO16,FLNW17,CGMV17]
- Our focus: MPC with 3 parties



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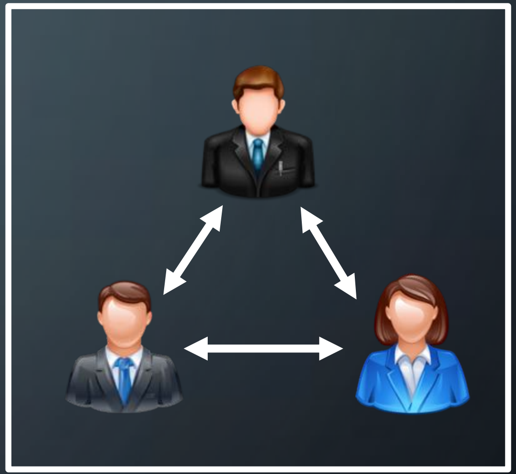

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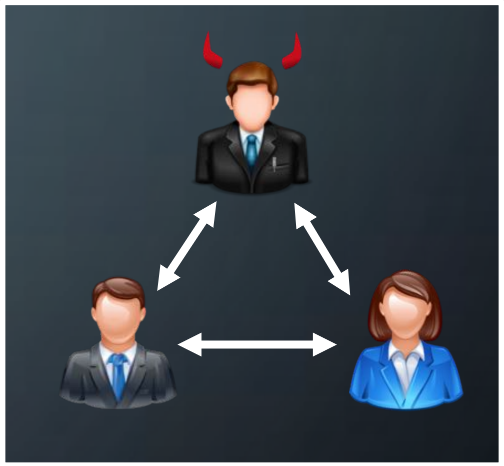
  - Majority of the parties are honest
  - 3PC - at most 1 corruption



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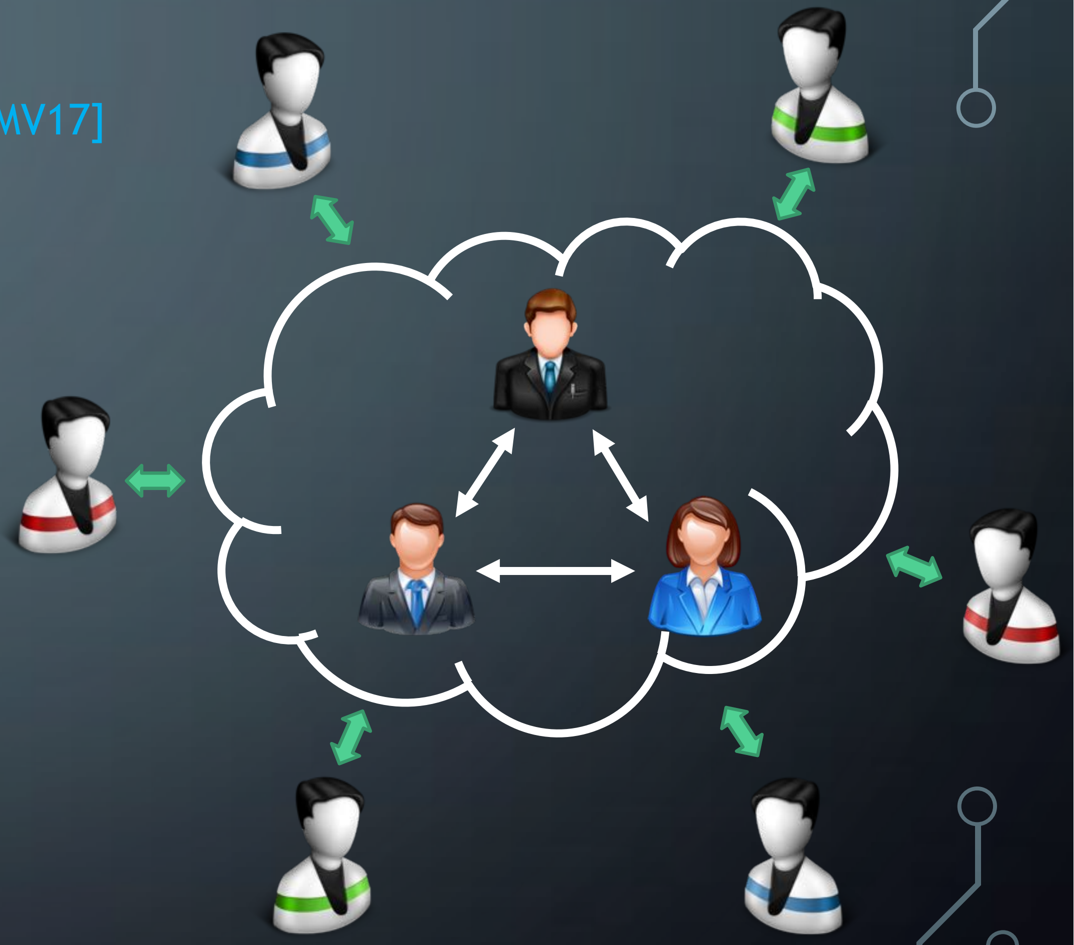

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- **Pre-processing Model**
  - **Pre-processing phase**

- Data-independent Computation
- Relatively slow and expensive

MPC for small number of parties

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- **Outsourced Computation**
- **Pre-processing Model**
  - **Pre-processing phase**
  - **Online Phase**

MPC for small number of parties

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- **Outsourced Computation**
- **Pre-processing Model**
  - **Pre-processing phase**
  - **Online Phase**

- Minimized communication
- Blazing fast

BLAZE PROTOCOL

BLAZE Protocol

S_0

S_1

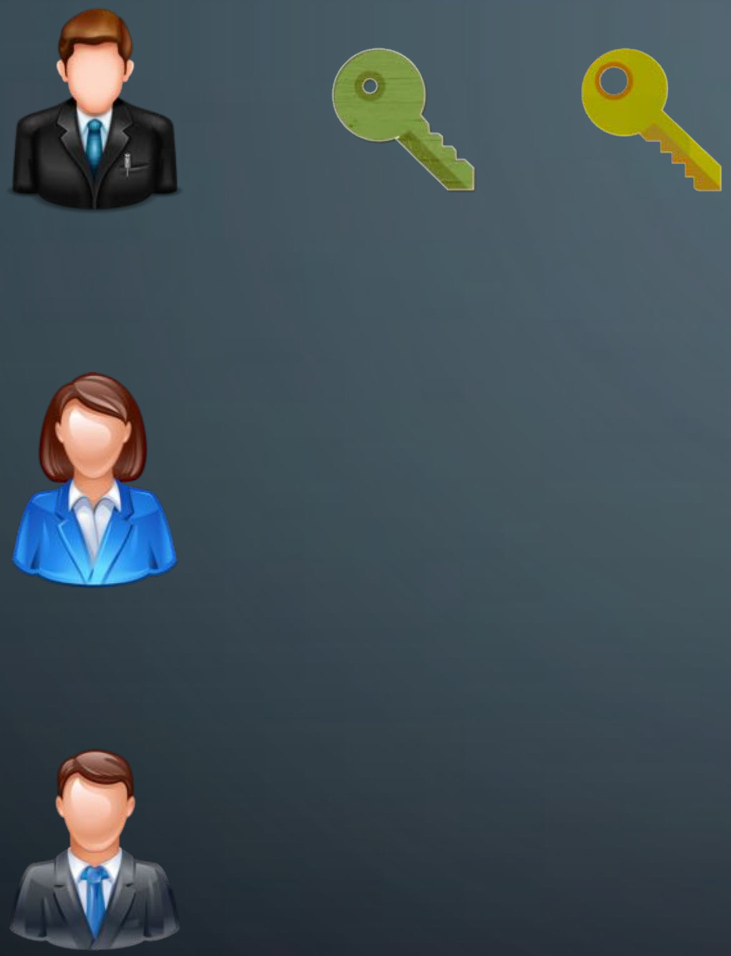
S_2

BLAZE Protocol

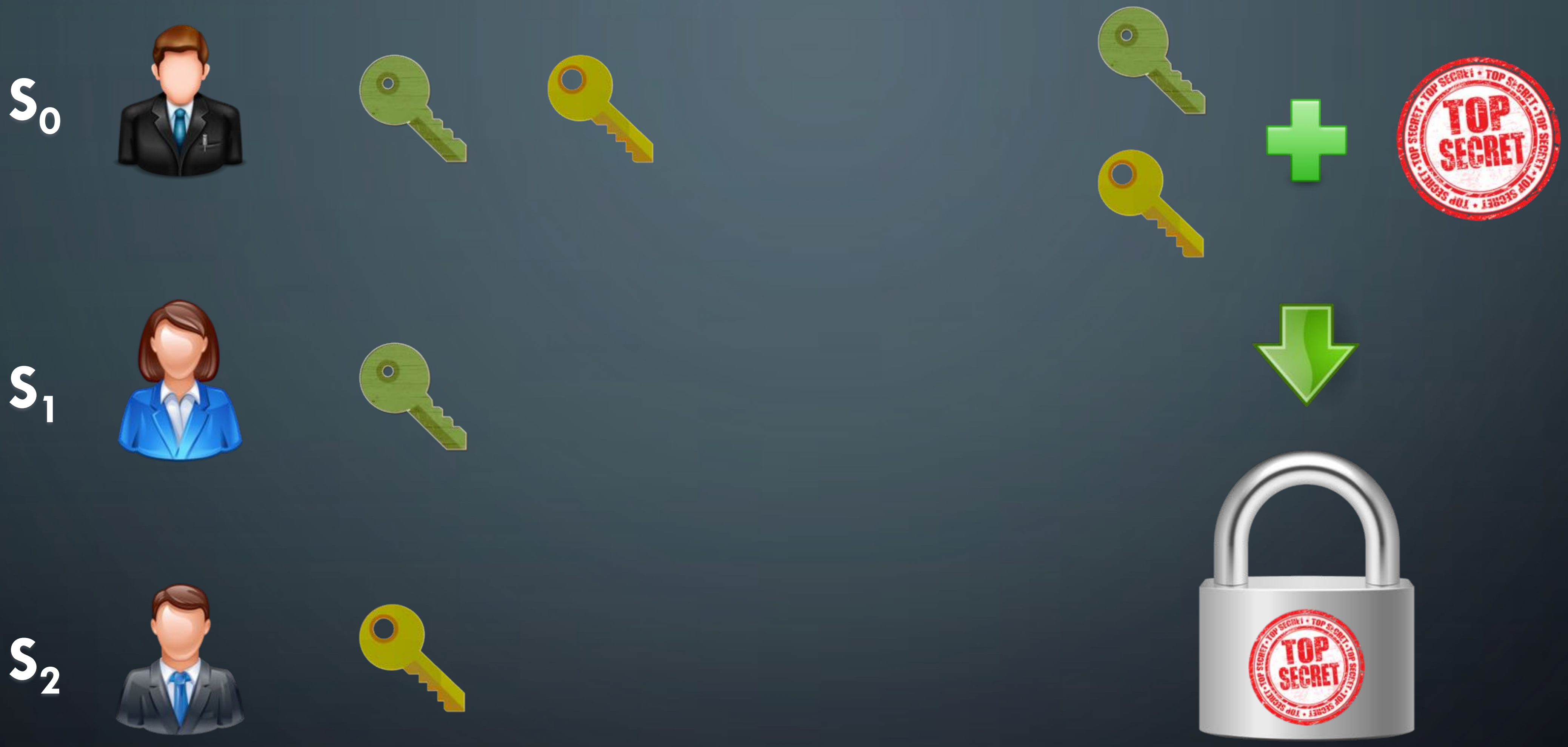
S_0

S_1

S_2



BLAZE Protocol



BLAZE Protocol

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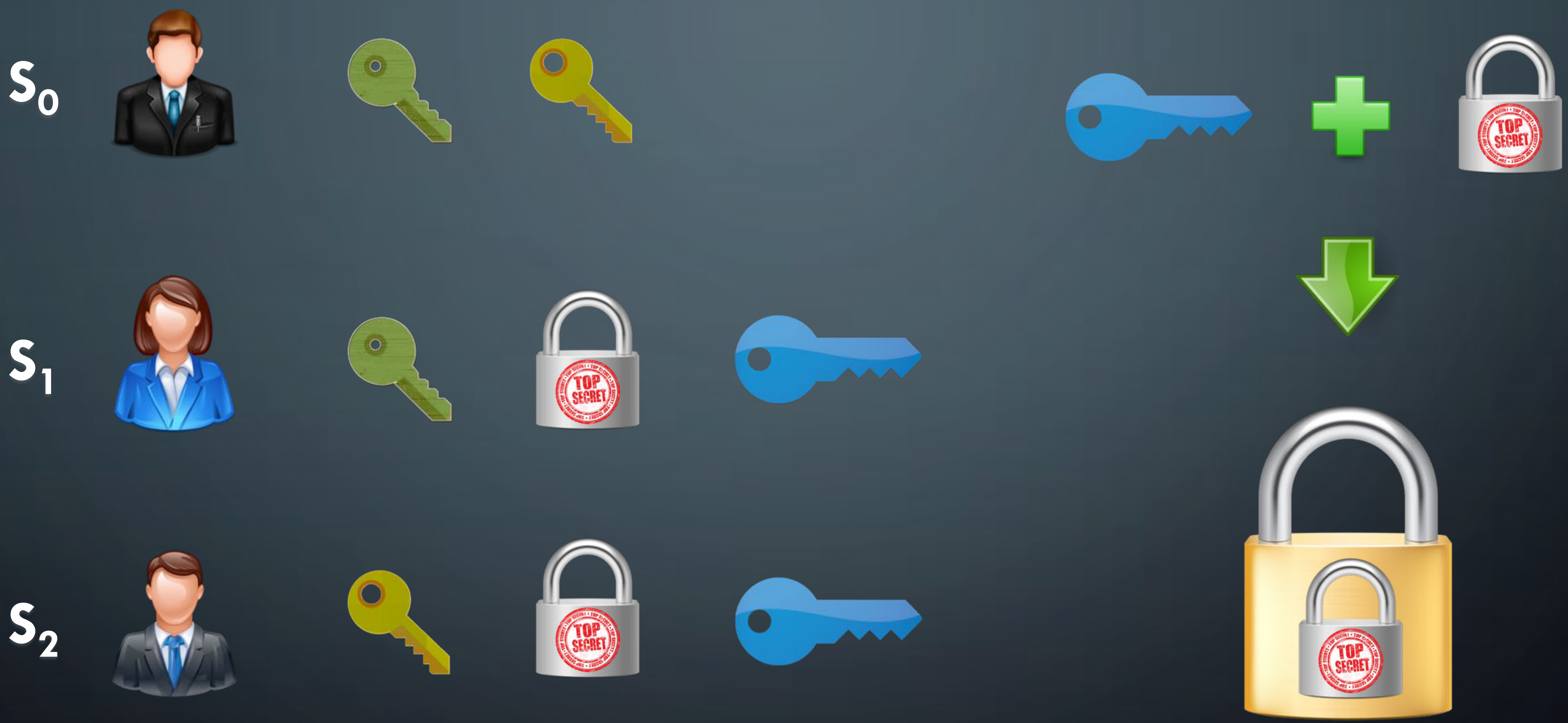

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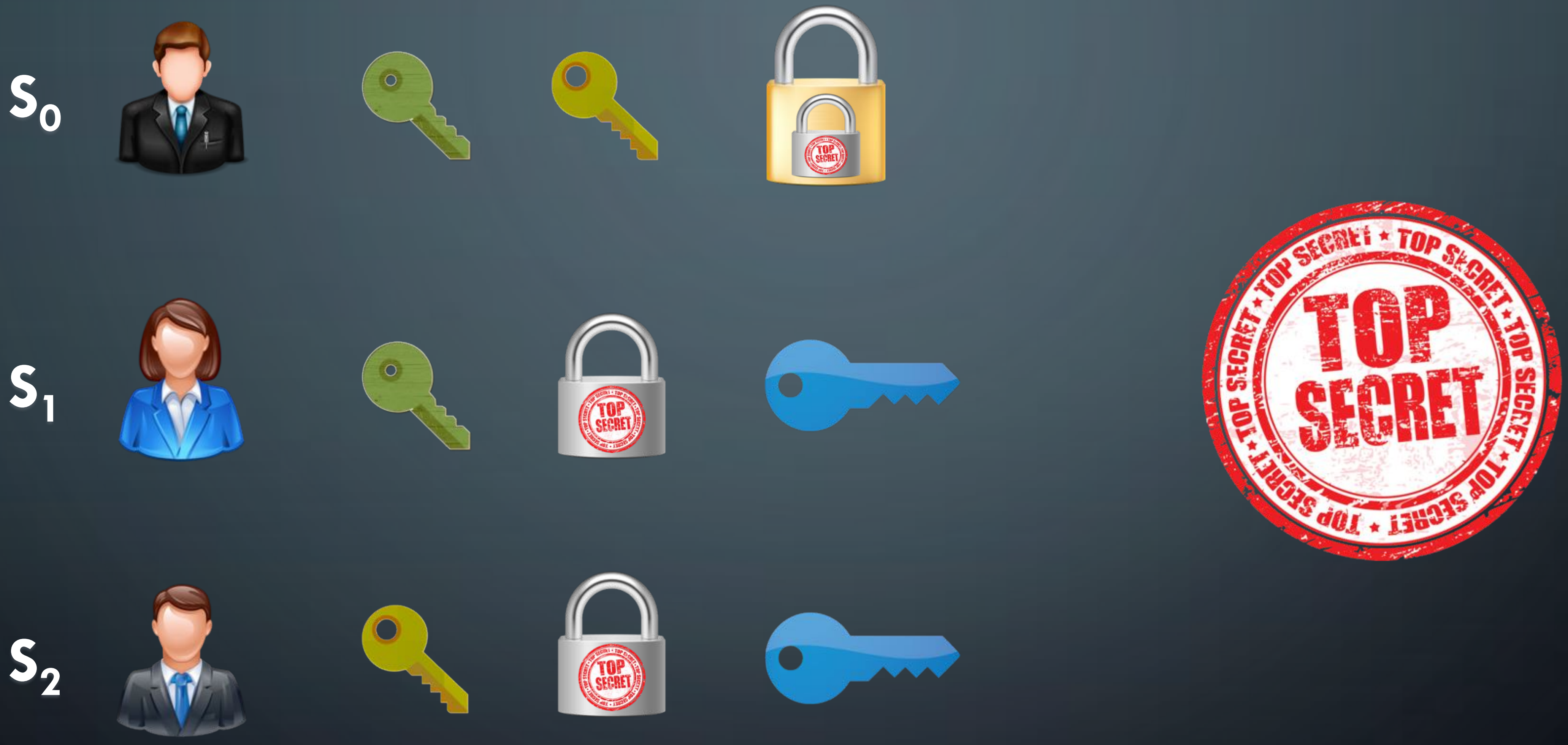

BLAZE Protocol

Communication Cost per
Multiplication Gate (malicious)

$Mult: x.y$

BLAZE : https://eprint.iacr.org/2020/042

BLAZE Protocol

Ref	Pre-processing (#elements)	Online (#elements)	Security
Araki et al'17	12	9	Abort

Communication Cost per
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BLAZE Protocol

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BLAZE Protocol

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Communication Cost per Multiplication Gate (malicious)

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BLAZE	**3**	**3**	**Fair**

Communication Cost per
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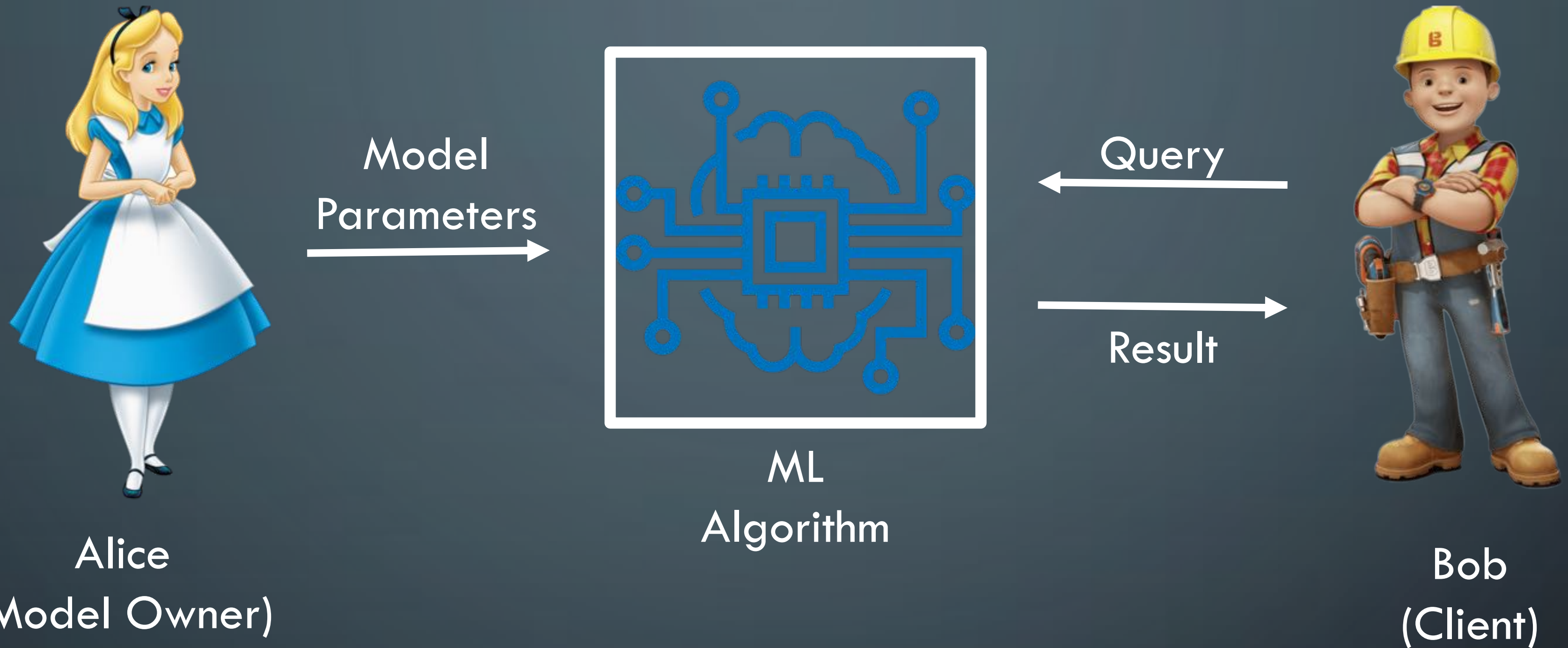
Privacy Preserving Machine Learning (PPML)

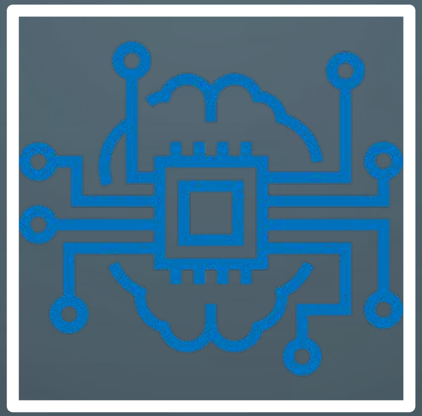


Privacy ??

Privacy Preserving Machine Learning (PPML)

Alice
(Model Owner)

Model Parameters



ML Algorithm

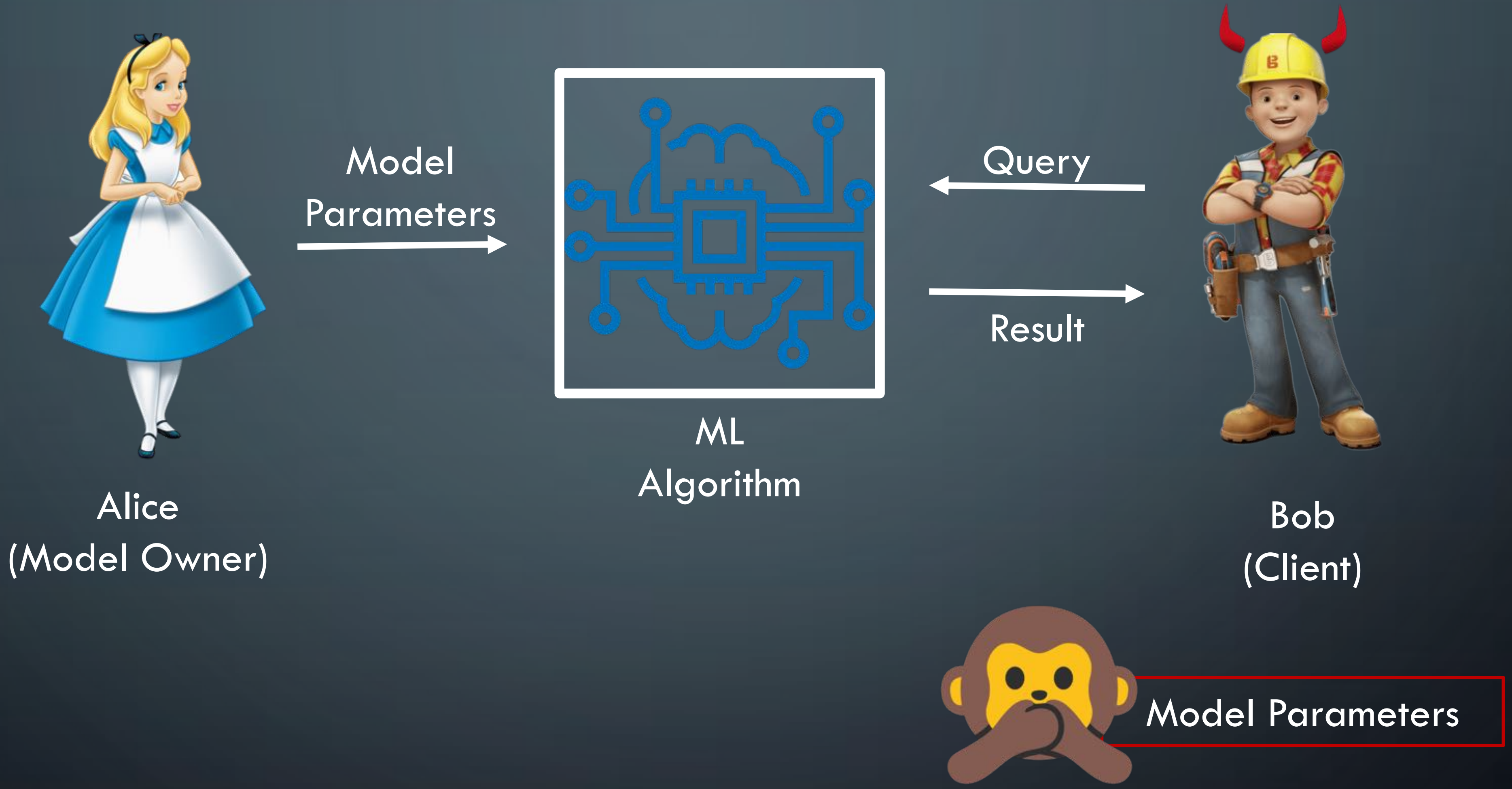
Query

Result

Bob
(Client)

Query

Privacy Preserving Machine Learning (PPML)

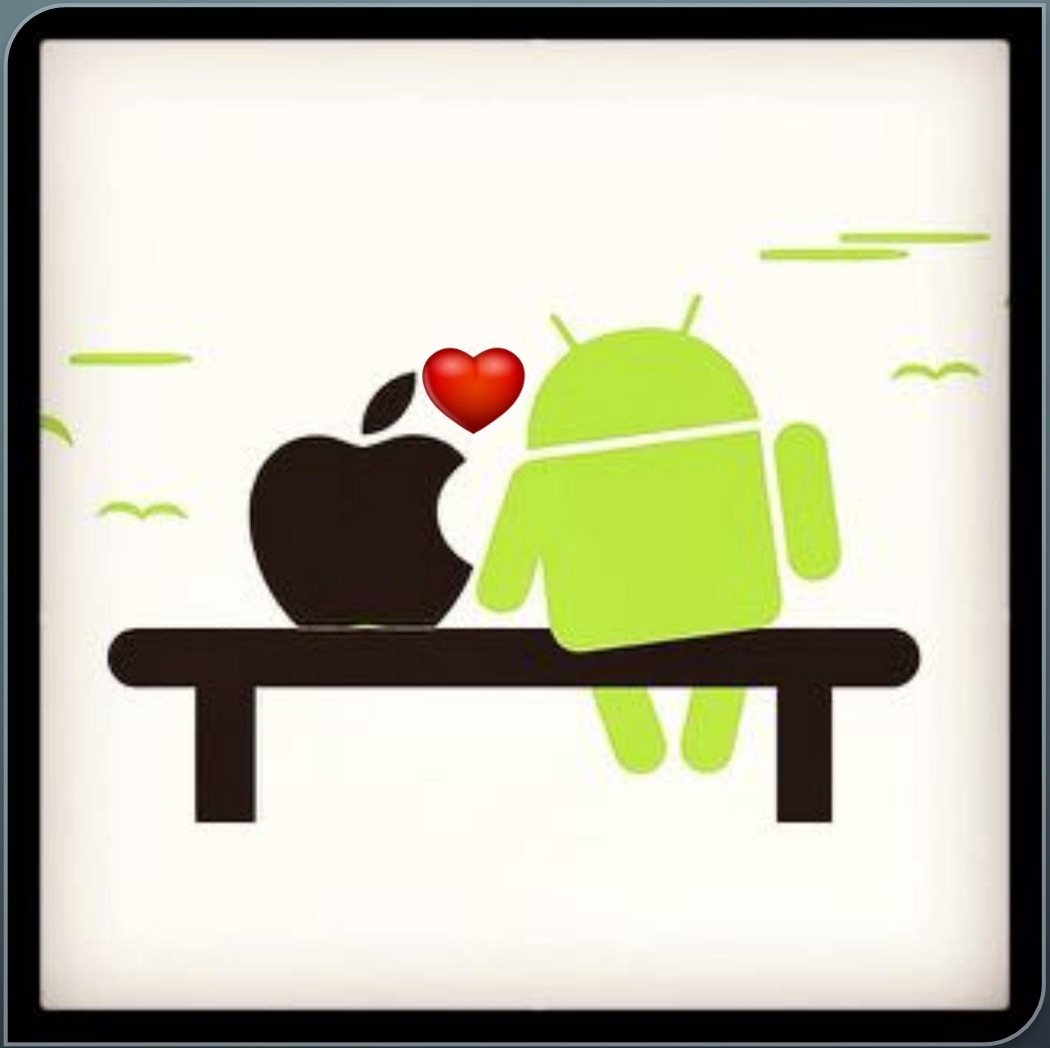


Solution ??

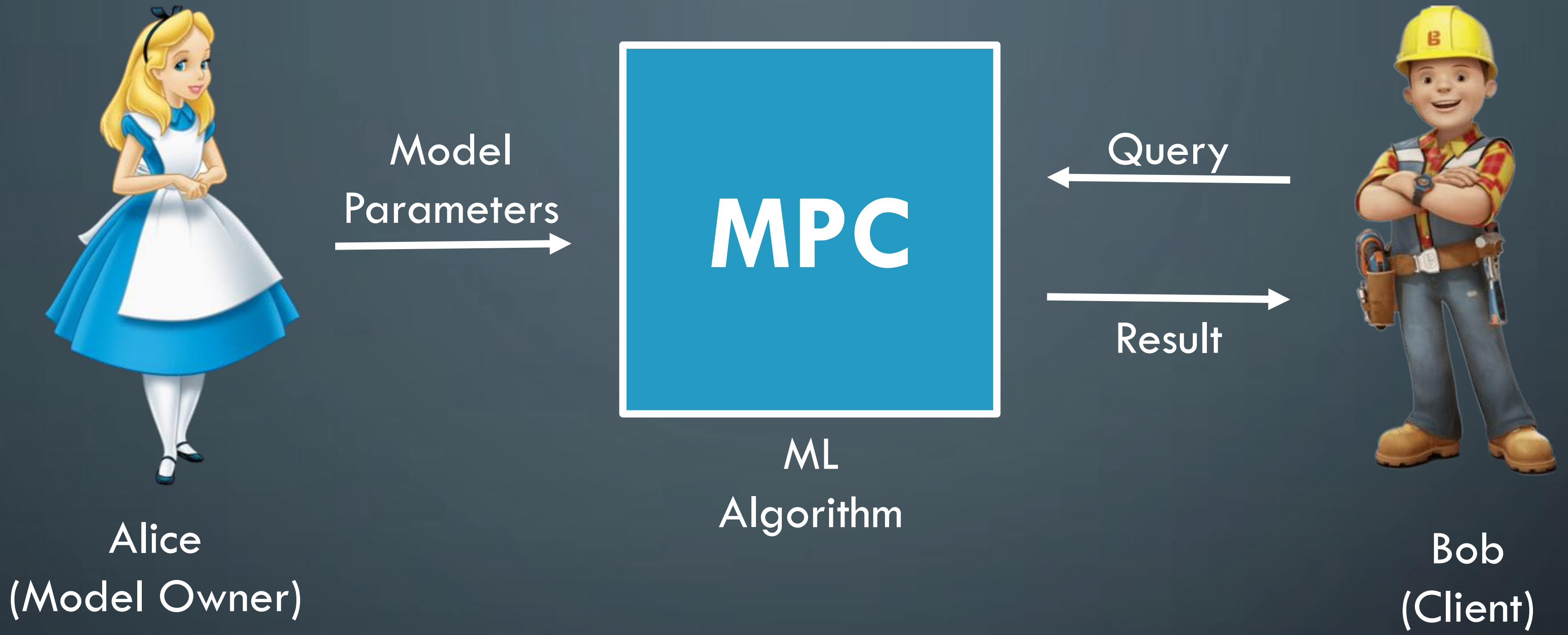
ML

MPC

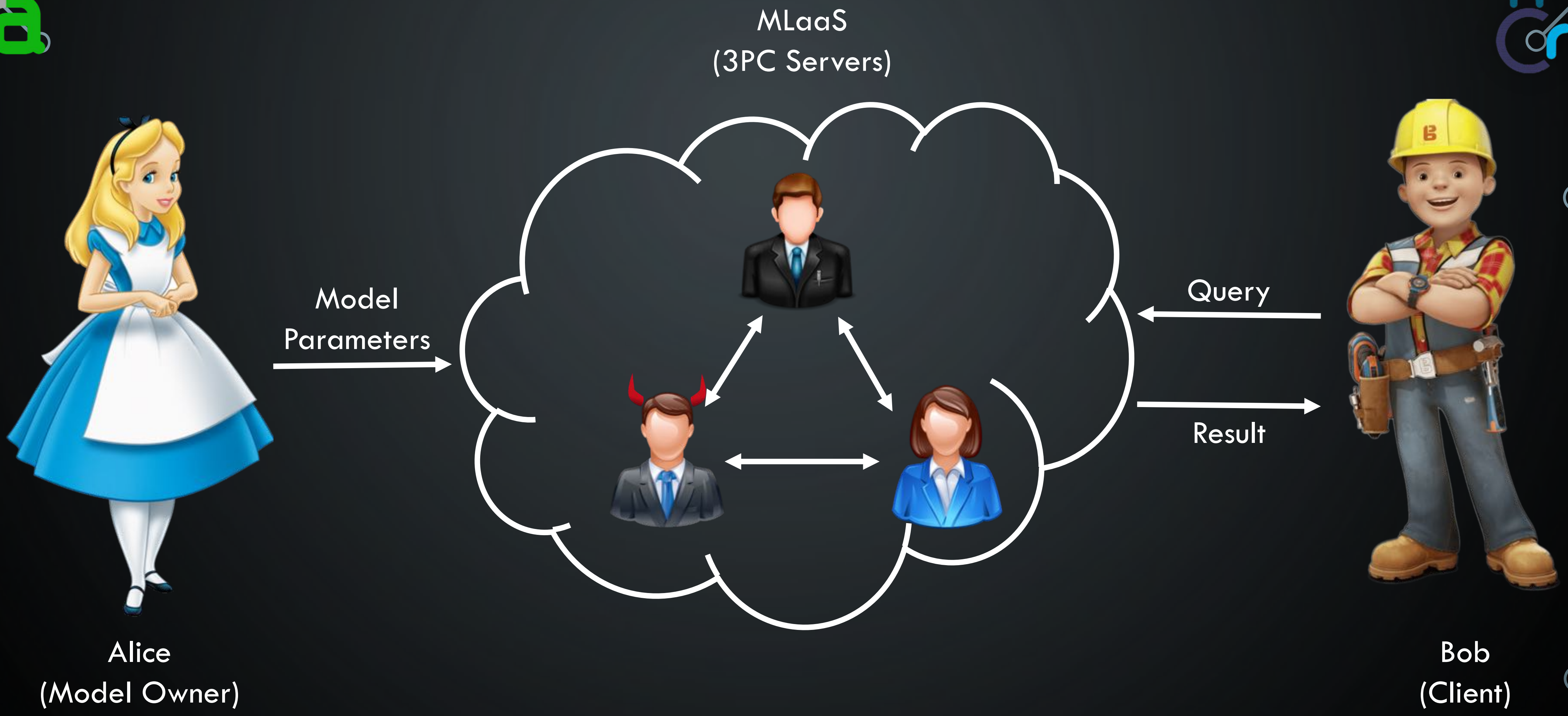
MPC MEETS ML



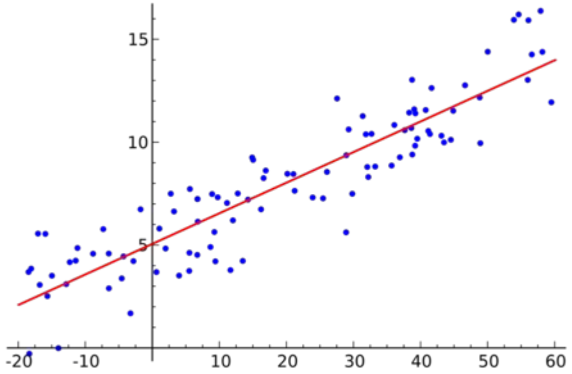
Privacy Preserving Machine Learning (PPML)



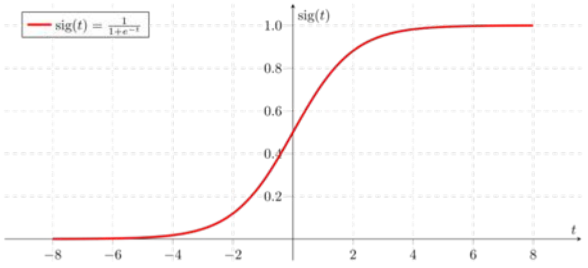
Use MPC to achieve privacy



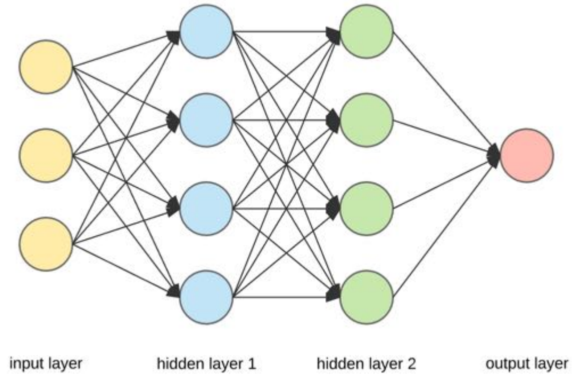
SECURE OUTSOURCED SETTING (SOC)



Linear Regression



Logistic Regression

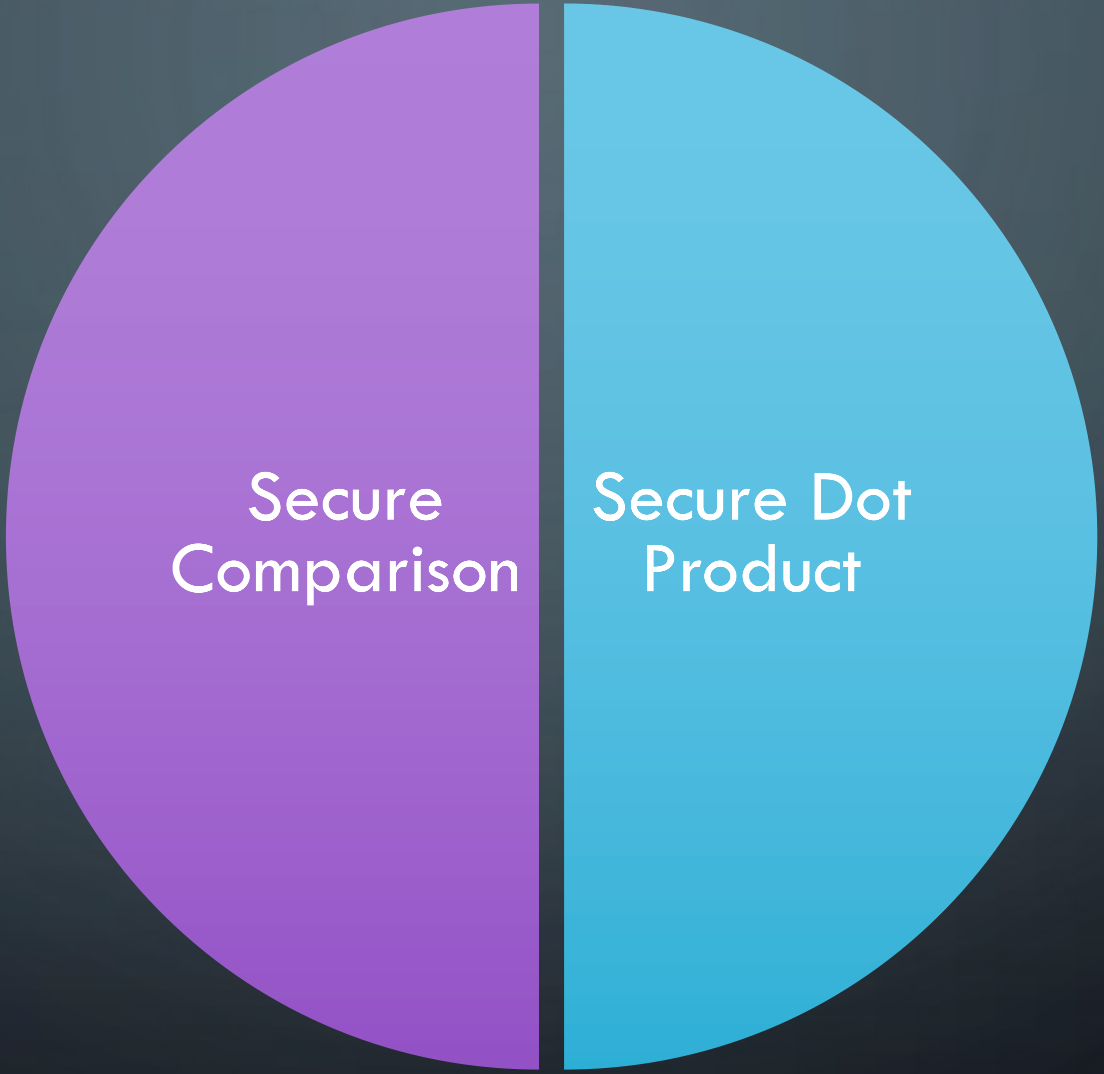


Neural Networks

ML ALGORITHMS CONSIDERED

Secure Dot Product

PPML using MPC: Hurdles to Clear



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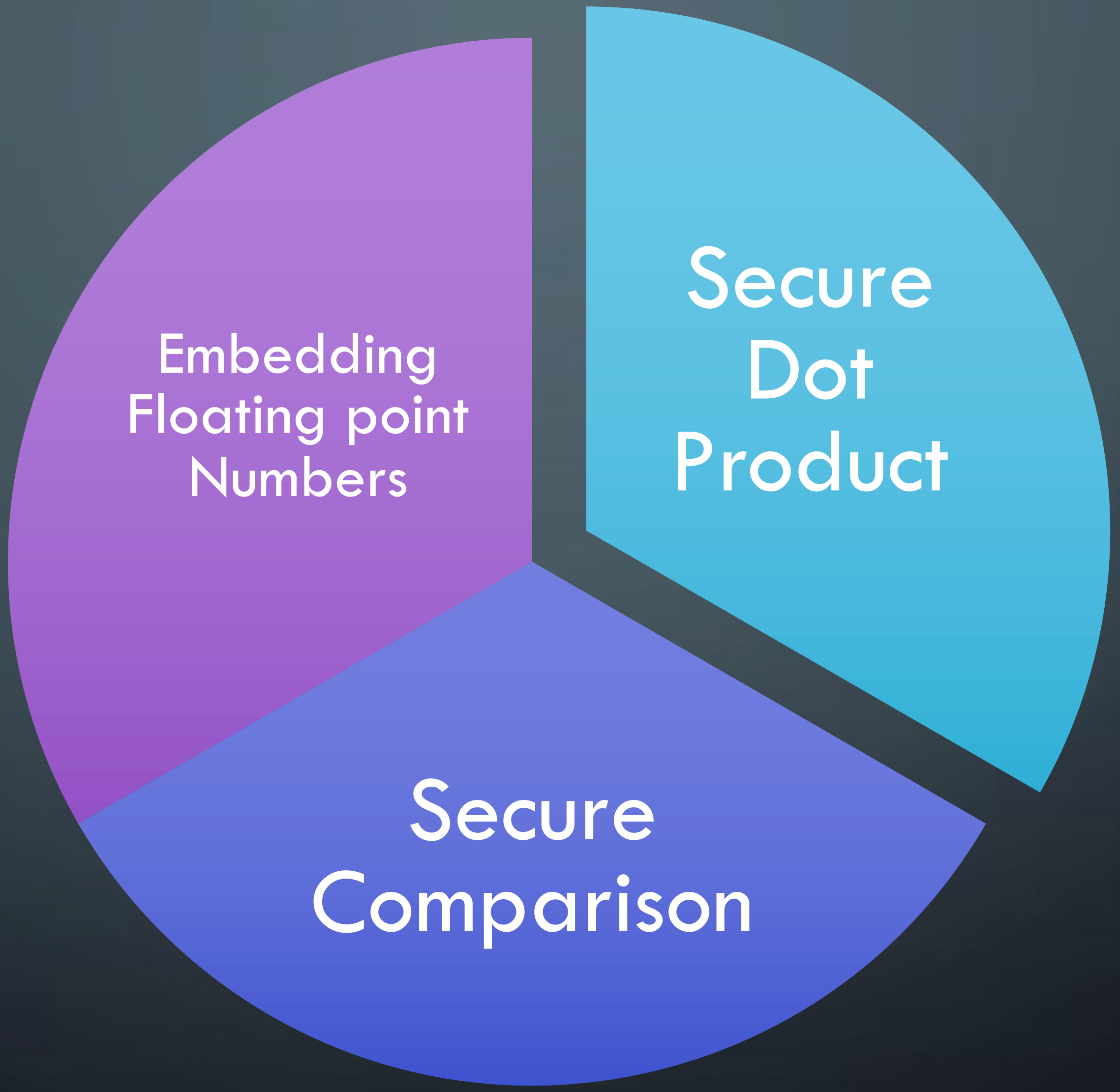

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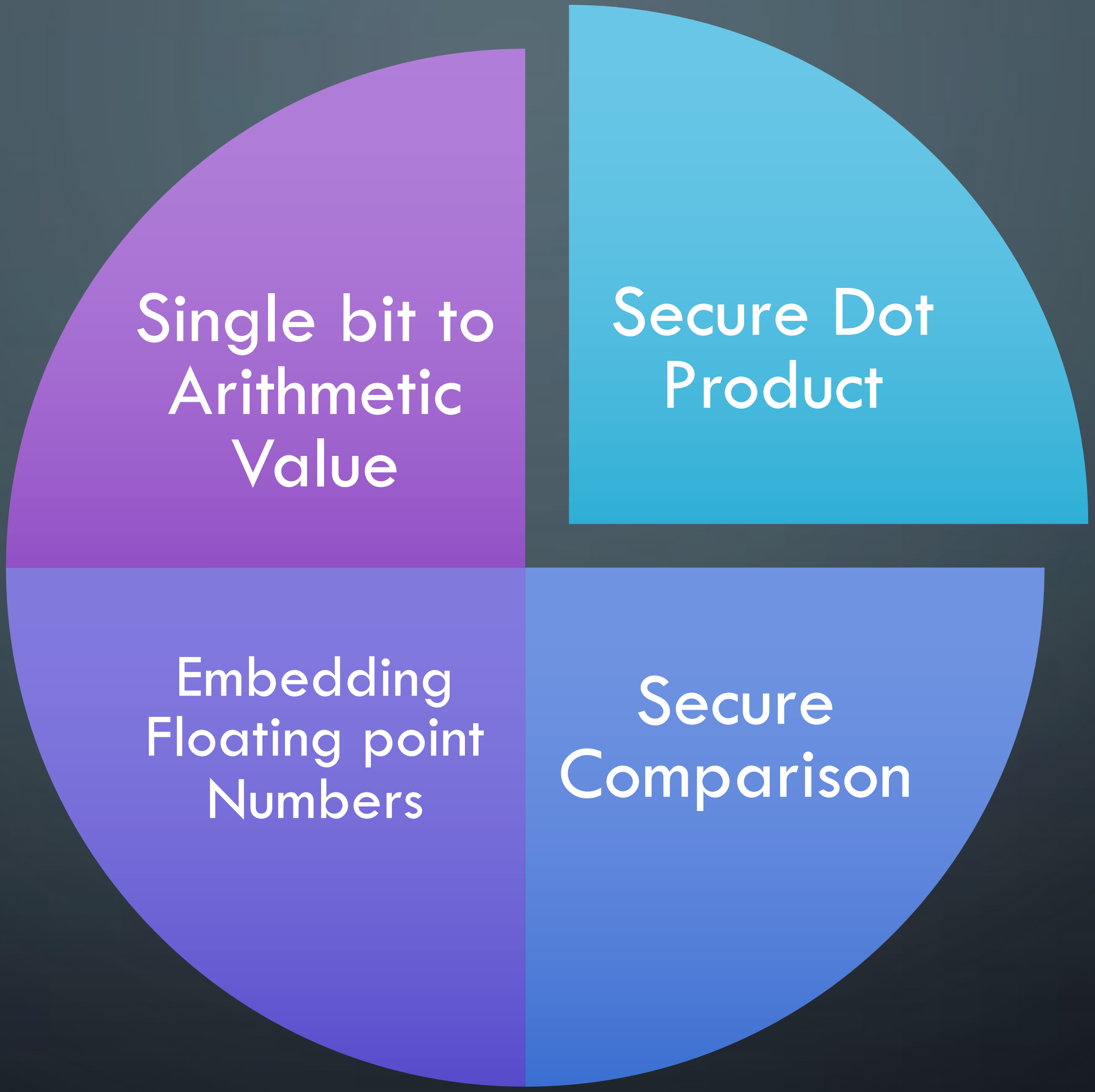

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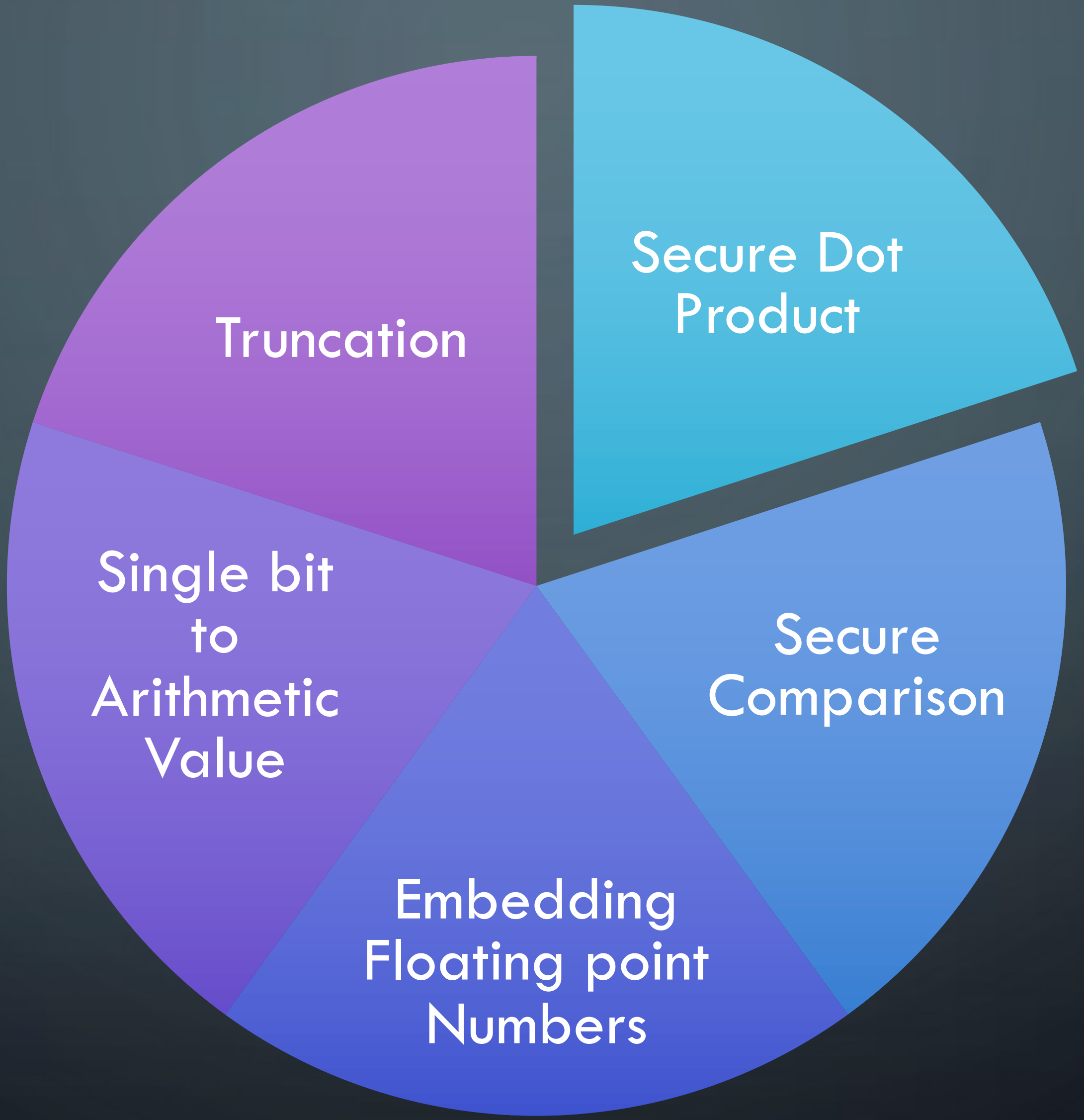

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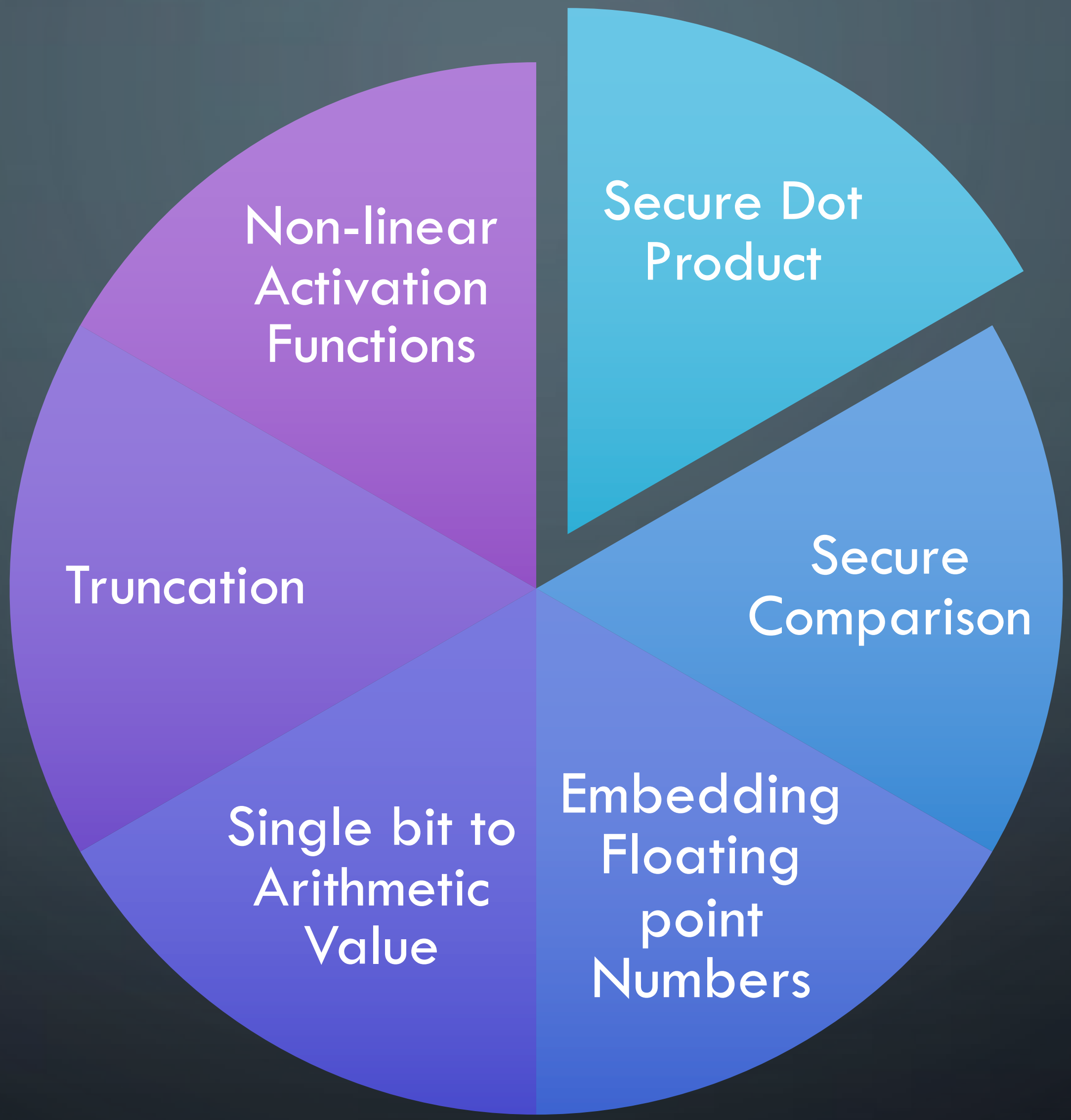

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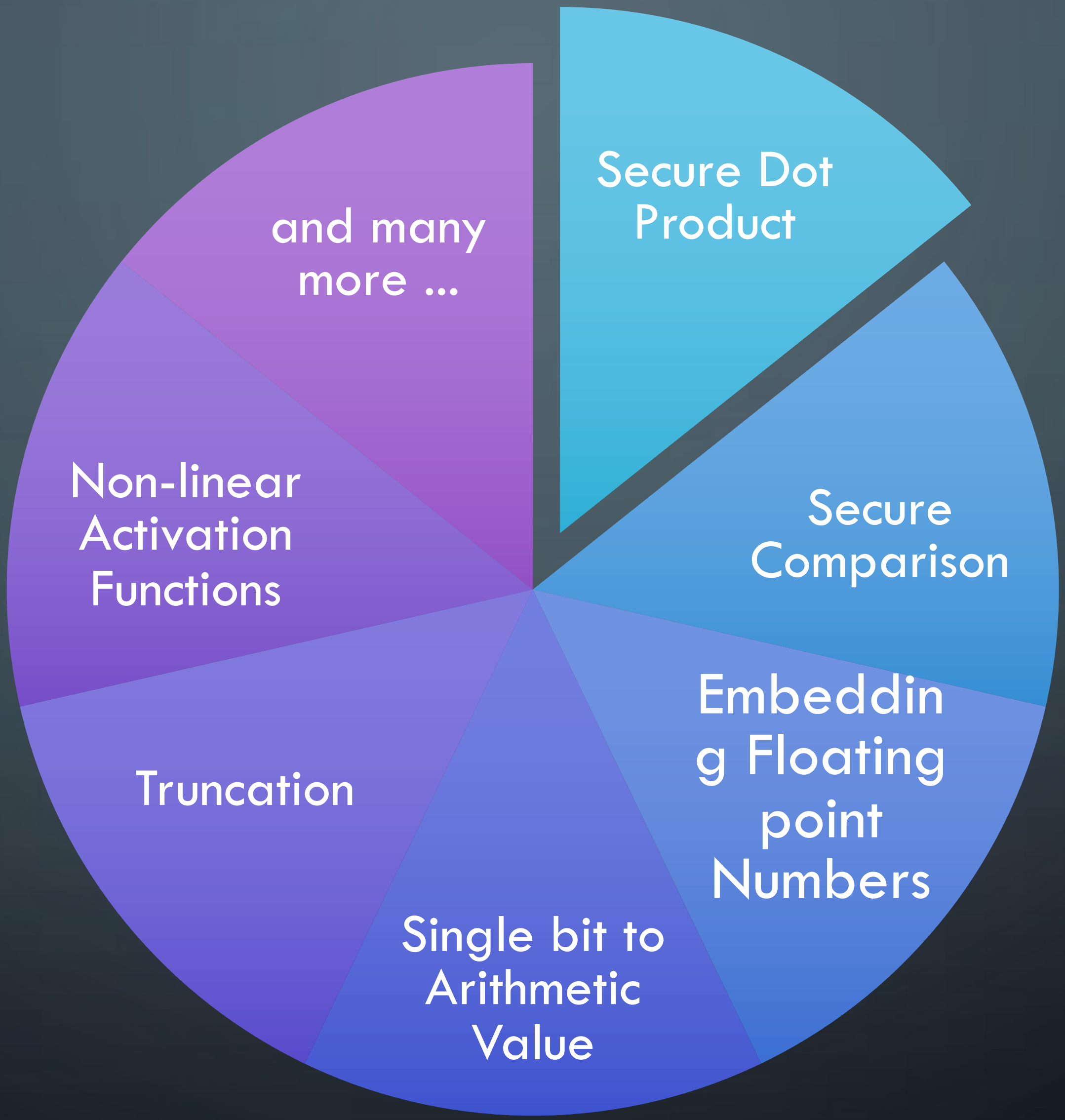

BLAZE Protocol

Ref	Pre-processing (#elements)	Online (#elements)	Security
ABY3	12d	9d	Abort

Communication Cost per Dot Product

$$X \blacksquare Y = \sum_{i=1}^{d} x_i \,.\, yi$$

BLAZE : https://eprint.iacr.org/2020/042

d – #elements in each vector

BLAZE Protocol

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d – #elements in each vector

Summary of Our Benchmarking Results

Algorithm	Improvement in terms of Online Throughput over State-of-the-art protocols over WAN	
	Training	**Prediction**
Linear Regression	333.22 x	194.86 x
Logistic Regression	53.19 x	27.52 x
Neural Networks	-	276.31x

*Throughput for Training - #iterations processed by servers / minute

*Throughput for Prediction - #queries processed by servers / minute

Summary of Our Benchmarking Results

Algorithm	Ref.	Preprocessing		Online	
		TP	Gain	TP	Gain
Linear Regression	ABY3	61.02		30.61	
	BLAZE	**244.74**	**4.01×**	**4449.55**	**145.35×**
Logistic Regression	ABY3	60.71		60.99	
	BLAZE	**243.81**	**4.02×**	**1945.24**	**31.89×**

TABLE VI: Throughput (TP) for ML Training for a batch size B-128 and feature size n-784

Algorithm	Ref.	Preprocessing		Online	
		TP ($\times 10^3$)	Gain	TP ($\times 10^3$)	Gain
Linear Regression	ABY3	15.57		15.67	
	BLAZE	**62.61**	**4.02×**	**2660.53**	**169.75×**
Logistic Regression	ABY3	15.41		15.55	
	BLAZE	**62.13**	**4.03×**	**366.68**	**23.57×**
Neural Networks	ABY3	0.10		0.14	
	BLAZE	**0.41**	**4.01×**	**33.74**	**245.74×**

TABLE VII: Throughput (TP) for ML Inference for a feature size of n-784

THANK YOU!

References

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