ABY - A Framework for Efficient Mixed-Protocol Secure Two-Party Computation

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Joint work with
Daniel Demmler and Thomas Schneider

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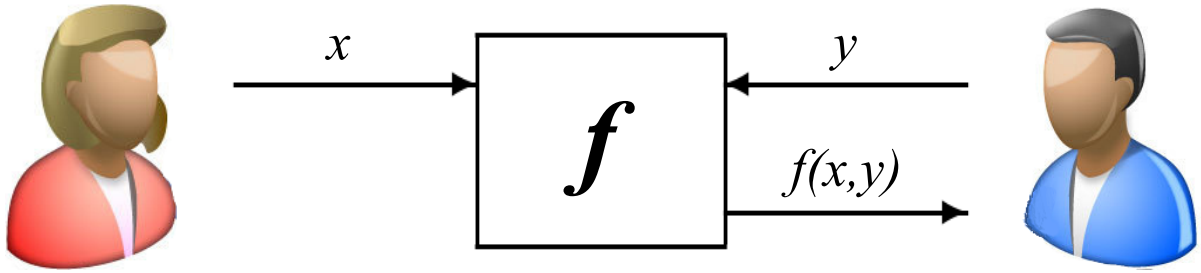
Secure Two-Party Computation



This work: **semi-honest (passive)** adversaries

Applications

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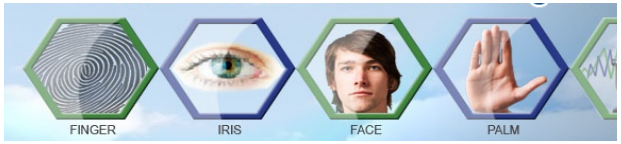
Auctions [NPS99], ...

Private Set Intersection [PSZ14], ...

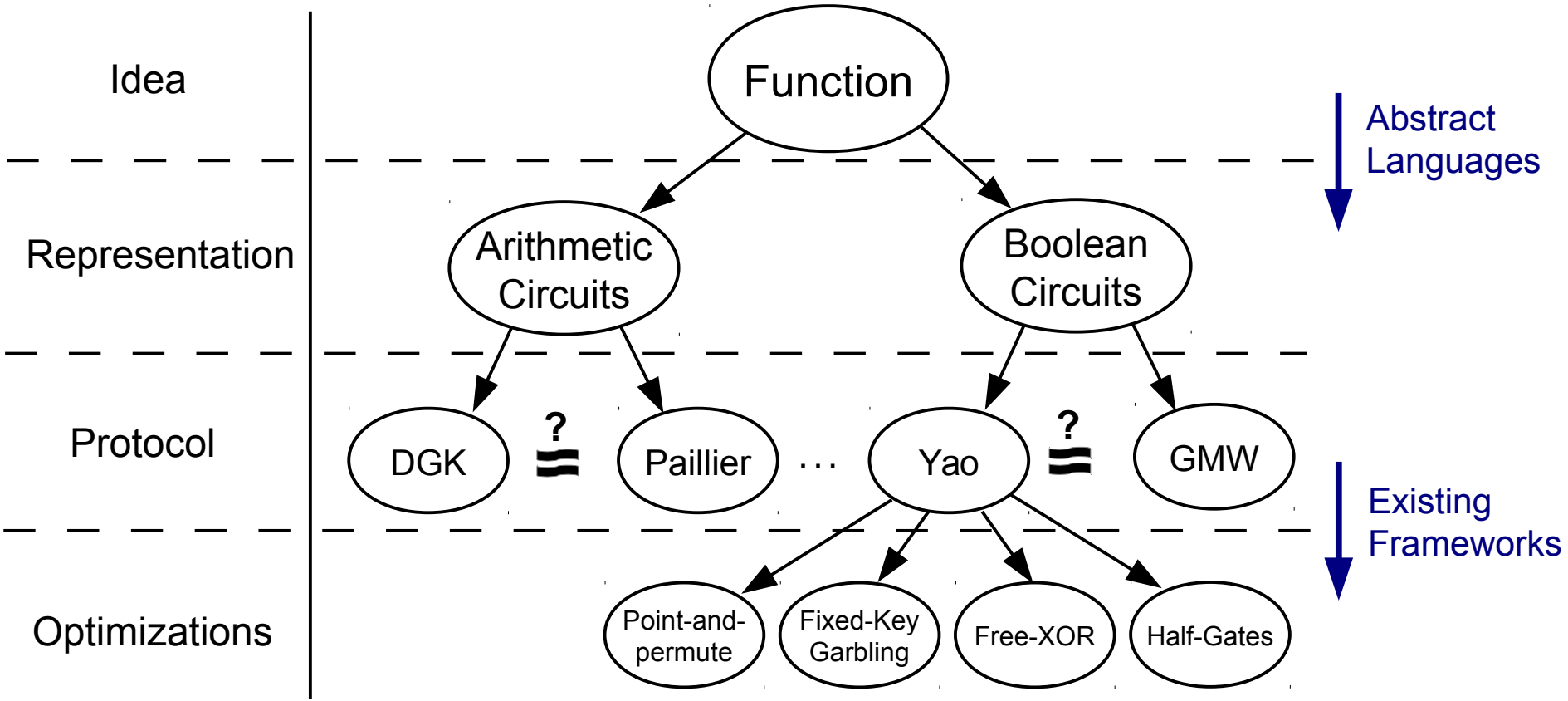
Machine Learning [BPTG15], ...



Biometric Identification [EFGKLT09], ...

- several cool applications from different fields

Protocol Development



Secure computation is a vast area and protocol development is a tedious task

Example: Minimum Euclidean Distance

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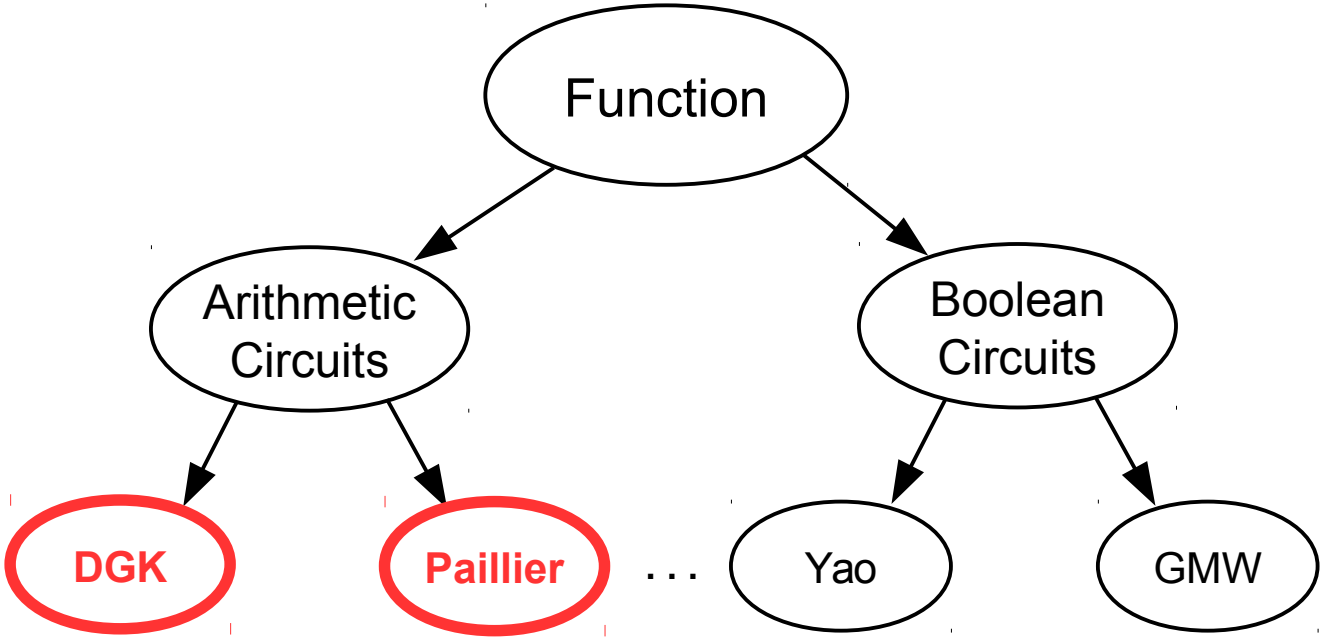
Minimum Euclidean Distance: $\min(\sum_{i=1}^{d}(\mathbf{S}_{i,1} - \mathbf{C}_i)^2, \ldots, \sum_{i=1}^{d}(\mathbf{S}_{i,n} - \mathbf{C}_i)^2)$

- Server holds database $\mathbf{S}$, client holds query $\mathbf{C}$
- Used in biometric matching (face-recognition, fingerprint, …)



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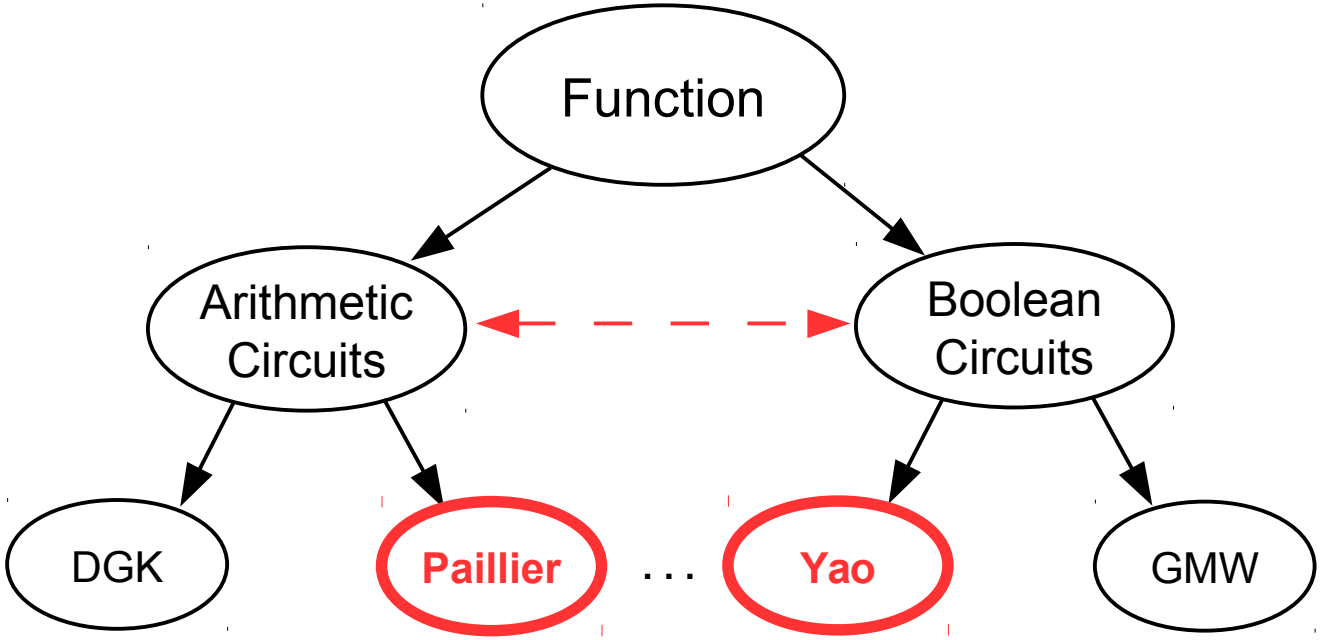

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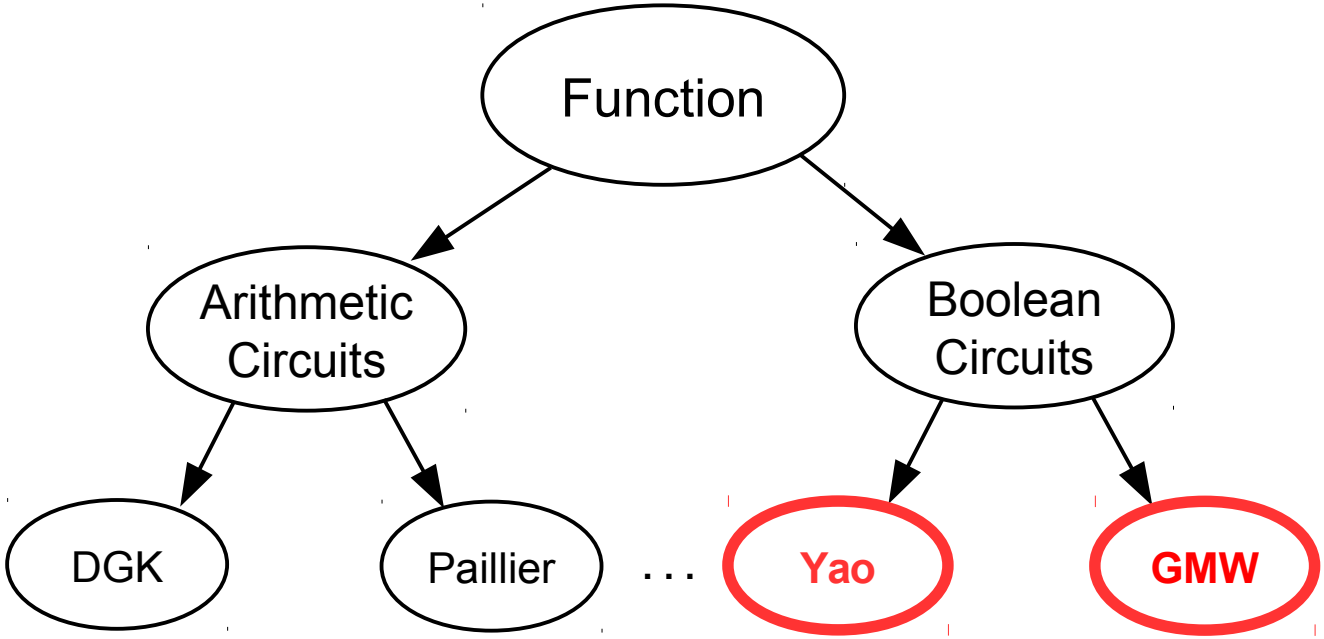

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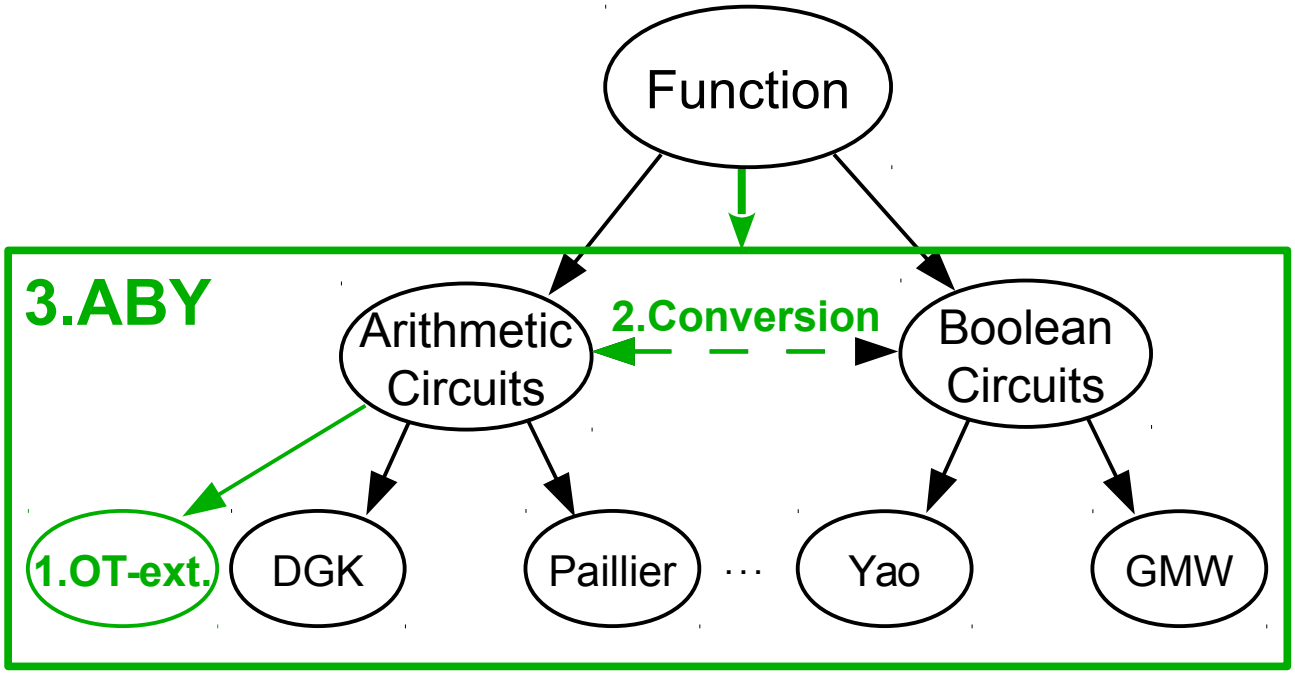
Our Contributions



1) More efficient multiplication using symmetric crypto

2) More efficient conversion

3) Mixed-protocol framework called ABY

Multiplication using OT Extension

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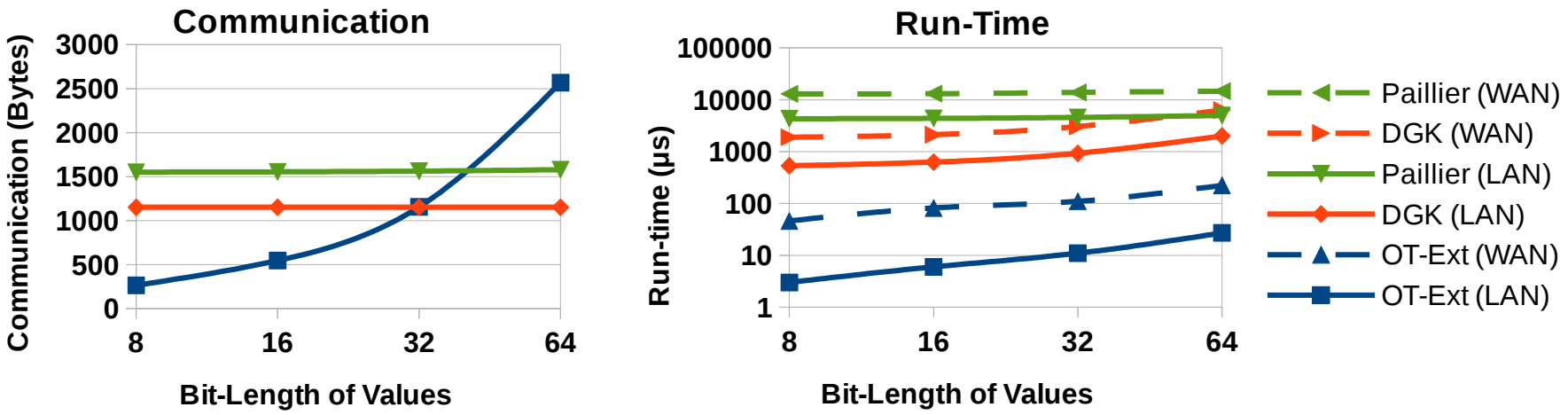
Use a multiplication protocol that is based on **OT extension**

- Requires **symmetric-key** cryptography only

Compare one multiplication using Paillier, DGK, and OT extension



Communication and run-time for 1 multiplication in LAN and WAN for long-term security

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The ABY framework

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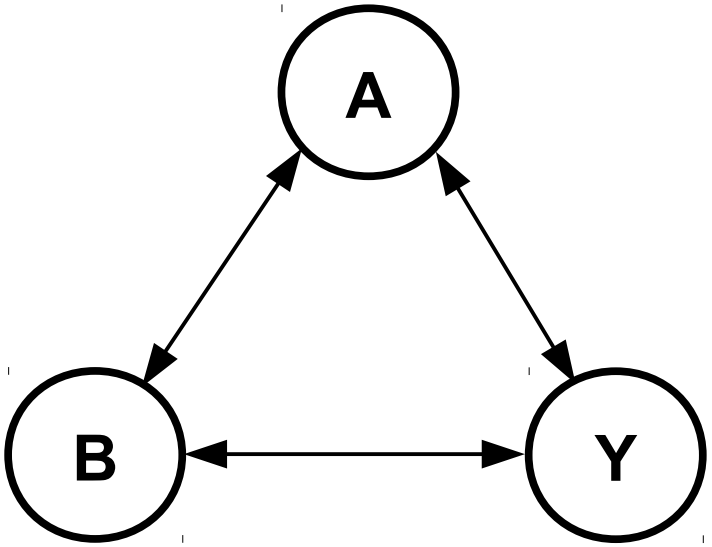
Combine:

- **A**rithmetic sharing
- **B**oolean sharing (GMW)
- **Y**ao's garbled circuits



Efficient conversions between schemes

Use **best practices** in secure computation:

- batch pre-compute crypto
- use symmetric crypto where possible
- use sub-protocols with recent optimizations

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ABY Secure Computation Schemes

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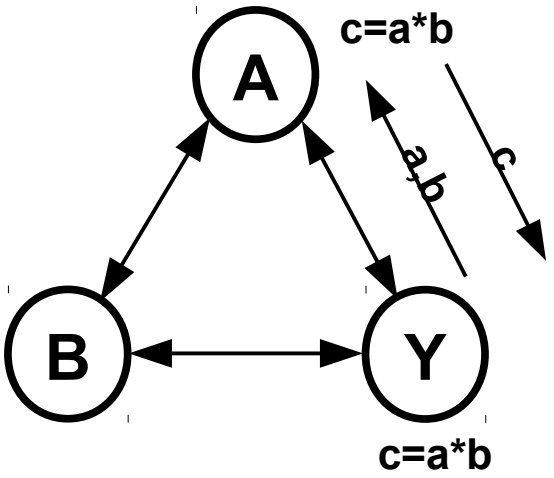
A rithmetic sharing:
- Free addition / cheap multiplication
- Good for multiplication

B oolean sharing:
- Free XOR / one interaction per AND
- Good for multiplexing

Y ao's garbled circuits:
- Free XOR / no interaction per AND
- Good for comparison



Multiplication		
Protocol	***Yao***	***Mixed***
LAN [µs]	**1.1**	**0.1**
Comm. [KB]	**100**	**5**

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Example: Minimum Euclidean Distance

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Minimum Euclidean Distance: $\min(\sum_{i=1}^{d}(\mathbf{S}_{i,1} - \mathbf{C}_i)^2, \ldots, \sum_{i=1}^{d}(\mathbf{S}_{i,n} - \mathbf{C}_i)^2)$

```
01. share* min_euclid_dist(share*** S, share** C, uint32_t dbsize, uint32_t dim,
    share** Ssqr, Circuit* dist, Circuit* min
02.     share **distance, *temp, *mindist;
03.     ...
04.     for (uint32_t i=0, j; i < dbsize; i++) {
05.         distance[i] = dist->PutMULGate(S[i][0], C[0]);
06.         for (j=1; j < dim; j++) {
07.             temp = dist->PutMULGate(S[
08.             distance[i] = dist->PutADD
09.         }
10.         temp = min->PutADDGate(Ssqr[i]
11.         distance[i] = min->PutSUBGate(
12.     }
13.     ...
14.     return min->PutMinGate(distance, dbsize);
15. }
```

dist	min	LAN [s]	WAN [s]	Comm [MB]	#Msg
Y	**Y**	2.55	24.62	147.7	**2**
B	**B**	2.43	39.41	99.9	129
A	**Y**	**0.19**	**3.42**	5.0	8
A	**B**	0.21	26.41	**4.6**	101

Euclidean distance for n = 512 values of 32-bit length and d = 4.

Take Away Message

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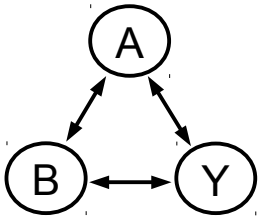
Developed a **mixed-protocol** secure computation framework



Abstract from underlying secure computation protocol

Use only **fast symmetric key crypto**

Code is available at **GitHub**: http://encrypto.de/code/ABY

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Questions?

Contact: http://encrypto.de
Code: http://encrypto.de/code/ABY

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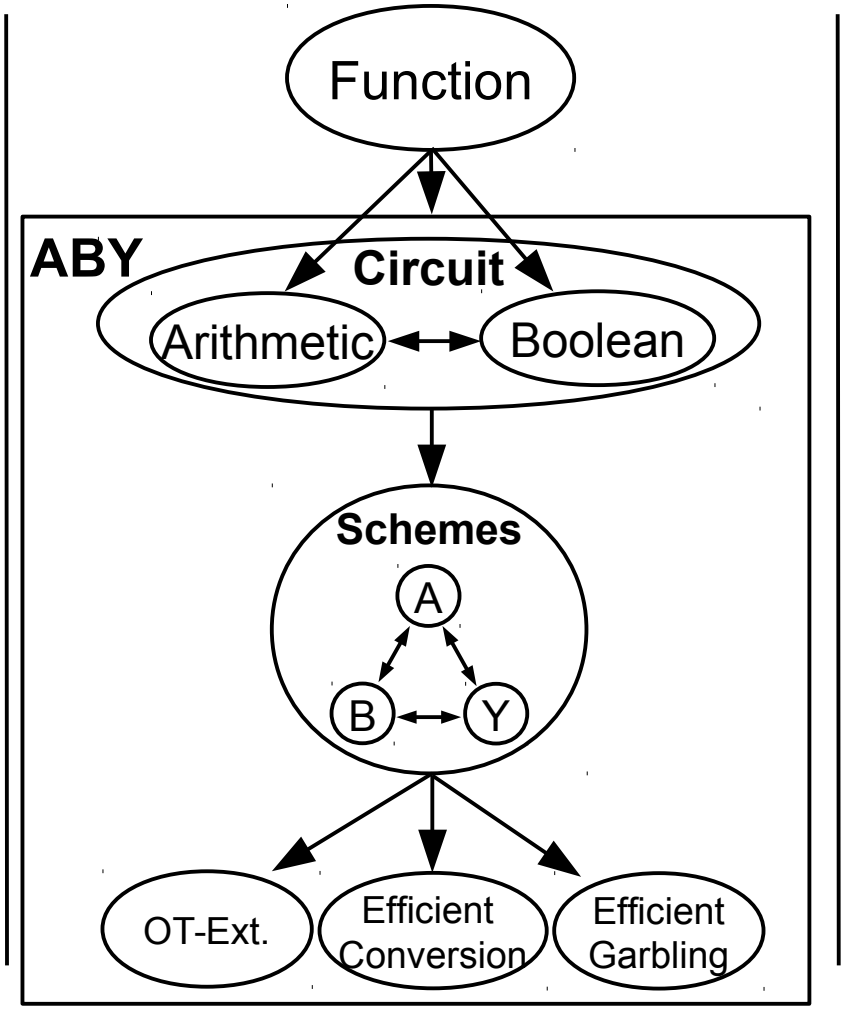
ABY Development



Idea

Representation

Protocol

Optimizations

Extensibility

Special purpose circuits

Optimize existing / implement new schemes

Implement further optimizations

Future Work

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- Implement new **special purpose** operations

- **Automatically** assign operations to protocols [KSS14]

- Add support for **malicious adversaries**
  - TinyOT (Boolean circuits)
  - SPDZ (Arithmetic circuits)

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Mixed-Protocols

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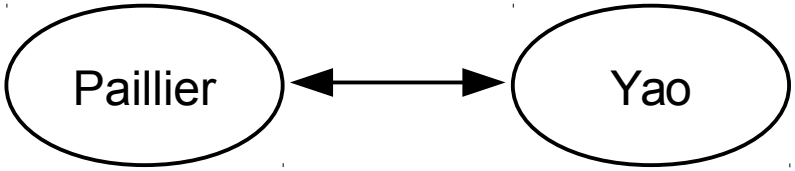
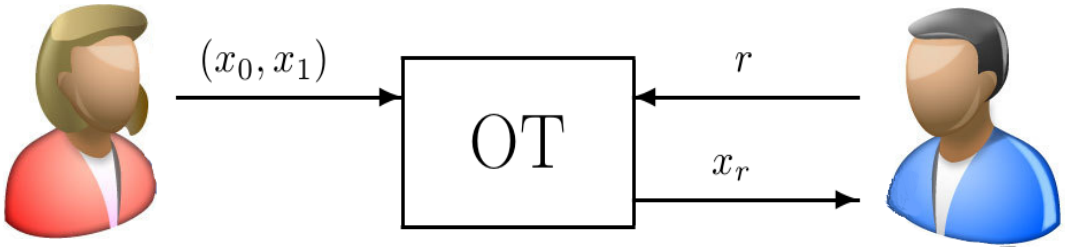
- Some functionalities have a more efficient circuit representation
  - Multiplication in Boolean circuits: $O(n^2)$
  - Comparison in Arithmetic circuits: $O(n)$ multiplications of q-bit values

- TASTY [HKSSW10] combines Paillier (Arithmetic) and Yao (Boolean)



- **Multiplication** and **conversion** requires public-key operation
  - For long-term security, Yao-only is often most efficient [KSS14]

OT Extension



Input: Alice holds two strings (x_0, x_1), Bob holds a choice bit r

Output: Alice learns nothing, Bob only learns x_r

Traditionally, OT requires public-key crypto

OT extension allows extending few “real” OTs to arbitrary many OTs using symmetric key cryptography only

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[HKSSW10]: Wilko Henecka, Stefan Kögl, Ahmad-Reza Sadeghi, Thomas Schneider, Immo Wehrenberg: TASTY: tool for automating secure two-party computations. ACM Conference on Computer and Communications Security 2010: 451-462.

Protocol Overview