How MPC Frameworks Use Threshold Cryptography

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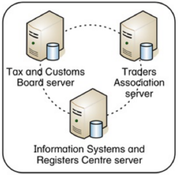
Secure multi-party computation (MPC) in practice

Blind auction
[BCD+08]

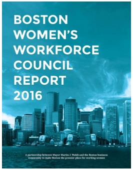


Tax and Customs Board server
Traders Association server
Information Systems and Registers Centre server

Fraud detection
[BJSV16]

ZCASH

Parameter computation
[BGM17]



BOSTON WOMEN'S WORKFORCE COUNCIL REPORT 2016

A partnership between Mayor Martin J. Walsh and the Boston business community to make Boston the premier place for working women

Financial statistics
[BLV17]

CYBERNETICA

PARTISIA

Government applications

BOLT LABS

UNBOUND
(MATH OVER MATTER)

Private companies

Modern end-to-end frameworks for MPC

- Goal: general-purpose tools that can execute any computation

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- Protocols assumed impractical until Fairplay [MNPS04]

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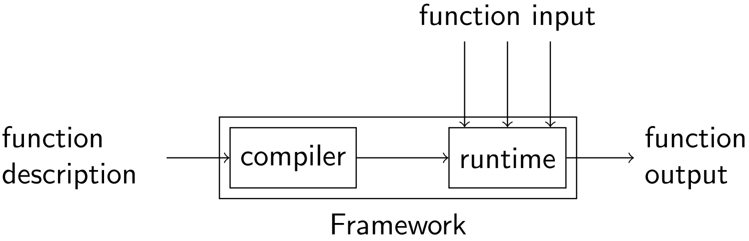

Modern General-Purpose Frameworks

Questions for our survey

- Who are frameworks designed for?
- What types of MPC algorithms do they implement?
- Are they suitable for use in large-scale applications?

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Questions for this workshop

- Which frameworks already implement threshold schemes?
- Does this survey provide insight into what we should standardize?

Contributions

General purpose frameworks for secure multi-party computation [HHNZ19]

Survey

- Surveyed 9 frameworks and 2 circuit compilers
- Recorded protocol, feature, implementation details
- Evaluated usability criteria

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Open-source framework repository

- Three sample programs in every framework
- Docker instances with complete build environments
- Documentation on compilation and execution

`github.com/mpc-sok/frameworks`

Findings

Our original questions

- Diverse set of threat models and protocols
- Expressive languages are suitable for real applications
- Engineering limitations
- Barriers to usability (documentation)

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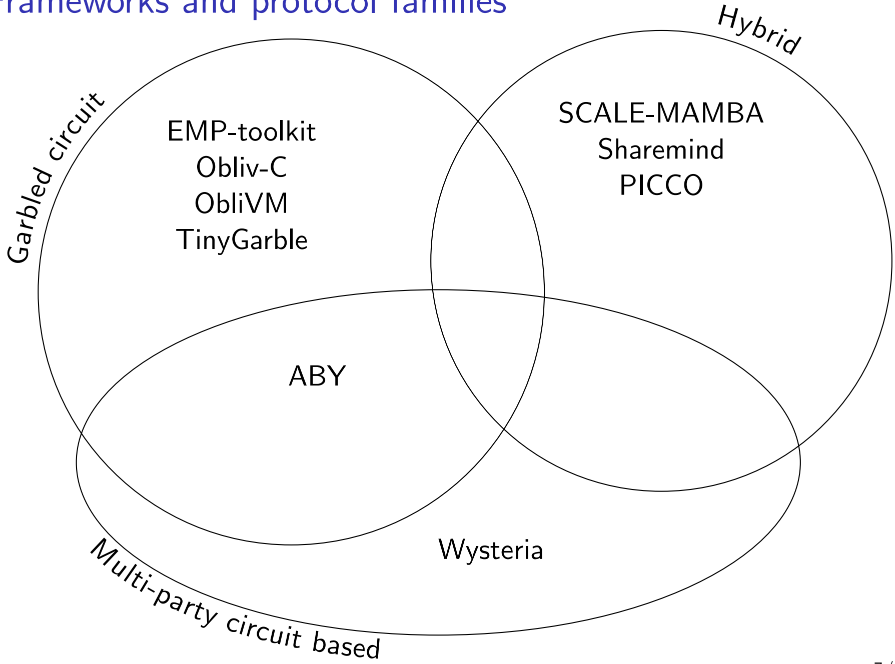
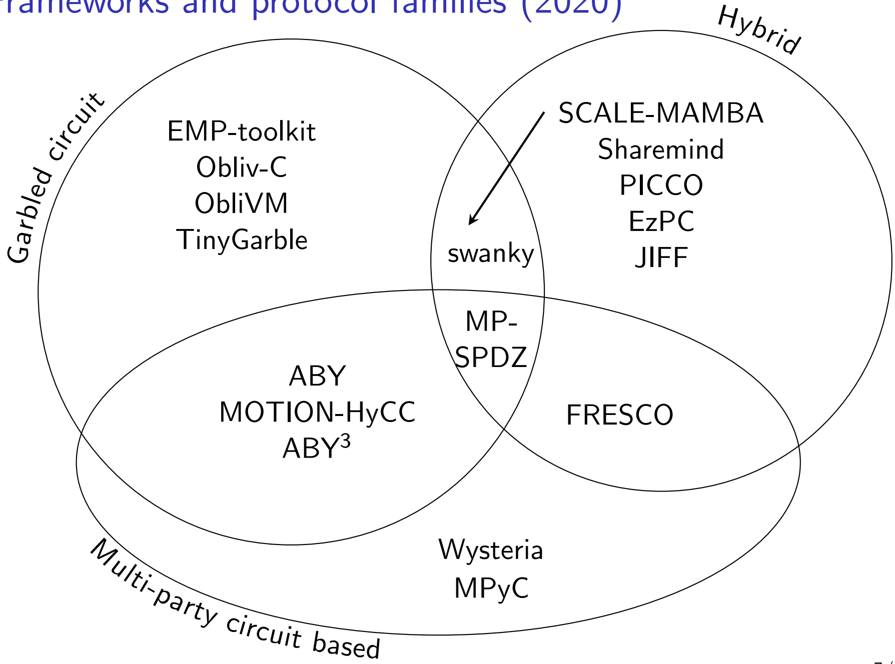
Threshold questions

- A growing proportion of frameworks support threshold operations
- They all do it via secret sharing

Frameworks and protocol families



Frameworks and protocol families (2020)



EMP-toolkit
Obliv-C
ObliVM
TinyGarble

SCALE-MAMBA
Sharemind
PICCO
EzPC
JIFF

swanky

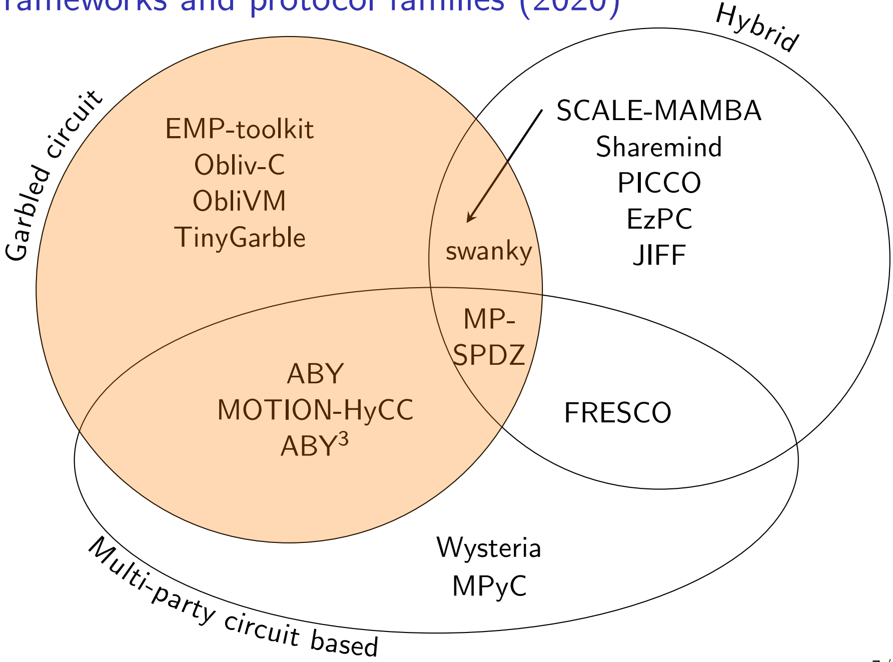
MP-SPDZ

ABY
MOTION-HyCC
ABY^3

FRESCO

Wysteria
MPyC

Frameworks and protocol families (2020)



Garbled circuit

EMP-toolkit
Obliv-C
ObliVM
TinyGarble

Hybrid

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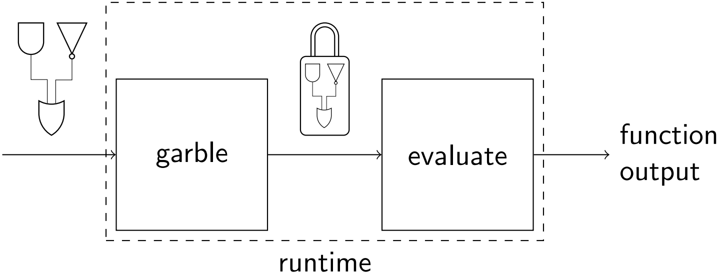
Multi-party circuit based

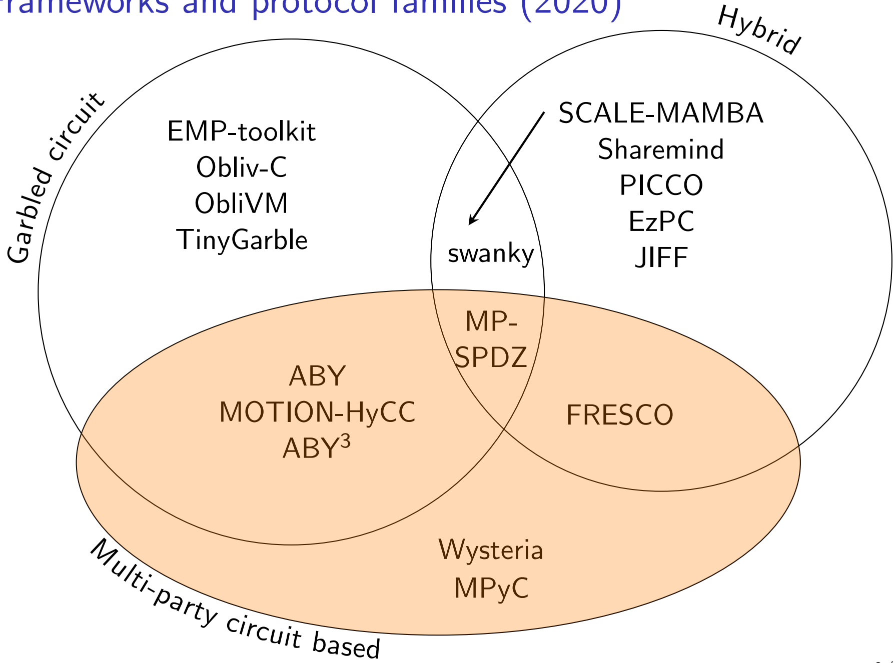
Garbled circuit protocols

Introduced by [Yao82, Yao86]



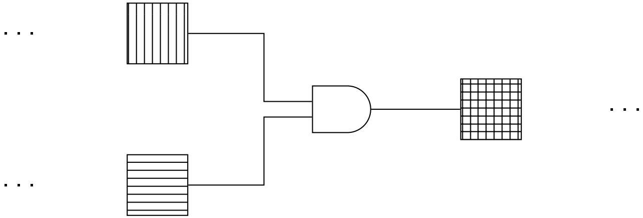
- Functions represented as Boolean circuits
- Often 2-party semi-honest, but exceptions are growing

Frameworks and protocol families (2020)



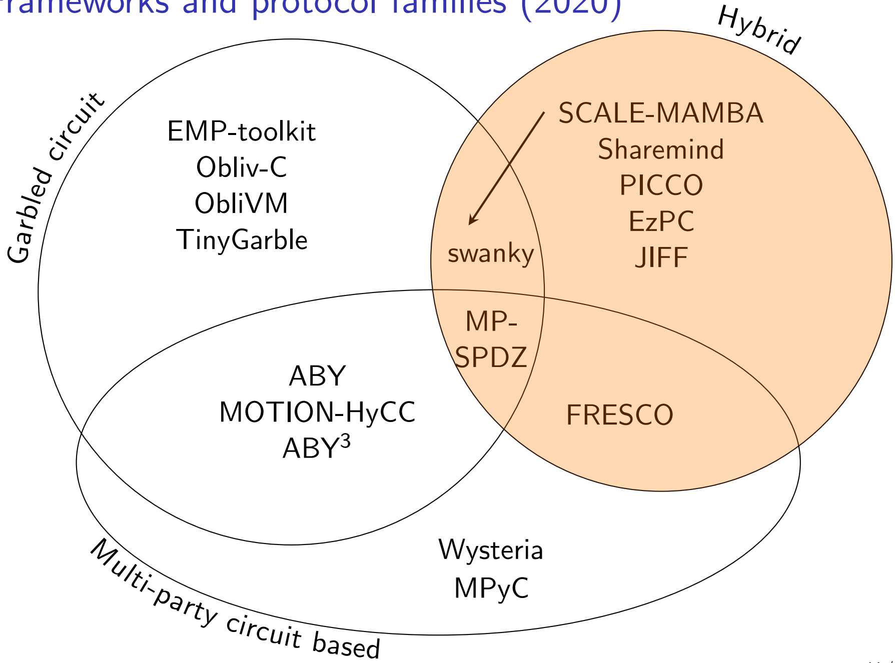
Multi-party circuit-based protocols

Introduced by [GMW87, BGW88, CCD88]

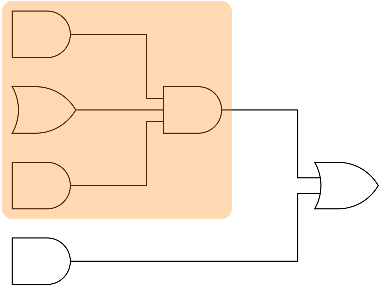


- Functions represented as Boolean or arithmetic circuits
- Data represented as linear secret shares
- Various threat models and protocol types
  (information-theoretic or cryptographic)

Frameworks and protocol families (2020)



Hybrid protocols



- Integrates optimized subprotocols for common functions
  - Bitwise operators in arithmetic settings
  - Matrix operations
- Seamless front-end experience (no explicit protocol selection)
- Currently: One-to-one mapping from operations to protocols

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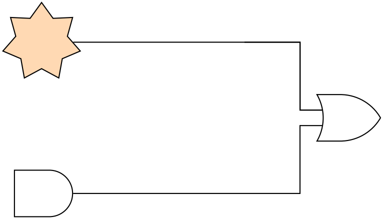

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What does “threshold” mean for MPC?

Threshold adversary

- Up to k corrupted parties cannot learn honest inputs
- They can block output (sometimes)
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What does “threshold” mean for MPC?

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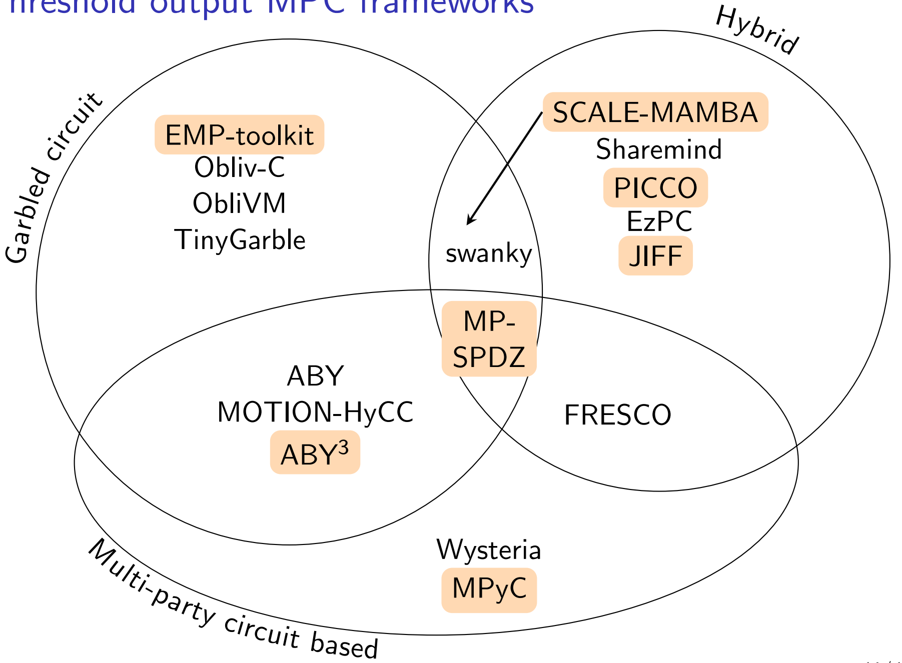
Threshold output

- A qualified group of *k* parties can retrieve output
- This might only be true at certain points in the protocol

Threshold output MPC frameworks



Threshold secret sharing schemes used in MPC frameworks

Shamir sharing

- Used by SCALE-MAMBA, PICCO, MP-SPDZ, MPyC, JIFF
- Mostly use classic [Shamir '79]
- Standards: NISTIR 8214, ISO/IEC 19592-2

Replicated sharing

- Used by SCALE-MAMBA, MP-SPDZ, ABY^3
- Schemes based on [Benaloh and Leichter '09] [Araki et al. '16]

Details of these findings are in the frameworks wiki

`github.com/mpc-sok/frameworks/wiki`

Performance evaluation

In theory

Measure circuit size

Measure rounds and volume of communication

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In practice

- Many frameworks don't produce traditional circuits

Performance evaluation

In theory

Measure circuit size
Measure rounds and volume of communication

In practice

- Many frameworks don't produce traditional circuits
- Non-crypto variables can wildly affect performance (network channels, message batching, IO, language)
- See [Keller '20] for performance comparison and caveats

Lesson for standardizers

Be careful about abstractions when you standardize a "whole" MPC scheme

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