SIMAP

Secure Information Management and Processing

Martin Geisler, Mikkel Krøigaard,
Janus Dam Nielsen, and Tomas Toft

BRICS Research School
University of Aarhus

SMCL

The Secure Multiparty Computation Language

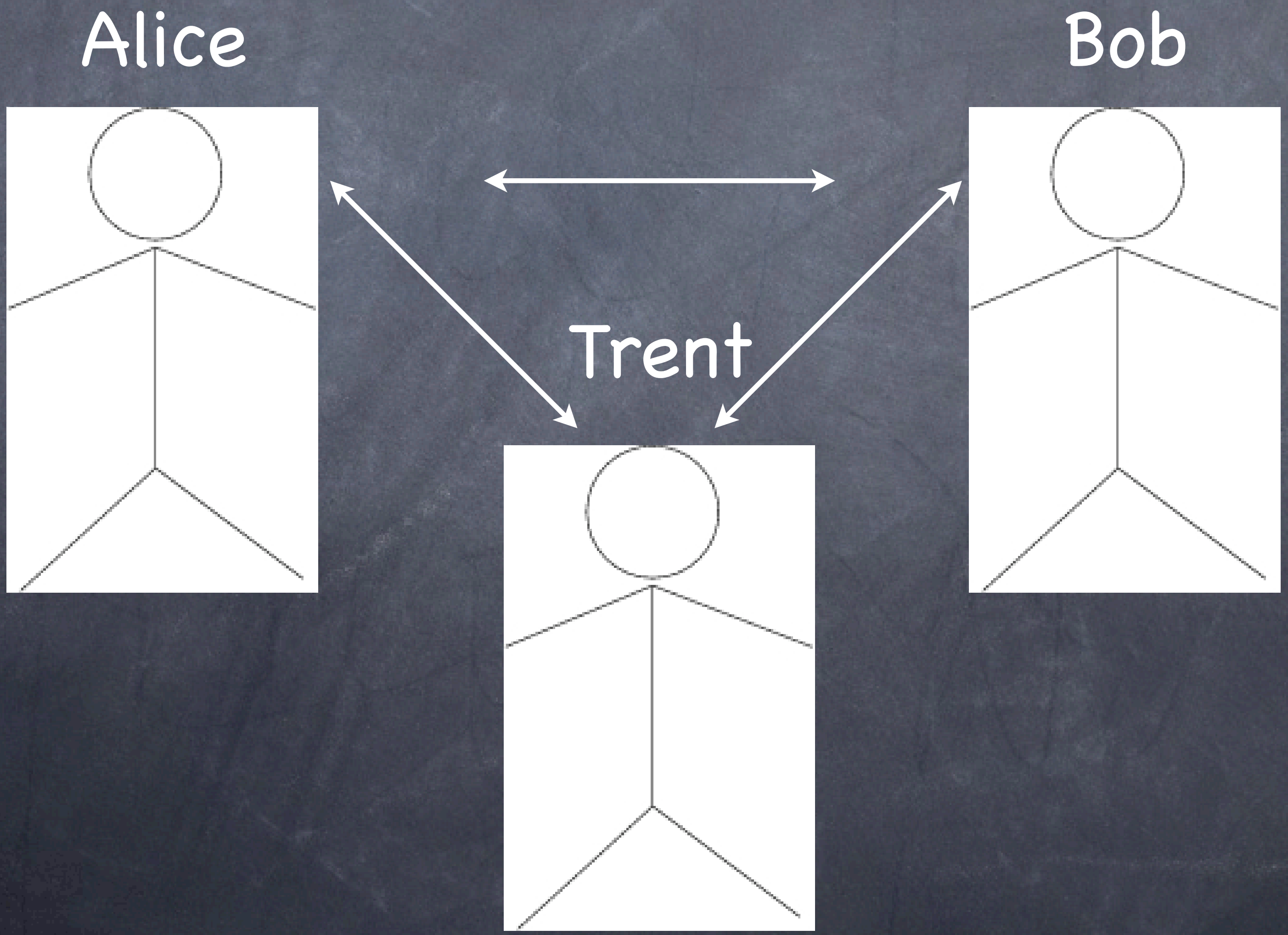
Work in progress

Outline

- Motivation
- Secure Multiparty Computation
- SMCL
  - Why and What?
- SMCR (How?)

Motivation

The Millionaire's problem, Yao 1982



Secure Multiparty Computation

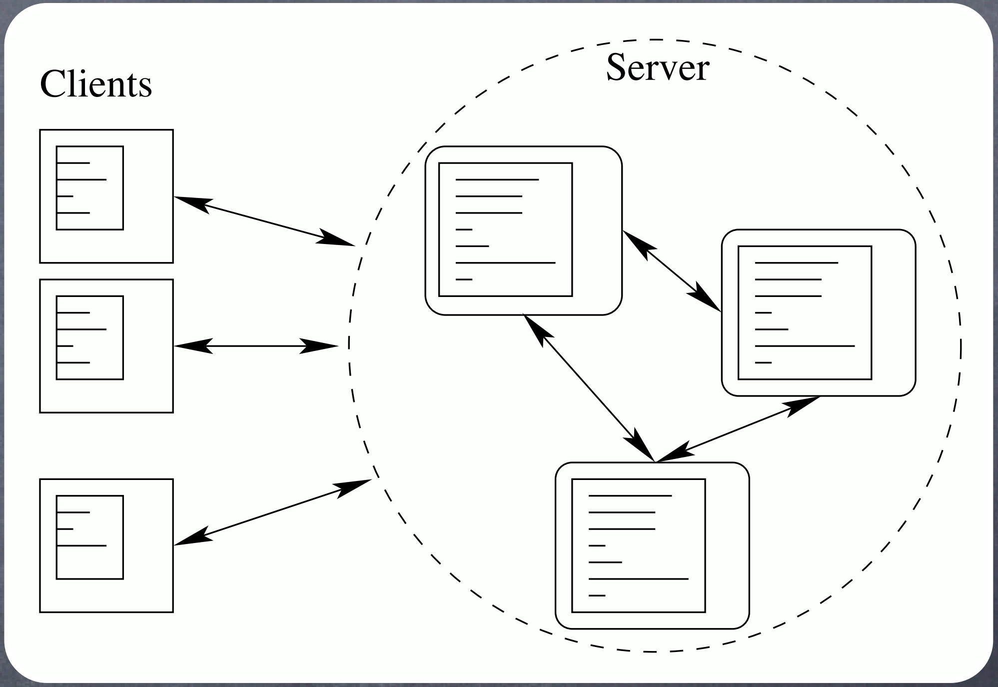
- n parties P1,...,Pn wish to jointly compute the computable function: f(x1,...,xn)
- Party Pi only knows the input value xi which must be kept secret from the other parties.
- Even if some adversary has power to corrupt some subset of the parties

SMCL - Why?

- Writing SMC programs is tedious and error-prone
- DSL:
  - Important concepts up front(concise)
  - Efficiency
  - Management
  - Analyze(security)

SMCL - What

- Highlevel domain specific language
- Language support for fundamental concepts
- Parties are separated into clients and servers



SMCL

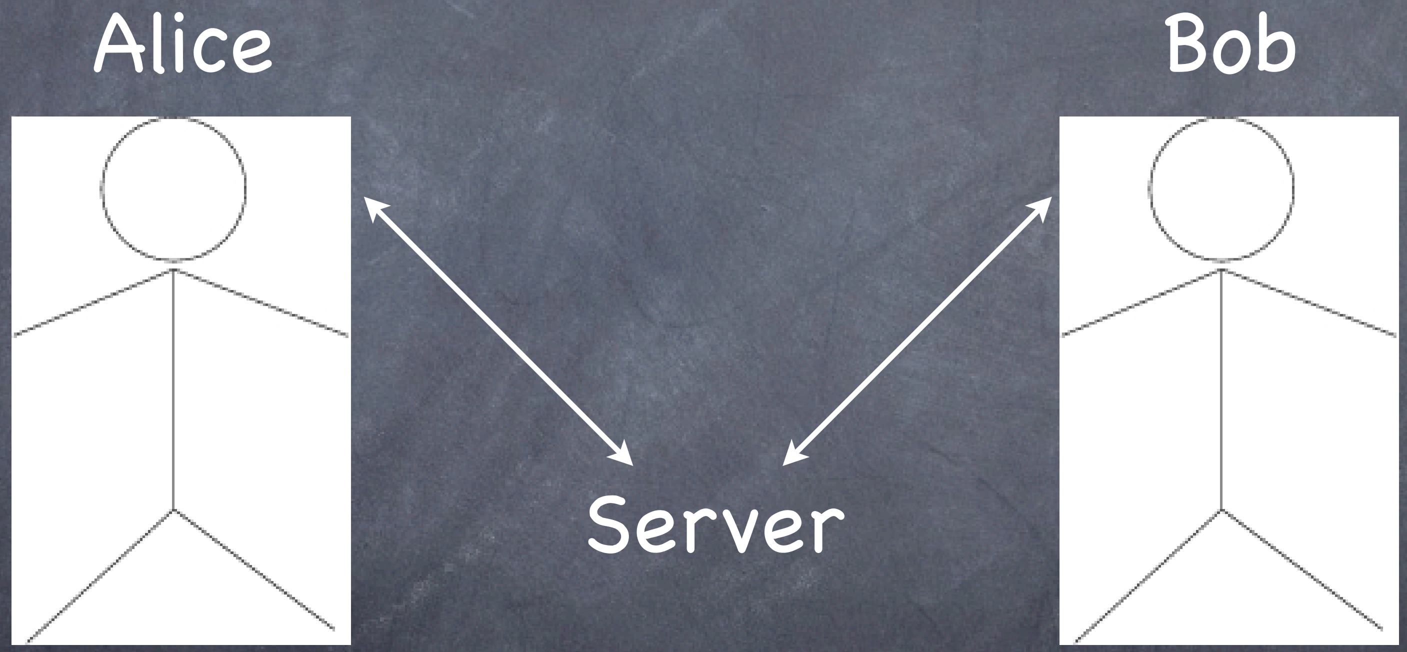
The Millionaire's Example

```
Declare Client Millionaires:
  Tunnel of sint netWorth;
  function void main(int[] args) {
    ask();
  }
  function void ask() {
   netWorth.put(readInt());
  }
  function void tell(bool b) {
   if (b) {
    display("You are the richest!");
   } else {
    display("Make more money!");
   }
  }
```

```
Declare Server Max:
  Group of Millionaires mills;
  function void main(int[] args) {
   sint max = 0;
   sclient rich;
   foreach (client c in mills) {
    sint netWorth = c.netWorth.take();
    if (netWorth >= max) {
     max = netWorth;
     rich = c;
    }
   }
   foreach (client c in mills) {
    c.tell(open(c==rich|rich));
   }
  }
```

max = b*netWorth+(1-b)*max

The server is the Trusted Third Party



Concepts

Clients:

Public values
- (Bools, Ints, Records)

Fields

Tunnels

Functions
- callable from server

Server:

Public & secret values
- (Bools, Ints, Records, clients)

Fields

Groups of clients

Functions

Security

at the language level

- Preventing covert channels:
  - Direct and indirect information flow
  - Timing and termination leaks
  - Open and responsibilities
  - etc.

Security

```
sbool h = ...;
sint i = 0;
int l = 0;
if (h) {
 i = 7 * h;
 l = 7;
} else {
 l = 42;
}
open(i|h);
```

SMCLc

- Compiler: SMCLc (alpha)
- Available from www.BRICS.dk/SMCL/

SMCR

The Secure Multiparty Computation Runtime

Overview of the Runtime

- Implements an ideal functionality
- Provides the primitives used by the compiler:
  - Secret sharing input
  - Opening sharings
  - Arithmetic (addition and multiplication)
  - Comparison
- Security against passive adversaries

Design of the Runtime System

- Decoupled from the language (thin interface to compiler)
- Modularity
  - Ability to exchange implementation of primitives

Primitives: Sharing and Opening

- Input is secret shared using an additively homomorphic secret sharing system over Zp
- Basic shares are standard Shamir-sharing
  - Other techniques for sharing used in special cases (e.g. PRSS)
- Output is reconstructed by opening shares when enough parties agree

Primitives: Addition

- Add shares together
- Requires no communication, free in our complexity model
- Corollary: arbitrary linear combinations are free

Primitives: Multiplication

- Standard GRR: multiply shares, reshare result
- Requires a round of communication
- Basic unit of complexity

Primitives: Comparison

- Complex protocol using the other arithmetic primitives
  - Seen as a primitive by the compiler
- Most expensive operation: 10-12 communication rounds
  - Number of multiplications: linear in bitlength
  - With preprocessing: ~2 communication rounds
- Faster special cases: equality, public result, comparison of public and secret integers, etc.

Primitives: Comparison

- Some ideas for computing "a>b?":
  - Compute $c = 2^l + a - b$, extract the l´th bit of c (e.g. compute c mod 2^l)
  - Extract the bit of a at the most significant bit position where a and b differ (assuming bit sharings are available)

Possibilities for Optimization

- Multiplications require a round of communication
  - Run independent multiplications in parallel!
- Do the same for comparison
- Tradeoff between round complexity and number of multiplications

Future Work

- Explore possibilities for better primitives
- Construct and implement applications: e.g. simplex
- Intermediate language for writing complex primitives for thin runtime system.
- Security against active adversaries and self-trust

Questions?