Building a universal secure computation platform based on protection domains

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Cybernetica

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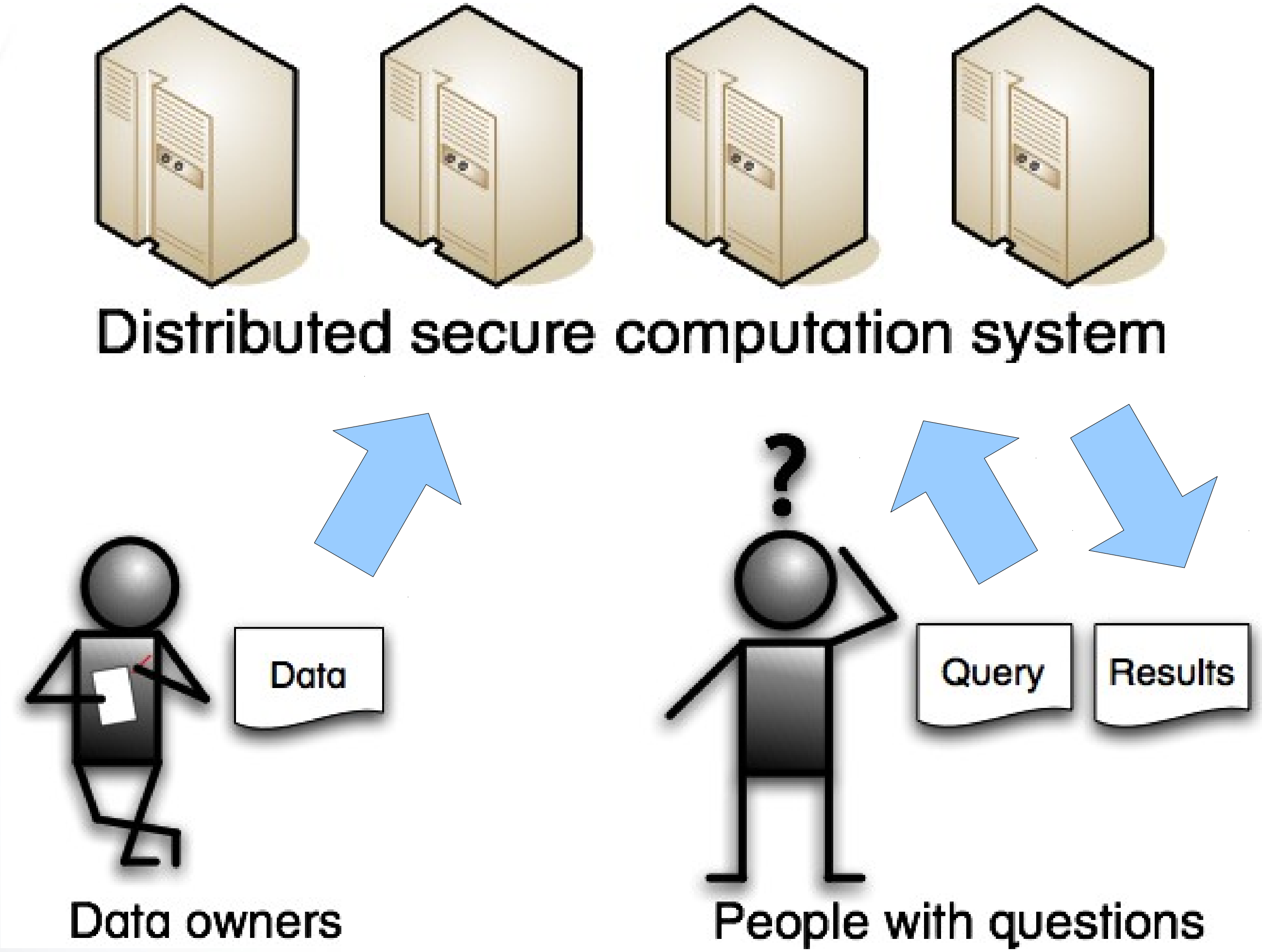
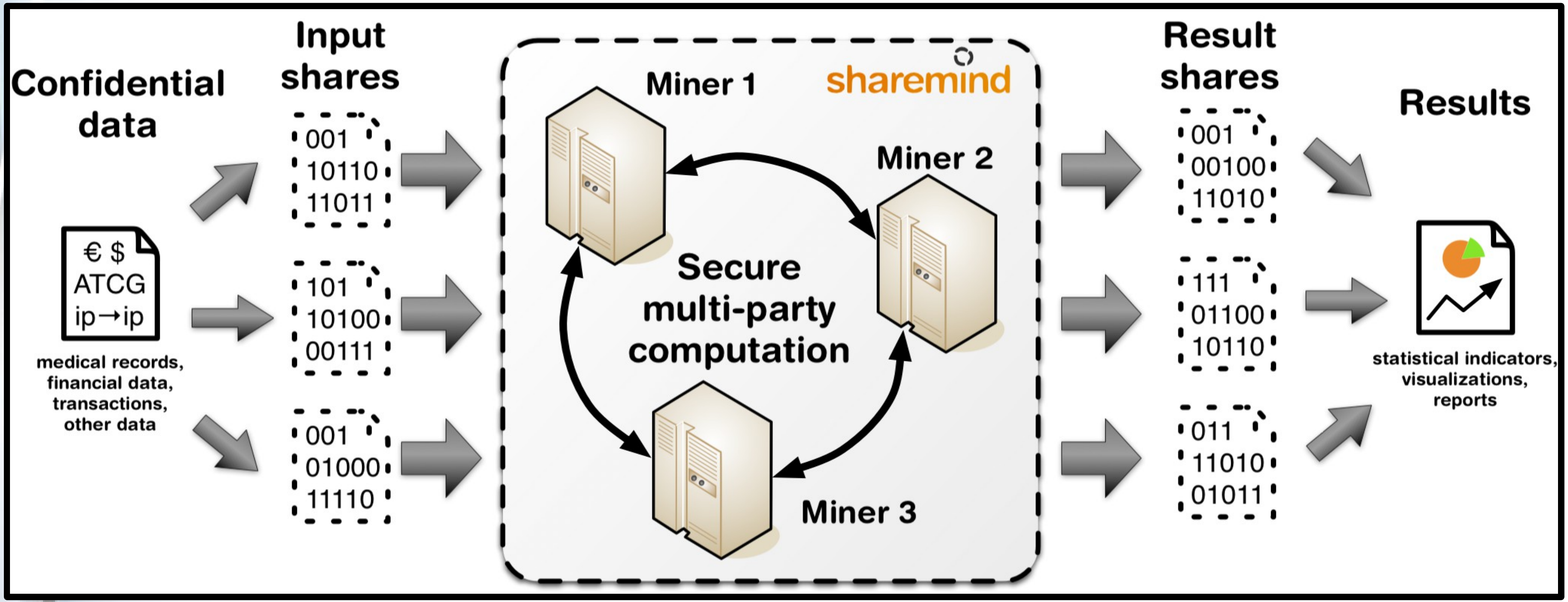
Basic scenario



Earlier work: Sharemind 2



How Sharemind works

- Algorithms for processing data are deployed on the servers.
- Client applications send in the data and query parameters.
- The server performs secure computation on the provided data.
- The server returns the results to the client application who made the query.

Earlier work: SecreC

```
// SecreC is an algorithm language with
// built-in visibility supertypes private and public
// private values become public through declassify

void main () {                 // main function
  private int a, b, c;         // private data
  a = b + c;                   // private computation
  public int d;                // public data
  d = declassify (a);          // make private public
  publish (d);                 // send to client
}
```

Sharemind 3 & SecreC 2

- We need to be able to quickly adapt new secure computation techniques and security models.
- These techniques should be easily accessible in the SecreC language.

- We are updating both the virtual machine and the language.

Sharemind 3 design goals

- The virtual computer acts like an *ideal functionality* or a *trusted party*.
- The computer can support various secure computing technologies.
- The computer has features for both short-term and long-term storage.
- The computer can also work with public data.

Protection domains

A *protection domain* (PD) is a set of data that is protected with the same resources and for which there is a well-defined set of algorithms and protocols for computing on that data while keeping the protection.

Protection domain kinds

A *protection domain kind* is a set of data representations, algorithms and protocols for storing and computing on protected data.

Each protection domain belongs to a certain protection domain kind. Each protection domain kind can have several protection domains.

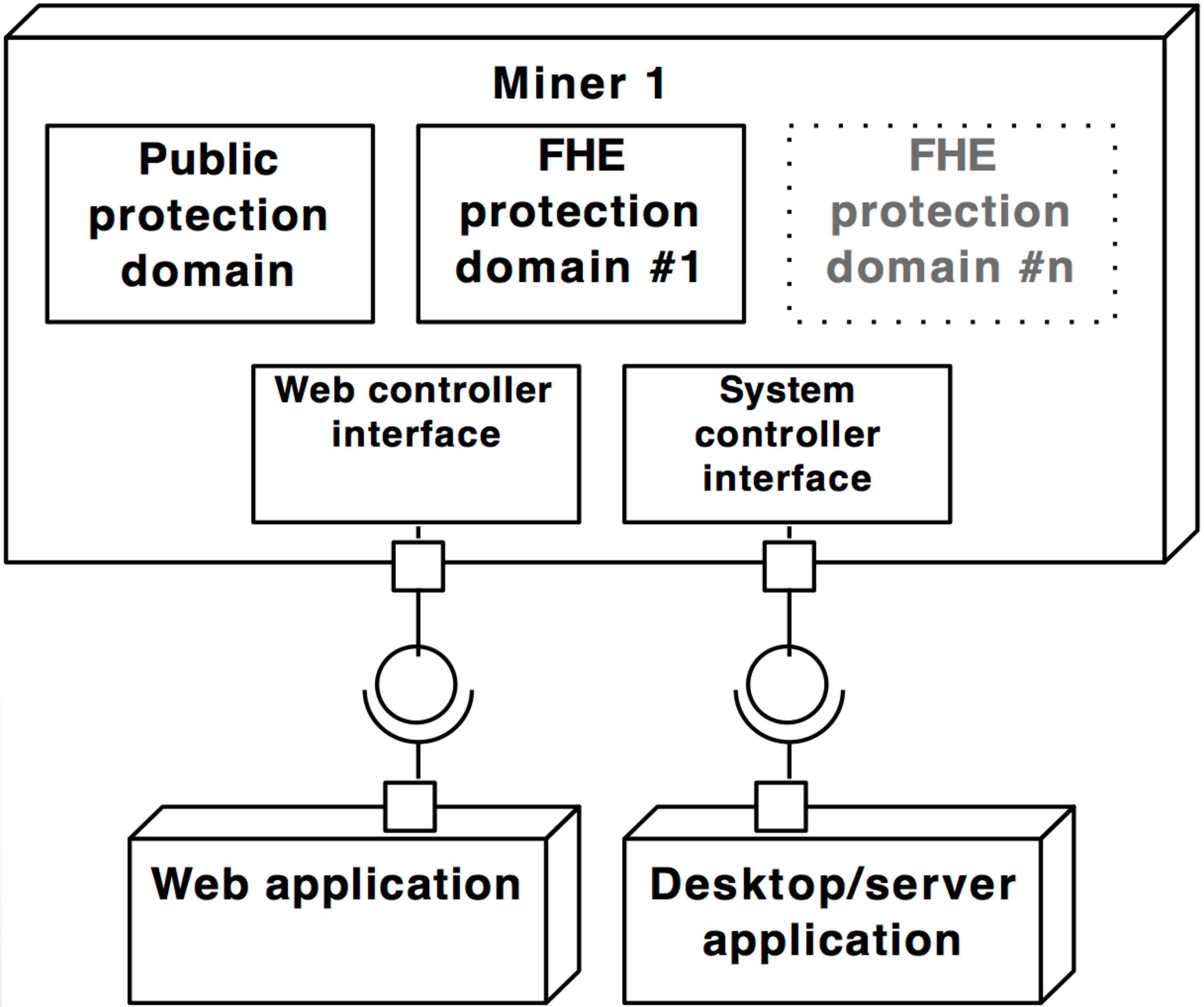
Examples of PD-s

- An FHE system running under a single key is a protection domain.
- A single physical MPC instance is a protection domain.
- A public machine is a protection domain.

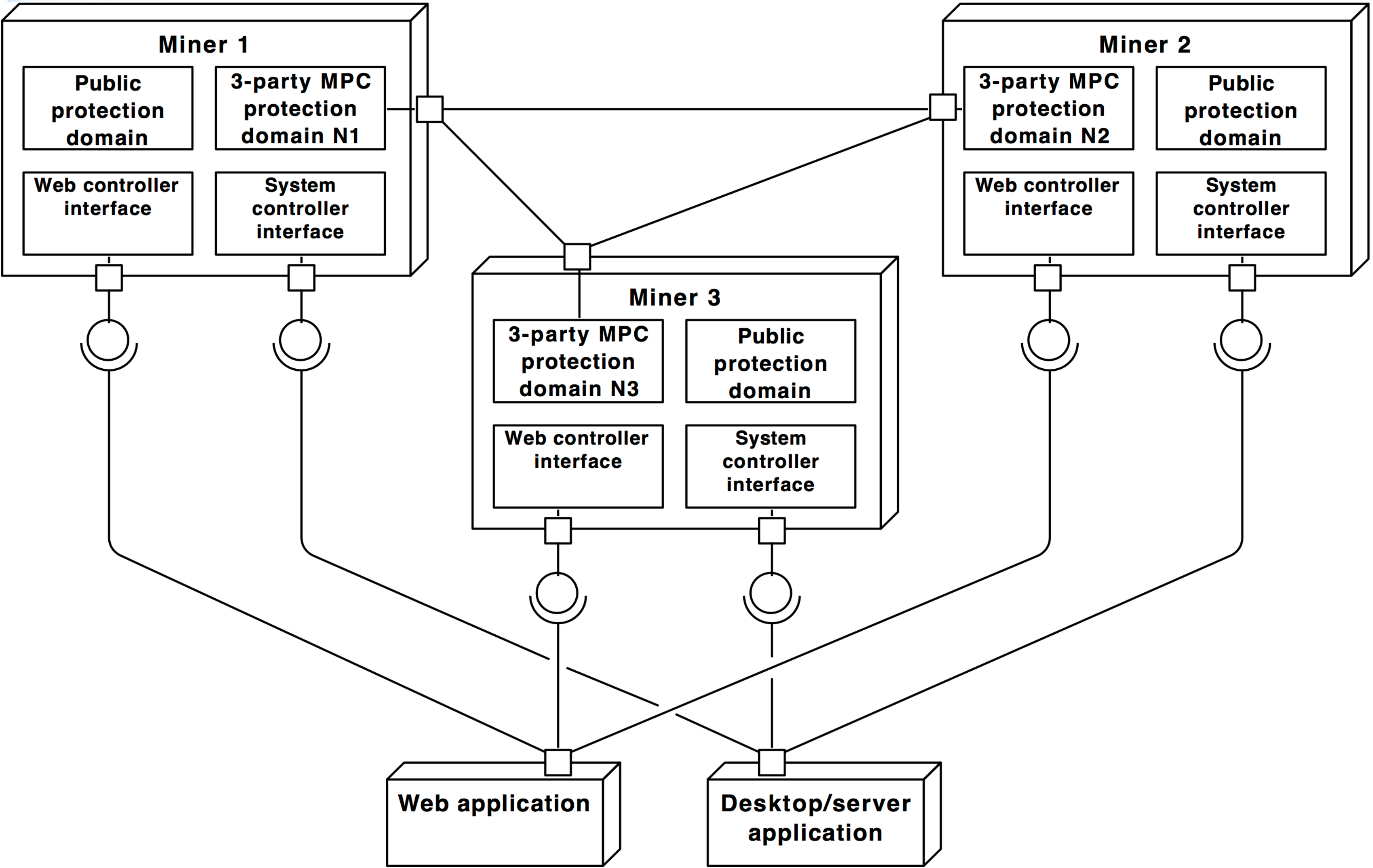
Examples of PD kinds

- A FHE system specified by its algorithms is a protection domain kind.
- A MPC system specified by its protocols is a protection domain kind.
- Public computation systems are a protection domain kind.

Single node with FHE PDs



Three nodes with a MPC PD


Miner 1
Public protection domain
3-party MPC protection domain N1
Web controller interface
System controller interface
Miner 2
3-party MPC protection domain N2
Public protection domain
Web controller interface
System controller interface
Miner 3
3-party MPC protection domain N3
Public protection domain
Web controller interface
System controller interface
Web application
Desktop/server application

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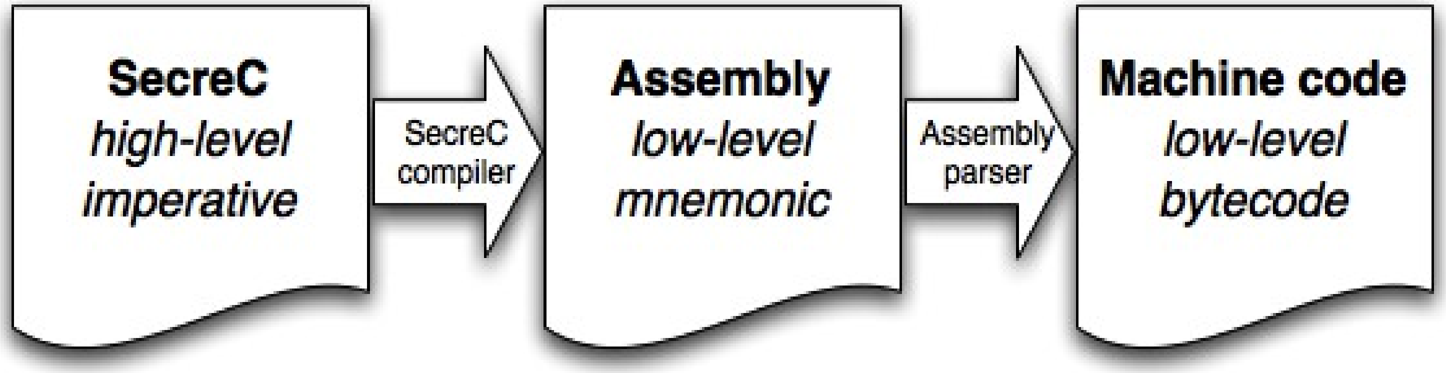
Programming the machine



- The developer writes SecreC code.
- The resulting assembly code is deployed in the virtual machine.-
- The virtual machine parses it and stores it in memory as bytecode.

The low-level machine

- The basic machine is public.
- I.e, the program flow is not hidden.
- It has a stack and registers.
- Non-public PDs are used through system calls to their implementation.

SecreC 2 design goals

- SecreC is a high-level algorithm language for expressing algorithms that process confidential data.
- It has a type system supporting protection domains.
- The language is designed for implementing data mining algorithms.

Example of SecreC 2 code

```
kind additive3p;              // declare PD kind
domain private additive3p;    // instance of the PD

void main () {                // main function
  private int a, b, c;        // private data
  a = b + c;                  // private computation
  public int d;               // public data
  d = declassify (a);         // make private public
  publish (d);                // send to client
}
```

Writing library functions

```
template<domain T1, domain T2, domain T3>
T1 int [[1]] operator* (T2 int[[1]] x, T3 int[[1]] y)
{
  T1 int [[1]] result (size(x));
  public int i;
  assert(size(x) == size(y));
  for (i = 0; i < size(x); i++) {
    result[i] = x[i] * y[i];
  }
  return result;
}
```

PD specialization

```
template<domain T1:additive3p>
T1 int [[1]] operator* (T1 int[[1]] x, T1 int[[1]] y)
{
  // make a system call to a special function
  // implemented within the protection domain,
  // passing x and y as parameters
}
```

- Useful, when a PD implementation has a „hardware-accelerated“ implementation of a certain primitive.

Future work

- Sharemind 3 and SecreC 2 will become usable in 2012.
- We are interested in collaborating to implement new protection domains and protocol suites.
- We are looking for interesting applications and people interested in developing them.