universal composability from essentially any trusted setup

Mike Rosulek | The University of Montana | CRYPTO 2012

secure computation. . .

Several parties wish to carry out an agreed-upon computation.

- Parties have individual inputs / output
- Security guarantees:
  - Privacy (learn no more than your prescribed output)
  - Input independence
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Example:

- Set intersection $A \cap B$ (*function evaluation*)
- Generate a fair coin toss (*randomized*)
- Online poker without a dealer (*reactive*)

good news, bad news. . .

Good news [Canetti01]

Universal Composition (UC) framework = realistic security model for Internet protocols.

good news, bad news...

Good news [Canetti01]

Universal Composition (UC) framework = realistic security model for Internet protocols.

Bad news [CanettiFischlin01,CanettiKushilevitzLindell06]

UC security is impossible for almost all tasks that we care about ☹

the next best thing. . .

Slightly relax UC framework:

- Assume bounded network latency [KalaiLindellPrabhakaran05]
- Uniform adversaries, non-uniform simulators [LinPassVenkitasubramaniam09]
- Superpolynomial-time simulators [Pass03, PrabhakaranSahai04, BarakSahai05, MalkinMoriartyYakovenko06, CanettiLinPass10, ...]

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- Trusted setup: Protocols can use ideal functionality
  - Bit-commitment [CanettiLindellOstrovskySahai02]
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  - Trusted hardware device [Katz07]

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How useful is $\mathcal{F}$ as a trusted setup?

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  - $\Leftrightarrow$ $\mathcal{F}$ already has a UC-secure protocol without setups
- **Intermediate:** something between these two extremes
- **Complete**: *all* tasks have UC-secure protocols in presence of $\mathcal{F}$

take-home message. . .

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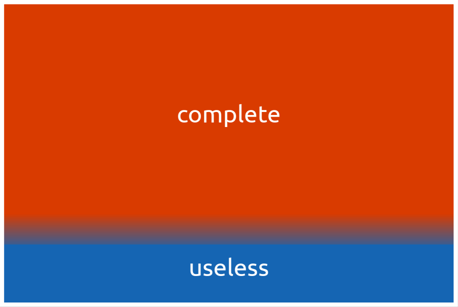

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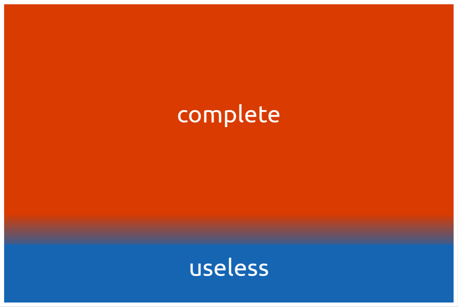

Characterize *reactive, randomized* functionalities, w/ behavior depending on security parameter!

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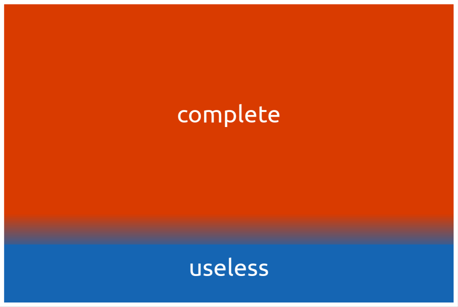

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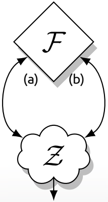
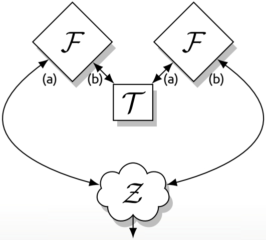
[MajiPrabhakaranRosulek10] restricted to deterministic & constant-sized.

“splitting game” for $\mathcal{F}$…





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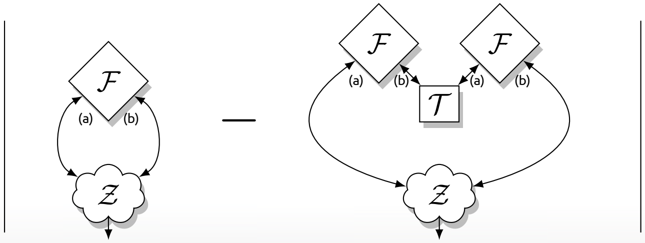

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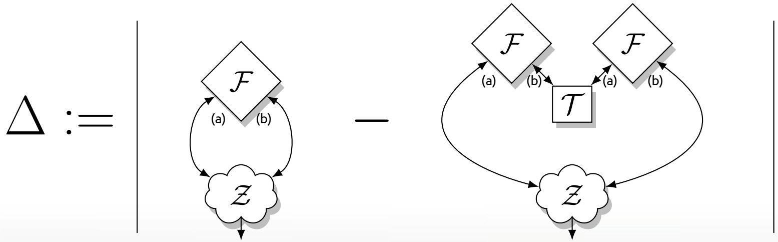

Definitions

$\mathcal{F}$ is **splittable** if $\mathcal{T}$ has a winning strategy. [PrabhakaranRosulek08]

$\Leftrightarrow$ $\exists \mathcal{T} : \forall \mathcal{Z} : \Delta$ negligible. *(“$\mathcal{T}$ fools all environments”)*

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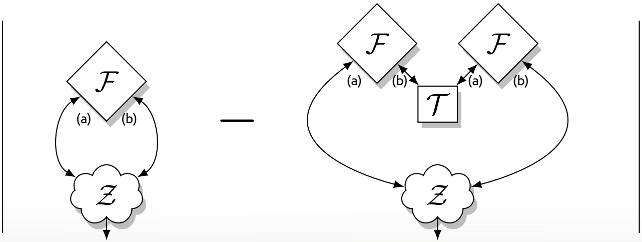

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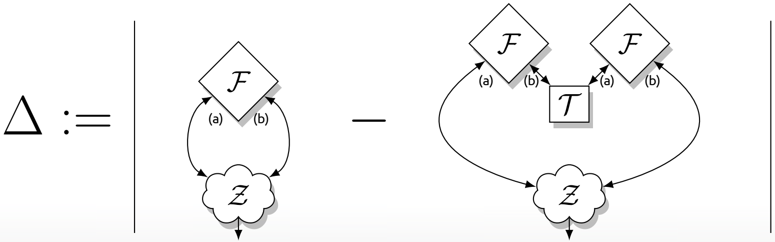

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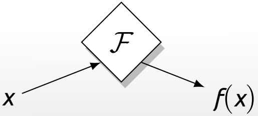
- Some (arguably unnatural) $\mathcal{F}$ admit no winning strategy for $\mathcal{Z}$ or $\mathcal{T}$!
- Applies to arbitrary (reactive, randomized, etc) functionalities.

quiz: splittable or not?...



... where f is a OWF

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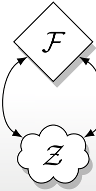

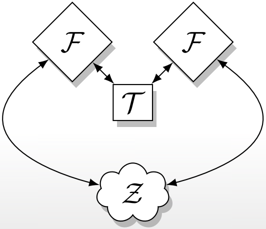

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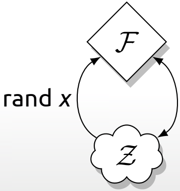

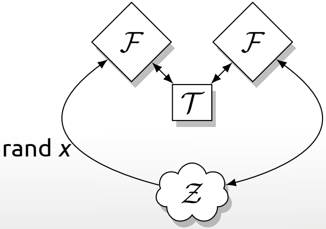

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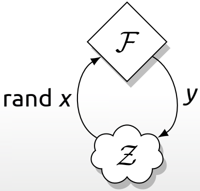

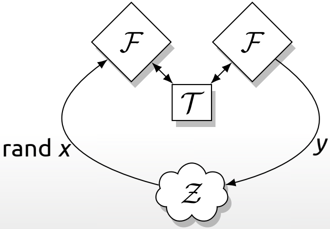

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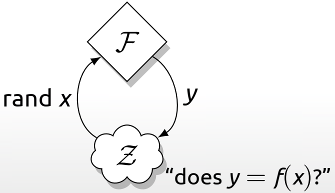

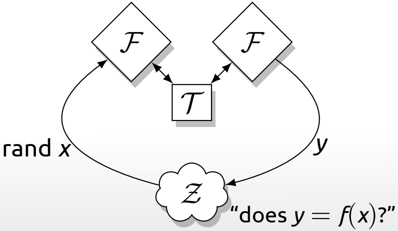

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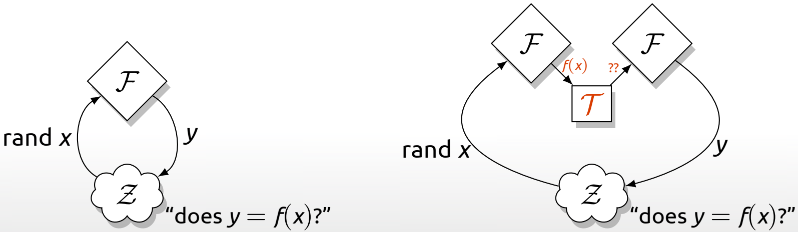

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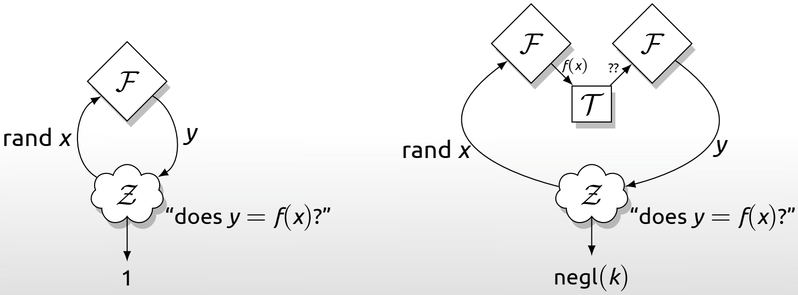

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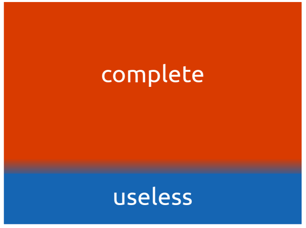
$\Rightarrow$ This $\mathcal{Z}$ detects every $\mathcal{T}$

$\Rightarrow$ $\mathcal{F}$ is strongly unsplittable

the characterization. . .



$\mathcal{F}$ useless $\Leftrightarrow$ $\mathcal{F}$ splittable

[PrabhakaranRosulek08]

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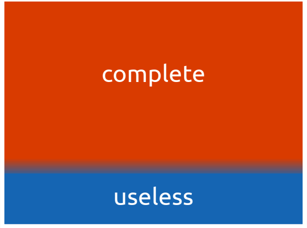

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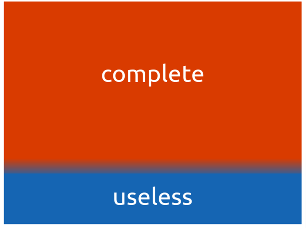

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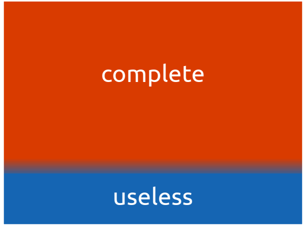

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[PrabhakaranRosulek08]

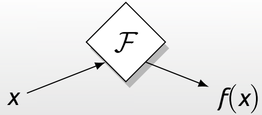
Outline: Strong Unsplittability $\Rightarrow$ Complete

Suffices to construct UC-secure **commitment protocol**

1. UC-commitment is complete [CanettiLindellOstrovskySahai02]

commitment protocol...

How to do it (using our example)...



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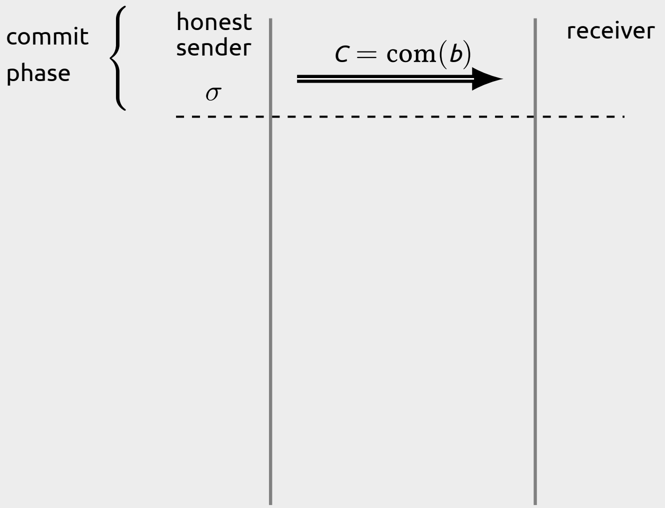

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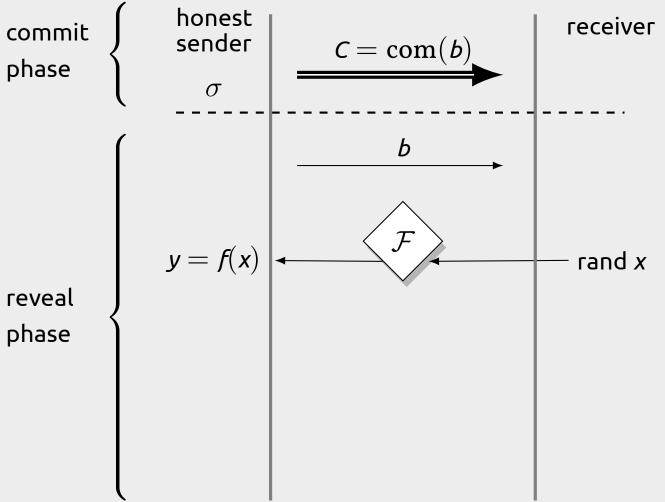

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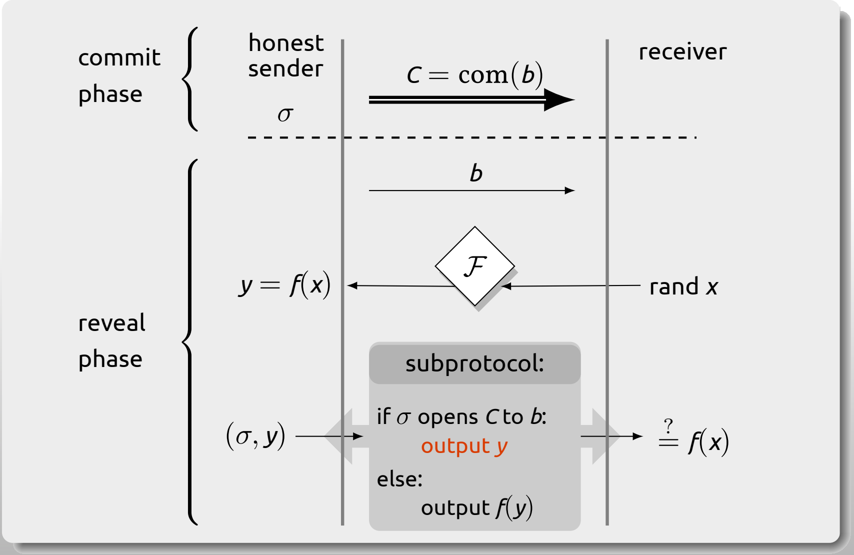

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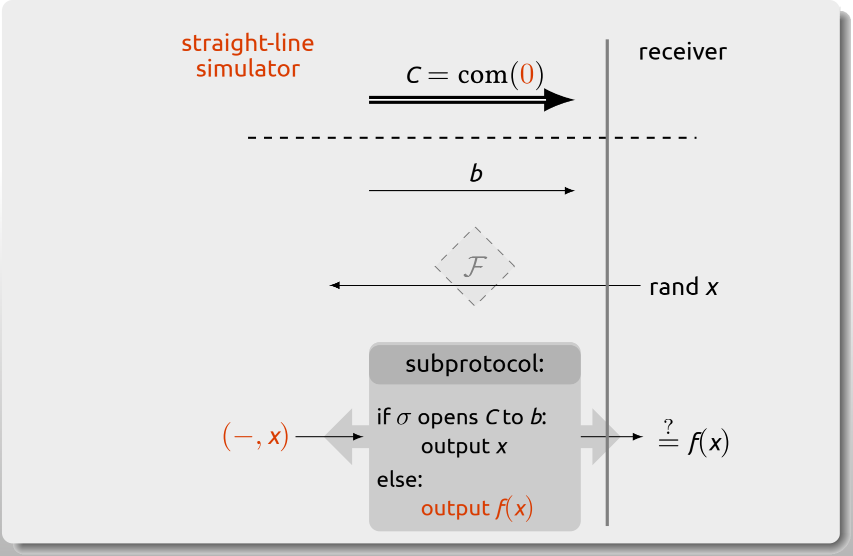

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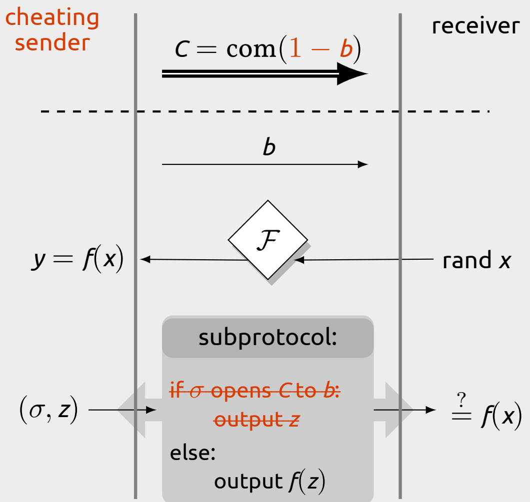

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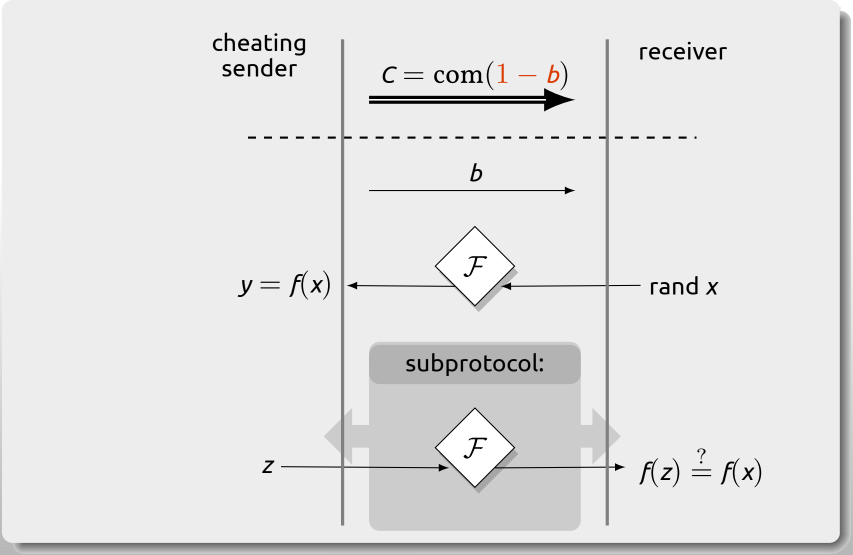
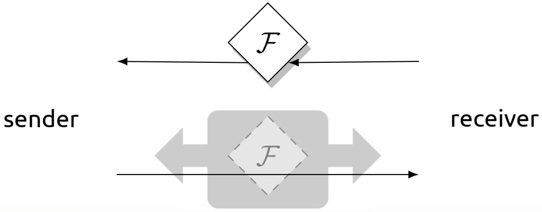


protocol: key idea. . .



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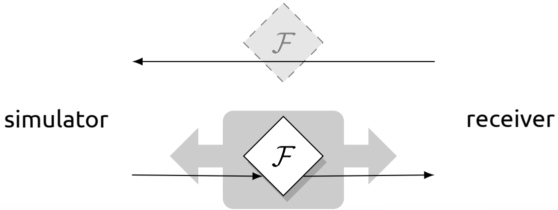

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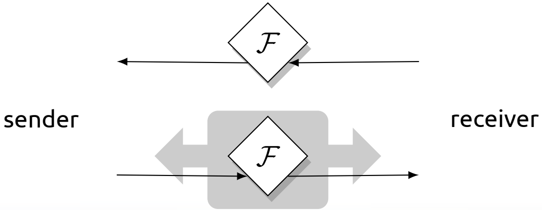

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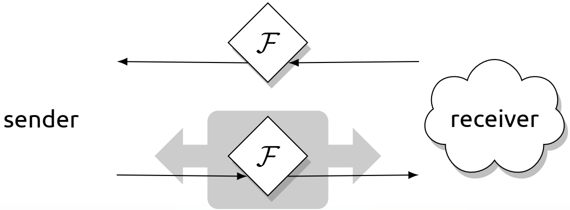

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Strong Un-Splittability

There is a way for receiver to behave which can distinguish:

- Interacting with a single instance of $\mathcal{F}$ (#1, #2)
- Interacting with *any* "split" $\mathcal{F}$ (#3)

wrap-up. . .

Other things in the paper (full version @ `eprint/2011/240`):

- Get from “one-sided” to full-fledged UC commitment
- Subtleties, caveats for *reactive* $\mathcal{F}$
- Complete $\Rightarrow$ strongly unsplittable? (almost!)

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Summary:

> *Every "natural" functionality (reactive, randomized, etc.) is either* **useless** *or* **complete** *as a UC setup.*

The End