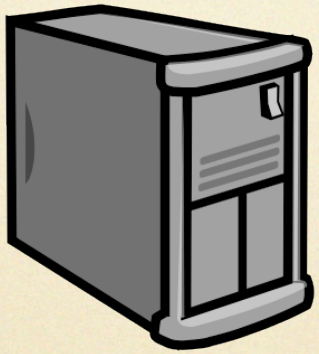
Securing services running over untrusted clouds : the two-tiered trust model

Aggelos Kiayias (U. Athens & U. Connecticut)

Joint work, **Juan Garay, Ran Gelles, David Johnson, Moti Yung**
(AT&T – UCLA - AT&T - Google)

Outsourcing your service to the cloud

Moo(. . .)



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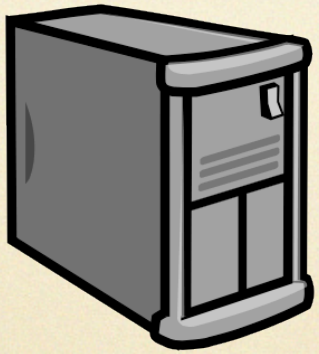

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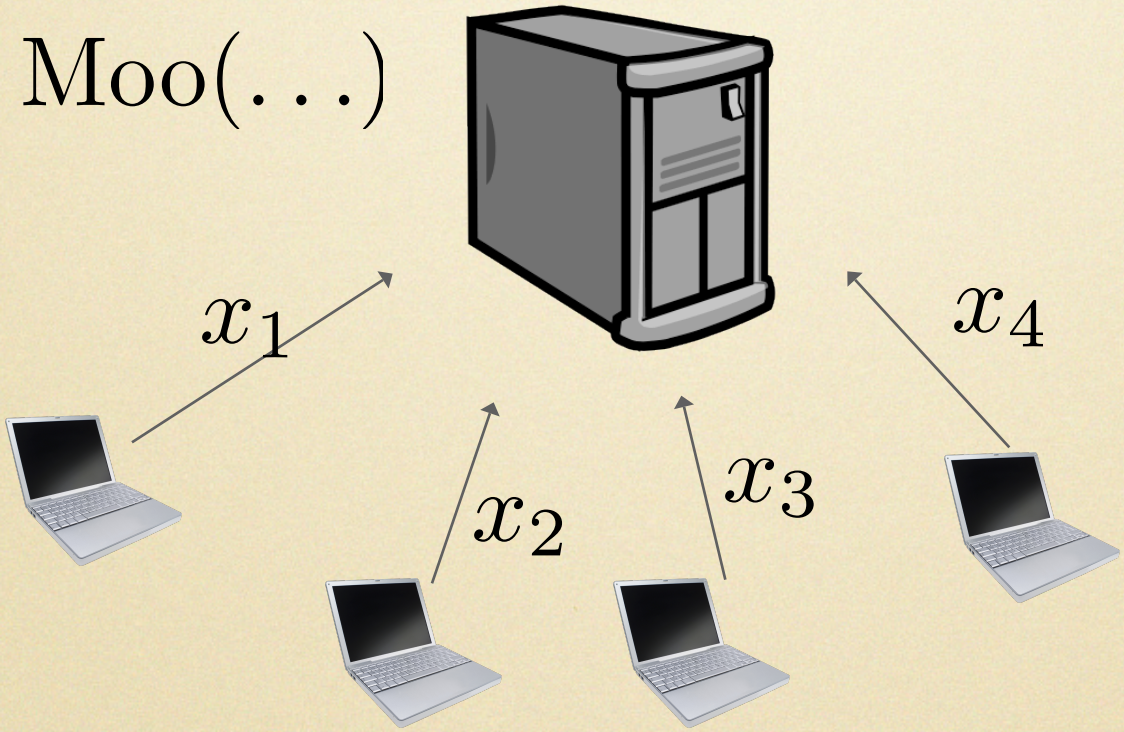

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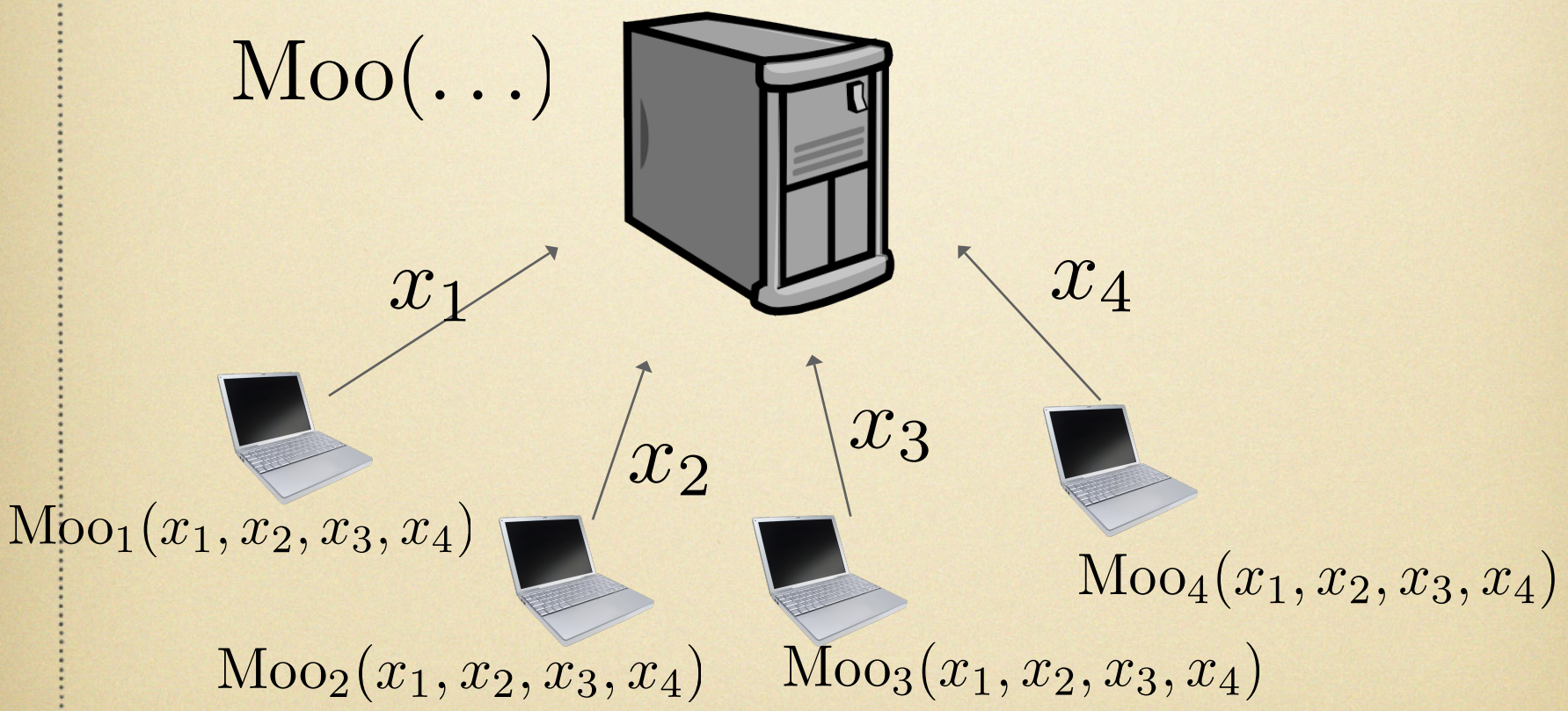
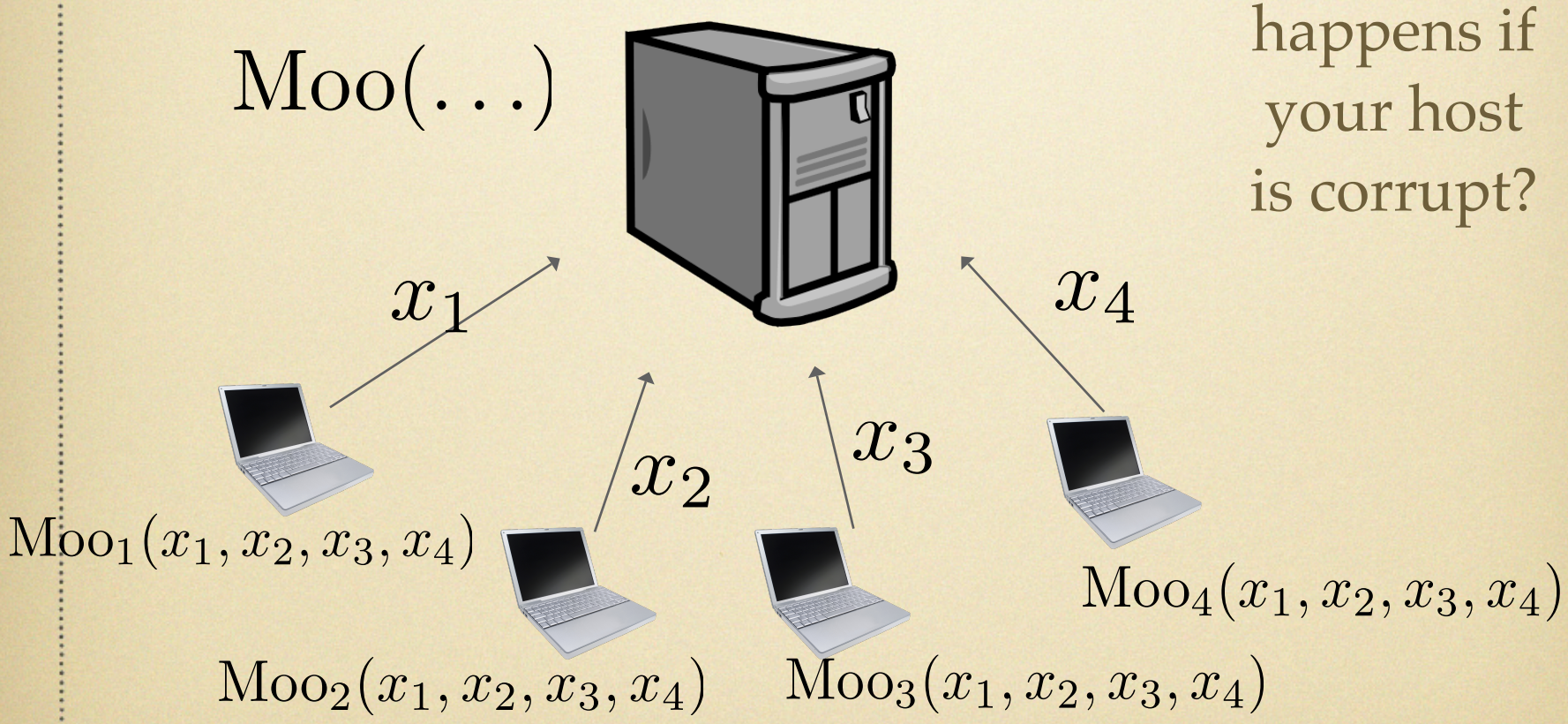


Outsourcing your service to the cloud

what happens if your host is corrupt?



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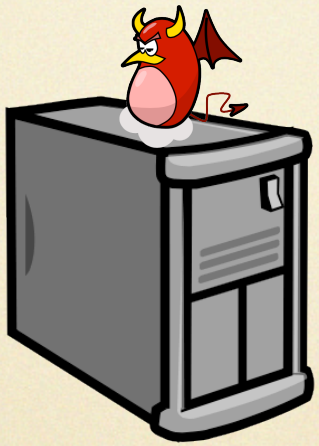

$\mathrm{Moo}(\ldots)$

x_1

x_2

x_3

x_4

$\mathrm{Moo}_1(x_1, x_2, x_3, x_4)$

$\mathrm{Moo}_2(x_1, x_2, x_3, x_4)$

$\mathrm{Moo}_3(x_1, x_2, x_3, x_4)$

$\mathrm{Moo}_4(x_1, x_2, x_3, x_4)$

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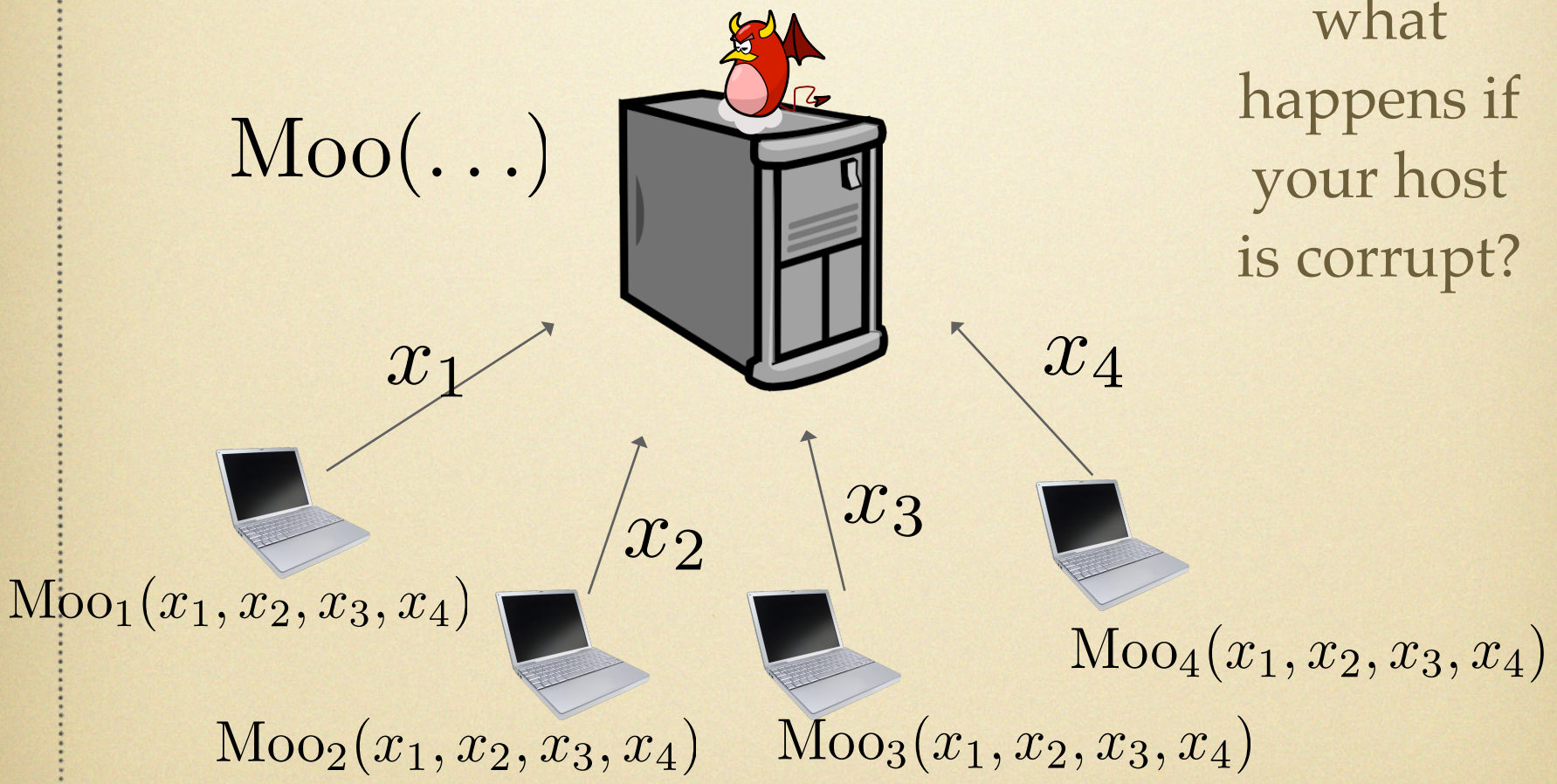
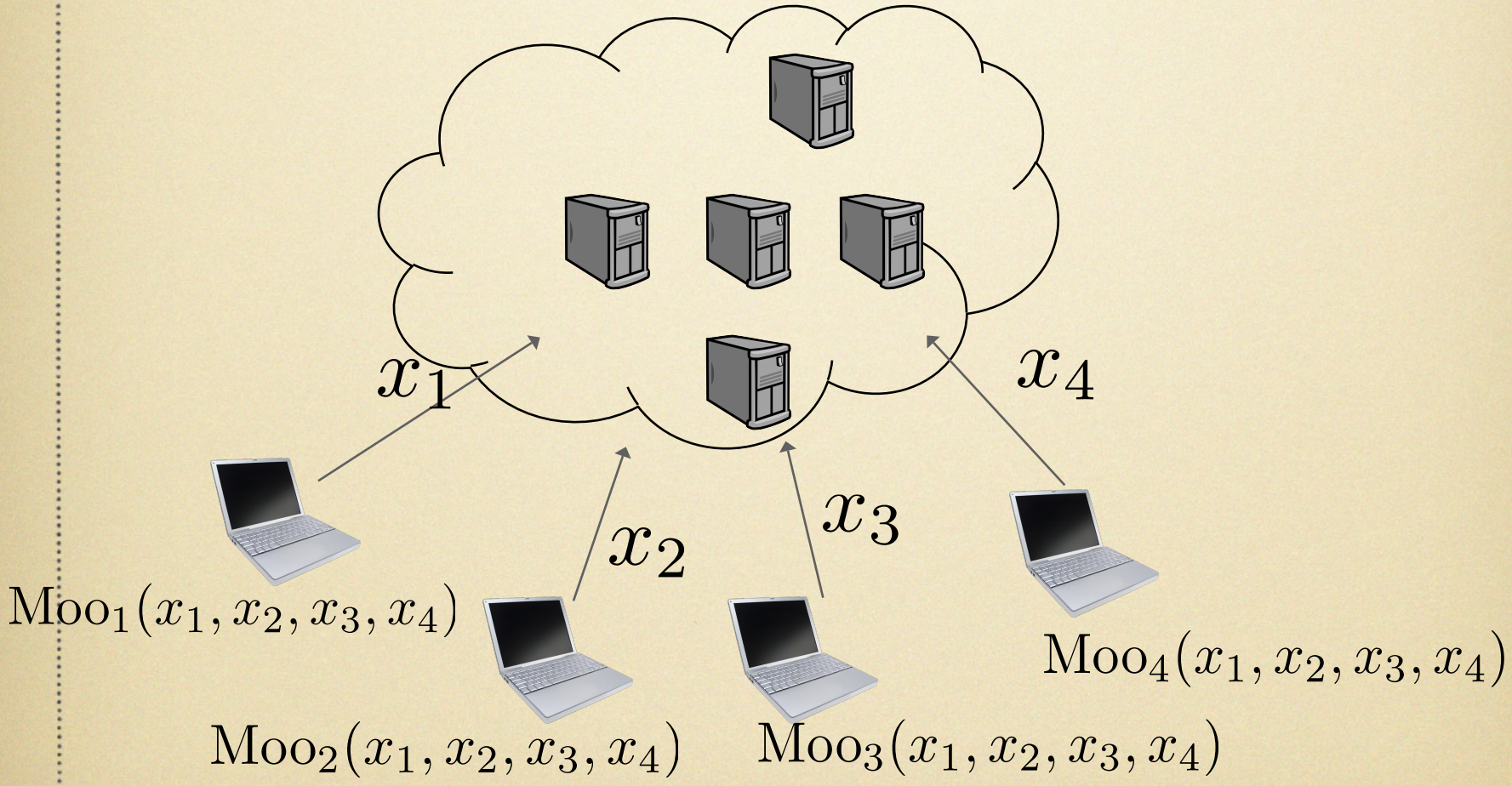


encryption / signatures cannot help here

what is at stake?

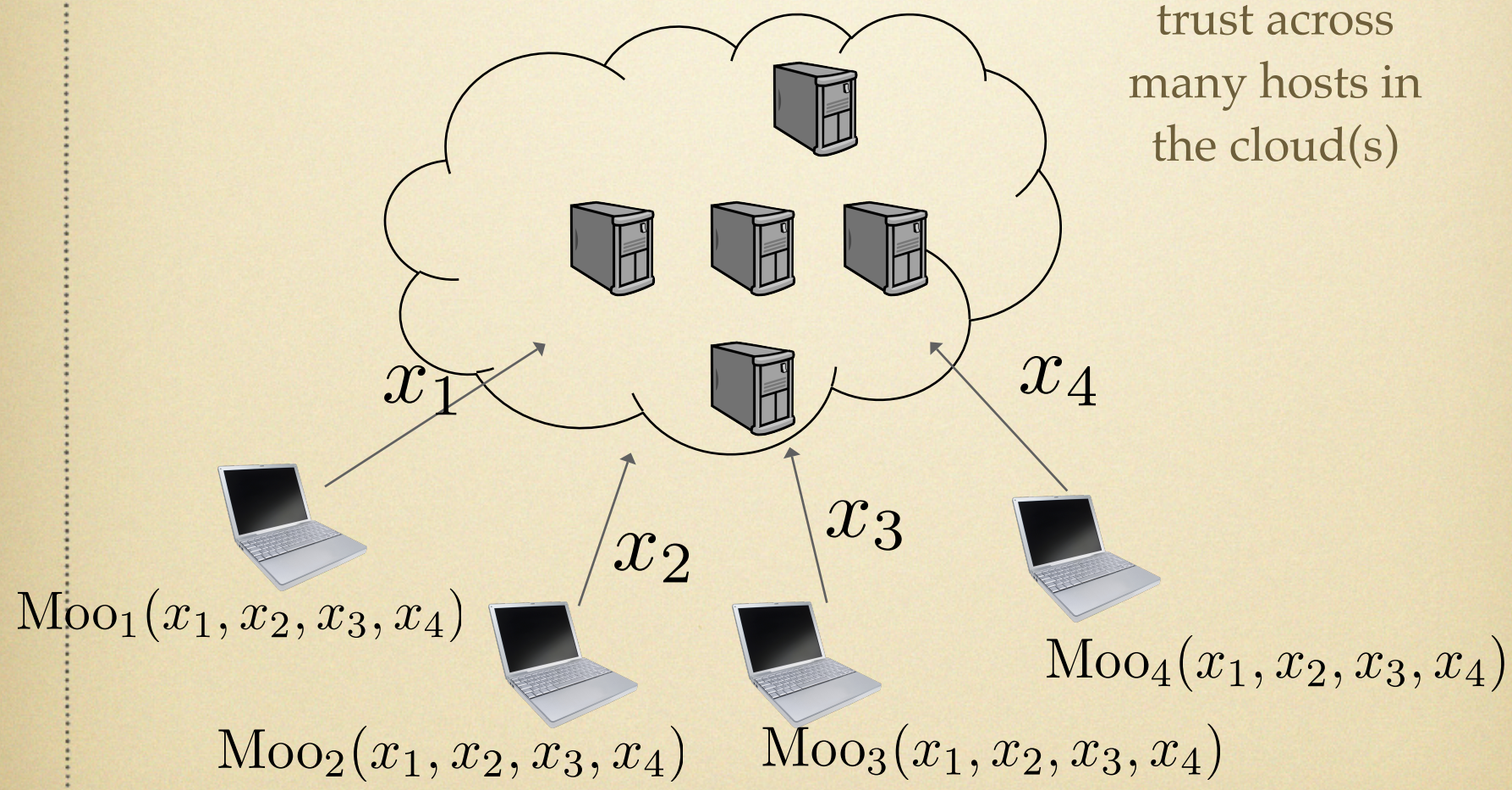
- Privacy of user inputs.
- Guaranteed Output Delivery.
- Fairness.
- Input-independence.

Distributing Trust



Distributing Trust

Spread trust across many hosts in the cloud(s)



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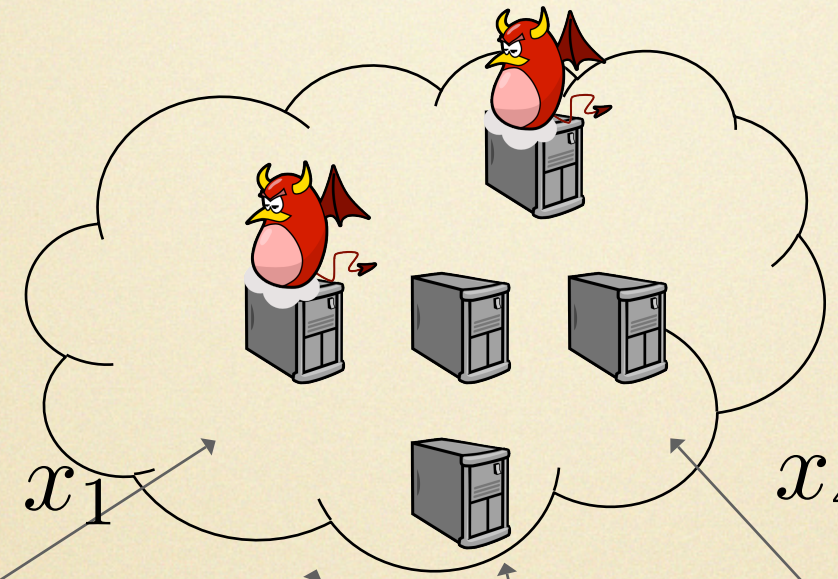

x_1

x_2

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x_4

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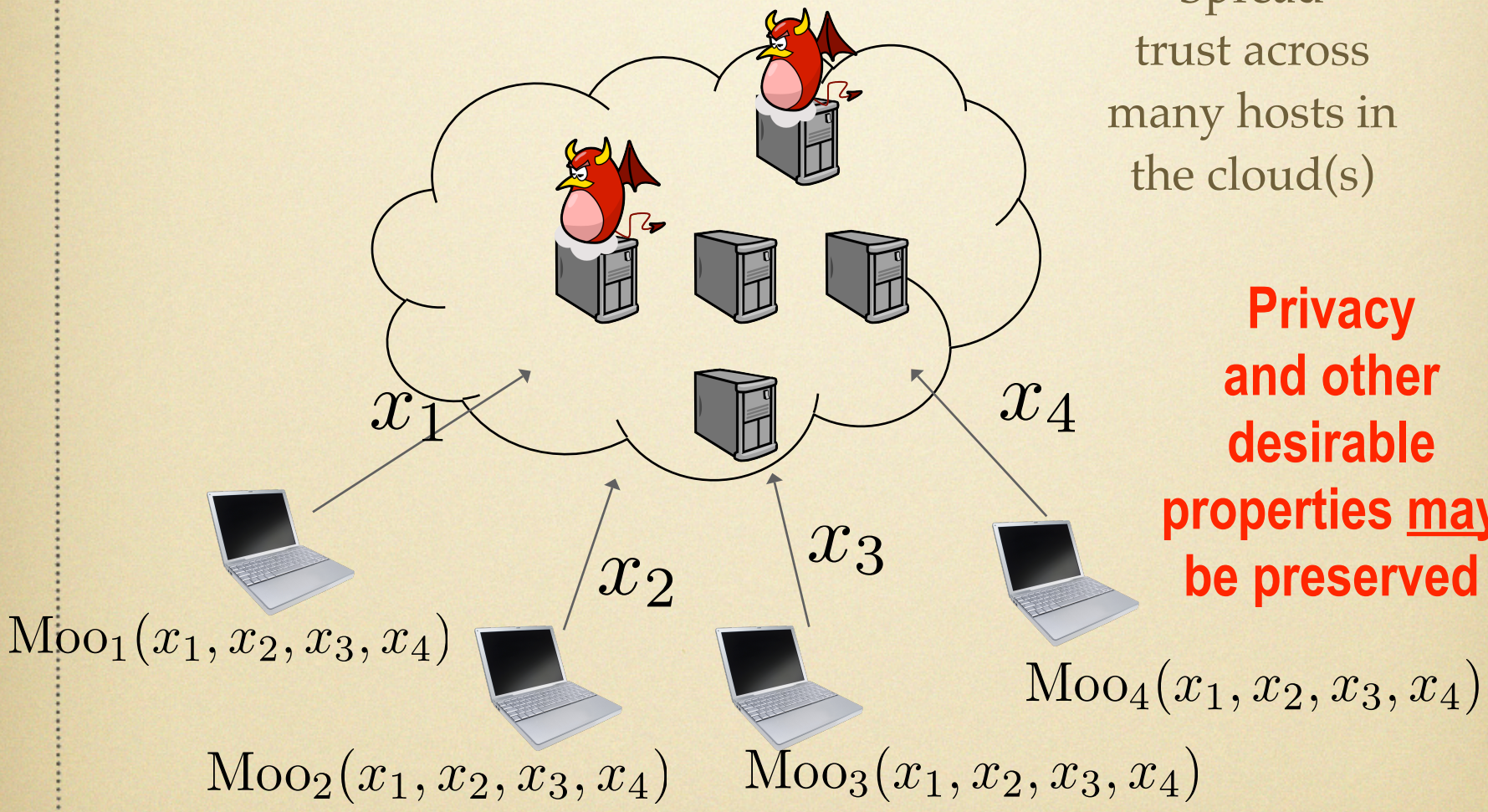

Spread trust across many hosts in the cloud(s)

Privacy and other desirable properties may be preserved

Crypto Protocols

for distributing trust.

Crypto Protocols

for distributing trust.

- An adversary controlling any *minority* of the servers cannot prevent the secure computation of *any efficient functionality* defined over their inputs [Yao82, GMW87]
- Similar results hold over secure channels (and no add'l crypto) with an (computationally unbounded) adversary controlling less than a *third* of the servers [BGW88, CCD88]

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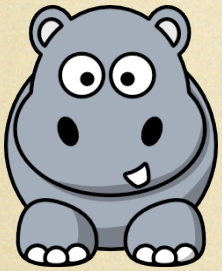
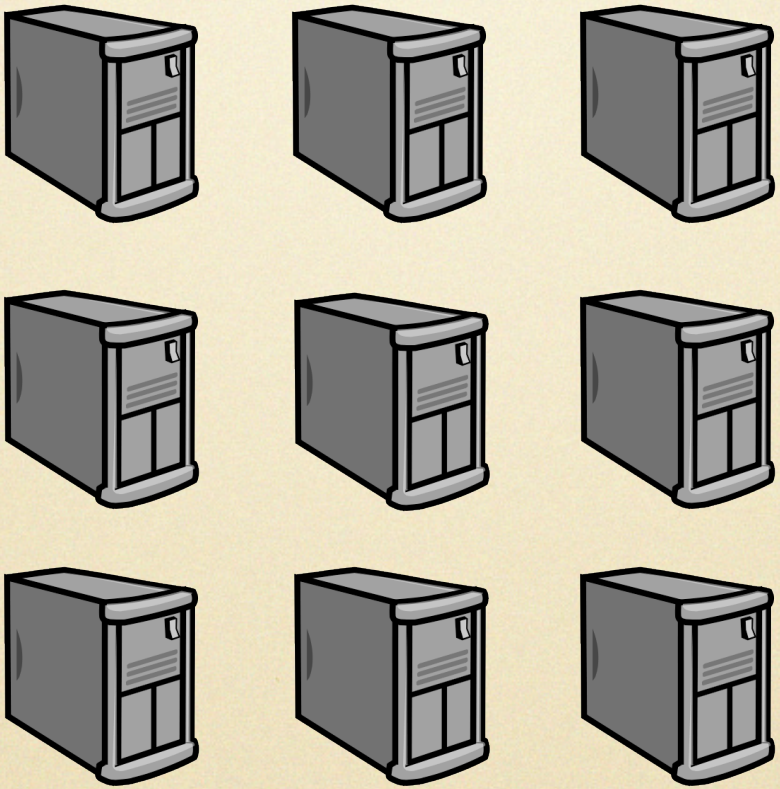
the doomsday scenario





The service provider may never be entirely sure

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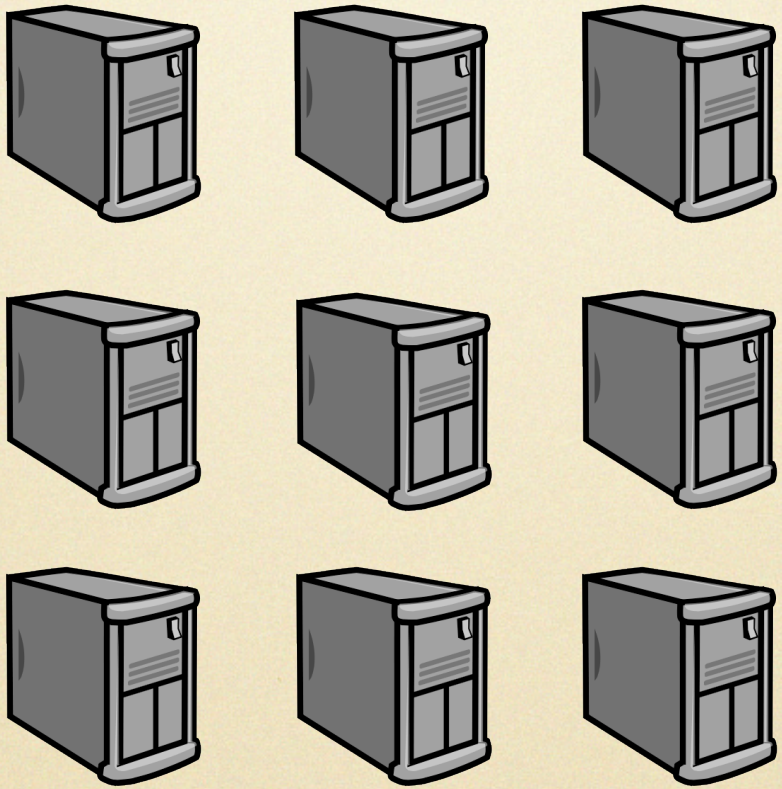

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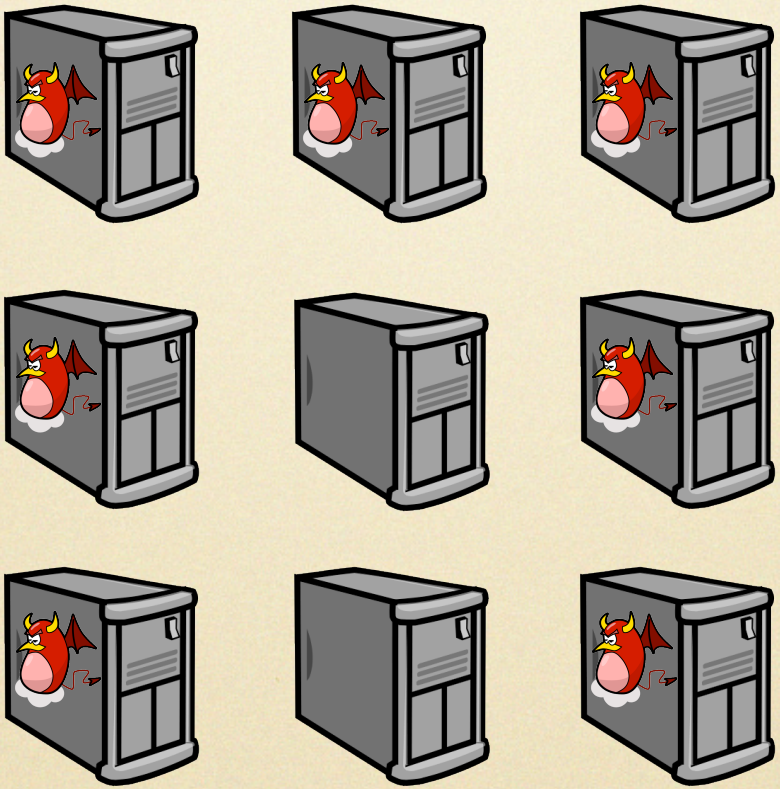

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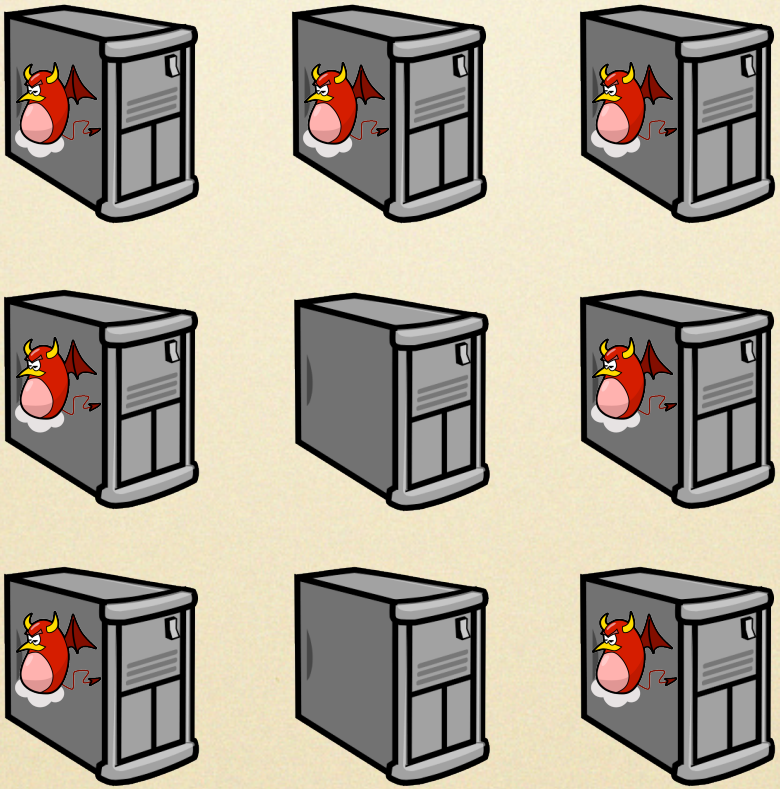
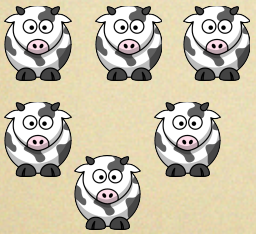


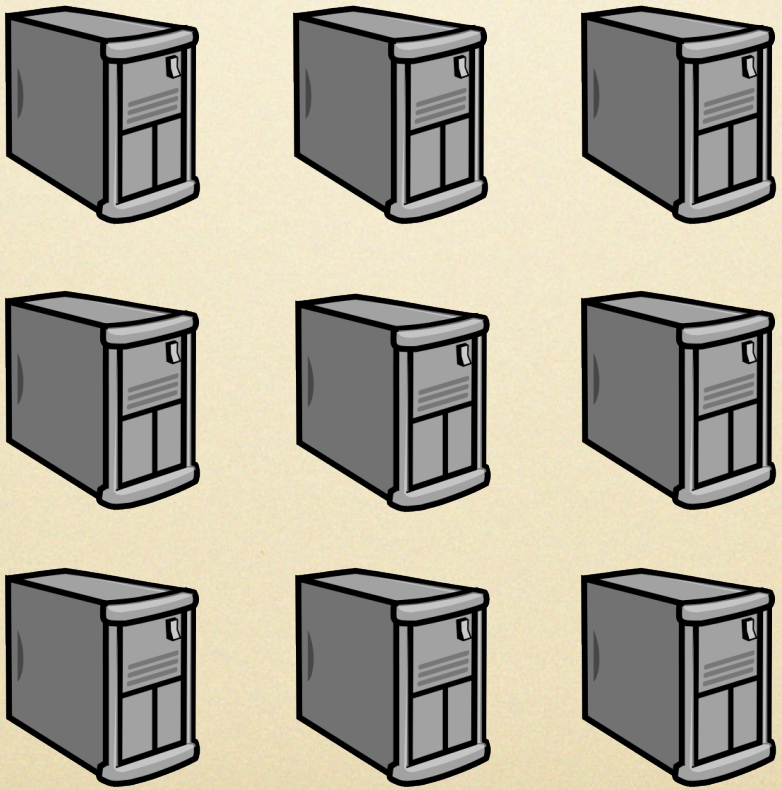
The service provider may never be entirely sure

the service may be subverted from the get-go

the outsourcing SP point of view

the SP is considering to start an MPC service over a cloud of servers





The cloud is already operational

what is the trust guarantee it provides?

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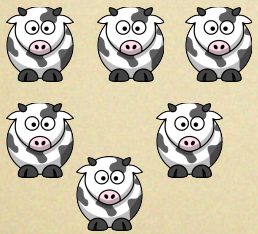

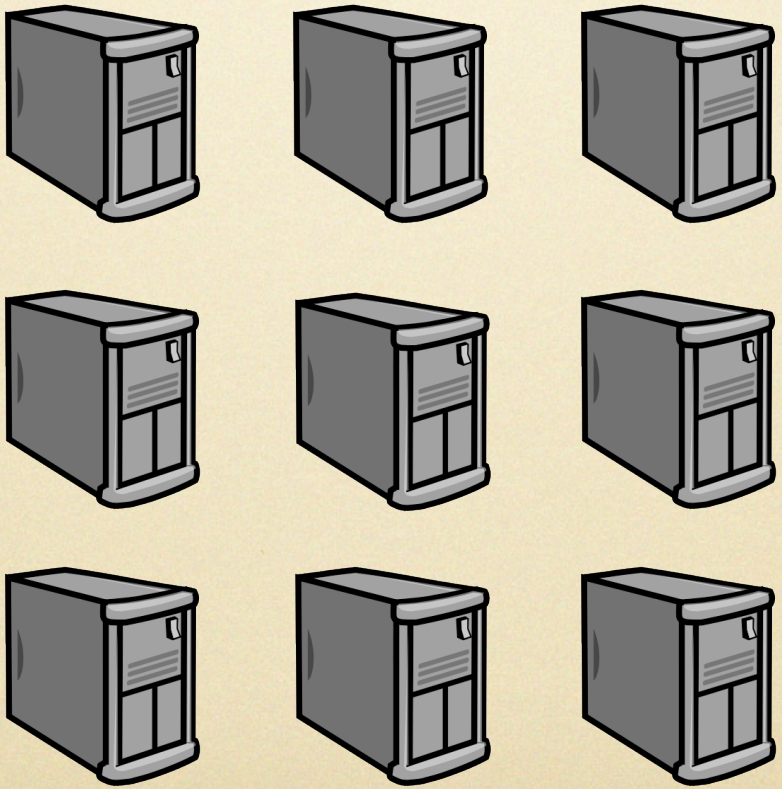

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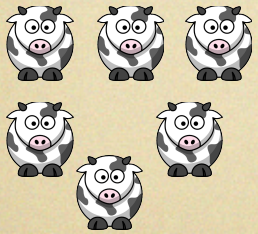

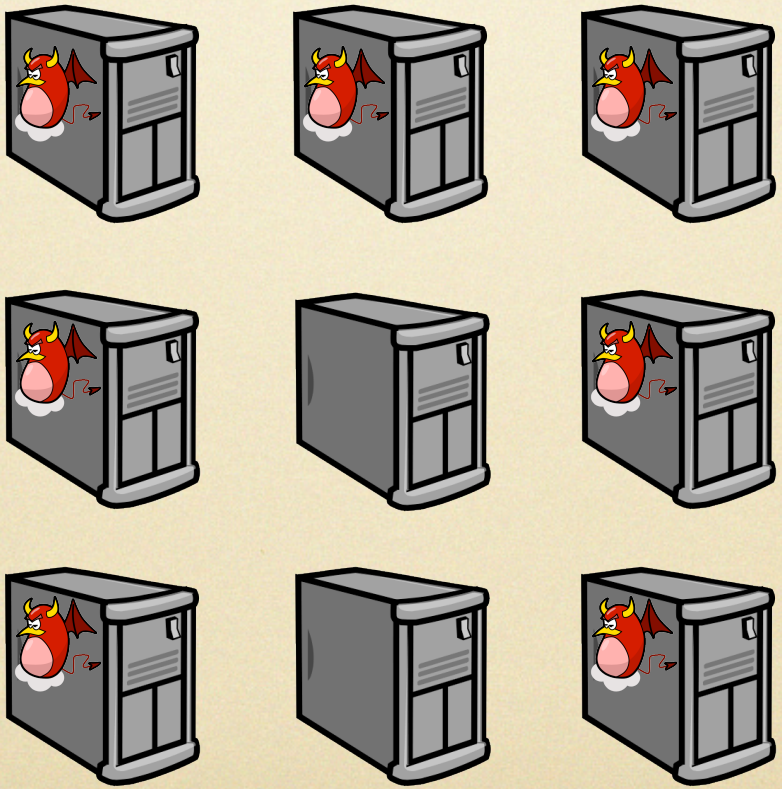

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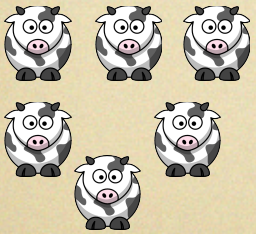

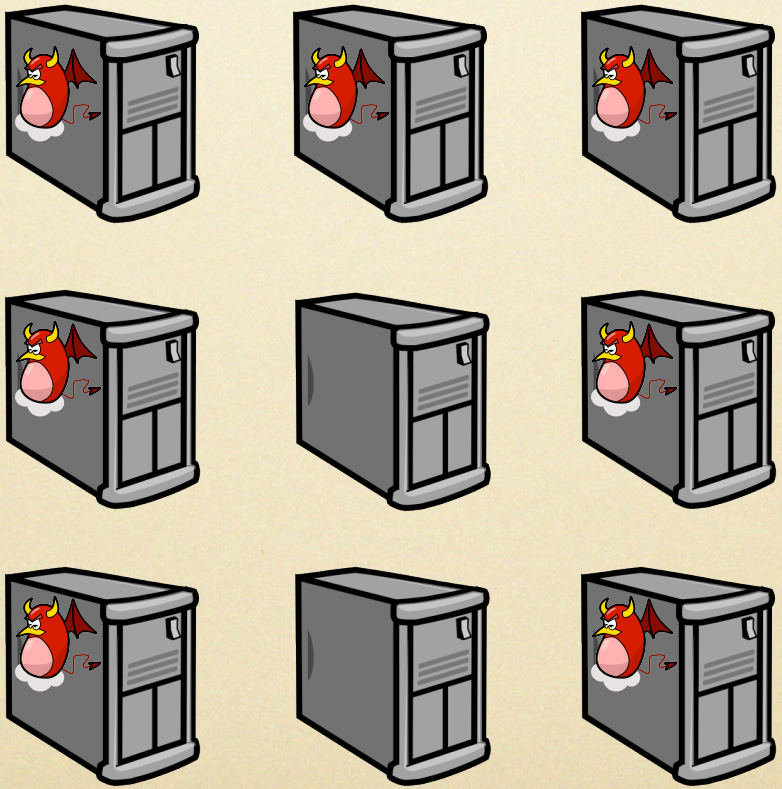

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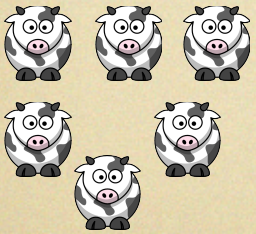

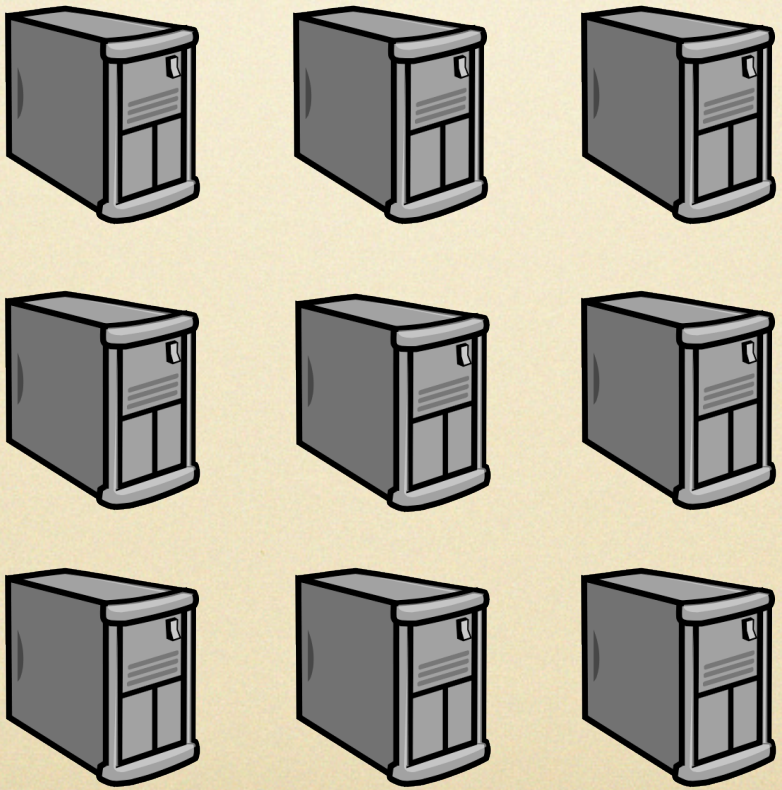

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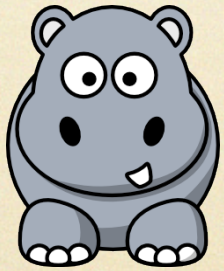
what is the trust guarantee it provides?

the outsourcing SP point of view, 2

how certain are you about your the hosts provided by your cloud provider(s) ?

how much effort/cost is needed to become certain?



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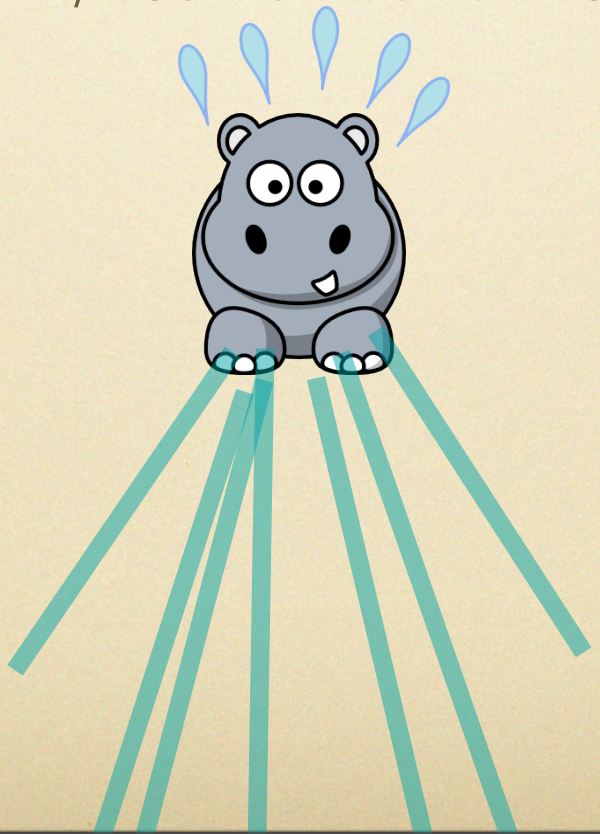


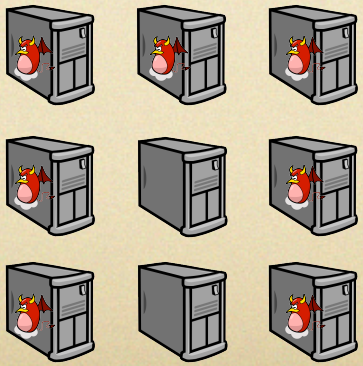
abstracting it as a game : SP vs adversary

1. Introduces n servers

2. Corrupts an α fraction of servers

3. Decides to initiate an MPC service. Inspects a fraction β of servers & possibly repairs

4. After service commences continues to corrupt a γ fraction

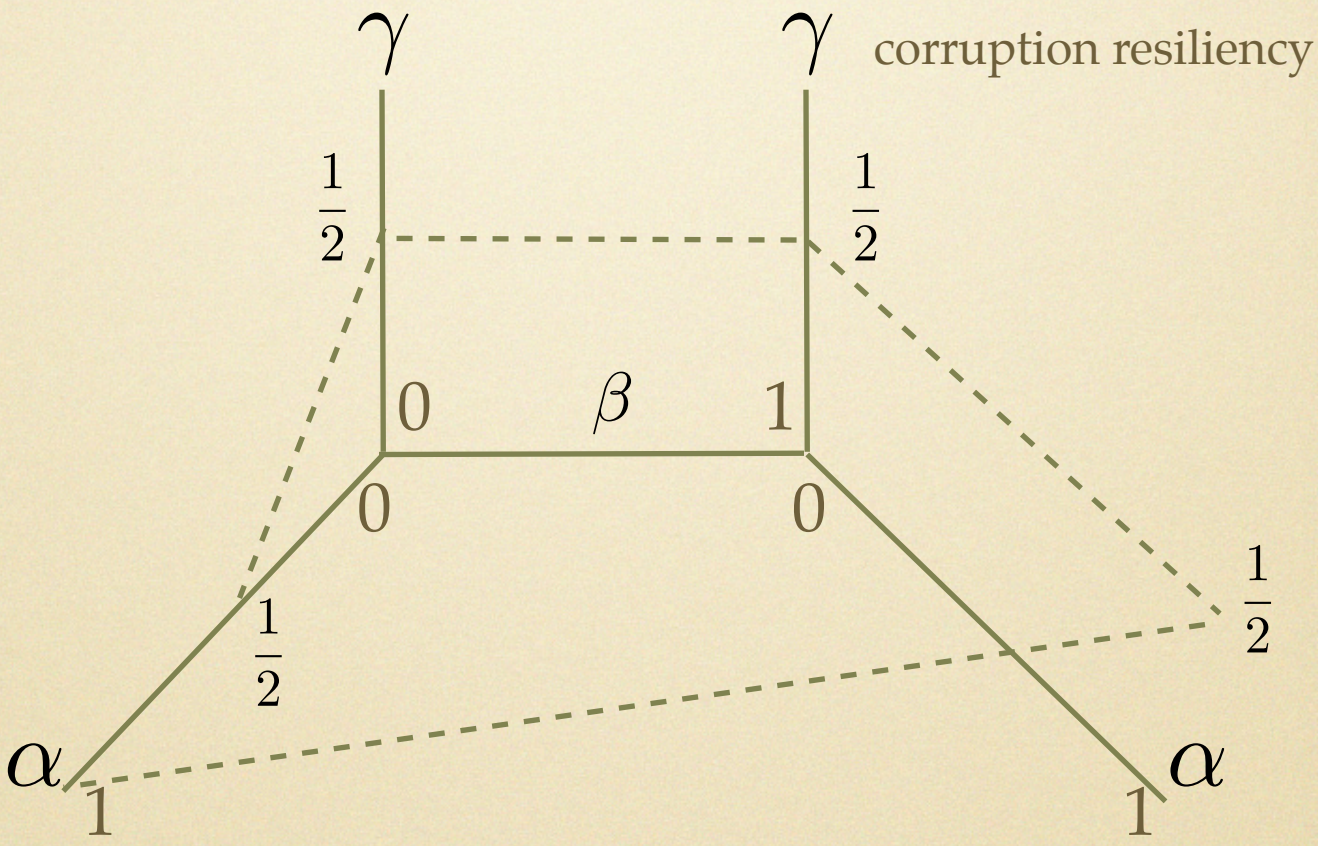


for what values of (α, β, γ) the service can be maintained?

to simplify: assume (α, β, γ) public

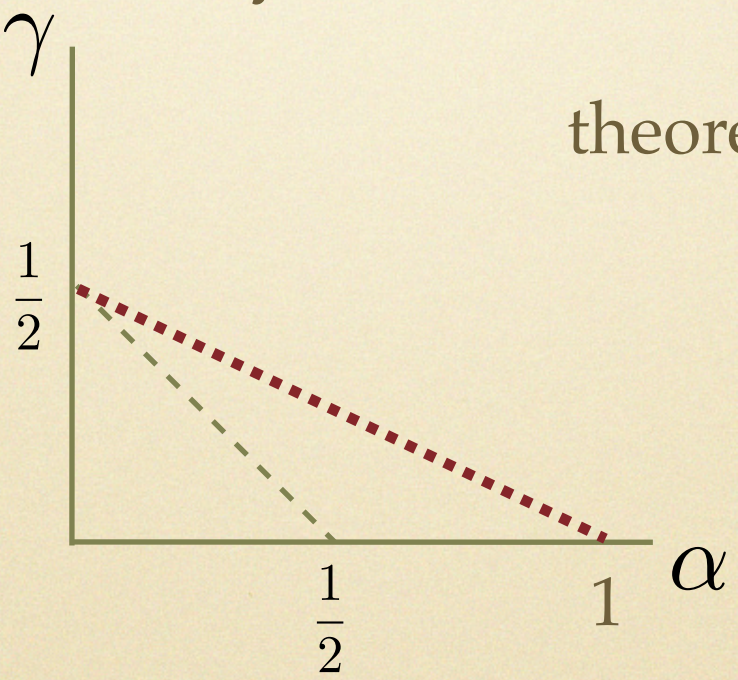
The boundary cases

are implied by standard cryptographic results



The $\beta = 0$ case.

corruption resiliency



theoretically available:

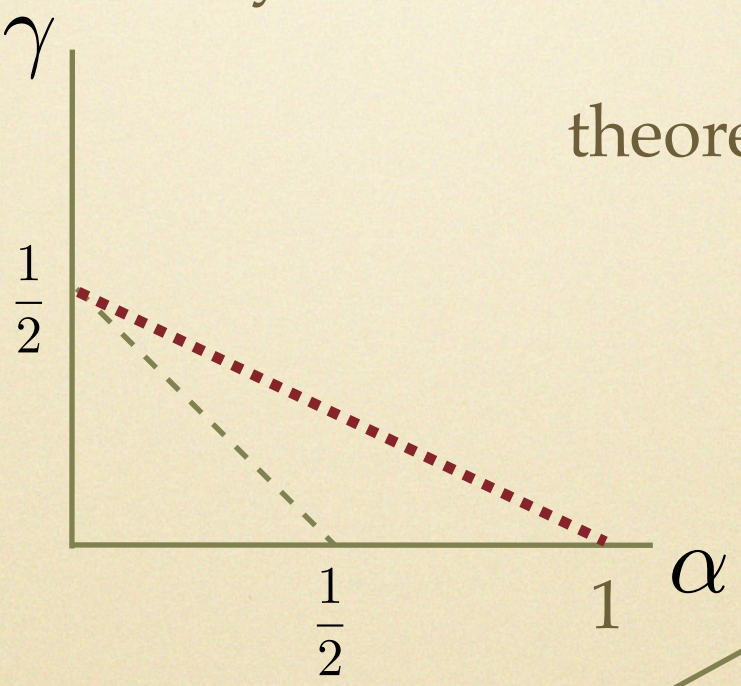
$$\gamma = \frac{1-\alpha}{2}$$

achievable via standard crypto:

$$\gamma = \frac{1}{2} - \alpha$$

The $\beta = 0$ case.

corruption resiliency



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achievable via standard crypto:

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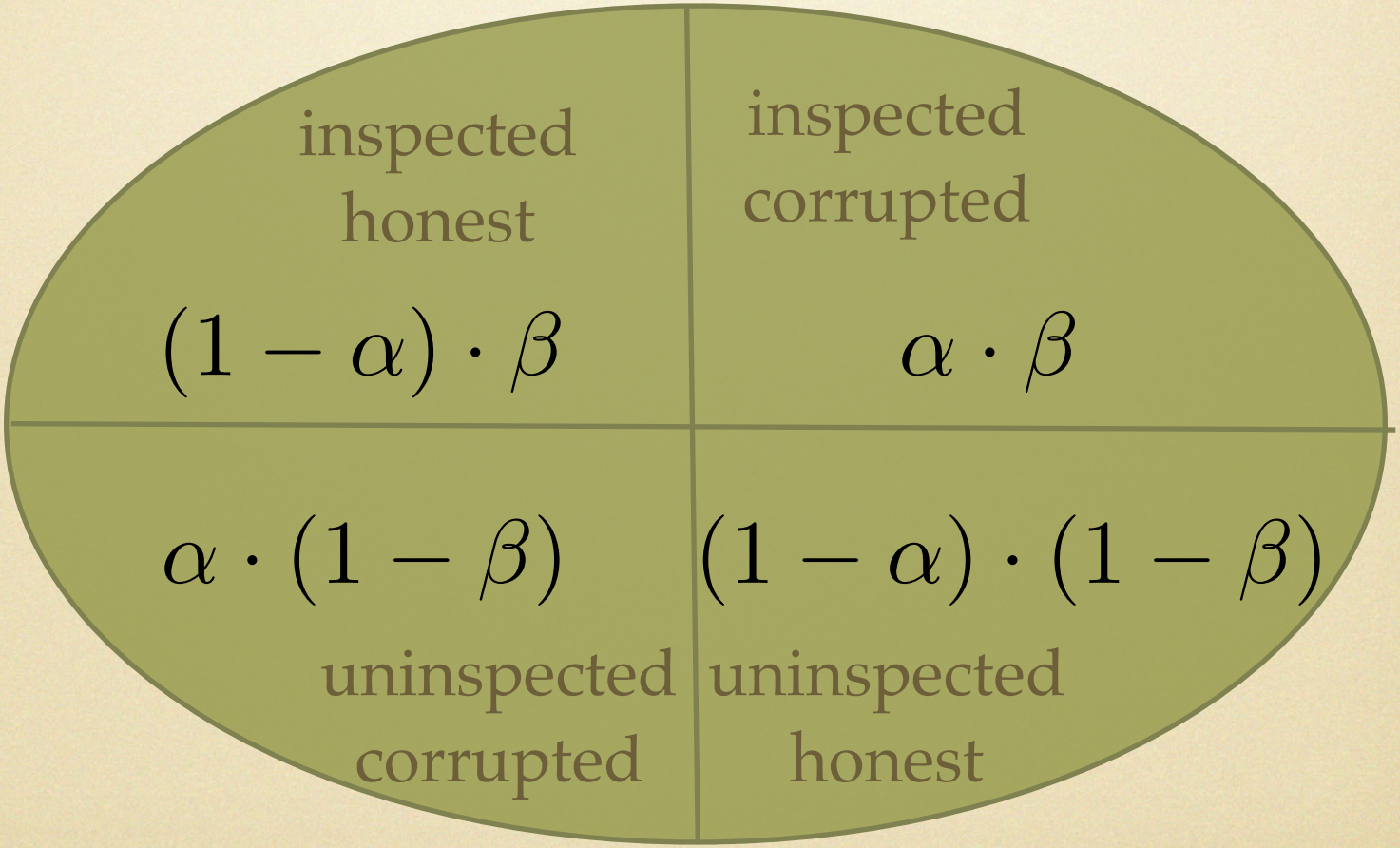
a gap of $\frac{\alpha}{2}$

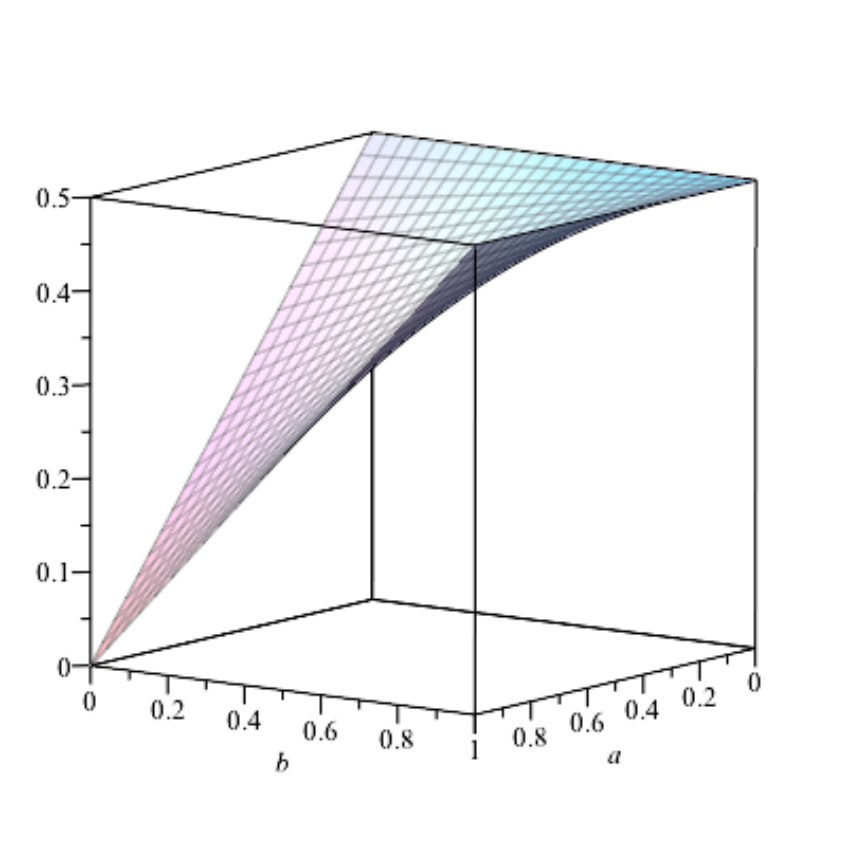
In general

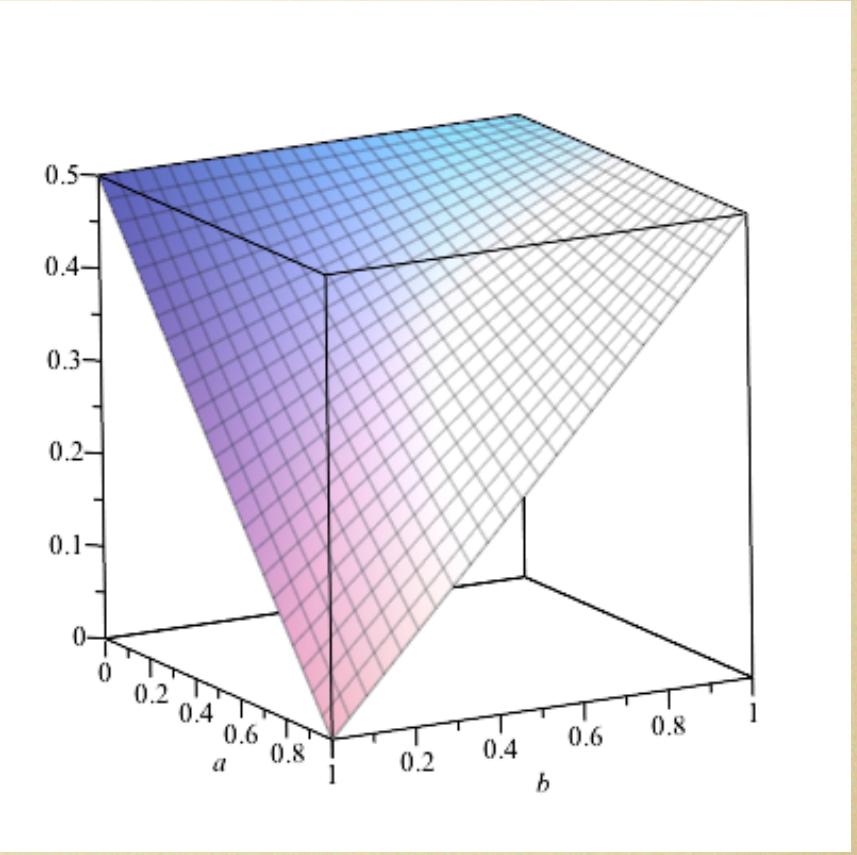

inspected
honest
$(1-\alpha)\cdot\beta$
inspected
corrupted
$\alpha\cdot\beta$
$\alpha\cdot(1-\beta)$
uninspected
corrupted
$(1-\alpha)\cdot(1-\beta)$
uninspected
honest

The ‘dream’ bound

on corruption resiliency of the total system

$$\gamma < (1 - \alpha + \alpha \cdot \beta)/2$$





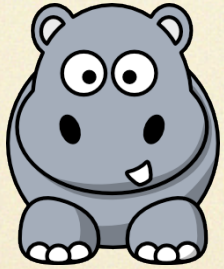
A Fundamental Question

- How to harness the power of any remaining honest servers that are lost in a pool of corrupted ones?
  - are the dream bounds of corruption resiliency approximable without requiring the SP to invest a lot ? (i.e., using a high β)

our new crypto protocols

- we show that, under reasonable system assumptions, there is a way to utilize the honest servers even though we don't know where they are!

The 2-tiered model

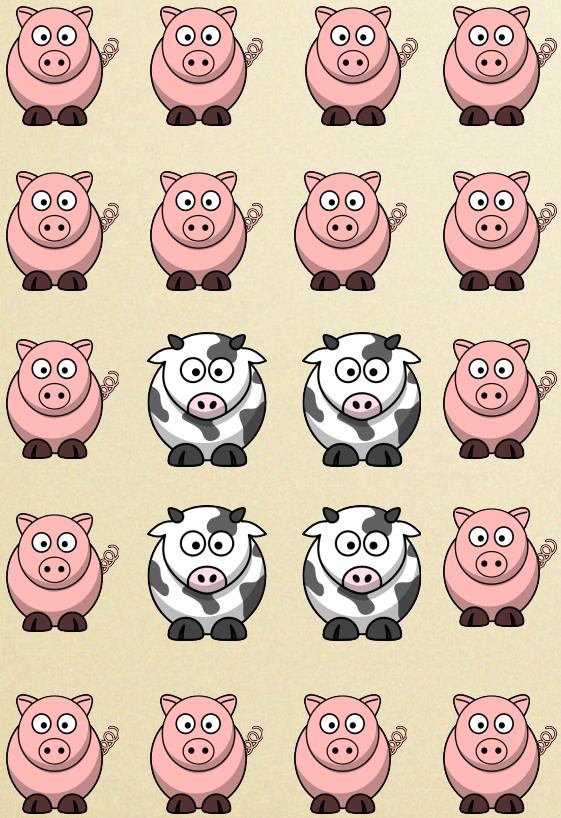


Consider an SP that has two kinds of servers:

cows : always good

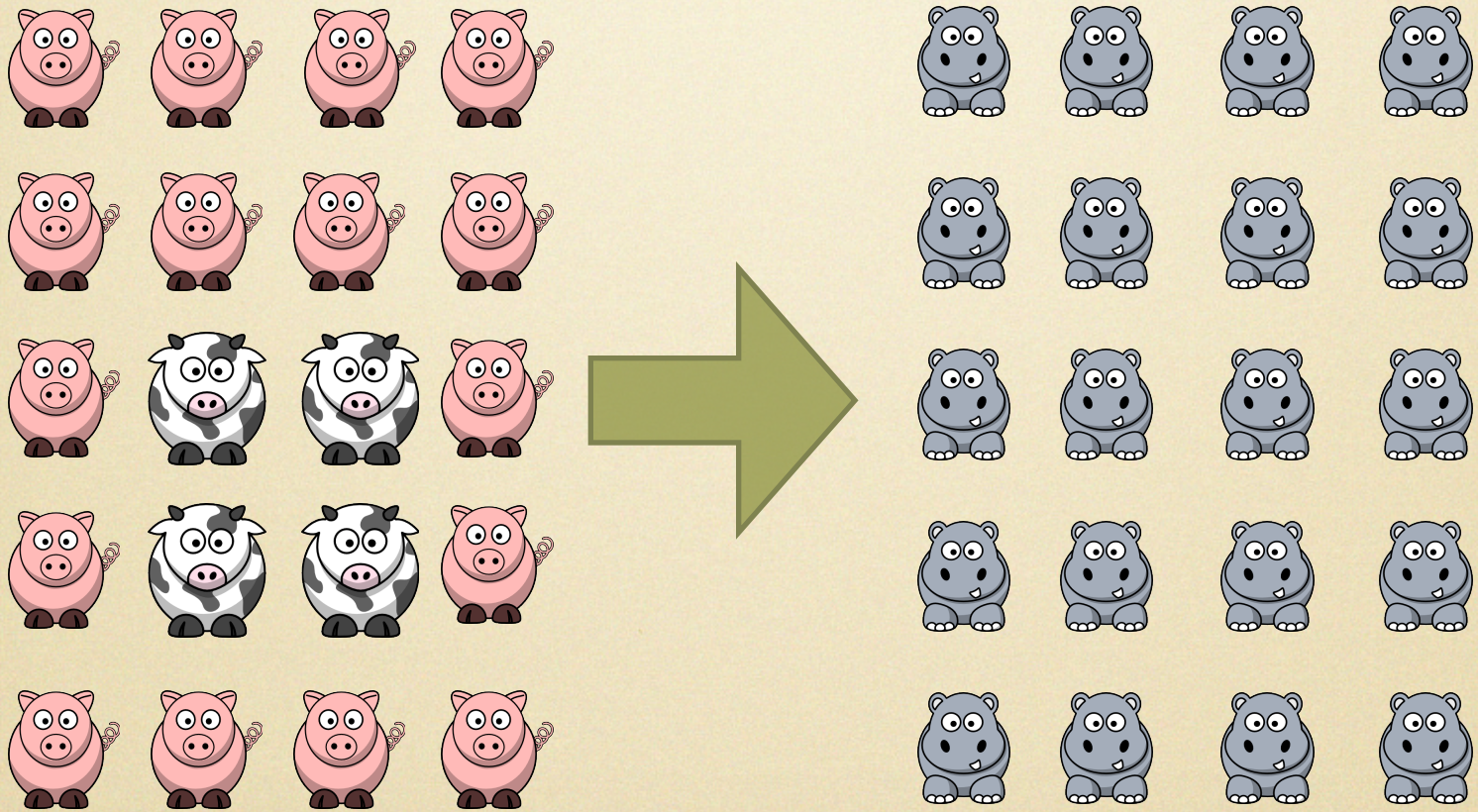
pigs : sometimes good

The two-tiered model for MPC



Assumption: servers are indistinguishable in the eyes of the adversary

The two-tiered model for MPC



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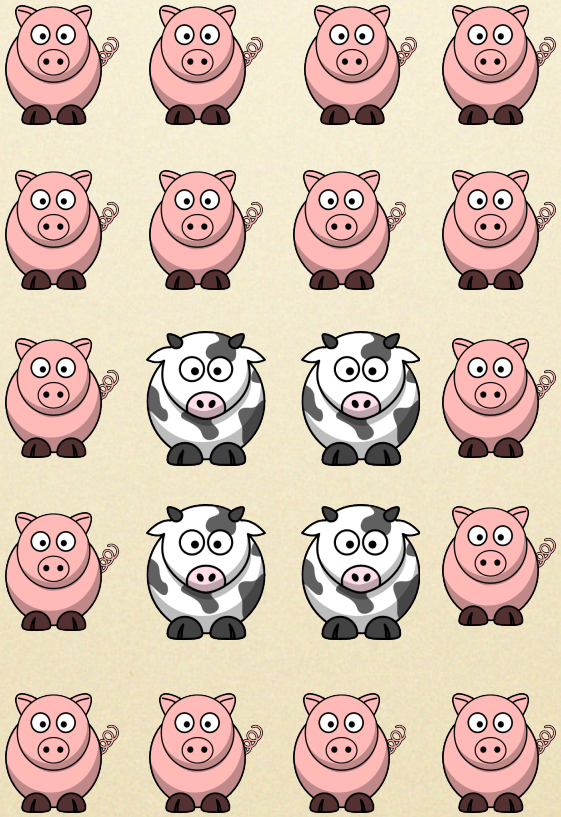

Corruption is like picking balls from an urn without replacement.

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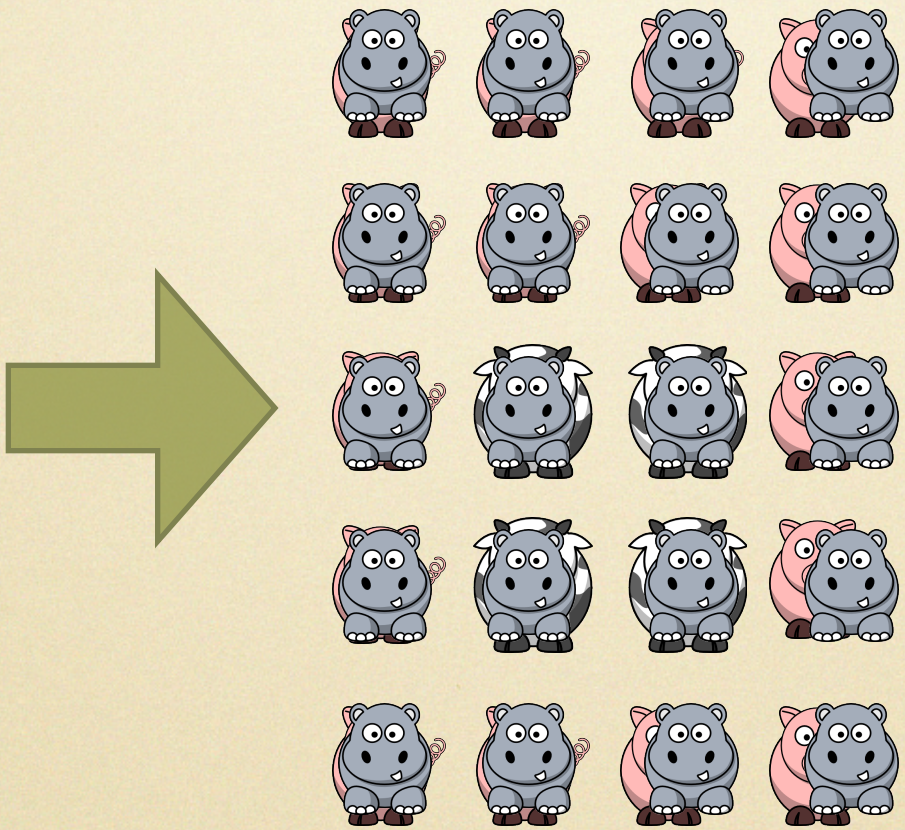

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Main Technical Lemma & Corollary

Starting with n servers (pigs + cows)
it is possible via a protocol that uses anonymity to approximate the maximum
"corruption resiliency" of the system, by utilizing only $\omega(\log n)$ cows.

Corollary. The dream bounds of corruption resiliency are attainable asymptotically assuming server anonymization.

Thank you

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