RSA Conference2016

San Francisco | February 29 – March 4 | Moscone Center

Connect to Protect

SESSION ID: CRYP-W03 - Secure Multiparty Computation

Hybrid Publicly Verifiable Computation

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Background

Verifiable Outsourced Computation

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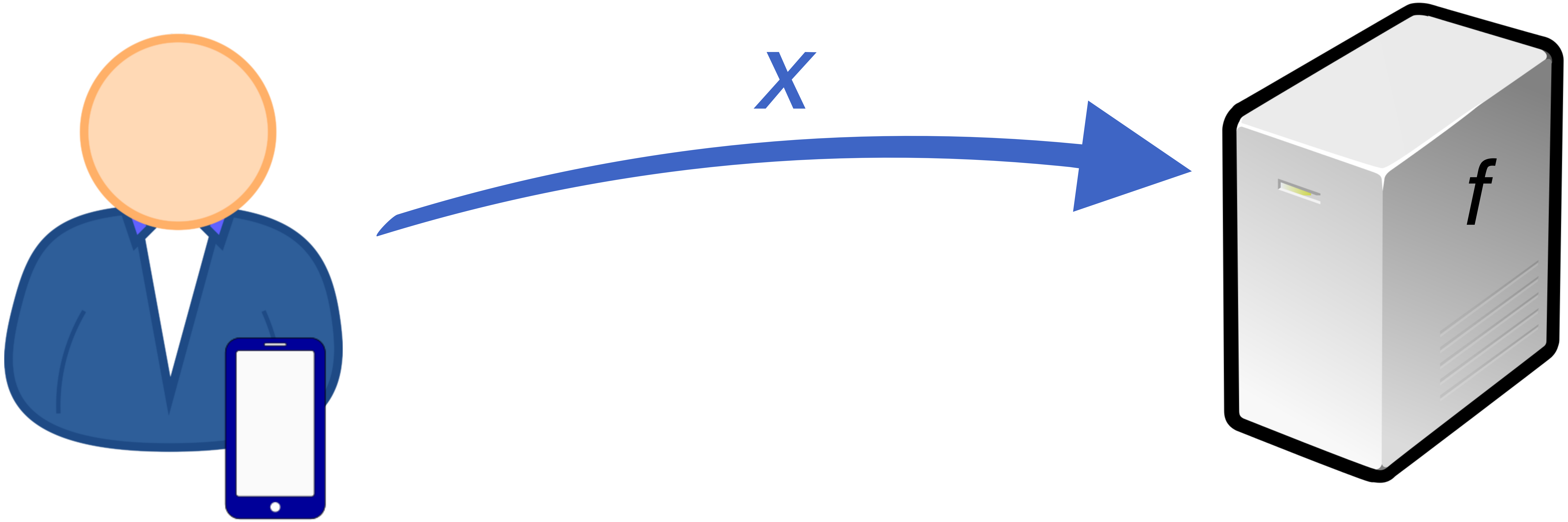
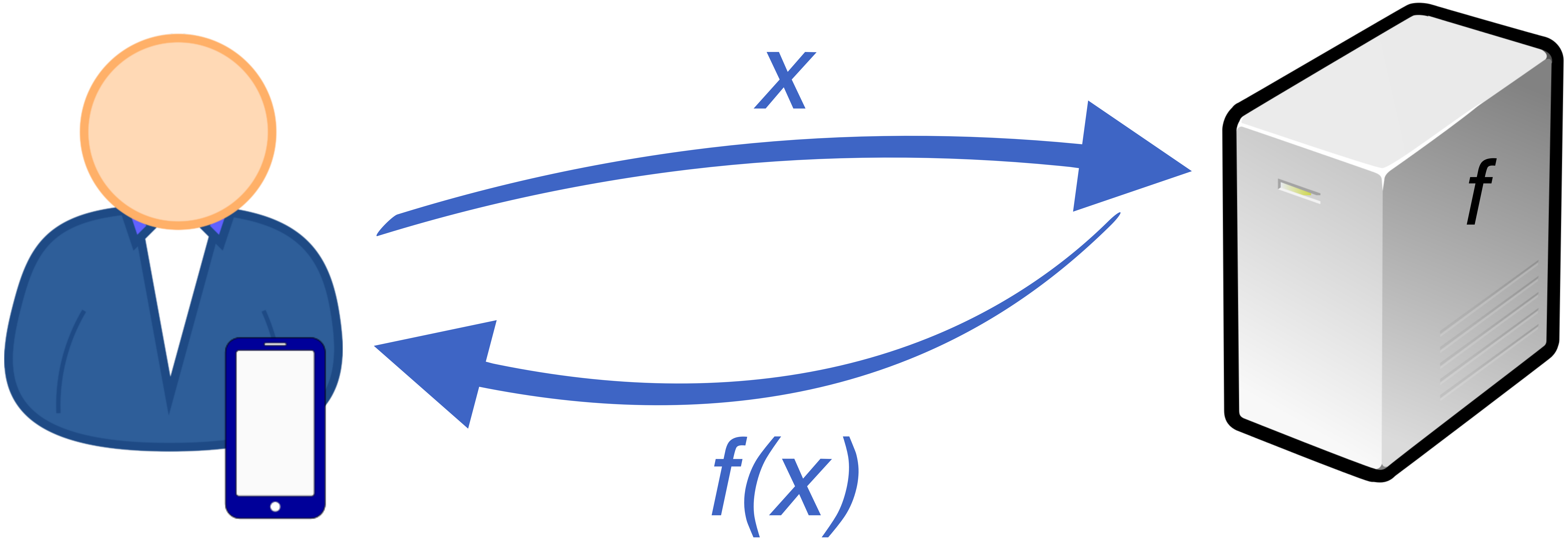


Verifiable Outsourced Computation



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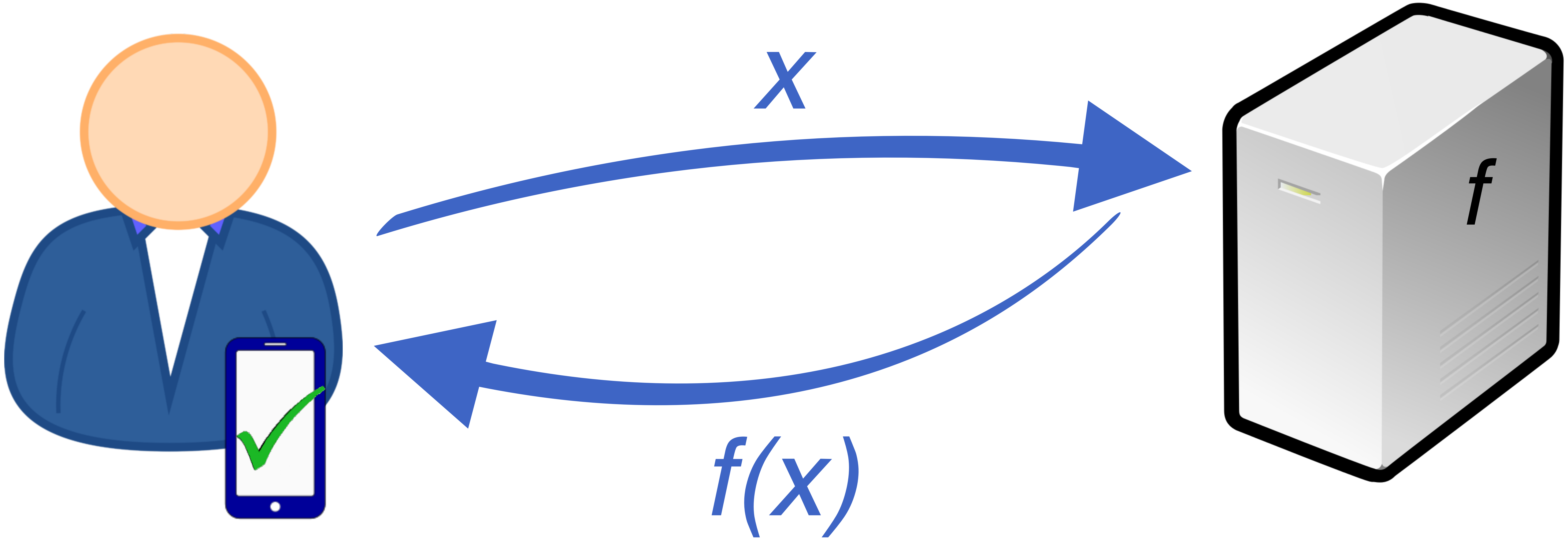

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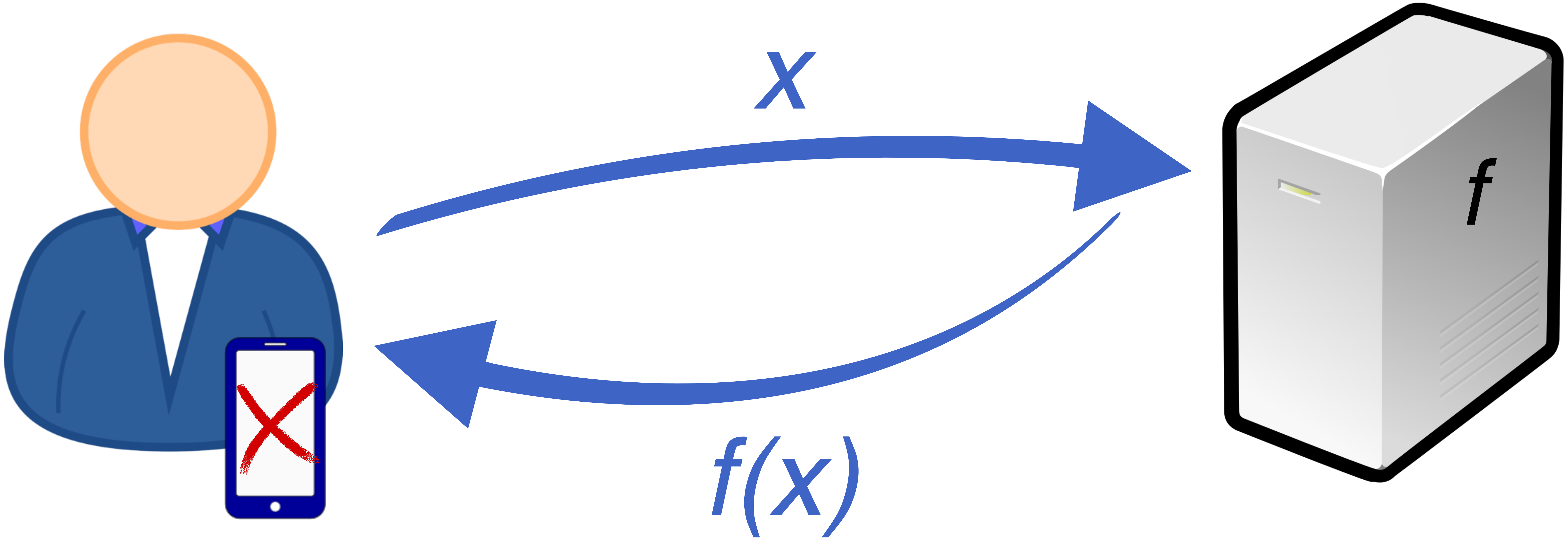

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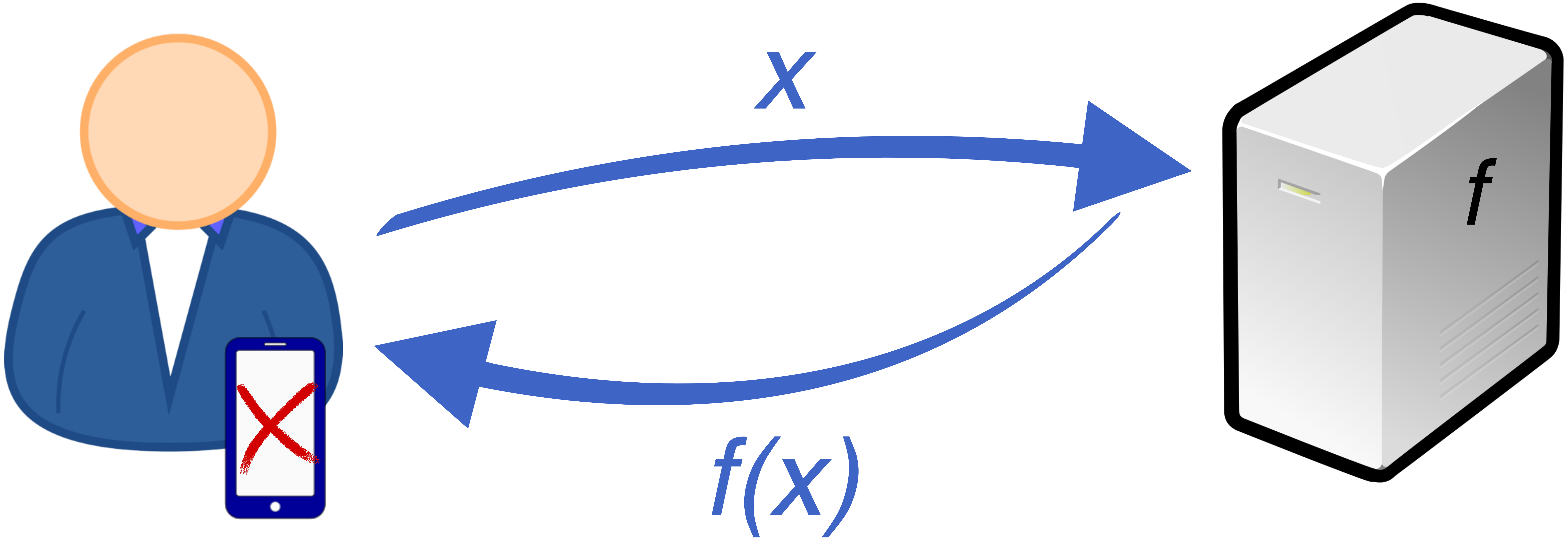
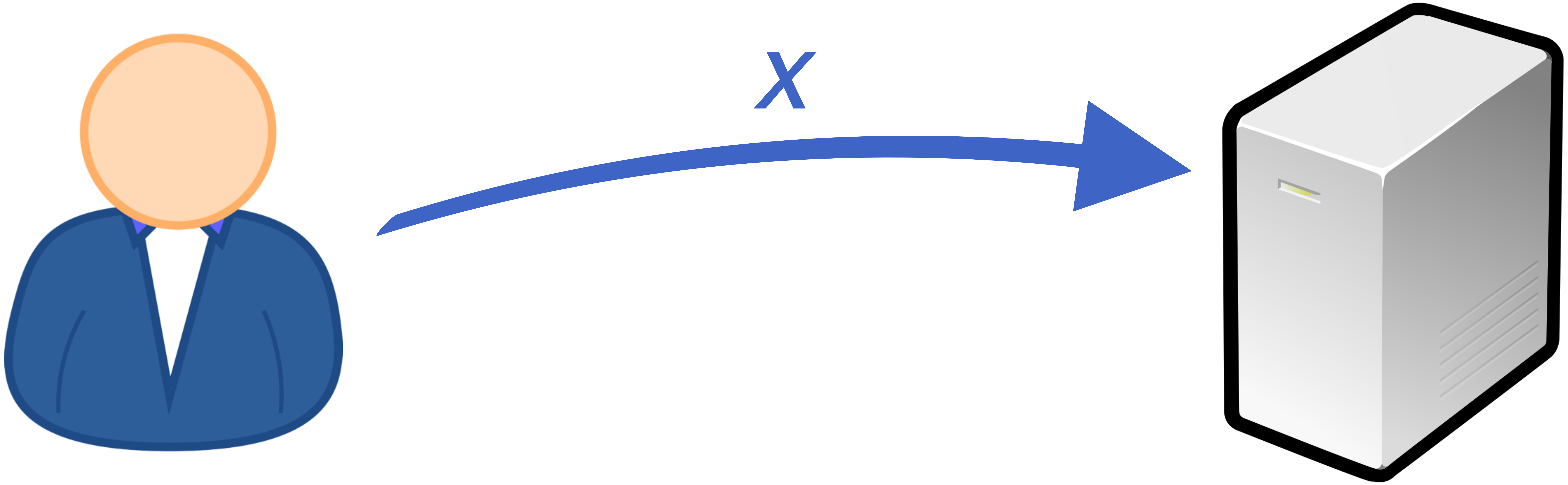


Outsourcing and verifying must be cheaper than computing f(x) locally

Searchable Encryption/Memory Delegation



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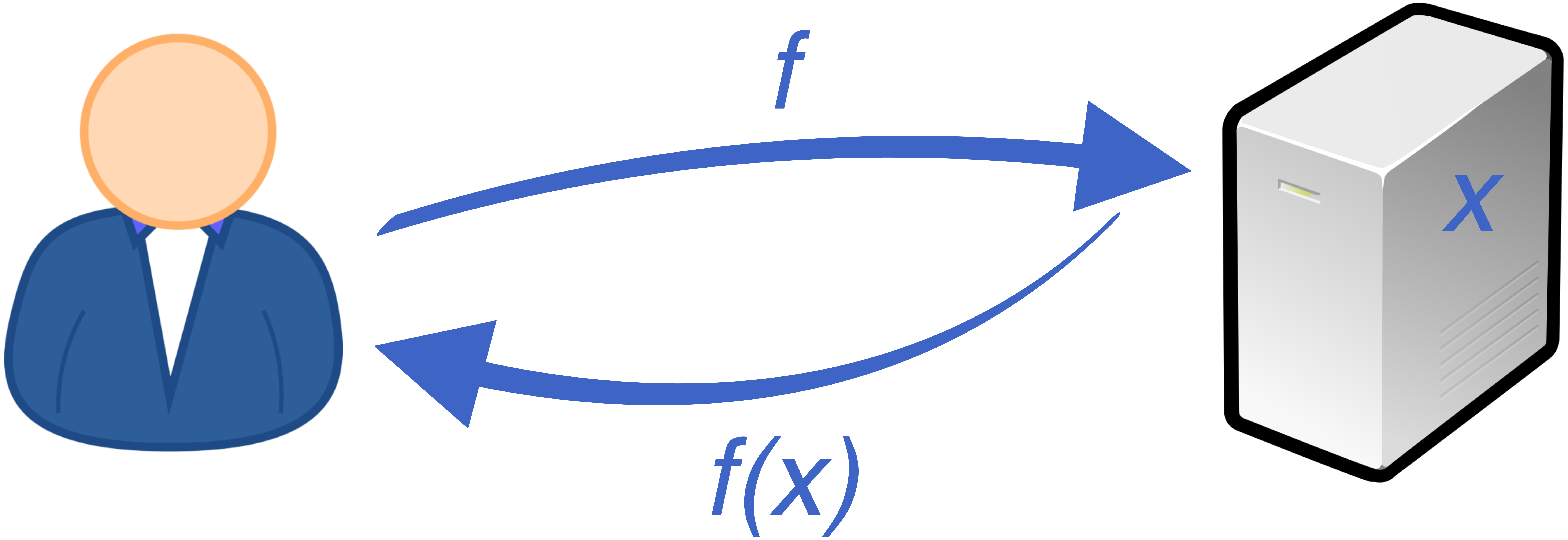

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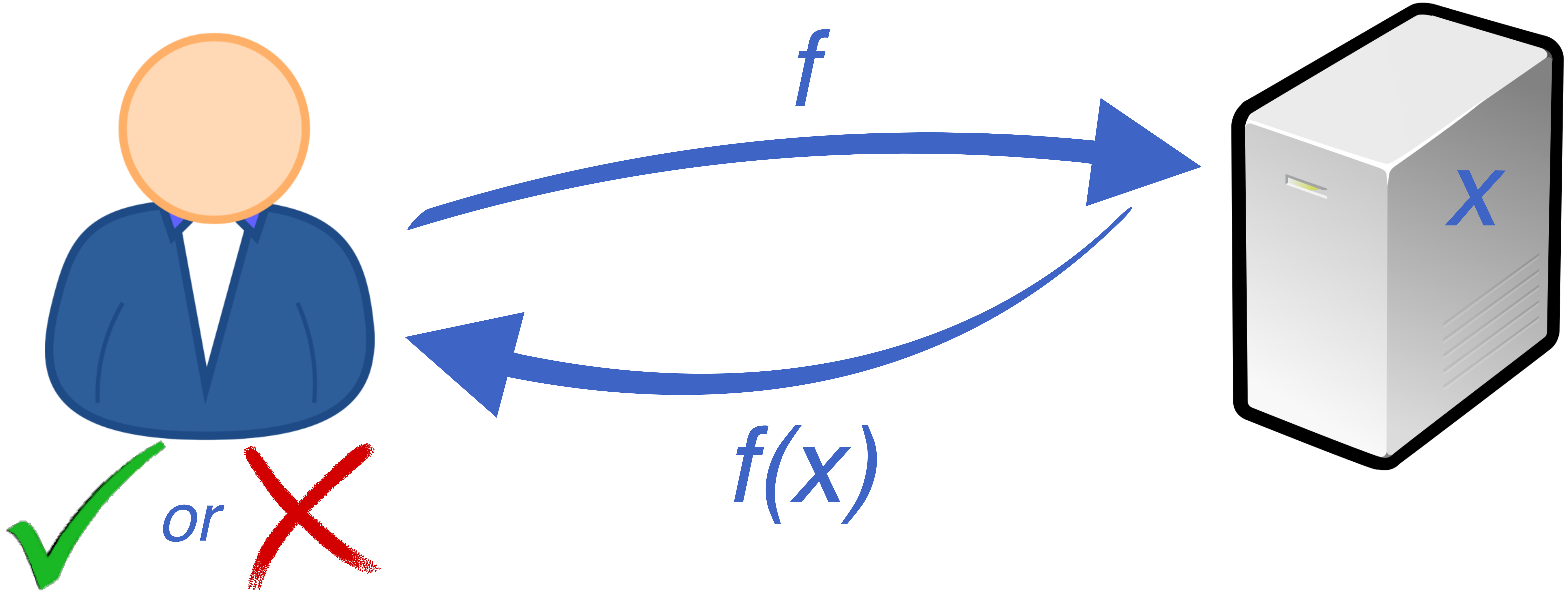

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Our work

Our work - a hybrid system

- Entities can act as both servers and clients as required
- Can sell spare resources to perform computations for others, or request computations when resources run low
- Data to be processed may be provided by the client or stored at the server
- Can restrict which servers can perform a given computation

Modes of Operation

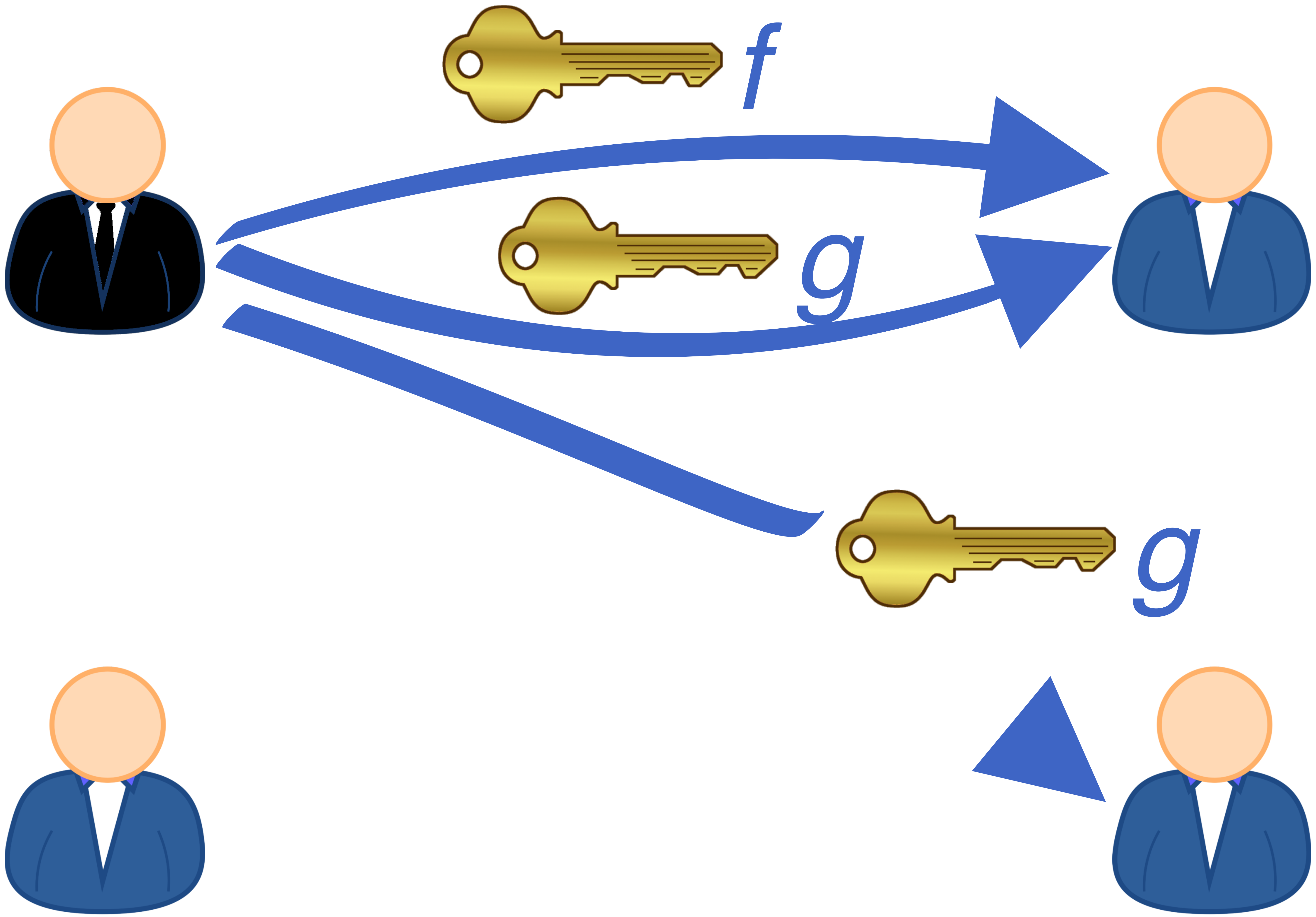
- We allow three modes of operation:
  - **Revocable Publicly Verifiable Computation (RPVC)**: client provides data, anybody can verify correctness, misbehaving servers can be revoked
  - **Revocable Publicly Verifiable Computation with access control (RPVC-AC):** as above, but can restrict the servers that may compute on a given input
  - **Verifiable Delegable Computation (VDC):** server holds data, clients request computations using public labels of the data, anybody can verify correctness

Definition

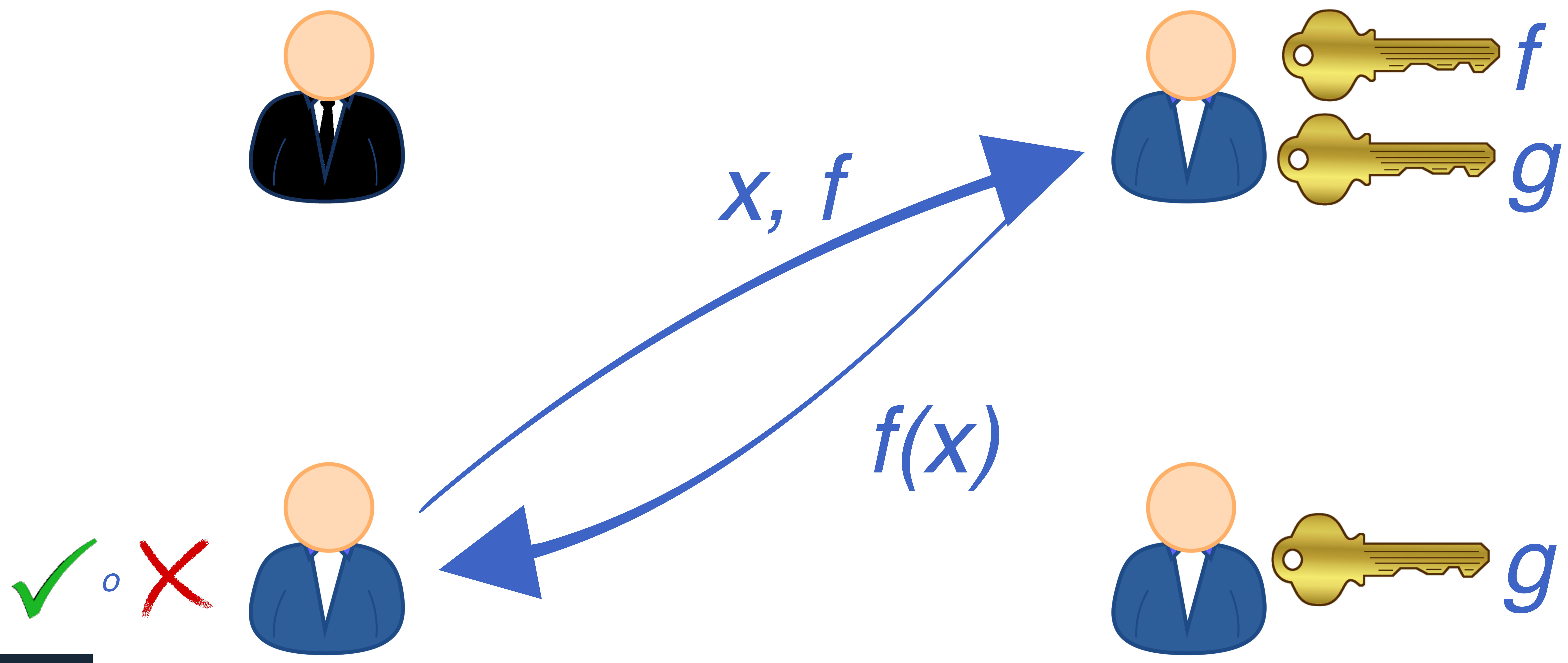
- $(PP, MK) \leftarrow$ **Setup**$(1^k, F)$
- $PK_F \leftarrow$ **FnInit**(F, MK, PP)
- $SK_S \leftarrow$ **Register**(S,MK,PP)
- $EK_{(O,\psi),S} \leftarrow$ **Certify**$(mode, S, (O, \psi), L_i, F_i, MK, PP)$
- $(\sigma_{F,X}, VK_{F,X}) \leftarrow$ **ProbGen**$(mode, (\omega, S), L_{F,X}, PK_F, PP)$
- $\theta_{F(X)} \leftarrow$ **Compute**$(mode, \sigma_{F,X}, EK_{(O,\psi),S}, SK_S, PP)$
- $(y, \tau_{F(X)}) \leftarrow$ **Verify**$(\theta_{F(X)}, VK_{F,X}, PP)$
- $UM \leftarrow$ **Revoke**$(\tau_{F(X)}, MK, PP)$

Our model

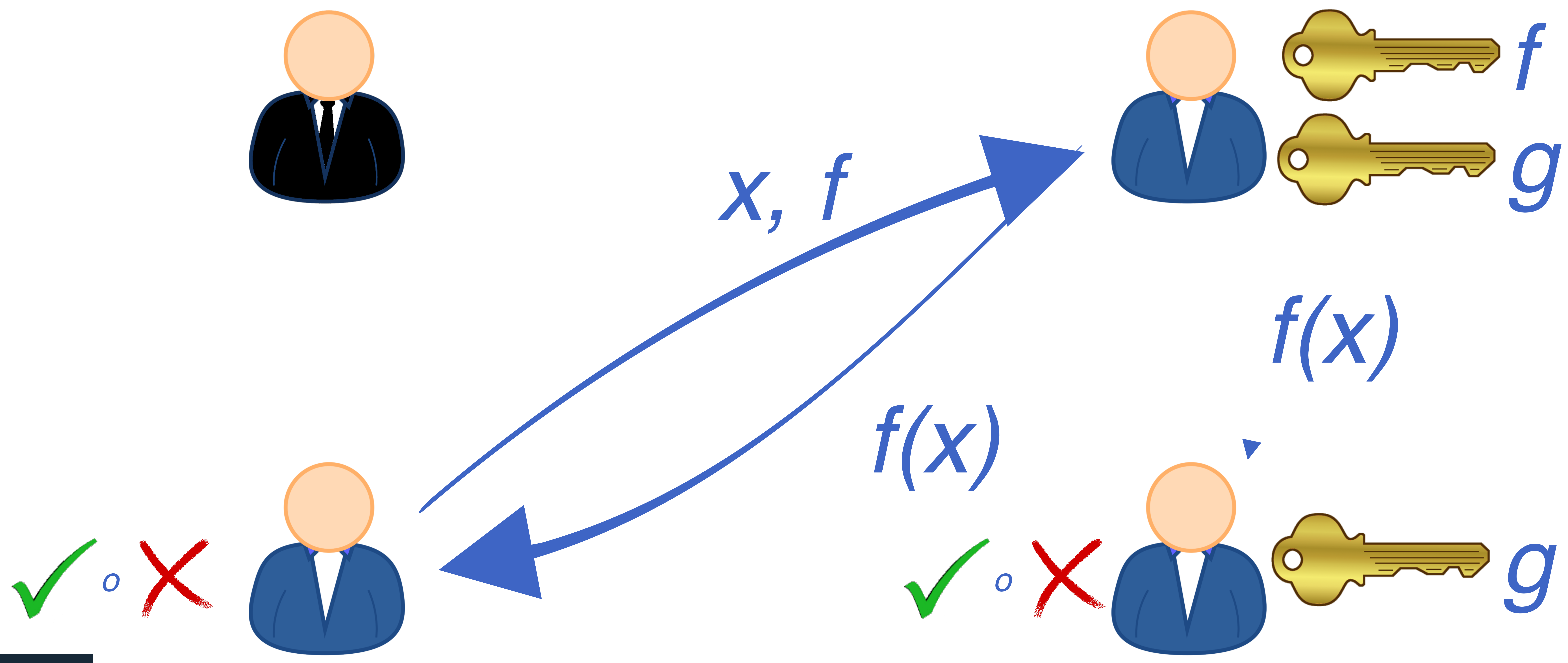
Our model - certifying servers



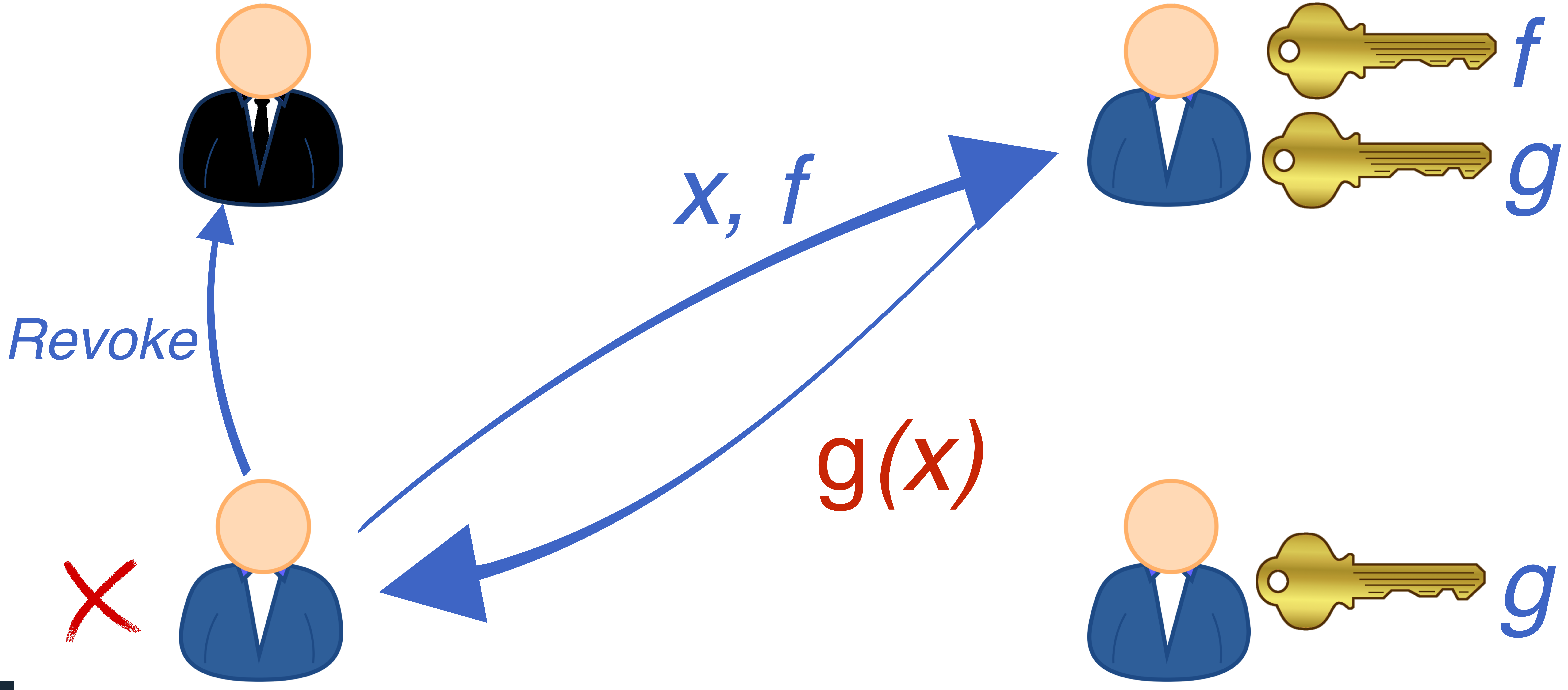
Our model - RPVC



Our model - public verifiability



Our model - revocation



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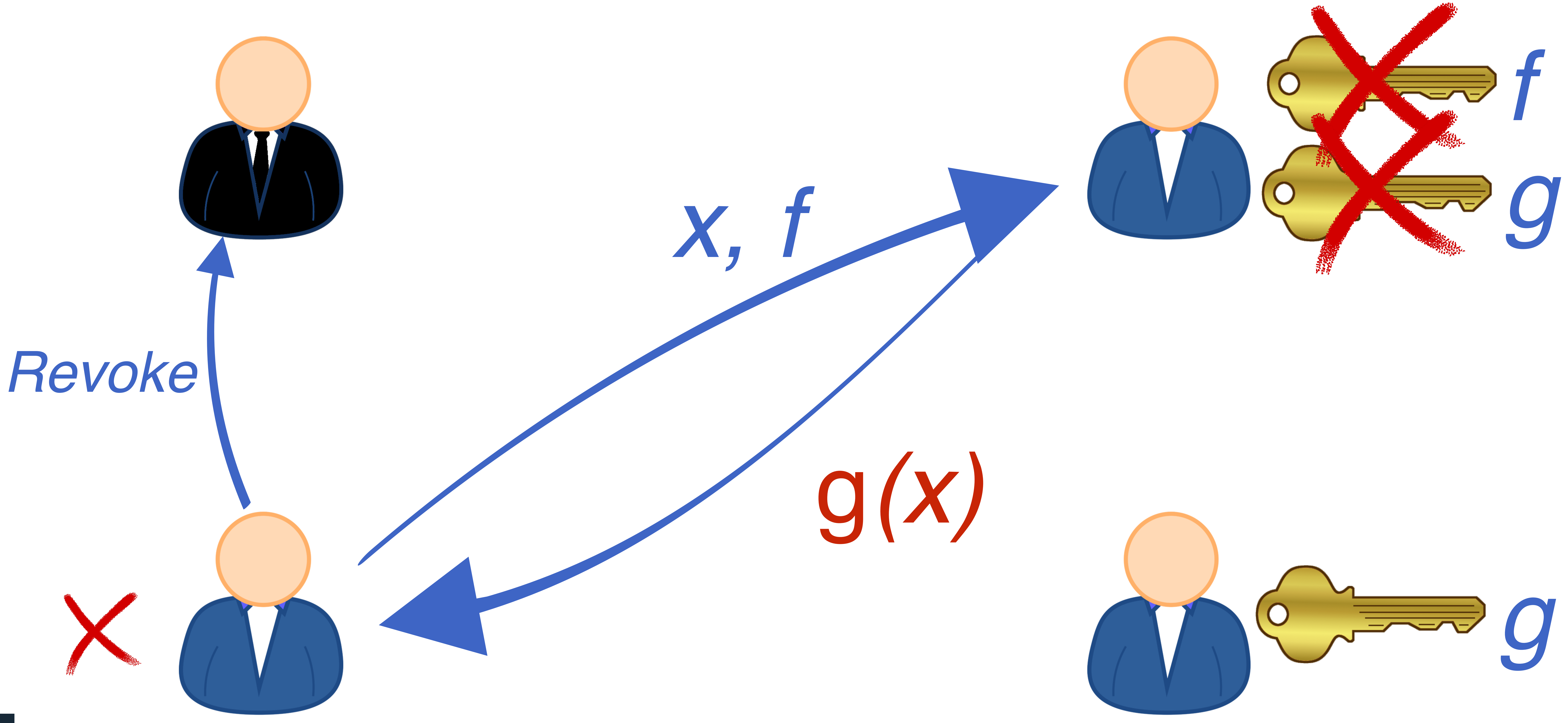

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Our model - RPVC with Access Control

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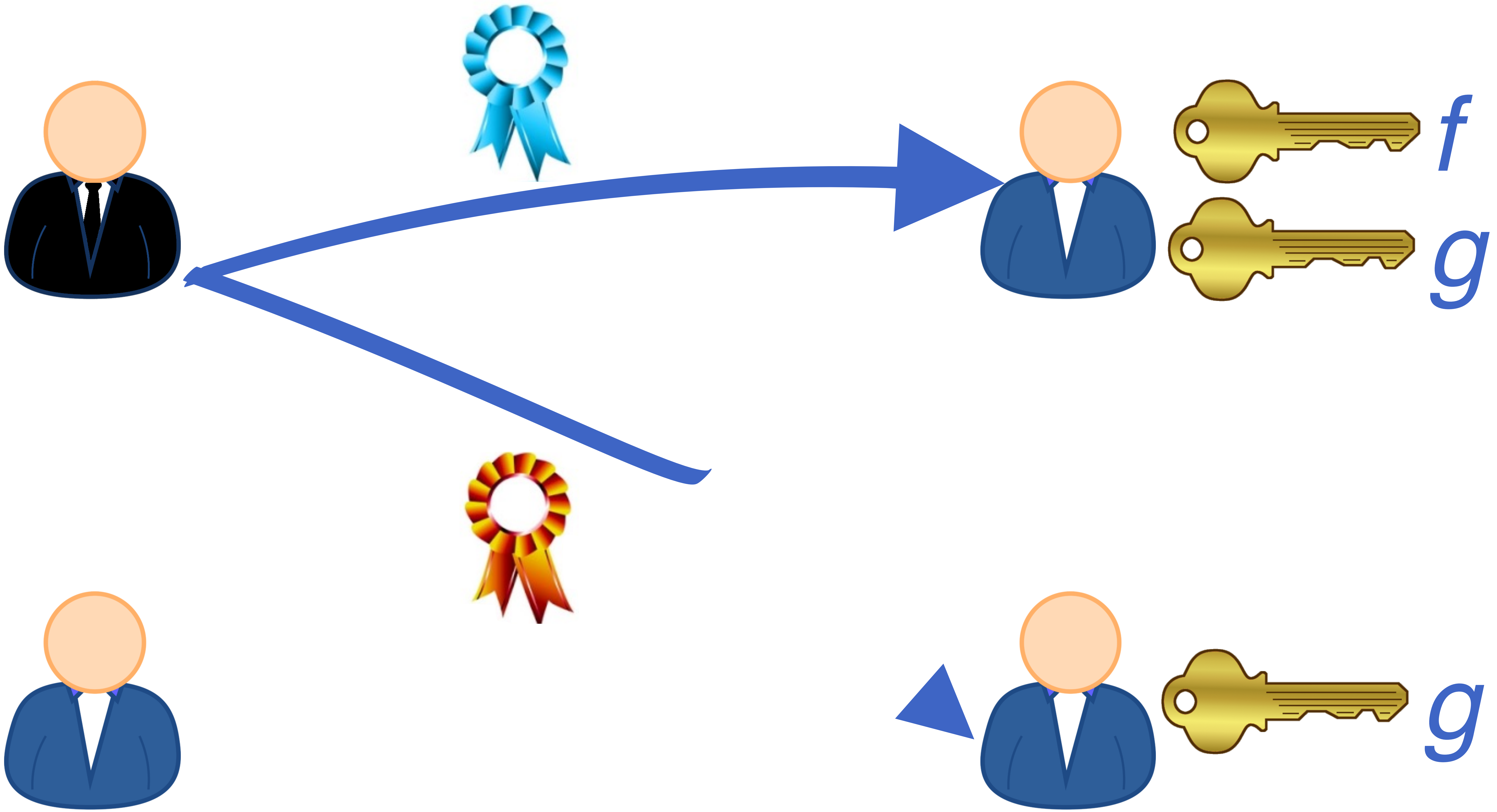
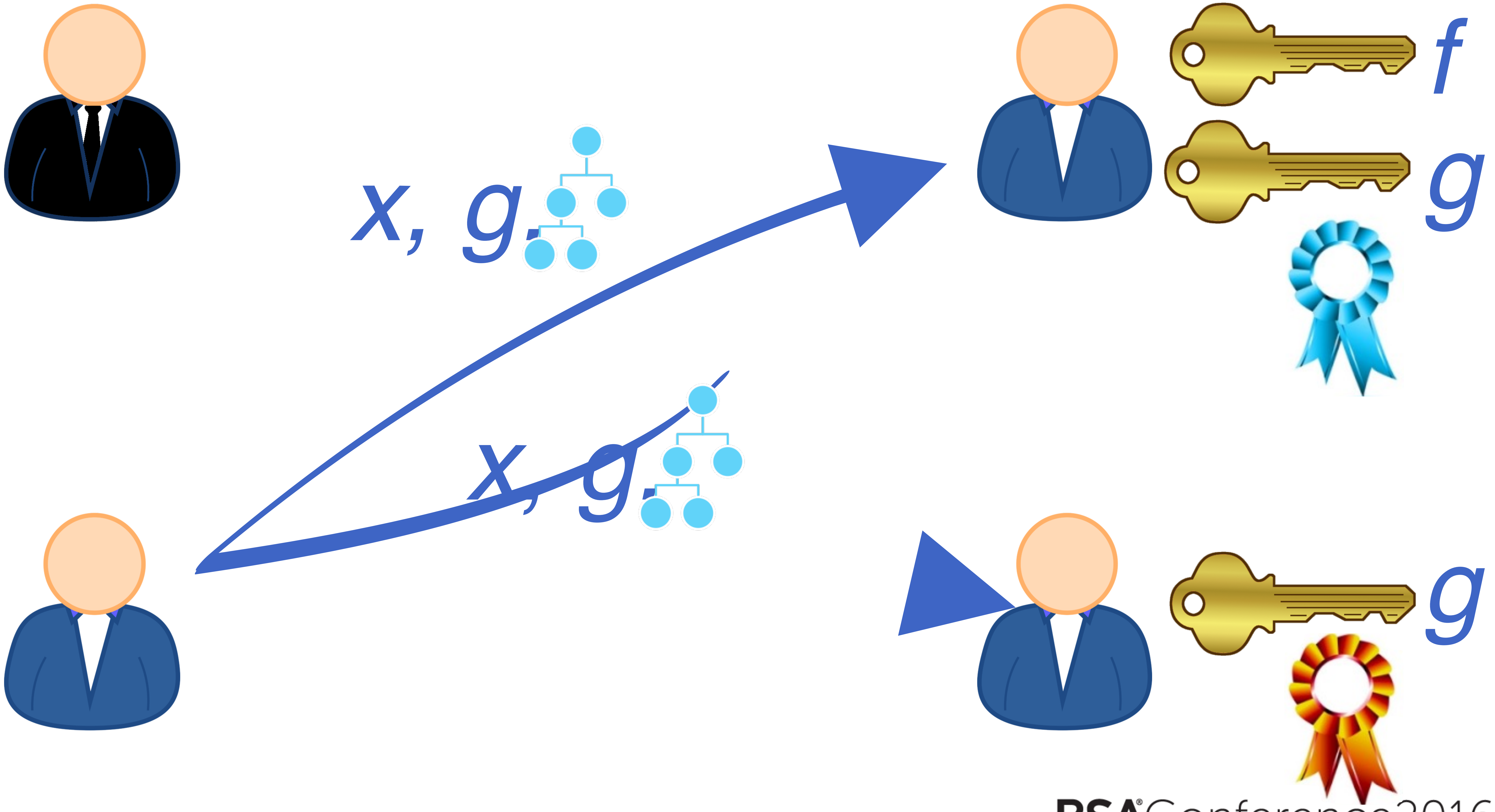
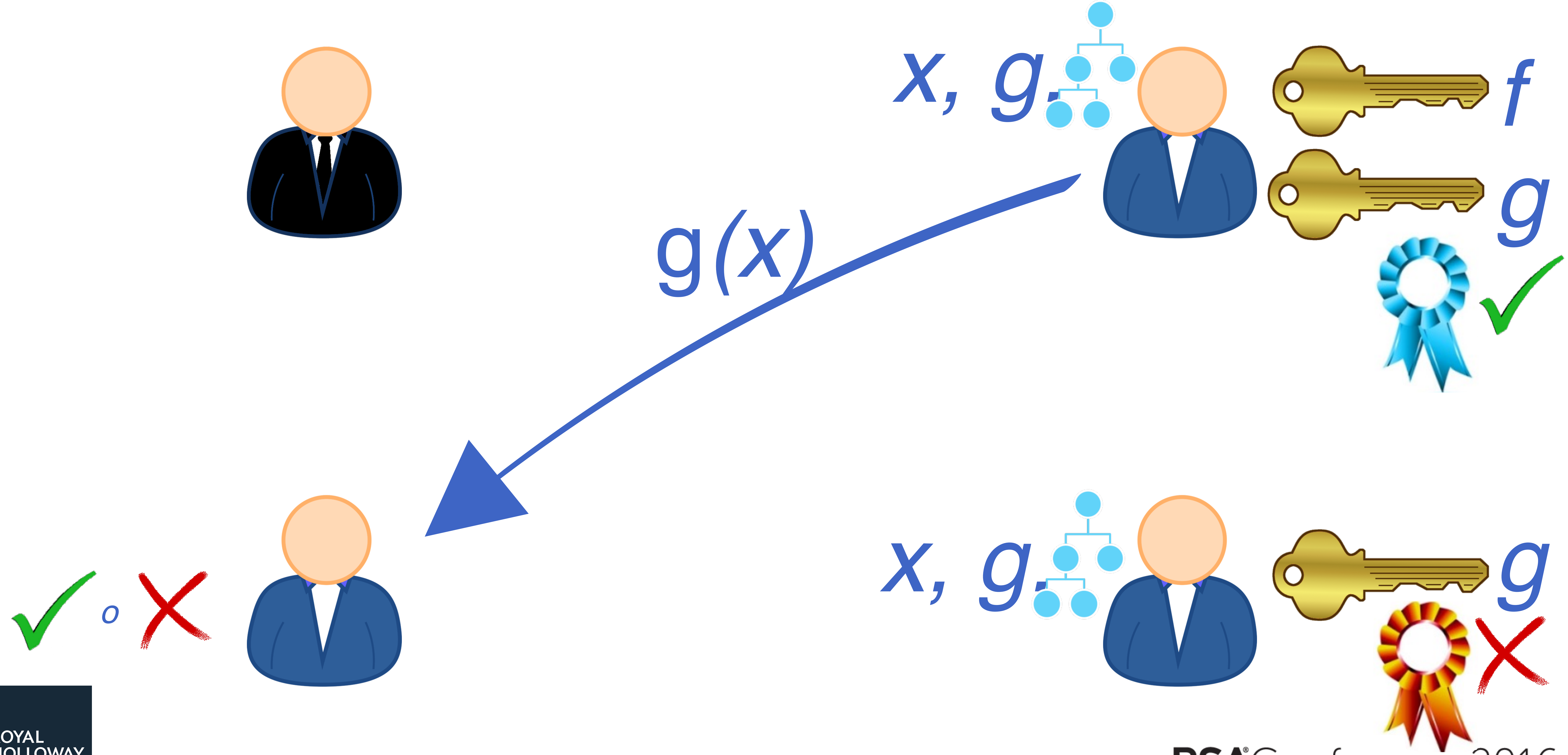


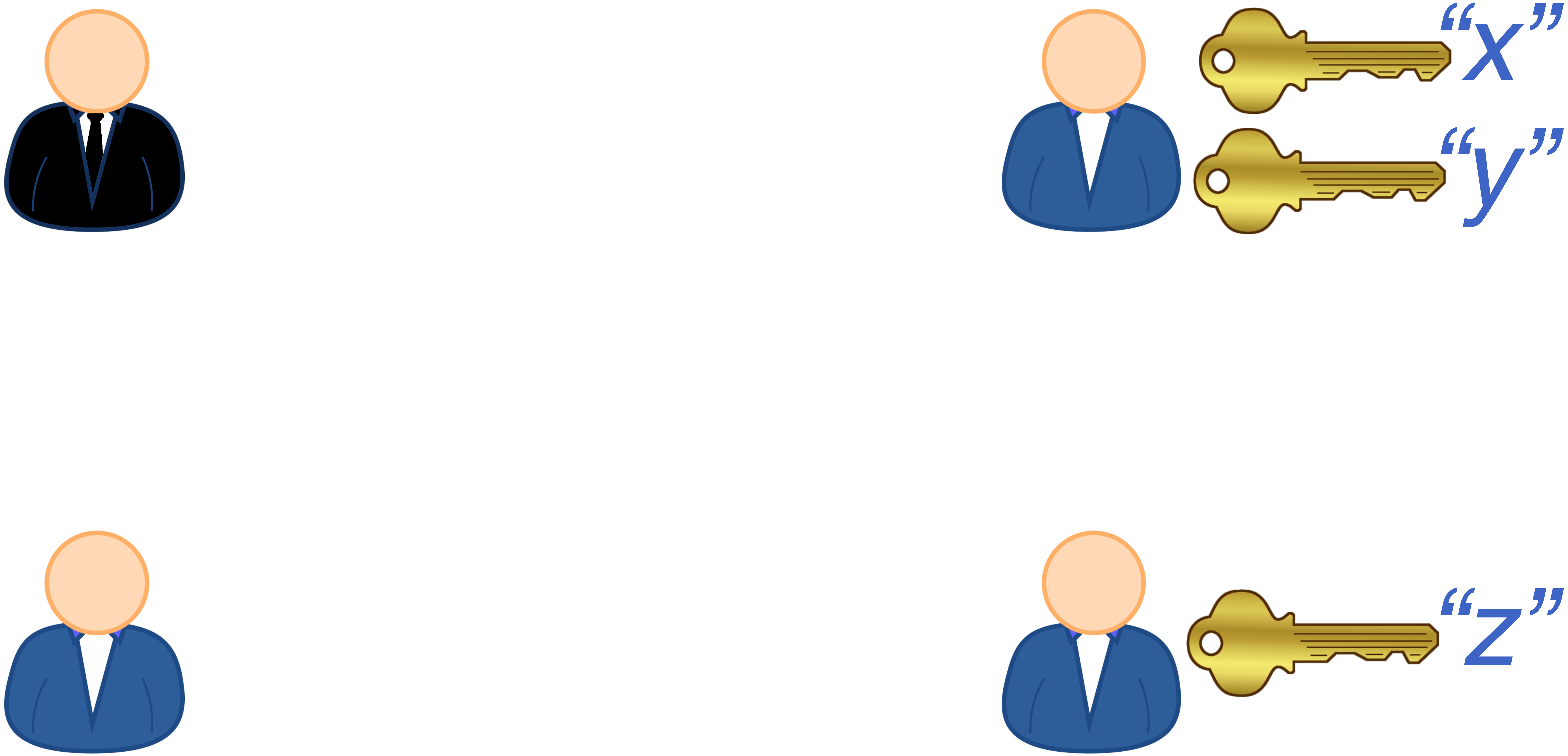
Our model - RPVC with Access Control



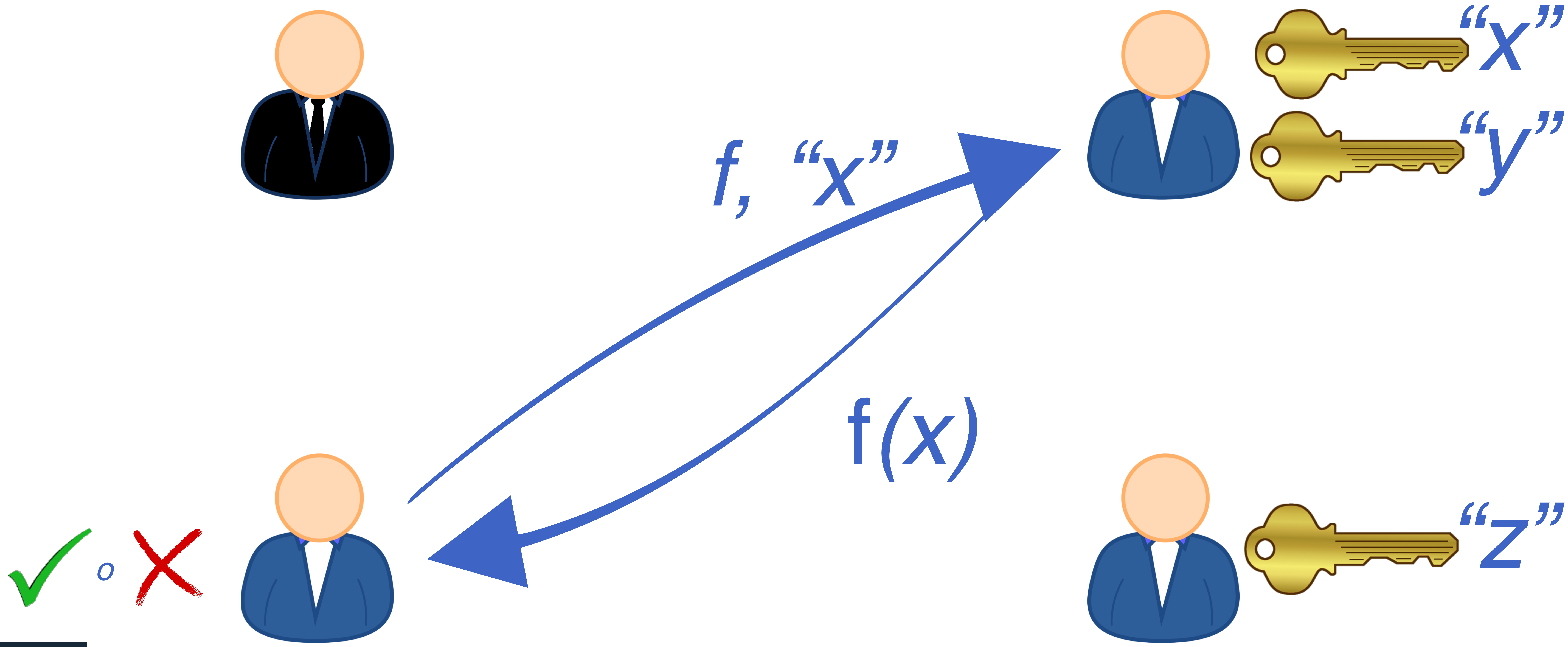
Our model - RPVC with Access Control



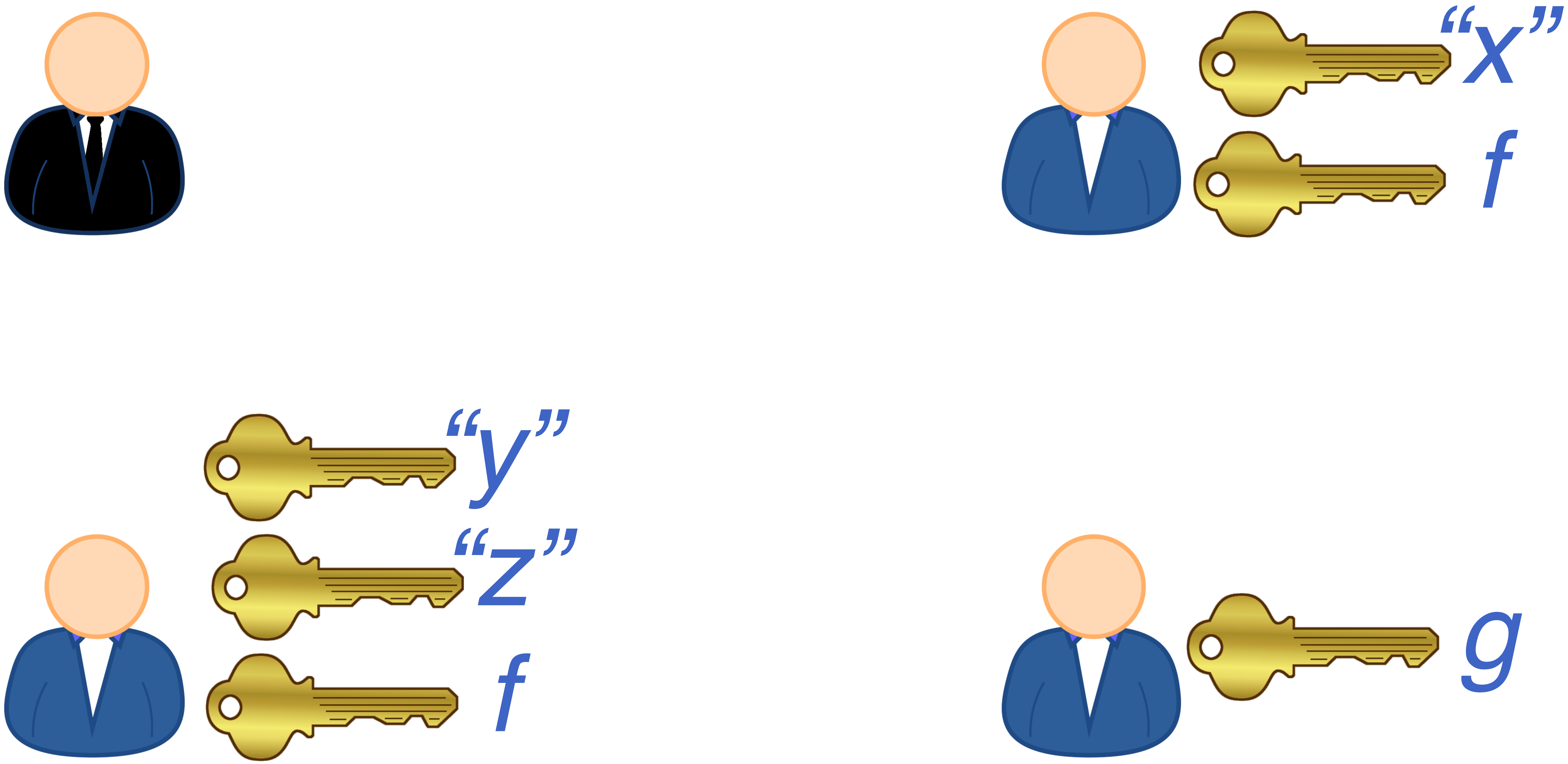
Our model - VDC



Our model - VDC



Our model - hybrid



Technical Details

Our approach

- Our approach extends the key-policy attribute-based encryption scheme of Parno et al. [TCC '12] for Boolean functions
- Functions are encoded as attribute-based policies
- Input data is encoded as attributes
- Outsourced computations are encryptions of random messages under the input attributes
- Successful decryption ⇒ Policy satisfied ⇒ Function evaluates to 1 on input. Repeat for the compliment function

Our approach

- We introduce Revocable-Key Dual-policy Attribute-based Encryption
- DP-ABE combines key-policy and ciphertext-policy attribute-based encryption
- RPVC mode uses KP-ABE (functions in server evaluation keys)
- VDC mode uses CP-ABE (data in server evaluation keys)
- RPVC with access control mode uses both — server key comprises function and authorisation attributes, ciphertext comprises input data and authorisation policy

Revocable-key DP-ABE

- (PP, MK) ← **Setup**(1^k , U)
- $CT_{(\omega,\mathcal{S}),t}$ ← **Encrypt**(m, (ω, $\mathcal{S}$), t, PP)
- $SK_{(\mathcal{O},\psi),ID}$ ← **KeyGen**(ID, ($\mathcal{O}$, ψ), MK, PP)
- $UK_{R,t}$ ← **KeyUpdate**(R, t, MK, PP)
- m ← **Decrypt**($CT_{(\omega,\mathcal{S}),t}$,($\omega$,$\mathcal{S}$),$SK_{(\mathcal{O},\psi),ID}$,($\mathcal{O}$,$\psi$),$UK_{R,t}$,PP)
  - if and only if $\omega \in \mathcal{O}$ and $\psi \in \mathcal{S}$
  - if and only if $\mathcal{O}(\omega) = 1$ and $\mathcal{S}(\psi) = 1$

$\mathcal{S}$, $\mathcal{O}$ policies
ψ, ω attribute sets

Definition

Recall:

- $(PP, MK) \leftarrow$ **Setup**$(1^k , F)$
- $PK_F \leftarrow$ **FnInit**(F, MK, PP)
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- $(y,\tau_{F(X)}) \leftarrow$ **Verify**$(\theta_{F(X)},VK_{F,X},PP)$
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Parameter Choices

- Recall: key has policy $\mathcal{O}$ and attributes ψ
- Ciphertext has policy $\mathcal{S}$ and attributes ω

Mode	$\mathcal{O}$	ψ	ω	$\mathcal{S}$	label	F_i
RPVC	F	$\{T_o\}$	x	$\{\{T_S\}\}$	"F"	F
RPVC-AC	F	p	x	$\mathcal{P}$	"F"	F
VDC	$\{\{T_o\}\}$	x	$\{T_o\}$	F	"x"	$F_1, F_2, \ldots, F_n$

$\mathcal{S}$, $\mathcal{O}$ policies
ψ, ω attribute sets
T_o, T_S dummy attributes
p authorisation attributes
$\mathcal{P}$ authorisation policy

Security Models

- **Public Verifiability** — cheating servers are detected, servers can't use evaluation keys for different functions
- **Revocation** — revoked servers can't produce acceptable outputs
- **Authorised Computation** — only servers that satisfy the authorisation policy can produce acceptable outputs
- **Indistinguishability against selective-target with semi-static query attack (IND-sHRSS)** — security model for revocable-key DP-ABE

Summary

- We introduce a hybrid framework for flexible outsourcing of computations
  - RPVC - revocable outsourcing on local data
  - RPVC-AC - RPVC with access control policies detailing which servers can perform the computation
  - VDC - verifiable querying on remote data
- We introduce Revocable-Key Dual-policy Attribute-based Encryption to enable revocation of misbehaving entities

Thank you

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A framework for user centred privacy and security in the cloud