Privacy, Discovery, and Authentication for the Internet of Things

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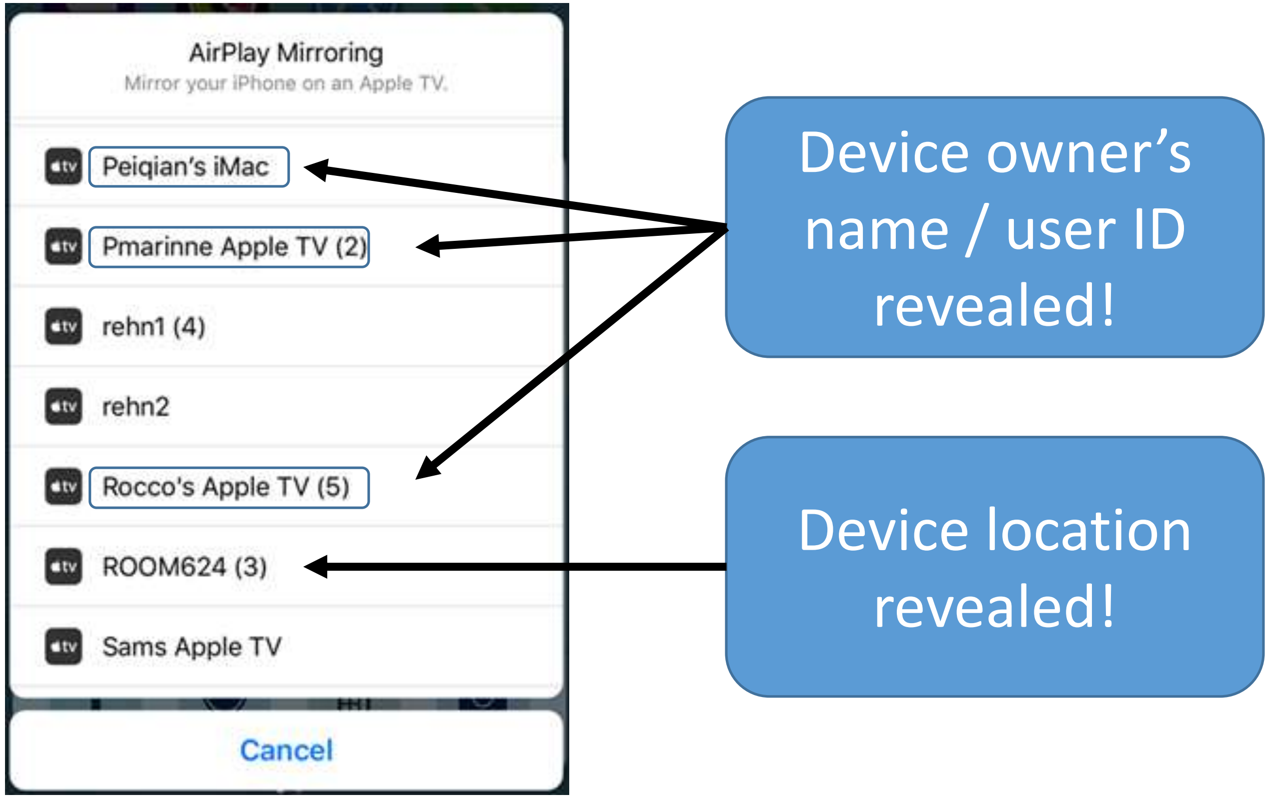
The Internet of Things (IoT)

Lots of smart devices, but only useful if users can discover them!

Private Service Discovery

Many existing service discovery protocols: Multicast DNS (mDNS), Apple Bonjour, Bluetooth Low Energy (BLE)

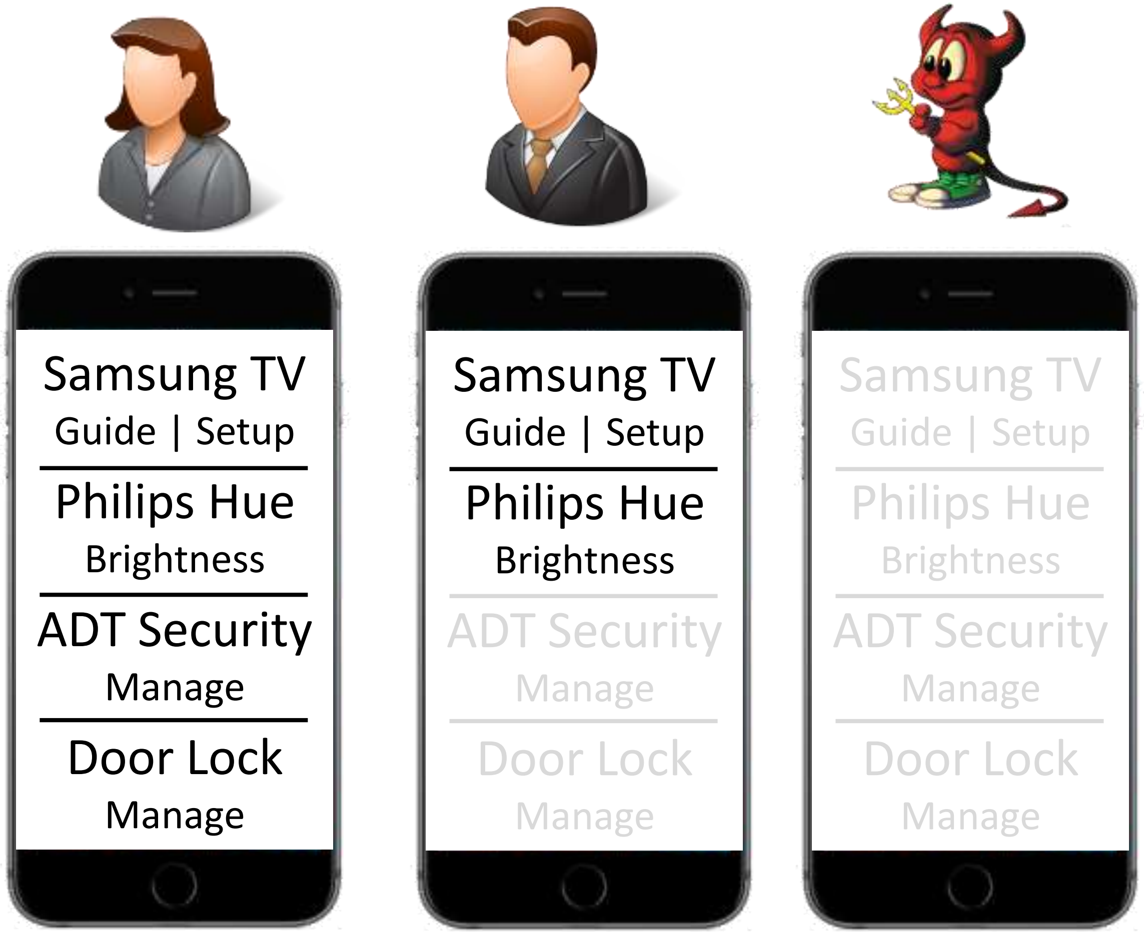
A typical discovery protocol



Screenshot taken on a public Wireless network

Private Service Discovery

Each service specifies an authorization policy



Alice Guest Stranger

Private Service Discovery

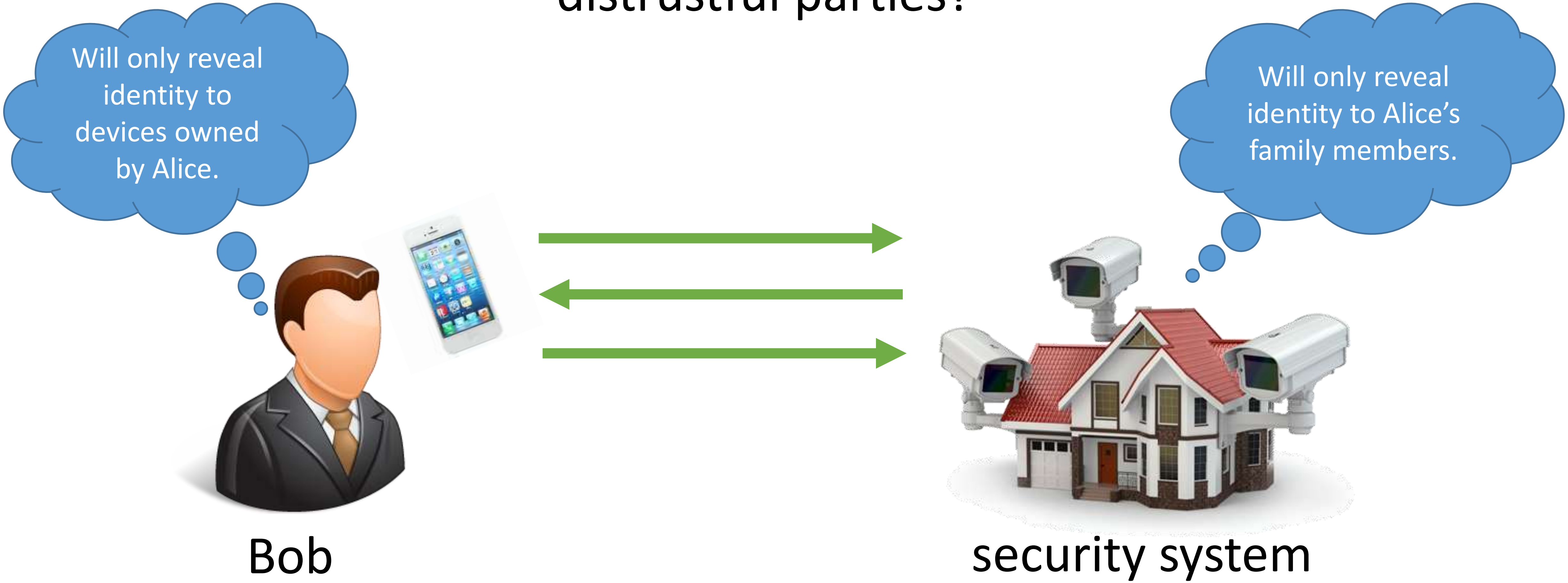
Each service specifies an authorization policy

Mutual privacy: privacy should also hold for devices trying to discover services!

Alice Guest Stranger

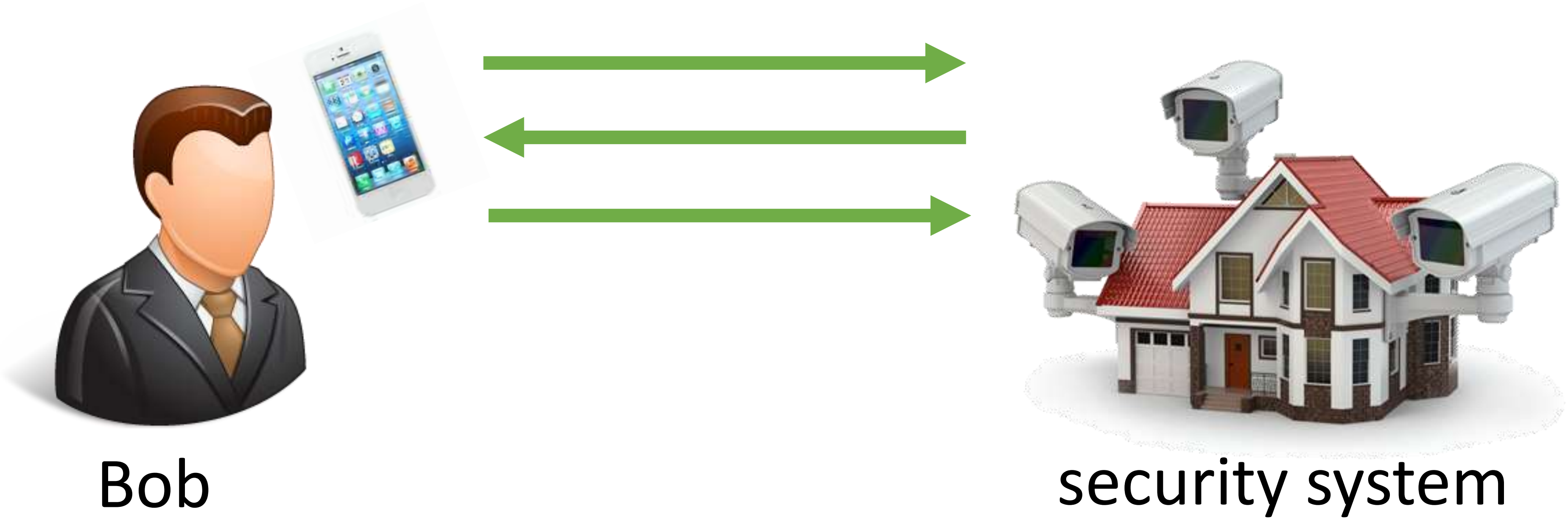
Private Mutual Authentication

How to authenticate between mutually distrustful parties?



Private Mutual Authentication

In most existing mutual authentication protocols (e.g., TLS, IKE, SIGMA), one party must reveal its identity first



Primary Protocol Requirements

- **Mutual privacy:** Identity of protocol participants are only revealed to authorized recipients

- **Lightweight:** privacy should be as simple as setting a flag in key-exchange (as opposed to a separate protocol – e.g., using secret handshakes [BDSSSW03])

Identity and Authorization Model

Every party has a signing + verification key, and a collection of human-readable names bound to their public keys via a certificate chain

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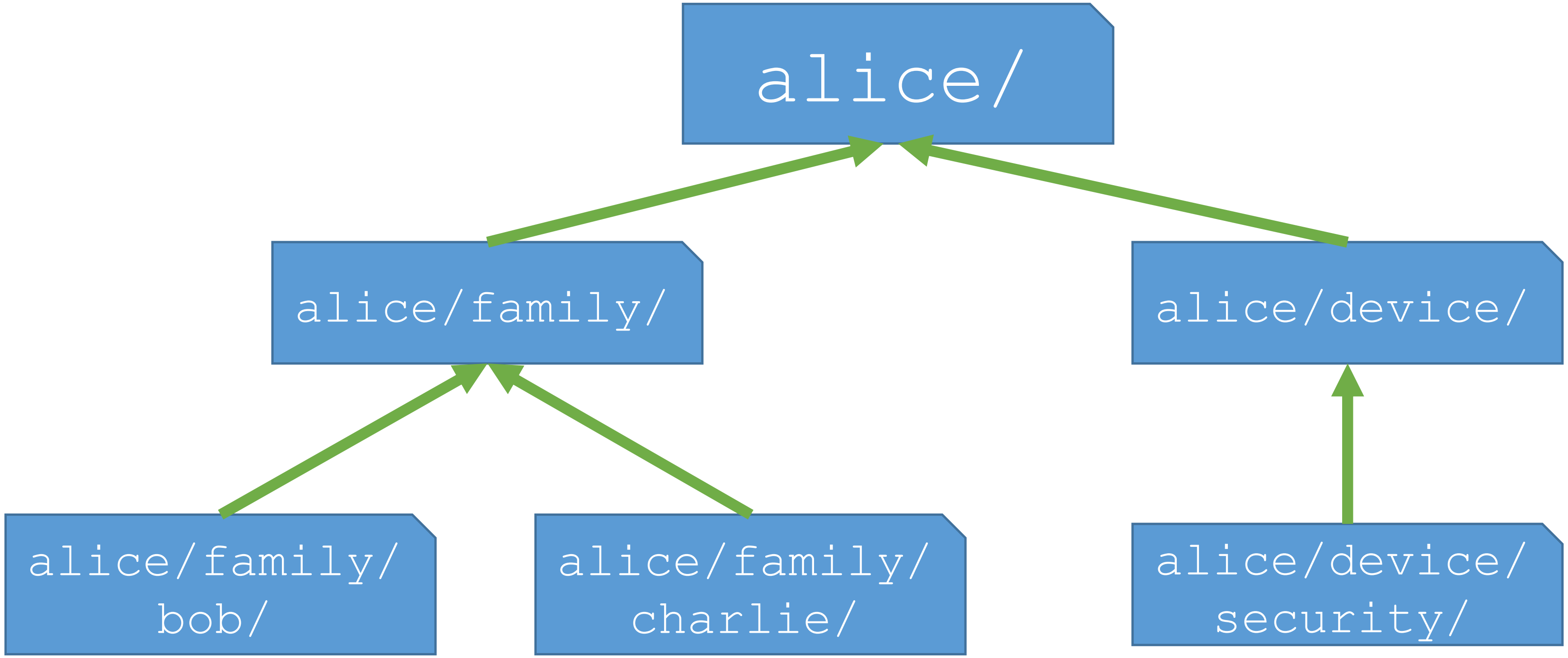
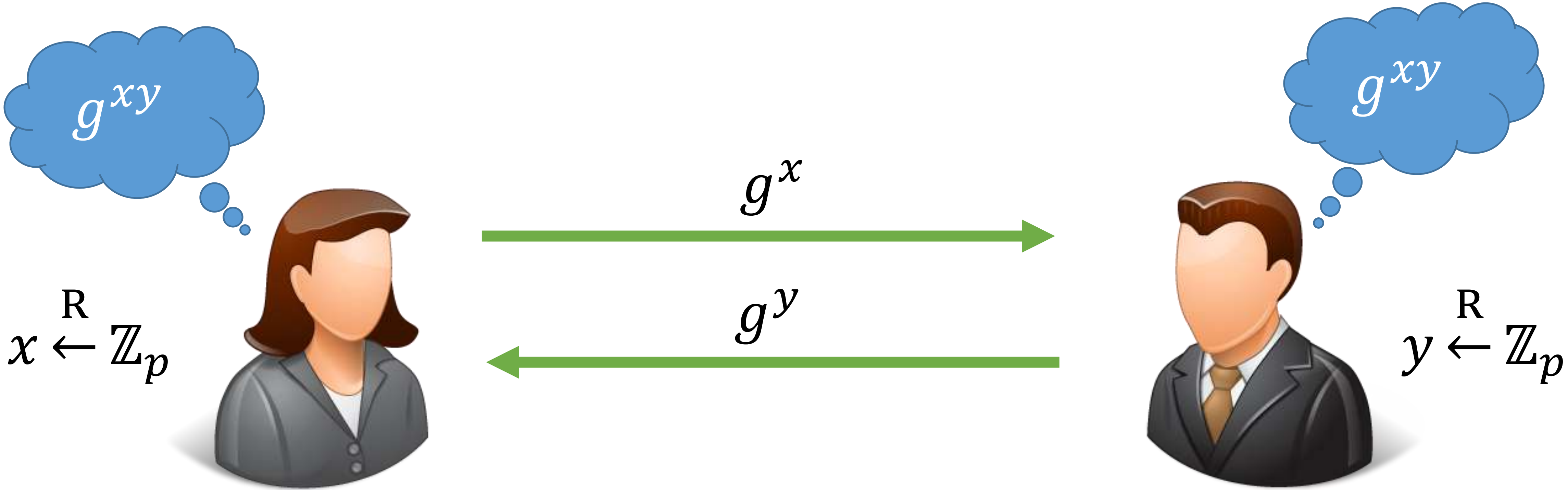


Identity and Authorization Model

Authorization decisions expressed as prefix patterns

Protocol Construction

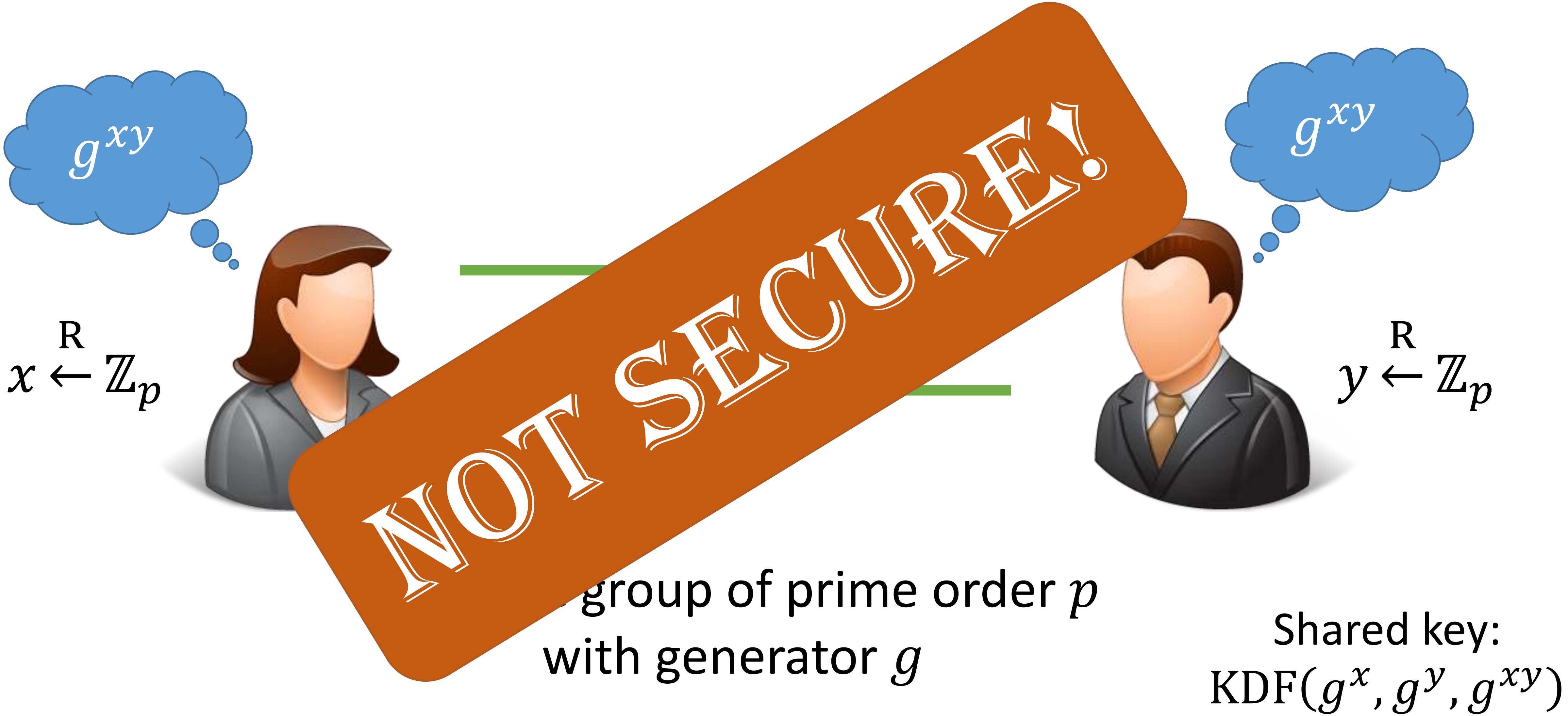
Starting Point: Diffie-Hellman Key Exchange



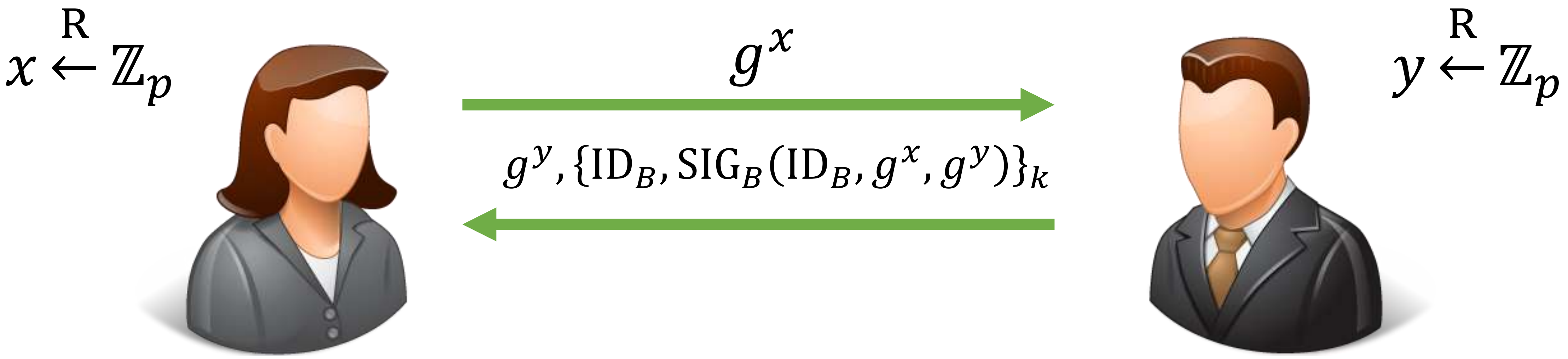
$\mathbb{G}$: cyclic group of prime order p
with generator g

Shared key:
$\text{KDF}(g^x, g^y, g^{xy})$

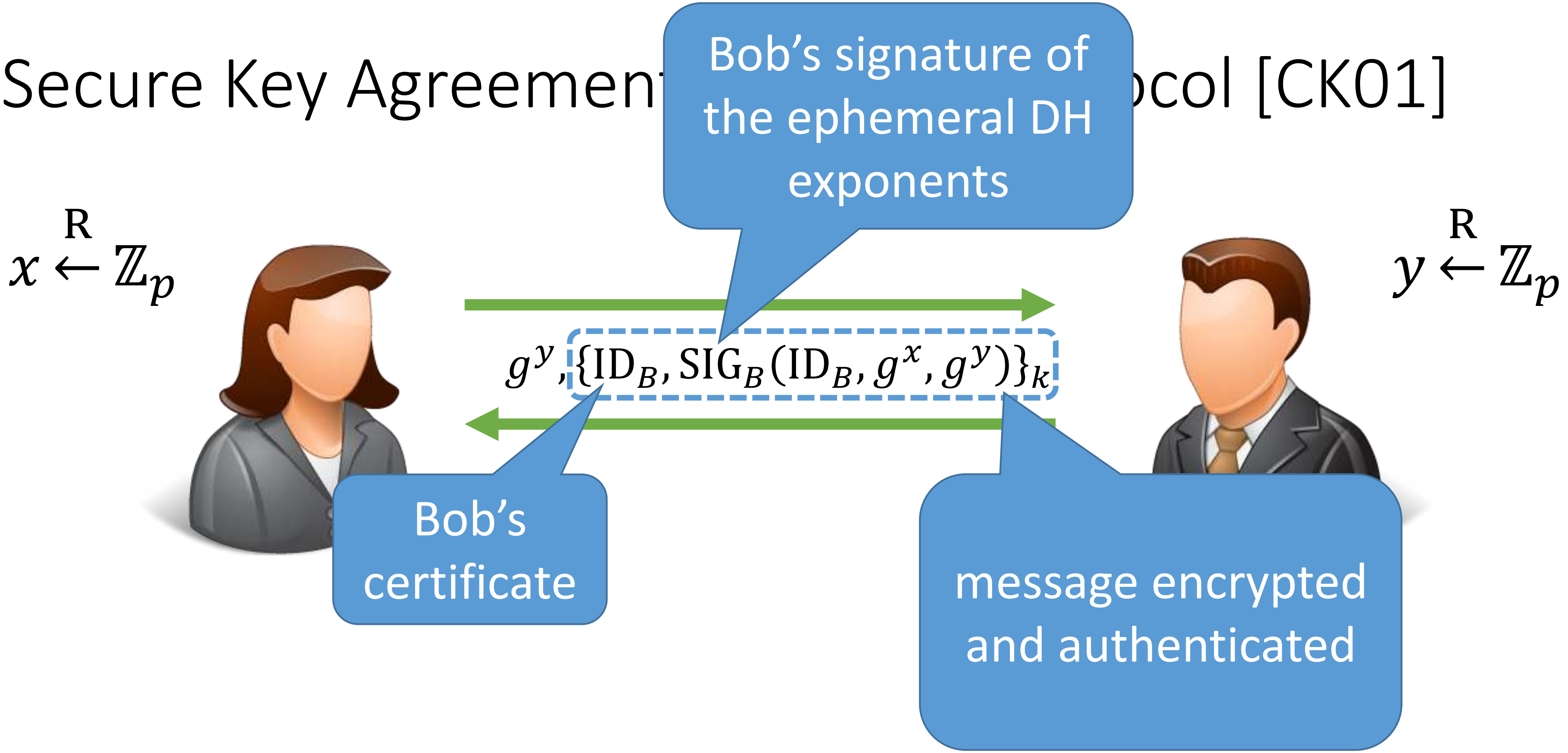
Starting Point: Diffie-Hellman Key Exchange



Secure Key Agreement: SIGMA-I Protocol [CK01]



Secure Key Agreement ... ocol [CK01]



Note: in the actual protocol, session ids are also included for replay prevention.

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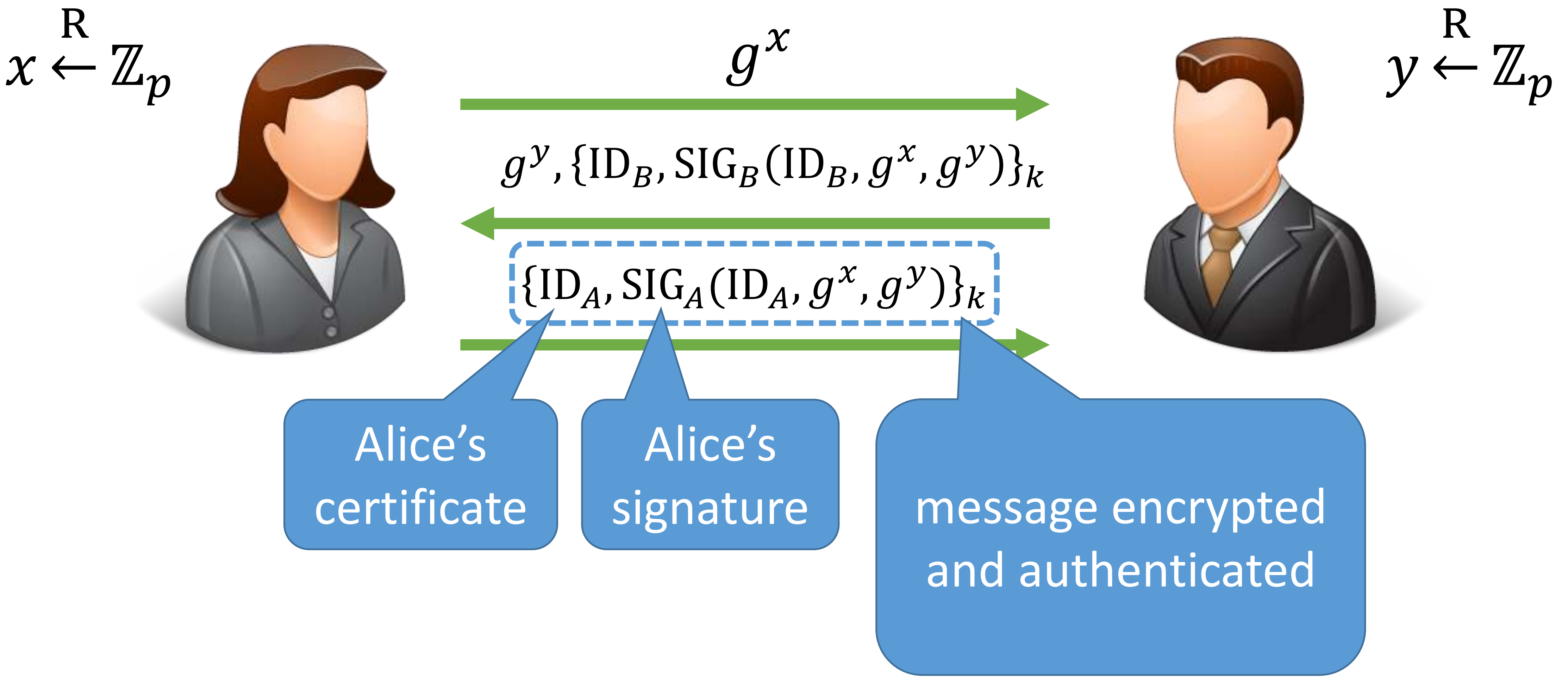

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Secure Key Agreement: SIGMA-I Protocol [CK01]

$x \xleftarrow{R} \mathbb{Z}_p$

g^x →

← $g^y, \{\mathrm{ID}_B, \mathrm{SIG}_B(\mathrm{ID}_B, g^x, g^y)\}_k$

$\{\mathrm{ID}_A, \mathrm{SIG}_A(\mathrm{ID}_A, g^x, g^y)\}_k$ →

$y \xleftarrow{R} \mathbb{Z}_p$

session key derived from

$$(g^x, g^y, g^{xy})$$

Note: in the actual protocol, session ids are also included for replay prevention.

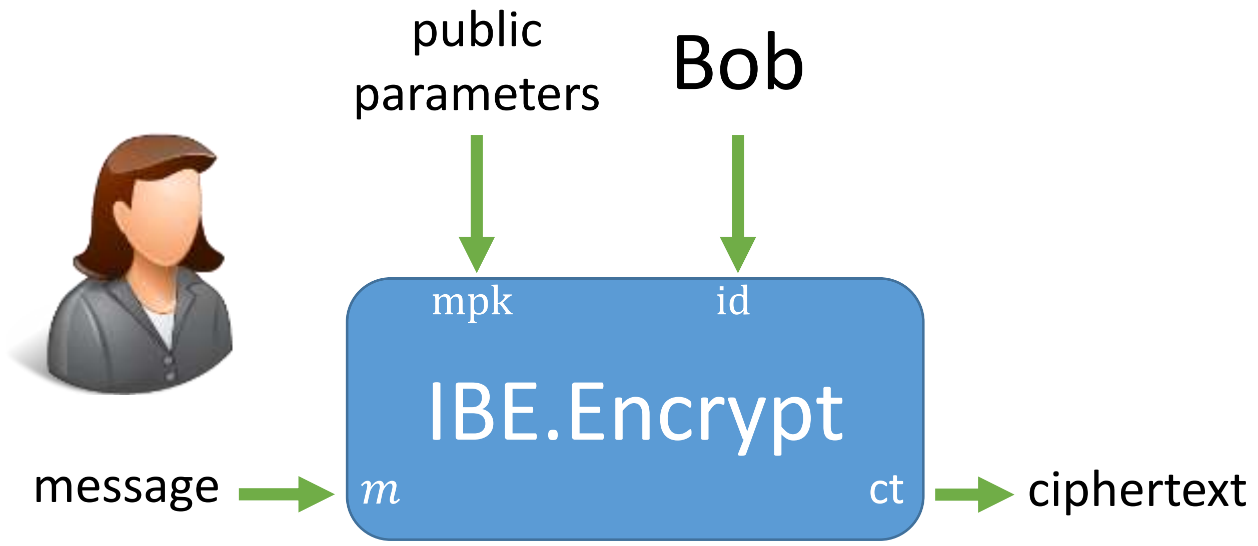
Properties of the SIGMA-I Protocol

- Mutual authentication against active network adversaries
- Hides server’s (Bob’s) identity from a passive attacker
- Hides client’s (Alice’s) identity from an active attacker

- Bob’s identity is revealed to an active attacker!

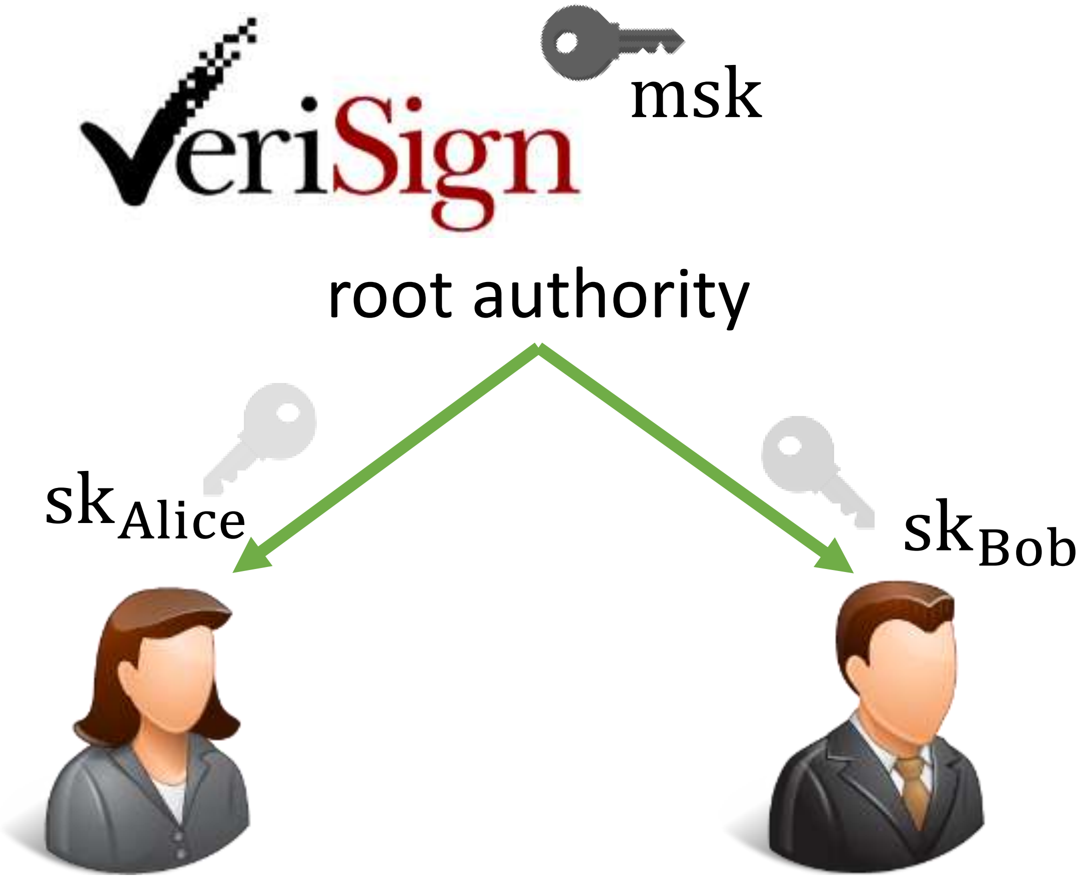
Identity Based Encryption (IBE) [Sha84, BF01, Coc01]

Public-key encryption scheme where public-keys can be arbitrary strings (identities)



Alice can encrypt a message to Bob without needing to have exchanged keys with Bob

Identity Based Encryption (IBE) [Sha84, BF01, Coc01]

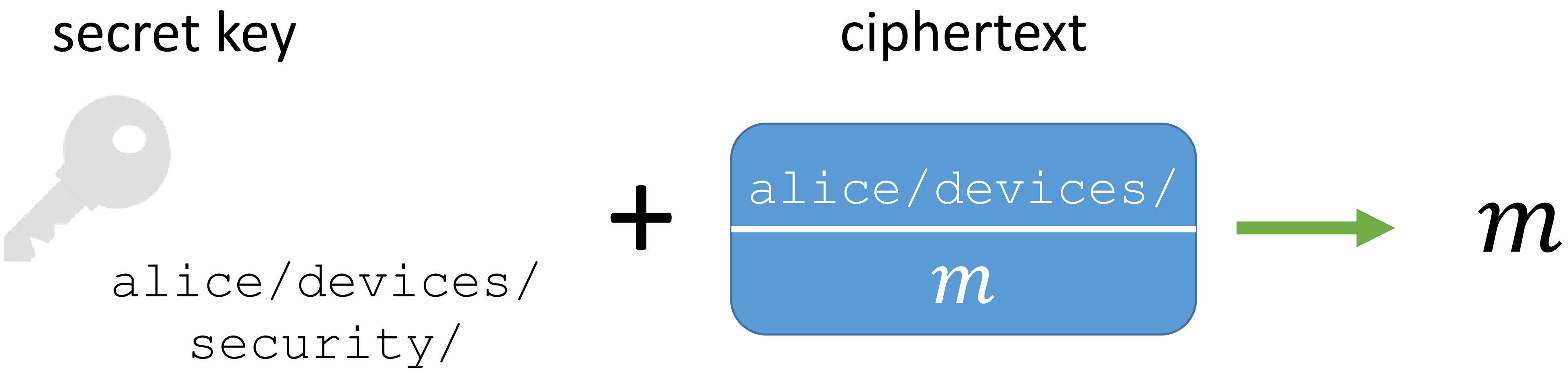


To decrypt messages, users go to a (trusted) identity provider to obtain a decryption key for their identity

Bob can decrypt all messages encrypted to his identity using $\mathsf{sk}_{\mathsf{Bob}}$

Prefix-Based Encryption

Secret-keys and ciphertexts both associated with names



Decryption succeeds if name in ciphertext is a prefix of the name in the secret key

Prefix-Based Encryption

Can be leveraged for prefix-based policies

Bob encrypts his message to the identity `alice/devices/`. Any user with a key that begins with `alice/devices/` can decrypt.

Prefix-Based Encryption

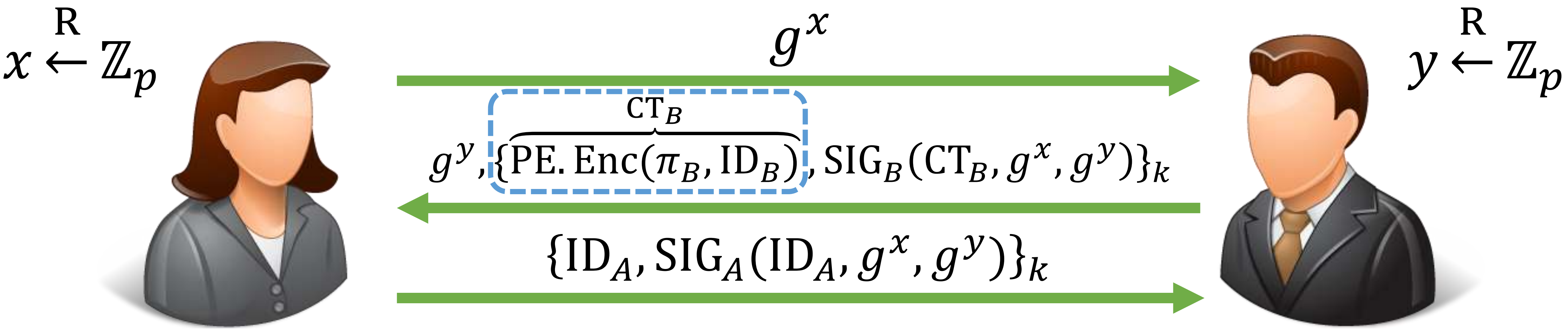
Can be leveraged for prefix-based policies

Bob en the
identit ny
use ith
alice/ rypt.

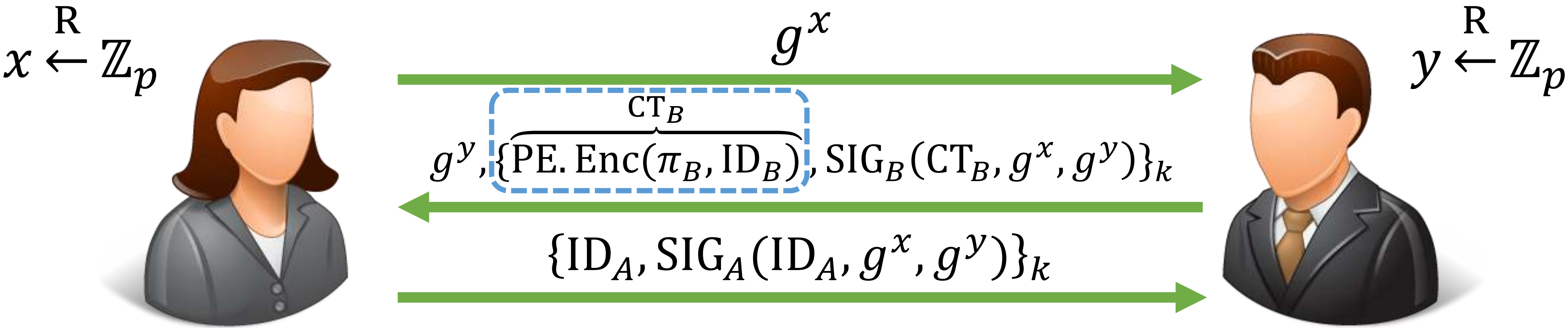
Can be built directly from IBE!

Private Mutual Authentication

Key idea: encrypt certificate using prefix-based encryption



Private Mutual Authentication



- **Privacy for Alice's identity:** Alice sends her identity only after verifying Bob's identity
- **Privacy for Bob's identity:** Only users with a key that satisfies Bob's policy can decrypt his identity

Private Service Discovery

Prefix-based encryption can also be leveraged for *private* service discovery

See paper for details:
http://arxiv.org/abs/1604.06959

Implementation and Benchmarks

- Instantiated IBE scheme with Boneh-Boyen (BB_2) IBE scheme (`DCLXVI` library)

- Integrated private mutual authentication and private service discovery protocols into the Vanadium open-source framework for building distributed applications

`https://github.com/vanadium/`

Implementation and Benchmarks



	Intel Edison	Raspberry Pi	Nexus 5X	Desktop
SIGMA-I	252.1 ms	88.0 ms	91.6 ms	5.3 ms
Private Mutual Auth.	1694.3 ms	326.1 ms	360.4 ms	9.5 ms
Slowdown	6.7x	3.7x	3.9x	1.8x

Comparison of private mutual authentication protocol with non-private SIGMA-I protocol

Note: x86 assembly optimizations for pairing curve operations available only on desktop

Conclusions

- Existing key-exchange and service discovery protocols do not provide privacy controls
- Prefix-based encryption can be combined very naturally with existing key-exchange protocols to provide privacy + authenticity
- Overhead of resulting protocol small enough that protocols can run on many existing devices

Questions?

Paper: `https://arxiv.org/abs/1604.06959`