Session Logical Relation for Noninterference

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Joint work with Stephanie Balzer and Limin Jia
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Session types in a nutshell

Propagation of sensitive information

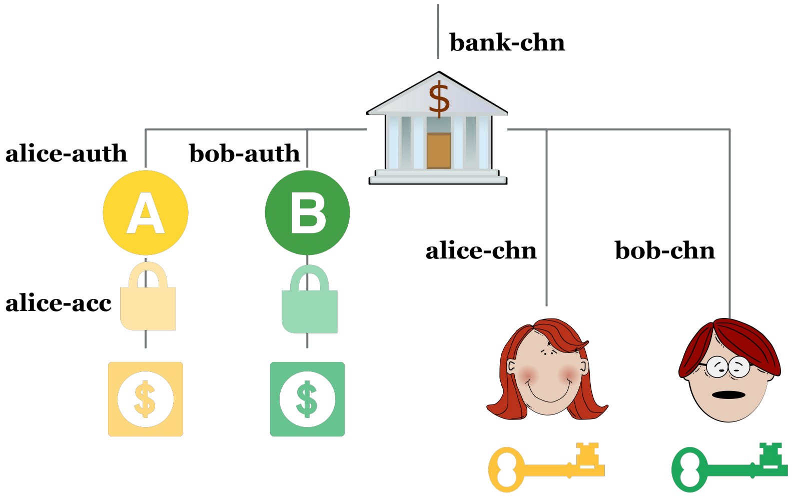
Session type: Protocol for message exchange along channels

?int;!bool;1

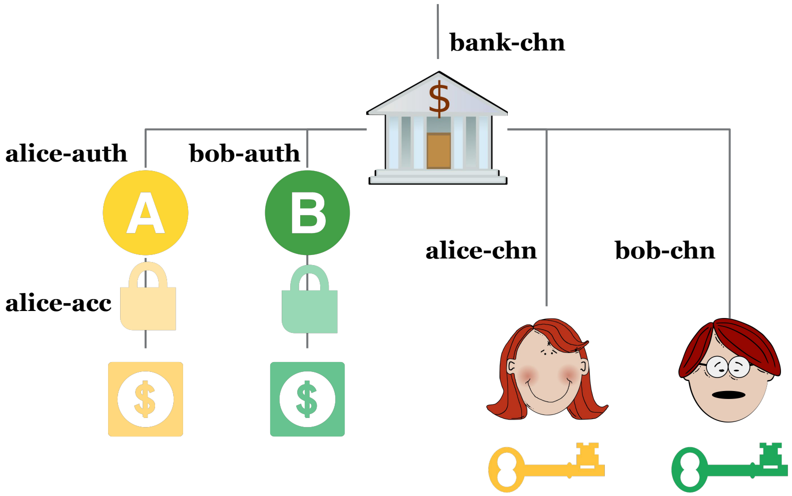
Message passing concurrency paradigm

Erlang, Go, Rust

Information flow control



Information flow control



[*Protocols*]

$$\texttt{alice-chn} : \; \mathsf{customer} = \mathsf{auth} \multimap 1$$

$$\texttt{alice-auth} : \; \mathsf{auth} = \&\{tok_1 : \oplus\{succ : \mathsf{account} \otimes 1, fail : 1\}, \ldots, tok_n : \oplus\{succ : \mathsf{account} \otimes 1, fail : 1\}\}$$

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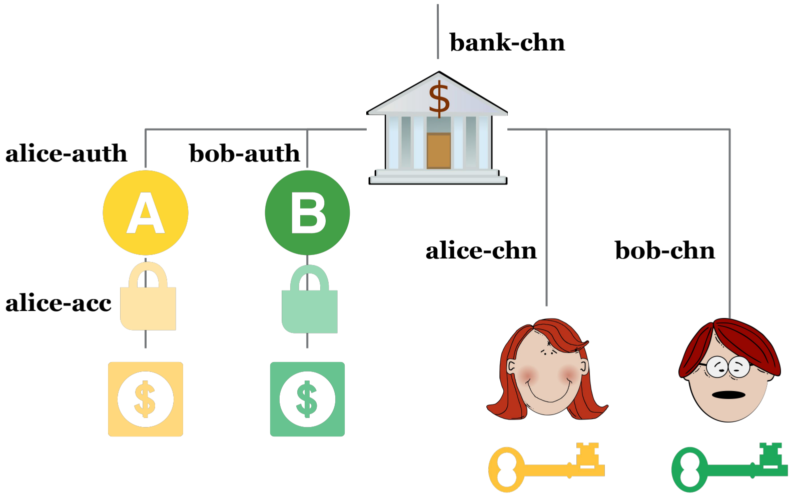

Process term

$$\textbf{Bank}: \\ \quad \texttt{send alice-auth alice-chn;} \\ \quad \texttt{send bob-auth bob-chn;}$$

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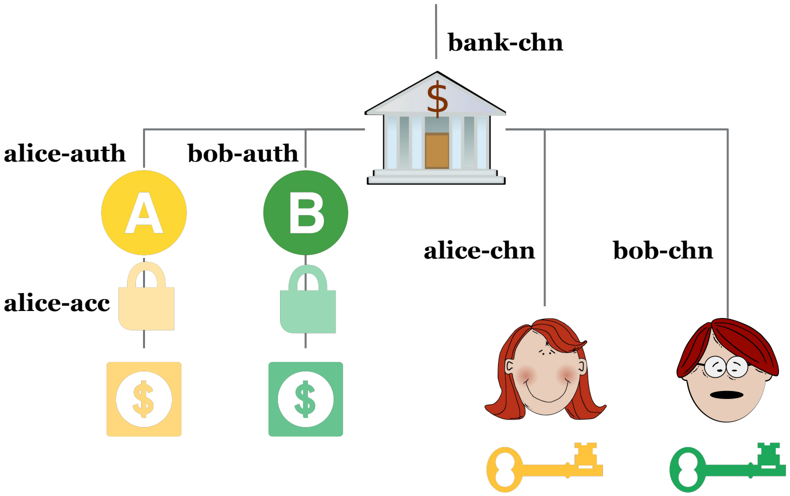

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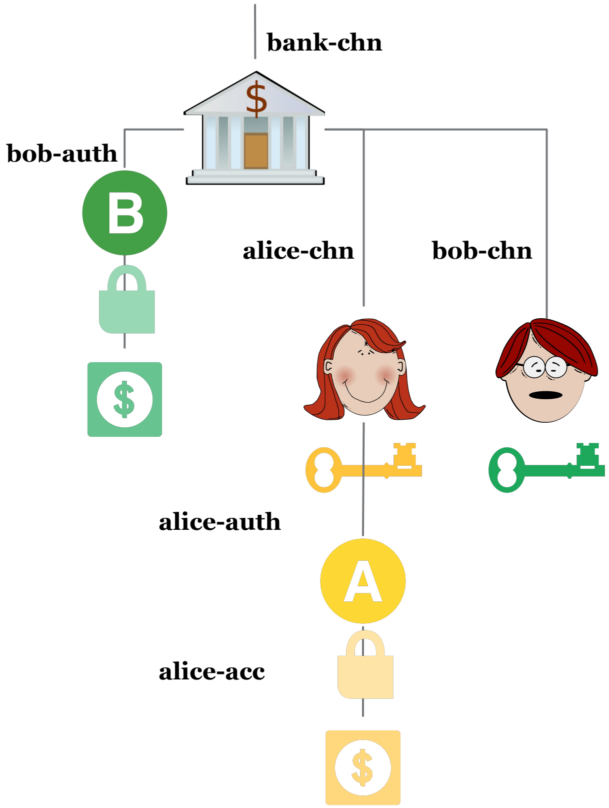

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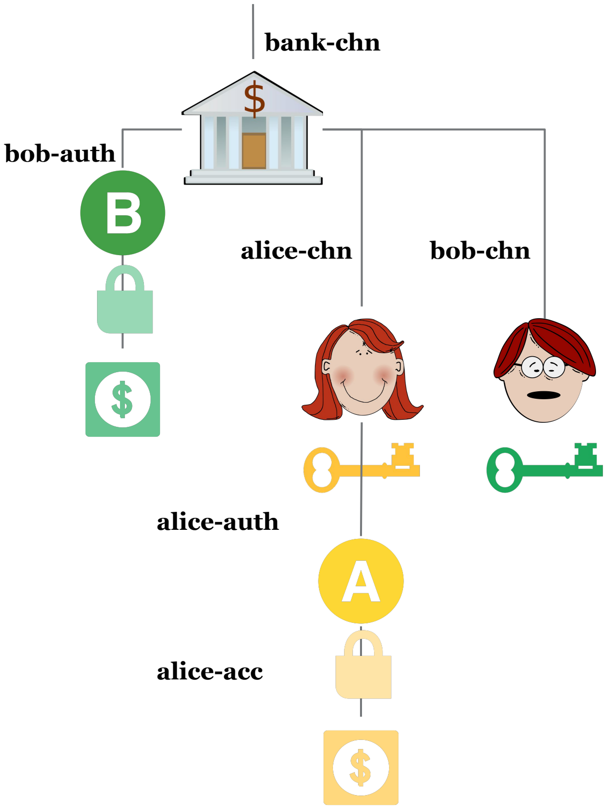

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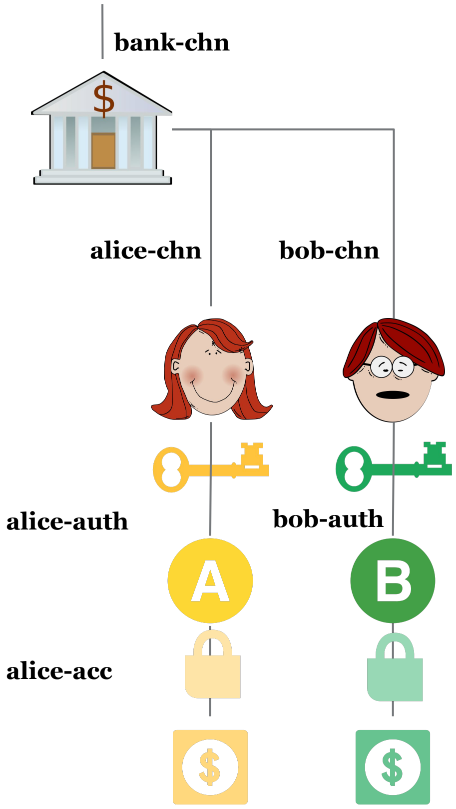

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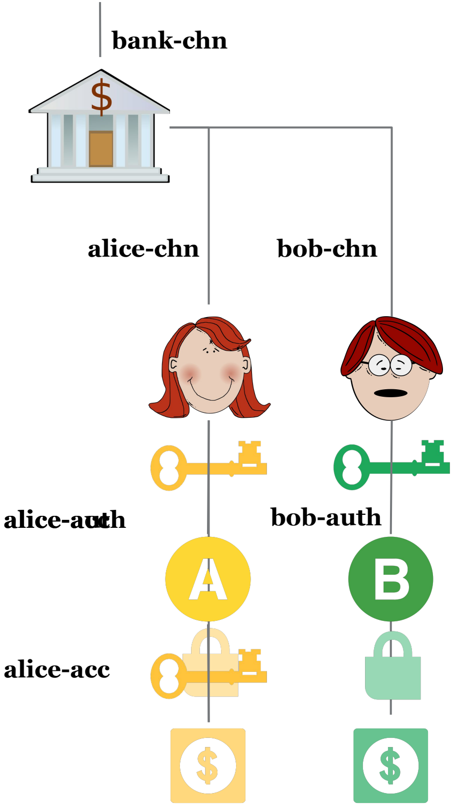

Process term

Alice–Auth–Process :

$$\textbf{case}\ \texttt{alice–auth}\ (tok_{yellow} \Rightarrow \texttt{alice–auth}.succ;\ \textbf{send}\ \texttt{alice–acc}\ \texttt{alice–auth}; \cdots \mid tok_{i \neq yellow} \Rightarrow \texttt{alice–auth}.fail; \cdots))$$

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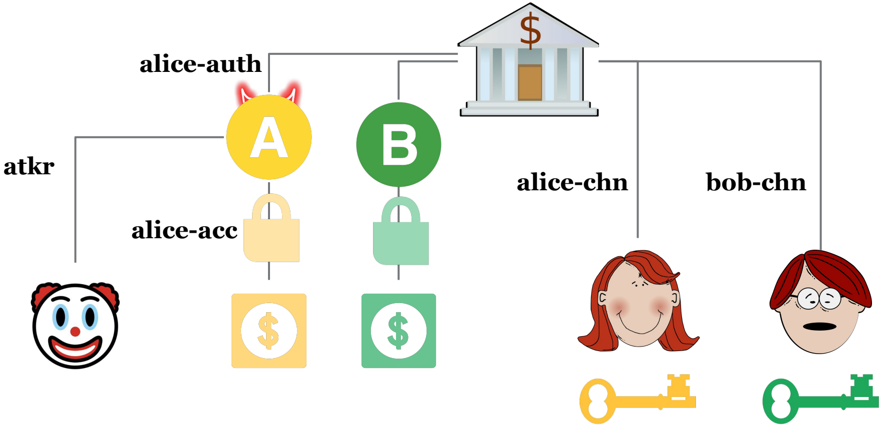
Information leakage: indirect flow



[Process term](#)

SneakyaAuth :

$$\textbf{case}\; x\; (tok_{yellow} \Rightarrow x.succ; u.s; z.s; \text{// insecure send}$$
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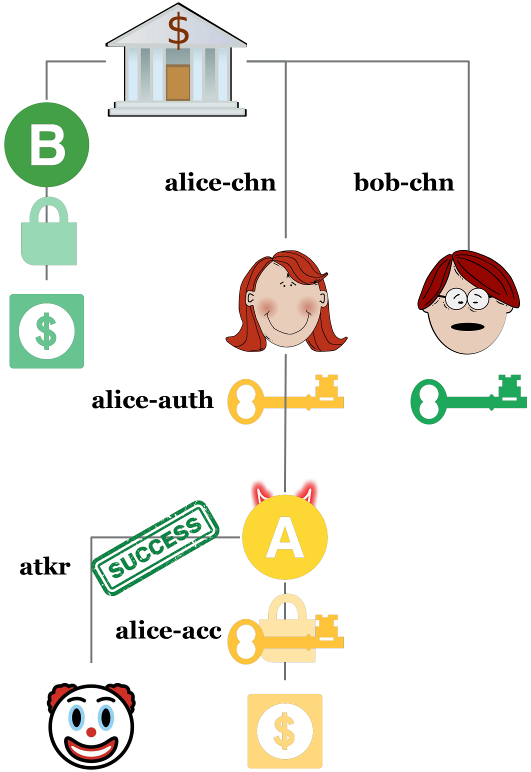

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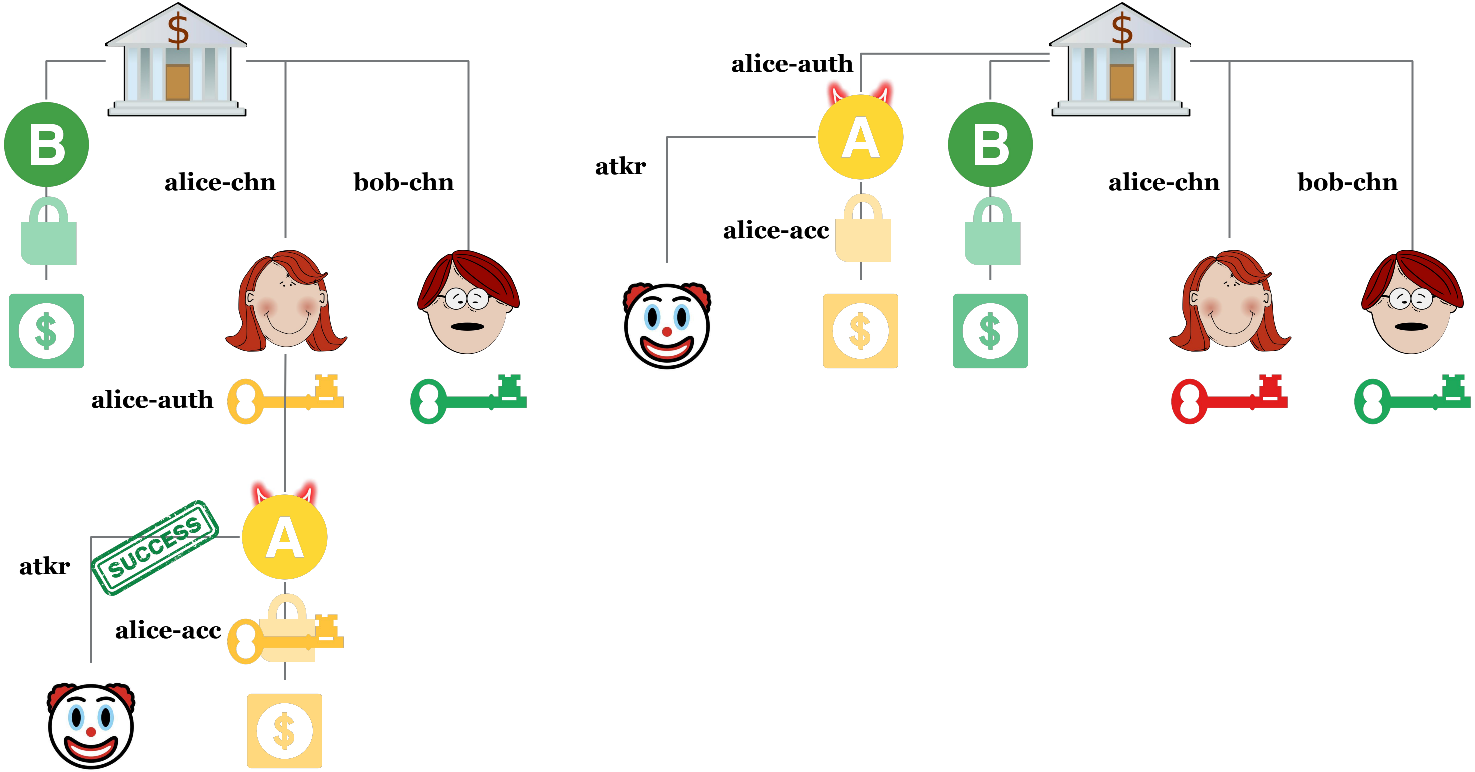

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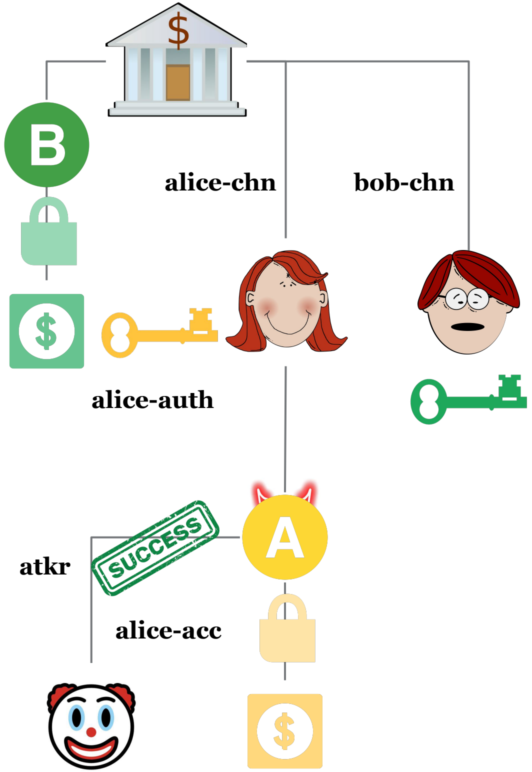
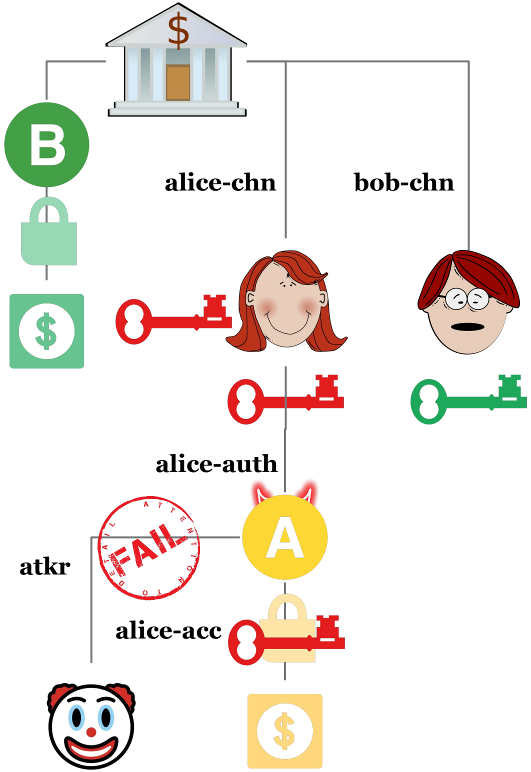
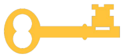




The secret  vs 

Not secret  vs 

IFC for message passing concurrency

Direct and indirect malicious leakages can be prevented by an ***information flow control (IFC) type system.***

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Session types to prescribe the protocols of **message passing** systems.

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Session types to prescribe the protocols of **message passing** systems.

➔ ***Enrich session types to prevent information leakage.***

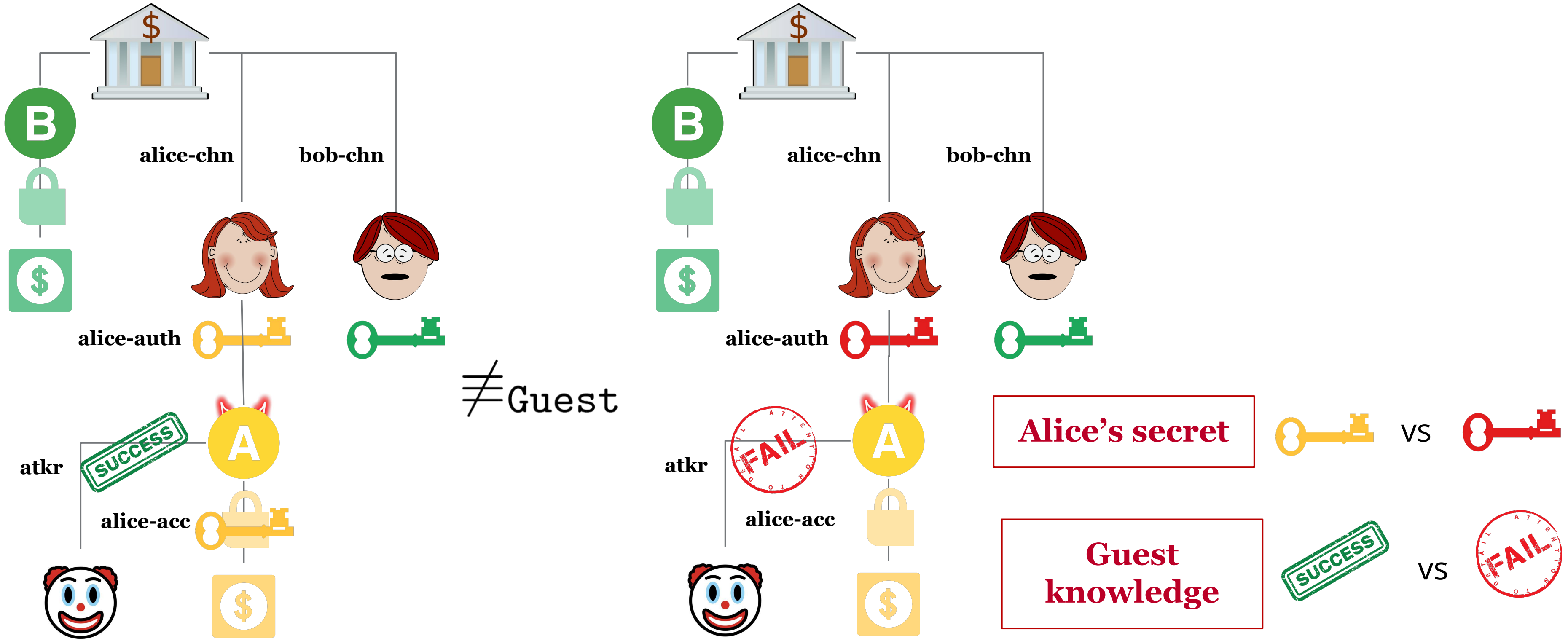
➔ *Capture* **noninterference** *with* ***a novel logical relation.***

Noninterference

Program equivalence up to observable messages

- ➔ ***Assume***: a process receives related messages along low-secrecy channels.
- ➔ ***Assert***: it sends the same messages along those channels.

Noninterference: Program equivalence up to observable messages



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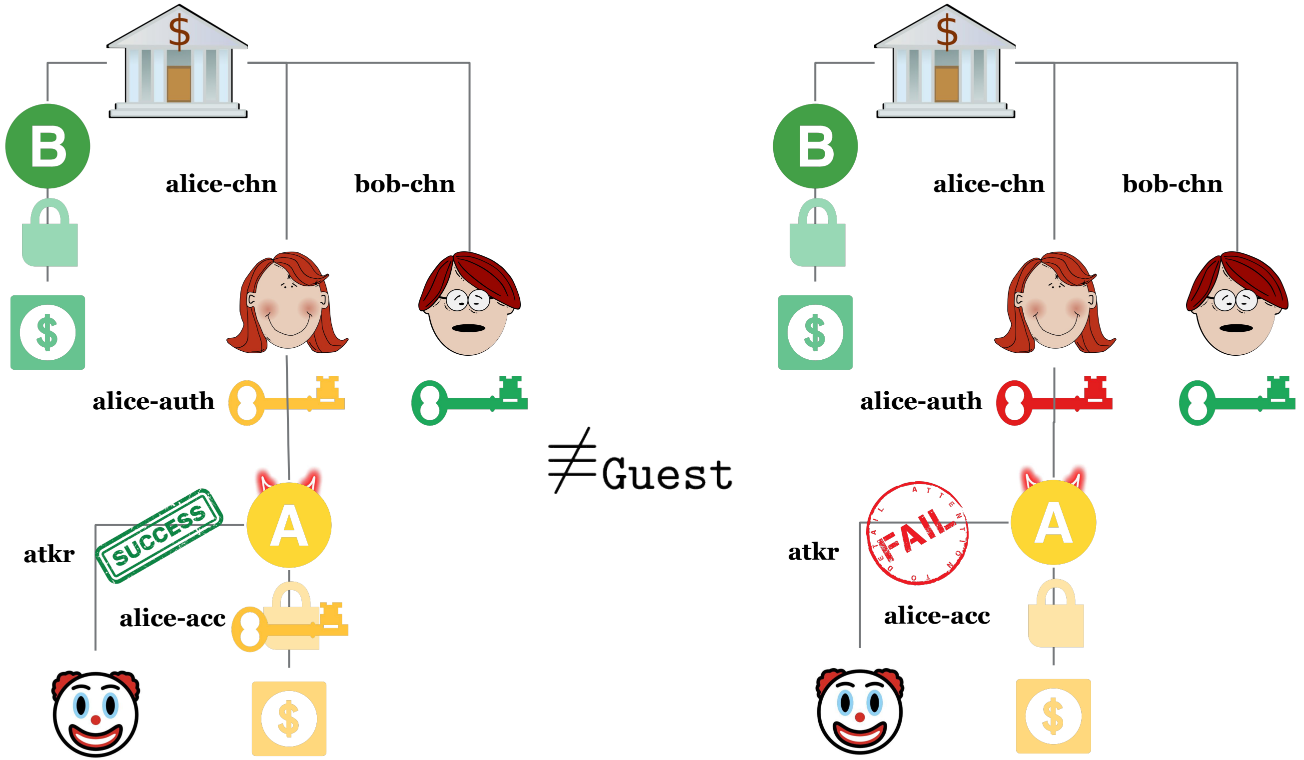

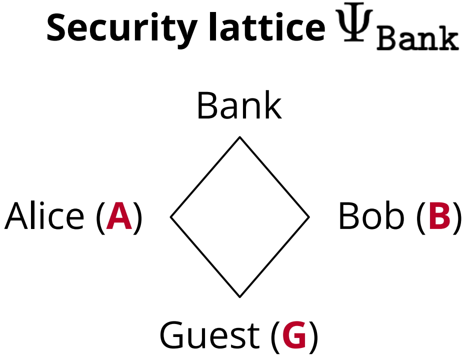

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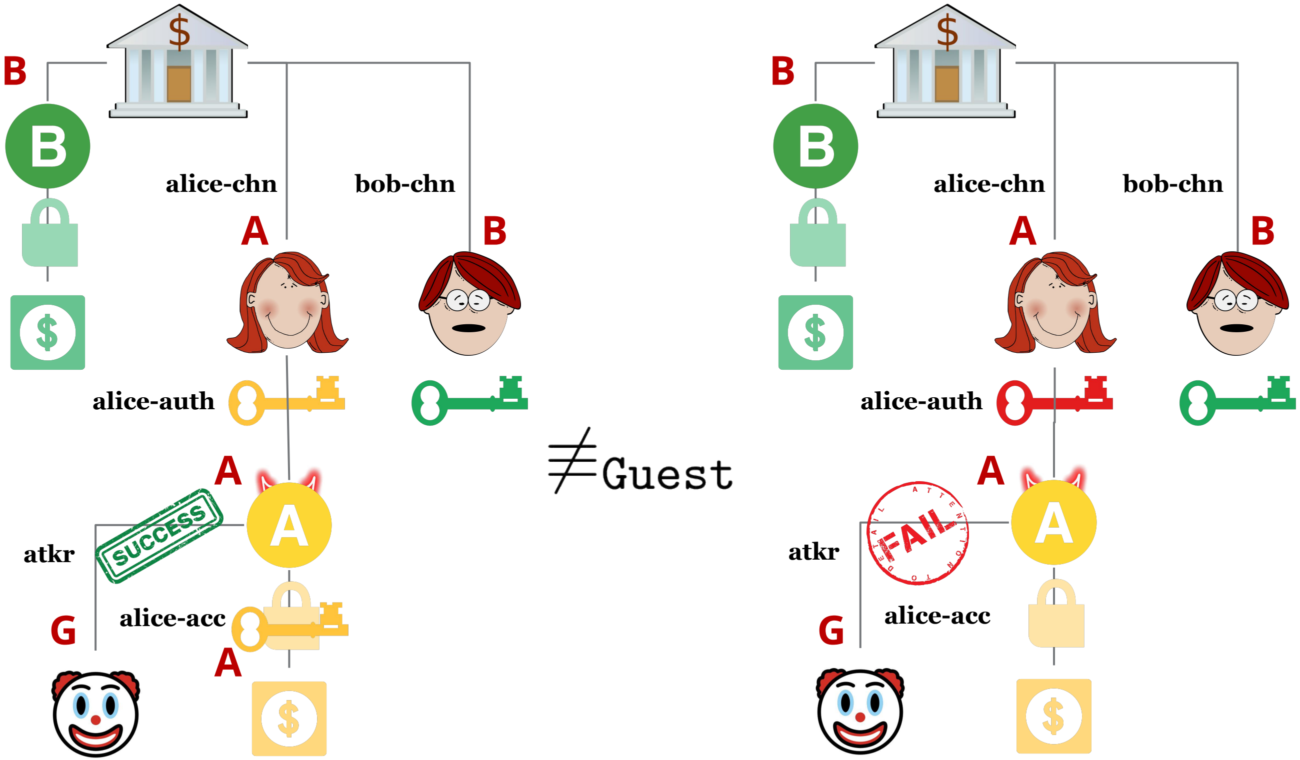
- ➔ ***Assert***: it sends the same messages along those channels.

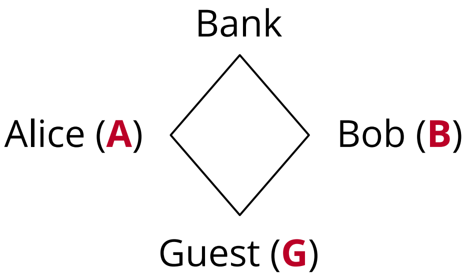
Maximal secrecy

- ★ The **security clearance** of a process.
- ★ The *maximum secrecy* that a process can receive *w/o violating the security lattice*.

Maximal secrecy: The security clearance of the process



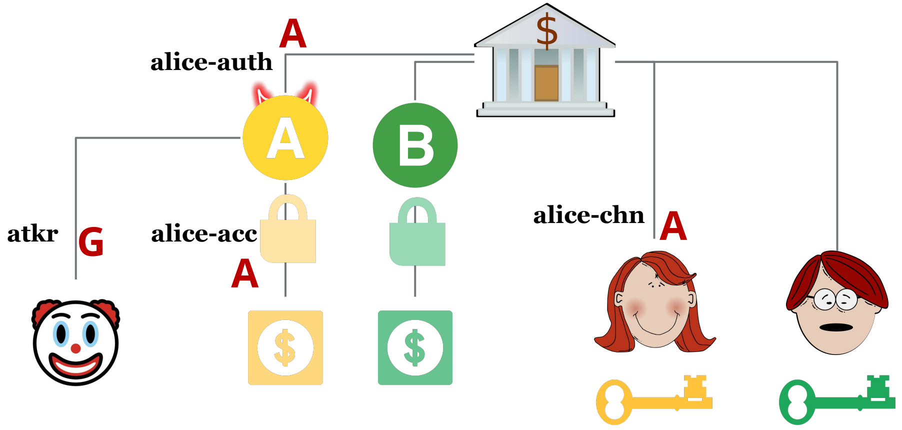
Security lattice $\Psi_{\mathtt{Bank}}$

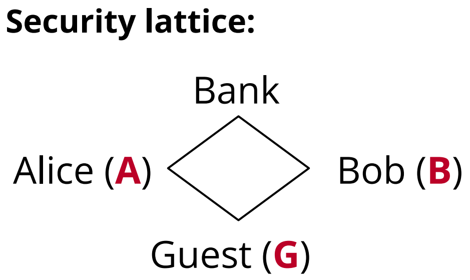


Running secrecy

Reflection of **the level of secret information a process has obtained** so far.

Running secrecy: the highest level of secret information obtained so far





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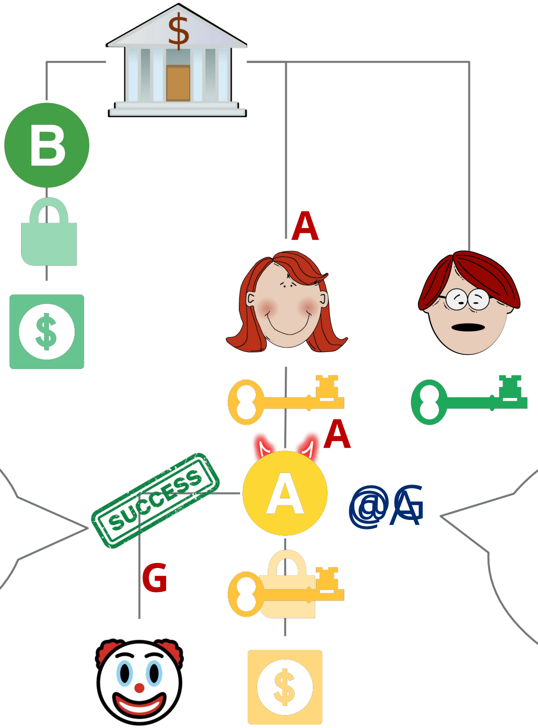
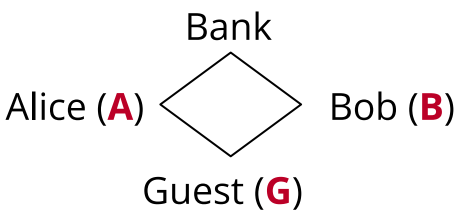
Running secrecy: the highest level of secret information obtained so far

Indirect flow 🚫



Security lattice:



Does not type check
Process A of running secrecy Alice cannot send along z of lower secrecy Guest.

Running secrecy of A is increased to Alice after receiving from x of secrecy Alice.

SneakyaAuth :

@Alice

$\textbf{case}\, x\, (tok_{yellow} \Rightarrow x.succ; u.s; z.s;$ // insecure send

error: Guest<Alice

@Guest

$\mid tok_{i \neq yellow} \Rightarrow x.fail; u.f; z.f;$ // insecure send$)$

Typing judgments with possible worlds

$$\Delta \vdash P \qquad :: (x{:}A)$$

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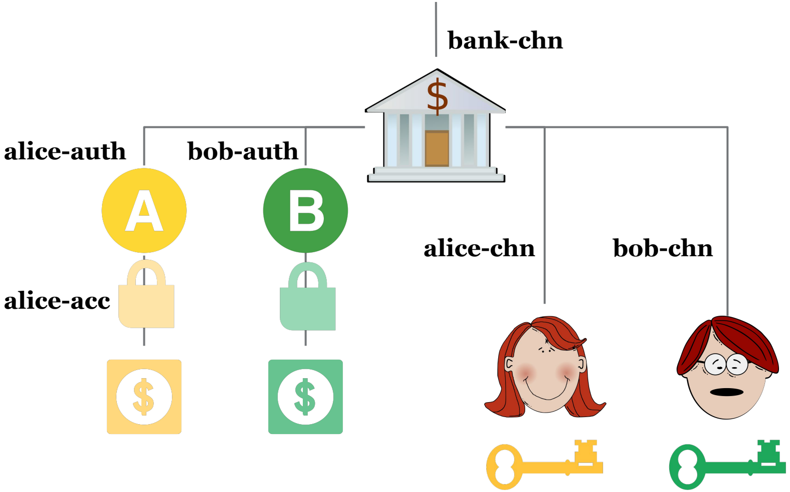

$\texttt{alice-auth:auth}, \texttt{bob-auth:auth}, \texttt{alice-chn:customer}, \texttt{bob-chn:customer} \vdash \textbf{Bank} :: (\texttt{bank-chn}:1)$

Typing judgments with possible worlds

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Typing judgments with possible worlds

Security lattice

Maximal secrecy

$$\Psi; \Delta \vdash P @ c :: (x{:}A[d])$$

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Running secrecy

The running secrecy is a reflection of **the level of secret information a process has obtained** so far.

1. *Adjust on receives:* increase the running secrecy to ***at least*** the secrecy of the channel you receive from,

2. *Guard on sends:* the running secrecy of the sending process is ***at most*** the secrecy of the channel you send to .

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Running secrecy

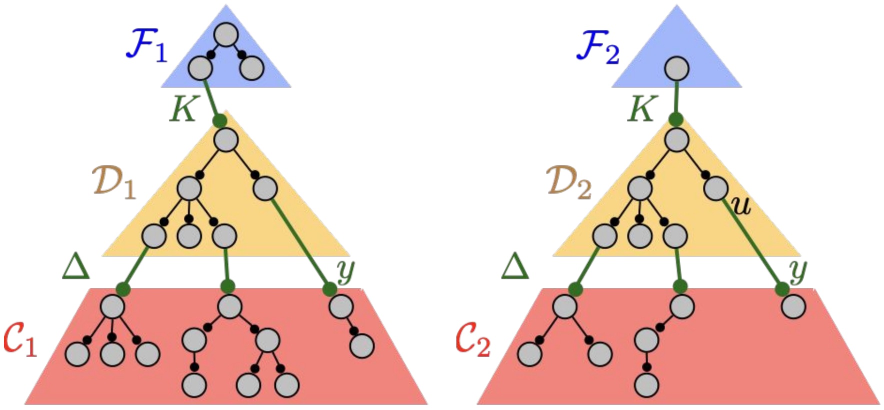
Tree invariant:

1. the *maximal secrecy of a child* is at most as high as the *parent's node*,
2. the *running secrecy* of the parent node is capped by its *maximal secrecy* (d).

A node can never obtain more secrets than it is licensed to.

Main contributions

- **IFC type system** for intuitionistic linear binary session types using possible worlds
- **Session logical relation** for noninterference supporting open programs



$$(\mathcal{C}_1\mathcal{D}_1\mathcal{F}_1, \mathcal{C}_2\mathcal{D}_2\mathcal{F}_2) \in \mathcal{E}^{\xi}_{\Psi}[\![\Delta \Vdash K]\!]$$

Future work

- **Noninterference of recursive session-types**
  - **Progress sensitive**
  - **Progress insensitive** system with **certified downgrading**
    - more flexible but not as safe!

- Integrate our results with **sharing**

Conclusions

Summary:

- **IFC type system** for intuitionistic linear binary session types using possible worlds
- **Session logical relation** for noninterference supporting open programs

Observations:

- Session types make explicit knowledge of information learned through **message exchange**
- Session logical relation allows for more **nuanced equality expression**, possibly paving the way for other investigations
- Possible worlds bear resemblance to **Kripke logical relations**, yet *internalizing the worlds into the type system*