Provably Authenticated Group Diffie-Hellman Key Exchange :

The Dynamic Case

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Outline

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- The Problem
- Related Work
- Security Model
- Security Definitions
- A Secure Authenticated Group Diffie-Hellman Protocol
- Security Theorem
- Conclusion

Motivation

- An increasing number of distributed applications need to communicate within groups, e.g.
  - — collaboration and videoconferencing tools
  - — replicated servers
  - — stock market and air traffic control
  - — distributed computations (Grids)
- An increasing number of applications have security requirements
  - — privacy of data
  - — protection from hackers (public network)
  - — protection from viruses and trojan horses
- Group communication must address security needs

The Problem

- Group Diffie-Hellman Characteristics
  - group relative small (up to 100 members)
  - no centralized server
  - members have similar computing power
  - membership is dynamic (members join and leave the group at any time)

- Goals for Group Key Exchange
  - Authenticated Key Exchange (AKE)
    - implicit authentication: only the intended partners can compute sk
    - semantic security: a session key is indistinguishable from a random string
  - Mutual Authentication (MA)

Prior Work : The Static Case

- “Provably Authenticated Group DH Key Exchange”, ACM CCS’01

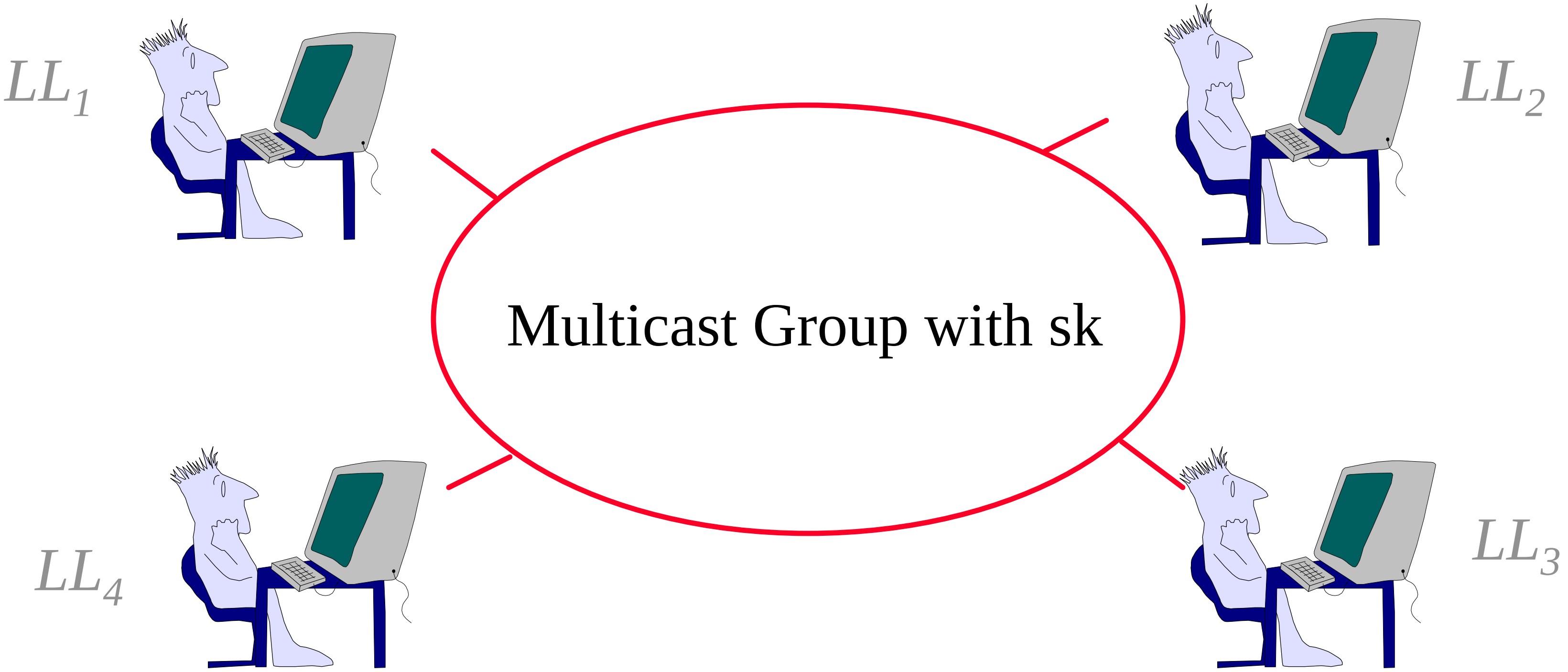
  — static membership (all the members join the group at once)

  — model of computation in the Bellare-Rogaway style
  - players are modeled via oracles
  - adversary controls all interactions among the players
  - adversary’s capabilities are modeled by queries to the oracles
  - adversary plays a game against the players

  — an authenticated group Diffie-Hellman key exchange protocol

Model of Communication

- A set of *n* players
  - — each player is represented by an oracle
  - — each player holds a long-lived key (LL)
- A multicast group consisting of a set of players



LL_1

LL_2

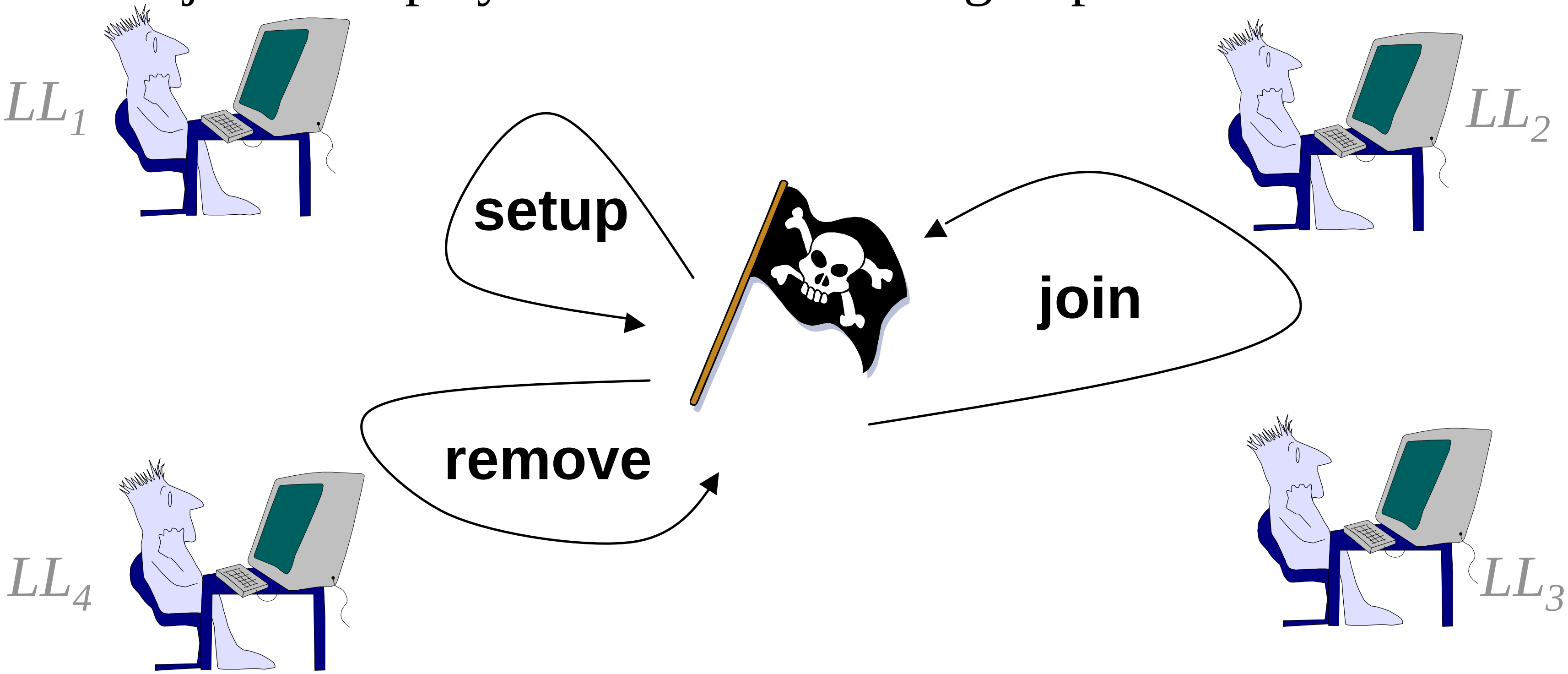
Multicast Group with sk

LL_4

LL_3

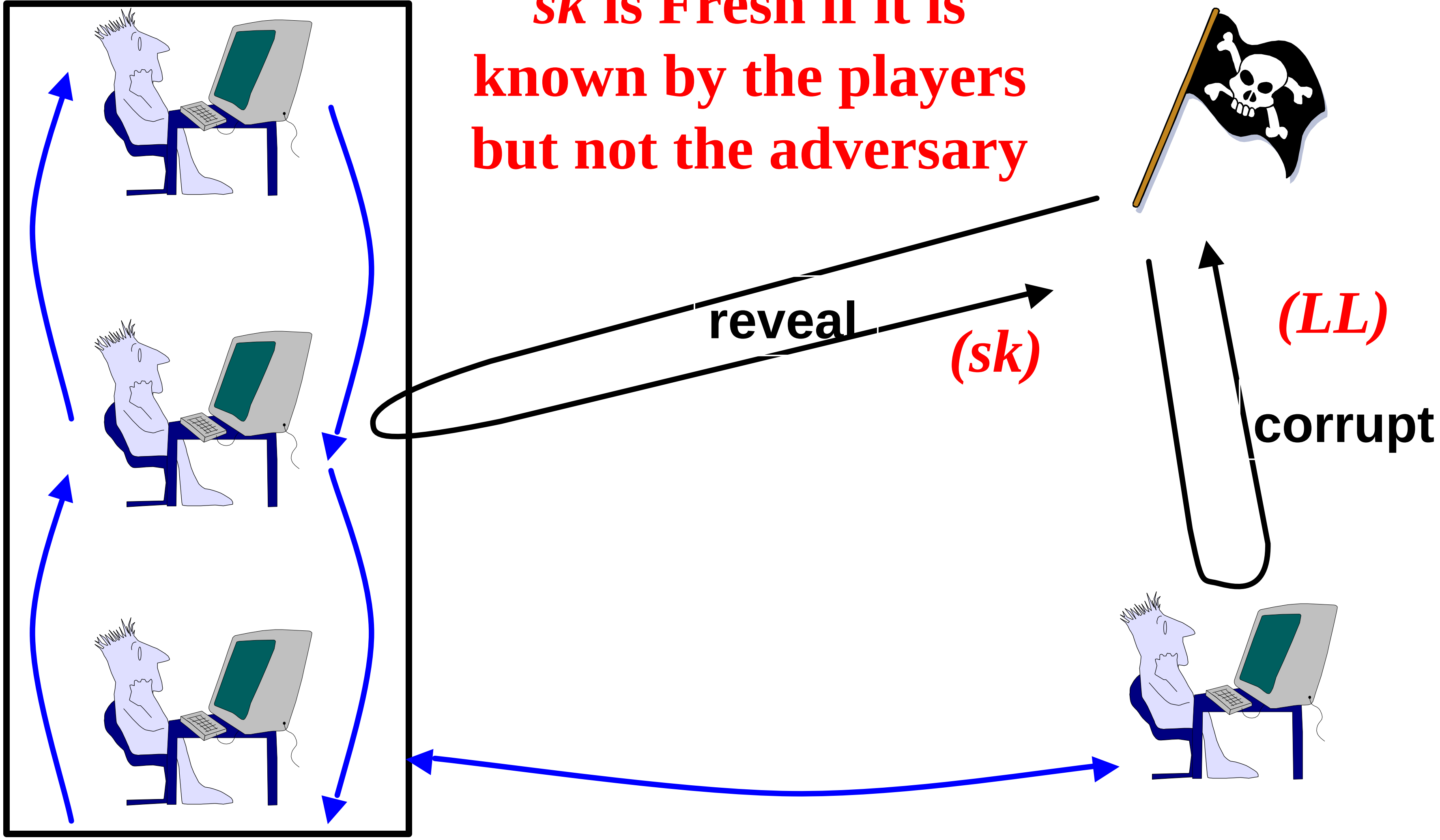
Modeling the Adversary

- Adversary’s capabilities modeled through queries
  - — setup: initialize the multicast group
  - — remove: remove players from multicast group
  - — join: add players to the multicast group

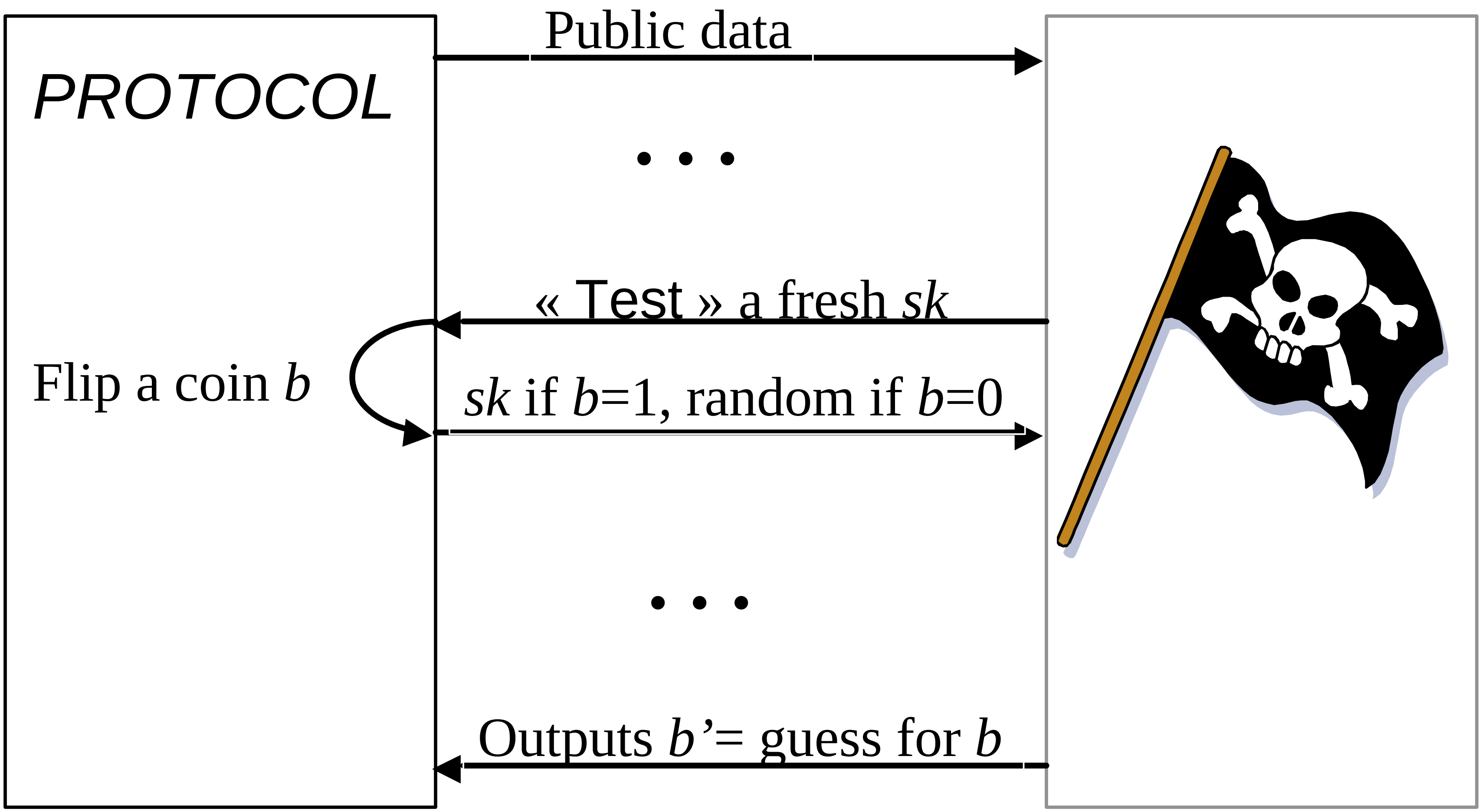


Freshness Related Queries

***sk* is Fresh if it is known by the players but not the adversary**



Security Definitions (AKE)



PROTOCOL

Public data

• • •

« Test » a fresh sk

Flip a coin b

sk if b=1, random if b=0

• • •

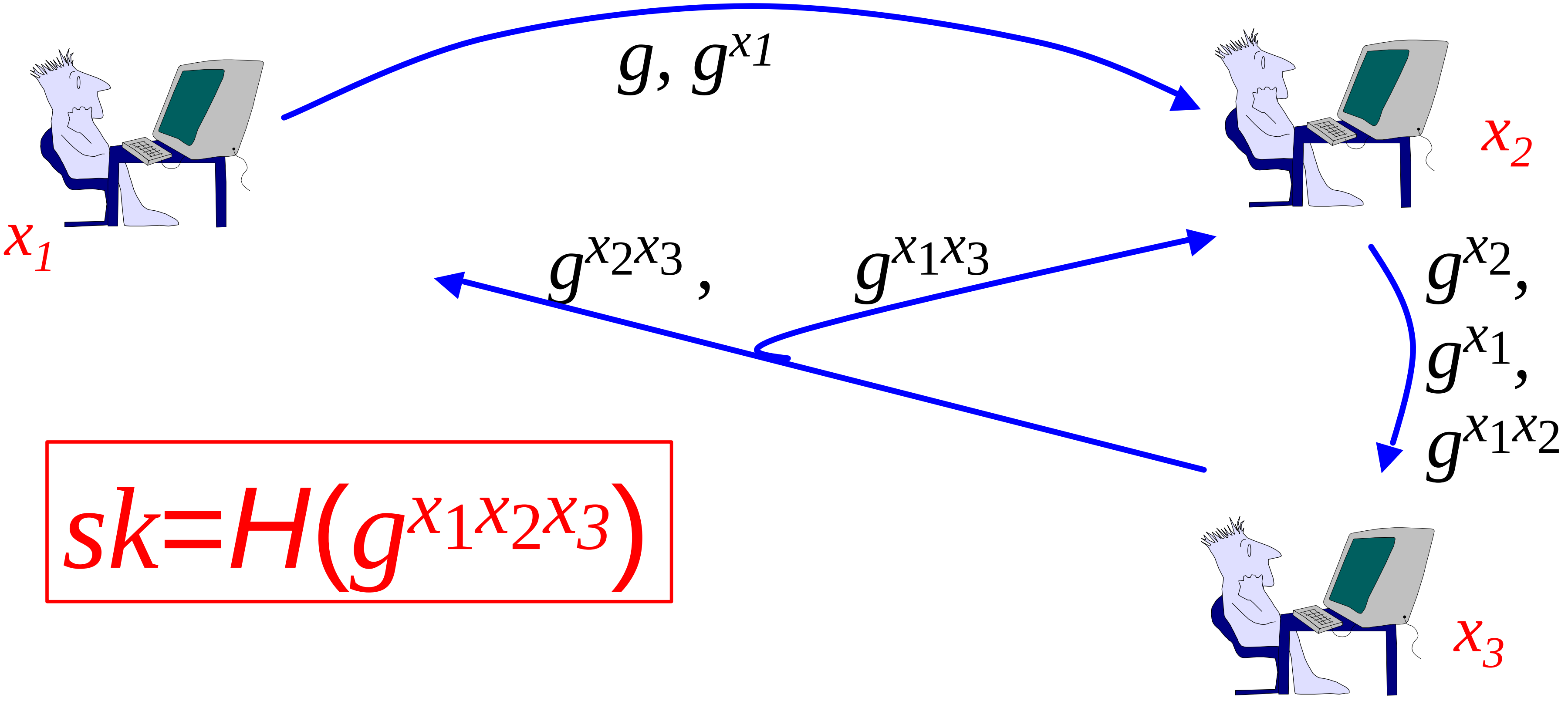
Outputs b'= guess for b

A Secure Authenticated Group Diffie-Hellman Protocol

- The session key is
  - $sk=H(g^{x_1 x_2 \cdots x_n})$
- Ring-Based with flows
- Defined by three algorithms
  - SETUP
  - REMOVE
  - JOIN
- Many details abstracted out

The SETUP Algorithm

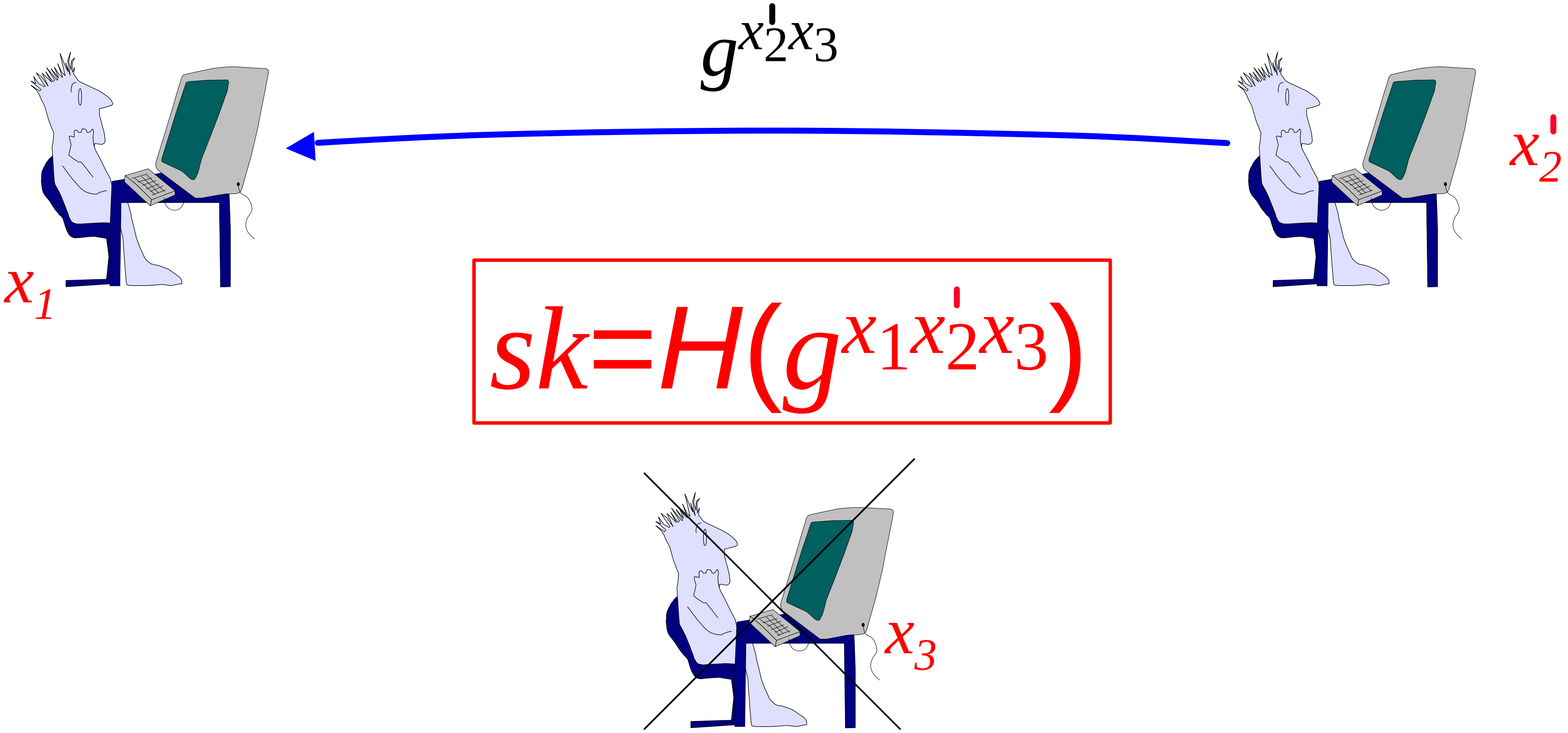
- Up-flow: U_i raises received values to the power of x_i and forwards to U_{i+1}
- Down-flow: U_n processes the last up-flow and broadcasts



$$\boxed{sk=H(g^{x_1x_2x_3})}$$

The REMOVE Algorithm

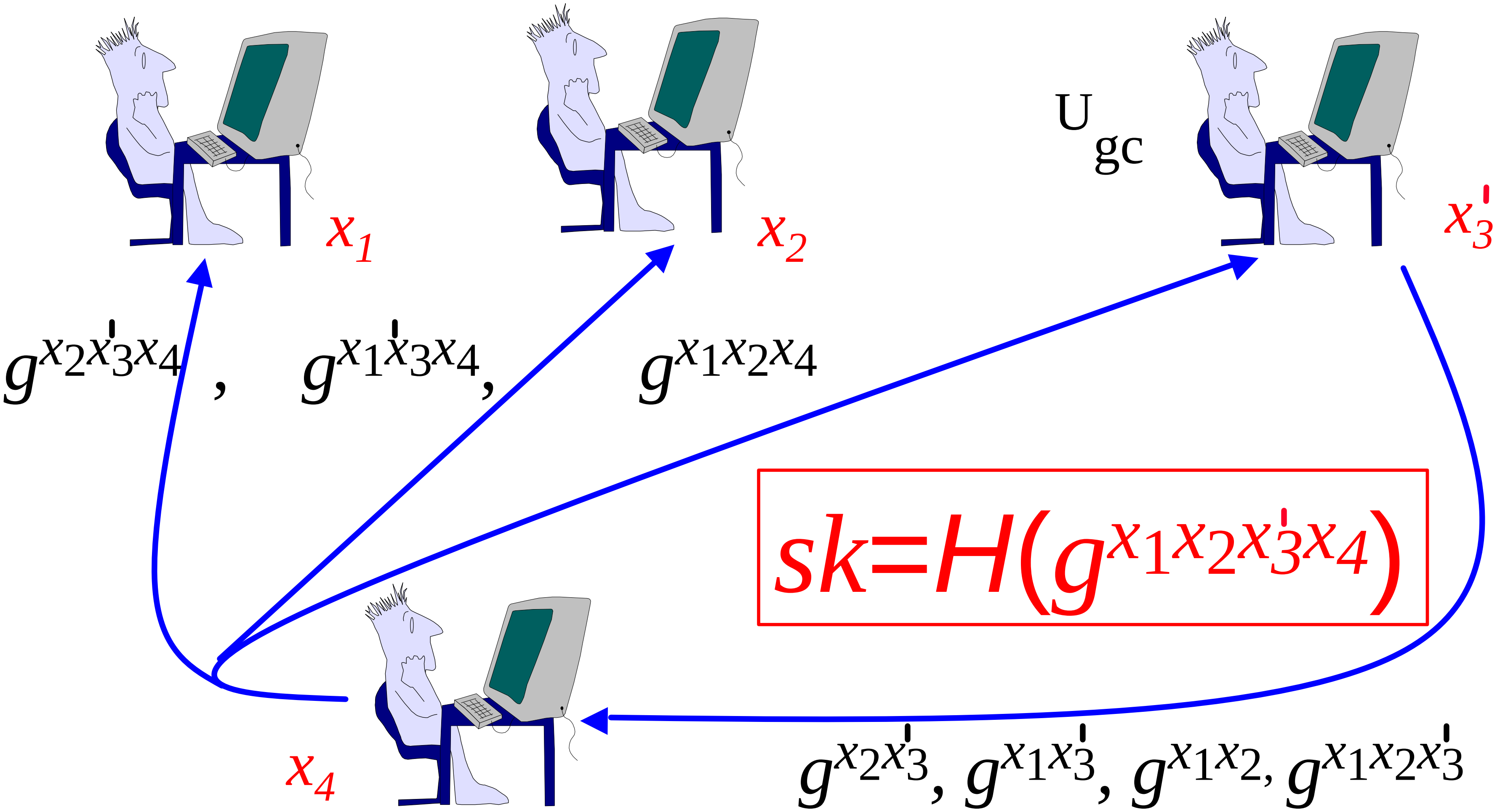
- Down-flow of the SETUP algorithm



$$\boxed{sk=H(g^{x_1 x_2' x_3})}$$

The JOIN Algorithm

- SETUP initiated by player with highest index in group (U_{gc})



x_1

x_2

U_{gc}

x_3'

$g^{x_2 x_3' x_4}$, $g^{x_1 x_3' x_4}$, $g^{x_1 x_2 x_4}$

$$\boxed{sk=H(g^{x_1 x_2 x_3' x_4})}$$

x_4

$g^{x_2 x_3'}, g^{x_1 x_3'}, g^{x_1 x_2}, g^{x_1 x_2 x_3'}$

Security Theorem (AKE)

- Random-oracle assumption
- Theorem

$$\mathrm{Adv}^{ake}(T,Q,q_s,q_h) \;?\; 2 \cdot n \cdot \mathrm{Succ}^{cma}(T')$$
$$+ 2 \cdot Q \cdot (^{n}{}_{s}) \cdot s \cdot q_h \cdot \mathrm{Succ}^{gcdh}(T')$$
$$T', T'' \;?\; T + (Q+q_s) \cdot n \cdot T_{exp}(k)$$

- Adversary breaks AKE in two ways:

(1) assume that the adversary forges a signature w.r.t some player 's LL-key => it is possible to build a forger

(2) asume that the adversary is able to guess the bit b involved in the Test-query

=> it is possible to come up with an algo that solves an instance of the Group Diffie-Hellman problem

Conclusion and Future Work

- Summary
  - — A security model for the dynamic case
  - — A secure protocol
  - — A proof of security in the random-oracle model
- Limitations
  - — sequential executions only
  - — random-oracle assumption
- “Concurrent Executions for Authenticated Dynamic Group DH Key Exchange using Crypto-Devices”, Work in Progress
  - — concurrent executions
  - — standard model
  - — weak-corruption and strong-corruption models