Berner Fachhochschule - Technik und Informatik

e-Voting Protocols

Overview and Comparison

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Outline

Introduction

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Cryptographic Basics

Symmetric Encryption	$c = E(m, k)$
Symmetric Decryption	$m = D(c, k)$
Message Digest	$h(m)$
Public/Private Keys	X_e, X_d
Asymmetric Encryption	$c = E(m, X_e)$
Asymmetric Decryption	$m = D(c, X_d)$
Signature	$s = S(m, X_d)$
Verification	$V(m, s, X_e) \in \{yes, not\}$

Blind Signatures

- Blind signatures were proposed by Chaum (1983)
- Based on RSA
- Random number r (relative prime to N)
- Blinding factor: r^{X_e}
- Blinded message: $m \times r^{X_e}$
- Blind signature: $s' = S(m \times r^{X_e}, X_d) = (m \times r^{X_e})^{X_d} = m^{X_d} \times r$
- Unblinded signature: $s = s' \times r^{-1} = m^{X_d} = S(m, X_d)$

  $\Rightarrow$ the message is signed without its content being revealed

Anonymous Channels

- Many voting protocol rely on *anonymous channels* to cast vote ballots
  - → Mix-net approach (Chaum, 1981)
  - → DC-net approach (Chaum, 1988)
  - → Onion routing (Goldschlag, Reed, Syverson, 1999)
- The idea is to establish anonymity (vote privacy) using untraceable or hard-to-trace messages
- Voters use digital pseudonyms to conceal their identities
- An anonymous channel consists of a *chain* of proxy servers (mix agents), which establish the unlinkability between voters and pseudonyms
- If all but one of the proxy servers are compromised by the tracer, untraceability can still be achieved

Homomorphic Encryption

- Form of encryption where one can perform a specific algebraic operation on the plaintext by performing a (possibly different) algebraic operation on the ciphertext (Cramer et al. 1997)
  - → using zero-knowledge
- Encrypted votes can be counted without being decrypted
- If the list of encrypted votes are published, every voter can
  - → verify if his/her vote is on the list
  - → recount the votes
- Only applicable if votes are additive (e.g. yes/no votes)
- Implemented by Lehtonen (2001) and the commercial product VoteHere, but otherwise not very popular in practice

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Classification of Protocols

- Most practical voting protocols use a PKI
  - → most of them use blind signatures
  - → most of them use anonymous channels
- Most protocols use 2 administering servers (some use 1 or 3)
  - → Validator: checks the voter's eligibility, issues the ballot
  - → Tallier: collect, counts, and publishes the votes
- Full trust in both the validator and the tallier is usually not necessary (the ideal case)
- Most protocols are not *receipt-free* (vote buying is possible)
- see Røsland (2004) for a good survey

Early History of Voting Protocols

- Salomaa (1991): Two-agency protocol
  - → no blind signature
- Nurmi, Salomaa, Santean (1991): One-agency protocol
  - → no blind signature
  - → uses ANDOS (all-or-nothing disclosure of secrets)
- Fujioka, Okamoto, Ohta (1992)
  - → blind signature
  - → uses anonymous channels
  - → not receipt-free
  - → predecessor of many other protocols
- FOO92 with slight modifications is generally regarded as the best voting protocol

FOO92-Based Protocols I

- Baraani-Dastjerdi, Pieprzyk, Safavi-Naini (1994)
  - → improvement of FOO92
- Okamoto (1996, 1997)
  - → receipt-free versions of FOO92
- Cranor, Cytron (1997): Sensus
  - → variant of FOO92
  - → implemented and tested at the Washington University
- Herschberg (1997), DuRette (1999): EVOX
  - → implementation of FOO92 (master thesis, bachelor thesis)
  - → MIT campus-wide student elections
- Ohkubo, Miura, Abe, Fujioka, Okamoto (1999)

FOO92-Based Protocols II

→ an improvement of FOO92

- Riera, Borrell (1999)
  - → protocol based on mix-nets and blind signature
  - → implemented in SCYTL (used in Neuchâtel)
- Ray, Ray, Narasimhamurthi (2001)
  - → similar to FOO92 and Sensus
  - → 3 administrating agents (ballot distributor, certifying authority, vote compiler)
  - → no anonymous channel
  - → session may be traced back to an IP address but not to a voter
  - → implemented at BFH-TI, see Aeby and Wiget (2007)
- Kim (2002): Votopia
  - → built for WorldCup 2002 Korea/Japan

FOO92-Based Protocols III

- → used to choose MVP and best goalkeeper
- → based on Ohkubo et al. (1999)

- Kofler, Krimmer, Prosser (2003):
  - → 2-phase variant of FOO92
  - → voter registering is separated from vote casting
- Joaquim, Zuquete, Ferreira (2004): REVS
  - → fault tolerant variant of the EVOX implementation
- Baiardi et al. (2005): SEAS
  - → variant of the Sensus protocol
  - → prototype implementation (Java applet, XML)
- Anane, Freeland, Theodoropoulos (2007)
  - → another prototype implementation of FOO92

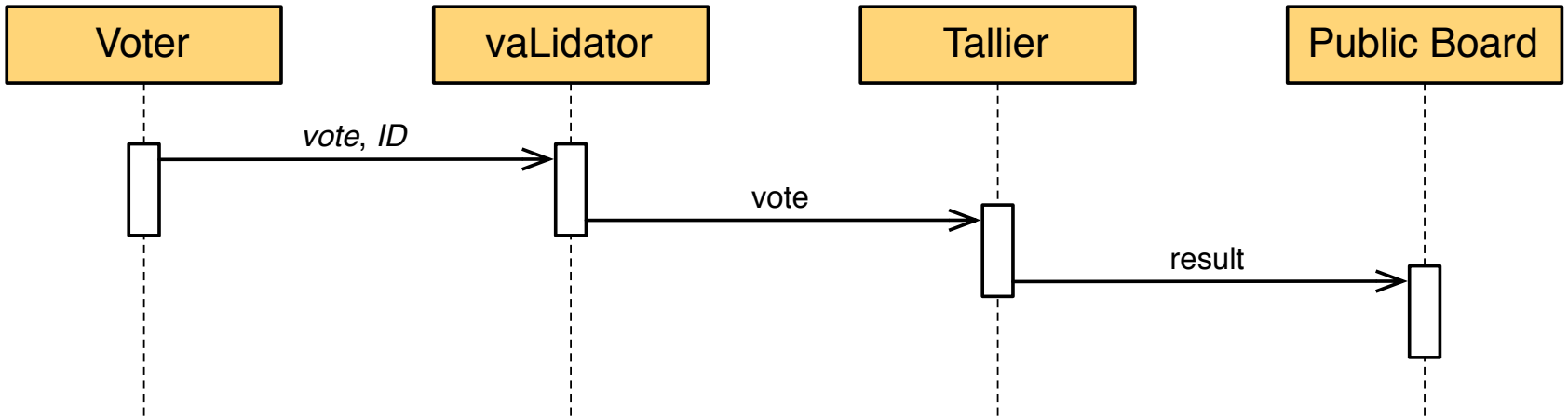
Commercial Systems

Kiayias et al. (2006) survey several voting systems from the commercial world. These proprietary systems do not generally make their implementations publicly or freely available, nor do they appear to offer coercion resistance. The California top-to-bottom review of commercial electronic voting systems suggests that these systems offer completely inadequate security.

$\Rightarrow$ http://www.sos.ca.gov/elections/elections_vsr.htm

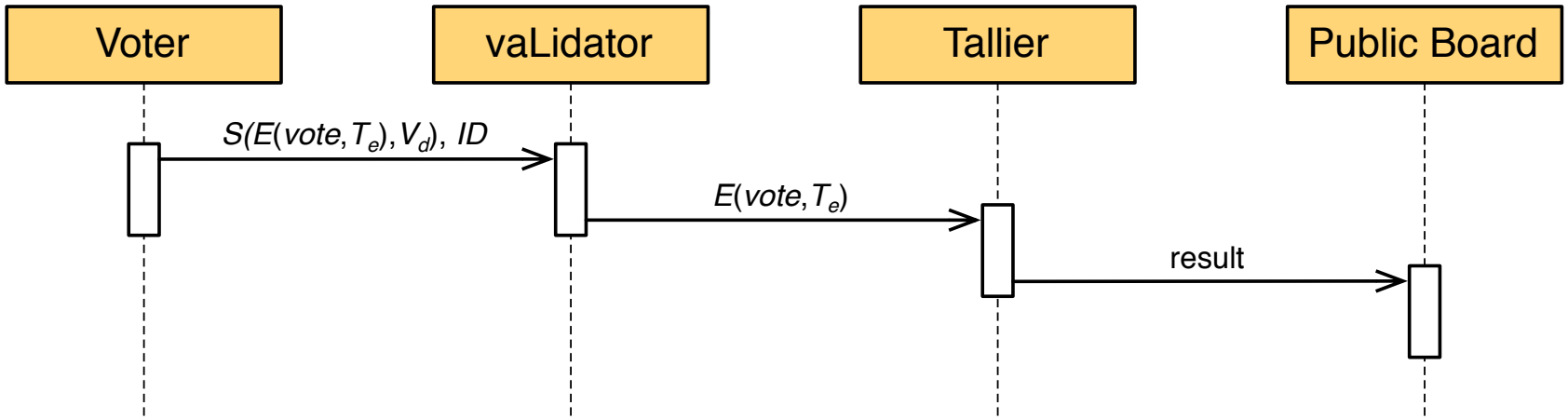
Outline

A Simple (Non-Crypto) Protocol



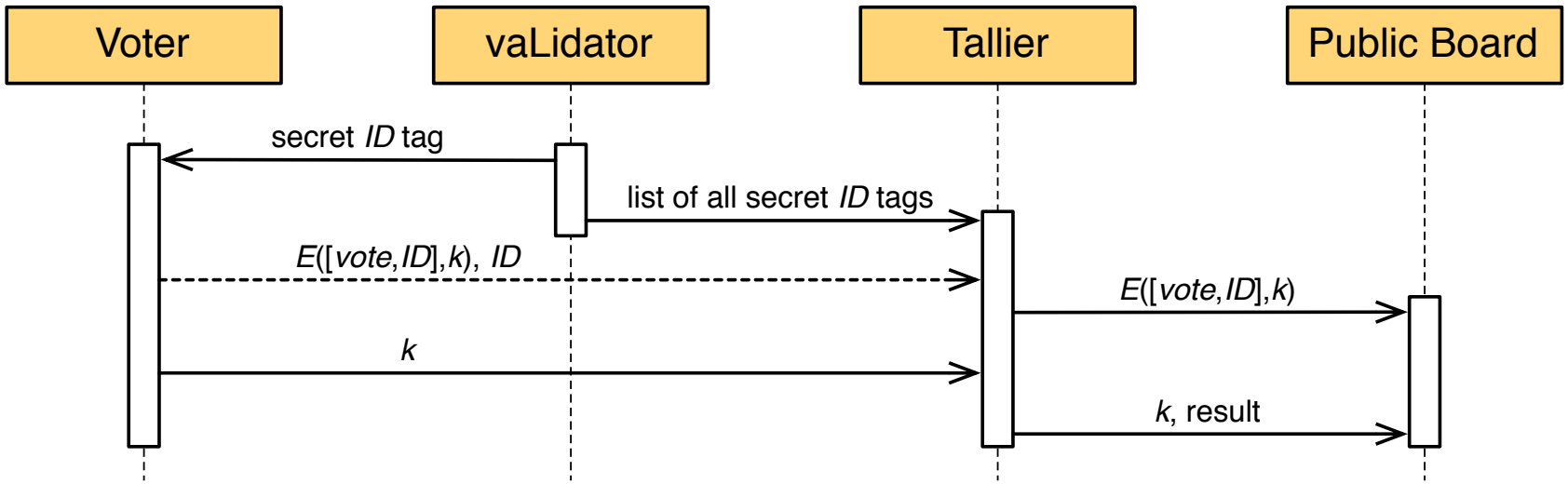
- Good: simple, flexible, mobile
- Bad: inherently insecure

A Simple Cryptographic Protocol



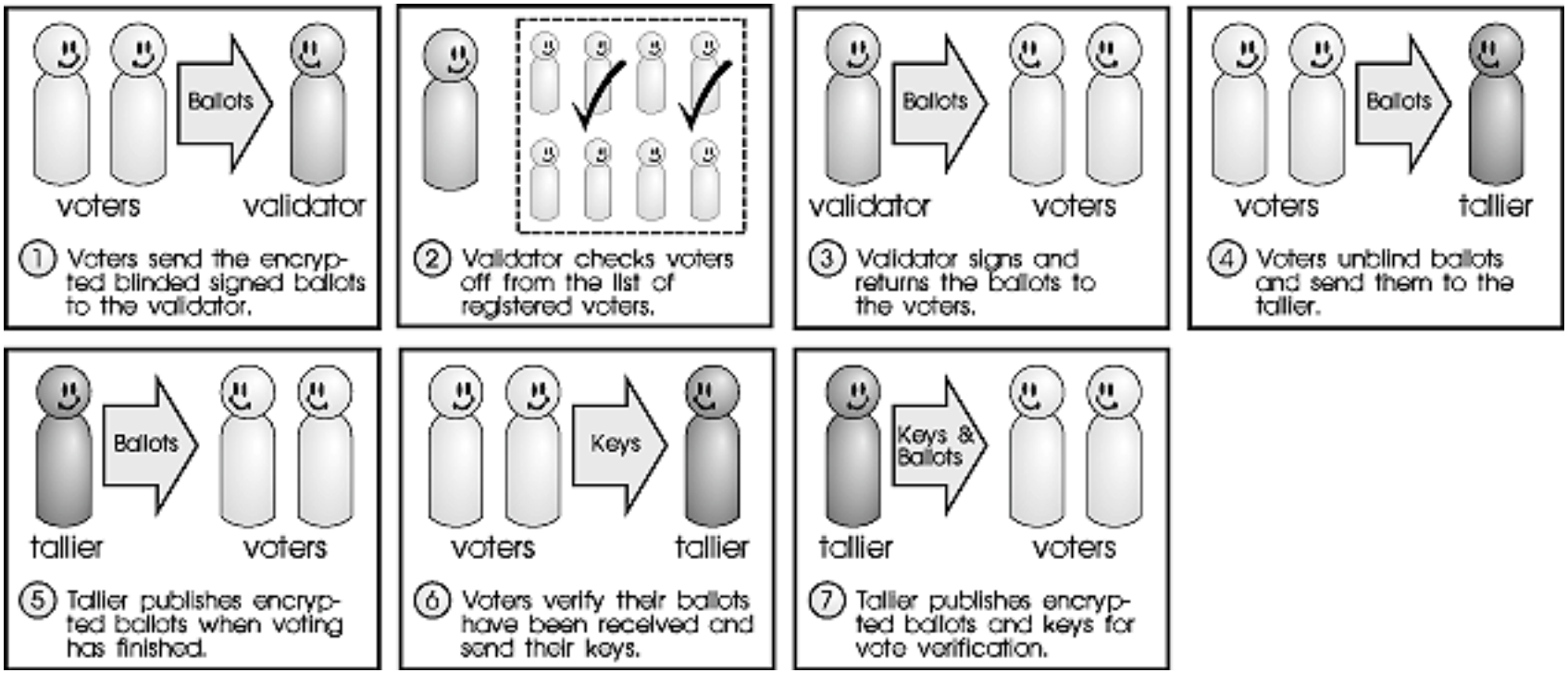
- Requires PKI
- Bad: compromised vote privacy if validator and tallier collude
- The Estonian system is based on such a scheme

Two-Agency Protocol (Salomaa, 91)



- Does not require PKI
- Good: protocol is verifiable by individual voters
- Bad: collusion between validator and tallier is still a problem
- Are the Geneva/Zürich systems based on such a scheme?

FOO92 Protocol



FOO92 Protocol (cont.)

- Requires PKI
- Blind signature guarantees vote privacy
- Individually and universally verifiable
- Problems:
  - → Validator may cast votes for abstaining voters (violates accuracy)
  - → The mechanism that allows voter to verify that their votes were counted also allows them to prove they voted in a particular way (violates receipt-freeness = allows vote buying)

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