A network voting system using a mix-net in a Japanese private organization

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Background: Electronic Voting in Japan

- Law established in 2001, effective 2002
  - voting at polling place
  - for local government election only
  - no network between polling place and tallying center
  - absentees ballot are still paper-based, all write-ins
- Held in nine local elections
  - Objections raised in two elections
    - Unable to vote over an hour for machine problems
      Mismatch in # of voters and # of votes by 6.
    - 2582 blank votes in a 49 votes difference race (60,000votes)

Overview of our work

- Aim: a voting system for private organization
  - That votes are cast over network
  - That uses verifiable mix-net for tallying
- The system was actually used
  - For voting and anonymous surveys
  - With 17,000 eligible voters
  - uses intranet
  - On a regular basis starting Feb 2004. Second vote was held in April 2004, and the third scheduled in June

Technical descriptions

- Universally verifiable mix-net implementation
- History of speed for 10,000 votes, 3 mixers using 3
  PC(1Ghz CPU)
  - before 2000: estimation 100hrs cut &choose
  - 2000 implementation: 8 hrs, cut&choose
  - permutation matrix-based proof scheme[Crypto 01]
  - [FC 02] 20 minutes (ordinary Zp*)
  - Now FC02 algorithm implemented using Elliptic Curve
    6.5 minutes

Proving a shuffle using Permutation Matrix

A description of a shuffle usng matrix
ex) 3inputs

$$\begin{pmatrix} \beta \\ \gamma \\ \alpha \end{pmatrix} := \begin{pmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{pmatrix} \begin{pmatrix} \alpha \\ \beta \\ \gamma \end{pmatrix}$$

$\begin{pmatrix} a & b & c \\ d & e & f \\ g & h & i \end{pmatrix}$ is permutation matrix

$$\Longleftrightarrow$$

for all (x, y, z) the following are satisfied

$$(ax+by+cz)^3+(dx+ey+fz)^3+(gx+hy+iz)^3 = x^3+y^3+z^3$$

$$(ax+by+cz)^2+(dx+ey+fz)^2+(gx+hy+iz)^2 = x^2+y^2+z^2$$

Technical descriptions(II)

- History of permutation matrix-based proof scheme

  (# exponentiations prove+verify, n voters)

  – CRYPTO 01 (9n+12n)

  – FC 02 (9n+10n) merged shuffle+dec proof

  – PKC 04 (8n+6n) with special q
- cf. Groth PKC03 (7n+8n) ZK
- Neff (webpage) (8n+10n) ZK

Why not Zero-knowledge

- Zero knowledge:
  - for any V*, exists a simulator, s.t. no Distinguisher succeeds in distinguish between a real protocol and simulated result for any input x.
  - Our non-ZKIP protocol:

    A distinguisher who can decrypt input encryption can distinguish!

    (ZKIP definition is too strong)

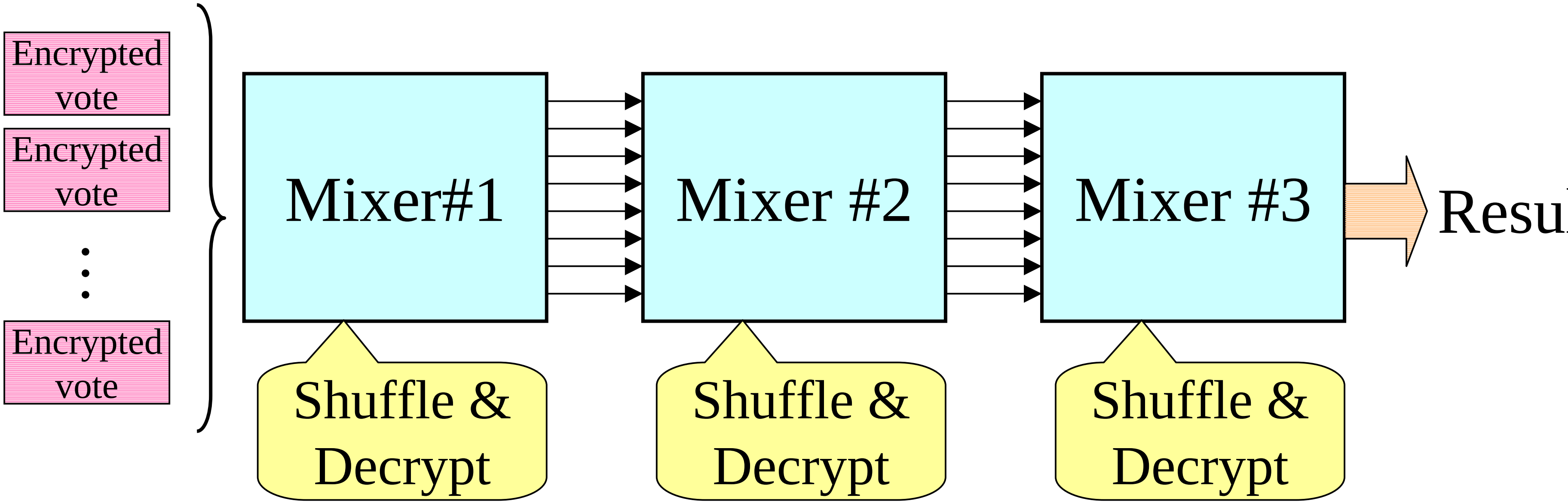
New notion on security

- Whatever adversary can learn about permutation from the protocol is what he could have learned by himself. (permutation hiding)
- All of our scheme satisfies this notion
- Proving and verifying modules are casettable:

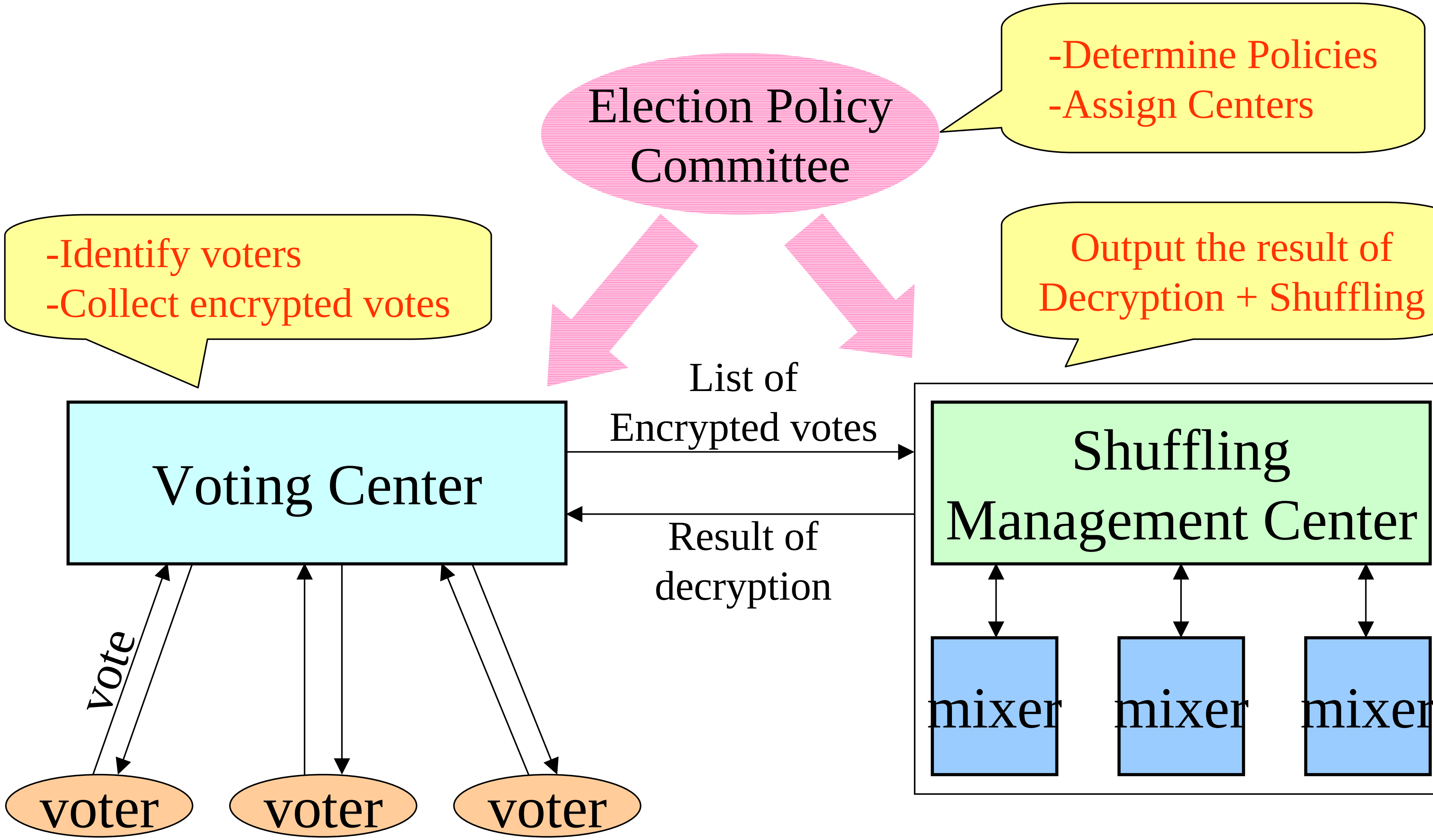
Implementational Aspects

- disclaimer: I did not implement all

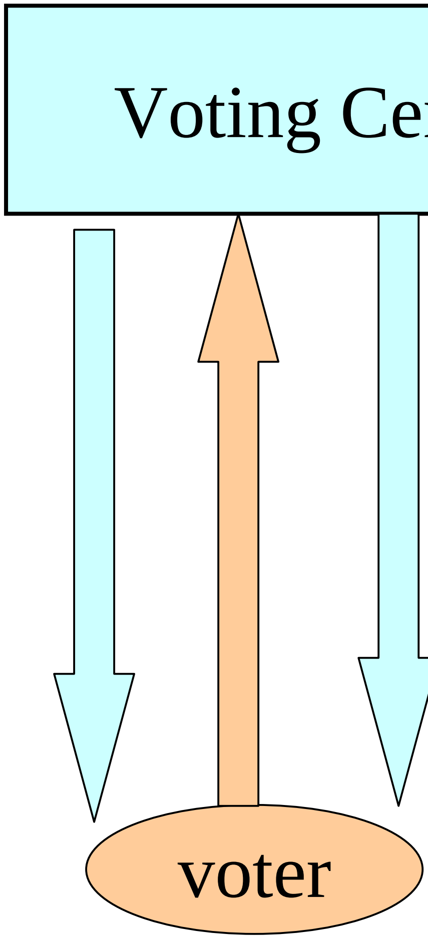
Mix-net as is described as:



System Model



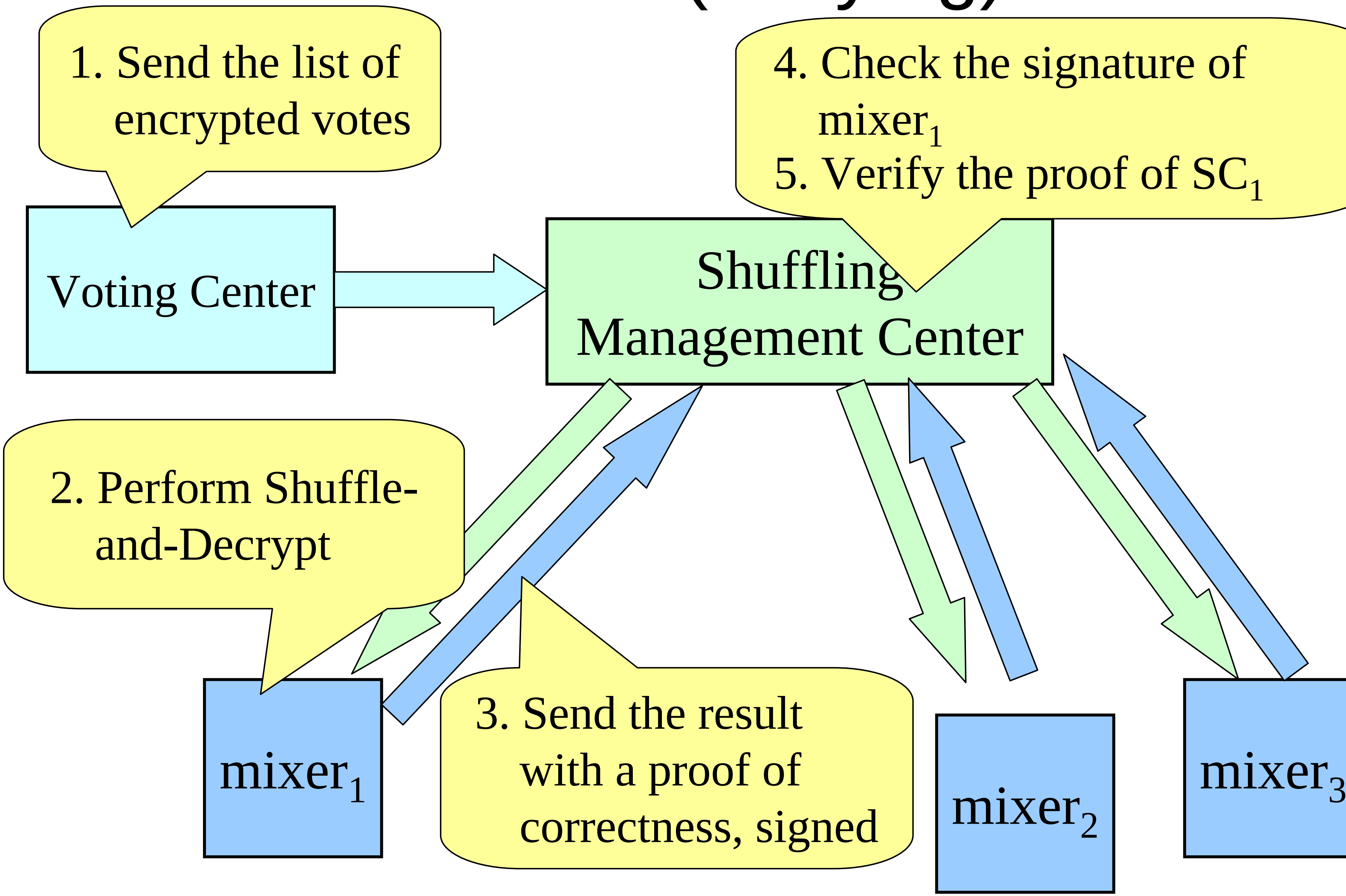
Protocol (Vote Casting)



4. Authenticate voter, verify he hasn’t voted before
5. Aknowledge reception

1. Receive parameters from
2. Encrypt a vote
3. Send it to the Voting Center with a proof of knowledge of the vote *m* (which prevent the vote duplication attack)

Protocol (Tallying)



How we modified it to our customer

- They wanted it used their own member authentication system (based on passwords)
- Voters to vote from their PCs: vote casting software in Java Applets
- Members in 6 different divisions: tallying in each divisions
- A mixer is made active only by an operator with a smart card.
- Faster output of outcome. Correctness proofs and verification in an idle time.
- Proofs are locally stored at election committee.

How they liked it

- Flexible number of mixers.
- Speed(3 mixers)
  - Largest(6500voters)80 sec tally +150sec verify
  - Smallest(700voters)13 sec tally + 19sec verify
- Less claims from its members
- Running cost is 1/10 compared to previous paper voting(mostly manpower cost)
- Invalid ballots were decreased to 1/4.
- Stable show-up rates (80%-85%)

That’s all.
Thank you!