# Scratch, Click & Vote

Mirosław Kutyłowski, Filip Zagórski

Institute of Mathematics and Computer Science
Wroclaw University of Technology, Poland

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# Voter vs Election Authority

- Voter obtains a ballot from Election Authority
- How does voter know if her ballot is correctly encoded? – *randomized partial checking* or zero knowledge proof during pre-election audit
- How can one protect voter's privacy?
  Use ballot box (in SCV votes are cast through Proxy server)
- How one can assure that public data (commitments etc) does not reveal keys used for ballot-generation (covert-channel) – use *verifiable random function* or similar techniques

# Voter vs voting machine (PC) part I

Machine cannot change voter's choice – voter obtains a receipt, which can be used to detect machine's misbehaviour.

But at the same time, ballot and a receipt cannot be used to prove voter's choice

Achieving these two properties is the hardest part in the system design.

# Voter vs PC part II

If a machine has the same knowledge as a voter:

- machine knows exactly how voter voted (privacy threat)
- machine can change voter's choice (in some schemes)
- online vote selling is possible
- virus attacks are possible

Solution: voter obtains additional "information" during registration (untappable channel) so:

- PC learns voter's choice but does not know if vote will be counted (fakekey) [JCJ WPES05]
- PC does not learn voter's choice [Chaum's SureVote, KZ IWSEC07, KZ SCV08]

# Voter vs PC consequences – usability

PC learns voter's choice but does not know if vote will be counted (fakekey) [JCJ WPES05]

- if voter votes ones – machine learns her choice
- in fact voter is obliged to cast many (fake) votes to keep her choice secret
- election with 3 runs with 1 out of 3 candidates each – 27 possibilities – vote 27 times (???)

PC does not learn voter's choice [Chaum's SureVote, KZ IWSEC07, KZ SCV08]

- SureVote – verifiability vs secrecy
- KZ IWSEC07 – voter computes shift of the candidates
- SCV – ThreeBallot-like vote casting

# Scratch, Click & Vote – ideas

SCV is verifiable hybrid voting scheme:

- **registration** ballots and encoders are delivered to voters by: traditional mail or email or physical visit in a registration office,
- **voting** votes are cast over the Internet

voter's computer is not trusted:

- **secrecy** PC does not learn voter's choice
- **integrity** PC cannot change voter's choice even into a random one

receipt obtained by a voter does not prove voter's choice

- **masking** ThreeBallot-like receipt
- **ambiguity** voter may use many encoders

# Scratch, Click & Vote – ideas

**human verifiable:** a receipt obtained by a voter is human-readable and easy to examine by a moderately educated voter,

**voter friendly:** a voter (and her computer) needs not to perform any complicated (and hard to understand by an average voter) operations like: re-encryption, blind signatures etc.

**malware immune:** integrity of the elections and privacy of votes do not rely on any assumption on trustworthiness of the equipment used by the voter,

**efficient:** computational overhead as well as communication volume are low.

# Actors & vocabulary

Actors:

**Election Authority** (EA) authority responsible for ballots preparation

**Proxy** authority responsible for preparation of encoders (simulates a ballot box)

**Registrar** authority responsible for the distribution of ballots and encoders

**Voter's PC** device used by a Voter

Vocabulary:

**ballot** sheet of paper which a voter obtains from the Election Authority

**encoder** sheet of paper which a voter obtains from the Proxy, used to mask voter's choice from PC

# SCV – short scheme description

V1 Start with straightforward Internet-version of the ThreeBallot (in fact "four-ballot"):

- a voter visits *Proxy* webpage
- Strauss'-like attacks on receipts
- $2k+1$ clicks in 1 out of $k$ race & PC knows the choice!

V2 Encoder (prepared by Proxy) is introduced:

- exactly $k$ clicks – every option gets exactly one click – PC does not know voter's choice,
- PC can change voter's choice only with some probability, but Proxy still knows voter's choice

V3 Ballots (prepared by EA) with permuted list of candidates:

- confirmation codes – voter knows that vote is delivered
- Proxy does not learn voter's choice
- EA does not learn who cast a vote (communicates directly with Proxy)

# Encoder

Voter obtains a *ballot* from Election Authority

Voter obtains many *encoders* from “Proxy” (many Proxies may be used)

Voter lays them side by side

| Candidate | *R* | *S* | *T* | *U* |
|---|---|---|---|---|
| 2 Jerry | | | | |
| 3 Edgar | | | | |
| 0 Ervin | | | | |
| 1 Donald | | | | |
| $S_l$ | | | | |

ballot (from EA)

| | | | | |
|---|---|---|---|---|
| | n | Y | n | n |
| | n | Y | n | n |
| | Y | n | n | n |
| | n | n | n | Y |
| | $S_r$ | | | |

encoder (from Proxy)

| *Candidate* | *R* | *S* | *T* | *U* |
|---|---|---|---|---|
| 2 Jerry | n | Y | n | n |
| 3 Edgar | n | Y | n | n |
| 0 Ervin | Y | n | n | n |
| 1 Donald | n | n | n | Y |
| $S_l$ | $S_r$ | | | |

ballot + encoder

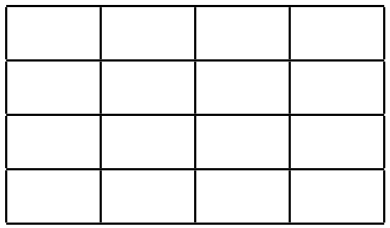
# Vote casting

Voter clicks on the screen on boxes which correspond to `Y` next to her candidate

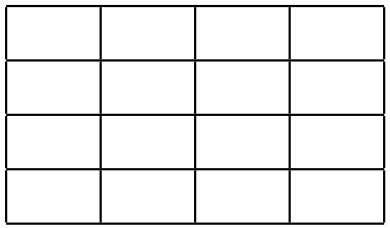
ballot

| *Candidate* | *R* | *S* | *T* | *U* |
|---|---|---|---|---|
| 2 Jerry | n | Y | n | n |
| 3 Edgar | n | Y | n | n |
| 0 Ervin | Y | n | n | n |
| 1 Donald | n | n | n | Y |
| $S_l$ | $S_r$ | | | |

PC screen



transform (by Proxy)



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| *Candidate* | *R* | *S* | *T* | *U* |
|---|---|---|---|---|
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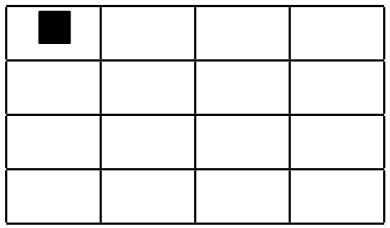
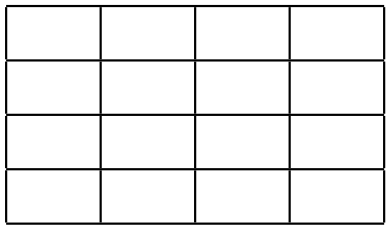
| 3 Edgar | n | Y | n | n |
| 0 Ervin | Y | n | n | n |
| 1 Donald | n | n | n | Y |
| $S_l$ | $S_r$ | | | |

PC screen



transform (by Proxy)



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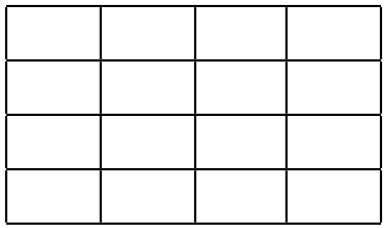
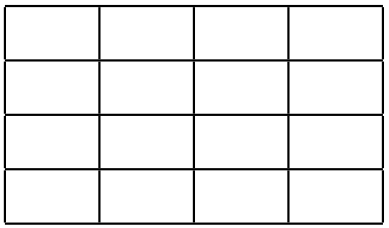
|---|---|---|---|---|
| 2 Jerry | n | Y | n | n |
| 3 Edgar | n | Y | n | n |
| 0 Ervin | Y | n | n | n |
| 1 Donald | n | n | n | Y |
| $S_l$ | $S_r$ | | | |

PC screen



transform (by Proxy)



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Voter clicks on the screen on boxes which correspond to `Y` next to her candidate

ballot

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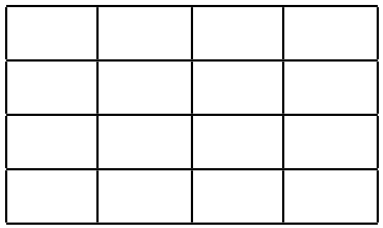
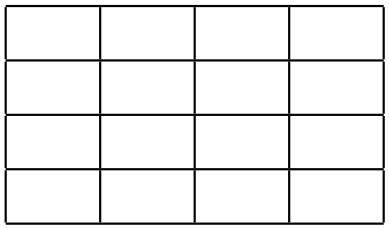
|---|---|---|---|---|
| 2 Jerry | n | Y | n | n |
| 3 Edgar | n | Y | n | n |
| 0 Ervin | Y | n | n | n |
| 1 Donald | n | n | n | Y |
| $S_l$ | $S_r$ | | | |

PC screen



transform (by Proxy)



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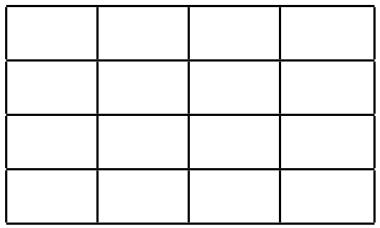
Voter clicks on the screen on boxes which correspond to `Y` next to her candidate

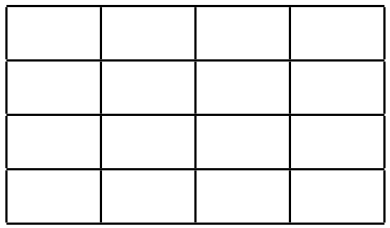
ballot

| *Candidate* | *R* | *S* | *T* | *U* |
|---|---|---|---|---|
| 2 Jerry | n | Y | n | n |
| 3 Edgar | n | Y | n | n |
| 0 Ervin | Y | n | n | n |
| 1 Donald | n | n | n | Y |
| $S_l$ | $S_r$ | | | |

PC screen



transform (by Proxy)



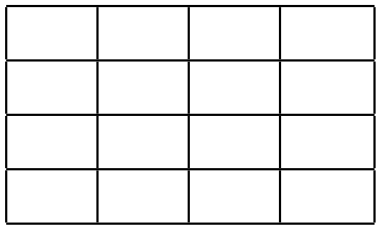
# Vote casting

Voter enters $S_r$ (encoder serial number), proxy "translates" voter's choice into FourBallot form

ballot

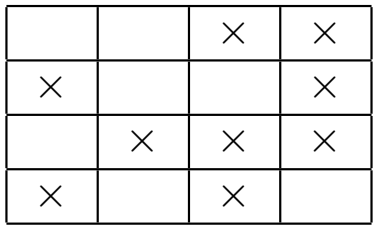
| *Candidate* | *R* | *S* | *T* | *U* |
|---|---|---|---|---|
| 2 Jerry | n | Y | n | n |
| 3 Edgar | n | Y | n | n |
| 0 Ervin | Y | n | n | n |
| 1 Donald | n | n | n | Y |
| $S_l$ | $S_r$ | | | |

PC screen



$S_r$

transform (by Proxy)



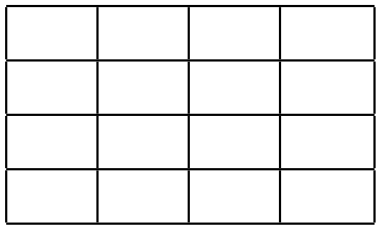
# Vote casting

Voter enters $S_l$ (ballot serial number), Proxy sends FourBallot form to the Election Authority

ballot

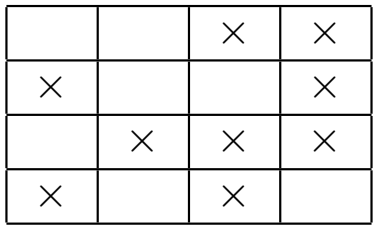
| *Candidate* | *R* | *S* | *T* | *U* |
|---|---|---|---|---|
| 2 Jerry | n | Y | n | n |
| 3 Edgar | n | Y | n | n |
| 0 Ervin | Y | n | n | n |
| 1 Donald | n | n | n | Y |
| $S_l$ | $S_r$ | | | |

PC screen



$S_r$

transform (by Proxy)



$S_l$

# Vote casting

Voter obtains as a receipt one of the FourBallot form ballots (oblivious transfer like protocol used)

ballot

| *Candidate* | *R* | *S* | *T* | *U* |
|---|---|---|---|---|
| 2 Jerry | n | Y | n | n |
| 3 Edgar | n | Y | n | n |
| 0 Ervin | Y | n | n | n |
| 1 Donald | n | n | n | Y |
| $S_l$ | $S_r$ | | | |

transform (by Proxy)

| | | | |
|---|---|---|---|
| | | × | × |
| × | | | × |
| | × | × | × |
| × | | × | |

$S_l$

receipt

| *T* |
|---|
| × |
| |
| × |
| × |

*t*

$t = sign_{EA}(T, S_l)$ - confirmation token (like in Sure Vote)

# Security - PC/virus

Voter's PC can change voter's choice (with some probability):

- PC does not know which row corresponds to the chosen candidate
- modification can be detected by Proxy – $\frac{1}{3k}$, where $k$ is the number of candidates
- modification can be detected by voter – receipt ($\frac{1}{4}$)

# Security - Proxy, Election Authority

Proxy can change voter's choice into a random one, but then a receipt will change - detection with probability $\frac{1}{4}$

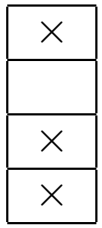
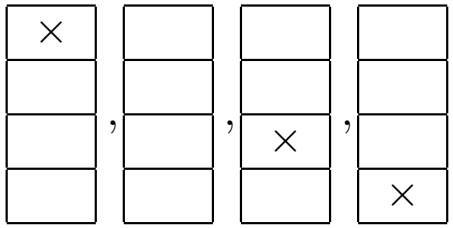
Election Authority – negligible probability: Pre- and Post-election audits

# Security - other attacks

There are known attacks on ThreeBallot (Strauss, Appeal):

FourBallots is much more immune – better probability distribution – Strauss' attack inefficient

moreover, it is easy to implement following modification (only electronic version) – instead of publishing every ballot, every ballot is split into masked ballots:

a ballot column:  , masked ballot columns: 

# SCV - Implementation

Elections 8-10 VI 2009 `e-glosowanie.org`, 6 500 voters

Techniques used: Java, MySQL, PHP, Apache/Idea web servers, Solaris (EA), Red Hat (Proxy), Sun Cryptographic Accelerator (secret sharing, efficiency, admin passwords/master keys outside server's memory)

See how it works (fully internet version – ballots are sent by email): `zagorski.im.pwr.wroc.pl/scv`

# Summary - problems of Internet Voting

Main problem of remote-voting systems is *physical coercion* (e. g. by the voter's spouse) but it is accepetable – mail-in voting.
(Solution: well designed voter's registration)

Why we do we really affraid of internet voting?:

- possibility of massive undetectable fraud (malware on voter's PC)
- possibility of massive online vote-selling (sell-your-vote software)

SCV is immune against both!

Thank you for your attention