# Distributed Protocols at the Rescue for Trustworthy Online Voting

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# Outline

1 Voting in the Digital Age

2 Distributed Online Voting

3 Review and Taxonomy

4 Outlook

# Impact of Technology on Voting I

Figure: Digital Natives. (Flickr/antmcneill CC by-sa)

Figure: Paper-based Voting. (Flickr/coventrycc CC by-nc-nd)

# Impact of Technology on Voting II

## Impact on Expectations

- comfort on a par with other online services
- flexibility
- automation for cost efficiency

## Impact on Security

- hidden body cameras
- invisible ink
- fingerprint databases
- DNA analysis

# Generic Paper-based Voting

1. **Preparation Phase**
   central voter registry issues list of eligible voters,
   prints undistinguishable voting ballots
2. **Casting Phase**
   on-site, public supervision, voting station(s) run by citizens
3. **Aggregation Phase**
   tallying of casted ballots
4. **Evaluation Phase**
   computation of the voting outcome from public tally
5. **Verification Phase**
   observation during the vote (eye-sight), recounts

# Challenge: Conflicting Protocol Properties

Ensure set of security properties at the same time:

- unconditional secrecy of the ballot
- universal verifiability of the tally
- eligibility of the voter

Achievable only with unrealistic assumptions[1]:

**compromise required**

[1] B. Chevallier-Mames et al. "On Some Incompatible Properties of Voting Schemes". In: Towards Trustworthy Elections: New Directions in Electronic Voting. Springer, 2010.

# Online Voting

## Online Voting

remote electronic voting

- no chain of custody verifiable per eye-sight
- electronic signals are easy to duplicate

Need for new concepts to ensure security properties.

# Classical Online Voting Security Concepts

- **Trusted Authorities**
  essentially give up secrecy and correctness
- **Anonymous Voting**
  assume unlinkability of distinct communication channels
- **Random Pertubation**
  assume shuffle of encrypted votes before their decryption
- **Homomorphic Encryption**
  assume aggregation of encrypted votes before decryption

Identified Issues

- concentration of power (assumed trust)
- concentration of data

# Distributed Protocols

Without consensus on trusted authorities, it is reasonable to omit authorities altogether.

**Compare development to:**

- **Bitcoin**
  gold, fiat money, online banks, Bitcoin
- **BitTorrent**
  circulating disks, FTP (web server), Bittorrent

# Empowerment of Voters

## Assumption of a Distributed Online Voting Protocol

- no authority
- equally privileged, equipotent voters

Promises

- reflects democratic principle of equally powerful voters
- all voters are potential voting officers
- all voters responsible to enfore policy of protocol
- with no weakest link, promise of improved resiliance against DDoS attacks
- balance of knowledge among voters

# Notions of Distribution in Online Voting

1. **Degree of Specialisation**
   from equipotent voters to specialised authorities
2. **Topology** of communication/responsabilities
   from centralised over decentralised to distributed
3. **Phase**
   consider phases that are actually distributed

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## *Fully distributed* Protocol

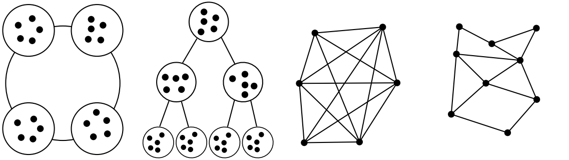
- equipotent voters, no authorities,
- distributed topology
- in all phases (but the registration)

# From Centralised to Distributed Online Voting

What if all voters become authorities?

- reuse existing protocols with:
  distributed key generation and threshold decryption
- fits the purpose of small board room votings
- does not scale

# Review of Distributed Online Voting



(a) DPol (b) SPP (c) SMC (d) Blockchain

- **Secure Multi-party Computation (SMC)**
  communication in $\mathcal{O}\left(n^2\right)$, for board room votings
- **Distributed Polling (DPol)**
  secret sharing scheme applied to groups aligned in a circle
- **Secure and Private Polling (SPP)**
  SMC and threshold decryption applied to groups in a tree
- **Blockchain-based Voting**
  Bitcoin to aggregate votes (coloured coins)

# Taxonomy of Distributed Online Voting

| Protocol | Degree of Special. | Topology | Distrib. Phases |
|---|---|---|---|
| Paper-based | none (flexible) | distributed | all |
| Helios,[2] | selected authorities | centralised | verification |
| SPP,[3] | random authorities | structured, tree | aggregation |
| DPol,[4] | none | structured, ring | all |
| Blockchain-based | none (flexible) | distributed | all |

[2] B. Adida. “Helios: Web-based Open-Audit Voting.” In: USENIX Security Symposium 17 (2008), pp. 335–348.

[3] S. Gambs et al. “Scalable and Secure Aggregation in Distributed Networks”. In: (2011). DOI: `10.1109/SRDS.2012.63`.

[4] R. Guerraoui et al. “Decentralized polling with respectable participants”. In: Journal of Parallel and Distributed Computing 72.1 (Jan. 2012), pp. 13–26. DOI: `10.1016/j.jpdc.2011.09.003`.

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**Remarks:**

- Blockchain-based protocols are most promising for their similarity with paper-based voting
- To our knowledge: no publication yet on Blockchain-based protocols

# Ongoing Work

**Novel fully distributed Online Voting Protocols**

- different compromise between secrecy and verifiability
- probabilistic definitions: confidentiality and individual verifiability
- probabilistic results: almost correct with high probability
- assume that voters are always connected (cf. IoT)
- assume trust in technology (instead of in authorities)

A proposition for such a protocol has been submitted.

# Open Questions

- defense against adversaries
  (Byzantine fault-tolerance, 51% attack)
- proofs of properties are not streight-forward
- interesting legal issues due to probabilistic approach