Improvements to DKG for use in a real-world setting

An EPFL IN Semester Project

23.01.2018

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Outline

Motivation

Swiss Federal Council
And their law passing method

The Swiss Federal Council

7 councillors (& 1 chancellor)

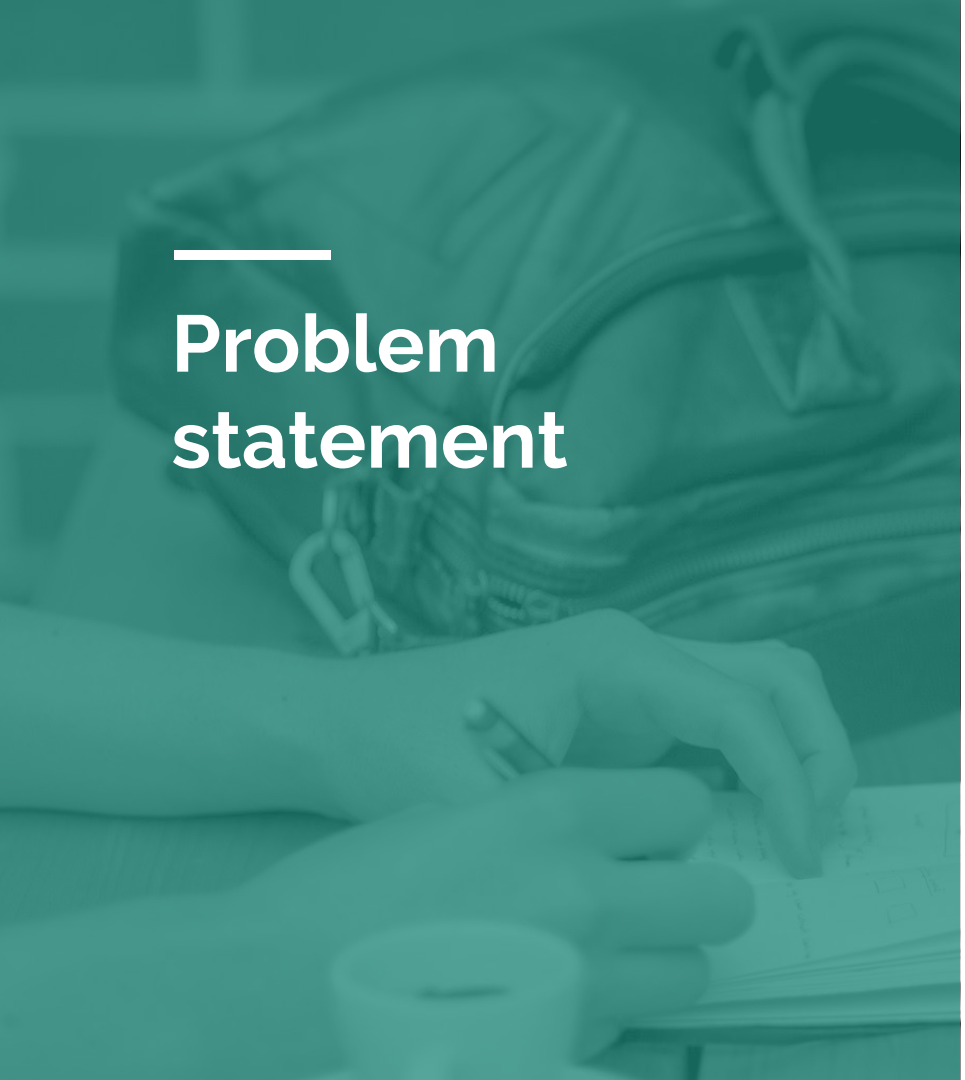
The council wants to pass a law

- Some key is needed to pass the law
- Decentralized, no trusted 3d party
- 7 councillors participate
- At least 5 need to agree to pass

Distributed Key Generation, of course!

But this is 2018...

- Distributed Key Generation was invented in the 90's
- The council wants to do this over the internet
- DEDIS to the rescue
- Connection problems, congestion, etc...



Problem statement

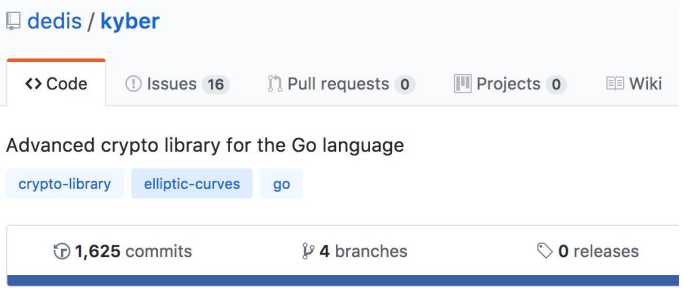
The limitations of the current implementation of DKG are such that it is not performant in the real-world setting, due to a strict timing assumption.

This project overcomes these limitations by reducing the timing assumption, and use round termination procedures to provide certain guarantees.

Setting: Kyber, VSS & DKG

Kyber

- Advanced crypto library for Go
- Provides cryptographic primitives
- For applications that need more than signing and encryption
- Used by Cothority



The kyber repository on GitHub.

VSS (in Kyber)

1. Dealer chooses a random polynomial $f(z)$ of degree t:

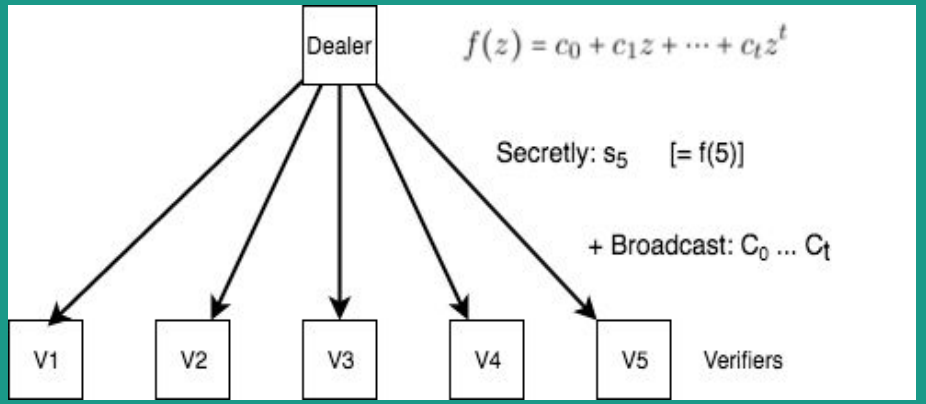
$$f(z) = c_0 + c_1 z + \cdots + c_t z^t$$

The dealer broadcasts $C_k = g^{c_k} \mod p$ for $k = 0, \ldots, t$.
The dealer also computes the shares $s_j = f(j) \mod q$ for $j = 1, \ldots, n$ and sends s_j them secretly to each verifier A_j.

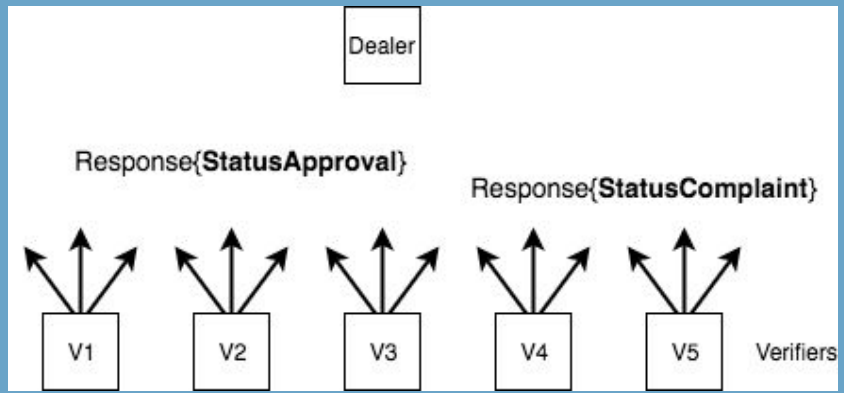
2. Each A_j verifies the shares he received from the dealer by checking:

$$g^{s_j} = \prod_{k=0}^{t} (C_k)^{j^k} \mod p \qquad (1)$$

The verifier broadcasts a *response*, containing either *StatusApproval* if the check succeeds or *StatusComplaint* to incriminate the dealer.



Part 1 of a VSS secret share

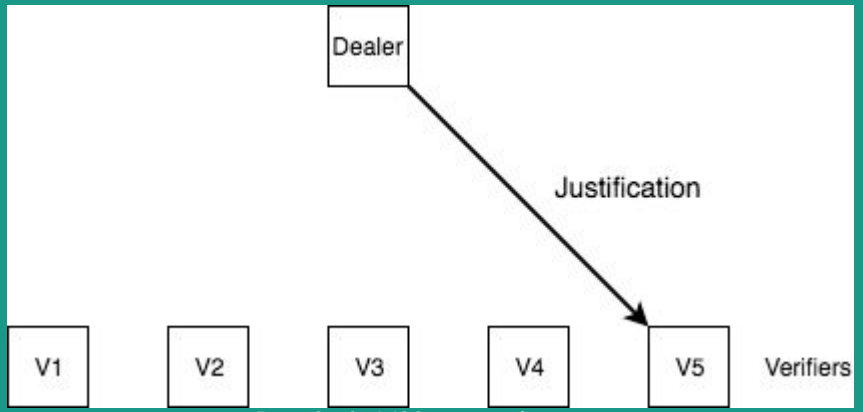


Part 2 of a VSS secret share

VSS (cont'd)

3. The dealer reveals the share s_j matching (1) for each complaining verifier A_j, by means of a *justification*. If any of the revealed shares fails this equation, dealer is disqualified.

4. If any participant has at least t correct shares from the verifiers, they can find the key s_0 by polynomial interpolation.



Part 3 of a VSS secret share

DKG (in Kyber)

Can be understood as: *n* parallel instances of VSS.

In each instance one participant is the VSS dealer, others are verifiers

2 Implementations in Kyber:

1. Pedersen (Joint Feldman VSS)
2. Rabin (Use of 2 polynomials)

The synchronicity issue

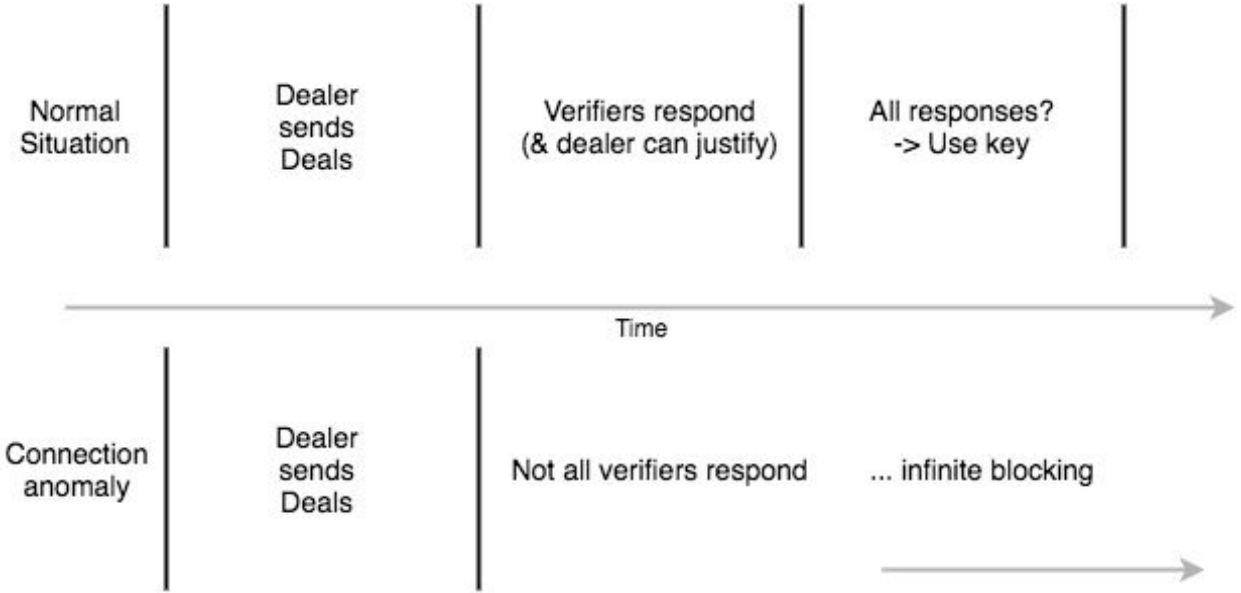


Diagram showing possible complications in one round of VSS

Solution

Solution

- Enable protocol to continue with absent participants
- Use round termination signal
- Adapt VSS, DKG, and their tests in function of this.

Solution implementation

- "SetTimeout" methods added to both VSS and DKG
- Trigger for termination procedure
  - Mark unresponsive participants
  - Check all responses
  - Decide on validity of key
- Guarantee the correctness with tests
  - New edge cases were found

Discussion

Discussion

- Changes allow use in more general setting
- Protocol continue to function correctly
- Performance is not greatly different

Future work:

- Long term keys are no good
- Share renewal

Conclusion

- Project target: Improve Kyber DKG for real-world use
- Problem focus found on timing assumption
- Changes to allow round termination implemented
- Protocol remains correct
- Target accomplished ✓

Questions?

References

[Sha79] Adi Shamir. "How to share a secret". In: *Communications of the ACM* 22.11 (1979), pp. 612–613. DOI: https://dl.acm.org/citation.cfm?doid=359168.359176.

[Her95] Amir Herzberg. "Proactive Secret Sharing". In: *Crypto '95* LNCS.963 (1995), pp. 339–352.

[Rab07] Tal Rabin. "Secure Distributed Key Generation for Discrete-Log Based Cryptosystems". In: *Journal of Cryptology* 20 (Oct. 2007), pp. 51–83.