Round2:

PQ KEM and PKE

Round2 Team

Philips Security Technologies
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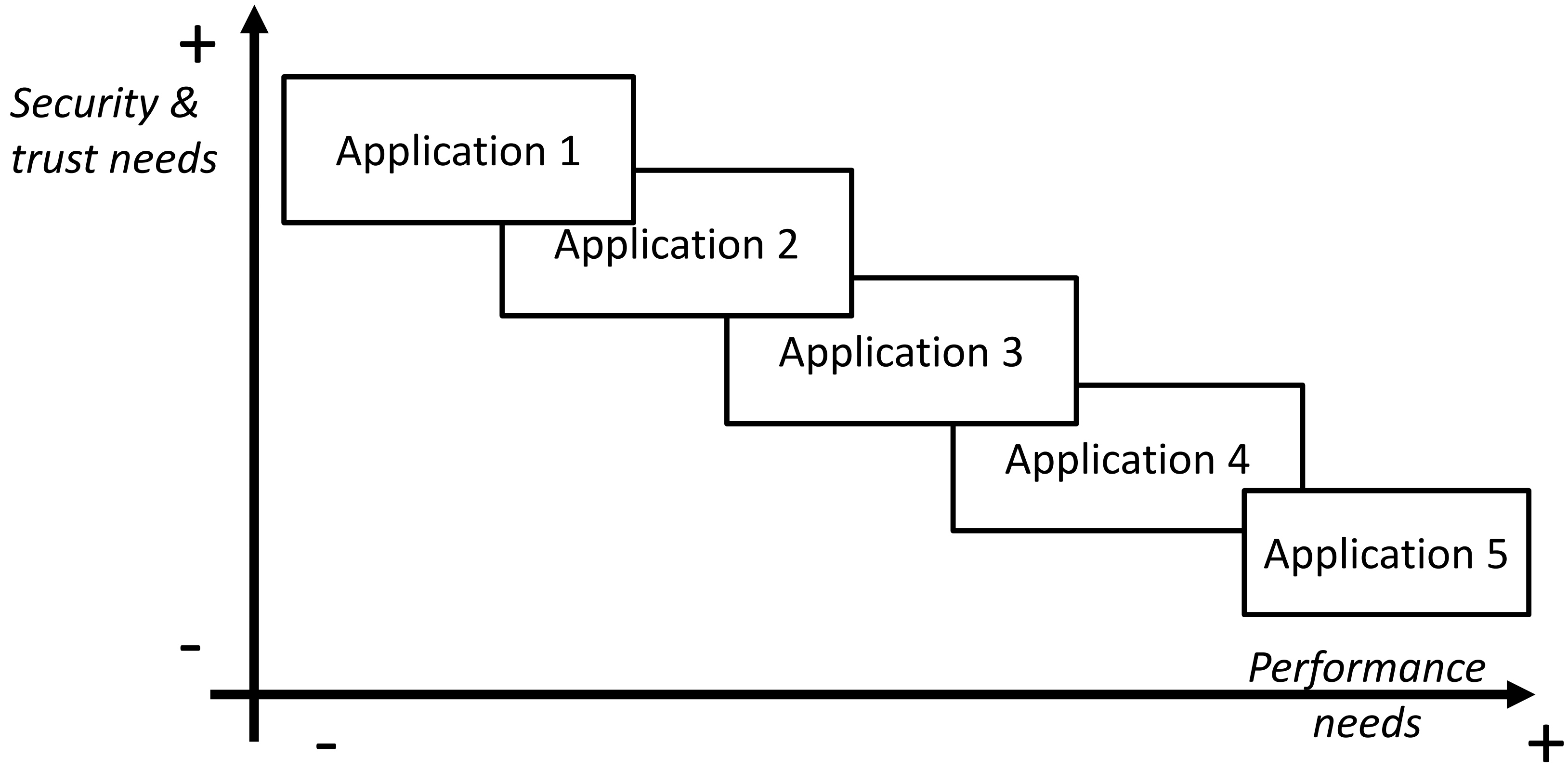
Motivation:

Different applications, different needs



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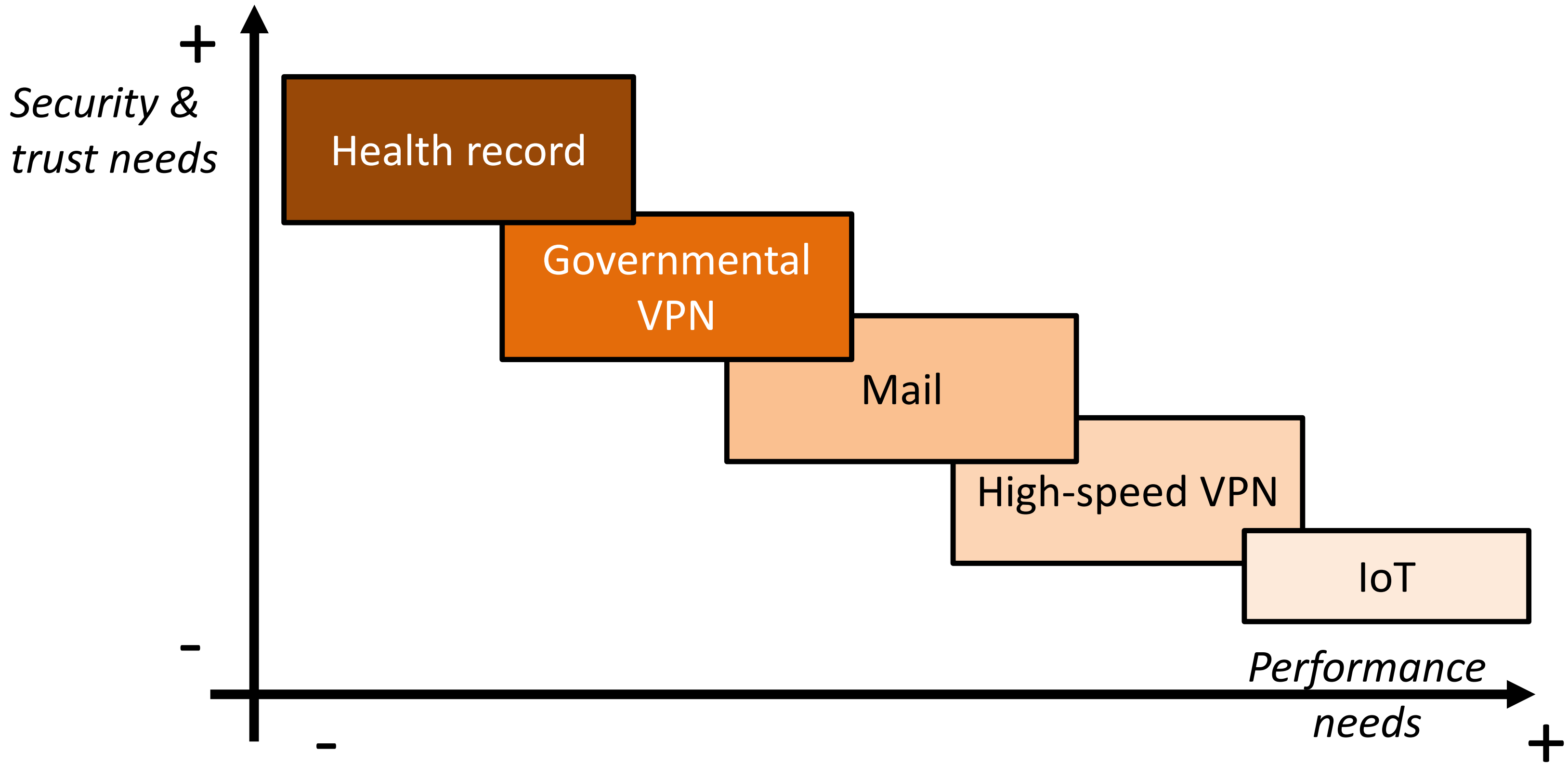
Different applications, different needs



Note: the applications in this figure are only examples to illustrate that different applications have different security & performance needs.

Main features

- One **unified design** to fit all use cases,
  - Ring and non-ring support.
  - Round2.KEM and Round.PKE with same building blocks.
- Fine-grained scaling of parameters to any required security level.
- Great bandwidth.
- Great computation speed.
- LWR, well-studied lattice problem.

Main features

LWR-based

- Builds on LWR problem:

  Search LWR: public integers *p,q,* public matrix $A \in Z_q^{d \times d}$, secret $s \in Z_q^d$, public vector $b = \left\lfloor \frac{p}{q} As \right\rceil$ (mod *p*). Find *s*.

- Compared with LWE:
  - Improved bandwidth ($p < q$).
  - Improved computation.
  - No noise sampling needed.

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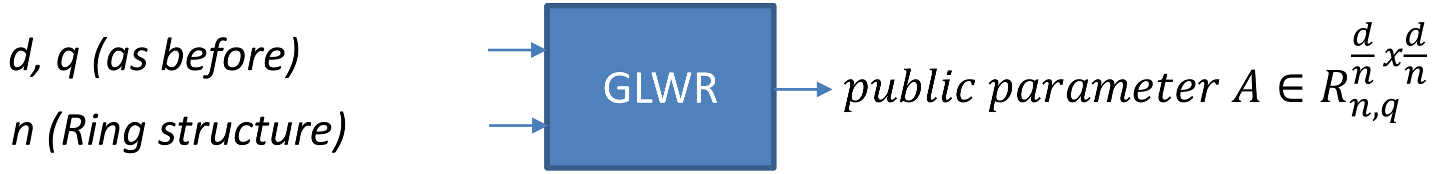
Main features

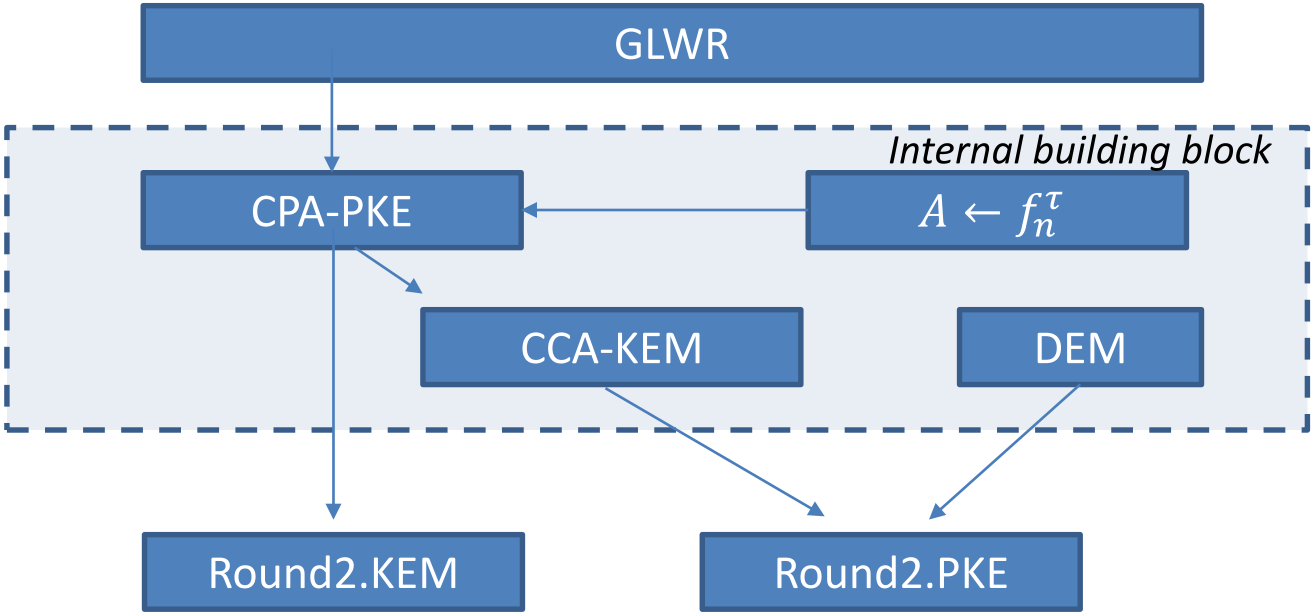
General LWR (GLWR) unifies LWR and RLWR



- Allows for unified design and implementation:
  – Ring $R_{n,q}$, for $n = 1$, $R_{n,q} \equiv \mathbb{Z}_q$.
- Fits applications with different trust needs (presence/absence of ring structure).

Main features

Common building blocks for *INDCPA* and *INDCCA* security



Round2.KEM and Round.PKE support applications with different performance/security needs:

- Using common building blocks.
- Secure email can rely on Round2.PKE (INDCCA).
- IPSec VPN can use faster (~2x) Round2.KEM (INDCPA).

Main features

Common building blocks for *INDCPA* and *INDCCA* security

- Received official comment on INDCPA proof.
- Easily solvable as indicated by SABER team in their official comment.
- No change to parameters.

Main features

Prime cyclotomic ring

$$R_n = \frac{x^{n+1} - 1}{x - 1}$$

- Security
  - Provable: Known reductions from RLWE and (Ideal) lattice problems.
  - Practical: Parameters chosen to avoid subrings (and thus, potential attacks).
- Scalable (bandwidth and security level) due to many choices for n.

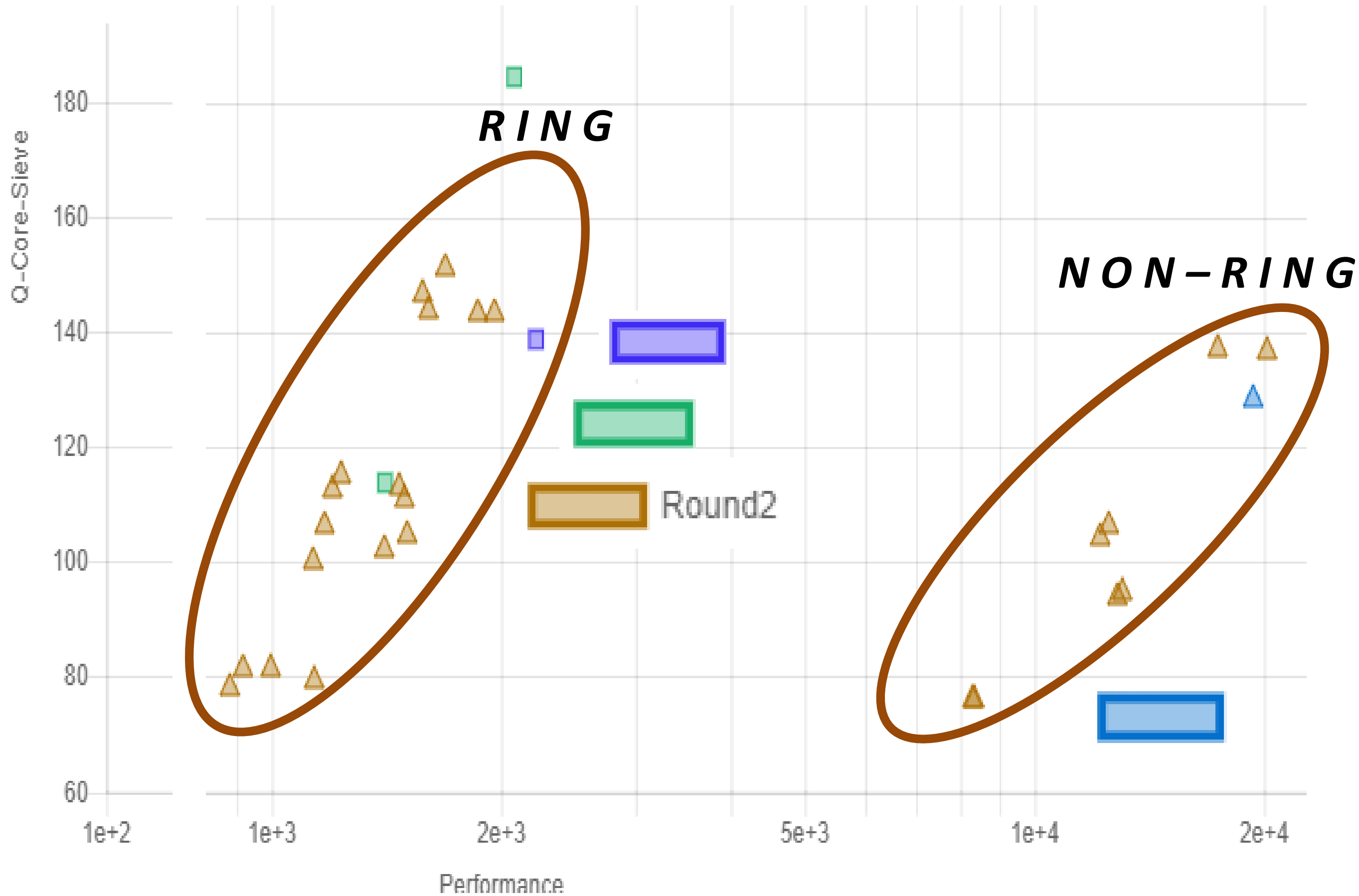
$\boldsymbol{n}$	**418**	**676**
Public-key (Bytes)	435	709
Ciphertext (Bytes)	482	868
Failure probability $(\log 2)$	-81	-65
Best (quantum) attack (bits)	75	139
Best (classical) attack (bits)	79	144

https://bitwiseshiftleft.github.io/estimate-all-the-lwe-ntru-schemes.github.io/graphs

Main features

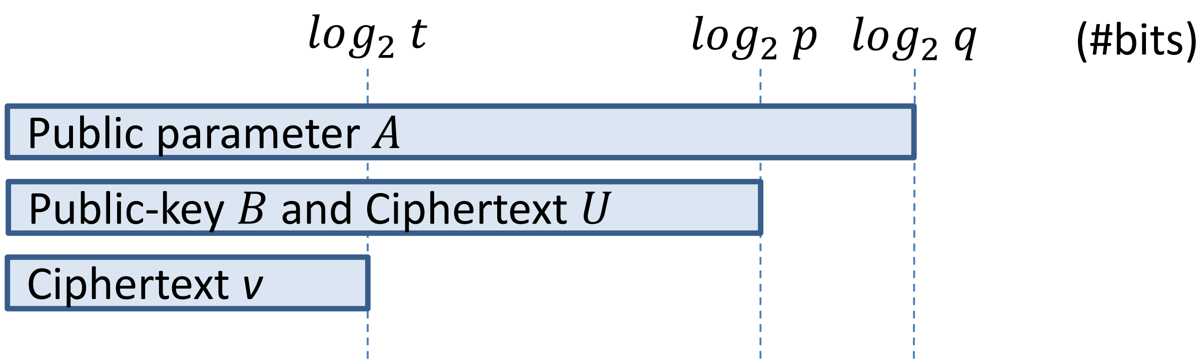
GLWR and ring choice lead to great bandwidth performance

- For similar security level (bits), Round2 offers better performance.
- Round2 is scalable: parameters easily configured to offer ***any required*** security target.



Main features

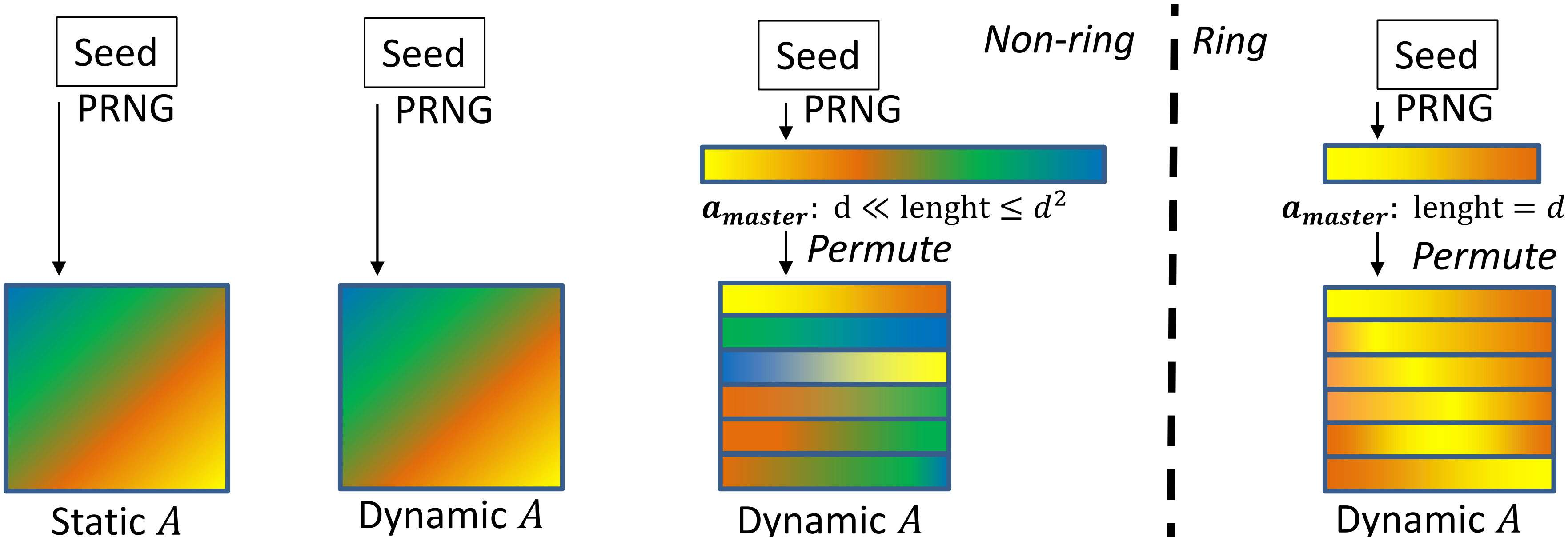
Power of two moduli q, p, t



- p, t: Optimized bandwidth (transmit only $log_2\, p, log_2\, t$ bits).
- t: Allows to finely tune failure probability (depends on t).
- q: Optimized CPU performance in both ring and non-ring settings.

Main features

Generation of public parameter: $A \leftarrow f_n^{\tau}$



CPU (1x)
No unified
Pre-computation attack

CPU (11.7x)
No unified
~~Pre-computation attack~~

CPU (1.4x)
Unified
~~Pre-computation attack~~

CPU (< 1)
Unified
~~Pre-computation attack~~

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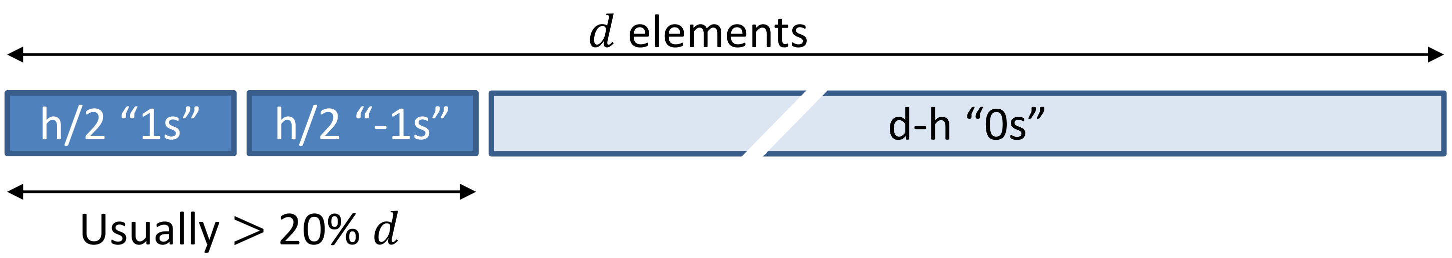
Main features

Sparse trinary secrets with fixed hamming weight



- Definition depends on d, and not on n, to enable unified implementation
  - Matrix-based multiplication involves always d dimensional vectors, independently of ring or non-ring settings.

- Great performance.

- Low failure probability.

Main features

Parameter sets

- uRound2: unified implementation for ring and non-ring
  - Main submission.
  - One implementation, any set of parameters.
    - q power of two.
    - Ring or non-ring.
    - Any security level.
    - Always, great performance.

- nRound2:
  - Specialized parameter set to support NTT.
  - Chooses prime q.

Conclusions & Remarks

- Different applications have different security/performance needs.
- Round2 is an efficient & scalable scheme that fits needs of different applications.

- Lattice-based proposals should be compared based on same methodology to give security estimates.
- Explicit failure probability target required for comparing different proposals.
- Minimal KEM proposal by Mike Hamburg makes lots of sense.

Questions?

Thank you