GLUE: Generalizing Unbounded Attribute-Based Encryption for Flexible Efficiency Trade-Offs

Marloes Venema[1,2] Greg Alpár[3,2]

[1]University of Wuppertal, Wuppertal, Germany

[2]Radboud University, Nijmegen, the Netherlands

[3]Open Universiteit, Heerlen, the Netherlands

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Motivation

- Attribute-based encryption (ABE) is a versatile primitive that has been considered extensively to securely manage access to data
- Various properties can be supported, e.g., unlimited use of attributes, negations (NOTs)

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- Schemes typically provide a fixed efficiency trade-off
- In particular, schemes with many (desirable) properties typically have an inefficient decryption
- **Our goal:** creating a scheme that can support many such properties with a flexible efficiency trade-off
- Can be fine-tuned e.g., to have a very efficient decryption

High-level overview

1. Introduction to ABE
2. GLUE
3. Conclusion

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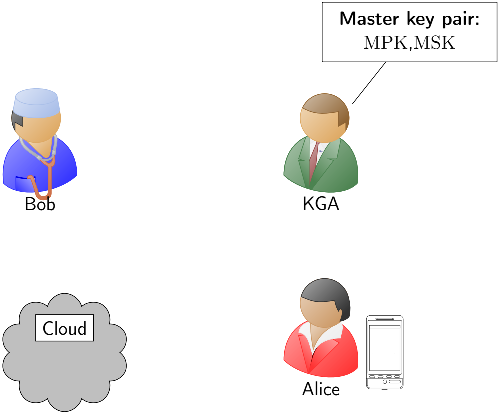
Ciphertext-policy attribute-based encryption (CP-ABE)

Setup:



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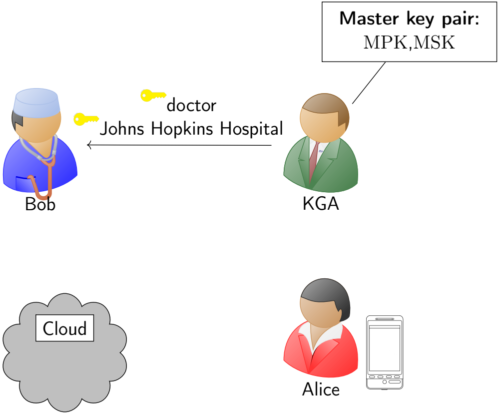
Key generation:



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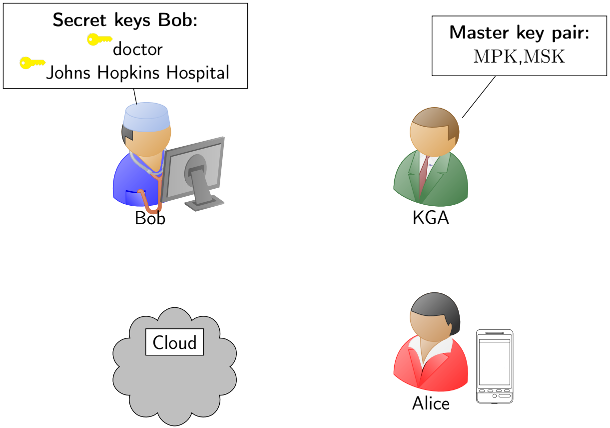

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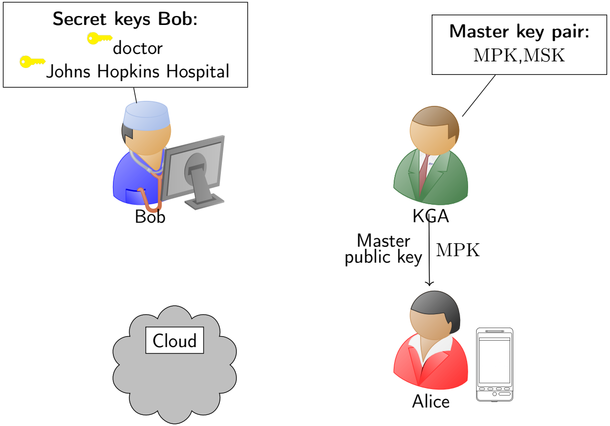
Encryption:



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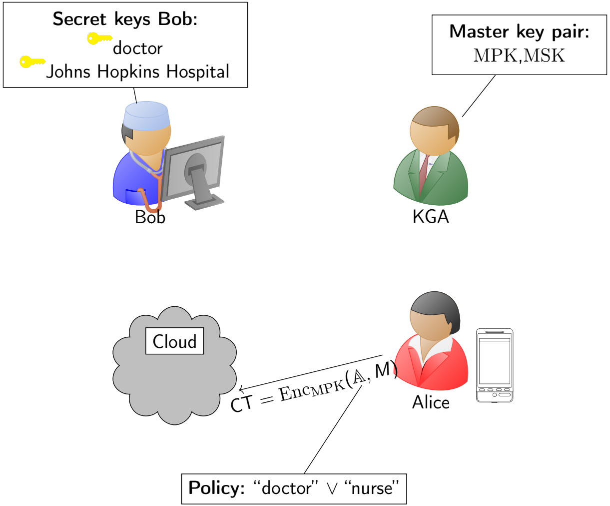

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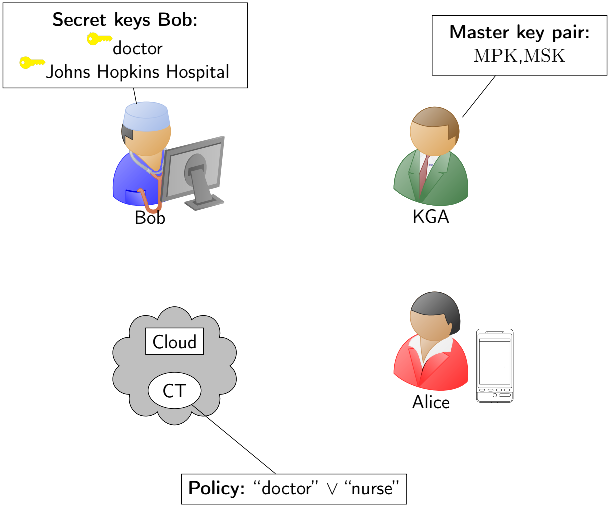

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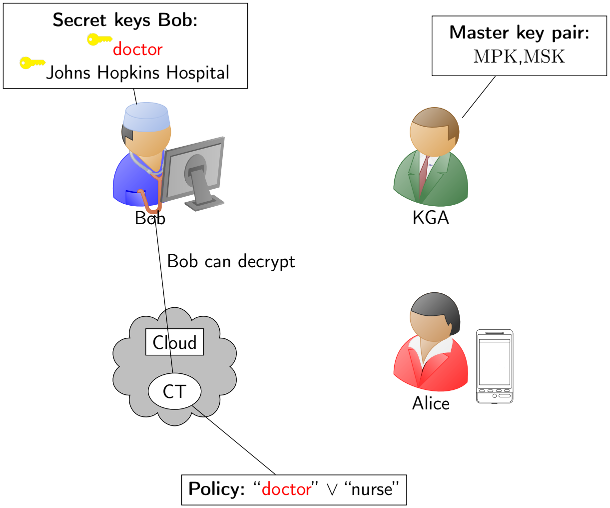
Decryption:



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- The European Telecommunications Standards Institute (ETSI) considers several use cases for ABE, e.g., Cloud, IoT
- More recently, Cloudflare has presented an updated version of their Geo Key Manager: Portunus

Requirements for ABE

These use cases share many common requirements for ABE:

- **Expressive policies:** policies should support Boolean formulas consisting of AND and OR operators
- **Large universes:** attribute could be any arbitrary string, e.g., names, roles, MAC addresses
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Storage and computational efficiency requirements may vary per use case.

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- To understand why non-monotone schemes are less efficient than monotone schemes, we observe them
- At the core, all these schemes have the same underlying structure using polynomials
- Polynomials are used to support large universes

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  - W11b [Wat08]: n-degree polynomial $\rightarrow$ two pairings per n attributes
- All unbounded schemes have a 1-degree polynomial and thus require two pairings per attribute during decryption
- High-level idea: generalize the hash!

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- Note that RW13 is a monotone scheme

Partitioning to minimize pairings

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The higher n_k and n_c, the more efficient decryption is.

Security of GLUE and its extensions

- Security proof combines and generalizes proof techniques of [Wat08, RW13, AC16] using a new trick
- By proving security in the symbolic pair encodings framework [AC17], we achieve properties like non-monotonicity for free [AT20, Amb21]

Performance estimates

Rough estimates[1] of the storage costs of the secret keys and the ciphertexts in kilobytes (KB), where 1 KB = 1024 bytes, and the computational costs incurred by the key generation, encryption and decryption algorithms of $\mathsf{GLUE}_{(n_k,n_c)}$ and RW13, expressed in milliseconds (ms), for 10 and 100 attributes.

	Storage costs					Computational costs					
		SK		CT		KeyGen		Encrypt		Decrypt	
Scheme	$\lvert\mathrm{MPK}\rvert$	10	100	10	100	10	100	10	100	10	100
RW13	1.42	4.86	44.58	4.05	33.58	26.0	238.7	32.9	305.9	46.2	375.2
$\mathsf{GLUE}_{(3,3)}$	2.08	3.53	30.02	3.39	26.36	18.9	160.7	59.8	571.4	24.3	133.9
$\mathsf{GLUE}_{(5,5)}$	2.74	3.09	26.93	3.17	24.83	16.5	144.2	82.3	800.4	17.0	82.8
$\mathsf{GLUE}_{(10,5)}$	3.28	2.87	24.72	3.17	24.83	15.4	132.3	102.1	998.4	15.1	64.5

[1] On a 1.6 GHz Intel i5-8250U processor for the BLS12-446 curve

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Conclusion

- ABE implements access control on a cryptographic level
- Various use cases require various different properties
- Previously, non-monotonicity was difficult to achieve without impacting the decryption efficiency
- GLUE addresses the need for support of negations while allowing for more efficient decryption

Thank you for your attention!

https://ia.cr/2022/613

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