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Security and Privacy for 21st Century Metrology

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Modern metrology

- What is metrology?
- Legal metrology & security (& NIST)
- Liberalization impact
- Digital networked meters
- Digital security & privacy

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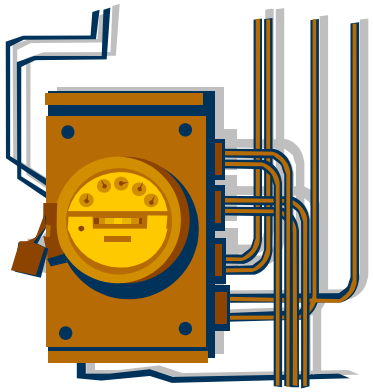
Example: smart electricity meter

Measures power consumption
Over every 15-30 minutes (KW/h)

Utility

- Real time aggregates
- Billing
- Forecasting
- Fraud detection

Registers for input / output (micro generation) and multiple channels



Remote disconnection

Stores readings for up to 13 months.

Tamper resistance

Pre-payment

Wide area network
Communications for control and readings

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Metering Security or privacy today

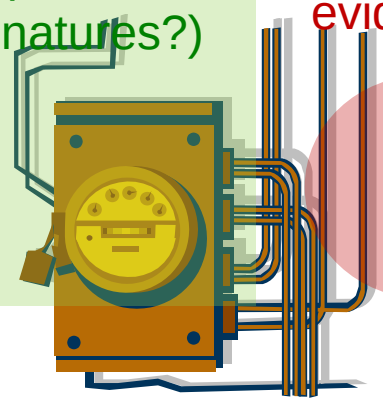
Certification & Tamper evidence (Signatures?)

Chain of evidence gap

Transport security

Exposed readings

Electricity readings per ½ hour



Meter
(Electricity, time)
(Gas, time)

Display

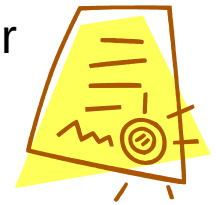
Bill Verification?

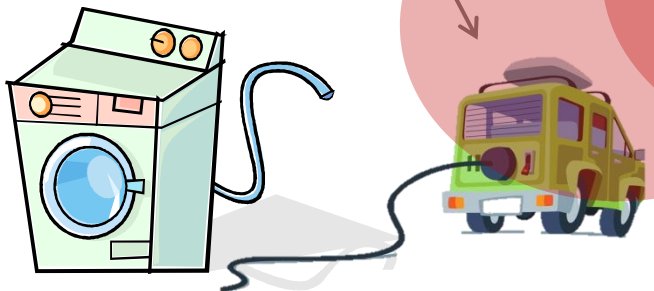
Utility Provider

User control?

Access to data?

Payment





User

Policy
Dynamic rates per ½ hour
Fixed plan of rates
(Non-linear rates -- taxation)

Desirable security properties

- End-to-end integrity and authenticity
- End-user privacy / information self-determination

- Versatility & public policy objectives
- Robust security engineering

Integrity & Authenticity

- **End-to-end** property:
  - Establish the authenticity & integrity of a reading throughout the life time of the reading.
  - “Valid reading from specific certified metrology unit”
- **Universal** / public verifiability:
  - No need for secrets to verify readings => all parties can verify them.
- Stronger: **integrity of computations**.
  - Interaction with privacy = not trivial.
  - **Software independence** = no chain of custody / can use untrusted hardware.

Privacy & self-determination

- Some readings are **personal data** (DP!)

- Confidentiality / Privacy
  - Gold standard: only data subject has access to raw readings.
  - **Data minimization**: e.g. private aggregation.
  - But: others should still be able to **compute** on them.

- Informational self-determination:
  - Subject can **use readings further** with 3rd parties.
  - **Audit computations** performed on personal data.
  - Use **any device / OS**.

Public policy

- Meters as part of **platform**
  - Need for versatility, extensibility, choice.
  - Lifetime: open to future technologies.
- Support **competition**:
  - No lock-in for any party.
  - High-quality readings for all.
  - Ability to use any user device.
- Support **secondary uses**.
  - Aggregation: with privacy.
- **Need for standardization!**

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Robust security engineering

- Minimal Trusted Computing Base
  - Minimal trusted hardware
  - Ideally: just the **certified metrology unit**.
  - Amenable to **formal verification**.

Standardization!

- Trusted third parties
  - Ideally: **no TTP**
  - 4C: Cost, Collusion, Corruption, Compromise.

Security & Privacy technologies for metrology

- Special signature scheme
  - Allows for end-to-end integrity & authenticity + privacy friendly computations.

Hint: Sign Pedersen commitments of readings.

- Special encryption scheme
  - Allow for aggregation from ciphertexts to get statistics.

Hint: Blind readings with shares from other meters.

- Standard zero-knowledge techniques
  - Perform computations on user machines while preserving privacy and integrity.

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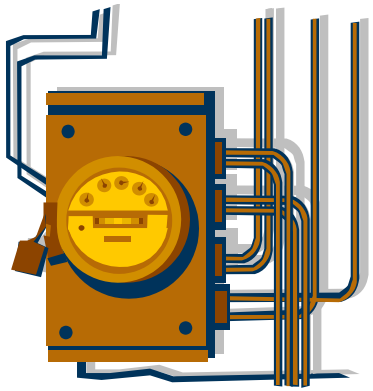
Illustration in a smart meter setting

(A) Certified readings & policy (B) Proof of bill & verification



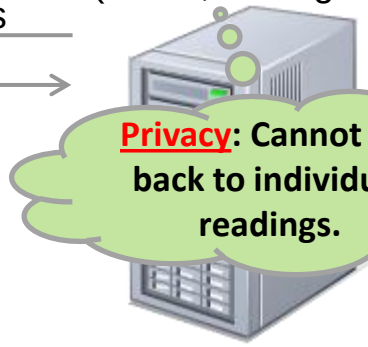
Meter
(Electricity, time)

Shared key K

Define aggregation groups & request readings

Extract aggregates
(Sums, averages, variances)

Signed & encrypted electricity readings per ½ hour



Privacy: Cannot get back to individual readings.

Signed & encrypted readings

Certified Policy
Dynamic rates per ½ hour
(Non-linear rates -- taxation)

Utility Provider

Privacy: readings Do not leave the user device

User Device

Can verify correctness of computation without access to secret readings!

Certified Bill
& Zero-knowledge
Proof of correctness

Two flavours of computations

- Fast linear computations (Billing protocol):
  - Special case: policy is public, and selection of rate independent of reading.
  - Very fast: process 3 weeks of all UK data in 12 days on 1 CPU.

- Generic computations protocol:
  - Supports any tariff policy that can be expressed as table look-ups and polynomial splines.
  - In theory supports any computation (some faster than others)

- Technical report & other resources:
  - http://research.microsoft.com/en-us/projects/privacy_in_metering/

General computations?

- Fast protocol:
  - Linear algebra: $Result = \Sigma_i x_i \cdot r_i$
- General zero-knowledge proofs:
  - Multiplication $Result = x_i \cdot r_i$
  - Lookup: $Result = Table[\, r_i \,]$
  - Range: $Result = Table[\, min < r_i < max \,]$
  - Polynomial: $Result = a\, r_i^3 + b\, r_i$
  - Any circuit (decompose into gates)

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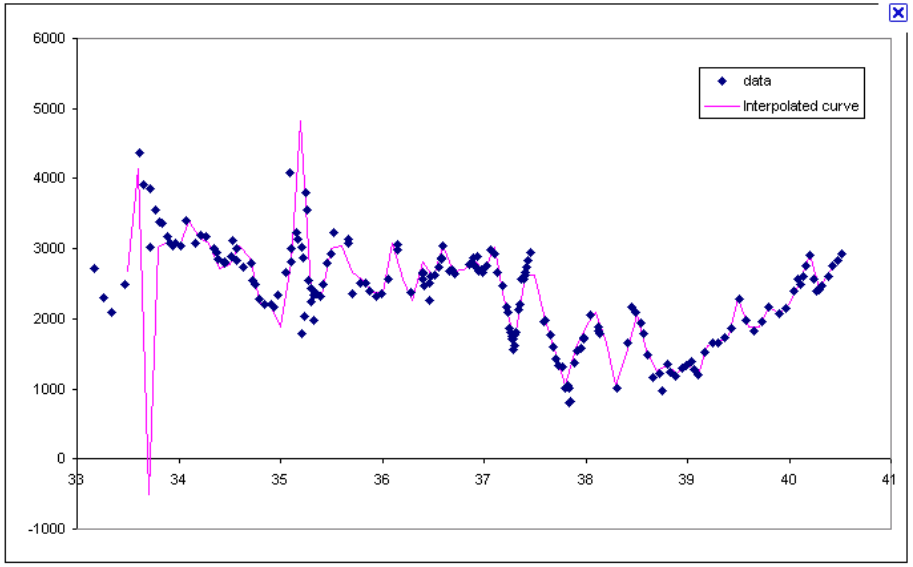
Really any function!

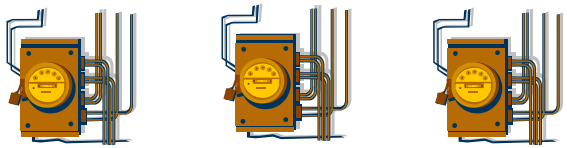
- Ranges + polynomials
  = splines
  = any function



- "*" or Table[]
  = NAND gate
  = any circuit

INPUT A	B	OUTPUT A NAND B
0	0	1
0	1	1
1	0	1
1	1	0

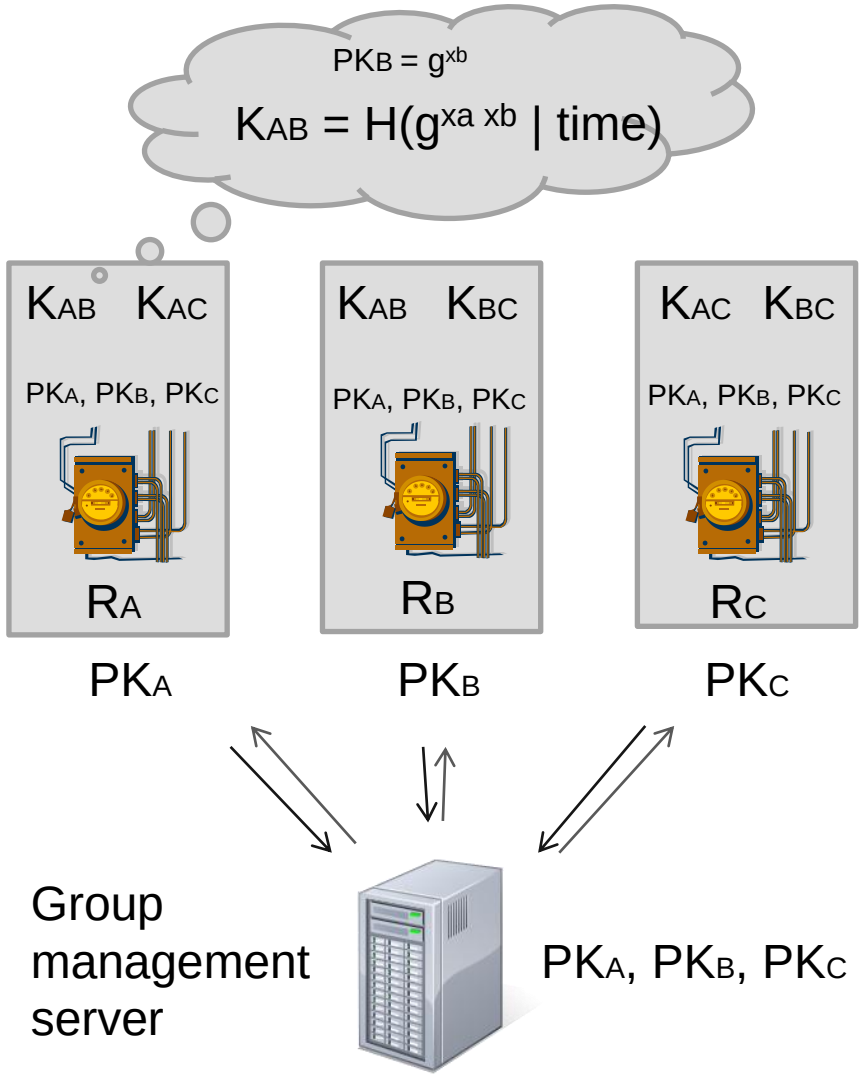
Privacy friendly aggregation



R_A R_B R_C

- Aim:
  compute sum without revealing readings.
- 2 Phases:
  - Distribute keys
  - Compute readings

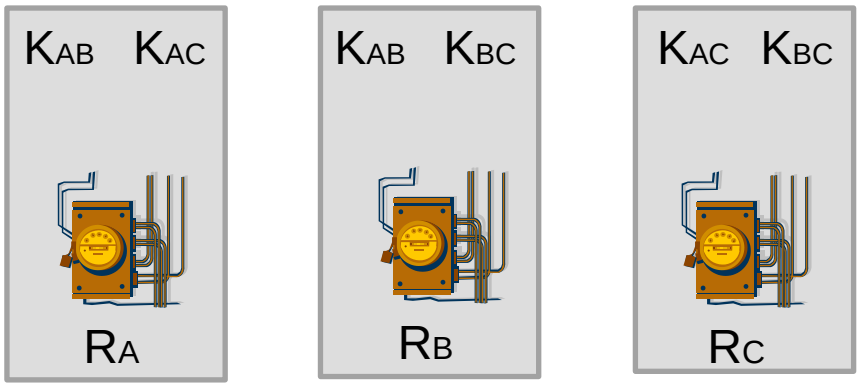
Privacy friendly aggregation



- Aim:
  compute sum without revealing readings.

- 2 Phases:
  - **Distribute keys**
  - Compute readings

Privacy friendly aggregation



- Aim:
  compute sum without revealing readings.
- 2 Phases:
  - Distribute keys
  - **Compute readings**

Deployment?

We have augmented
real-world smart meters
to support privacy-friendly
computations and aggregation.

How to deploy?
What is the eco-system?
What is the bigger picture?

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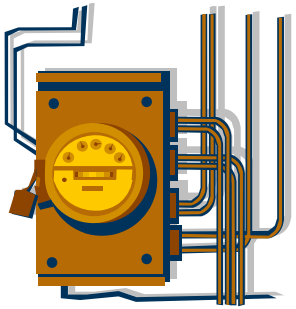
Deployment: HAG



Metrology unit

Home Access Gateway (HAG)

Description of computation

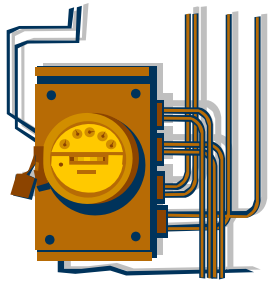
Supplier

- Certified
- Sign + Encrypt readings

- Untrusted HW / SW
- Perform computation
- Audit

- Get aggregates
- Verify computation

Deployment: Cloud + Browser



Metrology unit

- Certified
- Sign + Encrypt readings

Utility Cloud

- Get aggregates

Check + download
Encrypted readings

User Browser

- Untrusted **browser** (js)
- Perform computation

Supplier

- Verify computation

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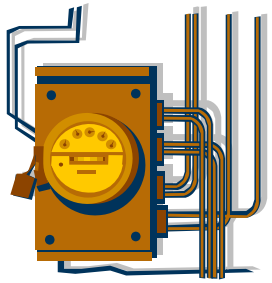
Deployment: Cloud + Smart Phone



Metrology unit

- Certified
- Sign + Encrypt readings

Utility Cloud

- Get aggregates

Push readings

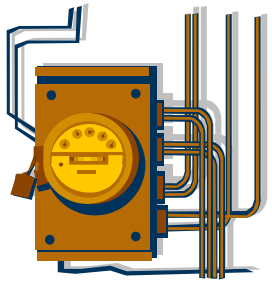
Phone App

- Untrusted **Phone App**
- Perform computation

Supplier

- Verify computation

Deployment: (Cloud | LAN) + PC



Metrology unit

- Certified
- Sign + Encrypt readings

or

Utility Cloud

- Get aggregates

Push / Pull readings

Supplier

- Verify computation

- Untrusted **PC / Laptop**
- Perform computation
- Audit
- Store other uses

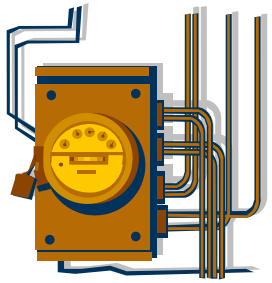
PC

3rd Party service

- Verify computation

Deployment: Cloud + Cloud

My grandmother has no smart phone!



Metrology unit

- Certified
- Sign + Encrypt readings

- Get aggregates

Utility Cloud

Push / Pull readings

Supplier

Verify computation

3rd Party service
(user trusts with readings)

Or *granddaughter*

Authorize!

PC / snail mail

- Delegation
- Perform computation
- Audit
- Store for other uses

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Key message:

A simple metrology unit enables secure & private uses of readings

What cost?

- Tamper resistant metrology unit
- Key generation (once)
- Pseudo-random functions (negligible)
- Generation of a commitment per reading (2 exp)
- Batch signature of commitments. (2 exp)
- Encryption of readings (aggregation)

- **No communication overhead!**
- **Easy to formally verify!**

Enables …

- End-to-end integrity + authenticity
- Privacy friendly computations
- Privacy-friendly aggregation
- Software independent integrity
- Choice of devices
- Auditability
- Generic & future proof
- …

Leave options open!

Conclusion

- **Metering can be done without violating privacy + with very high integrity**
- **Paradigm shift: Trustworthy computations in the client domain for privacy.**

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Resources

Technical report & other resources:
http://research.microsoft.com/en-us/projects/**privacy_in_metering/**

- Alfredo Rial & George Danezis. Privacy-friendly smart metering. Microsoft Research Technical Report MSR-TR-2010-150. November 19, 2010.
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