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RESEARCH FORUM®

Smart Grid invoice privacy in the Cloud

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Smart Grid

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- A “participant-aware” electricity network that consists of
  - Multiple different electricity network actors
  - Smart Meters at customer premises
  - Infrastructure for connecting the meters
- For the customers the Smart Grid offers:
  - Reduced bill through energy awareness
  - Services for monitoring own electricity consumption
  - Improved quality of the electricity network
  - Accurate invoices (real consumption, not an estimate)
- For the companies:
  - Energy efficiency via better, real-time load balancing
  - Better and faster detection of disruptions in the electricity network

The consumption data

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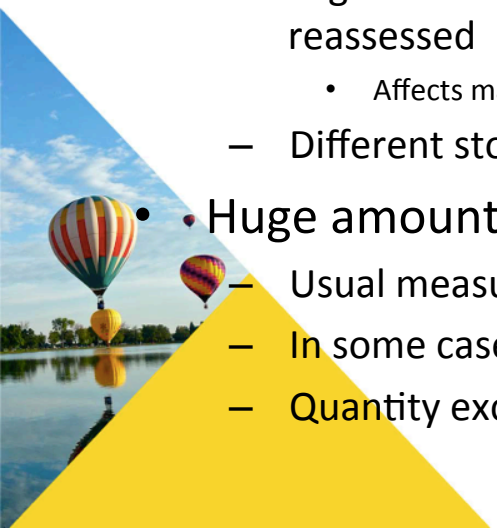
- Is measured with Smart Meters from customer's premises, contains:
  - Customer identification (customer id, meter id, location etc.)
  - Consumed electricity (e.g., in kWh)
  - Power signatures of used appliances (mainly in raw measurement data)
- Has lots of privacy related issues
  - Proof of data exploits and abuse for poorly protected data has been found
    - Presence and sleep cycles
    - Appliance usage, e.g. TV watching habits
    - In general the consumption data can be used to identify an individual
  - Legislation on private information (EU Data Protection Directive 2012) is being reassessed
    - Affects managing the consumption data
  - Different storage times for the data in different countries (e.g. in Finland: 6 years)
- Huge amounts of information is collected daily
  - Usual measurement interval is once per hour
  - In some cases even more often (every 15min)
  - Quantity exceeds petabytes → storage issues



Invoice calculation

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- In general is a resource, time and money consuming operation
- Invoices consist of:
  - Consumption data from certain period
  - Electricity pricing data
- Invoices need to be calculated:
  - Monthly (for billing the customer)
  - On demand (by the customer)
- Cloud computing is seen as a viable option that can offer:
  - Increased computational resources for calculation
  - Flexibility
  - Scalability
  - Expandable storage resources
  - Common services for different actors of the Smart Grid

Invoices in the cloud

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- Multiple ways to utilize cloud computing with Smart Grids have been researched, e.g.:
  - Fang et al. (2012) An information management approach for integrating Smart Grids and cloud computing
  - Rusitschka et al. (2010) Complete Smart Grid Data Cloud (SGDC) for all operations
  - Luo et al. (2012) Hybrid cloud approach (private cloud and community cloud)
- Cloud computing is seen as a way for:
  - Combining existing resources
  - Leveling the playground between new and old actors
- It has, however, lots of potential problems and challenges:
  - Legislation (Safe Harbour, local Smart Grid laws, EU DPD)
  - Who takes the responsibility in case of information breach?
  - Access restrictions (Who can access and how it can be monitored)
  - Data ownership (defined by the contracts between the actors)
  - Privacy (Seen as an issue in each of the aforementioned research)

Solutions for problems

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- To quote Sir Isaac Newton: “To every action there is always an equal and opposite reaction”
- Proposed solutions for protecting Smart Grid consumption data
  - Anonymization: Cavoukian et al. (2010), Efthymiou and Kalogridis (2010)
  - Aggregation: Mármol et al. (2012), Lu et al. (2012)
  - Although aggregation is criticized for generating inaccuracies (Erkin et al. (2013))
  - Obscuring the load signatures: Kalogridis et al. (2010)
- A vision for securing cloud computing and preventing insider attacks (Chow et al. (2009))
  - Encrypted data with encrypted queries
  - Constant monitoring of data usage
  - Trusted Computing model

Analyzing different approaches

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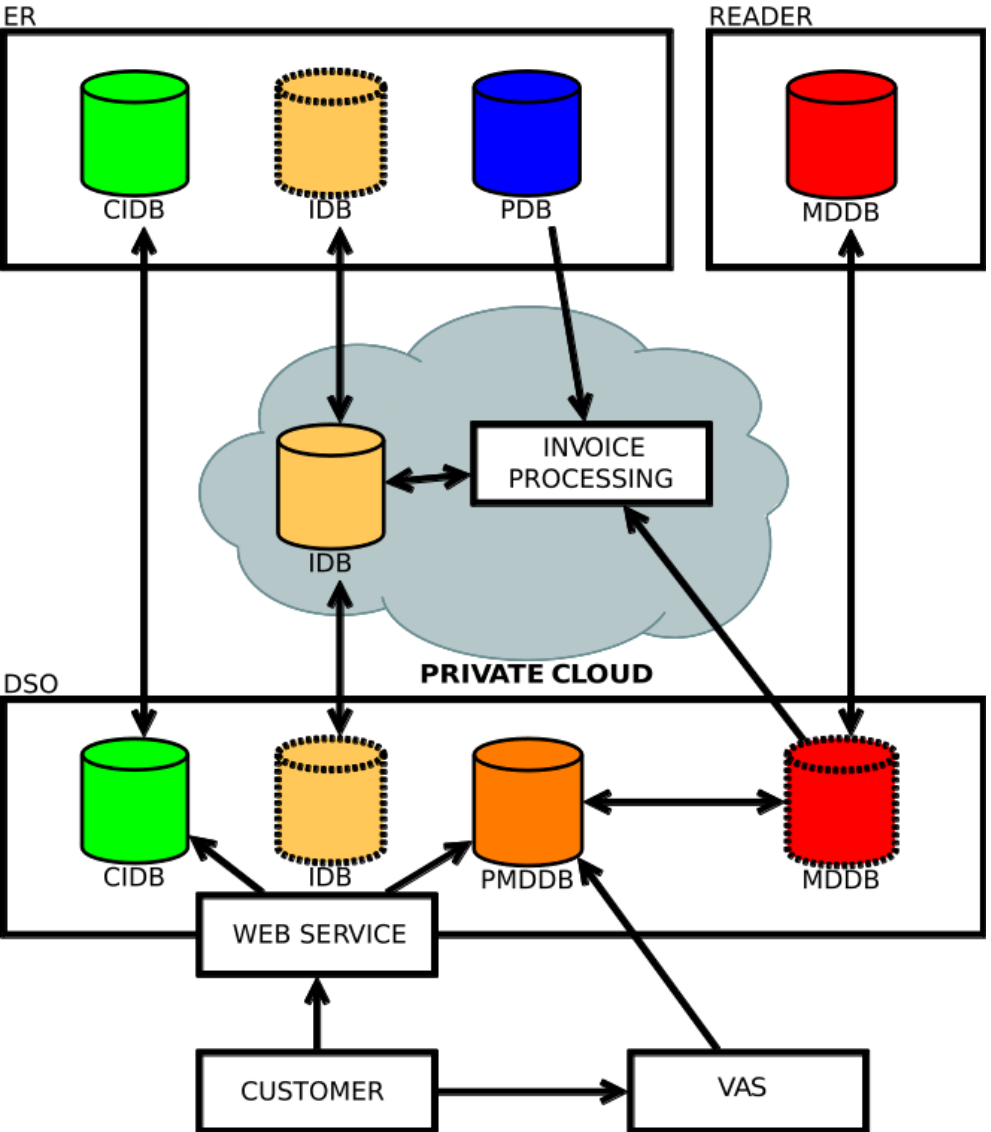
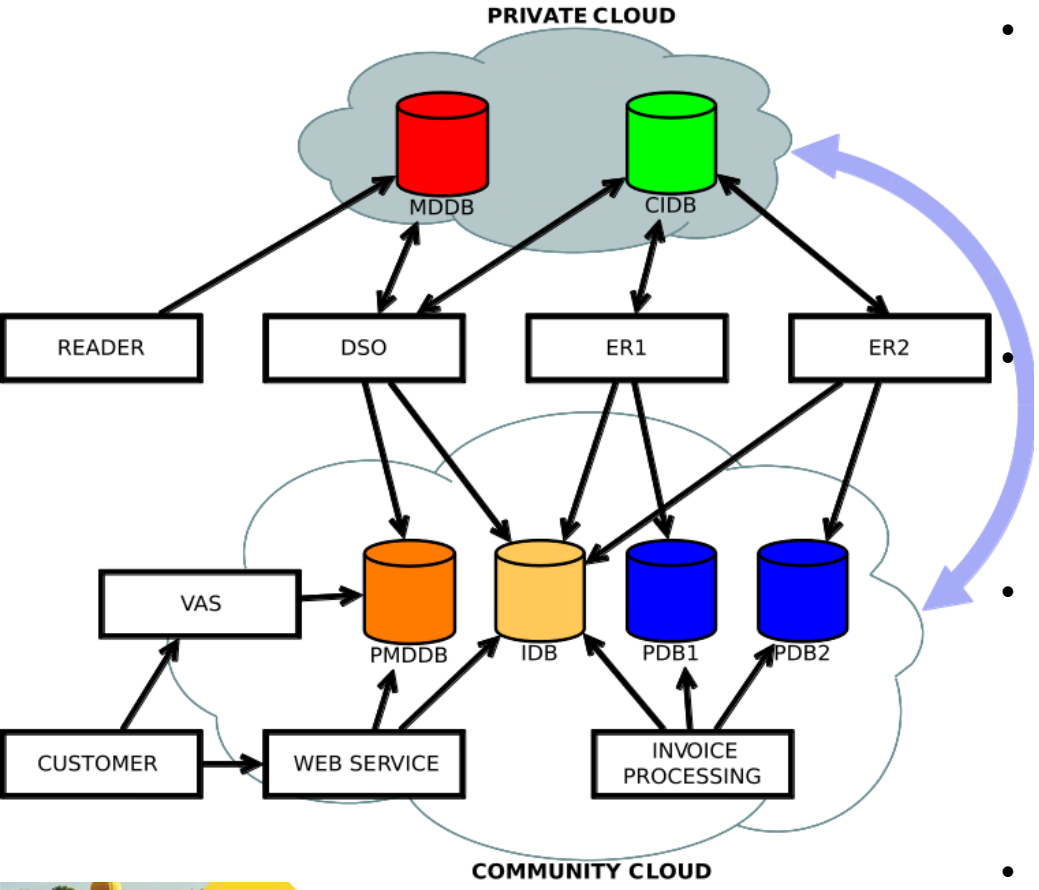
- There are multiple different approaches for utilizing cloud in Smart Grid operations
- Also different privacy issues of combining Smart Grid and cloud computing are analyzed
  - Simmhan et al. (2012), Mohsenian-Rad et al. (2010)
- The layout for databases in cloud computing needs to be assessed
  - Based on the "privacy by design" principle
  - We divide the required databases into five
    - Customer information DB (CIDB)
    - Measurement data DB (MDDB) and Processed measurement data DB (PMDDB)
    - Electricity market price DB (PDB)
    - Invoice DB (IDB)
- We analyze and compare three different scenarios relating them to architecture that is used in Finland (Laakkonen et al. (2013))
  - Only invoices in the cloud (SaaS)
  - Hybrid cloud approach with private clouds and a community cloud
  - A complete cloud based solution for Smart Grids (SGDC)

1. Only invoices in the cloud



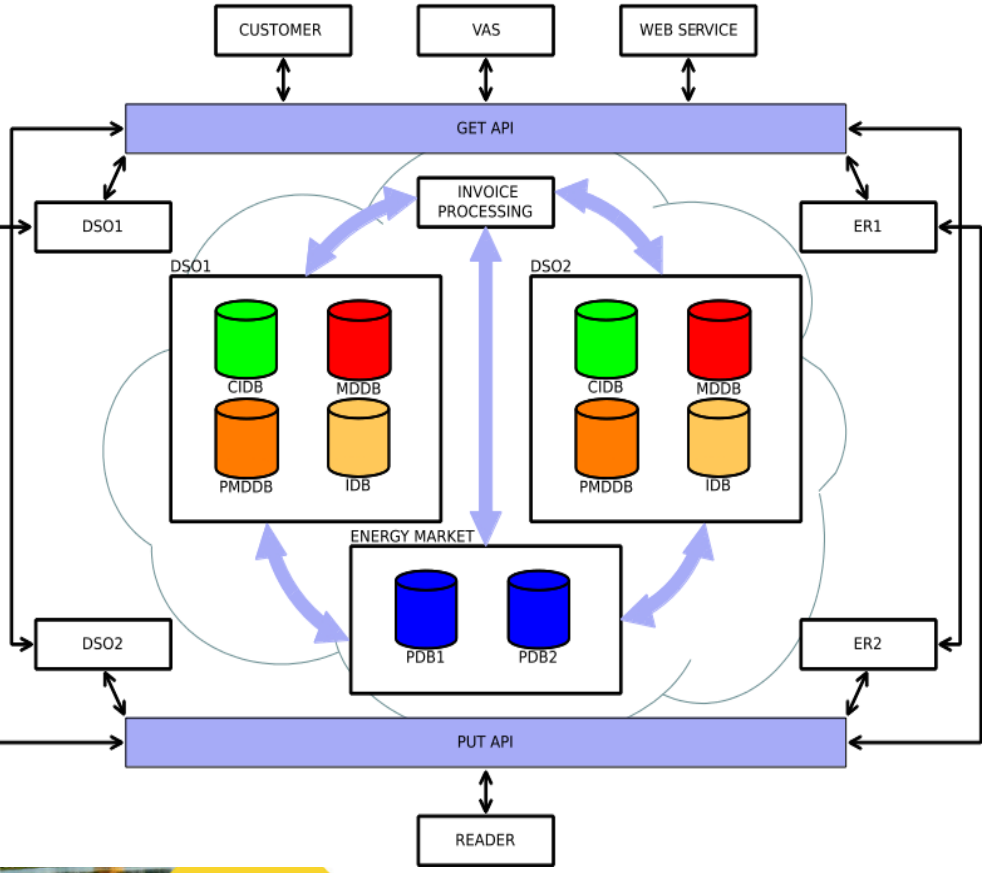
- The most basic approach (SaaS)
- Possibility of database duplicates
- Data sent to cloud can be strictly limited, both the amount and the storage/processing location
- Invoice calculation is problematic:
  - Information sent to cloud has to be accurate (accurate invoices)
  - But the resolution should be sufficiently low (to ensure privacy)
- Privacy depends on the security and the access restrictions of the cloud, in addition to what is defined in the contracts
- Changing of ER is fairly easy
- Some problems may occur with customer and VAS service implementations

2. Hybrid Cloud



- Consists of a community cloud and private clouds of different actors (DSOs)
  - Private cloud resources are shared
  - Community cloud contains the services and processing capabilities
  - The resources of multiple actors can be combined (shared expenses)
- Data shared to community cloud can be limited
  - Private cloud can be localized because of legislative requirements – can be problem with community cloud
- Privacy depends on the private cloud security
  - Virtualization offers a secure way to access the different resources
  - Only anonymized or processed information in the community cloud
- Common services for customers and other service providers
  - Common rules and ways for, e.g., changing ER
  - Clear way to access data and to grant access

3. SGDC



- A complete cloud based approach
  - Separate tenant spaces for actors
  - Common services and computational resources for all
- Good for preserving privacy of the customers
  - Common interfaces which results in less errors and less access violations
  - Enables the use of efficient access monitoring
- Problems with legislation - has to be geographically limited (Safe Harbor)
- Each tenant can limit information sharing and protect sensitive info
- Best use of the cloud for customers' point of view (fast common services)
- Easy to change ER, service provider etc.
  - Common methods for changing access'
  - Common ways to access data and to grant access

Summary

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- Best approach from privacy perspective : 2. Hybrid cloud
  - Good flexibility and scalability
  - Best control of the data and access
  - Best tools for managing customer accounts and contract changes (among the 3. SGDC)
  - Best privacy without sacrificing:
  - Usability
  - Manageability
  - Accessibility
- The SGDC (3.) can provide the best flexibility, scalability and ease of use from all viewpoints
  - Good privacy protection (common interfaces for access and separate tenant spaces)
  - Potential issues with legislation
  - Access restriction issues
- The simplest approach (1.) can offer full control of the data
  - Problems with information sharing
  - Expenses are much higher than with combined resources (2. and 3.)

Conclusion

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- The cloud computing will play a major role in Smart Grids in the future
  - Currently most solutions are too expensive for individual companies
  - With approaches like hybrid cloud:
    - The expenses can be shared
    - The entry barrier for smaller companies can be lowered
    - The quality of the service operation increases
  - The privacy of the customers depends on the cloud security
    - Can be enhanced by limiting the information in the cloud (data type, data resolution and amount)
- The privacy issues must be resolved before cloud computing can be fully utilized
  - Data privacy → protection methods, access control and limitation of availability and identifiability
  - Legislative issues must be assessed for offering global services (Safe Harbour, EU DPD)
  - A “privacy by design” layout for different actors and their resources in the cloud has to be devised, analyzed and accepted