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Model-based Performance Evaluation of Large-Scale Smart Metering Architectures

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Agenda

- Motivation & Vision
- Experiment Design
  - Use Cases
  - Architecture
  - Variant Table
- Simulation Results
- Related Work
- Conclusion & Future Work

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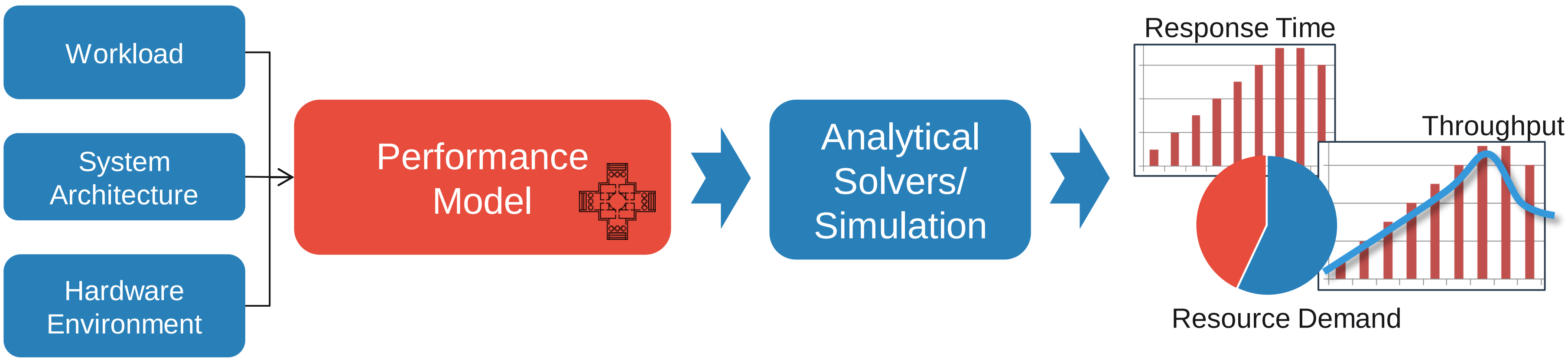
Motivation & Vision

- Smart meter devices supersede conventional energy meters (Zheng et al. 2013)
- Advanced Metering Infrastructures (AMI) and smart grid systems interlink smart meters (Zheng et al. 2014)
- Data analytics need to be performed by smart grid systems in near real-time in order to ensure power grid stability (Ilic et al. 2013)
- Since the introduction of smart meters continuously grows, …
  - performance issues can raise quickly.
  - smart grids systems must be able to scale accordingly.

Motivation & Vision

- To support architectural decisions during smart grid system design by using performance models to….
  - evaluate software architectures for different use cases and workloads.
  - plan the required capacity .
  - evaluate scalability characteristics.



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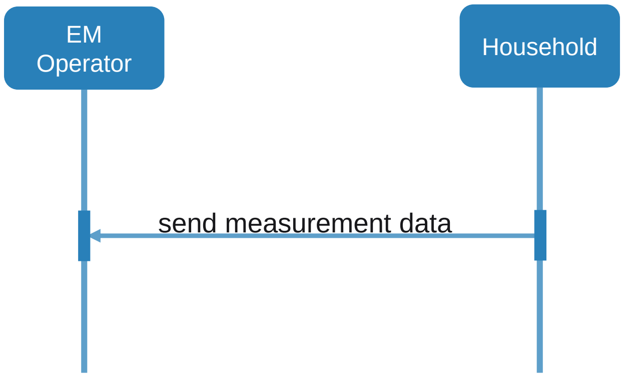
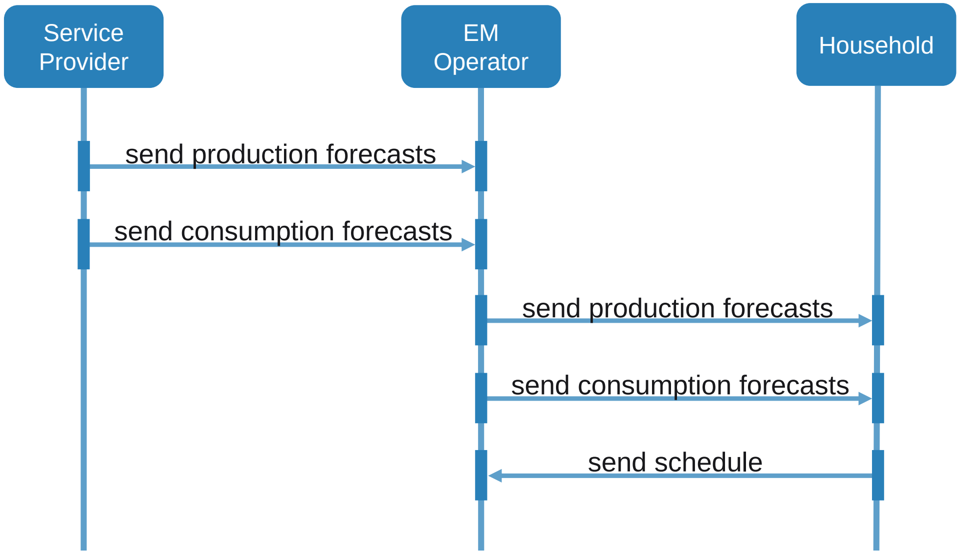
Experiment Design

Use Cases

Read Smart Meters



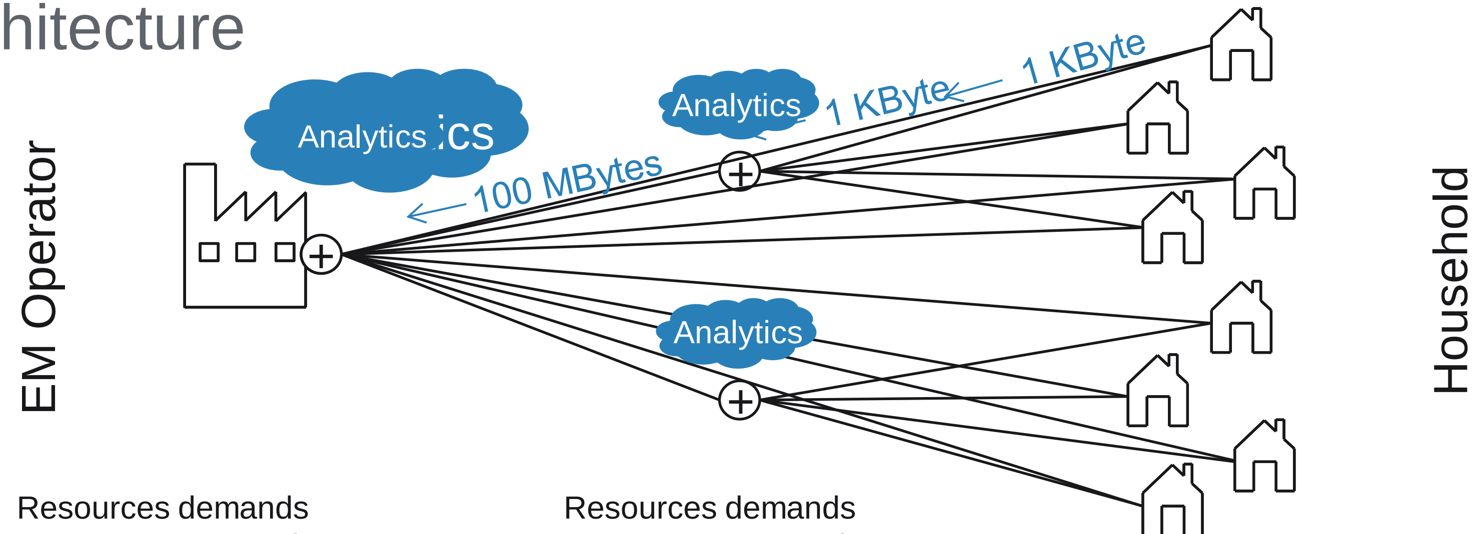
Local Optimization



adapted from Irlbeck and Koutsoumpas (2013)

Experiment Design

Architecture

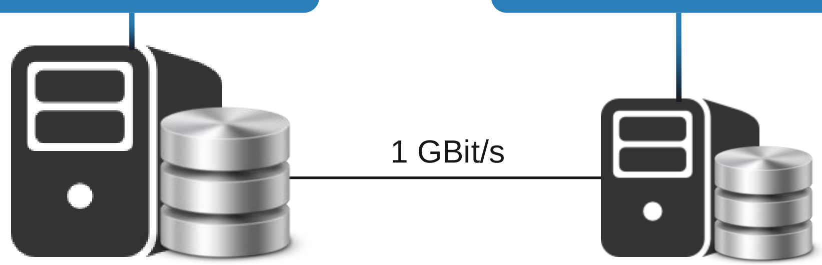


Resources demands
- CPU: Message size * 0.002 CPU
- HDD: Message size

Algorithm 1

Resources demands
- CPU: Message size * 0.001 CPU
- HDD: Message size

Algorithm 2



N = 1
- CPU Processing Rate: 1000 ms
- HDD Processing Rate: 146 MBytes/s

N = 4
- CPU Processing Rate: 1000 ms
- HDD Processing Rate: 146 MBytes/s

Experiment Design

Variant Table

Workload		System architecture	Hardware environment
Use case	Households		
Read smart meters	100,000	Centralized	Constant
		Decentralized	
	150,000	Centralized	
		Decentralized	
	200,000	Centralized	
		Decentralized	
Local optimization	100,000	Centralized	
		Decentralized	
	150,000	Centralized	
		Decentralized	
	200,000	Centralized	
		Decentralized	

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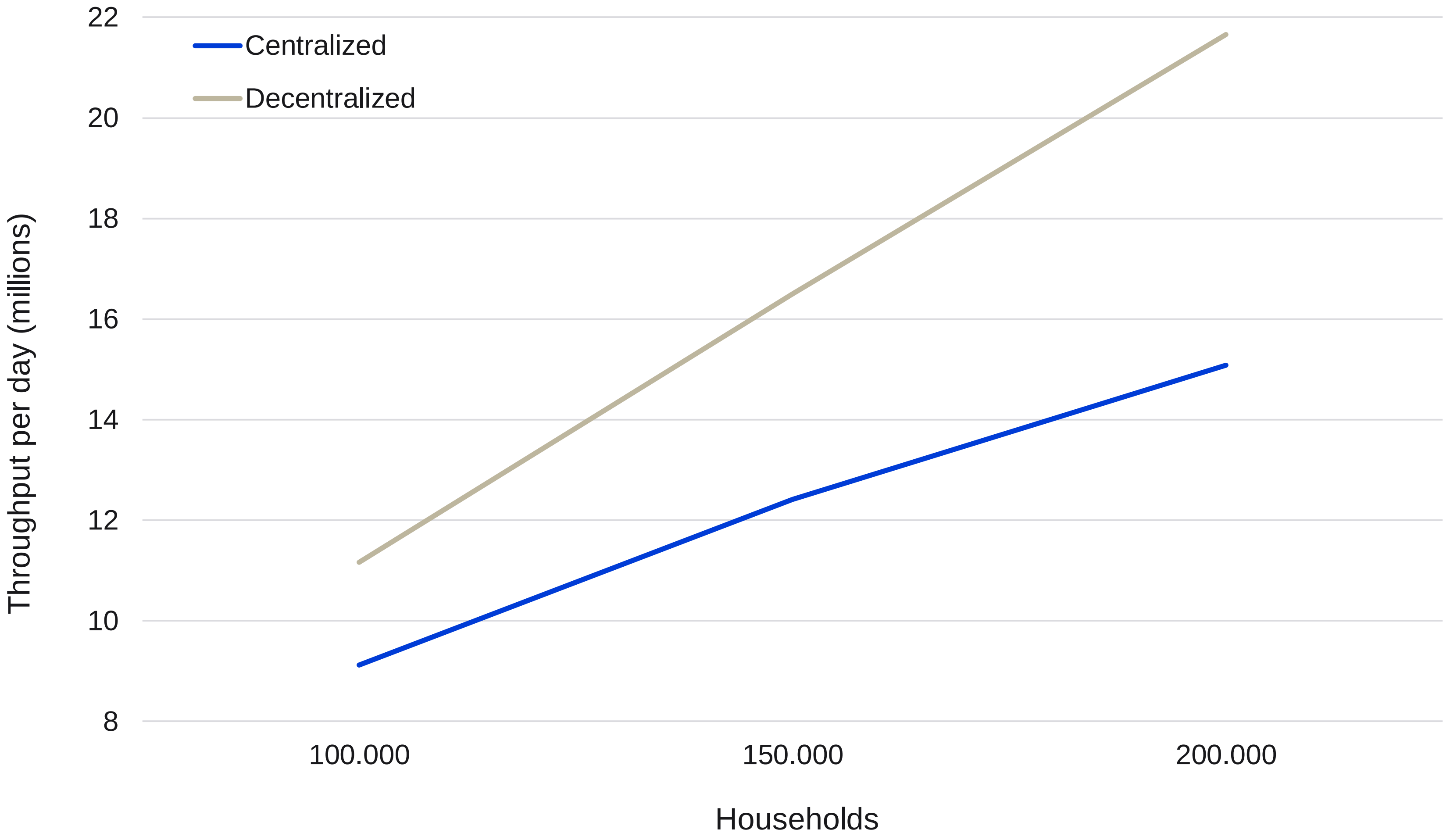
Simulation Results

Throughput for Use Case “Read Smart Meters”



Simulation Results

Mean CPU utilization for Use Case “Read Smart Meters”

Households	Centralized (EM operator)	Decentralized (Mean for each of the four aggregators)
100,000	21.10 %	3.82 %
150,000	28.73 %	5.37 %
200,000	34.91 %	6.86 %

- Less IT capacity is required in the decentralized architecture (Overall CPU utilization is lower)
  - Achievable with two-step processing on centralized architecture?

Simulation Results

Response Time Sending Consumption Forecasts for Use Case "Local Optimization"

Households	Centralized (EM operator)	Decentralized (Mean for the four aggregators)
100,000	21.62 minutes	5.79 minutes
150,000	31.98 minutes	6.81 minutes
200,000	42.34 minutes	7.62 minutes

- Time for optimization (mapping demand and consumption) needs to be fast:
  - e.g., the European Energy Exchange (EEX) adapts prices in 15 minute intervals in the EPEXSPOT Intraday Auction

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Related Work

- Several solutions have been proposed to model AMI and smart grid systems
- Most approaches focus on modeling and evaluating the network e.g.,
  - Mora et al. (2009) modeled the network for smart grids
  - Lin et al. (2011) similarly focused on network communication
  - Wang et al. (2011) discuss several communication architectures and requirements
- A model-based performance evaluation for smart grid systems could not been found in our literature review

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Conclusion & Future Work

- Conclusion
  - We showed how performance models can be used to model and evaluate scenarios in the smart grid area
  - We implemented two common use cases and simulated them for two different smart metering architectures and large-scale smart meter installations

- We plan to extend our performance models in several ways
  - Adding measured resource demands for analytical algorithms
  - Including reliability as additional aspect in our model-based evaluation
  - Adding additional actors such as the European Energy Exchange (EEX)
  - Simulating multiple use cases in parallel in order to evaluate system scalability and performance characteristics in a greater extent

Discussion

- Request for feedback
  - Are there other/better ways to plan the required capacity in smart grid systems (e.g., using measurement-based techniques)?

- A thought-provoking statement or discussion question about the area
  - Are existing performance modeling techniques scalable enough to evaluate such system-of-systems architectures?
    - We are targeting for simulations of several million households

Thank you for your attention!

Questions?

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