UNIVERSITÄT ZU LÜBECK
INSTITUTE OF COMPUTER ENGINEERING

Lossless Compression of Cloud-Cover Forecasts for Low-Overhead Distribution in Solar-Harvesting Sensor Networks

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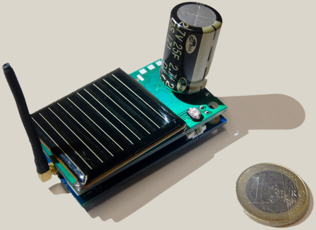
November 6th, 2014

Making the Most of Harvestable Energy

Objective	perpetual operation
Challenge	changing weather conditions
Instrument	load adaptation
Prerequisite	energy harvest prediction



Sources of Harvest Variation

Global

Weather conditions

- Inter and intra-day variation
- Seasonal effects

- Distribution required
- Unused

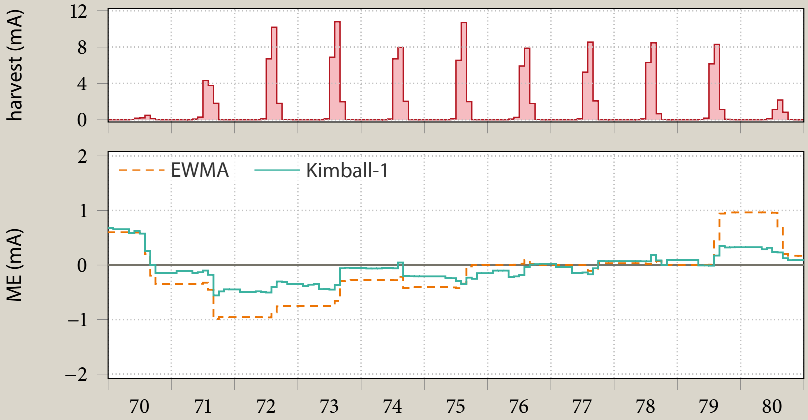
Local

Location-specific pattern

- Shades of buildings and trees
- Dirt deposits
- Hardware aging

- Locally available
- Frequently used

Advantages of Integrating Cloud Cover Forecasts



Data Distribution

Challenge

- One-to-many communication (data distribution)
- Reversed data flow ↔ data collection
- Elevated network energy expenditure

Approach

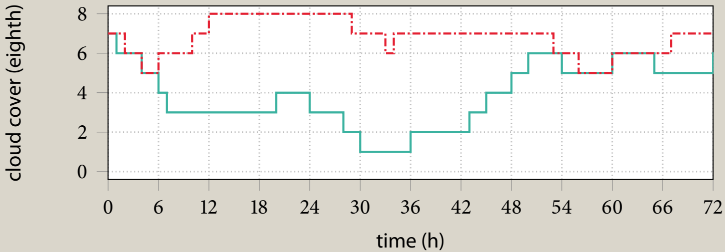
- Piggy-back on collection data acknowledgments
- Reduces energy overhead
- Requires small size ⇝ compression

Lossless Compression

Compression Checklist

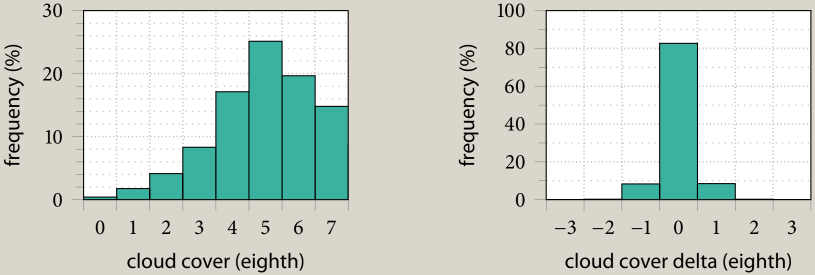
- Complete forecasts
  differential data problematic in case of packet loss
- Lossless compression
  coarse-grained input data, no experience with lossy forecasts
- Light-weight decoding
  execution on resource-constrained sensor nodes, decoding consumes energy
- Exploit data properties and patterns

Cloud-Cover Forecasts



- Cloud cover in eighths
- Hourly resolution
- Multi-day horizon
- Hourly updates

Data Analysis



- difference of adjacent forecast values (deltas) is
  - zero in 82% of all cases
  - at most one in 99% of all cases
- deltas have lower entropy than absolute values

Compression Algorithms

Delta Coding (DC)

- Huffman encoding of delta values (-8, ..., 8)
- First value unencoded (absolute value)

Cloud-cover forecast	5	5	6	5	5	5	8	8
Deltas	5	0	+1	-1	0	0	+3	0
Encoding	0101	0	10	110	0	0	1111110	0

Compression Algorithms

Partial Delta Coding (PDC)

- Huffman encoding of delta values -1, 0, 1
- Larger deltas encoded as absolute values with prefix
- First value unencoded (absolute value)

Cloud-cover forecast	5	5	6	5	5	5	8	8
Deltas	5	0	+1	-1	0	0	+3	0
Encoding	0101	0	10	110	0	0	111 1000	0

Compression Algorithms

Daylight Delta Coding (DDC)

- PDC encoding
- Omit night slots
- Indicate number of values before sunrise / sunset

Cloud-cover forecast	5	5	6	5	5	5	8	8
Deltas	5	0				0	+3	0
Encoding	0101	0				0	111 1000	0

Evaluation

Setup and Metrics

Data set

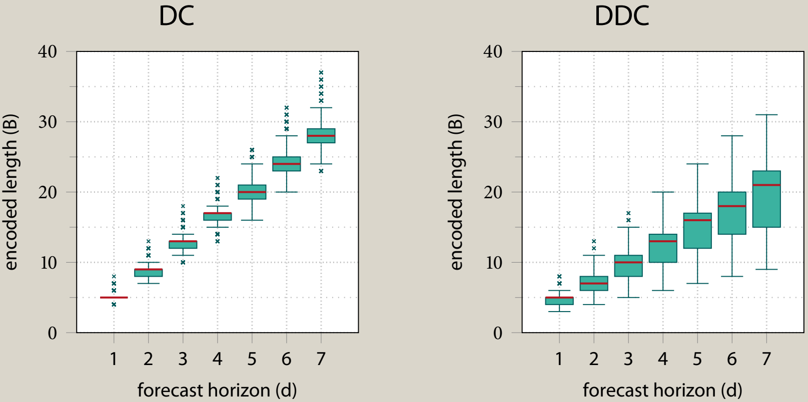
- Cloud-cover forecasts from an online weather forecast service
- April 2013 to July 2014
- 10 590 forecasts
- Hourly resolution, 10-day horizon
- Sunrise and sunset times from sunrise equation

Compression

- DC, PDC, DDC
- Message sizes (including all static information)

Results

Compression Performance and Comparison



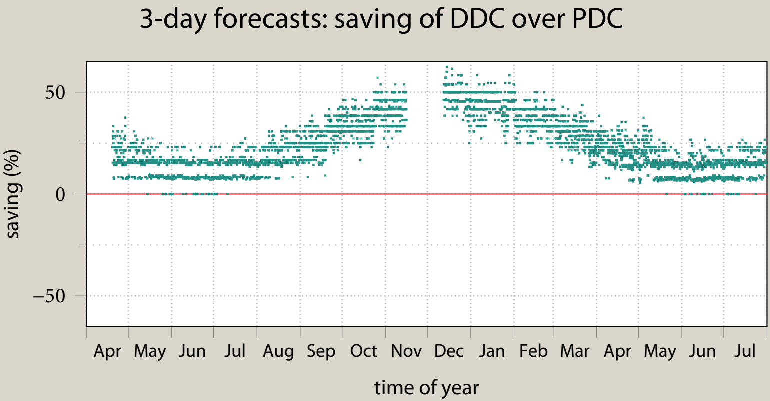
Results

Optimality Study

horizon (d)	avg. compression code length (bit/value)			
	optimal	DC	PDC	DDC
1	1.00	1.50	1.51	1.43
2	0.94	1.41	1.42	1.14
3	0.92	1.37	1.38	1.04
4	0.91	1.35	1.36	0.99
5	0.90	1.34	1.35	0.95
6	0.90	1.32	1.33	0.93
7	0.89	1.31	1.32	0.91

Results

Seasonal Daytime Influence



Summary

Results

- DDC achieves best results
- Compression of up to 76%
- Forecasts of up to 3 d consume at most 17 byte
- Efficient (decoding) implementation

Conclusion & Future Work

Conclusion

Cloud-cover forecasts

- improve (solar) harvest prediction accuracy
- are compressible to a few bytes with low computation overhead
- can be distributed into the network via acknowledgment piggy-backing

Current and Next Steps

- Implementation for TinyOS
- Latency evaluation for piggy-backed data distribution
- Field test
- Compression / distribution of other weather metrics
  e.g., sunshine duration per hour

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