A Comparative Analysis of High-Level vs. Low-Level Simulations for Dynamic MAC Protocols in Wireless Sensor Networks

Shama Siddiqui, Anwar Ahmed Khan, Indrakshi Dey

Walton Institute for Information and Communication Systems Science, Waterford, Ireland

Introduction and Motivation

- Hundreds of MAC protocols for general as well as specific applications have been developed for the low power devices (Wireless Sensor Nodes & Networks) in IoT over the past two decades.
- A need to conduct comparison of the theoretical simulations results with detailed testbed level implementation of the proposed protocols.
- We present a comparison of results obtained for ADP-MAC.
  - High-level simulations performed over MATLAB
  - Detailed implementation was performed over AVRORA Emulator

Relevant Work

- An adaptive dynamic duty cycle mechanism for energy-efficient medium access control (ADE-MAC) for Wireless Multimedia Sensor Networks (WMSNs)
  - Dynamically adjusts the duty-cycles based on the incoming traffic rate and queuing delays at each node
- A variable duty cycle MAC (DC-MAC)
  - Only closely located nodes follow the same duty cycle, while the far-off nodes may follow a different.
- Adaptive and Dynamic Polling-MAC (ADP-MAC)
  - Statistical coefficient of variation (Cv) to identify the incoming arrival patterns and select the corresponding polling intervals

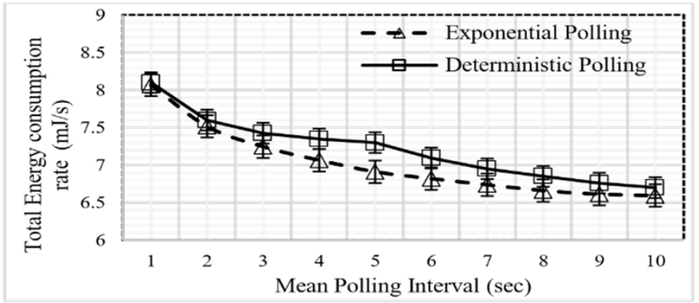
MATLAB Simulation Settings

Simulation Duration	**5000 secs**
Mean inter-arrival duration	5 secs
Mean polling interval	1-10 sec
Size of Data Packet	50Byte payload + 11Byte overhead
Size of Acknowledgement (ACK) Packet	10B
Size of Preamble	2B
Maximum no. of Concatenated in a Super packet	5
Energy consumed in Data transmission	0.5 mJ/Byte
Energy consumed in Single Data packet transmission	30.5 mJ
Energy consumed in ACK transmission	5 mJ
Energy consumed in channel polling	1 mJ

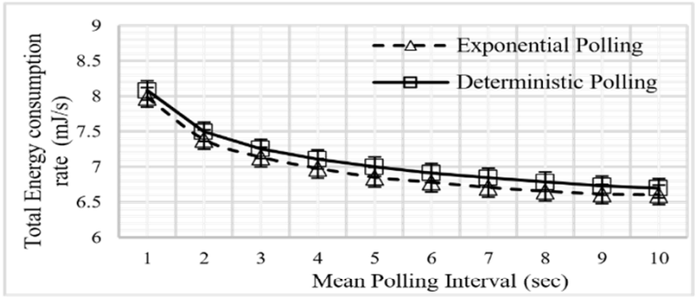
Testbed Simulation Settings

Simulation Parameters	Value for ADP-MAC
Common Parameters	
Bit rate	18.78 kbps
Arrival Patterns	CBR/Poisson
Polling Interval Distributions	Deterministic/Exponenti-al/Dynamic
Total Nodes	10
Message Generation Interval	50 Sec
Number of packets transferred	20 packets generated by each node
Distance between the Nodes	1 m between each source and sink
Duration of Each Cycle T_{cycle}	10 sec
Threshold value of Cv	0.8
Size of Super Packet	Up to 5 data packets

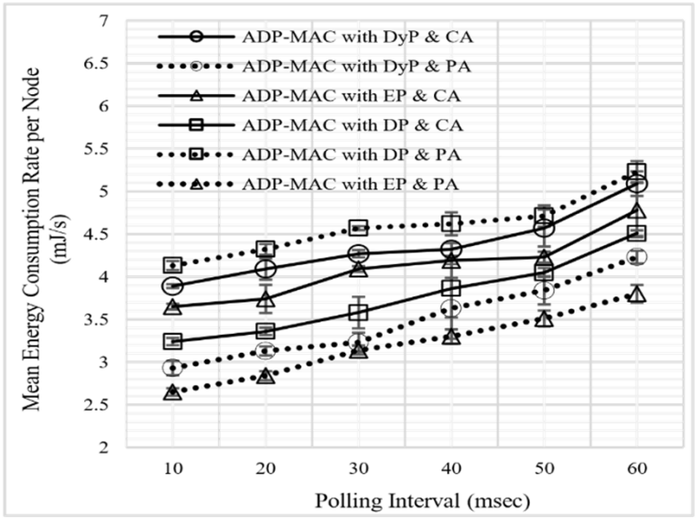
Results


Exponential Polling
Deterministic Polling
Total Energy consumption rate (mJ/s)
Mean Polling Interval (sec)
9
8.5
8
7.5
7
6.5
6
1
2
3
4
5
6
7
8
9
10

(a)

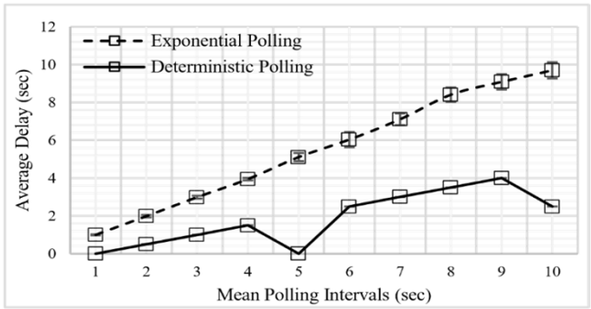

Exponential Polling
Deterministic Polling
Total Energy consumption rate (mJ/s)
Mean Polling Interval (sec)
9
8.5
8
7.5
7
6.5
6
1
2
3
4
5
6
7
8
9
10

(b)

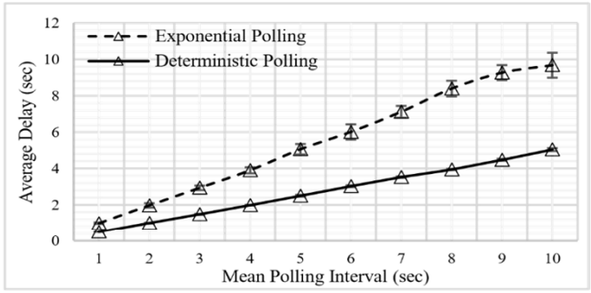

ADP-MAC with DyP & CA
ADP-MAC with DyP & PA
ADP-MAC with EP & CA
ADP-MAC with DP & CA
ADP-MAC with DP & PA
ADP-MAC with EP & PA
Mean Energy Consumption Rate per Node (mJ/s)
Polling Interval (msec)
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
10
20
30
40
50
60

(c)

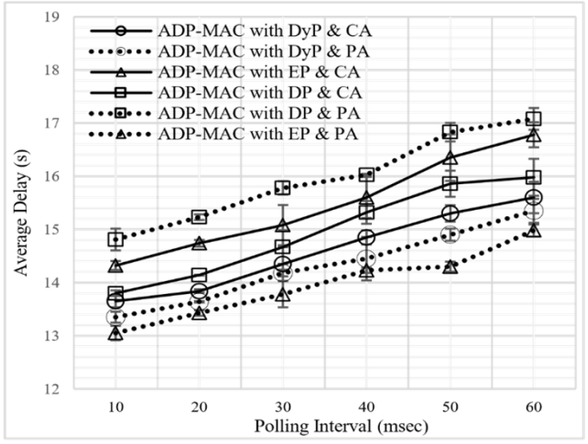
Results


Exponential Polling
Deterministic Polling
Average Delay (sec)
Mean Polling Intervals (sec)

(a)


Exponential Polling
Deterministic Polling
Average Delay (sec)
Mean Polling Interval (sec)

(b)


ADP-MAC with DyP & CA
ADP-MAC with DyP & PA
ADP-MAC with EP & CA
ADP-MAC with DP & CA
ADP-MAC with DP & PA
ADP-MAC with EP & PA
Average Delay (s)
Polling Interval (msec)

(c)

Analysis

- MATLAB implementations showed a trade-off between energy and delay performance of the proposed polling scheme.
- Both the energy consumption and delay increased with the increasing polling intervals in the testbed implementations
- High-level prediction results are based on several assumptions:
  - The energy consumption was calculated based on the assumptions about the level of energy consumed in polling activities and data & ACK transmissions.
  - For both the deterministic and exponential polls, the mean number of polls were always shown to be the same with only a change in their distribution
  - The energy savings was depicted through the transmission of reduced bytes due to packets received as concatenated and block acknowledgements
  - There was no implementation of the preamble transmissions, collisions, Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA) process and retransmissions

Conclusion and Future Work

- We presented the results of performance evaluation conducted for an adaptive and dynamic MAC protocol (ADP-MAC).
- Differences have been obtained for the performance evaluation trends between the high level and low-level implementations.
- In future, we plan to implement ADP-MAC in large-scale, real-world testbeds to evaluate its performance.
- We also aim to explore enhancements that address challenges such as heterogenous traffic management, potentially through emerging machine learning-based optimization techniques.

References

- S. Siddiqui, S. Ghani, and A. A. Khan, "ADP-MAC: An Adaptive and Dynamic Polling-Based MAC Protocol for Wireless Sensor Networks.," IEEE Sensors Journal, vol. 18, no. 2, pp. 860-874., 2018.
- A. A. Ahmed and M. Abazeed, “Adaptive dynamic duty cycle mechanism for energy efficient medium access control in wireless multimedia sensor networks,” *Transactions on Emerging Telecommunications Technologies*, vol. 32, no. 12, p. e4364, Dec. 2021, doi: 10.1002/ETT.4364.
- R. Subramanyam, G. J. Bala, N. Perattur, and E. G. M. Kanaga, “Energy Efficient MAC with Variable Duty Cycle for Wireless Sensor Networks,” *International Journal of Electronics*, vol. 109, no. 3, pp. 367–390, Mar. 2022, doi: 10.1080/00207217.2021.1892202.