LEACH protocol and LEACH-C protocol simulation using Contiki-NG

Airi KOKURYO
University of California Santa Cruz

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Project Goal

To compare the performance of the original LEACH protocol to one of the LEACH successor protocols

<u>Used network simulator:</u>

Contiki-NG in Cooja

<u>Chosen LEACH successor protocol:</u>

LEACH-C (LEACH Centralized)

LEACH Protocol

- It is an energy-efficient communication protocol for wireless microsensor networks.
- A clustering-based protocol that choose different CH randomly every round. This protocol evenly distributes the energy load among the sensors in the network.

LEACH-C (Centralized)

- Produces excellent clusters by scattering the CH throughout the sensor network
- Since set-up phase is completely executed at the edge gateway (decides which nodes become the CH at the first advertisement phase).
- The steady-state phase of LEACH-C is the same as the original LEACH protocol.

Motivation

LEACH is the first protocol proposing the idea of the clustering-based routing for wireless sensor networks

However…

LEACH has a problem where it does not guarantee the position and number of the CHs in each round

Therefore…

By comparing the succeeded model of LEACH to the original LEACH using a network simulator, visualize how the protocol has improved in data freshness, overhead, and energy efficiency.

Related Work (Papers)

- LEACH (2000)
- LEACH-C (2002)
- "A Survey on Successors of LEACH Protocol,“
- " Clustering objectives in wireless sensor networks: A survey and research direction analysis “
- HEED (2004)
- PEGASIS (2016)

Approach- LEACH Specifications

- All nodes are homogeneous, so it runs the same program
- Only the edge gateway (sink) runs its own program
- All nodes are one hop away from the edge gateway, so it only uses the one-hop unicast and broadcast
- NullNet for communication
- 100 nodes and 1 gateway
- Probability P = 0.05
- Transmission range: 150 m

Approach- LEACH Implementation

1. The edge gateway sends out a broadcast advertisement to all nodes within the range (Only once)

```
00:00.458    ID:55    [INFO: LEACH Node] [0] Received packet: address 101
```

2. Starts round: 0
3. Cluster heads are decided

```
1:45:00.501  ID:99   [INFO: LEACH Node] [0] Cluster head process
1:45:00.501  ID:99   [INFO: LEACH_Node] random value: 0.050000 0.020432
1:45:00.501  ID:99   [INFO: LEACH_Node] [0] is_ch: 1
1:45:00.501  ID:99   [INFO: LEACH Node] [0] Sending out broadcast
```

Approach- LEACH Implementation

LEACH

$$T(n) = \begin{cases} \frac{P}{1 - P * (r \bmod \frac{1}{P})} & \text{if n} \in \text{G} \\ 0 & \text{otherwise} \end{cases}$$

LEACH-C

$$K = \sqrt{\frac{N}{2\Pi} \frac{\epsilon_{fs}}{\epsilon_{mp}}} \frac{M}{d_{toBS}^2}$$

$$P_i(t) = \begin{cases} \frac{k}{N - k * (r \bmod \frac{N}{k})} & : \quad C_i(t) = 1 \\ 0 & : \quad C_i(t) = 0 \end{cases} .$$

Approach- LEACH Implementation

4. CHs send out the advertisement broadcast, and non-CHs keep the address of the CH with the strongest signal(RSSI)

```
1:45:00.537  ID:5    [INFO: LEACH_Node] [0] Receiving advertisement broadcast from 99
```

5. After receiving all the advertisements, non-CHs send out a unicast message to the strongest neighbor CH

```
1:50:00.062  ID:85   [INFO: LEACH_Node] [0] Sending unicast response
1:50:00.062  ID:85   [INFO: LEACH_Node] [0] sent out unicast to 99
```

Approach- LEACH Implementation

6. Upon receiving unicast from the neighbors, the CH will create a TDMA schedule for the non-CH cluster members

```
2:00:00.501   ID:99   [INFO: LEACH_Node] [0] Sending TDMA schedule
```

7. The non-CH will receive the broadcast only from their strongest neighbor CHs, and start sending data using the received TDMA schedule

```
2:10:00.062   ID:85   [INFO: LEACH_Node] [0] Sending with TDMA process
```

Approach- LEACH Implementation

8. After CH receives all the data from its cluster members, it will fuse the data and send it to the edge gateway

```
2:20:00.690  ID:26   [INFO: LEACH_Node] [0] Sending fused data
```

9. Edge gateway will receive the data

```
2:20:00.717  ID:101  [INFO: App       ] Received data from cluster head: 26
```

10. All the collected data will be freed

```
2:36:40.062  ID:85   [INFO: LEACH_Node] [0] Freeing cluster neighbor information
```

Experimental Methodology

- This experiment will be done multiple times using different random seeds and placement.
- It will collect the energy consumption for 100 rounds and compare the mean of the observed values.
- The energy consumption will be observed using the energest API from Contiki-NG
- By comparing the total seconds used for listening to the radio, transmission time, and node sleep time.

Results

After running 100 times:

listen/total time	transmit/total time	off/total time
98.9114%	0.0001%	1.0886%

```
169:16:40.013   ID:69   Energest:
169:16:40.013   ID:69    CPU          606300000000s LPM       0s DEEP LPM 0s   Total time 606300000000s
169:16:40.013   ID:69    Radio LISTEN 599699602848s TRANSMIT 374152s OFF        6600023000s
```

It is listening during the time it should be sleeping, so it is not following the LEACH concept of nodes sleeping outside of their transmission time.

As I have not implemented LEACH-C protocol, I do not know the result for comparing between LEACH and LEACH-C performances.

Conclusion/Future Work

- Cooja was good for implementing LEACH, because it had an API for NullNet, which allowed simple communication between the nodes (unlike IPv6 which operates with the MAC layer)
- I would like to implement the correct energy calculation closer to the approach done by the paper
- Fix the LEACH sleep function
- Implement the LEACH-C protocol for comparison

Citations

- Amin Shahraki, Amir Taherkordi, Øystein Haugen, Frank Eliassen, Clustering objectives in wireless sensor networks: A survey and research direction analysis, Computer Networks, Volume 180, 2020, 107376, ISSN 1389-1286, https://doi.org/10.1016/j.comnet.2020.107376Links to an external site.. (https://www.sciencedirect.com/science/article/pii/S1389128620303121Links to an external site.)
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- W. B. Heinzelman, A. P. Chandrakasan and H. Balakrishnan, "An application-specific protocol architecture for wireless microsensor networks," in IEEE Transactions on Wireless Communications, vol. 1, no. 4, pp. 660-670, Oct. 2002, doi: 10.1109/TWC.2002.804190.
- keywords: {Wireless application protocol;Microsensors;Energy efficiency;Delay;Signal processing algorithms;Remote monitoring;Intelligent networks;Robustness;Wireless communication;Access protocols},