ENERGY EFFICIENT RPL ROUTING PROTOCOL IN SMART BUILDINGS

Master's Seminar

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OUTLINE

- Introduction
- Problem statement
- Es metric
- Transmission power control
- Evaluation
- Summary

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SMART OBJECT NETWORKS

- Billions of smart objects over the next ten years (Cisco and Ericsson)

- Low-power and Lossy Networks (LLNs)
  - » Restricted processing power, memory and energy
  - » Interconnected by lossy, low data rate and instable links

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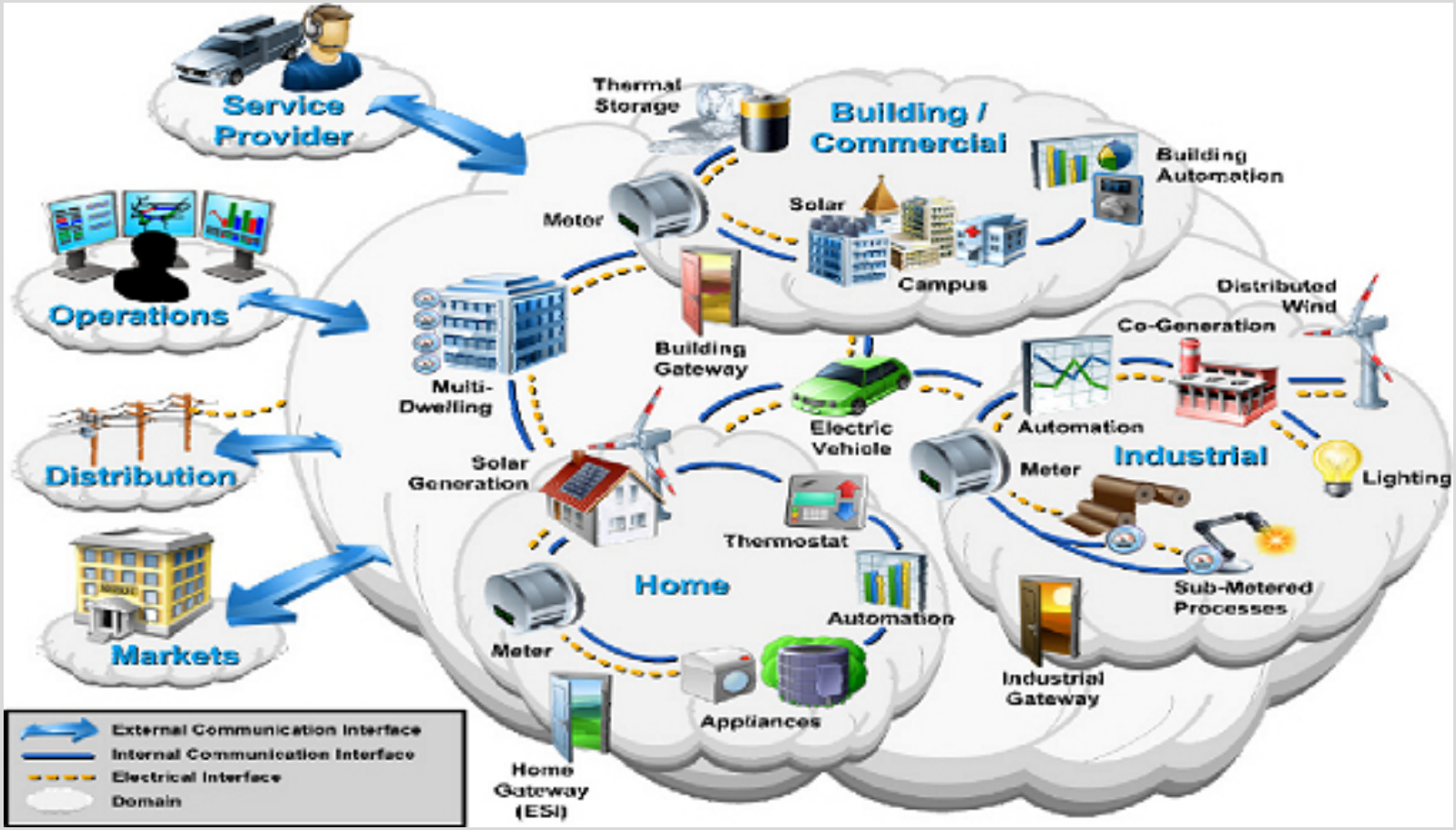
SMART OBJECT NETWORKS



Ref: www.sensorsmag.com

SMART OBJECT NETWORKS

- Different application requirements
  - » Smart homes: mainly main-powered, less interference and mobility
  - » Smart industry: mainly battery-powered, large number of nodes, more interference

- => different routing requirements

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RPL

- Routing Protocol for Low power and lossy networks (RPL)
  - » IPv6 Routing Protocol for LLNs
  - » Distance vector protocol
  - » Logical DAG routing topology

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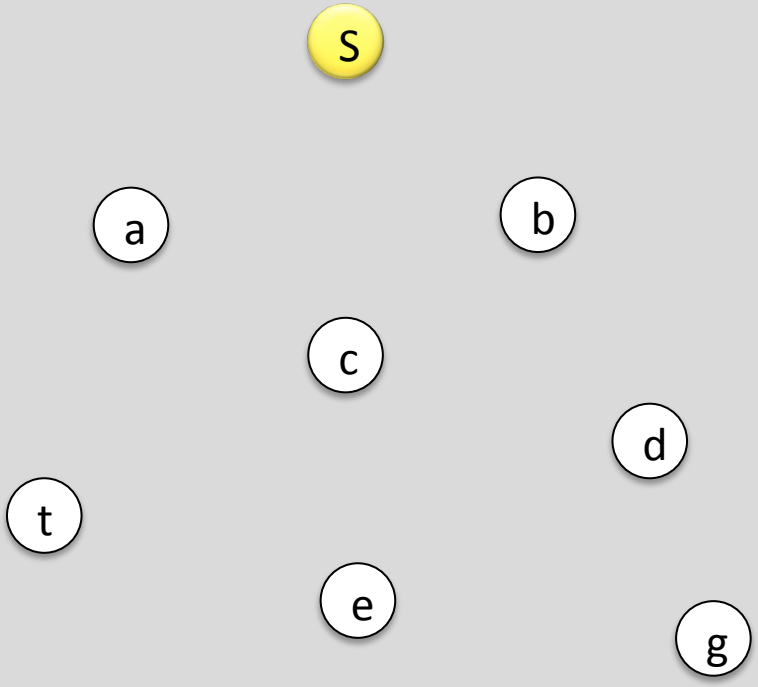
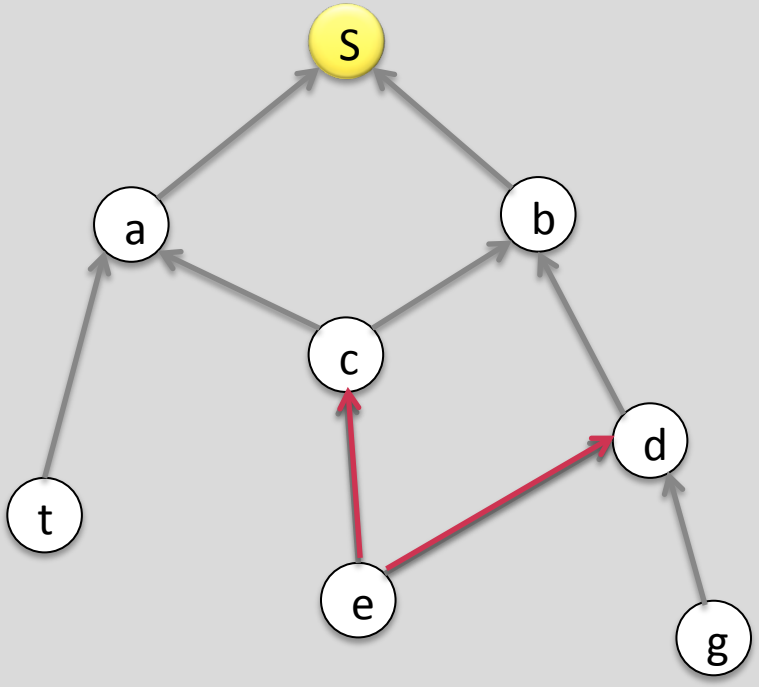
RPL

Network

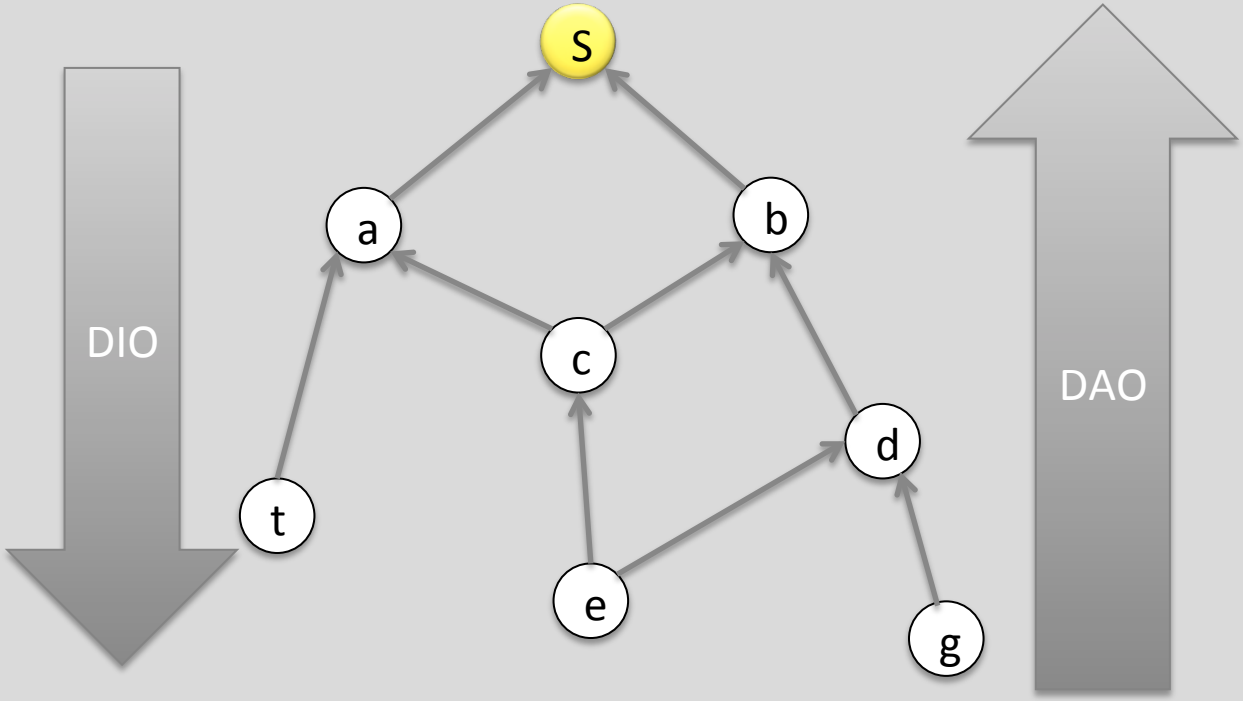


DAG



RPL

RPL supports different traffic types.



RPL

- RPL defines how to build a DAG
- Characteristics of the DAG are specified by an objective function.

ROUTING METRIC

- More routing metrics strategies are required for LLNs
  - » Objective function (OF)
  - » Routing metric/constraint
  - » Rank
- Example
  - » OF: Find the path where minimum link quality is maximized
  - » Routing metric: link quality
  - » Rank: nodes are ranked based on their link quality towards the root.

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OBJECTIVE FUNCTION

- Existing OFs
  - » Hop-count
  - » ETX (Expected number of transmission)

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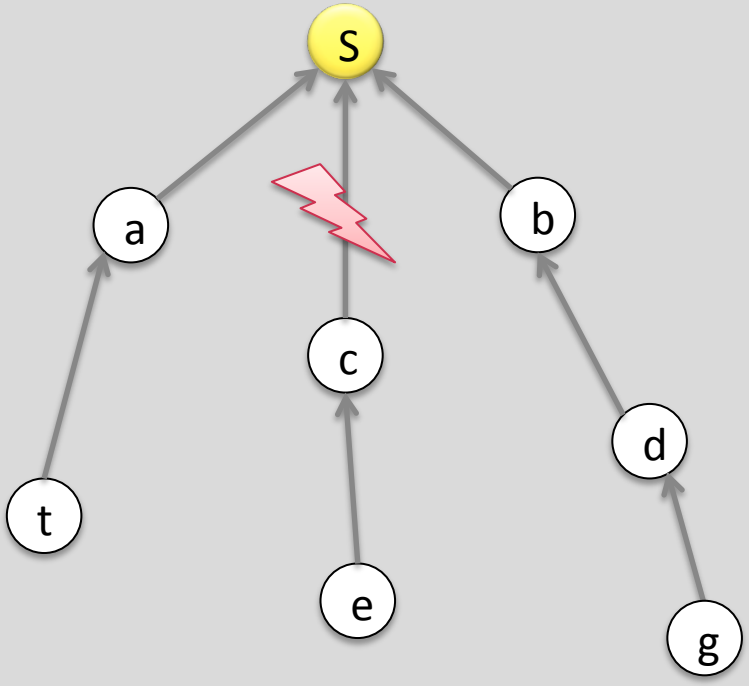
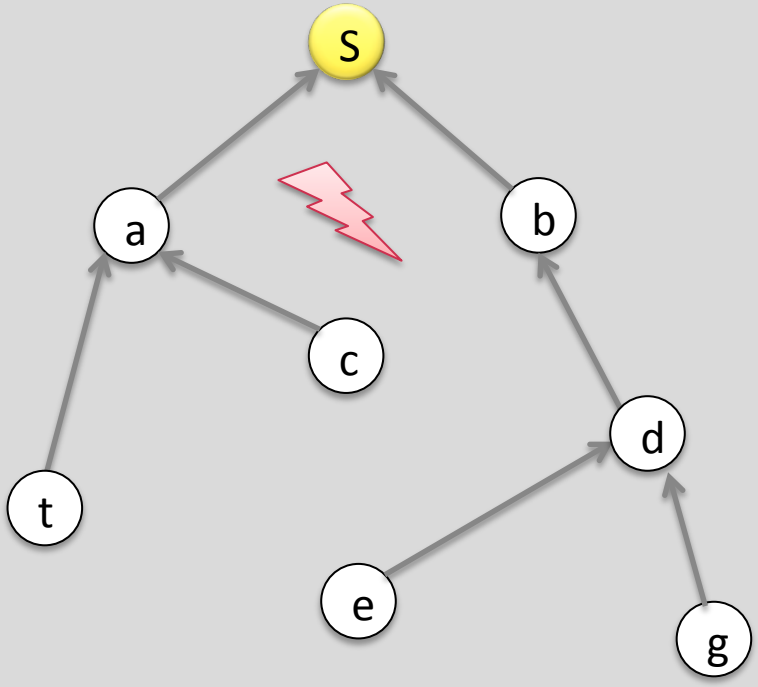
OF

Hop-Count



ETX



ES OF

- Primary constraint is energy
  - » Radio transceiver is the main energy consumer
- OF: find the best path that required transmission energy is minimized
  - » Routing metric: estimate the required energy to successfully send a packet on a link

ES METRIC

- Energy consumption for a successful transmission
  - » P: transmission power
  - » λ: link transmission rate
  - » L: packet size

$$E_s = ETX * P * \frac{L}{\lambda}$$

$$E_s = ETX * P$$

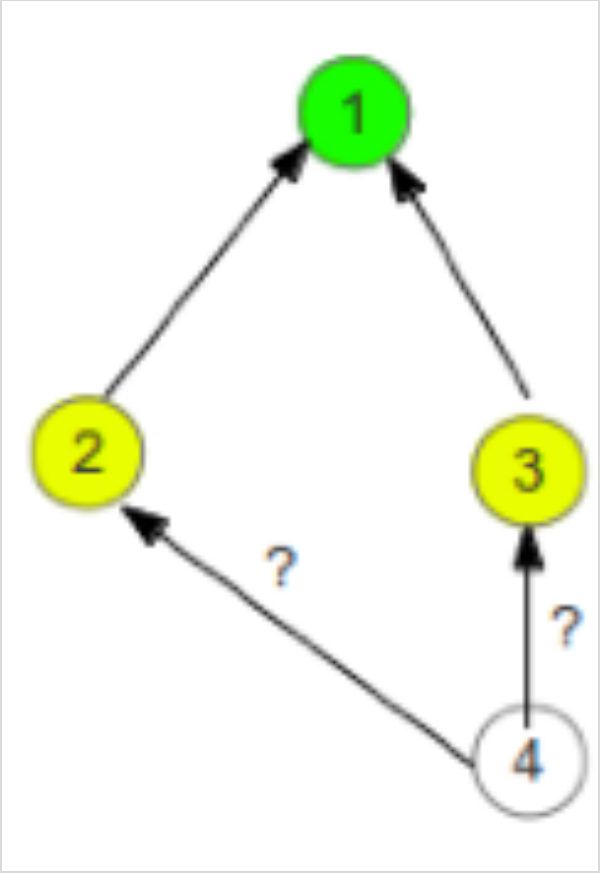
ES METRIC

Metric

$$E_s(4,2) = ETX(4,2) * P(4)$$

Path cost

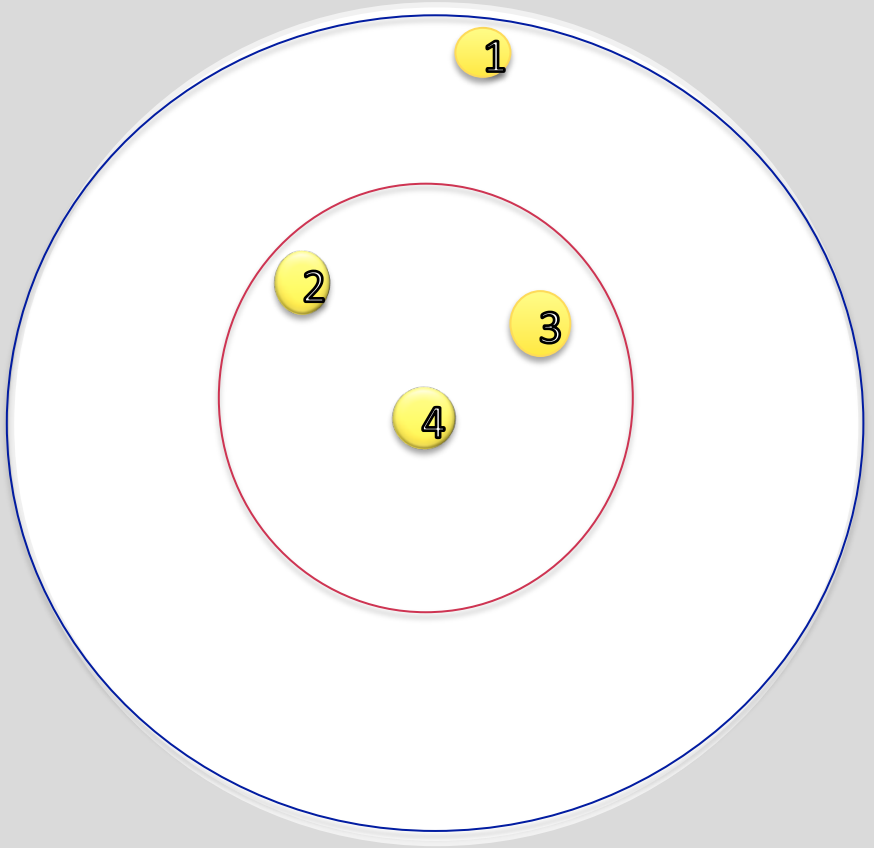
$$E_s(4,1) = E_s(4,2) + E_s(2,1)$$



TRANSMISSION POWER CONTROL

Transmission power affects

- » Link quality
- » Interference
- » Connectivity
- » Parent selection



TRANSMISSION POWER CONTROL

- Choose transmission power such that transmission energy consumption is minimized
  - » Initialization phase
  - » Environment change phase

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TRANSMISSION POWER CONTROL

Find potential preferred parent set (P_t)

Probe P_t set with different Tx

Find node and transmission power that has minimum path cost

Set transmission power and preferred parent

TRANSMISSION POWER CONTROL

- Potential preferred parent set
  - » Up to three parents

$$\hat{RSSI}(p) > -90$$

$$age(p) < 10$$

PROBING

Send N probes to node p

Receive number of transmissions by MAC layer

Compute PDR by EWMA

Return ETX=1/PDR

EVALUATION

- Design choices
  - » Cooja simulator and Contiki OS
  - » Zolertia Z1
  - » MRM propagation model

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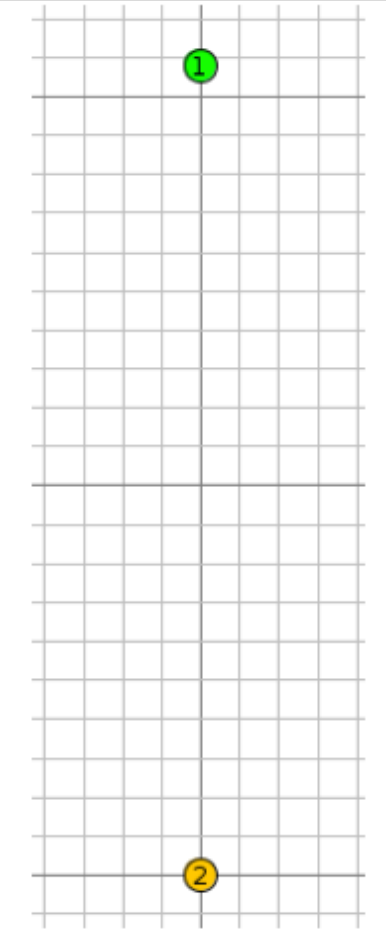
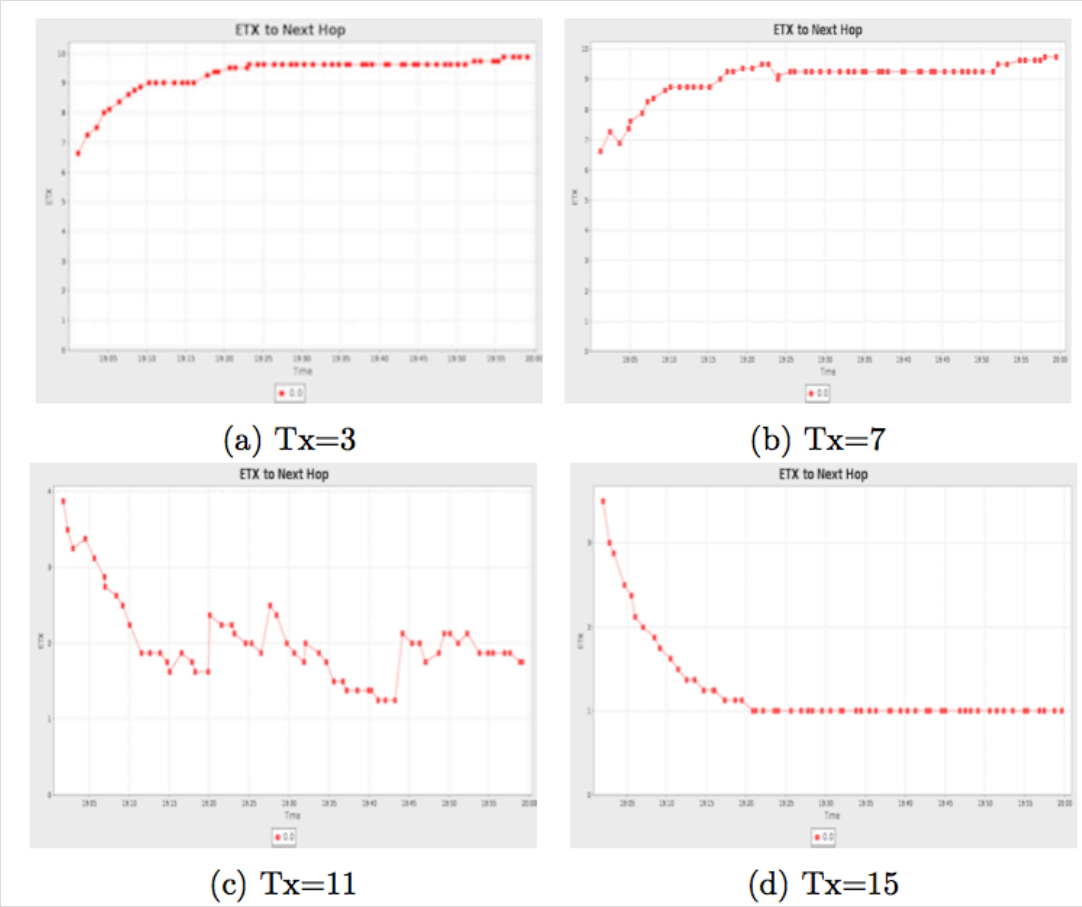
SIMULATION

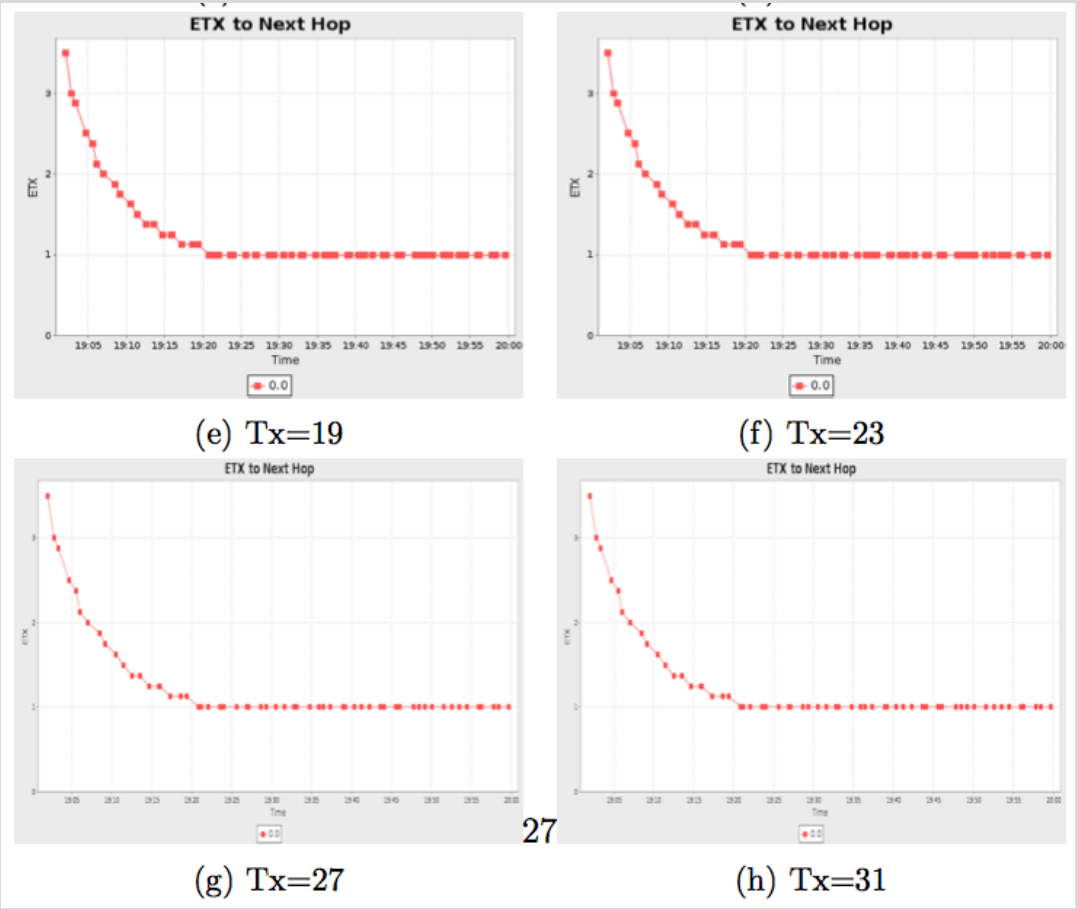
Traffic: one hello message per minute for anhour



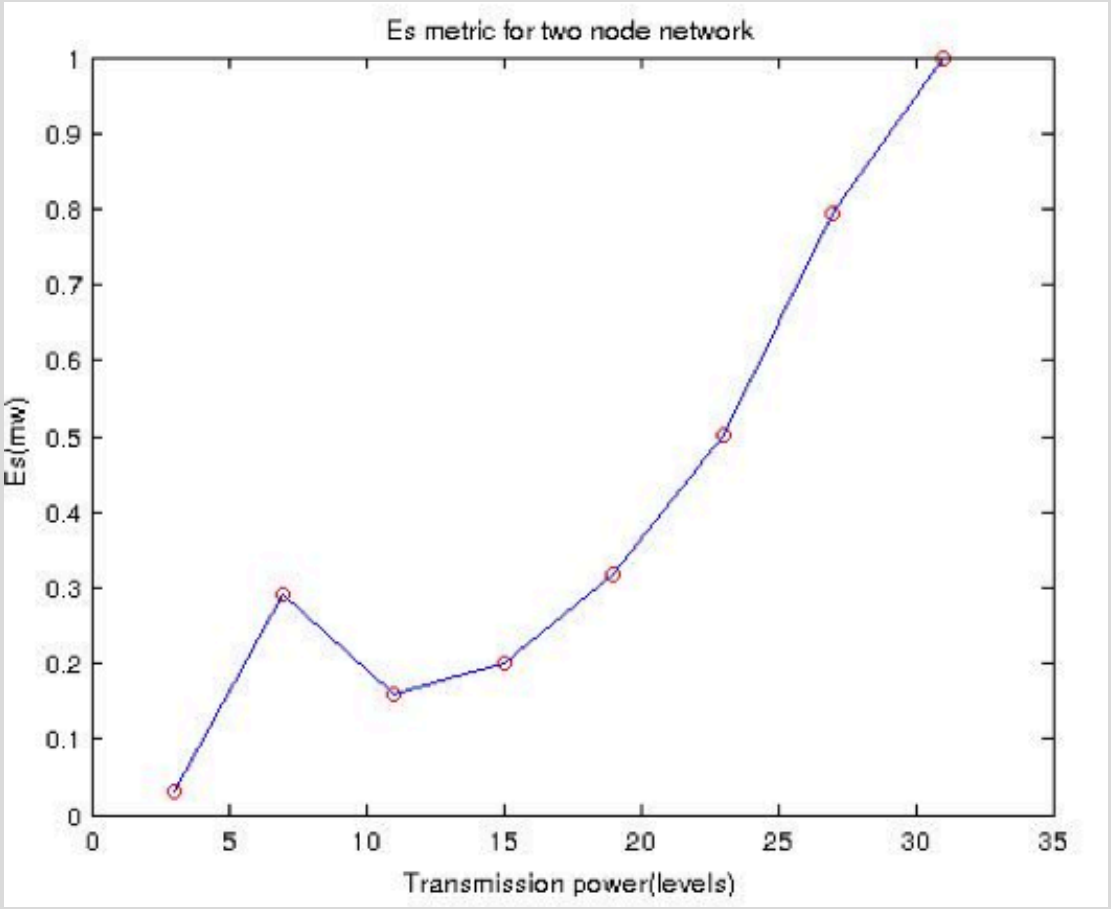
SIMULATION


ETX to Next Hop
(a) Tx=3
ETX to Next Hop
(b) Tx=7
ETX to Next Hop
(c) Tx=11
ETX to Next Hop
(d) Tx=15

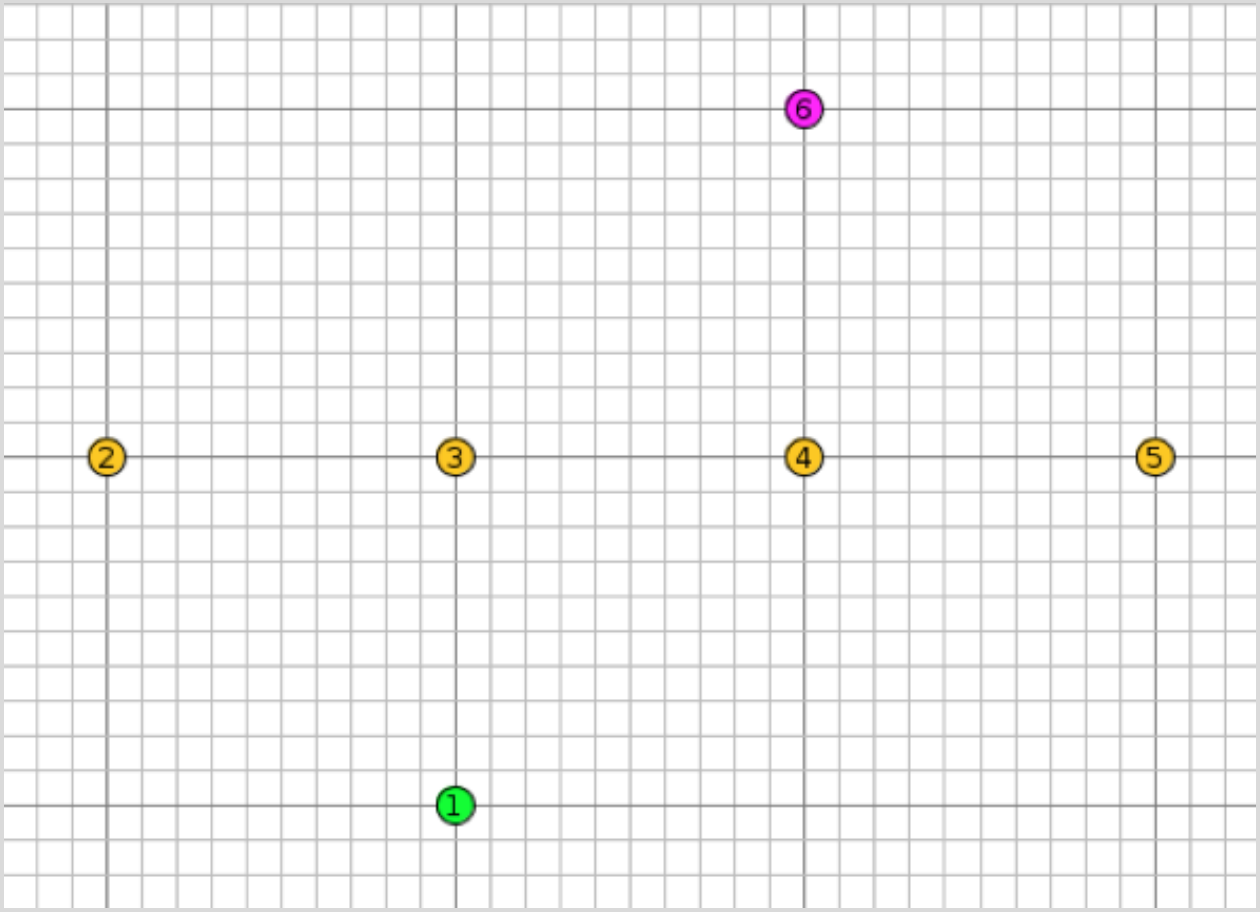
SIMULATION


ETX to Next Hop
ETX
Time
0.0
(e) Tx=19
ETX to Next Hop
ETX
Time
0.0
(f) Tx=23
ETX to Next Hop
(g) Tx=27
ETX to Next Hop
(h) Tx=31

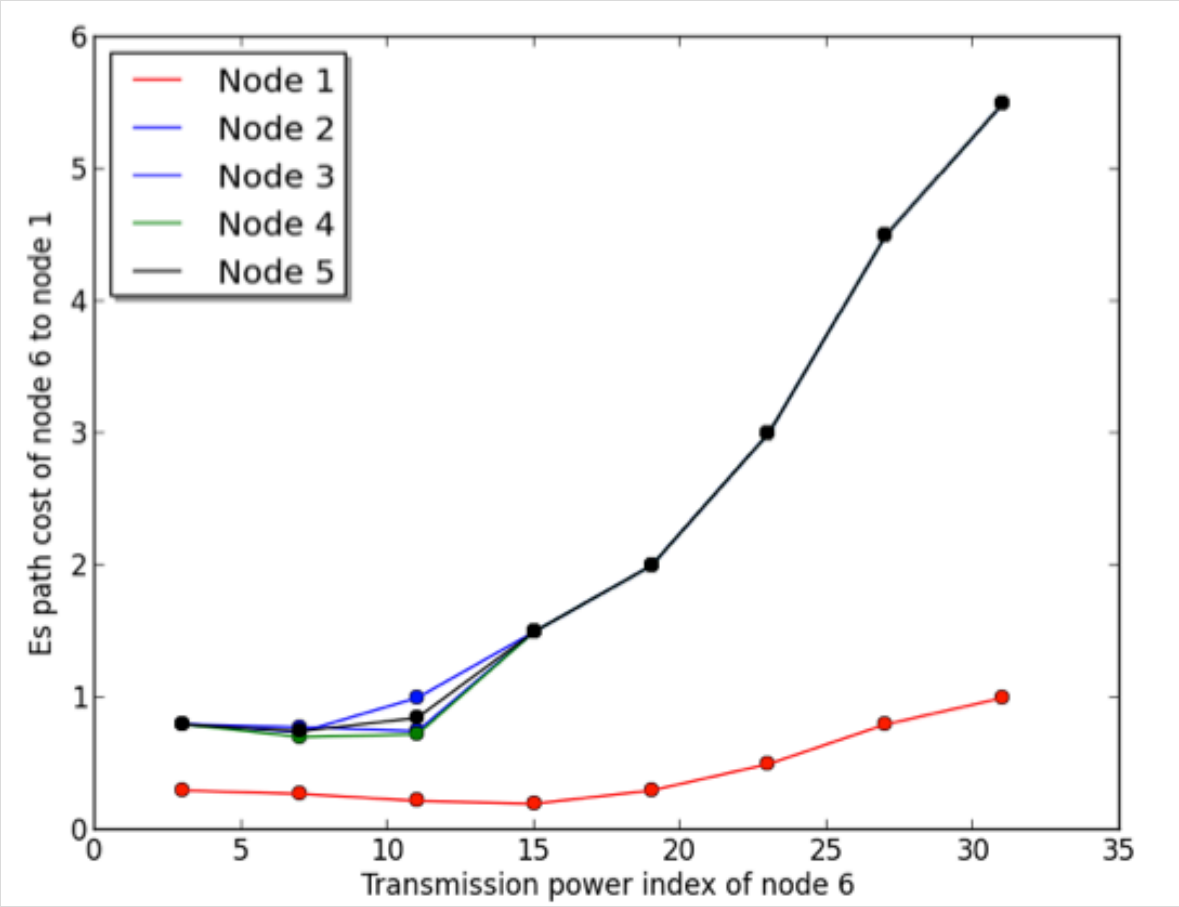
SIMULATION


Es metric for two node network
Es(mw)
Transmission power(levels)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
5
10
15
20
25
30
35

SIMULATION



SIMULATION


Node 1
Node 2
Node 3
Node 4
Node 5
Es path cost of node 6 to node 1
Transmission power index of node 6
0
1
2
3
4
5
6
0
5
10
15
20
25
30
35

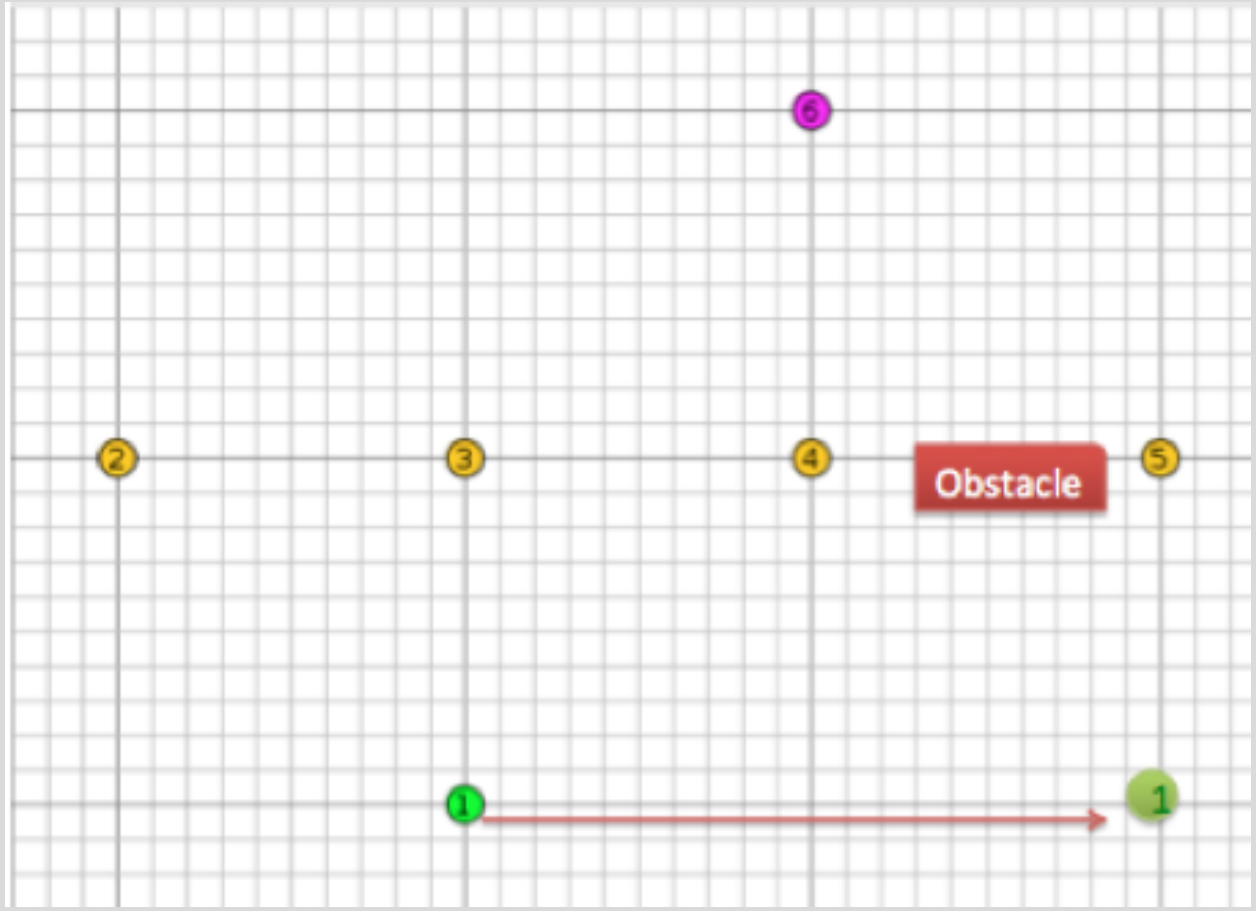
NETWORK ENERGY CONSUMPTION

- Standard RPL energy consumption was 3.41mJ

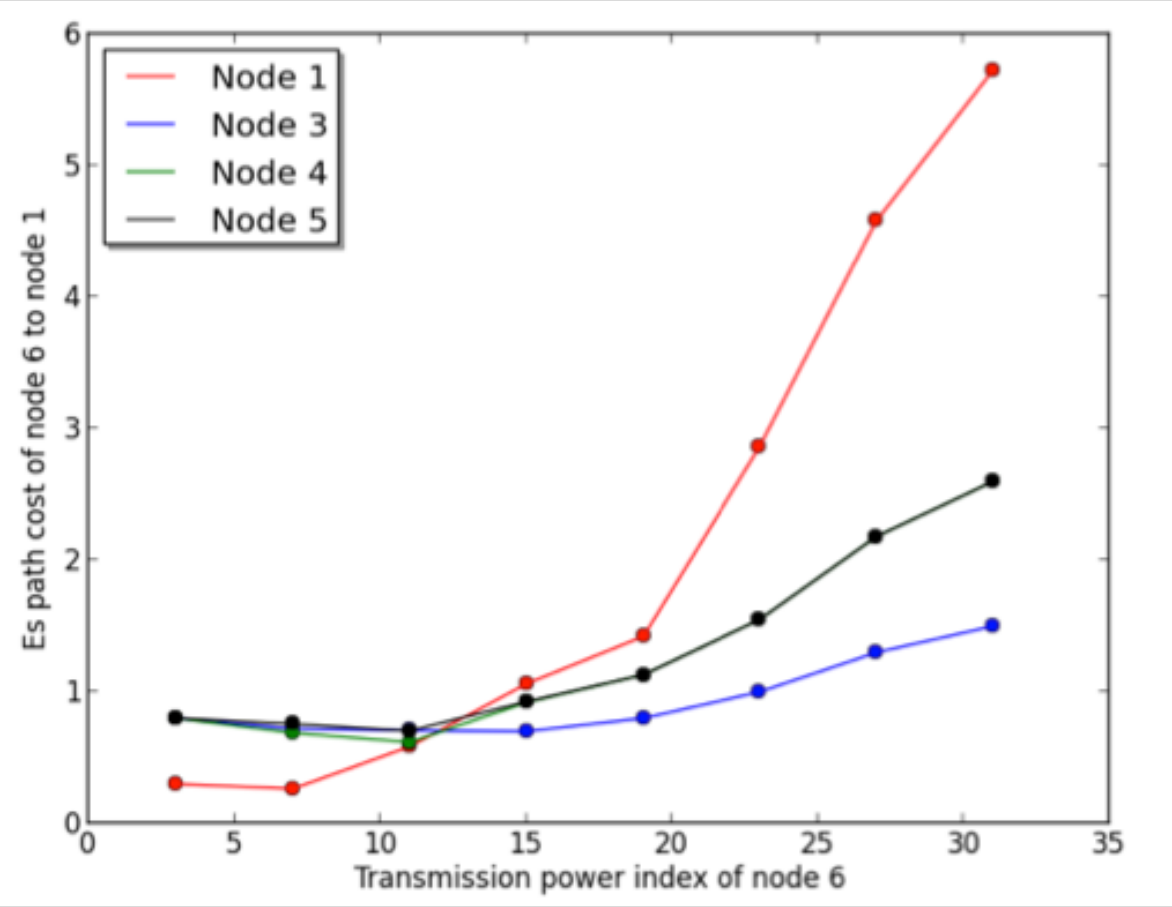
Tx	3	7	11	15	19	23	27	31
Energy	-	3.78	2.74	2.53	2.62	2.83	3.18	3.41

- 26% improvement

SIMULATION



SIMULATION

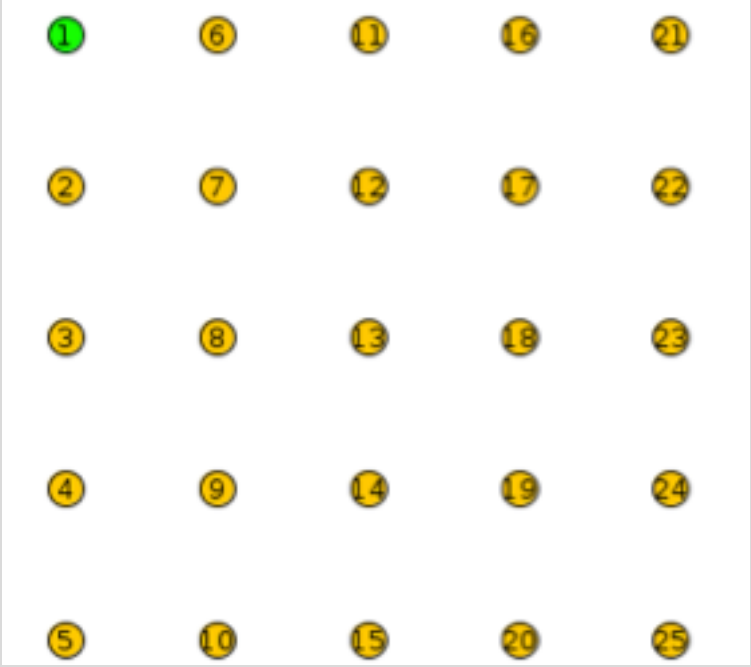

Node 1
Node 3
Node 4
Node 5
Es path cost of node 6 to node 1
Transmission power index of node 6
0
1
2
3
4
5
6
0
5
10
15
20
25
30
35

- The total energy consumption of standard RPL is 9.87mJ.

Tx	3	7	11	15	19	23	27	31
Energy	-	4.980	3.524	3.904	4.183	5.374	6.866	7.886

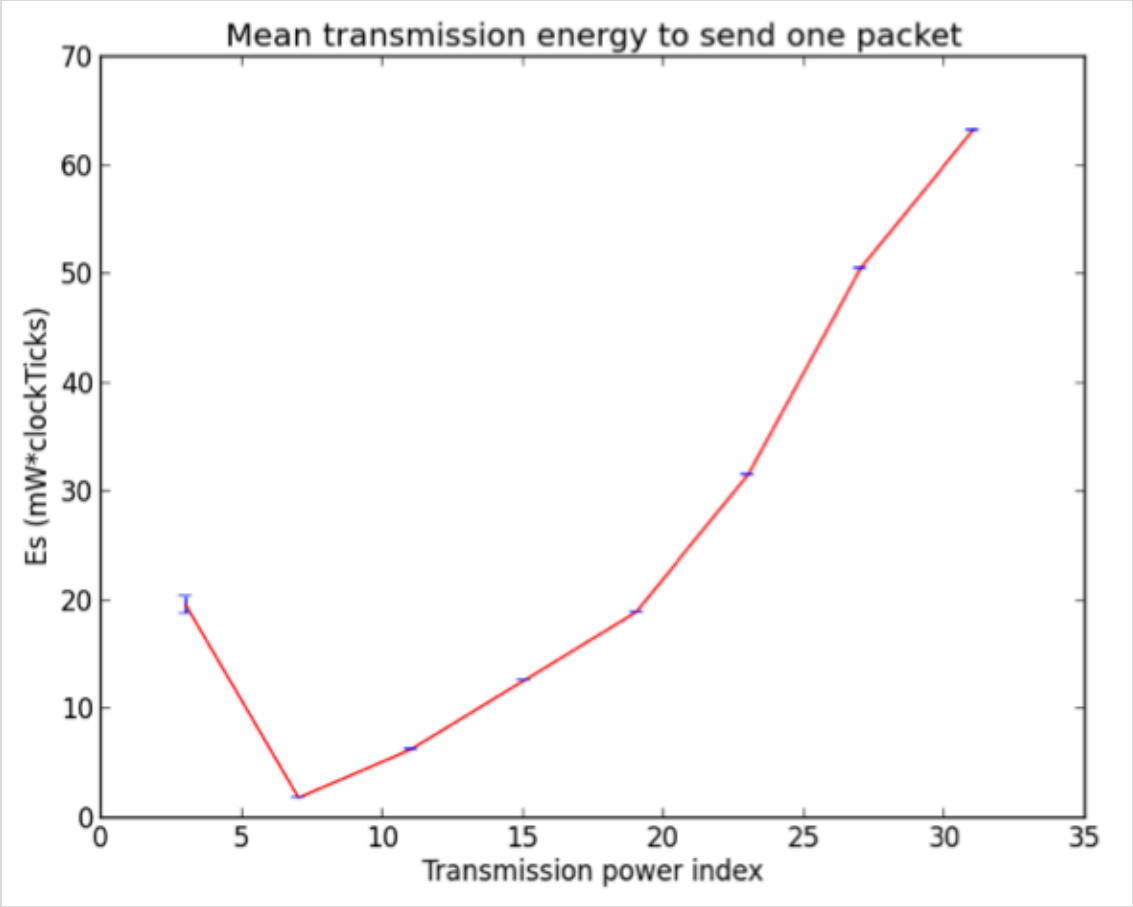
=> 36% improvement

SIMULATION



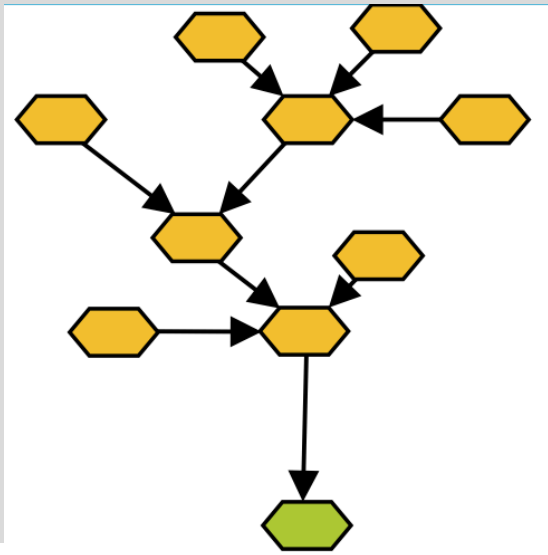
- 12% energy consumption improvement.

IMPLEMENTATION



CONCLUSION

- Designing an energy-aware objective function for smart buildings
- Designing energy-aware transmission power control in RPL



FUTURE WORK

- Including the energy balanced property in Es metric (energy efficiency)
- Modeling ETX probing