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A novel context-aware RPL algorithm based on a triangle module operator

Key words: Triangle module operator; Membership function; Context-aware; Routing protocol for low-power and lossy networks (RPL); Routing metrics

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Motivation

- Routing protocol for low-power and lossy networks (RPL) is a valuable tool for networks with harsh and complex communication conditions.
- In this paper, we propose a novel context-aware RPL algorithm based on the triangle module operator (CAR-TMO). CAR-TMO includes the novel composite context-aware routing metric (CA-RM), novel membership functions, a new comprehensive context-aware objective function (CA-OF), novel rank calculation mechanisms, and novel preferred parent (next hop) selection mechanisms. Through these newly designed mechanisms, CAR-TMO can improve the network performance.

Contents

1. Designing novel composite CA-RM:

(1) Synchronously evaluating the residual energy index (REI), buffer occupancy ratio (BOR), expected transmission count (ETX), delay (D), and hop count (HC);

(2) REI and BOR of a candidate parent and their next hop should be evaluated recursively to reduce the influence of upstream parents;

(3) The sum, mean, and standard deviation of ETX and D of links can be synthetically used in a lexical manner to ensure a better performance.

2. Designing novel membership functions of routing metrics.

3. Constructing a comprehensive membership function based on the triangle module operator.

Contents

4. Designing a comprehensive CA-OF based on the comprehensive membership function, maximum membership principle, and network characteristics.
5. Designing novel rank calculation mechanisms based on CA-OF.
6. Proposing novel preferred parent selection mechanisms according to CA-OF, rank, and the candidate parent set number.
7. Implementing simulation evaluations of CAR-TMO and state-of-the-art algorithms.

Major results

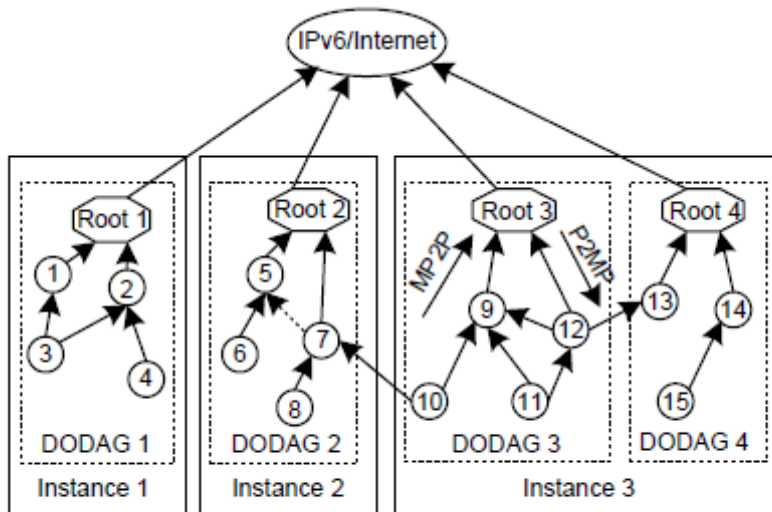


Fig. 1 RPL network topology with four DODAGs in three instances

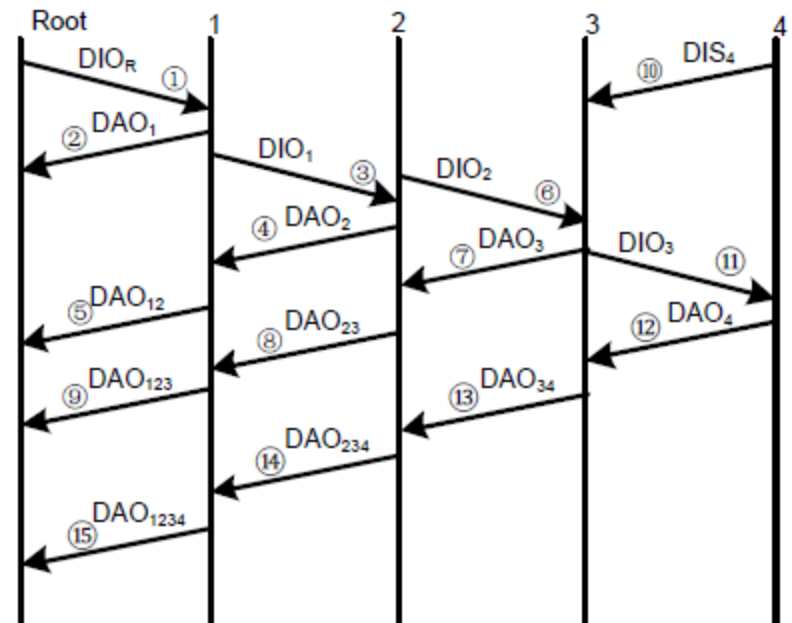


Fig. 2 DODAG simple construction process

Major results

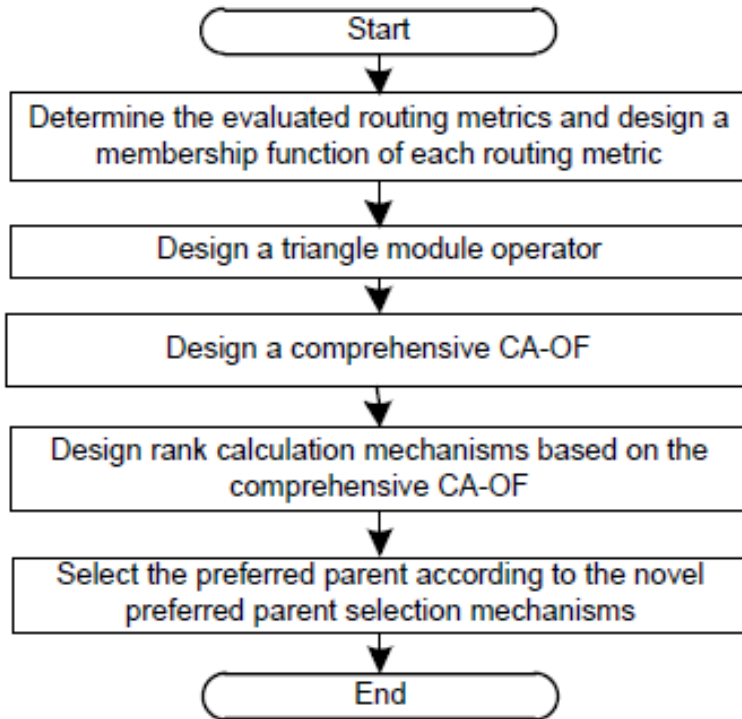


Fig. 5 CAR-TMO flowchart

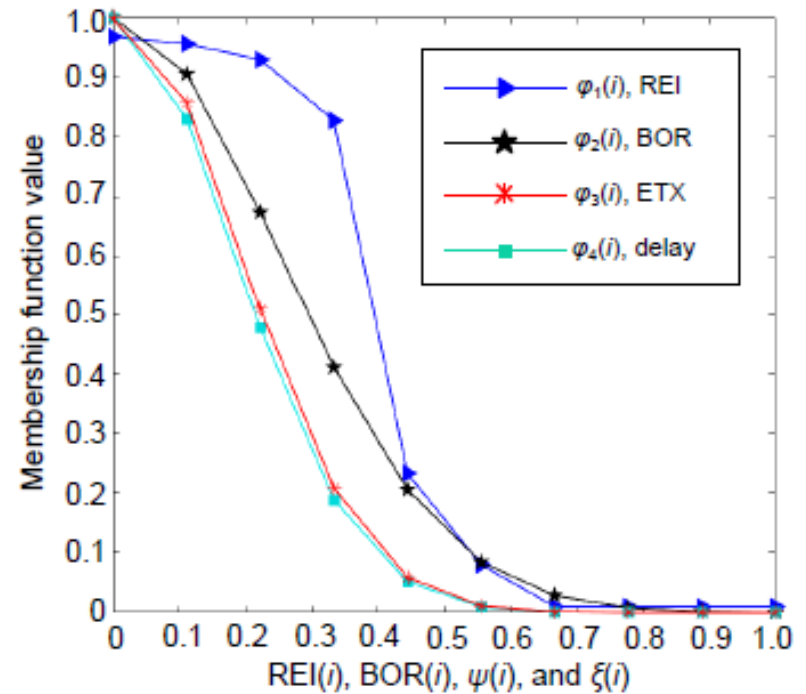


Fig. 6 Membership function curves

Major results

Triangle module operator

$$f[\varphi_1(i), \varphi_2(i), \varphi_3(i), \varphi_4(i)] = \frac{\prod_{j=1}^4 \varphi_j(i)}{\prod_{j=1}^4 \varphi_j(i) + \prod_{j=1}^4 (1 - \varphi_j(i))}$$

Novel comprehensive CA-OF

$$OF_{CA}(i) = \frac{1}{f[\varphi_1(i), \varphi_2(i), \varphi_3(i), \varphi_4(i)] + 1}, \quad i = 1, 2, \dots, n,$$

$$OF_{CA} = \min \{OF_{CA}(i)\}, \quad i = 1, 2, \dots, n.$$

Novel rank calculation method

$$R_c(i) = R_{cp}(i) + (OF_{CA}(i) + 1), \quad i = 1, 2, \dots, n.$$

Simulation results

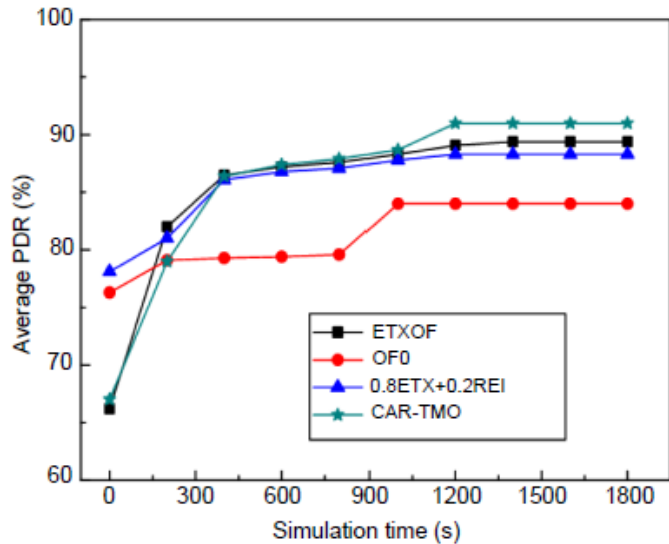


Fig. 7 Average packet delivery ratio (PDR)

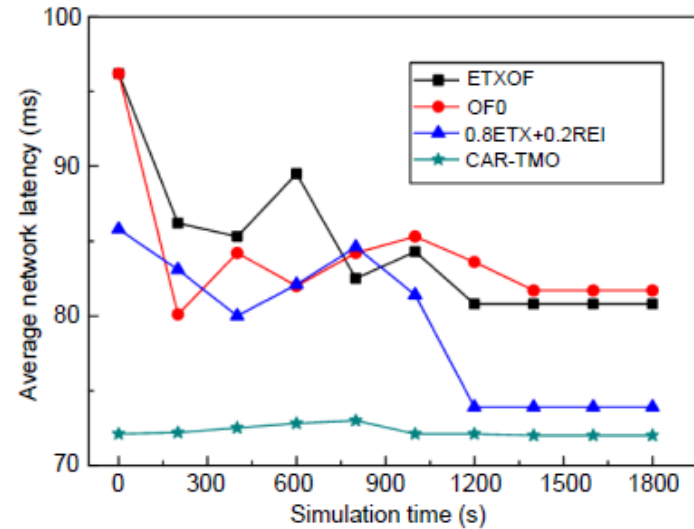


Fig. 9 Average network latency

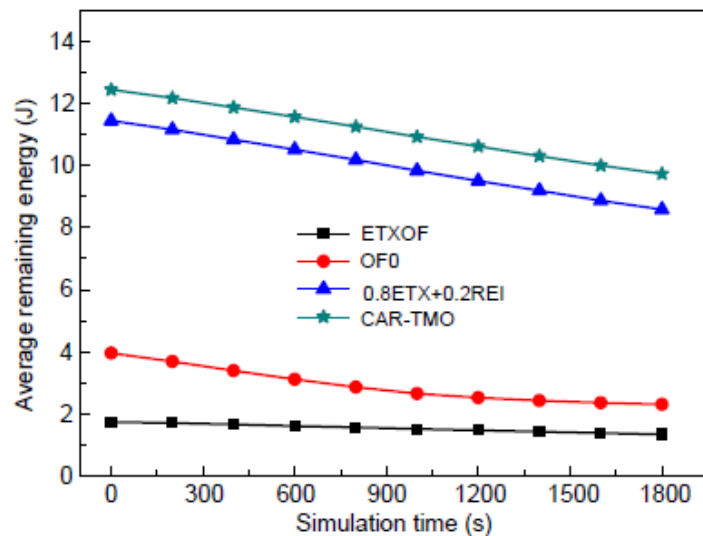


Fig. 12 Average remaining energy

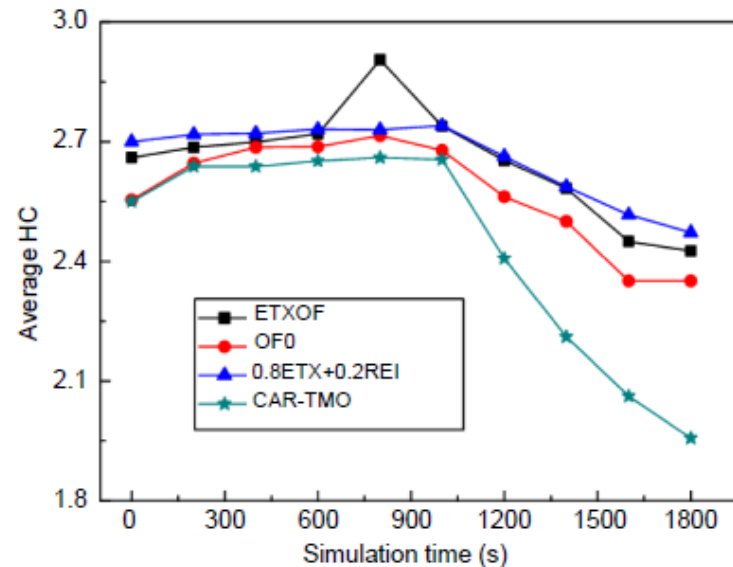


Fig. 14 Average hop count (HC)

Conclusions

- Our scientific work focuses on RPL used in networks under harsh and complex communication conditions.
- A novel context-aware RPL algorithm based on the triangle module operator (CAR-TMO) was designed.
- Theoretical analysis and simulation of CAR-TMO and several state-of-the-art RPL algorithms were conducted.
- Results showed that CAR-TMO outperforms several state-of-the-art RPL algorithms in terms of the packet delivery ratio, energy efficiency, etc. CAR-TMO can improve the network performance and guarantee the network topology stability.