Yanan CAO, Hao YUAN, 2021. A novel context-aware RPL algorithm based on a triangle module operator. *Frontiers of Information Technology & Electronic Engineering*, 22(12):1583-1597. https://doi.org/10.1631/FITEE.2000658

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

Corresponding author: Hao YUAN
E-mail: yuanhao19880520@163.com
ORCID: https://orcid.org/0000-0001-5781-9816

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

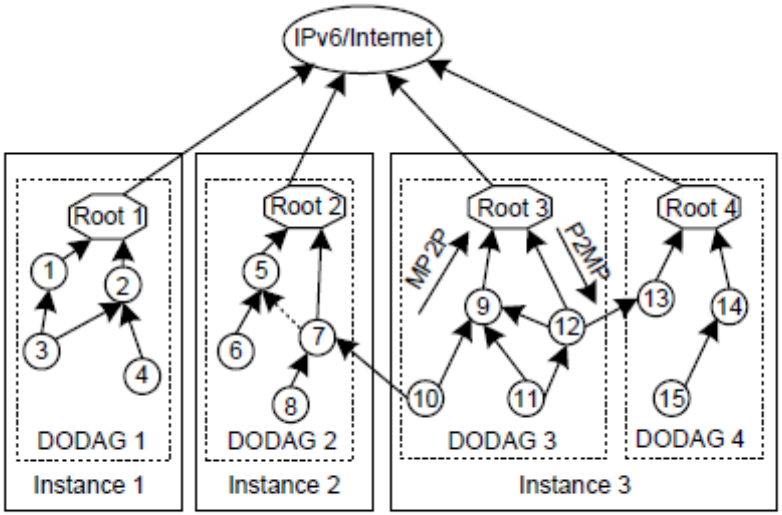

Fig. 1 RPL network topology with four DODAGs in three instances

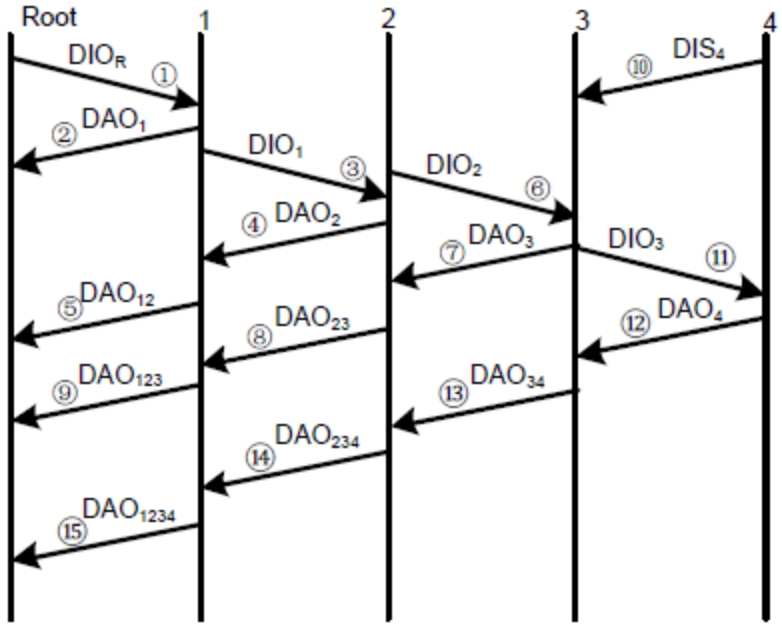

Fig. 2 DODAG simple construction process

Major results

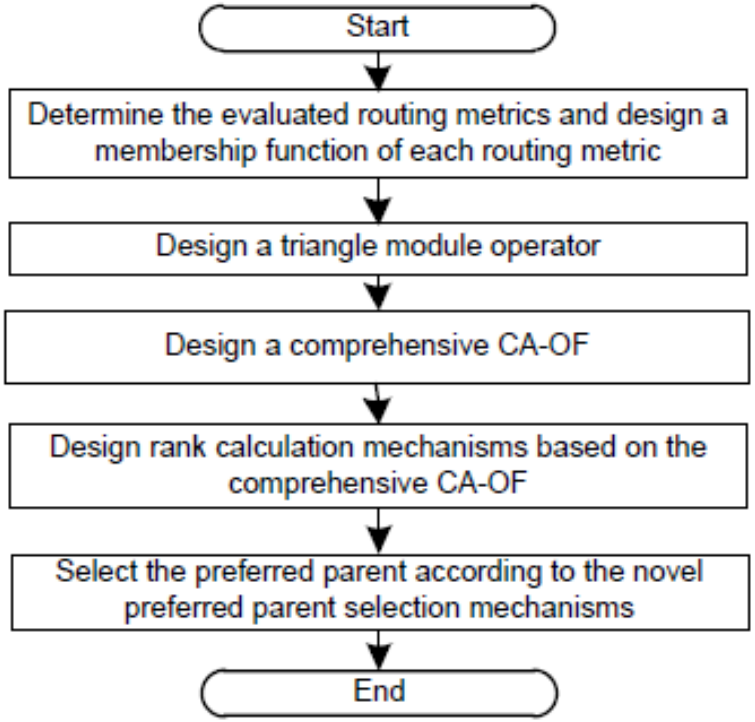

Fig. 5 CAR-TMO flowchart

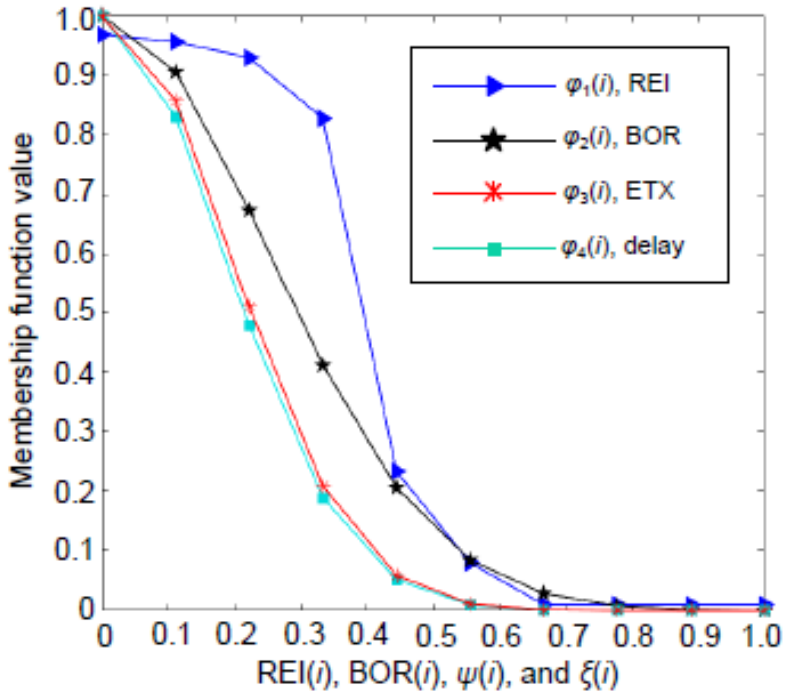

Fig. 6 Membership function curves

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

$$\mathrm{OF}_{\mathrm{CA}}(i)=\frac{1}{f[\varphi_1(i),\ \varphi_2(i),\ \varphi_3(i),\ \varphi_4(i)]+1},\ i=1,2,\cdots,n,$$

$$\mathrm{OF}_{\mathrm{CA}}=\min\left\{\mathrm{OF}_{\mathrm{CA}}(i)\right\},\ i=1,2,\cdots,n.$$

Novel rank calculation method

$$R_c(i)=R_{\mathrm{cp}}(i)+(\mathrm{OF}_{\mathrm{CA}}(i)+1),\quad i=1,2,\cdots,n.$$

Simulation results

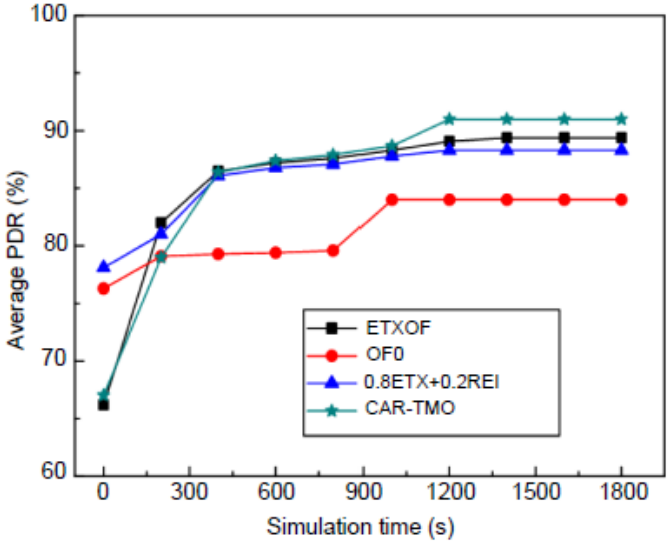

Fig. 7 Average packet delivery ratio (PDR)

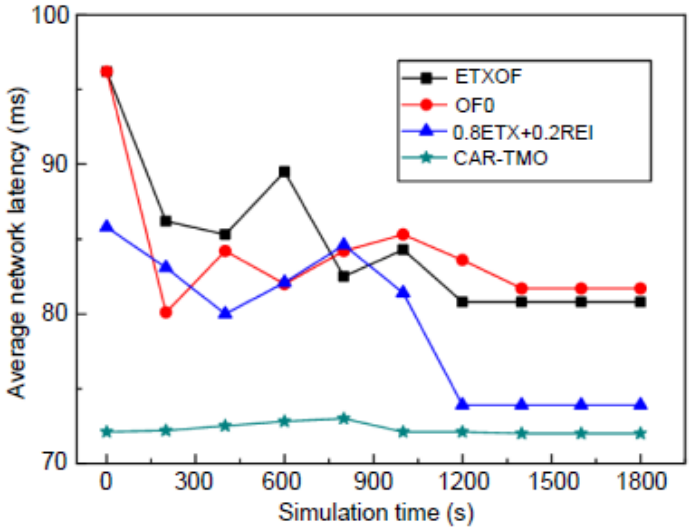

Fig. 9 Average network latency

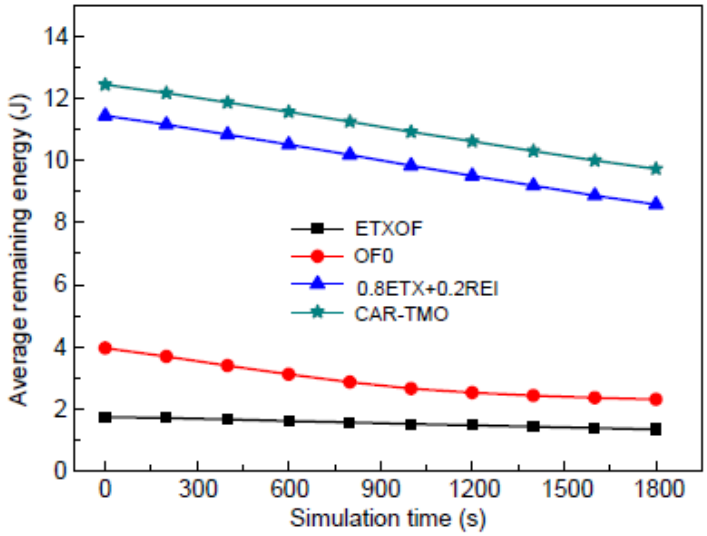

Fig. 12 Average remaining energy

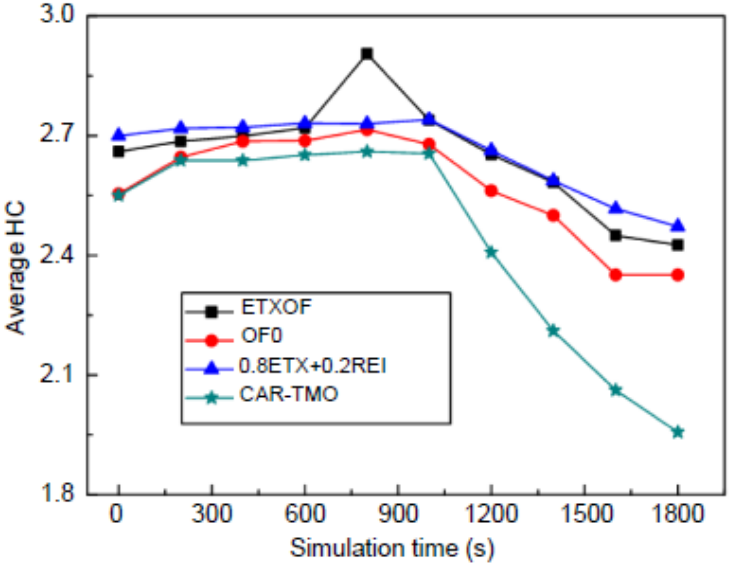

Fig. 14 Average hop count (HC)

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.