International Symposium on Performance Evaluation of Wireless Ad Hoc, Sensor, and Ubiquitous Networks

ROPS: Recursively Optimized Prepartitioning Strategy to allocate Key Devices Positions in Large-Scale RF Mesh Networks

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Contents

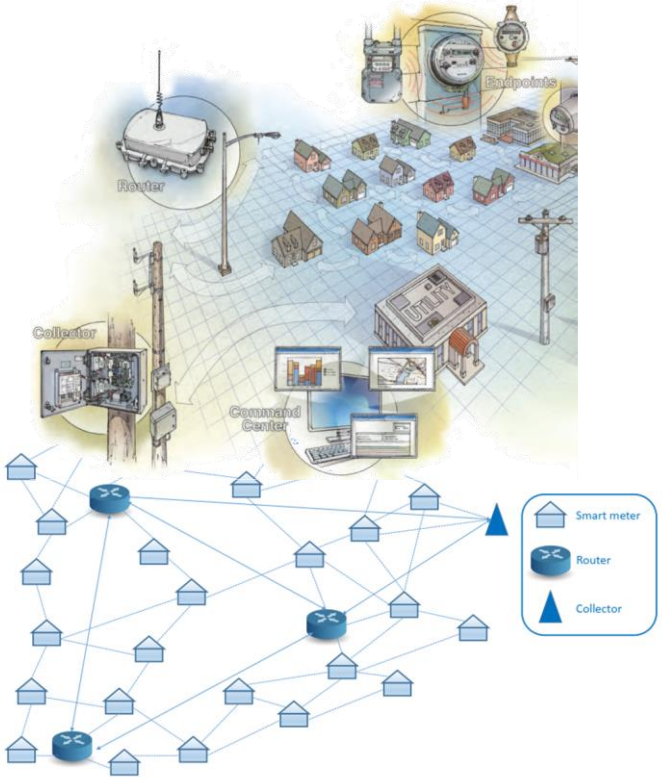
Introduction

Importance

- RF – Mesh networks are extensively used in smart grids
- Physical locations of "Key devices" impacts the overall communication performance

Contribution

- We propose a recursive partitioning approach to positioning key devices in large-scale RF - Mesh networks with emphasis on reducing its execution time



Goal

Reduce the computational time of our optimization algorithm without affecting QoS metrics

Evolution of our work

Optimal position of key devices in RF mesh networks

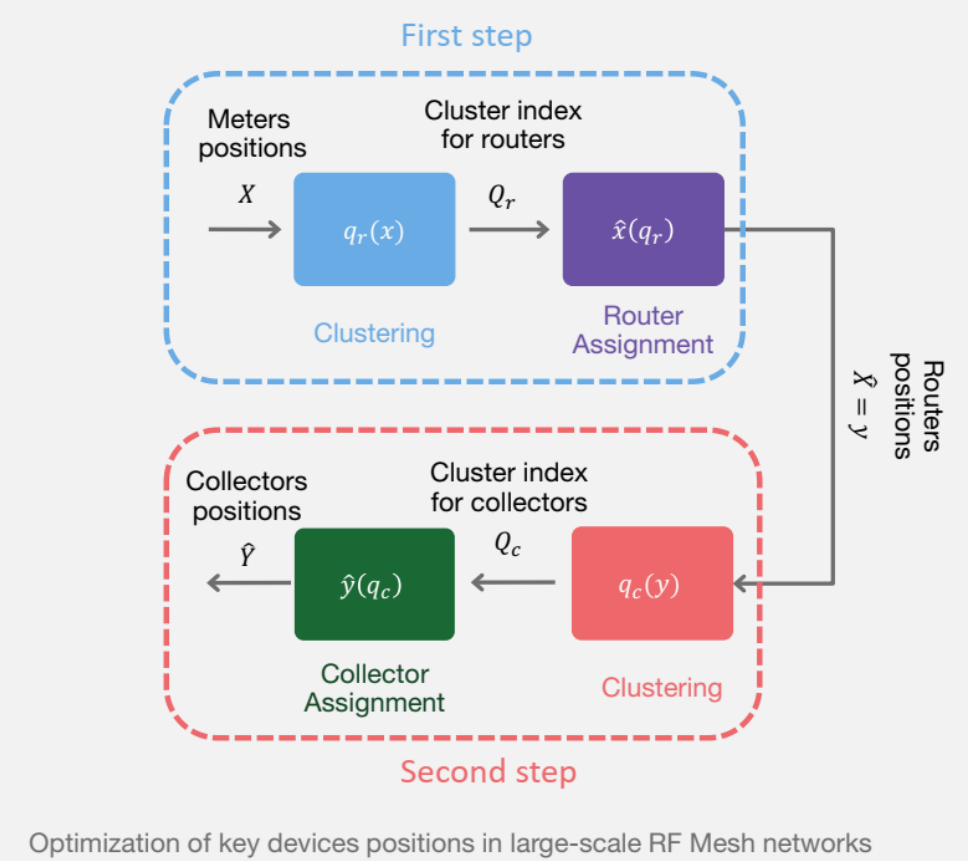
Ahmad Mohamad Mezher, Nisha Rajendran, Pedro Enrique Iturria Rivera, Carlos Lester Dueñas Santos, Julian Meng, and Eduardo Castillo Guerra. 2019. Optimization of Key Devices Positions in Large-Scale RF Mesh Networks. In *Proceedings of the 16th ACM International Symposium on Performance Evaluation of Wireless Ad Hoc, Sensor, Ubiquitous Networks (PE-WASUN '19)*.

Computational efficiency strategy. OPS : Optimized Prepartitioning Strategy

Ahmad Mohamad Mezher, Pedro Enrique Iturria Rivera, Julián Cárdenas-Barrera, Julian Meng, and Eduardo Castillo Guerra. 2020. Efficient strategy to optimize key devices positions in large-scale RF mesh networks. *Ad Hoc Networks* 106 (sep 2020), 102192. https://doi.org/10.1016/j.adhoc.2020.102192

Improvement of Computational efficiency strategy. ROPS

OPS: Optimized Prepartitioning Strategy



Optimization of key devices positions in large-scale RF Mesh networks

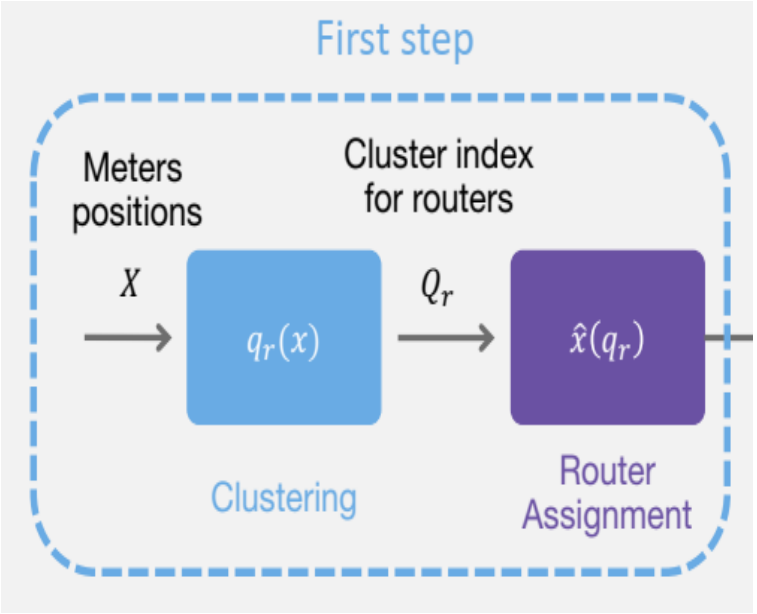
The execution time of the proposed strategy is proportional to :

- ✓ The total number of end nodes
- ✓ The number of routers
- ✓ The number of collectors
- ✓ The number of iterations of k-means clustering technique

Speedup 13 times at a negligible cost in terms of average percentage of packet delivery ratio and end-to-end delay

ROPS: Recursively Optimized Prepartitioning Strategy

The target is to further reduce the running time of the first step of the previous designed strategy applying prepartitioning recursively for *j* number of steps



The total execution time after applying our optimized pre-partitioning strategy for a general case with *j* steps will then be:

$$t_j = 2i\left(m\sum_{i=1}^{j} d_i + \frac{rm}{\prod_{i=1}^{j} d_i}\right)$$

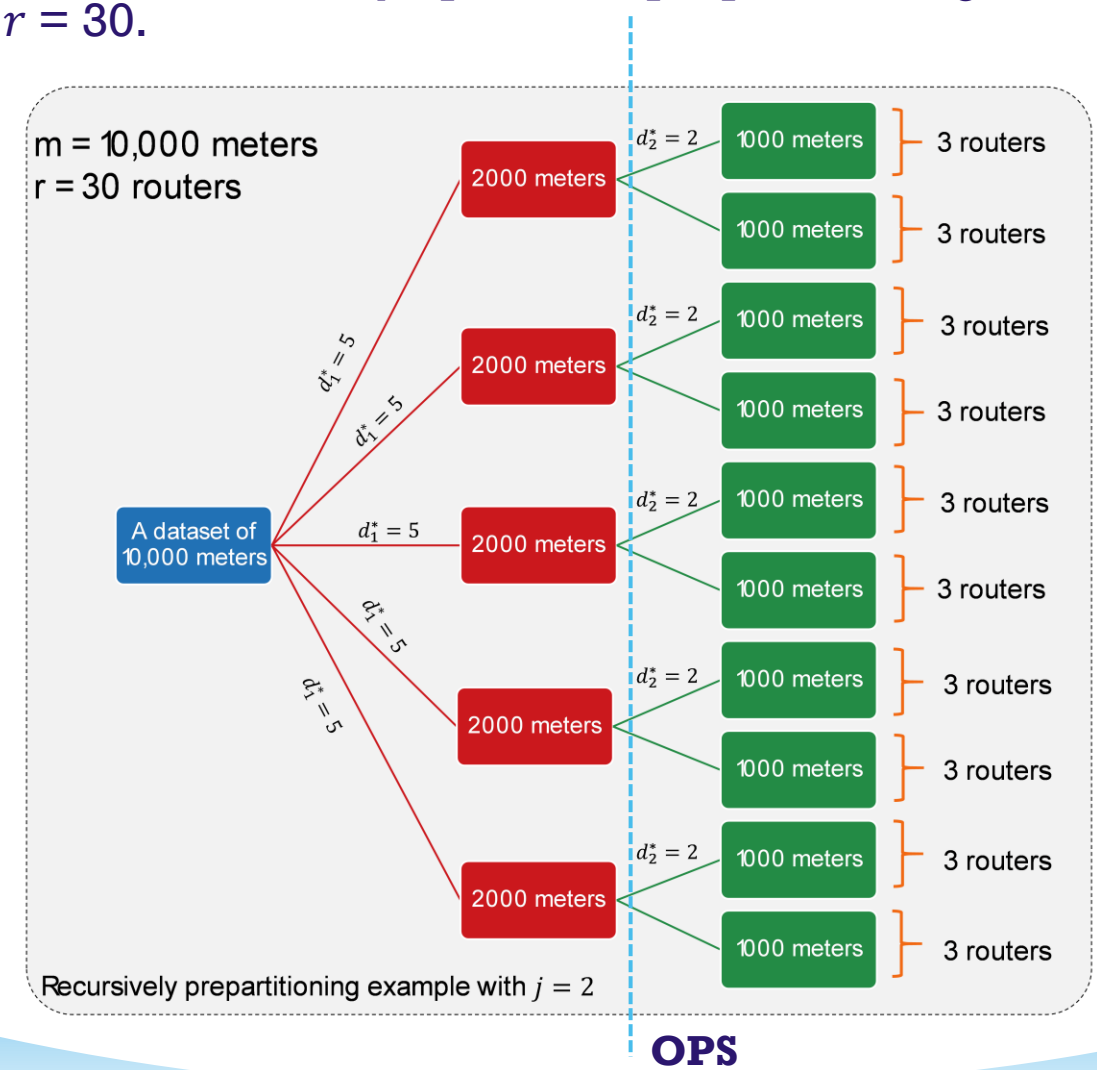
- m *is the total number of end nodes*
- r *is the number of routers*
- j *is number of steps or recursive calls*
- tj *is the running time after applying pre-partitioning with j steps,*
- dj *is number of prepartitions values d1, d2, ….dj after applying pre-partitioning with j steps*

The optimal value of dj for *j* steps is:

$$d_j^* = r^{\frac{1}{2^j}} \xrightarrow{j=1} d_1^* = \sqrt{r} \xrightarrow{j=2} d_2^* = \sqrt{\sqrt{r}}$$

ROPS: Recursively Optimized Prepartitioning Strategy

An example of the recursively optimized prepartitioning strategy with $m = 10,000$ and $r = 30$.

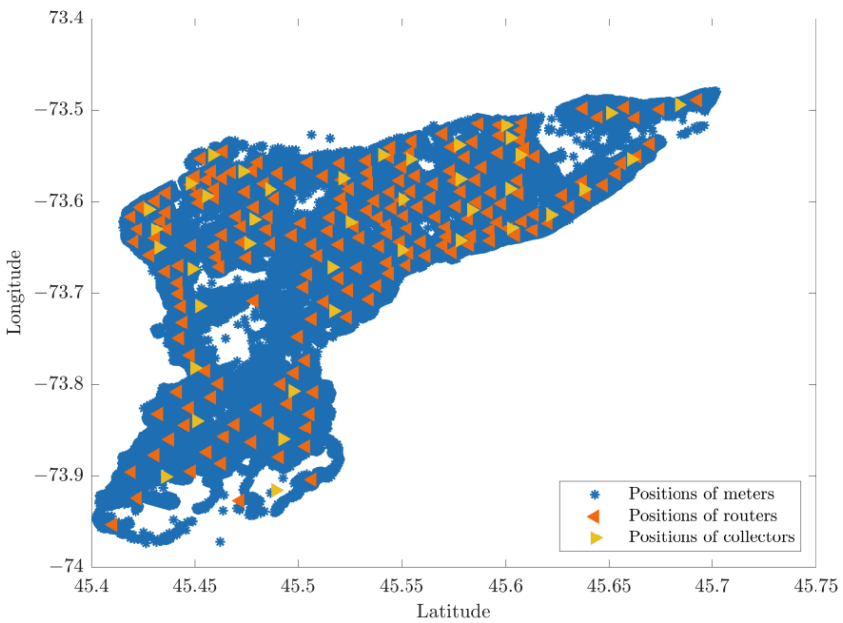


Experimental description

Scenario: A public dataset from Montreal City, Canada.

Part I: Apply ROPS to get the optimal positions of routers and collectors and compare the speedup with previous strategies.

Part II: Use the positions from the first part to analyze the network performance in QoS terms.



Map zone	Montreal city
Area	431 km^2
Number of AMIs	335297
Number of routers	196
Number of collectors	40
Transmission range of AMI	300 m
Transmission range of Router	2500 m
Transmission range of Collector	3218 m
MAC specification	IEEE 802.15.4
Carrier Frequency	915 MHz
Transmission bit rate	115.2 kbps
Packet size	1000 bits
Simulation time	18000 s
Routing protocol	Geographical routing protocol [3]

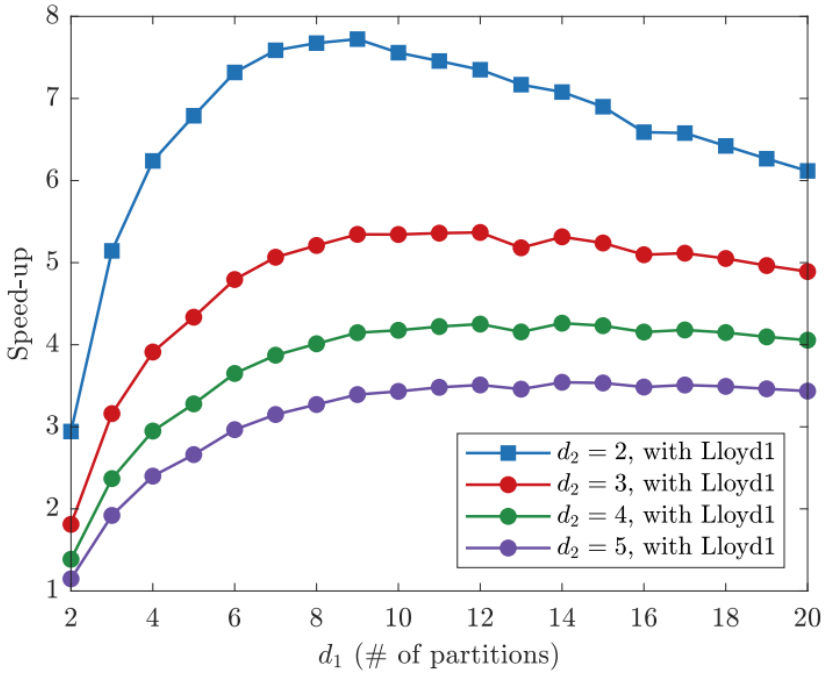
Network simulator: OMNeT++

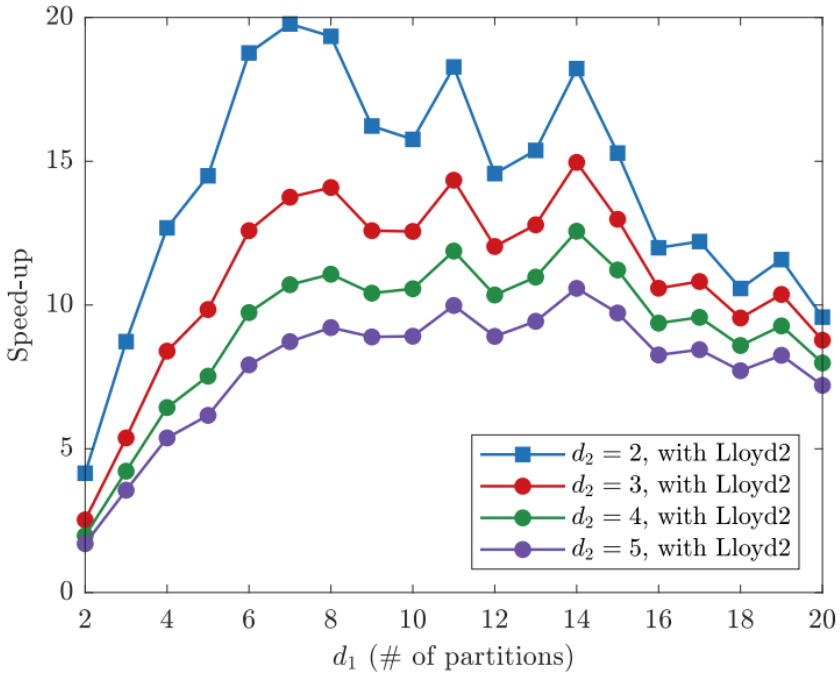
Experimental results (Part I)

Experimental speed-up for different number of prepartitions $d1$ and $d2$ using two implementations of the Lloyd algorithm, Lloyd1 (left) and Lloyd2 (right).

Lloyd1: stops when the maximum number of iterations has been reached.

Lloyd2: stops either the maximum number of iterations has been reached or if the previous centroids of the previous iteration are very similar to the ones obtained in the current iteration.





For optimal values of d1 and d2 we are able to speed up our algorithm up to 8 times using Lloyd1 and until 20 times using Lloy2

Experimental results (Part II)

From OMNeT to see how the network performance is affected

Strategy	PDR[%] Less	Average end-to-end delay [s]	Speedup
No prepartitioning	99.82	1.74s	-
OPS	99.09	1.89s	13×
ROPS	99.63	1.37s	20×

Conclusions

1. We have proposed a recursively optimized prepartitioning strategy named RPOS to further improve the optimized prepartitioning strategy (OPS) previously designed by us.

2. Results have shown that the new strategy have increased the speedup up to 20x instead of 13x achieved with the previous strategy.

3. ROPS has a negligible effect on quality of service (QoS) parameters.

Future work

1. Introduce in our strategy QoS metrics other than distance to enhance the overall performance of the RF Mesh network especially when several traffic patterns are added to the network.

Thank You !