Dribble: A learn-based timer scheme selector for mobility management in IoT

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Universidade Federal de Ouro Preto

Agenda

1. Introduction
2. Background
3. Dribble
4. Evaluation
5. Conclusion and Future work

Contextualization

- Smart devices are part of our daily routine

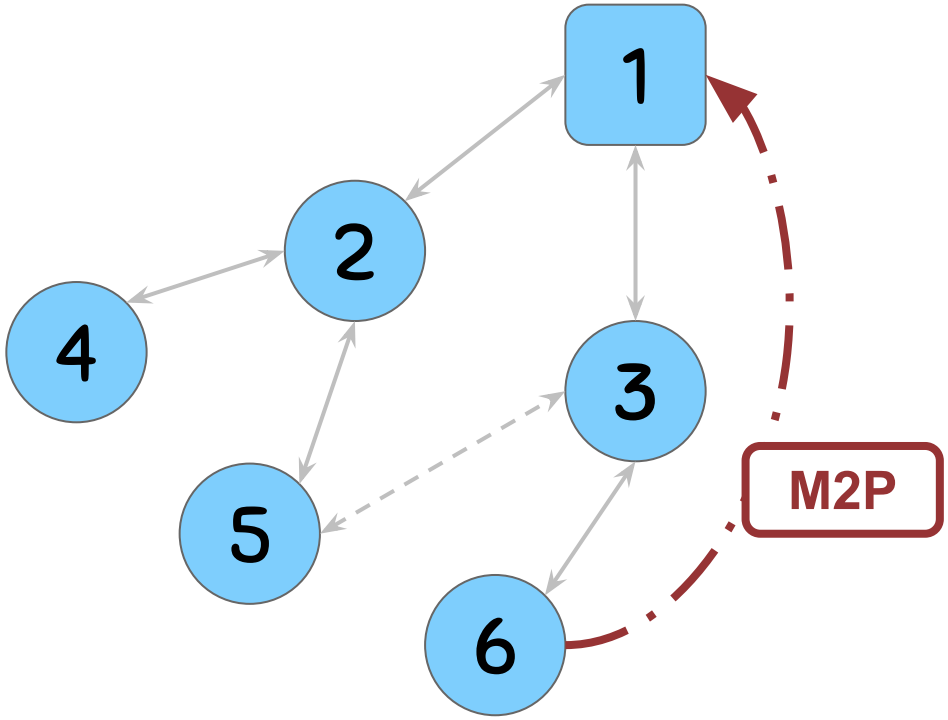
Mobility is a key challenge!

- IoT - Challenges
  - Internet adaptations
  - Heterogeneous devices
  - Constrained resources (Energy, CPU, Memory…)
  - Mobility

Mobility is a key challenge!

- IoT - Challenges
  - Internet adaptations
  - Heterogeneous devices
  - Constrained resources (Energy, CPU, Memory…)
  - **Mobility**
- We are interested in handle Mobility
  - Key aspect for mobile and wireless environment
  - Mobility from routing protocol lens

IoT routing in a nutshell



Data traffic patterns
over routing structures

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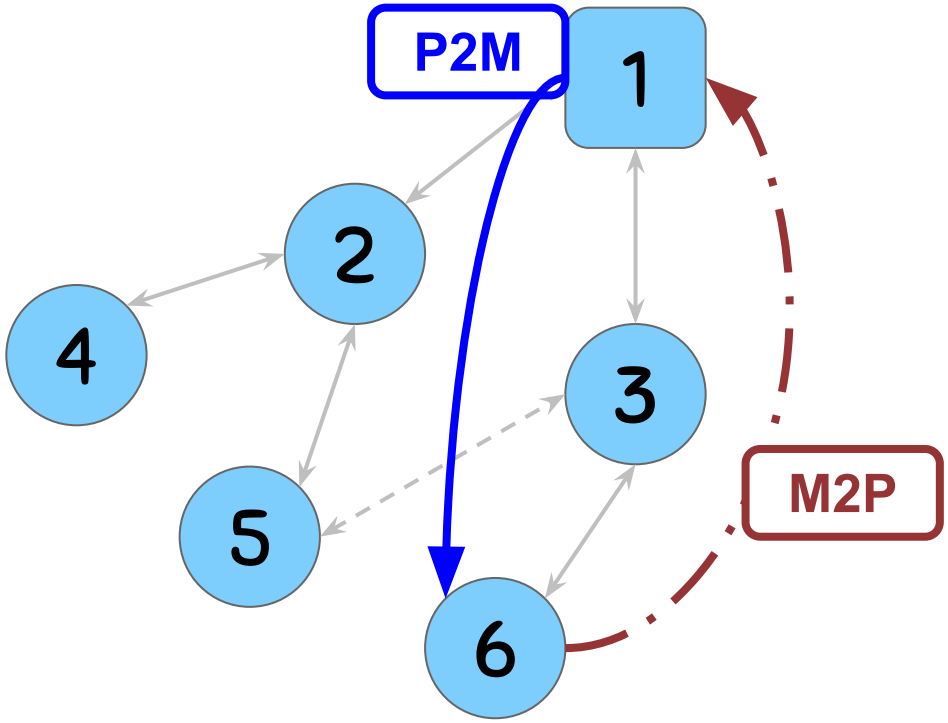

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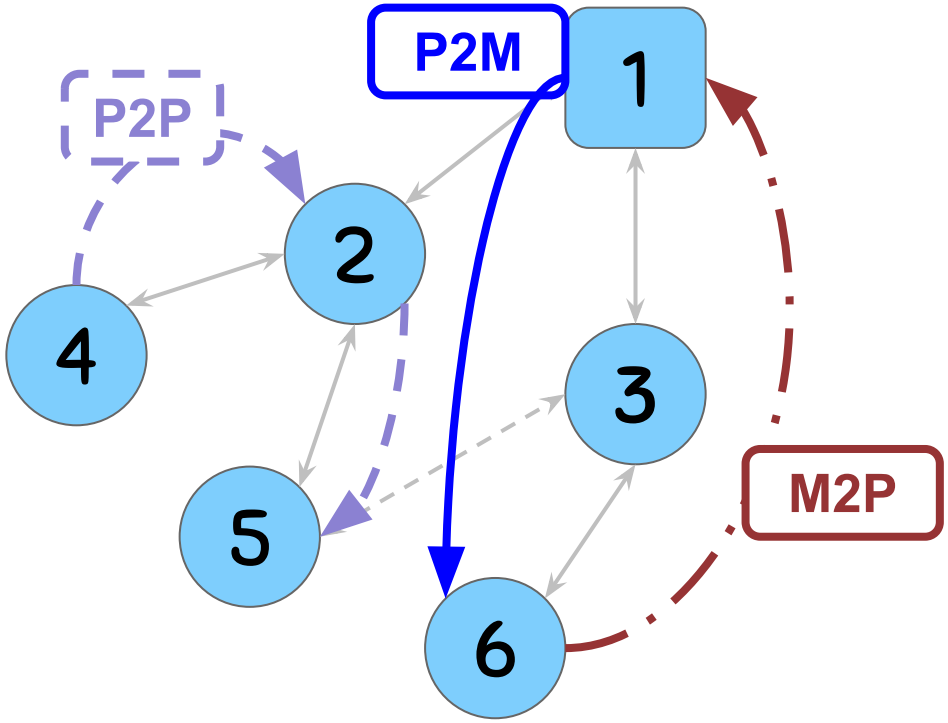


Data traffic patterns
over routing structures

IoT routing in a nutshell

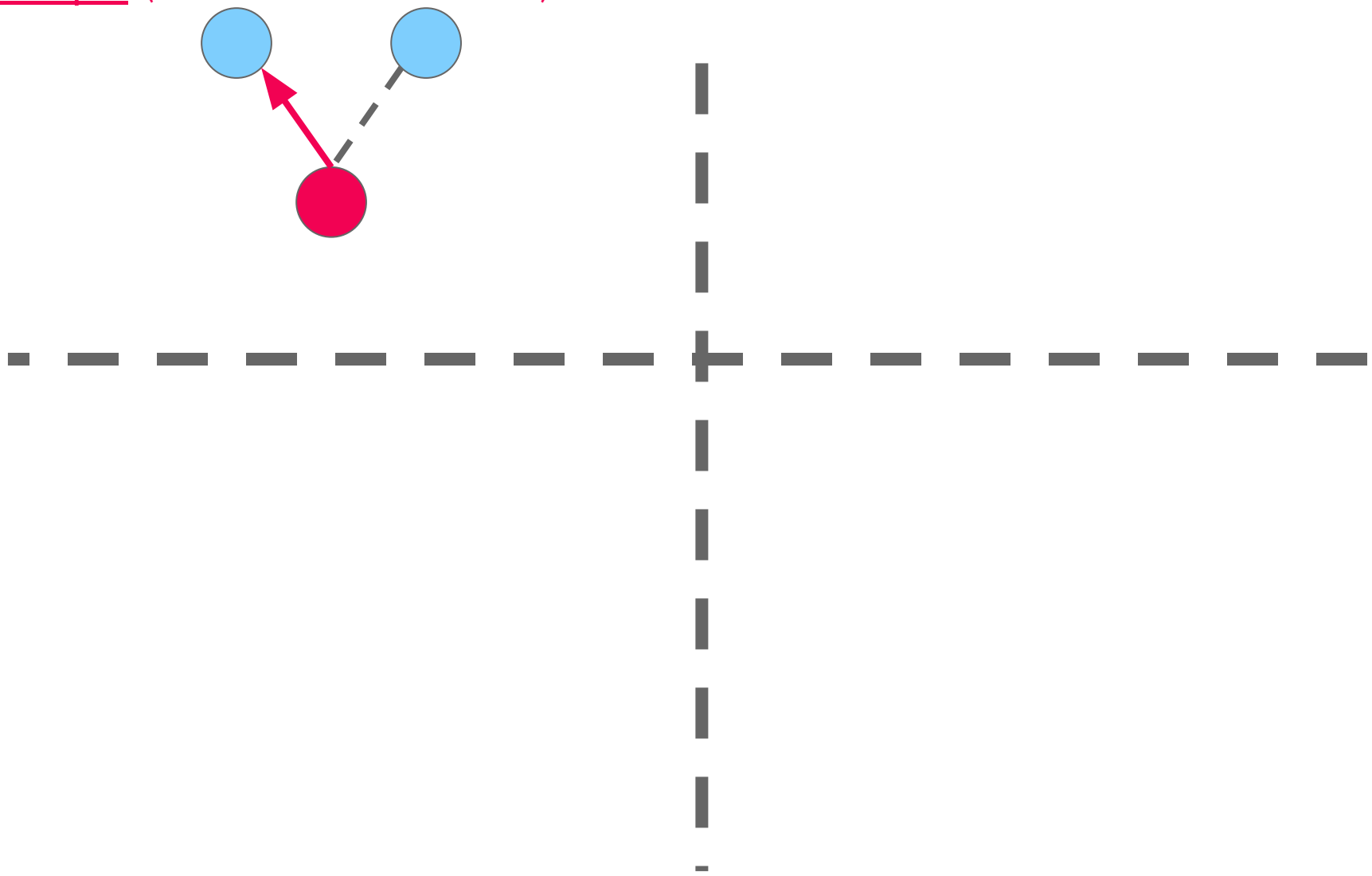
- Literature routing protocols
  - RPL (*de facto* the state-of-the-art)
    - Several RPL adaptations for mobile scenarios
      - Co-RPL, MRPL, MMRPL, ERPL...
  - Mobile Matrix
  - Hydro
  - XCTP
  - ...

Routing under mobility events

- Mostly of routing protocols for mobile IoT have one timer scheme
  - It governs the communication structure construction and maintenance

Routing under mobility events

Example. (note there are other solutions)



Routing under mobility events

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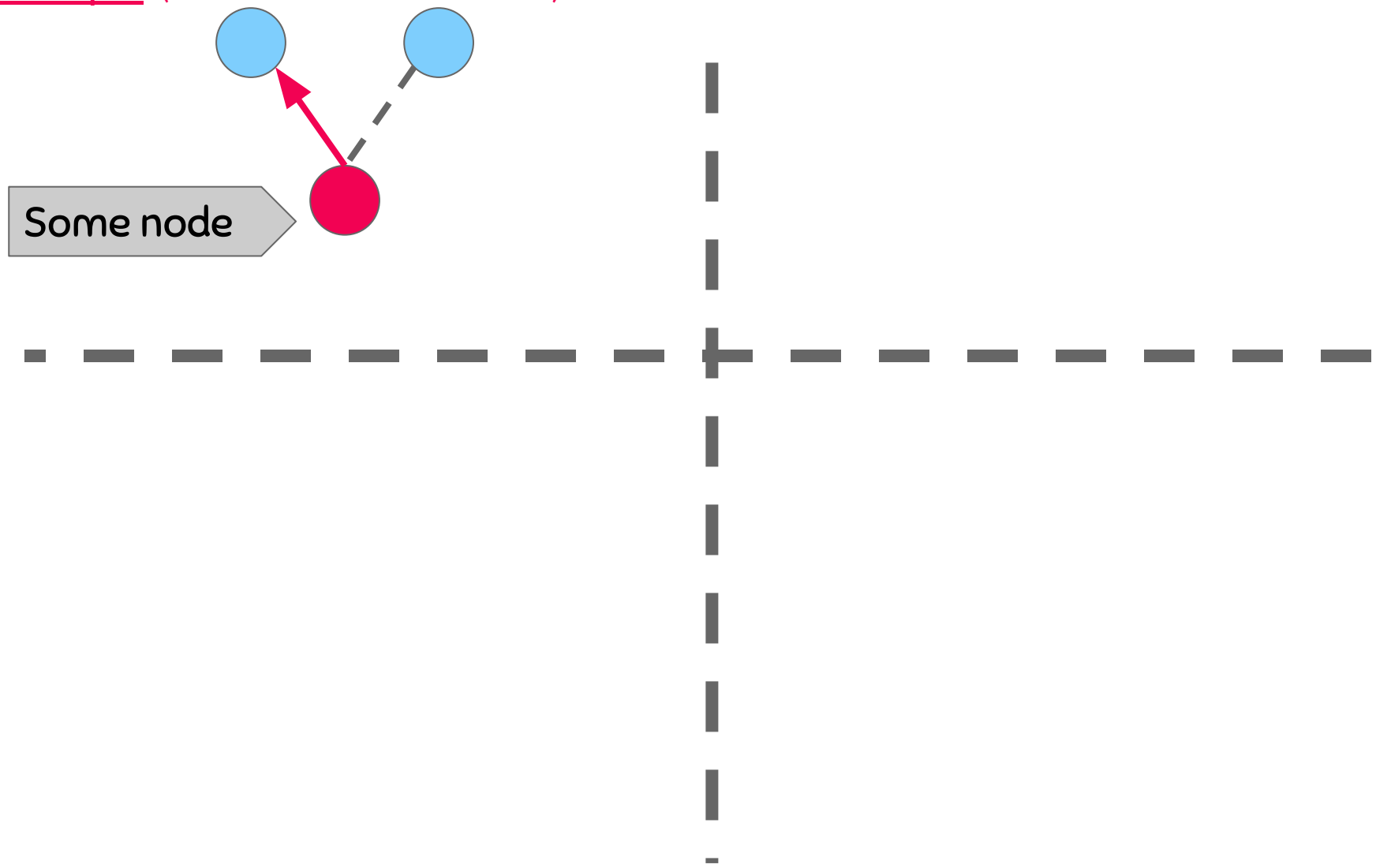

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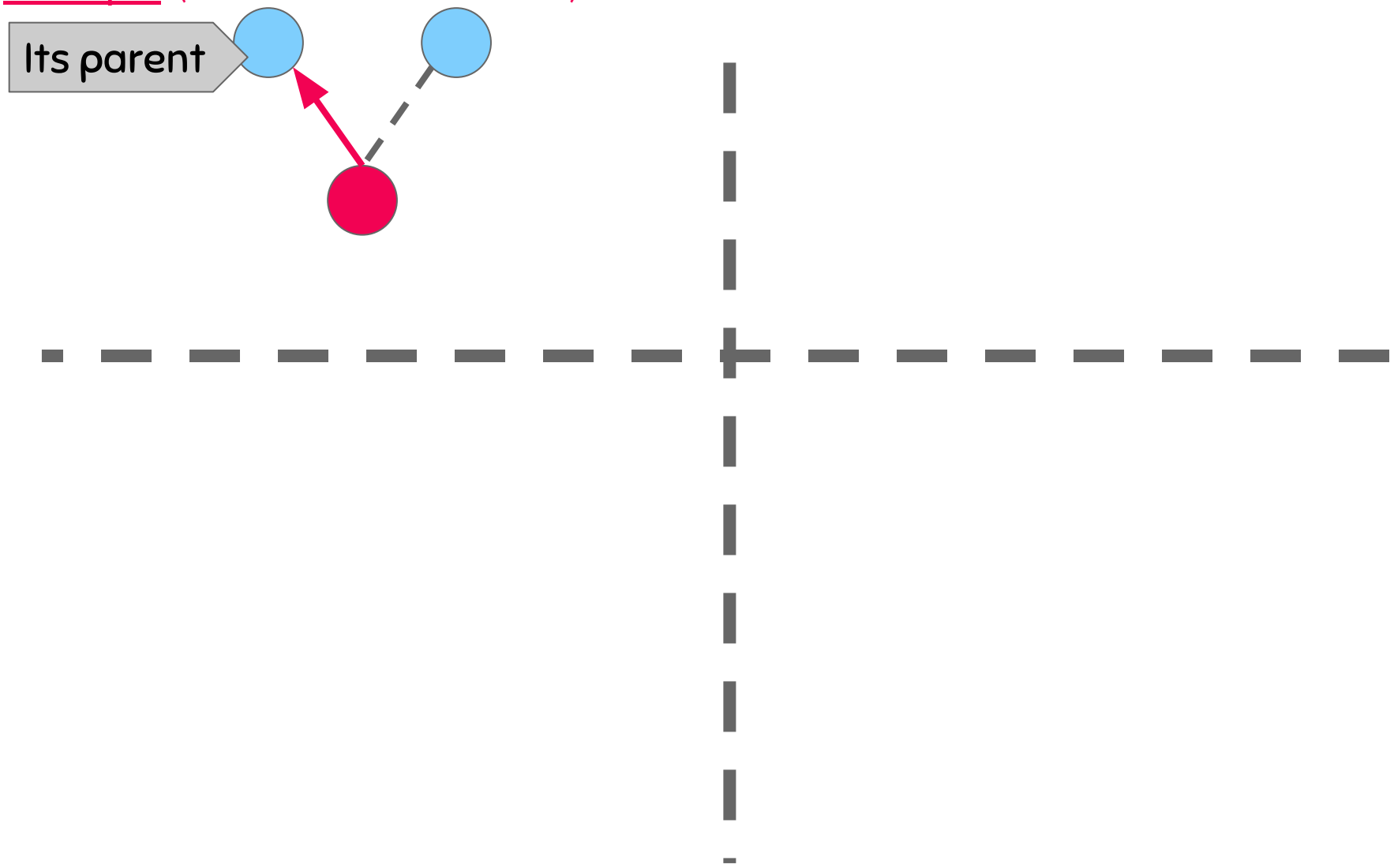

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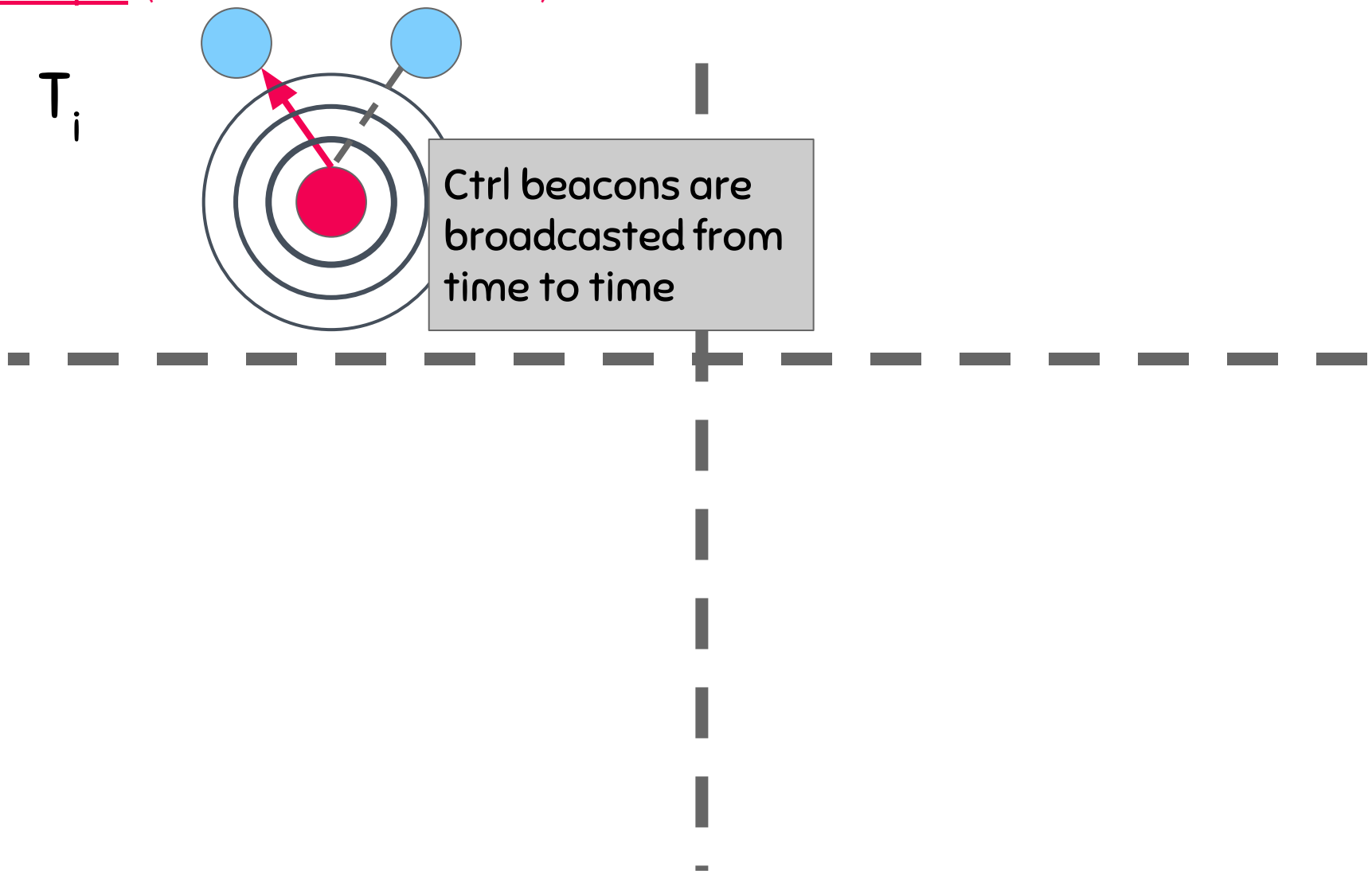

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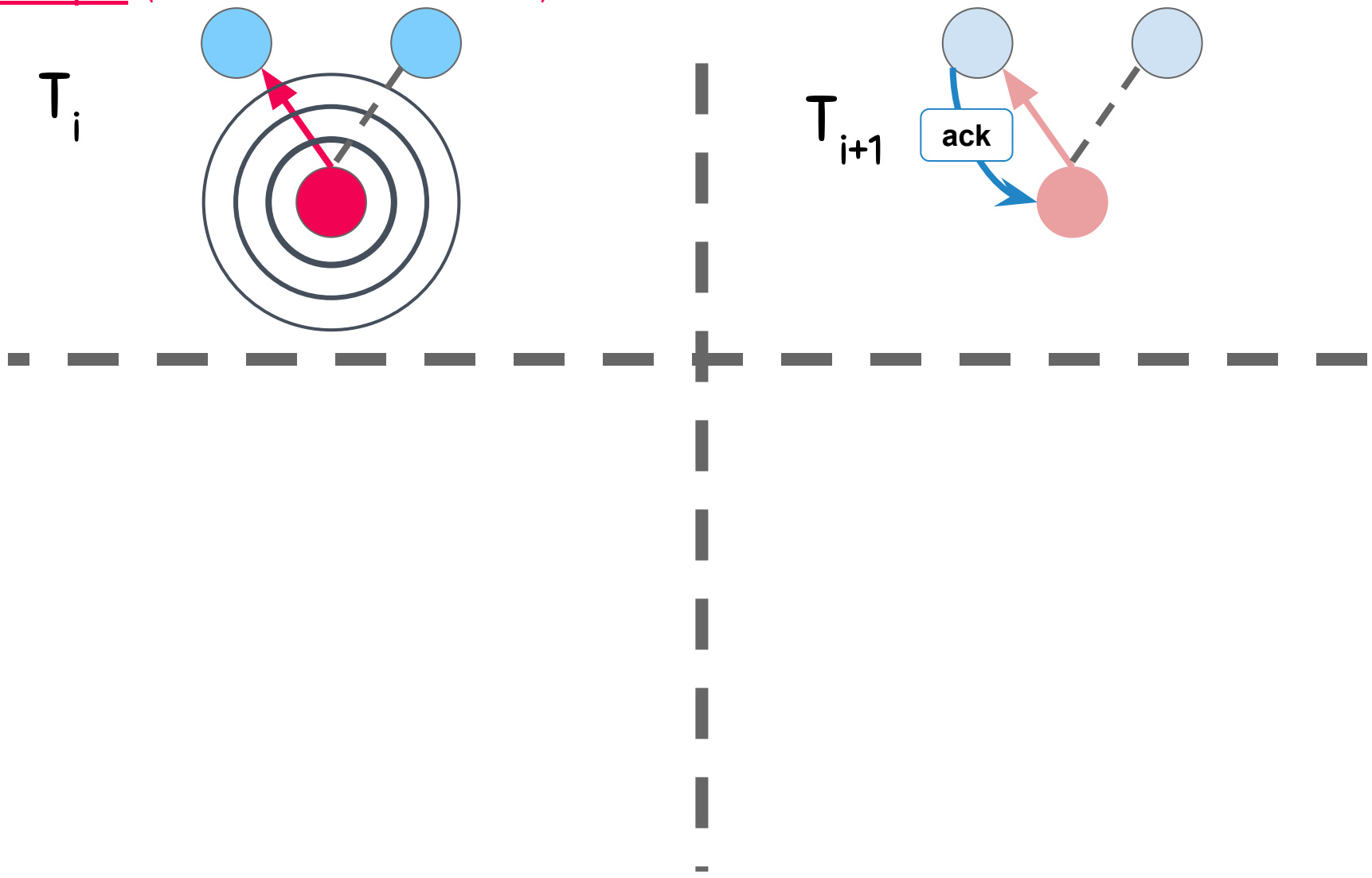

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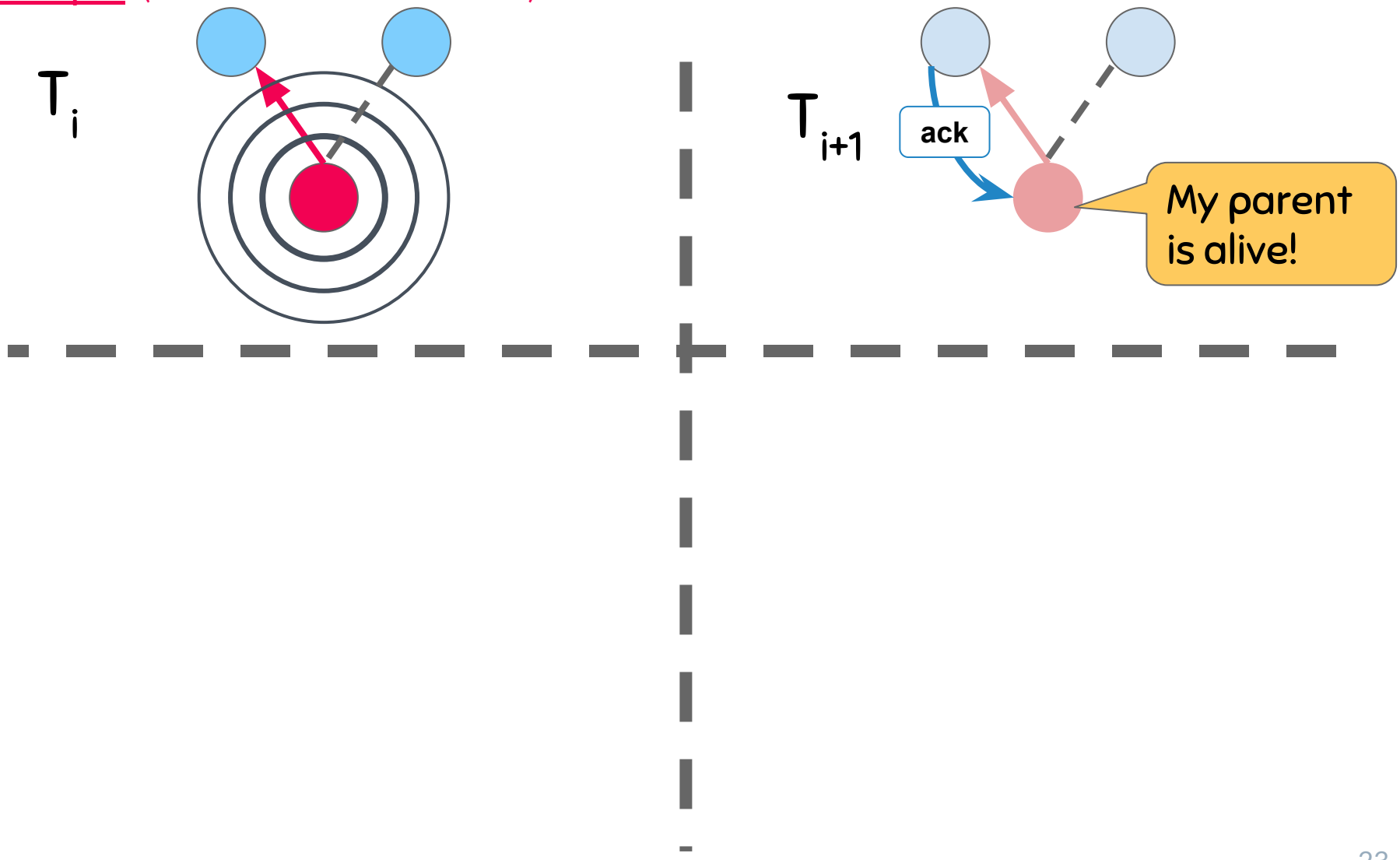

Routing under mobility events

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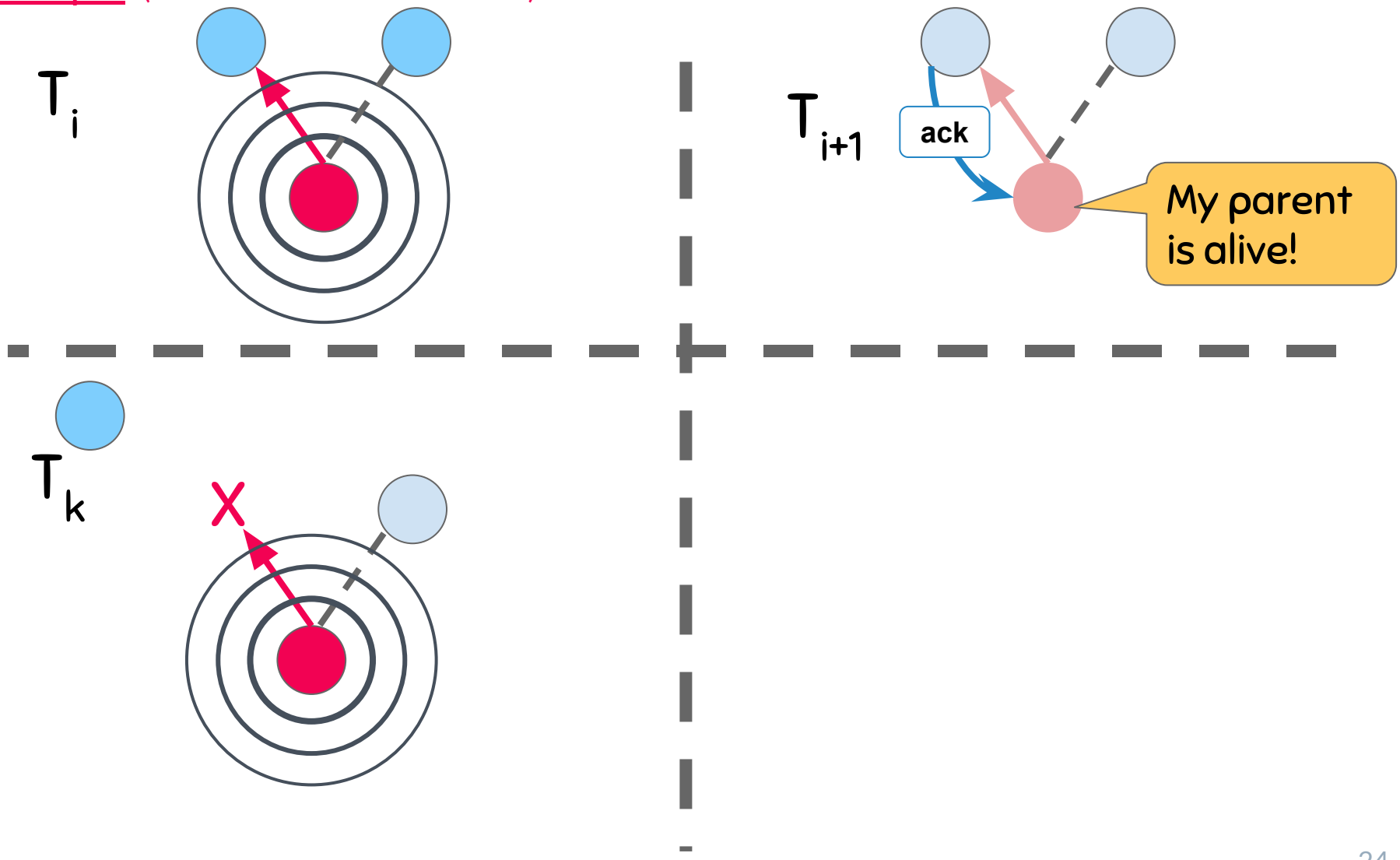

Routing under mobility events

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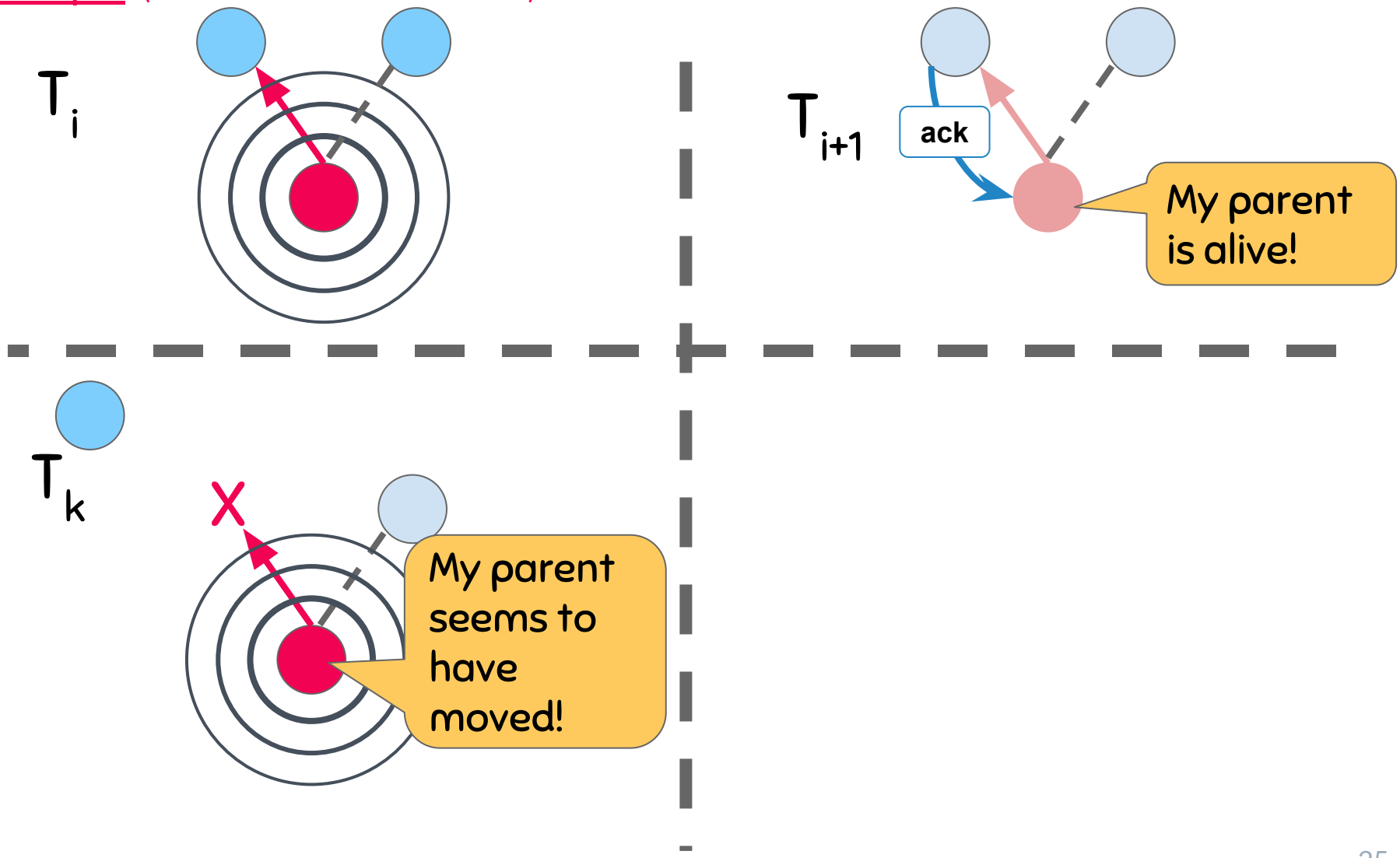

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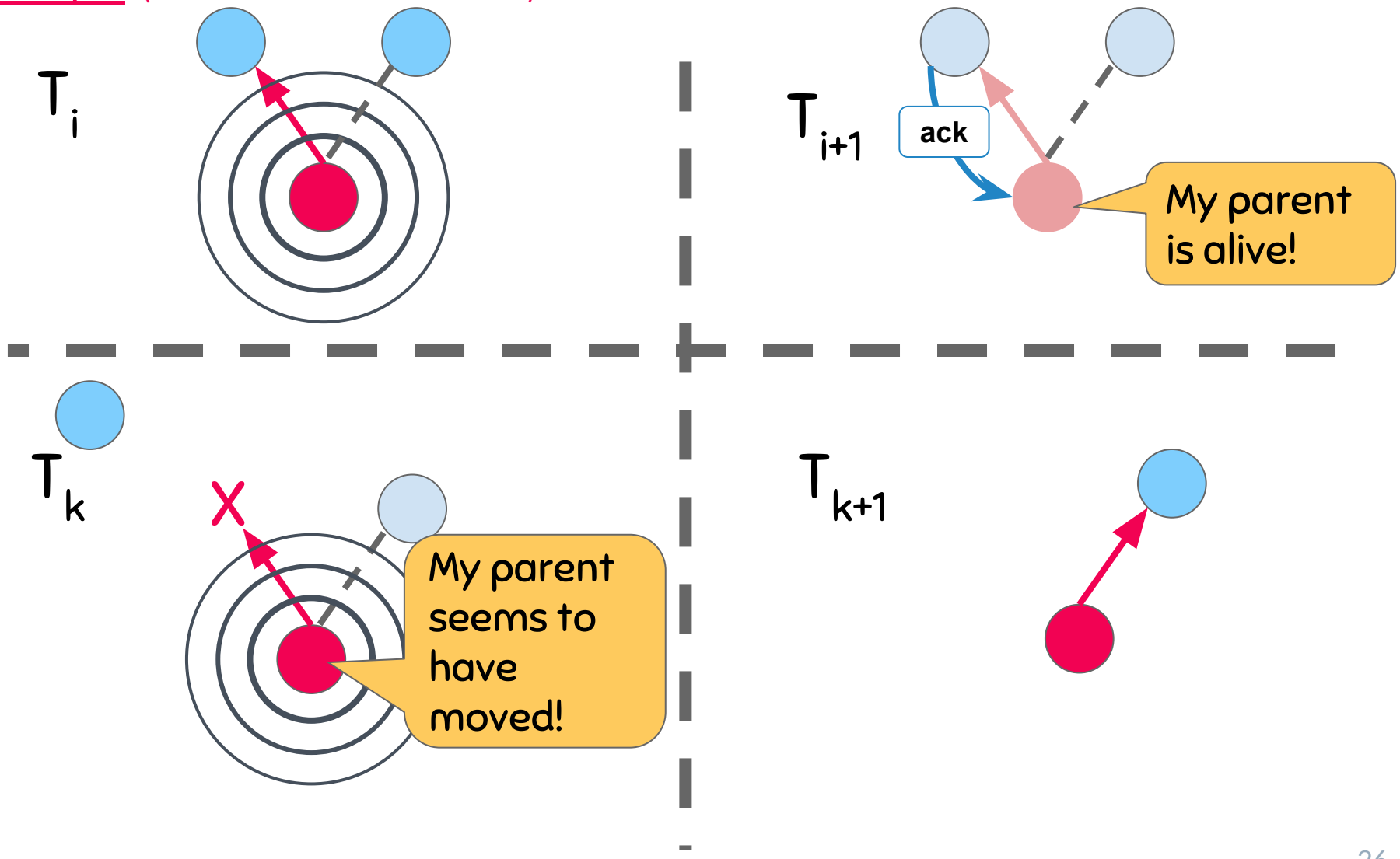

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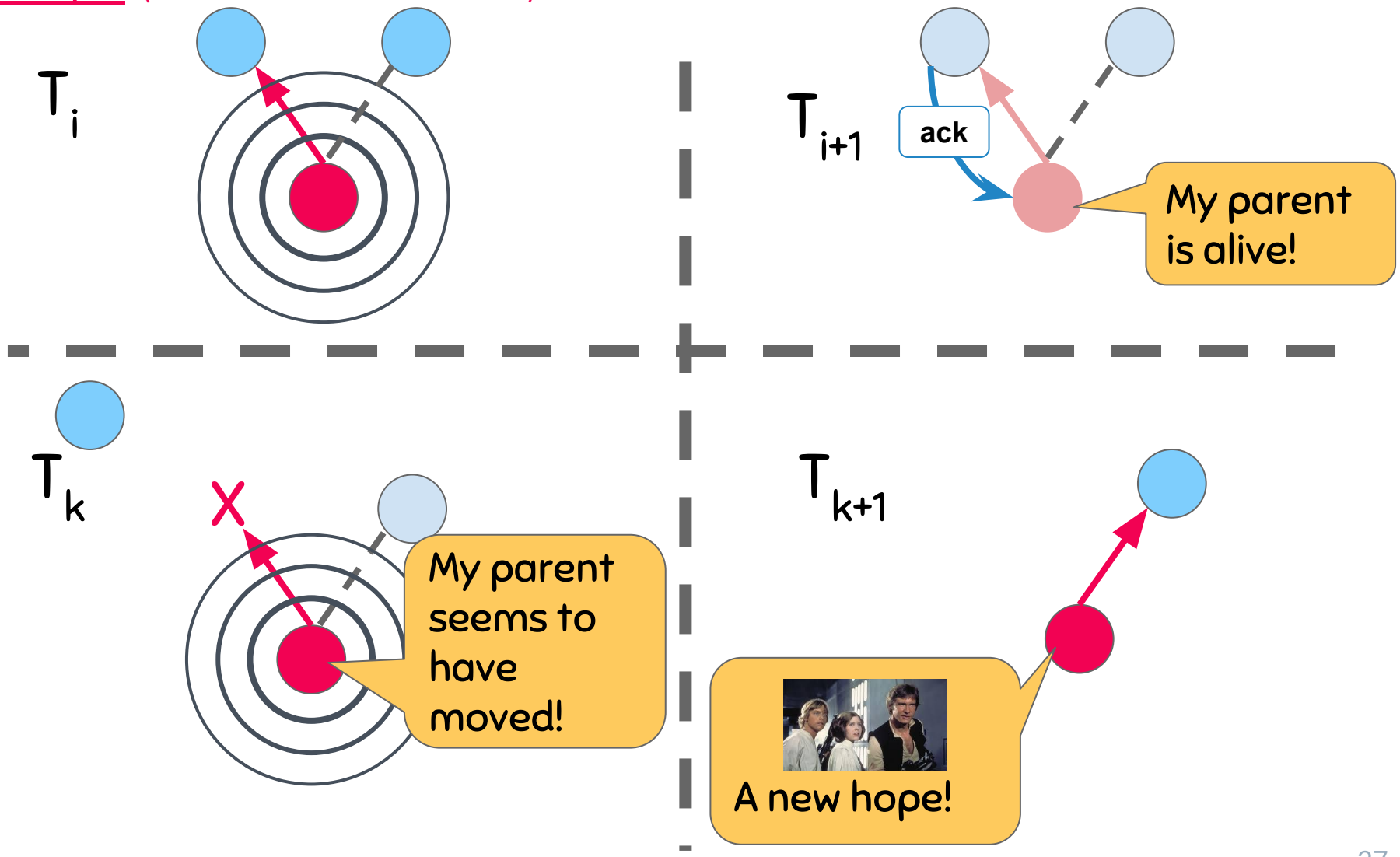
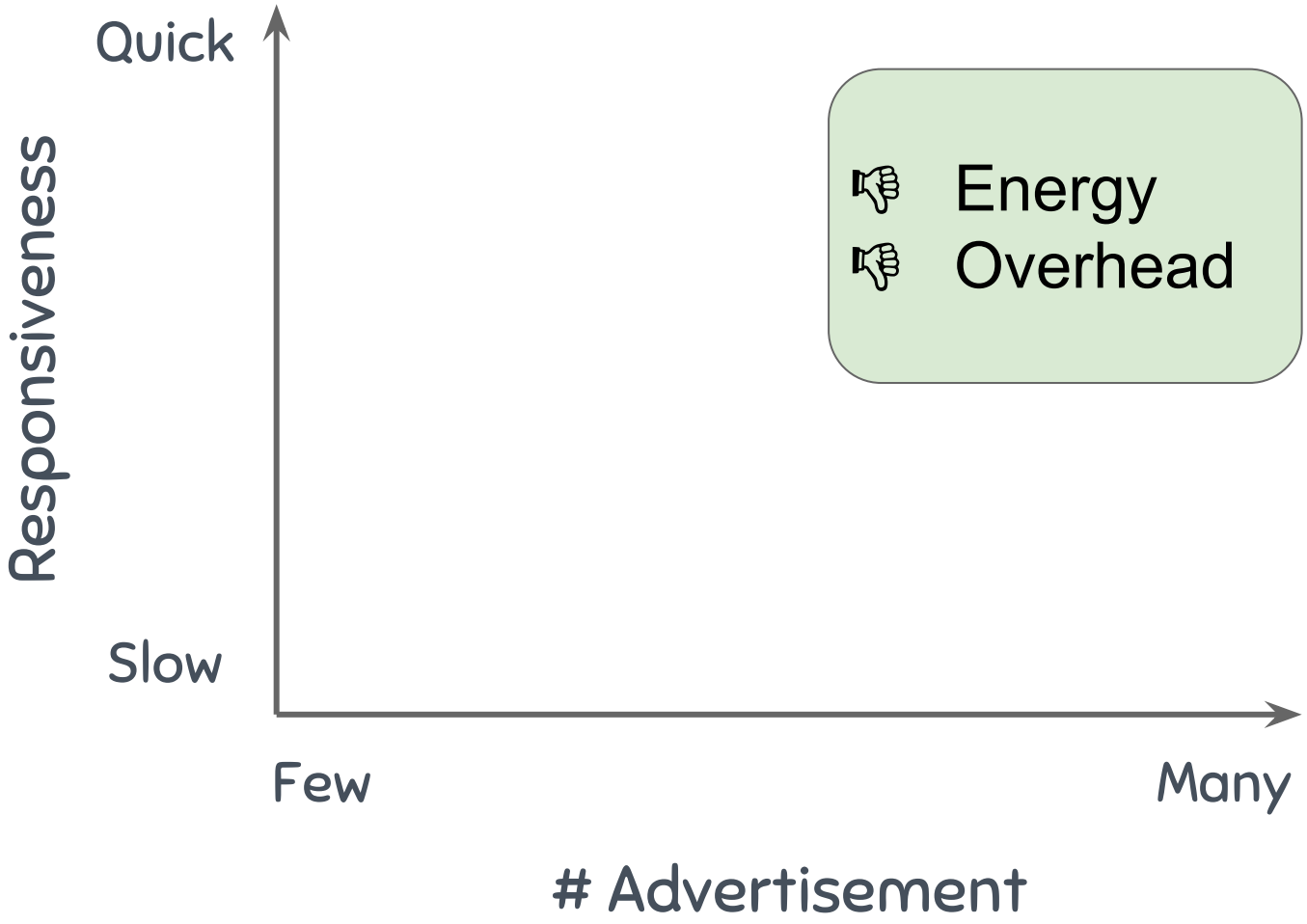


Timer scheme trade-off



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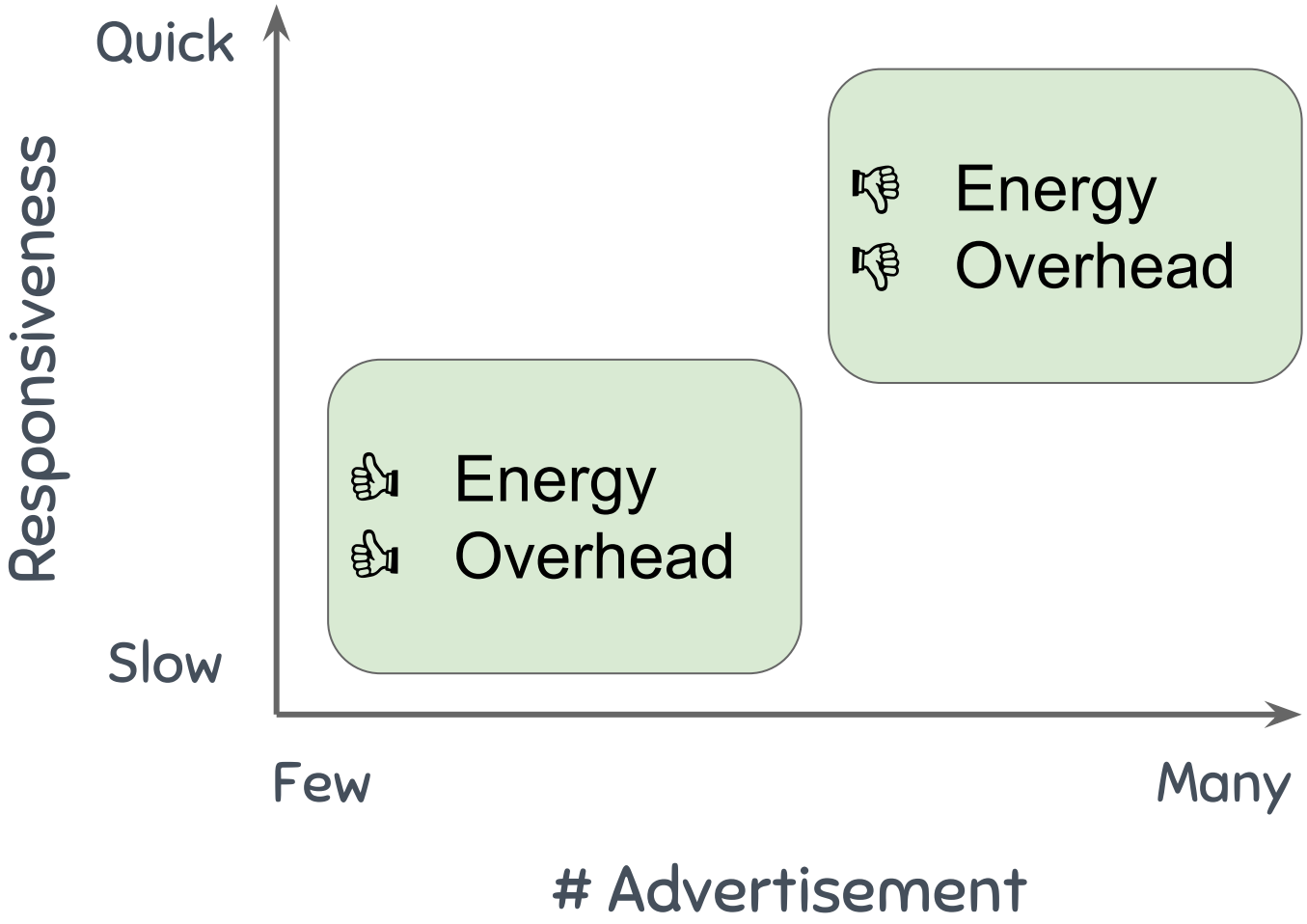
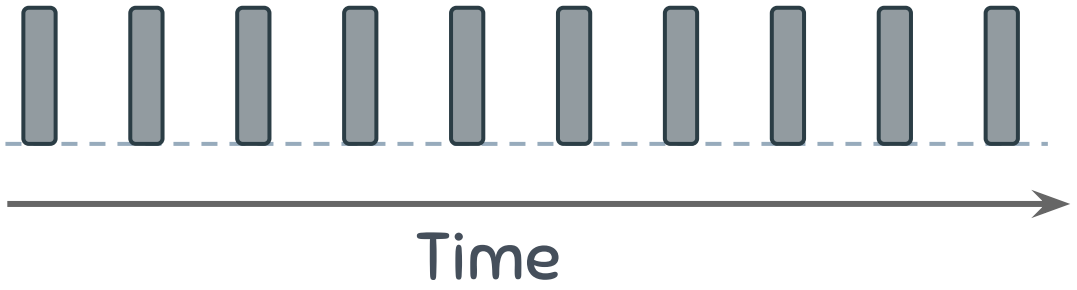


Dealing with mobility and link dynamics

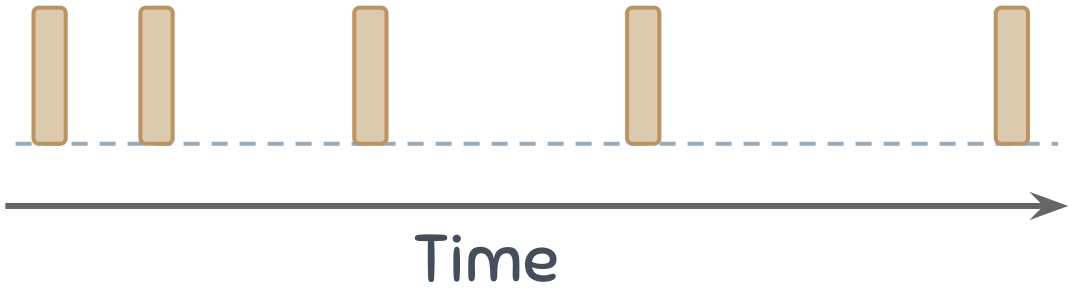
- Timer schemes
  - Control advertisements
  - Govern the communication structure construction and maintenance
- What timer schemes are most commonly used?

Dealing with mobility and link dynamics



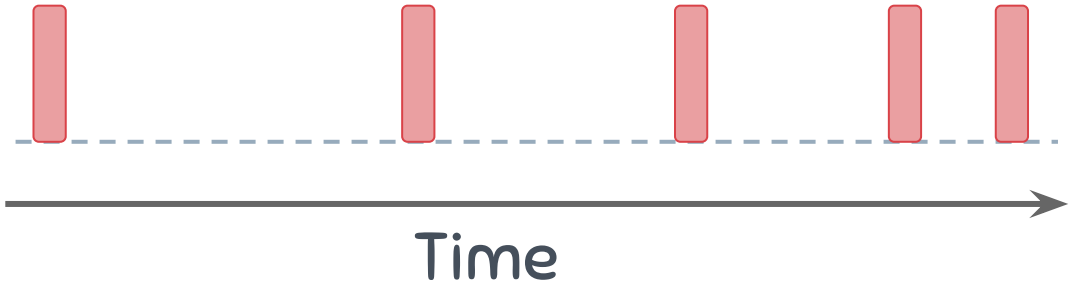
- **Periodic**
  - Large interval
    - 👍 Low channel and energy usage
    - 👎 Slow responsivity
  - Small interval
    - 👎 High channel and energy usage
    - 👍 Quick responsivity

Dealing with mobility and link dynamics



- **Trickle Timer**
  - Assumes that network will be stable (few link changes)
  - Fires bursts of advertisements when some inconsistency is detected
  - Decrease advertisement rate exponentially
  - Maximum interval ~2.3 h (RFC 6550) or ~20 min (ContikiOS)

Dealing with mobility and link dynamics



- **Reverse Trickle Timer**
  - The “opposite” of Trickle Timer
  - Assumes that as long as a node remains connected to a parent, it is likely that node will move away
  - Increase advertisement rate exponentially
  - Authors use ~20 min in their experiments

Dealing with mobility and link dynamics

1. **Reverse Trickle Timer,**
2. **Trickle Timer,**
3. **Periodic.**

- Such schemes assume:
  - 👎 Only one scheme governs the entire network
  - 👎 All devices follow the same mobility pattern

Dribble

A learn-based timer scheme selector for mobility management in IoT

- It learns the IoT device mobility pattern
- Automatically assign a proper timer scheme
  - Better balance the timer scheme trade-off

How it works...

Start with a default timer scheme

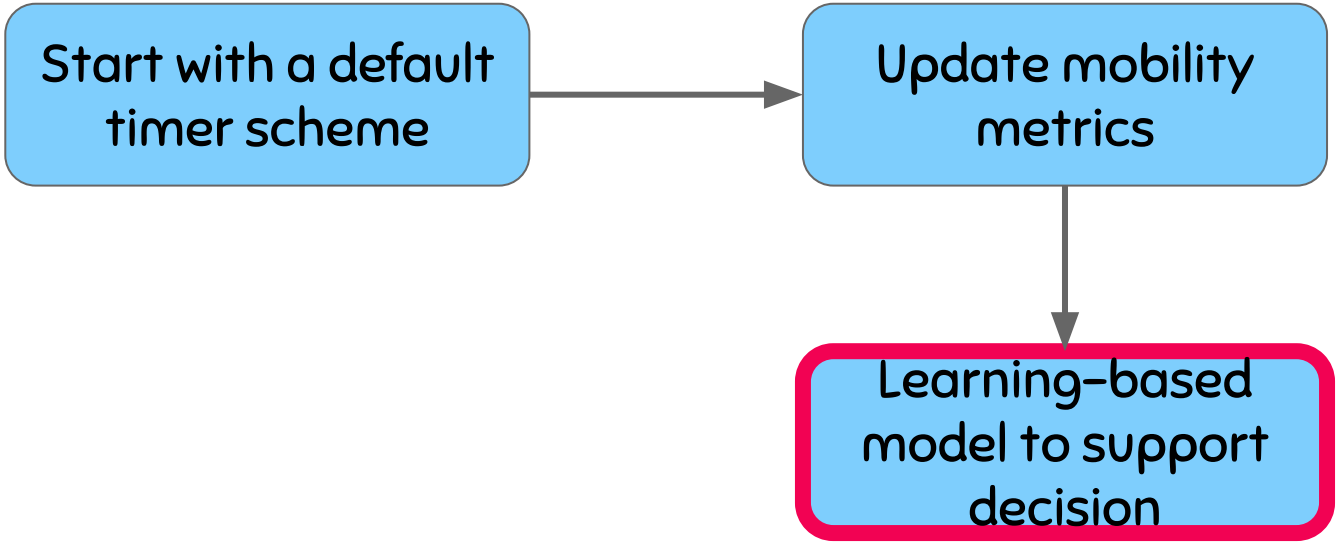
Ex:
Trickle Timer

How it works...

Ex:

- **Speed,**
- **GPS,**
- **Travel Distance,**
- **Visit Time,**
- **Interconnection Time**

How it works...

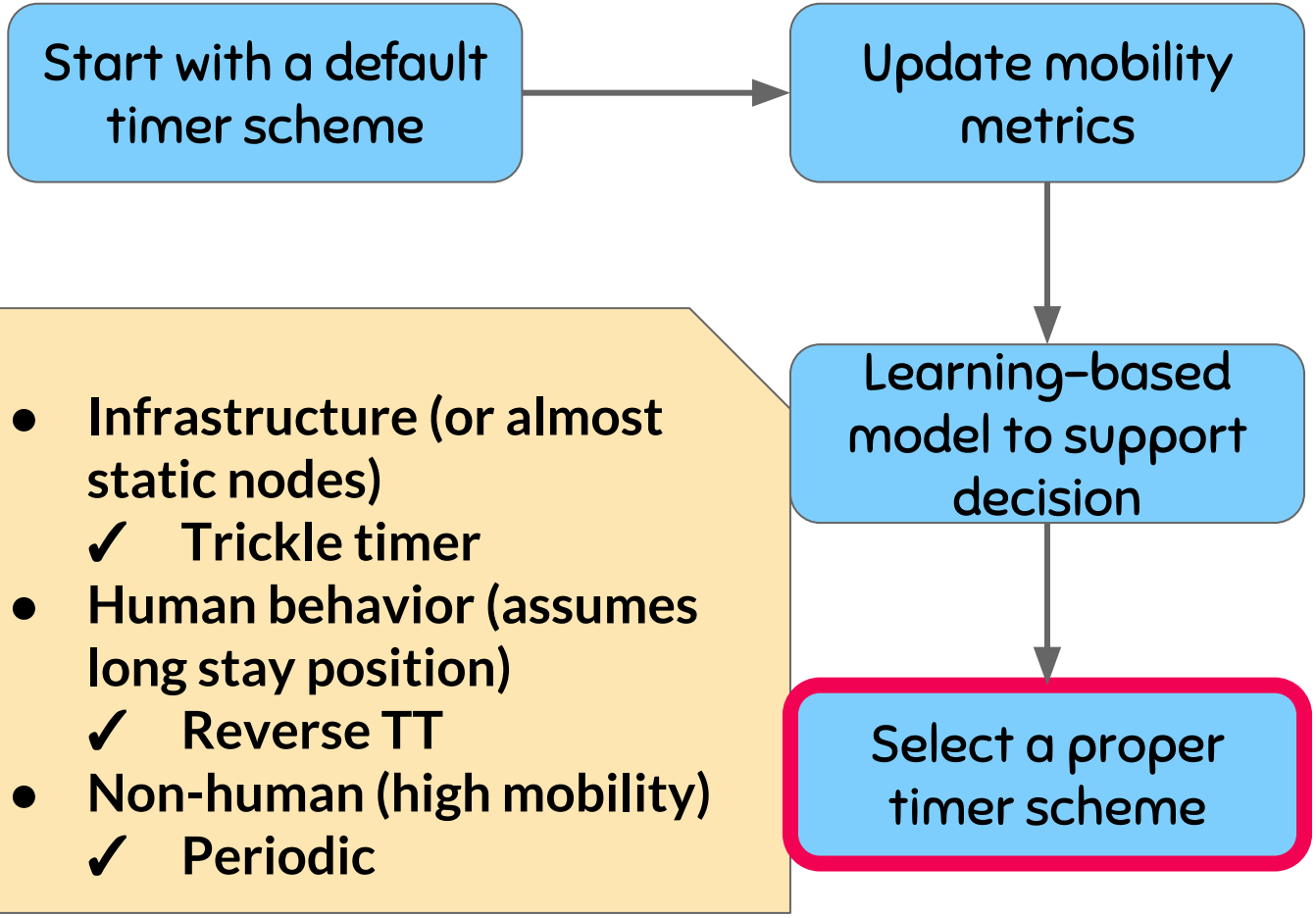


- We've tested
  - Supervised and unsupervised models
  - But we have labeled data
- Multi-Layer Perceptron classifier as learning algorithm

$$f : R^m \rightarrow R^p$$

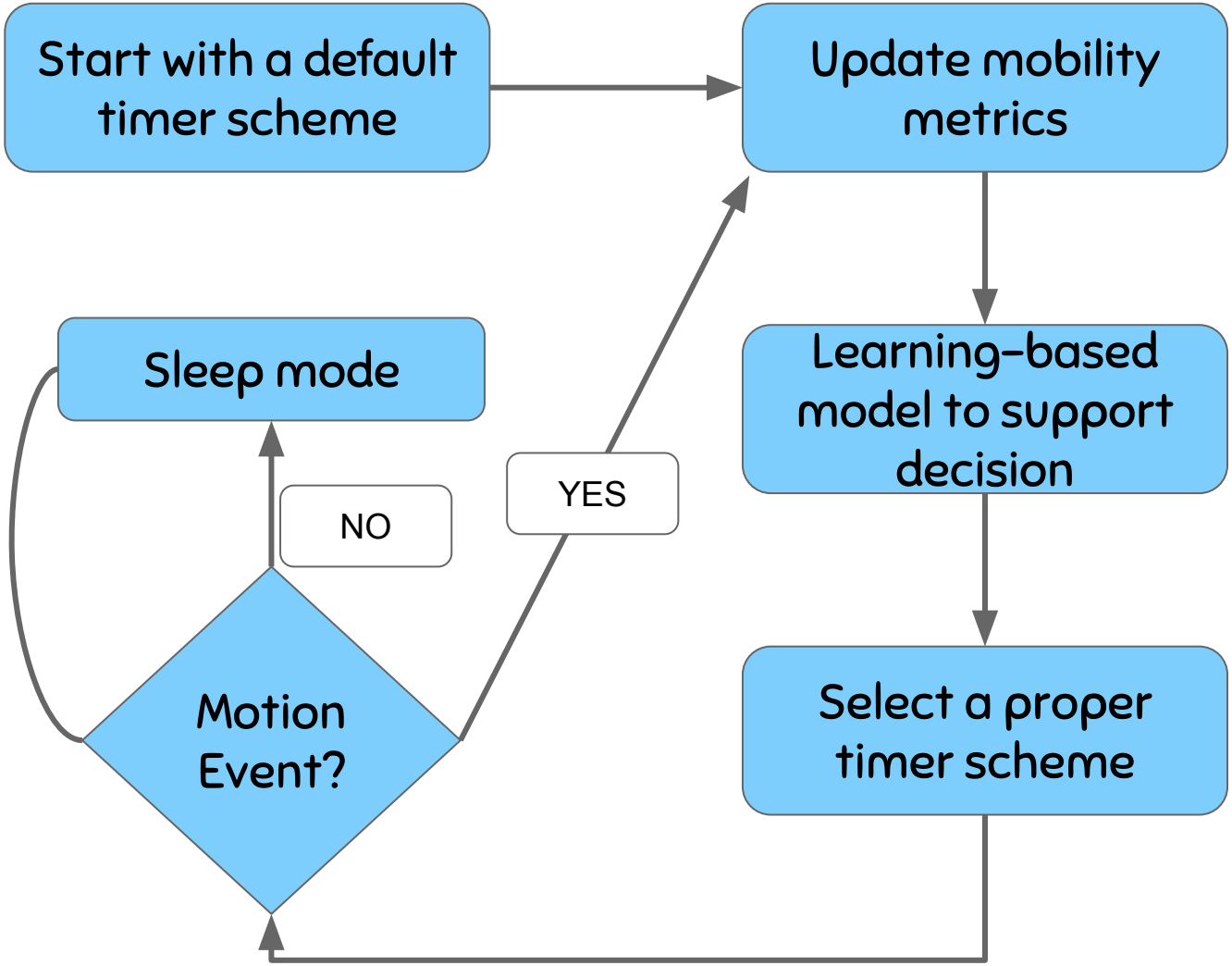
m is the mobility metrics
p is the mobility patterns

How it works...



- Infrastructure (or almost static nodes)
  - ✓ Trickle timer
- Human behavior (assumes long stay position)
  - ✓ Reverse TT
- Non-human (high mobility)
  - ✓ Periodic

How it works...


Start with a default timer scheme
Update mobility metrics
Learning-based model to support decision
Select a proper timer scheme
Motion Event?
YES
NO
Sleep mode

Experimental environment

- Sinalgo simulator
- RPL as routing protocol
  - Tree data traffic enabled: M2P, P2M, and P2P
  - Storing mode
  - ETX as Objective function

Simulation setup	
Duration	15 days

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# nodes	200
Base station	1 (center)
Distribution	Random

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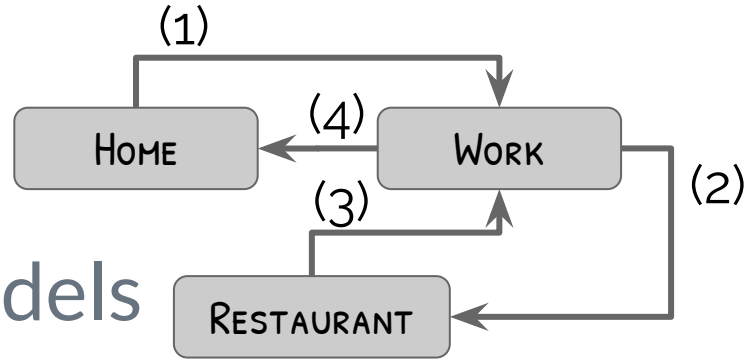
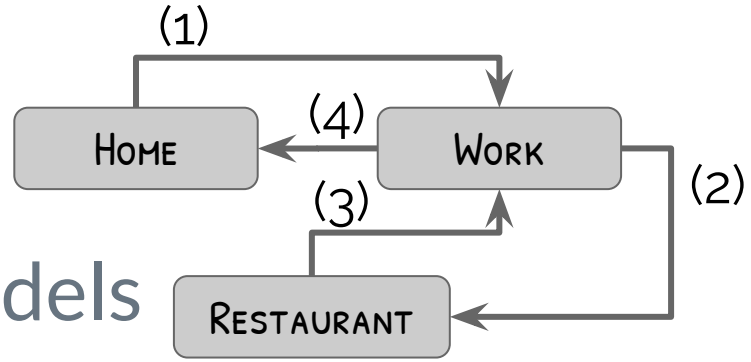
Simulation setup	
Duration	15 days
# nodes	200
Base station	1 (center)
Distribution	Random
DIM	1500m x 1500m (campus)
Radio Range	100 (m)
Transmission Model	CC2420-like
# random topologies	15
Timer schemes	
Trickle and Reverse Trickle timers	Min = 1s, Max = ~20 min
Periodic	60s

Device mobility modelling



- We use two mobility models
  - Group Regularity Mobility model (GRM)
    - Human-like

Device mobility modelling



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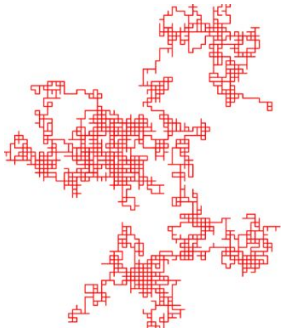
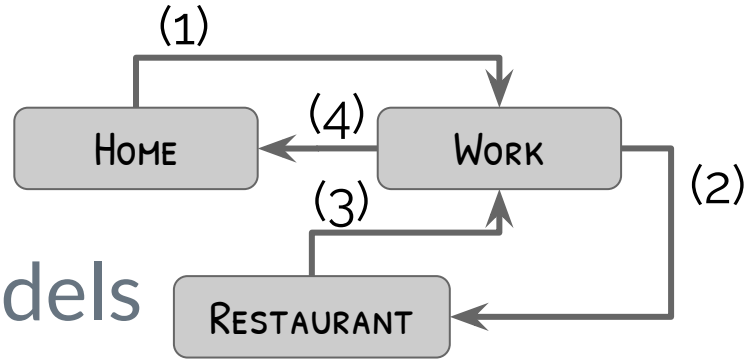
  - Cyclical Random Waypoint Mobility Model (CRWP)
    - Non-human



Evaluation

Device mobility modelling



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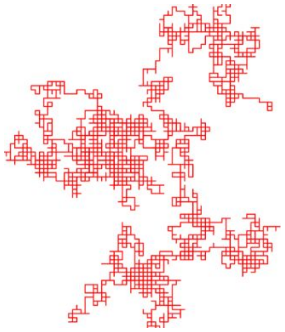
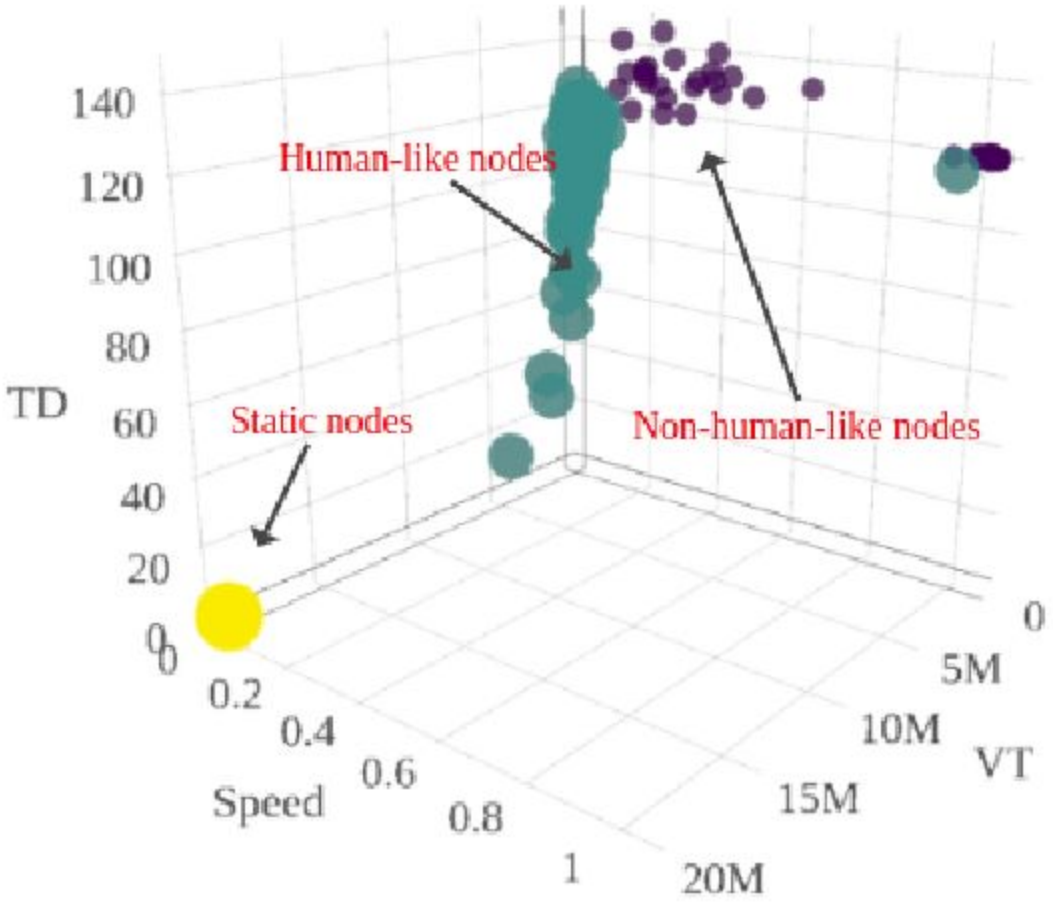
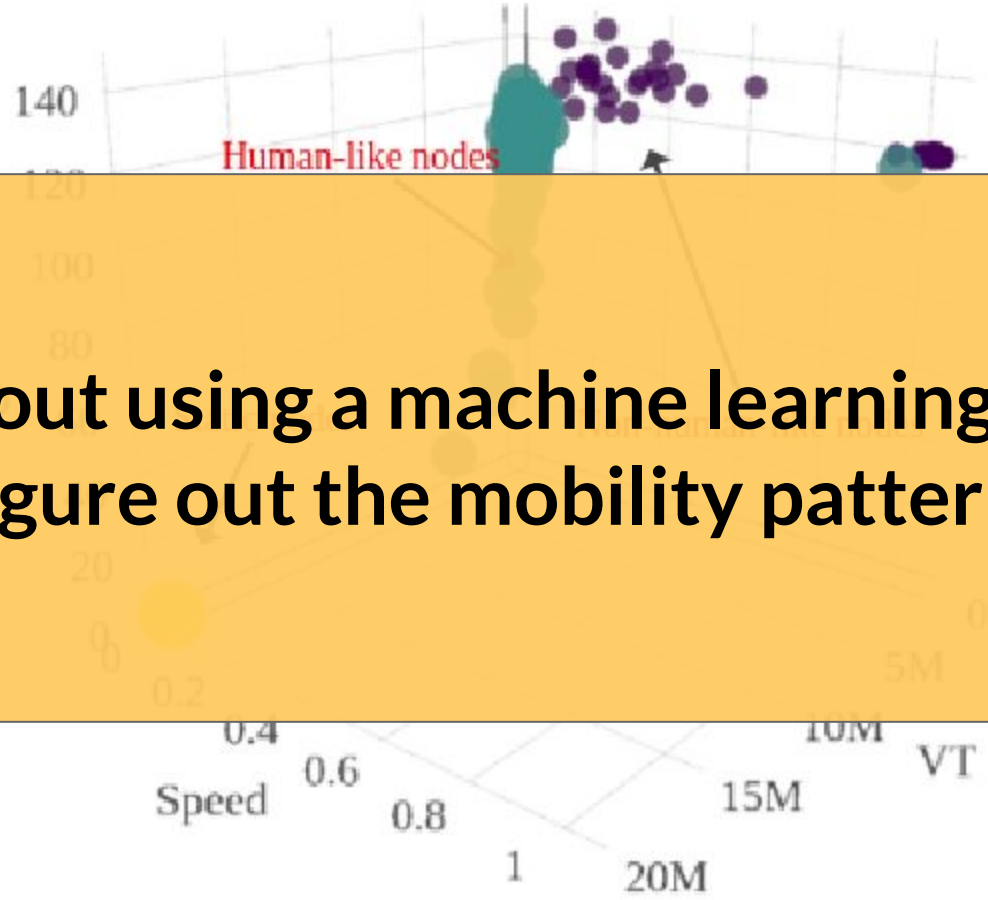


- Some static nodes to represent the infrastructure


Human-like nodes
Static nodes
Non-human-like nodes
TD
140
120
100
80
60
40
20
0
0.2
0.4
0.6
0.8
1
Speed
0
5M
10M
15M
20M
VT



What about using a machine learning model to figure out the mobility pattern?

Neural Network (Multi-Layer Perceptron) Architecture and parameters

Architecture	1 Hidden layer with 100 neurons

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# epochs	500
Weight optimization	Adam
Train dataset	10 random topologies
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Architecture	1 Hidden layer with 100 neurons
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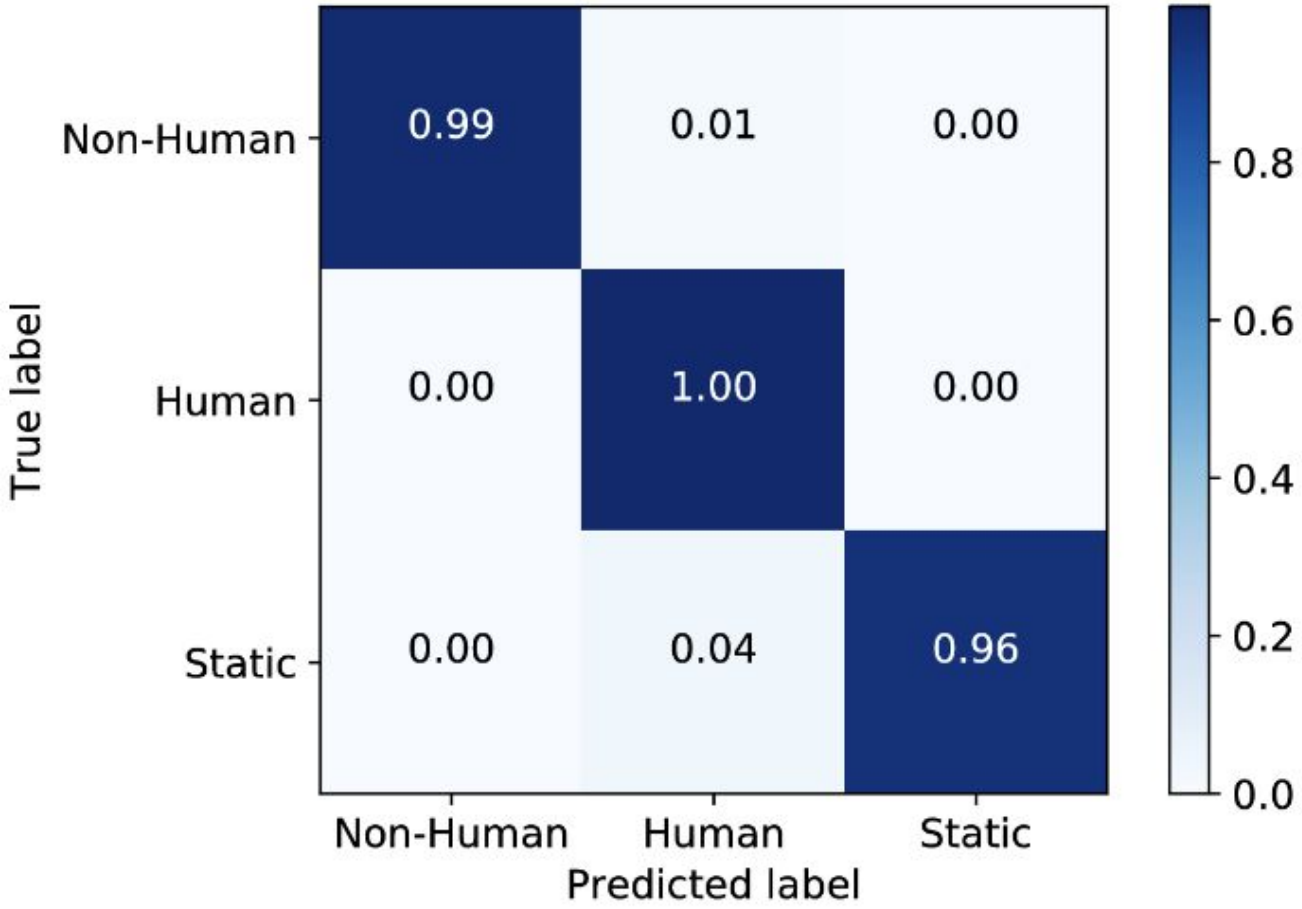
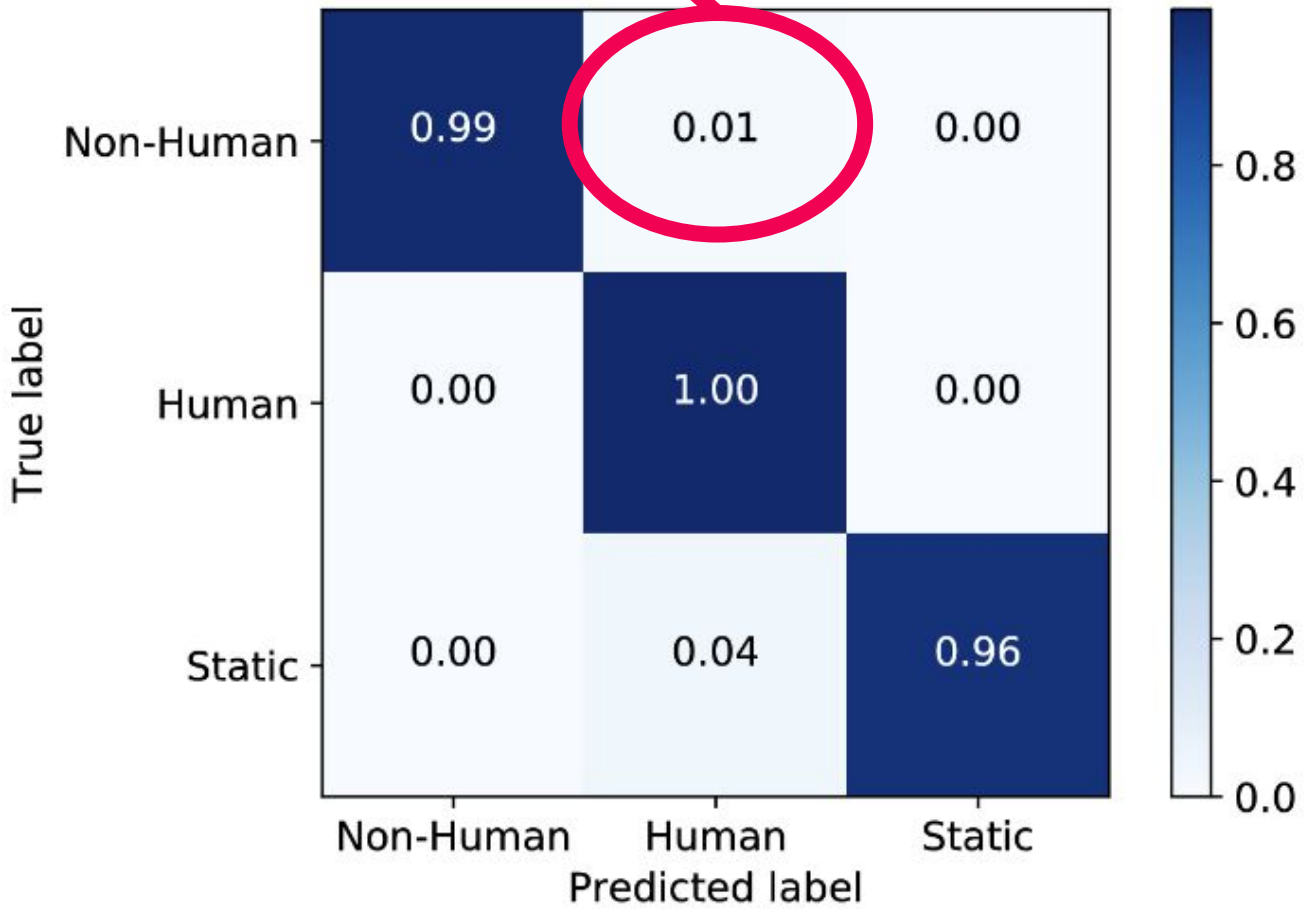
	Precision	Recall
Non-Human	1	0.99
Human	0.98	1
Static	1	0.96
Avg/Total	**0.99**	**0.99**


Non-Human
Human
Static
True label
0.99
0.01
0.00
0.00
1.00
0.00
0.00
0.04
0.96
Non-Human
Human
Static
Predicted label
0.8
0.6
0.4
0.2
0.0

1% of Non-human were misclassified as human



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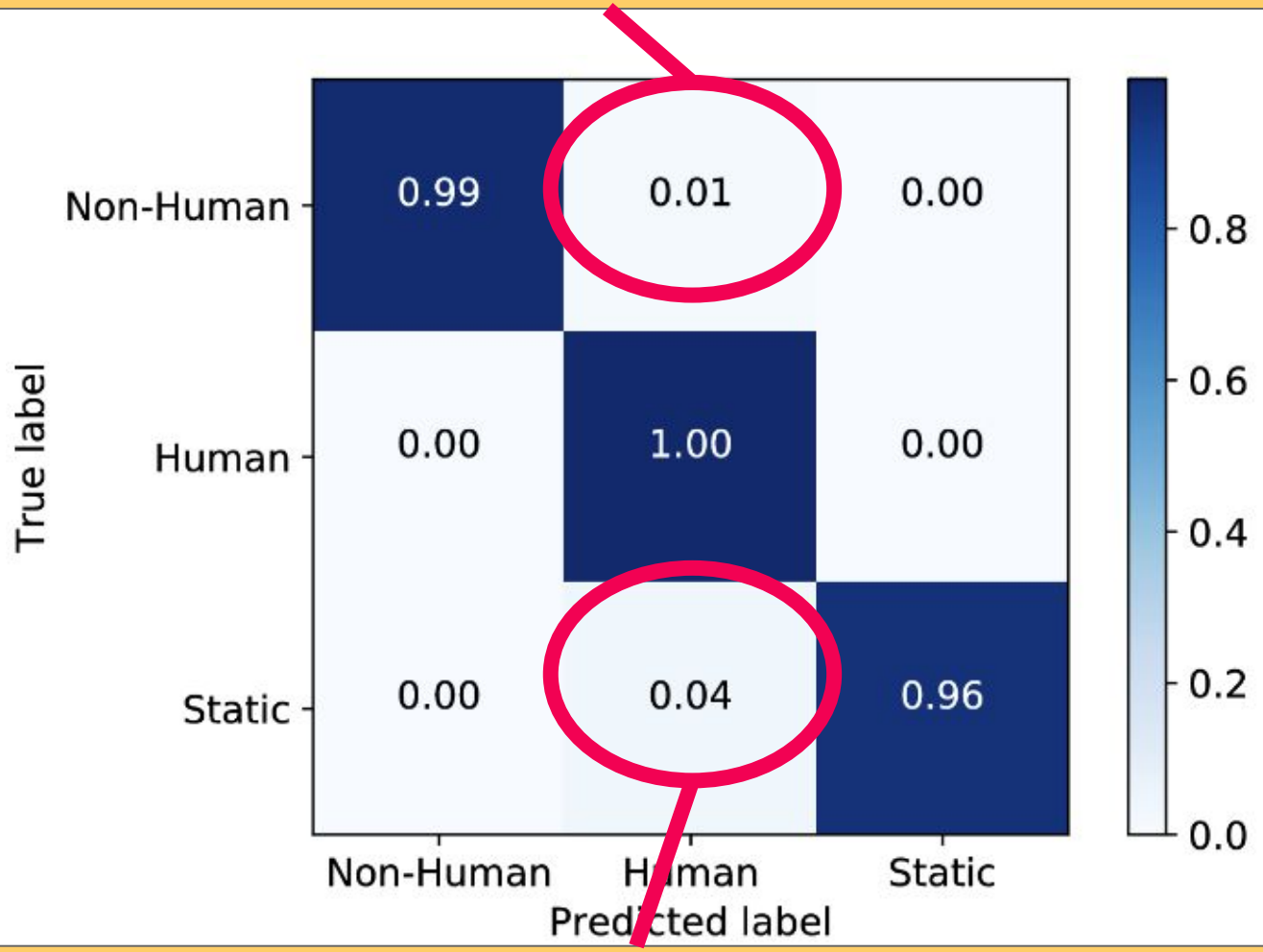
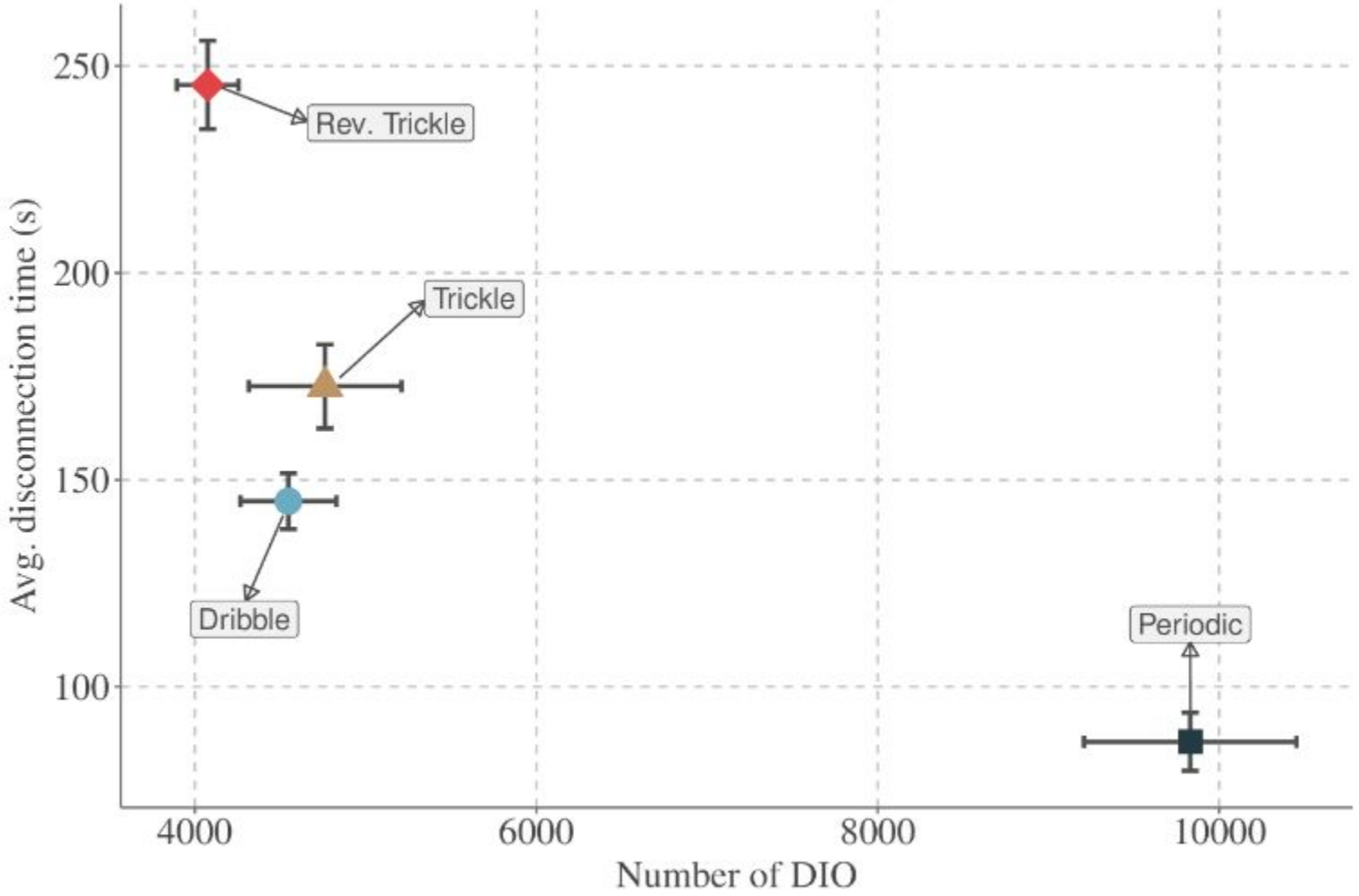


4% of static were misclassified as human

Evaluation

Trade-off balance



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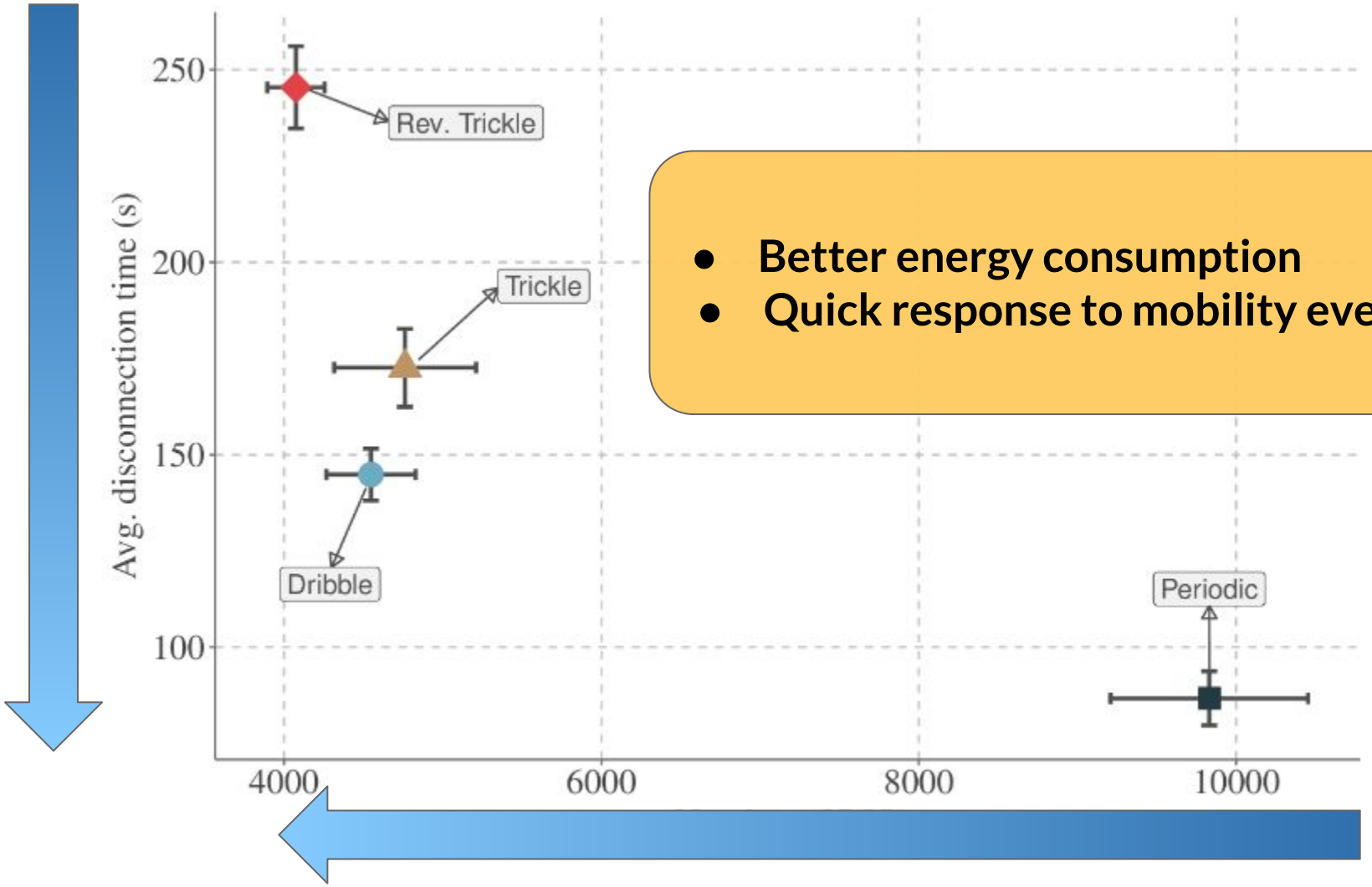
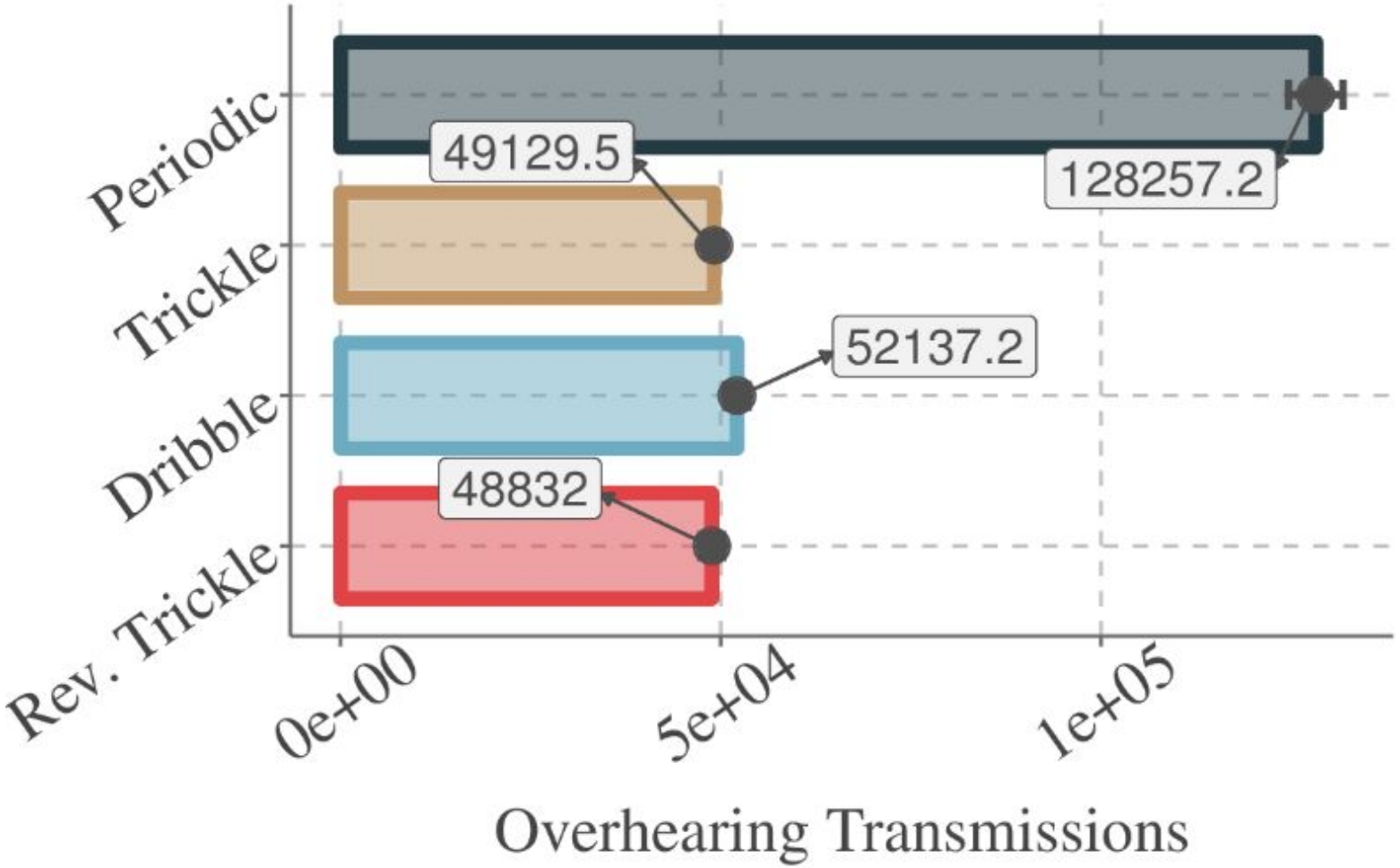


- **Better energy consumption**
- **Quick response to mobility events**

Evaluation

Overhead



Conclusion and future work

- We have proposed Dribble
  - A learn-based time scheme selector
  - It sets a custom timer scheme given the mobility pattern of a IoT device
  - Also, Dribble presented a better timer scheme trade-off balance

Conclusion and future work

- We intent to extend Dribble to support:
  - Automatic parametrization of timer schemes
  - Automatic way to associate mobility patterns to timer schemes.

Thanks!

Any questions?

You can find us at:

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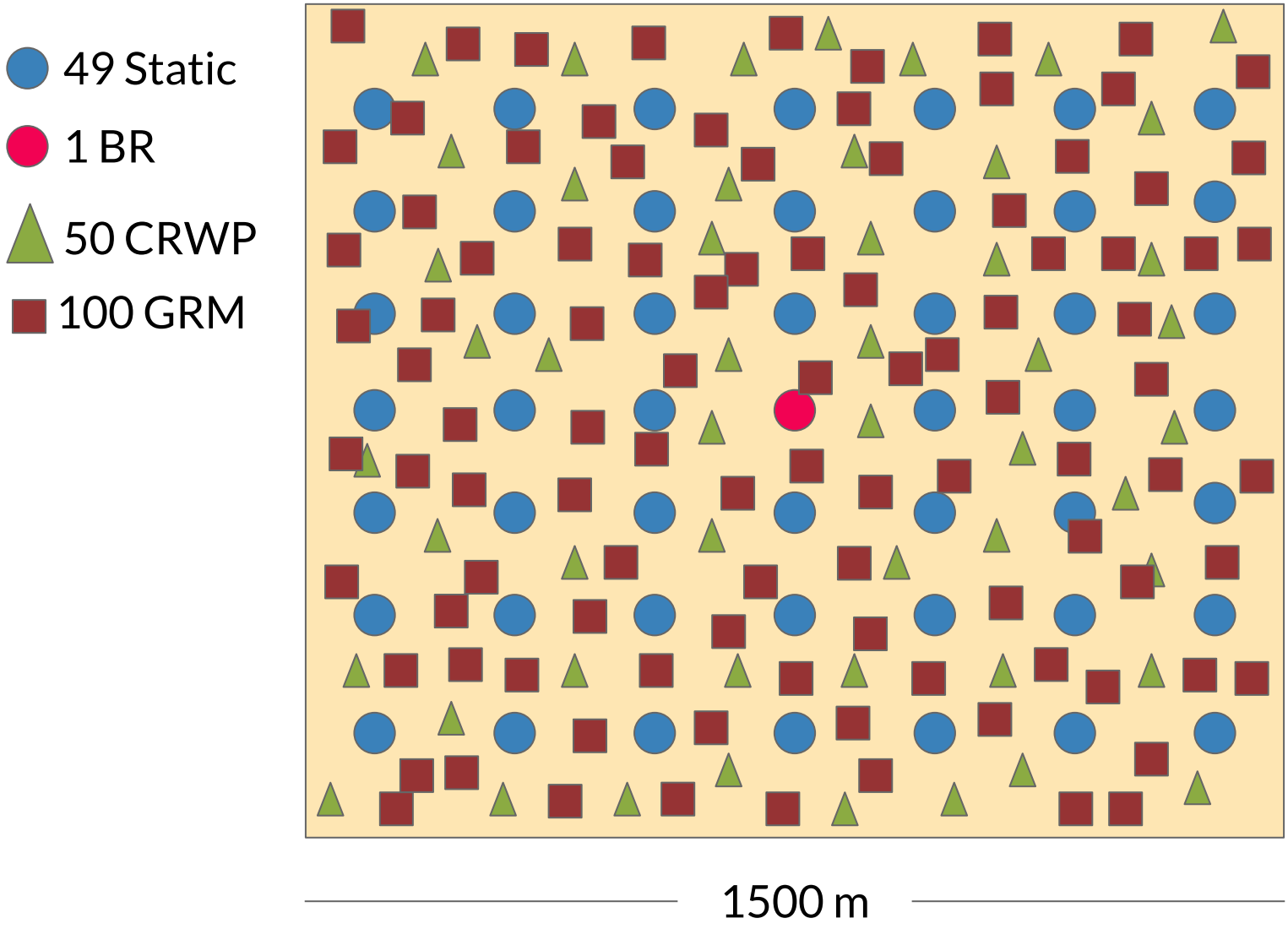
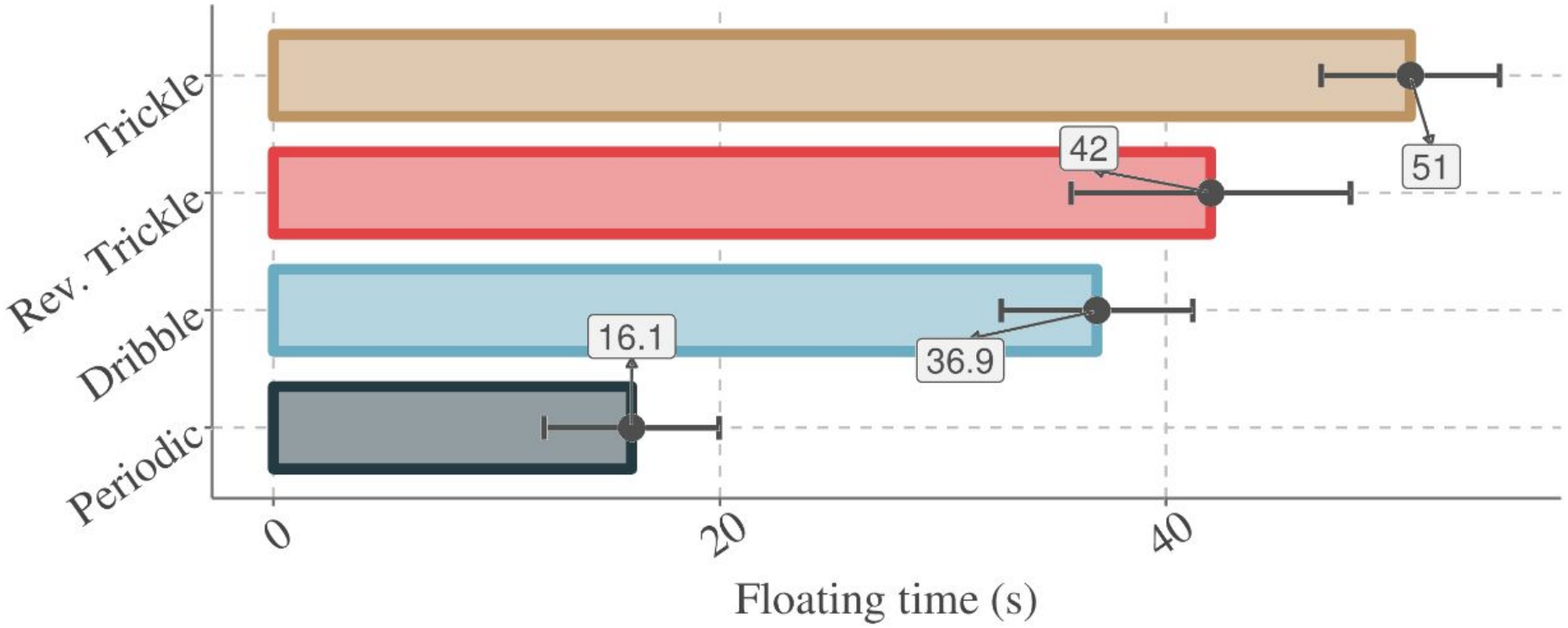
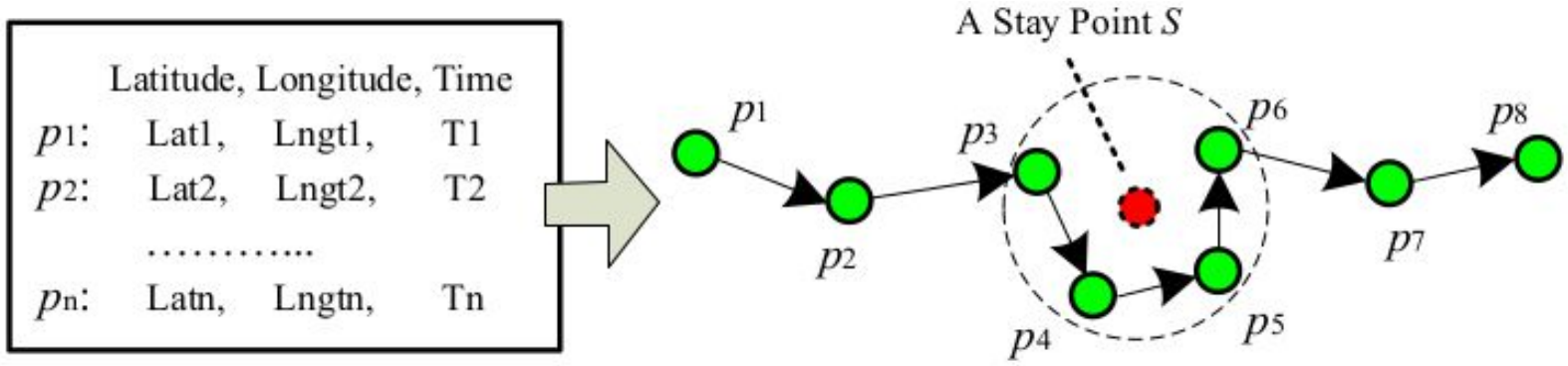
- rettore@dcc.ufmg.br
- lfvieira@dcc.ufmg.br
- loureiro@dcc.ufmg.br


49 Static
1 BR
50 CRWP
100 GRM
1500 m

Time of disconnection



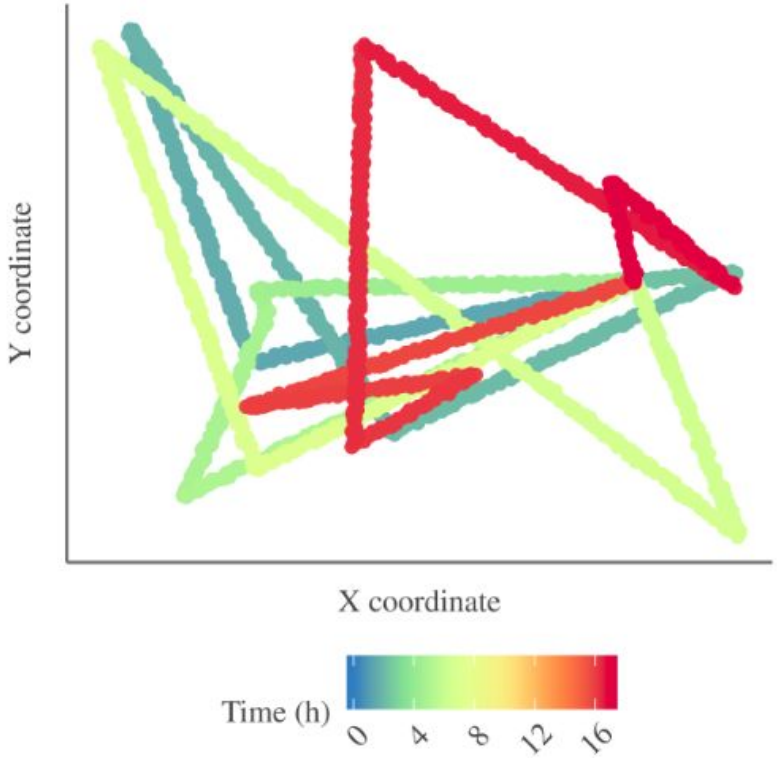
When do updates?



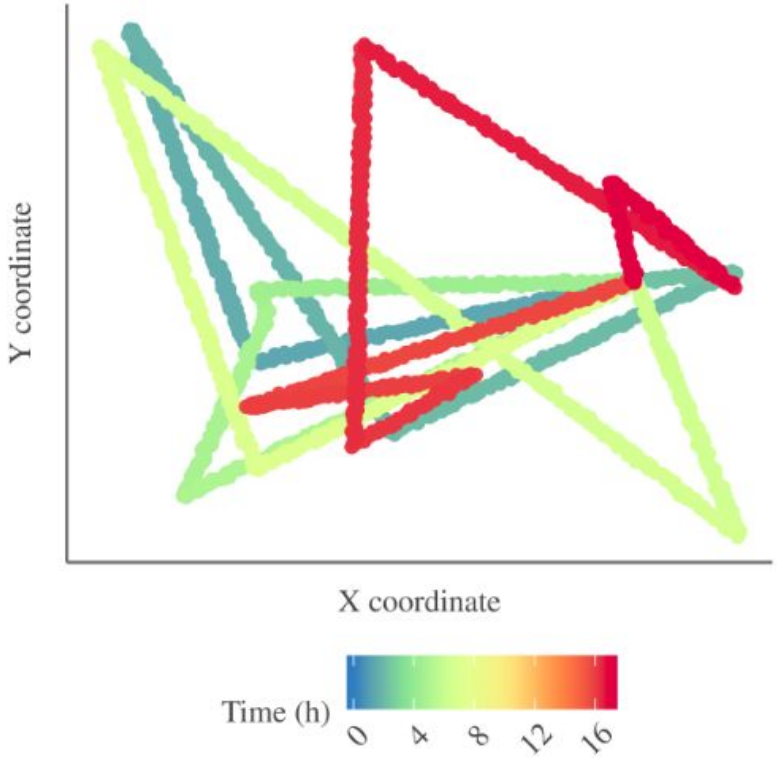
GPS points: $P = \{p_m, p_{m+1}, \dots, p_n\}$ $\forall$ $m < i \leq n$

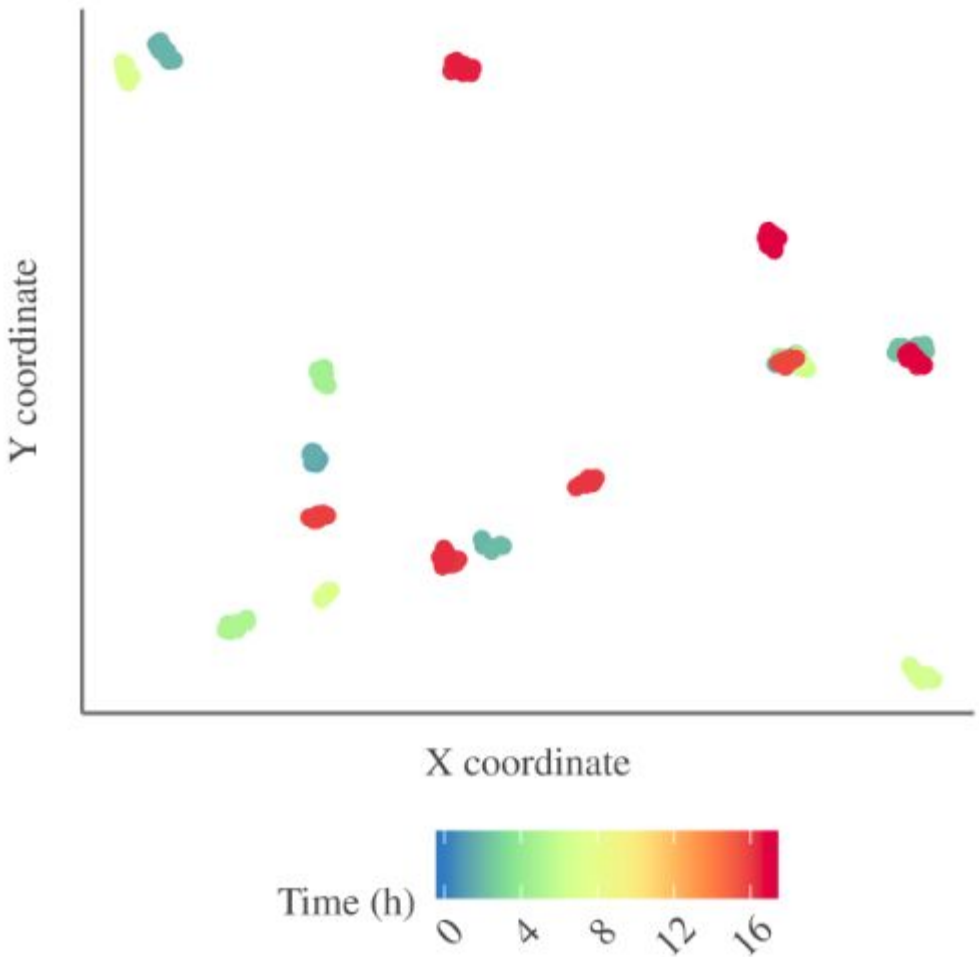
- $Distance(p_m, p_n) \leq D_{threshold}$ and
- $|p_n.T - p_m.T| \geq T_{threshold}$

Zheng, Y., Zhang, L., Xie, X., & Ma, W. (2009). Mining Interesting Locations and Travel Sequences from GPS Trajectories.

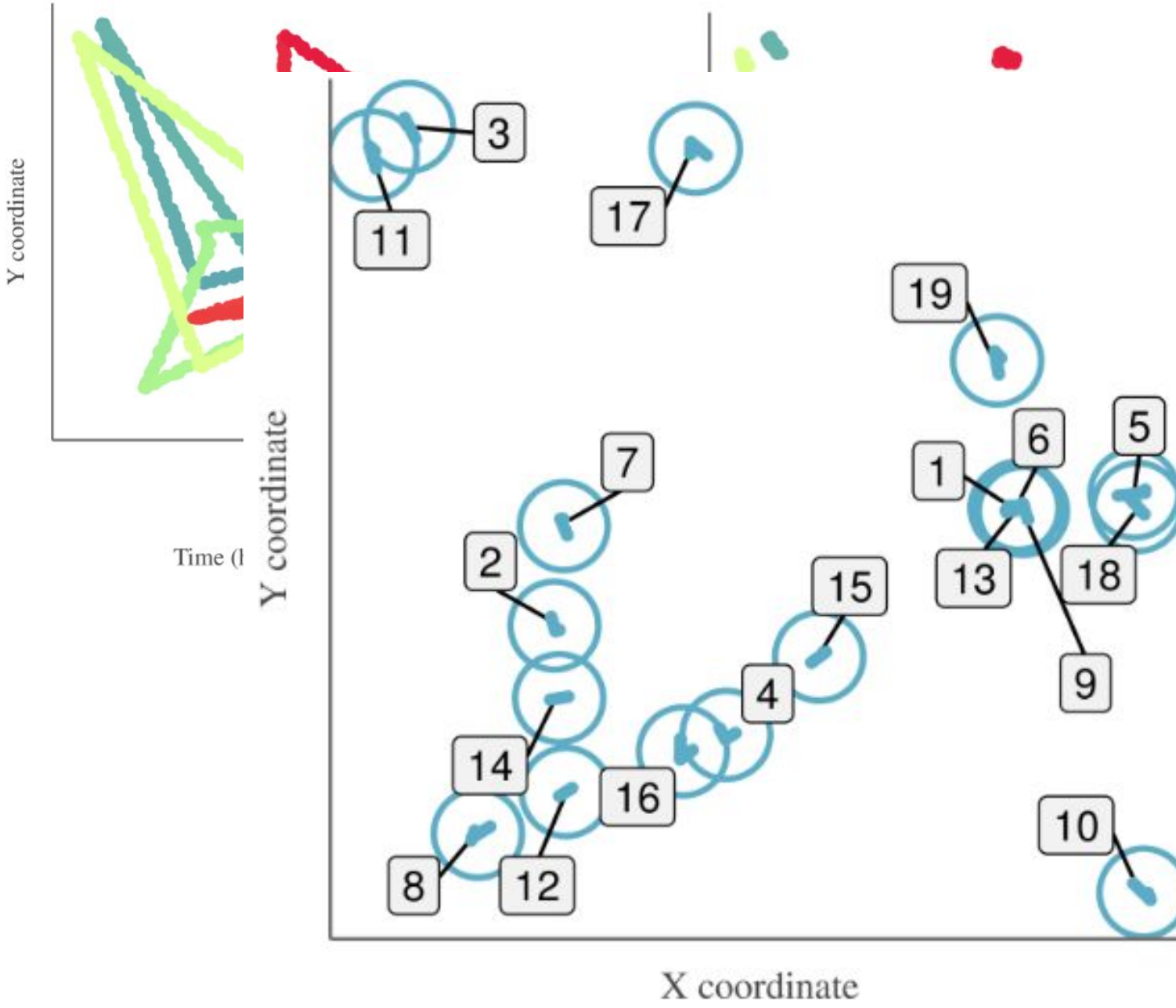


Raw data





Stay locations


Y coordinate
Time (
Y coordinate
3
11
17
19
7
2
15
1
6
5
13
18
9
4
14
16
10
8
12
16
X coordinate