A Brownian Motion Model for Last Encounter Routing

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The problem

- Routing in mobile, wireless ad hoc networks

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- *Proactive* or *table-driven* protocols
  - Routing tables with up-to-date information
  - High maintainance overhead

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- *Proactive* or *table-driven* protocols
  - Routing tables with up-to-date information
  - High maintainance overhead
- *Reactive* or *demand-driven* protocols
  - No information maintained
  - Routes discovered dynamically through flooding

An alternative approach

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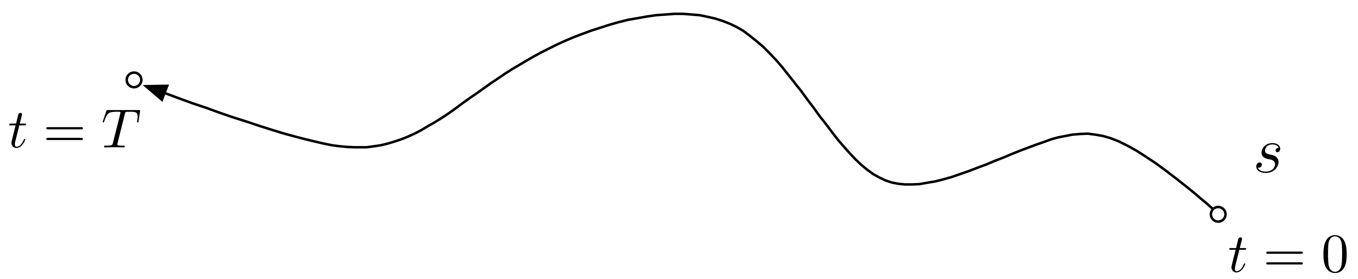
  - Routing may lead to failure; resort to flooding
- Grossglauser & Vetterli [GV03]: Last Encounter Routing (LER)

Overview

- Description of LER
- Cost for evaluating LER performance
- Previous results
- A Brownian motion model
- LER perfomance under the BM model

LER: Building routing tables



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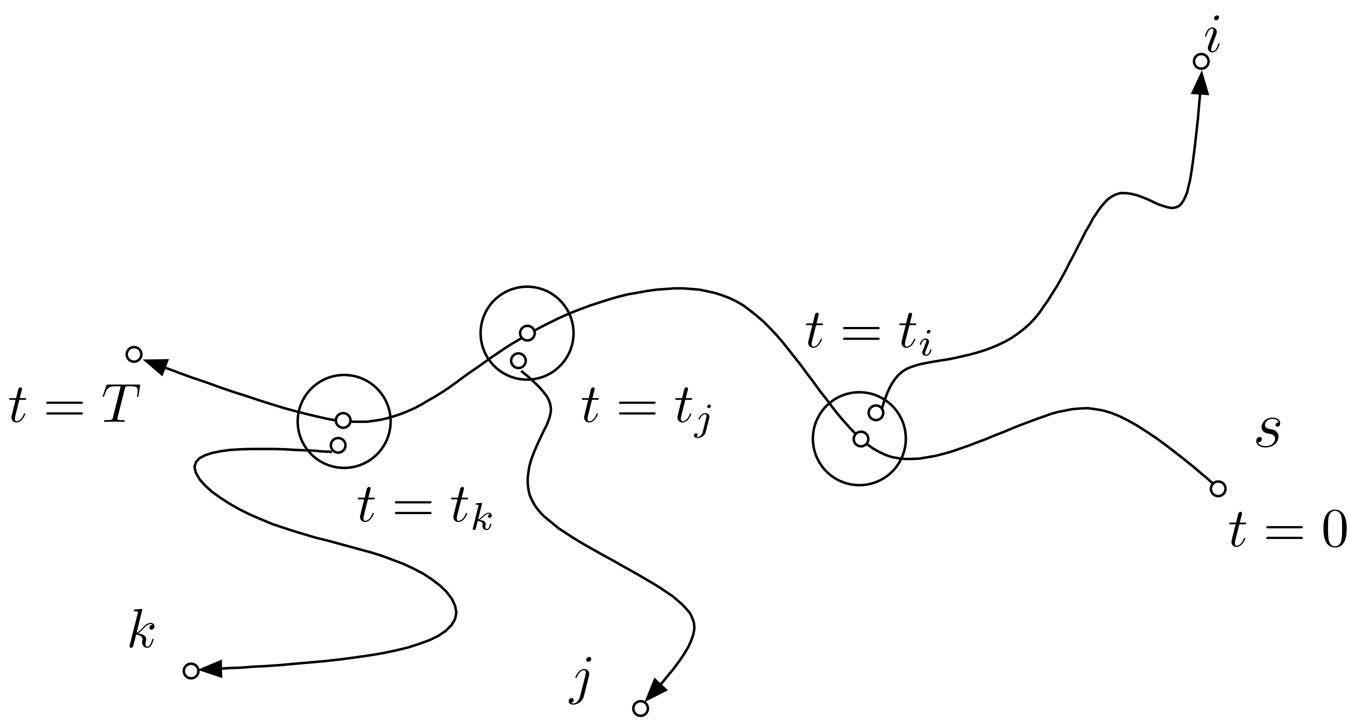

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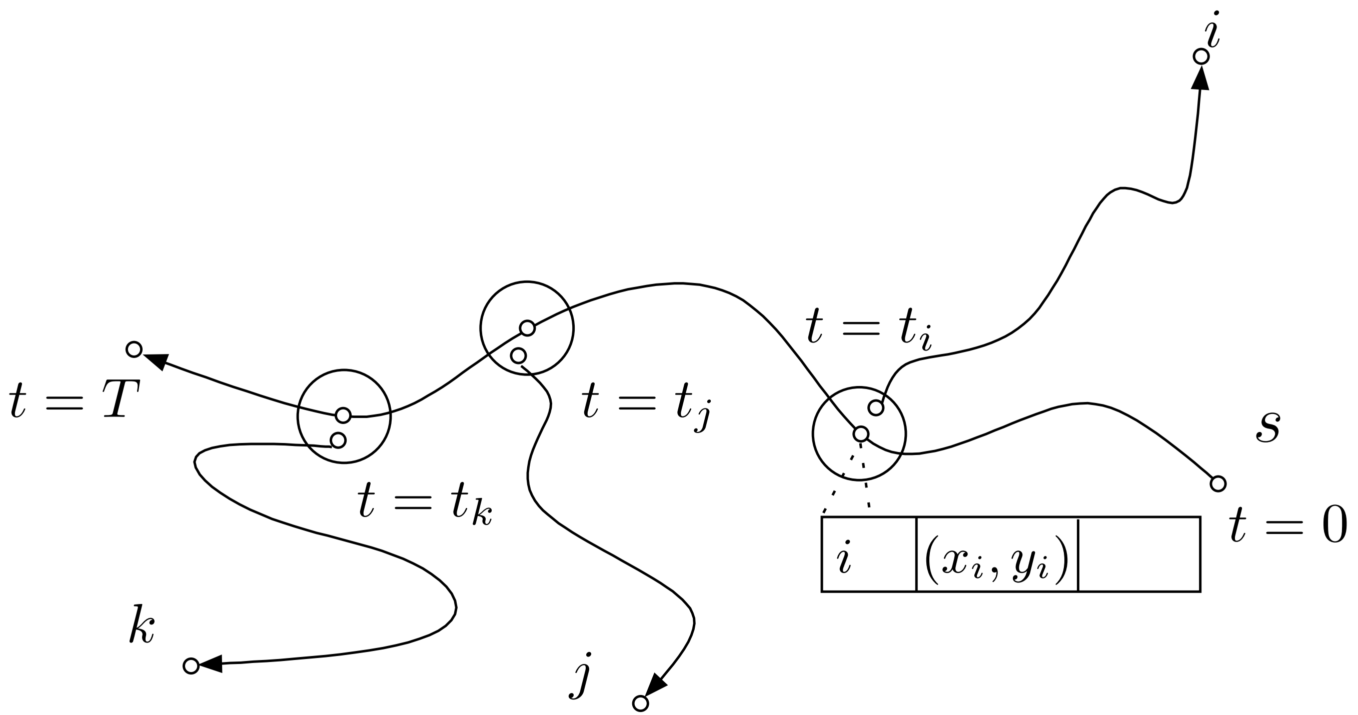
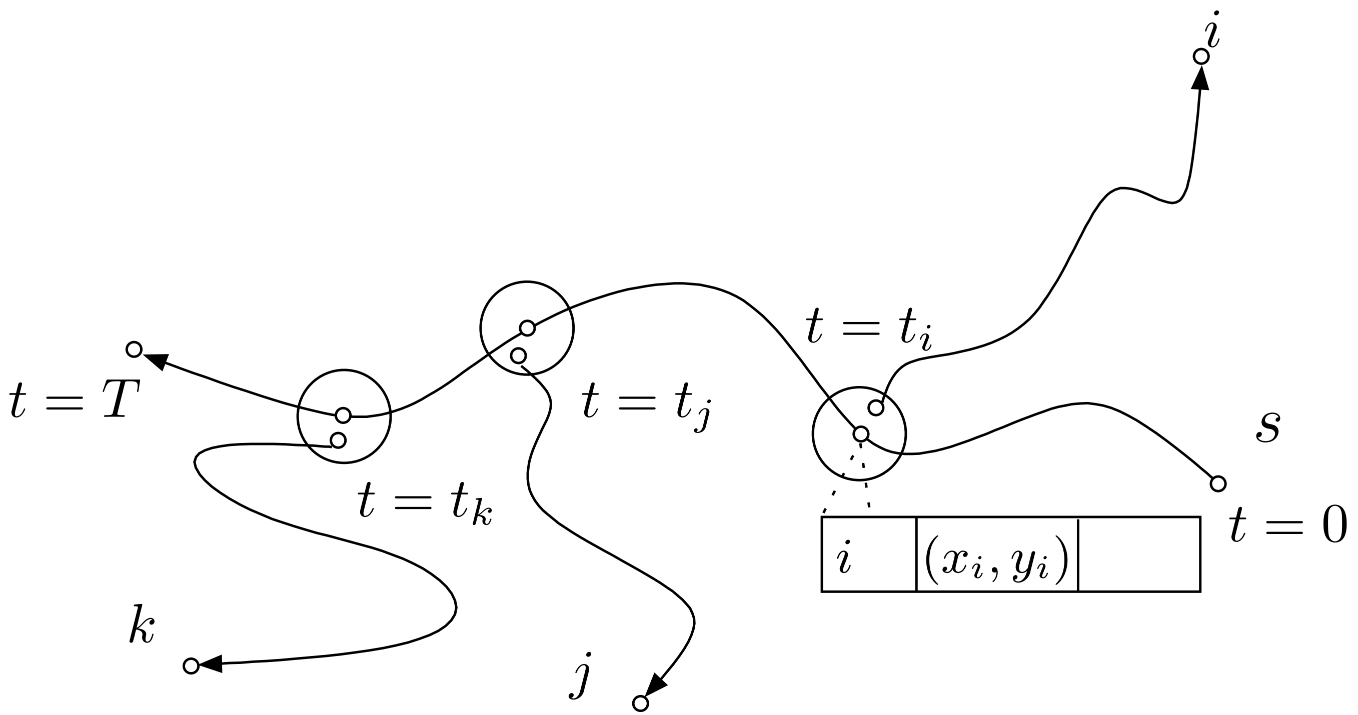


- (x_i, y_i): estimate of i's position

LER: Building routing tables



- age $T - t_i$ of table entry indicates accuracy

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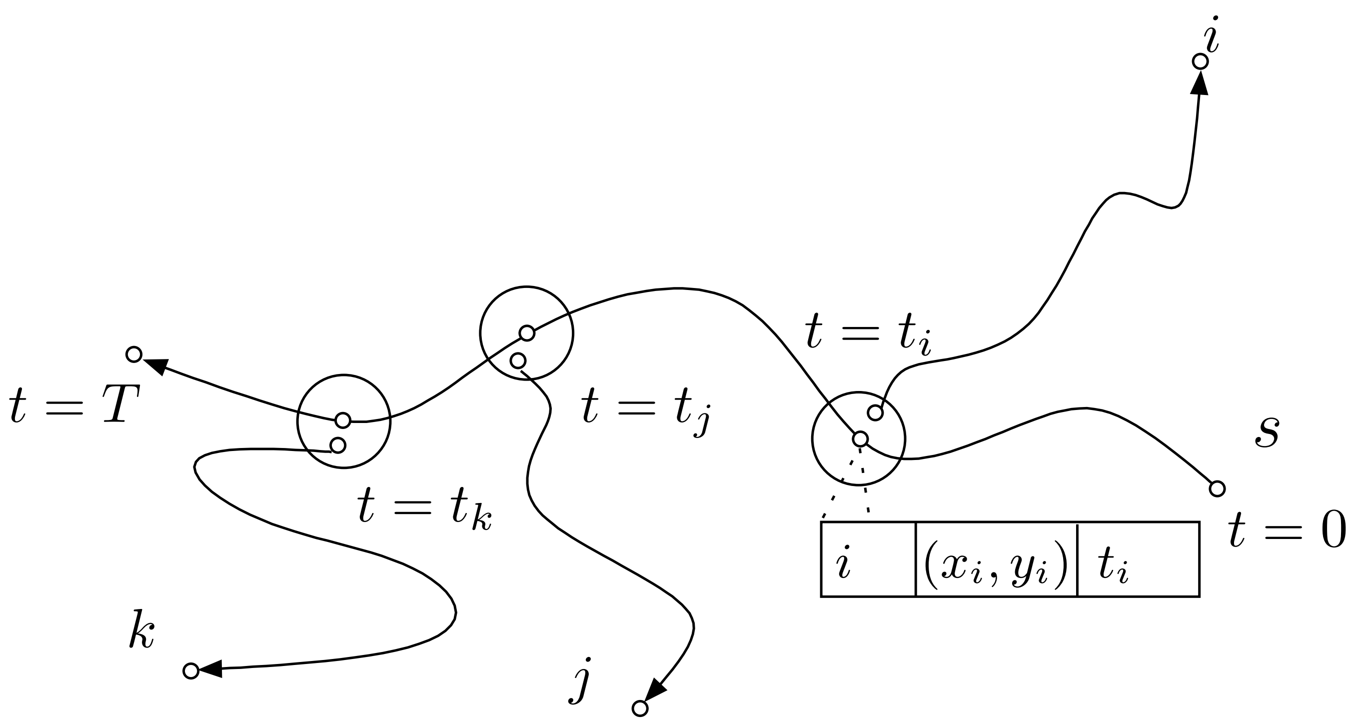

- t_i: timestamp

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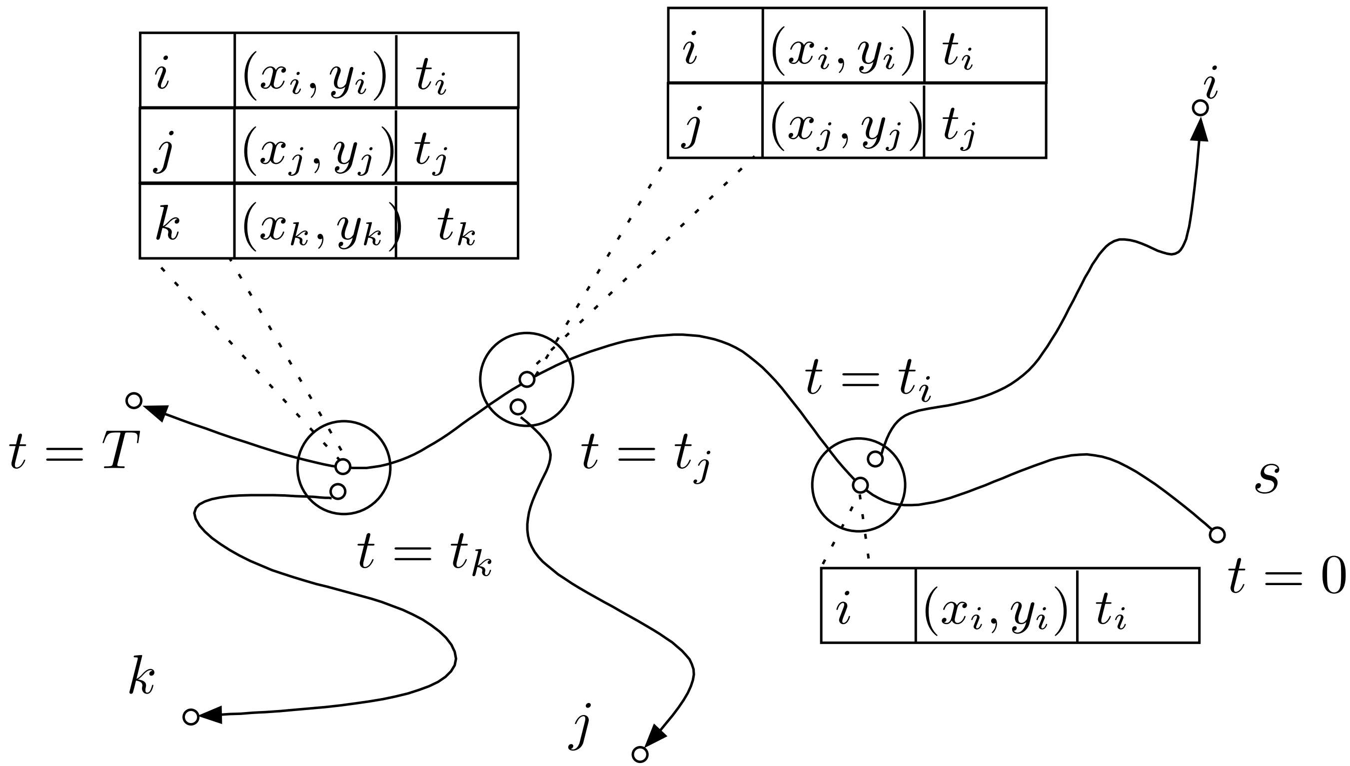

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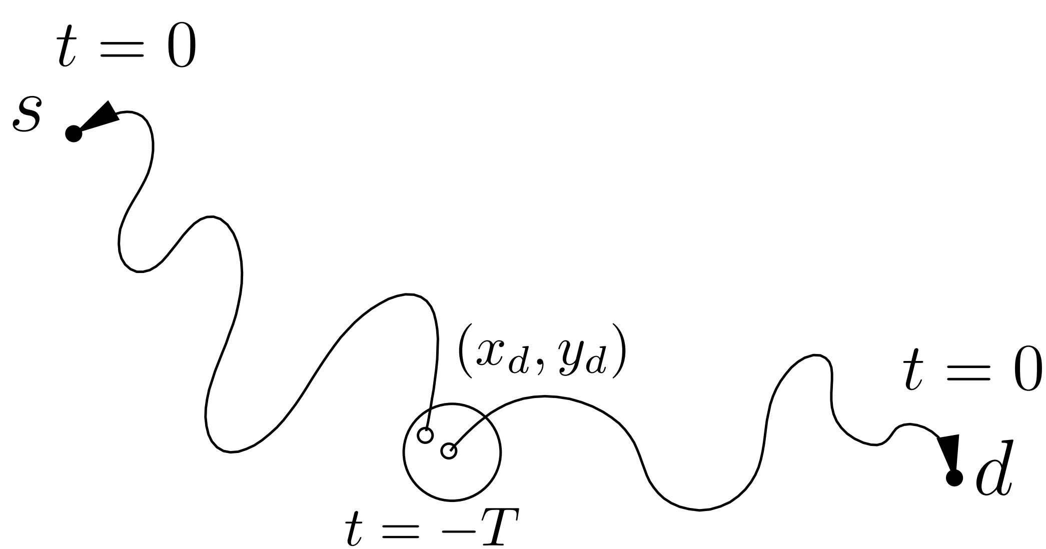

- T time units ago, s met d

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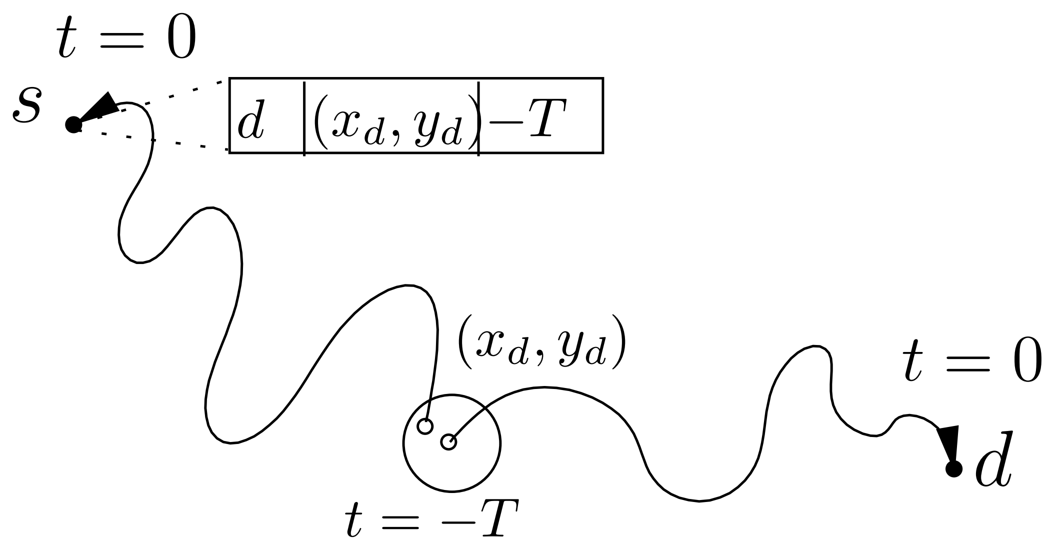

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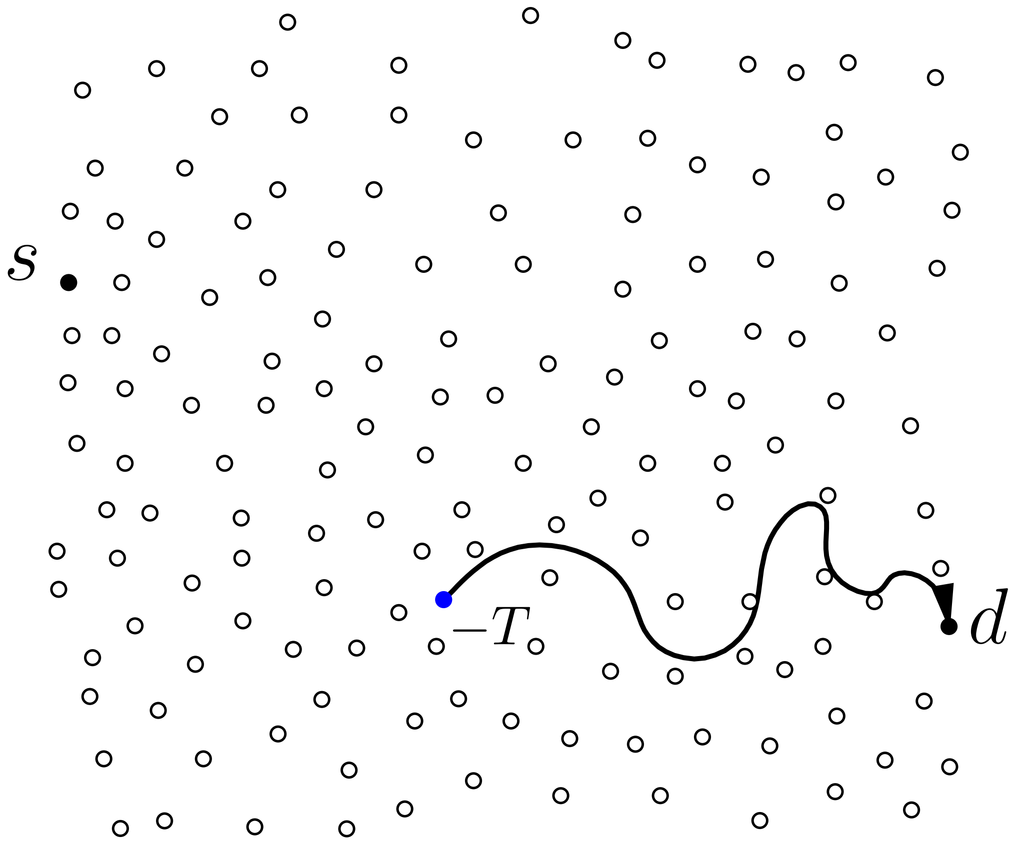

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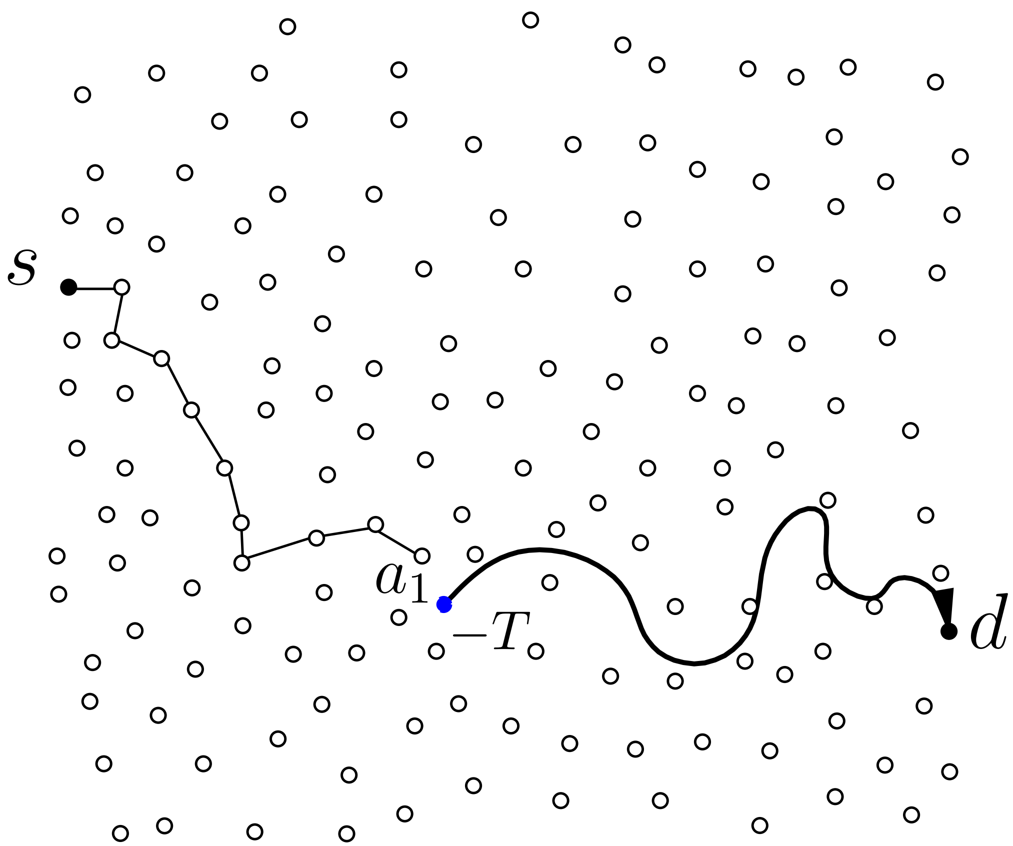

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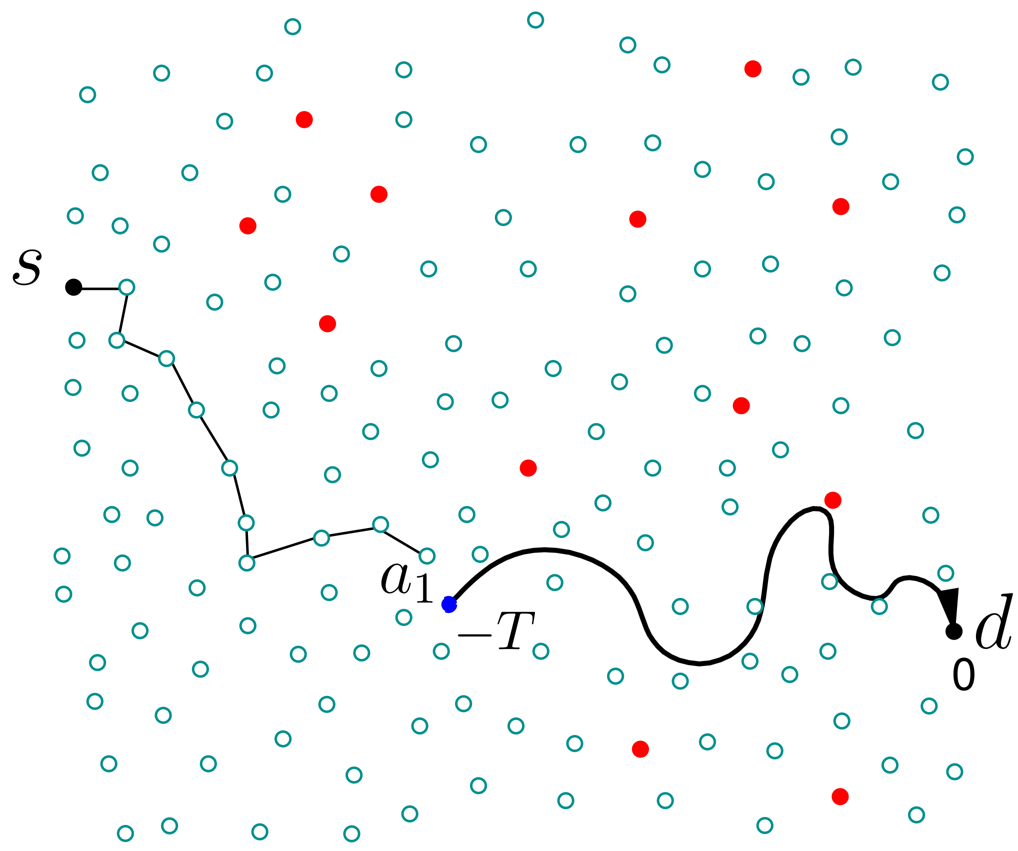

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- *messenger nodes*: age (accuracy) of d-entry: $t < T$

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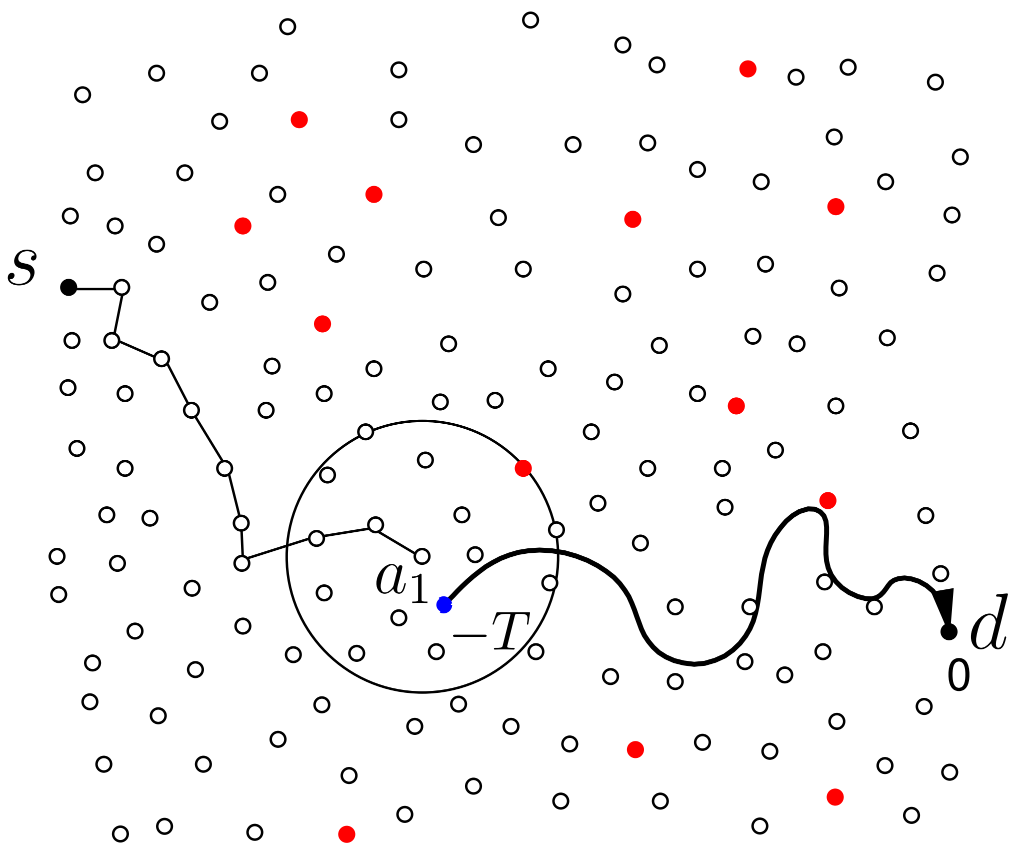

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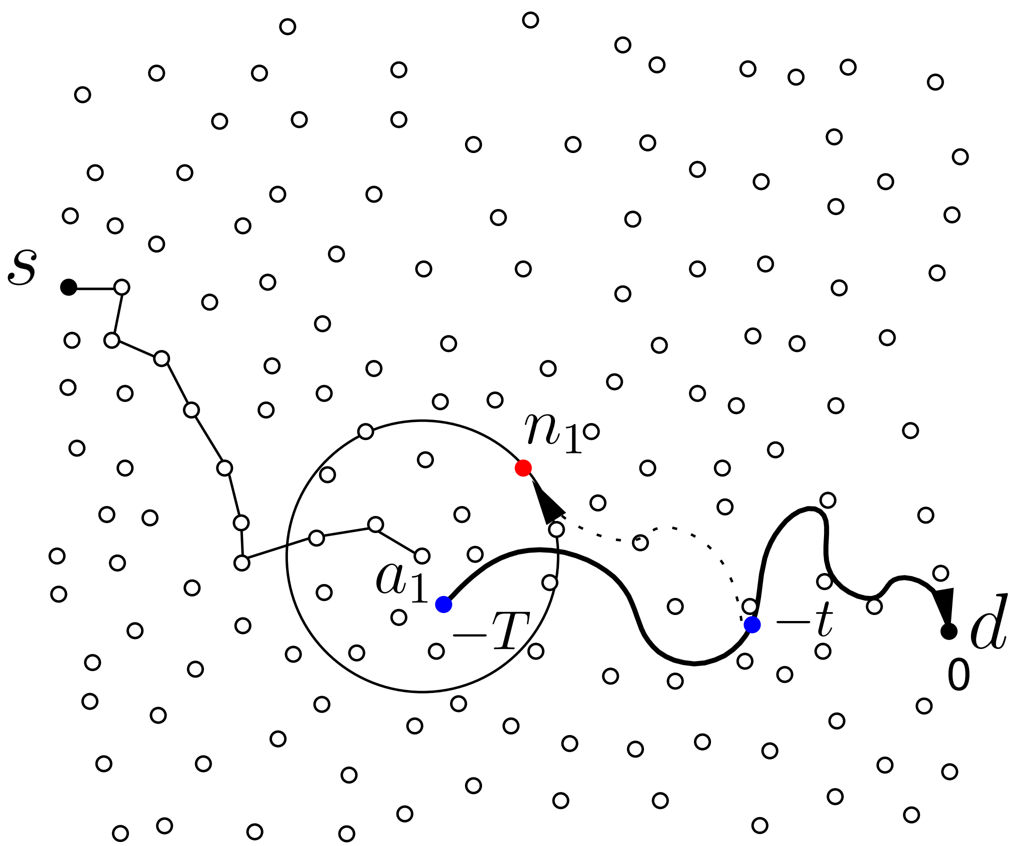

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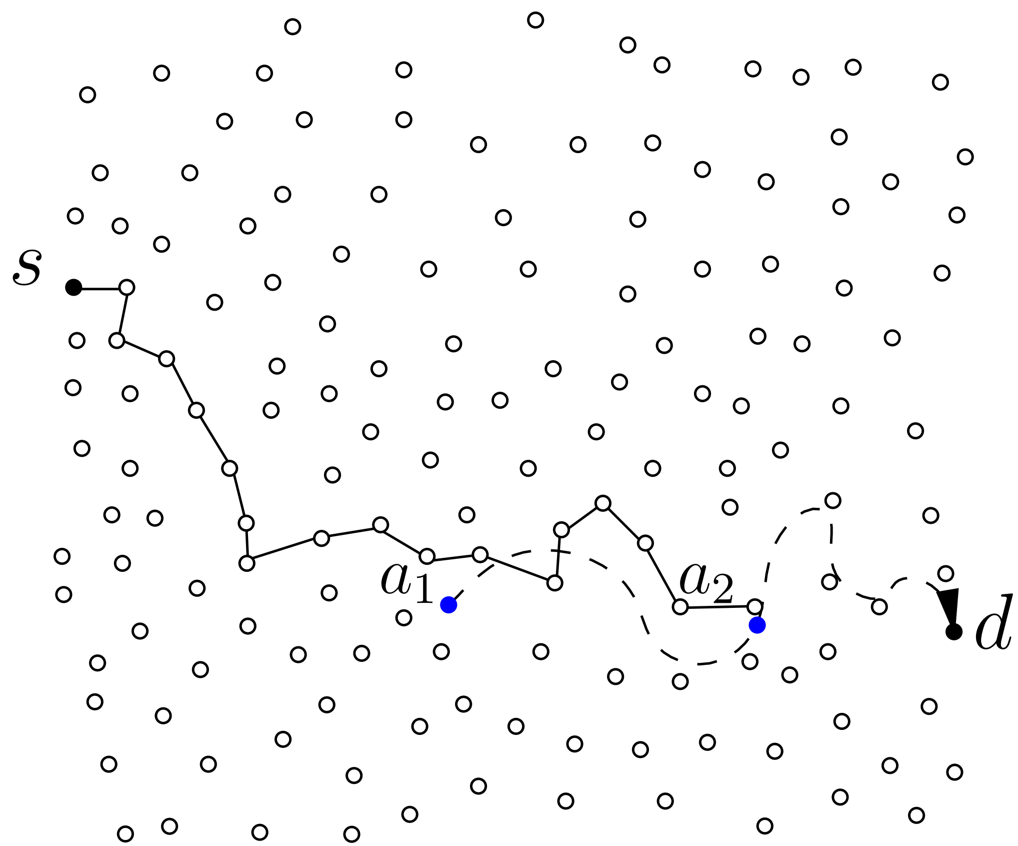

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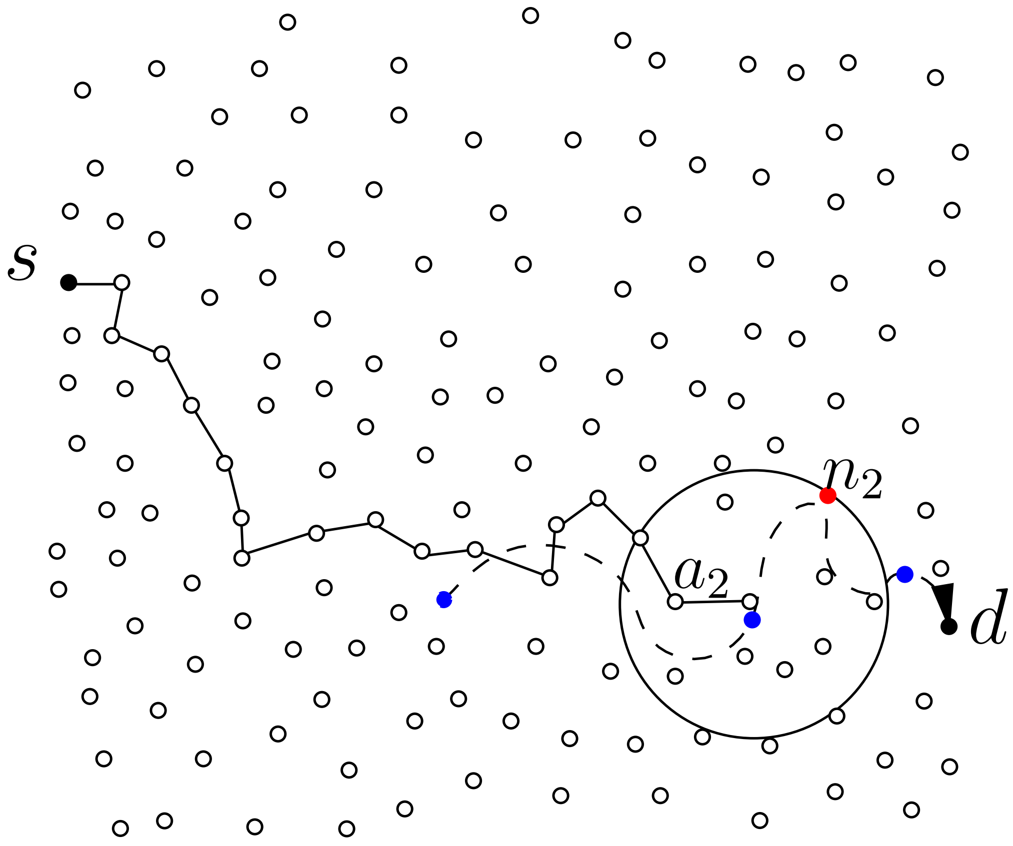

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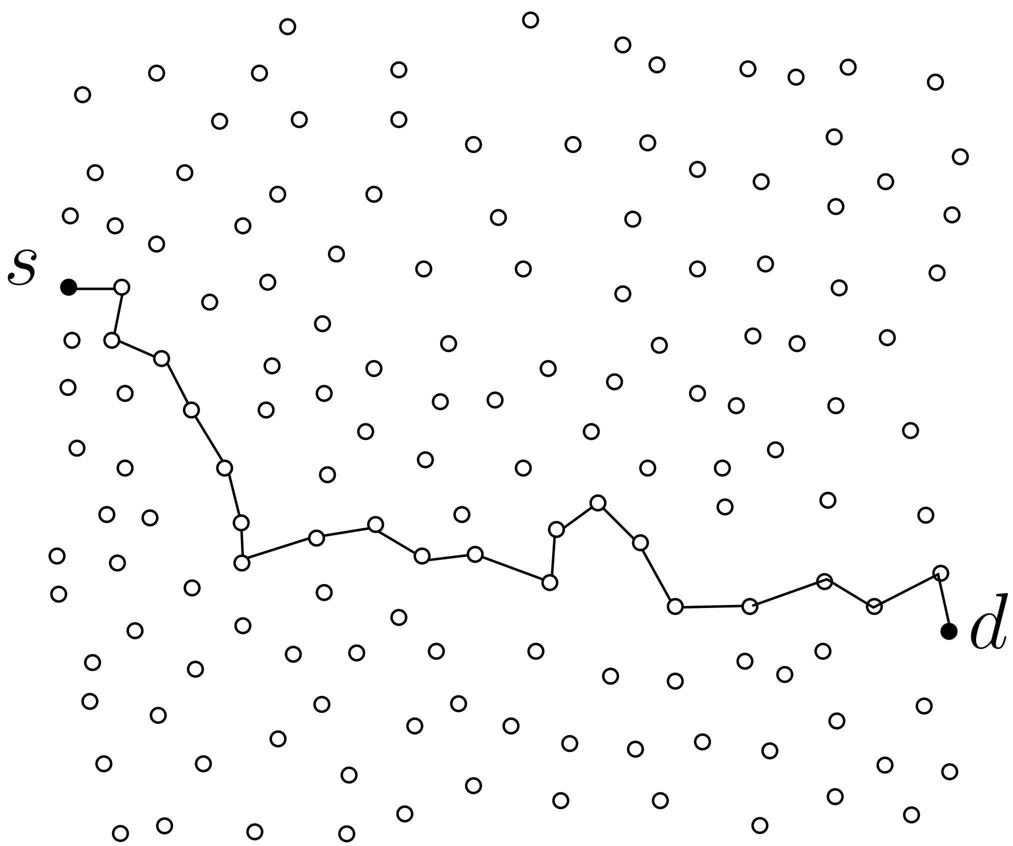

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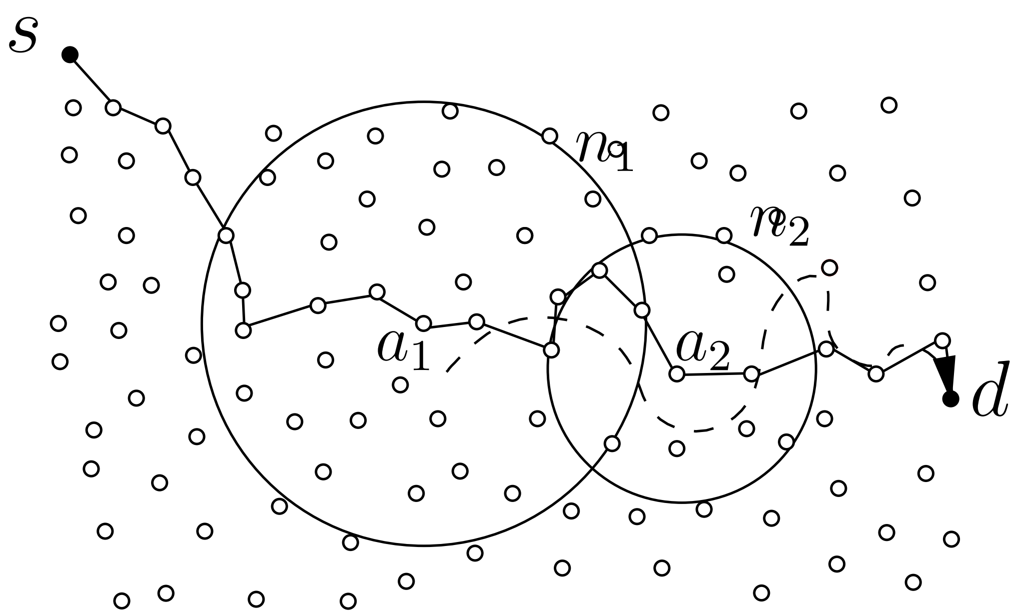
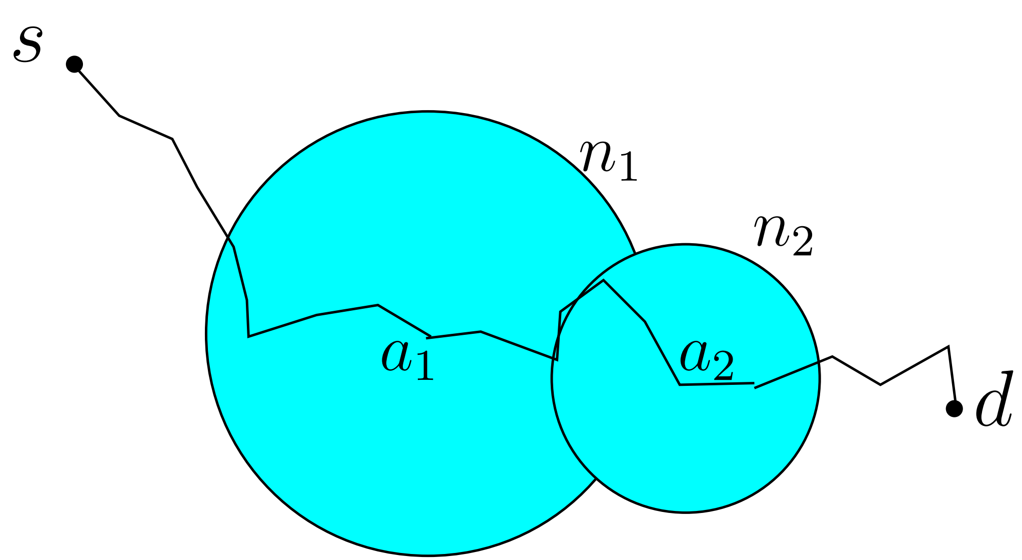
LER cost



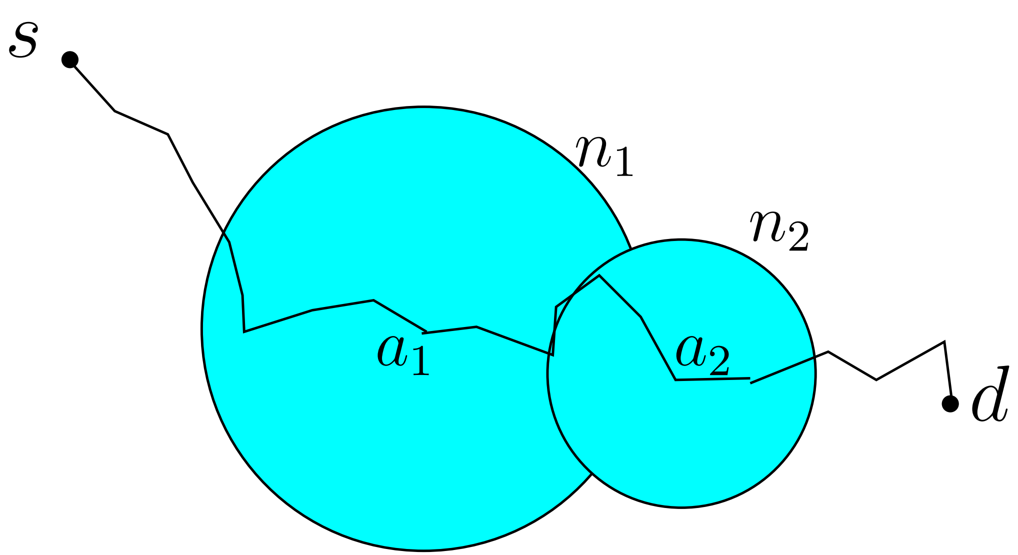
- A cost for performance

LER cost



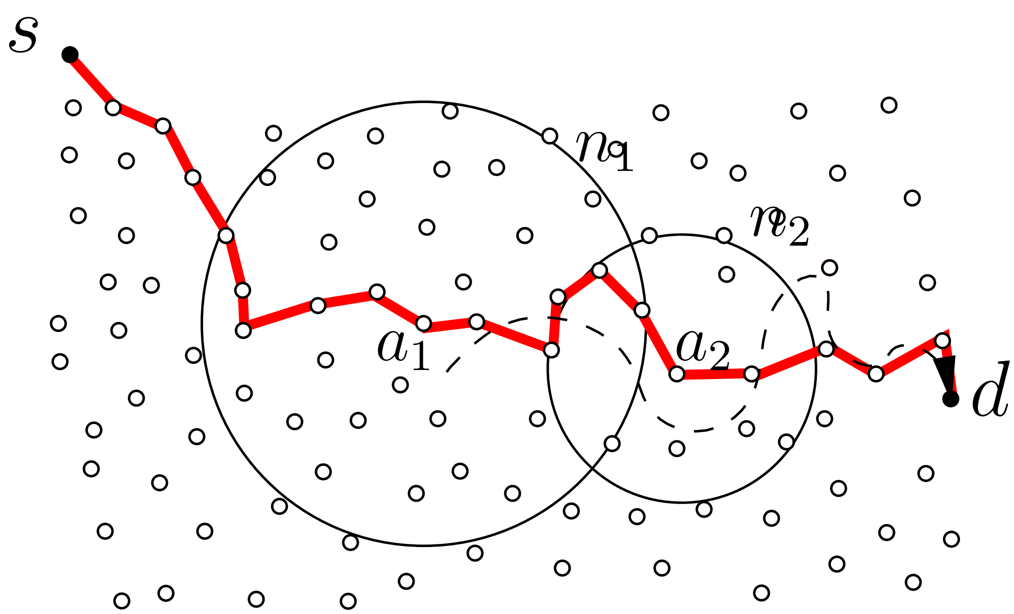
- $Q(T)$: Expected total area flooded (function of age T).

LER cost



- Flooding overhead: $\sim \rho Q(T)$

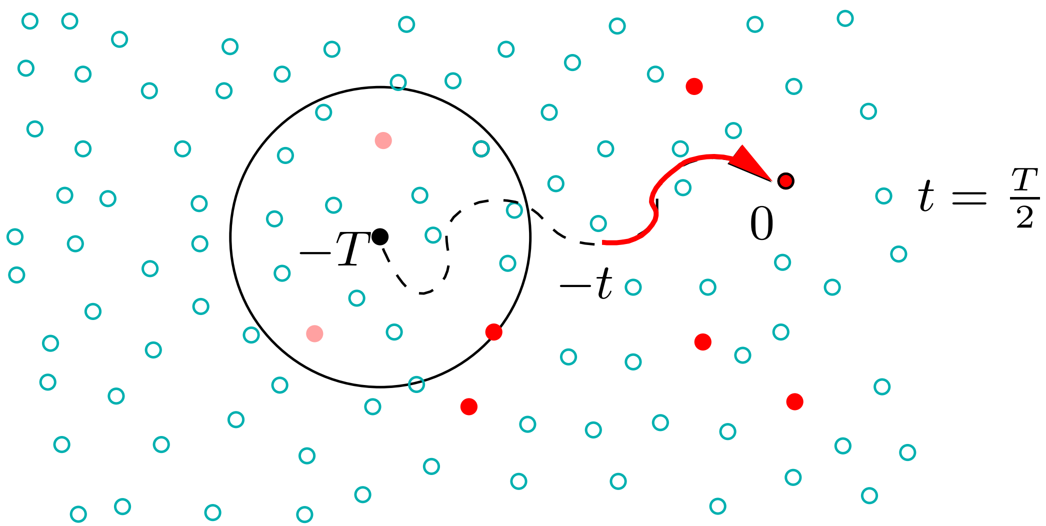
LER cost



- Forwarding overhead

Related Work

EASE [GV03],[GV06]:



Flood until the closest messenger node with age $t < T/2$ is located

Related Work

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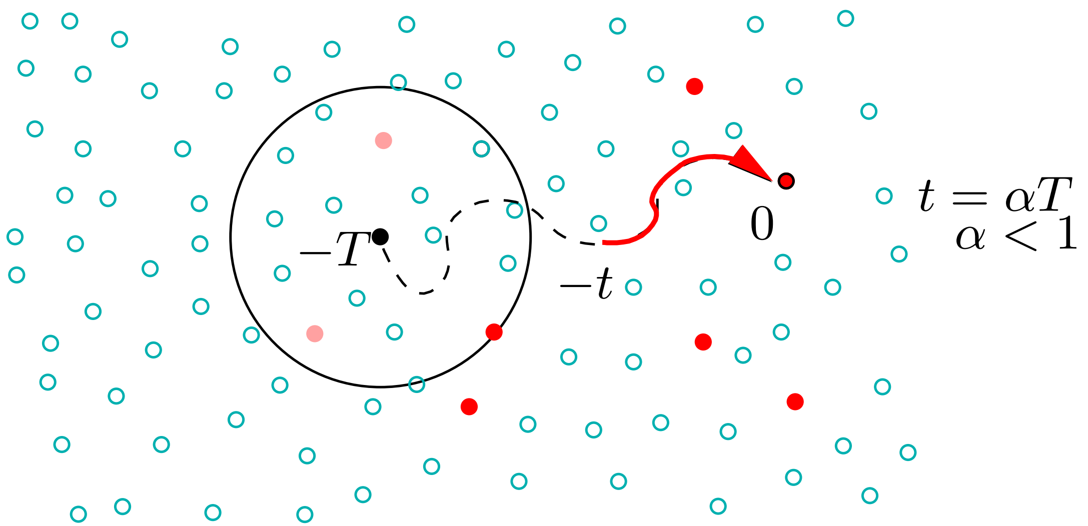

Flood until the closest messenger node with age $t < \alpha T$ is located, $\alpha < 1$

Related Work

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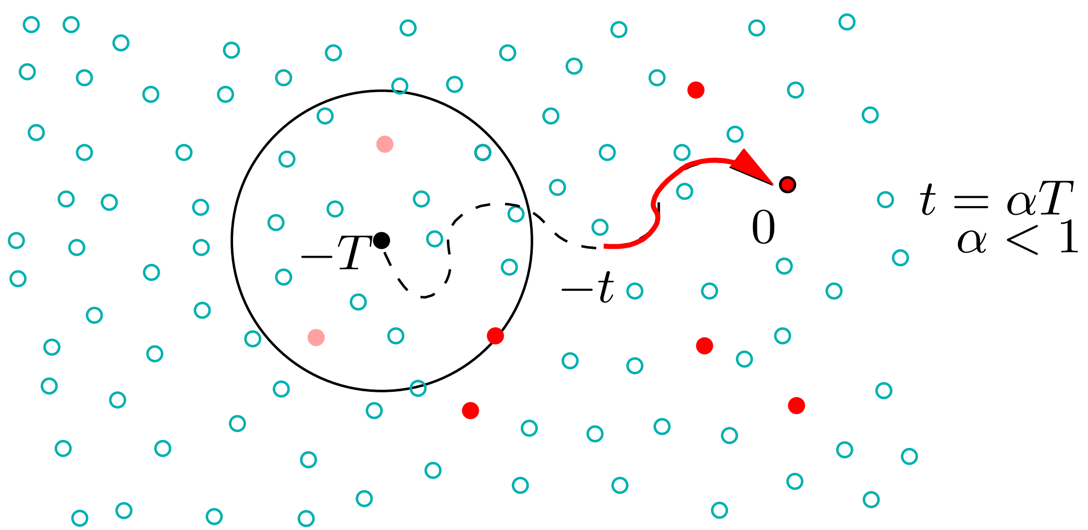

Random walks on a finite grid

Related Work

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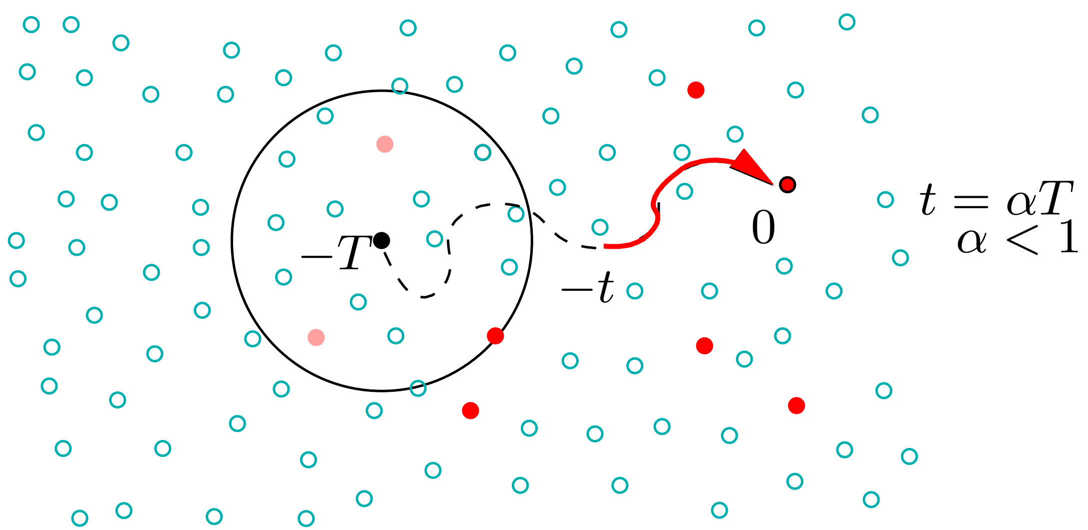

Expected total flooding area (and overhead) is $O\left(\sqrt{T}\right)$, forwarding overhead is $O\left(\sqrt{T}\right)$

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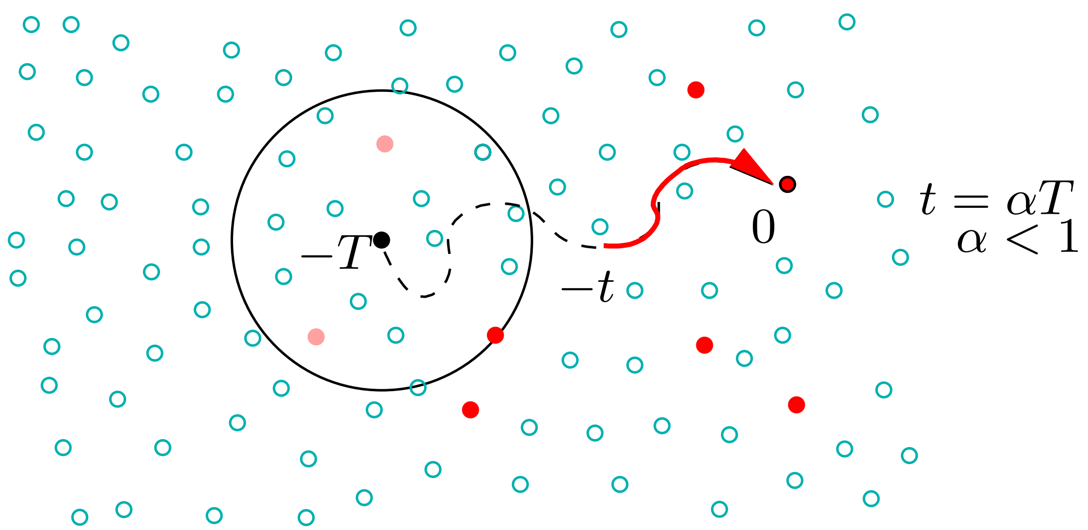
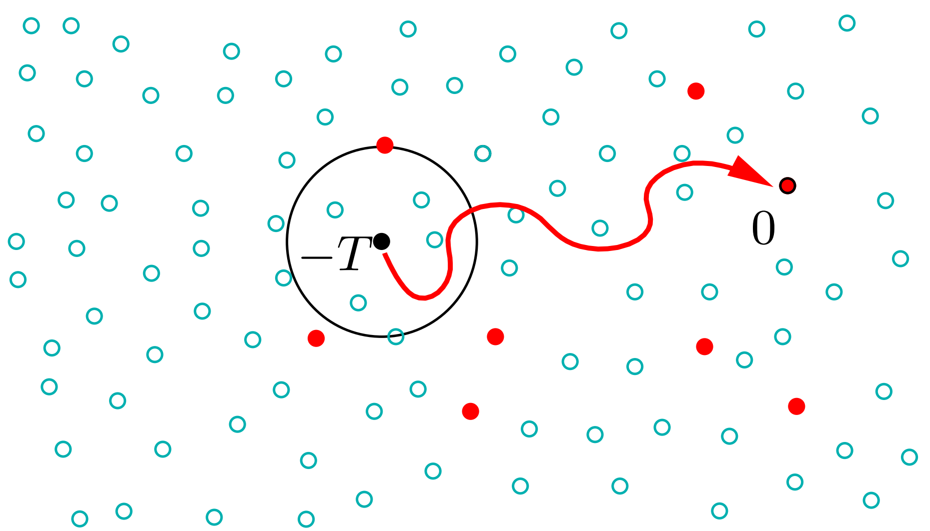


EASE overhead $O\left(\sqrt{T}\right)$ - of the order of shortest path!

Versions of LER we study

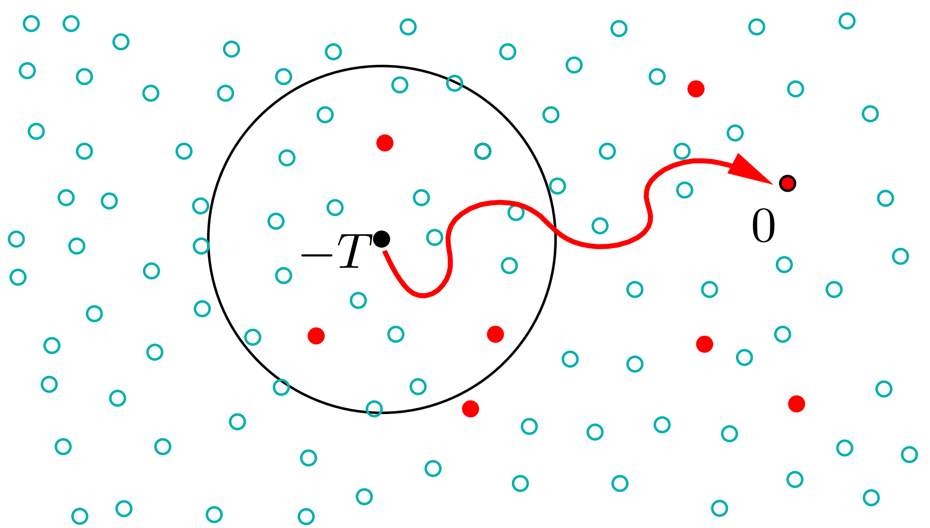
LER$_0$: (LER as presented earlier)



- Flood until the closest messenger node is located

Versions of LER we study

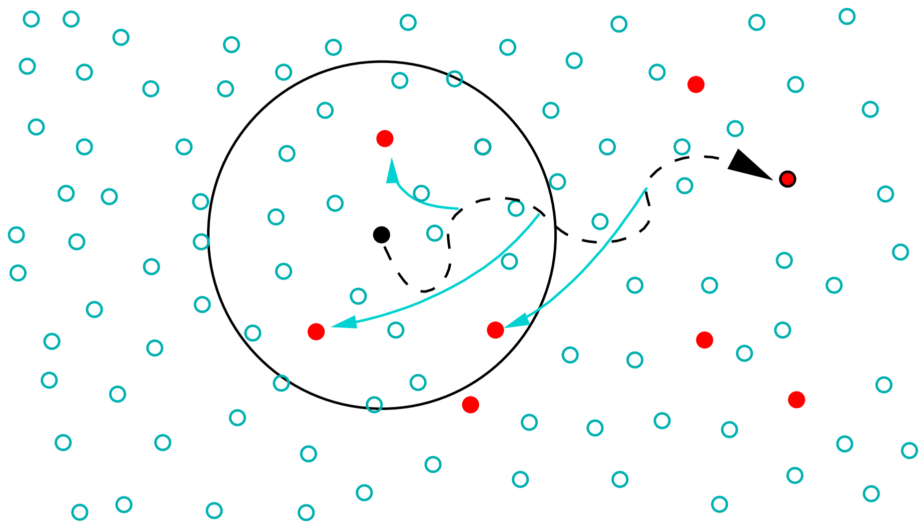
LER$_1$



- Flood a predetermined area

Versions of LER we study

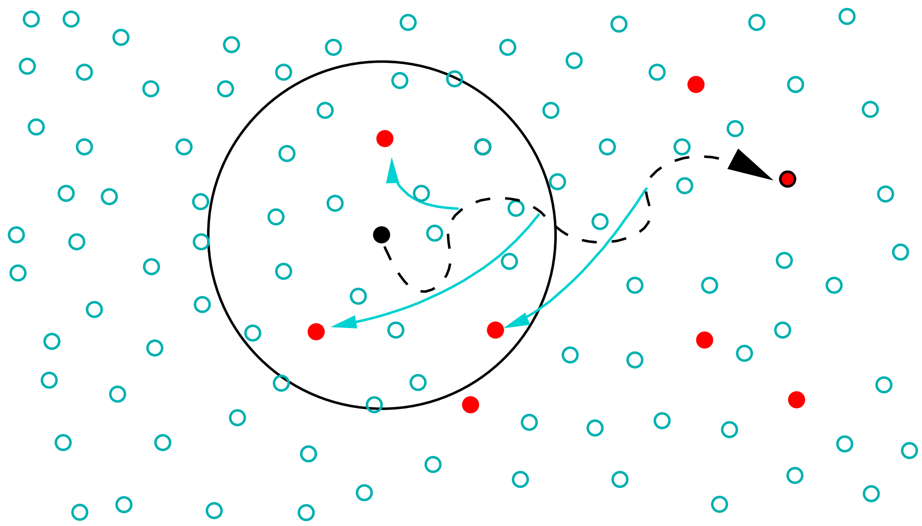
LER$_1$



- Use the most accurate information

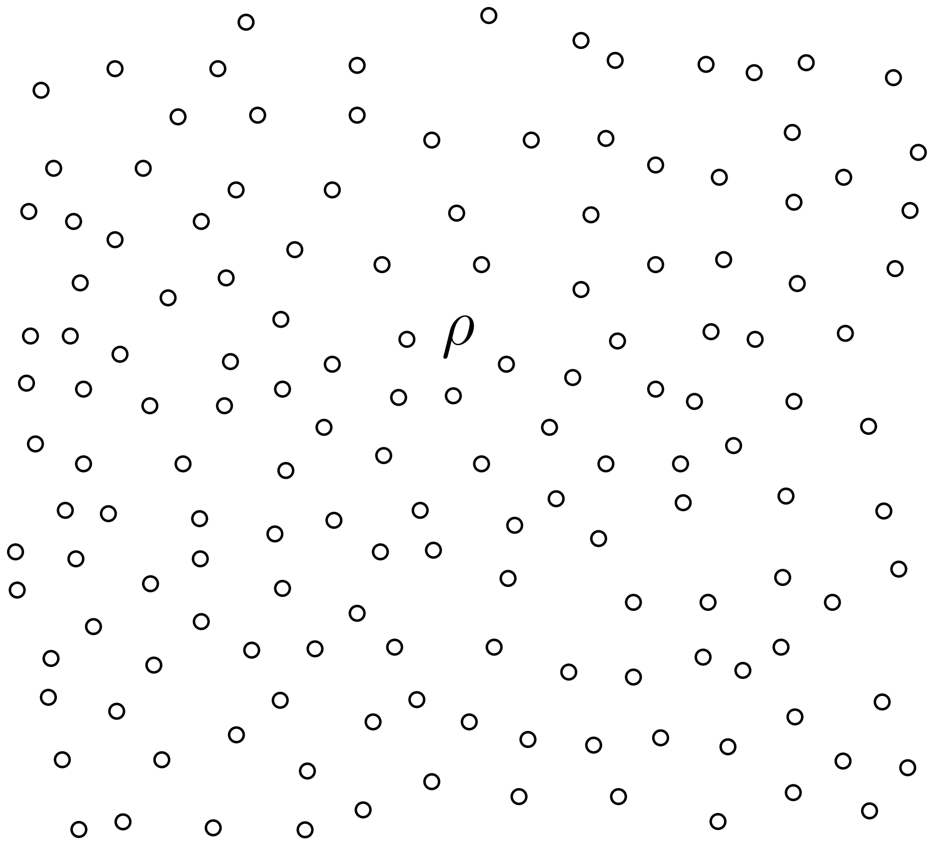
Versions of LER we study

LER$_1$



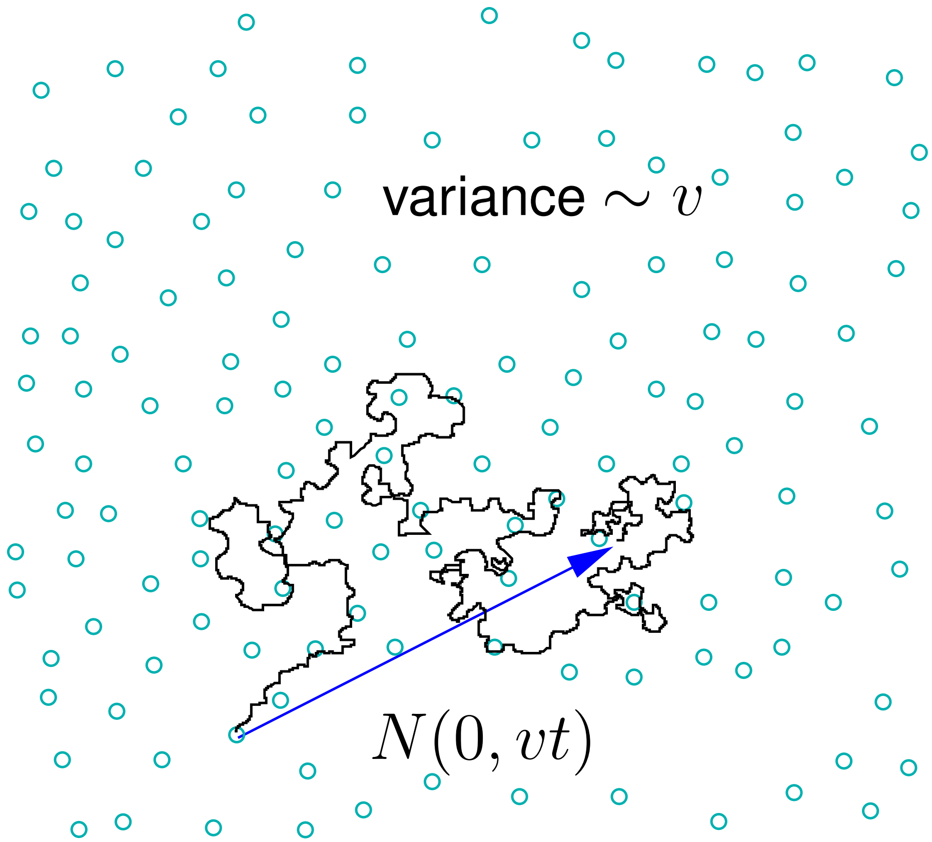
- If no messenger nodes were in the area, revert to LER$_0$

Network, Mobility and Cost Models



- Poisson field

Network, Mobility and Cost Models



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- Brownian motion

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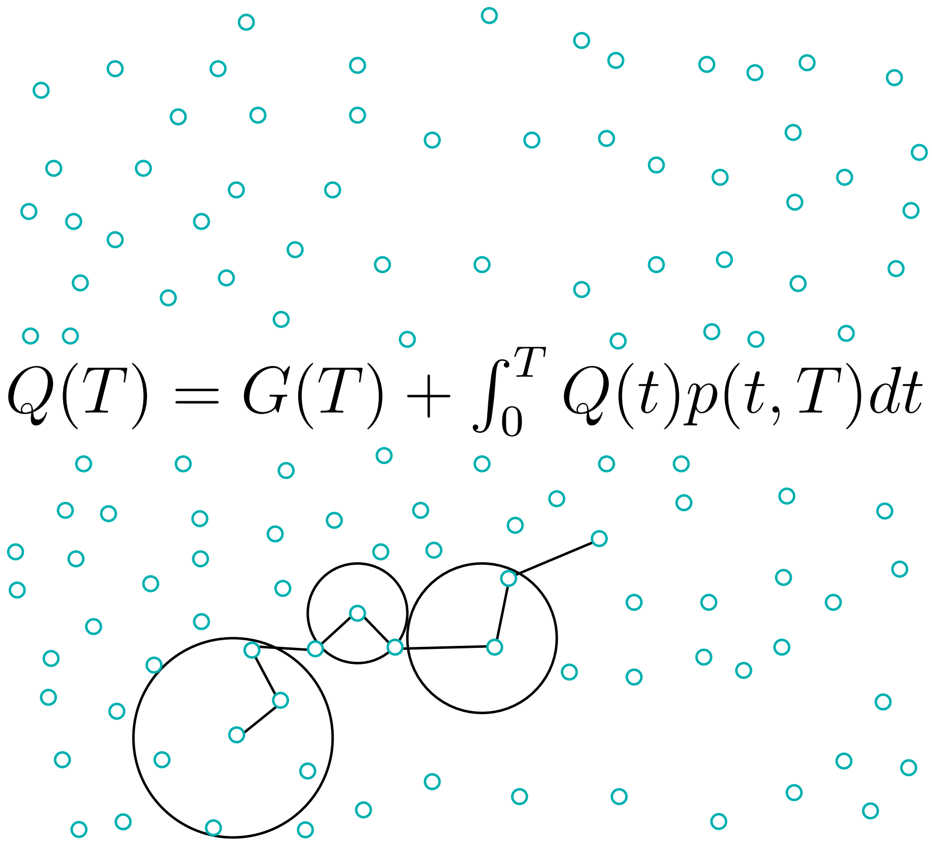

$$Q(T) = G(T) + \int_0^T Q(t)p(t,T)dt$$

- Poisson field
- Brownian motion
- Volterra equation

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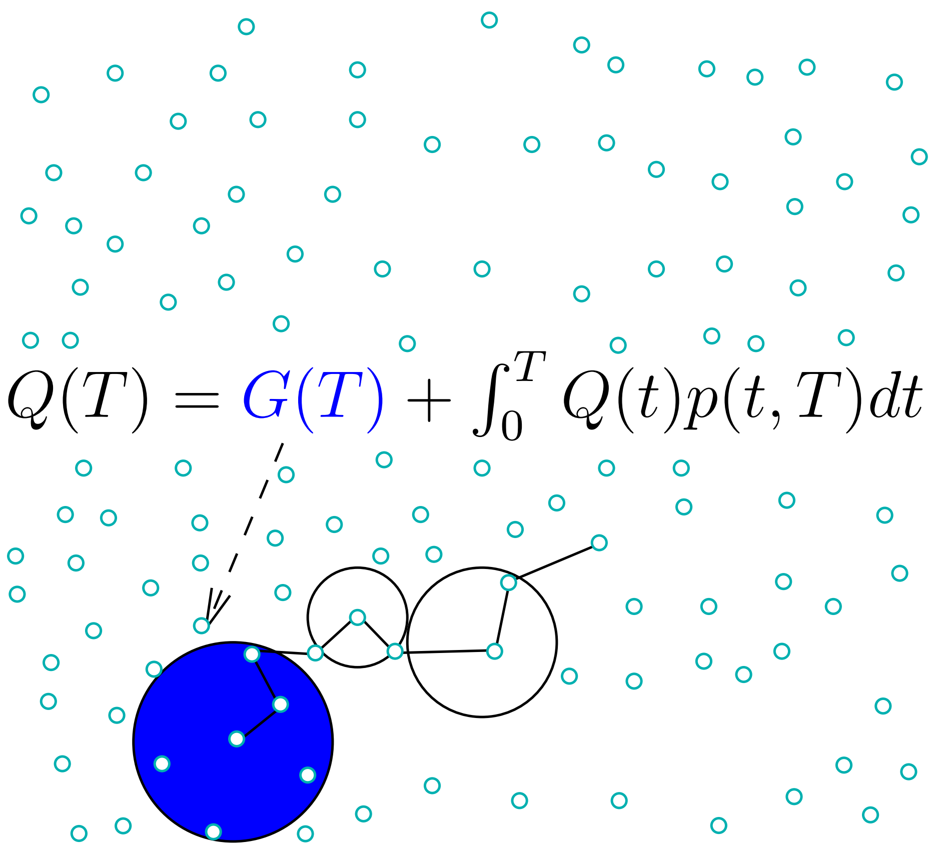

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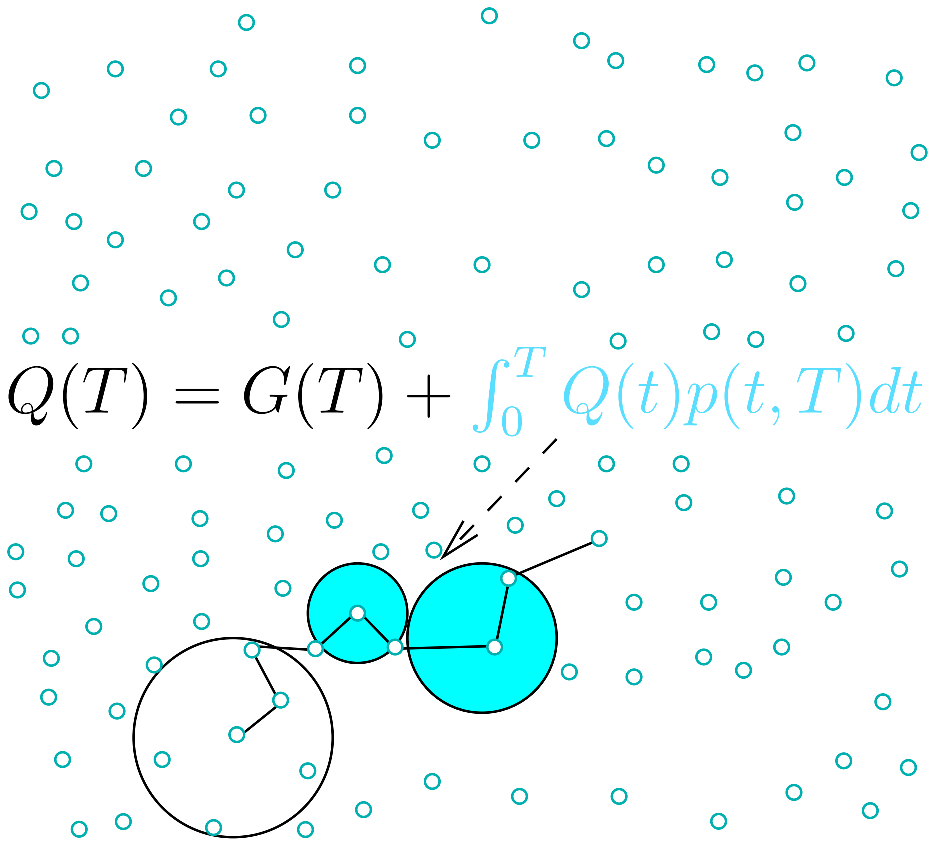

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Results under our model

Fact: Simple flooding $\Theta(T)$, shortest path $\Theta\left(\sqrt{T}\right)$

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Results under our model

Fact: Simple flooding $\Theta\left(T\right)$, shortest path $\Theta\left(\sqrt{T}\right)$

- The expected total flooding area of LER_0 is $O(T)$
- The expected total flooding area of LER_1 is $o(\log^{2+\varepsilon} T)$, for any $\varepsilon > 0$
- Forwarding overhead of LER_1 is $O\left(\sqrt{T}\right)$ (not in paper)

Conclusions and Future work

- Using approximate information pays off
- What about other approximate information protocols, different mobility models?
- What about location in other highly dynamic systems?

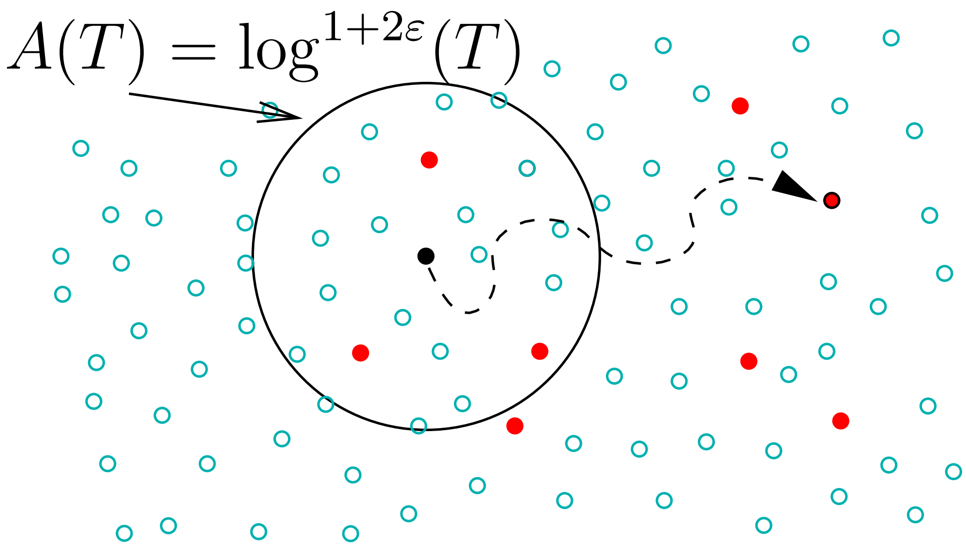
Thank you!

References

[GV03] Matthias Grossglauser and Martin Vetterli. Locating nodes with EASE: Mobility diffusion of last encounters in ad hoc networks. In *IEEE Infocom2003*, San Francisco, 2003

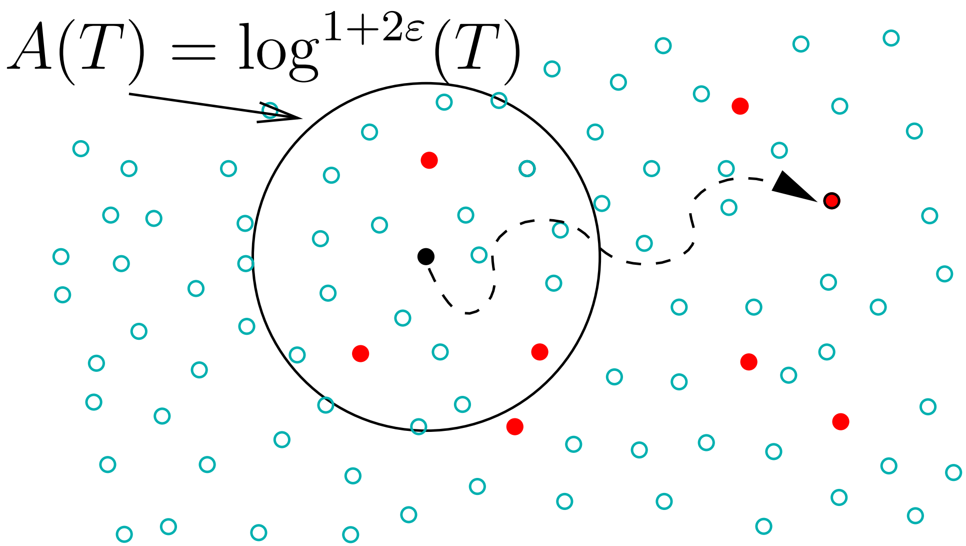
[GV06] Matthias Grossglauser and Martin Vetterli. Locating nodes with EASE: Learning efficient routes from encounter histories alone. *Transactions on Networking*, 2006

Sketch of proof of LER_1 bound



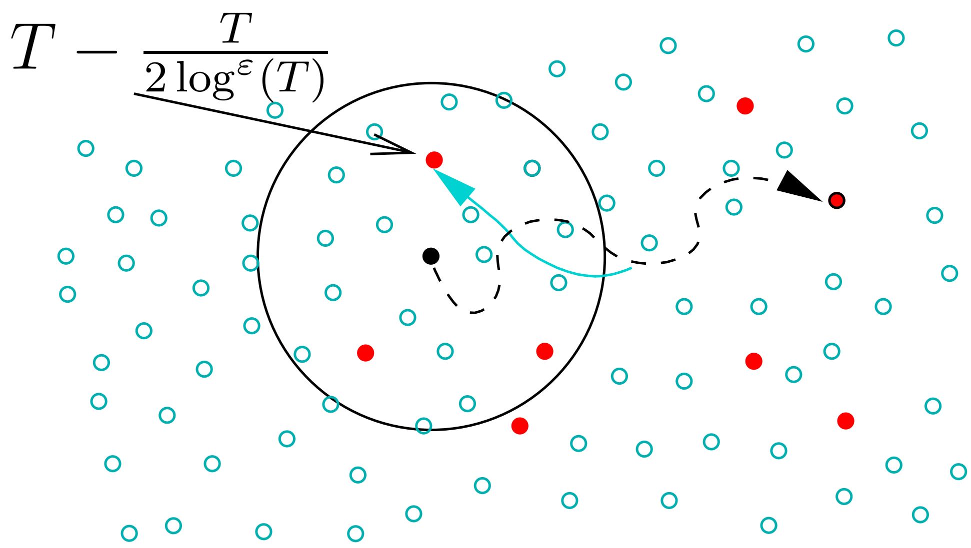
- Flood an initial area $A(T) = \log^{1+2\varepsilon}(T)$

Sketch of proof of LER_1 bound



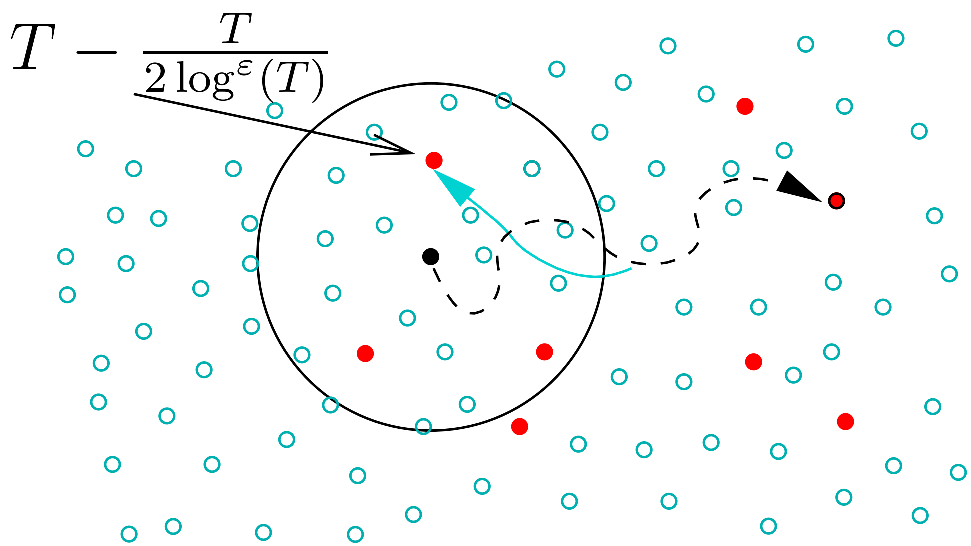
- For large T, the area flooded per step will be $\log^{1+2\varepsilon}(T)$

Sketch of proof of LER_1 bound



- For large T, w.h.p. a node with age less than $T - \frac{T}{2\log^{\varepsilon}(T)}$ will be within this area

Sketch of proof of LER_1 bound



- For large T, the number of steps taken will be $O(\log^{1+\varepsilon}(T))$

Sketch of proof of LER$_1$ bound

- Asymptotically, the cost will be

$$O(\log^{1+2\varepsilon}(T) \cdot \log^{1+\varepsilon}(T)) = O(\log^{2+3\varepsilon}(T))$$