On attractant scheduling in networks based on bacterial communication

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Background

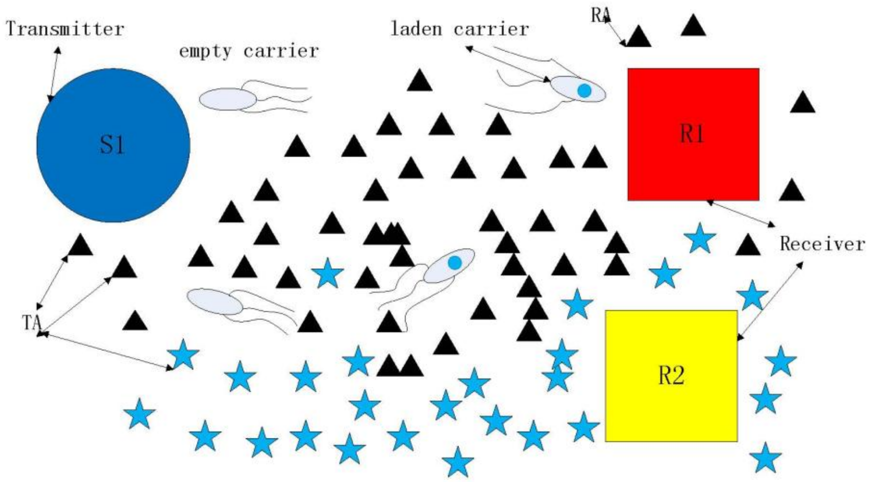
- Nanotechnology is the study of manipulating matter at the atomic and molecular scales.
  - nanomachine performs very simple tasks
  - Nanonetwork expands capabilities of single nanomachines.
  - Several potential applications

Motivation

- Traditional communication technologies are not directly applicable in nanonetworks
- Common natural phenomenon of molecular communication networks with multiple Transmitter-Receiver (T-R) pairs
- Limited number of attractants for bacteria

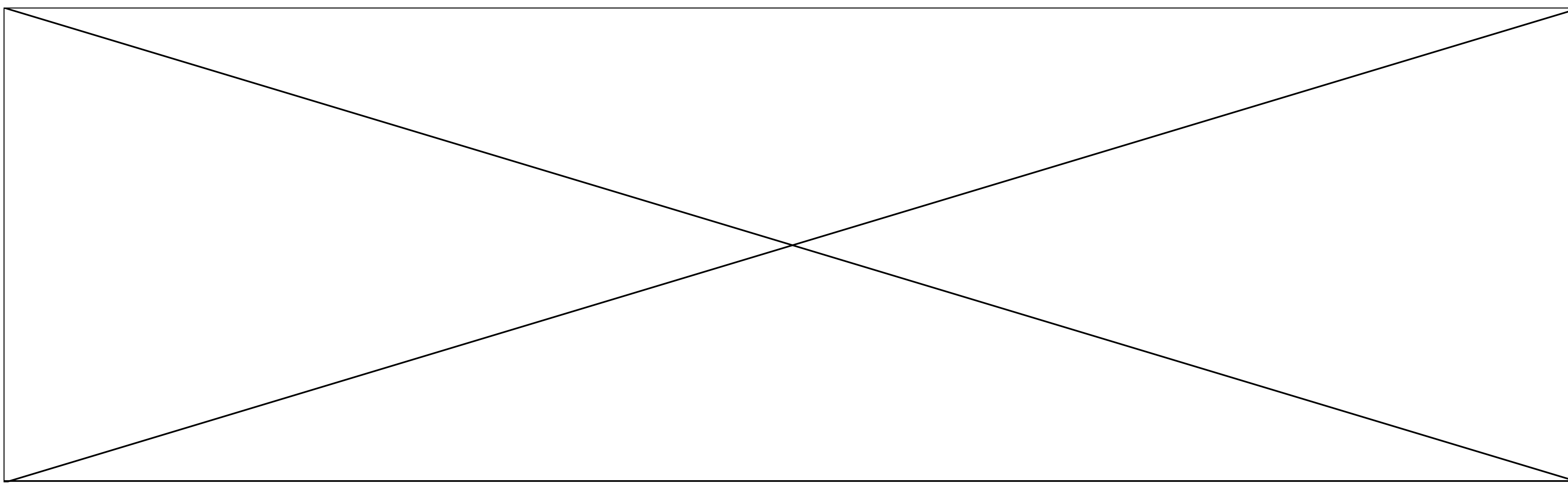
Network Architecture

- Transmitter
- Receiver
- Information Carrier
- Message
- Medium



Bacterial Communication

- Chemotaxis
  - Attractant Properties
- Communication Process



Problem Description

- Total system delay with multiple T-R pairs:

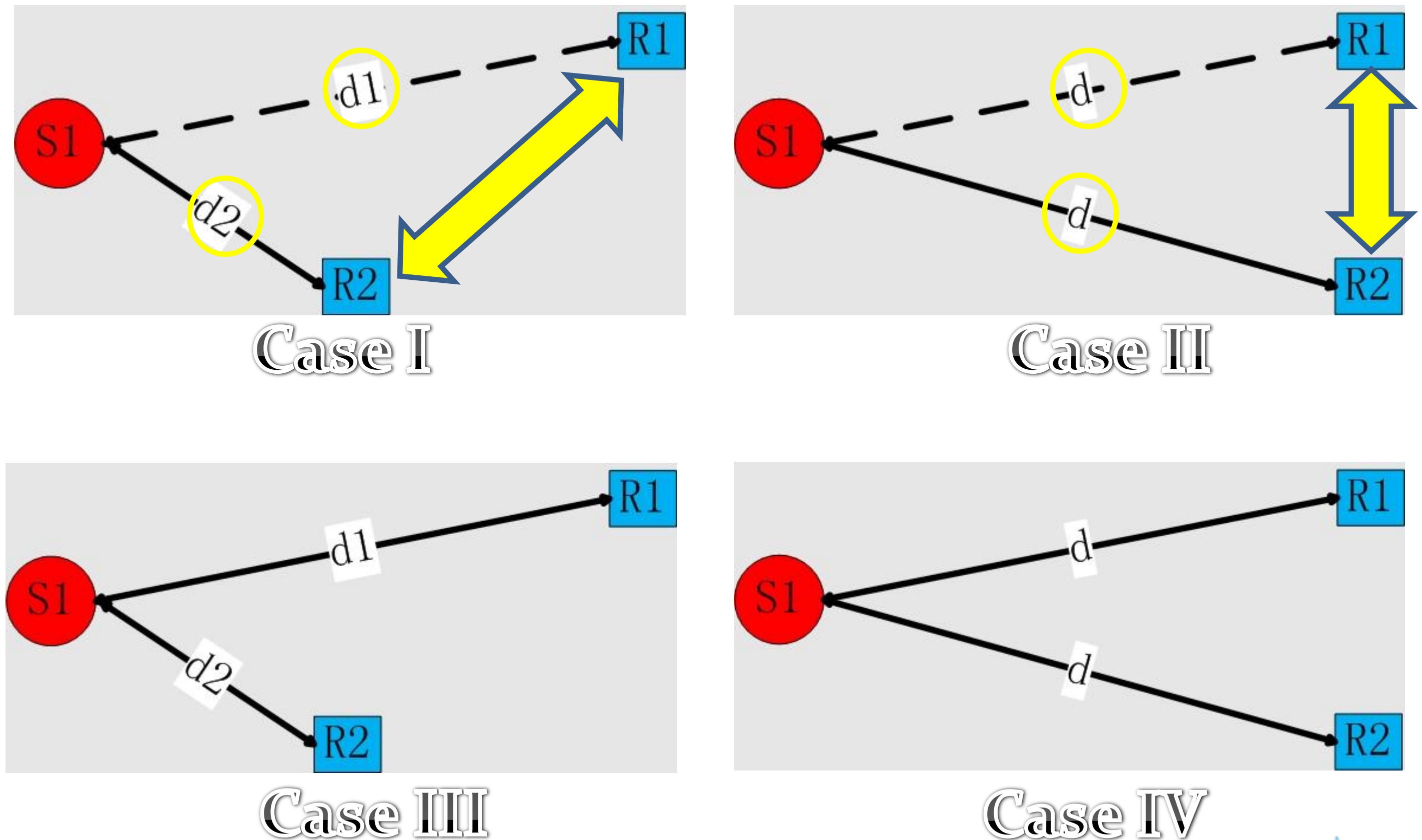
$$D = \sum_{i=0}^{n} t_i(x_{T_i}, x_{R_i}, y_{T_i}, y_{R_i}, m, N)$$

m: number of attractants

N: required number of packets

n: number of receivers

Discussion of Two-Link Topology



System Delay and Packet Loss Analysis

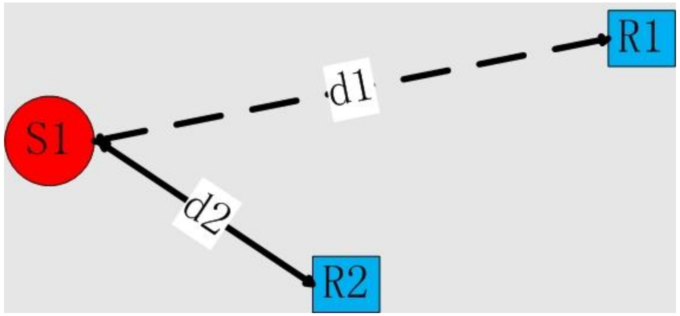
- For Case I and II, the delay for a single packet is:

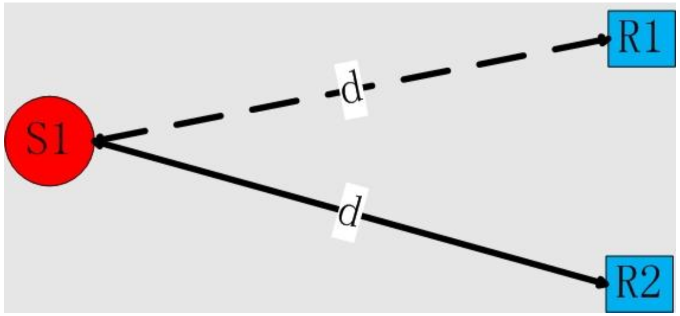
$$D = T_p(d_1) + T_p(d_2) + 2T_c$$

- Empirical equation for $T_p(d)$ is:

$$T_p(d) = 1.82d^2 + 4.49d + 0.17$$

- The Packet Loss is 0.





System Delay and Packet Loss Analysis

- For case III, assume :

$$P \propto U(d) = \frac{1}{1000}\frac{Q}{4D\pi d}$$

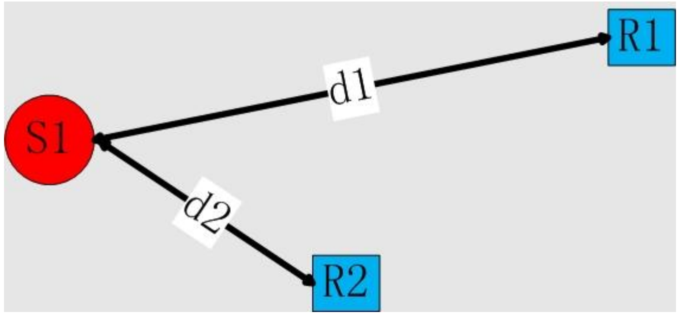
Therefore, the system delay is:

$$D = \max_i\{T_p(d_i)\} + \frac{T_c}{P_1} + \frac{T_c}{P_2}, i = 1,2$$

where $P_1 = \frac{d_2^2}{d_1^2+d_2^2}$, $P_2 = \frac{d_1^2}{d_1^2+d_2^2}$.

- The packet loss is:

$$L = \frac{d_1^4 + d_2^4}{(d_1^2 + d_2^2)^2}$$



System Delay and Packet Loss Analysis

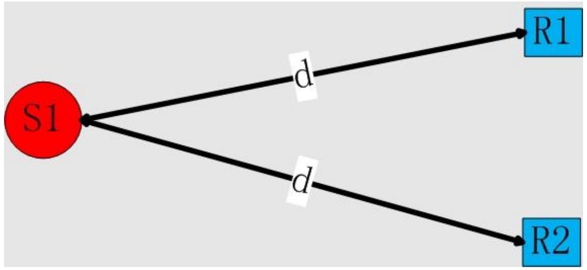
- For case IV, modeling the two states as follows:
  - Running: move with constant velocity and drift with the angular derivation of 1.12 rad.
  - Tumbling: stop and change its direction:

$$\theta_{t+1} = \theta_t + \gamma$$

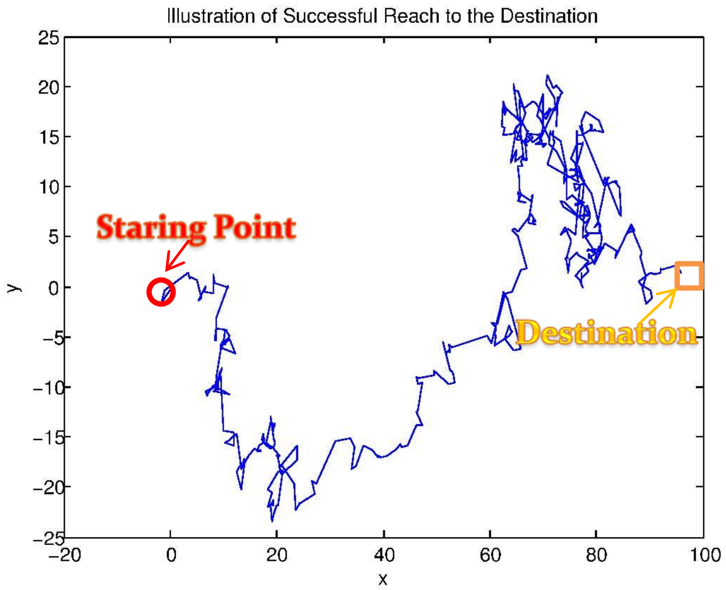
where the p.d.f. of γ is subject to:

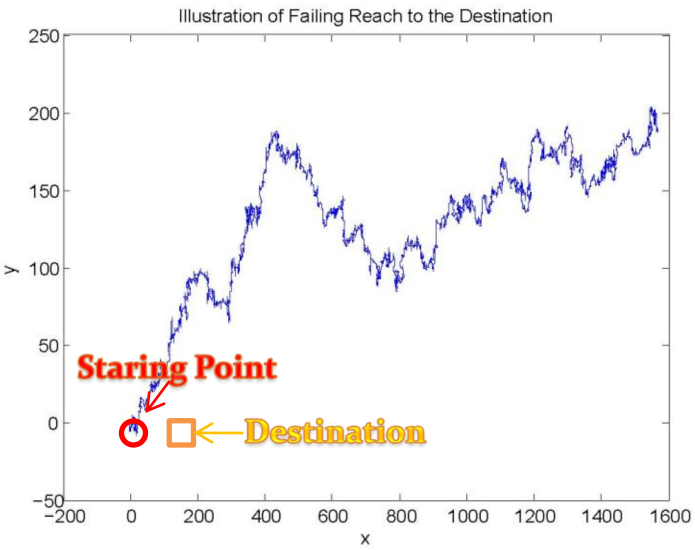
$$f(\gamma) = \begin{cases} \frac{1}{4}\cos\frac{\gamma}{2}, & |\gamma| \le \pi \\ 0, & |\gamma| > \pi \end{cases}$$

- Exponential Distribution

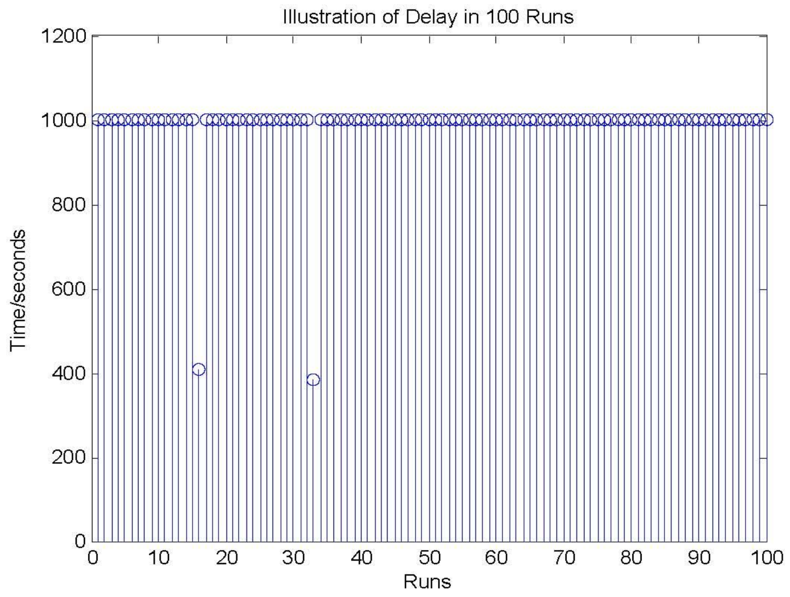


System Delay and Packet Loss Analysis





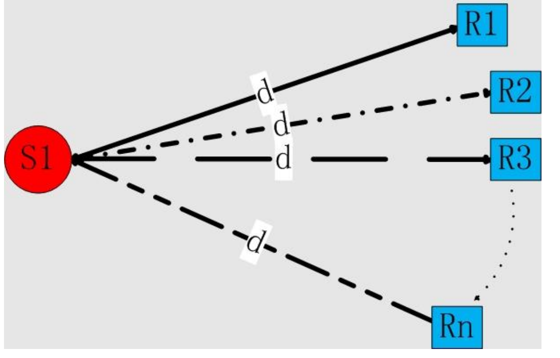
System Delay and Packet Loss Analysis



- For case IV, $D = T_p(d) + 4T_c$, and $L = \frac{1}{2}$.

Network with Same-Distance Receivers

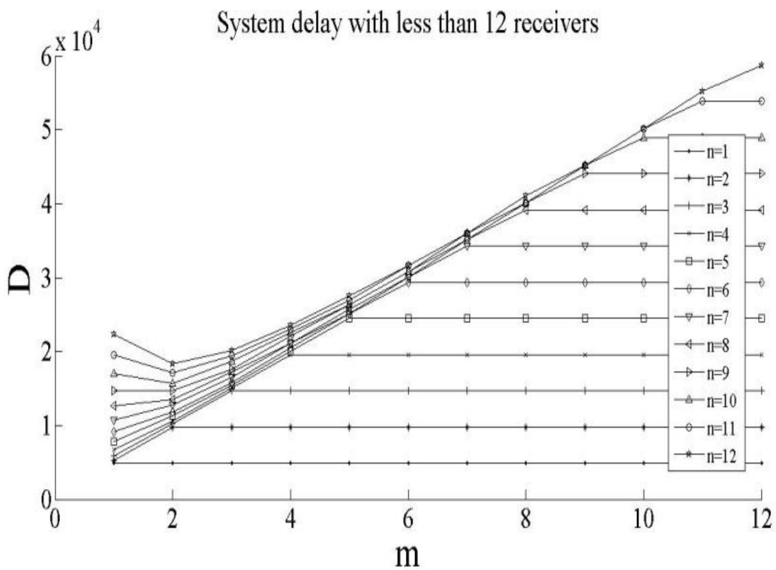
- One transmitter transmitting data to different receivers with same the distance:
- $D = m \cdot T_p(d) + \sum_{i=1}^{m} m_i^2 \cdot T_c$

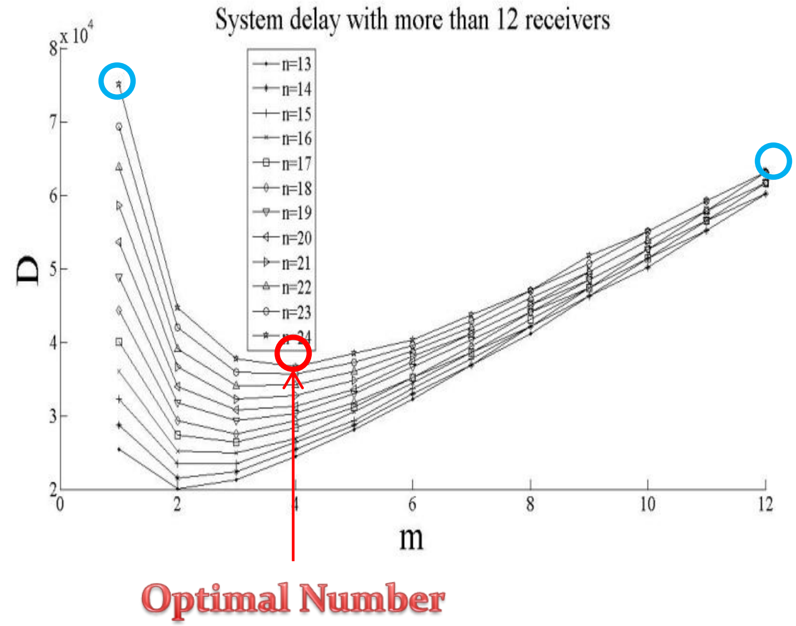


  - Tradeoff between the propagation delay and the fixed delay.

Insight 1: allocating the attractants equally among the receivers.

Simulation Result



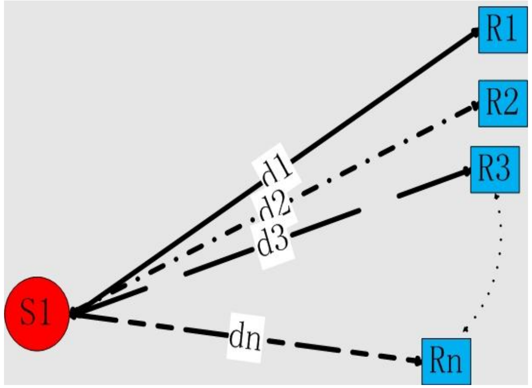


Network with Different-Distance Receivers

- One transmitter transmitting data to receivers with different distances:

$$D = T(Propogation) + T(Fixed)$$

$$T(Fixed) = \sum_{i=1}^{m} m_i^2 \cdot T_c$$



Network with Different-Distance Receivers

- Insight 2: *Partitioning the n links into m groups after rearranging the receivers in the decreasing order of distances*

I. Two-tier Comparison Algorithm

```
Initiate D=0, D_sys = [];
while m ≤ 12
do{
   if m ≤ n
      D_sys(m) = the minimum system delay for each partition under the constraints of m ;
   else break;
   end if
   m++
}
D = min{D_sys(m)}
```

Conclusion Remarks

- Network Delay and Packet Loss for two-link topology
- Modeling of the movement pattern of E. coli under no concentration gradient
- Insights for attractant scheduling
- Extent to scheduling with multiple T-R pairs

Questions?

Thank you for listening!

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