Unreliable Multi-hop Networks Routing Protocol For Age of Information-Sensitive Communication

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Outline

- Introduction
- The Problem
- The Solution of the Problem
- Simulation
- Future Work

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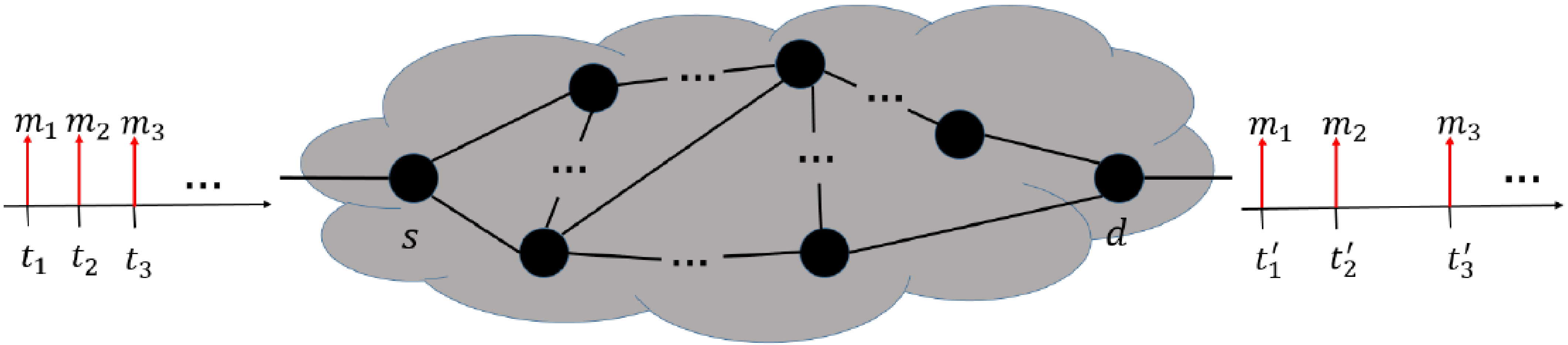
Introduction

- In multi-hop communication networks, it is important to study the problem of having unreliable links with different reliability values.

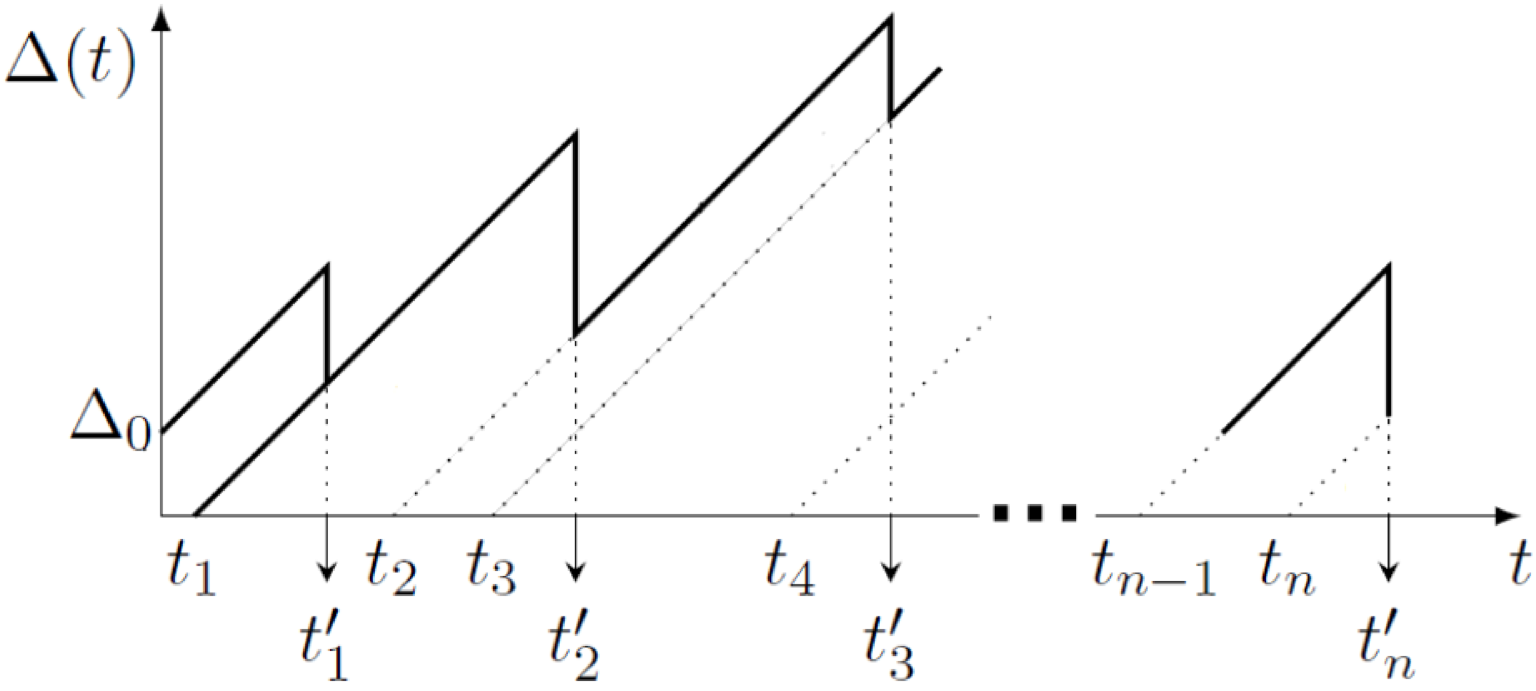
- We consider that the nodes would incur different forwarding cost values.

- The timeliness of the delivered messages is also important in many applications.

Introduction: Network Model



Introduction: Age of Information



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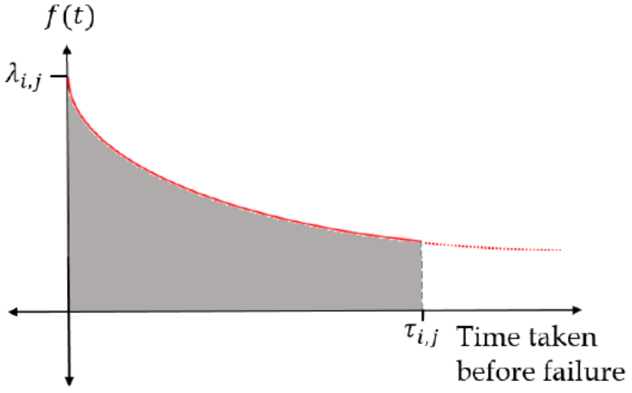
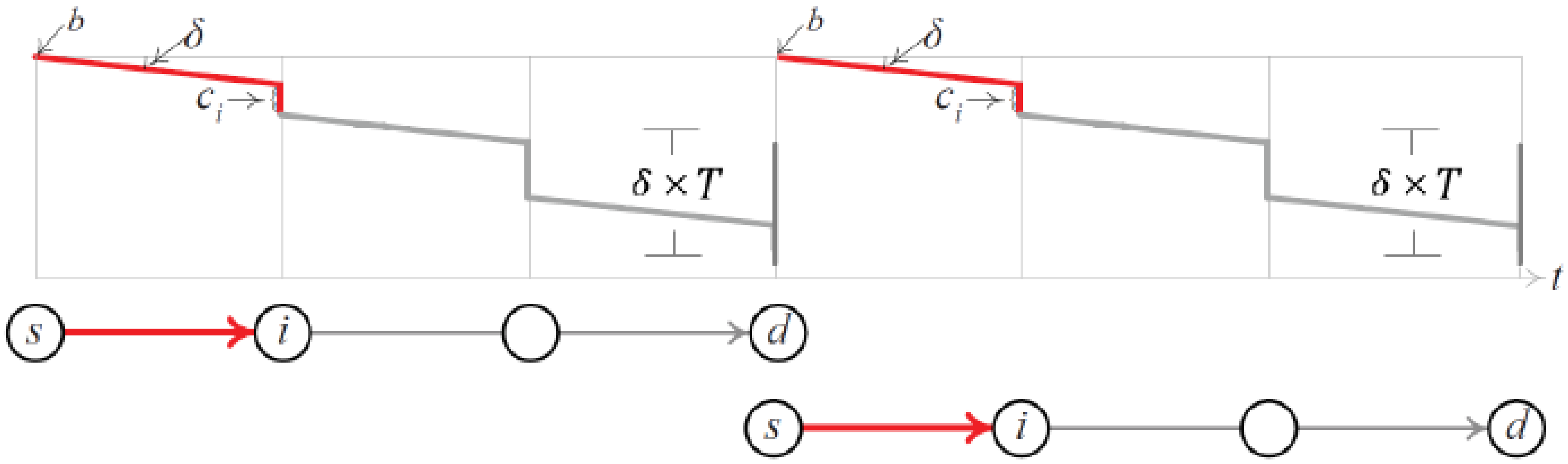
The Problem

- We consider an unreliable network with the source node s and the destination node d.
- Those nodes are linked with probabilistically unreliable links.
- The time delay in case of failure follows the exponential distribution.
- This distribution is characterized with both the time in case of success $\tau_{i,j}$ and the probability of success $p_{i,j}$.

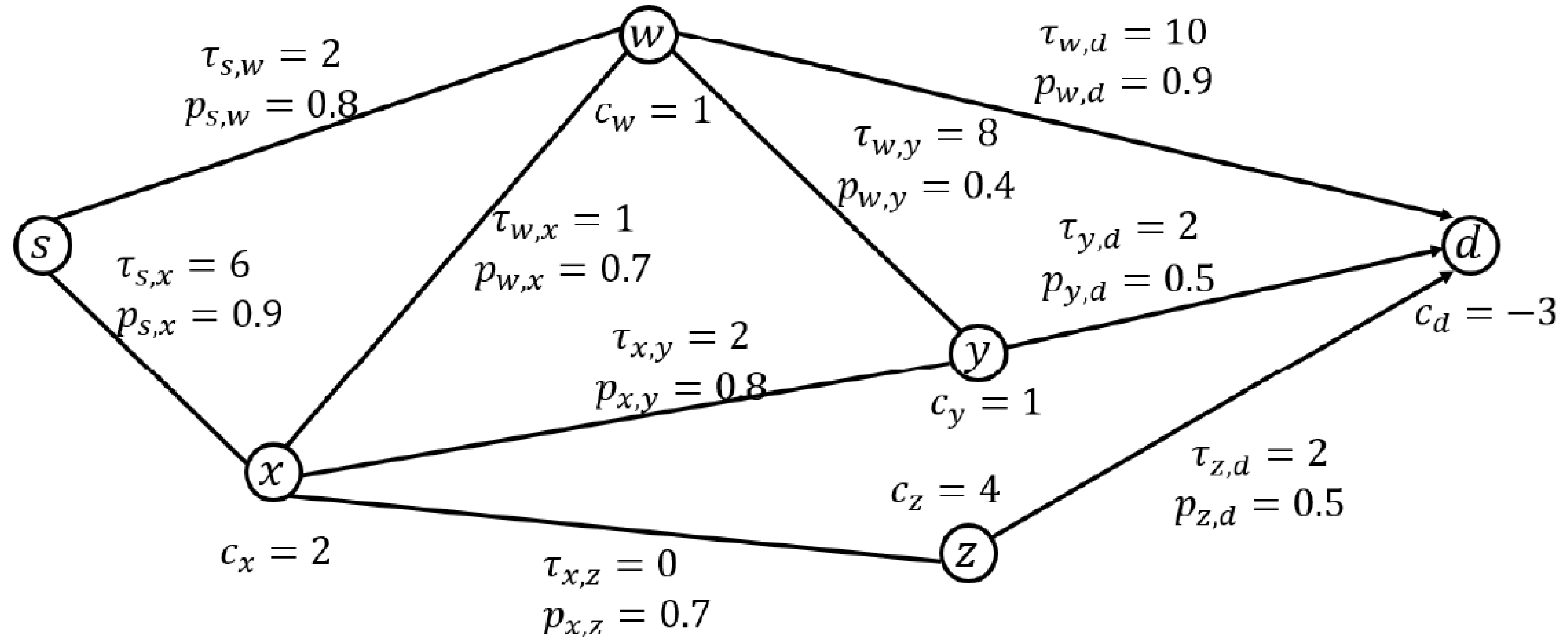


The Problem: The Utility Model



$$u(t) = max\{-C, b - \delta\Delta(t) - C\}$$

The Problem: An Example



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The Solution of the Problem

- We first evaluate the expected total utility reduction.

$$\begin{aligned}\mathbb{E}[R_{i,j}] &= 1 \times R^s_{i,j} + (1/p_{i,j} - 1)R^f_{i,j} \\ &= (1 - p_{i,j})\lambda_{i,j}\delta/p_{i,j} + c_i/p_{i,j}\end{aligned}$$

The Solution of the Problem

- Then we minimize the total expected reduction in utility.

Algorithm 1 Determining the Optimal Path.

Require: δ, T, V, E. //i.e. nodes and links sets V and E.
Ensure: Minimum cost $(C + \delta\Delta(t))$ from s to d.
Initialization: $\forall i \in V, \mathbb{E}[D_k[i]] = \infty \ \forall k, \pi(i) = \text{NIL} \ \forall i \in V$.
$c_d = -\delta T$.
$\mathbb{E}[D_k[s]] = 0 \quad \forall k$.
for k from $1 \rightarrow (|V| - 1)$ **do**
  for $(i, j) \in E$ **do**
    Evaluate $\mathbb{E}[R_{i,j}]$ from Equation 2.
    if $\mathbb{E}[D_{k-1}[i]] + \mathbb{E}[R_{i,j}] < \mathbb{E}[D_{k-1}[j]]$ **then**
      $\mathbb{E}[D_k[j]] = \mathbb{E}[D_{k-1}[i]] + \mathbb{E}[R_{i,j}]$.
      $\pi[j] = i$.
    else $\mathbb{E}[D_k[j]] = \mathbb{E}[D_{k-1}[j]]$.
return the optimal path $\pi[d], \pi[\pi[d]], \ldots$

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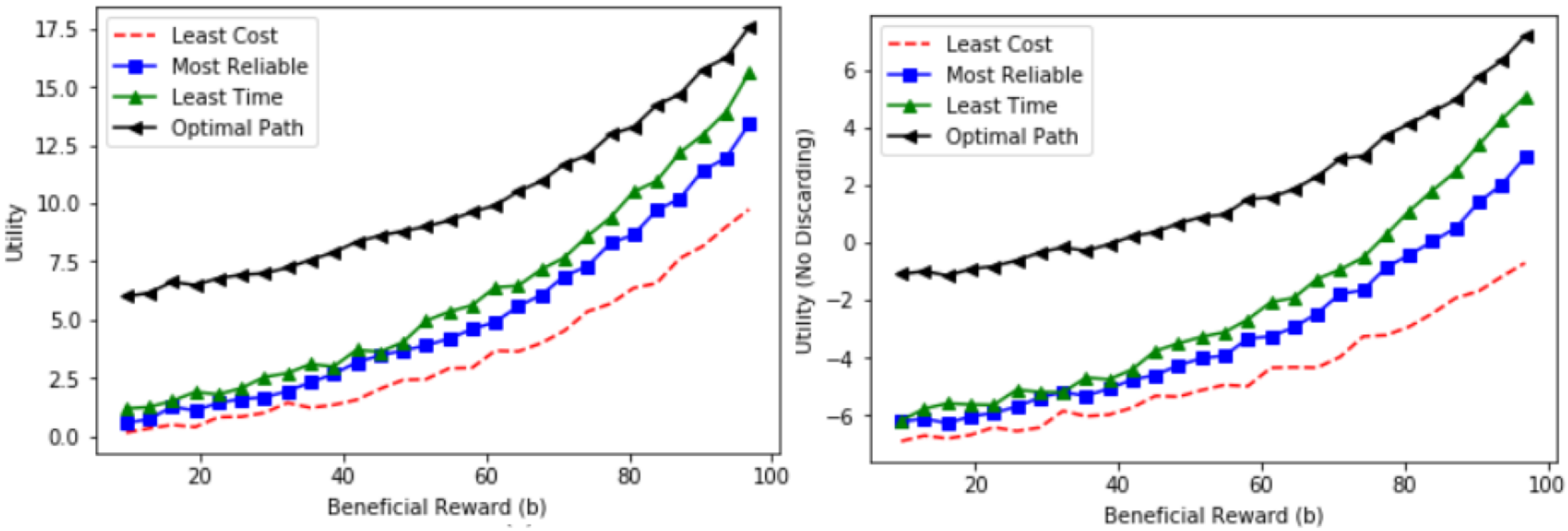
Simulation


Least Cost
Most Reliable
Least Time
Optimal Path
Utility
Beneficial Reward (b)
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
20
40
60
80
100
Least Cost
Most Reliable
Least Time
Optimal Path
Utility (No Discarding)
Beneficial Reward (b)
6
4
2
0
−2
−4
−6
20
40
60
80
100

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Future Work

- Our future work will include more in-depth analysis and simulation.
- We will consider the stochastic generation of messages at the source node.
- We will study the case of multiple messages sent at the same time, where redundancy of the same message is allowed.

Q&A

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