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

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• Introduction
• The Problem
• The Solution of the Problem
• Simulation
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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.

\[
E[R_{i,j}] = 1 \times R_{i,j}^s + \left(1/p_{i,j} - 1\right)R_{i,j}^f \\
= (1 - p_{i,j})\lambda_{i,j}\delta/p_{i,j} + c_i/p_{i,j}
\]
The Solution of the Problem

• Then we minimize the total expected reduction in utility.

Algorithm 1 Determining the Optimal Path.

Require: $\delta, T, V, E$. /i.e. nodes and links sets $V$ and $E$.
Ensure: Minimum cost $(C + \delta\Delta(t))$ from $s$ to $d$.
Initialization: $\forall i \in V, \mathbb{E}[D_k[i]] = \infty \ \forall k, \pi(i) = \text{NIL} \ \forall i \in V$.

1: $c_d = -\delta T$.
2: $\mathbb{E}[D_k[s]] = 0 \ \forall k$.
3: for $k$ from 1 → (|V| − 1) do
4:   for $(i, j) \in E$ do
5:     Evaluate $\mathbb{E}[R_{i,j}]$ from Equation 2.
6:     if $\mathbb{E}[D_{k−1}[i]] + \mathbb{E}[R_{i,j}] < \mathbb{E}[D_{k−1}[j]]$ then
7:       $\mathbb{E}[D_k[j]] = \mathbb{E}[D_{k−1}[i]] + \mathbb{E}[R_{i,j}]$.
8:       $\pi[j] = i$.
9:     else $\mathbb{E}[D_k[j]] = \mathbb{E}[D_{k−1}[j]]$.
10:   return the optimal path $\pi[d], \pi[\pi[d]], \ldots$
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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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