Path Optimization and Trusted Routing in MANET: *An Interplay Between Ordered Semirings*

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Motivation

- Trust is a critical objective for routing in MANETs
- Unlike traditional metrics, trust metrics live in abstract ordered sets
  - Consequently, trust metrics cannot be trivially combined with other routing metrics such as delay.
- Multi-criteria optimization techniques are needed for trusted routing

Contributions

- Modeling the Delay-Trust routing problem as a Pareto optimality problem.
  - Combining shortest path and spanning tree solutions
- General optimization principle – in combining (min,sum) and (min,max) algebras
  - Polynomial time algorithms

Outline

- Pareto optimality
- Delay-Trust routing
- Haimes method for Delay-Trust routing

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Vector valued function

$\mathcal{X}$ Decision Set

$\mathcal{Y}$ Objective Set

$\underline{f} : \mathcal{X} \rightarrow \mathcal{Y}$ Vector valued map

For the bi-objective case

$$\underline{f} = \begin{bmatrix} f_1 \\ f_2 \end{bmatrix}$$

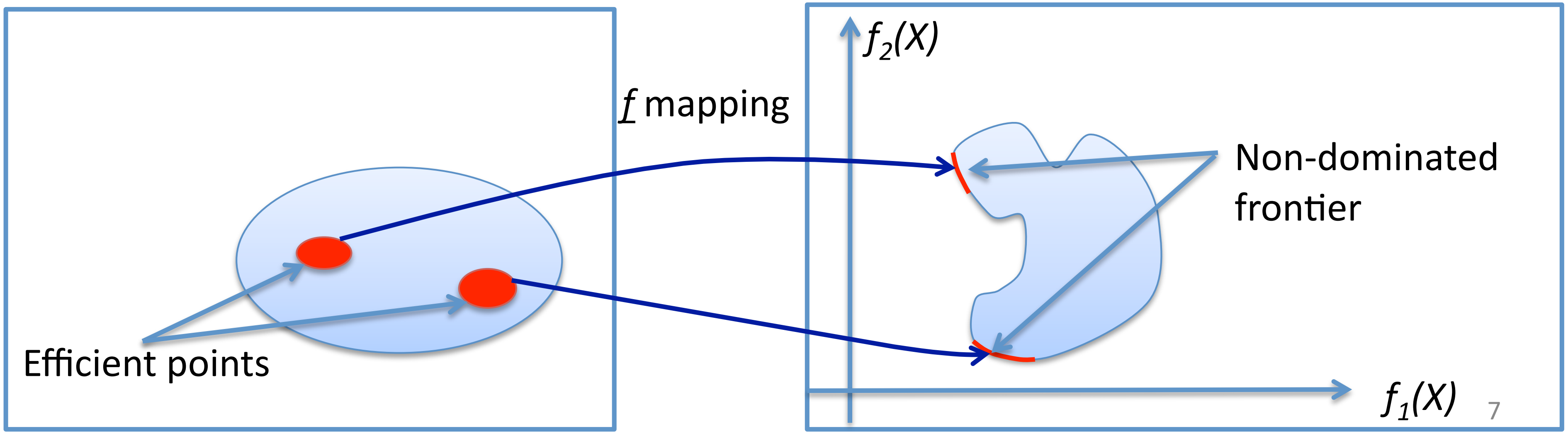
$$\mathcal{Y} = S1 \times S2$$

Where S1 and S2 are two ordered sets.
Note: The orders might no be commensurable

Minimality, Non-Dominance, Efficiency

$\underline{f} : X \rightarrow \mathbb{R}^n$ is a vector-valued function.

$x^* \in X$ is efficient if there exists no other $x \in X$ such that $\underline{f}(x) < \underline{f}(x^*)$. $\underline{f}(x^*)$ is said to be non-dominated



ε-relaxed Haimes method

- Relax all but one of the objectives
- With the other objectives as constraints, solve a single objective function.

$$\begin{aligned} \min_{x \in X} \quad & f_1(x) \\ \textit{subject to} \quad & f_2(x) \le \varepsilon \end{aligned}$$

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- Pareto optimality
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- Haimes method for Delay-Trust routing

Pareto Optimal Trusted Routing

- Consider two objectives for routing
  - Delay – additive along a path *p*

$$f_1(p) = \sum_{(u,v)\in p} d(u,v)$$

  - Dual Trust – bottleneck along a path *p*

$$f_2(p) = \max_{(u,v)\in p} t(u,v)$$

Pareto Optimal Trusted Routing

- Consider two objectives for routing
  - Pareto optimal Delay – Trust problem

$$\begin{bmatrix} f_1(p) \\ f_2(p) \end{bmatrix} = \begin{bmatrix} \sum_{(u,v)\in p} d(u,v) \\ \max_{(u,v)\in p} t(u,v) \end{bmatrix}$$

$$\min_{p\in P_{ij}}{}^{Pareto} \begin{bmatrix} f_1(p) \\ f_2(p) \end{bmatrix}$$

Pareto Optimal Trusted Routing

- Two objectives for routing – Two classical problems
  - Delay – shortest path problem – **(min,+)**

$$\min_{p \in P_{ij}} f_1(p) = \min_{p \in P_{ij}} \sum_{(u,v) \in p} d(u,v)$$

  - Dual Trust – spanning tree problem – **(min,max)**

$$\min_{p \in P_{ij}} f_2(p) = \min_{p \in P_{ij}} \max_{(u,v) \in p} t(u,v)$$

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Hamies method for Trusted Routing

$$\min_{p \in P_{ij}}^{Pareto} \begin{bmatrix} \sum_{(u,v)\in p} d(u,v) \\ \max_{(u,v)\in p} t(u,v) \end{bmatrix}$$

?

$$\min_{p \in P_{ij}} \quad \sum_{(u,v)\in p} d(u,v)$$

$$\textit{subject to} \quad \max_{(u,v)\in p} t(u,v) \le \varepsilon$$

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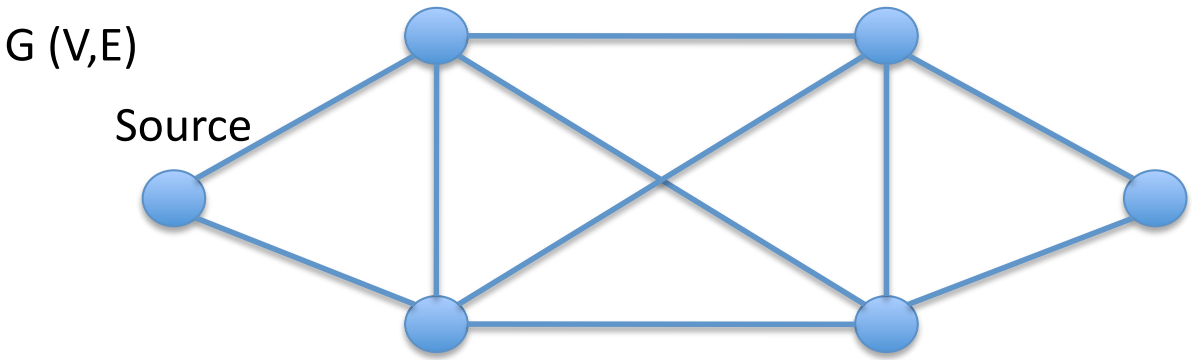
- Constraint

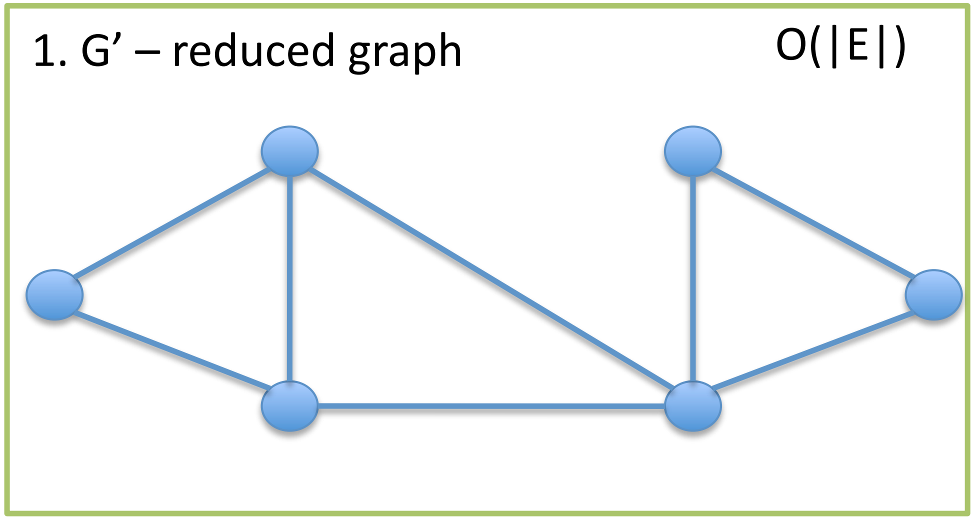
$$\max_{(u,v)\in p} t(u,v) \le \varepsilon$$

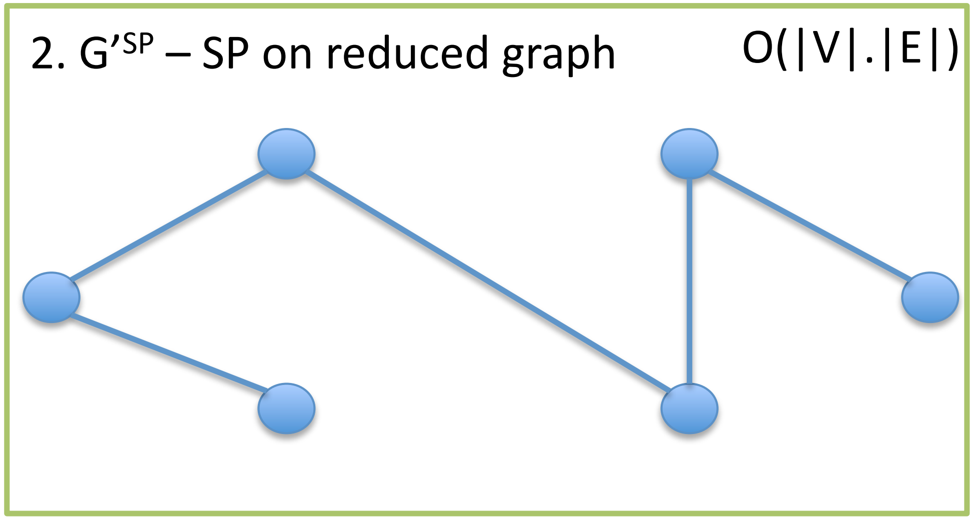
$$\Rightarrow \forall (u,v) \in p, \quad t(u,v) \le \varepsilon$$

→ Edge Exclusion

Haimes method – Two stage recipe







Summary

- Delay-Trust routing problem can be modeled as a Pareto optimal routing problem.

- Haimes method can be used to solve for Pareto optimality.
  - First solve the (min,max) problem and then the (min,+) problem
  - $O(|V|^3)$ solution