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Cost Optimization
For the unmanned aircraft delivery system with Public Transportation

vehicle routing problem

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Computer and Information Technology

General Overview

Drone delivery system uses UAV's instead of delivery driver

There are still some obstacles for delivery system.

- Deliver one item at a time

Figure 1: deliver back and forth

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  - If drone deliver packages, expected battery life will be reduced

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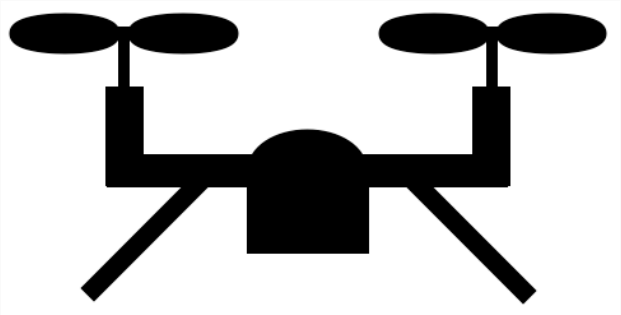
Introduction

Statement of Problem

What if UAV's can exploit current transportation system?



Adapting public transportation makes delivery system be able to deliver multiple packages at a same time and it reduces the total time of delivery.

Therefore, the new rendering algorithm will deliver massive packages in limited time by reducing cost.

Toy example

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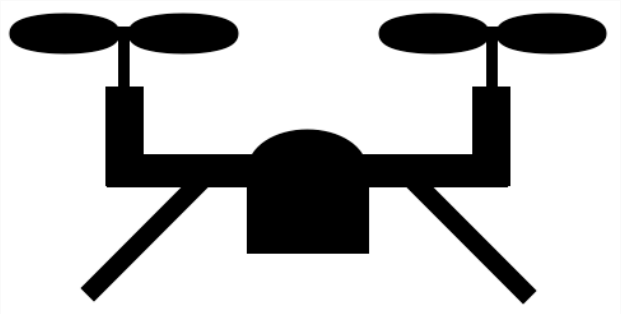
- Use only UAV's to deliver the packages
- Use public transportation to deliver packages to the nearest bus stops then deliver packages with UAV's
  – the optimization algorithm will approach in this way

Assumptions - UAV



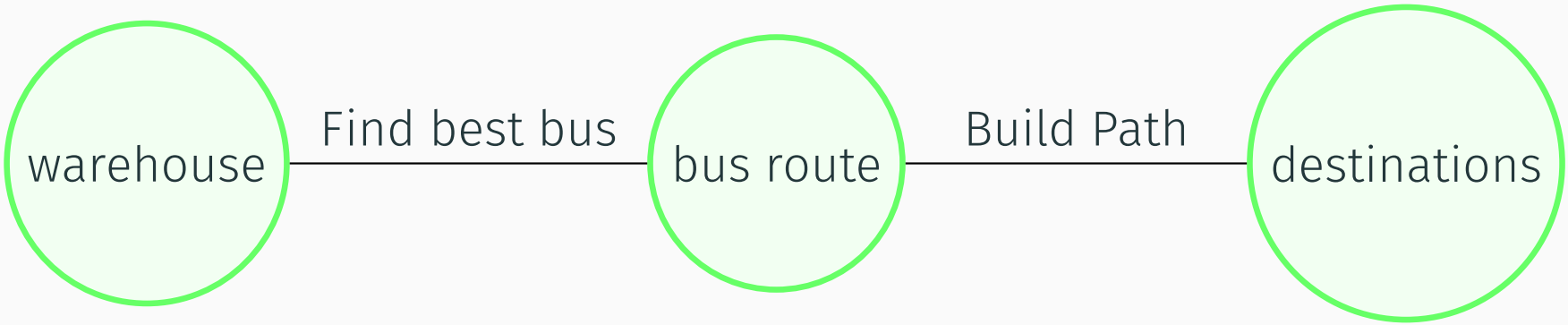
- Every UAV can deliver only one package at a time
- Every UAV can fly up to 15 minutes with its battery
- Every UAV can charge itself on top of the bus
    - The bus has the charging board on top of the bus and the bottom of the drone.
- Every UAV in this paper is a vertical take-off and landing (VTOL) aircraft.

Assumptions - Others

- Every agents already know where the bus is based on bus schedule.
    - The schedule is easily obtained in the homepage of the bus company. The average speed of bus is 14 km/h [2].
- Customer demands are known in advance.

Methodology

Study Design



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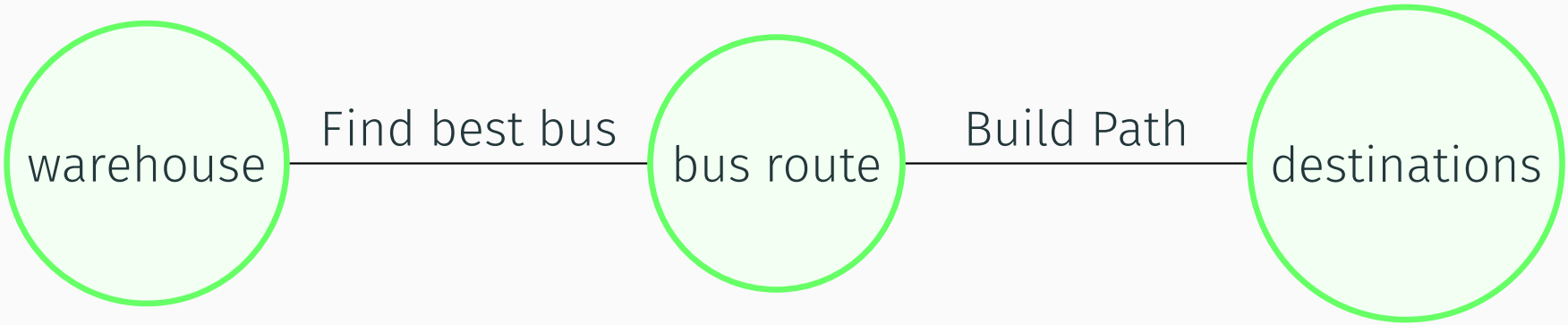
Study Design



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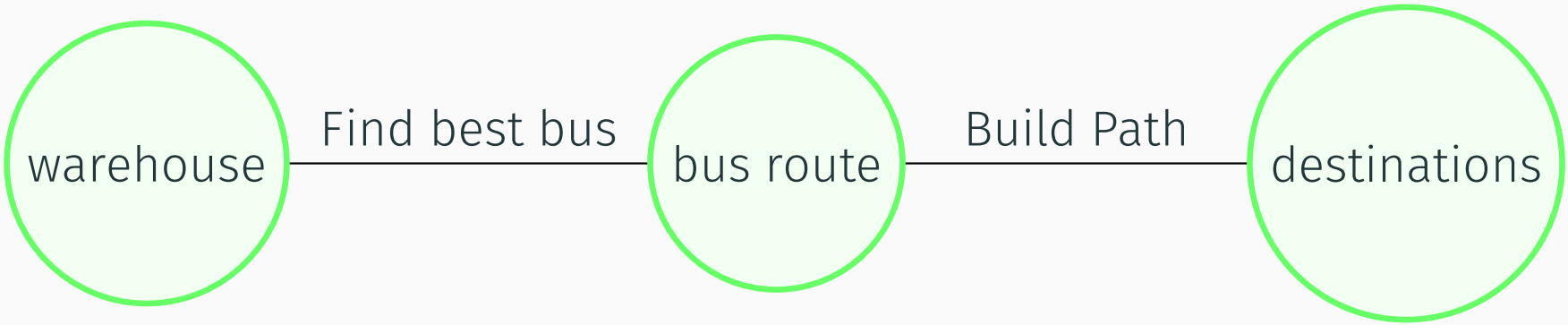

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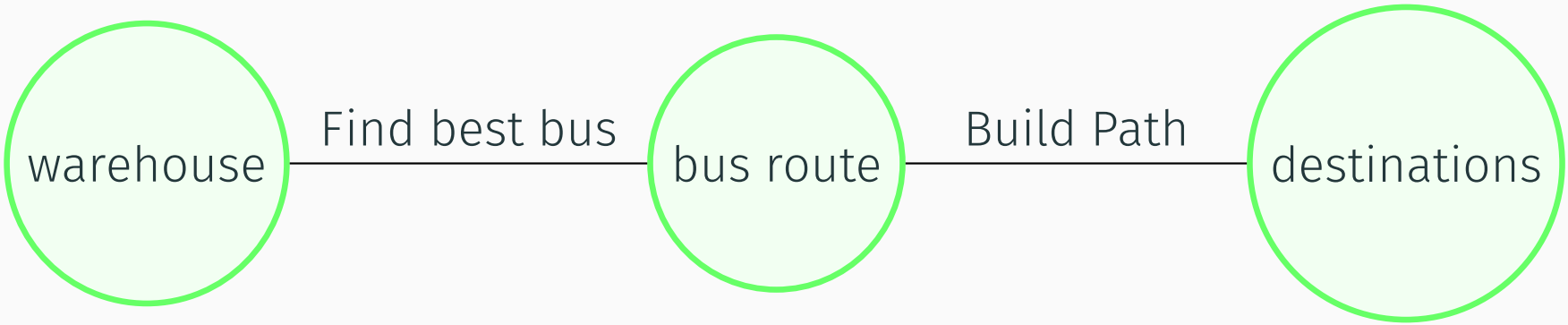

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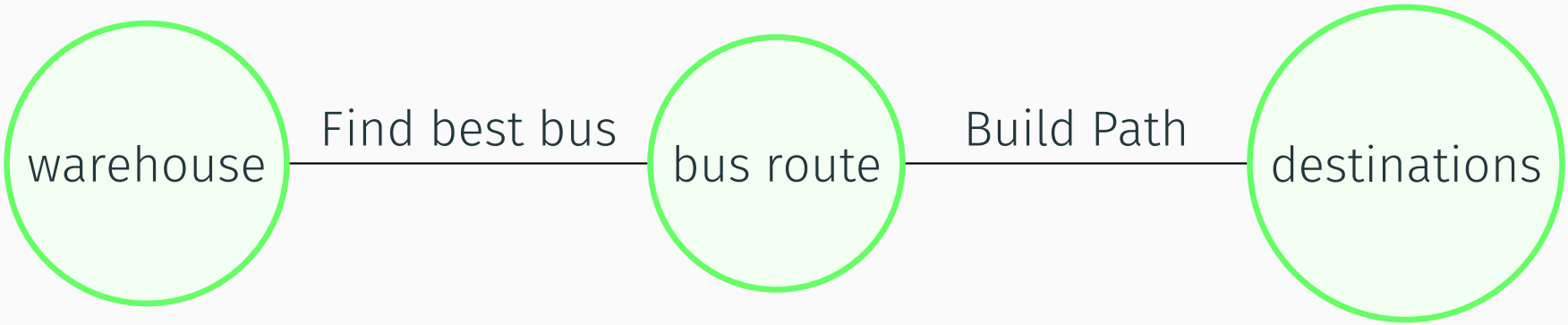

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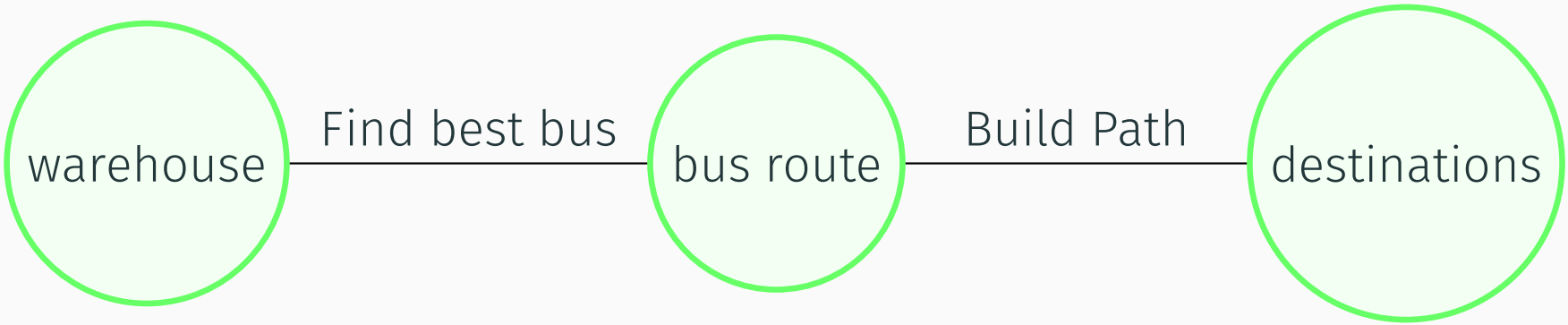

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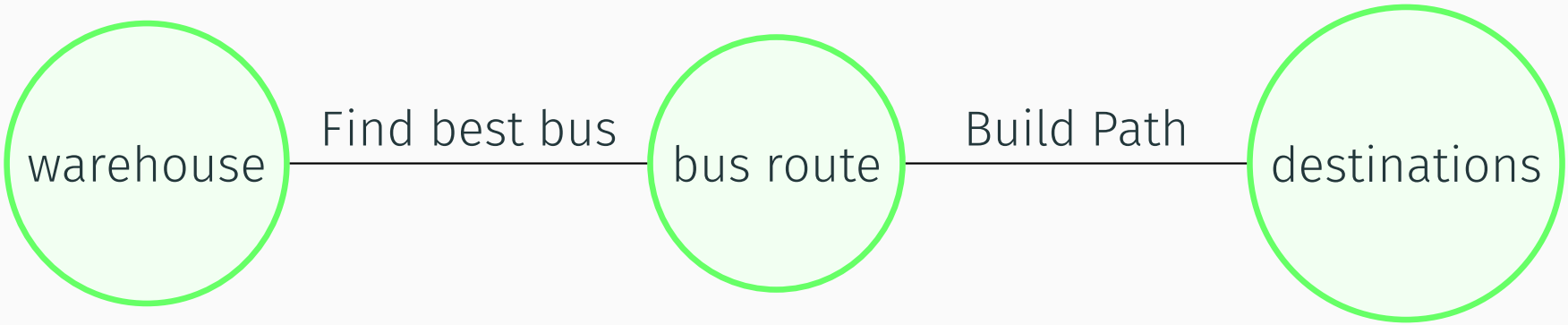

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   - If the destination is near from the warehouse, UAV's deliver directly to destination
2. Given bus with packages, build path from bus to the destination
   - Calculate distance between the bus stop and build pairwise distances
   - build graph model
   - convert graph by removing bus stops and update distances to accumulate them as stopovers

Build Path - Build Graph

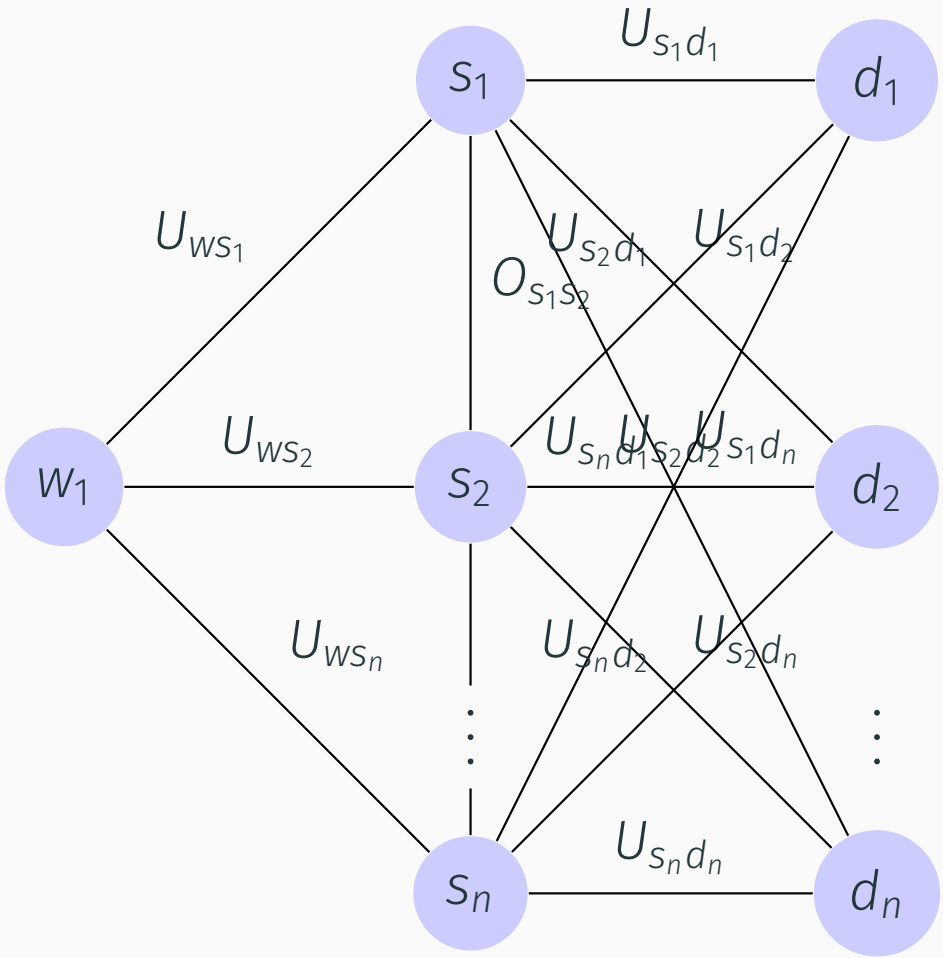
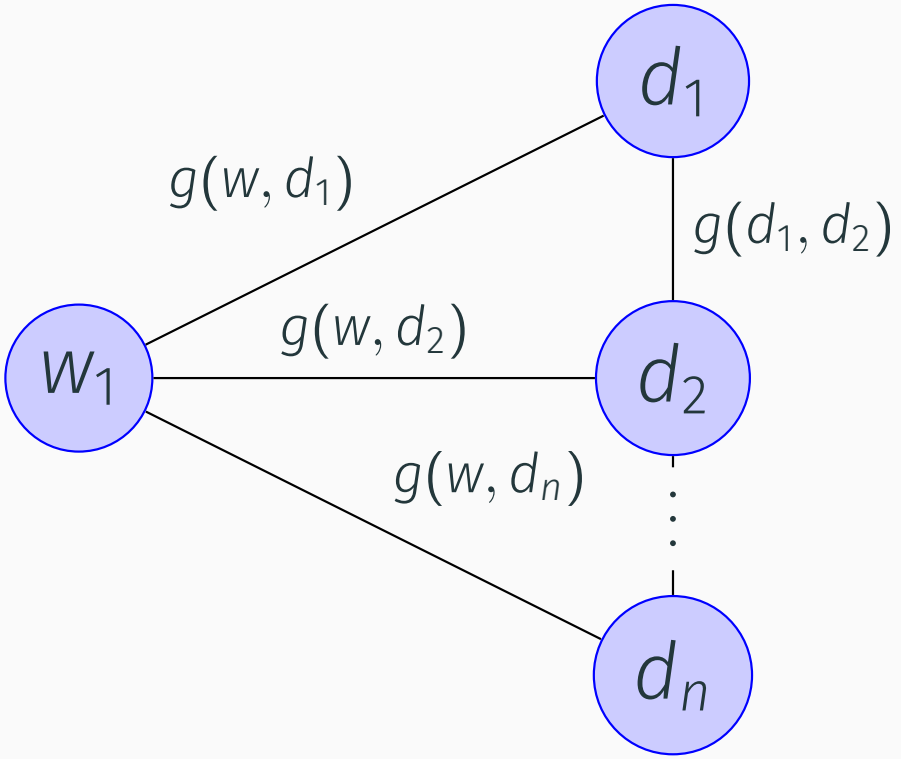


Figure 2: Simplified transportation graph

w_1 is a warehouse, s_n is n-th bus stop and d_n is n-th destination.

Build Path - Convert Graph



$$\text{minimal cost through bus } c_{wd} = \min_{ij \in S} U_{wi} + O_{ij} + U_{jd} \quad \text{where } i, j \in S \tag{1}$$

This converted graph is compatible with Traveling Salesman Problem(TSP).

Experiment Design

Goal

- to find the cost-effectiveness threshold of the number of packages compared to the current UAV's delivery system.

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- to find the cost-effectiveness threshold of the number of packages compared to the current UAV's delivery system.
- to find the best route for the UAV's delivery with the public transportation

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minimize total mileage of UAV's
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$$\min \sum_{i}^{V} \sum_{j}^{V} x_{ij} c_{ij} \tag{2}$$

$$W = \{w_1, w_2, \cdots w_m\}$$
$$D = \{d_1, d_2, \cdots d_n\} \tag{3}$$

$$x_i j = \begin{cases} 1, & \text{path from } i \text{ to } d,\ i \in W \cup D, j \in D. \\ 0, & \text{otherwise.} \end{cases}$$

Questions?

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