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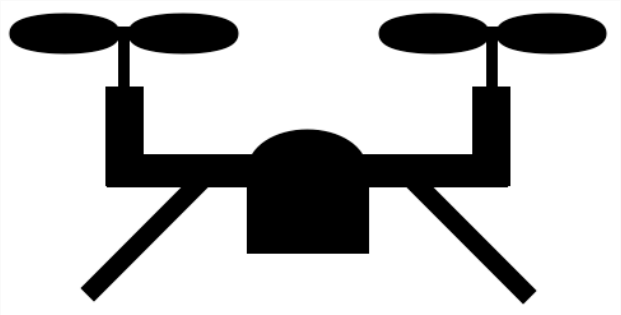
  - If drone deliver packages, expected battery life will be reduced

Table of contents

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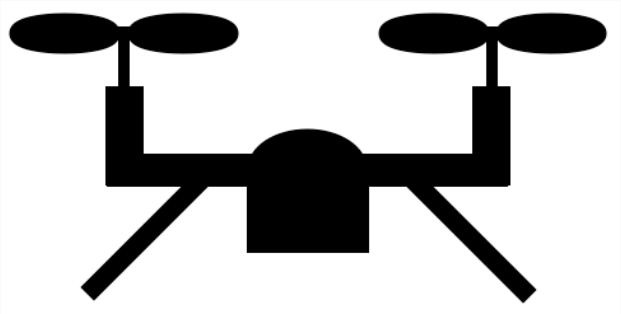
- Use only UAV's to deliver the packages
- Use public transportation to deliver packages to the nearest bus stops then deliver packages with UAV's
  – the optimization algorithm will approach in this way

Assumptions - UAV



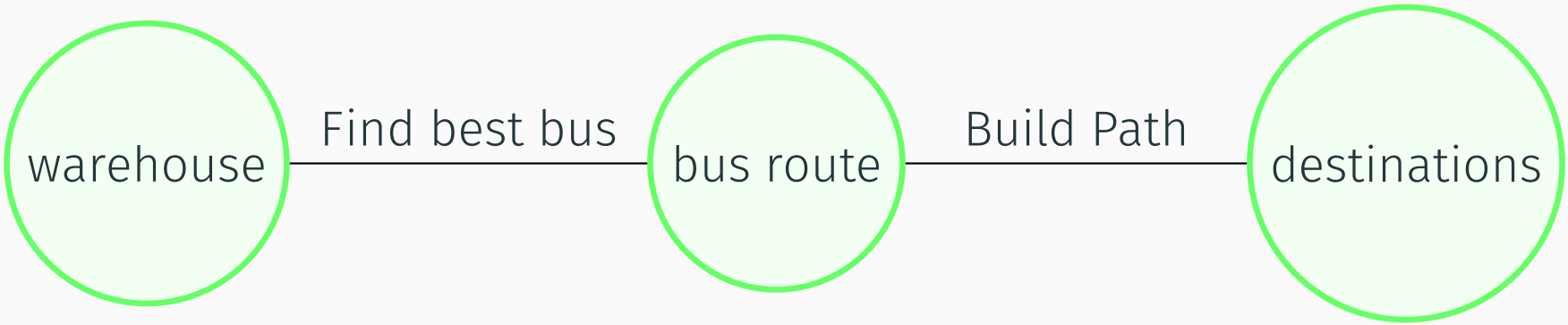
- Every UAV can deliver only one package at a time
- Every UAV can fly up to 15 minutes with its battery
- Every UAV can charge itself on top of the bus
  - The bus has the charging board on top of the bus and the bottom of the drone.
- Every UAV in this paper is a fixed-wing aircraft to enhance range, velocity and endurance and vertical take-off and landing (VTOL) aircraft. That means, UAV's can speed up to 100km/h.

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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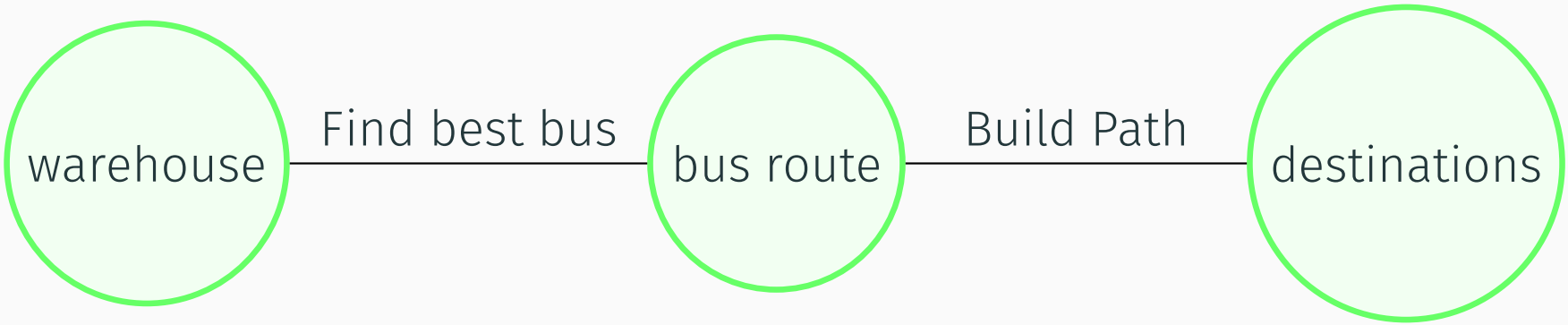

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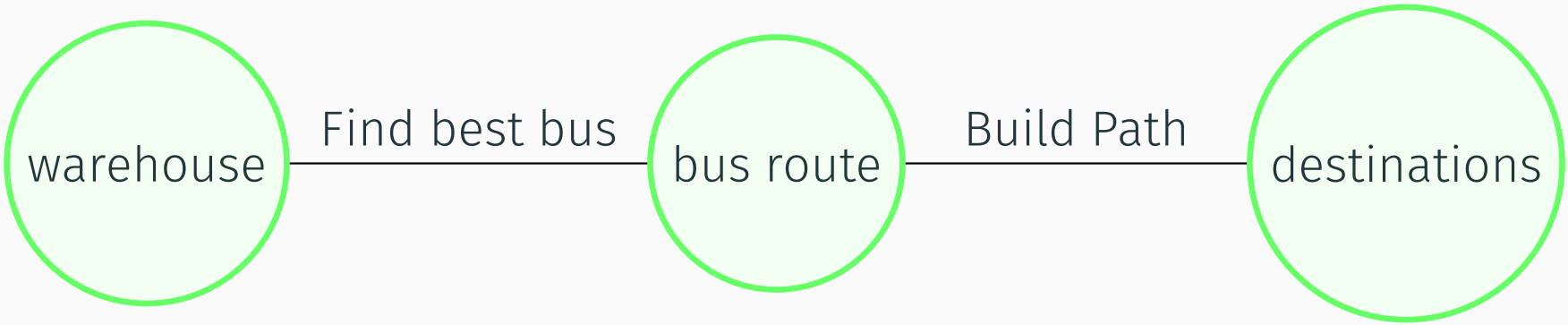

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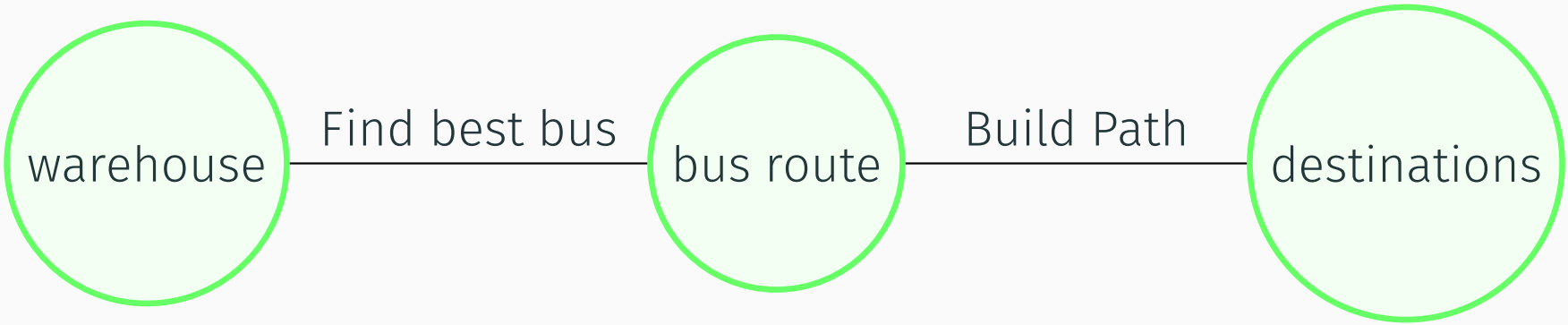

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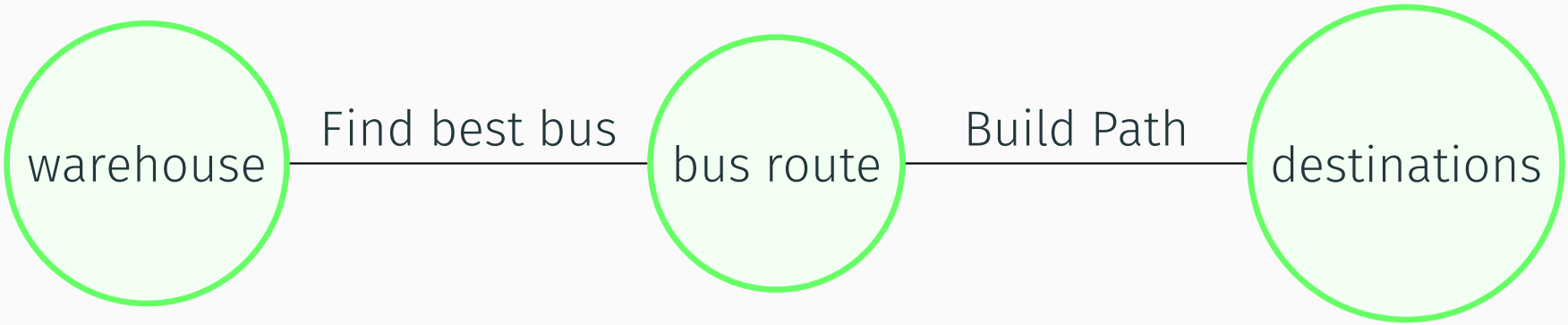

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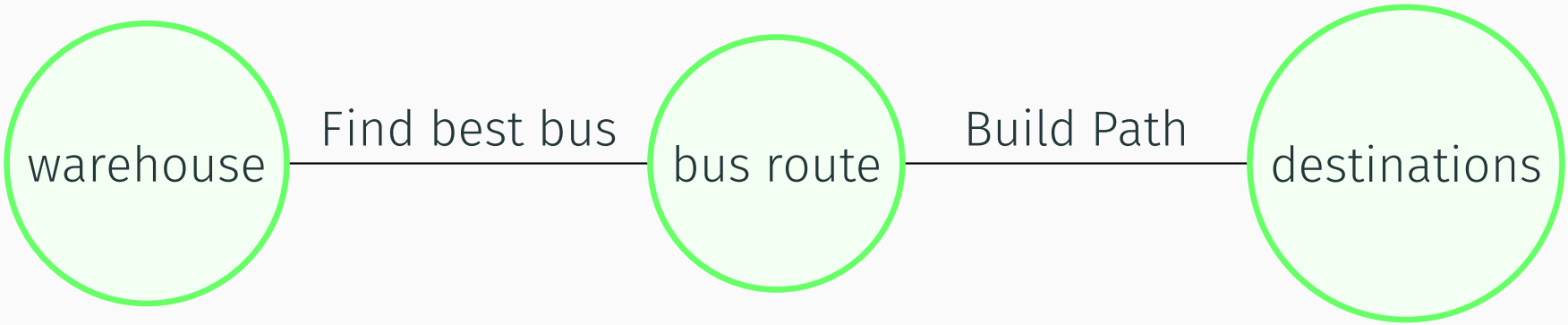

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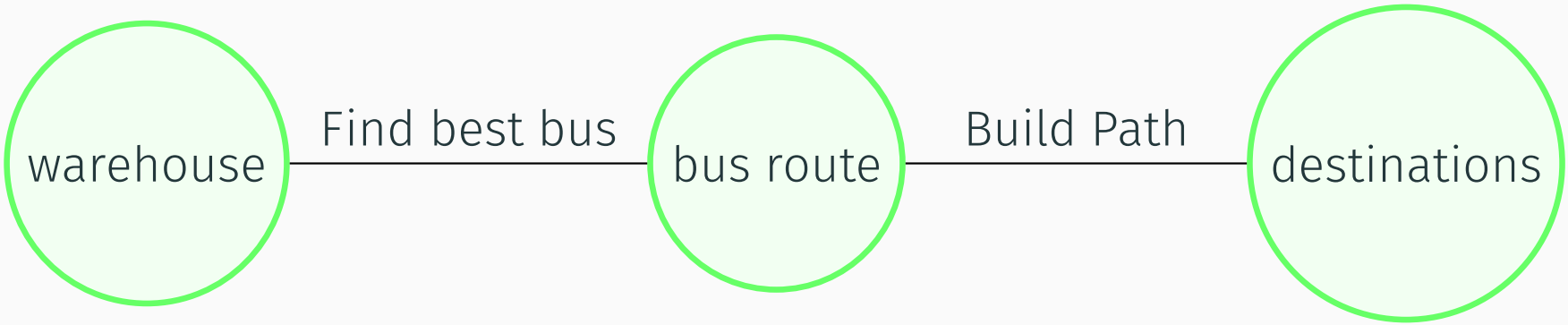

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   - Calculate distance between the bus stop and build pairwise distances
   - build graph model
   - convert graph by removing bus stops and update distances to accumulate them as stopovers

Build Path - Build Graph

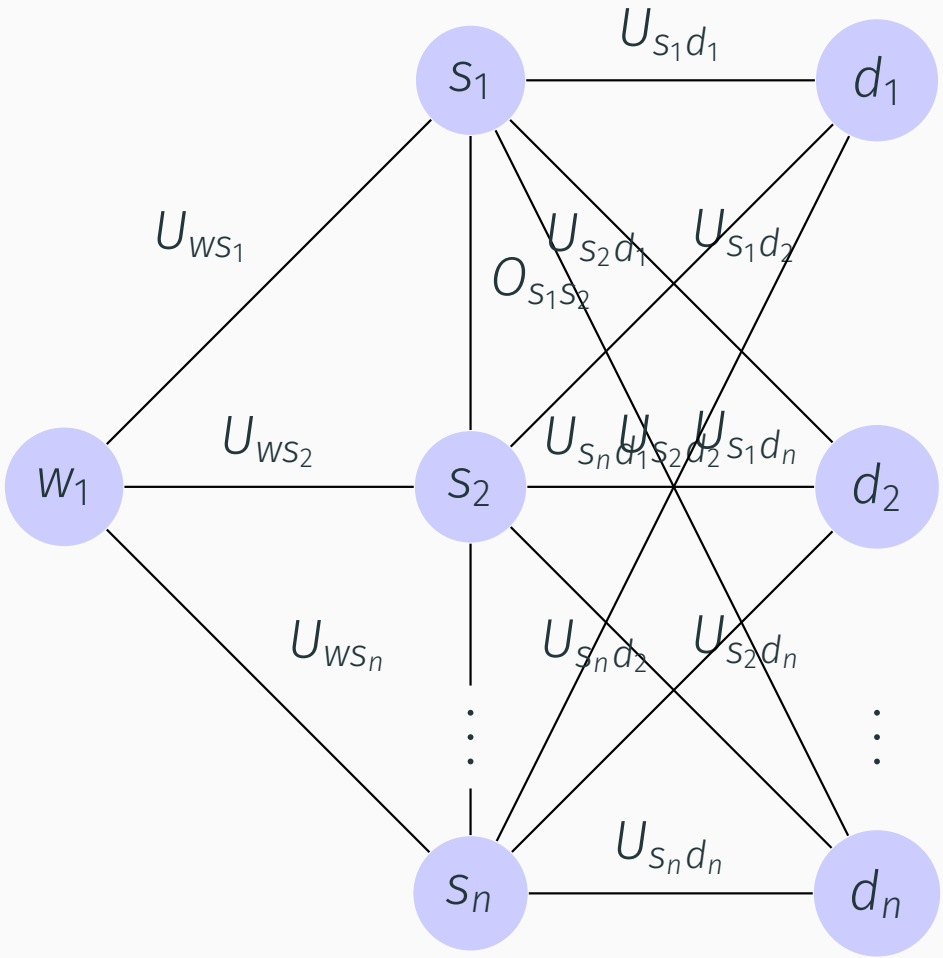
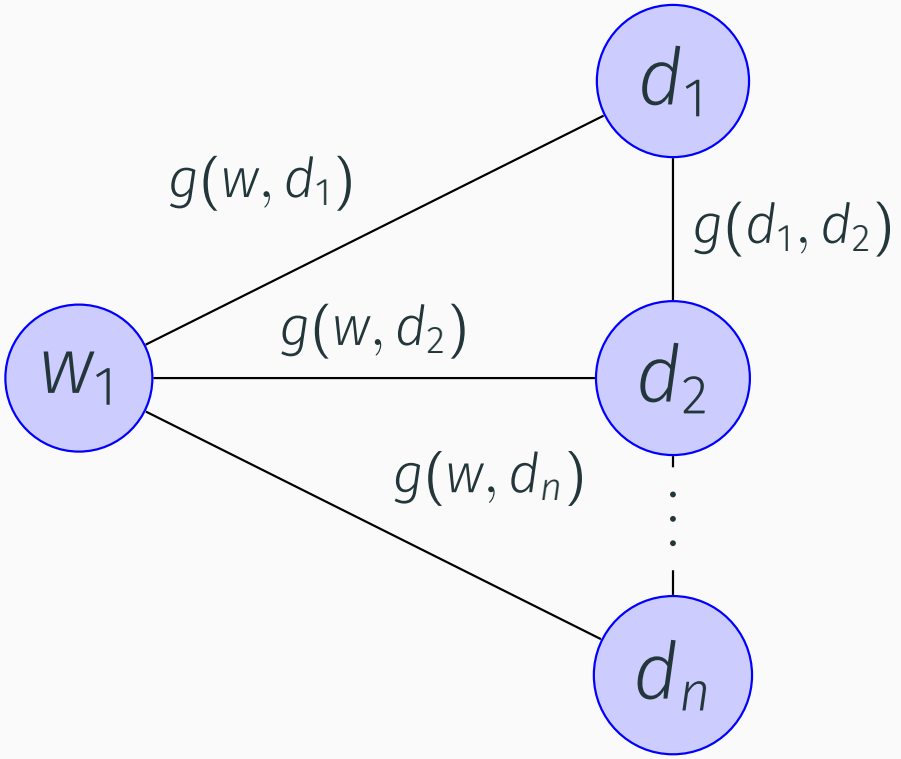


Figure 2: Simplified transportation graph

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

Build Path - Convert Graph



$$g(w, d) = \min_{ij \in S} U_{wi} + O_{ij} + U_{jd} \quad \text{where } i, j \in S \tag{1}$$

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

$$\min = \sum_{i=1}^{m} \sum_{i \neq j, j=1}^{n} g(w_i, d_j) x_{ij}$$
$$W = \{w_1, w_2, \cdots w_m\}$$
$$D = \{d_1, d_2, \cdots d_n\} \tag{2}$$
$$x_i j = \begin{cases} 1, & \text{path from } i \text{ to } d,\ i \in W \cup D, j \in D. \\ 0, & \text{otherwise.} \end{cases}$$

Questions?

References I

dronelife.com.
Buy a drone, 2016.
[Online; accessed 30-March-2016].

D. Hinebaugh.
Characteristics of bus rapid transit for decision-making.
Technical report, 2009.