An Evacuation Support System Based on Cooperative UAVs

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1 Introduction

Natural disasters are ubiquitous, not limited in Japan

- 2011.3.11：Great East Japan Earthquake (M9.0)

- 2019.10：Reiwa 1st Eastern typhoon (Typhoon #19)

  *Disaster Relief Act is most widely applied. ;

- 2021.2.10：Royalty Islands Earthquake (M7.7)

  ∗ Tsunami is observed at Vanuatu

1 Introduction

We have to consider:

Secondary Disaster

Have to be careful when evacuation.

Characteristics in Mountainous Area

（Older population，Populality of smartphone）

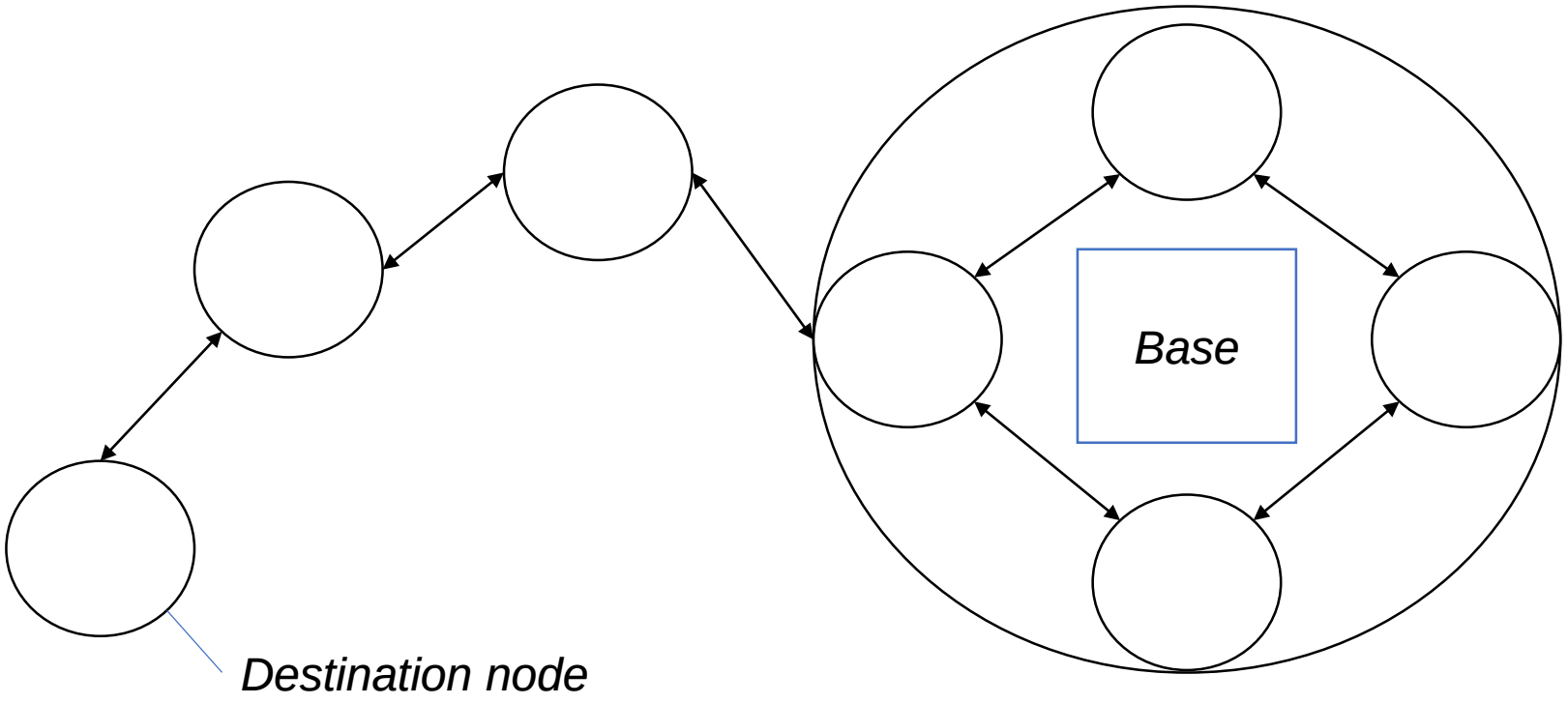
Image From Ministry of Land, Infrastructure, Transport and Tourism (http://www.mlit.go.jp/)

In this study

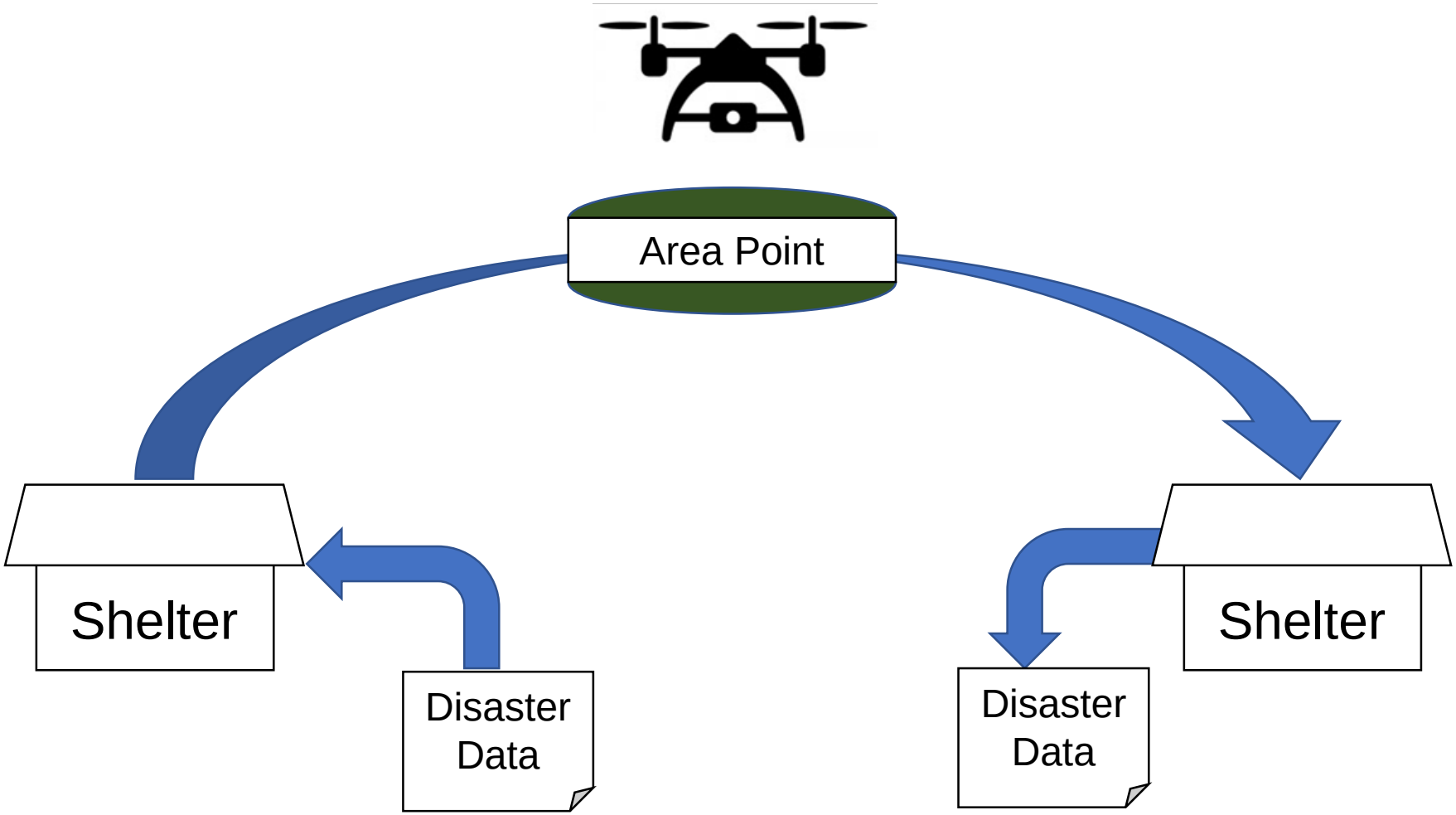
- We propose an approach for evacuation using priorities in mountainous
- Simulated how many people we can rescue

2 Proposed System

- DTN(Delay Tolerant Networking）



2 Proposed System



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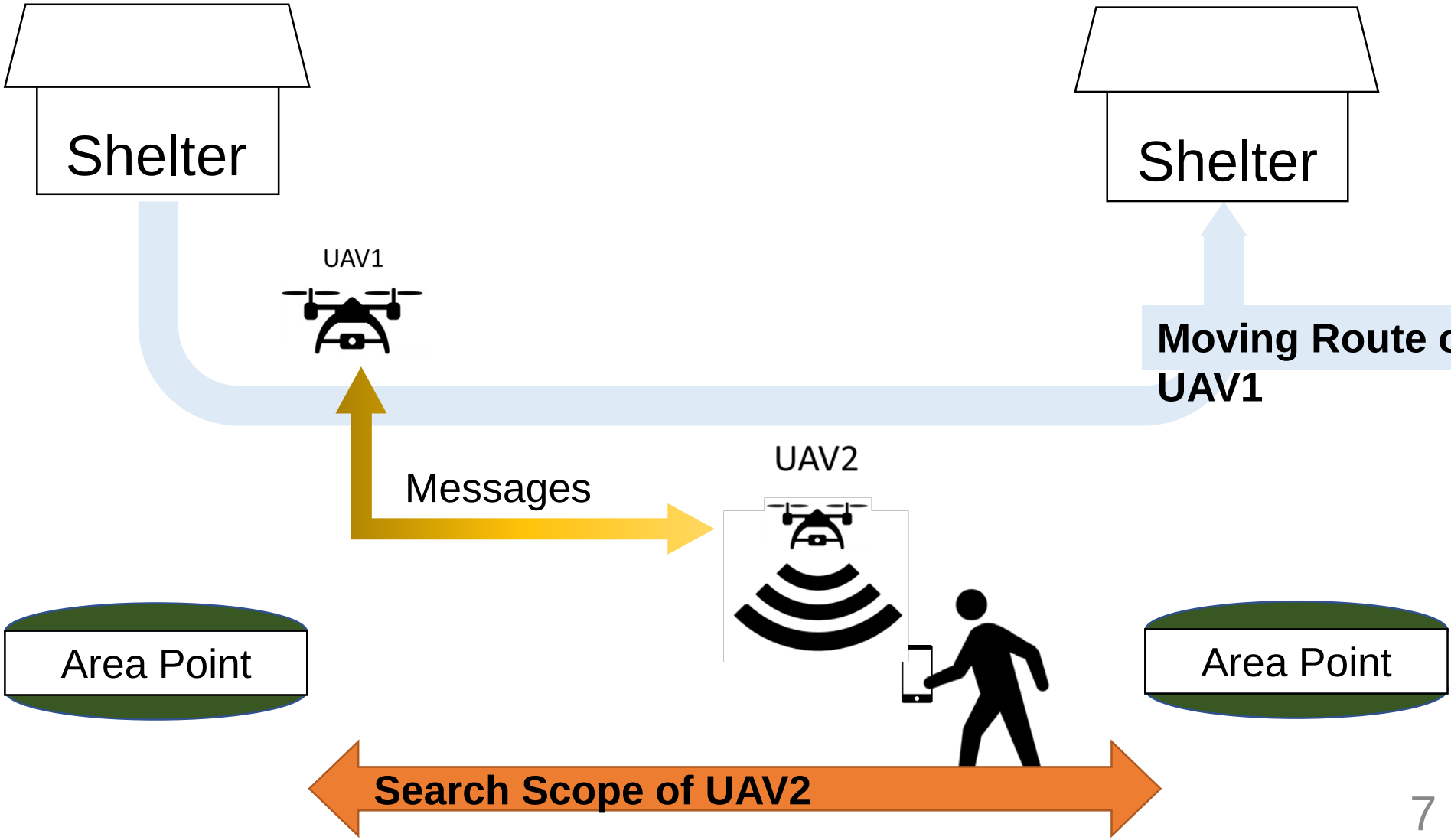

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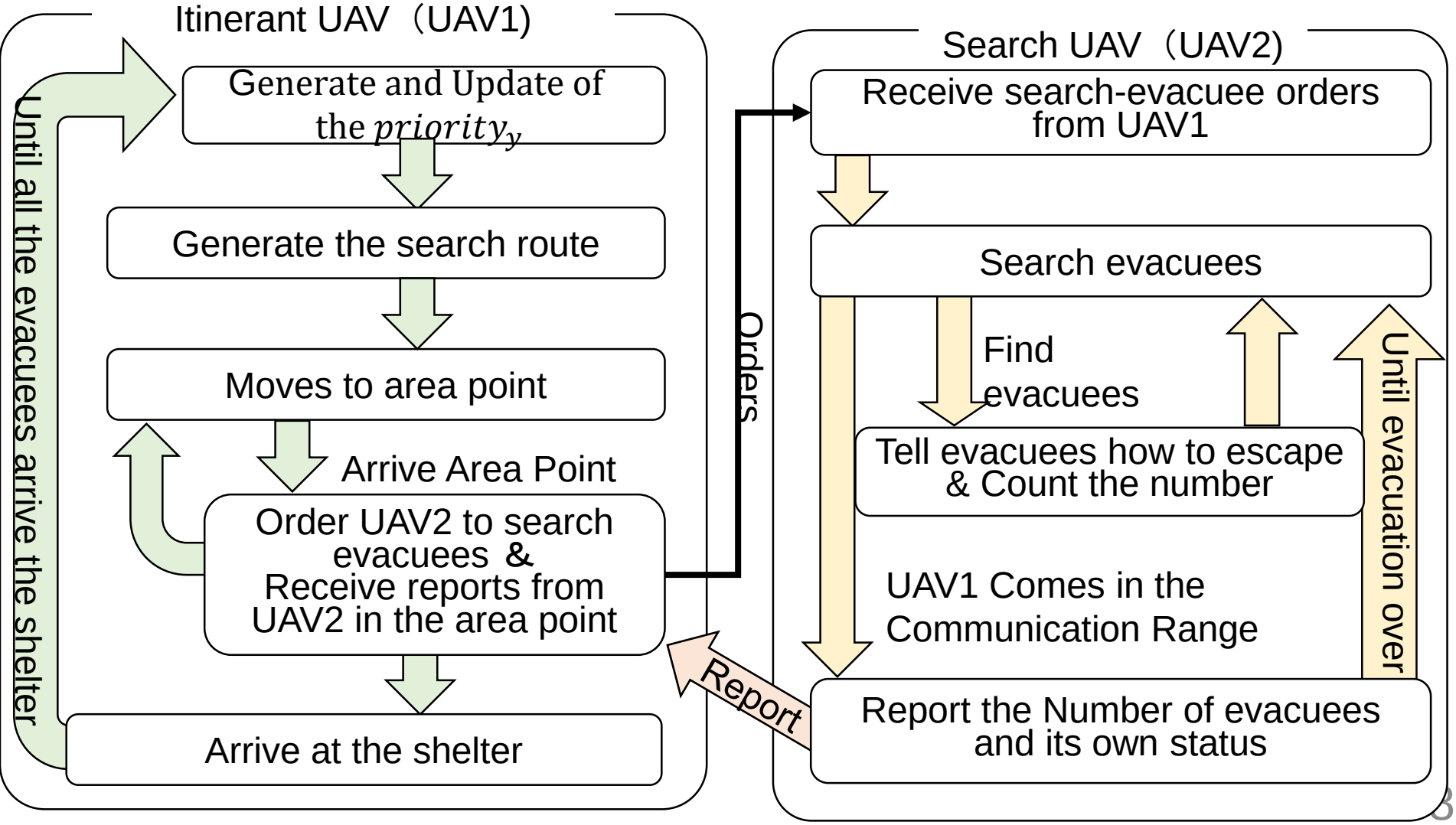
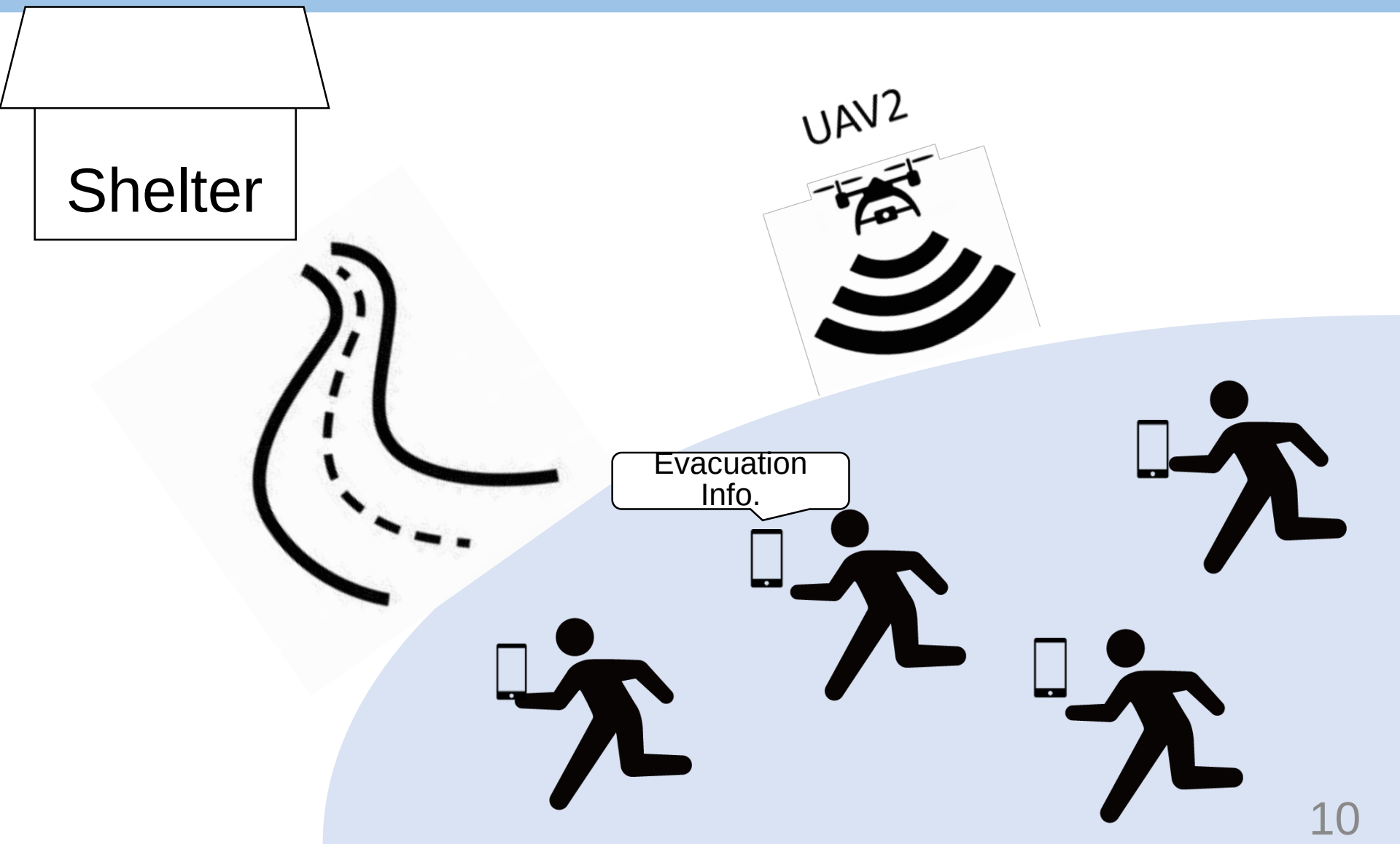


Agents

- **Calculate agent: on server, calculates priorities.**
- **Messenger agent: on UAV1, sends message to UAV2**
- **Find evacuee agent: on UAV2, sends environment information to UAV1**
- **Find route agent: on server, determine evacuation routes.**
- **UAV control agent: on UAV1, fly over the evacuation routes.**

2 Proposed System



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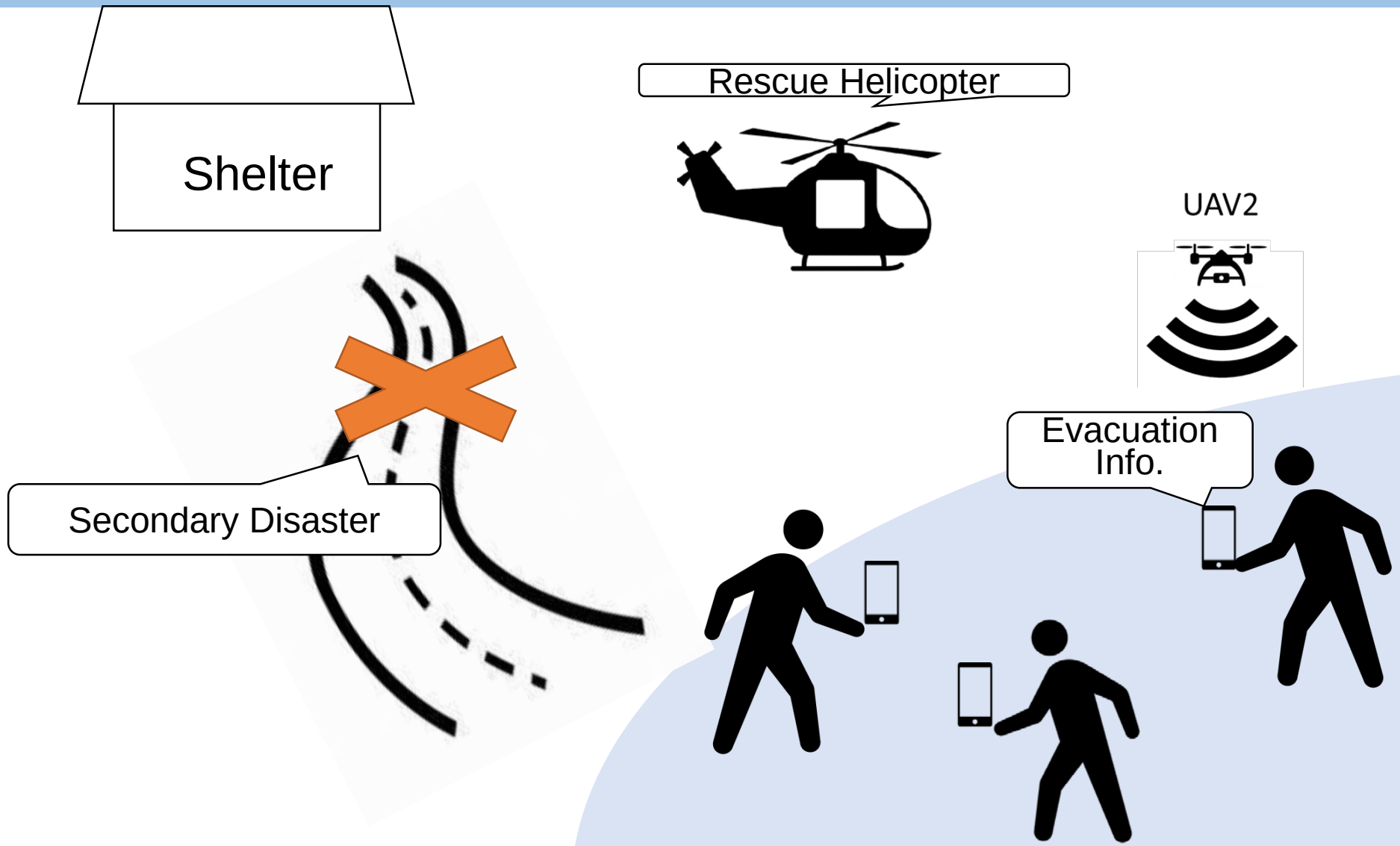


2 Proposed System

- $priority_y$:

  Priority for Mountainous Area

  Used for the movinf route for UAV1

$$priority_y = \alpha d + \beta t + \gamma U + \delta D$$

α	$=8.1 \times 10^{-4}$	arbitrary coefficients (based on preliminary experiments)
β	$=0.001$	
γ	$=0.99$	
δ	$=0.1$	
d	Distance between the area point (AP) and the nearest shelter	
t	Average time to reach to the nearest shelter	
U	Ration of evacuees per max population of the AP (0.00～1.00)	
D	Risk of secondary disasters around the AP (0.01～1.00)	

3 Experiments

- Location：Focus on mountainous area such as An-naka, Gunnma

＊Ratio of older people (2015)

National average	26.6%
Minato-ku, Tokyo	17.1%
Miyashiro, Saitama	30.1%
An-naka, Gunnma	32.5%

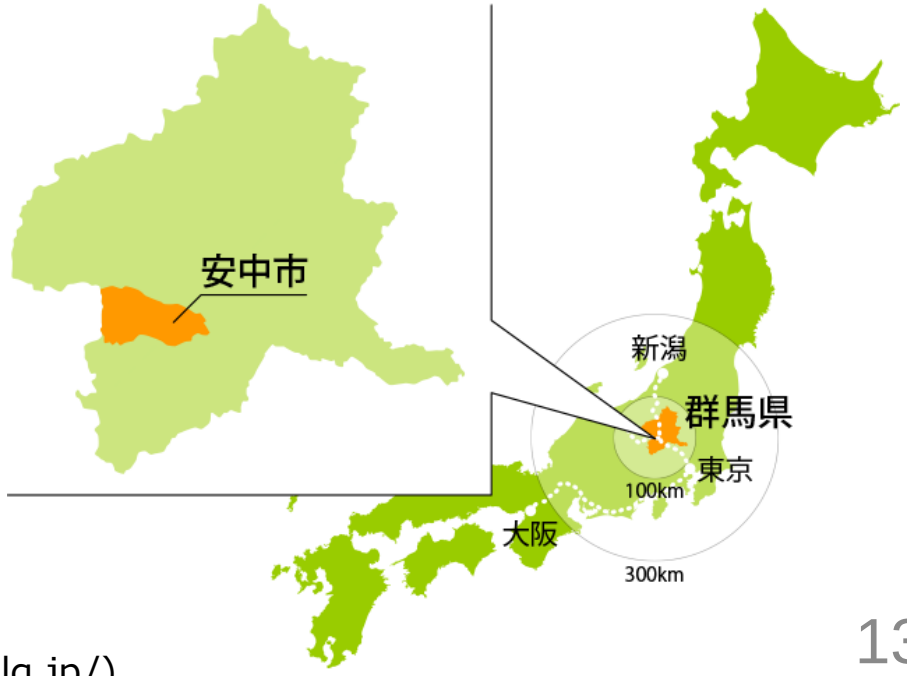


Image From An-naka city (https://www.city.annaka.lg.jp/)

3 Experiments

Google Map: Matsuida-machi, An-naka, Gunnma, Japan

Based on the Hazard Map An-naka (2014)

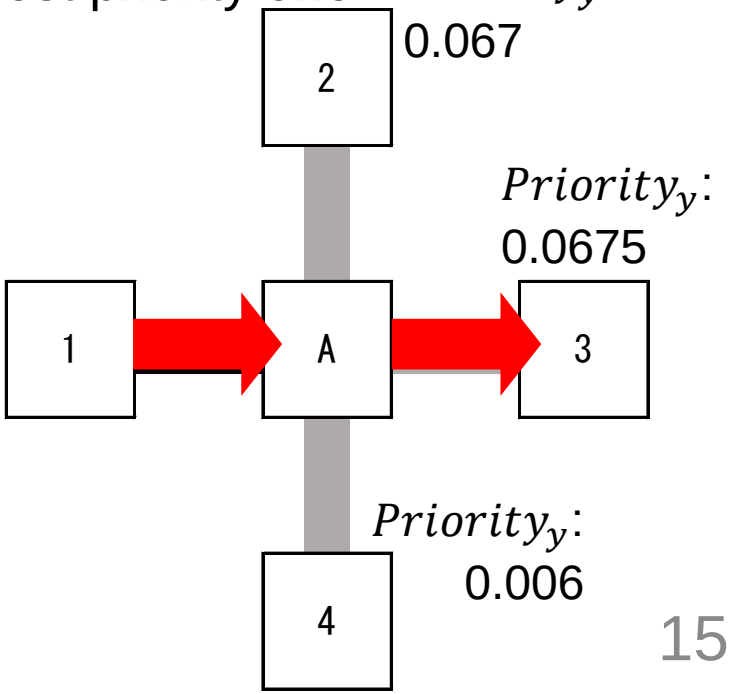
3 Experiments

＜determine the route of UAV1＞

Obtain the priority of the candidates of next communication point.

＊omit the previously visited points.

Select a communication point that has the highest priority one and moves to that point.



	発生時 (Step.1)	Step.2	Step.3	Step.4	Step.5	Step.6	Step.7	最終状態 (Step.8)	避難者数
S1	25	25	25	25	25	25	25	25	25
1	15	15	7	7	7	3	3	1	14
2	30	30	15	15	15	7	7	3	27
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	25	25	12	12	6	3	1	0	25
6	30	30	7	7	3	1	0	0	30
7	0	0	0	0	0	0	0	0	0
8	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**0**
9	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**0**
10	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**0**
11	40	40	20	20	10	5	2	1	39
12	35	17	17	8	4	4	2	2	33
13	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
16	12	6	6	3	1	1	0	0	12
17	20	10	10	5	2	2	1	1	19
18	25	12	6	3	1	1	0	0	25
19	32	16	8	4	2	2	2	1	31
20	45	22	22	11	5	5	2	2	43
S2	25	25	25	25	25	25	25	25	25
*1	349	263	170	135	96	74	60	51	
*2	50	136	229	264	303	325	339	348	

*1: エリアポイント周辺にいる，避難所にたどり着いてない人数
*2: 避難所に向かえた人数+避難所にいる人数(S1, S2)

3 Experiments/Results

＜initial state＞

- Population：399人
- Already in the shelters：50人

＜final state＞

- Saved population：348人(87.2%)
- Unsaved population：51人(12.8%)
- Area points not visited：3

4 Discussion

- Priorities of the sediment disaster caution areas and other areas are almost the same

  → Need to adjust the priorities of risky areas.

- Save 80%, but could not save 20%

  → Need to increase the number of UAV1s, and

  → Need to adjust the search routes.

4 Discussion

Need to consider the priorities of

“sediment disaster caution areas” and

“densely populated areas”

exists at the same time

Reconsider the formula of priority so that “sediment disaster caution areas” have higher priorities.

So that we can manage any situations.

5 Future Work (1)

- The simulator has only one UAV1
  → Situations of disasters and evacuees are not in real time.
  → Need to deal with unexpected situations.

⇒ Sophisticated simulation with multiple UAVs

5 Future Work (2)

- Shortest route finding algorithms such as Dijkstra method or Ford-Fulkerson method are not used.

  Because mountainous areas have few routes anyway.

  → about 20% population, we could not save.

⇒Route finding algorithms are useful?

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Thank you for very much.