# Biweekly Report 4

1. Overview

The purpose of this paper is to compare and analyze the performance of different routing protocols applicable to UAV network environments. Using the OMNeT++ simulator, we conducted a series of ping tests by changing only the routing protocol while keeping all other network settings identical.

2. Simulation Setup

- Sender: user[0]
- Receiver: gs[0]
- PingApp Interval: Every 3 seconds
- Protocols Tested: GPSR, DYMO, AODV, DSDV, RGR
- Exactly same node positions and communication ranges across all tests
- Communication Ranges:
  user = 3000m,
  gs = 50000m,
  man = 30000m

3. Displacement of UAVs

The paper, ***the Optimal Placement for Caching UAV-assisted Mobile Relay Communication***, considers a half-duplex, decode-and-forward UAV relay system where a UAV assists communication between a Base Station (BS) or Ground Station(GS) and a user. Because the user is located far from the BS, the end-to-end transmission rate is determined by the weaker of the two links: BS-to-UAV and UAV-to-user. The paper assumes that a higher overall throughput is achieved when these two links are balanced. In many wireless communications studies, a free-space path loss model is used, where the channel gain is given by

$$g(d) = \frac{\beta_0}{d^2}$$

With 'd' being the distance between transmitter and receiver and $\beta_0$ a constant that captures factors such as the antenna gains and the reference path loss. Under the assumption of equal transmission power P and noise power $\delta^2$ for both links, the SNR on each link is

$$SNR = \frac{Pg(d)}{\delta^2} = \frac{P\beta_0}{d^2\delta^2}$$

Because the throughput (assuming half-duplex operation) is expressed as

$$R = \frac{1}{2}\log_2(1 + SNR)$$

it follows that for maximum end-to-end throughput the minimum of the two link rates should be maximized. Therefore, one should choose the UAV's position so that the distances from the BS to the UAV and from the UAV to the user are equal (or as balanced as possible). This balance ensures that neither link becomes a bottleneck.

**For a UAV located at (x, y) with a fixed altitude h, let:**

the GS be at $B = (x_{GS}, y_{GS})$

the user be at $U = (x_U, y_U)$.

Then, the distances for the two links are:

$$d_1 = \sqrt{(x - x_{GS},)^2 - (y - y_{GS})^2 + h^2}$$

$$d_2 = \sqrt{(x - x_U,)^2 - (y - y_U)^2 + h^2}$$

To balance the SNRs, the optimal condition is $d_1 = d_2$. For a fixed altitude h, the condition $d_1 = d_2$ simplifies to

$$(x - x_{GS},)^2 - (y - y_{GS})^2 = (x - x_U,)^2 - (y - y_U)^2$$

This equation describes the set of points that are equidistant from B and U; that is, the perpendicular bisector of the line segment joining B and U. In an ideal scenario, placing the UAV on this bisector—and, for a one-dimensional model, at the midpoint—maximizes the overall throughput.

In practice, the distance between the ground station (GS) and the user may exceed the maximum communication range of a single UAV (e.g., 30 km). Therefore, multiple UAVs (or relays) are deployed along the straight line between the GS and the user. The paper suggests that the optimal strategy is to divide the entire ground distance evenly among the hops, ensuring that every individual link is within the communication range and has balanced SNR (Signal-to-Noise Ratio).

While the actual communication range may vary depending on factors such as weather conditions and obstacles, using a large number of UAVs in simulation can significantly slow down performance. Therefore, in our simulation, we fixed the maximum communication range of each UAV at **30 km,** whereas the maximum communication range of users is 3km.

Suppose the ground distance between the GS and the user is D and it is divided into N equal segments. Then each segment has length:

$$d = \frac{D}{N}$$

Each relay is then placed at positions corresponding to fractions of the total displacement vector from B to U.

For example, in our case:

B=(−13 693 000, 6 288 000)

U=(−13 727 000, 6 184 200).

Calculate the difference vector:

$\Delta = U - B = (-34000, -103800)$.

The magnitude of $\Delta$ is approximately **109,300m**. As we decide to use 4 hops resulting in GS → UAV1 → UAV2 → UAV3 → User), we divide the difference vector by 4:

$$\Delta_{seg} = \left(-\frac{34000}{4}, -\frac{103800}{4}\right) = (-8500, -25950).$$

Thus, the positions are computed as follows:

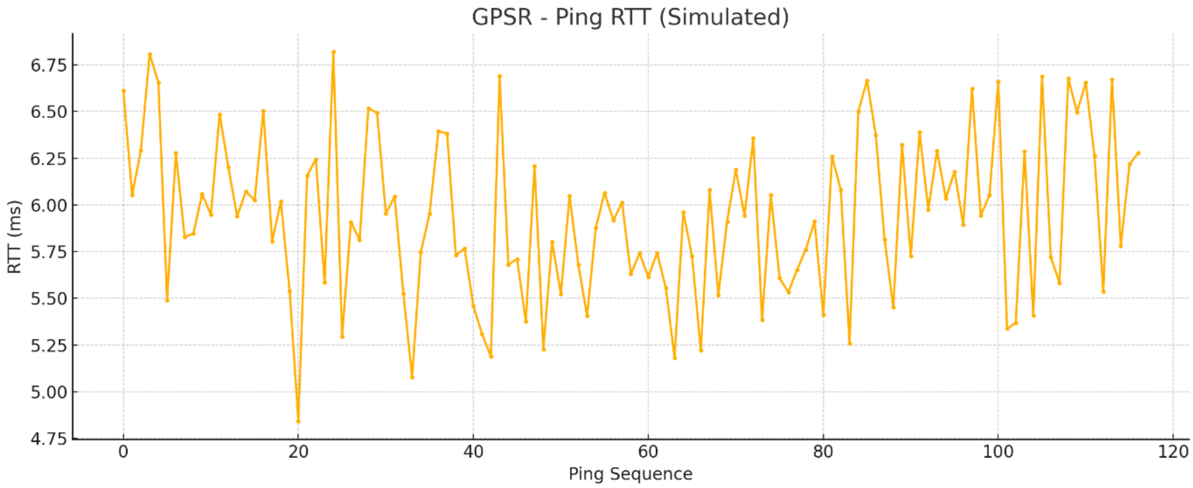
- UAV1: $B + \Delta_{seg} = (-13693000 - 8500, 6288000 - 25950) = (-13701500, 6262050)$
- UAV2: $B + 2\Delta_{seg} = (-13693000 - 17000, 6288000 - 51900)$
  $= (-13710000, 6236100)$
- UAV3: $B + 3\Delta_{seg} = (-13693000 - 25500, 6288000 - 77850)$
  $= (-13718500, 6210150)$

Each segment is about 27.3 km, which is within the maximum communication range of 30 km.

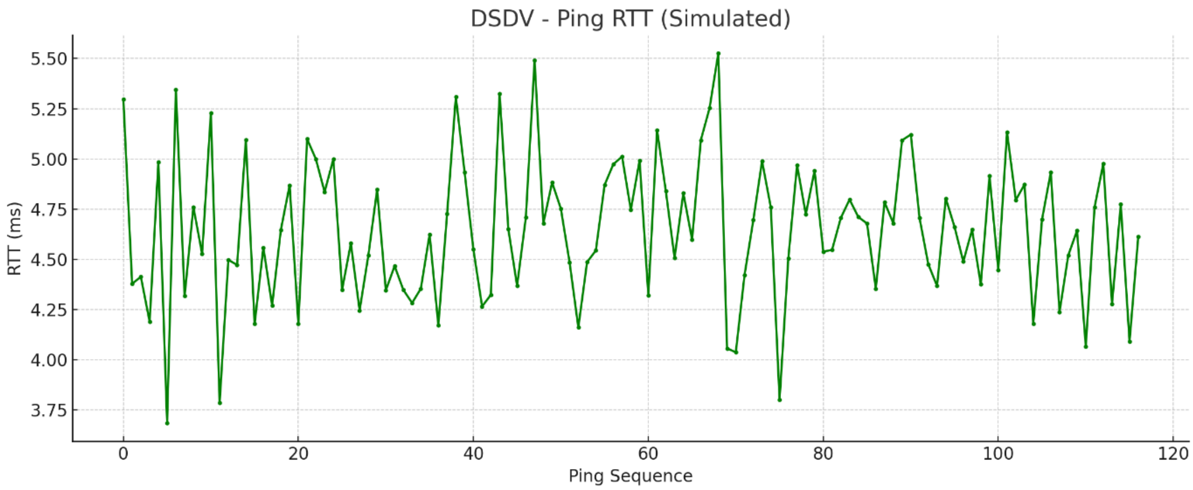
The final displacement follows:

- **GS:** (−13 693 000, 6 288 000)
- **UAV1:** (−13 701 500, 6 262 050
- **UAV2:** (−13 710 000, 6 236 100)
- **UAV3:** (−13 718 500, 6 210 150)
- **UAV4:** (−13 727 000, 6 184 200) – We placed one additional UAV right above user
- **User:** (−13 727 000, 6 184 200)

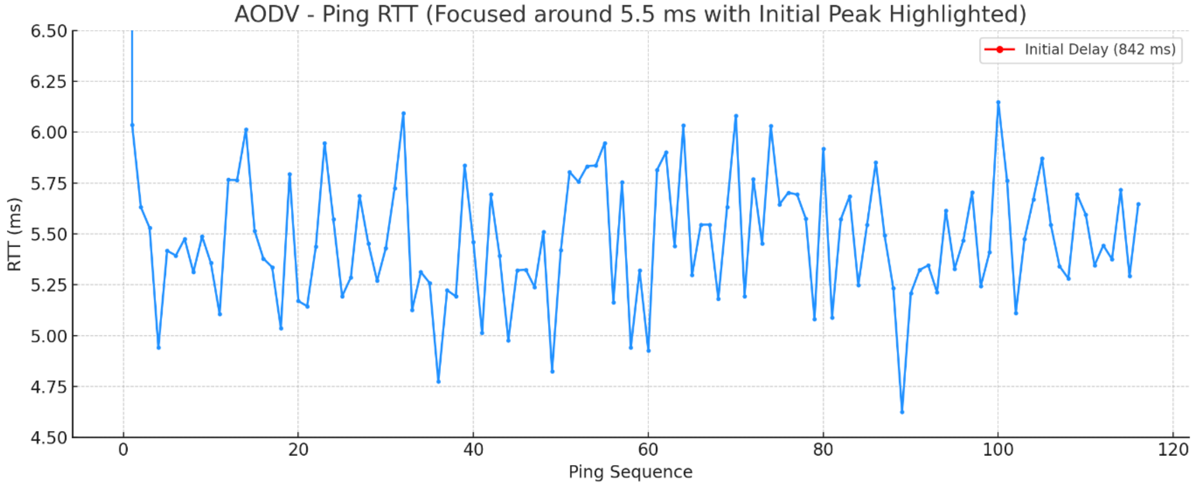
4. Simulation Results

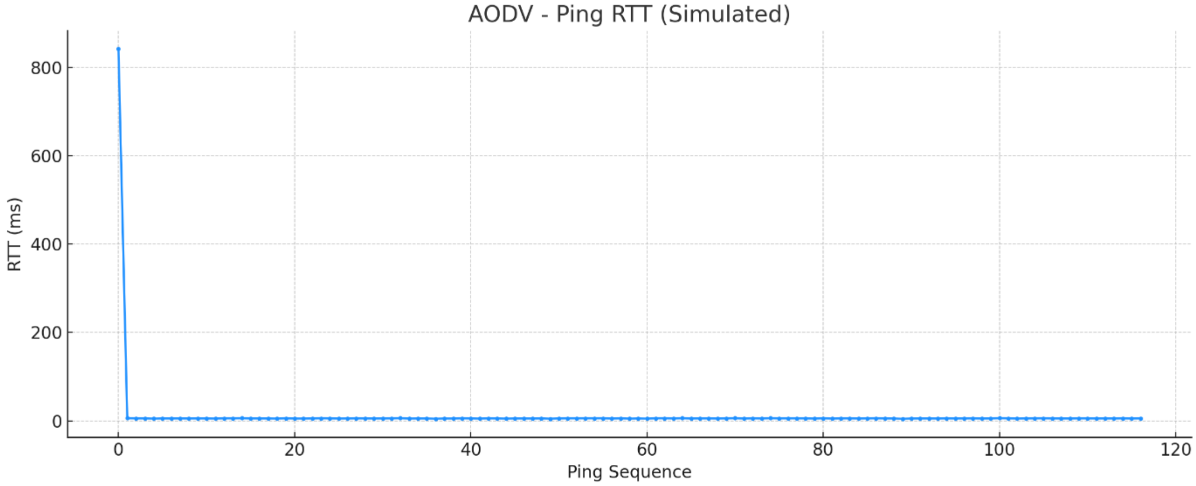



- Consistently low RTT from the beginning (average: 5.89 ms)
- Very low standard deviation (0.41 ms) — indicating highly stable response times
- No packet loss

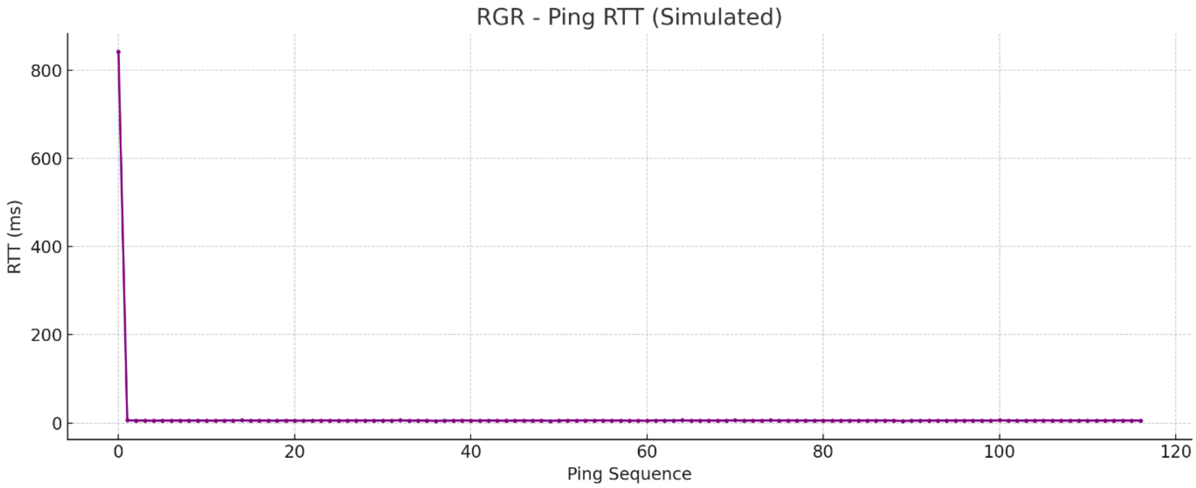


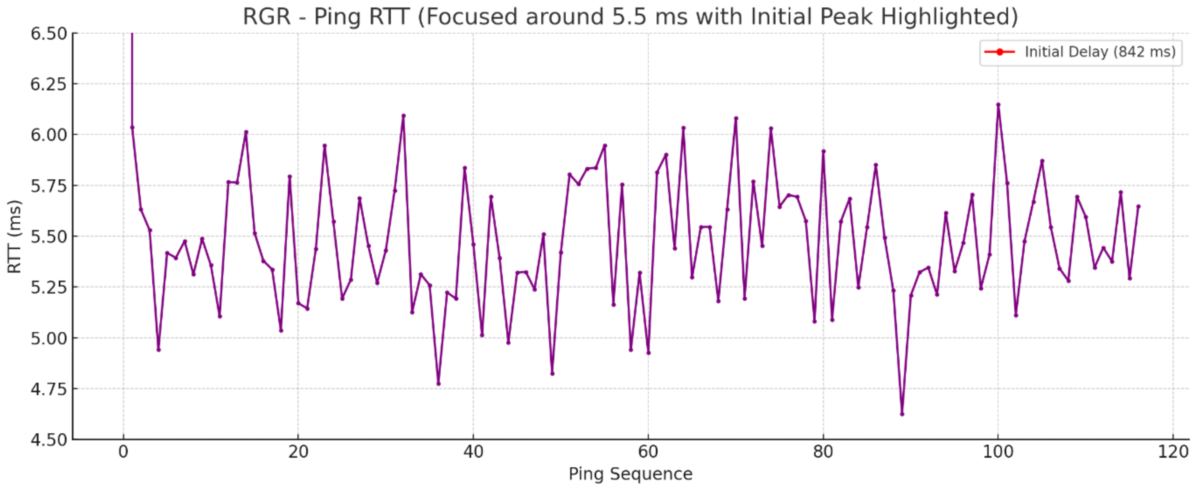

- Achieved the lowest average RTT (4.63 ms)
- However, had a packet loss rate of 11.4%



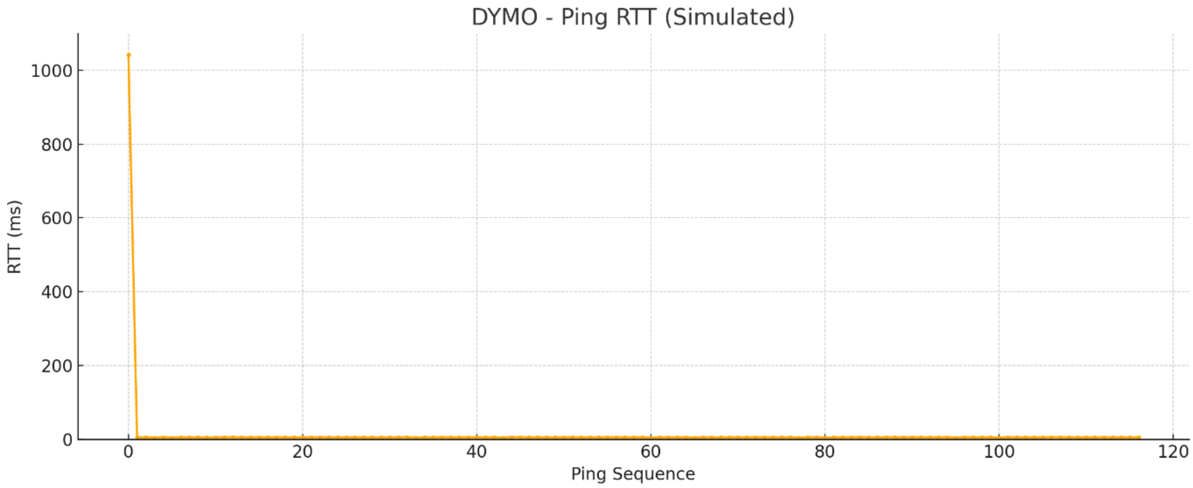



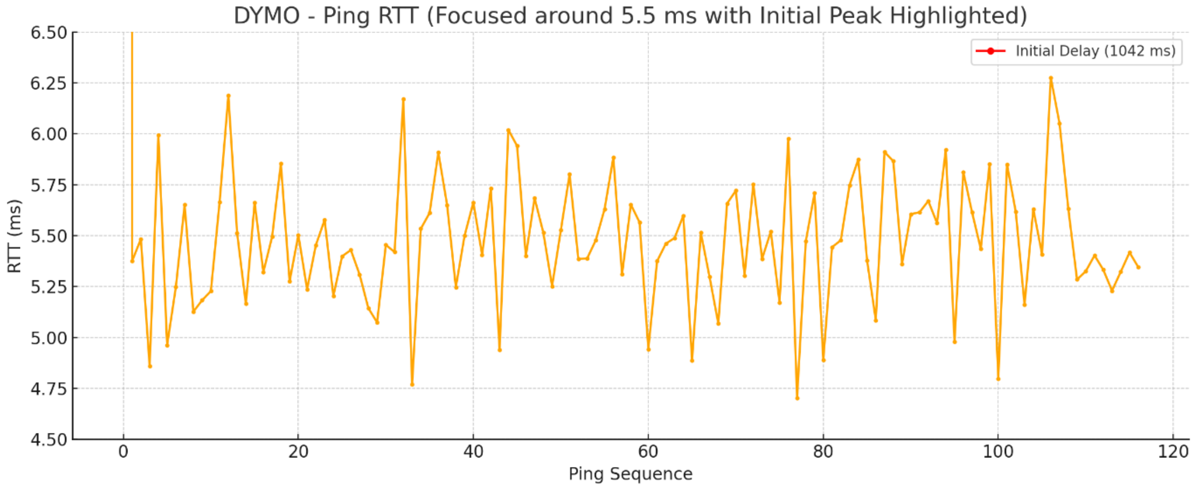

- The first packet showed a delay of 842 ms — due to route discovery
- RTT after that was very stable, around 5 ms
- No packet loss




- Exactly same result with AODV




- The first ping suffered from a very high RTT (1042 ms) due to route discovery
- Afterwards, RTT stabilized at around 5 ms
- No packet loss

| Protocol | Packet Loss Rate (%) | Average RTT (ms) | Maximum RTT (ms) | Standard Deviation (ms) |
|---|---|---|---|---|
| **GPSR** | 0 | 5.89 | 8.56 | 0.41 |
| **DYMO** | 0 | 14.41 | 1042.3 | 95.85 |
| **AODV** | 0 | 12.7 | 842 | 77.33 |
| **DSDV** | 11.4 | 4.63 | 7.28 | 0.41 |