Learning in DTN

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General Classification in DTN

Most of the studies in AI based routing for DTN fall in this spectrum

Replicating vs Forwarding

- In **replication,** multiple copies of same packet are disseminated across multiple paths simultaneously
- In **forwarding,** only one copy of packet is transferred from one node to another, and the source node deletes the packet after transfer.

AI in DTN

Predictive Routing

- **How it works**: Each DTN node collects data on its encounters with other nodes, including factors like encounter frequency, duration, time of day, and successful message deliveries. This data is used to train a classifier model.
- **Example:** A rover on Mars can use ML to predict which other rovers or orbiting satellites it's most likely to encounter in the near future and for how long. It would then prioritize forwarding bundles to the node with the highest predicted "delivery probability."

AI in DTN (Cont.)

Resource Management

- DTN nodes in space or IoT, have limited resources like buffer space and energy. ML can optimize how these resources are used.
- **How it works:** An ML model can be trained to predict the future buffer state of a node or to forecast network traffic. This allows the node to proactively manage its resources.
- **Example**: A satellite acting as a DTN node can use a time-series model to predict when its buffer is likely to become full based on historical data. It could then start dropping less critical bundles or negotiate with ground stations for a scheduled data dump to prevent a buffer overflow.

AI in DTN (Cont.)

Traditional approach: A message is given a fixed time limit to be delivered. If time runs out, it's deleted. This avoids infinite storage.

AI approaches: Create a message that uses AI to figure out its odds of getting through. Then, it can either:

- Give itself more time when the chances are good.
- Make a backup copy of itself, but only when it actually needs to.

Application 1: Smart Time Limits & Copies (Cont.)

- **Dataset:**
  - Real drive-test logs (per-minute): location, speed, signal level, operator, time-of-day/weekday.

Fig 1: Map showing drive-test paths at Sunway City [1]

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Application 1: Initial Results

Key Findings:

- Targeted/selective copies beat blind copies. Giving messages a little bit of intelligence about when to make a backup copy is much more effective than just blindly making copies.
- Flexible time limits beat fixed ones. When a message can adapt its own time limit, it gets through more often without using more network resources.

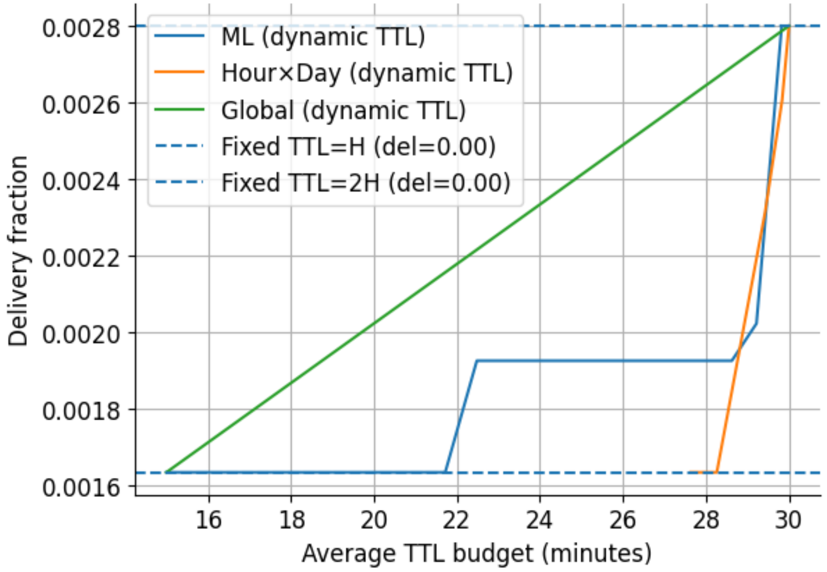

Fig 2: delivery vs average TTL (budget-neutral)

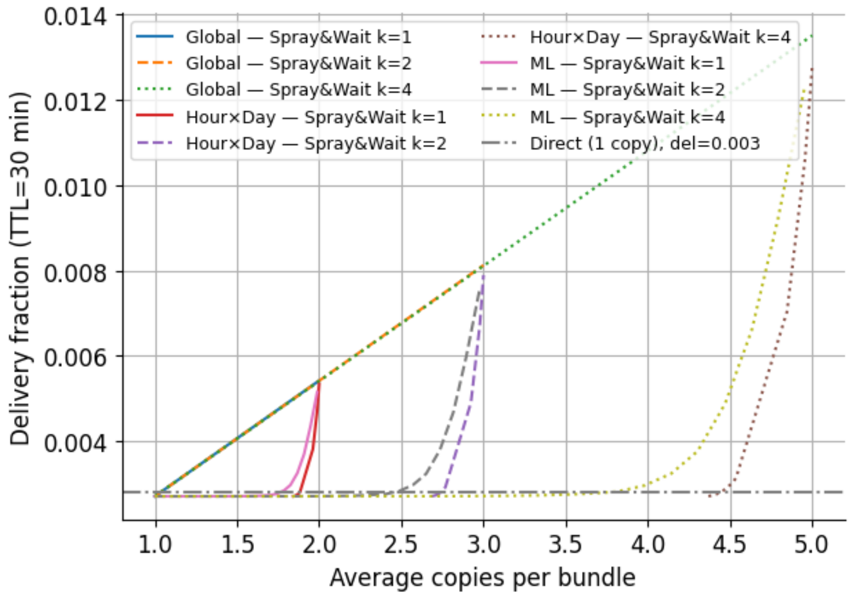

Fig 3: delivery vs average copies. (TTL=30 min)

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Application 2: Reinforcement Learning for DTN Decisions – The AI Coach

Idea: We test an "AI coach" that learns from experience. This coach tells a message:

- **When to Hold:** Wait for a better connection.
- **When to Forward**: Send the message to a nearby device.
- **When to Copy**: Make a backup copy if it's likely to succeed.

Application 2: Reinforcement Learning for DTN Decisions

Key Findings:

- The AI coach is much smarter than fixed rules.
- It learns exactly when to split (copy) and when to wait (forward).
- We get more delivery for the same budget because we don't "flood" the network with unnecessary copies.

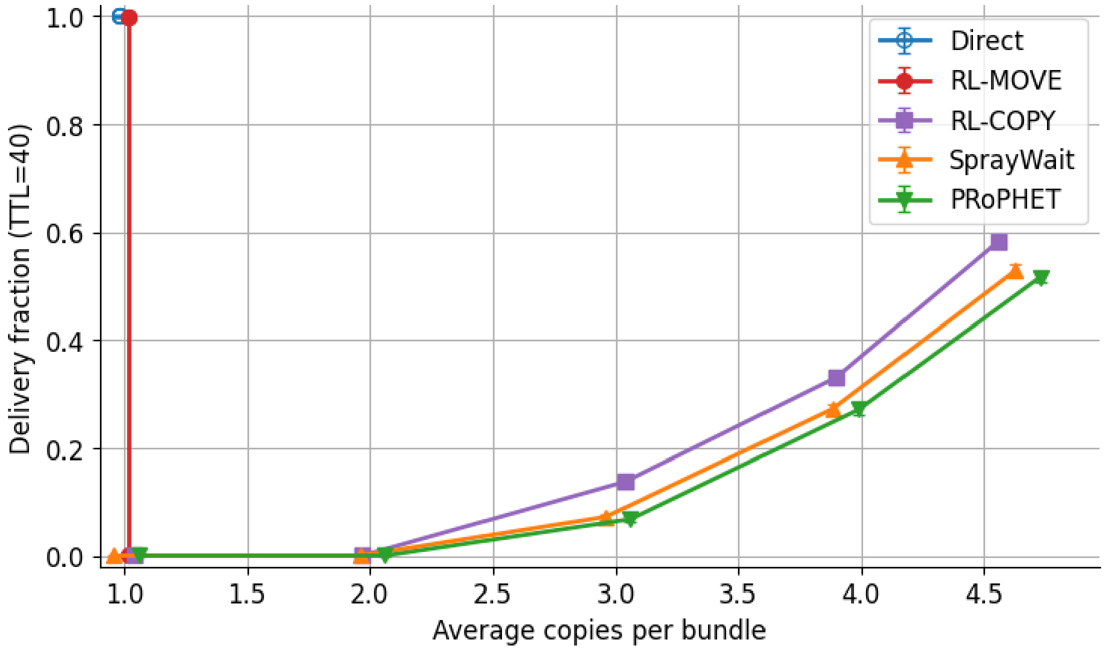

Fig 4: Delivery vs Overhead

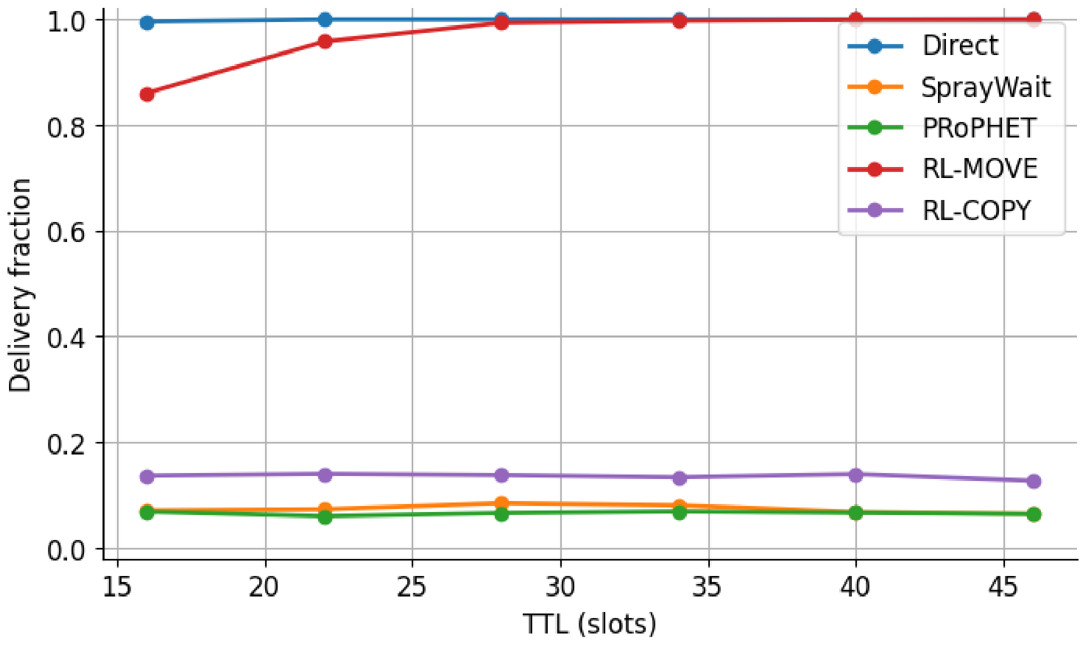

Fig 5: TTL–Delivery

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Then vs Now

Q2 : What should DTN theory look like in 6G?

Then vs. Now:

- **Then**: Networks were unpredictable.
- **Now (6G):** Networks are getting smarter. We have more information (like time of day and location) and more connections (to cars, drones, and smart devices).

The big question:
Are our modern AI solutions performing good because they're "smarter" or because they're taking advantage of this new, predictable information?

Our claim: AI is so effective because it sees predictable "corridors" of connectivity that classical theory never modeled.

In 6G, what will matter in terms of routing is:

- Deadline (TTL): how much time you have.
- Diversity: how many independent, time-respecting routes exist within that TTL.

- Extra copies are only valuable when diversity exists.
- We need a new theory framing that turns this intuition into math.

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