Network Slicing with Network Coding: An Optimal Approach for Resource Allocation

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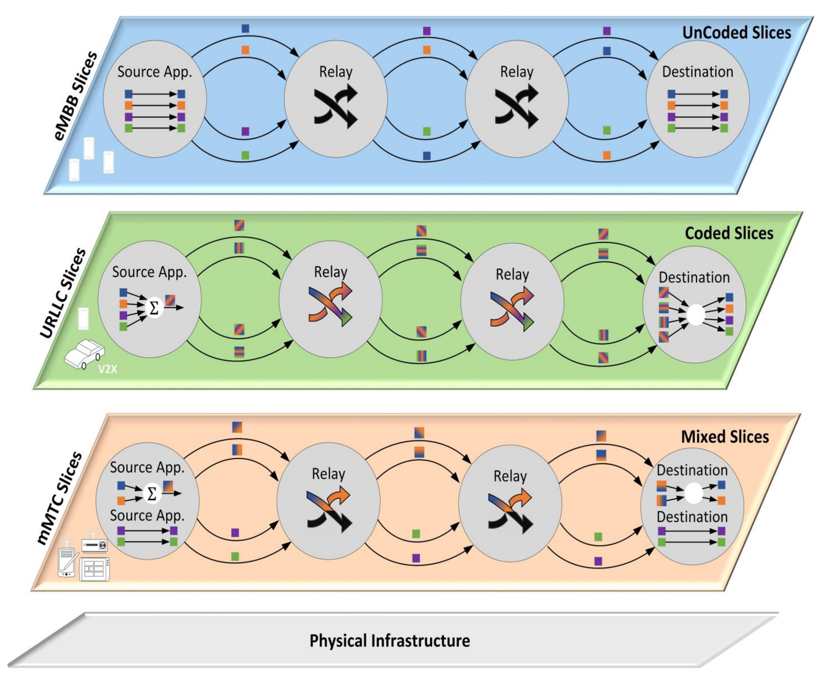
Motivation

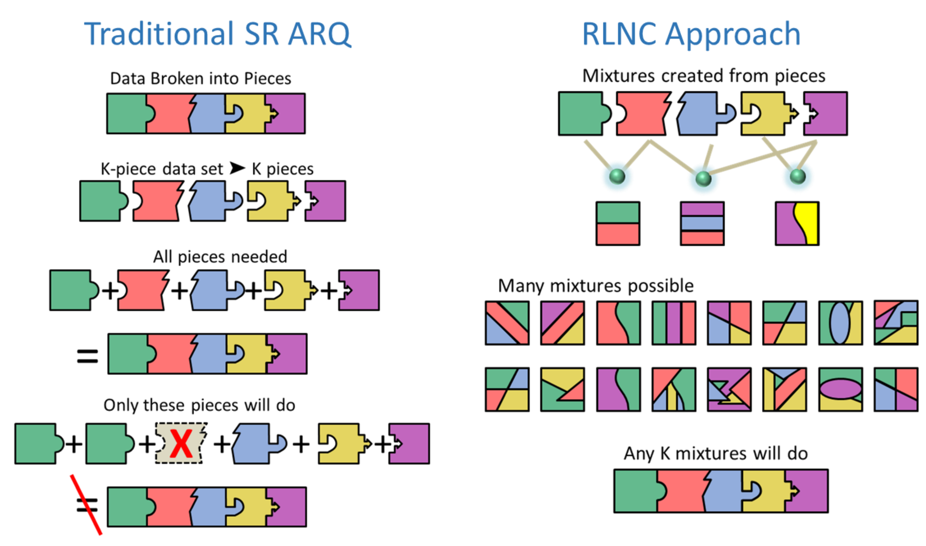
- 5G Use cases: serve applications with varying requirements.
- Sustainable cities: Aim for a net zero footprint (Aveiro Tech City Living Lab).
- Requires optimal resource utilization while preserving resources.



- **Network Slicing**: Split network resources to virtual networks tailored for specific applications.
- Share same infrastructure.
- Different communication protocols for different use cases.

- URLLC: Low Latency
- eMBB: High Throughput
- mMTC: Dense Networks

- **Network Coding** (NC): Communication solution to improve quality over lossy channels (e.g., reliability, latency, cost).



Our Approach

Applying NC over network slices enhances service quality (delivery delay) and ensures requirements are satisfied (throughput) with given resources.

Dynamic Slicing Solution: Resources are reallocated after service.

Key Performance Indicators

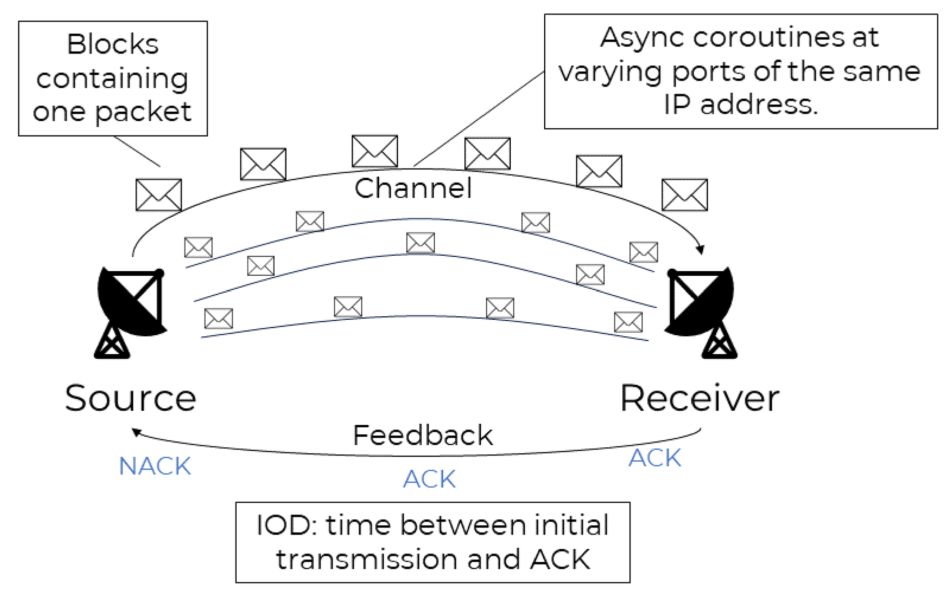
- **(In-Order) Delivery Delay**: Number of time slots it takes for an information packet to be delivered (in-order) at the destination.
- **Throughput**: Number of information packets delivered per time slot.
- **Completion Time**: Number of time slots it takes for an application to successfully deliver all information packets.

Methodology

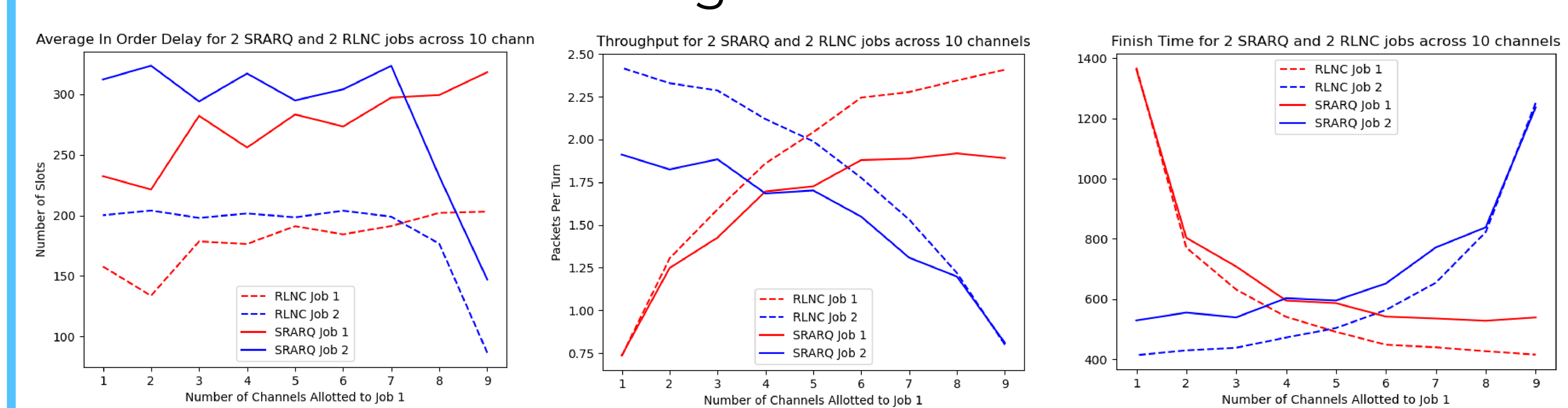
- Un-coded slice implementation: Selective Repeat ARQ (**SR-ARQ**).
- Coded slice implementation: Random Linear Network Coding (**RLNC**).
  - Apriori Forward Erasure Correction (FEC)
  - Feedback-based additional repair packets.
  - Follows coding-aware acknowledgment scheme.

Simulation Setting and Results

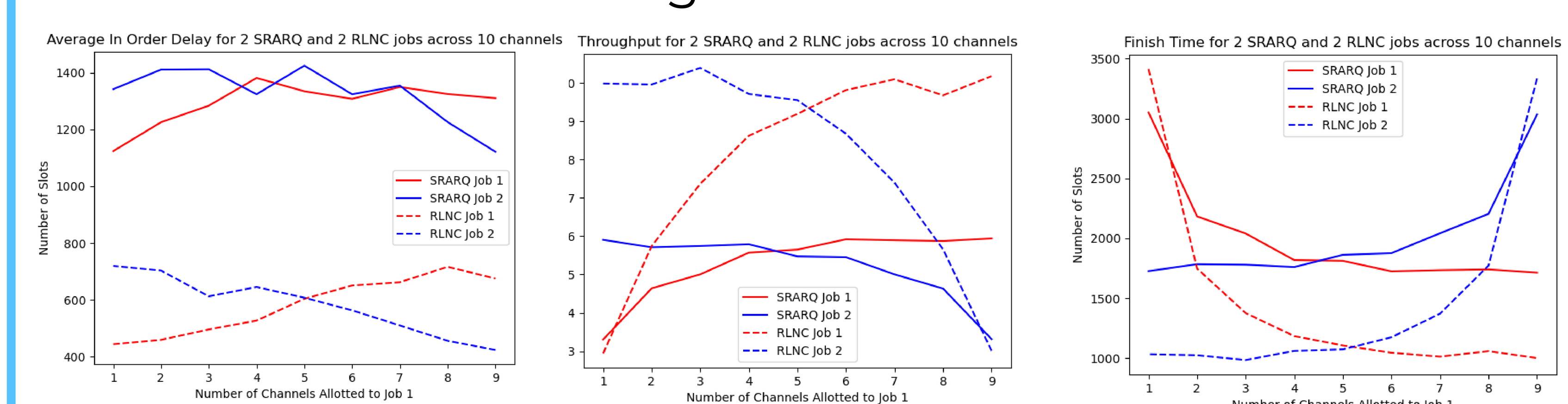
Parameters:
- 10 links
- 150 RTT
- 1000 packets
- 10 block size
- Homogeneous error (ε): 0.5.
- Heterogeneous error (ε): range between (0.00, 0.1).



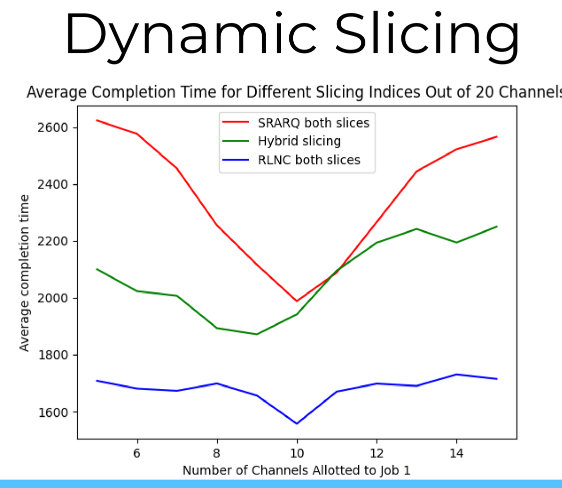
Heterogenous Losses



Homogenous Losses



Dynamic Slicing



- In-order delivery delay **scales with the number of links** allocated, as a loss interrupts several packets in transit.
- RLNC **manages the delay-throughput tradeoff and adapt** efficiently.
- RLNC **completes tasks quickly** and **releases resources** for the remaining slices.

Main Results

- Coded slices consistently result in **lower in-order delivery delay** and **completion time** with fewer allotted channels.
- RLNC achieves **URLLC requirements** with smaller number of channels.
- Having **at least one RLNC slice improves max throughput** by releasing more channels for SR-ARQ slices.
- Can employ a **mixed and dynamic slicing scheme** with dynamic reallocation.
- **Coding in at least one slice benefit the whole network!**

By viewing different applications of sustainable cities as different slices, strategically coding slices helps reach a net zero footprint by minimizing resource use and maintaining functionality.

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