# Code Design in Joint MAC Scheduling and Wireless Network Coding

Raheleh Niati
Systems and Computer Engineering Dept., Carleton University, Ottawa, Canada
Supervisors: Amir H. Banihashemi, and Thomas Kunz

## Introduction

Advantages of Network Coding:

- Increased throughput
- Robustness to packet losses and link failures
- Added security

**Wireless Network Coding**

- Significant gains through theoretical studies in multi-hop wireless networks
- Early results and code design schemes developed for wired networks

**Main Idea:** Designing wireless network codes using wired techniques. Not directly applicable because:

- Broadcast medium
- Interference

**Background**

Studying the existing wireless network code design techniques using wired network coding methods.

**Our Contributions**

1. Providing the necessary and sufficient conditions to have a capacity achieving solution for wireless networks.
2. Presenting a counterexample to show the insufficiency of conditions by previous studies.

**Figure 1. Wireless Butterfly Network**

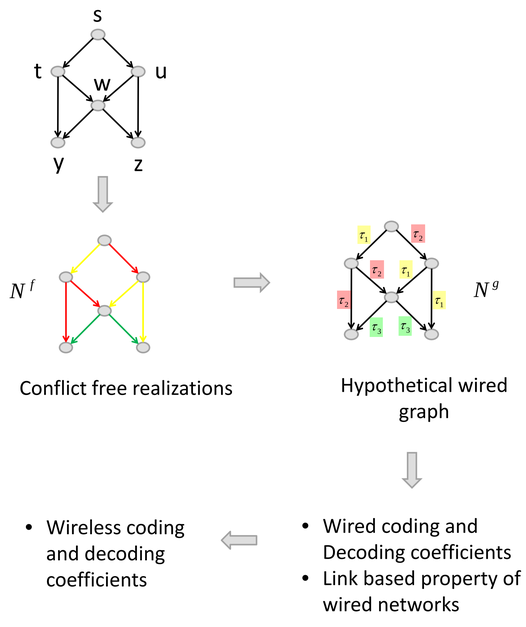
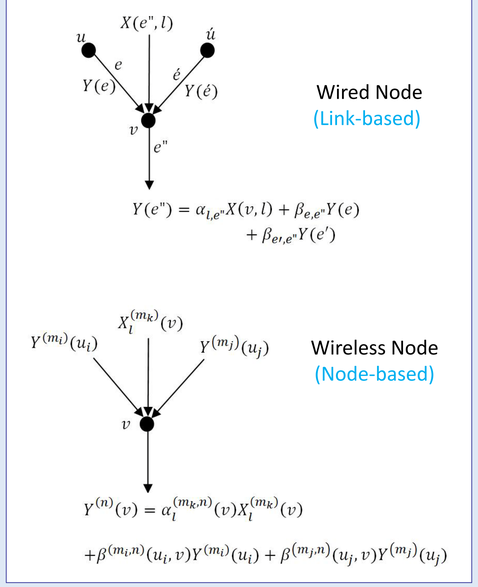



**Figure 2. Comparing wireless and wired nodes**




## Code Design

Wireless codes are derived from wired codes designed for $N^g$ therefore:

Wireless nodes should perform the same encoding and decoding operations as predetermined for $N^g$

**Necessary and Sufficient Mapping Conditions**

Two steps for a perfect mapping between wired codes and wireless codes:

1. Mapping between coding and decoding coefficients
2. Preserving the link-based property of $N^g$ in $N^f$ (Figure 2 compares the link-based and node-based property of wired and wireless networks).

**Counterexample**

The necessity of preserving the link-based property is shown with a counterexample in Figure 3. Result of LP optimization of wired counterpart graph of the example has non-equal time fractions.

**Proposed Solution**

Using repetitions of time fractions as a tool to preserve link-based property in wireless codes. Otherwise wireless graph may not achieve the same max flow as the wired graph.

## Methodology

Joint design of MAC scheduling and Network Coding

**MAC Scheduling**

- Dividing wireless transmissions into a number of interference free groups.
- Determining all of the network realizations is NP-hard ➔ heuristics.

**Hypothetical Wired Graph $N^g$**

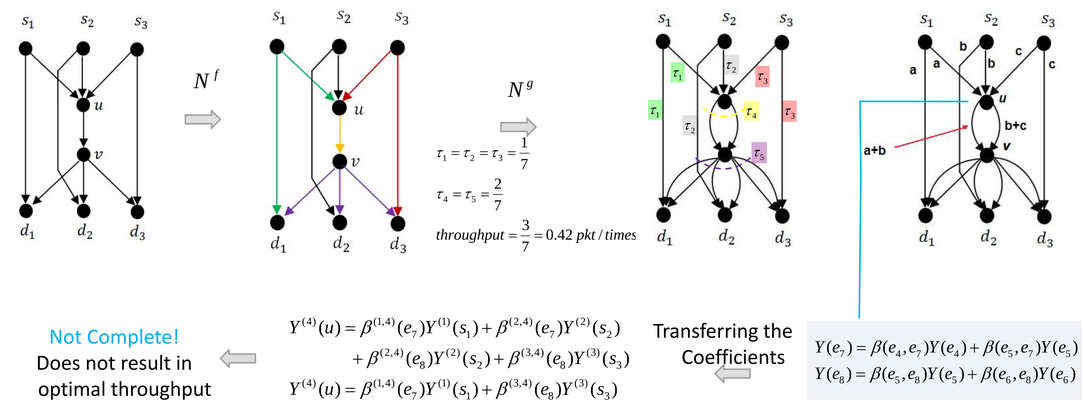
- Each network realization is active during a time fraction of wireless network's periodic timeslot.
- Time fractions are unknown.
- Values of time fractions are determined by assigning them as link capacities of a wired counterpart graph.
- Min Cut- Max Flow theorem

**Network Code Design**

- Set of network realizations ( $N^f$ ), and $N^g$ have the same cut values
- Designing codes for $N^g$ can work for $N^f$

Figure 1 shows the procedure for a butterfly network.

**Figure 3. Wireless Network Example**




Not Complete!
Does not result in optimal throughput

$$Y^{(4)}(u) = \beta^{(1,4)}(e_7)Y^{(1)}(s_1) + \beta^{(2,4)}(e_7)Y^{(2)}(s_2) + \beta^{(2,4)}(e_8)Y^{(2)}(s_2) + \beta^{(3,4)}(e_8)Y^{(3)}(s_3)$$
$$Y^{(4)}(u) = \beta^{(1,4)}(e_7)Y^{(1)}(s_1) + \beta^{(3,4)}(e_8)Y^{(3)}(s_3)$$

Transferring the Coefficients

$$Y(e_7) = \beta(e_4,e_7)Y(e_4) + \beta(e_5,e_7)Y(e_5)$$
$$Y(e_8) = \beta(e_5,e_8)Y(e_5) + \beta(e_6,e_8)Y(e_6)$$

Transferring coefficients and link-based property

$$Y_1^{(4)}(u) = \beta^{(1,4)}(e_7)Y^{(1)}(s_1) + \beta^{(2,4)}(e_7)Y^{(2)}(s_2)$$
$$Y_2^{(4)}(u) = \beta^{(2,4)}(e_8)Y^{(2)}(s_1) + \beta^{(3,4)}(e_8)Y^{(3)}(s_3)$$

Scheduling and network coding solution

| Timeslot | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Schedule | $s_1\vec{b}_1u$ | $s_2\vec{b}_2u$ | $s_3\vec{b}_3u$ | $ub_1 \oplus b_2v$ |
| Timeslot | 5 | 6 | 7 | - |
| Schedule | $v(b_1 \oplus \vec{b}_2)D$ | $u(b_2 \oplus \vec{b}_3)v$ | $u(b_2 \oplus \vec{b}_3)D$ | - |

## Results and Conclusions

- Studying wireless networks with non-equal time fractions showed the necessity of preserving link-based property in wireless codes.
- Link-based property is preserved using repetitions of bigger time fractions in one schedule period of wireless network.
- **Theorem:** The equivalent wired graph of a wireless graph will have parallel edges with different coding combinations, if and only if solving an LP optimization problem (of interest) for the set of conflict-free realizations of the wireless graph results in non-equal time fractions.

**Further Information:**

For a downloadable version of this poster please refer to: http://www.sce.carleton.ca/~rniati/

Email:
rniati@sce.carleton.ca