Maximum Weight Clique Search for Instantly Decodable Network Coding based-Broadcast

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Introduction
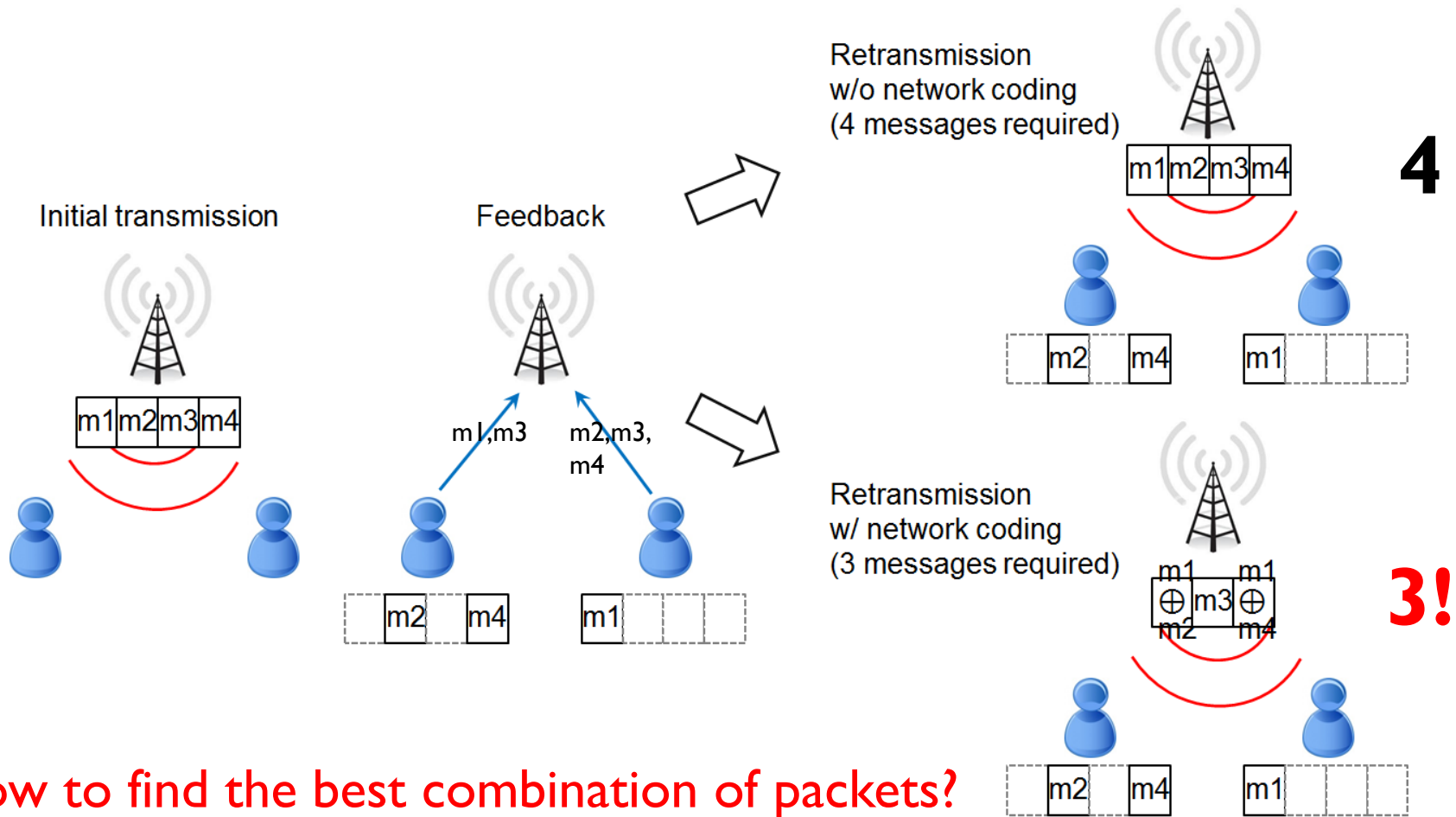
▸ Scenario

  ▸ Reliable broadcast
  ▸ Strict deadline
  ▸ Limited resource

▸ Without Feedback

  ▸ Powerful channel coding
  ▸ Fountain coding-based scheme

▸ With Feedback

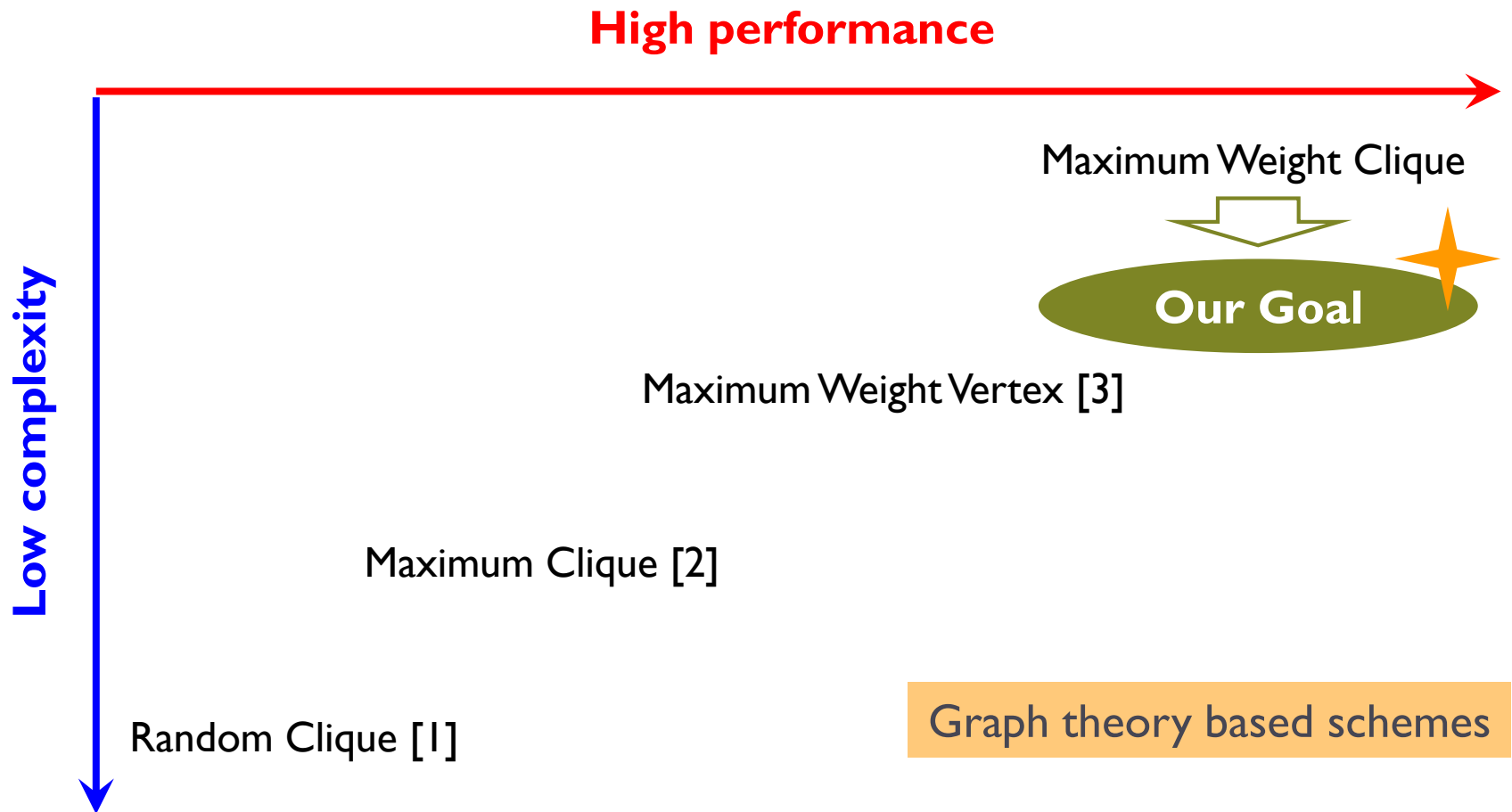 ▸ Traditional retransmission
  ▸ Network coding-based scheme

Local advertisement
Software update
Video streaming
File download
…
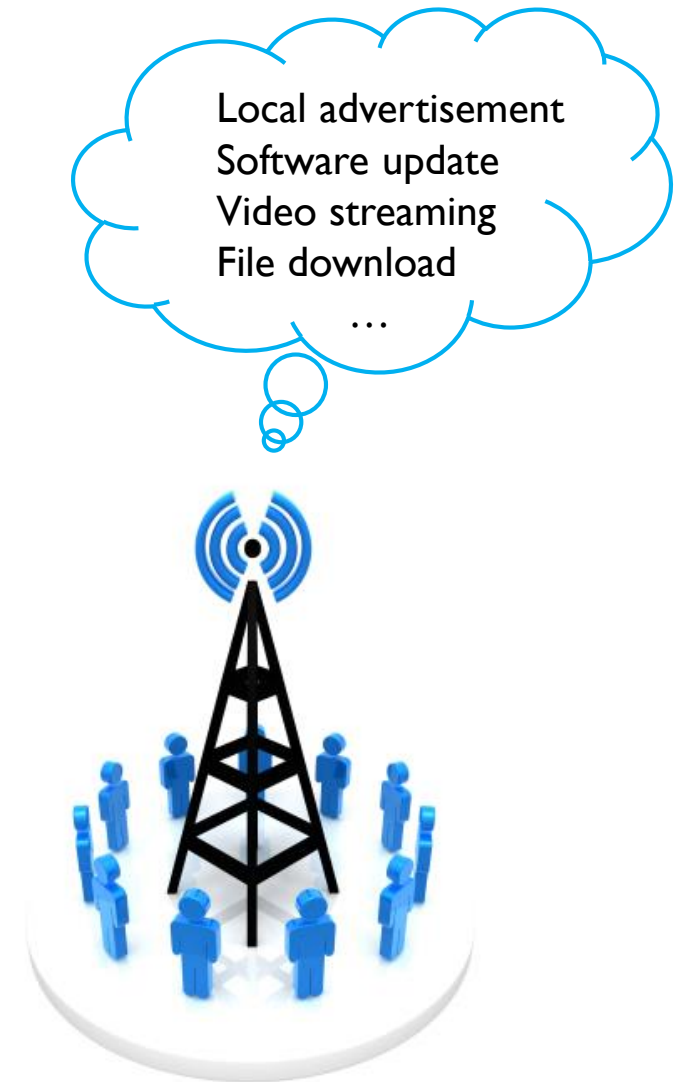
Reliable Broadcast with Feedback

▸ Resource Use Comparison

  ▸ With network coding vs. without network coding

Initial transmission

m1 m2 m3 m4

Feedback

m1,m3   m2,m3, m4

m2   m4   m1

Retransmission w/o network coding (4 messages required)

m1 m2 m3 m4

4

m2   m4   m1

Retransmission w/ network coding (3 messages required)

m1 ⊕ m3 ⊕ m1
m2   m4

3!

m2   m4   m1

How to find the best combination of packets?

Related Works of NC-based Broadcast

High performance

Low complexity

Maximum Weight Clique

Our Goal

Maximum Weight Vertex [3]

Maximum Clique [2]

Graph theory based schemes

Random Clique [1]

[1] S. Sorour and S. Valaee, "Adaptive network coded retransmission scheme for wireless multicast," IEEE ISIT, June 2009.

[2] A. Le, A. S. Tehrani, A. G. Dimakis, and A. Markopoulou, "Instantly Decodable Network Codes for Real-Time Applications," in Proc. Workshop on Network Coding, Theory and Applications (NETCOD), 2013.

[3] S. Sorour and S. Valaee, "On minimizing broadcast completion delay for instantly decodable network coding," IEEE International Conference on Communications (ICC '10), May 2010.

MCS for IDNC-based Broadcast
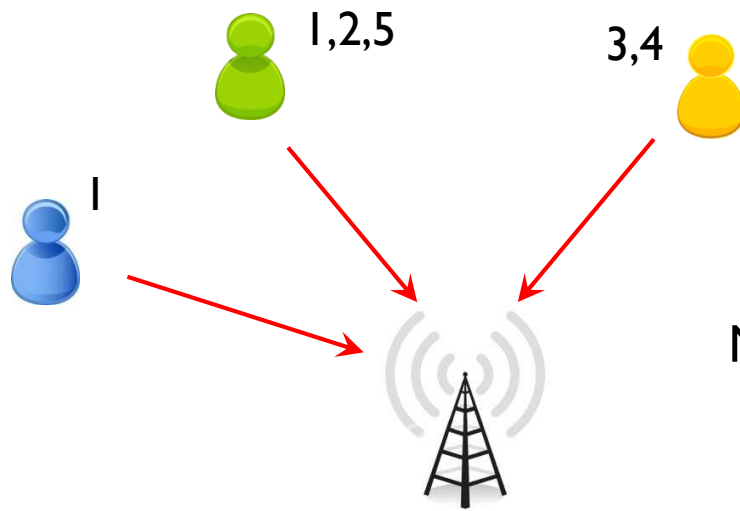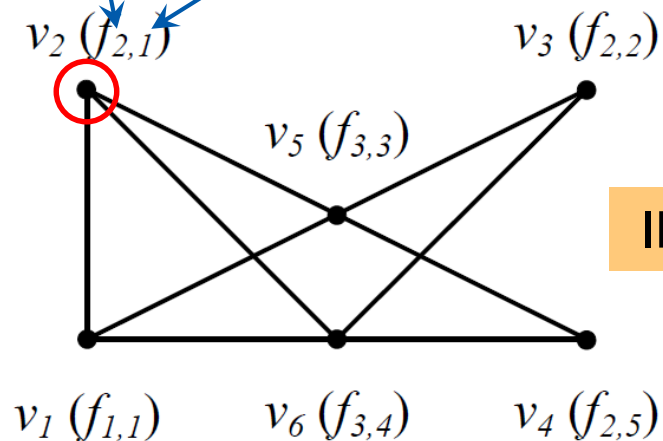
▶ Maximum Clique Search – simple but not optimal

Feedback matrix

$$F = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 1 \\ 0 & 0 & 1 & 1 & 0 \end{bmatrix}$$
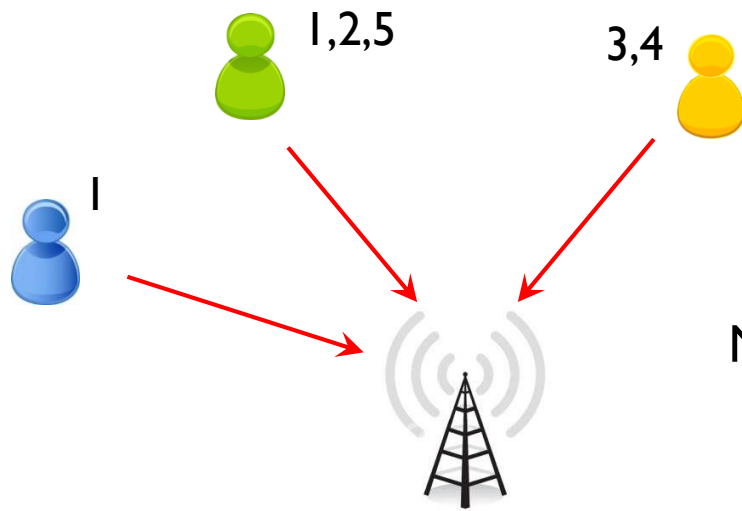
Node index   Packet index

IDNC graph

$v_2\ (f_{2,1})$ $v_3\ (f_{2,2})$

$v_5\ (f_{3,3})$

$v_1\ (f_{1,1})$ $v_6\ (f_{3,4})$ $v_4\ (f_{2,5})$
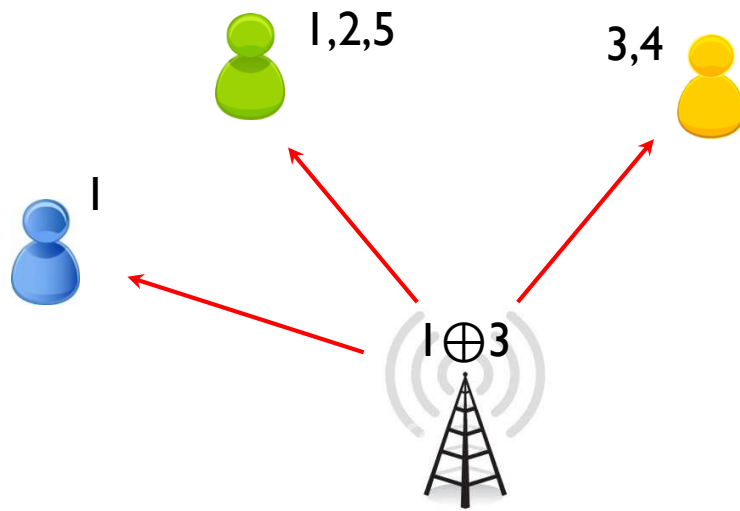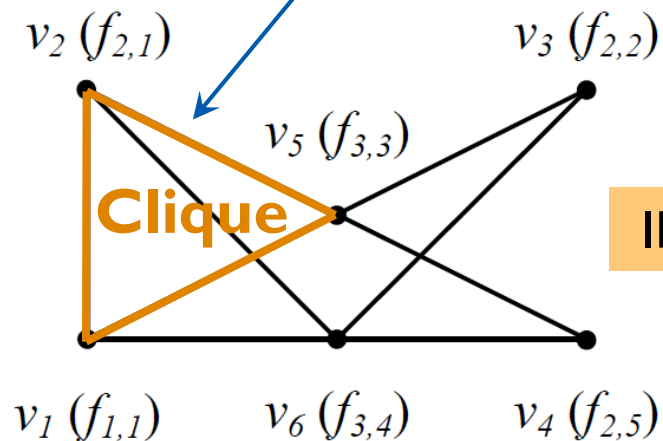
MCS for IDNC-based Broadcast

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MCS for IDNC-based Broadcast

▸ Maximum Clique Search – simple but not optimal

1,2,5

3,4

1

$1 \oplus 3$

Instantly Decodable
Packet Combination

$$F = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 1 \\ 0 & 0 & 1 & 1 & 0 \end{bmatrix}$$

Feedback matrix

$v_2\,(f_{2,1})$ $v_3\,(f_{2,2})$
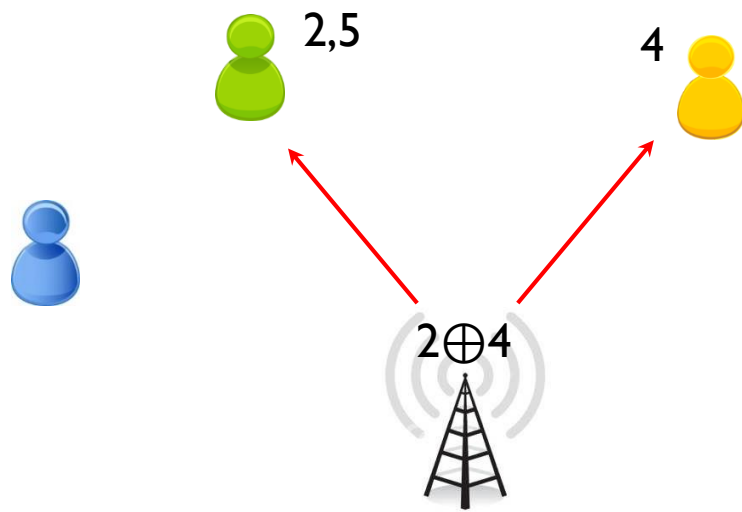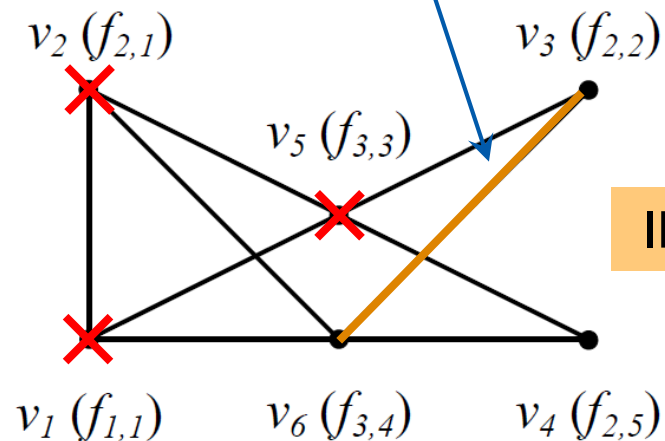
$v_5\,(f_{3,3})$

Clique

$v_1\,(f_{1,1})$ $v_6\,(f_{3,4})$ $v_4\,(f_{2,5})$

IDNC graph

MCS for IDNC-based Broadcast

▸ Maximum Clique Search – simple but not optimal

2,5

4

$2 \oplus 4$

Instantly Decodable
Packet Combination

$$F = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 1 \\ 0 & 0 & 1 & 1 & 0 \end{bmatrix}$$
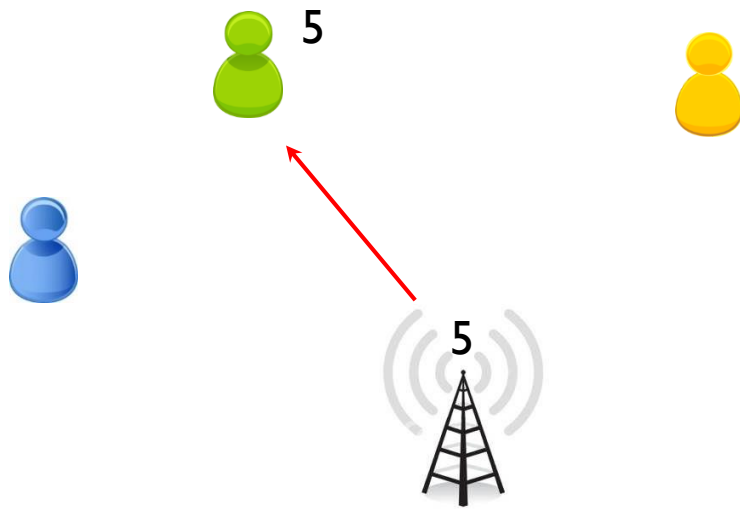
Feedback matrix

$v_2\ (f_{2,1})$

$v_3\ (f_{2,2})$

$v_5\ (f_{3,3})$

IDNC graph

$v_1\ (f_{1,1})$

$v_6\ (f_{3,4})$

$v_4\ (f_{2,5})$

MCS for IDNC-based Broadcast

▸ Maximum Clique Search – simple but not optimal

Instantly Decodable
Packet Combination

IDNC graph

$$F = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 1 \\ 0 & 0 & 1 & 1 & 0 \end{bmatrix}$$

Feedback matrix

$v_2 (f_{2,1})$ $v_3 (f_{2,2})$
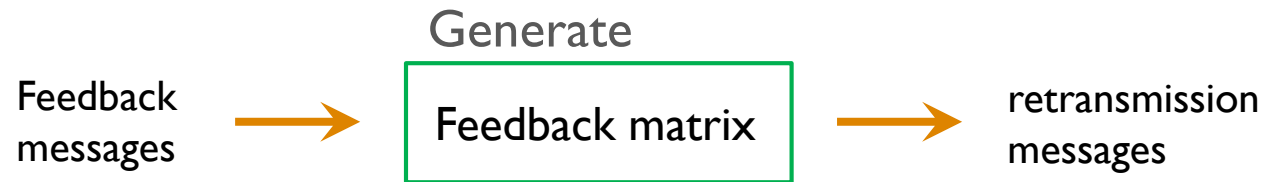
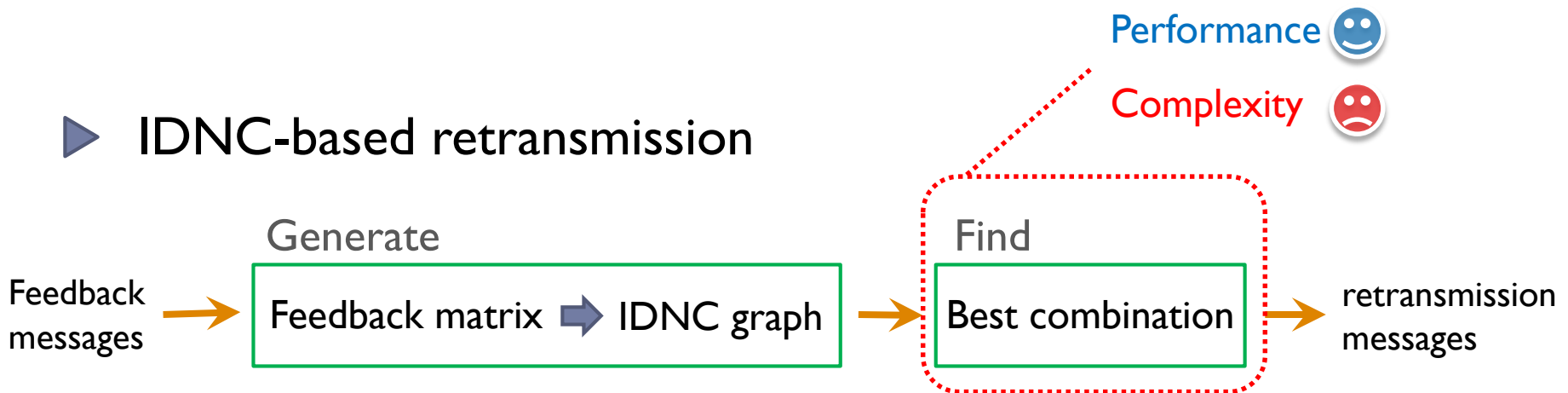$v_5 (f_{3,3})$

$v_1 (f_{1,1})$ $v_6 (f_{3,4})$ $v_4 (f_{2,5})$
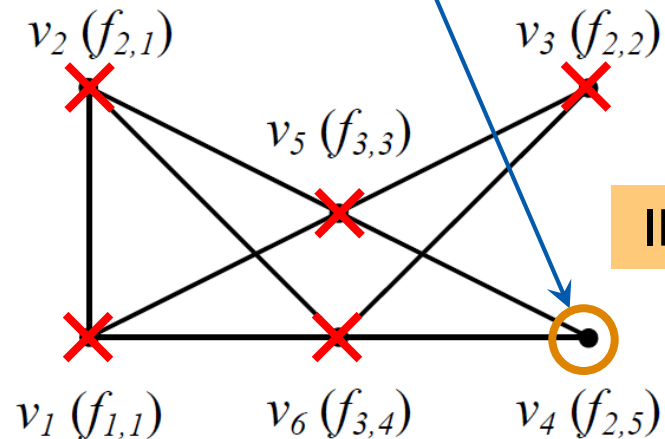
IDNC-based Broadcast

▷ **Traditional retransmission**

Feedback messages → Generate [Feedback matrix] → retransmission messages

▷ **IDNC-based retransmission**

Performance 🙂
Complexity 🙁

Feedback messages → Generate [Feedback matrix ➡ IDNC graph] → Find [Best combination] → retransmission messages

MWCS for IDNC-based Broadcast

▸ Maximum Weight Clique Search – optimal but high complexity

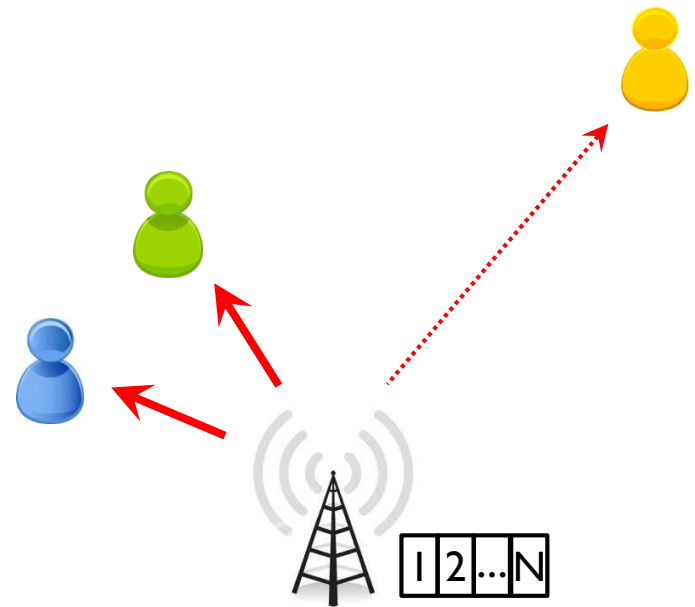 ▸ How to reduce the mean completion time?

Mean Completion Time **(Motivation)**

$$MCT = \frac{N}{1 - \max_{i \in \mathcal{M}} \{p_i\}}$$

N : # of packets (sufficiently large)
M : # of users
p_i : packet loss probability of i-th user

[4] D. Nguyen, T. Tran, T. Nguyen, and B. Bose, "Wireless broadcast using network coding," IEEE Transactions on Vehicular Technology, vol. 58, no. 2, pp. 914925, Feb. 2009.

MWCS for IDNC-based Broadcast

▶ Maximum Weight Clique Search – optimal but high complexity

   ▶ The weight for user with the worst channel condition should be increased
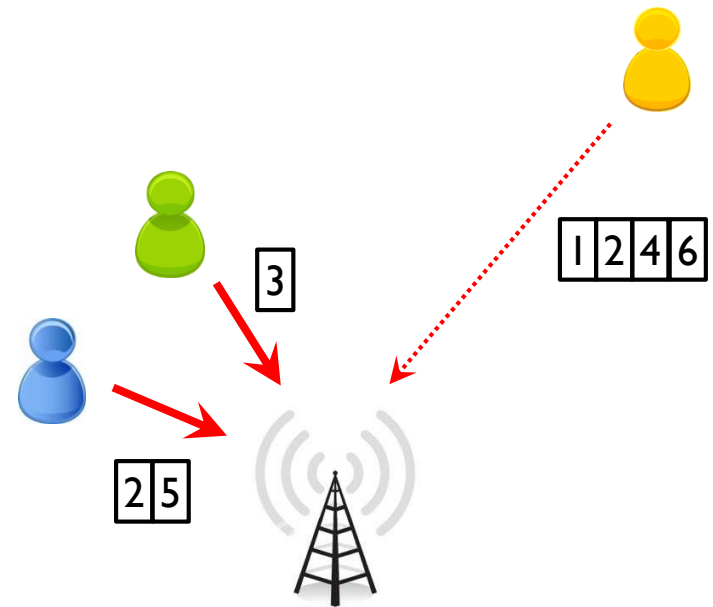
Weight for vertex v_n

$$w(v_n) = \frac{W_{user(v_n)}}{1 - p_{user(v_n)}}$$

$w(v_n)$: weight of vertex v_n

$user(v_n)$: user corresponding to vertex v_n
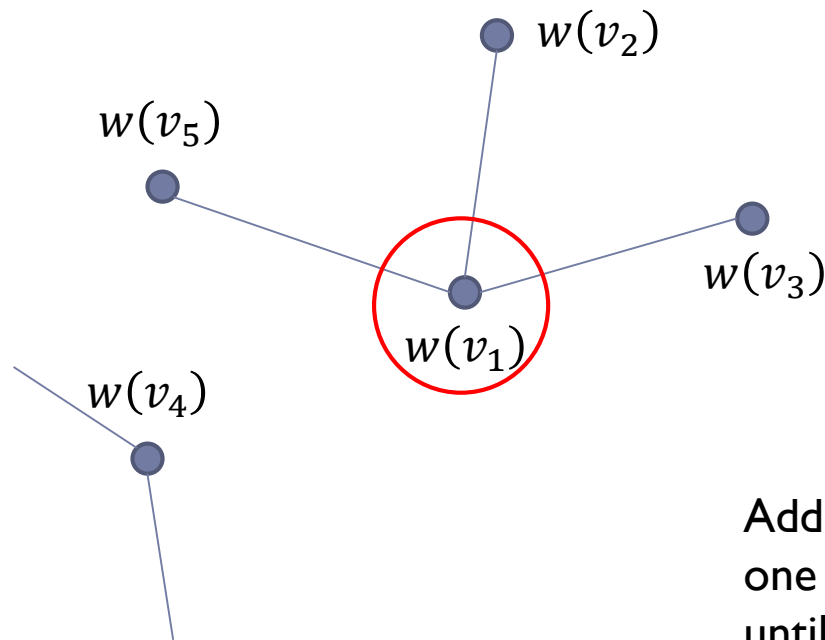
$W_{user(v_n)}$: # of packets for $user(v_n)$

$p_{user(v_n)}$: packet loss probability of $user(v_n)$

3

1 2 4 6

2 5

Now, how to find the maximum weight clique?

MWVS for IDNC-based Broadcast

▸ Maximum Weight Vertex Search – reduced complexity but not optimal

Adding a maximum weight vertex one by one which forms a clique until there is no candidate

[3] S. Sorour and S. Valaee, "On minimizing broadcast completion delay for instantly decodable network coding," IEEE International Conference on Communications (ICC '10), May 2010.

MWCS for IDNC-based Broadcast

▸ Maximum Weight Clique Search – optimal but high complexity
  ▸ How to reduce the complexity?
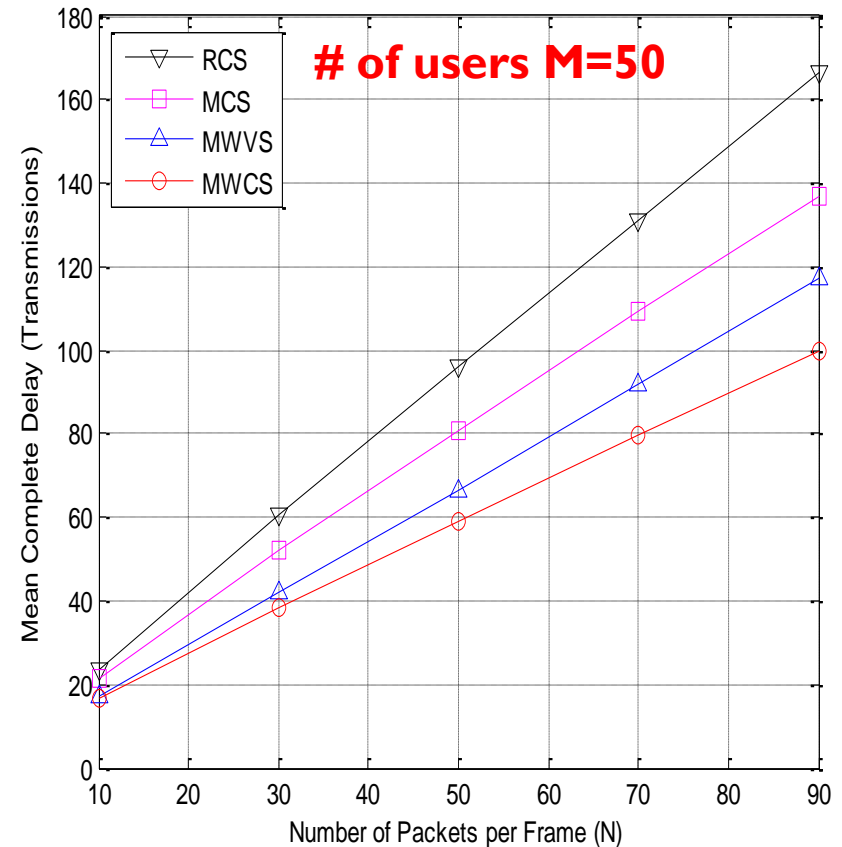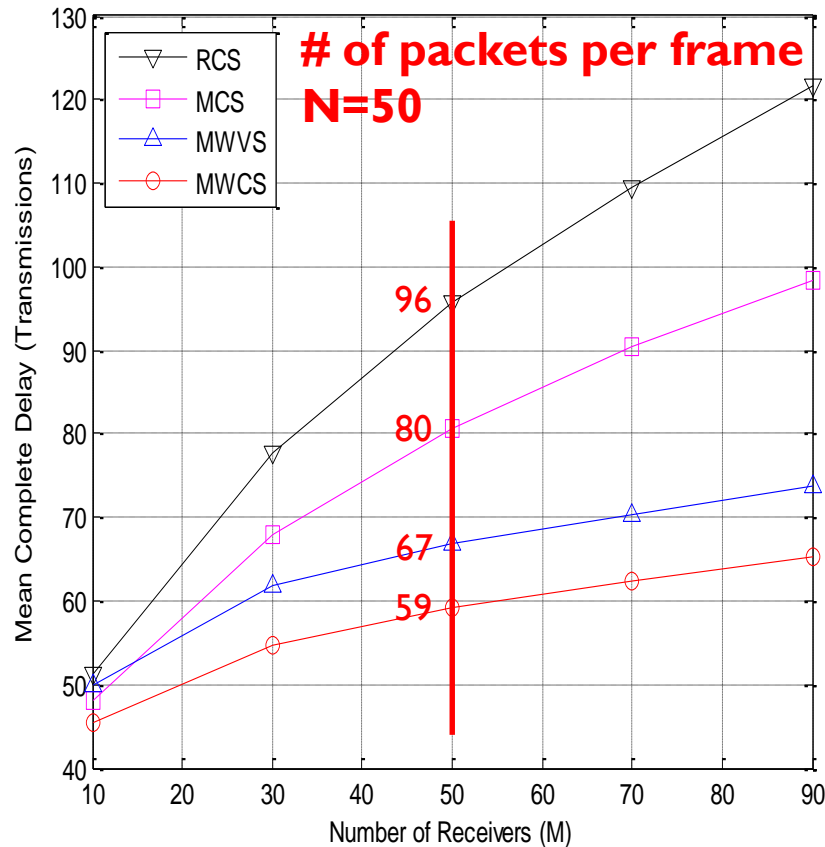   ▸ Branch-and-Bound technique

Proposed
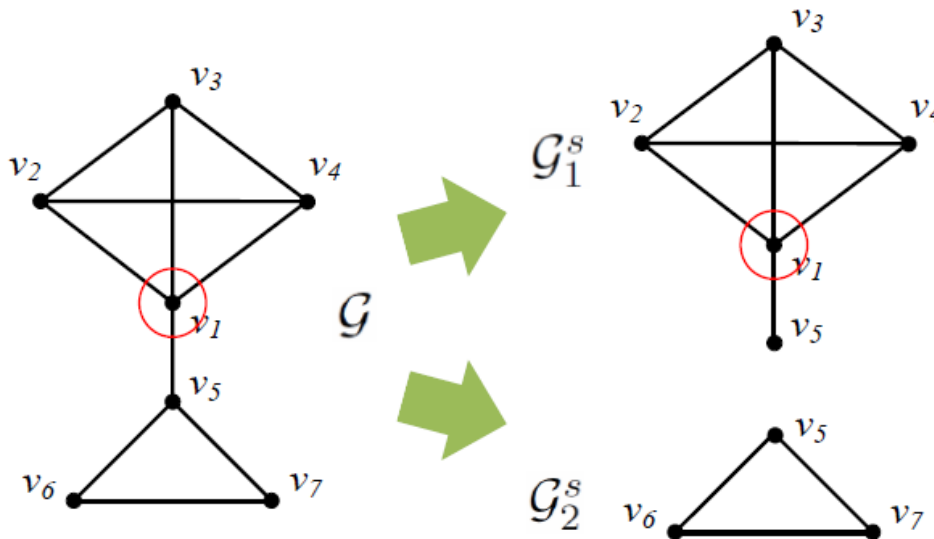
Weight sum of the founded clique: 5

Weight sum for all vertices : 4

Do not search cliques in this subset

Performance Comparison

Mean Completion Delay : # of retransmission until all users receive all packets
Packet loss probability : p=0~0.5

Conclusions

Thank You!
Questions?

▸ The proposed scheme

  ▸ performs the maximum weight clique selection using the **branch-and-bound technique**.

  ▸ has the **best performance** compared to other earlier published algorithms.

  ▸ can be applied to small size network effectively.