Reliable Videos Broadcast with Network Coding and Coordinated Multiple Access Points

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Agenda

- Introduction
  - Motivation
- Robust video streaming
  - Formulation
  - Proposed method
- Evaluations
- Conclusions

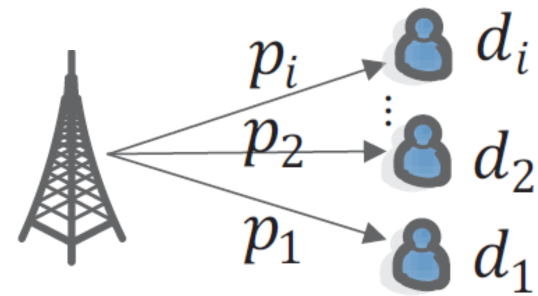
Introduction

- Advances in technology
  - Smartphones and tablets
  - Internet is accessible everywhere
  - Video streaming is used widely and frequently

- Video streaming is a dominant form of traffic on the Internet
  - YouTube and Netflix:
  - Produce 20-30% of the web traffic on the Internet

Introduction

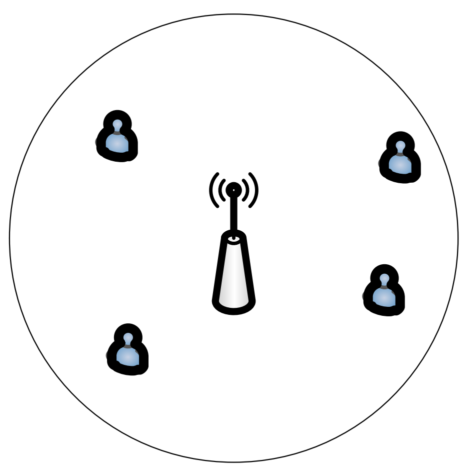
- A challenge in multicasting
  - Different link conditions
  - Loss rate, noise

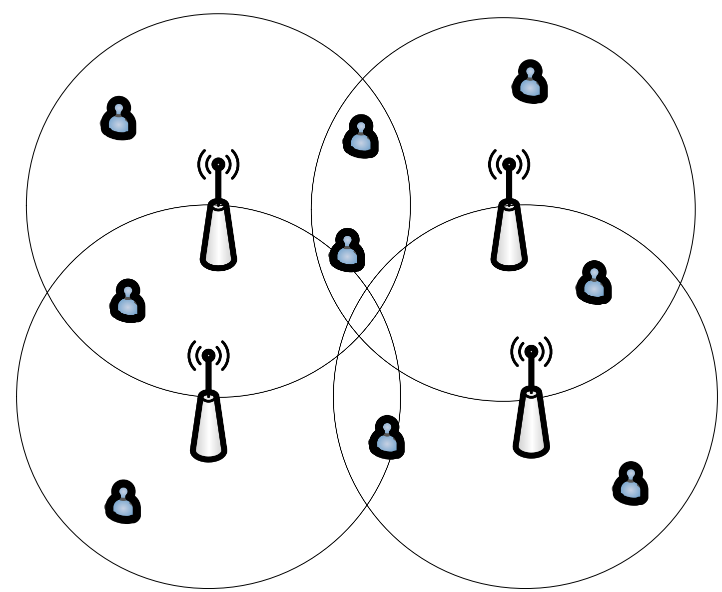


- Provide resilience
  - ARQ
  - Erasure codes
  - Hybrid-ARQ
  - Fountain codes (rateless codes)

Introduction

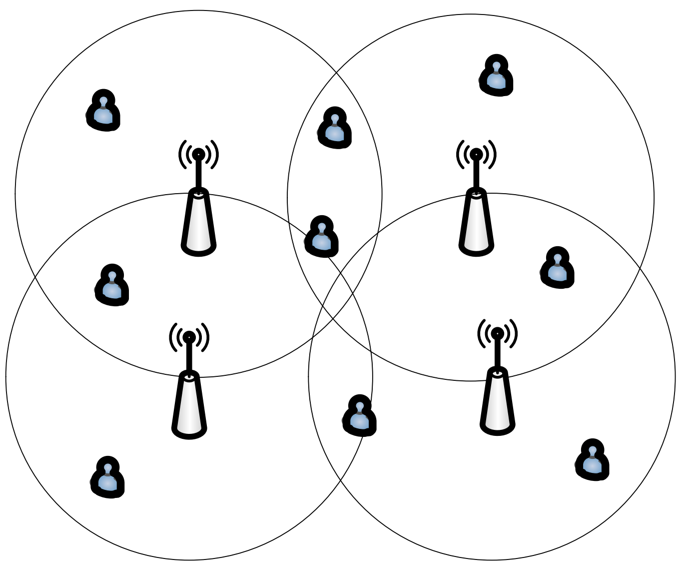
- Existing research on reliable video multicast
  - Most of the existing methods: single access point (AP)
  - Few research: multiple access point



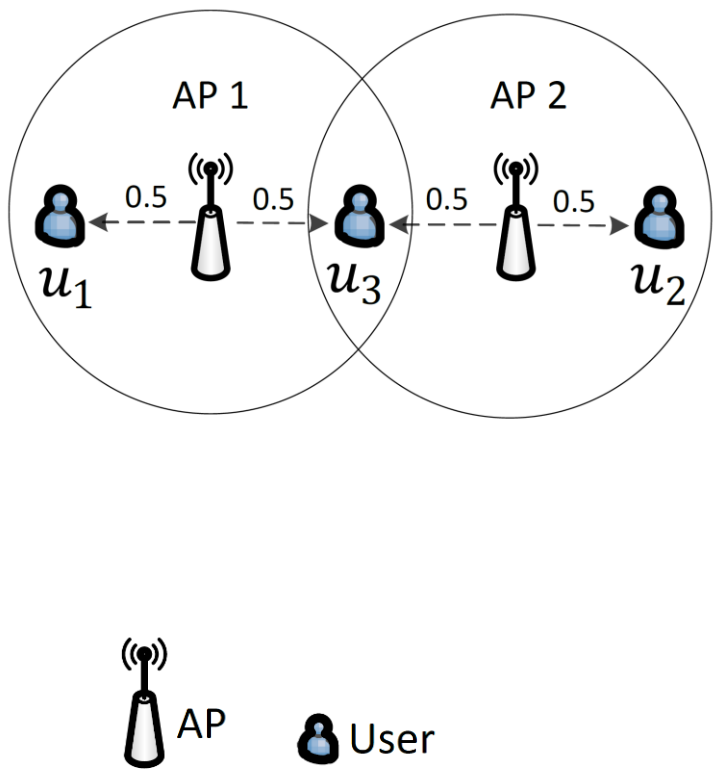


Introduction

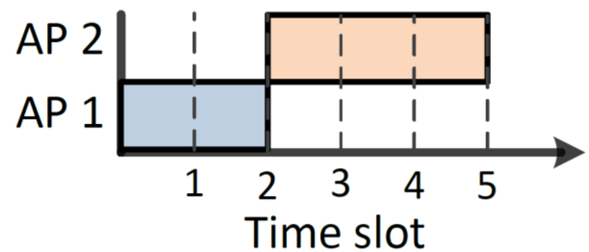
- Multiple access point
  - Users at cell boundaries might experience low packet delivery rates
  - Multiple APs help to serve each user with different APs and enhance the performance of the video streaming



Motivation

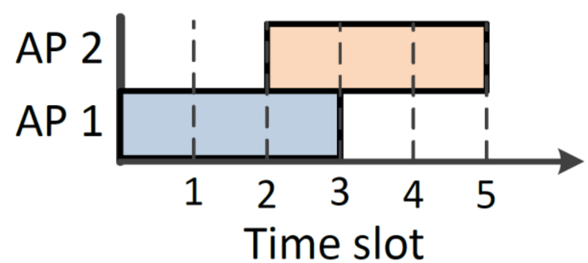


- Disjoint transmissions



User	Gain
u_1	10
u_2	15
u_3	25

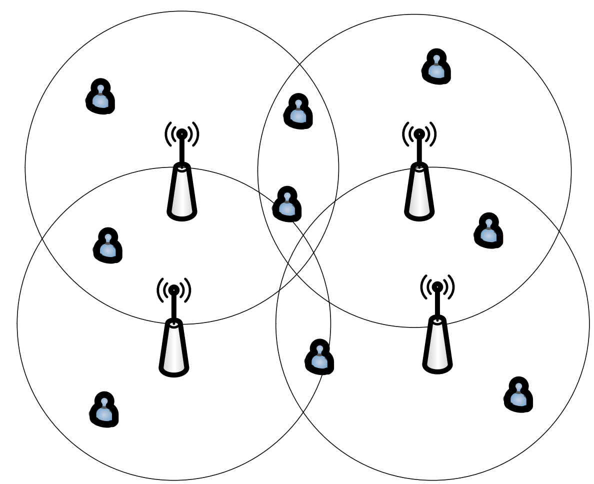
- Concurrent transmissions



User	Gain
u_1	15
u_2	15
u_3	20

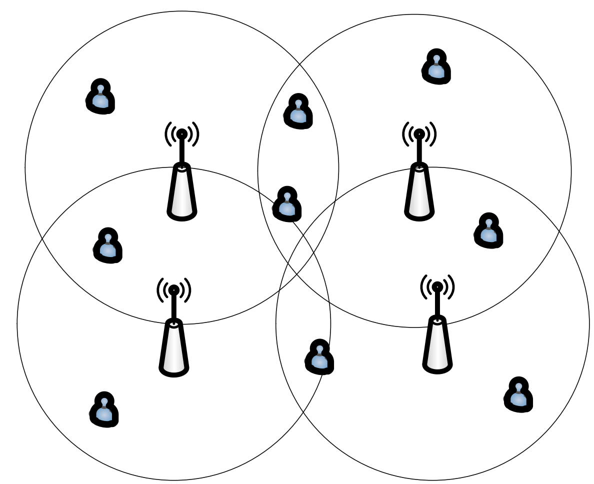
Setting

- Video servers forward a video stream to a set of neighboring APs
- APs and the video server are connected by wired links
  - They are not the bottleneck
- A set of wireless users
- Error-prone wireless links
- No feedback mechanism
  - Costly in multicast applications
- Each AP node has a circular coverage area.
  - The coverage area might overlap
  - Interference



Setting

- Objective
  - Maximize the expected number of packets that are received by the users
- Constraint
  - Providing a fair video multicast
- Approach
  - Allowing systematic overlapped transmission of the AP nodes
  - Using random linear network coding



Network Coding

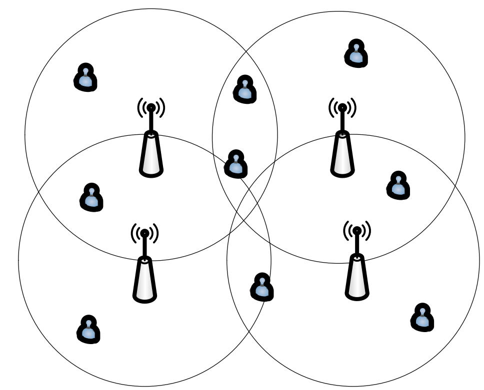
- Random linear network coding
  - Linear combinations of the packets
  - Gaussian elimination

$$\begin{cases} q_1 = \alpha_{1,1}p_1 + \alpha_{1,2}p_2 + \alpha_{1,3}p_3 \\ q_2 = \alpha_{2,1}p_1 + \alpha_{2,2}p_2 + \alpha_{2,3}p_3 \\ \vdots \\ q_\mathrm{n} = \alpha_{n,1}p_1 + \alpha_{n,2}p_2 + \alpha_{n,3}p_3 \end{cases}$$

- Applications of network coding
  - Reliable transmissions
  - Throughput/capacity enhancement
    - Distributed storage systems/ Content distribution/ Layered multicast

Scheduling Algorithm

- Number of possible scheduling in the case of *m* APs: $2^m - 1$



- Two-phase scheduling algorithm
  - **Phase 1:** finding the optimal scheduling in the case of disjoint transmissions
  - **Phase 2:** using the result of phase 1 as an initial solution, and trying to enhance the utility by allowing some concurrent transmission

Phase 1: Disjoint Transmissions Scheduling

- Linear programming formulation
  - Without fairness constraint

$$\max \sum_{i \in U} r_i$$

$$s.t \quad \sum_{j \in B} x_j \leq 1$$

$$r_i = \sum_{j \in C(i)} b \cdot x_j (1 - \epsilon_{ji}), \quad \forall i \in U$$

Phase 1: Disjoint Transmissions Scheduling

- Linear programming formulation
  - Considering fairness

$$\max \ y \tag{1}$$

$$s.t \quad \sum_{j \in B} x_j \leq 1 \tag{2}$$

$$r_i = \sum_{j \in C(i)} b \cdot x_j (1 - \epsilon_{ji}), \ \forall i \in U \tag{3}$$

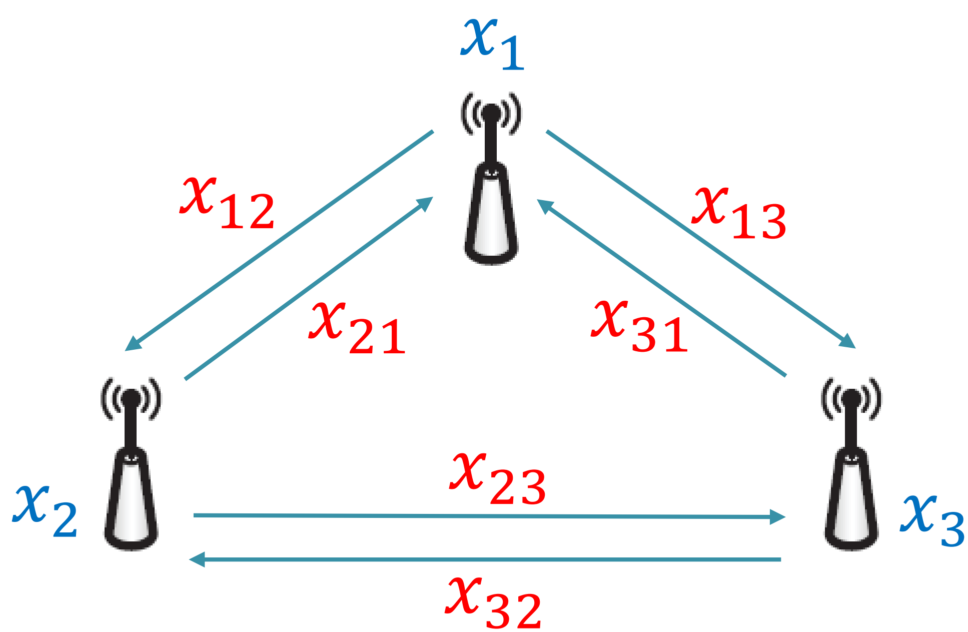
$$y \leq r_i, \quad \forall i \in U \tag{4}$$

Phase 2: Concurrent Transmissions Scheduling

- Using the output of phase 1 as the input of the optimization
- Only permitting 2 interfering APs to concurrently transmit
- Increase time x_j that node AP *j* is scheduled
  - Adding extra x_{kj} portion of time to AP *j*
  - x_{kj} is the fraction of time that is borrowed from AP node *k*

Phase 2: Concurrent Transmissions Scheduling

- Time borrowing



Phase 2: Concurrent Transmissions Scheduling

- Linear programming formulation
  - Without fairness constraint

$$\max \sum_{i \in U} s_i$$

$$s.t \quad \sum_{k \in B} z_{jk} \leq x_j \quad \forall j \in B$$

$$s_i \leq r_i + \sum_{k \notin C(i)} \sum_{\substack{j \in B \\ i \in C(j)}} b \cdot z_{jk}(1 - \epsilon_{ki})$$

$$- \sum_{j \in C(i)} \sum_{\substack{k \in C(i) \\ j \neq k}} b \cdot z_{jk}(1 - \epsilon_{ji}), \quad \forall i \in U$$

Phase 2: Concurrent Transmissions Scheduling

- Linear programming formulation
  - Considering fairness

$$\max \; y \tag{8}$$

$$s.t \quad \sum_{j \in B} z_{kj} \leq x_k \quad \forall k \in B \tag{9}$$

$$s_i \leq r_i + \sum_{k \notin C(i)} \sum_{\substack{j \in B \\ i \in C(j)}} b \cdot z_{kj}(1 - \epsilon_{ji})$$

$$- \sum_{j \in C(i)} \sum_{\substack{k \in C(i) \\ j \neq k}} b \cdot z_{kj}(1 - \epsilon_{ki}), \quad \forall i \in U \tag{10}$$

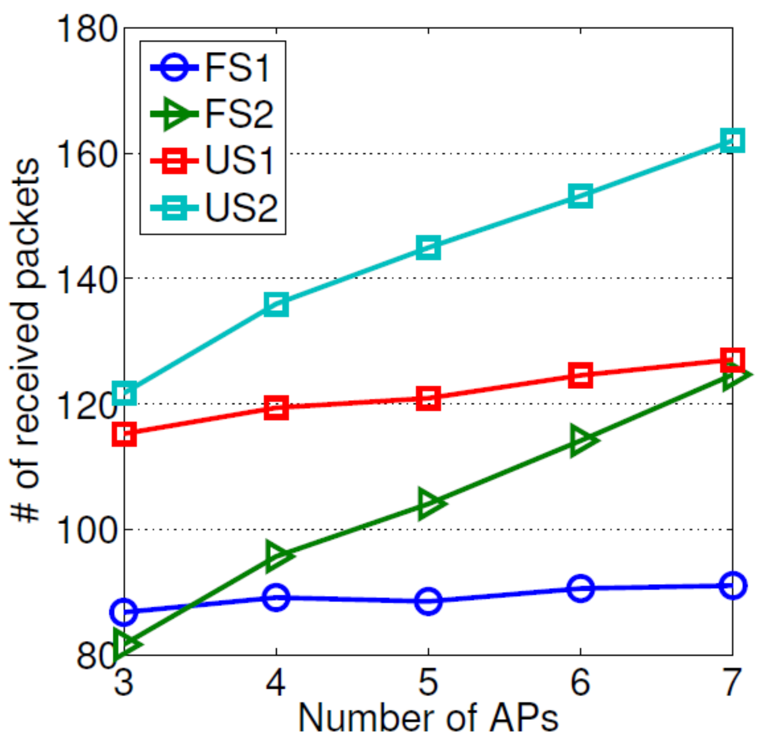
$$y \leq s_i, \quad \forall i \in U \tag{11}$$

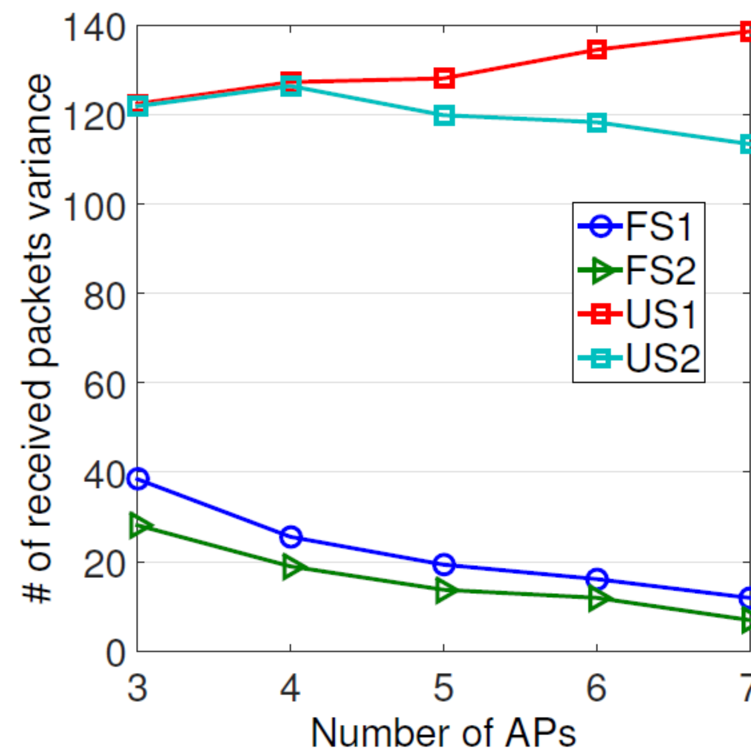
Evaluations

- Simulator in Matlab environment
- Random distribution of the nodes in a 20×20 M square area
- 1000 random topologies
- Successful delivery probability: Rayleigh fading model
- Comparing with non-overlapped transmissions

Evaluations

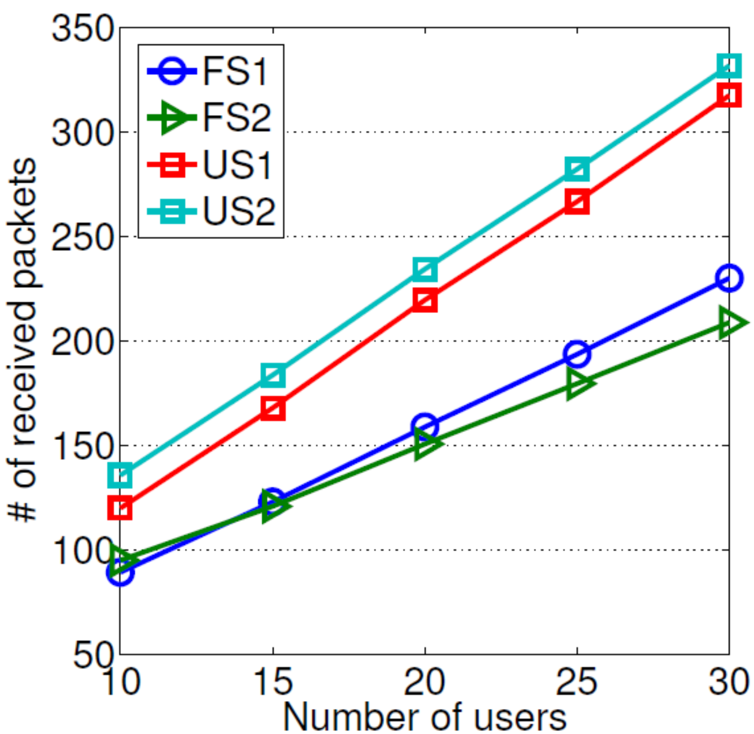
- 10 users

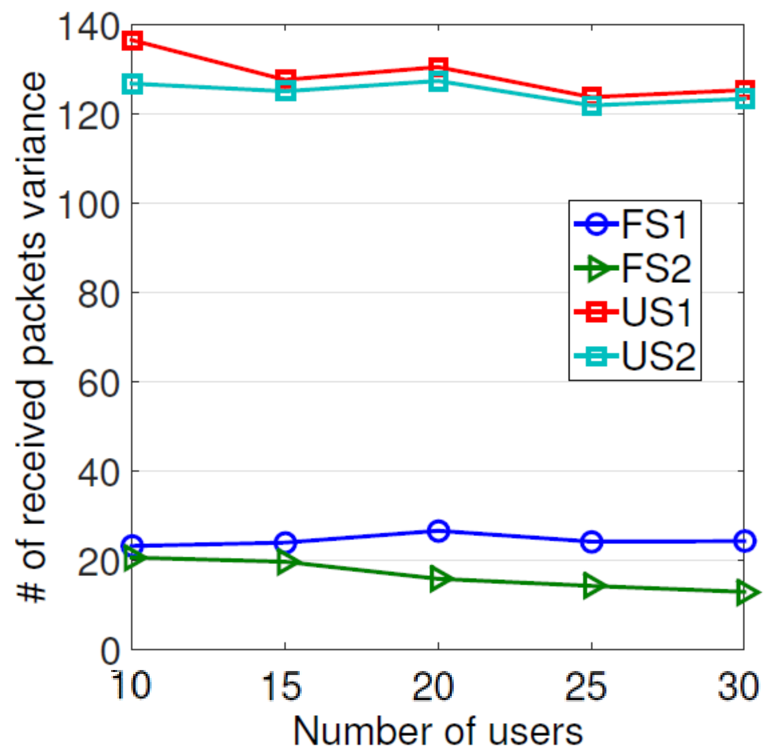




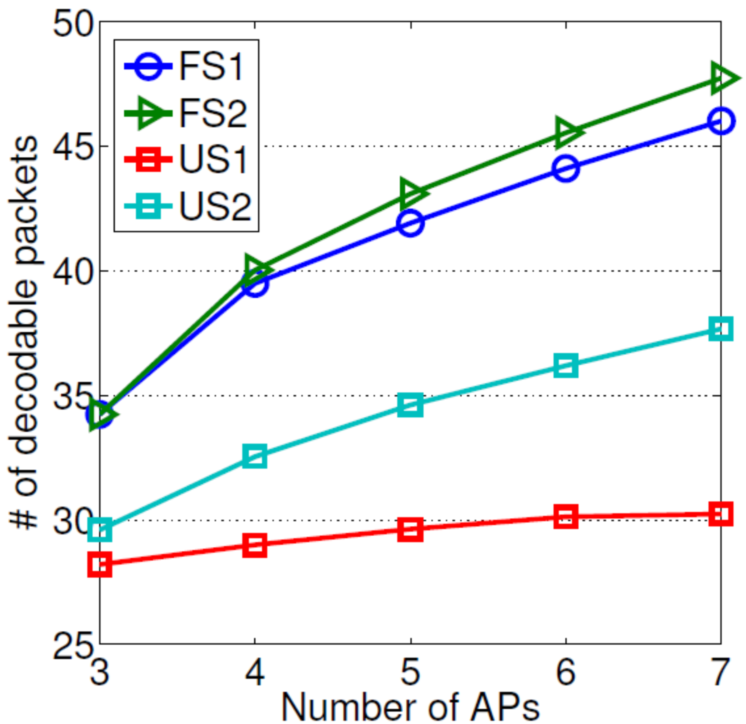
Evaluations

- 4 APs

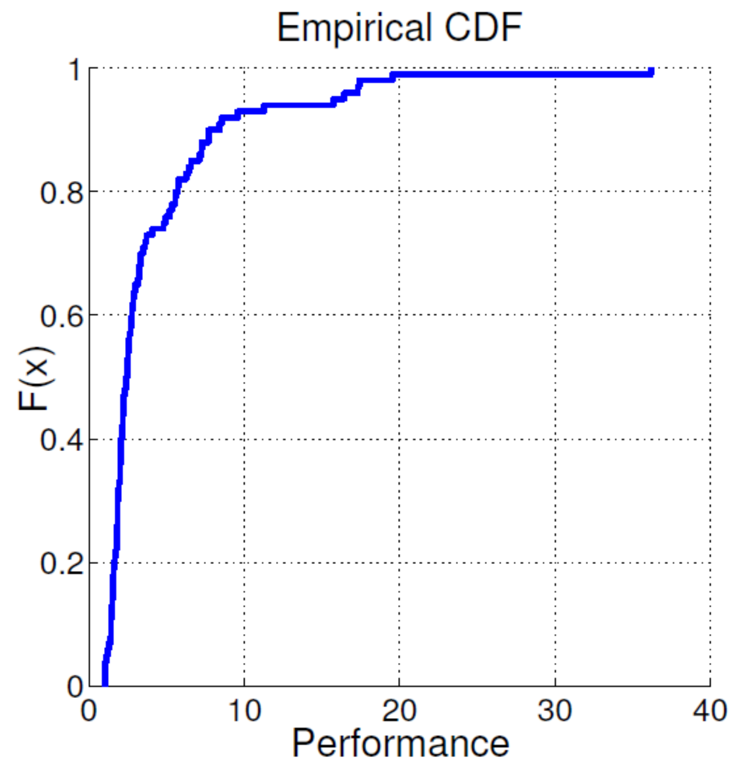




Evaluations



- 10 users



- 4 APs

Conclusion

- Using multiple APs to enhance transmission reliability
- Concurrent transmissions instead of disjoint transmissions
  - Increasing reliability
  - Providing fairness
- Reliable transmissions with network coding

Thank you