# Multimedia Communications
## @CS.NCTU

Lecture 15: Wireless Streaming

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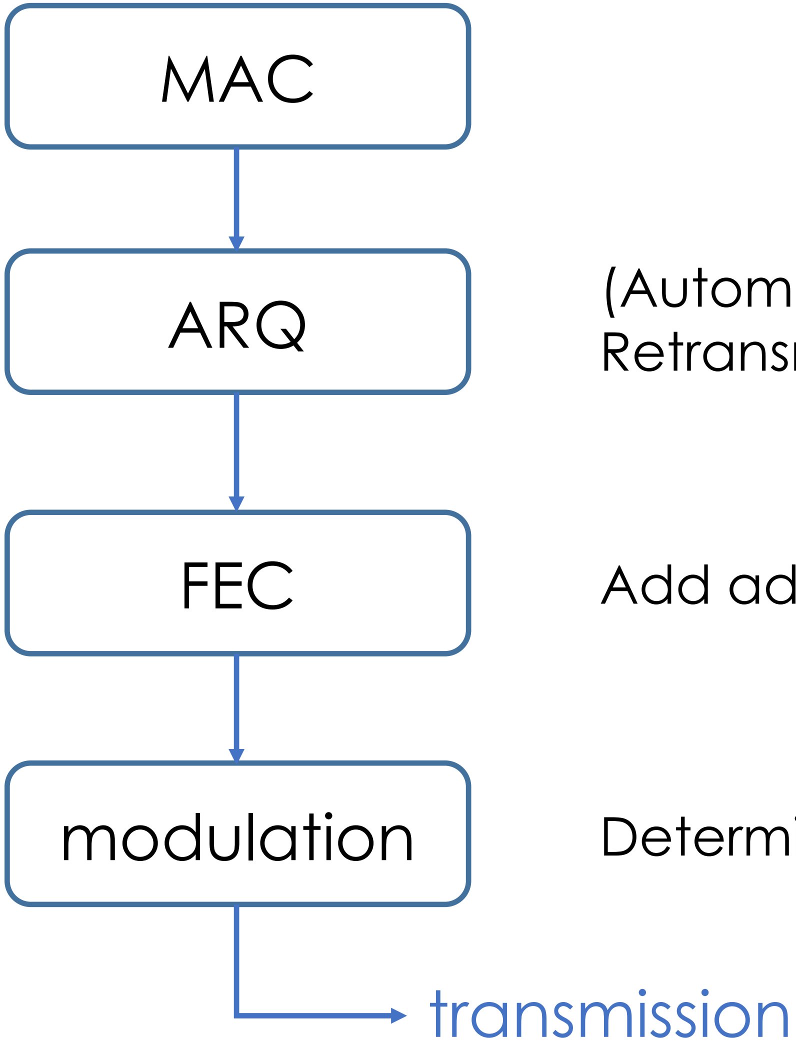
# Unequal Protection

- Wireless channels are noisy
  - Channel coding is required to reduce the number of errors
  - Modulation should be selected properly
- Video compression algorithms
  - leverage layer coding, in which each layer is not equally important
  - are effective against a certain level of errors
- What's unequal protection (UEP)
  - Bits that are required (referred) by others → more important → more protection
  - Bits that are NOT required (referred) by others → less important → less protection

# Technologies for Improving Reliability




(Automatic Repeat reQuest)
Retransmit erroneous/lost packets

Add additional redundancy

Determine modulation order

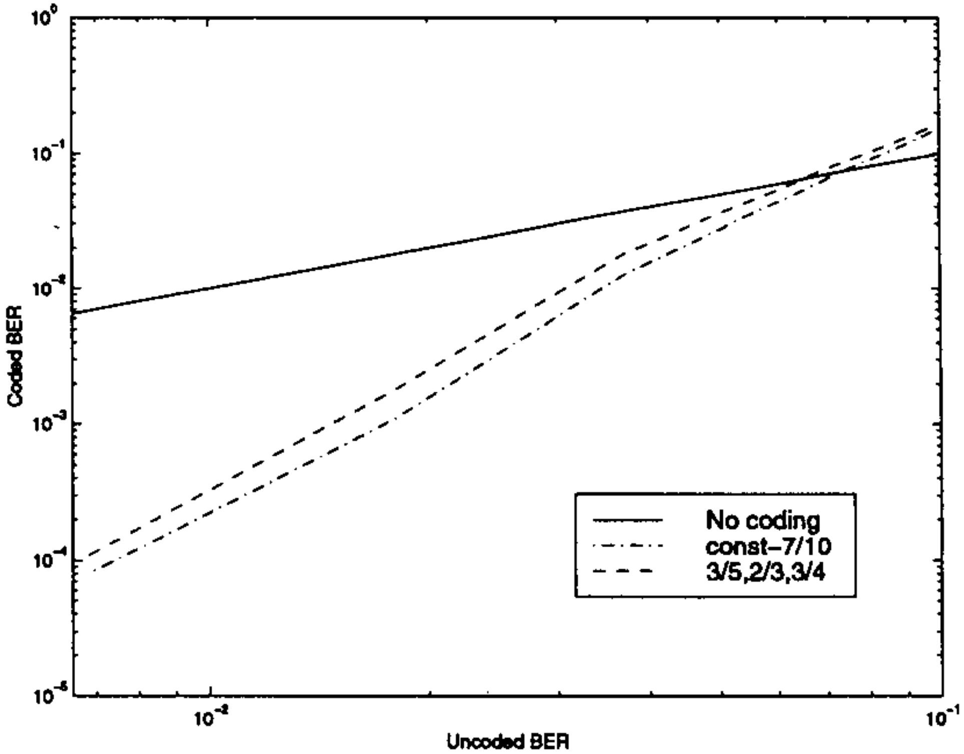
# Content-Aware FEC

- N/R FEC
  - For every N bits of data, add redundancy and send out R bits (R-N bits are for error correction)
  - Smaller N/R → more reliable
- Three classes
  - High priority:  header and stuffing bits
  - Median priority: motion bits
  - Low priority: texture bits
- UEP FEC
  - For example, (3/5, 2/3, 3/4) for (high, med, low) priority
  - 3/5 < 2/3 < 3/4 ← give more bits to important info

M. G. Martini and M. Chiani, "Proportional unequal error protection for MPEG-4 video transmission," ICC 2001

# BER of EEP and UEP

EEP 7/10-code vs. UEP (3/5, 2/3, 3/4) code

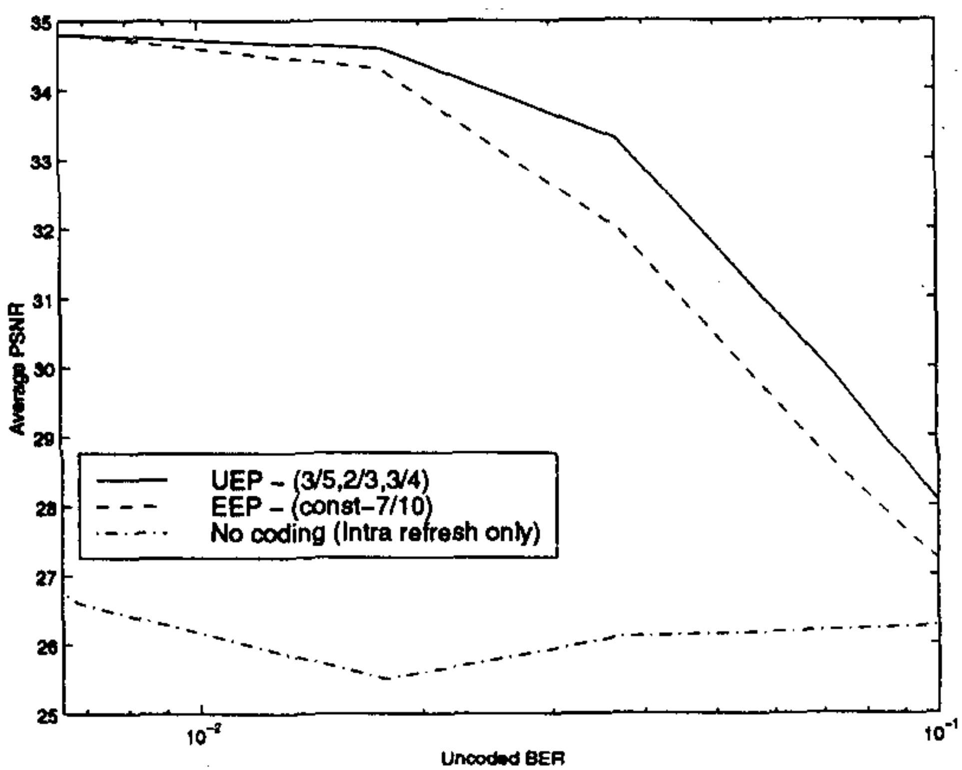



similar amount of data

- Given channel with 10% BER, FEC effectively reduces BER
- EEP and UEP experience similar effective BER

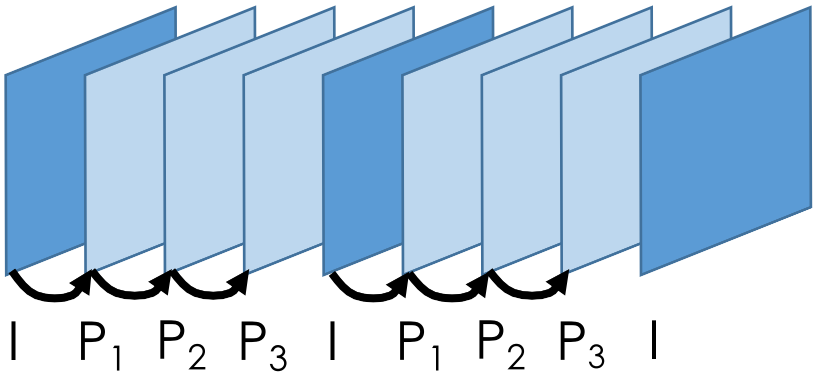
# PSNR of EEP and UEP

- Though EEP and UEP result in similar effectively BER, UEP achieves a higher PSNR

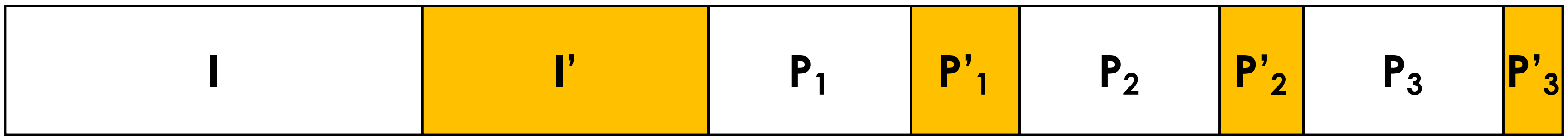


# UEP for Scalable Coding

- I-frame is the reference of P-frames
- Importance: I > $P_1$ > $P_2$ > $P_3$




- Redundancy: I > $P_1$ > $P_2$ > $P_3$

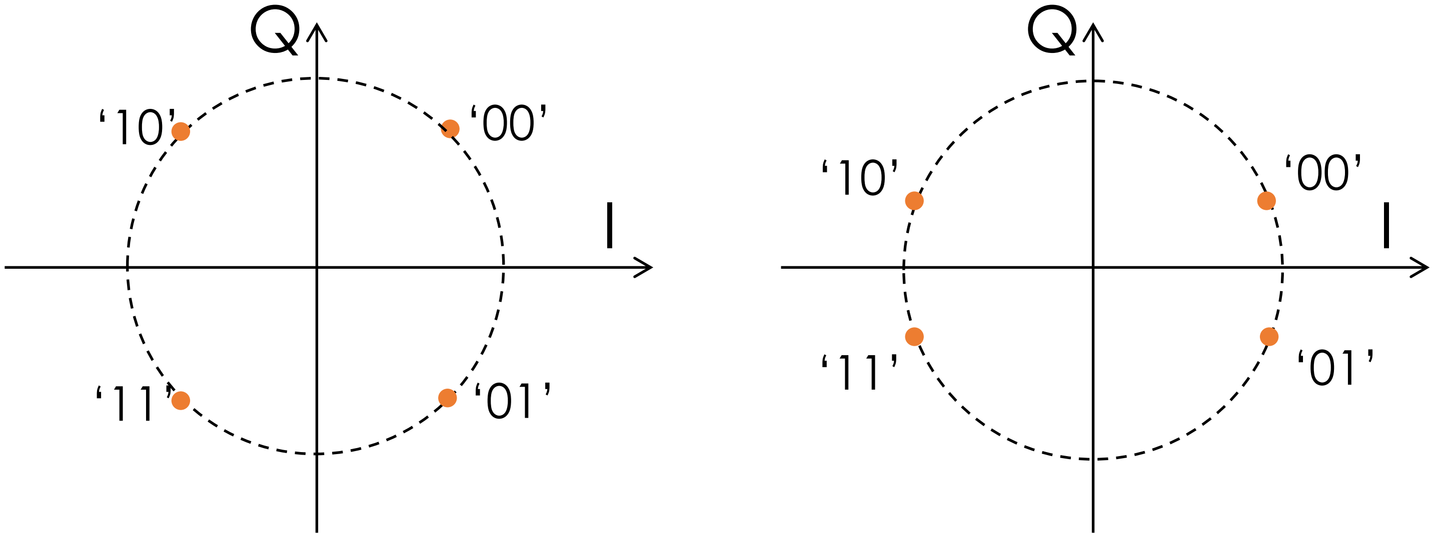


# Outline

- Unequal error protection
  - FEC-based solution
  - Modulation-based solution
  - Retransmission-based solution

# Modulation-Assisted UEP

- Exploit nonuniform QPSK to achieve UEP



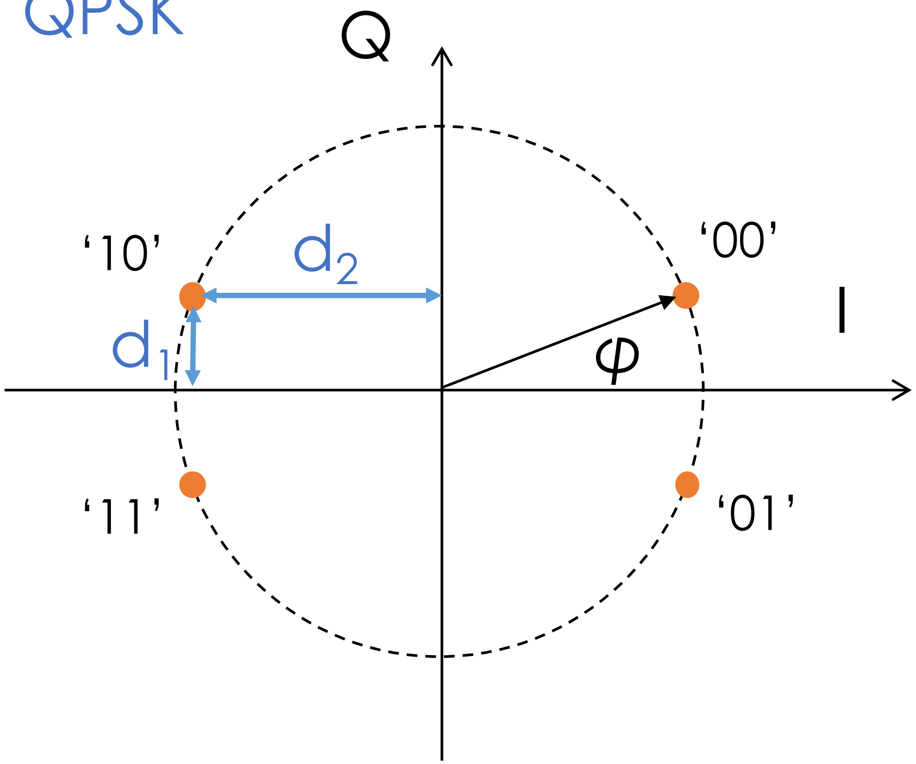

Uniform QPSK

Nonuniform QPSK

M. Sajadieh, et. al., "Modulation-assisted unequal error protection over the fading channel," in *IEEE Transactions on Vehicular Technology*, vol. 47, no. 3, pp. 900-908, Aug 1998

# Nonuniform QPSK

Nonuniform QPSK



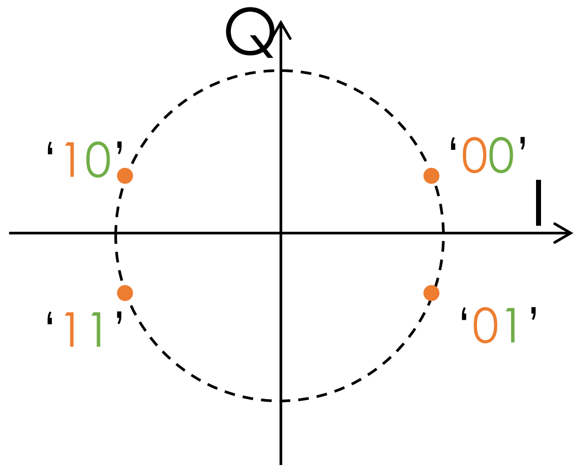

- $d_2 > d_1$ as $\varphi < \pi/4$
- BER(1st bit) < BER(2nd bit)

# UEP using Nonuniform QPSK

- Partition bits into class 1 (more important) and class 2 (less important)

class 1: 0 0 1 1 0 0 1 0 1 0 1 0 ....
class 2: 1 0 0 1 1 1 0 1 1 0 0 0 ....

Nonuniform QPSK




Send '01' '00' '10' '11' '01' '01' '10' '01' '11' '00' '10' ....

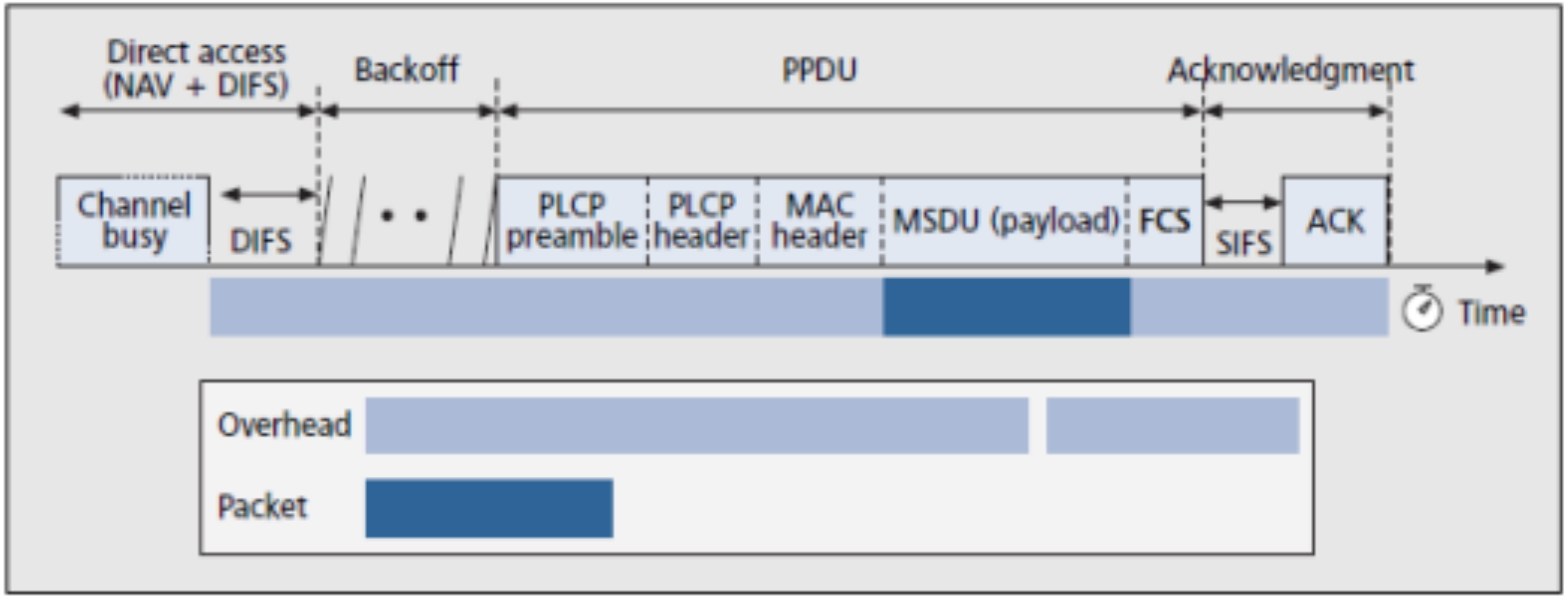
lower error probability

higher error probability

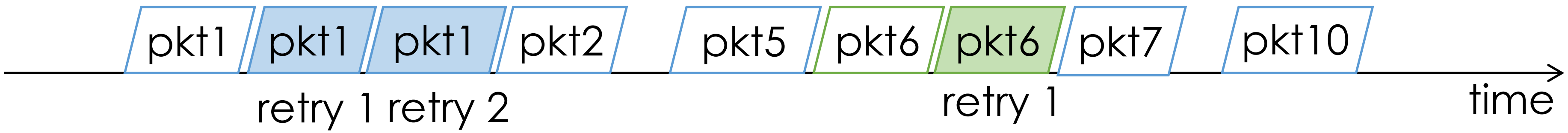
# Outline

- Unequal error protection
  - FEC-based solution
  - Modulation-based solution
  - Retransmission-based solution

# Recap

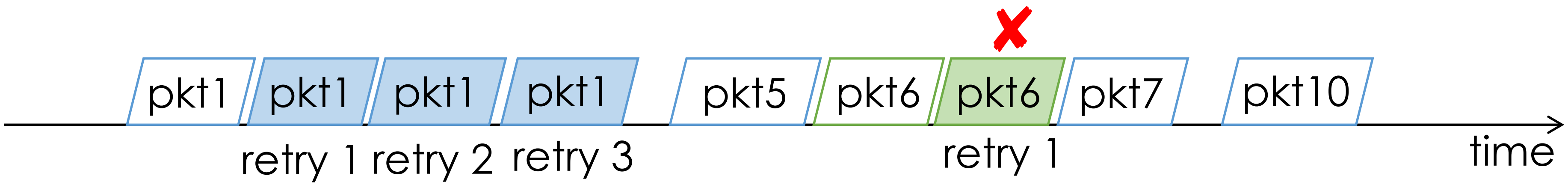



- Tx retransmits the frame when it does not receive ACK
- Retransmit the frame until the retry limit is reached



# Retry Limit Adaptation

- Increase the retry limit → enhance reliability



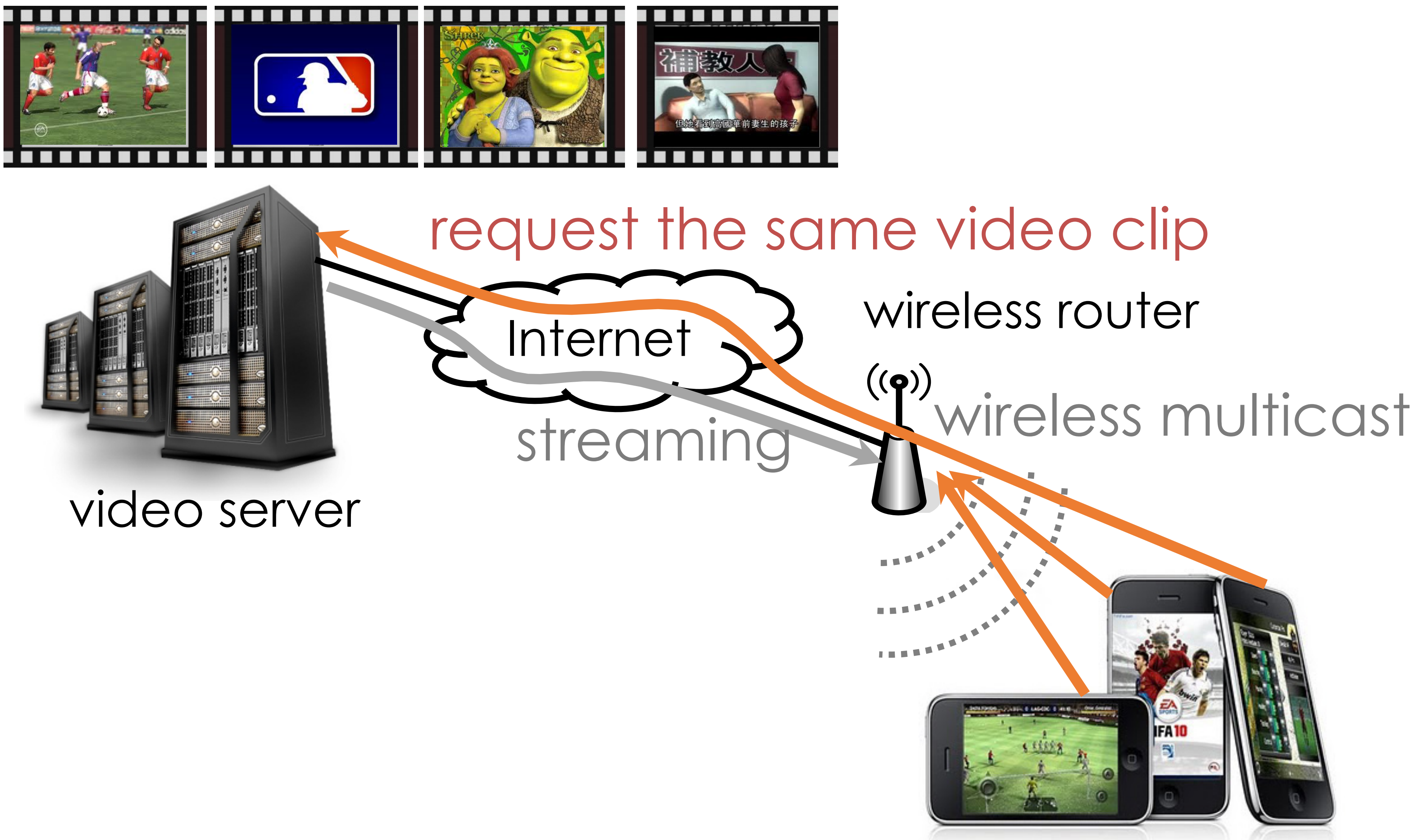

- Frame may still be lost if all reTx fail but the retry limit has been reached
- High priority bits → with a larger retry limit
  low priority bits → with a smaller retry limit
- Challenges:
  - A large retry limit might lead to buffer overflow → lose more frames
  - Tradeoff between delivery probability and buffer overflow rate

Qiong Li et. al., "Providing adaptive QoS to layered video over wireless local area networks through real-time retry limit adaptation," in IEEE Transactions on Multimedia, vol. 6, no. 2, pp. 278-290, Apr. 2004

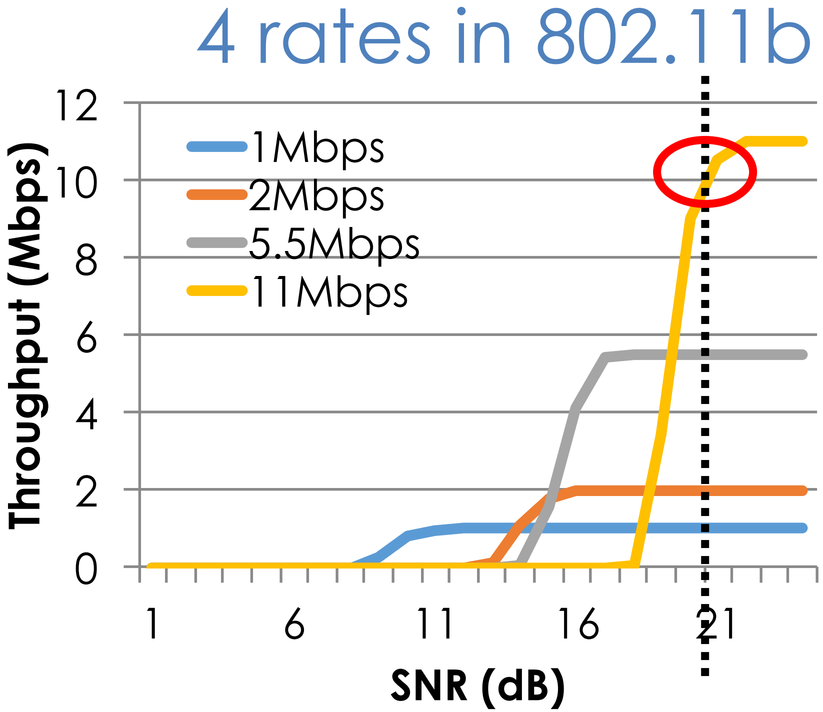
# Outline

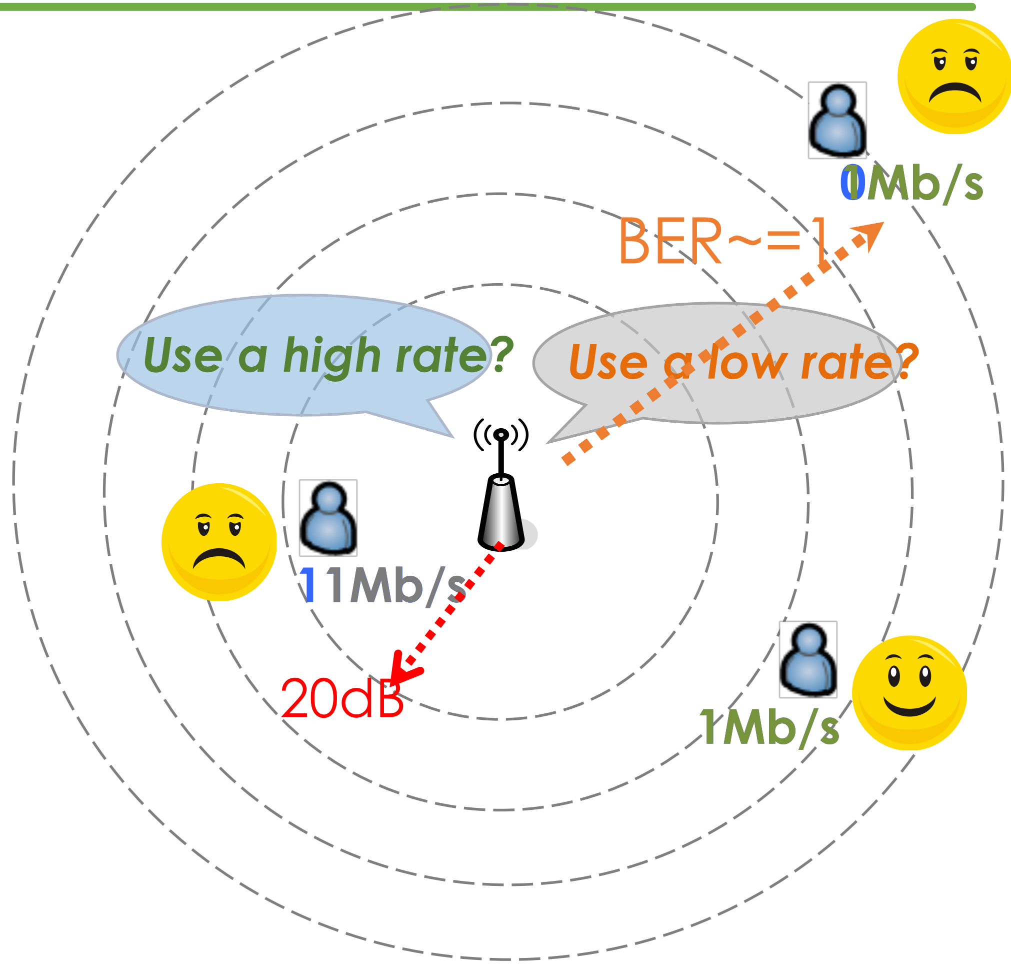
- Unequal error protection
  - FEC-based solution
  - Modulation-based solution
  - Retransmission-based solution
- Wireless Video Multicasting

# Wireless Video Multicast



# Heterogeneous Channel Conditions

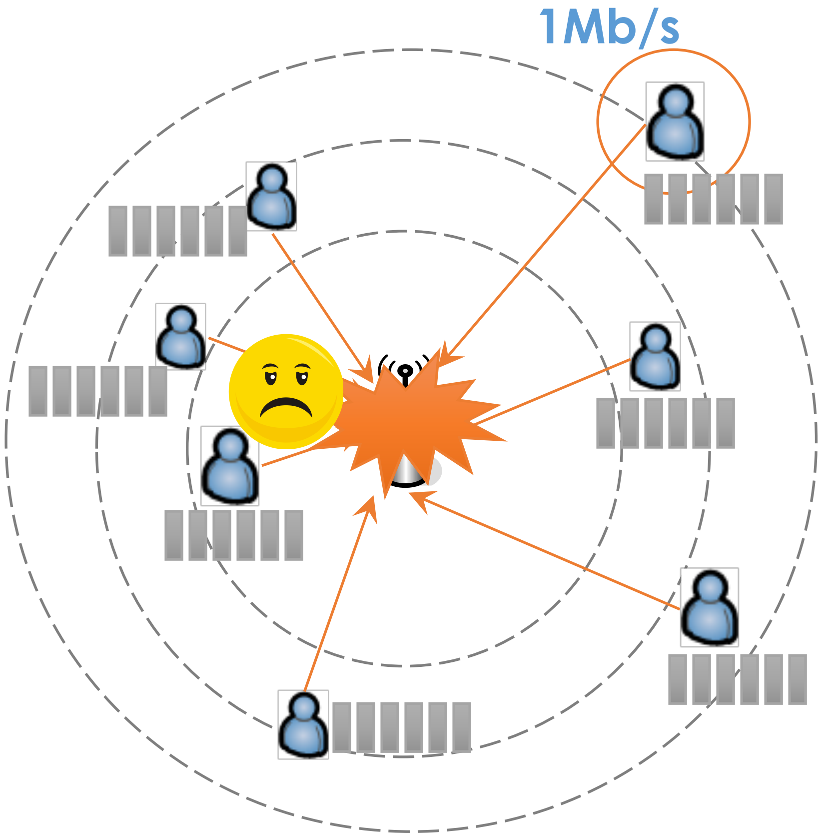


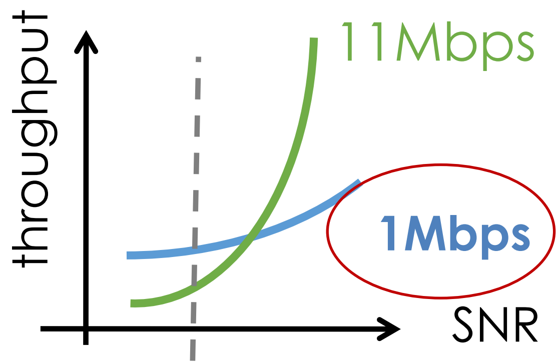

Higher rates provide a higher throughput, but a shorter coverage range

# Multicast Rate Adaptation

Adapt transmission bit-rates to dynamic channel conditions




- Leader-based scheme
- Collision due to concurrent feedback
- For reliable transmission



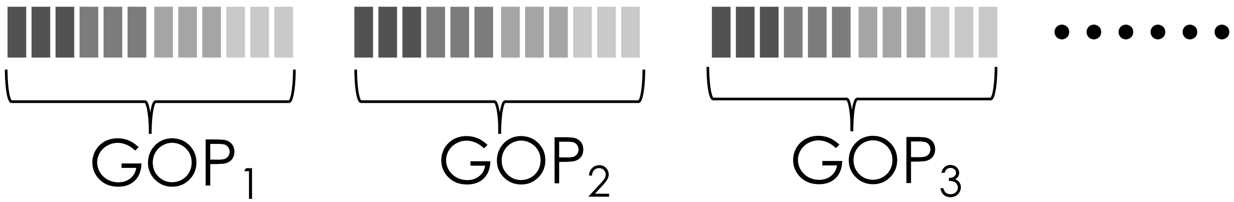

Y. Park, Y. Seok, N. Choi, Y. Choi, and J.-M. Bonnin, "Rate-Adaptive Multimedia Multicasting over IEEE 802.11 Wireless LANs," in *Consumer Communications and Networking Conference, 2006*

# For Multicast Streaming?

Layered video coding

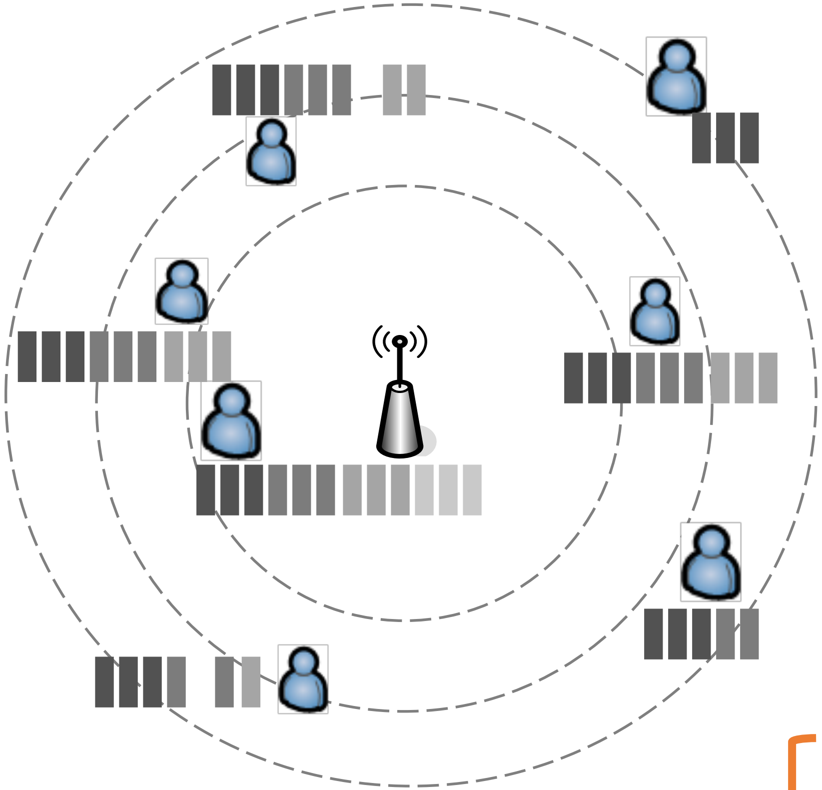
Differentiated video qualities

Playback deadline




Discarding frames after deadline

# Differentiated-Quality Multicast

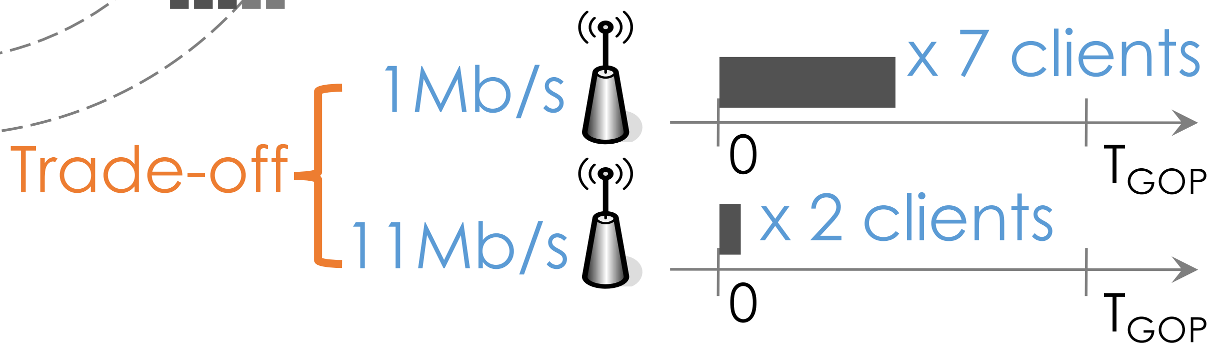


*Goal*:

- Differentiated quality matching their *channel conditions*

*Challenges*:

- Limited channel time
- Multiple bit-rates



# Rate Scheduling Problem


Objective: Maximize video quality

$$\max PSNR_{total} = \sum_{m \in M} PRNR(m)$$

Subject to

$$PSNR(m) \geq PSNR_{\min}, \forall m \in M$$ Min-quality guarantee

$$\sum_{f_k^n \in GOP^n} \frac{len(f_k^n) w_k^n}{r_k^n} \leq T_{GOP^n}(1 - a_{bg}), \forall GOP^n \in G$$ Deadline

# Clustering-based Rate Adaptation

## 1. Cluster Construction

- Cluster users according heterogeneous channel conditions

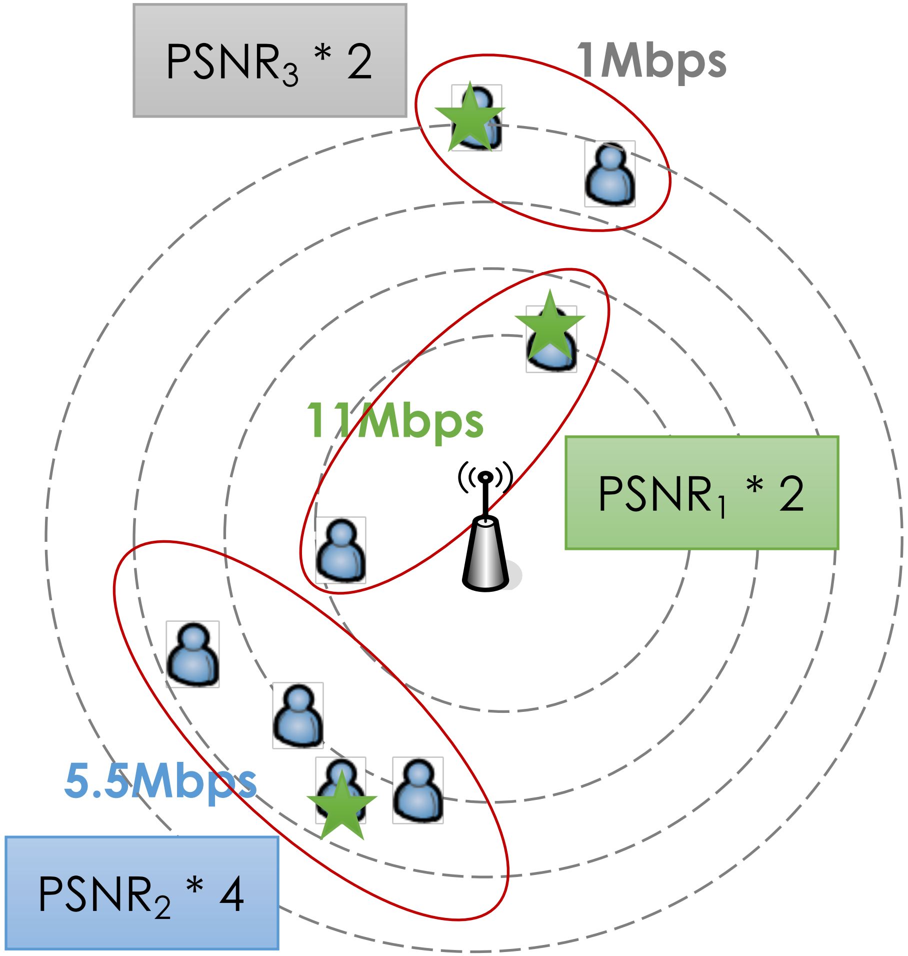
## 2. Sample-based Rate Selection

- Real-time sample channel quality

## 3. Rate Adaptation

- Adapt rates to network dynamics

# 1. Cluster Construction




Cluster clients with similar link quality

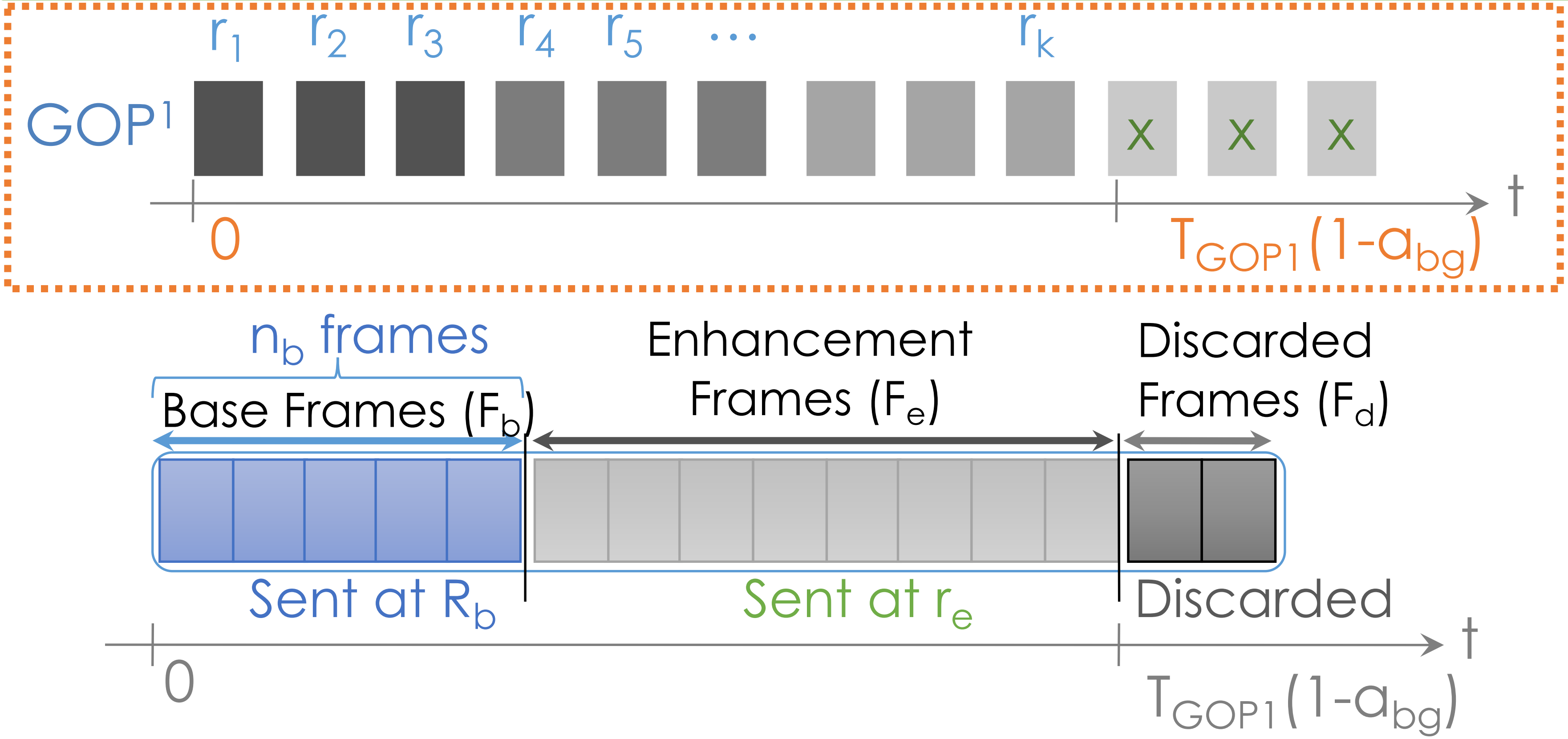
- Provide similar visual quality

Select cluster head

- Report channel visual quality
- Reduce feedback overhead

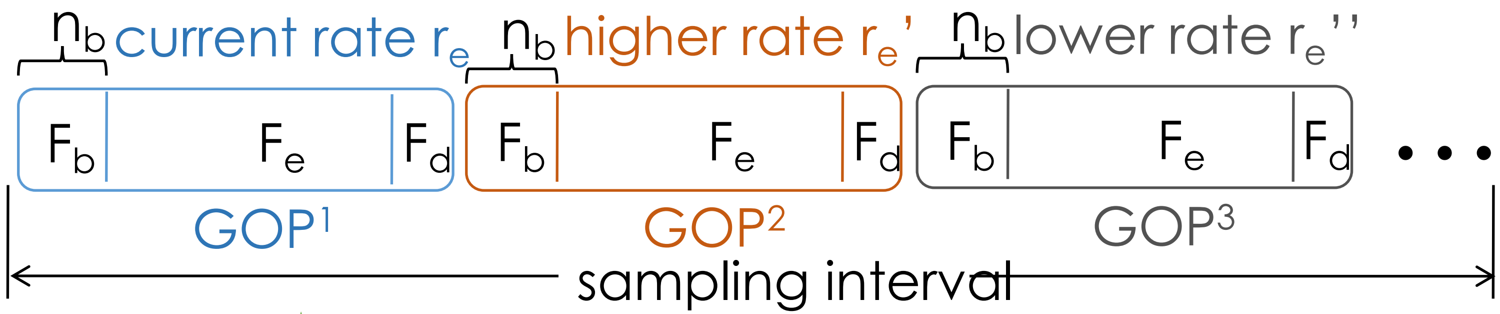
Estimate the overall visual quality

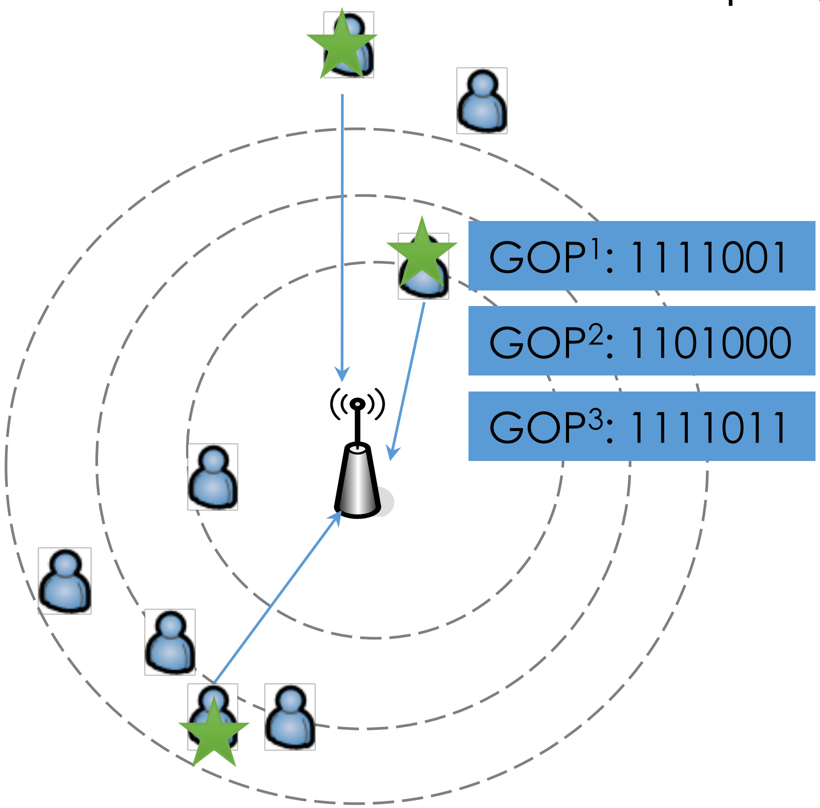
# 2. Sample-based Rate Selection




- Base frames
  - Fixed rate, dynamic size ($n_b$)
- Enhancement frames
  - Dynamic rate($r_e$), best-effort size

# 2. Sample-based Rate Selection



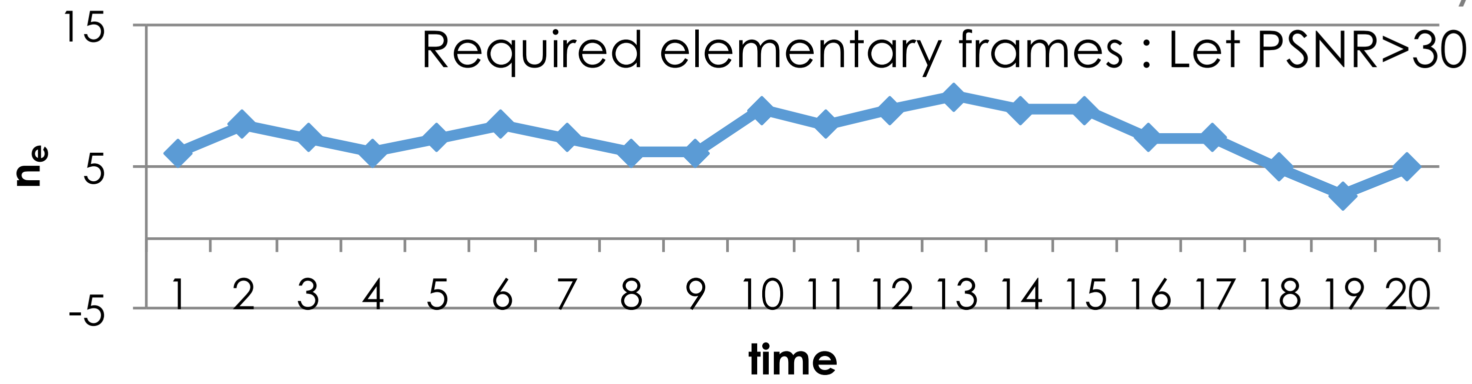

- Sample 3 different rates ($r_e$) for enhancement frames
- Cluster heads report a mask of reception
  - Sender computes visual qualities

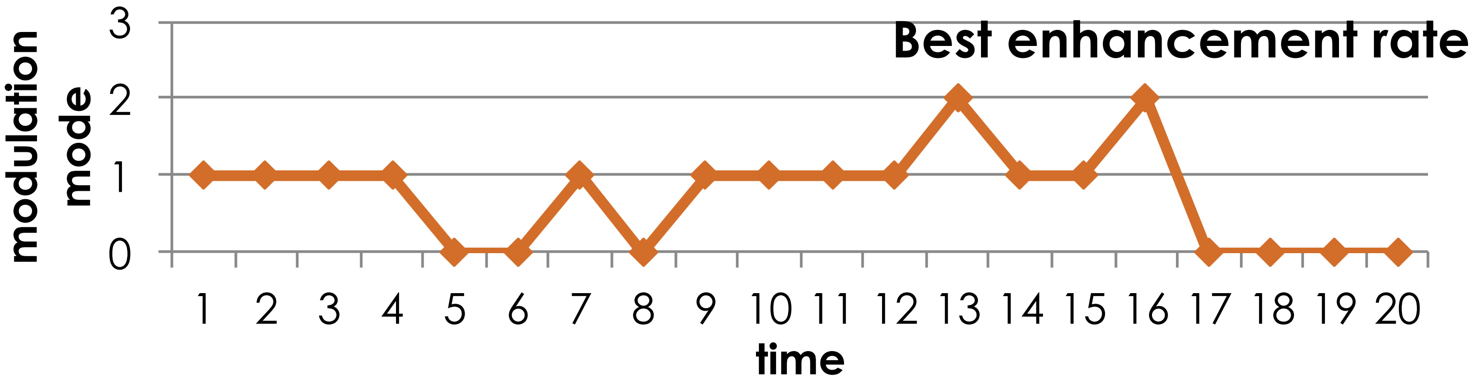
# 3. Rate Adaptation

Rate should be updated periodically

- Dynamic channel conditions
- Variable video bit-rates

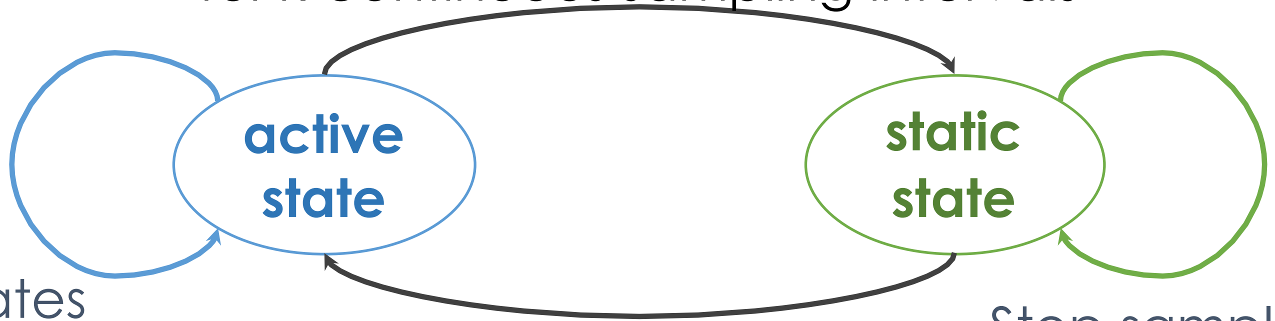
* stationary clients



# 3. Rate Adaptation

Detect the duplicated rate $r_e$
for $k$ continuous sampling intervals




Sample rates periodically

Any of CHs reports that
$PSNR_{static}(CH_i) < PSNR_{active}(CH_i) - \Delta$

Stop sampling; use the current selected rate

1. Adaptive state

   Rather sample periodically than keep using a wrong rate

2. Adaptive state -> Stable state

   Find duplicate samples

3. Stable state
   - Keep using the current rate
   - Track video quality by feedback

4. Stable state -> Adaptive state

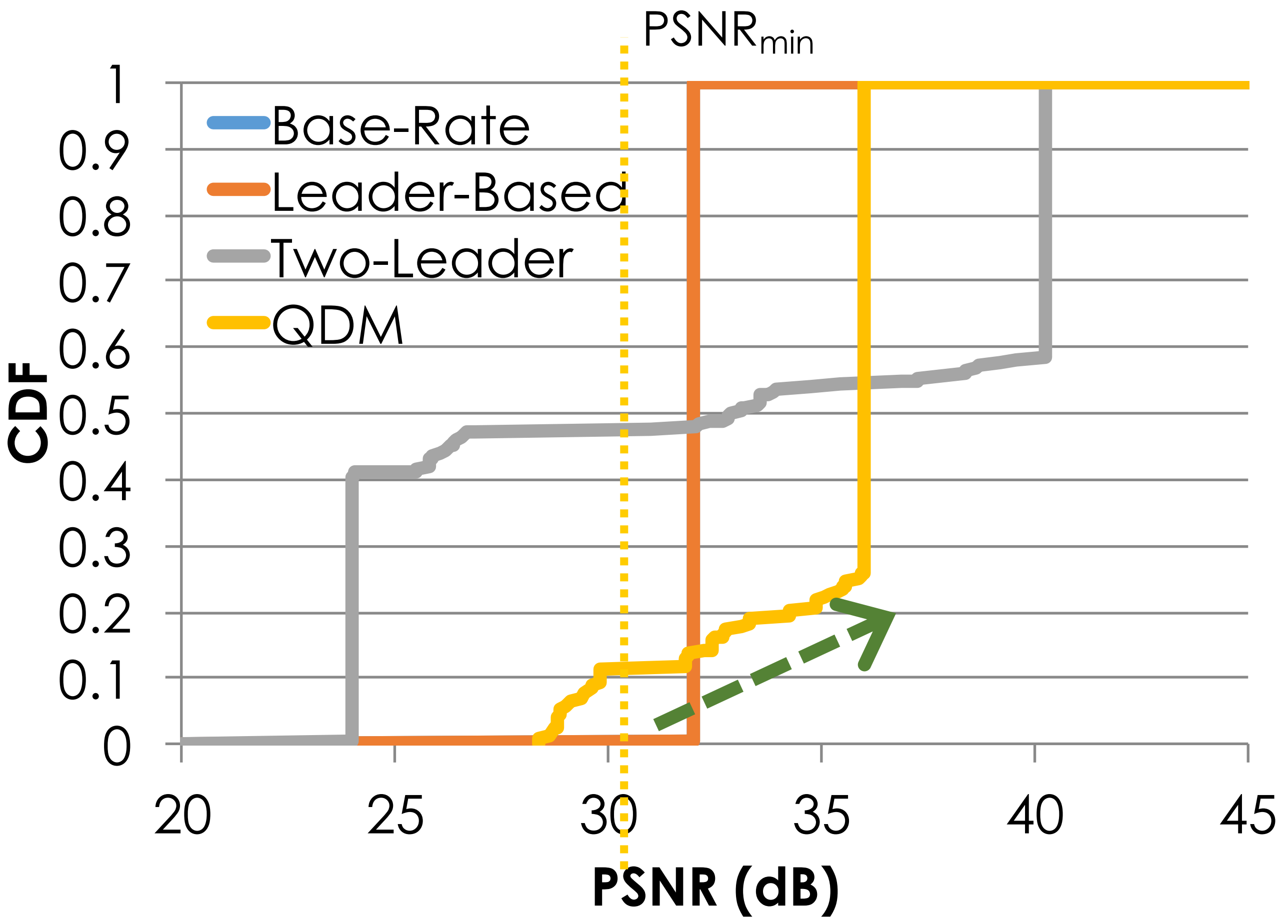
   Detect that visual quality degrades by ΔPSNR

# 3. Rate Adaptation

- Make a trade-off between sampling overhead and feedback overhead
  - *Sampling overhead*: transmit video frame at a unsuitable rate
  - *Feedback overhead*: transmit masks of reception

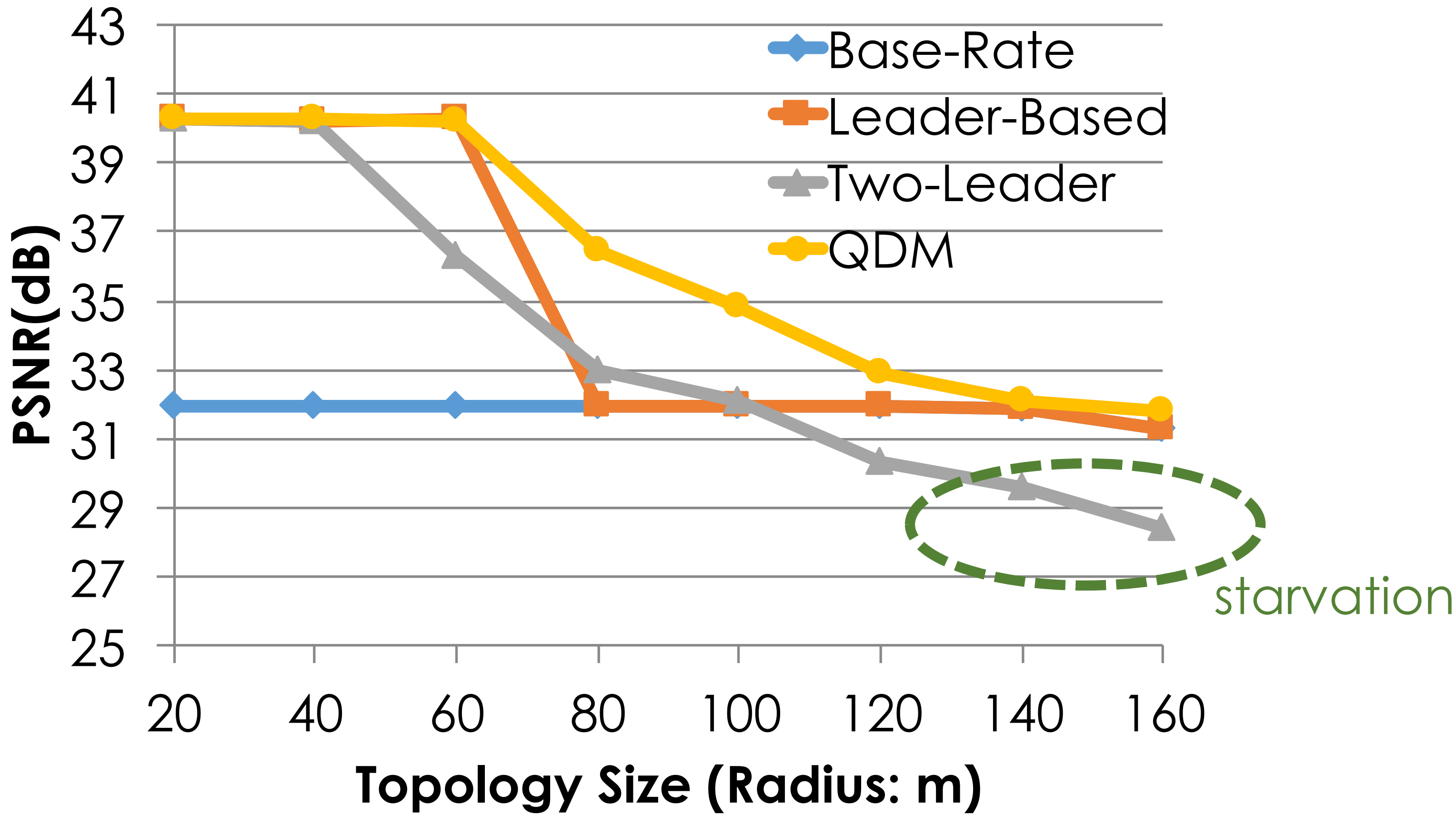
| | Two-state | | Periodical sampling | |
|---|---|---|---|---|
| Sampling overhead | 607(kb) | 6.9% | 1.43(mb) | 16.21% |
| Feedback overhead | 2.7(kb) | 0.03(%) | 1.8(kb) | 0.02% |

# CDF of Visual Quality




1. Clients perceive heterogeneous qualities
2. Most of clients obtain the minimum quality

# Impact of Node Distribution




Adapt rate based on node distribution