Cross-Layer Wireless Multimedia Transmission: Challenges, Principles and New Paradigms

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Overview of Presentation

- Multimedia transmission in wireless networks.
- Part 1: meeting QoS constraints
- Part 2: fairness and “coopetition”

Multimedia Transmission

- Quality of Service (QOS) constraints in multimedia:
  - Can tolerate some errors / dropped packets
  - Sensitive to delay
  - High Bandwidth

Cross-layer Optimization Background

- Link adaptation
- Channel-aware scheduling
- Optimal power control

- Don't consider characteristics of multimedia.
- Redesign existing protocols?

Layers being considered

- Applications (APP)
- Medium Access Control (MAC)
- Physical Layer (PHY)

PART 1: meeting QoS constraints

Definitions

- N_P, N_M, N_A denotes the number of PHY, MAC, APP adaptation and prediction strategies.
- Joint cross-layer strategy is defined as:

$$S = \{PHY_1, ..., PHY_{N_P}, MAC_1, ..., MAC_{N_M}, ..., APP_1, ..., APP_{N_A}\}$$

- Q denotes multimedia quality.
- $\mathbf{x}$ = (SNR, contention) represents the instantaneous channel condition

Cross-Layer Optimization Problem

- Optimal strategy denoted as:

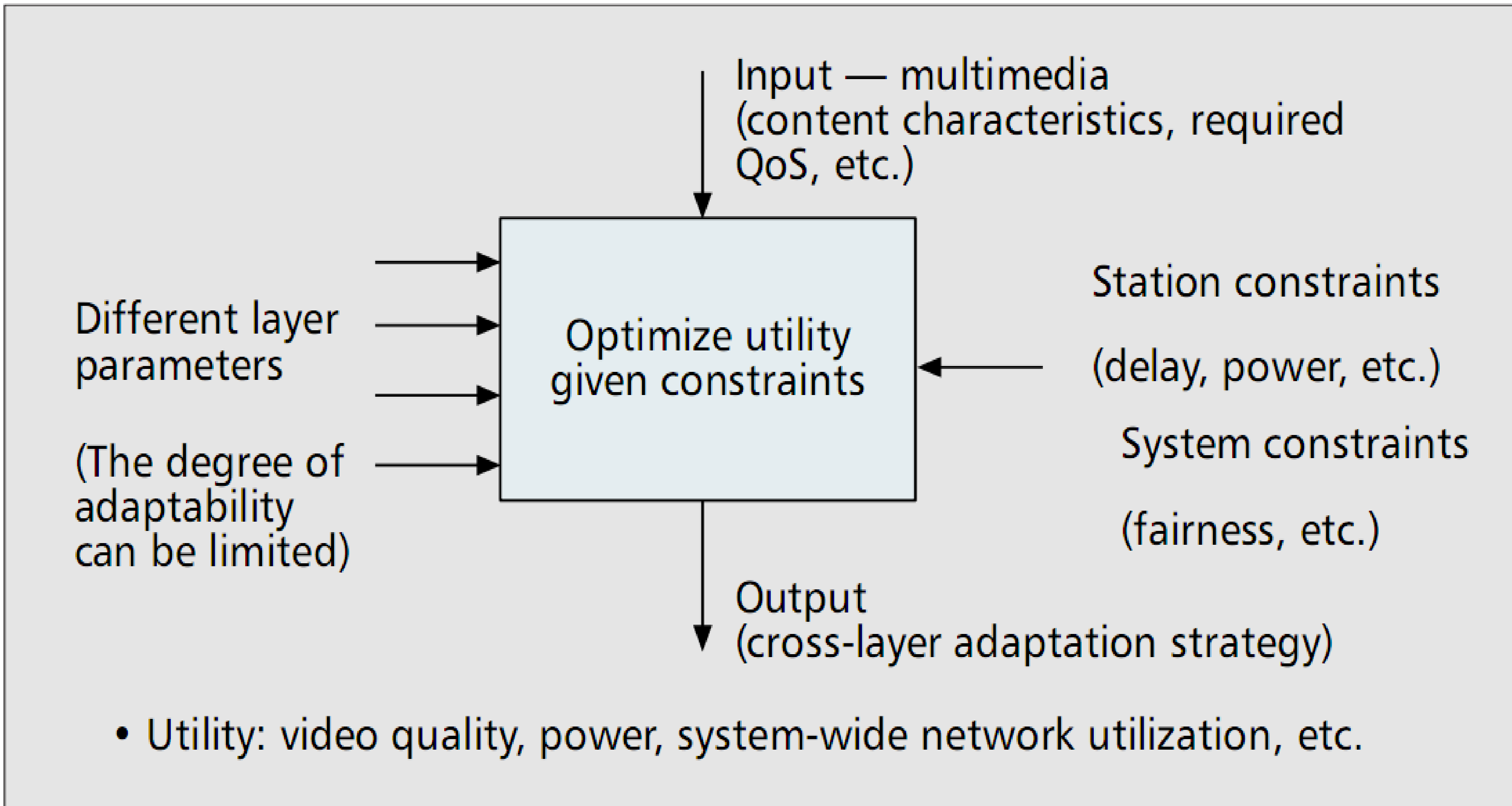
$$S^{opt}(\mathbf{x}) = \arg\max_{S} Q(S(\mathbf{x}))$$

with constraints:

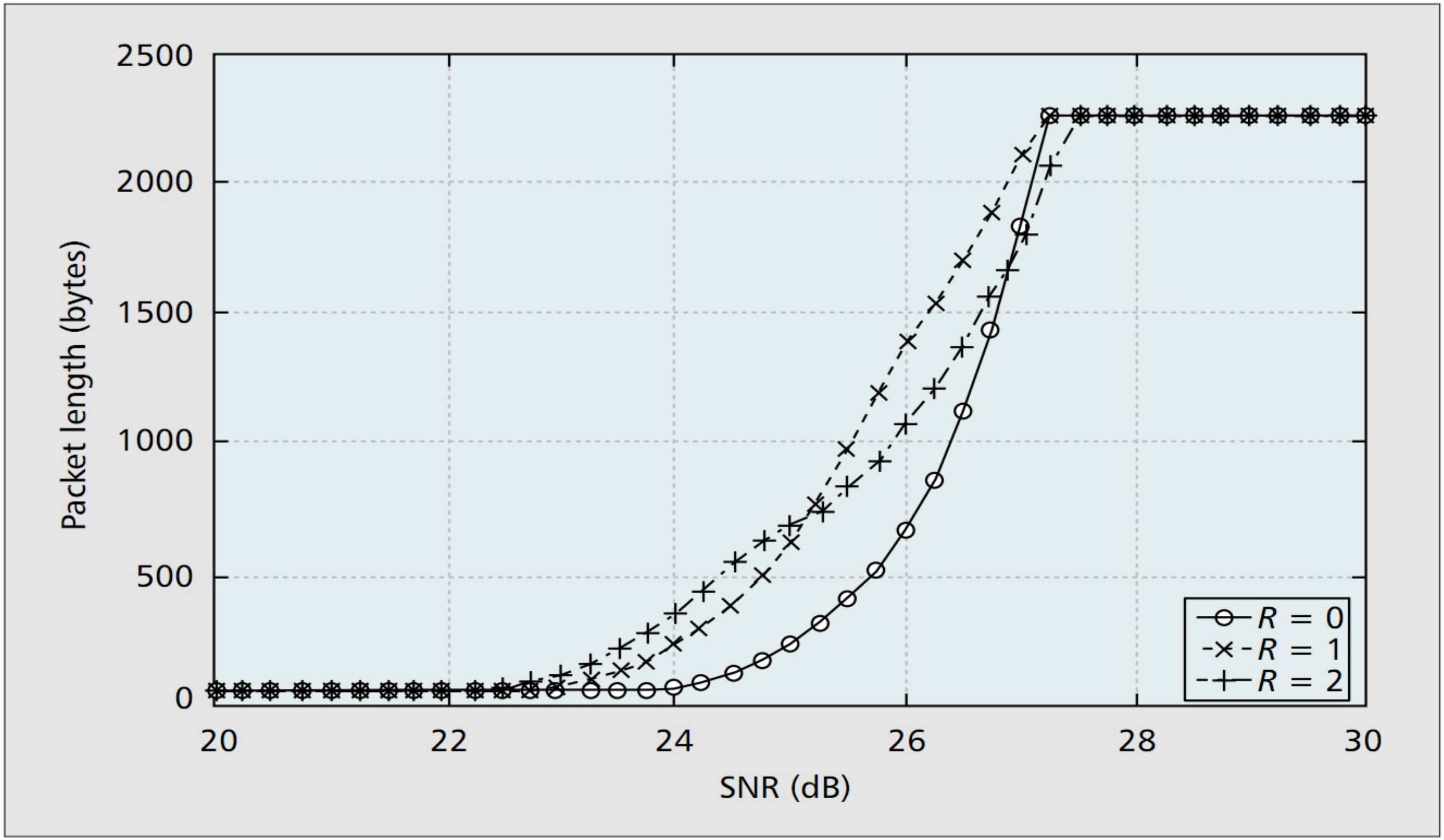
$$Delay(S(\mathbf{x})) \leq D_{\max}$$
$$Power(S(\mathbf{x})) \leq Power_{\max}$$

- Many approaches to this optimization problem.

Cross-Layer Optimization Problem



Minimum required APP-layer packet length as a function of SNR



R denotes MAC retry limit

Joint MAC/PHY Optimization

- Use received signal strength indicator (RSSI) via ACK to adapt modulation at PHY.
- Increase throughput.
- But this is not optimal for multimedia.

Joint MAC/PHY Optimization

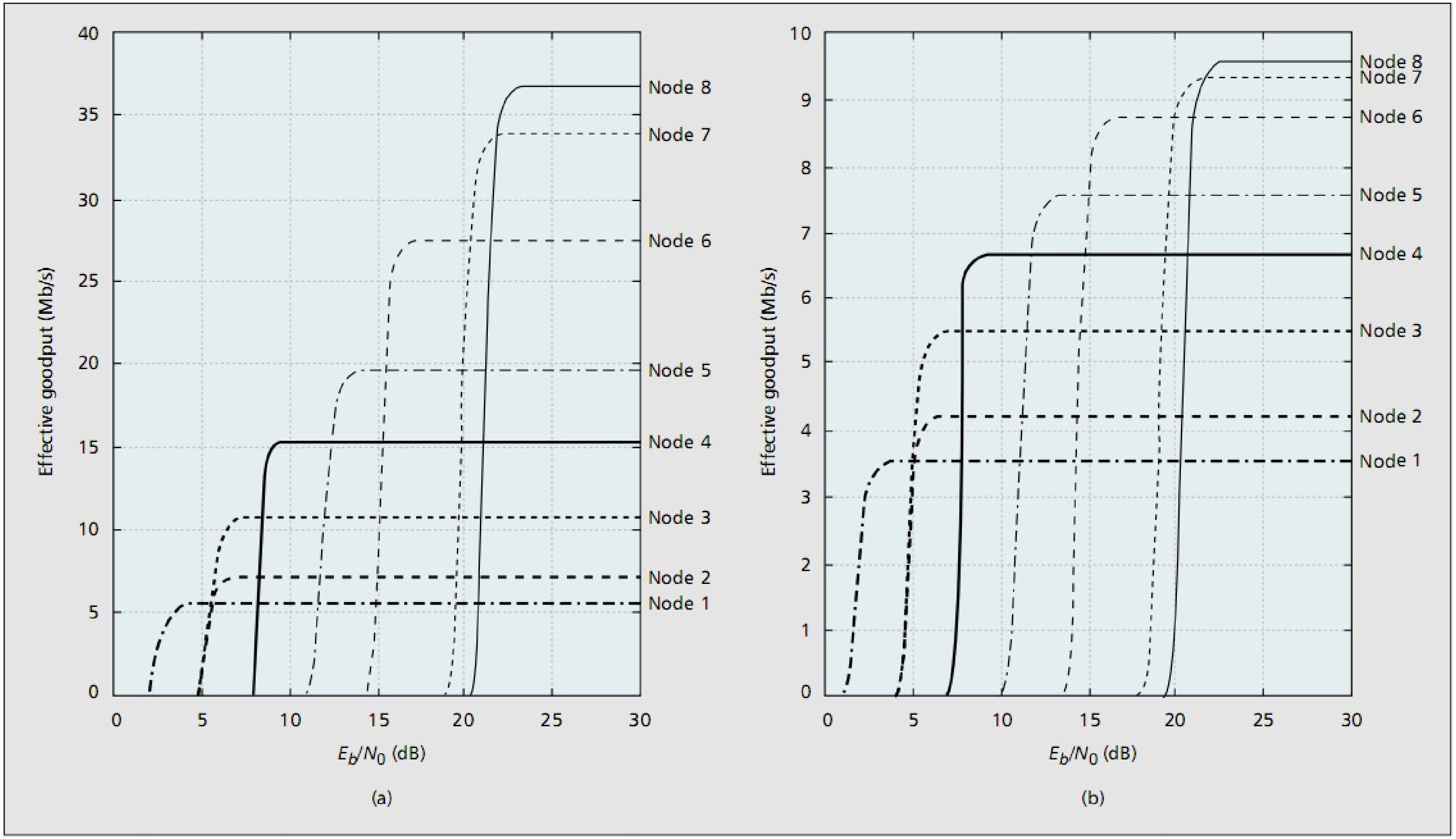


Figure 3. *Optimal modulation scheme as a function of SNR and frame size decided by the MAC [12]: a) MSDU size 2000 octets; b) MSDU size 200 octets.*

Joint APP/MAC/PHY Optimization

- R_{bl}, R_{el} denote the base layer and enhancement layer rates at the APP.
- P : MAC packet size.
- m : modulation strategy at PHY.

Joint APP/MAC/PHY Optimization

- Optimal strategy becomes:

$$S^{opt}(\mathbf{x}) = \arg\max_{S} Q(S(\mathbf{x}))$$

with $S(\mathbf{x}) = \{R_{bl}, R_{el}, P, m\}$

Joint APP/MAC/PHY Optimization

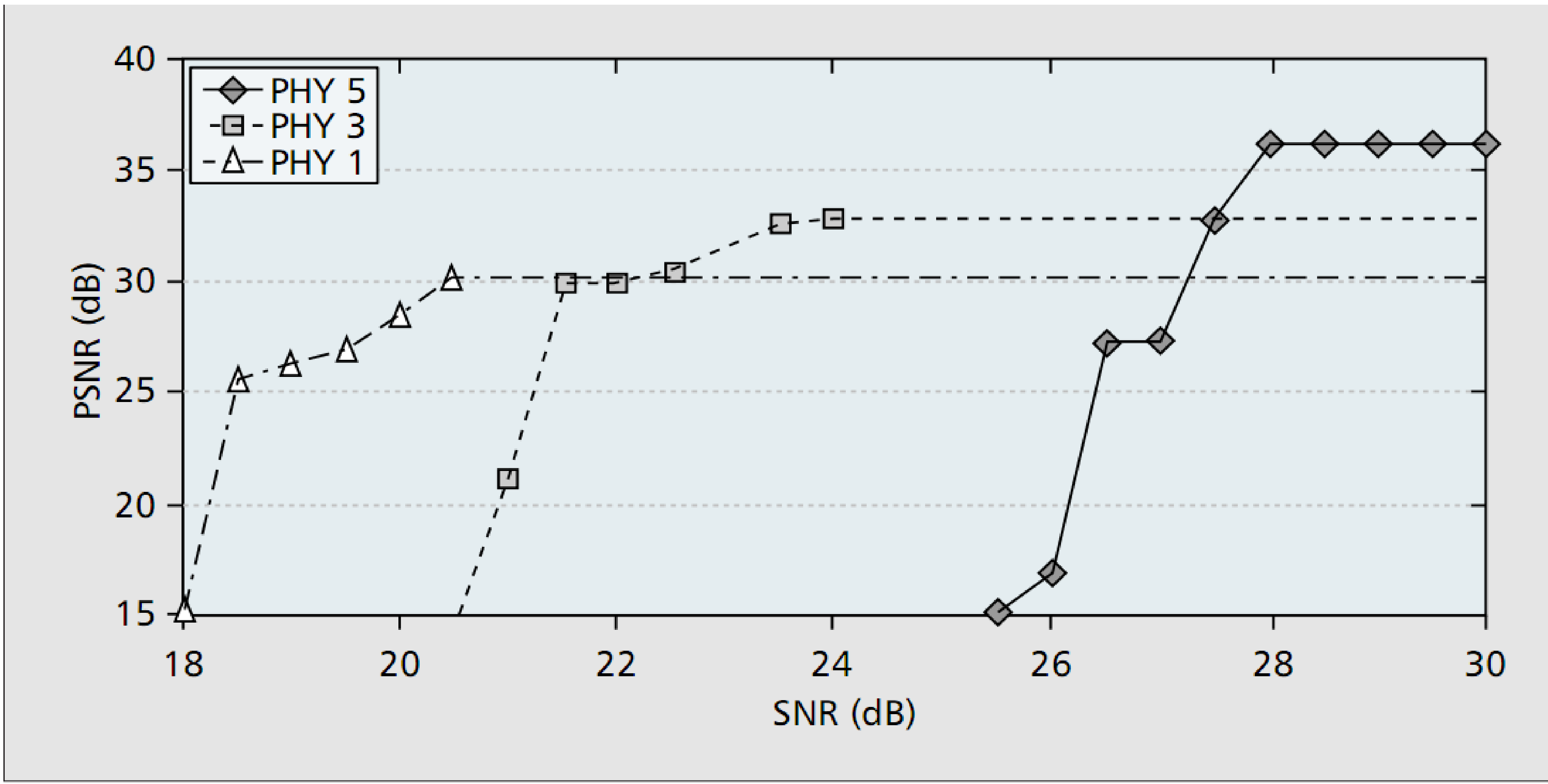


Figure 4. *Optimal modulation scheme decided by the APP-MAC-PHY as a function of SNR [13].*

Joint APP/MAC/PHY Optimization

Deployed strategies	Visual score
No optimization at MAC and APP	1.4
MAC layer optimization (RTRO)	1.9
APP layer optimization	3.8
Joint APP-MAC optimization	4.6

Table 1. *Subjective video quality experiment.*

PART 2: Fairness

Ideal Fair Scheduler Based on Generalized Processor Scheduler

- $W_i(t_1, t_2)$: amount of video flow from WSTA i at time interval (t_1, t_2).
- ϕ_i : weight based on requirements.
- Optimal policy is

$$\frac{W_i(t_1, t_2)}{W_j(t_1, t_2)} \geq \frac{\phi_i}{\phi_j}, j = 1, 2, ..., N$$

Proposed Idea: Time Scheduling

- $T_i(t_1, t_2)$: time allocated to video stream of i during time interval (t_1, t_2).
- ϕ_i : weight based on requirements.
- Fairness policy becomes

$$\frac{T_i(t_1, t_2)}{T_j(t_1, t_2)} \geq \frac{\phi_i}{\phi_j}, j = 1, 2, ..., N$$

Scenario 1: same cross-layer strategies for both WSTAs

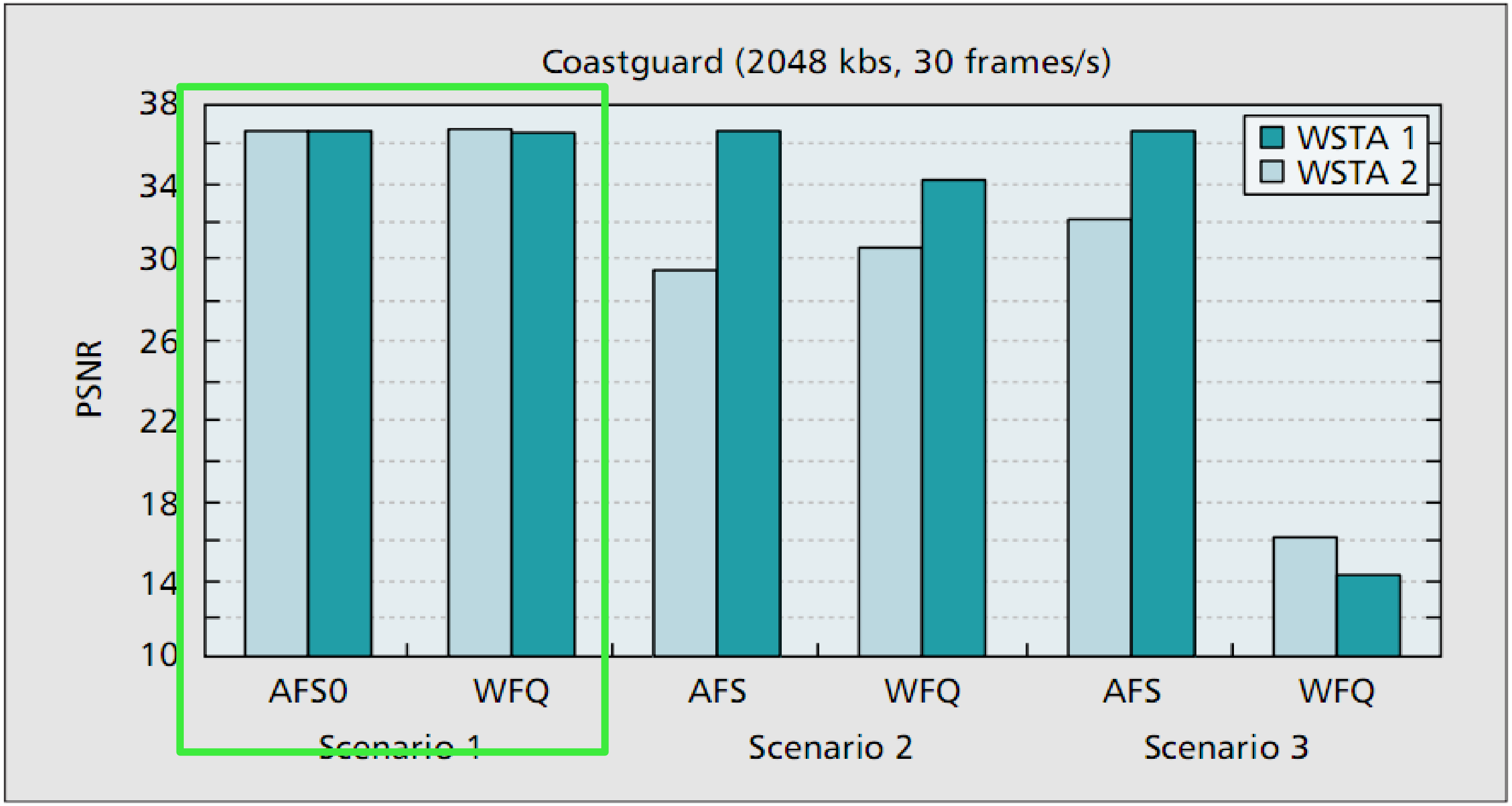


Figure 5. *The PSNR performance of multimedia for different fairness scenarios [20].*

Scenario 2: WSTA1 experiences more severe fading and interference

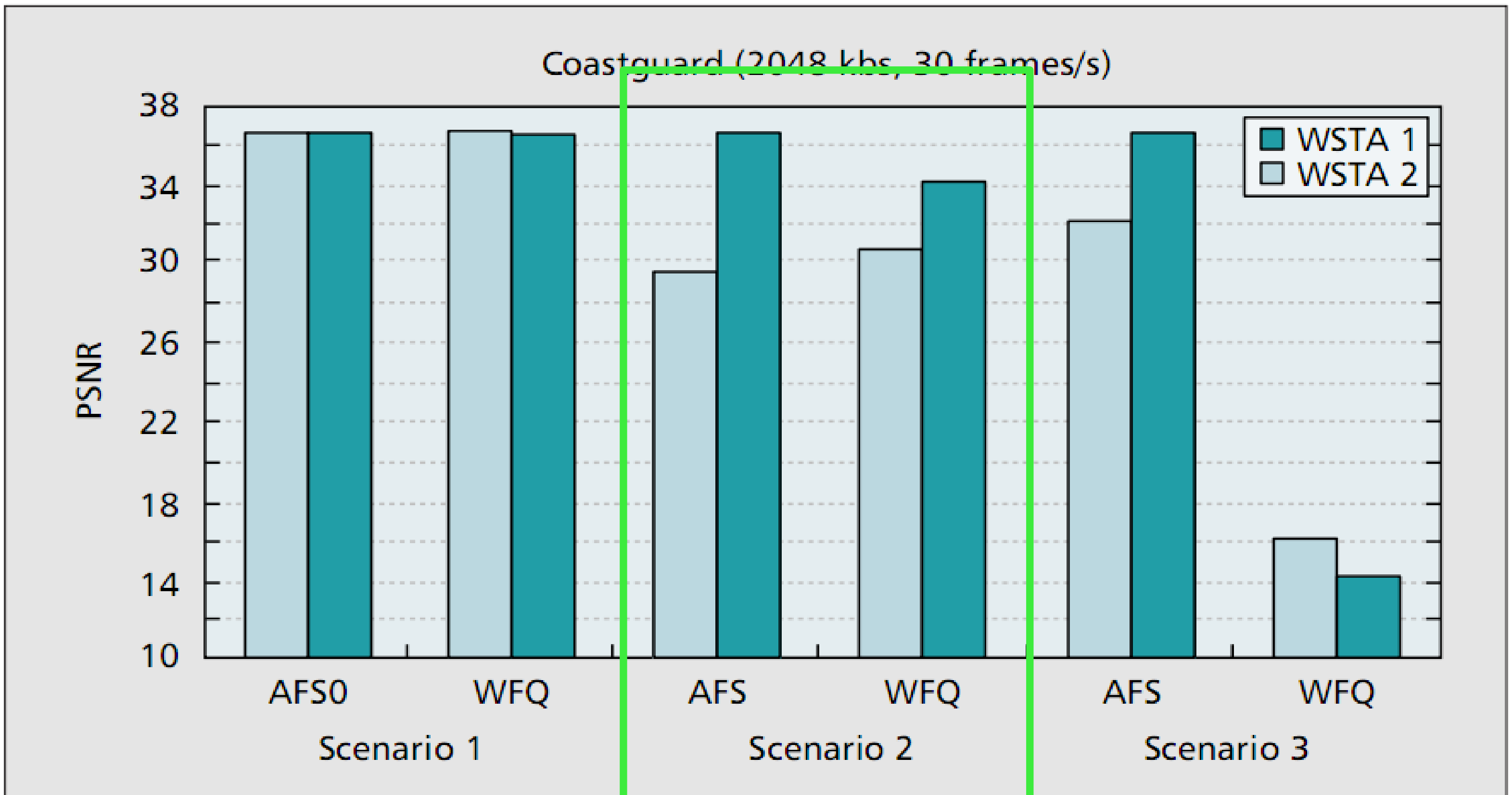


Figure 5. *The PSNR performance of multimedia for different fairness scenarios [20].*

Scenario 3: WSTA1 located further away from access point

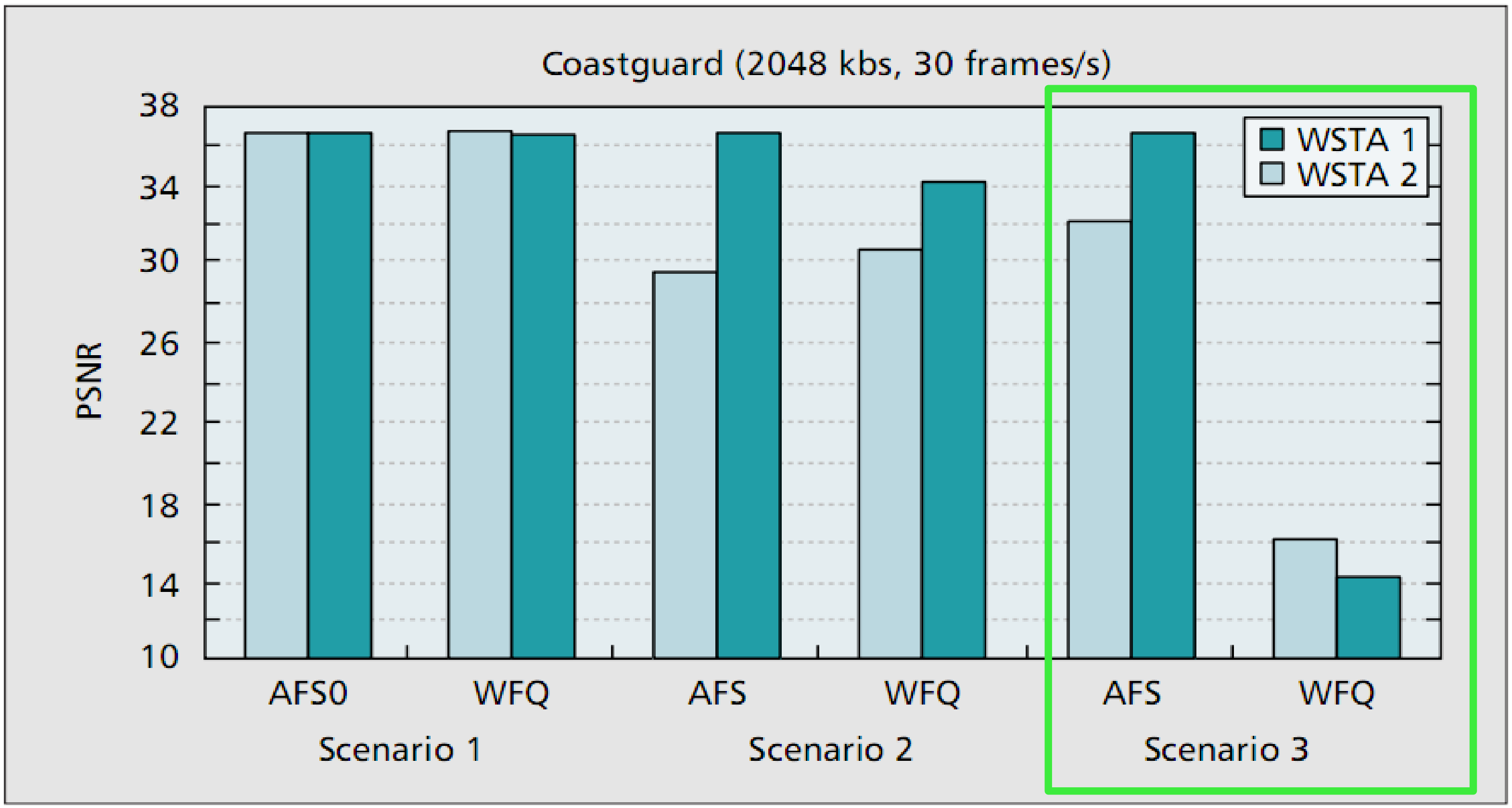
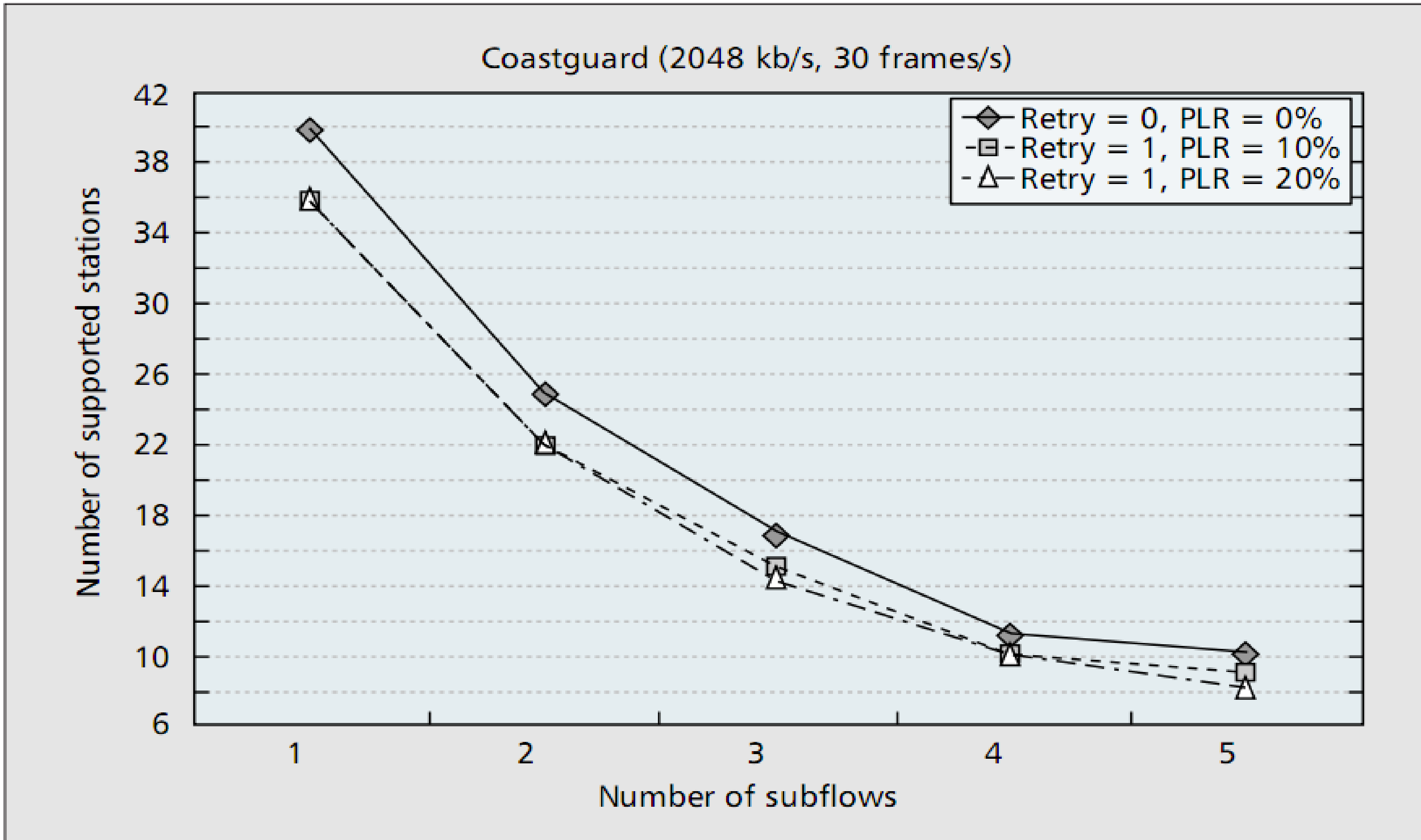


Figure 5. *The PSNR performance of multimedia for different fairness scenarios [20].*

Multimedia Quality Fairness

- Use information at APP to partition streams into multiple sub flows.
- Enforce minimum quality constraint for all stations.

Multimedia Quality Fairness



■ **Figure 6**. *Number of stations supported as a function of number of subflows [20].*

Conclusions

- Traditional cross-layer paradigms need to be adapted for multimedia transmission.
- Cross-layer optimization problem is exhaustive to solve deterministically.

Questions?