Energy-Aware MPEG-4 FGS Streaming

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Outline

- Wireless video streaming
- Scalable video coding
  - MPEG-2
  - MPEG-4 FGS (Fine-Granular Scalability)
- Energy-aware MPEG-4 FGS streaming
- Experimental results
- Conclusions

Wireless video streaming

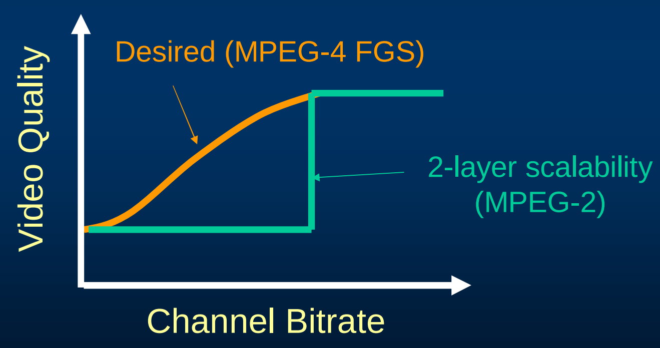
- Design targets for wireless video streaming
  - High video quality
  - Long service time
- Stable channel for real-time operation
  - Video quality degradation due to channel congestion for error rate
  - Scalable coding technique to be adaptive channel bandwidth variation
- Energy-aware operation to extend the battery lifetime
  - Optimal energy consumption to meet the required video quality

Scalable video coding in MPEG-2

- Scalable video coding
  - A base layer (BL) + an enhancement layer (EL)
- Temporal scalability
  - EL increases frame rate
- Spatial scalability
  - Using down/up sampling
  - EL increases spatial resolution (QCIF -→ CIF)
- Signal-to-noise ratio (SNR) scalability
  - Using different quantization accuracy
  - EL provides finer image

Deficiency of MPEG-2 scalable coding

- MPEG-2 only provides two layers
- Continuous video quality improvement is desirable to maximally utilize current channel bandwidth

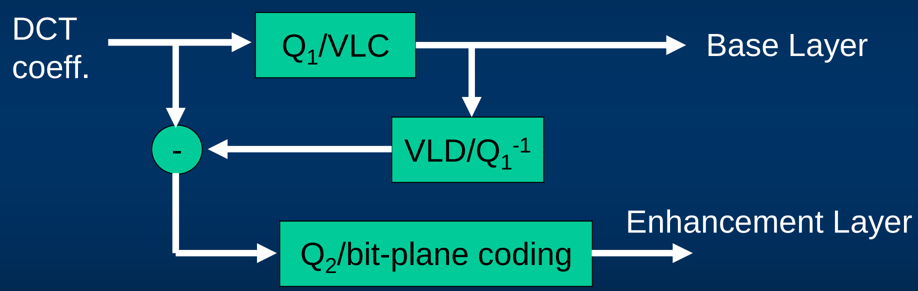


MPEG-4 FGS(Fine-Granular Scalability)

- Graceful degradation of video quality under bandwidth variation using hierarchical layer structure
  - A base layer (BL) + an enhancement layer (EL)
- BL guarantees the minimum acceptable video quality
- EL improves the video quality if sufficient channel bandwidth exists
- EL bit-stream can be truncated into any number of bits by using bit-plane coding
  - Provides continuous scalability as channel bit-rate varies

MPEG-4 FGS encoder structure

- Enhancement layer
  = original image – reconstructed image from base layer



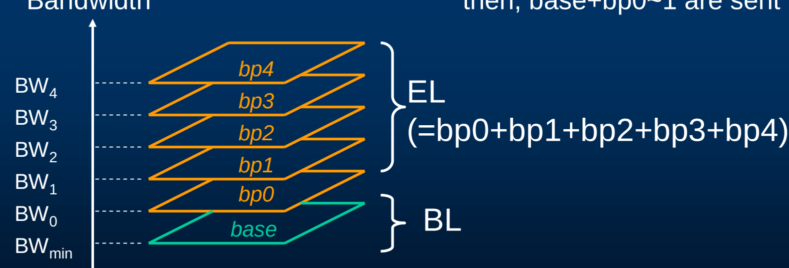
DCT : Discrete Cosine Transform
VLC : Variable Length Coding
VLD : Variable Length Decoding
Q_1, Q_2 : Quantization Factor for BL & EL

Bit-plane coding

- An enhancement layer consists of several bit-planes obtained by bit-plane coding
- As more bit-planes are decoded, the video quality increases

Channel Bandwidth

ex) if $BW_1 < BW_{act} < BW_2$
then, base+bp0~1 are sent



Energy consumption in video streaming

- Two sources of energy consumption in wireless video streaming
  - Communication energy
    - Transmitting packets (server)
    - Receiving packets (client)
  - Computation energy
    - Packetization (server)
    - Decoding bit-streams (client)
- We target a video streaming system with a server and a mobile client

Client-side energy consumption

- Energy consumption at the client
  - Receiving packets
  - Packet decoding

$$E_{CLIENT} = \underbrace{E_{COMM\_CLIENT}}_{K_P*(S*\alpha_{RX} + \beta_{RX})} + \underbrace{E_{COMP\_CLIENT}}_{C_{eff}*V^2*f_{CPU}T}$$

K_p : number of packets
S : packet size
α_{RX}, β_{RX} : regression coefficients

C_{eff} : effective capacitance
V : operating voltage
f_{CPU} : operating frequency
T : streaming time

Energy waste at the client

- Video streaming is a real-time operation
  - If the client cannot process all the packets from the server in a given deadline, then the communication energy is wasted with no improvement of video quality

ex) Arrived packet count : A
Decoded packet count : M

Video quality = min(M, A)

If A > M, then (A-M) packets are useless resulting in energy waste in handling those packets

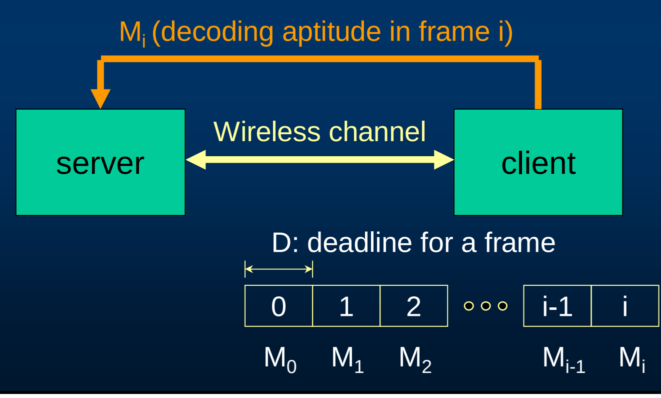
- For an energy-efficient streaming in which no energy is wasted, A should be equal to M

Decoding aptitude

- *Decoding aptitude* (M) of a mobile client is defined as the amount of data that can be decoded in a given deadline
- M can be changed by several factors such as the workload and the CPU freq
- Normalized decoding load, N
  - defined as the ratio A/M
  - represents the degree of energy waste
  - no energy waste when N is equal to 1
- To achieve N=1, the server should know the value of M
- Client-feedback video streaming

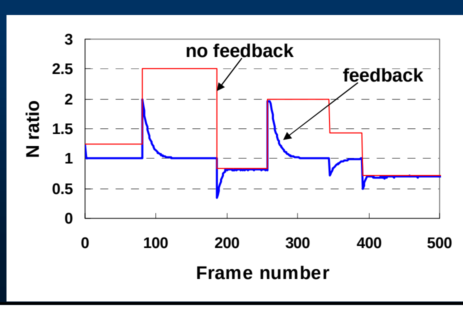
Client-feedback video streaming

- A status packet is periodically sent to the server at regular time intervals
- The server sets the amount of data to be transferred based on the client status: trying to ensure that $N_i=1$



Simulation results

- Variations in N_i with different M_i/B ratios
  - B : maximum number of packets the server can send
- M_i trace : 0.8B, 0.4B, 1.2B, 0.5B, 0.7B, 1.4B
- Wireless channel model
  - Gilbert-Elliot model with bit error rate (BER) of $1e^{-5}$ and $1e^{-4}$ for good and bad state, respectively

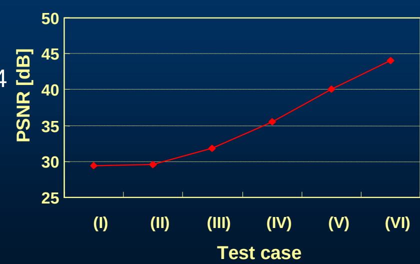


	Energy waste	
	No FB	FB
0.8B	18.74%	0.21%
0.4B	57.35%	2.57%
1.2B	0%	0%
0.5B	48.49%	6.27%
0.7B	28.69%	0%
1.4B	0%	0%

Experimental results (I)

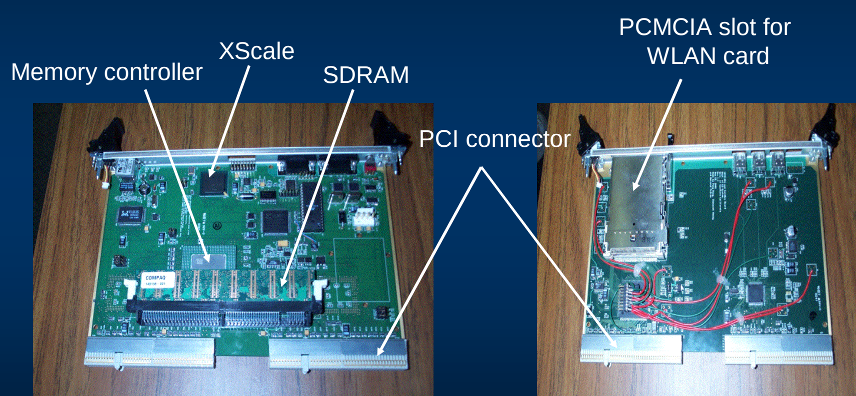
- Generated MPEG-4 FGS bit-streams using a QCIF test video
  - A base + FGS with five bit-planes(bp0~4)
  - 256-byte packet size
- Six test cases
  - (I) base layer only
  - (II) base + bp0
  - (III) base + bp0 + bp1
  - (IV) base + bp0 + bp1 + bp2
  - (V) base + bp0 + bp1 + bp2 + bp3
  - (VI) base + bp0 + bp1 + bp2 + bp3 + bp4
- Peak signal to noise ratio (PSNR) increases as more bit-planes are decoded

	Size (byte)	Packet number
Base	76	1
FGS Header	9	1
bp0	18	1
bp1	278	2
bp2	1007	4
bp3	2022	8
bp4	3358	14



Experimental results (II)

- Apollo testbed II

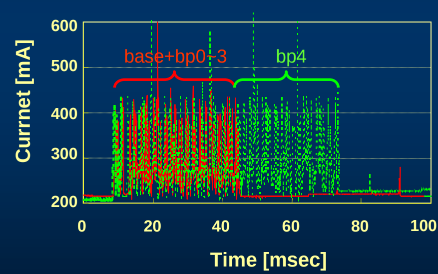


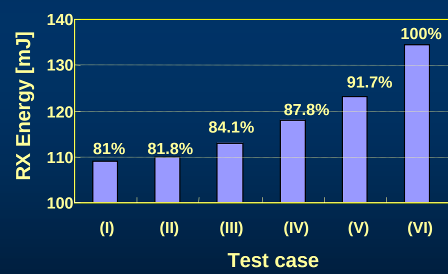
Main board

PCMCIA board

Experimental results (III)

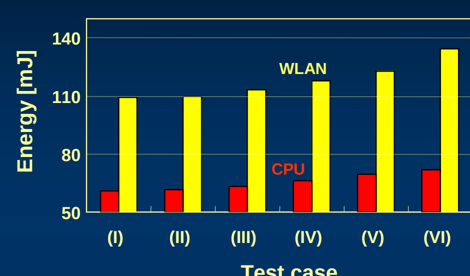
- Power consumption in wireless LAN card when receiving packets
- More energy is required to receive larger number of data packets



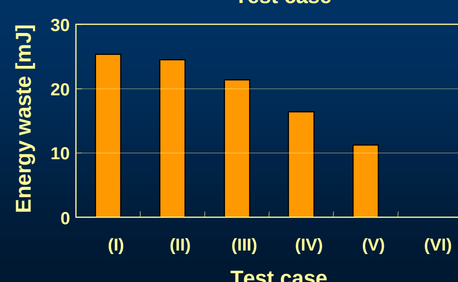


Experimental results (IV)

- Energy consumptions of the CPU and the WLAN
  - Frame rate 10, 733MHz



- For case (I), the lowest video quality, we achieve about 20% reduction in the WLAN energy consumption by using the proposed client feedback scheme



Conclusions

- A client-feedback power control method is proposed that reduces the redundant energy consumption in a wireless video streaming system
- By using the proposed method, about 20% reduction in the communication energy is achieved, which is up to 40% of the CPU energy
- In the future, we will consider the energy reduction of the total streaming system including both the client and the server