

1. Video Streaming over Networks: Technologies & Challenges

Prof. Chia-Wen Lin (林嘉文)
Department of CSIE
National Chung Cheng University
886-5-272-0411 ext. 33120
cwlin@cs.ccu.edu.tw

Digital Media World

- ◆ Many devices
- ◆ Wired or wireless
- ◆ Access from anywhere
- ◆ Software Integration
- ◆ Personalized delivery



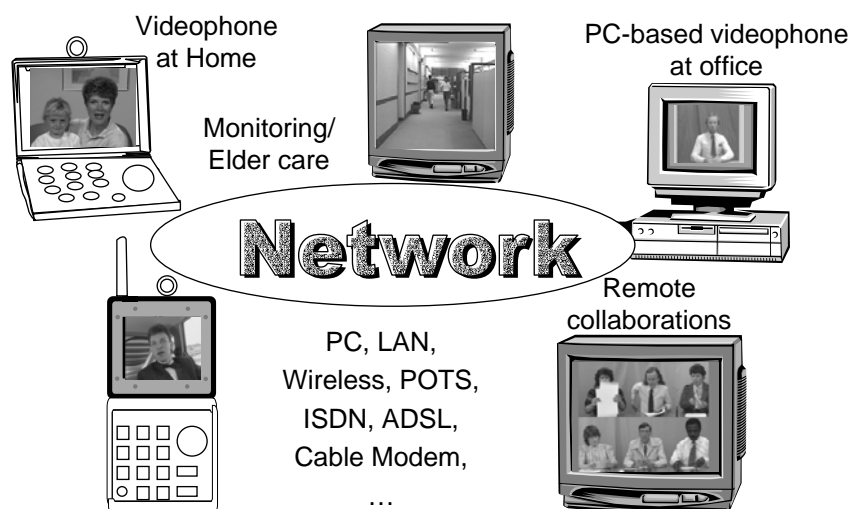
Rich Services

Visual Communication Applications (1/4)

- Applications driving the technology
- Visual communication needs evident from paintings in ancient caves



Visual Communication Applications (2/4)



Visual Communication Applications (3/4)

- **One-way applications**

Video streaming, video on demand, Video broadcasting, Video email, Video surveillance, Digital TV, HDTV, DVD, VCD, Digital camera, Digital camcorder, Digital VCR, Games, ...

Limitation: Bandwidth

- **Two-way applications**

Videophone, Videoconferencing, Distance learning, Remote collaboration, Games, ...

Limitations: Bandwidth, End-to-end Delay

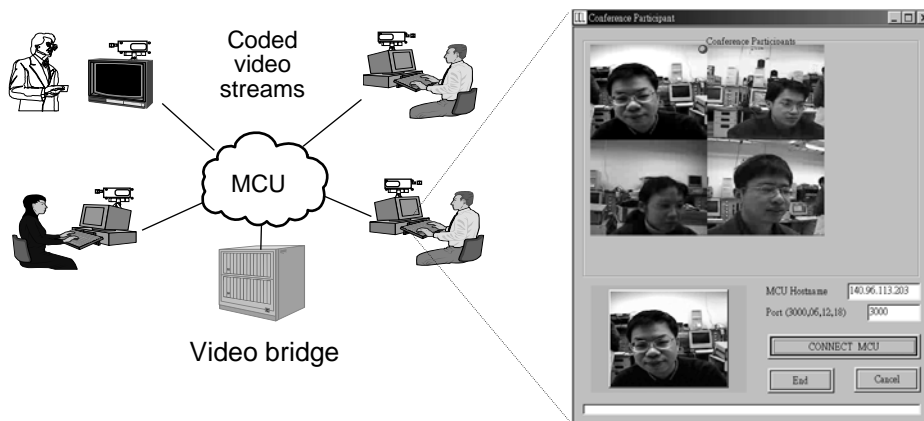
Application Example: Videophone

- e.g., Panasonic
- H.324 compliant
- Regular phone line



Application Example: Multipoint Videoconference

H.323 4-Way videoconference



Application Example: Video Browsing & Streaming



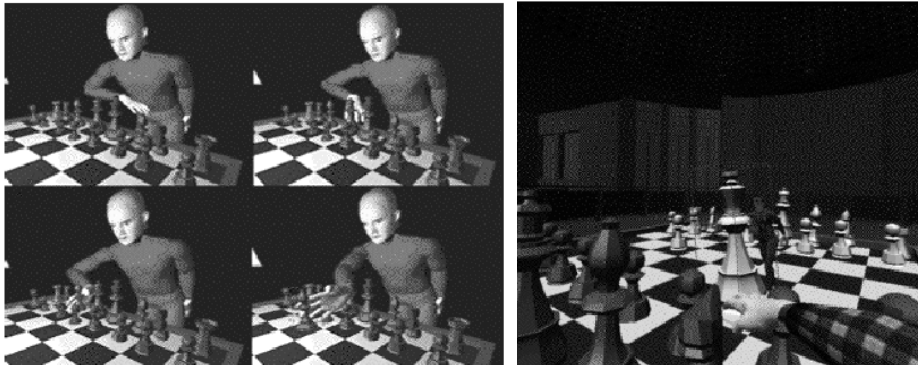
Application Example: Multimedia Messaging Services

The diagram illustrates the architecture of Multimedia Messaging Services (MMS). It shows the flow of data from the user interface to the network and storage. Key components include:

- PRESENTATION**: The user interface, represented by images of a laptop and a mobile phone.
- TRANSPORT/STREAMING**: The network layer, represented by a cloud labeled **Cellular Network**.
- Internet**: A separate network cloud containing a laptop icon.
- Messaging Server**: A central server component that interacts with the Cellular Network and the Internet.
- STORAGE**: A component that stores data, connected to the Messaging Server.
- CODING**: A component that processes data, connected to the Messaging Server.

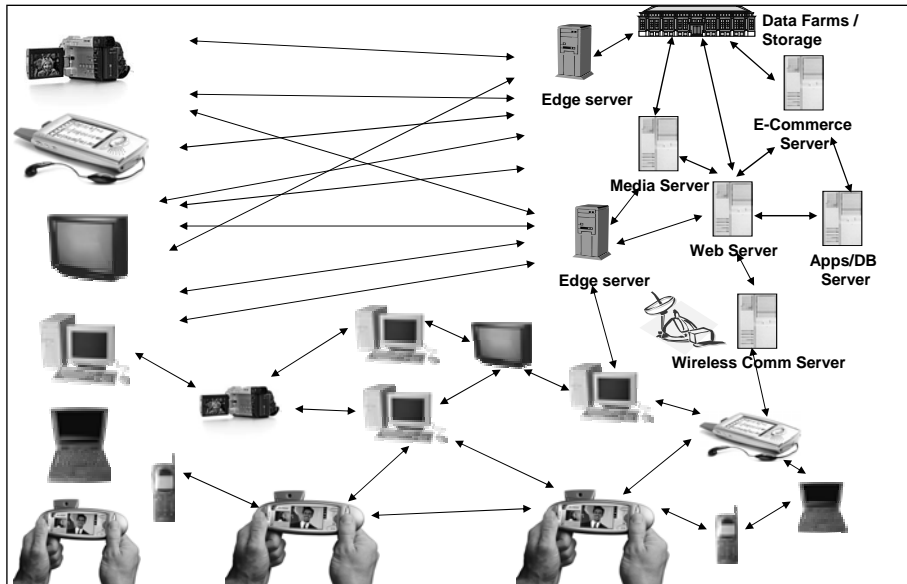
Arrows indicate the flow of data: from the **PRESENTATION** layer through the **TRANSPORT/STREAMING** layer, through the **Cellular Network** and **Internet**, to the **Messaging Server**, and finally to **STORAGE** and **CODING**.

Application Example: Networked Video Game



The image displays five screenshots of a 3D chess game. The top-left section contains four small, square screenshots arranged in a 2x2 grid, each showing a different angle of a 3D chessboard with a player's avatar. The bottom-right section features a larger, rectangular screenshot showing a 3D chessboard from a first-person perspective, with a player's avatar visible in the foreground.

Digital Media: from desktop, to Internet, to handhelds, to wireless, and to peer-to-peer



Digital Media Access & Pervasive Computing

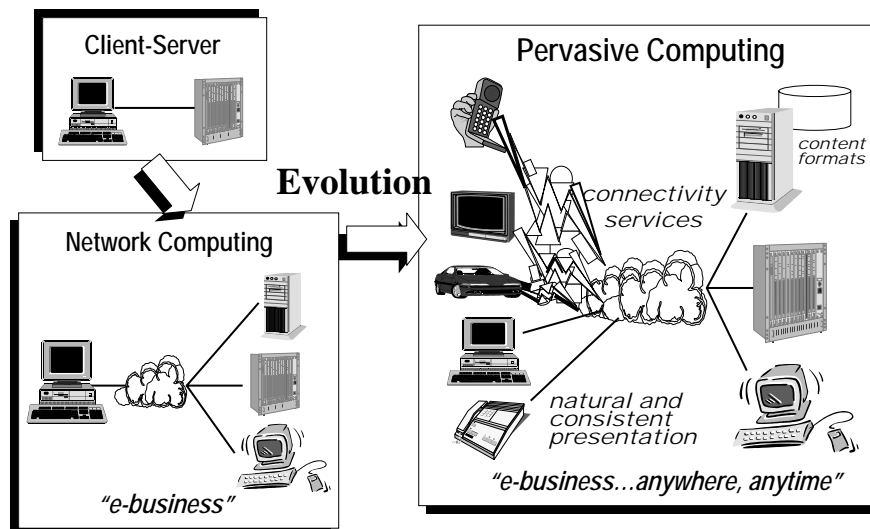
• Implications:

- Blurring of Core vs. Edge
- Migration from client-server to peer-to-peer framework
- Where should data come from?
- Where should computations be done?
 - Optimal partitioning of computations

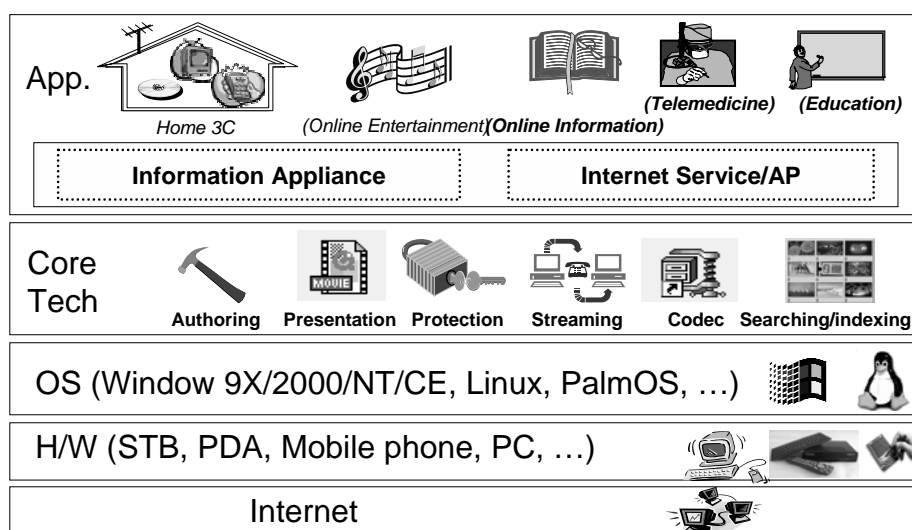
Inequality: compute, bandwidth, storage and display

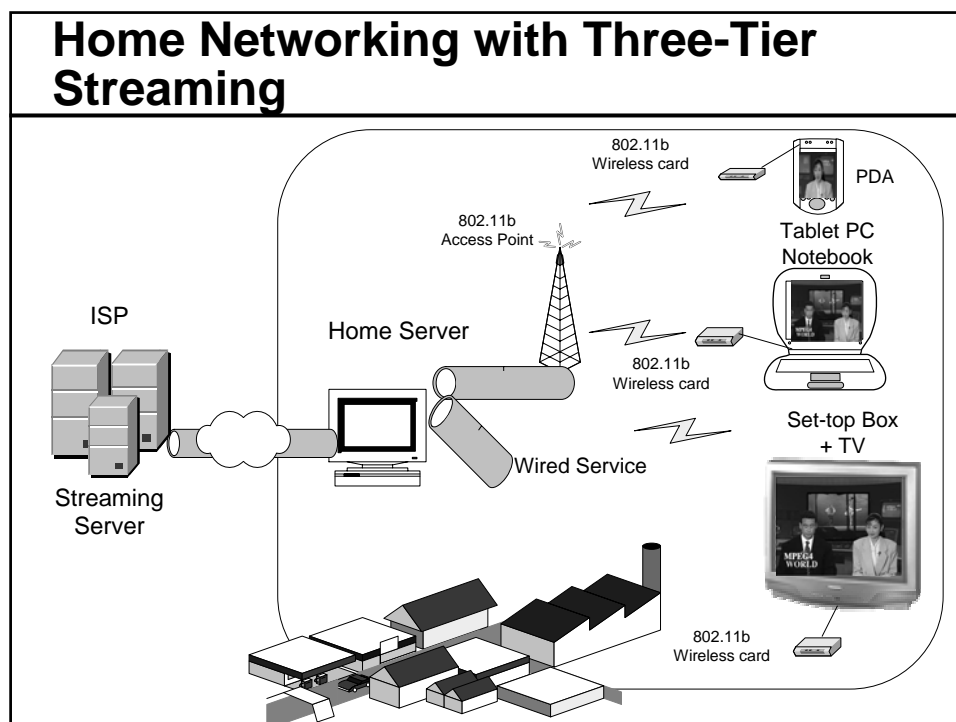
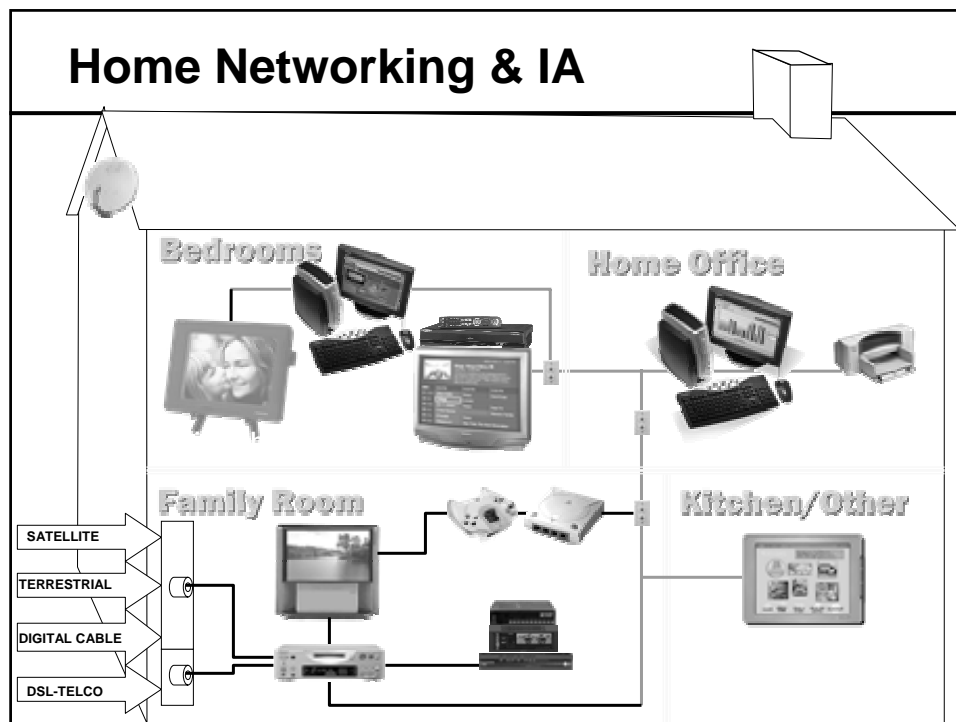
Platform	CPU	Memory	Storage	B/W	Screen
Server	Multiple 1GHz+	2GB	100G to Terabytes	1+ Gbps	N/A
PC	Single 1GHz+	256M	40G	100 Mbps	1600 x 1200
Laptop	600 MHz	128M	10G	100 Mbps	1024 x 768
Media PDA	200MHz	16M	8M	19.2 kbps	320 x 240
PDA	70MHz	8M	8M	19.2 kbps	160 x 160

Pervasive Computing

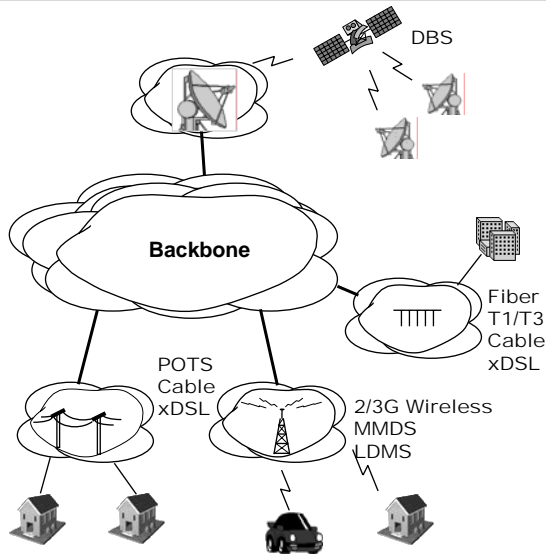


Networked Multimedia Tech. for 3C Industry





Networking

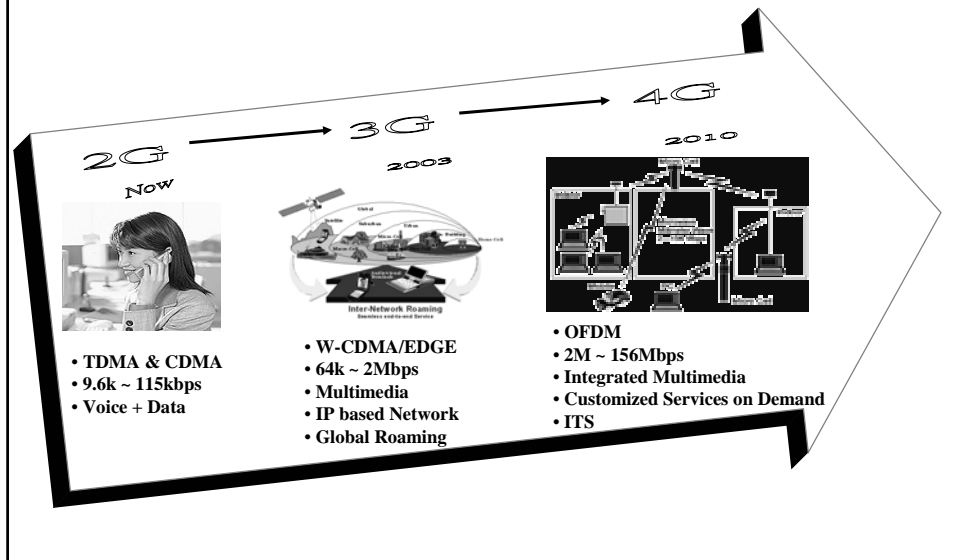


- Broadband Backbone
 - Multi-Gb/s Backbone
- Narrowband Access
 - POTS
- Broadband Access
 - Cable Modem
 - xDSL
- Wireless Access
 - DBS, LEOS
 - MMDS, LMDS
 - 3G IMT2000

Wire and Radio Networks for in-Home

Network	Scheme	Data-rate	Advantage	Disadvantage
CAT5+	4 Twisted pr.	1Gbps	Separate wiring; low cost; easy install. Telco compatible. "Fungible" wiring.	New wiring. Useful for audio and composite video. Inability to transmit CATV.
CATV	R6U Co-ax	1 GHz (150 6 MHz chs.)	Exists for TV sets; <i>could also serve IP throughout the home</i>	RF analog; no digital
Telephone	2-4 Tel. pr.	10 Mbps	Uses existing wiring	Questionable data-rate
Power	AC Power	?	Uses existing wiring	Unproven; safety
1394				Distance, lack of protocols
802.11b	Radio LAN	11 Gbps	No wires	Crowded spectrum, speed
802.11a	Radio LAN	50 Gbps	"	"
Bluetooth		1. Mbps	"	" Short distance, speed
Home RF		1 Mbps	"	" Low speed
Fiber	1394, SPDIF, etc.		Speed.	Install. skill; lack of home net equipment

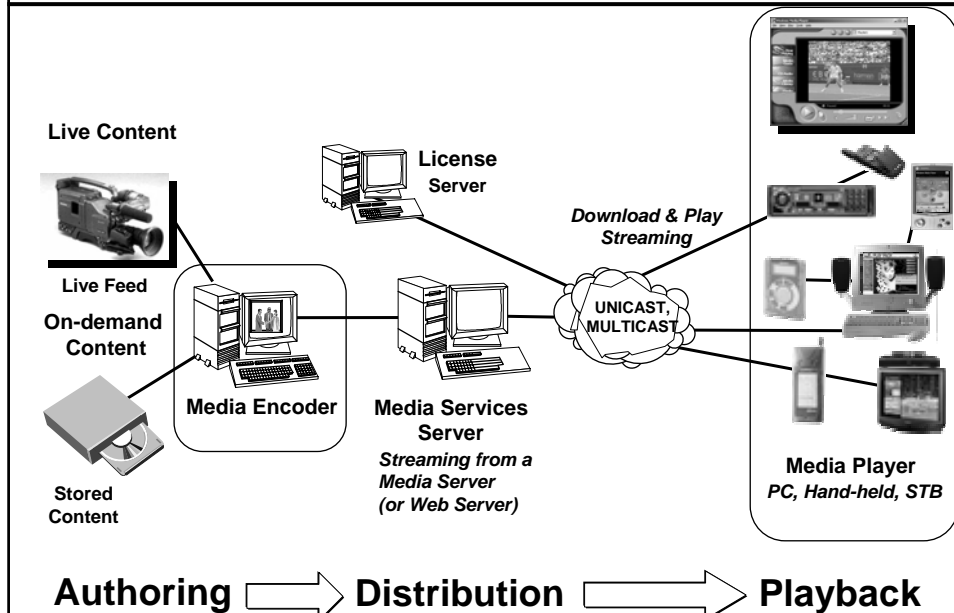
Wireless Network Evolution



Network Characteristics

- PSTN: up to 33.6 kbits/s, ubiquitous, low cost
- N-ISDN: 128 kbits/s, widely available, low cost
- ATM (B-ISDN): broadband cell-switched network, guaranteed QoS, variable bit-rate, priority, not widely available
- Ethernet: packet-switched network, non-guaranteed QoS, delay, delay variation, packet loss, congestion, widely available, low cost
- IsoEthernet: guaranteed QoS, not widely available, higher cost
- Mobile: low-bit-rate, fading, bit errors
- xDSL, cable, satellite, etc.

Components of Networked Multimedia



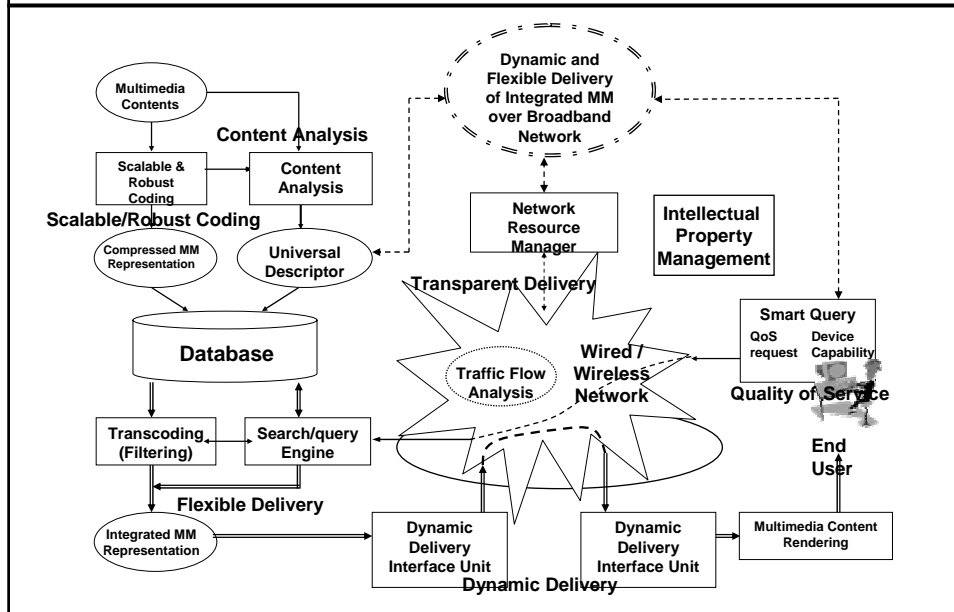
Components for Internet Video Delivery

- Content Creation: Digitization and Encoding
 - Most general purpose content starts life in analog form which needs conversion to digital form
 - Rich multimedia data types: audio, video, image, VRML, etc.
 - Lossy and lossless modes of compression
 - Download vs Broadcast (streamed) modes
 - Encoding tools typically have little knowledge of the distribution network or computational resources of the client playback device
 - Metadata for efficient search and retrieval
 - Rights of content provider must be insured

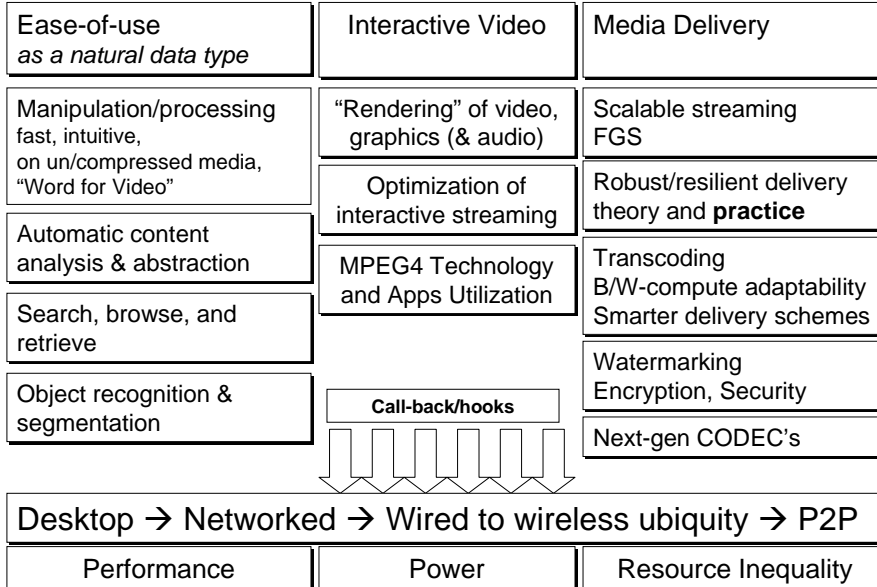
Components for Internet Video Delivery (Cont.)

- Transmission and Distribution
 - Live and pre-recorded Broadcast and VOD modes of operation
 - Redundant, Intelligent, and Reliable architecture needed
 - Redundant: Zero points of failure at each critical node of the distribution chain
 - Intelligent: Load balancing (dynamic capacity allocation) for efficient distribution
 - Reliable: Stream distributions that traverse public and private network segments; fortified against loss and congested
 - Architecture usually contains splitters/repeaters and caches for efficient usage of network/gateway capacity working in both a push and pull mode

Internet Media Delivery Framework



Building Blocks



Types of Networked Multimedia

Attribute	Value
Communication configuration	<ul style="list-style-type: none"> • Point-to-point • Point-to-multipoint • Multipoint-to-point • Multipoint
Symmetry of information flow	<ul style="list-style-type: none"> • Unidirectional • Bidirectional-symmetric • Bidirectional-asymmetric
Transmission control entity	<ul style="list-style-type: none"> • Source • Source and sink • Third party
Time aspects	<ul style="list-style-type: none"> • Real-time • Near-real-time • Non-real-time • Specified time
Media components	<ul style="list-style-type: none"> • Audio • Video • Text • Still picture • Graphics, data
Media component interrelations	<ul style="list-style-type: none"> • Synchronized • Independent
Time continuity	<ul style="list-style-type: none"> • Isochronous • Non-isochronous (i.e. supported by local storage)

Issues in Networked Multimedia

- Real-time constraints: delay, delay jitter
- Bandwidth requirement, VBR or CBR, symmetrical or asymmetrical
- Quality of Service (QoS): delay, delay jitter, packet loss, bit-error-rate, burst-error-rate, burst error length...
- Synchronization of video, audio, data, applications...
- Error robustness: error resilience, error concealment
- Cost

Problems in Internet Video streaming

- No QoS Guaranteed for current Network
 - No band width reservation;
 - No delay guarantee;
 - No packet loss guarantee
- Heterogeneity (multicast)
 - network: different users, different packet loss / delay
 - receiver: different latencies / visual quality requirements / processing powers / display formats

Key Areas in Internet Video streaming (1/3)

- Video Compression
 - Bandwidth variation, delay, packet loss
 - Functionality: VCR for pre-stored video, joining a live video, object manipulation
 - Complexity (real-time, non-real-time)
- Application-Layer QOS Control
 - Congestion control
 - server and/or receiver based rate control, rate shaping, etc.
 - Error control
 - FEC, delayed constrained retransmission, error resilient coding, error concealment

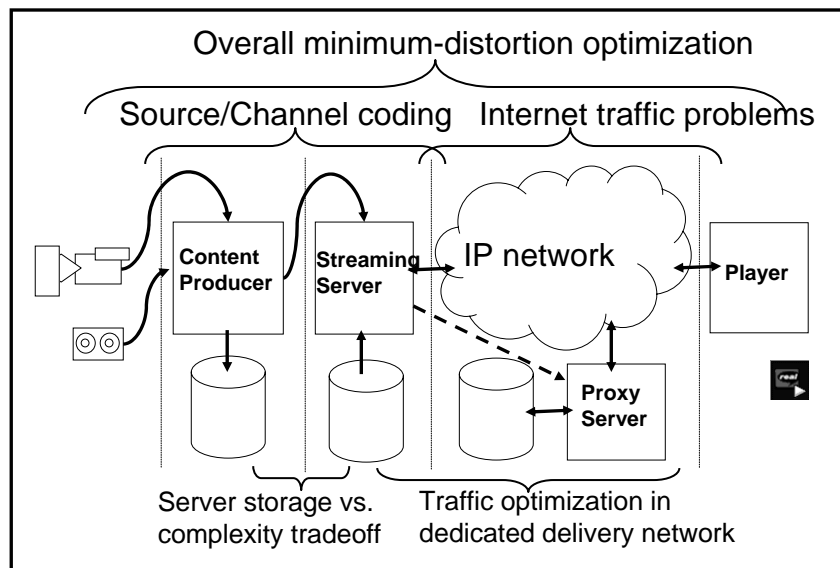
Key Areas in Internet Video streaming (2/3)

- Continuous Media Distribution Services
 - Network filtering
 - Application-level multicast
 - Content replication (mirroring, caching)
- Streaming Server
 - Real-time OS
 - Process management, resource management, file management
 - Storage System

Key Areas in Internet Video streaming (3/3)

- Media Synchronization
 - Intra-stream, inter-stream, and inter-object synchronization
- Protocols for Streaming Video
 - Network-layer protocols
 - IP
 - Transport protocols
 - UDP, TCP, RTP, RTCP
 - Session control protocols
 - RTSP, SIP

Open Problems in Internet Multimedia Delivery



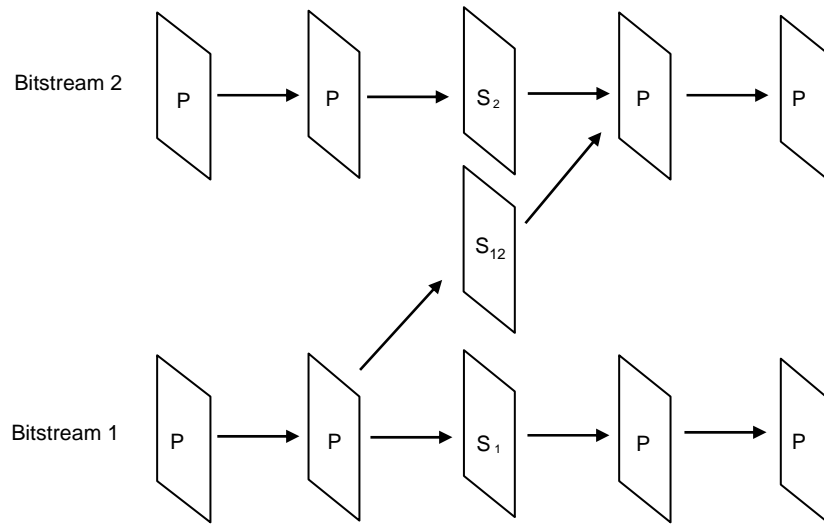
Bandwidth Variation

- “Broadband” Internet access has wider variation:
 - Cable modem: from < 100 to > 1000 Kbit/sec
 - DSL: from < 600 to > 6000 Kbit/sec

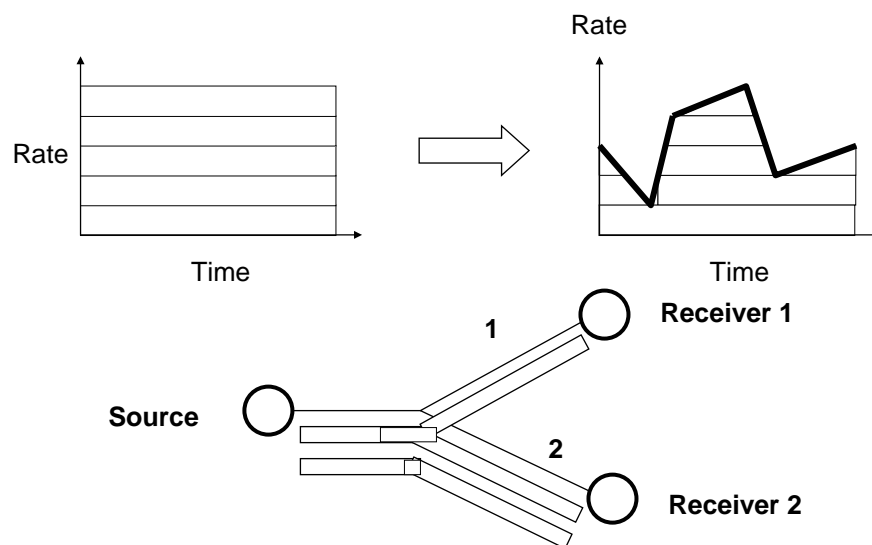
Video Adaptation for Heterogeneous Video Streaming

- Multiple Bit-streams pre-encoded with different bit-rates
 - Large storage
 - Drift problem
 - Complexity in bit-streams management and switching
 - H.264/MPEG-4 AVC SP/SI-frames (seamless switching)
- Real-time Transcoder
 - High complexity in the streaming sever
 - MPEG-21 RAE (Resource Adaptation Engine)
- Scalable video
 - Degree of scalability
 - MPEG-4 FGS (Fine Granularity Scalability), MPEG-21 SVC (Scalable Video Coding)

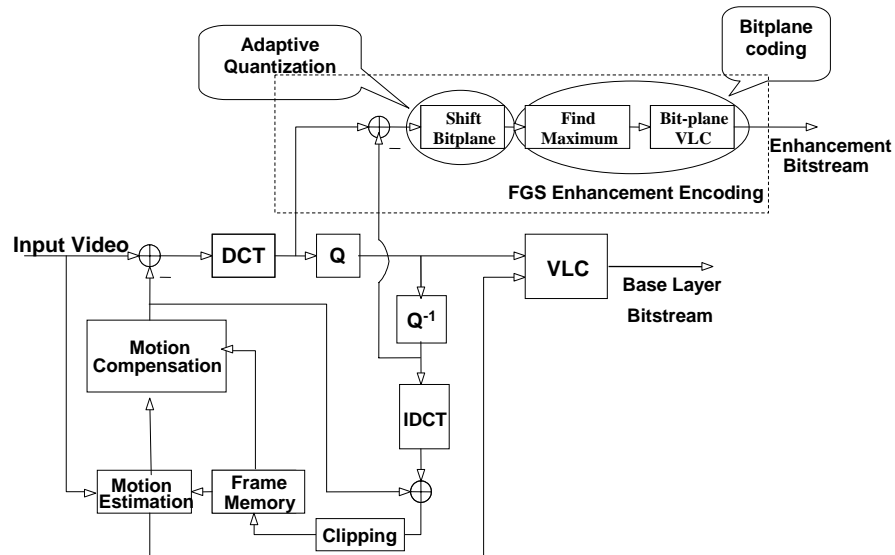
H.264 Bitstream Switching (SP-frames)



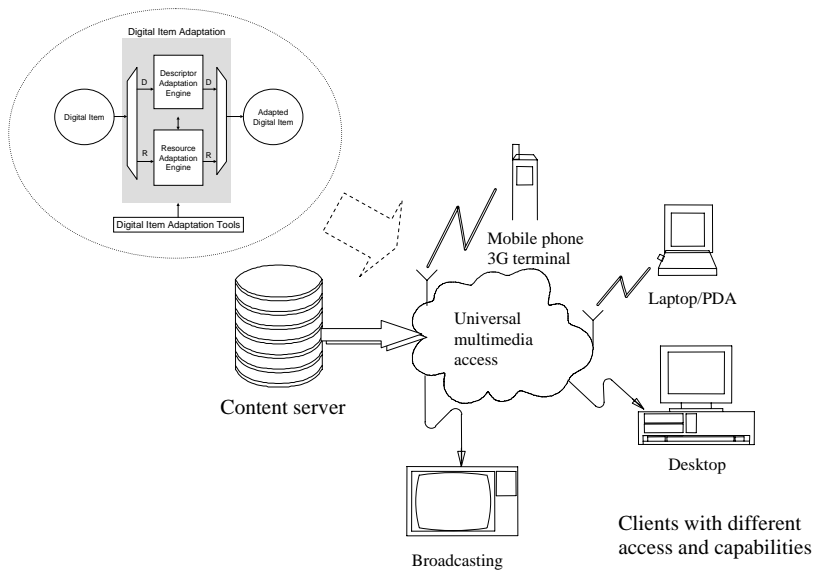
Scalable Coding



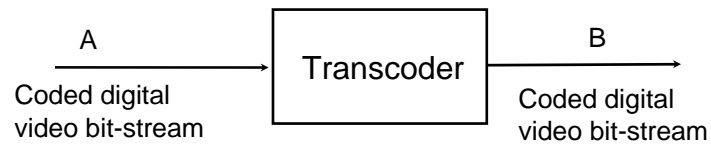
MPEG-4 Fine Granularity Scalability



MPEG-21: DIA for Universal Multimedia Access



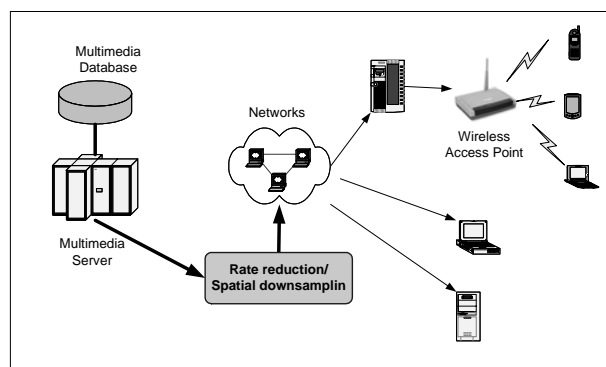
Video Transcoding



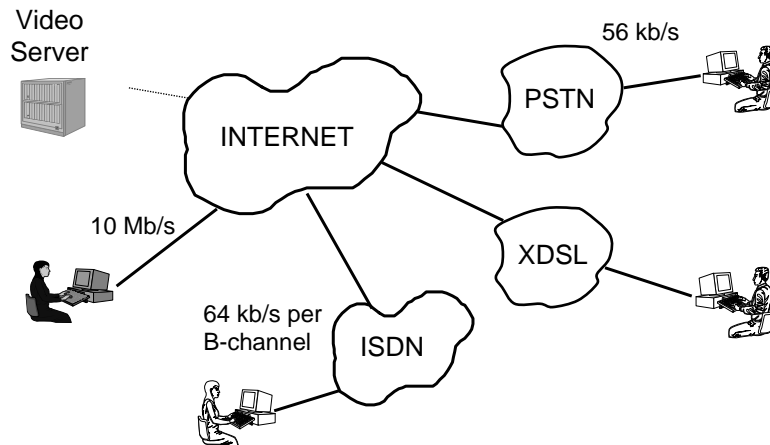
- Bit-rate adaptation
- Spatial/temporal resolution conversion
- Multipoint video conferencing
- Watermarking
- Error resilience
- Encryption
- Video multicast over heterogeneous networks

Heterogeneous Video Transcoding

- Adapting video streams to different types of terminals with different terminal capabilities such as screen size, amount of available memory, processing power and type of network access

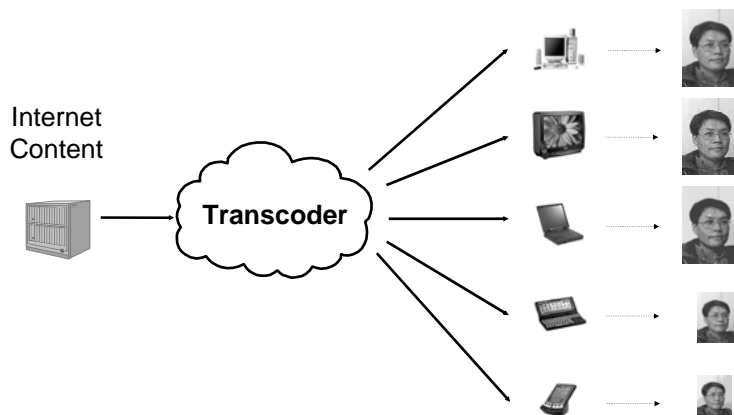


Video Transcoding: Heterogeneous Networks

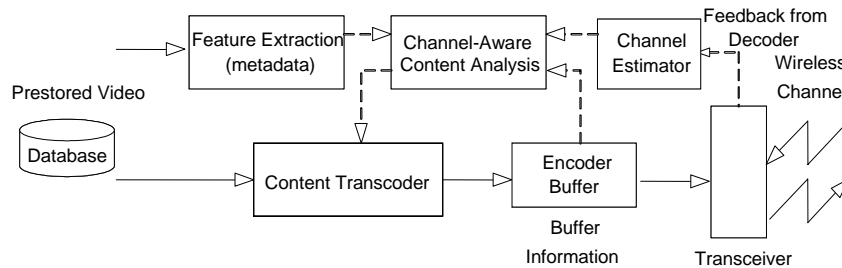


Video Transcoding: Heterogeneous Clients

To deliver multimedia data to diverse devices with different capabilities
(Universal Multimedia Access)

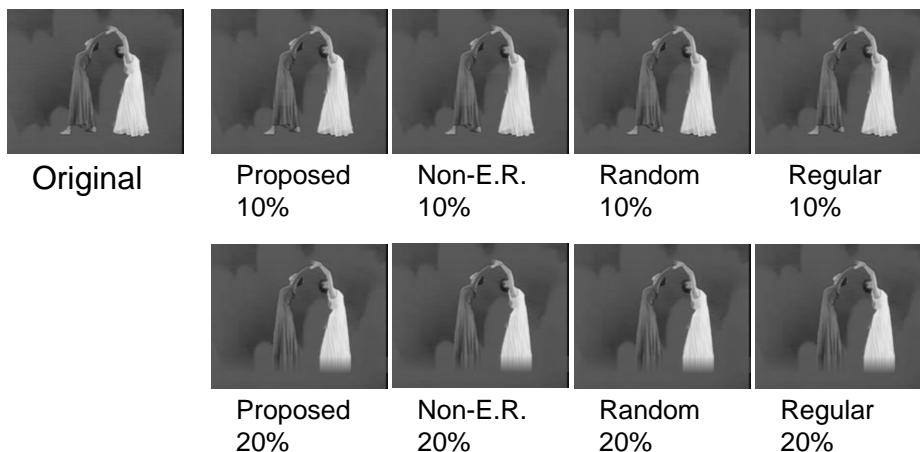


Example: Content-based Video Transcoding with Prestored Metadata



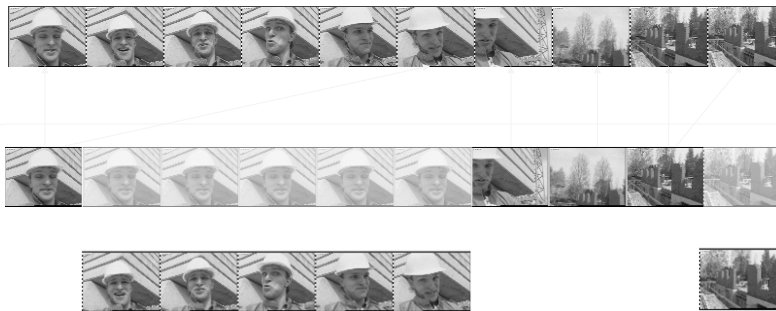
- Approach
 - The server offline extracts the compressed-domain features from the pre-encoded bit-stream
 - The features are then stored as auxiliary data to guide the content transcoding
 - Rate-distortion constrained transcoding

Demo: Content-based Error-Resilience Transcoding



Demo: Content-based Temporal Transcoding for Rate Adaptation

Combine temporal scalability and key-frames for heterogeneous channels and user terminals



Demo: Content-based Temporal Transcoding for Rate Adaptation

Original

Summary

Movie,
1132 frames,
70 key
frames

Movie,
1123 frames,
55 key
frames

h bitstream

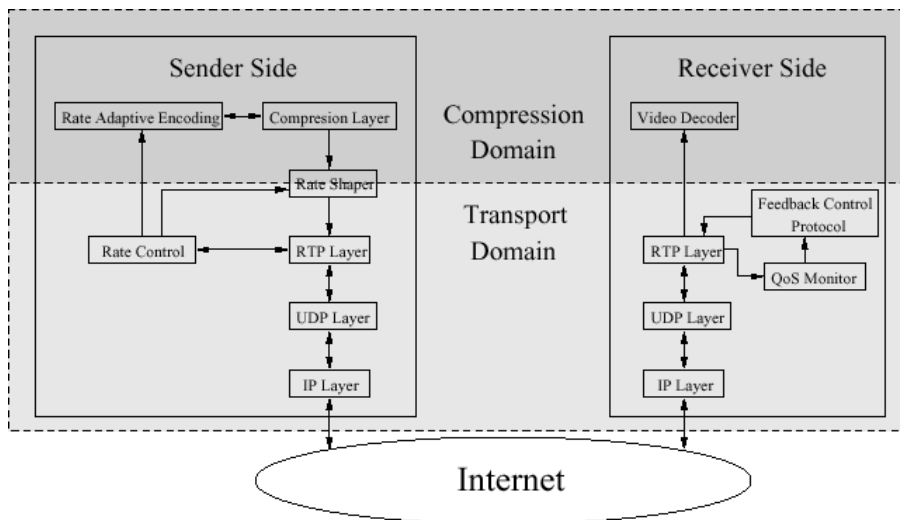
QoS Control for Networked Video

- Network Centric
 - next generation network providing QoS support
- End System-based
 - compatible with current network structure
 - congestion control
 - error control

QoS Control for Networked Video

- Congestion Control
 - To reduce packet loss and delay
 - Rate control, rate adaptive control and rate shaping
- Error Control
 - To handle video quality when packet loss happens
 - FEC, retransmission, error resilience and error concealment

Congestion Control



Congestion Control (Cont.)

- Rate control:
 - UDP replaces TCP for delay reason
 - no congestion control for QoS in UDP
 - rate-based control is usually employed (source based, receiver based and hybrid)

Congestion Control (Cont.)

- Rate control – rate-based control
 - source based: the sender regulates video stream applied to unicast & multicast
 - receiver based: receivers regulate the receiving rate; typically for multicast
 - hybrid

Congestion Control (Cont.)

- Rate control – source-based
 - Probe-based
 - AIMD (Additive Increase Multiplicative Decrease)
 - MIMD (Multiplicative Increase Multiplicative Decrease)
 - Model-based

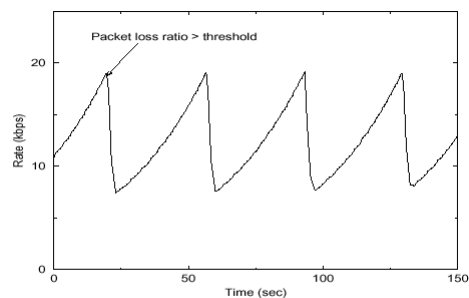


Fig. 5. Source rate behavior under the AIMD rate control.

Congestion Control (Cont.)

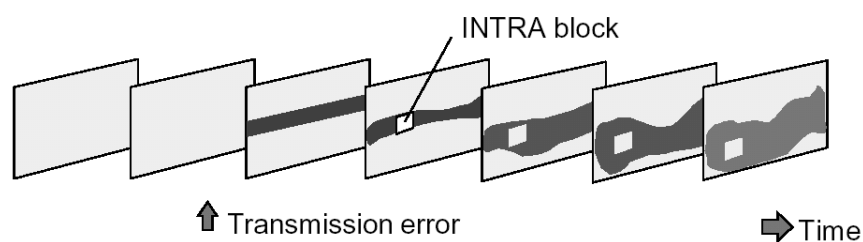
- Rate control – receiver-based
 - for solving the heterogeneity in multicast
 - probe-based approach
 - model-based approach
 - joint-leaving for large number of receivers
 - congestion
 - shared learning or synchronization control

Congestion Control (Cont.)

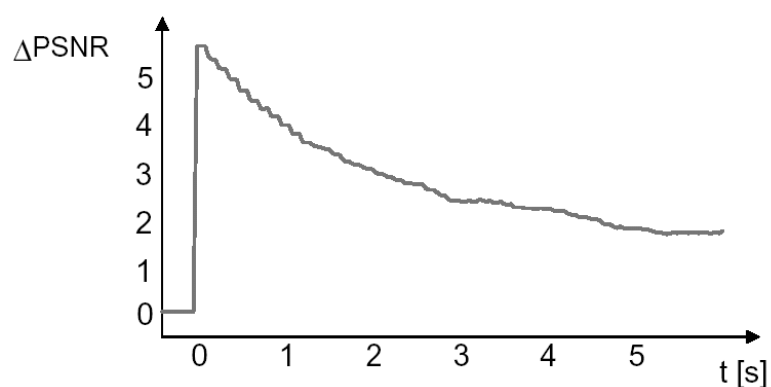
- Rate Shaping
 - adapt the video rate to target network rate constraint
- Server selective frame discard
- Selective DCT coefficient discard

Effect of Error Propagation

- The use of VLCs and predictive techniques in video coding leads to error propagation
- A single bit error can propagate to many bits
- MV prediction causes spatial error propagation
- Motion compensation causes temporal error propagation

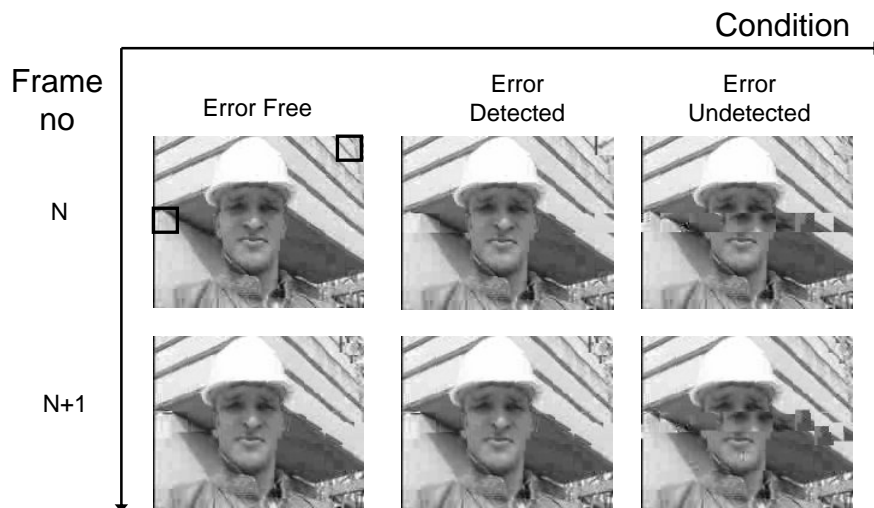


Effect of Error Propagation (Cont.)



- Single burst covering 1/3 of a frame
- Previous frame concealment
- Average over many trials
- No Intra

Effect of Error Propagation (Cont.)



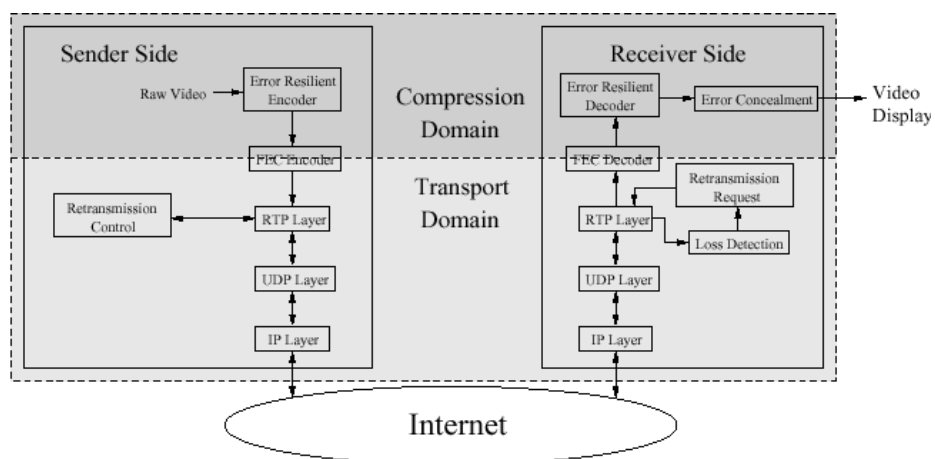
Error Control

- To prevent packet loss by matching the rate of video streams to the available bandwidth in the network.
- packet loss is unavoidable
- other mechanisms to maximize the video presentation quality

Error Control (Cont.)

- FEC
- Retransmission
- Error resilience coding
- Error concealment

Error Control (Cont.)



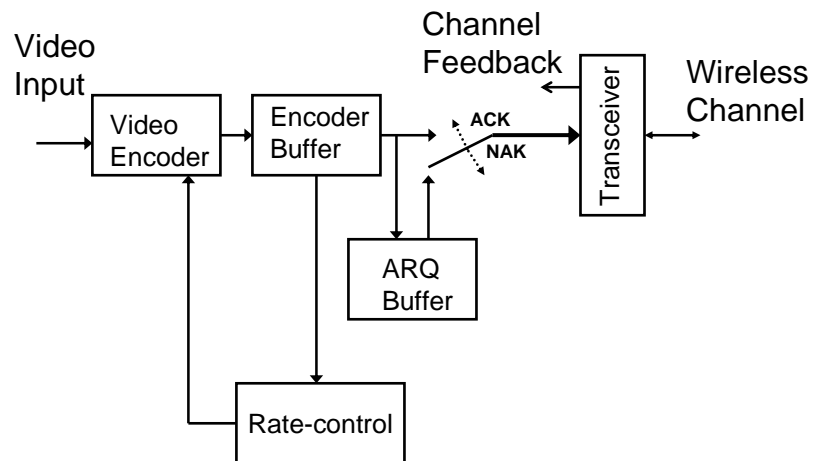
Error Control- FEC

- FEC – channel coding
- Unequal Error Protection and Equal Error Protection
 - increase transmission rate
 - increase delay: long block or interleaving
 - Not adaptive to varying loss characteristic

Error Control- ARQ

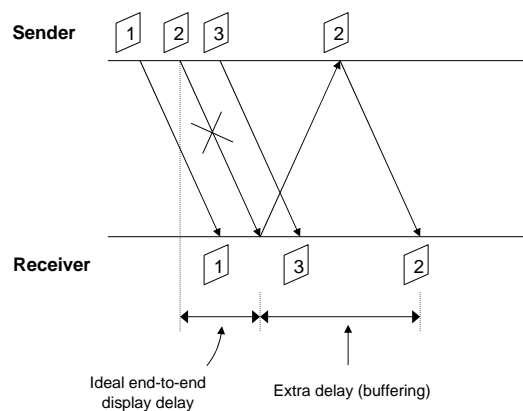
- ARQ
- Need 2-way communication channels
- Effective if round-trip delay is shorter than maximum delay allowed
- Delay-constrained retransmission
- Increase congestion

Error Control- ARQ (Cont.)



Error Control- ARQ (Cont.)

- Very effective with large de-jittering buffer
- Not realistic for delay stringent real-time applications



Error Control: Error Resilience Coding



- sequence number, duplicate packets, duplicate important information
- slice structure, resynch markers, intra-MBs, intra-slices, intra-pictures
- scalable coding with priority and unequal error protection
- multiple reference frames*, error tracking and intra-block refreshing
- video redundancy coding
- multiple description coding
- reversible variable length codes*
- error-resilience entropy coding*

...

Error Control: Error Concealment



Detecting errors through packet sequence number, packet error indicator, invalid codewords, invalid number of DCT coefficients, invalid range of parameters, incorrect sync-marker position, ...



- Temporal error concealment
 - Spatial error concealment
 - Hybrid error concealment
 - Late-cell/packet processing
 - POCS
- ...

DEMO: Error Resilience Coding



Original



Non-E.R. 10%



E.R. 10%



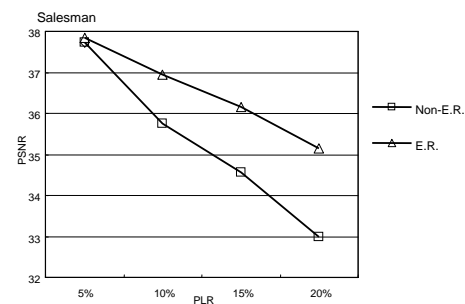
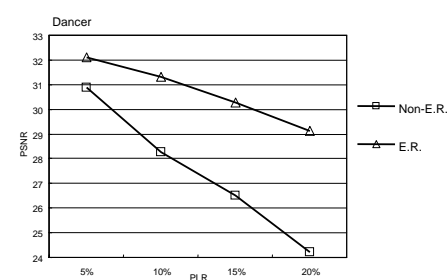
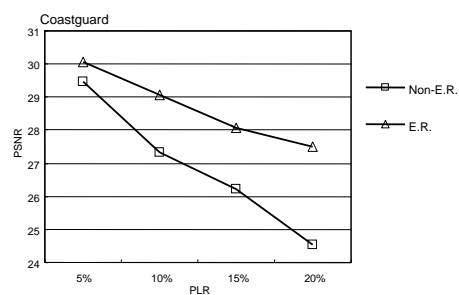
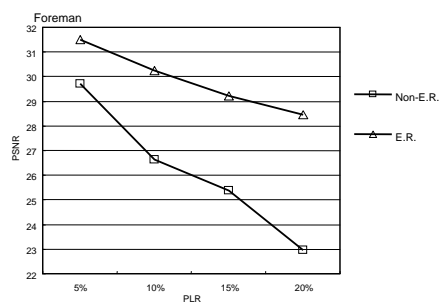
Non-E.R. 20%



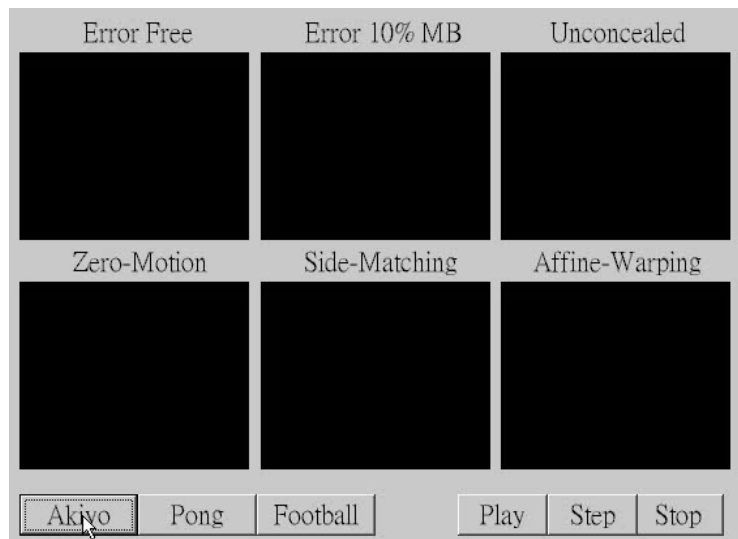
E.R. 20%

"Foreman" with packet loss rate = 10% & 20%

Performance Comparison: Error Resilience Coding



DEMO: Error Concealment



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