Video Transmission over Wireless LAN

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Introduction

- Introduction
- Wi-Fi Multimedia and IEEE 802.11e for QoS Enhancement
- Error Control Techniques

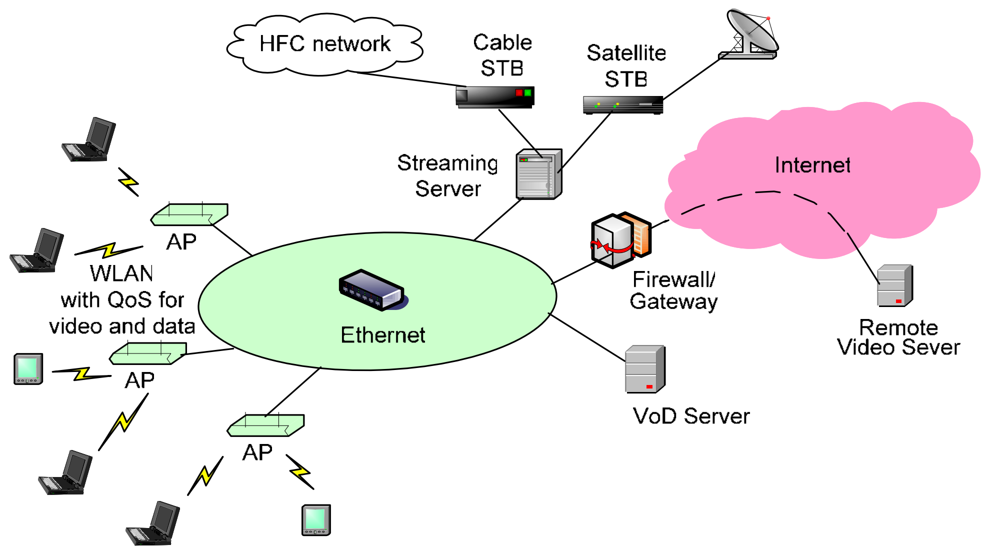
Introduction

- The proliferation of high-rate WLAN products is fueling the development of new applications such as video streaming and triple play offer for home, enterprise, and public access.
  - Entertainment programs and VoD in hot-spots
  - Wireless video distribution in the home
  - Wireless video conferencing and video training for enterprise users
- QoS support is key for video applications over WLAN
  - MAC/PHY layer
  - transport layer
  - application layer

What does QoS mean?

- QoS for video streaming requires
  - Sufficient transmission rate/throughput
    - Emerging standard WMM/802.11e EDCA can provide a higher priority to the video traffic
  - High reliability
    - Various error control techniques correct transmission errors.
  - Bounded delay
    - Admission control and rate control as well as traffic shaping prevent from buffer overflow or excessive delay due to network congestion.

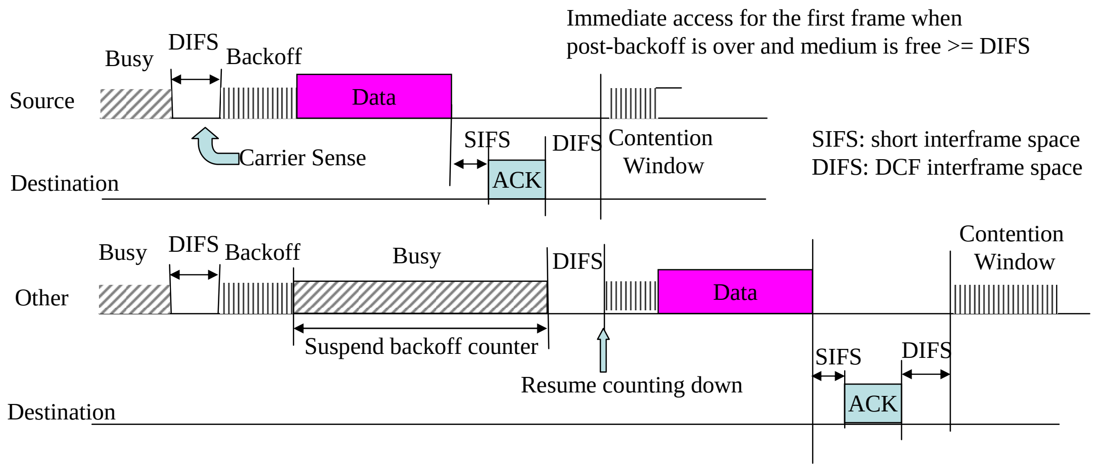
An Example for Video Distribution at Hot Spot



IEEE 802.11 Media Access Control (MAC)

- Distributed Coordination Function (DCF)
  - Carrier sense multiple access with collision avoidance (CSMA/CA)
    - Listen-before-talk
    - Random backoff following a busy medium condition for collision avoidance
    - Physical and virtual carrier-sense mechanism
  - No bandwidth guarantee for QoS support
- *Optional* Point Coordination Function (PCF)
  - Access point as a point coordinator
  - Contention-free polling mechanism
  - Limited bandwidth guarantee for QoS support
  - Currently not commercially available

802.11 Distributed Coordination Function



- No ACK and no MAC-level recovery in broadcast or multicast from AP to stations (STAs) – less reliable

IEEE 802.11e QoS Enhancement

- Enhanced Distributed Channel Access (EDCA)
  - Optimizes the way the network resources are shared among different applications based on a priority scheme - DiffServ QoS.
  - The traffic prioritization is realized with the different medium access parameters for different access categories (ACs).
  - Used in contention period (CP)
  - Simple and product available
- Hybrid Coordination Function (HCF) Controlled Channel Access (HCCA)
  - A QoS-aware hybrid coordinator (HC) at AP controls channel access.
  - HC can gain control of the channel in contention-free period (CFP) and CP with higher medium access priority.
    - Deliver frames to STAs or allocate TX opportunity (TXOP) to STAs by polling
  - The maximum duration that a STA can use the channel is controlled
    - Guarantee the contention-free bandwidth
  - Be able to support IntServ QoS with guaranteed bandwidth and low latency/jitter
  - Complex and not commercially available

Wi-Fi Multimedia (WMM)

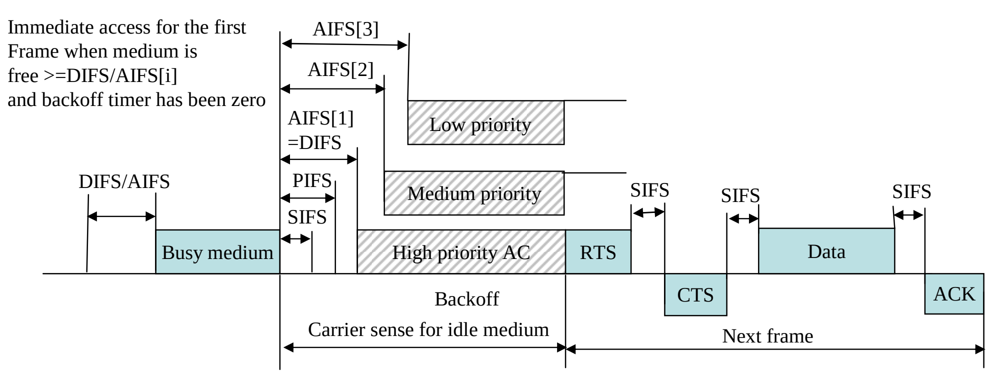
❖ Wi-Fi multimedia (WMM) is a profile of IEEE 802.11e based on Enhanced Distributed Channel Access (EDCA)

❖ WMM introduces traffic prioritization capabilities based on the four access categories (ACs).

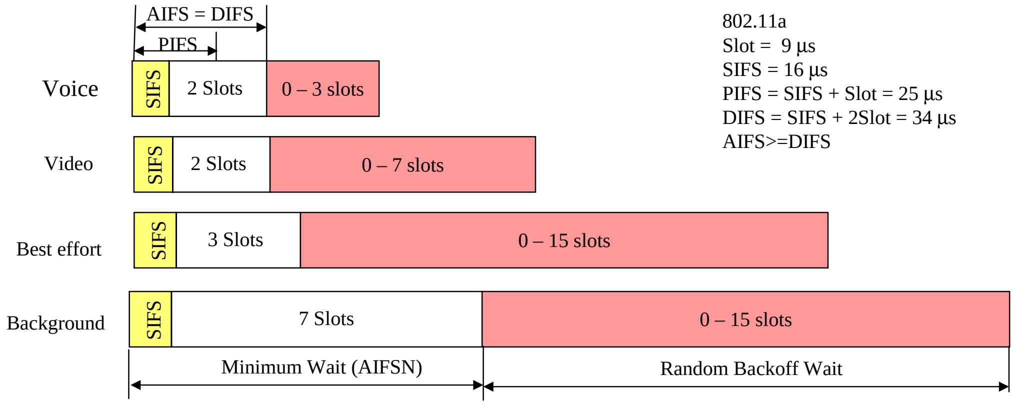
Access Category	Description
WMM Voice	Highest priority Allows multiple concurrent VoIP calls, with low latency and toll voice quality
WMM Video	Prioritize video traffic above other data traffic One 802.11g or 802.11a channel can support 3-4 SDTV streams or 1 HDTV stream
WMM Best Effort	Low Priority Traffic from legacy devices, or traffic from applications or devices that lack QoS capabilities Traffic less sensitive to latency, but affected by long delays, such as Internet surfing
WMM Background	Low Priority Low priority traffic (file downloads, print jobs) that does not have strict latency and throughput requirements

Traffic Prioritization in Wi-Fi Multimedia

❖ Traffic prioritization depends on timing parameters that vary for each AC:
- the minimum interframe space, or Arbitrary Inter-Frame Space Number (AIFSN)
- the Contention Window (CW), or the Random Backoff Wait.
- CWmin, CWmax, AIFS, and TXOP limit for each AC distributed in beacons and may be adjusted over time by the QAP.

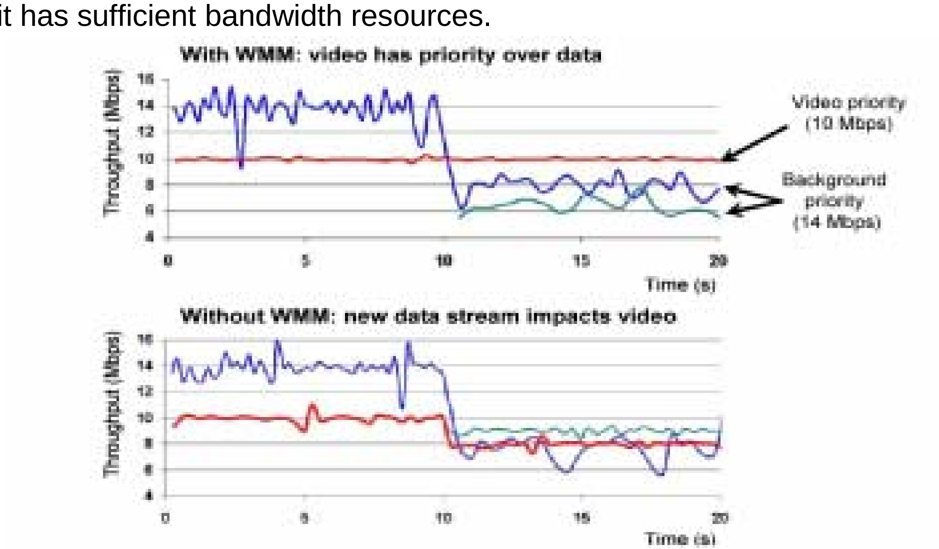


Voice, Video and Data Priorities



Co-existence of Video and Data Traffics

- WMM gives the video stream a higher priority for medium access to ensure that it has sufficient bandwidth resources.



- Source: Wi-Fi Alliance, http://www.wi-fi.com/OpenSection/pdf/WMM_QoS_whitepaper.pdf

Error Control for Reliable Video Transmission

- Wireless networks are unreliable
  - Link errors: random or burst transmission errors, time-varying due to fading, interference, and mobility.
  - Congestion errors: packet loss due to buffer overflow or excessive delay during network congestion
  - Handoffs: packets may be lost during handoffs
- Compressed video delivery requires
  - Low packet loss rate: sensitive to errors due to error propagation in temporal and spatial domains of the video stream
    - 10^{-3} packet loss rate (BER = 10^{-5}) for reasonable quality
  - Bounded delay: late arrival is equivalent to loss for real-time video
    - Interactive real-time visual communications: 100 - 400 ms
    - One-way video streaming (real-time or pre-encoded video): a few seconds (setup delay < 10 sec, transport delay variation < 2 sec)
    - Video downloading: much longer delay acceptable, e.g. file downloading
  - Low delay jitter: especially for real-time video

Error Control Techniques

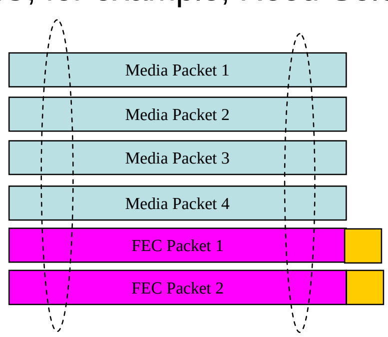
- At Radio PHY and MAC layers
  - Link adaptation at 802.11 radio PHY
  - MAC-Level retransmission
  - Frame fragmentation
  - Transmission power control
- Transport layer error control is *application-aware*
  - Forward Error Correction (FEC)
  - Interleaving
  - Automatic repeat request (ARQ)
  - Hybrid automatic repeat request (hybrid ARQ)
  - Adaptive packetization
  - Unequal error protection
  - Multiple description coding with temporal and spatial diversity
- Application layer
  - Error resilient video coding
  - Error concealment
- Cross-layer design

Error Control Techniques at 802.11 PHY and MAC

- Link adaptation at 802.11 radio PHY
  - 802.11 supports several transmission rates with different modulations and channel coding
    - 802.11a: *6*, 9, *12*, 18, *24*, 36, 48 and 54 mbps
    - 802.11g: *1, 2, 5.5, 11, 6*, 9, *12*, 18, *24*, 36, 48 and 54 mbps
  - Error rate depends on the link transmission rate,
    - the lower the rate, the more robust
  - How to adapt the rate to achieve optimal good throughput?
    - Unicast is supported by current standard
      - Measured received signal (open loop with symmetric channel)
      - No. of retransmissions or packet loss (close loop)
    - Multicast is not supported
- MAC-Level Retransmission
  - Very fast, ACK frame follows data frame
  - Only support unicast

Transport Layer FEC and Adaptive FEC

- Cross-packet FEC, for example, Reed-Solomon codes



- FEC code rate can be adapted based on channel conditions
  - How to estimate the link status?
  - How to adapt the FEC rate?

Transport Layer Retransmission

- ARQ can adapt to the channel errors
  - More efficient than pure FEC in terms of bandwidth utilization.
- However, the tradeoff is longer delay.
  - Limit the maximum number of retransmissions
- For multicast, ARQ is not that efficient.
- Hybrid ARQ combines ARQ and FEC.
- Compared to MAC layer retransmission, latency is much larger.
- Transport-layer ARQ is application-aware

Error Resilient Video Coding

- Add redundancy in video coding to help recovery from transmission errors
  - Trade off coding efficiency for error resilience
- Insert intra-mode frame/slice/macro-block periodically to stop error propagation
  - Random insert intra slices based on the channel error rate
  - Given a total rate as a constraint and channel error rate, minimize the distortion of the video stream by selecting the mode and QP.
- Divide the picture into multiple slices that provides synchronization by adding headers
  - Or just inserting sync markers to isolate the errors.
- Interleaving/flexible macroblock ordering to help error concealment
- Reference picture/area selection
  - With feedback: use correctly received and error concealed frames/regions as reference.
  - Without feedback: can generate multiple bit streams without cross-prediction (video redundancy coding, a simple multiple description coder)
- Insert redundant slices
- Adapting the above encoding parameters based on channel feedbacks

Decoder Error Concealment

- Recover damaged regions based on image/video characteristics and human visual system properties at the decoder
  - Use previous frame
  - Spatial: Interpolate from surrounding region for intra frame
    - Weighted pixel averaging
  - Temporal: Motion-compensated temporal interpolation
    - Replace a damaged MB by its corresponding MB in the reference frame
    - If the motion vector is also lost, recover it first from neighbors
  - More advanced schemes

Unequal Error Protection and Multiple Description Coding

- Unequal Error Protection
  - **Sending control parameters, sequence header and picture header via reliable out-of-band.**
  - **Data Partitioning**
    - Divide the video bitstream into multiple partitions.
    - High priority partitions such as frame headers and slice headers as well as intra coefficients is transmitted more reliably.
  - **Temporal and spatial layered coding**
    - Base layer provides acceptable quality, enhancement layer refines the quality
    - DiffServ: Base layer is transmitted more reliably
      - Bandwidth guarantee
      - more FECs, larger retry limits, etc.
    - Any error in the base layer causes severe degradation
    - The enhancement layer is useless by itself
- Multiple description coding with diversity
  - Generate multiple correlated descriptions for a video sequence
    - any description provides low but acceptable quality
    - additional descriptions provide incremental improvements
  - Spatial diversity: multiple access points, multiple paths
  - Temporal diversity: There is time delay between streams.

Cross Layer Design

- Joint source-channel coding
  - Tradeoffs between the source coding for higher quality video and the channel coding for error robustness
  - Given a total rate constraint, choose the source rate, error resilience mechanism, and channel rate to minimize the *distortion*.
  - Adaptation to channel conditions:
    - Estimate the packet loss rate
    - Adjust the source rate and the channel rate to optimize the performance
- Adaptive cross-layer protection
  - Different error control and adaptation schemes available in different layers
  - Certain protection strategies can be implemented simultaneously in several layers
  - Select appropriate protection schemes at each layer (PHYS, MAC. transport and application) to optimize overall performance (throughput, reliability, delay, efficiency) and complexity.
    - Using different radio link rates: *6*, 9, *12*, 18, *24*, 36, 48 and 54 mbps for WLAN
    - Maximum MAC retry limit
    - Application layer FEC
    - Adaptive packetization and packet size

Summary

- QoS is key to support video over wireless LAN.
  - Transmission reliability
  - Bandwidth
  - Delay and delay jitter
- Different error control and adaptation schemes available in different layers
- Select appropriate protection schemes to achieve optimal system performance
  - Layered coding with unequal protection
  - Multiple description coding with diversity
  - Adaptive cross-layer protection

Abbreviations and Acronyms

- AC access category
- AIFS arbitration inter frame space
- AIFSN arbitration inter frame space number
- BSS basic service set
- BSSID basic service set identification
- CA collision avoidance
- CAP controlled access phase
- CSMA carrier sense multiple access
- DIFS distributed (coordination function) interframe space
- EDCA enhanced distributed channel access
- EDCAF enhanced distributed channel access function
- ESS extended service set
- FCS frame check sequence
- FEC forward error correction
- FER frame error ratio
- HCCA HCF controlled channel access
- HC hybrid coordinator
- HCF hybrid coordination function
- HDTV High Definition TV
- IGMP Internet Group Management Protocol
- MAC medium access control
- NAV network allocation vector
- PC point coordinator
- PCF point coordination function
- PHY physical layer
- PIFS point (coordination function) interframe space
- QAP QoS access point
- QoS quality of service
- RSVP Resource reservation protocol
- RSSI Received signal strength indication
- SDTV Standard Definition TV
- SIFS short interframe space
- STA station
- TBTT target beacon transmission time
- TXOP transmission opportunity
- WEP wired equivalent privacy
- WM wireless medium
- WMM wi-fi multimedia