Broadcasting Video in Dense 802.11g Networks Using Application FEC and Multicast

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Dr James Martin
School of Computing
Clemson University
Clemson, SC
jim.martin@cs.clemson.edu

Dr James Westall
School of Computing
Clemson University
Clemson, SC
westall@cs.clemson.edu

Rahul Amin
ECE Department
Clemson University
Clemson, SC
ramin@clemson.edu
Introducing...*crowd spots*

- A crowd spot involves hundreds, thousands, or tens of thousands of people (and wireless devices) temporarily grouped together in dense formation.
  - Drivers: deployment of smartphones, move towards multi-modal devices, availability of infrastructure
  - Of particular interest are sports and entertainment venues
- 802.11 has supported large events since the early 1990’s.
  - Many studies point out the deficiencies of 802.11b – it does not scale.
    - Several works found many handoffs cause service interruption without ever moving the user (the device connects back to the same AP >50% of the time in one study)
- Crowd spots supported on managed networks – society is evolving....
  - Satellite to mobile devices – early form of the concept
  - NASCAR events provide handheld device video using Sprint’s licensed spectrum (now considered ‘outdated’)
- Wireless carriers recognize the need to support crowd spots – one way is to offload application data onto WiFi.
  - Economic models are being invented.....
Problem Statement

• For this study we focus on sports stadiums and assume the driving application is video
  – To scale to hundreds of users per Access Point, multicast is required

• Recent advances in application level forward error correction makes efficient coding feasible on hand held devices

• Problem Statement:
  1. What are the limits of this system? What are the sensitive parameters? How can we find the ‘optimal’ system settings?
  2. Develop a dynamic algorithm that keeps the system operating so as it can provide predictable levels of service quality.

In the research presented in this talk we address problem #1
Modeling Application Based Forward Error Correction

- For a given APFEC system parameterized by N,k
- The coding rate is k/N, referred to as r
- Let 1-r represent the redundancy (N-k)/N
- Let p represent the long term loss rate of the network
- Let p’ represent the long term loss rate experienced by the flow AFTER APFEC
- Our work assumes an ideal, modern coder such as one based on Raptor codes (we assume the ‘receiver overhead’ that can provide a balance between computational complexity and APFEC effectiveness is 0)
- And if we assume uncorrelated packet loss in the network, we expect:
  - If (1-r)>p, then p’ →0 as N goes to infinity
  - If (1-r)=p, then p’ →p/2 as N goes to infinity
  - If (1-r)<p, then p’ ->p as N goes to infinity
- If we assume correlated packet loss, then it depends on the details of the process (e.g., the intensity and level of correlation or loss events).
  - In general, you want to operate the system so that 1-r is larger than p
  - In addition, a larger block size offers better correction capability, however this causes packet delay to grow which requires a larger playout buffer which increases the ‘channel zapping’ time
  - Given that p is likely to change over time, the optimal system adapts based on current conditions
Simulation Model

- **Wired Server Node**: 1Gbps, prop delay: varied
- **AP**: 1Gbps, .5ms prop delay
- **Router**: 6 Mbps basic rate, 54 Mbps
- **AP FEC**: Source #1, Source #2
- **Monitor Server Node**: MBL Monitor flow
- **Unicast background traffic (DS or US)**
- **Monitor Station**: Distance between AP and ALL wireless nodes is either 10 M or 60 M
- **Background Traffic Nodes**: Unicast Flow 1, Multicast Flow 1, Multicast Flow 2
- **Streaming Server Node**: Node 1- Video session traced
- **Wireless Nodes with receive side APFEC, playback buffer, and viewer**
- **Artificial packet loss**
Performance Metrics

- Estimate the level of correlated loss

  Given the vector $m_i$ : for (i=1,2, ...n) denotes the number of loss bursts having length i the MBL is defined as follows:

  $$MBL = \frac{\sum_{i=1}^{n-1} im_i}{n-1 \sum m_i}$$

  More specifically, the MBL estimates the 1/r parameter assuming the loss process can be modeled by a two-state GE model

- APFEC Effectiveness

  $$Fec_{eff} = 1 - \frac{P_e}{P_{raw}}$$ where $P_e$ is the effective loss rate that is observed by the video stream receiver after FEC and $P_{raw}$ is the loss rate over the channel observed by the station before FEC is applied.
Performance Metrics

- **Latency**: The average one-way, end-to-end latency of UDP packets sent by the video server corresponding to a stream.
  - The metric can be specific to one stream or the average of multiple streams.

- **Artifact assessment**: all based on a trace of packets delivered to the streaming viewer (i.e., after APFEC). The trace is divided into intervals of fixed time duration (e.g., 20 seconds).
  1. **Loss Tolerance Artifact (LTA)**: The loss rate is computed for each interval. An artifact occurs each time the loss rate of an interval exceeds a threshold (e.g., 2%). The LTA estimates the number of intervals that are ‘in error’ per hour.
  2. **Minimum Throughput Artifact (MTA)**: The arrival rate of the stream under observation is computed for each interval. An artifact occurs each time the throughput observed in an interval is less than a threshold (e.g., 75% of the long term video encoding rate). The MTA estimates the number of intervals that are ‘in error’ per hour.
  3. **Playback Buffer Depletion Artifact (PBDA)**: Provides a measure of sustained throughput loss that is with respect to the size of the playback buffer. For time scales of multiple intervals, we estimate the amount of time a playback buffer can support the ‘outage’. Once depleted, we assume a ‘channel zap’ amount of time to fill the buffer. The PBDA assesses how frequently this occurs.
  4. **Channel Zapping Time**: the amount of time it takes to fill the playback buffer.
Baseline Analysis
Baseline Analysis
Baseline Analysis

a. Channel Zapping Time (seconds)

b. Average Packet Latency (seconds)
Baseline Analysis (fixed loss rate)
Impact of channel models
Conclusions

- If the goal is to support hundreds of multicast viewers in dense 802.11 deployments, the crucial factors:
  - Bandwidth allocation of basic rate to data rate (there’s a fairness issue here....)
  - Adaptive FEC / Video distribution system- challenging as multicast is involved
  - Very difficult to assess how the network is behaving. Best way is to tie the assessment to the resource allocation plane.
- Ideas for going forward
  - Prioritize multicast channel access (require the range of unicast DIFS/SIFS delays to be larger than those used for multicast transmissions)
  - Combine 802.11 with 3G/4G to increase the reliability.
- Next steps
  - Continue developing a ‘multicast streaming’ assessment/prediction tool- based on measured data it provides guidance on the best choice of (N,k).
  - Need MBL data points from a large scale crowd spot
  - Develop the adaptation algorithm
What have we missed ???

• Adapt analysis so that correlation is quantified in units of time rather than packets
• Interleaving (not sure if it’s required….depends on the extent of the correlated loss)
• 802.11n - the network will benefit from the improved RF capabilities. Other aspects of 802.11n that help?
• Any relevant IETF or IEEE work ?