Study of Video Transmission on TETRA Enhanced Data Service Platform

Vesa Vehkalahti
Helsinki University of Technology
Communications and Networking Department
Supervisor: Professor Raimo Kantola
Instructor: M.Sc. Pekka Parviainen

Content of Presentation

- Background
- Objectives of the thesis
- TETRA/TEDS
- Video measurements
  - Video measurements with the Bandwidth Limiter
  - Video measurements with the TEDS prototype
- Conclusions
- Possible future work

Background

- Thesis is part of and prepared within the framework of the CELTIC DeHiGate project (2005-2008) in Communications and Networking Department at TKK, jointly financed by TEKES, EADS Secure Networks and Suomen Erillisverkot
- The project demonstrates a secure broadband deployable mobile wireless communication system for emergency services
- Video measurements were conducted at EADS Secure Networks

Objectives of the Thesis

- Study essential settings / parameters which affect picture quality and functionality of video and total video delay during video transmission
  - Goal is to decrease total video delay as much as possible, and at the same time
  - achieve as good picture quality and functionality of video as possible by optimizing video transmission settings / parameters
- Find best suitable video codec for TEDS based on the results of the video measurements with the bandwidth limiter
- Do video measurements with the TEDS prototype using the best suitable video codec and examine video quality and performance
- Give an overview of selected video codecs and based on literature research find reasons for the performance of the codecs in the video measurements

TETRA/TEDS (1/2)

- TErrestrial Trunked RAdio (TETRA) is a digital trunked mobile radio standard developed by the European Telecommunications Standards Institute (ETSI)
- TETRA is developed to meet the needs of Professional / Private Mobile Radio (PMR) user organisations:
  - Especially public safety e.g. police forces, fire departments and ambulance services
- TETRA has been developed in Releases (phases)
- TETRA Release 1 provides only voice and low-speed data transmission up to 28.8 kbps (Multi-slot Packet Data, 4 slots)
  - uses only π/4 DQPSK modulation in a 25-kHz channel
    - DQPSK = Differential Quadrature Phase-shift Keying

TETRA/TEDS (2/2)

- TETRA Enhanced Data Service (TEDS) is a part of TETRA Release 2
- TEDS is fully backwards compatible and can be fully integrated with existing TETRA Release 1 networks
- TEDS enables a high-speed packet data service and multimedia service capabilities e.g. real-time mobile video transmission (>10 times faster data rate over TETRA)
- TEDS uses 4-QAM, 16-QAM and 64-QAM modulation schemes in 25-kHz, 50-kHz, 100-kHz and 150kHz channels
  - QAM = Quadrature Amplitude Modulation
- TEDS can reach packet data throughputs e.g.:
  - 64-QAM (4 slots) in 50-kHz channel, from 80 kbps up to 160 kbps
  - 64-QAM (4 slots) in 100-kHz channel, from 175 kbps up to 349 kbps
  - 64-QAM (4 slots) in 150-kHz channel, from 269 kbps up to 538 kbps

More information about TETRA/TEDS: http://www.tetra-association.com/

Video Measurements

Test Bed Equipment and Software

- Two identical Acer TravelMate 2480 laptops with:
  - Intel Celeron M 420 1.6 GHz / 512 MB of RAM
  - Intel GMA 950 integrated video controller with 224 MB of shared system memory, and 14.1” WXGA TFT LCD (1280x800 pixel resolution)
- Logitech QuickCam for Notebooks Deluxe web camera
- VLC (Video LAN Client) media player for video transmission
  - an open source based the cross-platform multimedia player and streaming server
  - supports many video codecs e.g. H.264, MPEG-4, div3, H.263 and Wmv2
- VLC has many versatile features and adjustable settings and parameters e.g.:
  - Video codec, bitrate, resolution, frame rate
  - Many kinds of delay and buffering parameters that affect the sender or receiver side during video transmission

Two identical laptops

Logitech web camera

Evaluation Methods

- Many different combinations of resolution and frame rate (e.g. 352 x 288 at 25 fps) were used
- Measurement time was five minutes for each combination
- Picture quality and functionality of video was evaluated with:
  - No motion in the video picture, with slow motion and with fast motion

Evaluation of Video Quality (1/2)

- Video quality evaluation was based on objective and subjective criteria
- Objective quality evaluation was based on:
  - Statistic data obtained from VLC media player:
    - Lost (video) frames at the receiving end (receiver laptop)
    - Send rate in kbps (sender laptop)
  - CPU usage of the sender and the receiver laptops
  - Total video delay measurements

Evaluation of Video Quality (2/2)

- Subjective quality evaluation was based on visual experience and assessments during video measurements
- Video functionality was evaluated using grades: **Excellent, Good, Satisfactory, Poor, Non-functional**
- Picture quality was evaluated using grades: **Excellent, Good, Satisfactory, Poor**
  - Also amount of fuzziness, pixelation (blockiness) and motion trails were observed

Video Functionality Grades

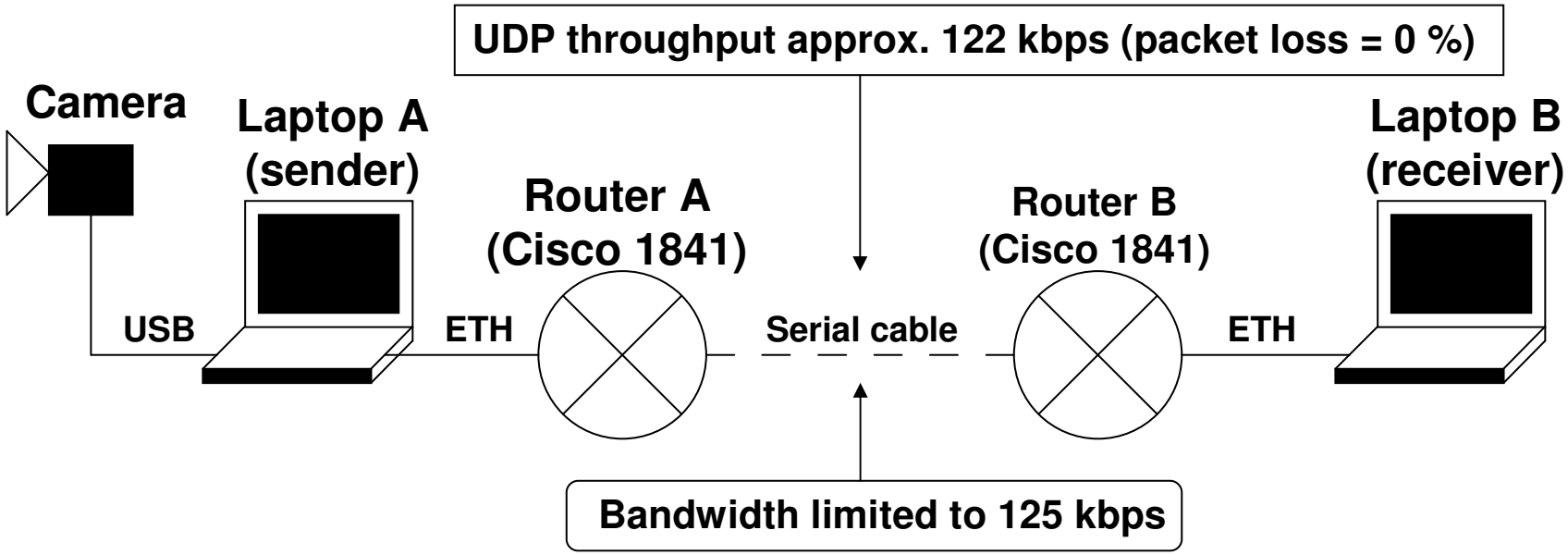
- **Excellent** → Video does not jam at all or only a few times for less than one second in the long run (i.e. during five minutes measurement time)
- **Good** → Video picture jams infrequently for two to five seconds at a time in the long run
- **Satisfactory** → Video picture jams frequently for less than two seconds at a time in the short run
- **Poor** → Video picture jams frequently at least for five seconds at a time in the short run
- **Non-functional** → Video picture is freezed on the screen from the beginning of measurement period to the end

Picture Quality Grades

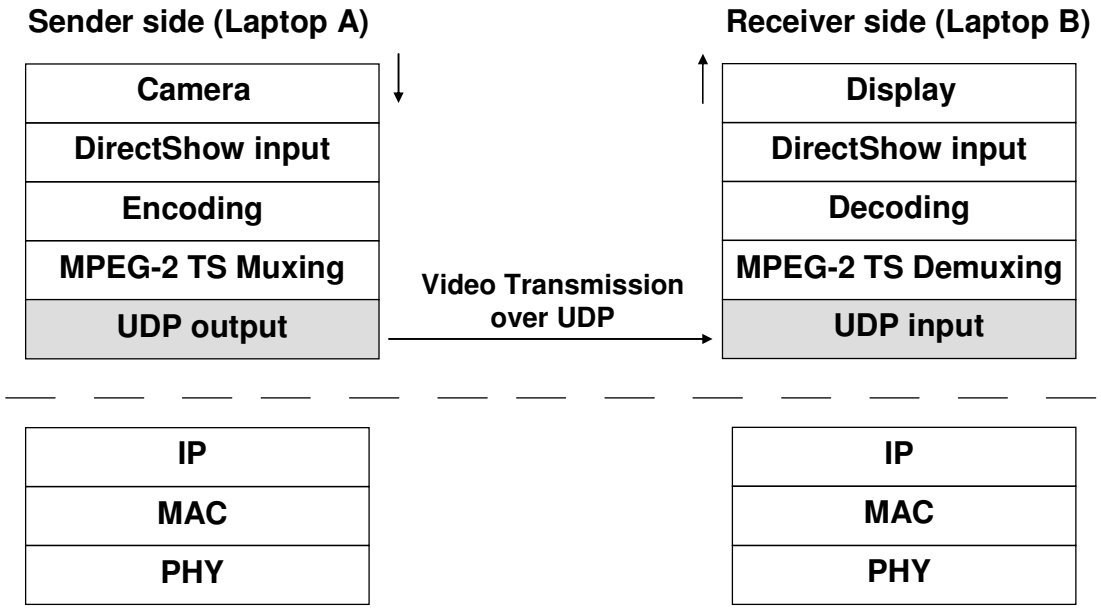
- **Excellent** → Video picture is very good quality and all the details in the picture are easy to observe
- **Good** → Video picture is of uniform quality and it is possible recognize most of details in the picture
- **Satisfactory** → Video picture is fuzzy and details in the picture are difficult to observe. However it is possible to recognize basic forms and some details.
- **Poor** → Video picture is so messy that it is impossible to observe details in the picture

Video Measurements with the Bandwidth Limiter

Network Topology of the Video Measurements with the Bandwidth Limiter

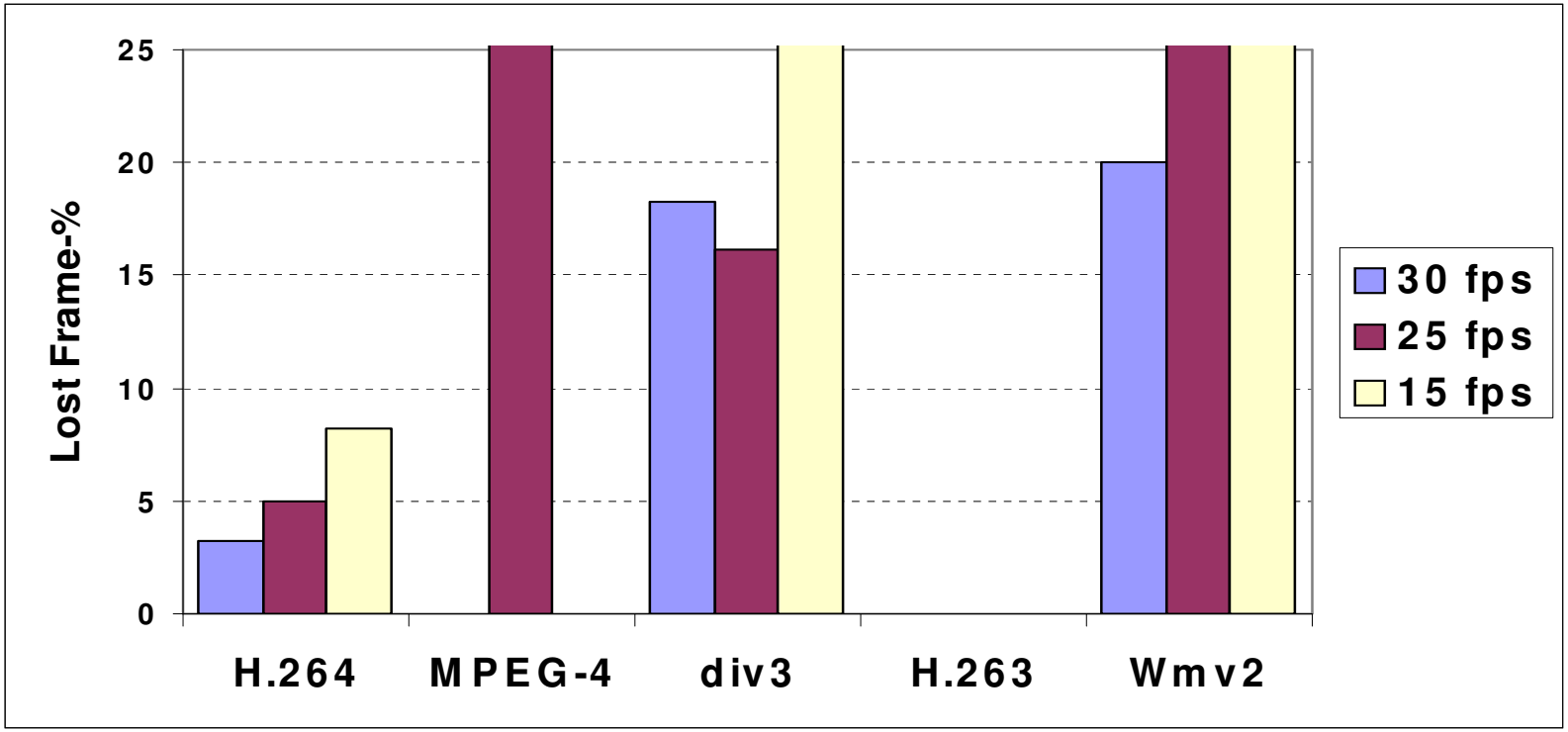


Video Transmission Using VLC



- **Used video codecs:**
  - **H.264** (same as MPEG-4 AVC / Part 10) is the newest video coding standard
  - **MPEG-4** Visual (same as MPEG-4 Part 2)
  - **div3 (DivX version 3)** is implementation of MPEG-4 Part 2
  - **H.263**
  - **Wmv2** (Windows Media Video version 8)

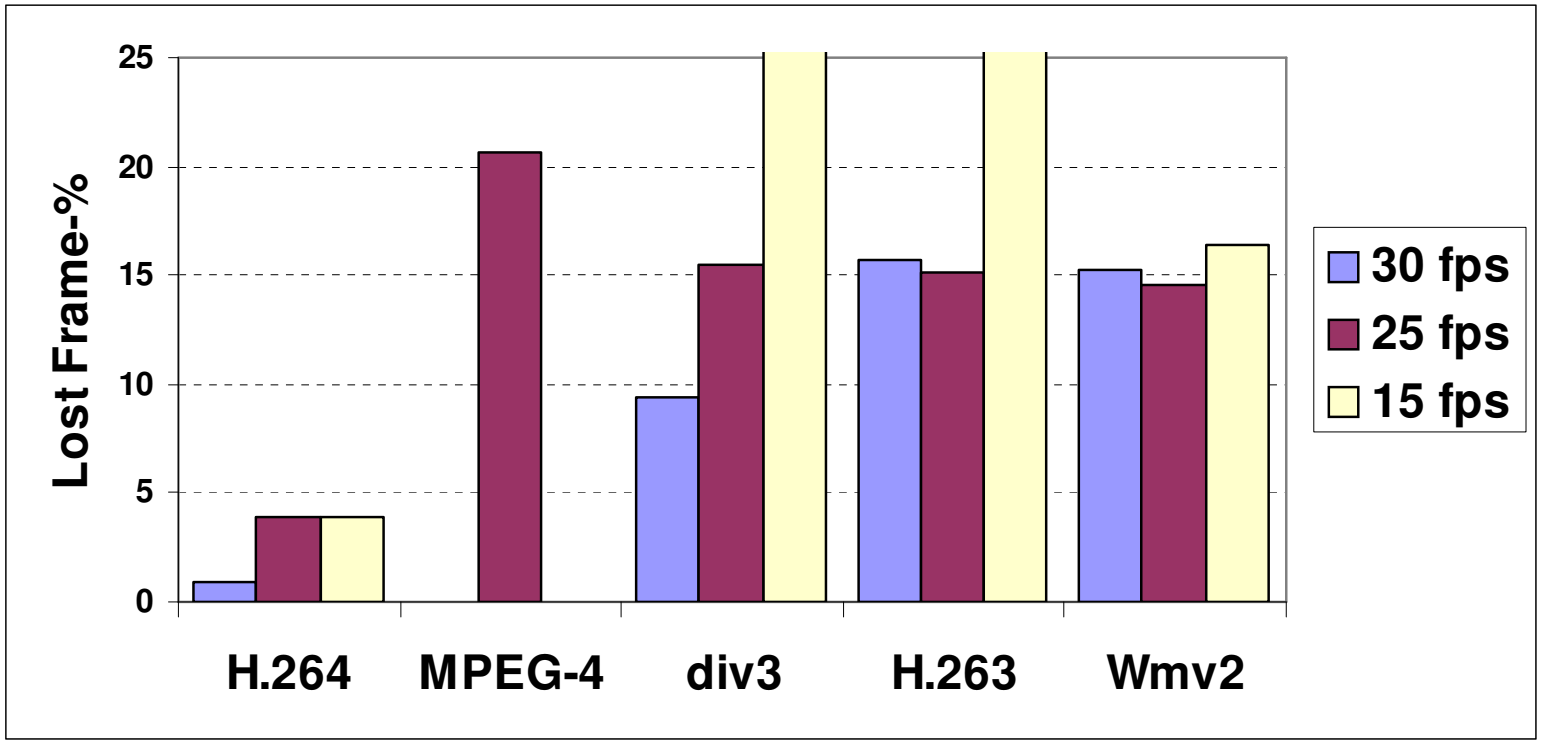
Lost Frame-% at the Receiving End (Resolution of 640 x 480)



OVERALL FUNCTIONALITY / PICTURE QUALITY IN MOTION:

- H.264 ➔ **Satisfactory**
- MPEG-4, div3, Wmv2 ➔ **Non-functional**
- Resolution of 640x480 is not supported by H.263
- 30 fps and 15 fps are not supported by VLC using MPEG-4

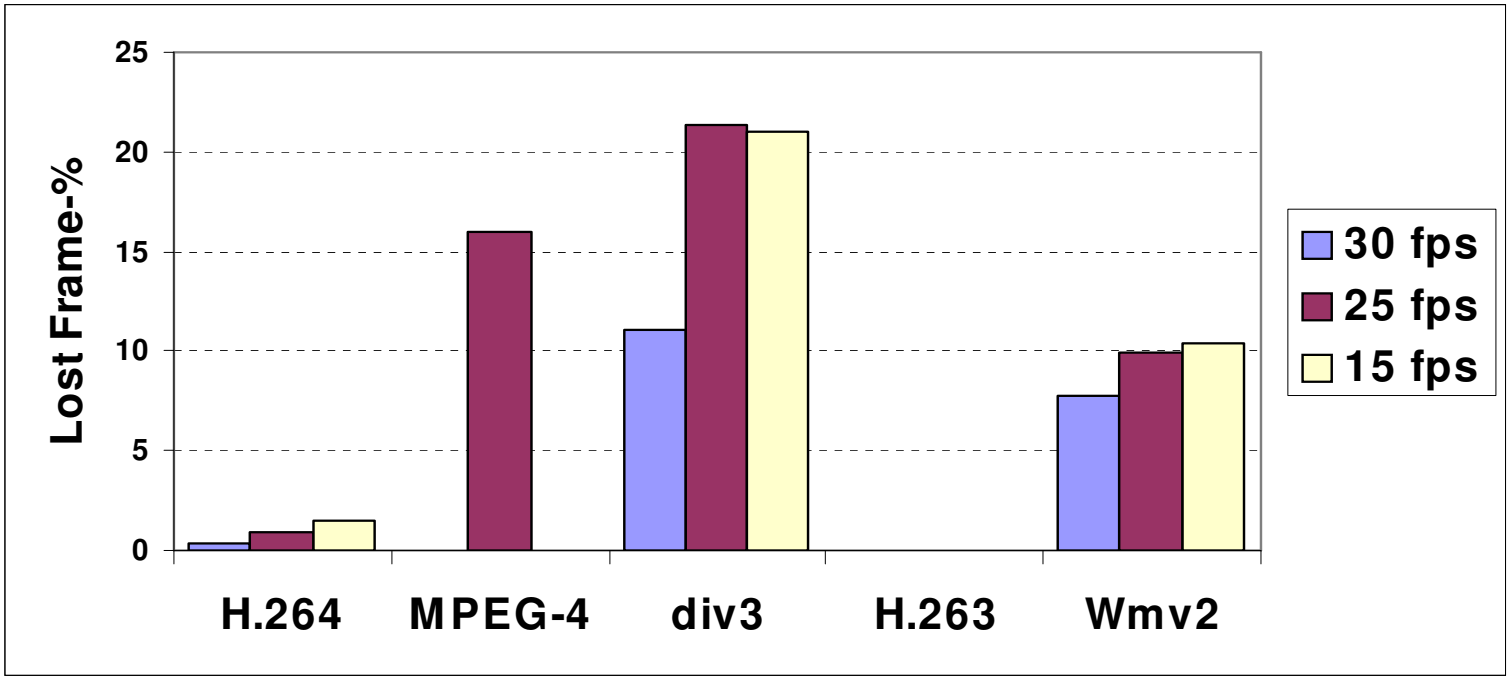
Lost Frame-% at the Receiving End (Resolution of 352 x 288)



OVERALL FUNCTIONALITY / PICTURE QUALITY IN MOTION:

- H.264 ➔ **Excellent** / **Good**
- MPEG-4, div3 H.263, Wmv2 ➔ **Poor** / **Poor–Satisfactory**
- 30 fps and 15 fps are not supported by VLC using MPEG-4

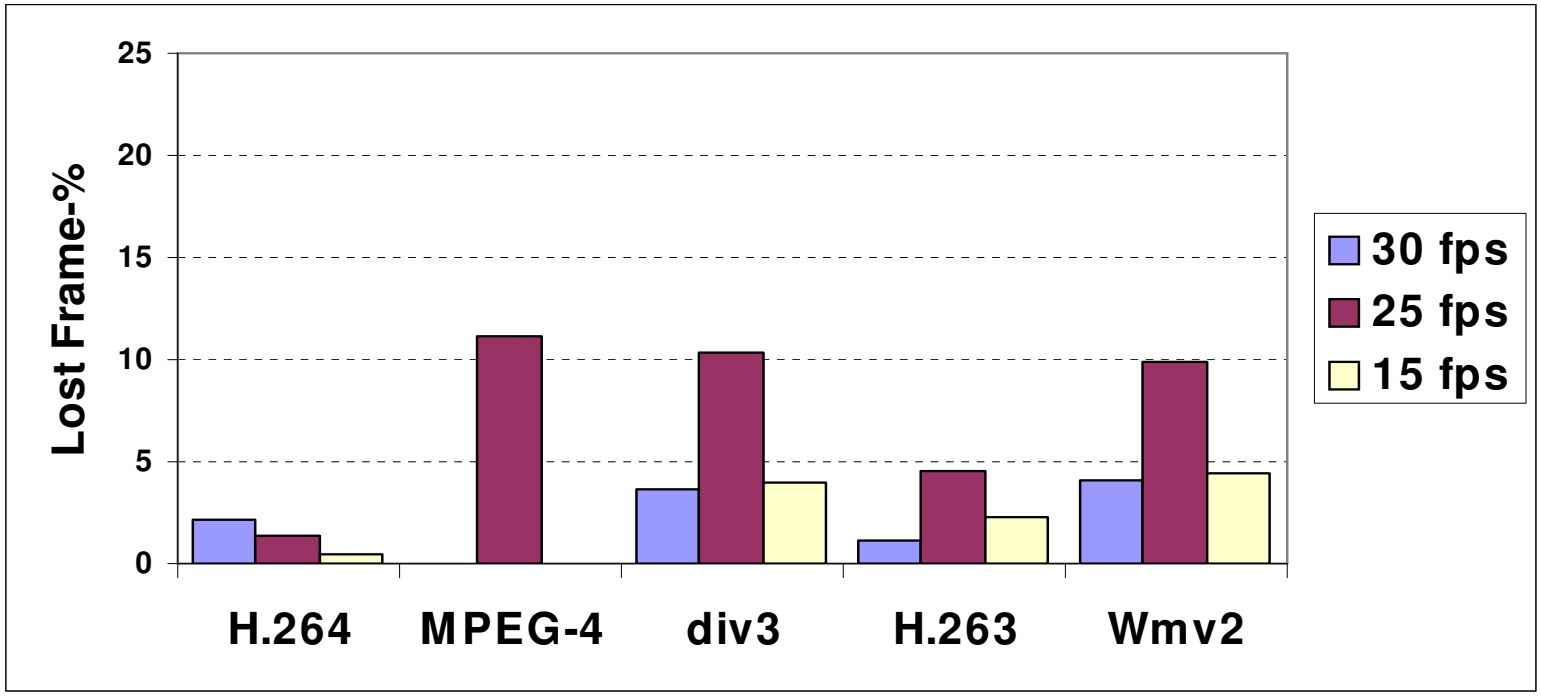
Lost Frame-% at the Receiving End (Resolution of 320 x 240)



OVERALL FUNCTIONALITY / PICTURE QUALITY IN MOTION:

- H.264 ➔ **Excellent** / **Excellent**
- MPEG-4, div3 H.263, Wmv2 ➔ **Poor** / **Poor–Satisfactory**
- Resolution of 320x240 is not supported by H.263
- 30 fps and 15 fps are not supported by VLC using MPEG-4

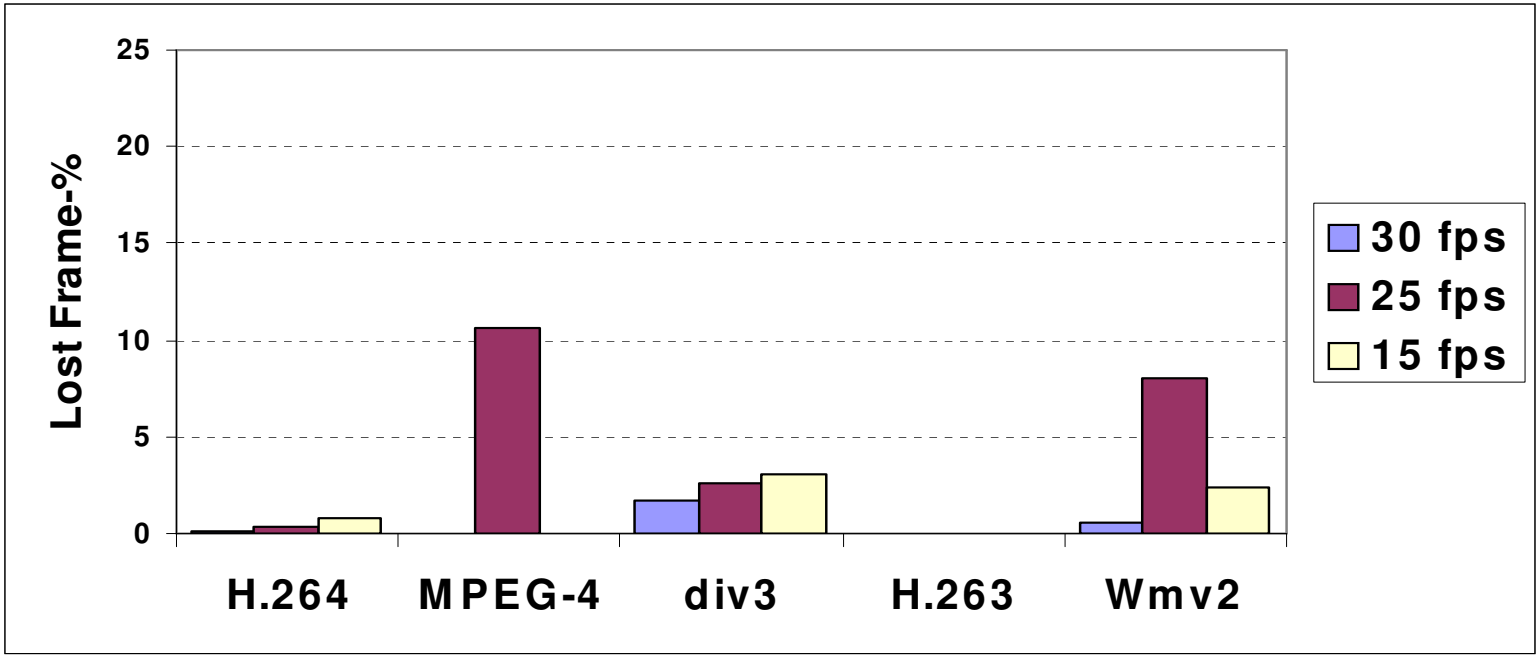
Lost Frame-% at the Receiving End (Resolution of 176 x 144)



OVERALL FUNCTIONALITY / PICTURE QUALITY IN MOTION:

- H.264 ➔ **Excellent** / **Excellent**
- MPEG-4, div3 H.263, Wmv2 ➔ **Good–Excellent** / **Poor-Satisfactory**
- 30 fps and 15 fps are not supported by VLC using MPEG-4

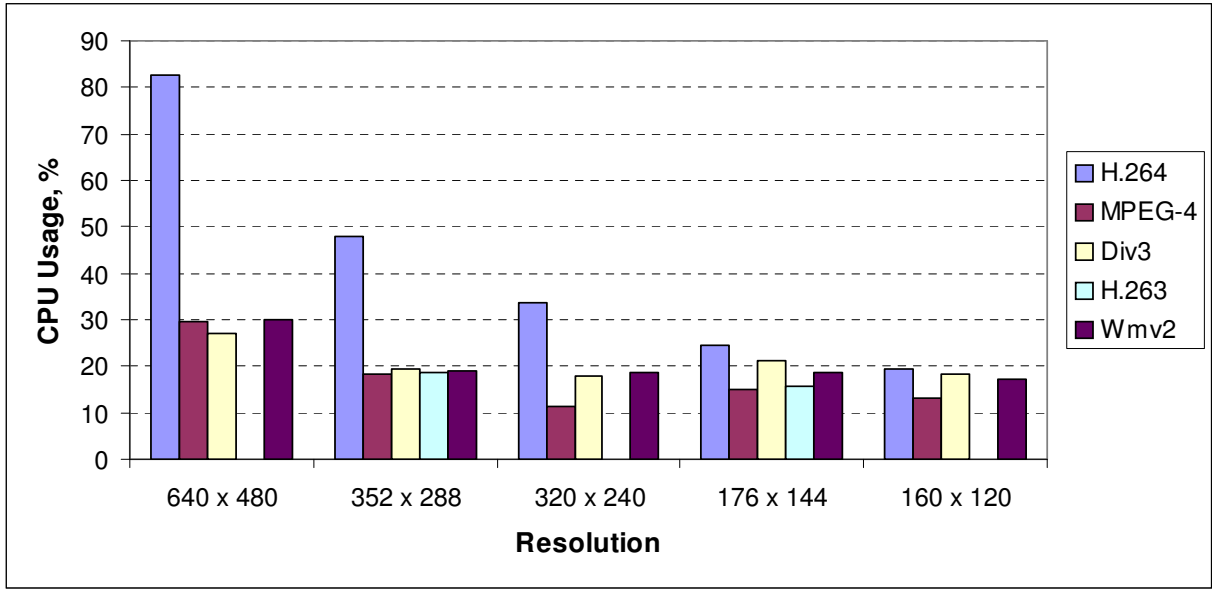
Lost Frame-% at the Receiving End (Resolution of 160 x 120)



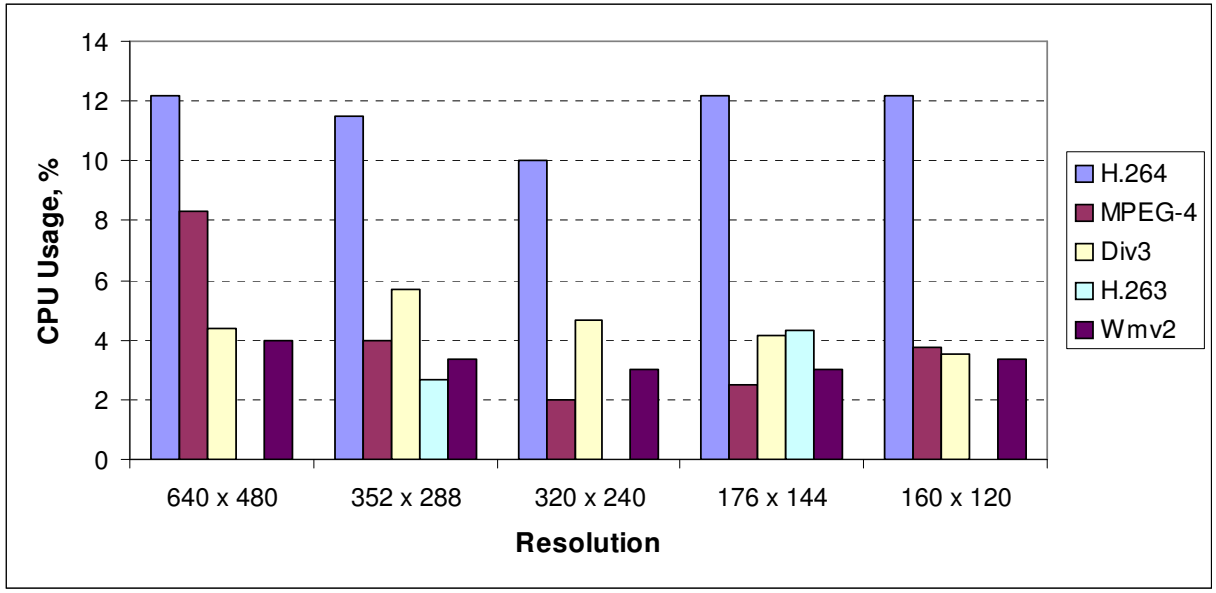
OVERALL FUNCTIONALITY / PICTURE QUALITY IN MOTION:

- H.264 ➔ **Excellent** / **Excellent**
- MPEG-4, div3 H.263, Wmv2 ➔ **Good–Excellent** / **Poor-Satisfactory**
- Resolution of 160x120 is not supported by H.263
- 30 fps and 15 fps are not supported by VLC using MPEG-4

Average CPU Usage

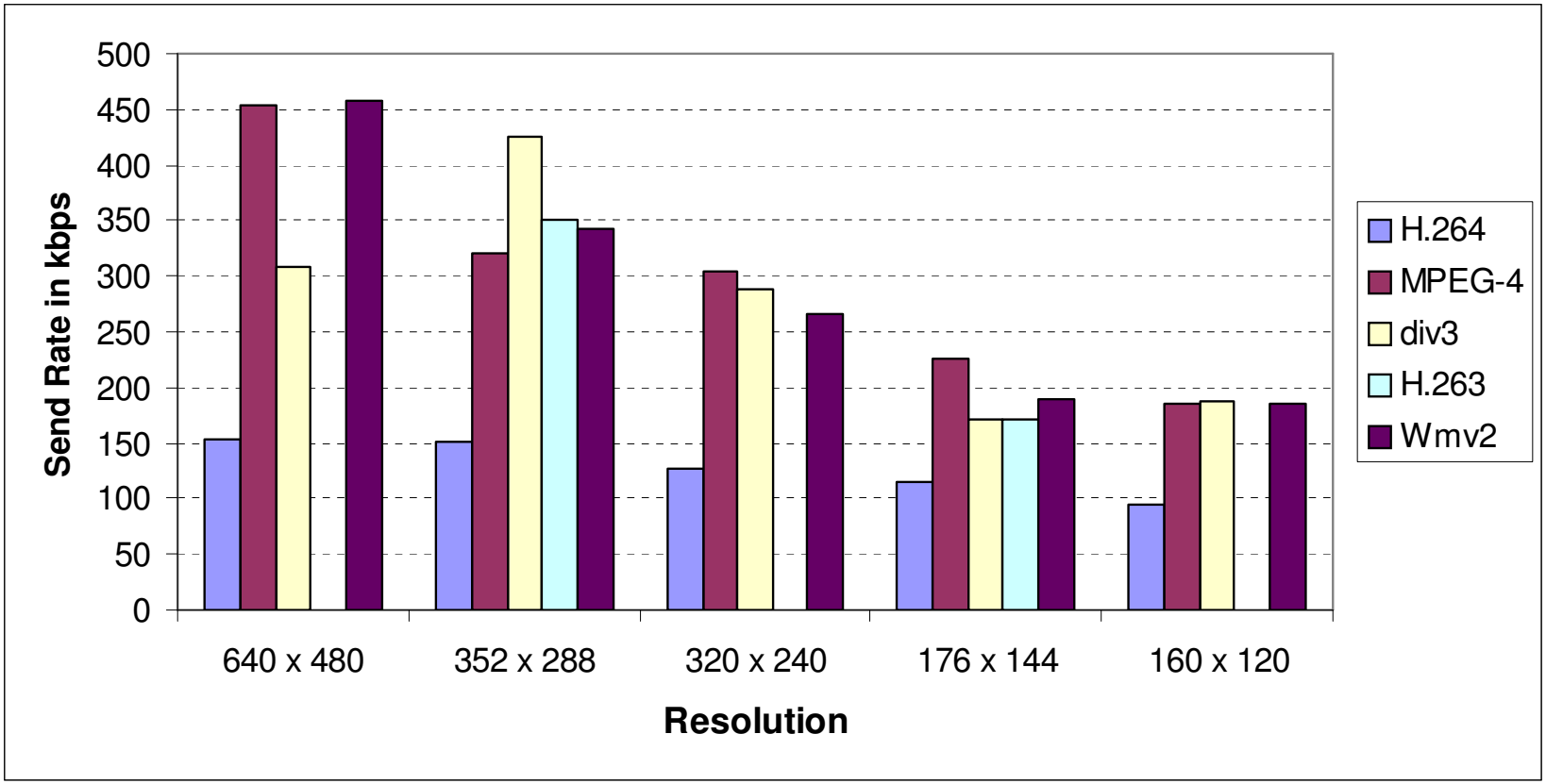


on the Sender Side



on the Receiver Side

Send Rate Peaks at 25 fps



Total Video Delay Measurement

- A picture of the counter times on both screens was taken with a digital camera using continuous shooting mode
- E.g. absolute value = 00:16:17.65-00:16:16.58 =1.07 s.
- Total video delay = average of ten absolute values

SENDER LAPTOP **RECEIVER LAPTOP**

H.264 ➔ 1.0 s
MPEG-4 ➔ 1.7 s
div3 ➔ 1.0 s
H.263 ➔ 1.1 s
Wmv2 ➔ 1.4 s

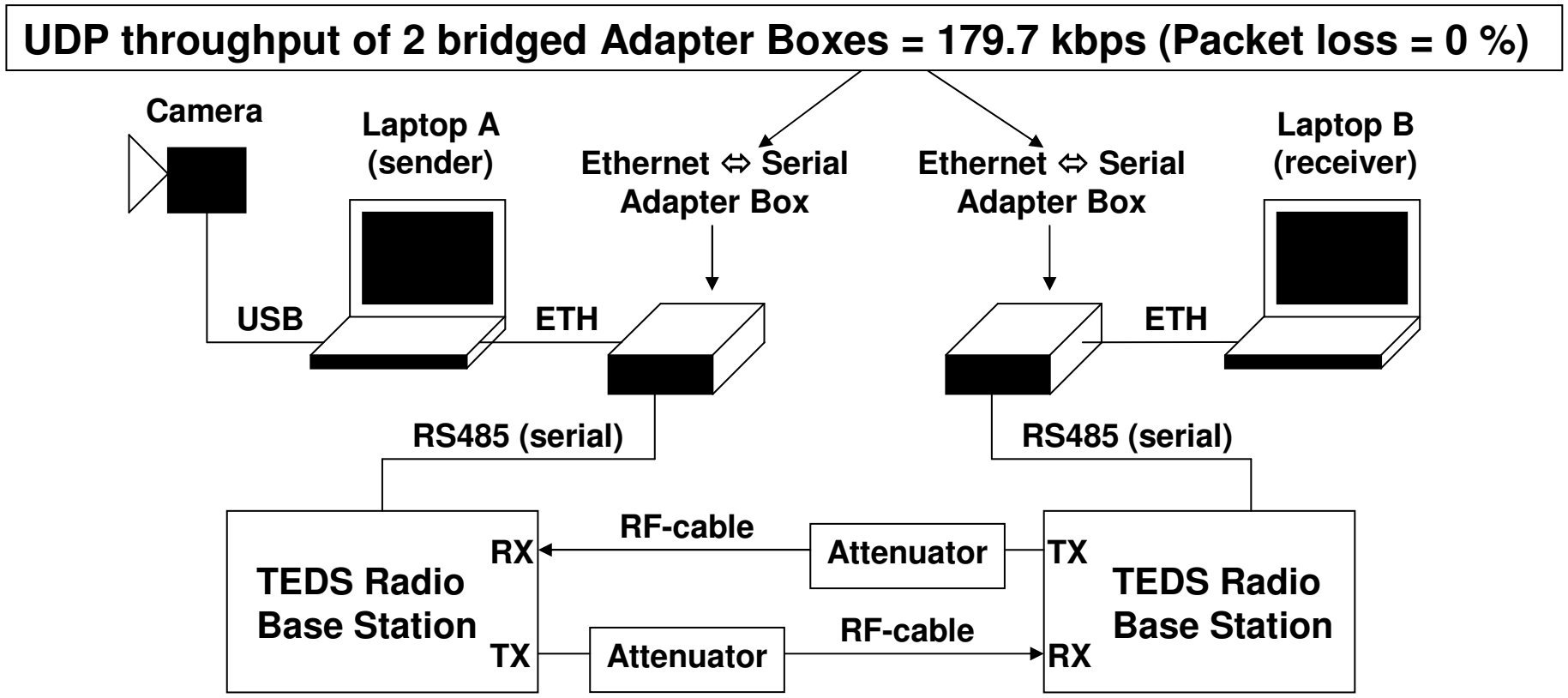
Total video delay was measured using 176x144 at 25 fps (margin of error +/- 0.05 s)

Summary of Video Measurements with the Bandwidth Limiter

- H.264 outperformed all other four tested video codecs (MPEG-4, div3, H.263, Wmv2) in picture quality and functionality of video due to its enhanced coding features
- H.264 had much lower bitrate peaks during video transmission than other four video codecs
- H.264 uses higher compression ratios and a more efficient mechanism and features for coding (compressing) motion video, and thus:
  - can operate at a much lower bitrate than other video codecs
  - the CPU usage of H.264 on the sender side was much higher than with the other video codecs

Video Measurements with the TEDS prototype using H.264

Network Topology of Video Measurements with the TEDS prototype



Test Bed and Total Video Delay Measurements with the TEDS prototype

- **Average one-way delay (RTT/2) was 54 ms**
  (min. 50 ms, max. 56.5 ms)
- **Average UDP delay jitter was 21.9 ms**
  (min. 0.277 ms, max. 64.3 ms)
- **Average UDP throughput was 111 kbps**
  (min. 101.1 kbps, max. 116.8 kbps)
  - **Average packet loss was 5.04 %**
    (min. 0.17%, max. 12.0%)

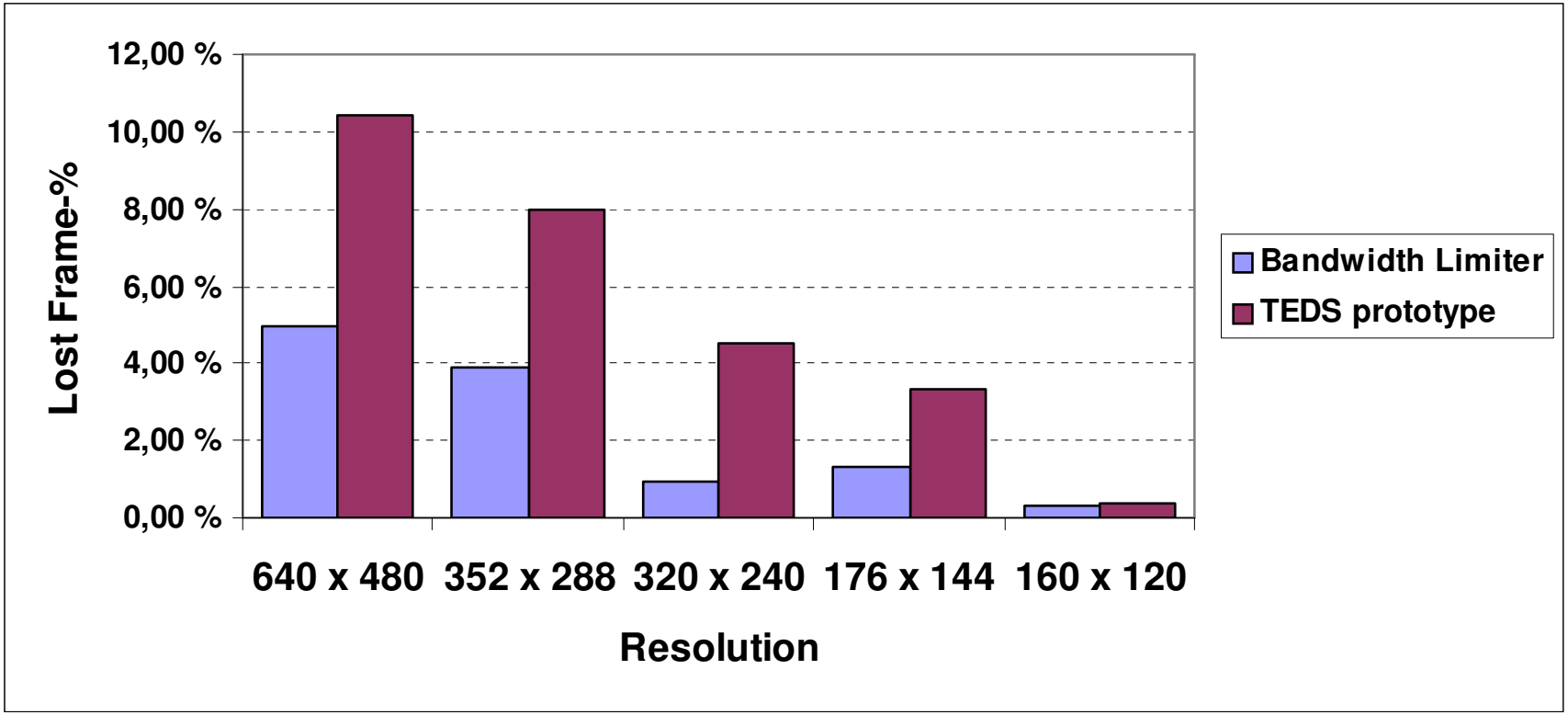
- **Total video delay with H.264 at 25 fps:**
  - Resolutions of 640x480 and 352x288 ➔ **1.1 s**
  - Resolutions of 320x240, 176x144 and 160x120 ➔ **1.0 s**

  (margin of error +/- 0.05 s)

Subjective Quality Evaluation

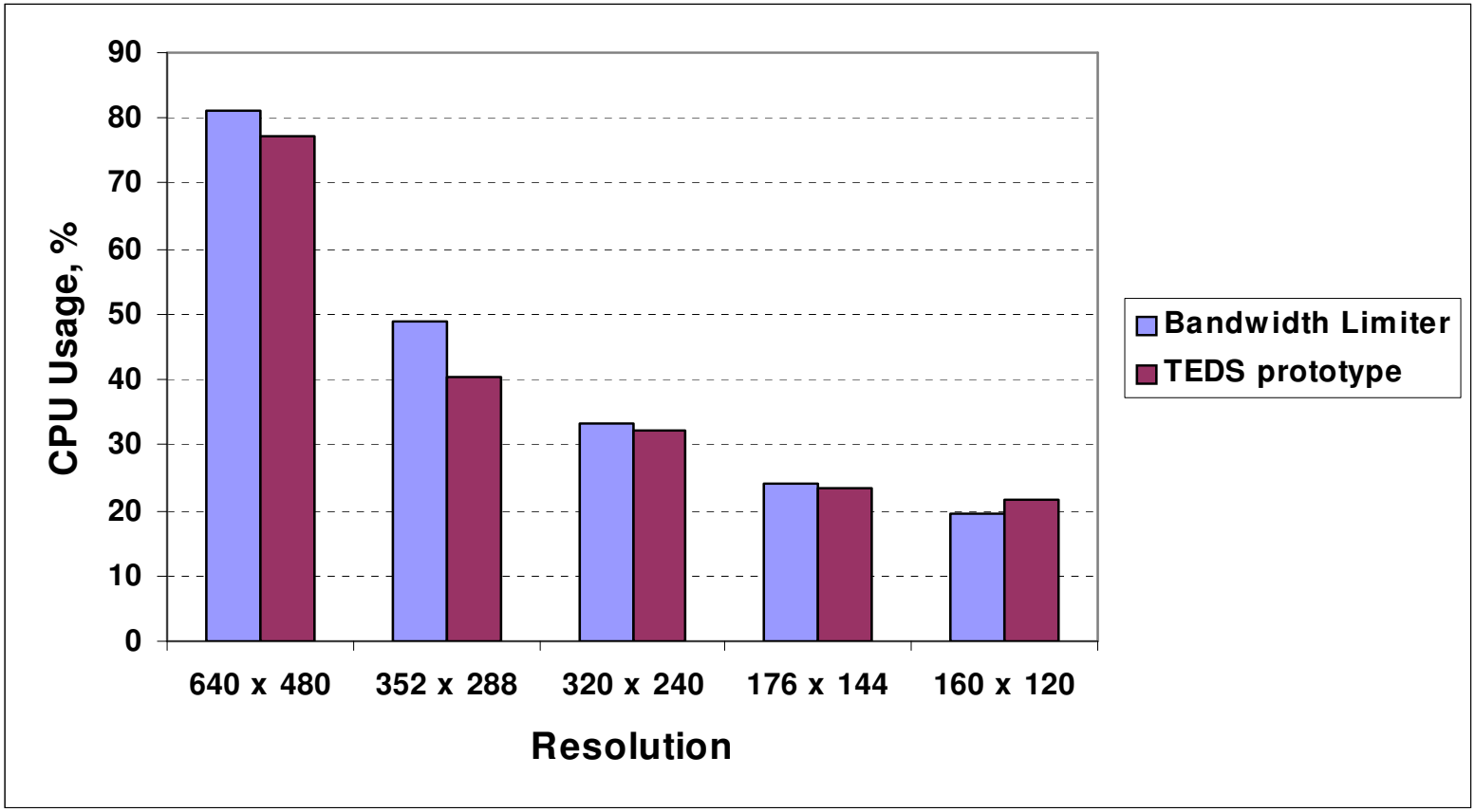
- Evaluation of visual video quality:
  - Was difficult due to variation in connection quality of the TEDS prototype which caused:
    - Occasional total / partial pixelation in the video picture
  - Was based on those time periods when there was no total / partial pixelation in the video picture

Lost Frame-% using H.264 at 25 fps Bandwidth Limiter vs. the TEDS prototype



Average CPU usage of H.264 on the Sender Side

Bandwith Limiter vs. the TEDS prototype



Summary of Video Measurements with the TEDS prototype

- Overall functionality and picture quality of video was very good from 352x288 to 160x120 when the connection quality of the TEDS prototype was good
- Occasional total / partial pixelation was only due to variation in connection quality and lack of better error correction feature
- Resolutions of 176x144 and 160x120 were the best for the TEDS prototype because:
  - All frame rates functioned continuously for longer periods without pixelation
  - After pixelation video picture recovered more quickly to normal

  compared to higher resolutions

Conclusions

- H.264 is the best suitable video codec for TEDS because it can provide very good video quality:
  - averagely at bitrate of 70-90 kbps
  - with all resolutions from 352x288 to 160x120 and frame rates from 30 fps to 5 fps
    - even when screen window size is enlarged to match original screen window size of 640x480 while observing the video
- The TEDS prototype can provide enough transfer rate for real-time video transmission (H.264)
- Versatile VLC media player is very suitable for video transmission over TEDS

Possible Future Work

- TEDS prototype is not yet a final product and thus needs development:
  - Many features defined by the standard have not been implemented
  - Variation in connection quality needs to be lowered / minimized
  - Error correction feature needs improvements
- Video transmission over improved TEDS prototype
  1. Using RF cable connection
  2. Using wireless RF connection
- Video transmission with two or more cameras