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ROBUST VIDEO BROADCASTING OVER 802.11a/g IN TIME-CORRELATED FADING CHANNELS

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Motivation for the work ...

- We want to broadcast video to large numbers of handheld devices using WiFi
- We want to enable new services such as personalised sports viewing or interactive city guides
- WiFi is ubiquitous and in most handsets ... but how do we improve the video quality when broadcast protocols are used?
- Key contribution is the study of application layer FEC (AP-FEC) in combination with H.264 encoded video
- We develop and use a cross-layer 802.11a/g MAC-PHY simulator to analyse video performance
- We consider the impact of user motion using a time-correlated fading channel model – this model is critical!

The VISUALISE project

- The work presented here was part of the VISUALISE project
- Spectators at sporting events (World Rally Championship) used PDAs and mobile phones to receive live and pre-recorded video streams together with leader board information, timing and positional data, and general competitor information



Wireless video broadcasting

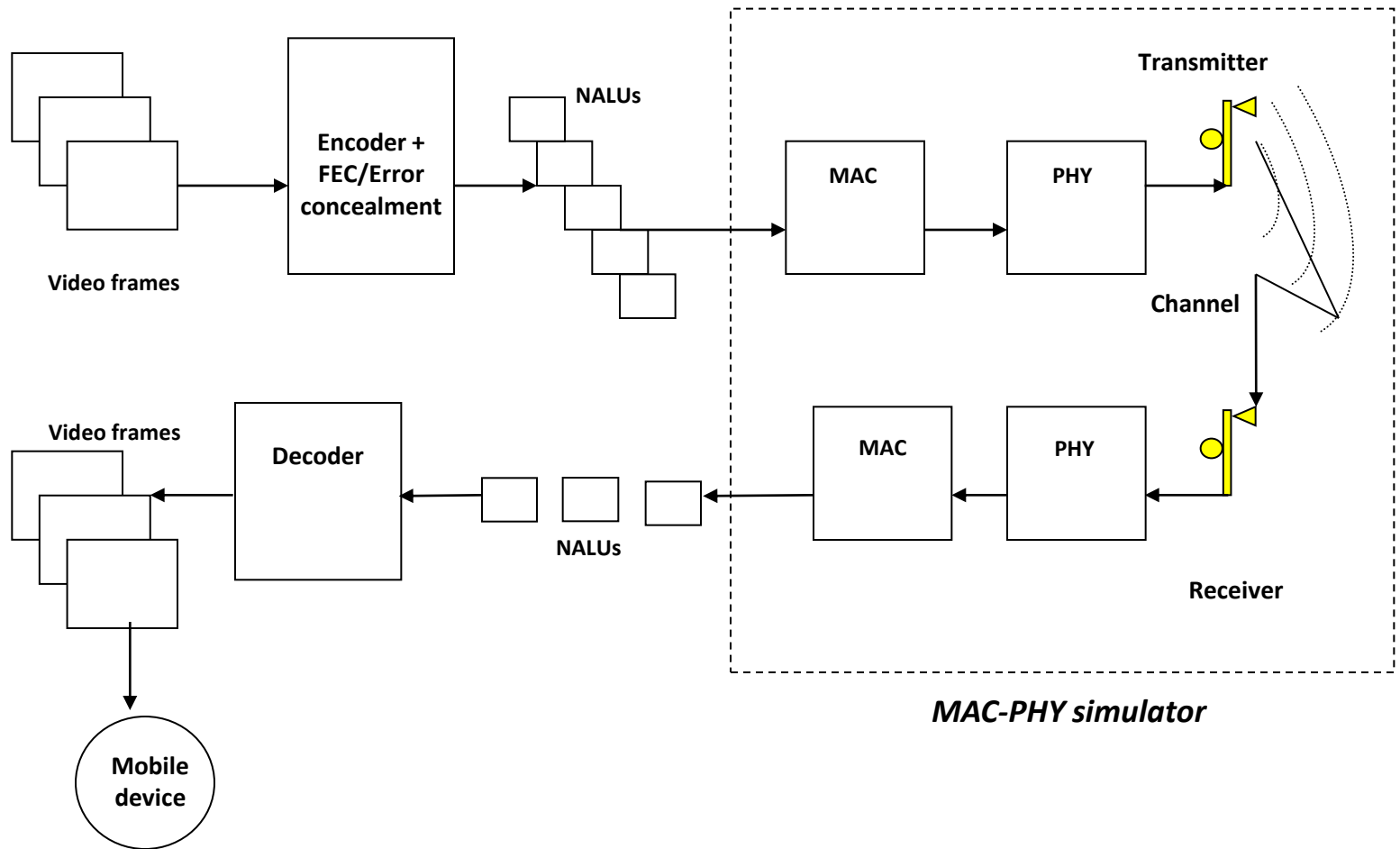
- The *reliable* broadcast of multi-channel video over WiFi to *large* numbers of handhelds is of great commercial interest
- Video quality deteriorates rapidly when WiFi broadcast protocols are used
- For Multicast/Broadcast there is no MAC frame retransmission in WiFi
- For an RTP application the packet loss rate at the application layer can be high (~10%)
- To improve the video quality we propose cross-packet AP-FEC with powerful error concealment in the decoder



The 802.11a/g Cross-layer Simulator

1. The cross layer simulator models the WiFi broadcast of H.264 encoded video packets over a time-correlated radio channel
 - A real video sequence is used to evaluate the received video quality at the handset
2. A time-varying fading channel is used to simulate the wireless transmission process. This accurately models the bursty nature of packet loss in a WiFi channel
3. An 802.11a/g MAC-PHY simulator is used to include the impact and overhead of the legacy 802.11 MAC protocol

Schematic of Cross-layer Simulator



1. Video transmission simulator

- A sequence of video frames are *H.264* encoded, sent and decoded with and without AP-FEC and error concealment
- Each video frame is translated into a number of *NAL units* and then 1:1 mapped to IP packets and WiFi MAC frames
- Video *PSNR* is evaluated at the encoder prior to transmission – used as the reference “error-free PSNR”
- *PSNR* of the decoded video is evaluated at the receiver after wireless transmission over the radio channel
- The video sequence is taken from inside a rally car

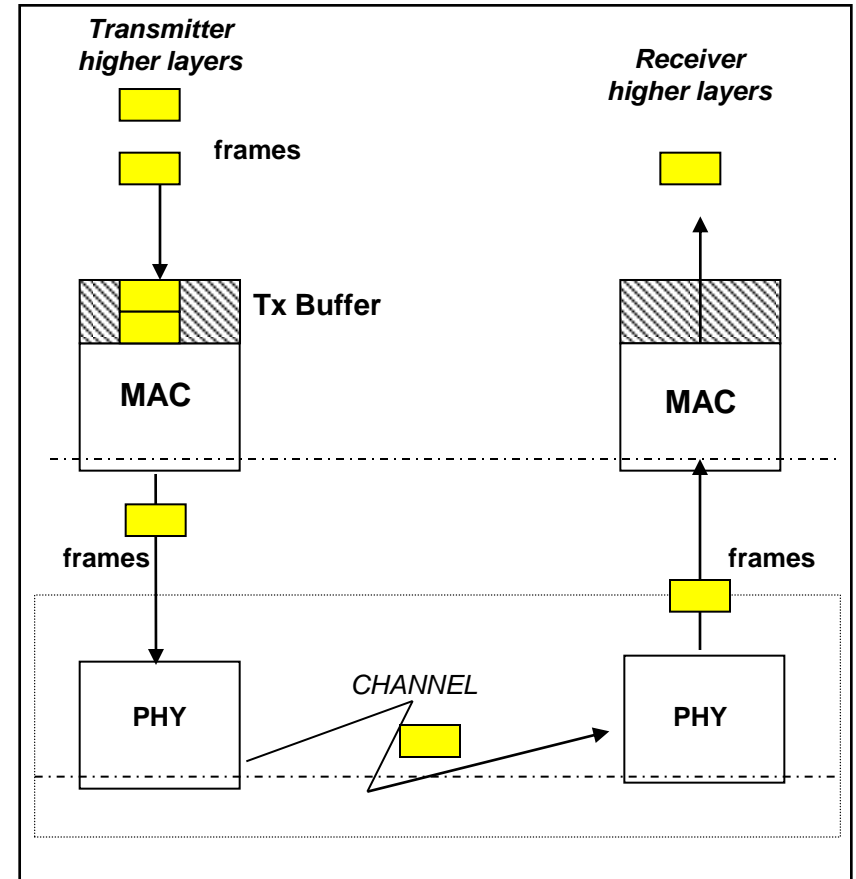


2. The time-varying channel model

- The multipath model assumes a Rayleigh fading process defined by the terminal velocity, carrier frequency and Doppler spectrum
- The spaced-time autocorrelation of the fading envelope is controlled by a Jakes PSD – this imposes *time correlation*
- The instantaneous signal is attenuated to model the desired *average* SNR at the receiver
- Maximum Doppler shift of 4Hz are considered (corresponding to a terminal speed of 1.8 km/h for a 2.4 GHz carrier).

3. The MAC-PHY simulator

- A time sequence of video frames enter the transmit MAC at CBR
- They are buffered in a transmission queue
- For each packet we use the complex channel gain that corresponds to the exact time of transmission
- If an error is detected then no MAC or IP layer retransmission is allowed and the packet is lost



Simulator outputs

MAC Layer

- Frame transmission delay MAC-to-MAC
- MAC Frame Loss Rate
- Throughput

Application Layer

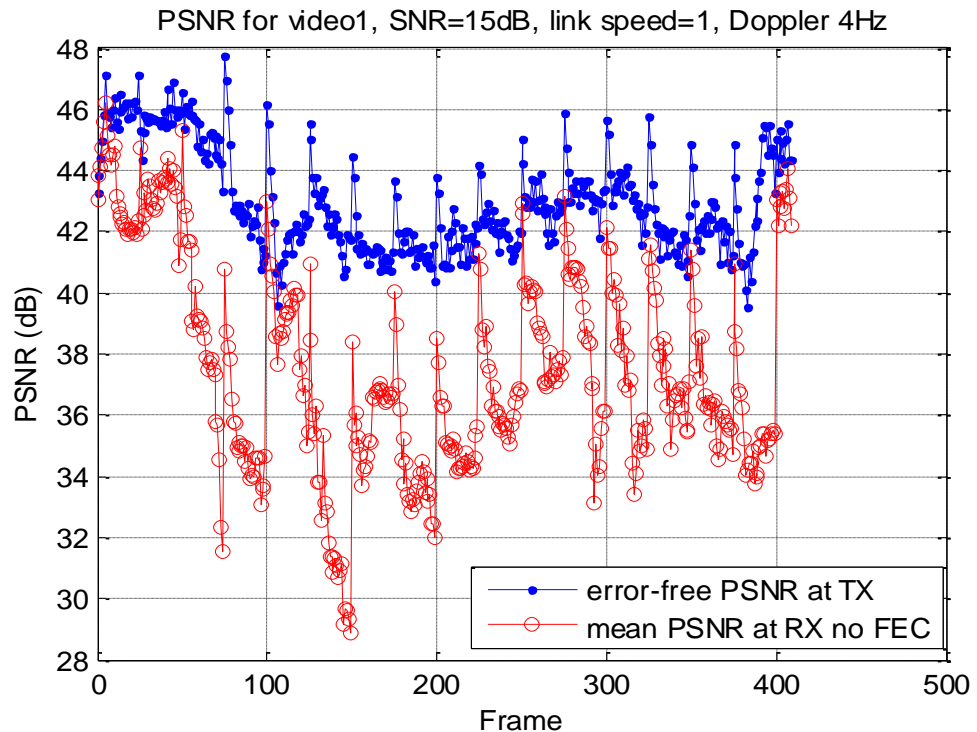
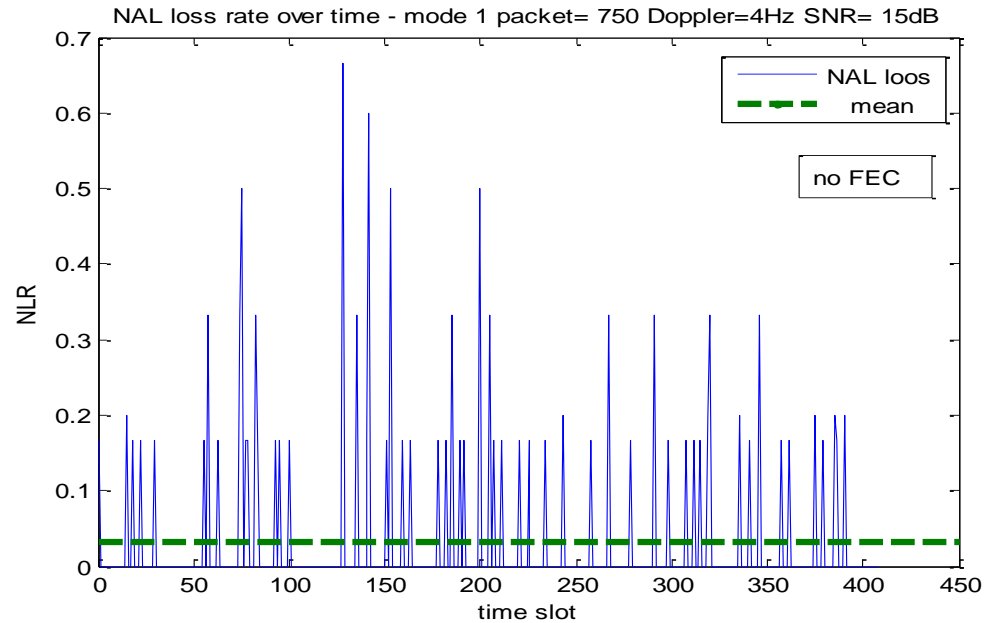
- NAL unit Loss Rate (NLR) per video frame
- PSNR per received video frame

Simulator parameters

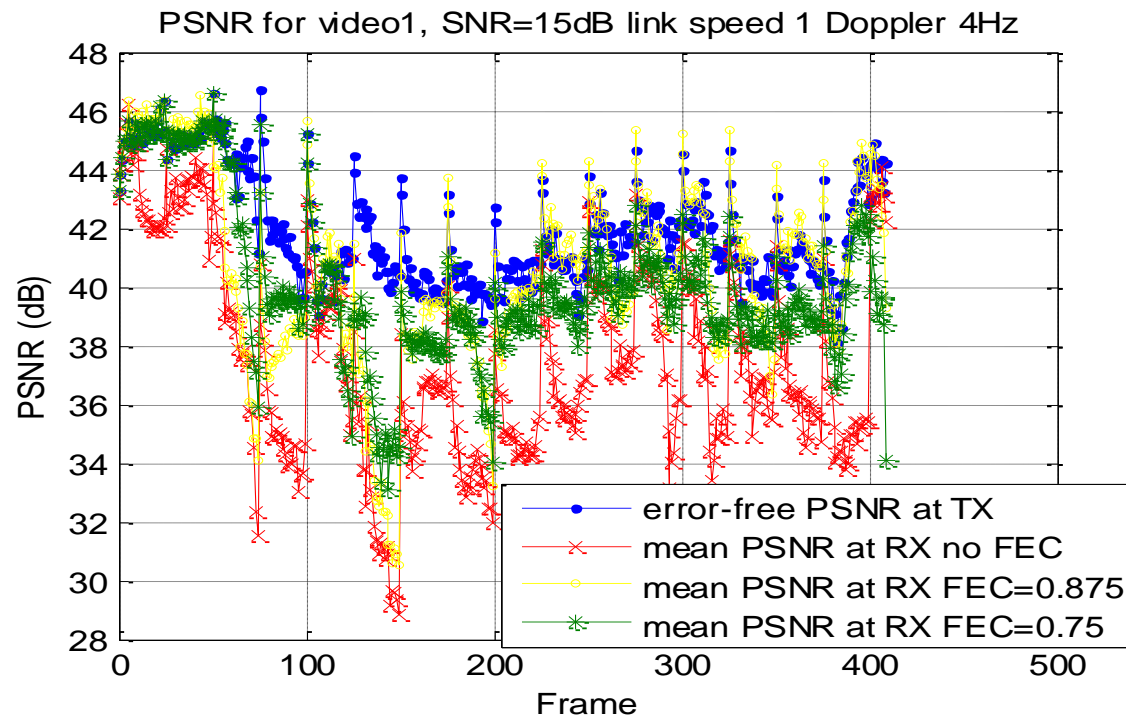
- Video sequence comprises 410 frames of H.264 encoded video at an average bit rate of 256kbps.
- Cross-packet AP-FEC can be added for further protection
- Equal frame protection AP-FEC with a depth of 8 packets is used based on an (n,k) Reed Solomon code at rates of 0.875 and 0.75
- Error concealment based on Previous Frame Copy
- Wireless channel modeled for a 4Hz Doppler shift
- Mean received SNR modeled in the range 5–25 dB
- All 802.11a/g link speeds are simulated

NLR and video PSNR

- NLR at the MAC averaged over a 132 ms window (i.e. a video frame)
- Received video PSNR calculated per video frame *without FEC*
- Results correspond to $\frac{1}{2}$ rate BPSK at 15dB SNR and 4 Hz Doppler
- Results averaged over 7 channel realisations
- Note the very bursty nature of the NLR
- Note the low PSNR that occurs with high NLR

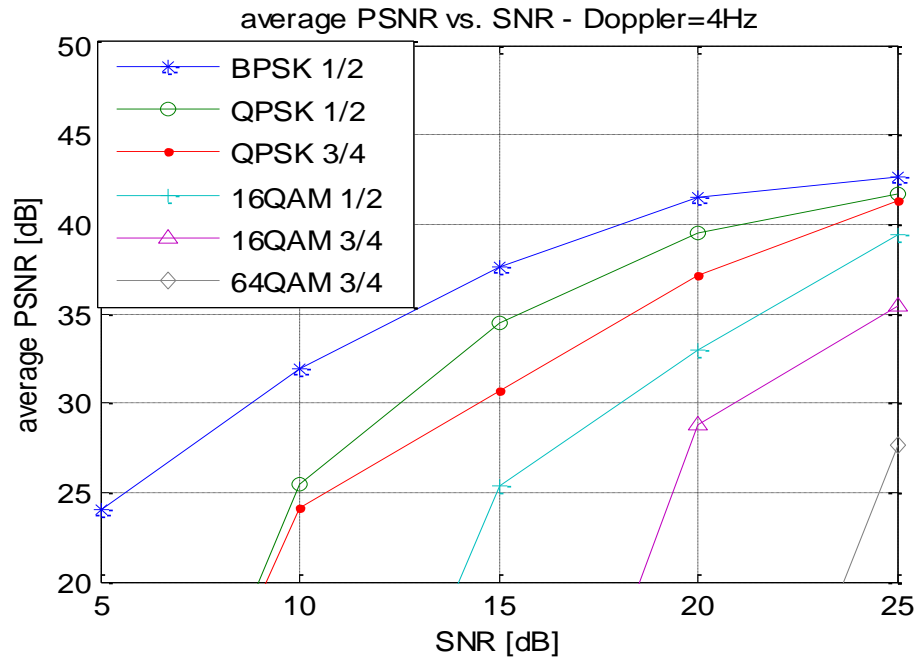


Impact of Cross-packet AP-FEC on PSNR



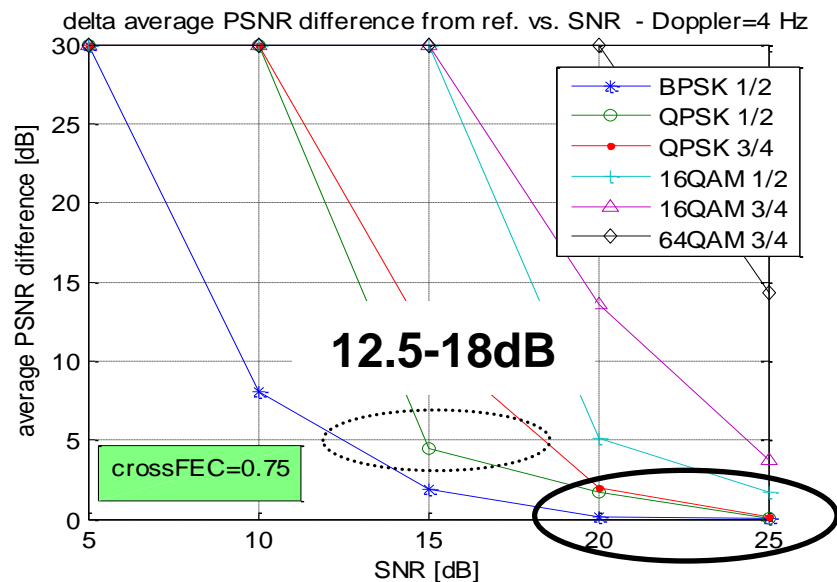
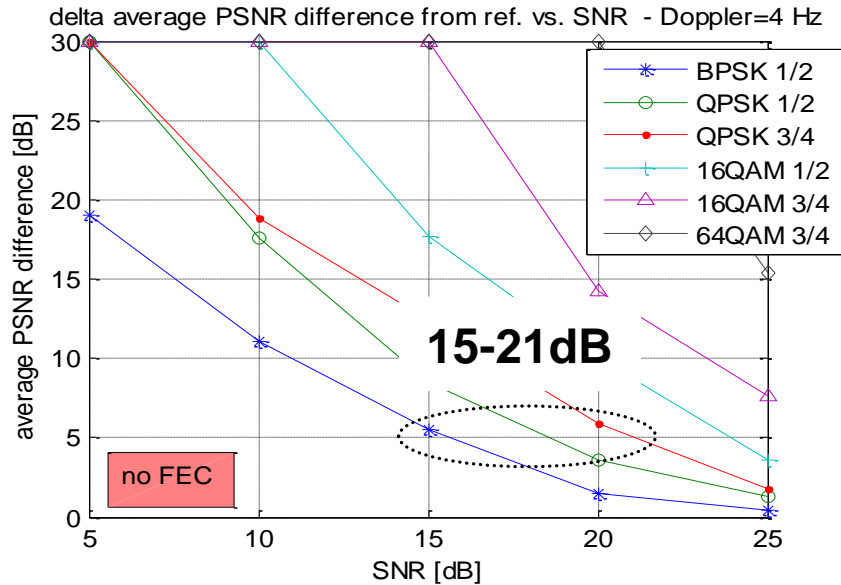
- Mean PSNR per frame *improves significantly* when cross packet AP-FEC is applied in a slow fading channel (Doppler = 4 Hz)
- AP-FEC with code rate 0.75 approaches the error-free PSNR

Link speed performance



- Plots show average PSNR over all frames (for all 7 channel realisations) versus SNR for all link speeds, *without FEC*
- For SNR ≥ 15 dB, link speeds 1-3 achieve a PSNR > 30 dB
- When a time decorrelated fading model is used the error burst lengths are very small and it is much easier to conceal the lost NALs – this gives misleading results for static users

PSNR improvement for a 4 Hz channel



- Average PSNR degradation shown over the entire video sequence as a function of mean SNR and link-speed
- PSNR improvements seen for when AP-FEC is applied
- Received PSNR is very nearly equivalent to transmit PSNR (no degradation) for SNR>20dB using 1/2 rate BPSK mode

Comparison of video quality in terms of PSNR



PSNR=19 dB



PSNR=26.3 dB



PSNR=33 dB



PSNR=38 dB

Conclusions

- In order to evaluate the received video quality it is vital to include a time correlated channel model to study the effects of error burst length and channel Doppler effects
- Use of cross-packet AP-FEC with a given depth and code rate can significantly improve the video quality in broadcast applications
- Good quality broadcast reception over 802.11a/g can be achieved for mean SNR ≥ 15 dB using error concealment and AP-FEC
- Analysis also needs to consider body shadowing and polarisation mismatch (see paper 8.3-5 at 10.05 tomorrow in Room N262 – “Delivering Live-Action to Handheld Devices: Experimental Results and Recommendations”)

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Thank you!

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