

EVSO: Environment-aware Video Streaming Optimization of Power Consumption

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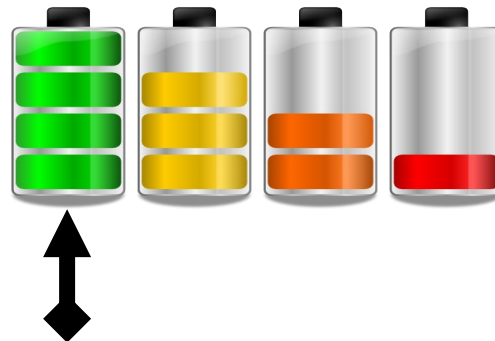


Motivation: **Observation**



Battleground Game Video, YouTube

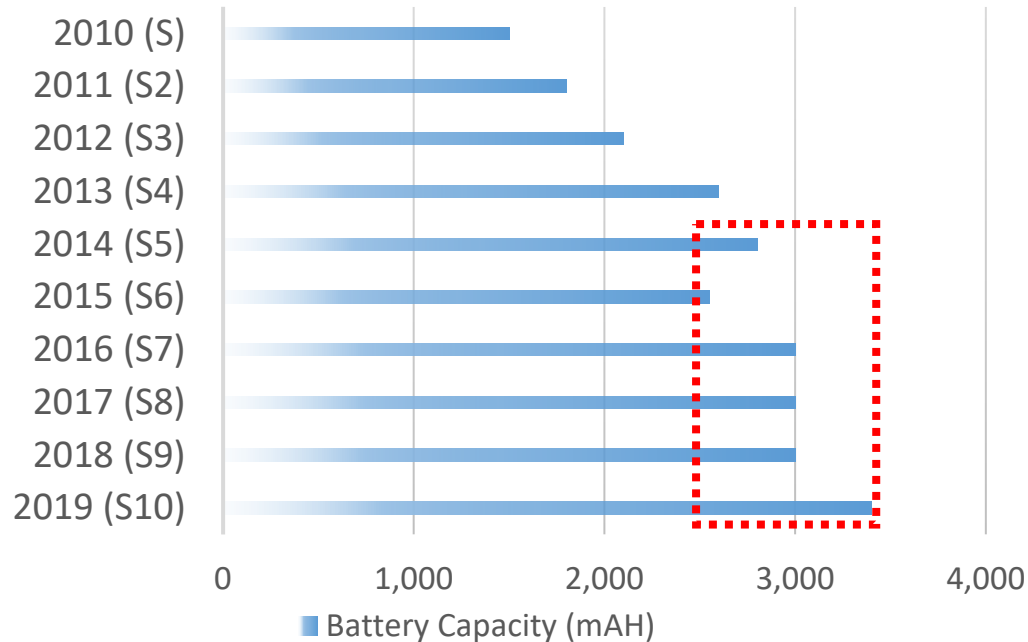
Battery Status



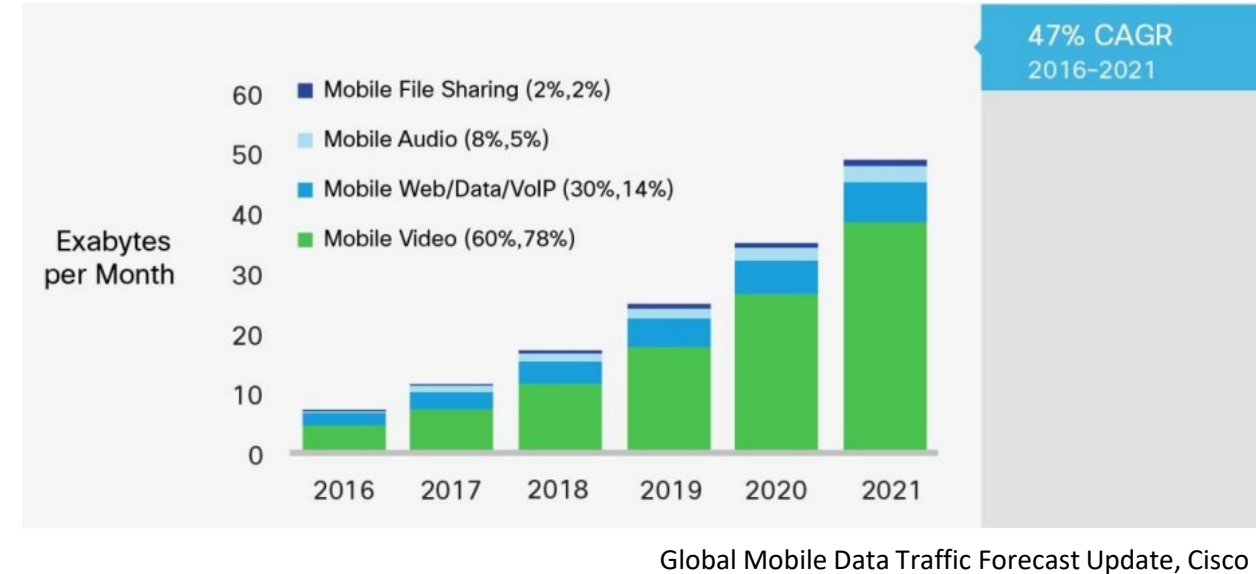
Motivation: Will Future Battery Capacity Help?

(CAGR: Compound Annual Growth Rate)

Tendency of Samsung smartphone battery capacity



Forecast of mobile video traffic



- CAGR of battery capacity: **8.53%**

- CAGR of video traffic: **47%**

If this imbalance continues, we can become **battery-slaves** in the near future! 😞

Simple Solution: Adjust the Video Quality according to the Battery Condition!



Reducing the video quality naively incurs a **severe degradation of the User eXperience (UX)**

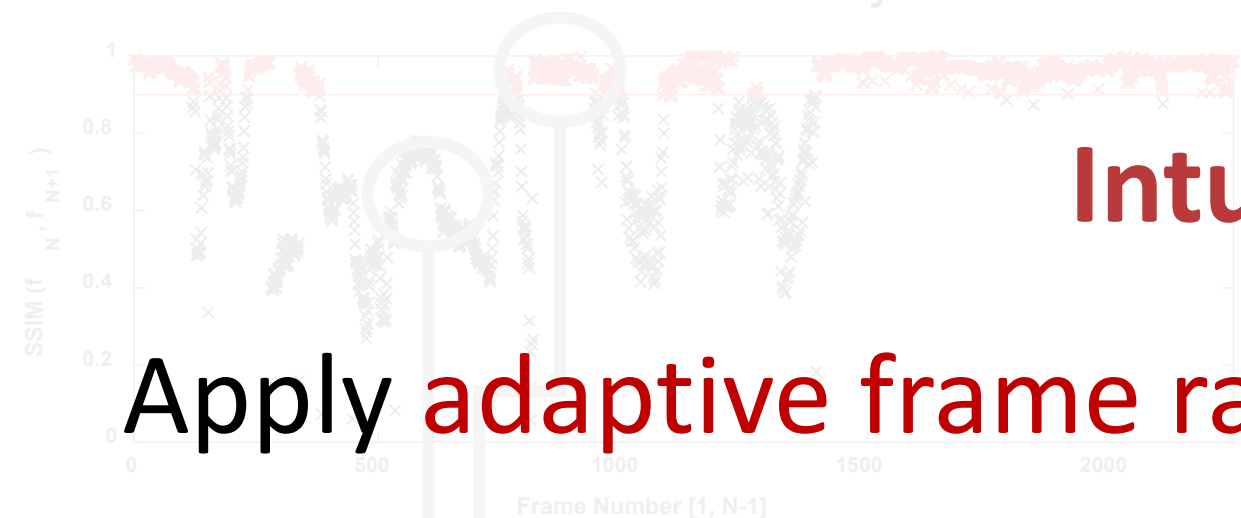


Motivation: Key Insight

(SSIM: Structural SIMilarity)

Variation of SSIM between adjacent frames

Baseball video



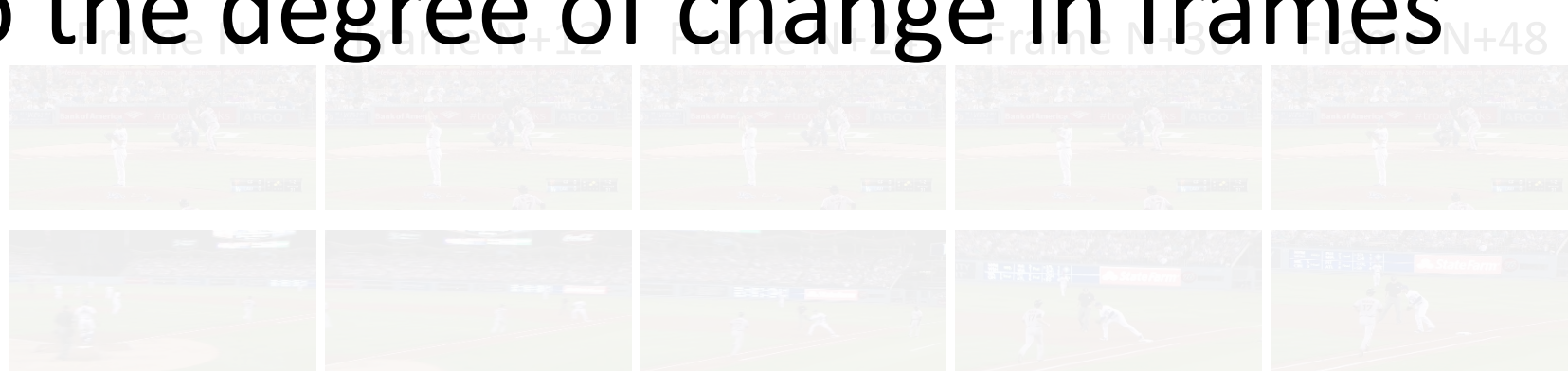
Intuition

Apply **adaptive frame rates** for parts of the video

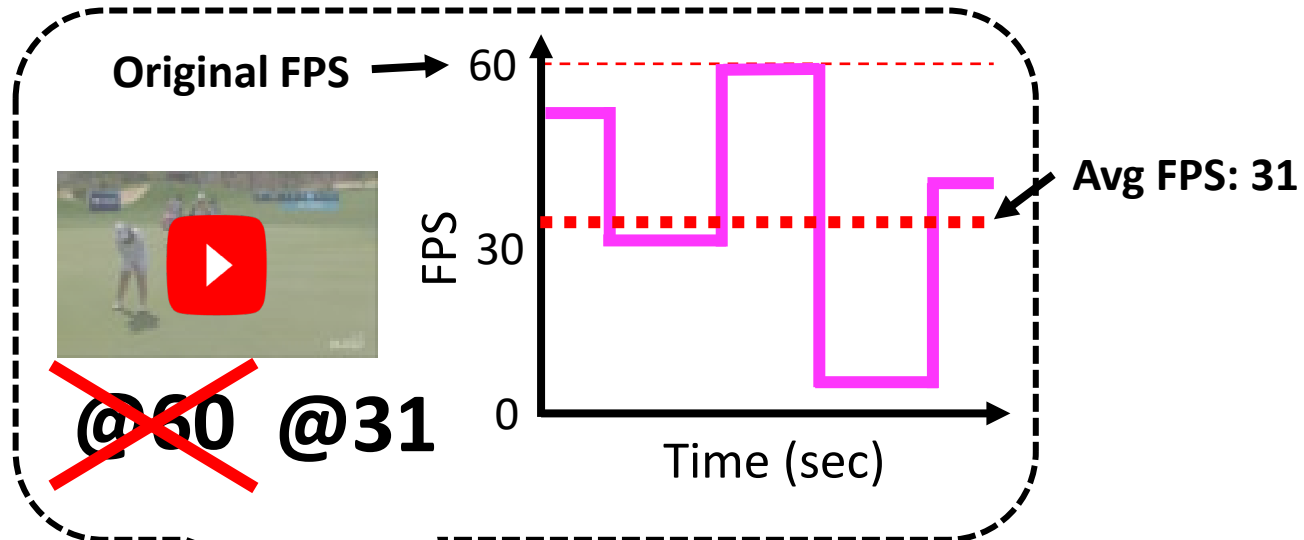
according to the degree of change in frames

Slow Movement
(Average SSIM: **90.75%**)

Fast Movement
(Average SSIM: **30.75%**)



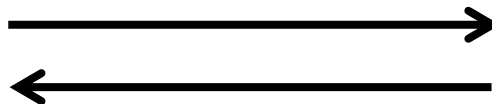
EVSO: Environment-aware Video Streaming Optimization



You **Tube**



Video Server



Video Client

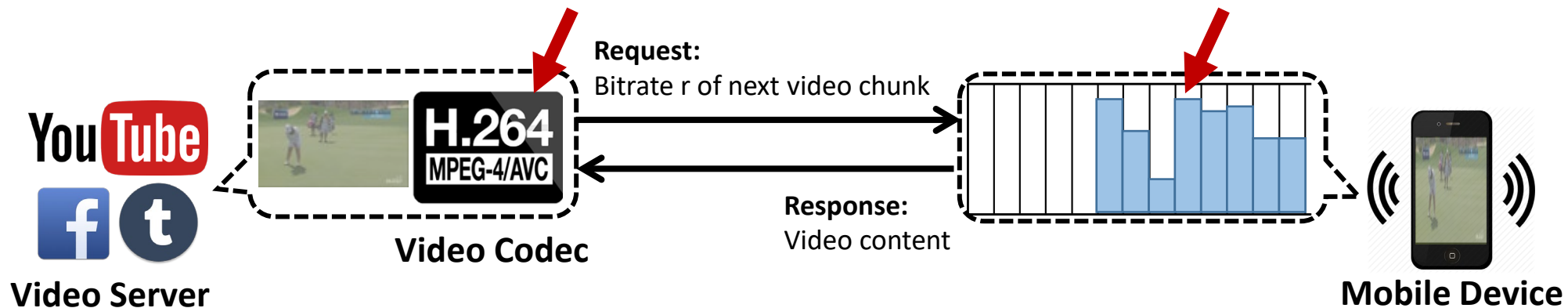
Average FPS of video
~~@60~~ @31

Contribution

1. Propose a new **perceptual measurement method** specialized in video streaming service
2. Present a novel **scheduling technique** that adaptively adjusts FPS according to motion intensity
3. Take into account **not only network conditions but also the battery status simultaneously**
4. Various experiments show that the **UX quality preservation** and **power reduction are effective**

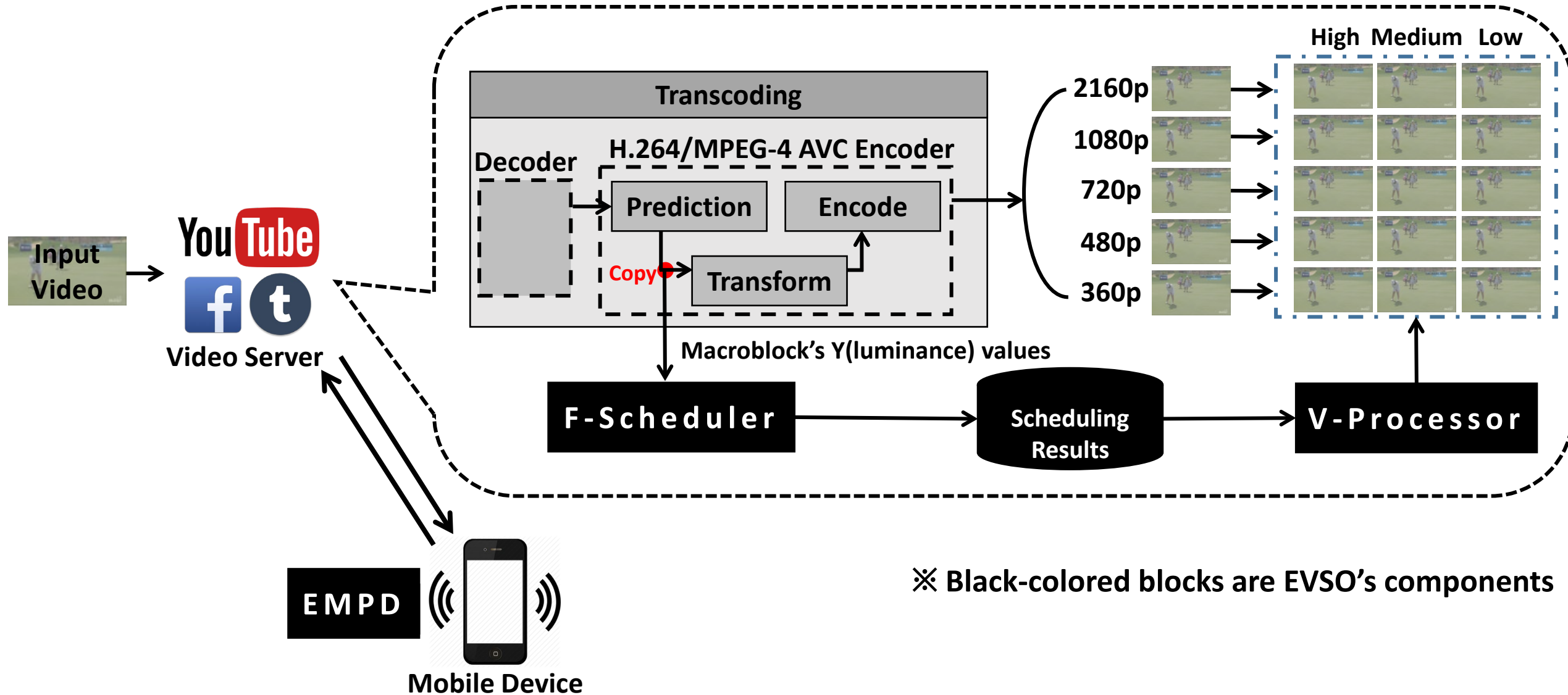
Previous Energy Saving Works when Streaming Video

- **Frame-skipping scheme** during compression and transmission
 - Lim et al. [Systems Journal'16]
 - ✓ No flexible way to adjust the frame rate according to the current battery status of the mobile device
 - ✓ Uses the SSIM method that incurs high computational overhead
- **Utilize playback buffer** to increase idle time of wireless interface that consumes a considerable power
 - Rao et al. [CoNext'11], Hu et al. [INFOCOM'15]
 - ✓ Waste the network bandwidth when users frequently skip or quit while watching the video

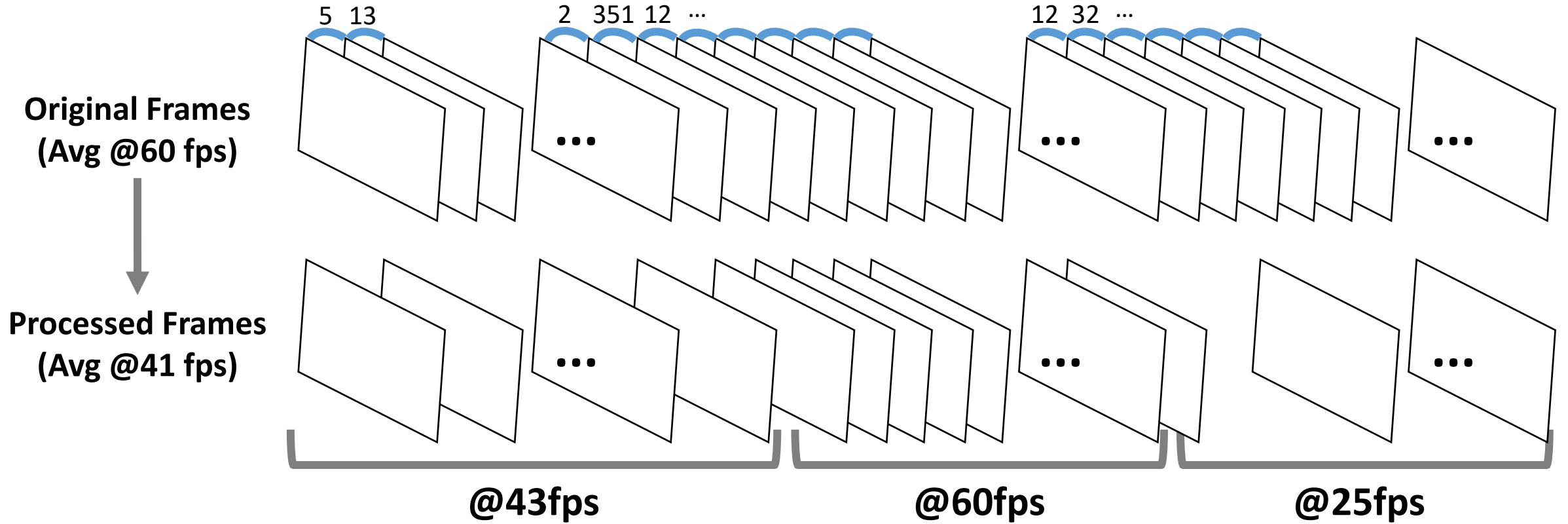


What is EVSO?

(MPD: Media Presentation Description)



What is EVSO?

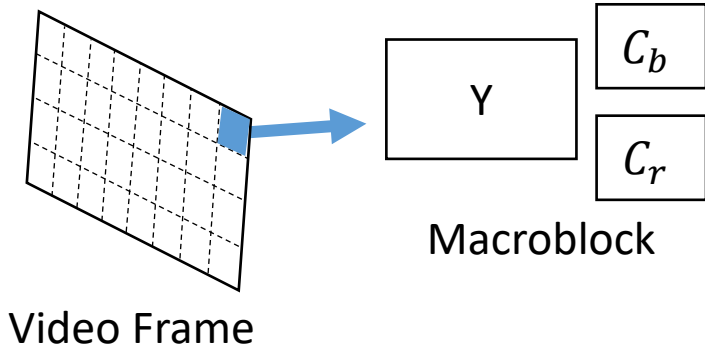


Step 0. Calculate Perceptual Similarity Score between Frames

Step 1. Split the Video into Multiple Video Chunks (F-Scheduler)

Step 2. Estimate Frame Rates for Video Chunks (F-Scheduler)

Step 0. Calculate Perceptual Similarity Score between Frames



✓ Human is more sensitive to changes in **brightness (Y)** than colors (C_b, C_r)

✓ **Y-Difference (Y_{Diff})** score of frames:

1. Similar accuracy to SSIM
2. Computationally efficient than SSIM

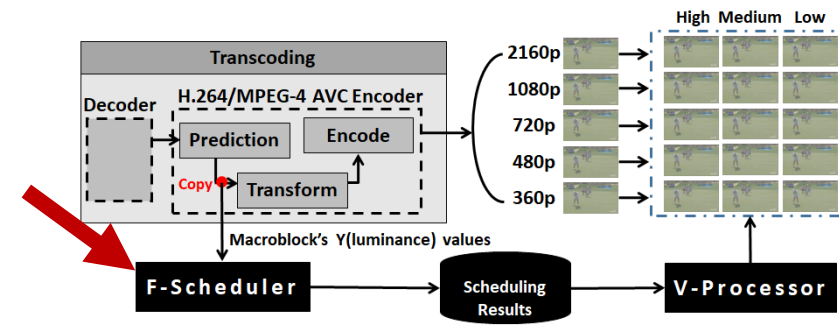
✓ Human is sensitive not only to brightness but also the **object motion**

∴ Y-Difference + Object Motion (Block-based) => M-Diff!

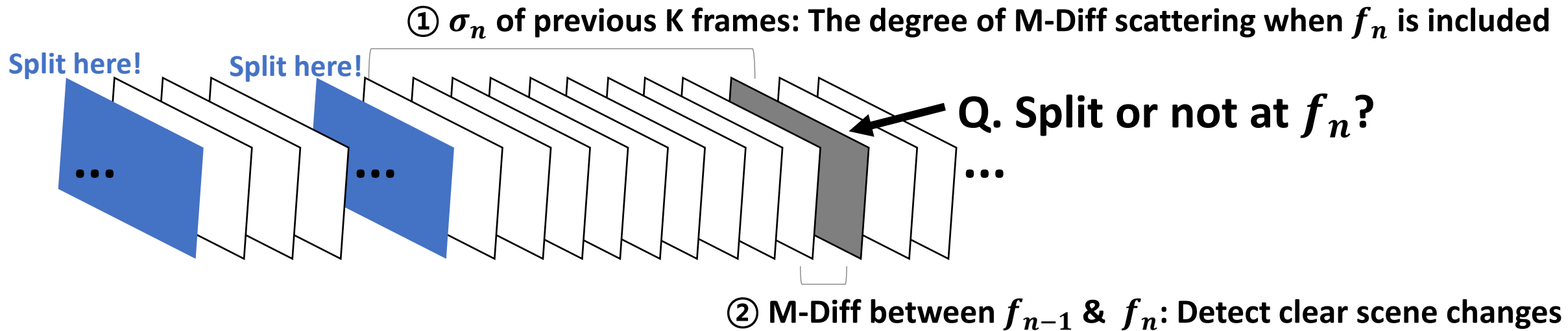
Similarity Score f_a & f_b **M-Diff** = $\sum \sum TH(f_a, f_b)$ Macroblock-based

$$TH(f_a, f_b) = \begin{cases} 1, & Y_{Diff}(f_a, f_b) > \theta \\ 0, & Y_{Diff}(f_a, f_b) \leq \theta \end{cases}$$

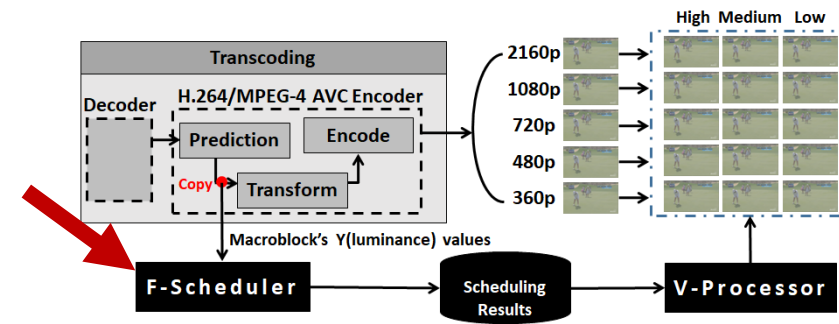
Step 1. Split the Video into Multiple Video Chunks



Goal: Separate the video into multiple video chunks with similar variability levels



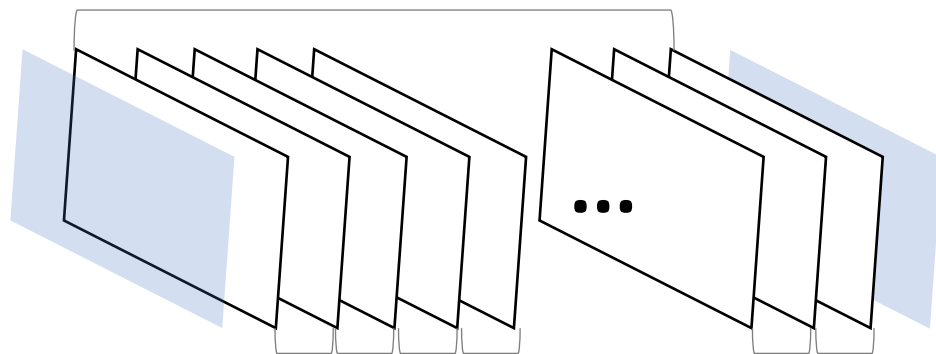
Step 2. Estimate Frame rates for Video Chunks



Goal: Obtain the appropriate frame rate for the video chunk

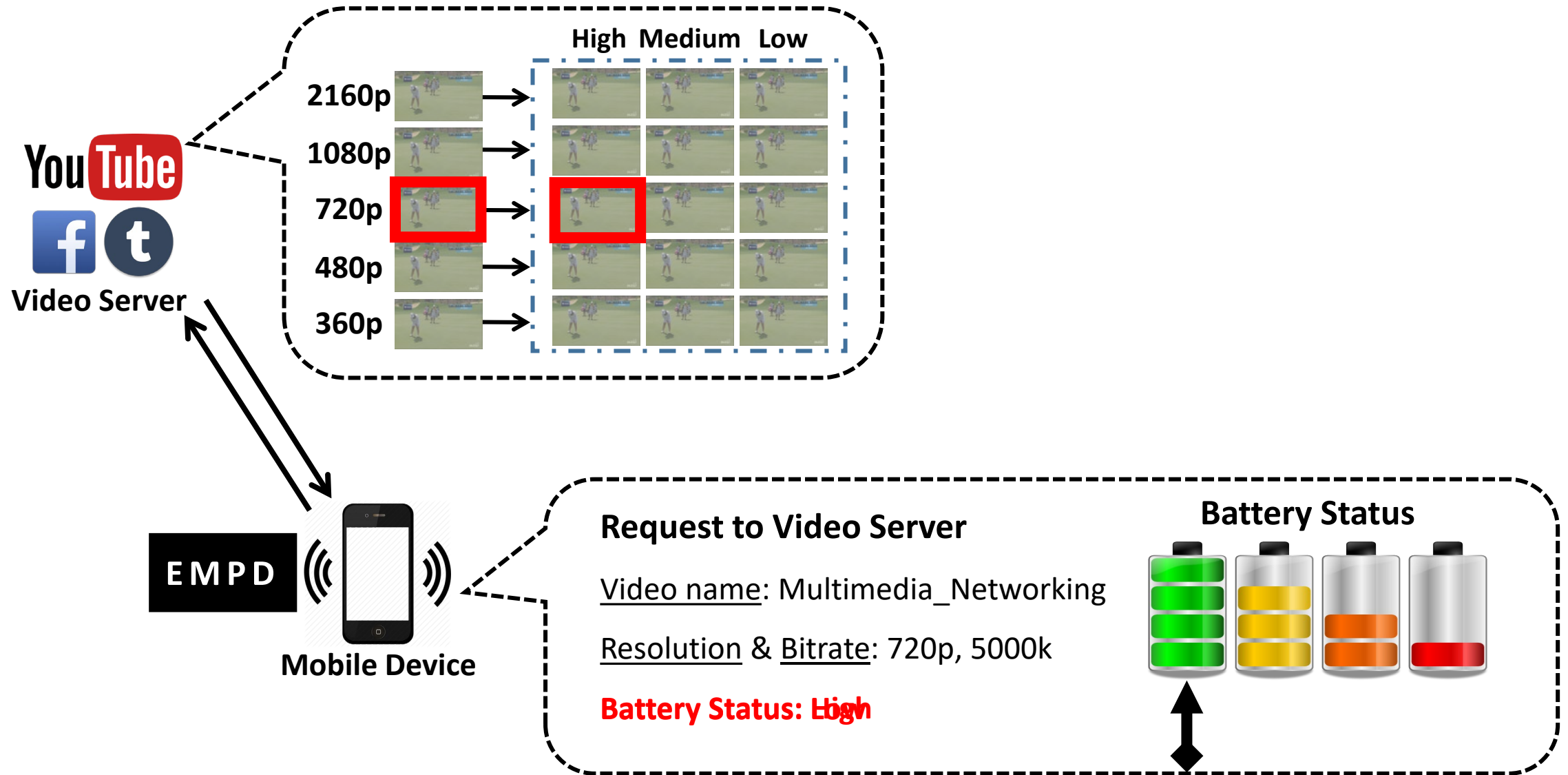
② σ_n of Video Chunk k : Whether the degree of M-Diff variation is constant or anomalous

Video Chunk k

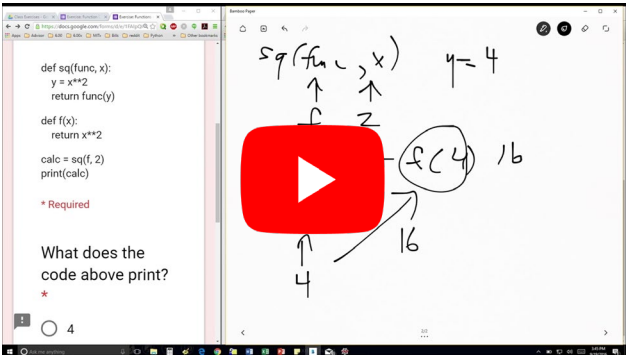




① Consider the M-Diff values between each adjacent frames

Extended MPD (EMPD)

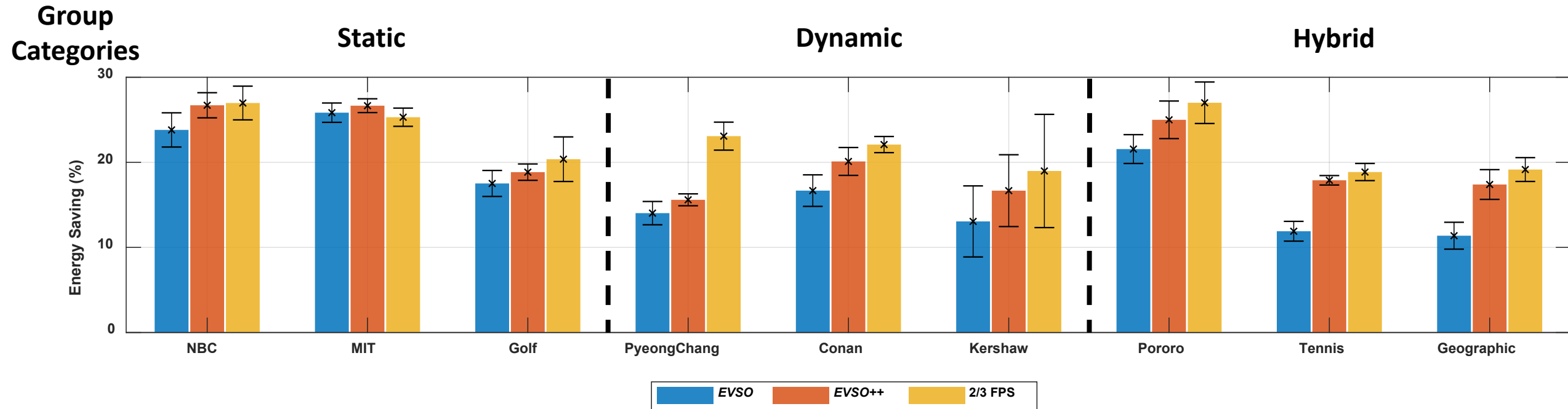


Evaluation: Experimental Setups

<p>Type A: Static</p>	 <p>MIT_Course.mp4</p>
<p>Type B: Dynamic</p>	 <p>Pyeongchang_olympic.mp4</p>
<p>Type C: Hybrid</p>	 <p>Tennis.mp4</p>

- **Nine videos** of various categories **with three types: Static, Dynamic, and Hybrid**
- Four different settings used for experiments:
 - **EVSO**
 - **EVSO+**
 - **EVSO++**
 - **2/3 FPS** (Experimental Group)
- The battery condition ↓, the more aggressive EVSO is used (denoted by more + signs)

Evaluation: How much total energy can be saved?



- The energy consumption is reduced by **as much as 27%** with an **average of 22%**
- The amount of energy saved **varies depending on the video characteristics**

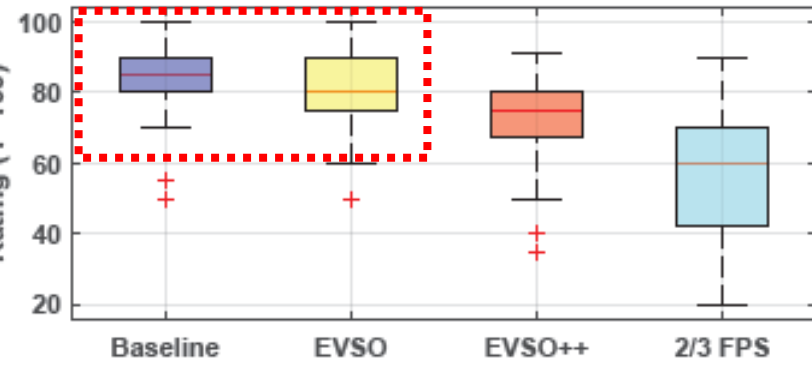
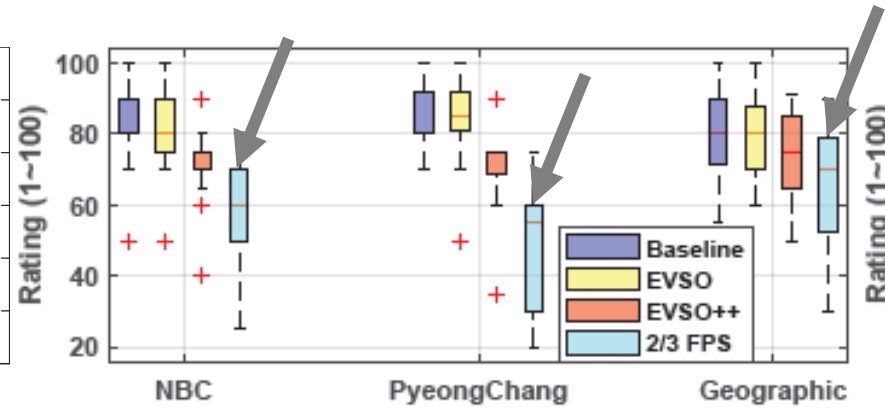
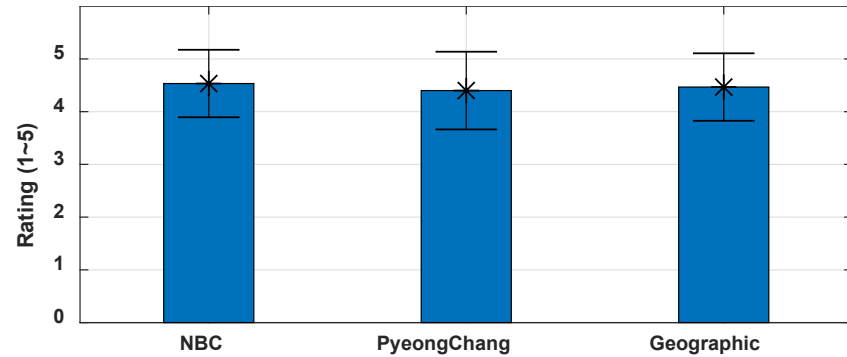
Evaluation: How well the video quality is maintained?

Group Categories	Video	EVSO			EVSO+			EVSO++			2/3 FPS		
		SSIM	VQM	VMAF	SSIM	VQM	VMAF	SSIM	VQM	VMAF	SSIM	VQM	VMAF
Static	NBC	99.53%	0.730	99.61%	99.41%	0.814	99.33%	99.06%	0.998	98.92%	98.52%	1.137	98.42%
	MIT	99.68%	0.235	99.30%	99.63%	0.256	99.05%	99.56%	0.289	98.69%	99.52%	0.318	98.65%
	Golf	98.64%	0.515	98.66%	98.50%	0.563	98.26%	98.03%	0.711	97.09%	96.95%	0.925	94.91%
Dynamic	PyeongChang	99.29%	0.366	99.27%	99.12%	0.431	98.77%	97.87%	0.847	95.63%	94.20%	1.527	85.57%
	Conan	99.04%	0.818	98.77%	98.76%	0.942	97.76%	98.20%	1.106	96.46%	96.66%	1.513	92.82%
	Kershaw	98.54%	0.707	98.81%	98.18%	0.839	98.20%	96.60%	1.324	95.72%	93.57%	1.866	91.01%
Hybrid	Pororo	98.92%	0.630	97.27%	98.50%	0.780	96.07%	97.62%	1.068	93.33%	95.94%	1.439	90.47%
	Tennis	98.90%	0.806	99.02%	98.76%	0.892	98.62%	98.42%	1.051	97.29%	97.93%	1.249	95.32%
	Geographic	99.12%	0.860	99.34%	98.94%	0.962	98.80%	98.73%	1.095	97.99%	98.45%	1.199	97.16%

- EVSO provides better video quality than 2/3 FPS in all video cases
- The most prominent quality gap occurs **in the dynamic group**

Metric	UX
SSIM ↑	😊
VQM ↑	😞
VMAF ↑	😊

Evaluation: How much the processed videos affect the UX?



- Recruited 15 participants
- The participants clearly discriminated 2/3 FPS as low qualities
- Most participants did not recognize the difference between the original & EVSO

One Video is Worth a Thousand Words! 😊

Original



EVSO



EVSO++



2/3 FPS



Summary

- ✓ EVSO effectively measures the similarity of frames: **M-Diff**
- ✓ EVSO adaptively adjusts the FPS of video according to the degree of motion intensity using M-Diff: **F-Scheduler**
- ✓ EVSO takes into account not only network conditions but also battery status: **EMPD**

**EVSO can save a lot of device energy
but has little impact on UX**

Q&A

THANK YOU!