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Optimizing Video Transmission for Mobile Devices

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Abstract
As mobile devices that can accommodate multimedia services are increasingly used, video data transmission consumes a significant amount of wireless channel bandwidth. On the other hand, the sizes and resolutions of mobile devices show large variations. In this paper, we investigate the optimal transmission of video data depending on the size and resolution of the mobile devices that include smartphones, tablets and notebooks. A series of subjective tests indicates the bandwidth consumption for multimedia services can be significantly reduced by considering the size and resolution of displays and content characteristics.

Introduction
Mobile devices that can show multimedia services have been increasingly employed in the market. With efficient video compression and a wide use of internet, a variety of video streaming services are consumed by the mobile devices. The data size of a typical video program is considerably larger than other data types such as voice or text data. Consequently, video data constitutes a dominant portion of internet traffic [1, 2]. Also the video data uses a significant amount of wireless communication channel.

Most OTT (over the top) service providers tend to transmit video data by using the maximum available bandwidth. On the other hand, the mobile devices come in various sizes and resolutions. Typical smartphones have 4-6s inch displays whereas tablets have 7~12 inch displays. The notebook may have 10~17 inch displays. With IPTV and internet TV services, many users watch video streaming services using big screen TV monitors whose sizes can be 30~100 inches.

In this paper, we investigate optimal video transmission for mobile devices by taking into account the size and resolution of displays and content characteristics. A number of subjective tests were performed using various displays (smartphones, tablet, TV monitor) and diverse video contents. By analyzing the perceptual quality of each display, it is observed that a significant reduction of bandwidth is possible by considering the display and content characteristics.

Displays and Subjective Test

Displays
Four displays were used in subjective tests, which include mobile phones, a tablet, and a TV monitor. Table 1 shows the characteristics of the four displays used in the subjective tests.

Subjective Tests
A number of subjective tests were performed using the four displays. Various source video sequences were used in the tests. The source video resolutions were 1080p (full HD). In many streaming services, the video resolution is first reduced and then encoded for improved video quality when the bandwidth is not sufficient. In the subjective tests, we reduced the full HD video sequences to lower resolutions (720p and 540p) and encoded the resized video sequences.

The viewing environment was prepared in accordance with ITU-T Recommendation P.910 [3]. For mobile devices (smartphones, tablet), a viewing booth was built to accurately control illumination conditions, which simulated a normal viewing environment for such mobile devices. The booth brightness was set to 500 lux at the desk level (Fig. 1).

As a subjective testing method, we used the absolute category rating (ACR) assessment method [4] since it can accommodate a large number of test conditions in a testing period. In the ACR method, the viewer watches a test clip that is about 8~10 seconds and then scores the clip. Table 2 shows the five grade scale of the ACR method and Fig. 2 shows the ACR presentation. At least 24 viewers participated in each subjective test after screening.

Table 1. Displays used in the subjective tests.

	Type	Resolution	Size
Display 1	Smartphone LCD	1,136 x 640	4 inch
Display 2	Smartphone AMOLED	1,920 x 1,080	5 inch
Display 3	Tablet LCD	2,048 x 1,536	9.7 inch
Display 4	TV monitor LCD	1,920 x 1,080	42 inch

Table 2. Five-grade scales of ACR.

Score	Category
5	Excellent
4	Good
3	Fair
2	Poor
1	Bad

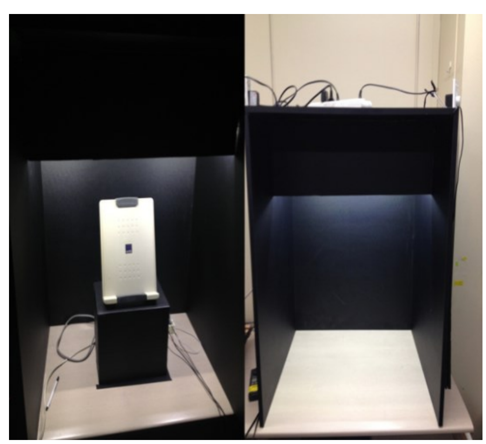

Figure 1. Viewing booth for the mobile devices.

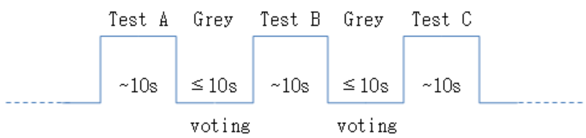

Figure 2. ACR presentation.

Experimental Results and Analyses

Subjective tests and analyses

In the first subjective test, the four displays of Table 1 were used. Table 3 shows the test conditions of the first test. H.264 was used to encode the video sequences (x264). The default setting was used and Table 4 shows the numbers of I, P and B frames along with content types.

Table 3. Test conditions for the first subjective test.

Resolution	Bitrates (Kbps)	Resolution	Bitrates (Kbps)	Resolution	Bitrates (Kbps)
540p	600	720p	800	1080p	1000
	1000		1200		2000
	1500		2000		3000
	2500		3000		4000
	4000		5000		6000
					8000

Table 4. GOP structure of the first test.

	I	P	B	genre
SRC01	2	415	3	document
SRC02	3	206	211	sports
SRC03	6	326	88	drama
SRC04	9	250	161	document
SRC05	13	268	139	animation
SRC06	2	413	5	document
SRC07	5	235	180	sports
SRC08	13	225	182	movie
SRC09	11	265	144	advertisement
SRC10	6	168	246	drama
AVG	7.0	277.1	135.9	

Fig. 3 shows the average MOS (mean opinion score) at the various bitrates of the four displays. The maximum perceptual quality of the four displays are very similar. For the four inch smartphone, the perceptual quality of 540p at about 3Mbps would be very similar to the perceptual quality of 1080p at 8Mbps whereas the perceptual quality of 540p at about 3Mbps was lower to the perceptual quality of 1080p at 8Mbps for the TV monitors. It is also noted that, at low bitrates, the perceptual quality of the reduced resolutions was better than that of the original resolution (1080p) for all the displays.

Fig. 3 also shows the perceptual quality levels that are statistically equivalent to the perceptual quality of 1080p at 8 Mbps. Tables 5-8 show the minimum bitrates that can provide statistically equivalent perceptual quality to the perceptual quality of 1080p at 8 Mbps. To achieve the statistically equivalent perceptual quality of 1080p at 8 Mbps (reference quality), the average minimum bitrates were 3.2 Mbps, 3.5 Mbps, 3.8 Mbps and 4.4 Mbps for the 4' smartphone, the 5'smartphone, the tablet and the TV monitor, respectively. As the display increases, the average minimum bitrate for the reference quality also increases as expected. Even for the TV monitor, the statistically equivalent perceptual quality could be achieved at lower bitrates for some contents (e.g., SRC01, SRC 05). For the smallest display (4' smartphone), the 540p contents at considerably lower bitrates could provide the reference quality in most cases. On the other hand, for large displays (e.g., tablet and TV monitor), many 540p contents failed to provide the reference quality in some cases.

Table 5. The minimum bitrates that can provide statistically equivalent perceptual quality (4' smartphone).

	540p	720p	1080p	Min
SRC01	4.0	5.0	6.0	4.0
SRC02	4.0	5.0	6.0	4.0
SRC03	2.5	3.0	6.0	2.5
SRC04	4.0	5.0	6.0	4.0
SRC05	1.5	2.0	2.0	1.5
SRC06	-	5.0	8.0	5.0
SRC07	4.0	2.0	3.0	2.0
SRC08	4.0	-	6.0	4.0
SRC09	-	3.0	8.0	3.0
SRC10	2.5	2.0	3.0	2.0
Average				3.2

Table 6. The minimum bitrates that can provide statistically equivalent perceptual quality (5' smartphone).

	540p	720p	1080p	Min
SRC01	-	5.0	6.0	5.0
SRC02	-	5.0	8.0	5.0
SRC03	-	5.0	4.0	4.0
SRC04	2.5	5.0	8.0	2.5
SRC05	4.0	3.0	3.0	3.0
SRC06	4.0	2.0	3.0	2.0
SRC07	-	5.0	6.0	5.0
SRC08	2.5	1.2	2.0	1.2
SRC09	-	5.0	6.0	5.0
SRC10	-	5.0	6.0	5.0
Average				3.5

Table 7. The minimum bitrates that can provide statistically equivalent perceptual quality (tablet).

	540p	720p	1080p	Min
SRC01	-	-	6.0	6.0
SRC02	-	-	6.0	6.0
SRC03	4.0	3.0	6.0	3.0
SRC04	4.0	3.0	3.0	3.0
SRC05	0.6	1.2	2.0	0.6
SRC06	4.0	5.0	6.0	4.0
SRC07	2.5	3.0	2.0	2.0
SRC08	-	-	6.0	6.0
SRC09	4.0	5.0	4.0	4.0
SRC10	4.0	5.0	3.0	3.0
Average				3.8

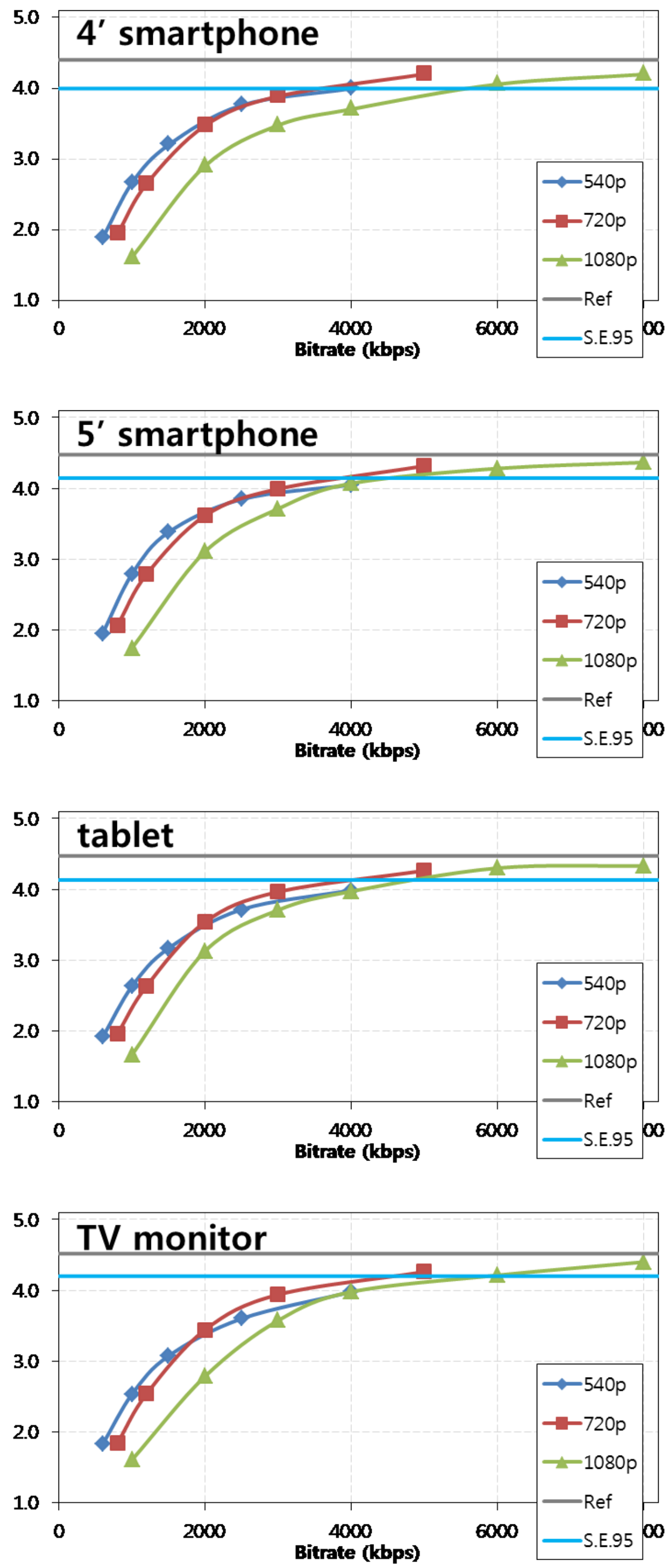

Figure 3. MOS as a function of bitrates of the four displays.

Table 8. The minimum bitrates that can provide statistically equivalent perceptual quality (TV monitor).

	540p	720p	1080p	Min
SRC01	4.0	3.0	4.0	3.0
SRC02	-	-	6.0	6.0
SRC03	4.0	3.0	4.0	3.0
SRC04	-	5.0	6.0	5.0
SRC05	-	2.0	3.0	2.0
SRC06	-	5.0	8.0	5.0
SRC07	-	5.0	4.0	4.0
SRC08	4.0	5.0	6.0	4.0
SRC09	-	-	8.0	8.0
SRC10	-	5.0	4.0	4.0
Average				4.4

Table 9. Test conditions for the second subjective test.

Resolution	Bitrates (Kbps)	Resolution	Bitrates (Kbps)	Resolution	Bitrates (Kbps)
540p	600	720p	800	1080p	1000
	1000		2000		2000
	2500		3000		3000
	4000		4000		4000
	6000		5000		6000
			6000		8000

Table 10. Source video characteristics.

	SI	TI	SI average	TI average
SRC01	46	45	25	8
SRC02	81	41	74	8
SRC03	60	56	31	7
SRC04	64	47	30	10
SRC05	65	59	47	6
SRC06	46	45	35	14
SRC07	62	48	36	25
SRC08	55	29	29	17
SRC09	112	50	87	5
SRC10	32	43	28	3

In the second test, the three mobile displays were used. Table 9 shows the test conditions of the second test. Table 10 shows the source video characteristics in terms of SI (spatial information) and TI (temporal information) as defined in [3]. Fig. 4 shows the average MOS (mean opinion score) at the various bitrates of the three displays. Fig. 4 also shows the perceptual quality levels that are statistically equivalent to the perceptual quality of 1080p at 8 Mbps. To achieve the statistically equivalent perceptual quality of 1080p at 8 Mbps, the average minimum bitrates were 2.6 Mbps, 2.7 Mbps, and 3.6 Mbps for the 4' smartphone, the 5'smartphone, and the tablet, respectively. Fig. 4 also shows the average PSNRs of the three resolutions (540p, 720p, 1080p) at the various bitrates. As the resolution increased, the maximum PSNR also increased. On the other hand, if PSNR >35~40, the perceptual video quality tends to be saturated.

Table 11 shows MOS values at the various bitrates for the 5' smartphone for some categories. In many cases, if the MOS value is larger than 3.5, the perceptual video quality would be acceptable. If the MOS value is larger than 4, the perceptual video quality would be very good. In case of sports, the minimum bitrates are about 1.7~2.0 Mbps for acceptable perceptual quality. For animations and drama, 1.2~1.5 Mbps can provide for acceptable perceptual quality in most cases.

Table 12 shows the minimum bitrates required to achieve MOS values of 3.5 and 4.0 for the 5' smartphone and the tablet (averages of four subjective tests). For sports, 2~3 Mbps are required to achieve high video quality. On the other hand, for movies and dramas, 1~2 Mbps would be sufficient in most cases.

Table 11. MOS values at the various bitrates for the 5' smartphone for some categories.

	Clip	Bitrate						
		0.5	0.7	1	2	3	6	8
Sports	1	1.1	1.2	2.2	3.5	3.9	4.3	4.2
	2		1.9	2.7	3.6	3.7		4
	3		2.2	2.7	4.1	3.9		4.3
	4		1.6	2.3	3.7	4.3	3.8	4.3
Movies	1		3.3	4				4.1
	2		3.4	3.3	4.3	4.2	4.3	4.2
	3		3.3	4.4				4.2
	4		3.6	3.4	4.2	4.3		4.3
Animations	1	1.2	1.7	2.7	3.6	4.3		4.1
	2	2.7	3.4	3.6				4.5
	3		1.5	3.5	4.3	4.2		4.6
	4		3.5	3.6				4.5
	5			3.5	4	3.9		4.3
Documentary	1	2.4	2.8	3.7				4.3
	2		3.7	4				4.1
	3		3.2	3.3	3.5	4.2	4.1	4.1
	4		1.5	2.8	3.7	4.1	4.2	4.2
Drama	1	2.3	2.8	4.3				4.6
	2		2.2	4.3	4.8	4.6		4.5
	3		3.2	3.8				4.8
	4		2.5	3.8				4.5
	5		1.4	3.9	4.3	4.3		4.2

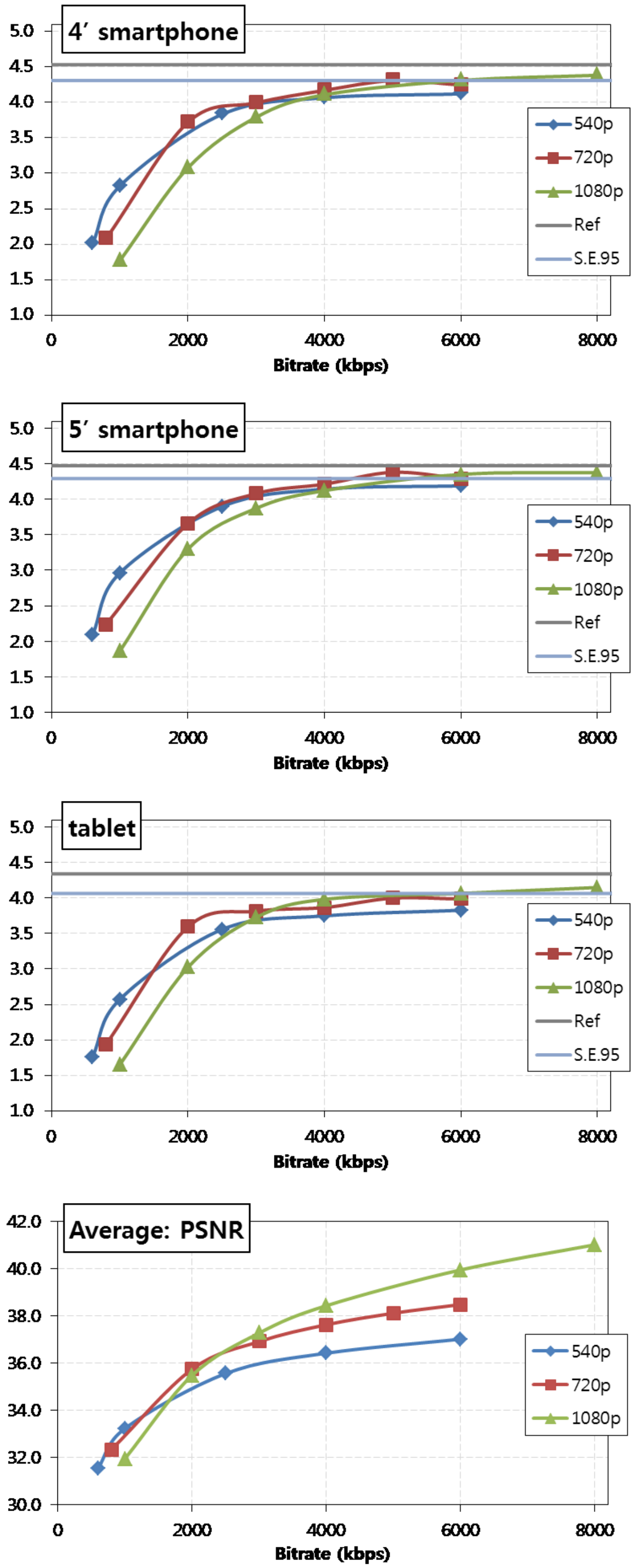

Figure 4. MOS as a function of bitrates of the three displays.

Table 12. The minimum bitrates required to achieve MOS values of 3.5 and 4.0.

	5' smartphone		tablet	
	MOS 3.5	MOS 4.0	MOS 3.5	MOS 4.0
Sports	2.0	2.6	1.9	3.1
Movies	0.8	1.5	1.2	1.8
Animations	1.5	2.4	1.4	2.0
Documentary	1.8	2.7	1.5	2.3
Drama	1.2	1.9	1.1	1.8

Predicting the minimum bitrate

It is desirable to estimate the minimum bitrate that can provide high perceptual video quality based on the display characteristics and source contents. In this paper, we explored the SI and TI values. Figs. 5-6 show scatter plots between the SI/TI averages and the minimum bitrates required to achieve the MOS value of 3.7. The correlations are not high. We also test a prediction function as follows:

$$B_{estimate} = w_0 + w_1 SI_{avg} + w_2 TI_{avg} \quad (1)$$

This linear combination of SI and TI values provide correlation coefficients of 0.315 ~0.471 (Table 13).

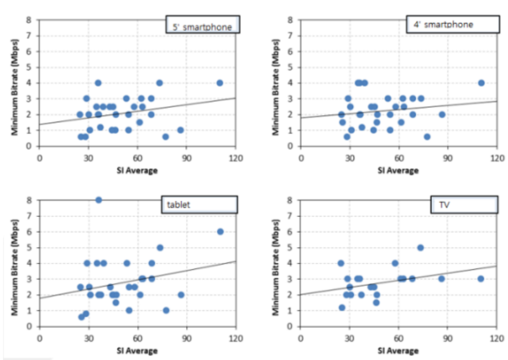

Figure 5. Scatter plot between the SI averages and the minimum bitrates required to achieve the MOS value of 3.7.

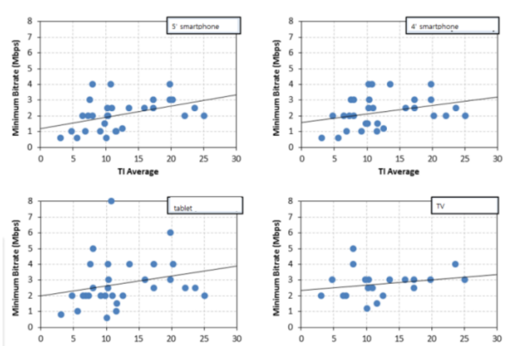

Figure 6. Scatter plot between the TI averages and the minimum bitrates required to achieve the MOS value of 3.7.

Table 13. Correlation coefficients between the estimation function and the minimum bitrates required to achieve the MOS value of 3.7.

5' smartphone	4' smartphone	tablet	TV
0.471	0.342	0.315	0.420

Conclusions

In this paper, we investigated the issue of minimizing the transmission bandwidth without sacrificing the perceptual video quality for mobile devices such as smartphones and tables. A subjective test indicates the bandwidth usage can be significantly reduced by considering the display and source content characteristics. Further studies will be required to accurately predict the optimal bitrate and transmission resolution by taking into account the display size and contents characteristics.

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