

# Online Appendix to: Designing Interactive Multiswimmer Exergames: A Case Study

WOOHYEOK CHOI and JEUNGMIN OH, Korea Advanced Institute of Science and Technology  
 TAIWOO PARK, Michigan State University  
 SEONGJUN KANG, Korea Advanced Institute of Science and Technology  
 MIRI MOON, SK Telecom  
 UICHIN LEE, Korea Advanced Institute of Science and Technology  
 INSEOK HWANG, IBM Research Austin  
 DARREN EDGE, Microsoft Research Asia  
 JUNEHWA SONG, Korea Advanced Institute of Science and Technology

## A. NETWORK PERFORMANCES DURING SWIMMING

Table I. Network Performance Measurement Results for Different Networking Technologies at Varying Depths

Setting	Depth	Min.	1st Quart.	Median	3rd Quart.	Max.	Mean	Std. Dev.
802.11g-100%	Air	1	3	3	6	185	5.51	10.44
	5cm	1	2	3	4	294	4.86	11.31
	10cm	2	4	7	13	2,709	36.38	171.78
	15cm	—	—	—	—	—	—	—
802.11n-100%	Air	1	3	4	7	202	6.55	12.19
	5cm	1	2	3	4	550	5.80	16.74
	10cm	1	3	4	11	6,179	33.02	289.13
	15cm	—	—	—	—	—	—	—
802.11g-50%	Air	1	3	3	6	255	5.74	11.20
	5cm	1	3	4	6	310	6.00	12.35
	10cm	2	5	8	16	2,433	22.28	71.93
	15cm	—	—	—	—	—	—	—
802.11n-50%	Air	1	3	4	6	200	5.98	10.76
	5cm	1	2	3	5	385	8.09	20.86
	10cm	—	—	—	—	—	—	—
	15cm	—	—	—	—	—	—	—
3G-KT Olleh	Air	46	67	101	243	962	165.00	130.03
	5cm	51	3,995	45,610	81,030	91,200	43,480.00	36,102.33
	10cm	—	—	—	—	—	—	—
	15cm	—	—	—	—	—	—	—
	20cm	—	—	—	—	—	—	—
LTE-KT Olleh	Air	24	43	50	56	552	50.04	13.10
	5cm	31	55	62	79	408	65.17	16.65
	10cm	31	51	59	72	404	61.84	16.05
	15cm	32	51	61	72	154	62.08	14.66
	20cm	—	—	—	—	—	—	—
LTE-LG U+	Air	35	46	50	53	216	50.21	7.70
	5cm	33	58	65	80	6,379	170.10	510.12
	10cm	38	64	76	114	8,071	201.20	463.80
	15cm	38	57	64	75	8,479	329.30	1,010.61
	20cm	38	66	82	1,664	23,420	2,026.00	4,316.37

(a) Round-trip time measurement results (in milliseconds) for different networking technologies at varying depths

(Continued)

Table I. Continued

Setting	Depth	Min.	1st Quart.	Median	3rd Quart.	Max.	Mean	Std. Dev.
802.11g-100%	Air	.00	.00	.00	.00	.00	.00	.00
	5cm	.00	.00	.00	.00	.01	.00	.00
	10cm	.04	.05	.06	.07	.34	.09	.09
	15cm	1.00	1.00	1.00	1.00	1.00	1.00	.00
802.11n-100%	Air	.00	.00	.00	.00	.00	.00	.00
	5cm	.00	.00	.00	.00	.00	.00	.00
	10cm	.01	.01	.02	.03	.55	.07	.17
	15cm	1.00	1.00	1.00	1.00	1.00	1.00	.00
802.11g-50%	Air	.00	.00	.00	.00	.00	.00	.00
	5cm	.00	.00	.00	.00	.02	.01	.01
	10cm	.06	.06	.07	.08	.11	.07	.02
	15cm	1.00	1.00	1.00	1.00	1.00	1.00	0.00
802.11n-50%	Air	.00	.00	.00	.00	.00	.00	.00
	5cm	.00	.00	.00	.00	.00	.00	.00
	10cm	1.00	1.00	1.00	1.00	1.00	1.00	.00
	15cm	1.00	1.00	1.00	1.00	1.00	1.00	.00
3G-KT Olleh	Air	.09	.09	.09	.09	.10	.09	.00
	5cm	.79	1.00	1.00	1.00	1.00	.97	.07
	10cm	1.00	1.00	1.00	1.00	1.00	1.00	.00
	15cm	1.00	1.00	1.00	1.00	1.00	1.00	.00
	20cm	1.00	1.00	1.00	1.00	1.00	1.00	.00
LTE-KT Olleh	Air	.00	.00	.00	.00	.00	.00	.00
	5cm	.00	.00	.00	.00	.00	.00	.00
	10cm	.00	.00	.00	.00	.00	.00	.00
	15cm	.00	.21	1.00	1.00	1.00	.68	.47
	20cm	1.00	1.00	1.00	1.00	1.00	1.00	.00
LTE-LG U+	Air	.00	.00	.00	.00	.12	.01	.04
	5cm	.00	.00	.00	.00	.01	.00	.00
	10cm	.00	.00	.00	.00	.09	.01	.03
	15cm	.00	.00	.00	.00	.05	.01	.01
	20cm	.00	.00	.07	.30	.57	.16	.21

(b) Packet loss rate measurement results for different networking technologies at varying depths

Setting	Depth	Min.	1st Quart.	Median	3rd Quart.	Max.	Mean	Std. Dev.
802.11g-100%	Air	-46	-45	-45	-45	-39	-44.55	1.30
	5cm	-69	-66	-66	-65	-60	-65.67	0.79
	10cm	-88	-81	-80	-80	-77	-80.62	1.41
	15cm	-93	-91	-91	-90	-87	-90.36	1.01
802.11n-100%	Air	-41	-40	-40	-40	-37	-39.83	0.53
	5cm	-74	-68	-67	-67	-63	-67.14	1.03
	10cm	-89	-79	-79	-79	-77	-79.05	1.32
	15cm	-90	-89	-89	-88	-86	-88.69	0.96
802.11g-50%	Air	-61	-59	-59	-59	-50	-58.70	1.30
	5cm	-80	-77	-77	-76	-72	-76.56	0.95
	10cm	-92	-90	-90	-90	-88	-90.01	0.69
	15cm	—	—	—	—	—	—	—
802.11n-50%	Air	-51	-49	-49	-49	-46	-49.17	0.51
	5cm	-88	-77	-77	-77	-73	-77.05	1.14
	10cm	—	—	—	—	—	—	—
	15cm	—	—	—	—	—	—	—

(Continued)

Table I. Continued

Setting	Depth	Min.	1st Quart.	Median	3rd Quart.	Max.	Mean	Std. Dev.
3G-KT Olleh	Air	-85	-85	-85	-85	-79	-84.36	1.49
	5cm	-113	-113	-111	-109	-95	-110.20	2.76
	10cm	-113	-113	-113	-113	-83	-112.90	1.76
	15cm	—	—	—	—	—	—	—
	20cm	—	—	—	—	—	—	—
LTE-KT Olleh	Air	-96	-95	-95	-95	-95	-95.02	0.12
	5cm	-117	-116	-116	-116	-116	-116.10	0.34
	10cm	-115	-115	-115	-115	-114	-114.90	0.32
	15cm	-121	-121	-121	-121	-120	-120.90	0.29
	20cm	—	—	—	—	—	—	—
LTE-LG U+	Air	-100	-96	-96	-96	-95	-96.10	0.70
	5cm	-125	-122	-121	-120	-114	-120.60	2.36
	10cm	-127	-120	-119	-117	-115	-119.10	1.90
	15cm	-126	-122	-121	-120	-116	-121.20	1.66
	20cm	-126	-124	-122	-121	-118	-122.40	1.56

(c) Received signal strength measurement results (in decibel-milliwatt) for different networking technologies at varying depths

Setting	Depth	Min.	1st Quart.	Median	3rd Quart.	Max.	Mean	Std. Dev.
802.11g-100%	Air	18	54	54	54	54	53.64	2.77
	5cm	1	2	11	11	36	9.04	7.33
	10cm	1	1	2	2	54	2.12	3.53
	15cm	—	—	—	—	—	—	—
802.11n-100%	Air	72	72	72	72	72	72	0
	5cm	19	39	39	52	58	44.64	8.35
	10cm	1	13	13	13	72	12.82	4.95
	15cm	—	—	—	—	—	—	—
802.11g-50%	Air	18	54	54	54	54	53.62	3.32
	5cm	1	2	5	11	36	5.71	5.46
	10cm	1	1	1	2	11	1.72	1.3
	15cm	—	—	—	—	—	—	—
802.11n-50%	Air	72	72	72	72	72	72	0
	5cm	19	39	39	52	58	43.61	8.68
	10cm	—	—	—	—	—	—	—
	15cm	—	—	—	—	—	—	—

(d) Link speed measurement results (in million bits per second) for different networking technologies at varying depths

Table II. Performance Comparison of Two LTE Providers at Different Sites

Provider	Site	Min.	1st Quart.	Median	3rd Quart.	Max.	Mean	Std. Dev.
KT Olleh	S1	33	43	48	54	259	48.84	9.16
	S2	30	43	49	53	240	48.88	9.79
	S3	28	44	49	55	250	50.00	9.37
	S4	34	49	56	62	588	58.52	25.17
LG U+	S1	33	49	54	58	279	55.29	11.25
	S2	34	49	52	55	257	52.51	8.33
	S3	38	50	53	58	158	54.34	7.21
	S4	38	50	53	58	202	54.17	8.08

(a) Round-trip time measurement results (in milliseconds) for two LTE providers at different sites

Provider	Site	Min.	1st Quart.	Median	3rd Quart.	Max.	Mean	Std. Dev.
KT Olleh	S1	-85	-84	-84	-83	-82	-83.80	0.55
	S2	-77	-73	-73	-72	-72	-73.12	1.23
	S3	-88	-85	-84	-84	-83	-84.53	0.79
	S4	-97	-97	-97	-97	-92	-96.28	1.53
LG U+	S1	-95	-93	-92	-92	-90	-92.10	0.79
	S2	-80	-79	-79	-77	-76	-78.29	1.02
	S3	-91	-90	-90	-90	-90	-90.02	0.14
	S4	-100	-99.5	-99	-98	-97	-98.69	0.96

(b) Received signal strength measurement results (in decibel-milliwatt) for two LTE providers at different sites

Table III. Round-Trip Time Measurement Results (in Milliseconds) for 802.11g and LTE-LG U+ with Different Swimming Styles

Network type	Swimming Style	Min.	1st Quart.	Median	3rd Quart.	Max.	Mean	Std. Dev.
802.11g	Overall	3	10	184	900	4,883	543.60	786.86
	Freestyle	4	8	50	611	1,721	342.38	467.77
	Backstroke	3	106	524	1115	2,249	643.64	568.31
	Butterfly	4	7	10	127	1,226	110.76	212.75
	Breaststroke	6	100	1,875	3,506	4,883	1,941.48	1,683.08
LTE-LG U+	Overall	35	65	144	440	2,403	320.63	385.89
	Freestyle	35	58	100	355	1,328	244.14	267.92
	Backstroke	41	64	84	186	1,760	164.77	209.02
	Butterfly	39	75	183	462	1,394	311.87	304.32
	Breaststroke	38	117	473	860	2,403	583.50	525.68