The exploration of 802.11ac under different scenarios

Feb.17th , 2023

Group X

Member:

National University of Singapore

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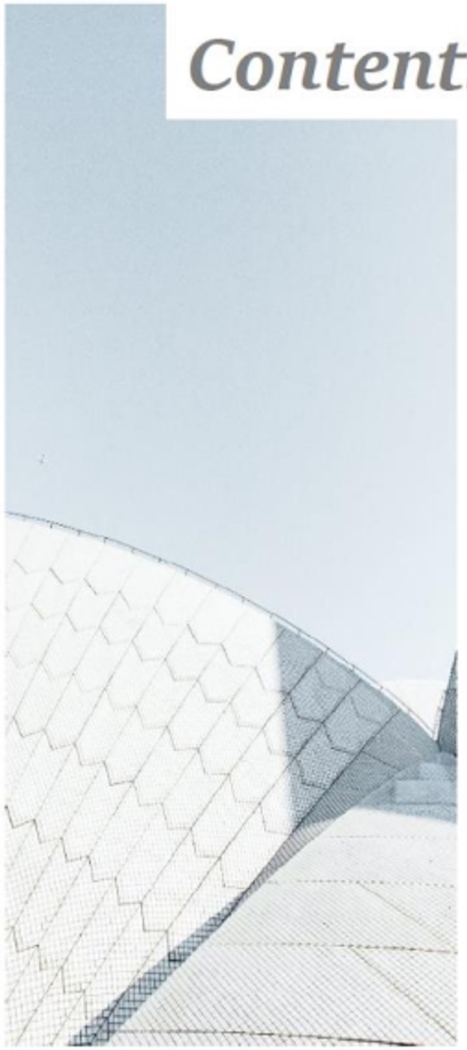


Introduction

- ***Background***
- *Scenario discussion*

Background

Wireless Generation	1G	2G	3G		4G	5G		
IEEE WLAN Standard	802.11	802.11b	802.11a	802.11g	802.11n	802.11ac Wave1	802.11ac Wave2	802.11ad
Date Ratified	1997	1999	1999	2003	2009	2012	2013	2012
Max. Theoretical Data Rate	2 Mbps	11 Mbps	54 Mbps	54 Mbps	600 Mbps	1.3 Gbps	6.7 Gbps	7 Gbps
Typically Achieved Data Rate	1 Mbps	6.5 Mbps	25 Mbps	25 Mbps	200 Mbps	400 – 700 Mbps	Yet to be tested	Yet to be tested
Frequency band	2.4 GHz	2.4 GHz	5 GHz	2.4 GHz	2.4/ 5 GHz	5 GHz	5 GHz	60 GHz
Max. Spatial Streams	1	1	1	1	4	3	8	-
Backward Compatibility	-	-	-	802.11b	802.11a/g, 802.11b	802.11n	802.11n	-
Coverage Area	-	30 m	30 m	30 m	50 m	70m	80m	Short range
Channel Bandwidth (MHz)	20	20	20	20	20,40	20, 40, 80	20, 40, 80, 160	2160
Modulation Scheme	FHSS, DSSS	HR-DSSS	OFDM	DSSS,OFDM	OFDM, 64-QAM	OFDM (256-QAM)	OFDM(256-QAM)	SC OFDM
Radio Architecture	SISO	SISO	SISO	SISO	MIMO	MIMO	MIMO	-
Typical Usage	Basic Wireless connectivity	Wireless connectivity in homes/offices	Web browsing, email, data transfer	Web browsing, email, data transfer	Video transmission, gaming	Real-time video/ audio, high density WLAN zones	Real-time video/ audio, high density WLAN zones, connectivity to multiple devices	High Definition Video, connectivity to multiple devices
Advanced Antenna Technologies	-	-	-	-	MIMO, up to 4 spatial streams	SU-MIMO	MU-MIMO, Transmit Beamforming	Beam-forming

FHSS: Frequency Hopping Spread Spectrum; DSSS: Direct-Sequence Spread Spectrum; HR-DSSSS: High-Rate Direct-Sequence Spread Spectrum; OFDM: Orthogonal Frequency-Division Multiplexing; QAM: Quadrature Amplitude Modulation; SC-OFDM: Single Carrier Orthogonal Frequency-Division Multiplexing; SISO: Single-Input Single-Output; MIMO: Multiple-Input Multiple-Output; SU-MIMO: Single-User Multiple-Input Multiple-Output; MU-MIMO: Multi-User Multiple-Input Multiple-Output;

Background

Prons:

- Higher transmission speeds
- Wider channel technology
- More perfect backward compatibility

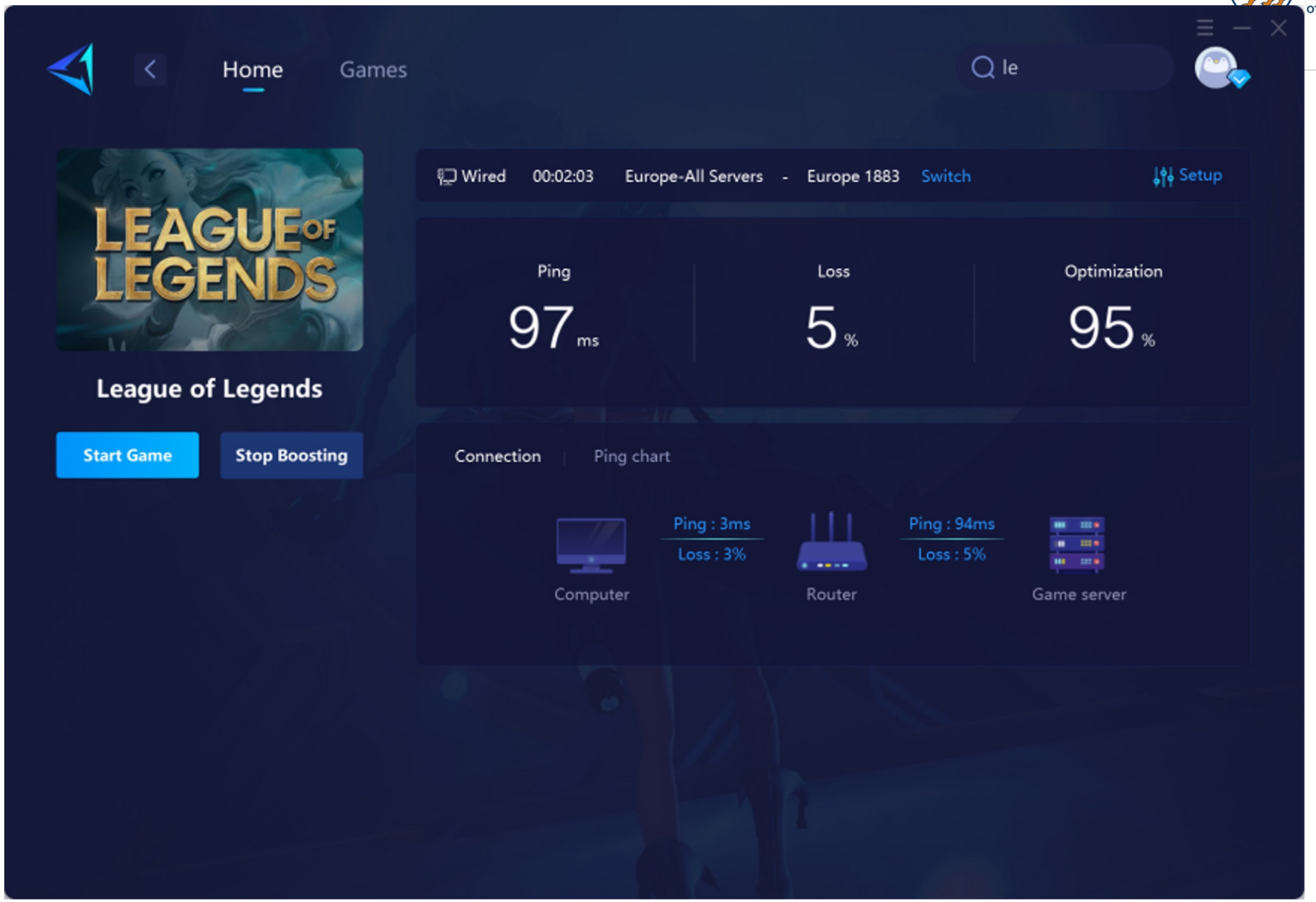
Our simulation task focus on the 802.11ac protocol

The main technology features:

- Improvement on Physical layer
  1. Denser modulation patterns
  2. Wider channel bandwidth
  3. More spatial streams
  4. Beamforming
  5. MU-MIMO

Scenario discussion

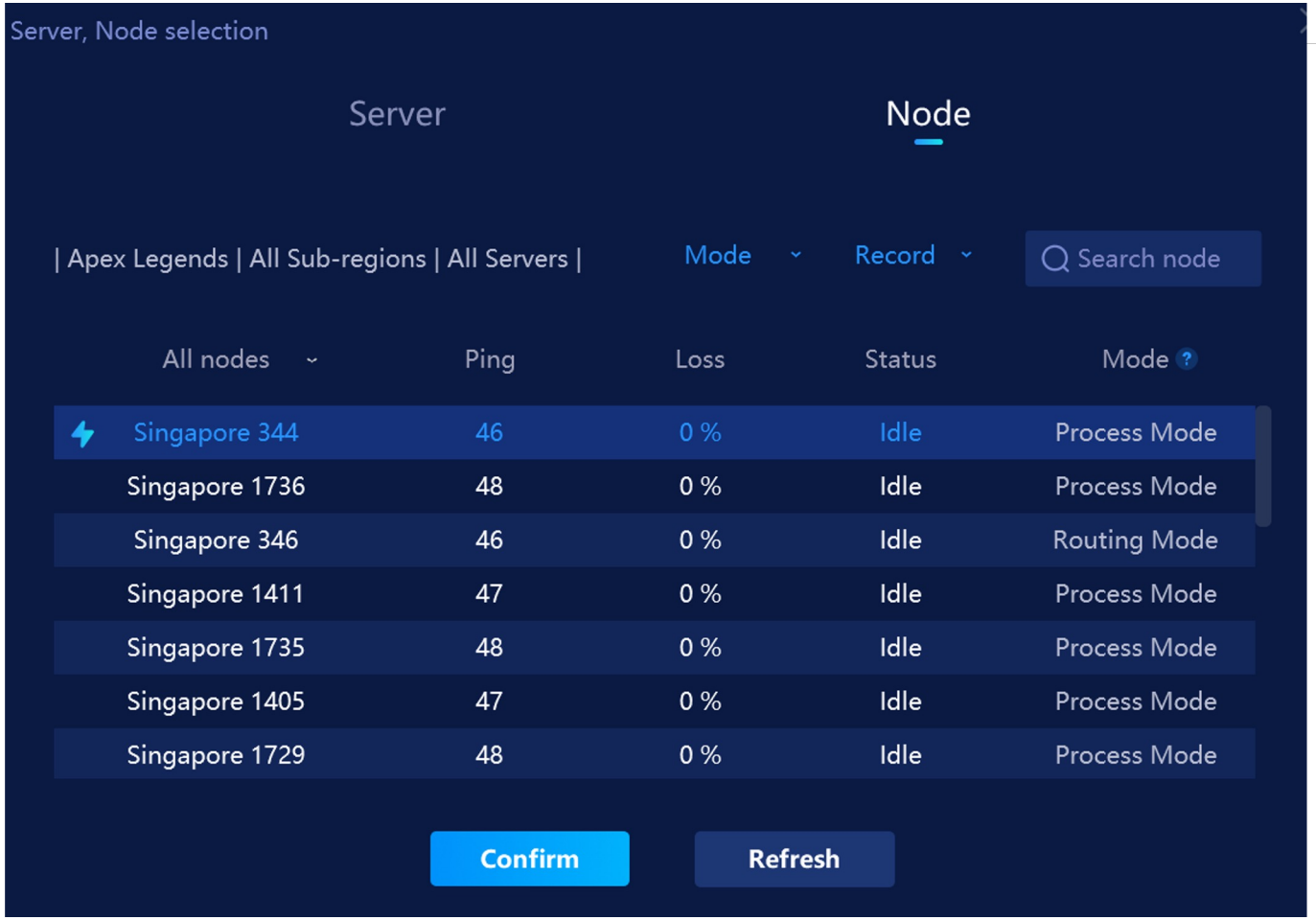
Scenario 1:
Life entertainment scenario
Video/Game/Web browsing



Scenario discussion

Target

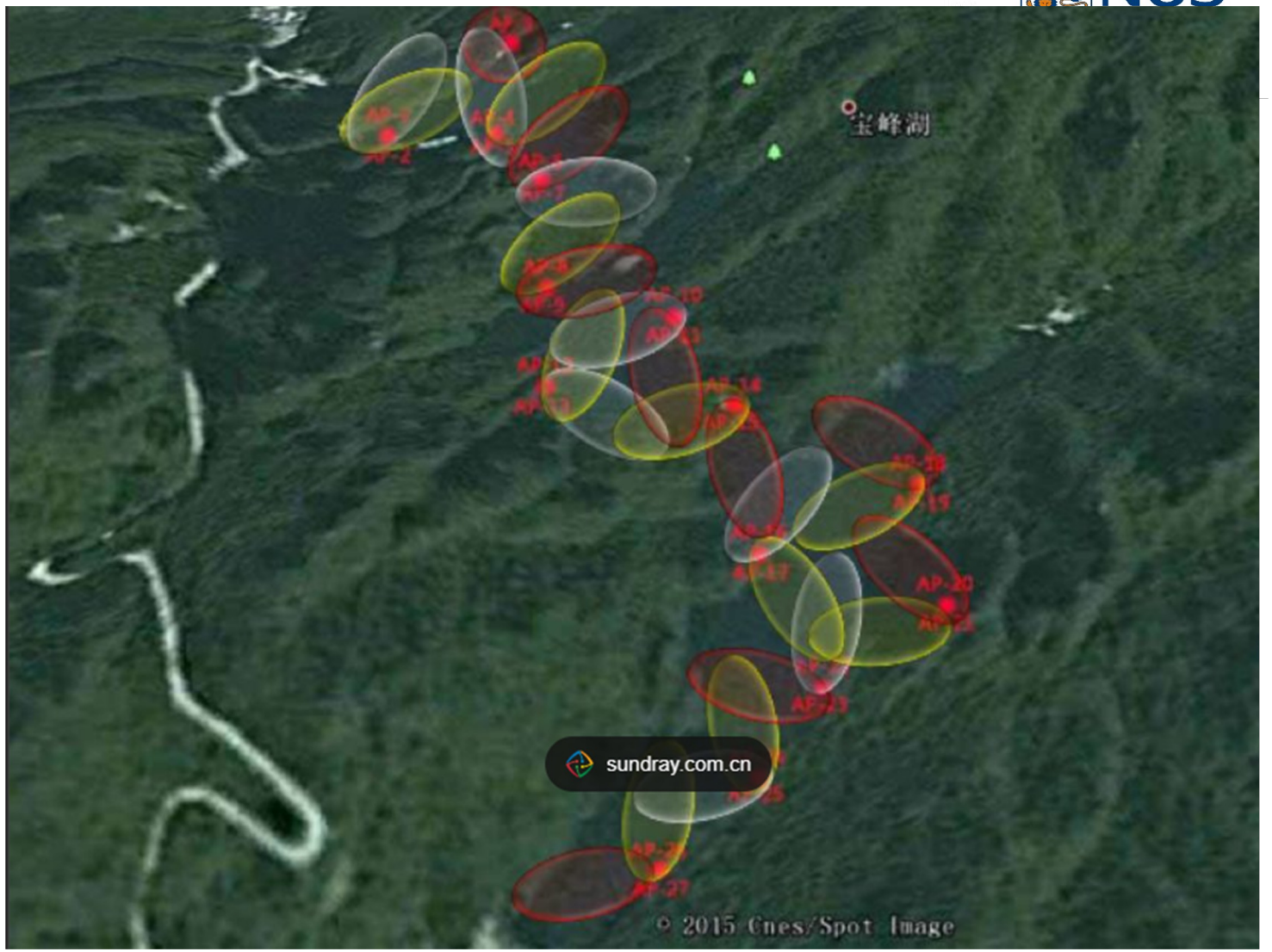
latency ≪100ms
the packet loss rate ≪ 10%



Scenario discussion

Scenario 2:
Performance in real environment

- Obstacle situation
- Height of the transmitter and receiver



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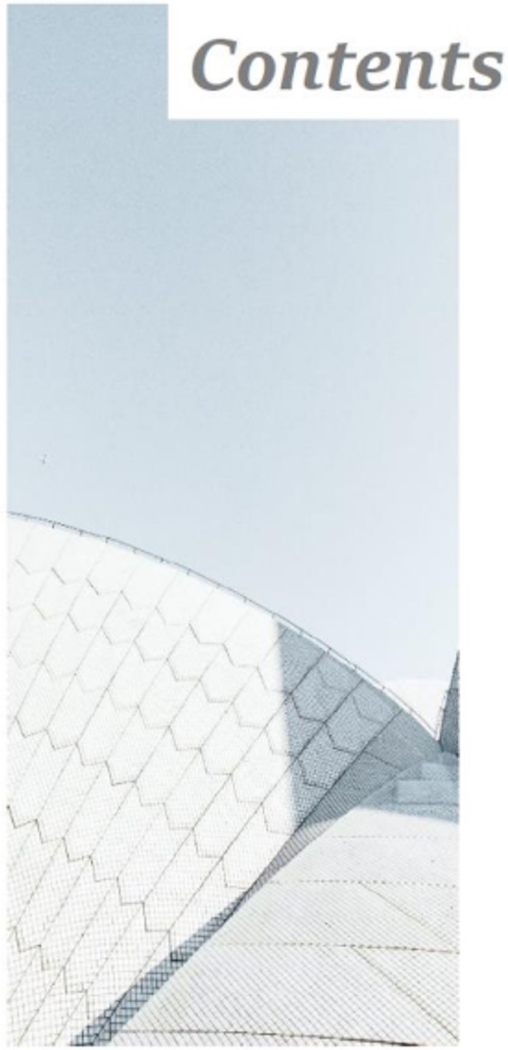


Experiment

- ***Protocol simulation comparison***
- *Nodes density effect*
- *Distance effect*
- *Topographical conditions*

The comparison of IEEE 802.11 protocols[1][2]

Feature/IEEE standard	802.11g	802.11n	802.11ac
Maximum data rate per stream (Mb/s)	54	>100	>500 (Assuming 80MHz channels)
Frequency band	2.4GHz	2.4GHz/5GHz	5GHz
Channel width (MHz)	20	20/40	20/40/80/160/80+80 (last two are optional)
Antenna technology	Single-input single-output (SISO)	Multiple-input multiple-output (MIMO)	Multi-user MIMO
Transmission technique	DSSS and OFDM	OFDM	OFDM
Maximum number of spatial streams	1	4	8
Beamforming-capable	No	Yes	Yes
Approximate coverage range (indoor/outdoor)	38m/140m	70m/250m	35m/NA
Date ratified by IEEE	2003	2009	2014

[1] Bejarano, Oscar, Edward W. Knightly, and Minyoung Park. "IEEE 802.11 ac: from channelization to multi-user MIMO." *IEEE Communications Magazine* 51.10 (2013): 84-90.
[2] Abdelrahman, Ramia Babiker Mohammed, Amin Babiker A. Mustafa, and Ashraf A. Osman. "A Comparison between IEEE 802.11 a, b, g, n and ac Standards." *IOSR Journal of Computer Engineering (IOSR-JEC)* 17.5 (2015): 26-29.

The application settings

App	PUSH
Type	CBR
Packet size	1250Kb
Interval time	1s

App	HTTP
Type	HTTP
Page count	10
Page size	2500Kb
Interval time	1s

App	VOICE
Type	VOICE
Packet size	187Kb
Interval time	20ms

App	VIDEO
Type	VIDEO
Frame	30/s
Pixel	921600
resolution	1280x720

App	EMAIL
Type	EMAIL
Email size	2500Kb
Interval time	1s

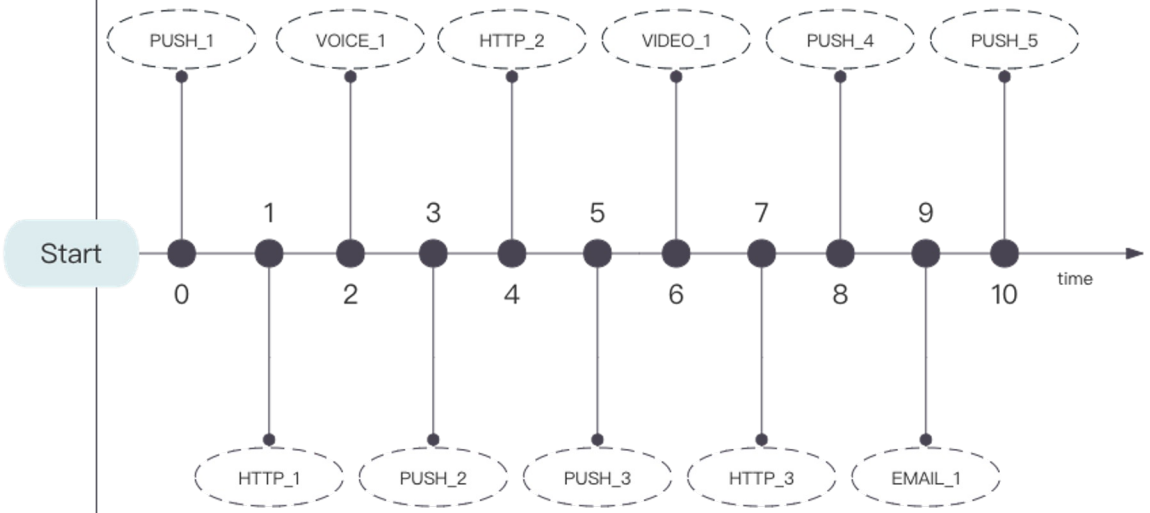


Fig.1 Application launch timeline

30 applications launch one by one in 30 seconds with 1 second interval, which generates up to 35Mbps data at last.

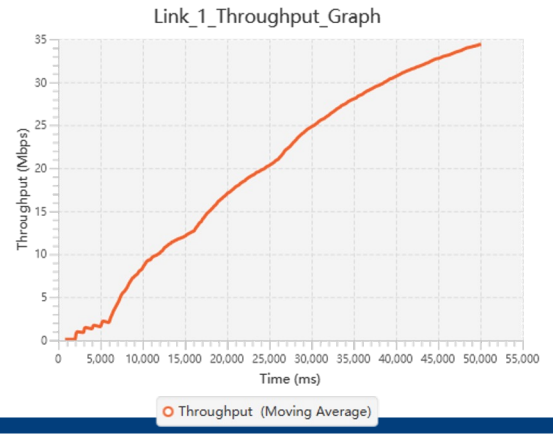


Fig.2 Total data generated by apps

Throughput comparison

Parameter setting

Feature/ IEEE standard	Transmitting power(mW)	Frequency band	Channel width	Transmitting antenna	Receiving antenna	Wireless nodes distribution	Simulation duration
IEEE 802.11g	100	2.4GHz	20MHz	1	1	Within 50m	50s
IEEE 802.11n	100	5GHz	40MHz	1	1	Within 50m	50s
IEEE 802.11ac	100	5GHz	160MHz	1	1	Within 50m	50s

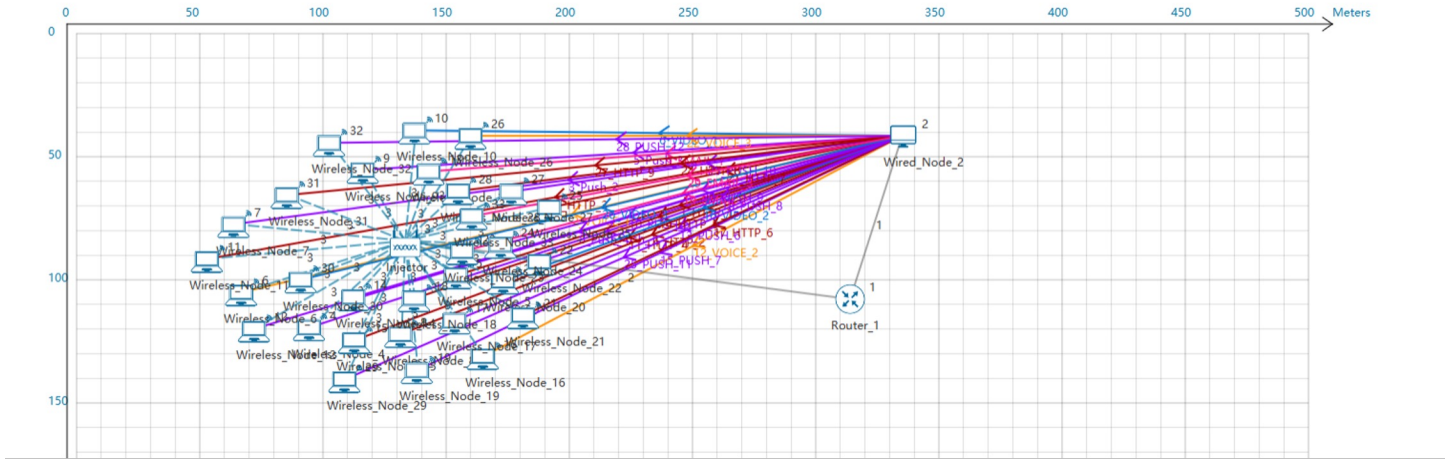
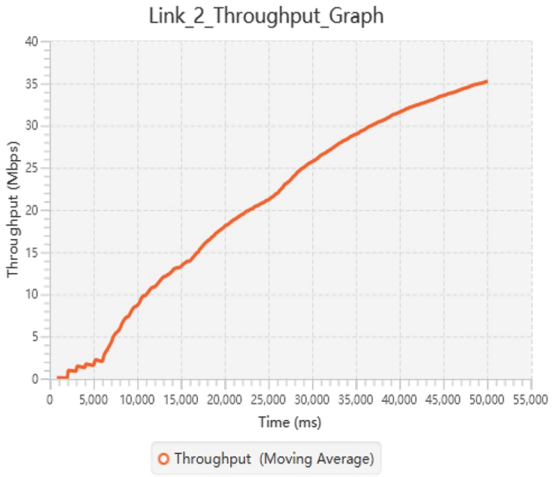


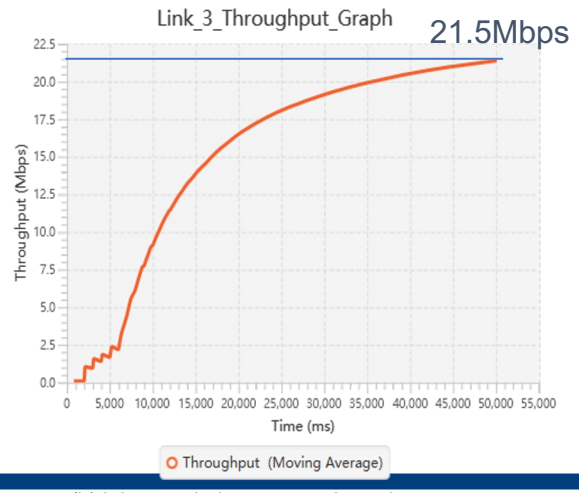
Fig.3 Wireless nodes distribution

Throughput comparison

All wireless link throughput

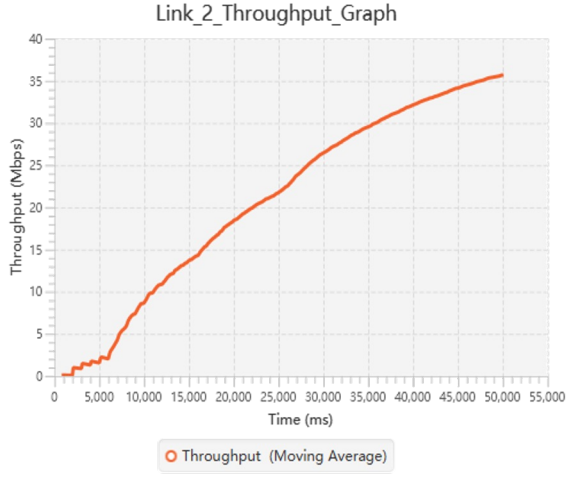


(a) Injector wire input throughput

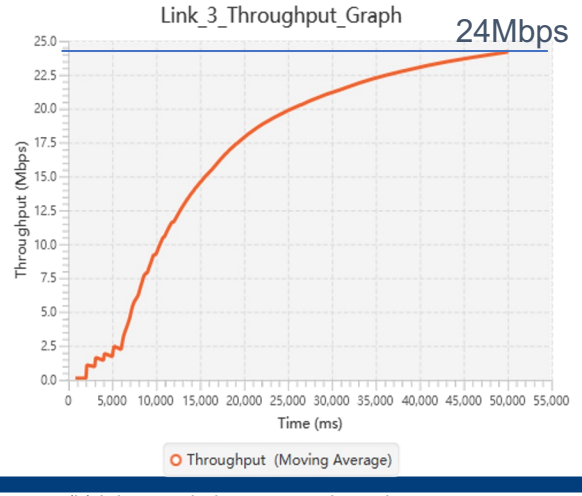


(b) Injector wireless output throughput

Fig.4 802.11g with 30 applications

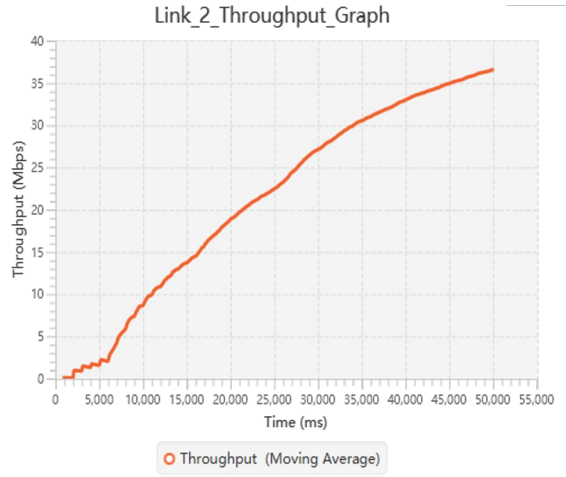


(a) Injector wire input throughput

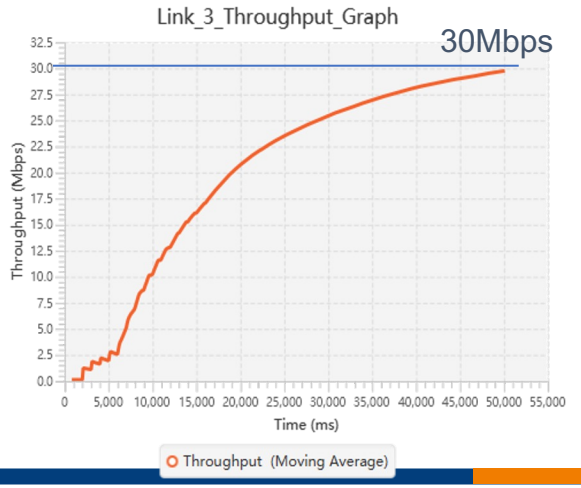


(b) Injector wireless output throughput

Fig.5 802.11n with 30 applications



(a) Injector wire input throughput

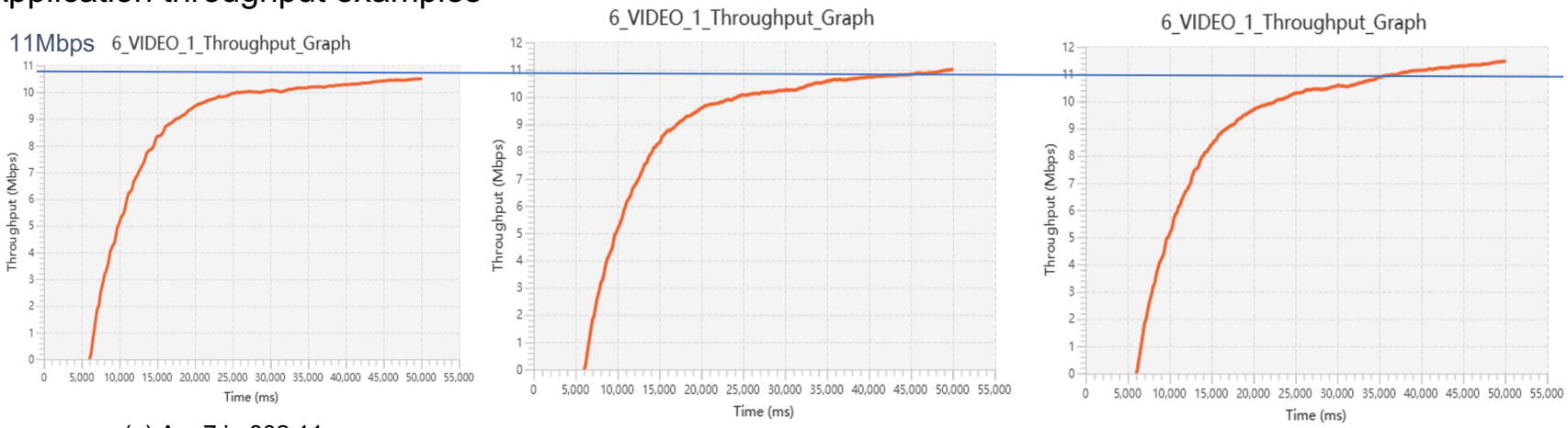


(b) Injector wireless output throughput

Fig.6 802.11ac with 30 applications

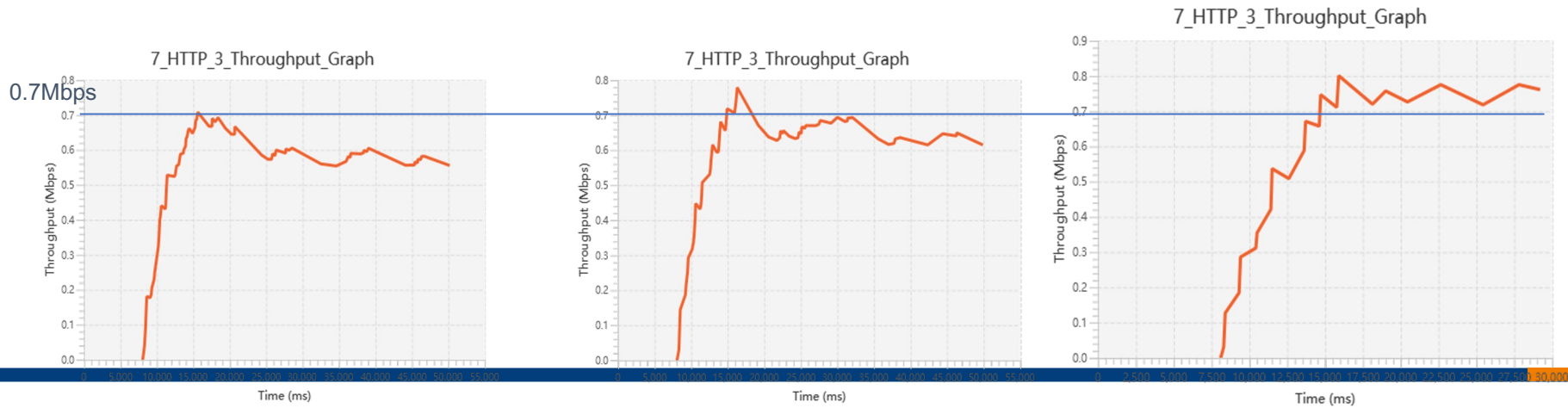
Throughput comparison

Application throughput examples



(a) App7 in 802.11g (b)App7 in 802.11n (c) App7 in 802.11ac

Fig.7 App6 throughput in different protocols



(a) App7 in 802.11g (b)App7 in 802.11n (c) App7 in 802.11ac

Fig.8 App7 throughput in different protocols

Throughput comparison

Full capacity performance

Application	IEEE 802.11g				IEEE 802.11n				IEEE 802.11ac			
	Packet generated	Packet received	Throughput (Mbps)	Delay(microsec)	Packet generated	Packet received	Throughput (Mbps)	Delay(microsec)	Packet generated	Packet received	Throughput (Mbps)	Delay(microsec)
21_HTTP_7	1	0	0	0	980	953	0.375575	3045750	1260	1084	0.427244	2228700
22_VOICE_3	2798	1761	0.278566	5052	2798	1780	0.27716	4870	2798	1829	0.2976	5009
23_PUSH_10	189	4	0.00173	1017843	189	3	0.001298	842539	189	25	0.010619	2531847
24_HTTP_8	280	280	0.123425	1691476	280	280	0.123425	3472511	1540	1332	0.587305	2576667
25_PUSH_11	175	10	0.004602	1621984	175	0	0	0	175	3	0.001402	768059
26_VIDEO_3	29892	6590	3.110232	433098	29892	8029	3.808418	377867	29892	10018	4.761769	326902
27_HTTP_9	420	415	0.20631	1871040	140	140	0.069565	8859421	1120	886	0.440445	2517314
28_PUSH_12	154	0	0	0	154	4	0.002124	13763000	154	19	0.009927	4227248
29_EMAIL_3	280	0	0	0	280	16	0.008731	13924744	280	24	0.013181	1861869

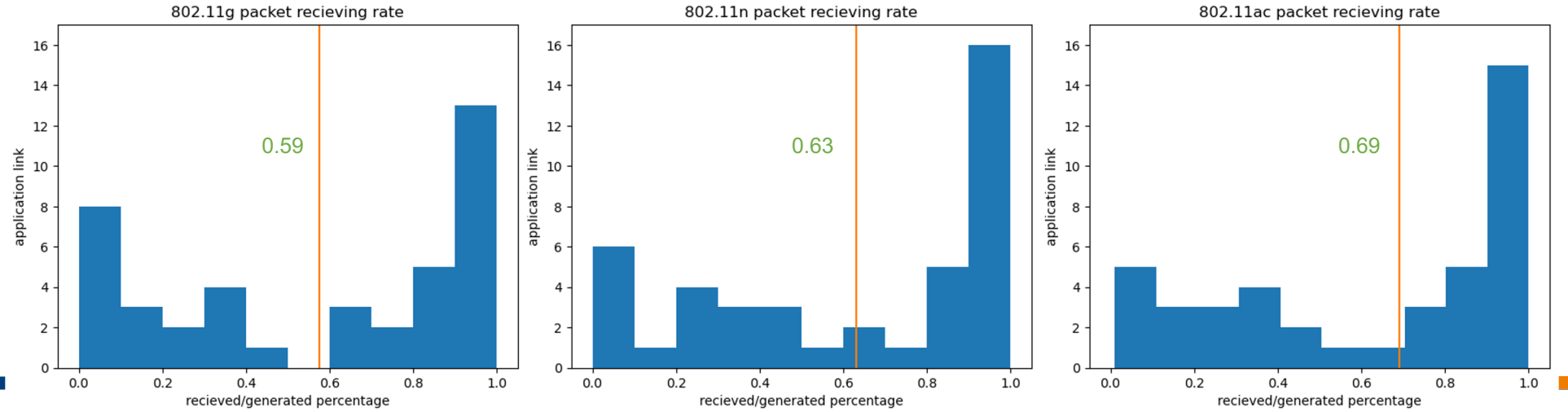


Fig.9 packet receiving rate of different protocols

Antenna technology comparison

Parameter setting

Feature/ IEEE standard	Transmitting power(mW)	Frequency band	Channel width	Antenna technology	Transmitting antenna	Receiving antenna	Wireless nodes distribution	Simulation duration
IEEE 802.11n	100	5GHz	40MHz	SISO	1	1	Within 50m	50s
IEEE 802.11n	100	5GHz	40MHz	MIMO	4	4	Within 50m	50s
IEEE 802.11ac	100	5GHz	40MHz	MU-MIMO	8	8	Within 50m	50s

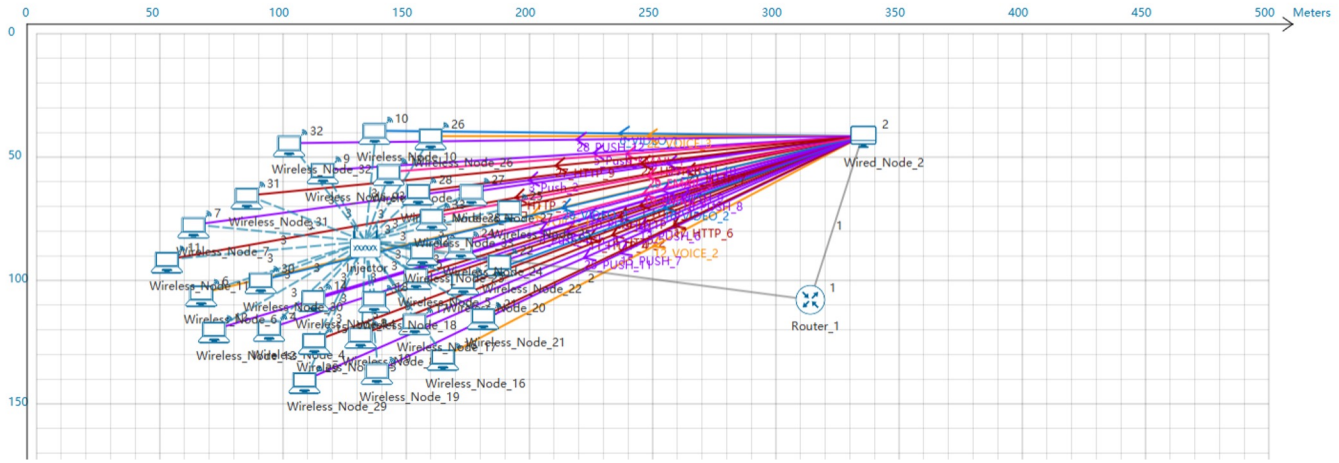


Fig.10 Wireless nodes distribution

Antenna technology comparison

All wireless link throughput

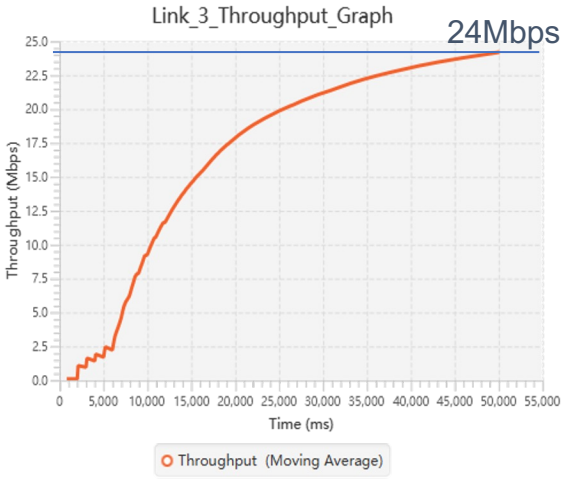


Fig.11 802.11n and SISO

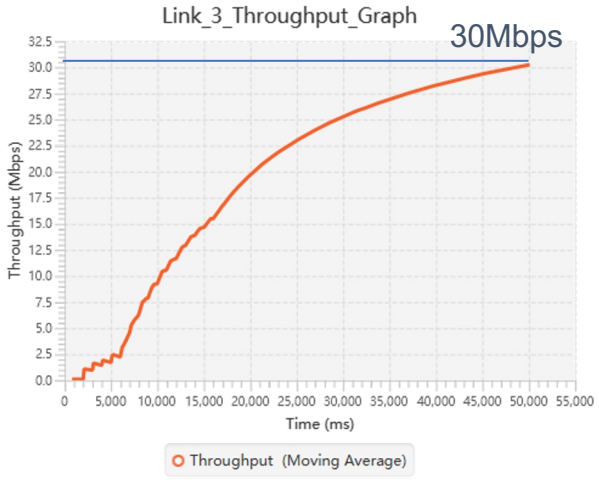


Fig.12 802.11n and 4x4 MIMO

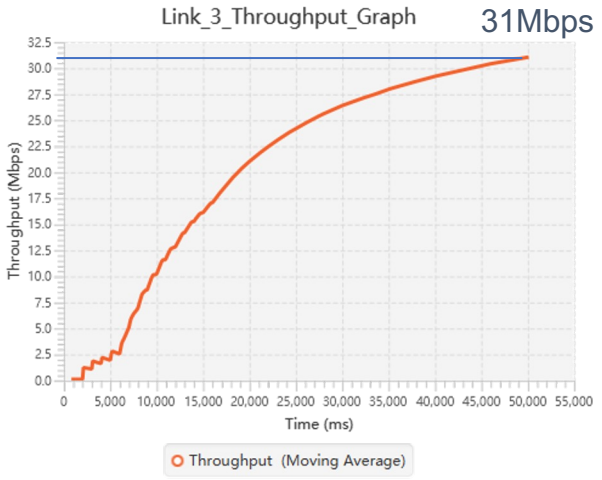


Fig.13 802.11ac and 8x8 MIMO

IEEE standard	802.11n	802.11n	802.11ac
Antenna technology	SISO	4x4 MIMO	8x8 MU-MIMO
throughput	24Mbps	30Mbps	31Mbps
Average throughput per stream	102.4Kb/s	128Kb/s	132.3Kb/s

Conclusion

Simulation result

Feature/IEEE standard	802.11g	802.11n	802.11ac
Access wireless nodes	30	30	30
Frequency band	2.4GHz	2.4GHz/5GHz	5GHz
Channel width (MHz)	20	40	160
Antenna technology	SISO	4x4 MIMO	8x8 MU-MIMO
Maximum throughput (Mbps)	21.5	25/30	33

Therefore, for the party scenario, IEEE 802.11ac protocol is the best choice.

The widest 160MHz channel band can offer a high theoretical maximum data rate. To further enhance the capacity, the access point is able to transmit 8 spatial streams by applying 8x8 MU-MIMO technology. Compared to IEEE 802.11n/g, these feature improve the performance of the wireless network. However, the more complex standard brings problems too. The efficiency decreases due to the longer header. Meanwhile, the data rate of 11n/11ac is lower than 11g at narrow bandwidth and low frequency.

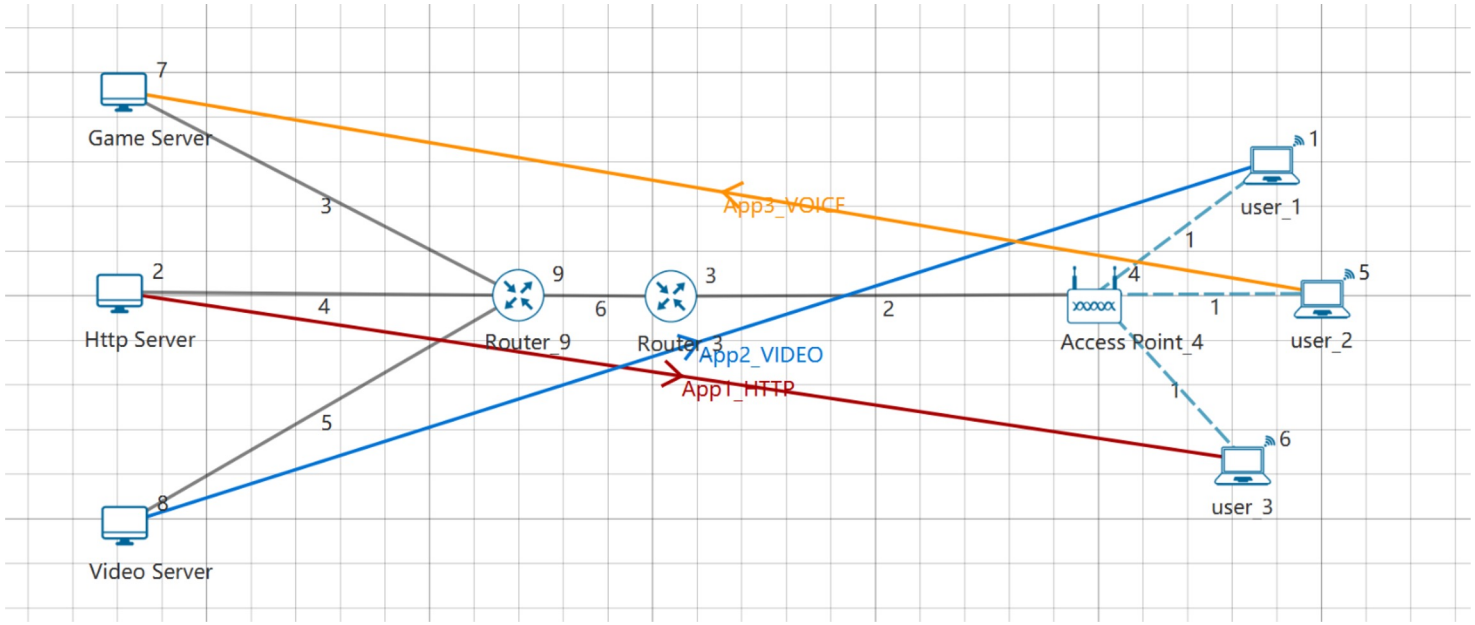
Content

Experiment

- *Protocol simulation comparison*
- ***Nodes density effect***
- *Distance effect*
- *Topographical conditions*

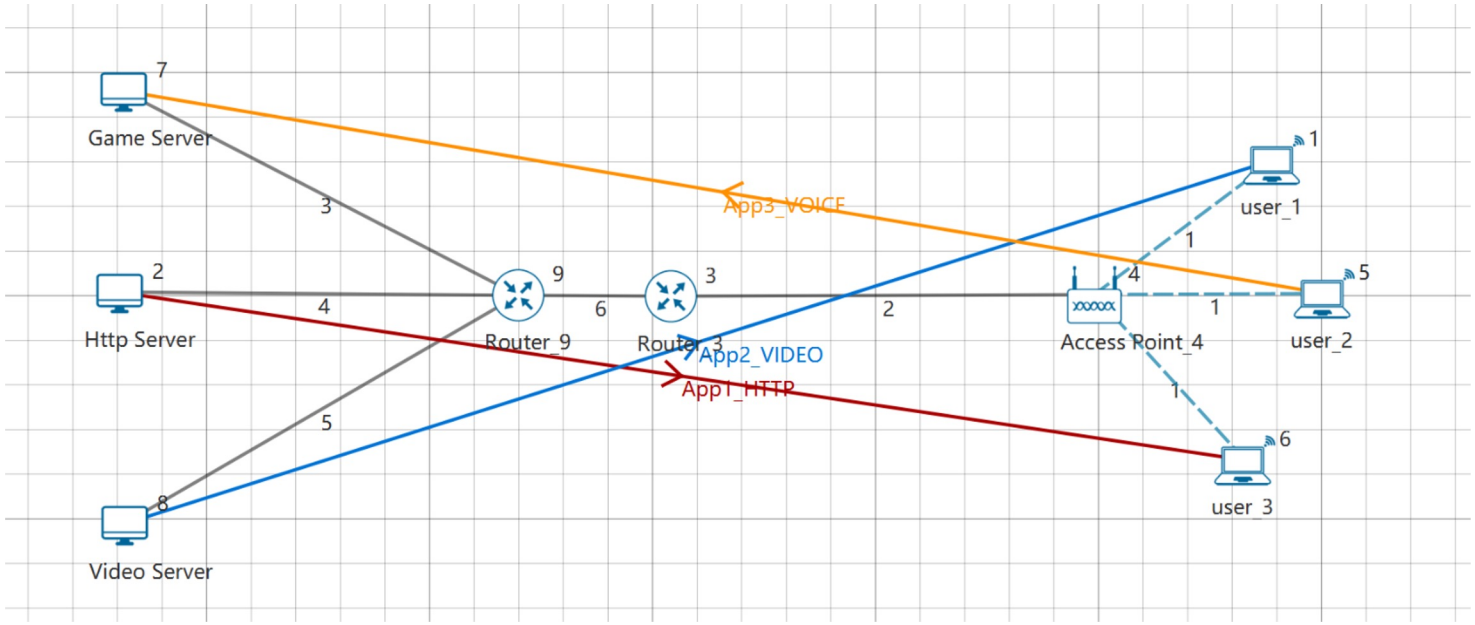
Key Notes

Simple model of my home network



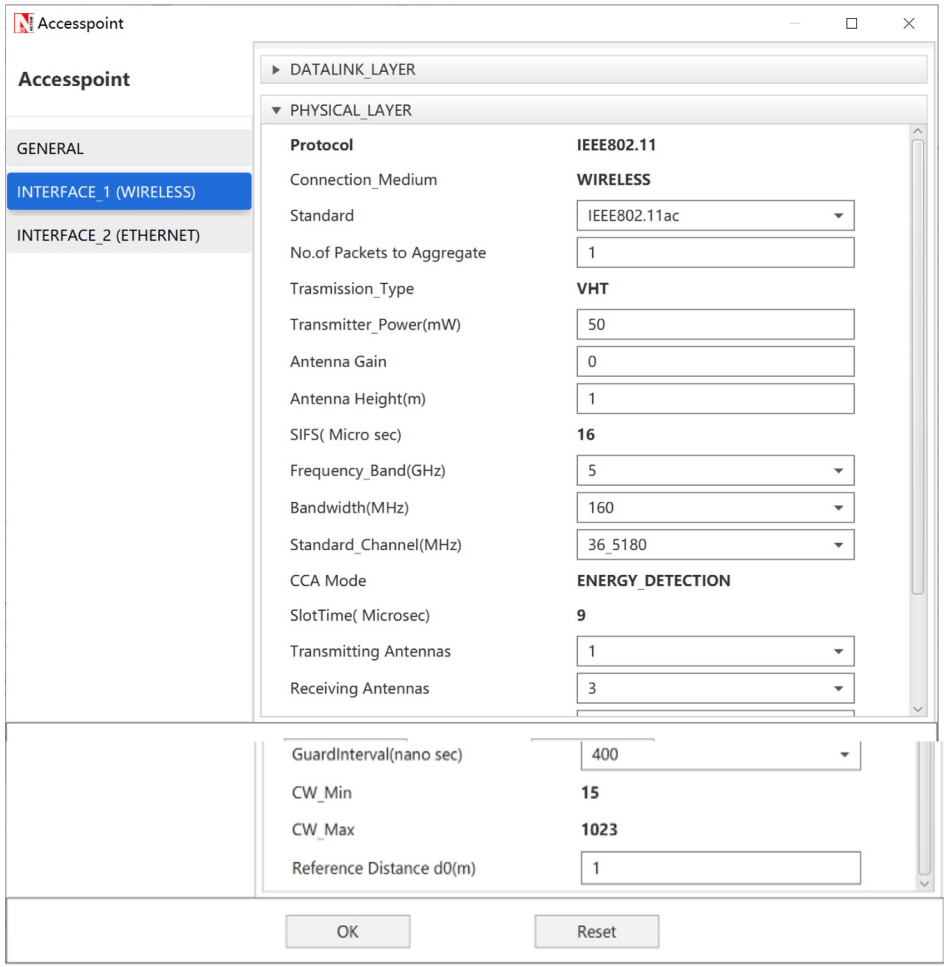
Key Notes

test how many groups can be accommodated under such network settings



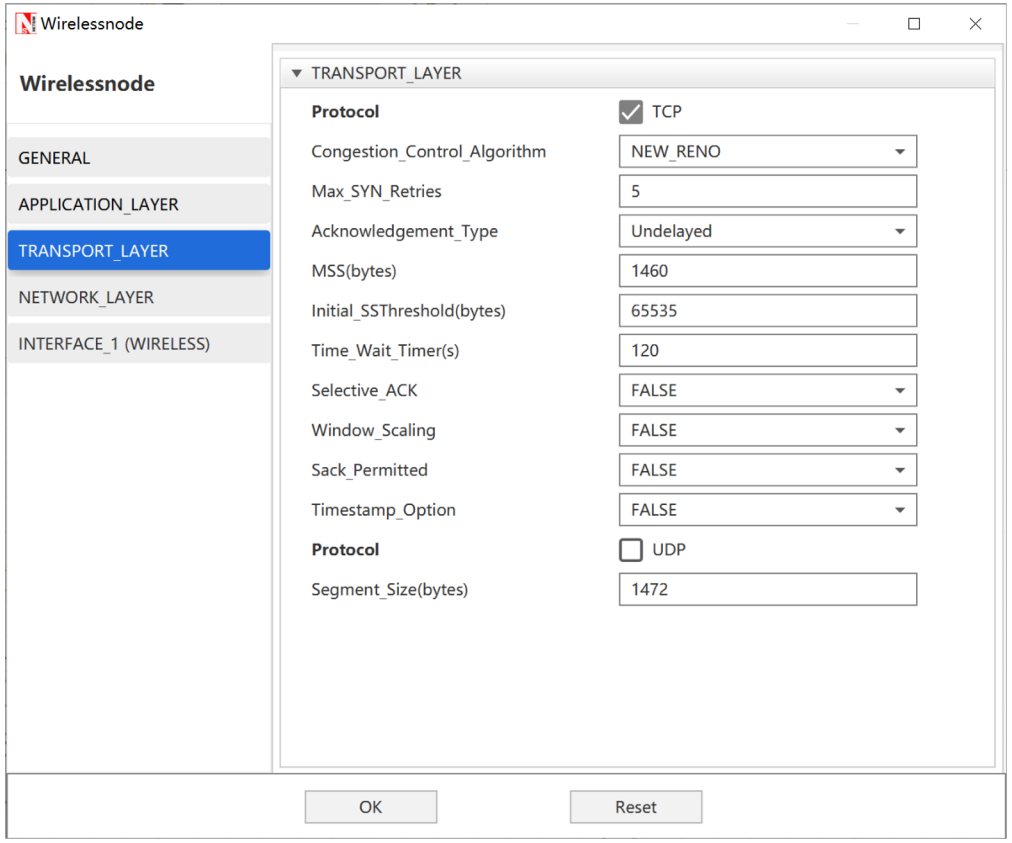
Key Notes

Accesspoint setting: Use the latest 802.11ac protocol also known as WIFI 5 protocol



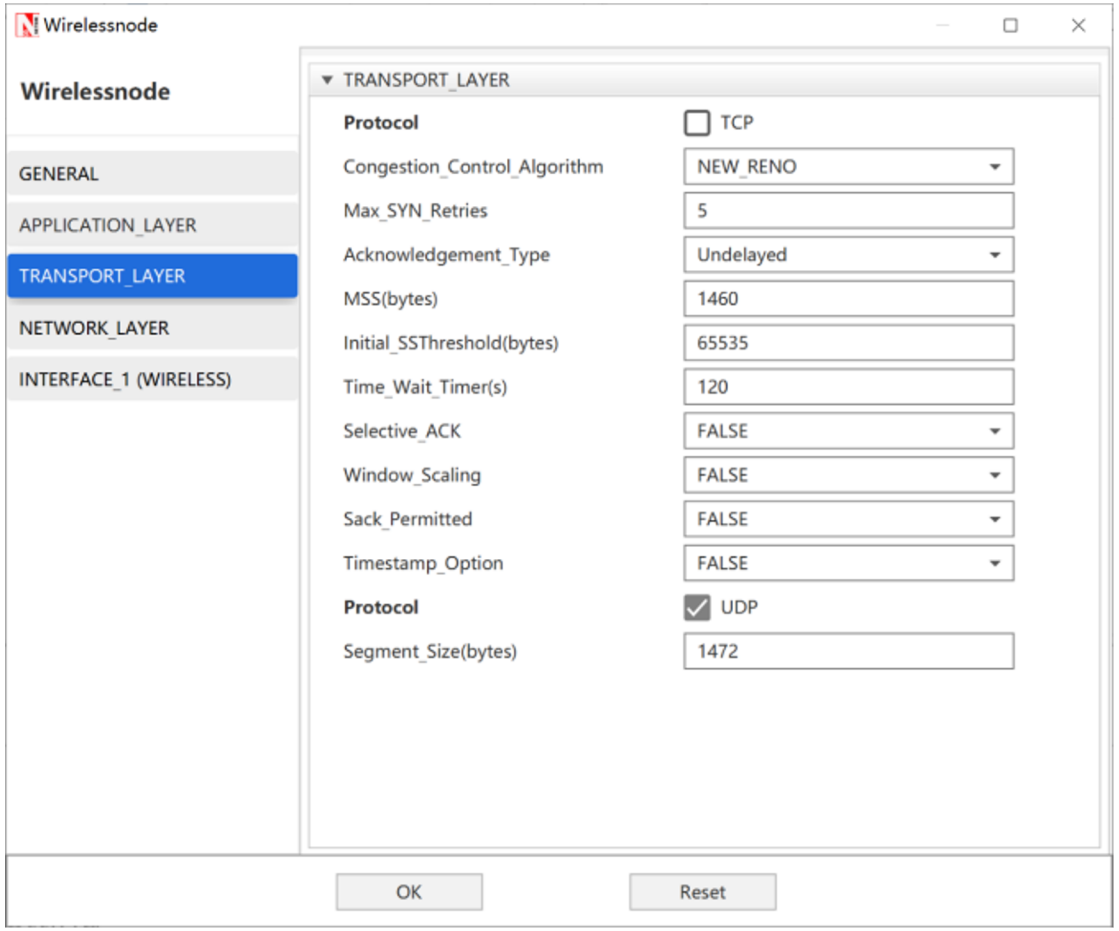
Key Notes

Http user transport layer setting



Key Notes

Game user setting:
Using voice application to substitute



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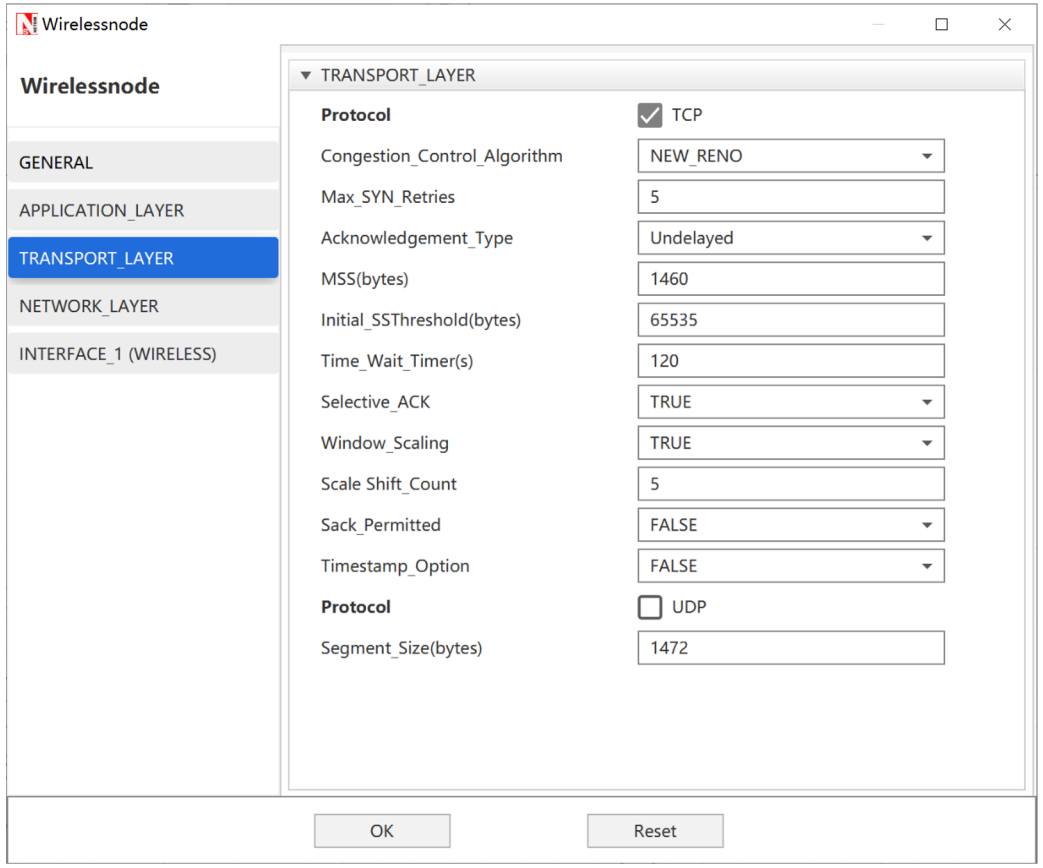
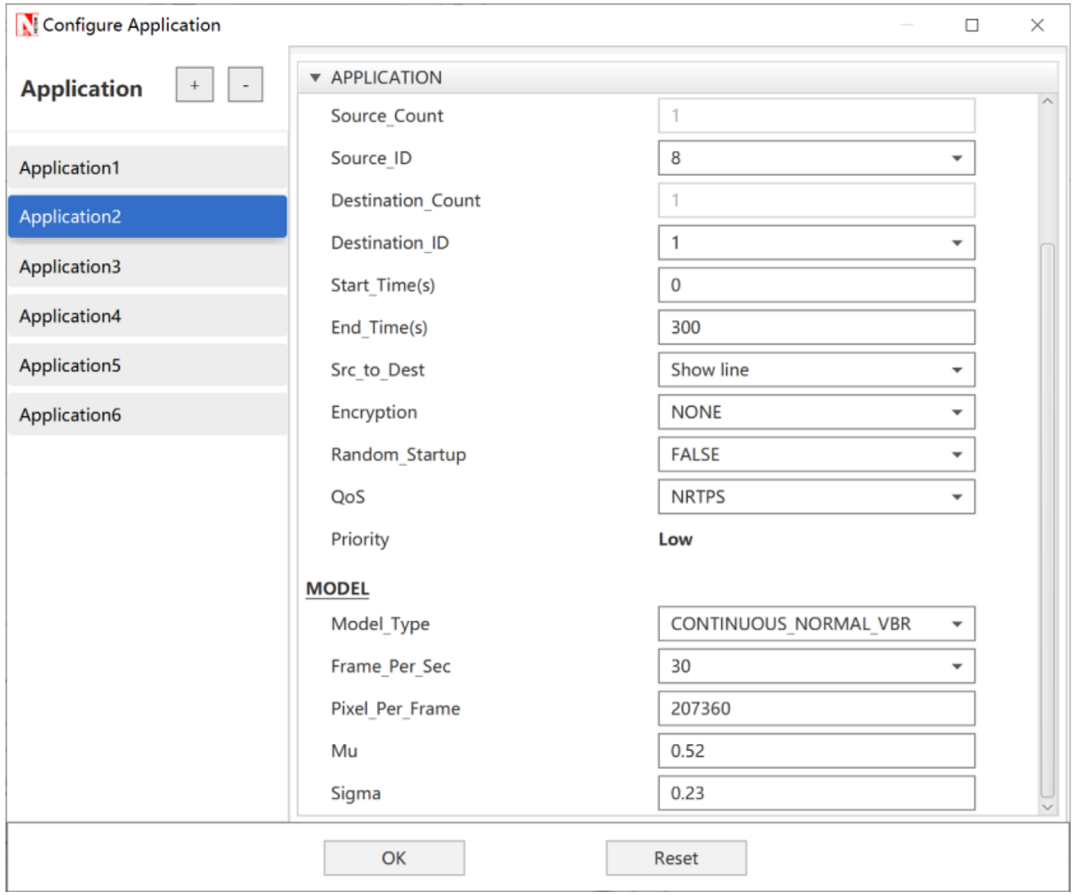
Key Notes

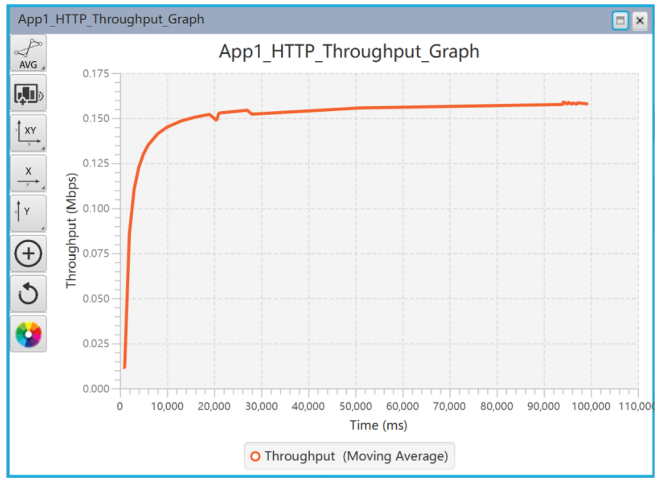
Video user transport layer setting

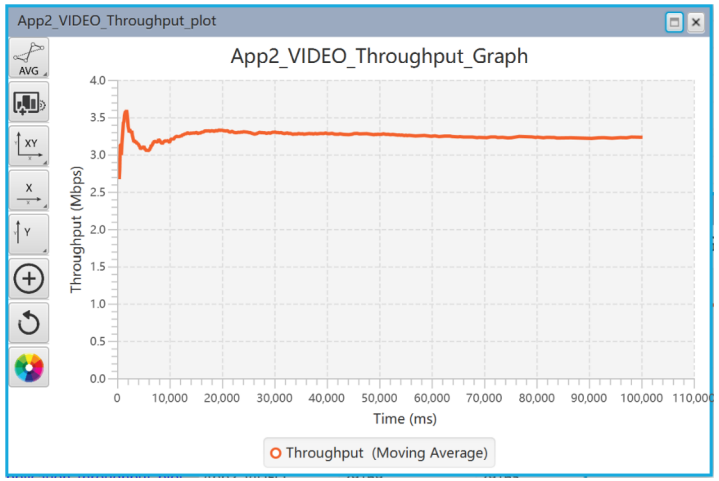


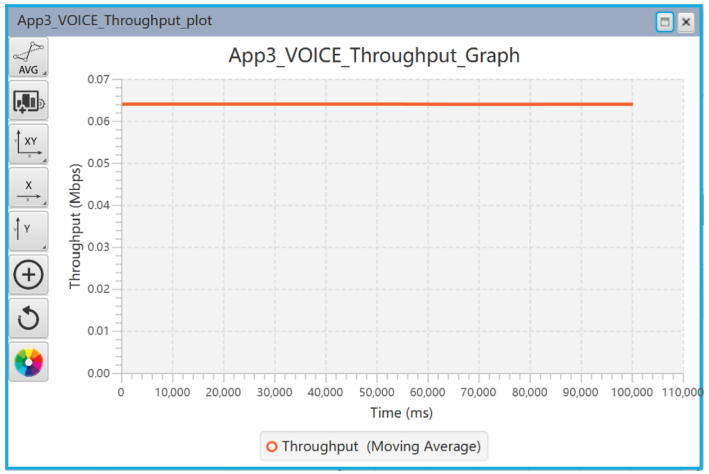
Key Notes

Application video setting:
1080p video
=1920×1080 pixels×
30 frams × time/10
*:Video compression







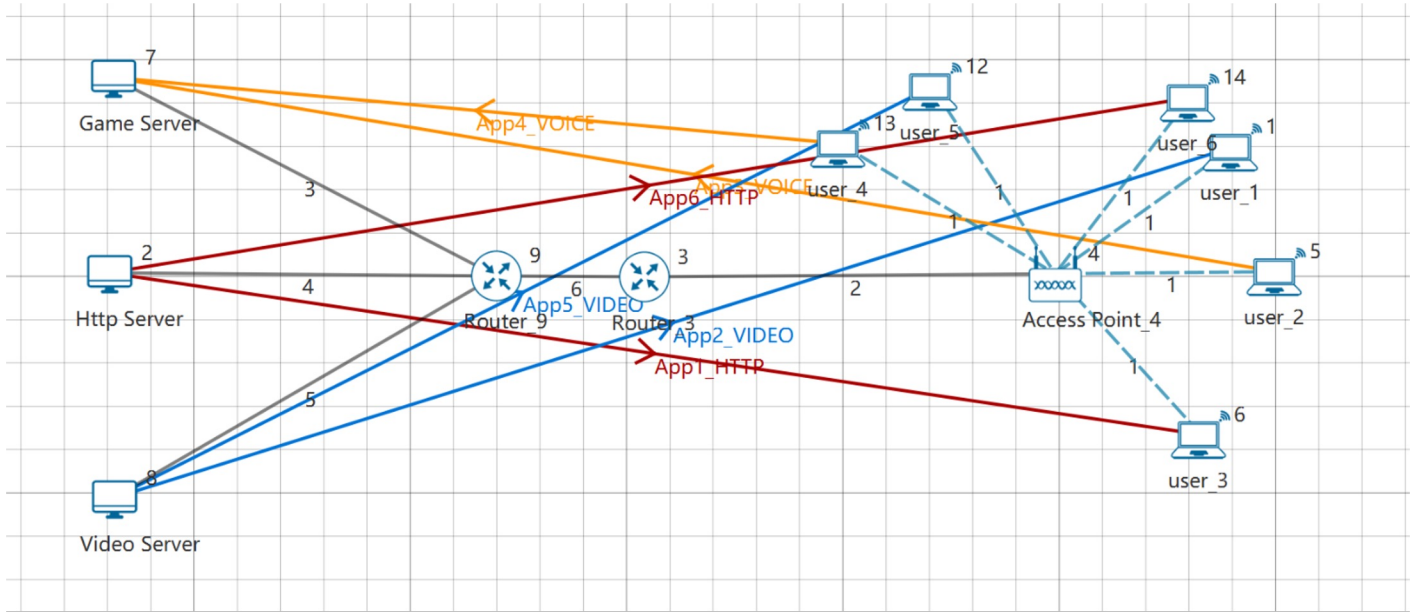


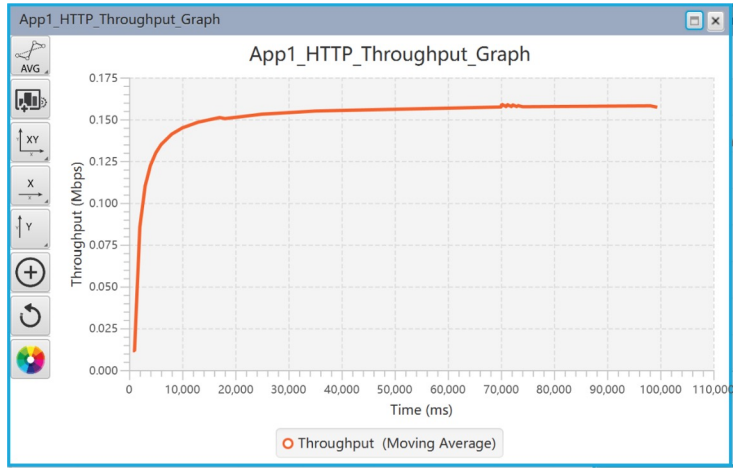
Application Name	Packet generated	Packet received	Throughput (Mbps)	Delay(microsec)	Jitter(microsec)
App1_HTTP	99	99	0.005940	997.135657	331.169796
App1_HTTP	1386	1380	0.157734	8680.738522	1510.989514
App2_VIDEO	29169	29165	3.230806	2814.712479	817.706885
App3_VOICE	4999	4996	0.063949	162.686105	14.288645

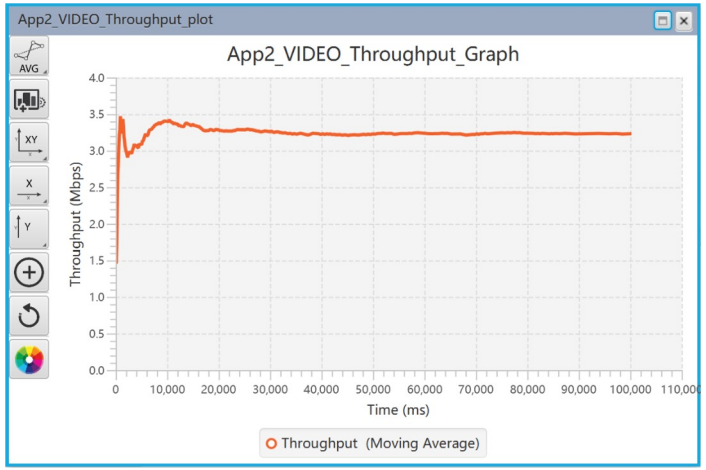
Packet loss rate is less than 1%, with the most delay-sensitive voice (game) delay around 0.6ms

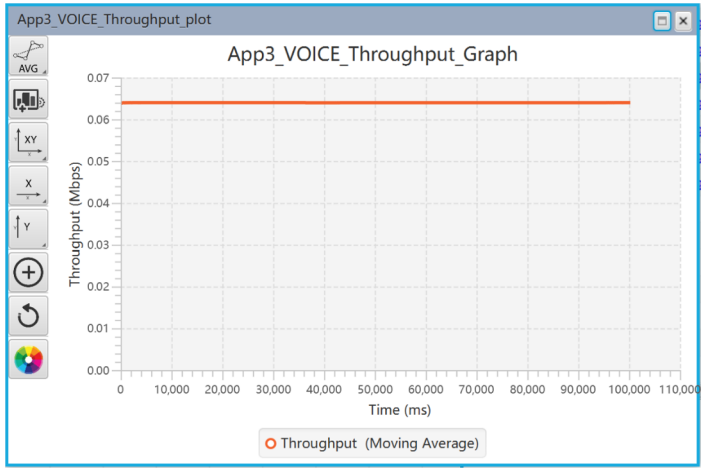
Key Notes

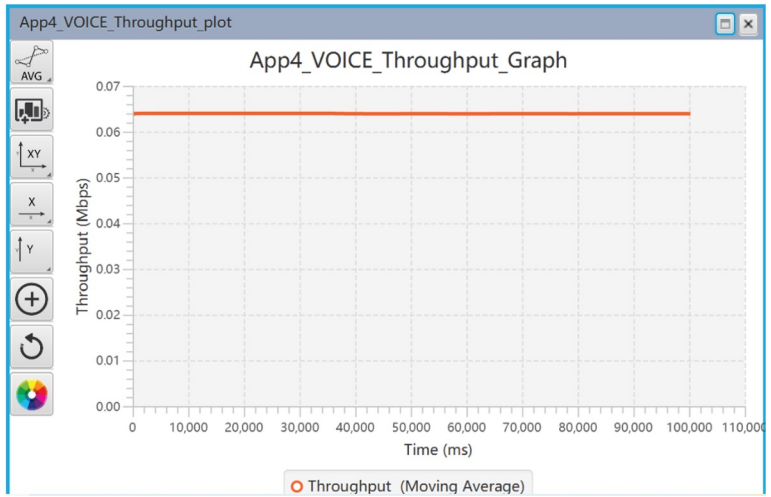
Two groups under such network

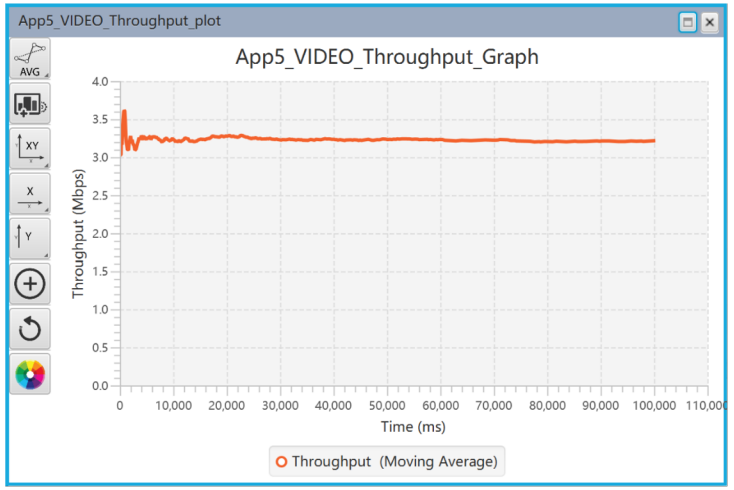


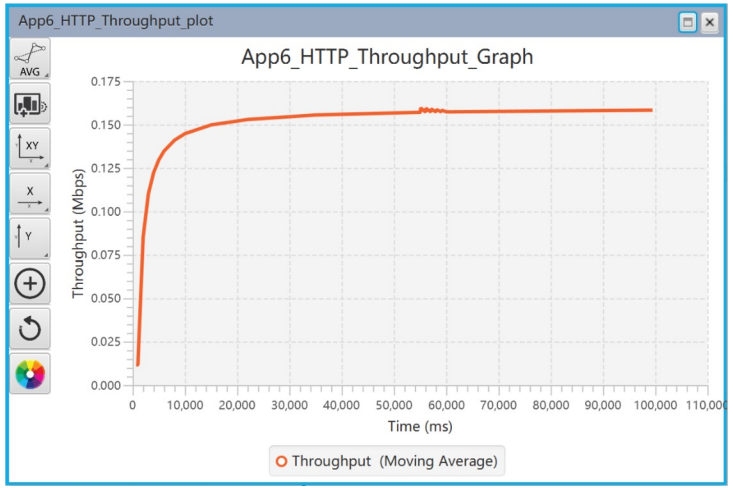










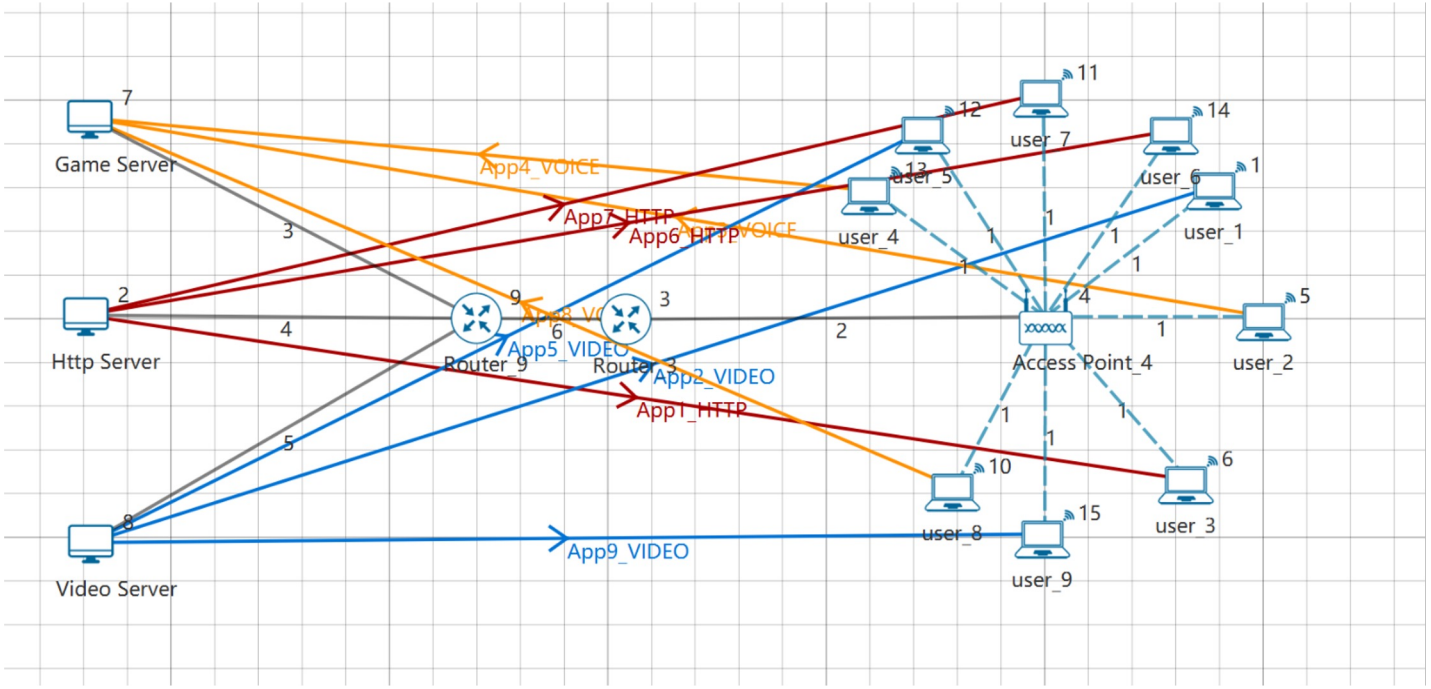


Application Name	Packet generated	Packet received	Throughput (Mbps)	Delay(microsec)	Jitter(microsec)
App1_HTTP	99	99	0.005940	1316.192424	600.827883
App1_HTTP	1386	1378	0.157536	4029.366783	867.930542
App2_VIDEO	29137	29126	3.230234	3146.822765	906.062899
App3_VOICE	4999	4998	0.063974	405.956437	214.112800
App4_VOICE	4999	4994	0.063923	408.601198	218.285230
App5_VIDEO	29085	29071	3.216477	7215.179492	1006.340449
App6_HTTP	99	99	0.005940	1560.864141	1174.694965
App6_HTTP	1386	1386	0.158400	4423.979477	1012.483723

Packet loss rate is less than 1%, with the most delay-sensitive voice (game) delay around 0.4ms

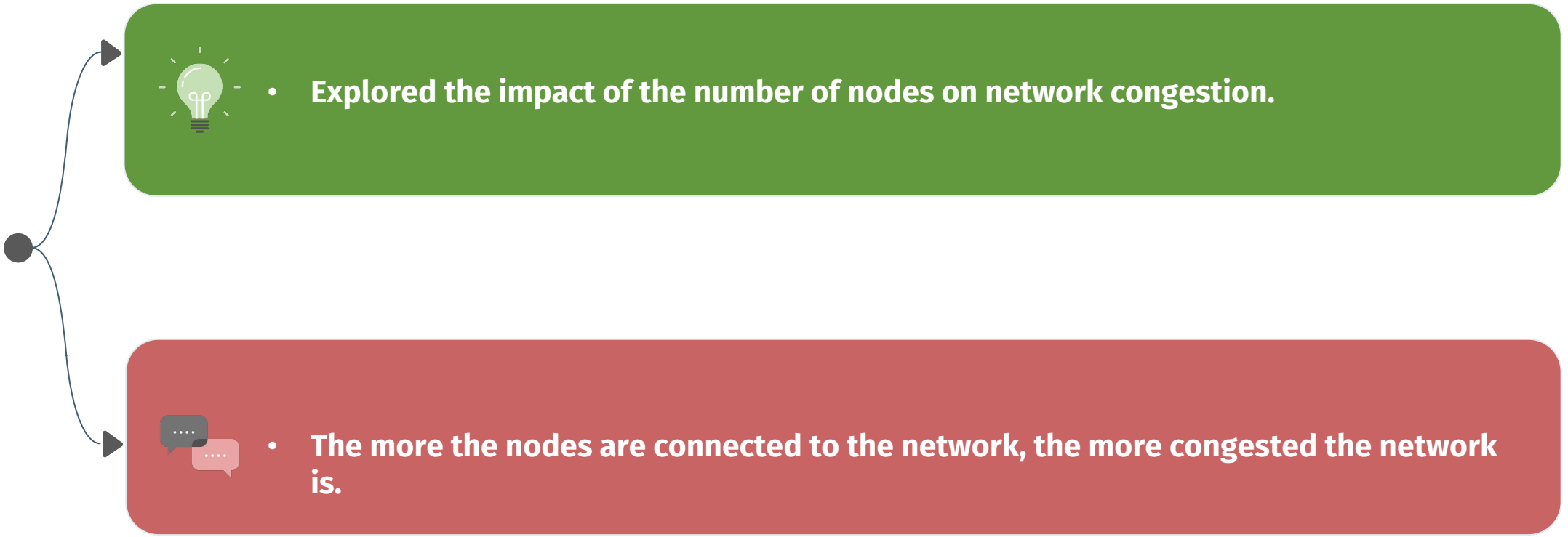
Key Notes

Three groups under such network



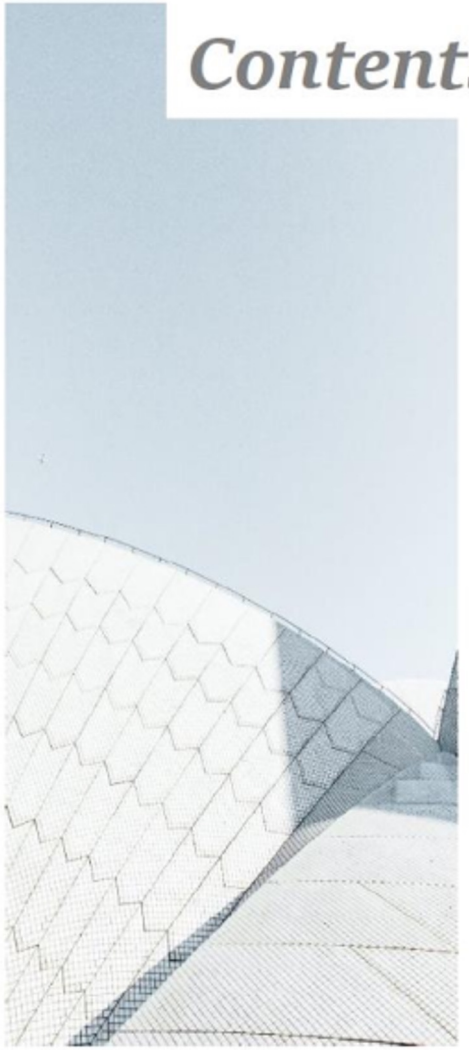
Application Name	Packet generated	Packet received	Throughput (Mbps)	Delay(microsec)	Jitter(microsec)
App1_HTTP	18	17	0.001020	180115.271176	192023.561875
App1_HTTP	238	0	0.000000	0.000000	0.000000
App2_VIDEO	29390	5815	0.644017	305752.991240	3476.367322
App3_VOICE	4999	1002	0.012826	391.742416	187.838313
App4_VOICE	4999	596	0.007629	535.287185	315.971476
App5_VIDEO	26426	17727	2.186459	19891241.873001	8880.285212
App6_HTTP	5	4	0.000240	23504073.252500	21000966.440000
App6_HTTP	56	56	0.006400	8963.854464	2070.111818
App7_VOICE	4995	524	0.006713	510.271370	305.566323
App8_HTTP	99	99	0.005945	2243.402381	2022.505628
App8_HTTP	1386	768	0.089285	8302478.608782	4434202.169151
App9_VIDEO	20147	0	0.000000	0.000000	0.000000

When three groups of people are playing games, watching videos, and brushing the web at the same time, the network becomes seriously clogged, and the stability and effectiveness of the network decreases sharply.



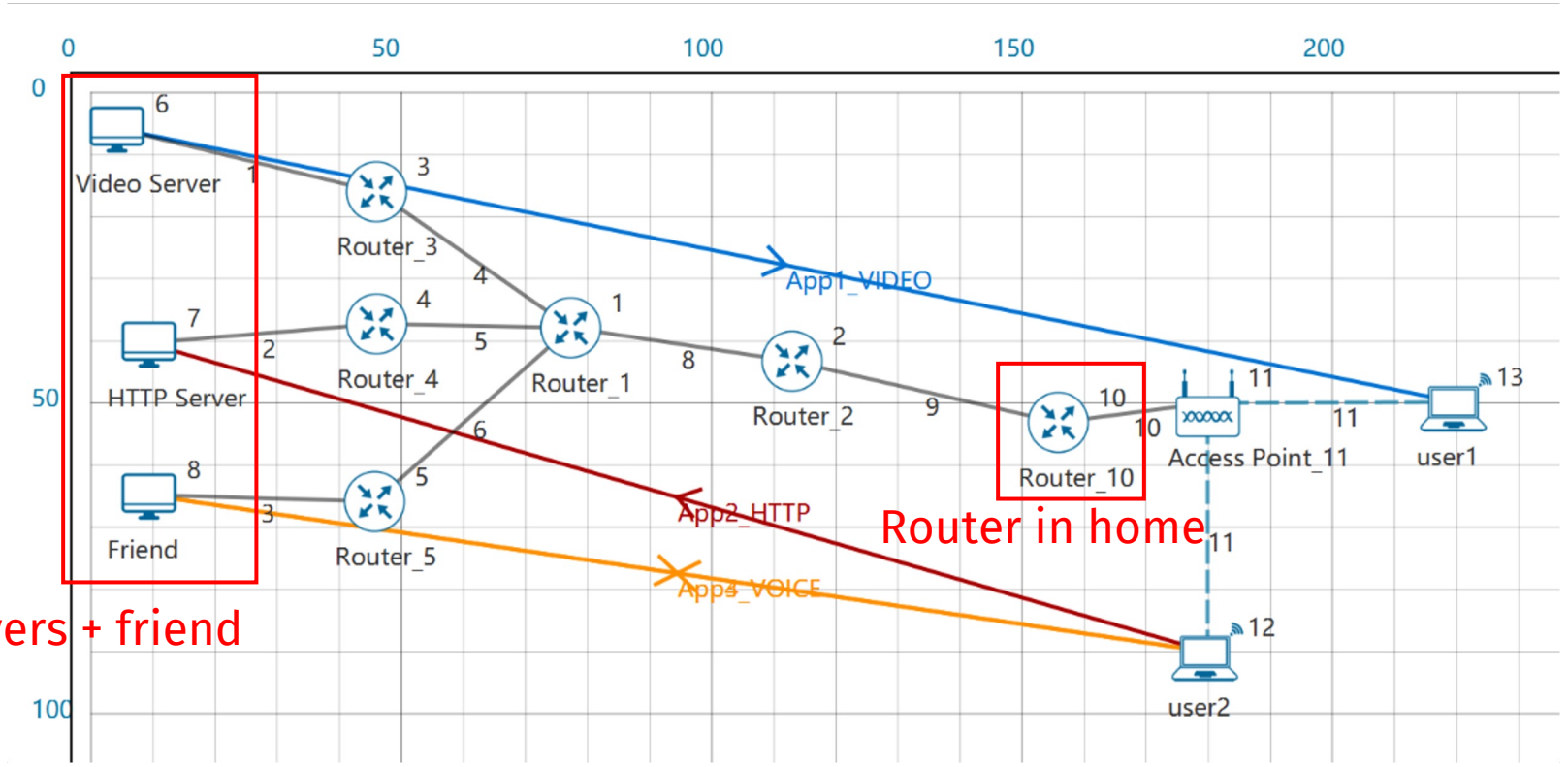
- Explored the impact of the number of nodes on network congestion.
- The more the nodes are connected to the network, the more congested the network is.

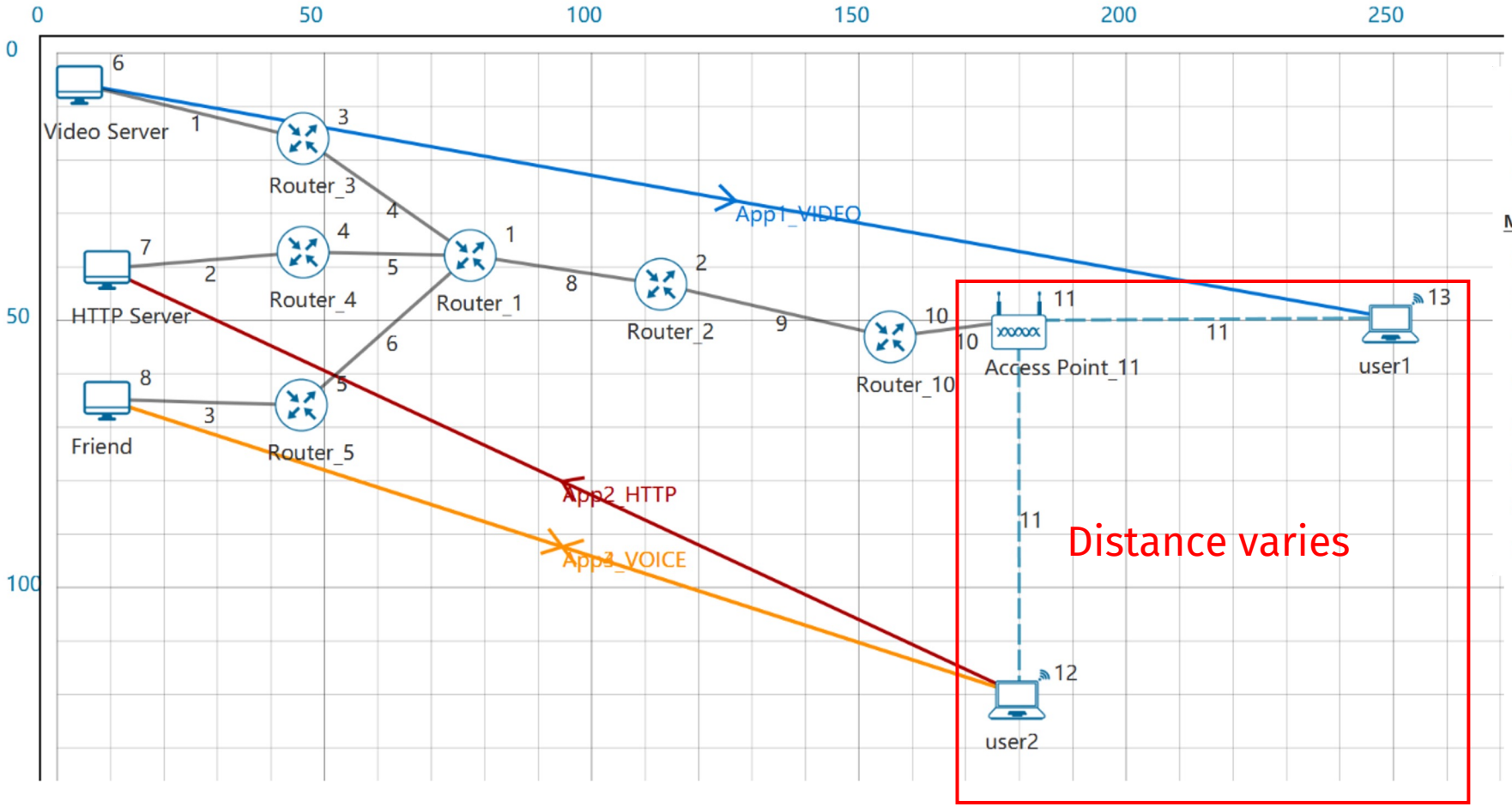
Content



Experiment

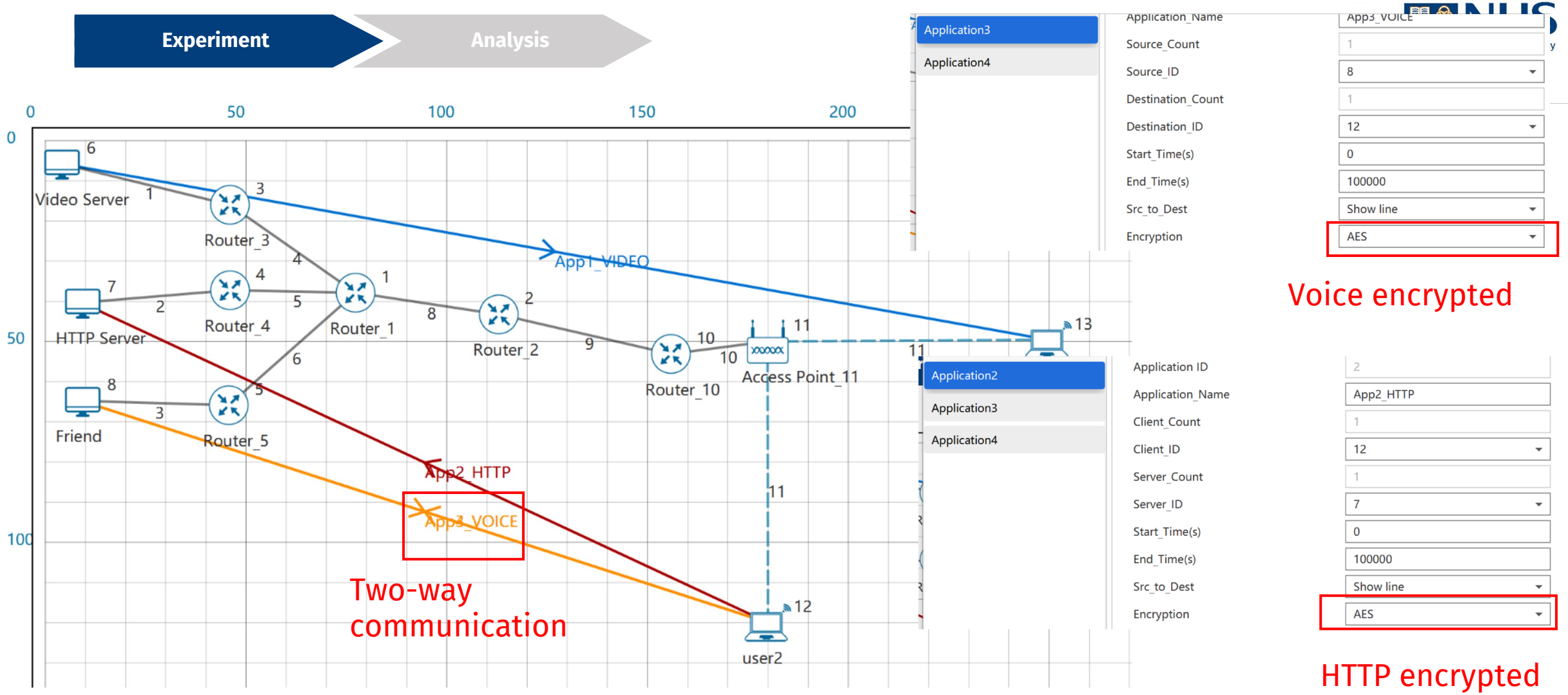
- *Protocol simulation comparison*
- *Nodes density effect*
- ***Distance effect***
- *Topographical conditions*





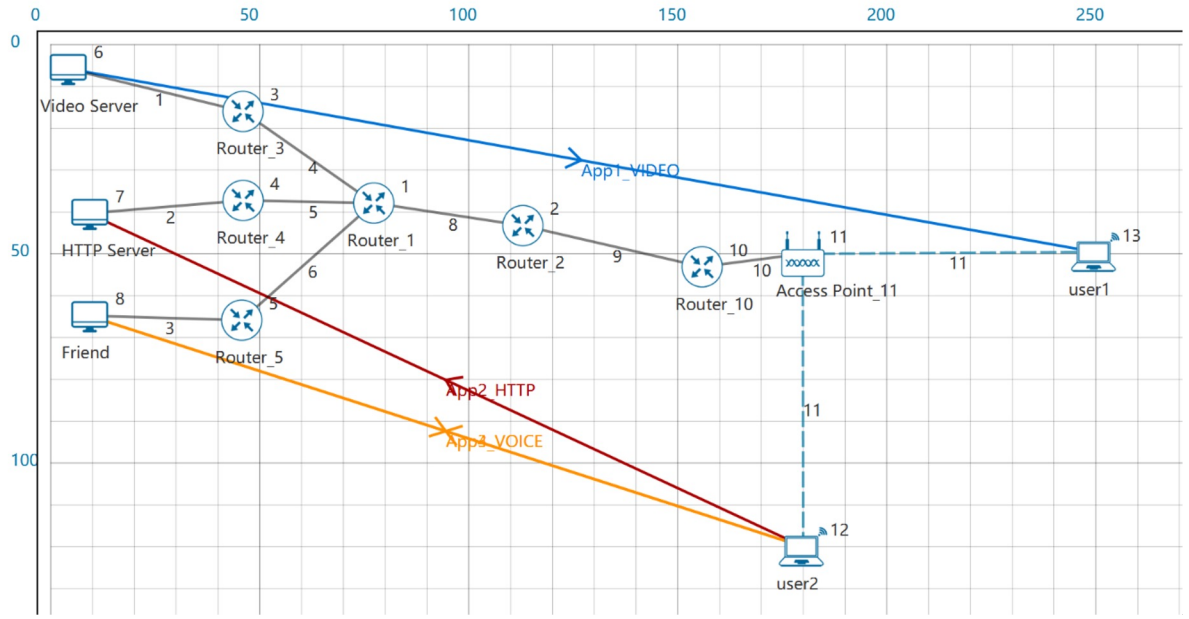
Link_Type	POINT_TO_MULTIPOINT
Link_Medium	WIRELESS
Link_Mode	HALF_DUPLEX
MEDIUM_PROPERTY	
Channel_Characteristics	PATHLOSS_AND_FADING_AN...
PathLoss_Model	INDOOR_HOME
PathLoss_Exponent(n)	3
Fading_Model	RAYLEIGH
Scale_Parameter (w)	1.00
Shadowing_Model	LOGNORMAL
Standard_Deviation(dB)	5
Propagation_Medium	AIR

Experiment | Analysis



Application Id	Application Name	Source Id	Destination Id	Packet generated	Packet received	Payload generated (bytes)	Payload received (bytes)	Throughput (Mbps)	Delay(microsec)	Jitter(microsec)
3	App3_VOICE	8	12	4999	4240	799840	678400	0.054272	550.876877	121.356611
4	App4_VOICE	12	8	4999	4236	799840	677760	0.054221	313.554223	152.345990

8 to 12 has higher delay



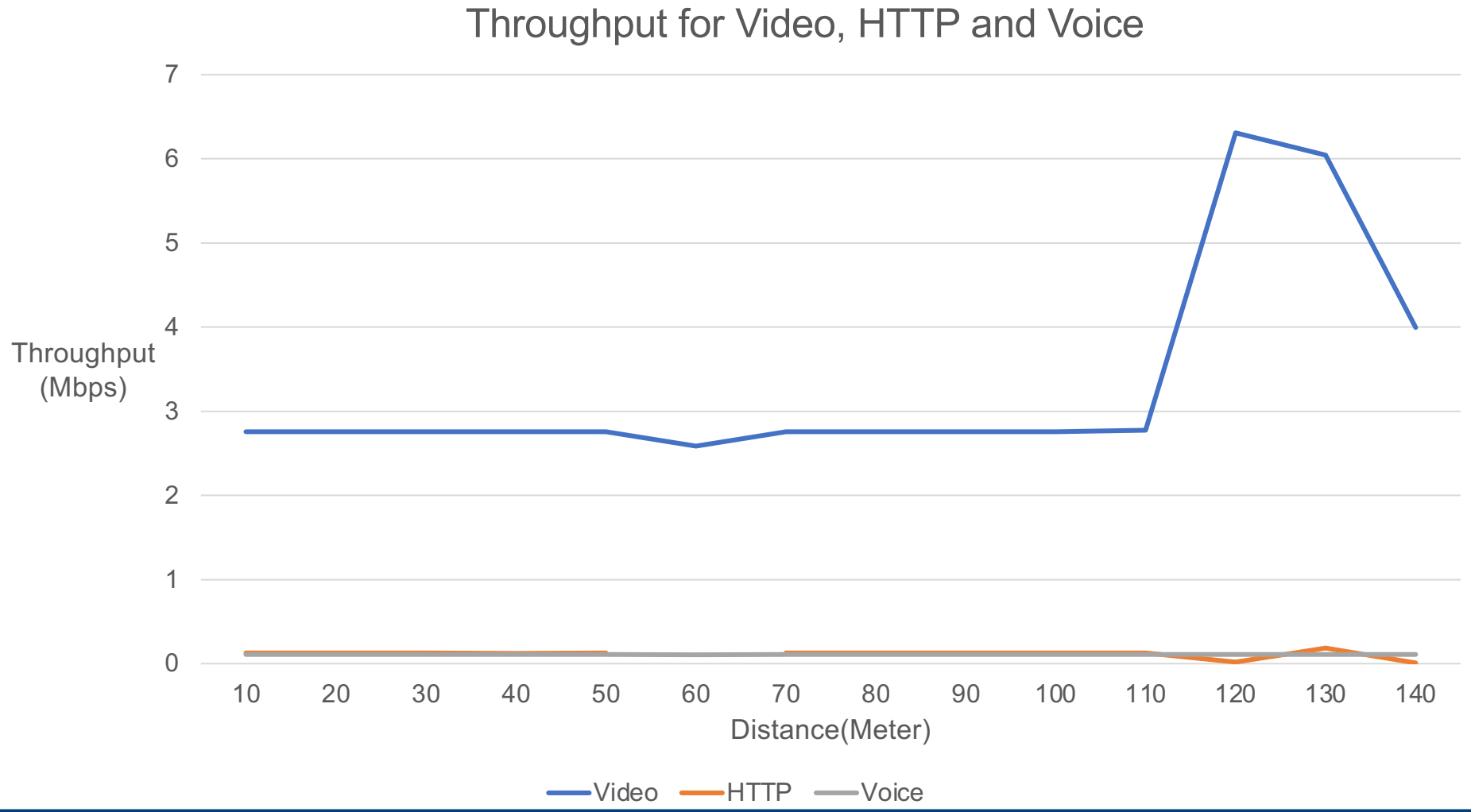
8 to 12 is down-link transmission
12 to 8 is up-link transmission which has less congestion

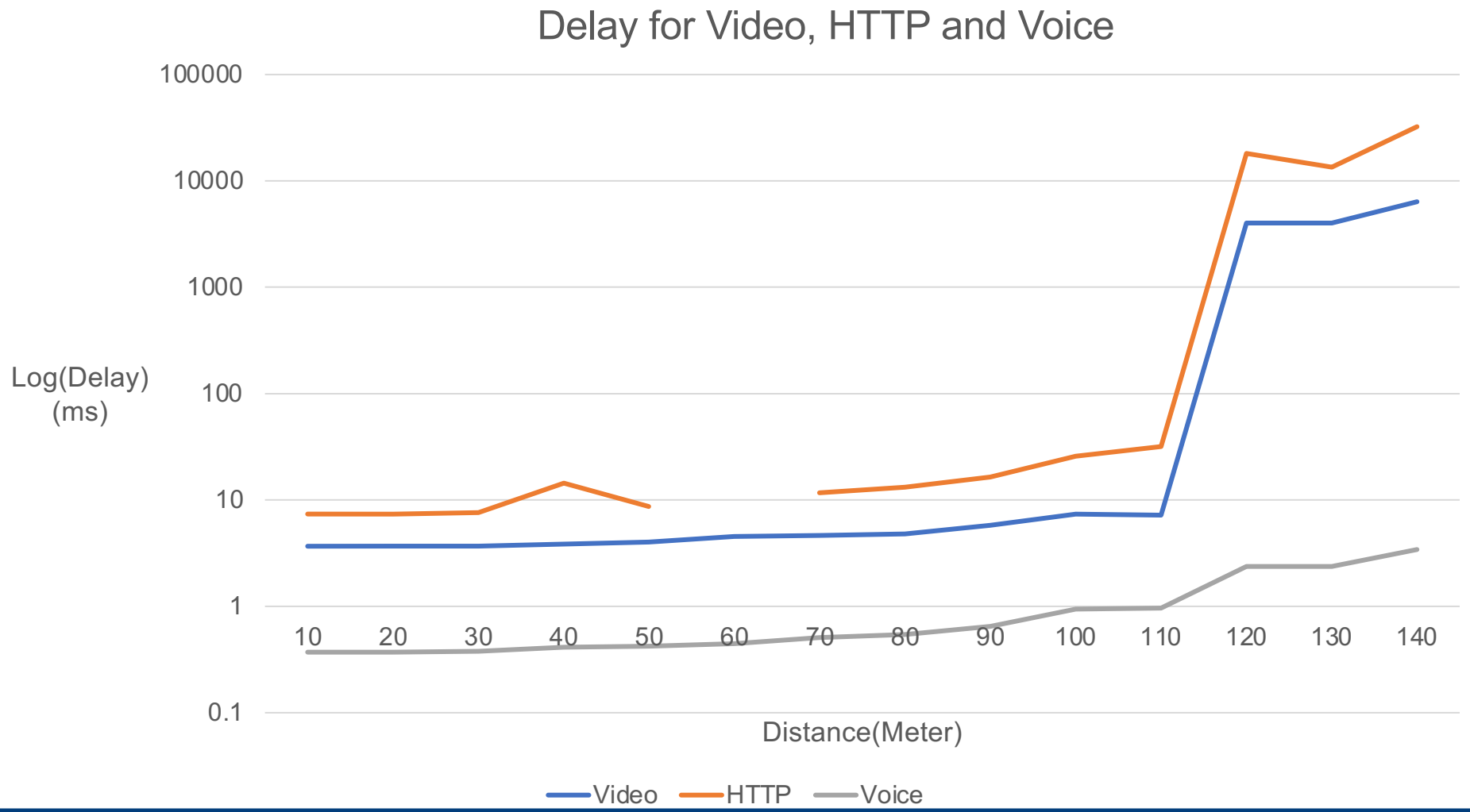
Application_Metrics

Application Id	Application Name	Source Id	Destination Id	Packet generated	Packet received	Payload generated (bytes)	Payload received (bytes)	Throughput (Mbps)	Delay(microsec)	Jitter(microsec)
1	App1_VIDEO	6	13	29381	24846	40726892	34431748	2.754540	4625.774851	1187.343165
2	App2_HTTP	12	7	80	80	60000	60000	0.004800	190164.330148	191450.787760
2	App2_HTTP	7	12	1120	1120	1600000	1600000	0.128000	8894.338021	2105.344517
3	App3_VOICE	8	12	4999	4240	799840	678400	0.054272	550.876877	121.356611
4	App4_VOICE	12	8	4999	4236	799840	677760	+ 0.054221	+ 313.554223	/2 152.345990

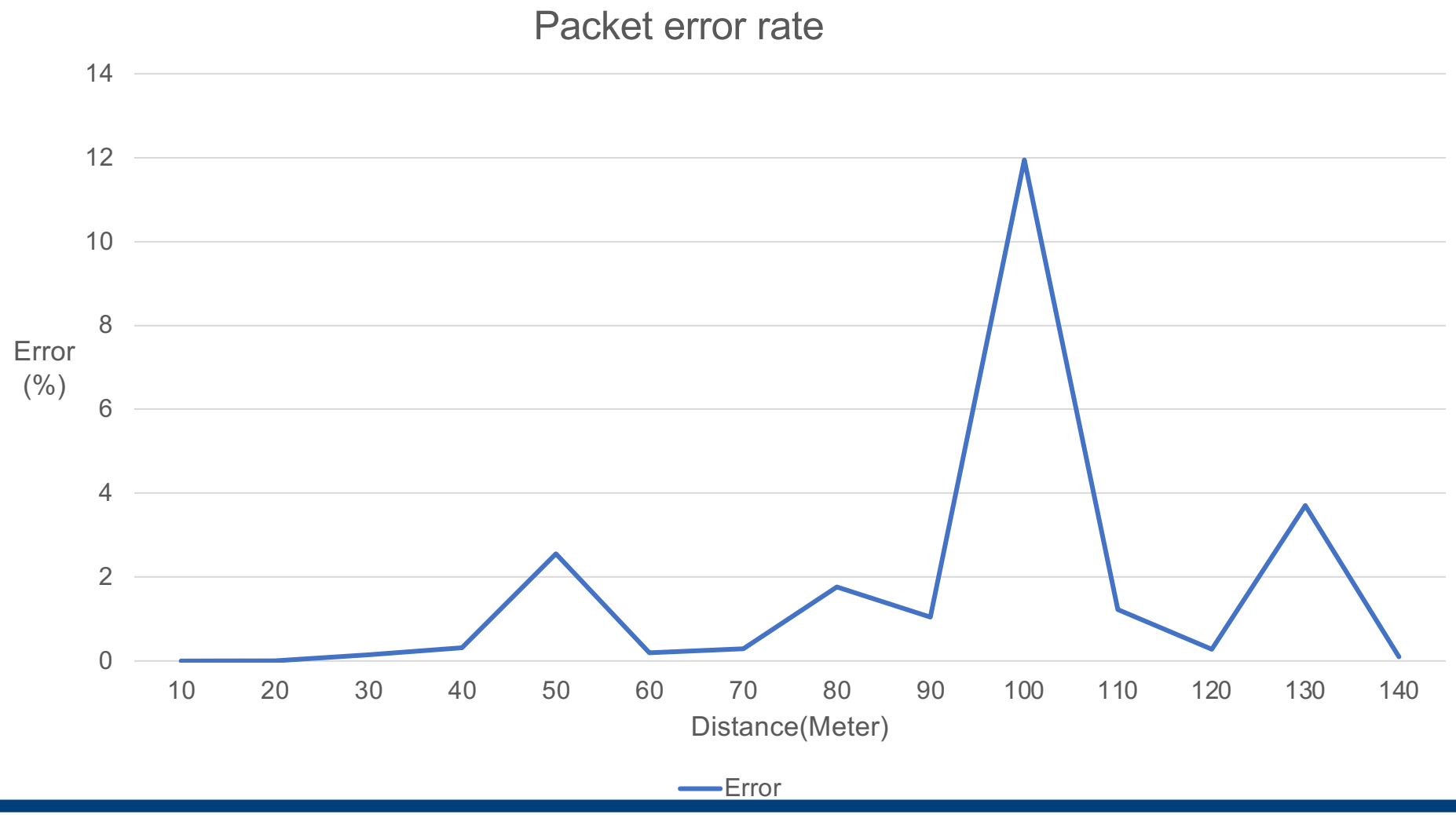
Link_id	Link_throughput_plot	Packet_transmitted		Packet_errored	
		Data	Control	Data	Control
11	NA	39414	38959	3569	0

Packet error rate (in wireless channel) = Packet_errored / Packet_transmitted





Experiment | Analysis



Content

Experiment

- *Protocol simulation comparison*
- *Nodes density effect*
- *Distance effect*
- ***Topographical conditions***

Topographical conditions

- Consider a party scenario, with **more and more people joining the party** and the **distance between people varies**. Some people are watching Netflix while some people are playing computer games.
- Watching movies and TV series need **high throughput** while playing computer games needs **low latency**.
- The impact of topographical conditions on urban area and bay is taken into consideration.

- **OpenStreetMaps** in NetSim design environment is utilized. It is commonly used in vehicular ad hoc network (VANET) simulation.

Experiment | Analysis

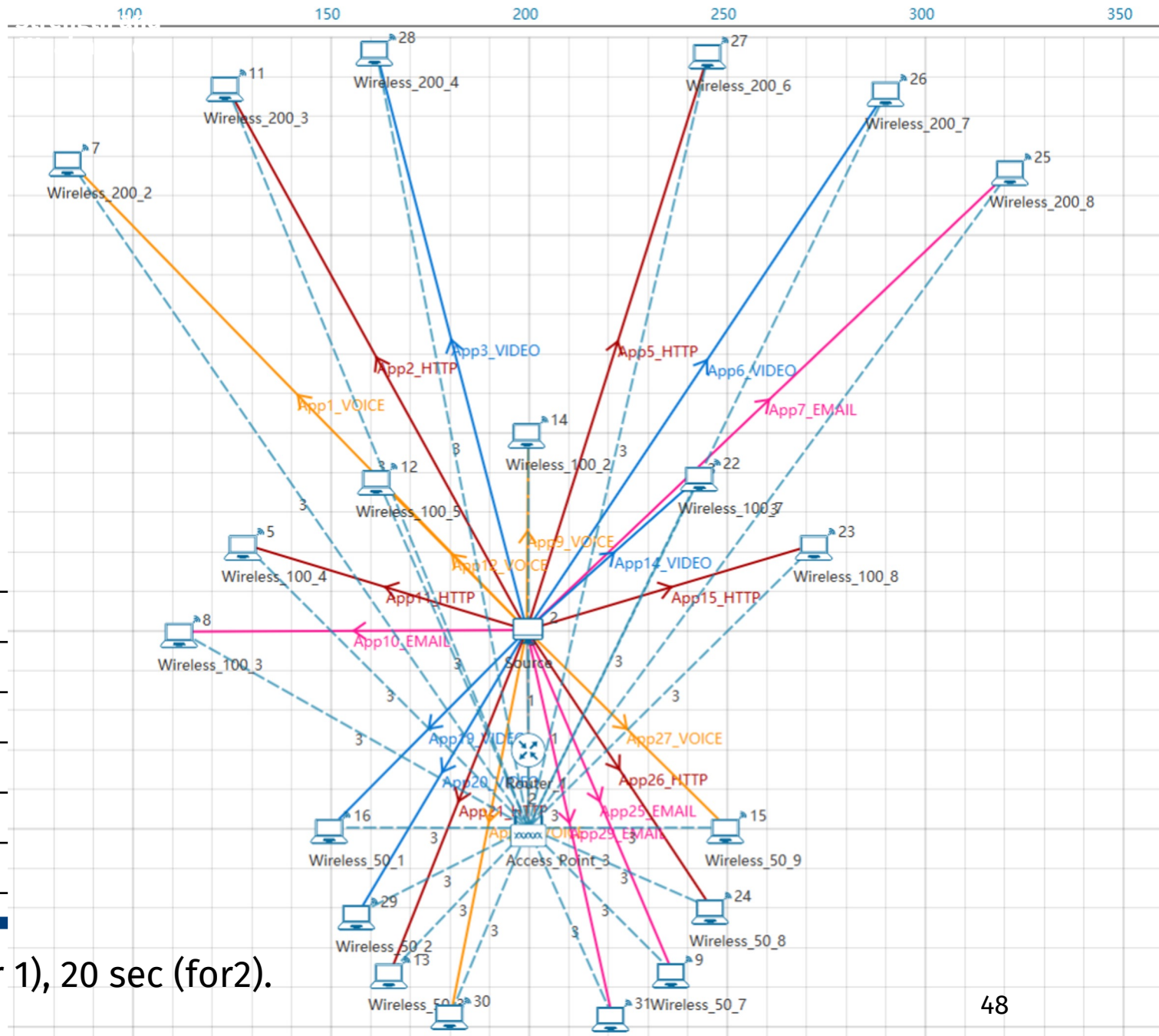
Grid environment

- Pt = 50dBm.
- Gt = 3dBi.
- IEEE802.11ac protocol.
- Frequency band = 5GHz.
- Bandwidth = 160MHz.
- No. of Tx & Rx: 1×1.

Parameters of nodes

Nodes	*200m*	*100m*	*50m*	***tot***
Voice	1	2	2	5
Video	2	1	2	5
http	2	2	2	6
Email	1	1	2	4
tot	6	6	8	20

Voice signal access at 0 sec (for 2), 10 sec (for 1), 20 sec (for2).



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Result of Grid Environment

Nodes	*200m*	*100m*	*50m*	***Delay***	***Throughput***
Voice	1	2	2	<10ms	>0.2Mbps
Video	2	1	2	<290ms	>2Mbps
http	2	2	2	<3.3s	Acceptable
Email	1	1	2	<5.3s	

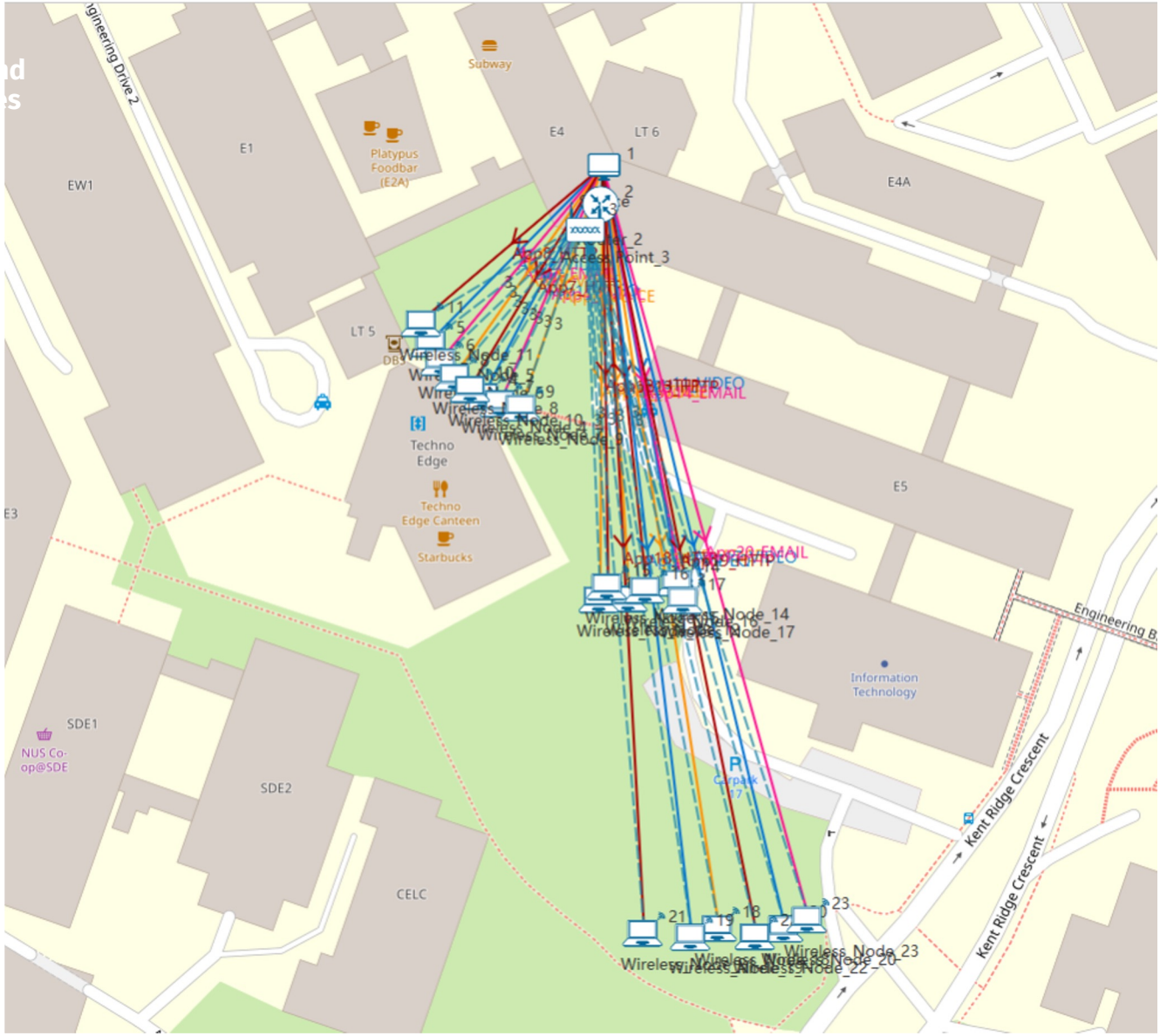
Link_id	*Packet_transmitted*		***Packet_errored***		***Packet_collided***	
	Data	*Control*	*Data*	*Control*	*Data*	*Control*
All	*479792*	*328922*	*0*	*0*	*24*	*92*
1	*182574*	*516*	*0*	*0*	*0*	*0*
2	*182574*	*516*	*0*	*0*	*0*	*0*
3	*114644*	*327890*	*0*	*0*	*24*	*92*

Map environment 1

- Pt = 50dBm.
- Gt = 3dBi.
- IEEE802.11ac protocol.
- Frequency band = 5GHz.
- Bandwidth = 160MHz.
- No. of Tx & Rx: 1×1.

Parameters of nodes

Nodes	*200m*	*100m*	*50m*	***tot***
Voice	1	2	2	5
Video	2	1	2	5
http	2	2	2	6
Email	1	1	2	4
tot	6	6	8	20



NUS Fac of ENG

Voice signal access at 0 sec (for 2), 10 sec (for 1), 20 sec (for2).

NUS National University of Singapore

Result of NUS Fac of Eng Map Environment

Nodes	*200m*	*100m*	*50m*	***Delay***	***Throughput***
Voice	1	2	2	<10ms, but 2 cannot receive	>0.09Mbps
Video	2	1	2	<150ms	>3.5Mbps
http	2	2	2	<210ms	Acceptable
Email	1	1	2	<330ms	

Link_id	*Packet_transmitted*		***Packet_errored***		***Packet_collided***	
	Data	*Control*	*Data*	*Control*	*Data*	*Control*
All	*429767*	*67586*	*816*	*0*	*27*	*21*
1	*181430*	*220*	*213*	*0*	*0*	*0*
2	*181217*	*220*	*253*	*0*	*0*	*0*
3	*67120*	*67146*	*350*	*0*	*27*	*21*

Experiment | Analysis

Map environment 2

- Pt = 50dBm.
- Gt = 3dBi.
- IEEE802.11ac protocol.
- Frequency band = 5GHz.
- Bandwidth = 160MHz.
- No. of Tx & Rx: 1×1.

Parameters of nodes

Nodes	*200m*	*100m*	*50m*	***tot***
Voice	1	2	2	5
Video	2	1	2	5
http	2	2	2	6
Email	1	1	2	4
tot	6	6	8	20

Voice signal access at 0 sec (for 2), 10 sec (for 1), 20 sec (for2).

Result of Marina Bay Map Environment

Nodes	*200m*	*100m*	*50m*	***Delay***	***Throughput***
Voice	1	2	2	<10ms, but 1 cannot receive	>0.05Mbps
Video	2	1	2	<200ms	>2.5Mbps
http	2	2	2	<3.4s	Acceptable
Email	1	1	2	<1.8s	

Link_id	*Packet_transmitted*		***Packet_errored***		***Packet_collided***	
	Data	*Control*	*Data*	*Control*	*Data*	*Control*
All	*428533*	*61654*	*2782*	*0*	*15*	*13*
1	*182752*	*212*	*216*	*0*	*0*	*0*
2	*182537*	*212*	*243*	*0*	*0*	*0*
3	*63244*	*61230*	*2323*	*0*	*15*	*13*

- The simulations show that the performances dive when it comes to real street map.

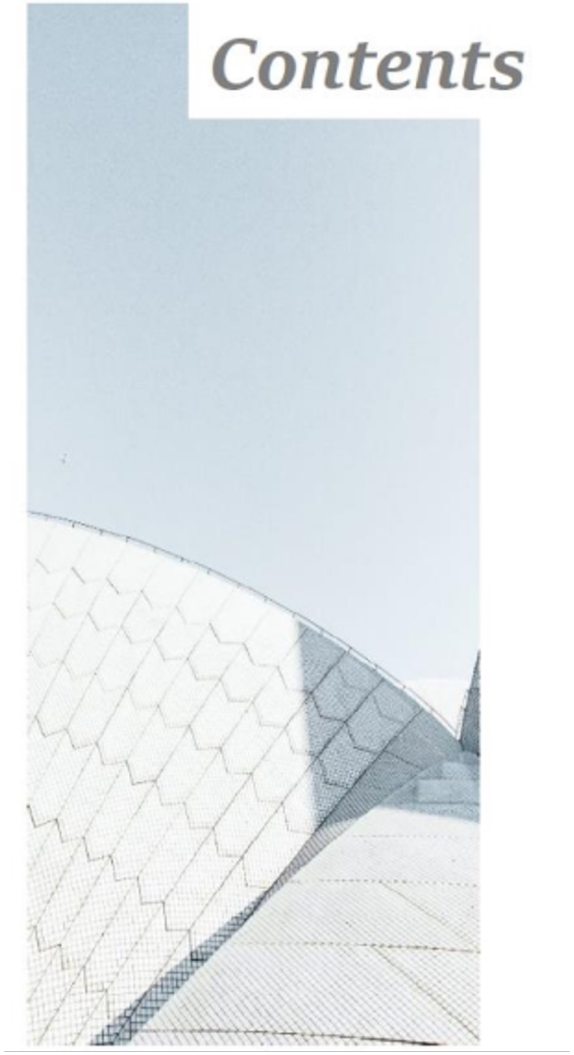
Comparison of 3 topographical conditions

Types	***Packet_transmitted***		***Packet_errored***		***Packet_collided***	
	Data	***Control***	***Data***	***Control***	***Data***	***Control***
Grid	*114644*	*327890*	*0*	*0*	*24*	*92*
NUS ENG	*67120*	*67146*	*350*	*0*	*27*	*21*
Marina Bay	*63244*	*61230*	*2323*	*0*	*15*	*13*

- In Map, not all of the nodes can receive signals successfully.
- The throughput of NUS environment is slightly higher, and the error rate is slightly lower than those of Marina Bay, but more nodes fail to connect.
- So, we suppose the network at NUS and Marina Bay also have different transmission performances. The better transmission environment should be decided by cases.

Comparison of 3 topographical conditions

Nodes	***Delay***			***Throughput***		
	Grid	***NUS ENG***	***Marina Bay***	***Grid***	***NUS ENG***	***Marina Bay***
Voice	<10ms	<10ms, but **2 cannot receive**	<10ms, but **1 cannot receive**	>0.2Mbps	>0.09Mbps	>0.05Mbps
Video	<290ms	<150ms	<200ms	>2Mbps	>3.5Mbps	>2.5Mbps
http	<3.3s	<210ms	<3.4s	Acceptable		
Email	<5.3s	<330ms	<1.8s			



Total Conclusion

- For the party scenario, IEEE 802.11ac protocol is the best choice. The widest 160MHz channel band can offer a high theoretical maximum data rate. To further enhance the capacity, the access point is able to transmit 8 spatial streams by applying 8x8 MU-MIMO technology. Compared to IEEE 802.11n/g, these features improve the performance of the wireless network.
- From the number of nodes' point of view, the more the nodes are connected to the network, the more congested the network is. From the distance point of view, the throughput and delay remain stable before 110 meters. Between 110 meters and 140 meters it becomes unstable. After 140 meters, the wireless network is no longer available.
- The performances dive when it comes from grid environment simulation to a real street map. It is found that the same network at NUS and Marina Bay have different transmission performances. The better transmission environment should be decided by cases.

THANK YOU

Q&A

Appendix

Throughput comparison

Parameter setting

Feature/ IEEE standard	Transmitting power(mW)	Frequency band	Channel width	Transmitting antenna	Receiving antenna	Wireless nodes distribution	Simulation duration
IEEE 802.11g	100	2.4GHz	20MHz	1	1	Within 50m	50s
IEEE 802.11n	100	2.4GHz	20MHz	1	1	Within 50m	50s
IEEE 802.11ac	100	5GHz	20MHz	1	1	Within 50m	50s

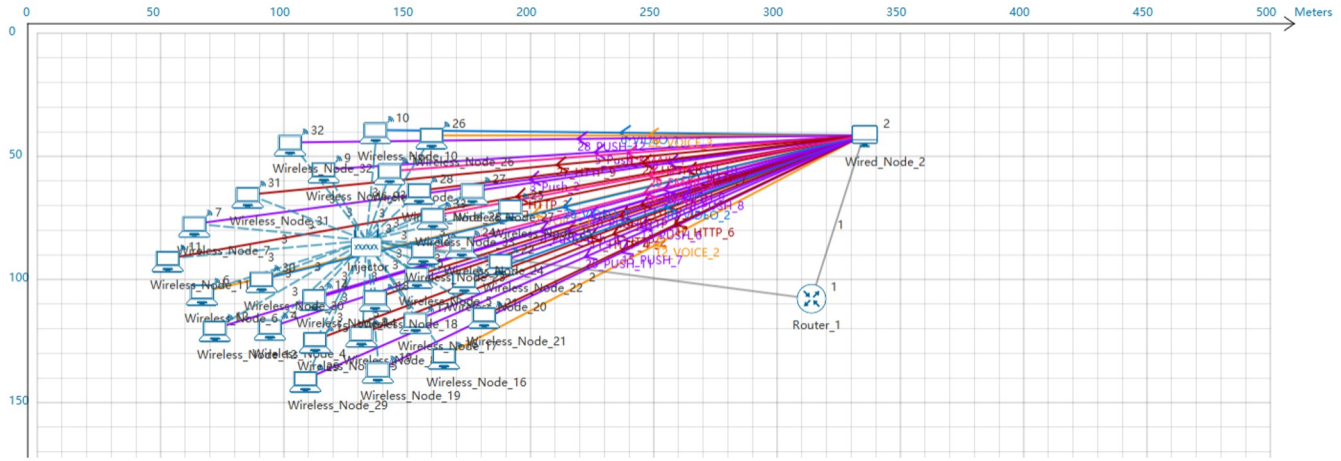
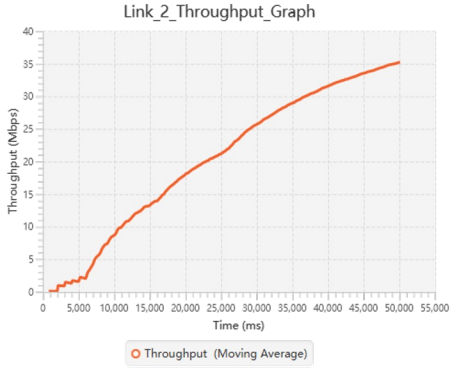


Fig.3 Wireless nodes distribution

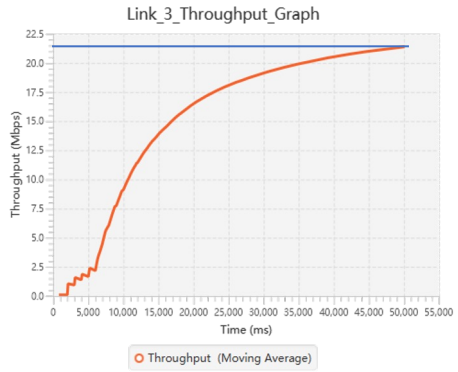
Appendix

Throughput comparison with same bandwidth

Simulation result

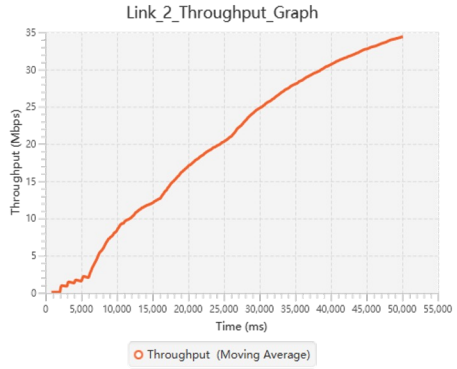


(a) Injector wire input throughput

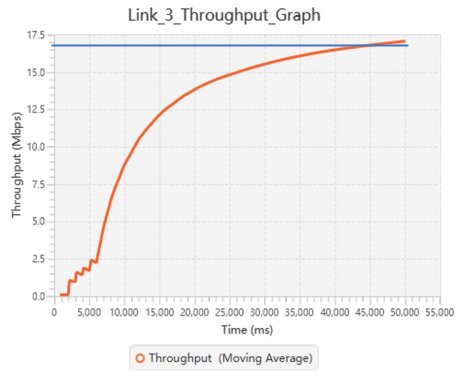


(b) Injector wireless output throughput

Fig.4 802.11g with 30 applications

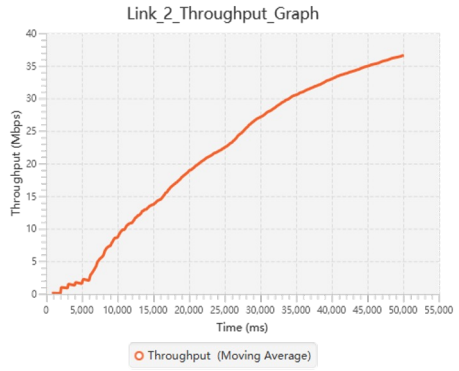


(a) Injector wire input throughput

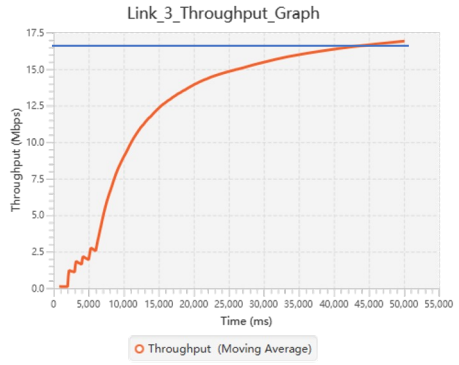


(b) Injector wireless output throughput

Fig.5 802.11n with 30 applications



(a) Injector wire input throughput



(b) Injector wireless output throughput

Fig.6 802.11ac with 30 applications

IEEE standard	802.11g	802.11n	802.11ac
throughput	21.5Mbps	17Mbps	17Mbps

Appendix

Throughput comparison with same bandwith

Simulation result