Performance measurement of multi-cell/AP networks in WiFi and LTE

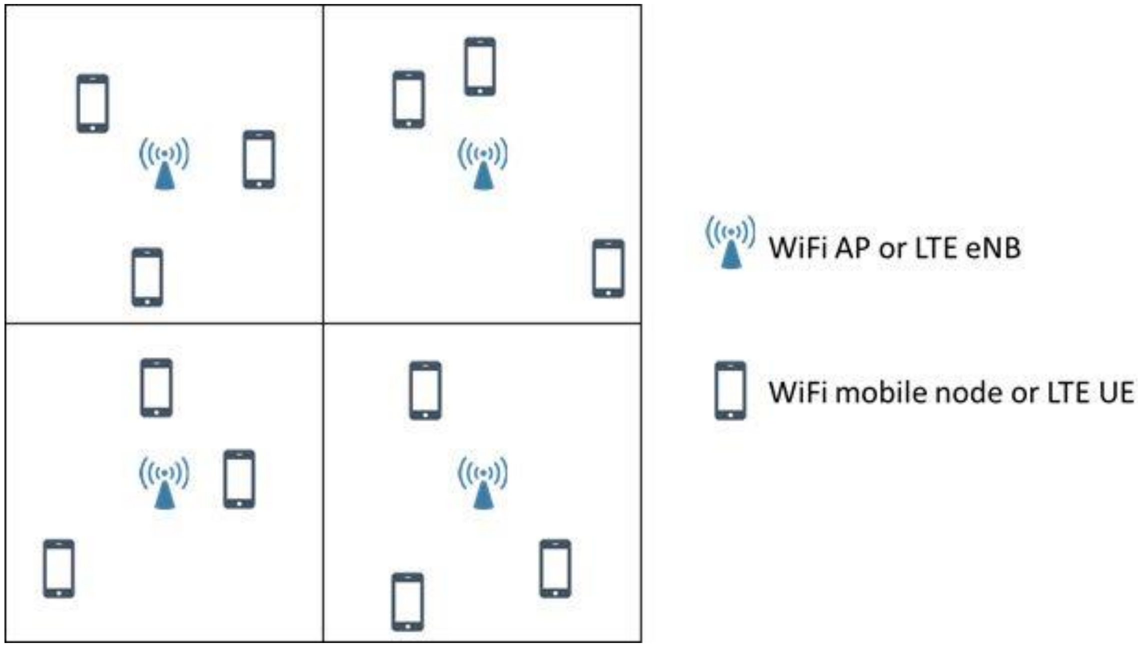
Tiancong Gu
Mian Tang
Ke Wang
Fanru Ye

1. Introduction:

The project of our group is to measure the performance of multi-cell in LTE (Long Term Evolution) network and performance of multi-AP networks in WiFi. The topology settings in these two types of networks are similar, both base on the 400x400 m^2 covered by 4 cells in 2x2 grid configuration, and both network use the same Path Loss Propagation Model during the simulation. And the difference between the two parts of the project is the basic standard for different networks. And the parameter requirement are showed in the following chart:

Parameters	WiFi	LTE
Cover area	400×400 m^2	400×400 m^2
Topology	4 cells in a 2×2 grid configuration	4 cells in a 2×2 grid configuration
Number of source nodes per cell	10	10
Number of WiFi AP/LTE eNB per cell	1	1
Channel bandwidth	22 MHz	20 MHz
Transmit power	10 dBm	20 dBm
Path loss propagation model	Log distance	Log distance
Frequency of operation	2.4 GHz	2.4 GHz
Stationary number of users	10	10
Version/Standard	802.11g	Default LTE
Application	CBR	CBR
Time of simulation	150 s	150 s

And the graph below shows the approximately topology of our project:



1.1 WiFi and IEEE 802.11g-2003

WiFi is a technology that allows electronic devices to connect to a wireless LAN or WLAN network. It is developed by WiFi Alliance, and there exist many specifications through its development. Nowadays WiFi technology is widely used to provide Internet access to devices that are within the range of a wireless network connected to the Internet. A WiFi network can be established to cover both a large area like a whole building, or a smaller scale like a single household.

IEEE 802.11g-2003, or simply 802.11g is one of the specifications, and is the one used in our project. 802.11g is one of the standards in the IEEE 802.11 standard set. It uses the 2.4GHz band and can achieve a maximum throughput of 54 Mbit/s. It uses Orthogonal Frequency-Division Multiplexing (OFDM) as the method of modulation. It can achieve a range of 125 ft. indoor or 460 ft. outdoor.

1.2 LTE (Long Term Evolution)

LTE is a standard for wireless communication of high-speed data for mobile phones and data terminals. It is based on the GSM/EDGE and UMTS/HSPA network technologies, increasing the capacity and speed using a different radio interface together with core network improvements. Several key technologies are applied in LTE, such as the Adaptive Modulation and Coding (AMC), Hybrid ARQ (HARQ), OFDMA and SC-FDMA, and the MIMO Transmission. And LTE technologies provide data transfer speeds of between 100 megabits per second and 1 gigabits per second, which is much faster than the WiFi performance. Besides, the LTE standards enable connected devices with widespread network coverage, typically nationwide. And the basic architecture of LTE is composed by eNBs (Evolved Node B), UEs (User Equipment) and the EPC (Evolved Packet Core) which plays as a gateway server for eNBs to connect.

2. Experiments Set Up

There are two main parts to be set up during the simulation, one is the topology of the networks and the other is the characteristics of standards. We will explain separately in the following two subparts, and illustrate the complete method for different circumstance under different standards.

2.1 Experiment Set Up for WiFi

To simulate the network, a .cc file is created containing all the code describing the network. At the beginning of the WiFi part, the AP and mobile nodes are created using NodeContainer. Since the AP nodes are always at constant positions, CostantPositionMobilityModel is used to allocate their positions. For the mobile nodes, RandomRectanglePositionAllocator is used to allocate position in a given rectangular space, and RandomWalk2DMobilityModel is used if the mobile nodes need to move.

YansWifiChannelHelper, YansWifiPhyHelper, and YansWifiMacHelper are used to set other properties including path loss propagation model, transmit power, and channel bandwidth.

Internet stacks are installed to all nodes, and with Ipv4AddressHelper, we assign IP addresses to all the nodes. We also install UDP servers on all the AP nodes, and UDP clients on all the mobile nodes. By linking the servers and clients with PointToPointHelper, we are able to exchange data between them, and OnOffApplication will generate CBR data.

2.2 Experiment Set Up for LTE

Actually we made lots of changes on our program and simulation after our presentation in first week, we mainly made improvements on the CBR (Constant Bit Rate) of application layer and the setting of the Gateway server. According to the statement in the project script, it said that the LTE eNBs are connected to the internet through a gateway server which we ignored at the beginning of our work. It means that we need a remote host to provide such function to the whole network. Besides, we also create the internet by using the PointToPointHelper, and setting the devices' attributes. Except the change above, the rest part of our program keep the same as we talked in the presentation.

We set up the topology according to the graph and description in the project script.
<1>. Choose the proper Header file for the LTE part;
<2>. Choose the proper LTE Helper for different attributes setting;
<3>. Create enbNodes at fixed position, by using the fixed values of x and y;
<4>. Create ueNodes randomly in a limited region, using the RandomRectanglePositionAllocator;
<5>. Create devices and install devices in the nodes;
<6>. Assign IP address on the UEs and set the default gateway for the UEs;
<7>. Attach UEs to the eNB in every single cell;
<8>. Install and start applications on UEs and remote host;
<9>. Set the start and stop time for the simulation;
<10>. Enable the trace file for the future calculate;
The steps mentioned above are the main part of our code and they help us to realize the part1 of the project, as for the part2, we use the "RandomWalk2dMobilityModel" to realize the roaming function of every UEs in the cell. To observe the automatic handover, we apply the "A2A4RsrqHandoverAlogorithm" through LTE Helper to realize.

3. Data Analysis
3.1 WiFi

Our simulation shows that the throughput varies in different tries, and the throughput also changes through time. Throughput is measured by the total number of bits successfully went through the network. Given that the positions of the mobile nodes are randomly generated, and the farther a node is away from the AP node, the worse the signal is, and the error rate may increase, which will affect the throughput. Hidden node problem may also affect throughput. When the mobile nodes are moving, their distances to the AP nodes will vary through time, and handoffs will happen, causing throughput to change through time. Part of the raw data is shown below.

Throughput	Throughput
1.15052 Mbit/s	1.13874 Mbit/s
1.76051 Mbit/s	1.15994 Mbit/s
2.50947 Mbit/s	1.55796 Mbit/s
4.49372 Mbit/s	1.20233 Mbit/s
1.85825 Mbit/s	1.87945 Mbit/s
1.24472 Mbit/s	2.56364 Mbit/s
1.42136 Mbit/s	3.67647 Mbit/s
1.42725 Mbit/s	1.83941 Mbit/s
1.38486 Mbit/s	1.40252 Mbit/s
1.59683 Mbit/s	1.33422 Mbit/s
0.645325 Mbit/s	2.38464 Mbit/s
1.53088 Mbit/s	2.66609 Mbit/s
0.936192 Mbit/s	1.63215 Mbit/s
1.66513 Mbit/s	1.33069 Mbit/s
1.92773 Mbit/s	1.63922 Mbit/s
1.58858 Mbit/s	1.16818 Mbit/s
1.33069 Mbit/s	0.931482 Mbit/s
1.31067 Mbit/s	1.22706 Mbit/s
1.16465 Mbit/s	4.06036 Mbit/s
1.26945 Mbit/s	0.931482 Mbit/s
1.4249 Mbit/s	1.48849 Mbit/s
1.51322 Mbit/s	1.78995 Mbit/s
1.55914 Mbit/s	1.38604 Mbit/s
0.899686 Mbit/s	1.63569 Mbit/s
2.69906 Mbit/s	2.94164 Mbit/s
2.15619 Mbit/s	2.34107 Mbit/s
0.989184 Mbit/s	1.30478 Mbit/s
2.23508 Mbit/s	2.84626 Mbit/s
1.88534 Mbit/s	1.33069 Mbit/s
1.49084 Mbit/s	1.82999 Mbit/s
1.26003 Mbit/s	1.59447 Mbit/s
3.10769 Mbit/s	1.74756 Mbit/s

Handoff is the process of the mobile node disconnecting from one AP node and re-associating with another. According to IEEE 802.11 standards, it is dictated by the mobile node. As the mobile node moves away from the AP node it is connected with, the Received Signal

Strength Indicator (RSSI) value will decrease. When RSSI reaches a threshold, the mobile node will send out probe packets to identify alternative AP nodes. If there are alternative AP nodes available, the mobile node will select the next AP node and send an authentication request and wait for the new AP to approve or reject the request. If the new AP approves the request, the mobile node will send a re-association request. Once the re-association is complete, the new AP sends out a disassociation packet to the old AP so that the routing tables are updated, and the handoff is completed.

We failed to discover proof of the existence of handoffs in the WiFi simulation though.

3.2 LTE

Before the gateway being set up for the whole network, we cannot even get the data for 4 cells, but after installing a gateway for the eNBs to connect, the data in the "DlRlcStates.txt" shows the process of data transmission of all 4 cells. And we can calculate the throughput according to these data.

/home/kewang1208/ns-allinone-3.23/ns-3.23/DlRlcStats.txt - NS3 - Editor - WinSCP

Encoding · Color ·

% start	end	CellId	IMSI	RNTI	LCID	nTxPDUs	TxBytes	nRxPDUs	RxBytes	delay	stdDe
0	0.25	1	1	6	3	2	3168	2	3168	0.0158929	
0	0.25	1	2	9	3	2	2112	2	2112	0.003	0
0	0.25	1	3	4	3	4	4224	4	4224	0.0178929	
0	0.25	1	4	2	3	4	4224	4	4224	0.0183929	
0	0.25	1	5	5	3	3	4224	3	4224	0.0185238	
0	0.25	1	6	7	3	4	4224	4	4224	0.0193929	
0	0.25	1	7	3	3	3	4224	3	4224	0.0181905	
0	0.25	1	8	1	3	4	4224	4	4224	0.0188929	
0	0.25	1	9	10	3	2	2112	2	2112	0.003	0
0	0.25	1	10	8	3	4	4224	4	4224	0.0101429	
0	0.25	2	11	7	3	5	4075	5	4075	0.0168714	
0	0.25	2	12	10	3	4	4226	4	4226	0.0175893	
0	0.25	2	13	8	3	6	4230	6	4230	0.0203571	
0	0.25	2	14	2	3	6	4230	5	4075	0.0180714	
0	0.25	2	15	3	3	6	4230	6	4230	0.0206905	
0	0.25	2	16	9	3	4	4224	4	4224	0.0186429	
0	0.25	2	17	1	3	4	4224	4	4224	0.0176429	
0	0.25	2	18	6	3	4	4224	4	4224	0.0181429	
0	0.25	2	19	5	3	4	4224	4	4224	0.0136429	
0	0.25	2	20	4	3	4	4224	3	3168	0.00592857	
0	0.25	3	21	8	3	3	3168	3	3168	0.0242619	
0	0.25	3	22	7	3	7	4232	7	4232	0.0187041	
0	0.25	3	23	1	3	6	4228	6	4228	0.0205238	
0	0.25	3	24	5	3	7	4232	7	4232	0.0198469	
0	0.25	3	25	6	3	4	4224	4	4224	0.0133929	
0	0.25	3	26	2	3	4	4224	4	4224	0.0173929	
0	0.25	3	27	9	3	4	4224	4	4224	0.0181429	
0	0.25	3	28	3	3	2	2112	2	2112	0.003	0
0	0.25	3	29	11	3	2	2112	2	2112	0.01	0
0	0.25	3	30	10	3	3	4224	3	4224	0.0128571	
0	0.25	4	31	5	3	4	4228	4	4228	0.0207857	
0	0.25	4	32	2	3	3	4224	3	4224	0.0188571	
0	0.25	4	33	8	3	3	4224	3	4224	0.0188571	
0	0.25	4	34	10	3	4	4226	4	4226	0.0185893	
0	0.25	4	35	4	3	3	4224	3	4224	0.0191905	
0	0.25	4	36	6	3	3	4224	3	4224	0.0131905	
0	0.25	4	37	7	3	3	4224	3	4224	0.0118571	
0	0.25	4	38	3	3	4	4224	4	4224	0.0183929	
0	0.25	4	39	9	3	4	4226	4	4226	0.0203393	
0	0.25	4	40	1	3	4	4224	4	4224	0.00989286	

Then, we can calculate the average uplink and downlink throughput per source node for each of the 4 cells:

Cell#1: Uplink: 11832.96bits/s Downlink: 11832.96bits/s
Cell#2: Uplink: 13088bits/s Downlink: 13088bits/s
Cell#3: Uplink: 11833bits/s Downlink: 11833bits/s
Cell#4: Uplink: 13519.36bits/s Downlink: 13519.36bits/s

So, the analysis above is our results for the simulation task1. And then we focus on the observation of the handoffs among the whole topology. In the simulation, we use the A2-A4-RSRQ handover algorithm, and there are some problem in our text file finally, and we cannot observe the handoff happens.

% time	cellId	IMSI	RNTI	rsrp	sinr
0.000214285	1	1	0	2.36068e-15	4.97675
0.000214285	1	2	0	1.20536e-13	254.112
0.000214285	1	3	0	2.59867e-14	54.7849
0.000214285	1	4	0	4.62893e-15	9.75864
0.000214285	1	5	0	3.05489e-15	6.44027
0.000214285	1	6	0	6.09321e-15	12.8456
0.000214285	1	7	0	2.15952e-15	4.55266
0.000214285	1	8	0	4.3819e-15	9.23786
0.000214285	1	9	0	2.46894e-15	5.20499
0.000214285	1	10	0	4.45979e-12	9402.05
0.483214	1	1	6	2.28662e-15	4.82062
0.483214	1	2	9	1.31529e-13	277.288
0.483214	1	3	4	2.68986e-14	56.7073
0.483214	1	4	2	4.61249e-15	9.72399
0.483214	1	5	5	3.01274e-15	6.35141
0.483214	1	6	7	5.97517e-15	12.5968
0.483214	1	7	3	2.11358e-15	4.45582
0.483214	1	8	1	4.36741e-15	9.20731
0.483214	1	9	10	2.46169e-15	5.18971
0.483214	1	10	8	8.36687e-12	17638.9

As for the pictures at different time showed above, we cannot observe the cell ID changing during the simulation, the UEs seem to stay in the origin cell. And when we try to illustrate the circumstance with the decreasing SINR value, there is still something wrong. For the same UE, its SINR value start decreasing as time goes, but when the SINR value meet the threshold, there is no change on the Cell ID, so we think it means that there is no handoff happens.

As for this handoff algorithm, the A2-A4-RSRQ Handover Algorithm, it is measured by reference signal received quality (RSRQ), and events A2 and A4 are the conditions for handover, and there are two parameters to determine the existance of the handoff during roaming. One is the ServingCellThreshold and the other is the NeighborCellOffset. And the handoff should happen when the SINR value is lower than the ServingCellThreshold, in other word, the UE will choose to connect the other eNB when the quality of the service is lower than some level. So the ServingCellThreshold straight determine the probability of the handoff and the frequency of handoff, moreover, the value of the NeighborCellOffset can lead hopping between two eNBs, which makes the service quality drop down significantly.

4. Conclusion

Our WiFi network successfully performed data exchange with reasonably high speed. The throughput of the network varies in different simulations and changes through time because the randomness of location and movement, handoffs and hidden node problem. We learned how to establish simulated WiFi network in NS3 and how the network works.

As for the LTE part, it exactly perform a high-speed service during the simulation, but we cannot observe the occurrence of the handoff among different cells finally. In the complete process of the project, we learned how to establish a LTE network with a gateway server, and understand the basic architecture of the LTE network. At the same time, we also have a deeply understanding on differences between LTE and WiFi through the topology setting and simulation process. But there are still some future work for us to do.