Evaluation of Listen Before Talk (LBT) mechanism fairness at LTE-Licensed Assisted Access (LAA) against Wi-Fi 5 GHz

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Abstract. LTE Release 13 allow the use of unlicensed frequency variations called Licensed Assisted Access (LAA). Combination of licensed LTE is used as primary cells to carry information and transport traffic data. Whereas the unlicensed spectrum is used as secondary cells that are proposed to increase capacity and distribute the spectrum fairly. The simulation results of scenario 1 produce a fairness index of 64 users for FTP over UDP in scenario 1 of 0.998, scenario 2 is 0.857 and scenario 3 is 0.997. Whereas for FTP over TCP in scenario 1 is 0.779, scenario 2 is 0.639 and scenario 3 is 0.74.

1. Introduction
LTE-LAA can utilize additional unlicensed frequency spectrum as a solution to meet the high traffic demand work by using carrier aggregation methods, with primary cells (operating in the licensed spectrum) to convey important information and guarantee quality of service (QoS), while secondary cells (operating in unlicensed spectrum) to increase the rate of data opportunistically. And the use of the Listen Before Talk (LBT) mechanism to ensure that the LTE-LAA network can be fair to other systems on the same frequency.

In previous studies, planning layout [1] with the use of the LBT mechanism has been developed [2] and will be used in this paper. There is also the use of LTE-LAA with the number of users observed being different [...] using 3 different scenarios [3] and observing the output at layer 3 [...] by considering the value of the fairness index.

This study presents the effect of implementing the Listen Before Talk (LBT) mechanism on LTE-Licensed Assisted Access (LAA) on 5 GHz Wi-Fi with an average fairness value of scenario 3 more than 90%.

2. System design

2.1. Simulation planning
Planning simulation is carried out using 2 operators consisting of LAA operator’s and Wi-Fi. The node is in a room with a length of 120 meters and a width of 50 meters [1]. Planning layout shows in Figure 1. Simulation is done using Network Simulator 3.
The operator’s node A is located at coordinates (20.25), (45.25), (70.25), (95.25) while operator B is at coordinates (20 + bsSpacing, 25), (45, 25), (70.25), (95.25). bsSpacing is the distance between nodes on different operators. Increasing distance influences the chance of interference getting smaller.

BS value this worm is 5 meters but can be set to get the best results.

2.2. Simulation scenario
From Table 1 above it can be seen a comparison between the scenarios performed. In scenario 1 the energy detection threshold is -62 dBm, user arrival time (\(\lambda\)) is 2.5, the duty cycle is 1 with the use of the duty cycle mechanism.

| Parameter                      | Scenario 1 | Scenario 2 | Scenario 3 |
|-------------------------------|------------|------------|------------|
| Bandwidth                     | 20 MHz     | 20 MHz     | 20 MHz     |
| Carrier frequency             | 5 GHz      | 5 GHz      | 5 GHz      |
| Transport protocol            | TCP and UDP| TCP and UDP| TCP and UDP|
| ED threshold                  | -62 dBm    | -62 dBm    | -72 dBm    |
| User arrival time             | 2.5        | 2.5        | 0.5        |
| Duty cycle                    | 1          | 0          | -          |
| Number of users               | 16, 40 and 64 | 16, 40 and 64 | 16, 40 and 64 |
| Mechanism                     | Duty cycle | Duty cycle | LBT        |

While scenario 2 uses the energy detection threshold -62 dBm, user arrival time (\(\lambda\)) of 2.5, the duty cycle of 2 with the use of the duty cycle mechanism. In scenario 3, the energy detection threshold is -72 dBm, user arrival time (\(\lambda\)) is 0.5 with the use of the LBT mechanism. Each of the above scenarios is carried out by observing the variable number of diverse users, namely 16, 40 and 64 total users. Simulation is based on FTP model 1 [4] where the value of user arrival time (\(\lambda\)) ranges from 0.5 to 2.5.

3. Result and discussion
Data obtained from the results of the simulation and testing scenarios will be analyzed based on the quality of service, namely throughput and latency. In the simulation results, data throughput is measured based on UDP and TCP transport for each of the 3 additional customer schemes. The process of coexistence is seen from the best value of throughput and latency obtained by the user.
Table 2. Simulation result of UDP and TCP

| Operator | Throughput (Mbps) | Latency (ms) | Throughput (Mbps) | Latency (ms) |
|----------|-------------------|--------------|-------------------|--------------|
|          | \( \overline{x} \) | \( \sigma \)  | \( \overline{x} \) | \( \sigma \)  |
| 8 UE per Operator |                      |              | 20 UE per Operator |                      |
| A | 63.4 | 10.2 | 38.8 | 11.6 | 26.0 | 13.6 | 13.8 | 5.3 |
| B | 70.6 | 4.59 | 31.4 | 3.52 | 11.5 | 1.73 | 9.10 | 1.8 |
| 32 UE per Operator |                      |              | Scenario 2 |                      |
| A | 65.4 | 5.19 | 38.1 | 9.17 | 37.6 | 8.09 | 13.3 | 3.0 |
| B | 71.3 | 0.32 | 31.5 | 3.68 | 11.5 | 1.73 | 9.10 | 1.8 |
| B | 85.0 | 14.0 | 26.2 | 8.40 | 52.4 | 10.7 | 2.5 | 2.2 |
| A | 112 | 19.1 | 20.9 | 3.37 | 8.79 | 3.1 |
| B | 100 | 17.8 | 24.0 | 5.01 | 36.1 | 16.4 | 6.08 | 3.4 |
| B | 112 | 18.7 | 20.8 | 5.01 | 21.2 | 2.78 | 8.96 | 3.0 |
| B | 99.6 | 18.3 | 26.8 | 50.7 | 81.3 | 15.8 | 6.08 | 2.8 |
| 32 UE per Operator |                      |              | Scenario 3 |                      |
| A | 111 | 20.8 | 22.6 | 19.6 | 20.5 | 4.08 | 9.64 | 4.4 |
| B | 100 | 18.3 | 21.9 | 8.05 | 79.7 | 16.1 | 6.02 | 2.0 |

In Table 2, it can be stated that the result of UDP and TCP simulation, where \( \overline{x} \) is mean and \( \sigma \) is standard deviation of value. UDP protocol is a full buffer which provides more opportunities for LAA to transmit data than Wi-Fi. On TCP transport, it was described as a finite buffer that provides flow control. It can be seen that throughput is directly proportional to latency. But, in this scheme obtain the lower quality of service of operator A then the previous UDP scheme because at finite buffer gives more opportunity at Wi-Fi operator to transmit data. With this theory, the simulation results in higher throughput and lower throughput value at LAA operator by using UDP and lower throughput and higher latency value at LAA operator by using TCP.
From Figure 2 and Figure 3, it can be seen that the throughput value obtained in scenario 3 is the highest and the latency value obtained is lowest compared to other scenarios. This can show that the use of the LBT mechanism can increase the effectiveness of the LAA network's performance on Wi-Fi. The use of the UDP which is connectionless-oriented protocol results in high throughput values (average > 100 Mbps for scenario 3) and low latency (average < 25 ms for scenario 3).
From Figure 4 and Figure 5, it can be seen that the use of TCP on the LBT mechanism which is a connection-oriented protocol produces a lower throughput value than UDP. The use of this protocol has a higher throughput and lower latency value obtained in scenario 3 for Wi-Fi operators because the LAA operator will build a channel before starting to transmit data.

| Scenario | 8 UE Throughput | 8 UE Latency | 20 UE Throughput | 20 UE Latency | 32 UE Throughput | 32 UE Latency |
|----------|----------------|--------------|------------------|--------------|------------------|--------------|
| Scenario 1 | 0.997 | 0.989 | 0.870 | 0.959 |
| Scenario 2 | 0.998 | 0.991 | 0.780 | 0.965 |
| Scenario 3 | 0.998 | 0.991 | 0.779 | 0.959 |

Based on Table 3, it obtained the average of fairness value is near to 1, it means that the index of fairness on LBT at LAA has been well. From the three scenarios that have been done, the third scenario has a simulation result with the best quality of service among the other scenario. It can occur because of the efficiency and use the right LBT mechanism. Besides that, for the case of interference from other system presents its own challenges and requires a mechanism that compatible with the system environment.
The higher value of fairness means LAA can be a good neighbor for Wi-Fi and didn’t interfere it. From the value of fairness throughput in Figure 6, UDP produces higher values than TCP (fairness > 85%). Figure 7 shows the fairness index of latency.

4. Conclusion
Fairness of LAA and Wi-Fi performance depends on factors including the use of a duty cycle mechanism which is a comparison between the use of LTE and Wi-Fi, the use of duty cycle = 1 in UDP produces Wi-Fi operators and LAA throughput for 64 users of 65.84 Mbps and 71.33 Mbps while the latency is 38.12 ms and 31.58 ms. While the use of duty cycle = 0 results in LAA and Wi-Fi operator’s throughput of 35.75 Mbps and 85.04 Mbps while latency is 64.38 ms and 26.21 ms. Another factor is the use of user arrival time (λ), use of λ = 0.5 with energy detection = -62 to get throughput on LAA operators and Wi-Fi by 112.85 Mbps and 101.38 Mbps while latency is 22.85 ms and 22.16 ms. While the use of λ = 2.5 produces a throughput of 106.90 Mbps and 88.04 Mbps while the latency is 25.09 ms and 25.59 ms.

The use of more UE numbers results in a lower quality of service. To be able to produce good parameters on high traffic a higher allocation is needed. Index fairness shows values in scenario 1 of 0.997 and 0.989 for UE 16 while 0.998 and 0.991 for 64 UE for successive throughput and latency on FTP over UDP. Whereas in FTP over TCP 0.870 and 0.959 for UE 16 while 0.779 and 0.959 for 64 UE for successive throughput and latency. This shows that the addition of UE numbers influences the performance of both the quality of service and fairness.
5. References

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