Performance Evaluation of Coexistence of WiFi and LTE Licensed-Assisted Access to Unlicensed Spectrum using Markov chain Analytical Model

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Abstract: LTE with the inclusion MIMO renders high data rate, we introduce a model for system performance evaluation considering typical coexistence of LAA LTE and WiFi. Currently, as the need for high bandwidth to satisfy high data rate demanding services increased significantly over the years, the operators are thinking about various answers for incrementing system limit. As the authorized range has been costly, utilizing LTE in the unlicensed spectrum will be a hopeful strategy to oblige trade requirement for versatile information. Expecting that LAA eNBs perform CCA as a similar way to WiFi CSMA, we utilize Markov chain to help assess the influenced execution of WiFi as well as the connection between the joint framework execution and LAA most extreme transmission time. Nonetheless, LTE needs to exist together with different heterogeneous system, particularly WiFi, prior in the unlicensed medium.
Keywords: LTE-LLA, MIMO, Markov Chain Model, LBT, BER, Throughput, SINR

I. INTRODUCTION

A licensed network in unlicensed spectrum is an effective complement in get going increasing traffic since its emergence. Presently, the interest for portable information traffic is becoming excessively quick. Pleasing this development authorized to explore variety of answers for incrementing system limit. Licensed wireless medium is too expensive. Since the authorized range is rare and costly, sending licensed technologies in the unlicensed spectrum would be the best technique to oblige the trade requirement for portable information. In any case, LTE needs to coincide with different heterogeneous system, particularly WiFi, previous in the unlicensed medium. This concurrence can present significant execution debasement for right now sent WiFi systems. In this investigation, accentuation is given in breaking down the execution of WiFi and LTE concurrence situation both logically and through reproduction. To this end, various arrangements are proposed to build the execution of WiFi.

Right off the bat, a numerical examination is performed to scientifically detail the issue of concurrence among WiFi and

LTE. Antecedently, this was limited to get going the mobile traffic onto unlicensed networks which have pervasive disposition and comparatively less cost. As of late, other than the information off loading, portable administrators are additionally hoping to work LTE in the unlicensed range. In any case, this sending can huge affect the activity of WiFi and presents a few difficulties for the two systems to appreciatively exist together in a mutual range. Considering the conjunction obstacles for both Wi-Fi and LTE systems needs a more intensive focus in the task in the physical layer and Mac Layer.

Notation: P or Prob represents Probability throughout the paper

II. RELATED WORK

The foundation work in the idea of concurrence of diverse systems is checked on concentrating on the emphasis on the conjunction of WiFi and LTE systems. Besides, interface adjustment method as an improving system act apparatus is investigated both in WiFi and LTE. In [1, 2] the conjunction of wireless with Radio Frequency (RF) obstructions from gadgets like Bluetooth headsets and cordless telephones has been researched. The exploration demonstrates that wireless system is truly helpless against obstructions of different gadgets actuating in its data transfer capacity. Some outrageous cases demonstrated that joins in WiFi systems can be hindered with signs which have just 1/1000 power dimension of 802.11 signs. In [3, 10, 12, 11] the conjunction of WiFi along with ZigBee is under thought. ZigBee is viewed as a major wellspring of impedance for WiFi correspondence. One noteworthy issue in this conjunction is that WiFi APs are unfit to distinguish the transmission of ZigBee gadgets since the transmitted bundles in ZigBee has a 20 dB lower control contrasted with WiFi parcels. The ignorance of their concurrence will result in a major likelihood of impact bringing about a poor act for the two systems. Besides, the conjunction among WiFi and WiMAX has been examined in [4] concentrating on concurrence impedance issues because of concurrent task of a few radio frequencies. Concurrence of LTE and WiFi with no modification to the two systems has been contemplated in a paper [5] distributed by Nokia Research. In this work, LTE and WiFi operation in the split spectrum has been assessed in an environment close to the TV White Space band. Their simulation experiment included offices with single floor and multi floor environments and different densities for unlicensed and licensed nodes. Researchers observe that the Wi-Fi execution gets degraded due to the presence of LTE in the selfsame band. On the contrary,

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LTE performance was not affected with existence of Wi-Fi achieving almost the same throughput as before. Besides, Babaei et al have proposed probabilistic and numerical investigation of this concurrence [9].

Their examination demonstrated that without changing the current conventions for similarity, Wi-Fi finishes up being in the listening mode. In [6] creators assessed the conjunction of LTE and WLAN. They have inferred that in spite of the fact that this concurrence negatively affects WLAN organize, the seriousness of the negative influence is sensible by constraining the LTE action. Improving the WiFi and LTE concurrence additionally has been tended to in a few investigations. The creators in [7] explore the idea of sending LTE into an unlicensed band (WiFi range) using the LTE pico-cells. Creators attempt to reuse the bearers by presenting an underlay of low power hubs in the full scale cell. They considered a kind of LBT procedure to alter LTE to exist together calmly with WiFi. Execution investigation showed the capacity of LTE pico-cells to convey significant measure of throughput notwithstanding when the LTE pico-cells were imparting their range to WiFi. In [8] a physical layer system for concurrent LTE and WiFi transmission and gathering has been introduced. In the proposed structure the Block Error Rate (BLER) for WiFi is somewhat bigger when the LTE causes the impedance contrasted with obstructions from another WiFi gadget.

III. SYSTEM MODEL

3.1 WiFi Link adaptation

Connection adjustment writing can be arranged into two primary gatherings. The first amass expects to adjust the connection by means of measurements of casing misfortune. In this methodology the measurements of progress and disappointment of past transmission will be utilized so as to adjust the connection for future transmission. These gatherings will build the transmission rate of having a high fruitful transmission history and will diminish the bitrate when disappointments become visit. Be that as it may, the second methodology will think about the got data as a base parameter for future connection adjustment. In this gathering of calculations, bit-rate will increment when the got flag has a high SNR and will diminish when flag quality is low.

3.2 CONNECTION ADAPTATION IN LTE

Connection adjustment in LTE is additionally comparative with WiFi, and includes choosing the regulation and coding plan (MCS) to accomplish the greatest information rate feasible for every transmission to the UE. In any case, interestingly with WiFi a versatile adjustment and the coding (AMC) innovation is utilized for the LTE, empowering higher phantom efficiency correspondence inside the system. So as to perform AMC activity in LTE, appropriate criticism must be conveyed from the equipment to the eNB.

The common course of action of the adaptive Coding procedure of LTE is given as below
• At First, variance of noise and the channel matrix H are to be determined on the basis of present channel scenario.
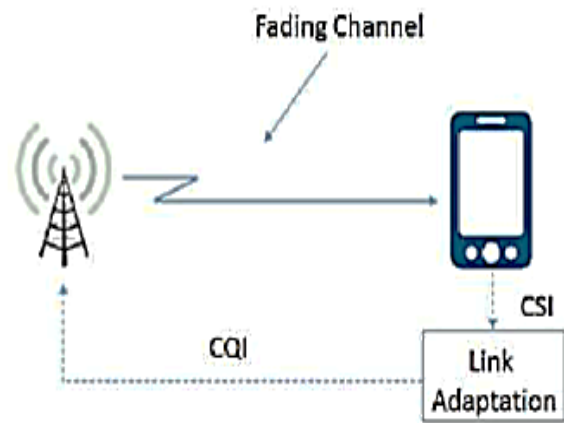• The posterior SINRs are also determined.

Fig 1: Link Adaptation in LTE Operation

• Link quality metric needs to be executed.
• For the modulation and coding process measured metric is mapped to a testimonial BLER using the CQI executive search loop and with a look-up table.
• Repeat the process until the current executive CQI gives BLER becomes less than a prescribed threshold of desired target value of BLER.
• Finally CQI chosen appears back at the side of the transmitter.

Effective SNR is the most frequent link quality metric. It is interpreted as the SNR observed by the code word as if it were sent over a flat-fading channel. A high SNR outcome results in greater level schemes of modulation having a better spectral efficiency.

IV. PROPOSED METHOD

In this section, a hypothetical assessment of the Wi-Fi throughput execution while working exists together with LAA-LTE is introduced. Moreover outcomes and dialogs for mathematical investigation dependent upon hypothetical assessments is shown.

4.1 WIFI PERFORMANCE WITHOUT INTERFERENCE

Bianchi [1] introduced an outstanding investigative model for Wi-Fi. According to that the CSMA or CA method accomplished for the layer was demonstrated as dependent on Markov Model [12] Chain idea. In the given prototype model with n Wi-Fi stations are used for conveying in a perfect scenario of channel. In this manner, it is presumed that the parcel transmitted in the situation will be either gotten effectively or slam into other bundle bringing about a communication disappointment. Every one of the stations are working in an immersion mode condition implying that for each transmission there is other bundle inline (the likelihood of incoming parcels in the line, q, is during enduring situation each station will transmit a parcel having likelihood $Prob_{tw}$. For effortlessness it has been accepted that in some random communication endeavor the impact likelihood seen by communicating station, $Prob_{cw}$ or essentially Pin Fig 1, is autonomous and consistent.

$Prob_{cw}$ can be determined dependent on the reality, that in a schedule vacancy the likelihood of crash for a communicating station is equivalent to the likelihood that at least one of the n − 1 stations communicate in the meantime

So,

$$Prob_{cw} = 1 − (1 − Prob_{tw})^{n−1} \quad (1)$$

$$Prob_{tr, w, N} = 1 − (1 − Prob_{tw})^{n} \quad (2)$$

$$Prob_{s, w, N} = nProb_{tw} (1 − Prob_{tw})^{n−1b} \quad (3)$$

The probability of collision in the overall network has been calculated in Bianchi's markov chain model in Fig.2 using the CSMA/CA back- mechanism
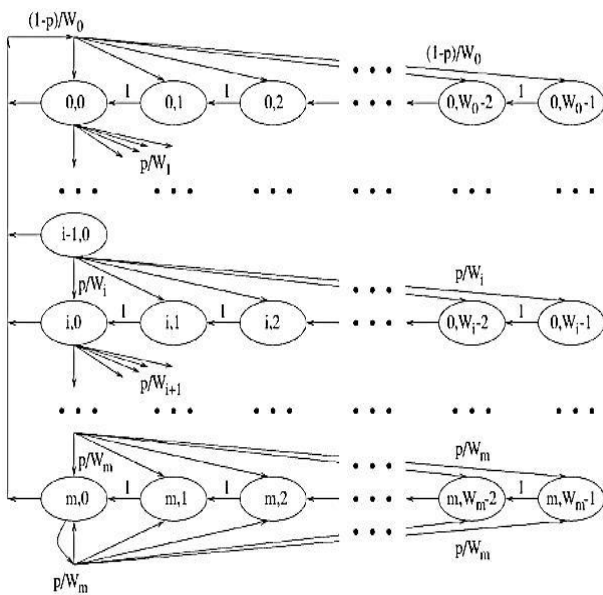

Fig 2: Carrier Sense Multiple Access/Collision Avoidance Markov Model

From this prototype model, with each successive disappointment in transferals the back-of window changes from W_i to W_{i+1} till the most extreme back-of window (W_M) is achieved, where $W_{i+1} = 2W_i$. Then again, after a fruitful transfer the back-off side window altered to the underlying least esteem. The window counter additionally lessens by inert schedule opening with likelihood (the likelihood of the channel being involved, P_b is zero out of an inactive availability right after the transferal). The processing of $Prob_{tw}$ could be dependent on the feasible examination of the developed chain of Bianchi's investigation W indicates the size of base window, m represents most extreme back-off arrange. With unraveling equations $Prob_{tw}$, $Prob_{cw}$ may be inferred mathematically.
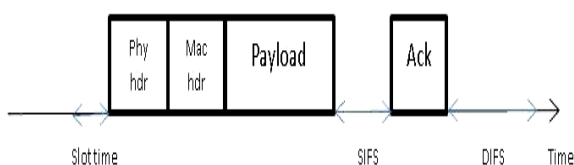

Fig 3: Time required for a successful transmission
Finding the payload bits transmitted over the required period is necessary for calculating the throughput for Wi-Fi.

$$Prob_{tw} = \frac{2(1-2Prob_{cw})}{(1-2Prob_{cw})(W+1)Prob_{cw}W(1-(2Prob_{cw})^m)} \quad (5)$$

$$S = \frac{Expectation(Noofpayloadbitstransmitted)}{Expectation(Timeperiod)} \quad (6)$$

Average rate number of the payload bits dispatched through the channel medium is $Prob_{swN}$ Expectation [L^{WiFi}], where [L^{WiFi}] represents dispatched packet length with excluded header. Duration of transferable made up of a void time slot and the probability of (1 − $Prob_{trwN}$), the success dispatch period (T_{sw}) and probability $Prob_{swN}$, collision period (T_{cw}) corresponding probability of $Prob_{cwN} = Prob_{trw} − P_{swN}$ .Throughput achievable can be estimated through (6):

$$S_W = \frac{Prob_{swn}Expectation([L^{WiFi}])}{(1-Prob_{trwn})^5 + Prob_{swn}T_{sw} + Prob_{cwn}T_{cw}} \quad (7)$$

δ is defined as per time period slot. From Fig 2-3, T_{cw} and T_{sw} can be computed through (8) and (9):

$$T_{sw} = \frac{Exp[L]}{R_W} + SIFS + \frac{Acknw}{R_W} + DIFS + \delta \quad (8)$$

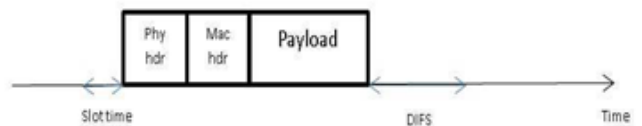$$T_{cw} = \frac{Exp[L]}{R_W} + DIFS + \delta \quad (9)$$

Fig 4: Time required for a crash
and Expec [L] represents bundle length in which header is included.R_w is the rate of transmission, SIFS the short interframe space and DIFS is DCF interframe space respectively. Ack represents length of the affirmation outline.

4.2CONJUNCTION PERFORMANCE OF LAA AND WI-FI
In this segment execution of Wi-Fi existing together with the LAA is examined. All the investigations center around the medium access procedure of the two advances namely CSMA or CA for Wi-Fi and also LBT for LAA. Out of the various divert get to plans in LAA the proposition examines just the Class 4 conspire which is progressively like Wi-Fi CSMA or CA and in this manner increasingly good in the conjunction. Class4 LBT performs CCA if there should arise an occurrence of new transmission. On the off chance that the channel is inert amid CCA. Whereas LAA communicates right away. LAA moves into all-inclusive CCA state (ECCA) beginning with an underlying conflict window (CW_{min}) of 32.

The CW copies each time achieving the most extreme CW (CW_M) size of 1024 when transmissions bomb sequentially (like CSMA/CA system to decrease the crash likelihood). On the off chance that another ineffective transmission occurs in the wake of achieving the CW_M.The dispute window will reset to CW_{min}. LAA transmits simply after irregular number which is being chosen over (0, CW), decreases to 0 value.In light of the investigation of the Class4 system it tends to be inferred i.e., varies from CSMA/CA in two principle parts. Right off the bat, CSMA or CA not at all like Class4 won't start the transmission following the CCA is effective (it needs to choose an irregular no and checks down to the 0 value). Besides, CSMA or CA do not start again because of impact. The territory of LBT is shown through S(t) and Z(t) where S(t) represents -dislikes the ECCA. Z(t) signifies counter.
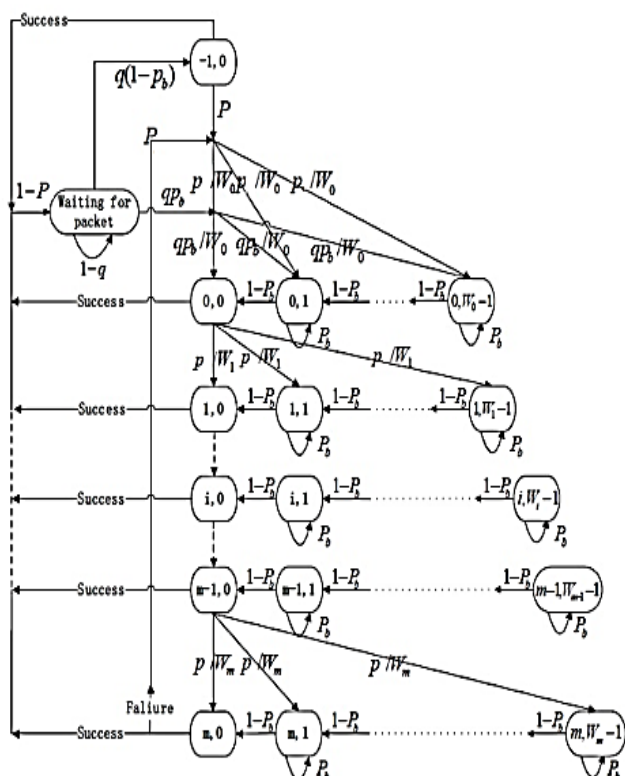

Fig 5: Markov chain model for the Cat4 LBT

As observed from the model in Fig 4;LBT at first sits tight for the entry of parcels. At the point when a bundle comes, CCA is effective with likelihood $q(1 - P_b)$, LAA begins the transmission. Something else, LBT enters the ECCA through an underlying conflict window of W_0. It tends to be finished up from the Fig 4 LAA is just ready to communicate when Z(t) = 0, S(t) belongs to (−1, 0, ..., m − 1, m). Investigation of the chain, creators inferred likelihood of Class4 transferal, P_{tL} as a component of likelihood of crash (P_{cL}) through (10).

$$Prob_{tl} = \frac{2(1-Prob_{cl})(1-2Prob_{cl})C}{A+WB(1-Prob_{cl})(1-2Prob_{cl})^{m+1}+BC(1-Prob_{cl})^2+2C(1-Prob_{cl})^3(1-2Prob_{cl})}$$

(10)

where A represents $= 2(1 − Prob_{cl})^2(1 − 2Prob_{cl})$, $B = 2Prob_{cl} − Prob_{cl}^2$ and $C = (1 − Prob_{cl}^{m+1})$.

4.3 ANALYTIC EVALUATION OF COEXISTENCE
At the point consider i Wi-Fi stations and j LAA Class4 clients (Fig 5 shows the under examined framework

demonstrate) the likelihood of crash for a communicating WiFi ($Prob_{cw}$) and LAA station ($Prob_{cl}$) are as per the following:

$$Prob_{cw} = 1 − (1 − Prob_{tw})^{i−1}(1 − P_{tl})^j$$

(11)

$$Prob_{cl} = 1 − (1 − Prob_{tw})^i(1 − Prob_{tL})^{j−1}$$

(12)

Comprehending equations 4, 10, 11 and 12 numerically, the likelihood of transferal and crash ($Prob_{tw}$, $Prob_{cw}$, $Prob_{tl}$, $Prob_{c,l}$ for Wi-Fi and LAA can be removed. Till finishing of this part, staying plausibleness examination depends on the numerical calculation of these four probabilities. Instinctively, likelihood of direct inhabitance in availabilities are figured dependent on the way that ought to have somewhere around single transferal through channel and thus separated by (13):

$$Prob_{tr} = 1 − (1 − Prob_{tw})^i(1 − Prob_{tL})^j \quad (13)$$

Medium tenancy expectation for Wi-Fi and LAA victorious transferal can be calculated through the following equations respectively:

In our particular model, the impact likelihood comprises of three various occasions:
1) Collision of Wi-Fi or LAA stations result in unsuccessful transmission.
2) Collision between Wi-Fi and LAA stations

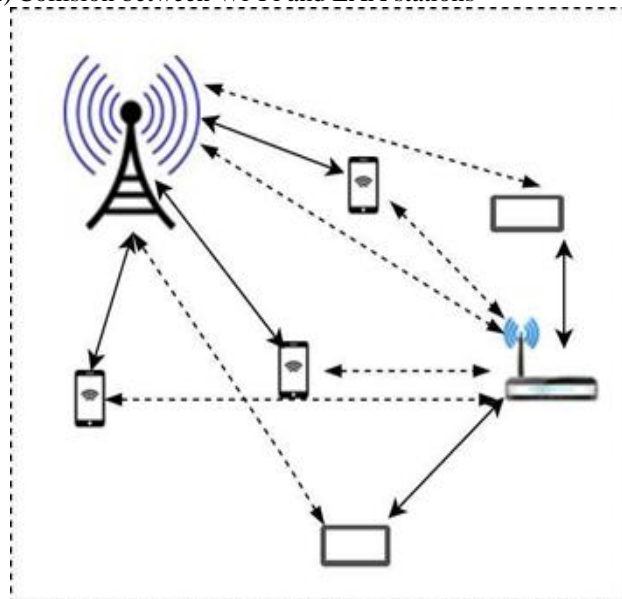**Fig 6:** Framework shows the concurrence of Wi-Fi and LTE. Strong **f**asteners demonstrate the present connections and dashed connectors show the potential associations.

For figuring the attainable throughput for Wi-Fi and LAA, we need to pursue a similar rationale of condition (5) and (6). The main variation is that the time interim **for** an effective transferal needs to incorporate additional time lengths adjacent to the recently referenced ones.

These new periods are the time length for effective transferal of LAA (T_{sL}) with likelihood of $Prob_{s,L,N}$, the time term of crash inside two LAA station (T_{cL}) with likelihood $Prob_{c,L,N}$, and the time for an impact among WiFi and LAA, max($T_{c,L}$, $T_{c,w}$), with likelihood $Prob_{c,wL,N}$.

V. RESULT ANALYSIS

With different mix of Wi-Fi and LAA clients is appeared so as to approve the task of the back-off arrange components of the two systems. In particular, the outcomes for the transferal and crash likelihood of Wi-Fi and LAA stations are displayed. For determining the transmission, impact probabilities we illuminated the (4), (9), (10), and (11) numerically for different mix of number of clients in the two advances. Figure6 delineates the transmission likelihood of one Wi-Fi station (blue line).

Since Wi-Fi will pick a window size of 32 the transferal likelihood of one Wi-Fi station in an unfilled schedule opening is less. In light of the determined results it is very well may be chosen that Wi-Fi stations are essentially working in the first and second back-off organize.

The normal transferal likelihood of a Wi-Fi station working in the first back-off arrange is 0.0625 as the window measure is 32 ($Prob_{t,w}$ = 1/16 = 0.0625).

The normal likelihood is determined under the suspicion that every station having a place with Wi-Fi or LAA has a similar likelihood of transferal and face a similar likelihood.
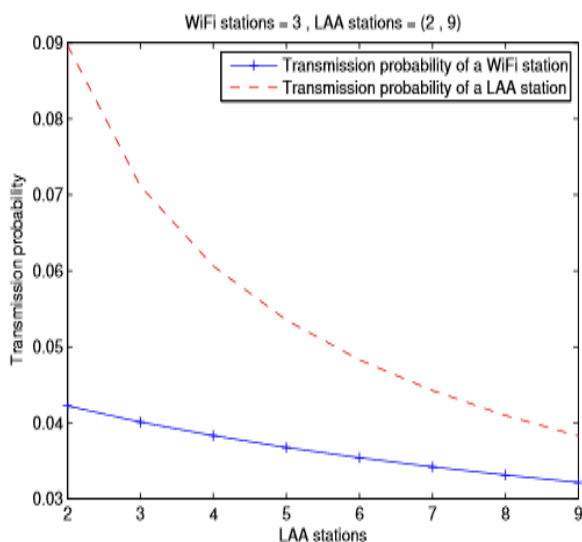

Fig7: Contrasts of transmission probability of Wi-Fi and LAA

Then again, the transferal likelihood of single LAA station is showing stations in normal work in the back-off phase of two, three.

In the back-off organize one; window measure is zero demonstrating that LAA can transmit after a void DIFS period. Hence, it tends to be perceived that the LAA likelihood of transferal is bigger than the Wi-Fi transferal likelihood. Moreover if the quantity of stations increments in the framework the transmission likelihood of Wi-Fi and LAA draw nearer to one another.

Fig 8 demonstrates the impact likelihood perceived by a communicating Wi-Fi and LAA stations (it is accepted that it is prepared to transfer and it isn't hanging tight for any back-off).. It is evident variation in second case inside the impact likelihood of Wi-Fi and LAA stations is a lot littler compared with first case.
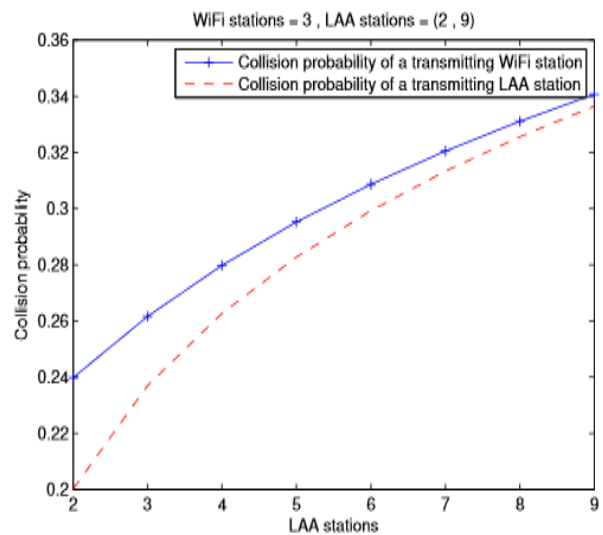

Fig 8: Contrast of collision probability of Wi-Fi and LAA

Fig 8 demonstrates the impact likelihood perceived by a communicating Wi-Fi and LAA stations (it is accepted that it is prepared to transfer and it isn't hanging tight for any back-off).. It is evident variation in second case inside the impact likelihood of Wi-Fi and LAA stations is a lot littler compared with first case.

For 2 stations

	Transmission Probability	Collision Probability
Wi-FI(3 in no)	0.043	0.24
LAA (2 in no)	0.09	0.2

For 9 stations

	Transmission Probability	Collision Probability
Wi-FI(3 in no)	0.035	0.34
LAA (2 in no)	0.09	0.335

VI. CONCLUSION

We explored imperative ideas of decency in the achieved throughput for the two systems. The two reasonableness criterion are the equivalent throughput for Wi-Fi and LAA independently, and the equivalent throughput for no of stations imparting into them. As indicated by the previously mentioned outcomes, bigger K punishes LAA-LTE as far as channel get to postpone however improves the throughput of Wi-Fi without debilitating SL. Our numerical analyses included changing the greatest parcel estimate both ideally and heuristically for the WiFi system to accomplish a decent amount from the system in the immersion condition. Additionally, we dissected the client portion to the two systems (expecting clients are furnished with handsets and collectors from the two advances) so as to accomplish a reasonable conjunction regarding reachable throughput. Our outcomes show that by legitimate tuning the greatest parcel estimate for the WiFi arrange a decent amount for the WiFi organize is attainable.

Likewise, legitimate designation of versatile clients inside the two advancements can additionally expand the reasonableness for the LAA/WiFi conjunction.

ACKNOWLEDGMENT

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