Enhancing Channel Assignment Performance in Wireless Mesh Networks Through Interference Mitigation Functions

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IEEE ANTS 2016

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- CA Classification based on IMF Module Placement
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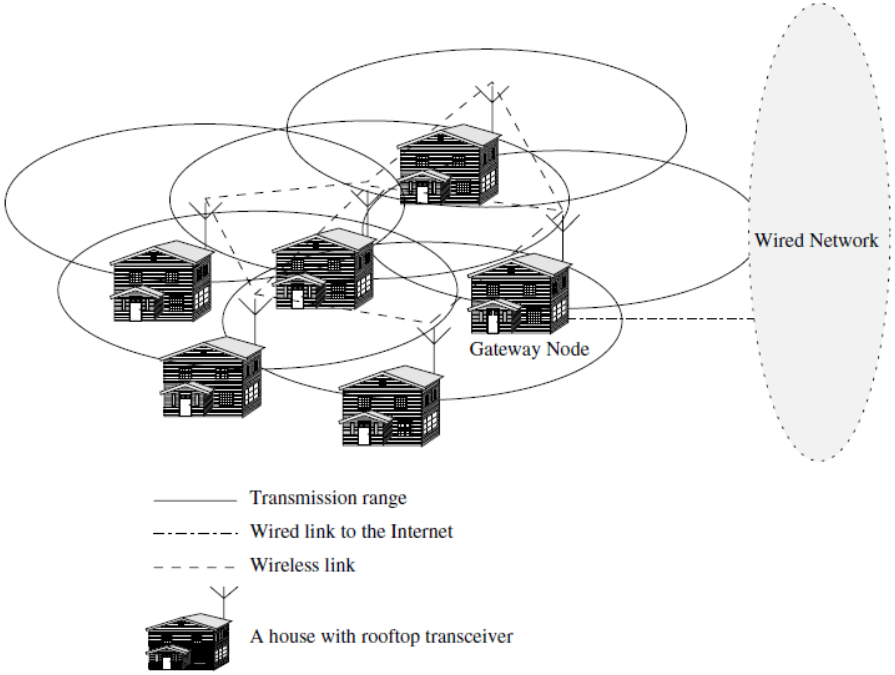
Introduction

- Multi-hop relaying is a primary characteristic of Wireless Mesh Networks (WMNs).
- Wireless transmissions give rise to transmission conflicts, when transmission is occurring on overlapping channels.
- The adverse impact of prevalent interference caused by transmission conflicts devours the network capacity of MRMC WMNs.
- Interference mitigation techniques include channel assignment (CA) to radios, link-scheduling, routing and beam-forming through directional antennas.



Interference Mitigation Function (IMF)

- Interference Estimation Metric offers an approximate measure of interference prevalent in the WMN.
  - ❖ E.g., Total Interference Degree (TID), $CDAL_{cost}$ and $CXLS_{wt}$

- IMF is a mechanism which involves
  1. an Interference Estimation Metric to assess the severity of potential link conflicts in the WMN
  2. a subsequent intelligent action to minimize the interference levels

- An IMF is often iteratively invoked in a CA scheme, until no further reduction in levels of interference is recorded.

Total Interference Degree (TID) [1]

- Conventional approach for estimating interference.
- Considers spatial proximity of links for interference estimation.
- Computed by halving the summation of the Interference Degree of all the links in WMN.
- Not a reliable metric.

Channel Distribution Across Links ($CDAL_{cost}$) [2]

- Considers statistical characteristics for interference estimation.
- Computed by finding Standard Deviation of Channel Link count for each channel.
- Channel-Link Count for a channel is number of links assigned to that channel.
- A better metric than TID.

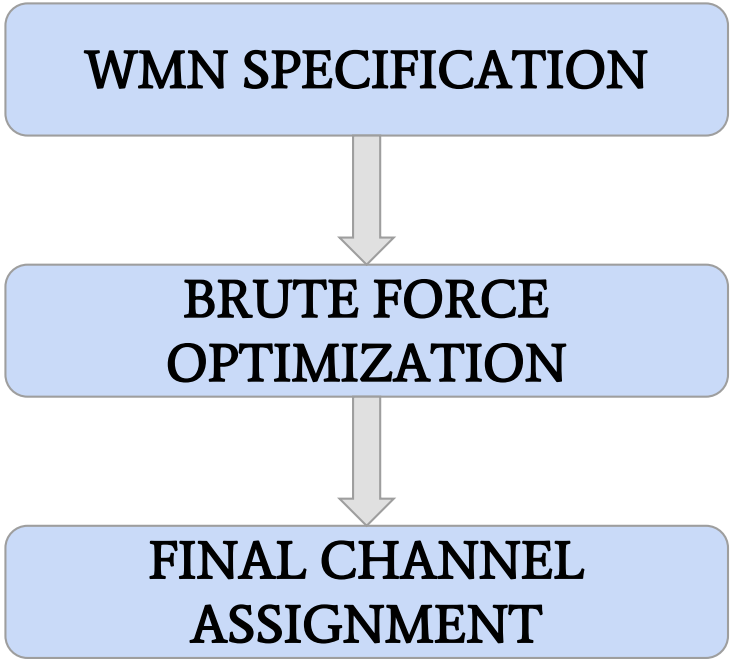
Cumulative X-Link-Set Weight ($CXLS_{wt}$) [3]

- Considers statistical characteristics and spatial proximity of links for interference estimation.
- Computed by finding all the X-links present in the topology and assigning them a weight based on the CA .
- Weight is higher when links are assigned different channels
- $CXLS_{wt}$ is the sum of weights of all the X-links.
- A better metric than TID and $CDAL_{cost}$.

CA Classification based on IMF Module Placement

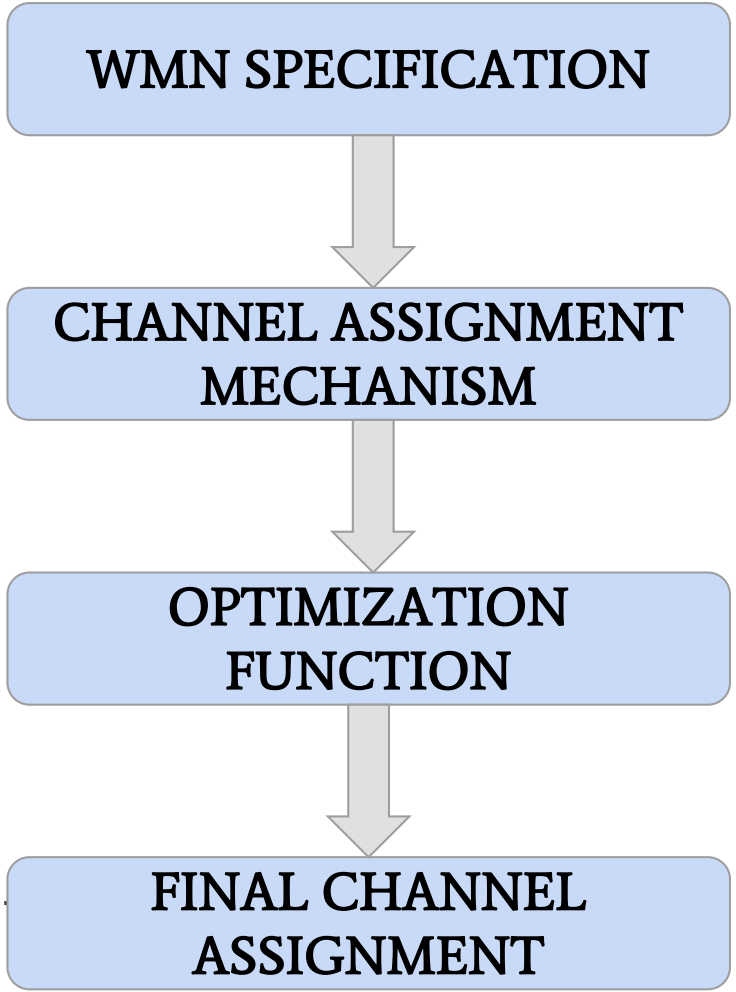
Bruteforce Interference Optimization (BIO)

- These CAs carry out a rudimentary and computationally intensive optimization by considering all possible scenarios.
- Computes interference estimate of each scenario and determining the minimal interference scenario.
- Rarely employed owing to their computational overhead but used as a benchmark against which performance of other CA classes can be assessed



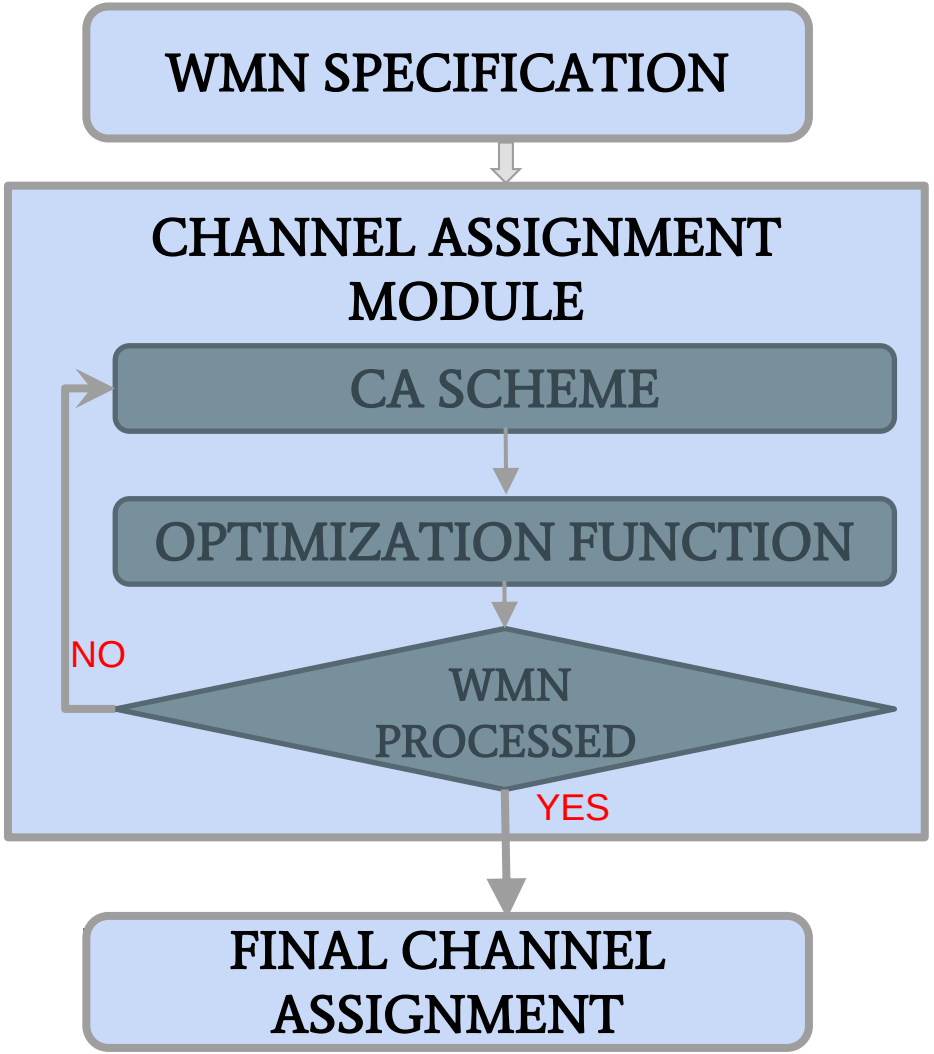
Post Channel Allocation Interference Optimization (PIO)

- Slight enhancement over the BIO class
- These CAs exploit heuristic techniques, graph approaches, genetic algorithms, etc. to carry out a preliminary channel allocation.
- The initial CA is then processed further through one or more iterations of an IMF to obtain a more efficient CA.
- So, the characteristic feature of CAs of this class is a 2-step mechanism.



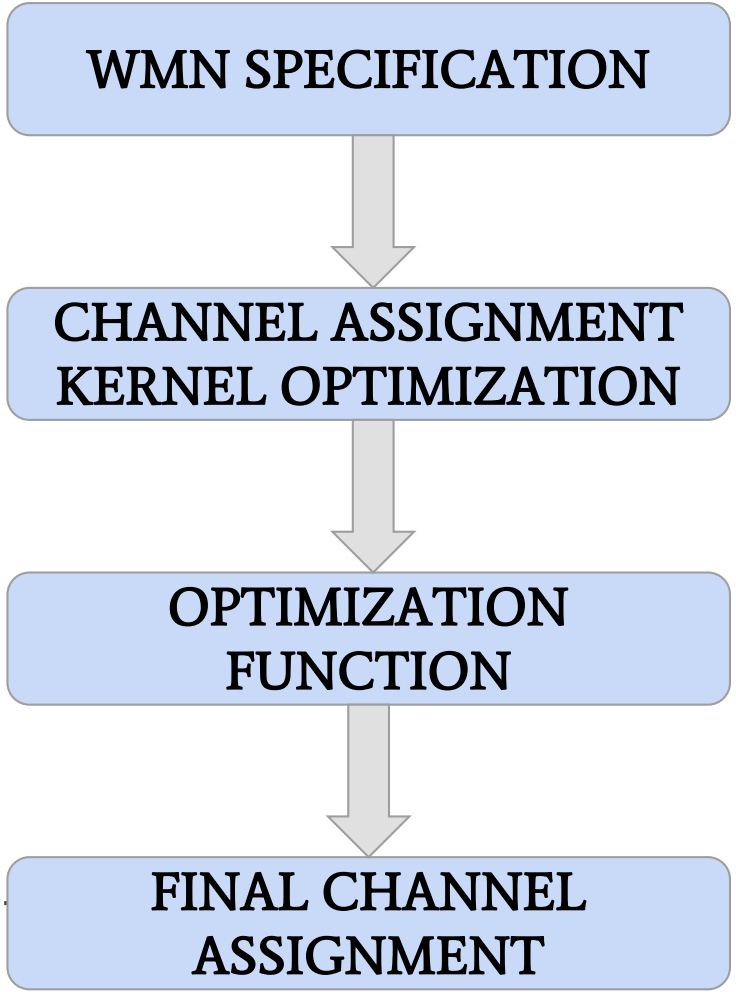
Kernel Optimization (KO)

- The schema for these CAs is complex and the IMF is embedded into the CA allocation mechanism, to form a Channel Assignment Module (CAM).
- These CAs employ a feedback mechanism to perform multiple iterations of CAM, until the CA can no longer be optimized.
- There are no clear functional divisions or steps in this CA mechanism but multiple iterations are the primary characteristic.
- Genetic Taboo Search based CA [4] scheme adopts this technique



Hybrid Optimization (HO)

- Most sophisticated CAs and offer best performance in terms of network capacity, end-to-end latency and network resilience.
- Its design involves a KO step and may exhibit the characteristics of one or more of the other two phases.
- They may also have some characteristics of their own.
- Adaptive Dynamic Channel Allocation (ADCA) [5] scheme and Elevated Interference Zone Mitigation CA (EIZM-CA) [6] are two CA schemes which adopt this technique



Simulations, Analysis & Results

- The correctness of the proposed work i.e., using $CDAL_{cost}$ and $CXLS_{wt}$ as the optimization functions in reducing interference is tested by running simulations on 802.11g ns-3 environment.

- EIZM-CA is used as the reference channel assignment since it adopts the HO classification, to develop the PIO and KO versions for analysis purpose.

- To analyze how $CXLS_{wt}$ and $CDAL_{cost}$ serve as IMFs, new versions of EIZM-CA with $CXLS_{wt}$ and $CDAL_{cost}$ as the underlying IMF are generated, termed as HO_{CXLS} and HO_{CDAL}. HO_{TID} uses TID as IMF.

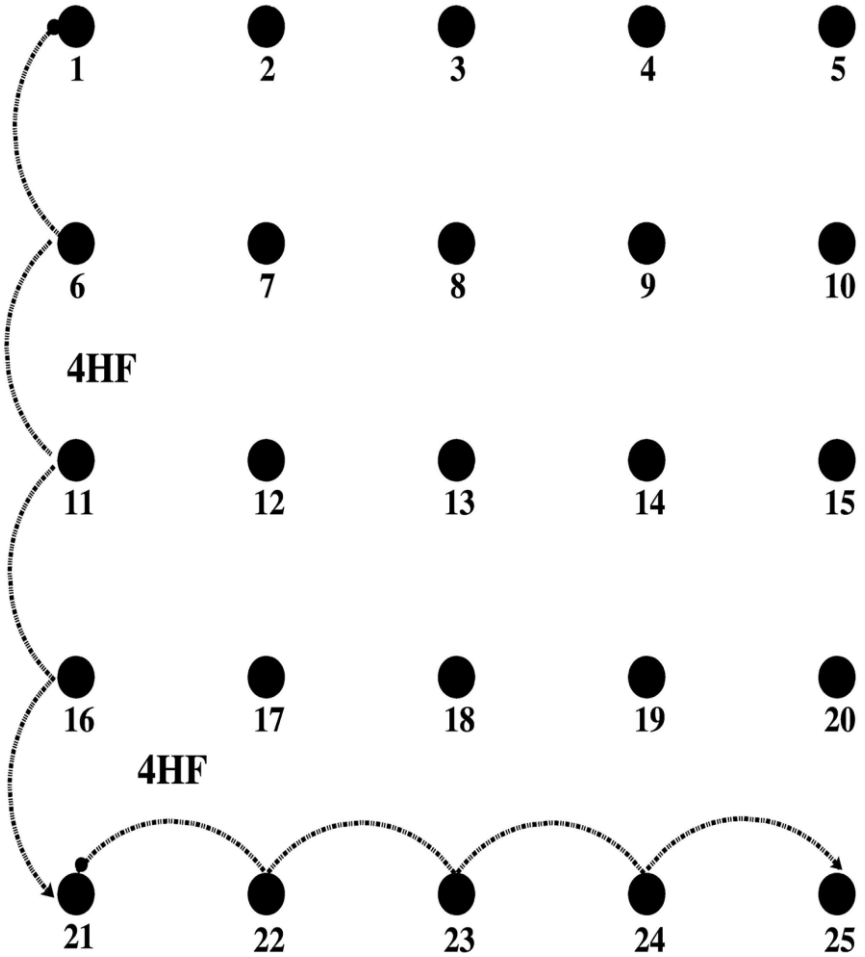
- For the other phases, BIO, PIO and KO, CAs will be referred as BF_{CXLS}, BF_{CDAL}, BF_{TID}, PIO_{CXLS}, PIO_{CDAL}, PIO_{TID}, KO_{CXLS}, KO_{CDAL} and KO_{TID}.

Simulation Parameters

Parameter	Value
Orthogonal Channels Utilized, No. of Radios per Node	3 (2.4 GHz), 2
Data file Size	5 MB
802.11g PHY Datarate	9/54 Mbps
ns-3 TCP model	BulkSendApplication
ns-3 UDP model	UdpClientServer
TCP Maximum Segment Size	1 KB
UDP Packet Size, Interval	1 KB, 0.05 sec
MAC Fragmentation Threshold	2200 Bytes
Routing Protocol	OLSR
Wi-Fi Rate Control	Constant Rate

Test Scenarios & Evaluation Procedure

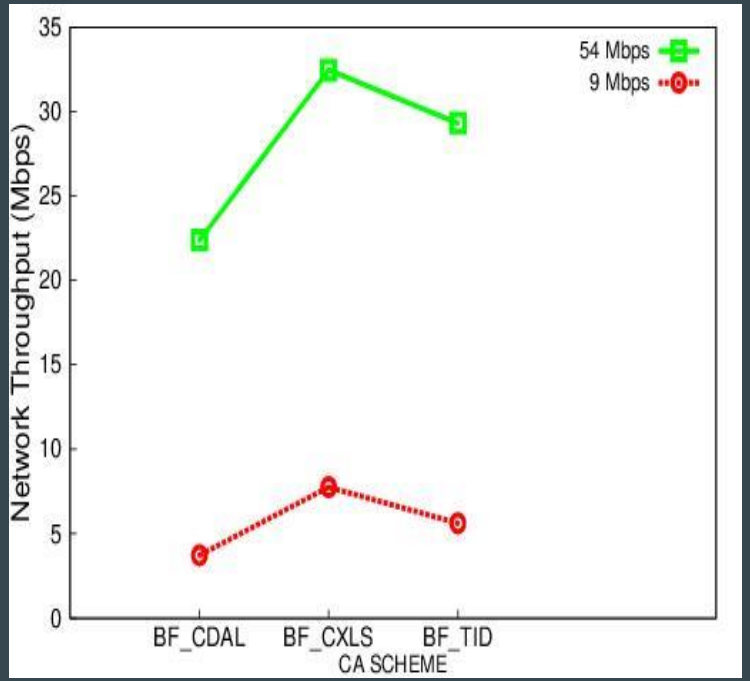
- Simulations were performed on a 5×5 grid WMN since a grid layout is a perfect scenario for evaluating the performance of any CA.
- 10 concurrent 4-hop flows, five horizontal and five vertical, starting from the first node of a row or column and ending at the last node of that particular row or column.
- In this test scenario, all the nodes will be exclusively used for data transmission so that we can thoroughly inspect the performance of CA.

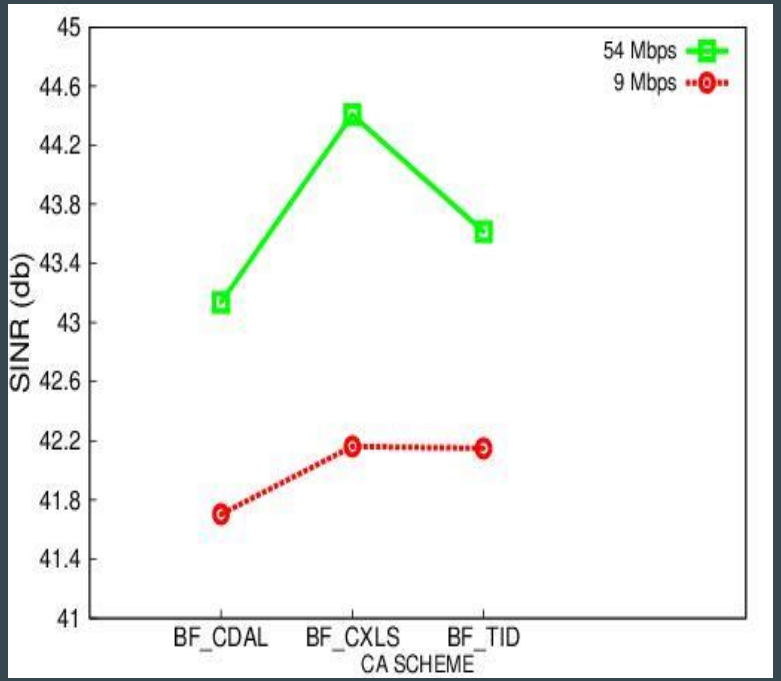


Performance Metrics

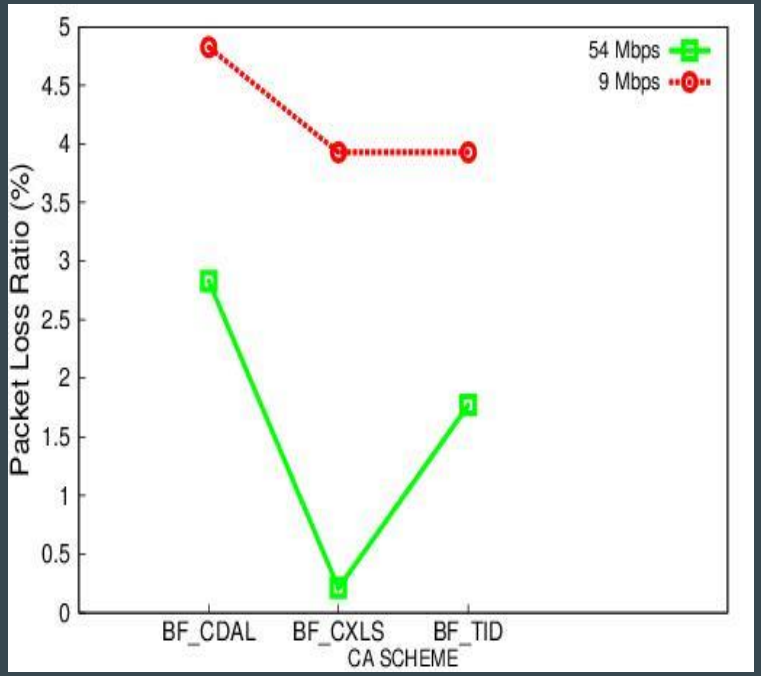
- Performance metrics for each test-case
    - Network Throughput (Mbps).
    - Packet Delivery Ratio.
    - Mean Delay (μs).
    - SINR (dB)
- For every performance metric, average of all test-cases is measured to obtain
    - Average Network Throughput (Throughput).
    - Average Packet Delivery Ratio (PDR).
    - Average Mean Delay (MD).
    - Average SINR (SINR).

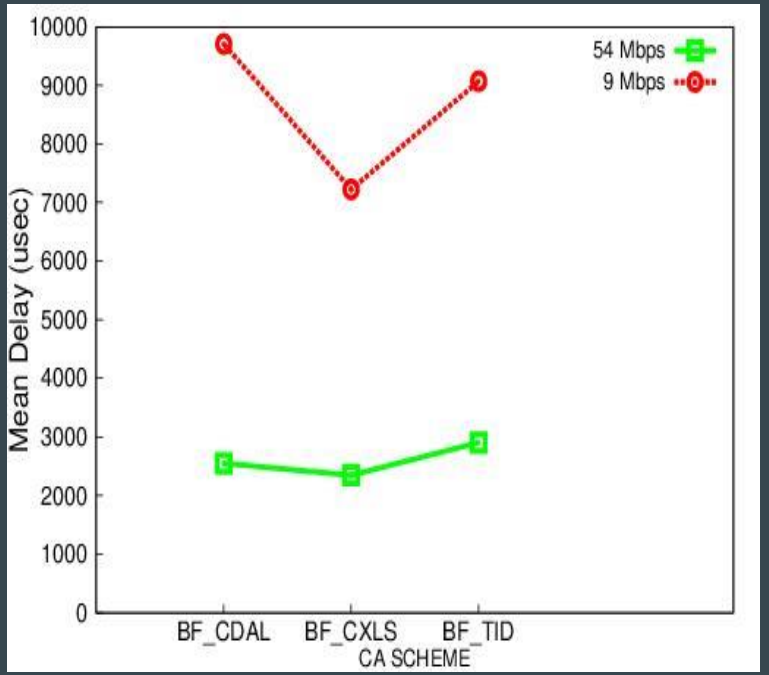
Results : Brute Force CAs





Results : Brute Force CAs





Results : Post Channel Allocation Interference Optimization CAs

Performance Metric	CHANNEL ASSIGNMENT SCHEME					
	PIO_{CDAL}		PIO_{CXLS}		PIO_{TID}	
	9 Mbps	54 Mbps	9 Mbps	54 Mbps	9 Mbps	54 Mbps
Throughput	2.59	15.32	4.37	22.47	4.08	20.24
PLR	13.91	16.8	0.6	3.94	3.19	7.29
MD	13432	2981	7944	1764	11756	2863
SINR	9.98	9.97	10.05	12.65	10.03	12.31

- $CXLS_{wt}$ works as the better IEM in all the performance metrics outrunning $CDAL_{cost}$ and TID at both 54 & 9 Mbps PHY data rates.

Results : Kernel Optimization CAs

Performance Metric	CHANNEL ASSIGNMENT SCHEME					
	KO_{CDAL}		KO_{CXLS}		KO_{TID}	
	9 Mbps	54 Mbps	9 Mbps	54 Mbps	9 Mbps	54 Mbps
Throughput	4.43	19.81	7.26	23.98	7.25	22.76
PLR	1.32	3.14	3.94	6.26	6.22	13.82
MD	12892	2757	9719	1651	9391	1883
SINR	10.09	11.09	10.03	11.64	10.02	10.86

- $CXLS_{wt}$ performs better except for the PLR metric at 54 Mbps PHY data rate where the $CDAL_{cost}$ performs better by a slight margin.
- At 9 Mbps PHY data rate, $CDAL_{cost}$ performs better by a negligible margin for PLR and SINR metrics.

Results : Hybrid Optimization CAs

Performance Metric	CHANNEL ASSIGNMENT SCHEME					
	HO_{CDAL}		HO_{CXLS}		HO_{TID}	
	9 Mbps	54 Mbps	9 Mbps	54 Mbps	9 Mbps	54 Mbps
Throughput	4.29	21.87	7.15	27.44	6.76	25.51
PLR	4.17	0.87	2.38	0.83	2.20	1.02
MD	7236	2520	8315	2387	9351	2440
SINR	42.52	44.02	43.34	44.04	43.42	43.95

- $CXLS_{wt}$ performs better in case of all the performance metrics when compared with $CDAL_{cost}$ and TID at 54 Mbps PHY data rate.
- At 9 Mbps PHY data rate, both $CDAL_{cost}$ and TID perform better than $CXLS_{wt}$ with a very less verge for PLR, MD and SINR.

Conclusions

- As the complexity of the approach increases from PIO to HO, the performance of CA increases, irrespective of the IEM employed at appropriate flow-points in the CA design.

- The performance of Hybrid Optimization CAs is very close to optimal Brute Force CAs, indicating the convergence towards optimality as CA architecture grows more complex.

- $CXLS_{wt}$ outperforms TID and $CDAL_{cost}$ as an IMF in most cases, owing to its spatio-statistical character.

- Although $CDAL_{cost}$ is a better IEM compared to TID, it does not perform better as an IMF, as it considers only statistical features of interference.

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