Poster: iCALM - A Topology Agnostic Socio-inspired Channel Assignment Performance Prediction Metric for Mesh Networks

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ABSTRACT

A multitude of Channel Assignment (CA) schemes have created a *paradox of plenty*, making CA selection for Wireless Mesh Networks (WMNs) an onerous task. CA performance prediction (CAPP) metrics are novel tools that address the problem of appropriate CA selection. However, most CAPP metrics depend upon a variety of factors such as the WMN topology, the type of CA scheme, and connectedness of the underlying graph. In this work, we propose an improved Channel Assignment Link-Weight Metric (*i*CALM) that is independent of these constraints. To the best of our knowledge, *i*CALM is the first universal CAPP metric for WMNs. To evaluate *i*CALM, we design two WMN topologies that conform to the attributes of real-world mesh network deployments, and run rigorous simulations in ns-3. We compare *i*CALM to four existing CAPP metrics, and demonstrate that it performs exceedingly well, regardless of the CA type, and the WMN layout.

KEYWORDS

*i*CALM, CALM, NETCAP, Channel Assignment Performance Prediction, Mesh Network Capacity, WMN

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1 INTRODUCTION

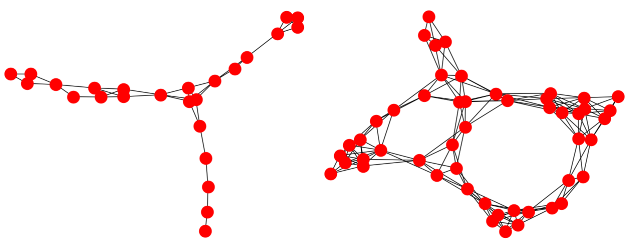
Interference is the single most debilitating factor effecting the performance of a Wireless Mesh Network (WMN). Consequently, substantial research effort is focused on mitigating and restraining its adverse impact through efficient Channel Allocation (CA) schemes [1, 2]. But having a multitude of CA schemes, without a robust framework to accurately predict CA performance makes CA selection for a particular WMN a rather tedious and resource intensive task. Several CA performance prediction (CAPP) metrics have been proposed in the research literature *e.g.,* TID, $CDAL_{cost}$, $CXLS_{wt}$ [3–5]. Channel Assignment Link Weight Metric (CALM) proposed in [6] is a CAPP metric inspired by social theory, employing the Durkheimian concept of a *sui generis social reality*. CALM is a non-conflict-graph interference estimation heuristic which generates *Link-Weights* (LW) that reflect the impact of interference on link quality. Further, CALM accurately determines the suitability of a CA scheme for a given WMN. CALM LWs are utilized by NETCAP, a Mixed Integer Programming heuristic, to predict the expected WMN capacity. CALM borrows ideas from social theory by making use of a Sociological Idea Borrowing Mechanism (SIBM), based on cybernetic hierarchy. Authors validate the efficacy of CALM through extensive simulations in ns-3, demonstrating accuracy of over 90%, which far exceeds that of TID, $CDAL_{cost}$ and $CXLS_{wt}$.

However, CALM estimates can only be used to compare CA schemes designed for a specific WMN layout, and not across different WMN topologies. Thus, for CALM based CA selection, *prior knowledge of the WMN topology* is a necessary prerequisite. Further, simulations to validate CALM were carried out only on planned grid WMN topologies that do not resemble real-world communication networks.

The motivations of this work are two-fold. First, we extend the research problem by attempting to compare expected performance of CA schemes designed for different WMN topologies. The objective is to offer more leeway to a WMN administrator by doing away with the constraint of a fixed WMN topology, as certain CA schemes may involve topology modification for enhanced performance. To achieve the objective of *topological universality*, we re-design the CALM algorithm and propose the Improved Channel Assignment Link Weight Metric (*i*CALM). Second, we carefully design two planned WMN (PWMN) layouts that conform to topological properties of real-world WMN deployments, and investigate performance of CALM, *i*CALM and NETCAP in the simulated PWMNs.

Table 1: Global Parameters' Values for PWMNs.

Parameter	Real-World Networks	$PWMN_{25}$	$PWMN_{50}$
δ	$0.05 - 0.1$	0.067	0.073
ε_{min} (m)	$2 - 22$	14.86	7.07
T	$0.1 - 0.8$	0.29	0.37



(a) $PWMN_{25}$ **(b) $PWMN_{50}$**

Figure 1: Planned WMN Topologies for Simulations.

2 EMULATING A REAL-WORLD WMN

Carefully planned topologies through appropriate placement of nodes in a simulated environment serve as a suitable alternative or as a preliminary platform for evaluation of technology demonstrations, prototype evaluations, and as in case of *i*CALM, concept validations. We design two PWMNs of 25 nodes and 50 nodes labelled $PWMN_{25}$ and $PWMN_{50}$, spread over a simulated deployment area of $1000m \times 1000m$ and $1500m \times 1500m$, and illustrated in Figure 1 (a) and Figure 1 (b), respectively. The two PWMNs conform to several important topological properties of actual wireless network deployments, as depicted in Table 1 [7]. The global parameters that we consider are *Network Density* (δ), *Radius or Minimal Eccentricity* (ε_{min}), and *Transitivity or Clustering Coefficient* (T).

3 IMPROVED CHANNEL ASSIGNMENT LINK-WEIGHT METRIC

The *i*CALM computation is presented in Algorithm 1. It takes Link-Weights generated by CALM as input and creates an estimate which is independent of topology. We will demonstrate through results that CALM values of CAs designed for different WMN topologies cannot be successfully compared. However any CA for any WMN layout can be fed as input to Algorithm 1, and the resulting *i*CALM estimates can be compared regardless of the CA type and the WMN topology. Thus, *i*CALM does away with the topology specificity of CALM, while maintaining high accuracy. Further, as CALM serves as the preliminary phase for *i*CALM, the Link-Weights are available to NETCAP to generate an estimate of expected WMN capacity.

Algorithm 1 Improved Channel Assignment Link-Weight Metric (*i*CALM).

Input: S_{WMN} : Set of WMN Layouts, S_{CA} : Set of CA schemes, CALM Algorithm.
Output: *i*CALM

1: **for** $CA \in S_{CA}$ **do**
2: Determine $NumTotLn, NumActiveLn$ $\{NumTotLn \rightarrow$ Total number of links in original WMN; $NumActiveLn \rightarrow$ Number of operational wireless links after CA implementation.$\}$
3: Determine Link-Weights using CALM.
4: $iCALM \leftarrow \dfrac{(\sum_{i=1}^{NumTotLn} Link-Weights_i) \times 100}{NumActiveLn}$
5: **end for**

4 SIMULATIONS AND EVALUATION

4.1 Experimental Set-up

We implement 10 CA schemes on each PWMN topology, which includes both, topology preserving (TPCA) and graph preserving (GPCA), CA schemes. We run simulations on ns-3 based on the parameters depicted in Figure 2 (a). We then correlate theoretical estimates of *i*CALM with the observed Network Aggregate Throughput (NAT) of CA schemes for each individual PWMN topology, and both PWMNs together to assess topology independence. Observed correlation is illustrated in Figures 2 (b), 2 (c), & 2 (d). We also implement the three CAPP metrics *viz., TID*, $CDAL_{cost}$, and $CXLS_{wt}$, for both PWMNs to compare their performance to CALM and *i*CALM. We determine the *Errors in Sequence* (EIS) by comparing the CA sequence based on observed NAT values (Reference Sequence) with CA sequences generated by theoretical CAPP metrics. Then, we compute the *Measure of Accuracy* (MoA) determined by the expression $MoA = (1 - (EIS/{}^{n}C_2)) \times 100$, where n is the number of CAs in the sequence. The MoA (as a %) of all five CAPP metrics considered in our work is presented in Table 2.

4.2 Evaluation and Future Work

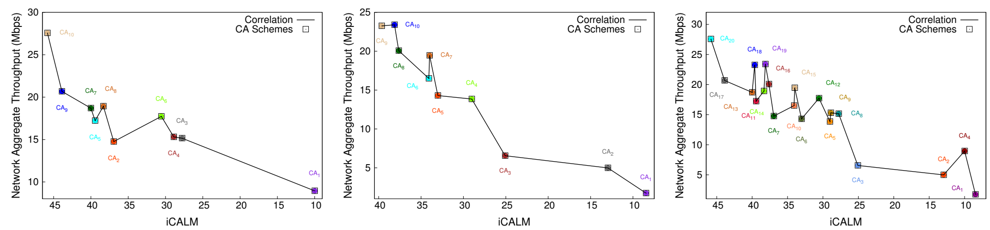
The CAPP metrics can be ordered in terms of improving overall performance as : $TID < CDAL_{cost} < CXLS_{wt} < CALM$

Table 2: Performance Evaluation Of CAPP Metrics.

WMN Topology	Errors In Sequence					Measure of Accuracy (%)				
	TID	$CDAL_{cost}$	$CXLS_{wt}$	CALM	*i*CALM	TID	$CDAL_{cost}$	$CXLS_{wt}$	CALM	*i*CALM
$PWMN_{25}$	24	19	8	6	6	46.67	57.78	82.22	86.67	86.67
$PWMN_{50}$	22	22	10	2	2	51.11	51.11	77.78	95.56	95.56
Topology Agnostic	87	82	52	63	30	54.21	56.84	72.63	**66.84**	**84.21**

Parameter	Value
IEEE Protocol Standard	802.11n
Orthogonal Channels	4 (5 Ghz)
Datafile Size	1 MB
802.11n Phy Datarate	54 Mbps
TCP ns-3 model	BulkSendApplication
TCP Max Segment Size	1 KB
TCP RTS/CTS	Enabled
Routing Protocol	OLSR
Loss Model	Range Propagation
Rate Control	Constant Rate

(a) ns-3 Simulation Parameters

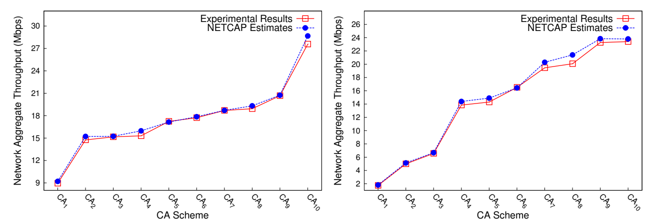


(b) *i*CALM : $PWMN_{25}$ **(c) *i*CALM : $PWMN_{50}$** **(d) *i*CALM : Topology Agnostic**

Figure 2: Simulation Parameters and Observed Correlation of Throughput & *i*CALM.

< *iCALM*. Observations in simulated PWMNs are similar to those recorded in grid WMNs [6], which further validates the accuracy of CALM. *TID*, $CDAL_{cost}$, and $CXLS_{wt}$ continue to perform poorly when we consider graph preserving CA schemes that may alter WMN topology, while performance of CALM is not effected by the type of CA chosen. However, in the topology agnostic assessment of CA schemes, all four existing metrics, including CALM, are found wanting. The necessary prerequisite of WMN topology places constraints upon an administrator during CA selection. *i*CALM overcomes this constraint, by offering the ability to compare expected performance of CAs regardless of the WMNs they are designed for. Despite the increased complexity of the research problem, *i*CALM registers an accuracy of 84%, while other CAPP metrics fail the test of reliability. Also, even in topology specific CA comparisons, *i*CALM offers accuracy equivalent to that of CALM. Thus, it maintains the accuracy of CALM despite *universalizing the WMN topological domain* over which CA schemes may be compared.
The expected network capacity predicted by NETCAP using CALM estimates is evaluated against the observed NAT results, and presented in Figures 3 (a), & 3 (b). The average deviation from observed NAT values is marginal, calculated to be 3.36% for $PWMN_{50}$, and a meager 1.85% for $PWMN_{25}$.

We plan to improve upon *i*CALM design through new ideas from social-theory *e.g.*, structural hole theory, and apply *i*CALM to mobile mesh and adhoc networks.



(a) NETCAP : $PWMN_{25}$ **(b) NETCAP : $PWMN_{50}$**

Figure 3: NETCAP Estimates for $PWMN_{25}$ & $PWMN_{50}$.

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