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Interference-Aware Channel Assignment in Wireless Mesh Networks

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The principal aim of this work is the definition of a channel allocation algorithm in a *multi-radio Wireless Mesh Network (WMN)*.

- General Features of a *WMN*
- Multi-Channel in *meshed networks*
- Description of the developed algorithm
- Simulation results
- Conclusions
The need of improve the coverage, flexibility and robustness of traditional wireless networks has kicked off the concept of **WMN**.

**Wired Infrastructure**

- **BSS** = Basic Service Set
- **ESS** = Extended Service Set

Interference-Aware Channel Assignment in Wireless Mesh Network
The need of improve the coverage, flexibility and robustness of traditional wireless networks has kicked off the concept of **WMN**.
The main characteristics of mesh networking based solutions are:

- *Wireless* infrastructure
- *Multi-hop* communication
- Mobility
- Interoperability and Compatibility
- Flexibility and robustness
Disadvantages of a 802.11 based WMN

One serious shortcoming in a 802.11 single-channel WMN is its limited network capacity scalability that asymptotically goes to

\[ O\left(\frac{1}{\sqrt{n \log n}}\right) \]

\( n \) is the number of nodes

The reason of this degradation is the fact that the standard plans to use the CSMA/CA access protocol over a single frequency/channel

- Hidden node problem
- Exposed node problem
- Inter-flow interference and intra-flow interference
Intra-flow interference and Inter-flow interference

Intra-flow interference

Flow 1
Intra-flow interference and Inter-flow interference

Flow 1

Flow 2

Inter-flow interference

Internet
One way to reduce interference problems in a multi-hop communication is to allow each node to contemporaneously operate over multiple channels.
One way to reduce interference problems in a multi-hop communication is to allow each node to contemporary operate over multiple channels.
One way to reduce interference problems in a multi-hop communication is to allow each node to contemporarily operate over multiple channels.

It is possible to classify channel allocation algorithms considering their approach:

- Centralized approach
- Distributed approach
- Joint Routing and Channel allocation approach
- MAC modification approach
Proposed Channel Allocation Algorithm

✓ The intended approach employs Graph Theory

✓ The problem of optimal channel assignment has been proven to be NP-hard

\[\text{Greedy heuristics solution}\]

✓ Each node is equipped with several NICs (Network Interface Card)

✓ We formulate the problem of channel assignment as a mesh topology control problem

✓ We apply a centralized approach considering the static nature of Mesh Nodes

✓ We assume that the large amount of traffic within the WMN is directed to or comes from external networks
CONNECTIVITY MODEL:

✓ We model a WMN by means of a bidirectional graph… … Connectivity Graph $G(V,E)$

- Each vertex $v \in V$ represents a Mesh Node
- Each edge $e_{ij} \in E$ represents a link between Mesh Nodes $i$ and $j$
INTERFERENCE MODEL:

- We model the interference in the WMN by means of a bidirectional graph…

... Weighted Conflict Graph $G_c(L,S)$

- Each vertex $l_{ij} \in L$ represents a link between nodes $i$ and $j$ in $G(V,E)$

- Two nodes $l_{ij}, l_{uv} \in L$ are connected if the links $(i,j)$ and $(u,v)$ in $G(V,E)$ interfere with each other

Interference-Aware Channel Assignment in Wireless Mesh Network
INTERFERENCE MODEL:

✓ We model the interference in the WMN by means of a bidirectional graph...

... *Weighted Conflict Graph* $G_c(L, S)$

The weights assigned to the edges of $G_c(L, S)$ depends on the model utilized:

- *Protocol Model*
- *Physical Model*

![Diagram of Interference-Aware Channel Assignment in Wireless Mesh Network](image-url)
Protocol Model:

- An interference range $D_i$ of radius $R'_i$ is assigned to each node $i$.

- Link $(u,v)$ interferes with link $(i,j)$ if $u$ or $v$ are within $D_i \cup D_j$.

Physical Model:

- Let $S_{ij}$ be the received power at node $j$ from node $i$.

- The communication has success if $\text{SNR}_{ij} \geq \text{SNR}_{th}$, where $\text{SNR}_{ij}$ is the signal to noise ratio at receiver.

The weights of the edges of $G_c(L,S)$ are binary, the real interference power is not taken into account.

Interference at transmitter is not taken into account.
**Proposed interference model:**

\[ IE(e_{ij}) = \text{all incident links on } i \text{ minus } j \cup \text{all incident links on } j \text{ minus } i \]

- The interfering power of link in \( IE(e_{ij}) \) is obtained as \( S^{iu} = \frac{\chi}{d^n} \)
- We consider a traffic typology through the definition of utilization factor \( \rho_{ij} \) of the interface of node \( i \) on the link with \( j \)

**Weights on edge IJ-UV in \( Gc(L,S) \):**

\[
W^{IJ/UV} = (1 - \rho_{JJ}) * I_I + (1 - \rho_{IJ}) * I_J
\]

Interference-Aware Channel Assignment in Wireless Mesh Network
Considering our assumption on traffic topology in the WMN, the links near the gateway will be more loaded than the others…

… we assign these links a higher priority for the channel allocation
How our algorithm works:

For each link $l=(i,j)$, we compute the interfering power received considering channel overlapping factor, external interference sources and interference that comes from the other interfaces of nodes of link $l$.
In order to fit strictly our model with the real scenarios we have added:

- Support of directional antenna
In order to have flexibility we have utilized 12 non overlapped channels.

Network Coloring Process:
- CCA
- CLICA
- Proposed Algorithm

The flows activated are…

In order to have flexibility we have utilized 12 non overlapped channels.
Interference-Aware Channel Assignment in Wireless Mesh Network

In order to have flexibility we have utilized 12 non overlapped channels

Network Coloring Process:

- Algorithms already present in literature
  - CCA
  - CLICA
  - Proposed Algorithm

The flows activated are…

- In order to have flexibility we have utilized 12 non overlapped channels

Simulated Network:
In order to have flexibility we have utilized 12 non overlapped channels. The flows activated are...

In order to have flexibility we have utilized 12 non overlapped channels.

Network Coloring Process:

- **CCA**
- **CLICA**
- **Proposed Algorithm**

Algorithms already present in literature.
Flow $I \rightarrow A$

End-to-end Throughput Vs Time

End-to-end delay Vs Time

Offered Load 2.21 Mbps
Packet size: 512 bytes
Flow $I \rightarrow A$

**Lost packets Vs Time**

**End-to-end Troughput** for several offered loads

*Offered Load 2.21 Mbps*
Flow $I \rightarrow A$

*End-to-end* delay for several offered loads
Conclusion

The developed algorithm show substantial improvement with respect to CCA and CLICA algorithms in terms of throughput and end-to-end delay

- We significatively reduce intra-flow interference and inter-flow interference among links

- The proposed algorithm produces a network configuration that saturates with a load significatively greater than CCA and CLICA