Channel Assignment in Wireless Mesh Networks

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References:

H. Skalli, S. Ghosh, S. Das, L. Lenzini, and M. Conti, “Channel Assignment Strategies for Multiradio Wireless Mesh Networks: Issues and Solutions,” IEEE Communications Magazine, pp. 86-93, Nov. 2007.

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Outlines

- Introduction.

- Channel Assignment:
  1. Objective & Challenges.
  2. Types
  3. Examples.
  4. Comparison.

Introduction

- Typical WMN (Single-radio/Single-channel).

  Connectivity/Interference.

- 802.11 support non-overlapping Multi-channel (Single-radio/Multi-channel).

  Flexibility/Dynamic switching overhead time & synchronization.

- (Multi-radio/Multi-channel).

  Throughput improvement/Channel assignment issue.

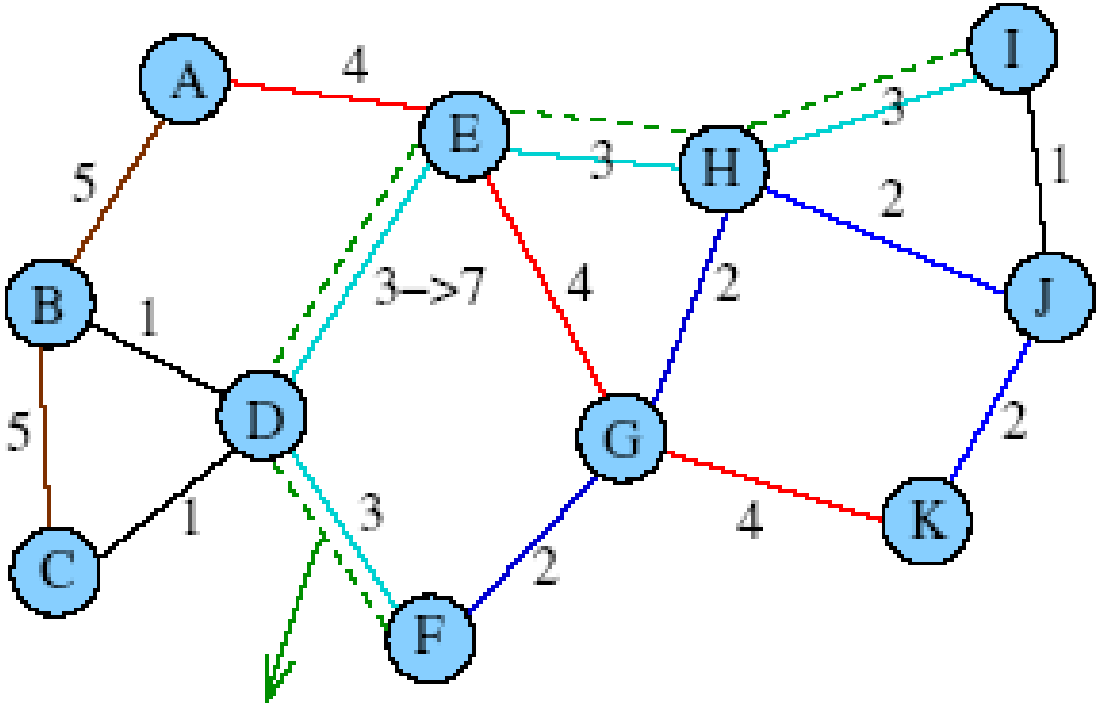
Multi-radio/Multi-channel

- Issues:

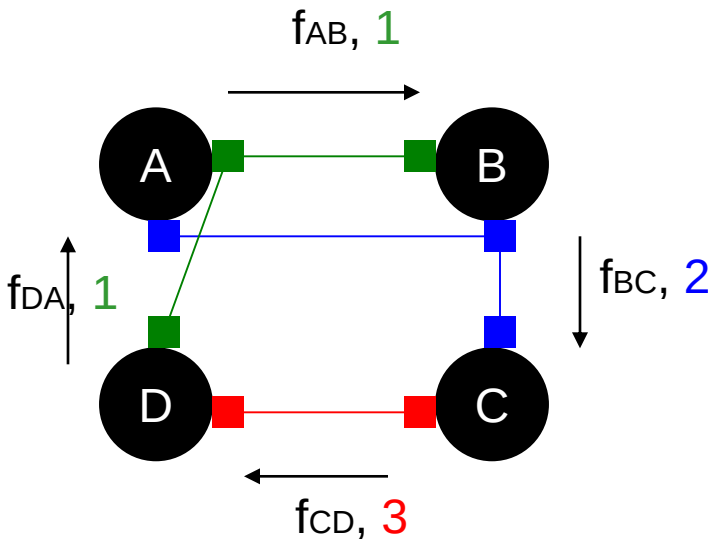
1. Network partitioning.
2. Channel Dependency problem.
3. Topology alteration and impact on routing.
4. Non-convergent behavior.

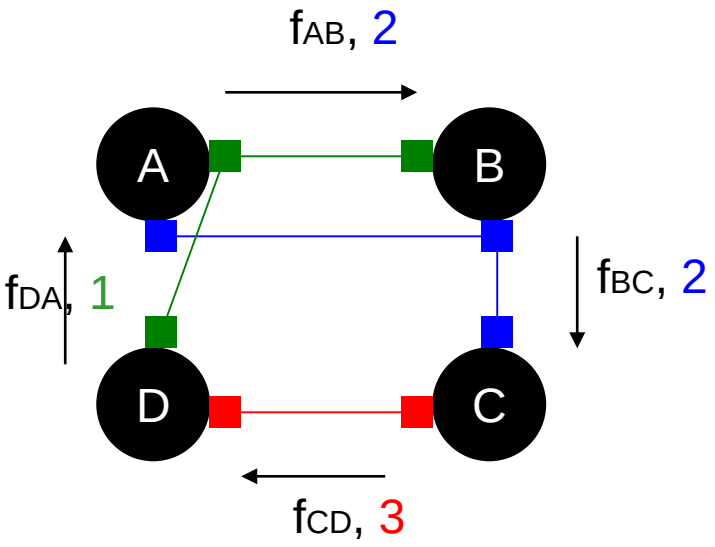
Ripple Effect Problem

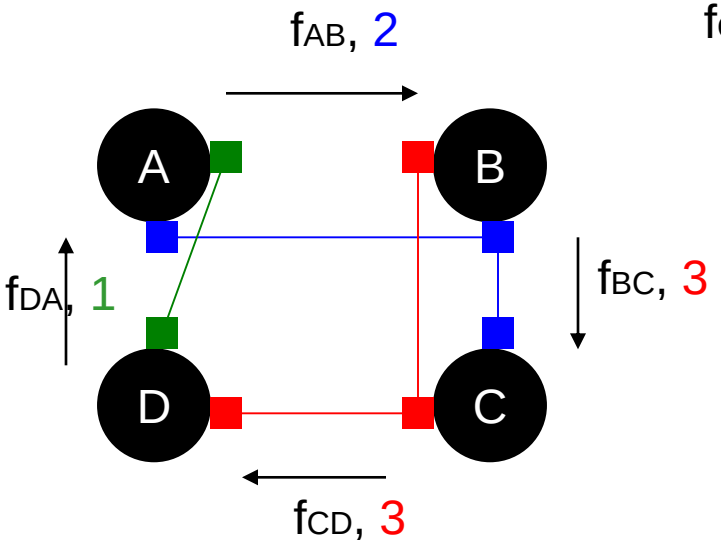
- Revisit the links that already have been assigned channels.



Non-convergent behavior







Channel Assignment (CA)

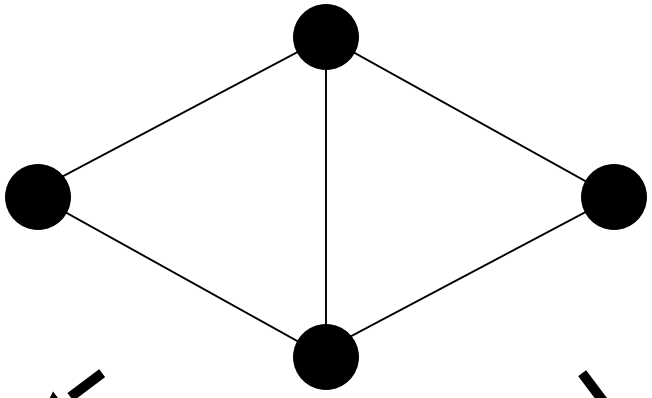
Objective

- Improve network throughput.

Challenges

- Maintain network connectivity.
- Topology control.
- Minimize interference.
- Consider Traffic pattern.
- Channel Utilization.

Connectivity vs. Interference

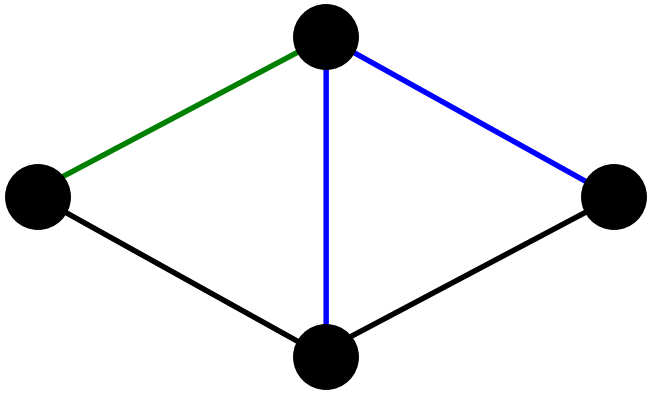


2 Radios/node.

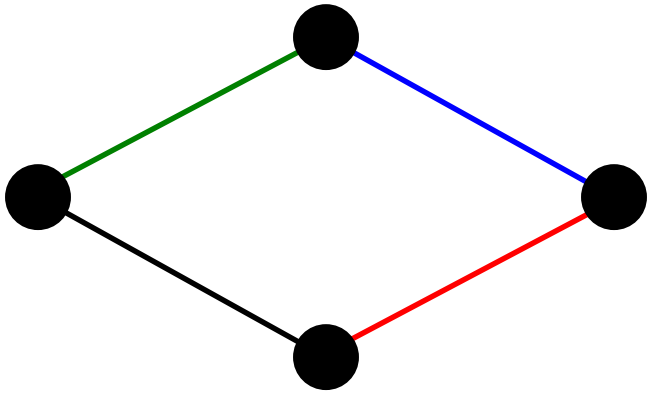
4 Channels

Max Connectivity

Min Interference

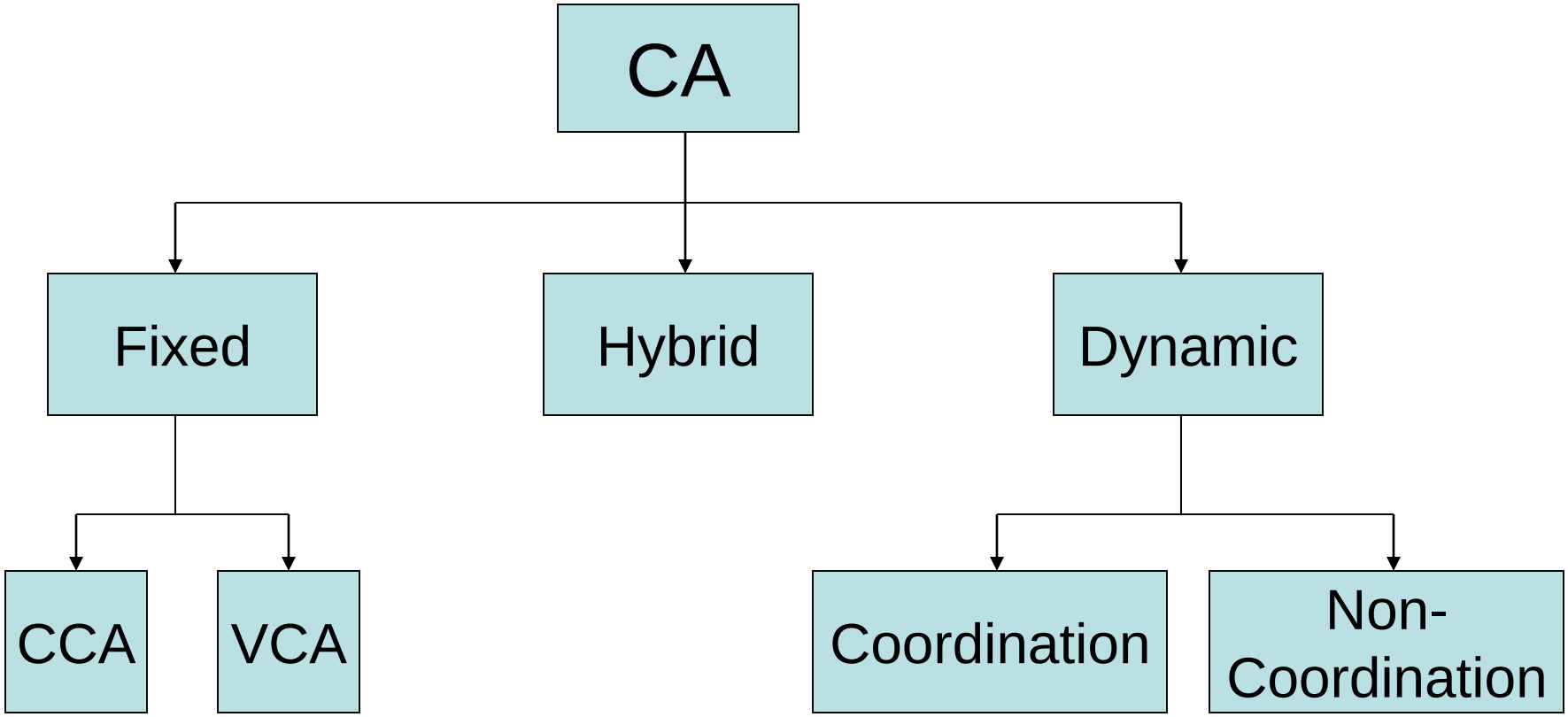


3 channels



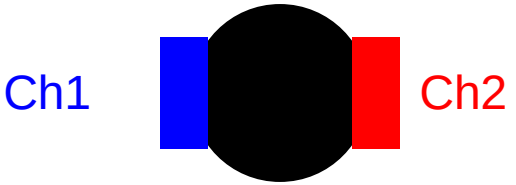
4 channels

Types


CA
Fixed
Hybrid
Dynamic
CCA
VCA
Coordination
Non-
Coordination

Fixed (Static) CA

1. Common CA (CCA)



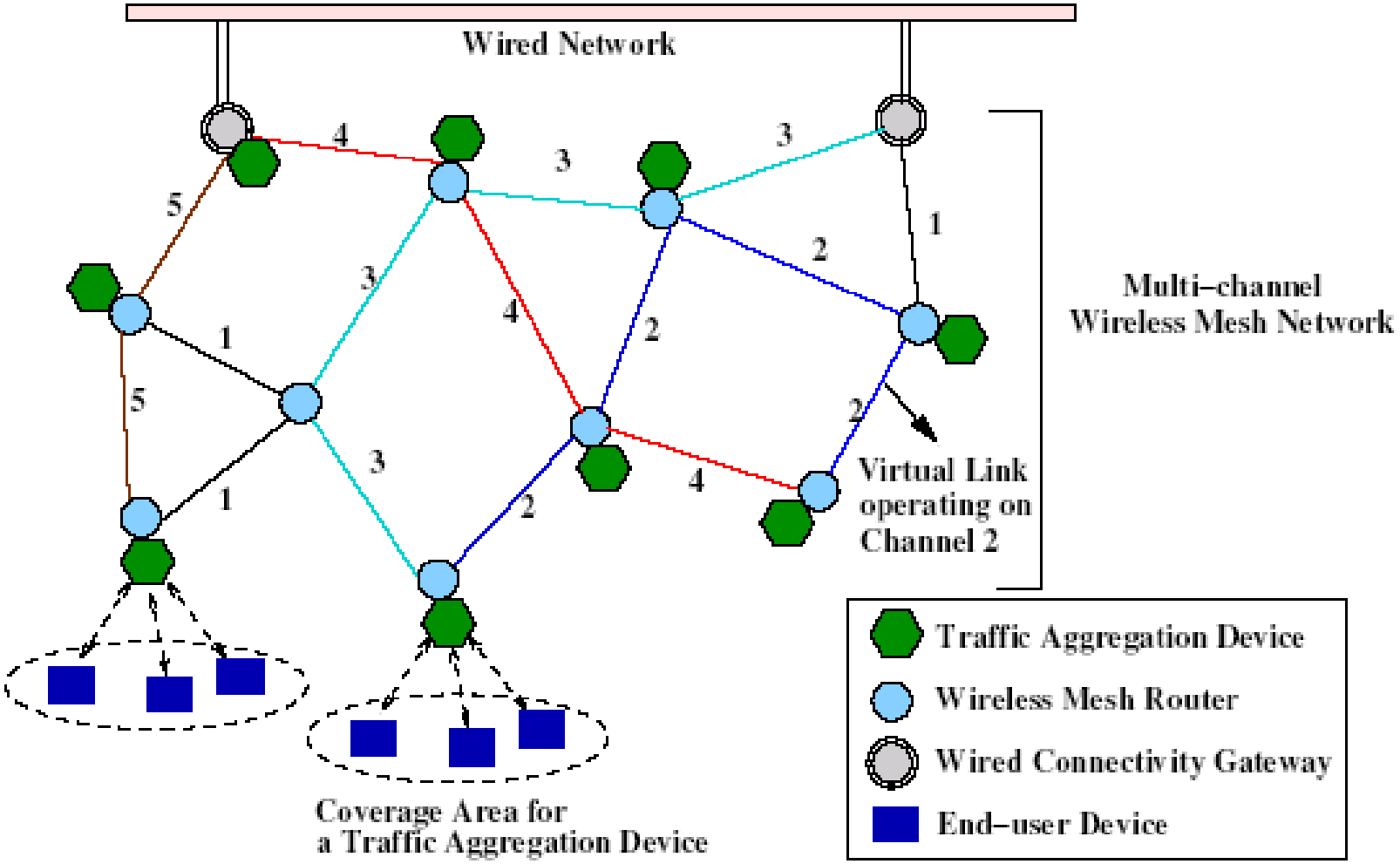
- Simplest CA scheme.
- All radios in a node are assigned to the same set of channels.
- Maintain connectivity and good performance.
- Fails to utilize the available non-overlapping channels (# of radios < # of channels).

Fixed (Static) CA

2. Varying CA (VCA)

- Radios in different nodes are assigned to different set of channels.
- Examples: C-HYA, CLICA, WFCA-MR, MesTiC, etc.
- Channel utilization based on CA.
- Changing network topology may lead to disconnected network.
- Increase path length.

Centralized CA for Hyacinth Architecture (C-HYA) [1]



C-HYA

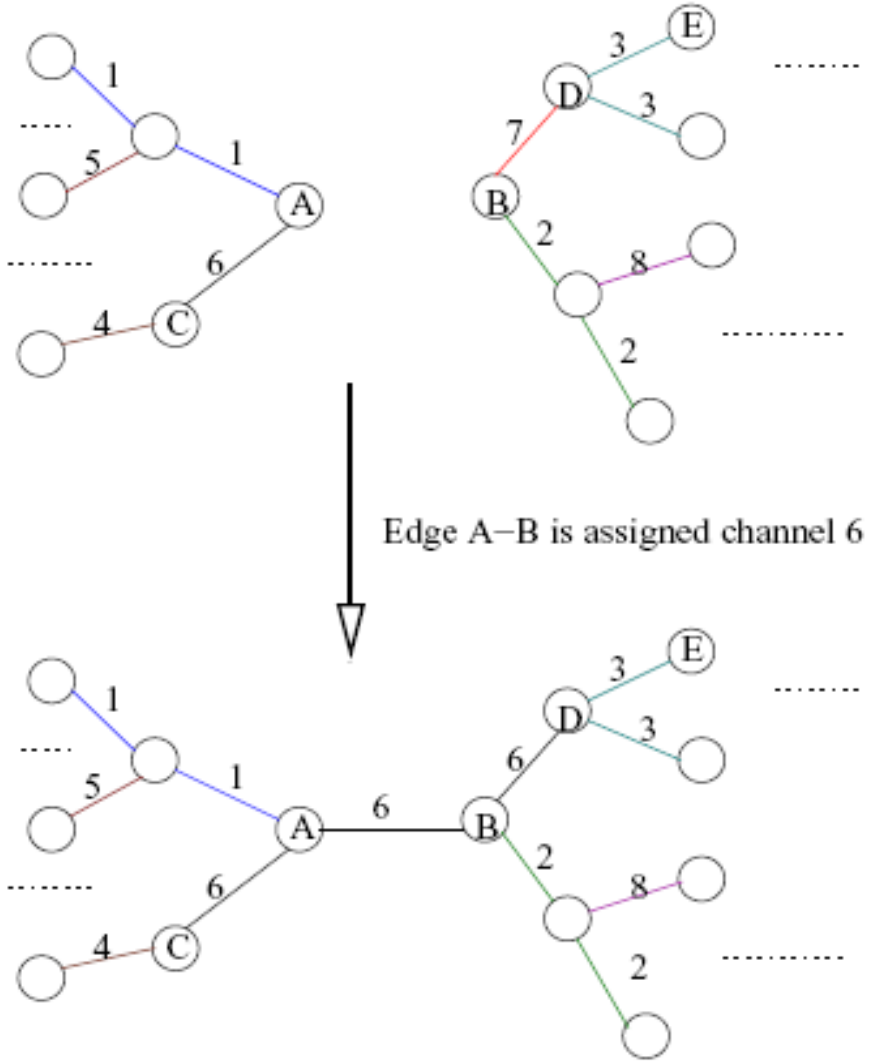
- Given the traffic pattern, estimate total expected load for each link.
- Sort links in decreasing order based on their expected load.
- Assign channels greedily to each link.

C-HYA

- Example:

Link Load Estimation.

Ripple effect problem ➔ increases time complexity.



Connected Low Interference CA (CLICA) [2]

- Conflict Graph (CG): each link in the connectivity graph is represented as a vertex in the conflict graph. An edge is created when links interfere with each other.
- Interference is modeled by adding the weights of all edges incident to each vertex in the CG.
- Node priority is selected based on Depth First Search algorithm (nodes found first are higher priority).
- While there is unassigned radio, the algorithm will pair this radio with unassigned radio at one of the neighbors and give it a channel.
- In CLICA, the network topology formulates the CA problem.

Mesh-based Traffic and Interference-aware CA (MesTiC)

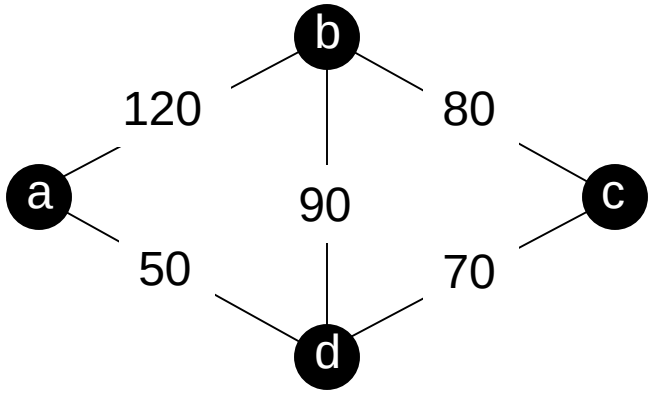
- Centralized CA based on Ranking nodes.
- Fixed CA maintain the network connectivity.
- Node Rank based on:
  1. Link Traffic (L_t),
  2. No. of interfaces per node (R),
  3. Min No. of hops to a Gateway (H).
- $Rank_n = L_{tn}/(R_n * H_n)$.

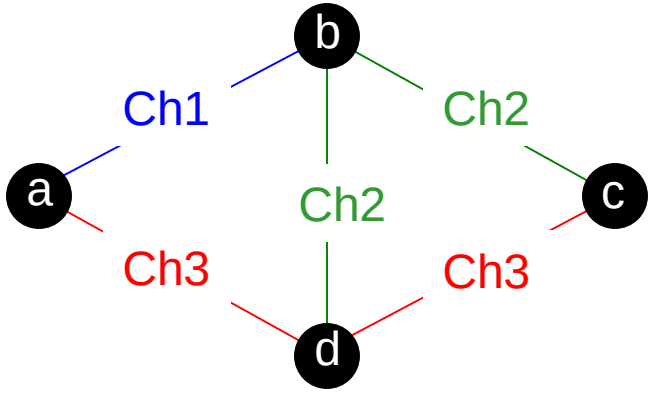
MesTiC

- Sort nodes based on their ranks in decreasing order.
- Gateway has the highest priority or rank.
- Give the least interference channel for the highest rank node.
- Each node has a default interface that is assign to a default channel.

MesTiC

- Given 3 channels, 2 interfaces/node.
- Node b is the Gateway.
- Rank in decreasing order is: d, a, c.





Dynamic CA

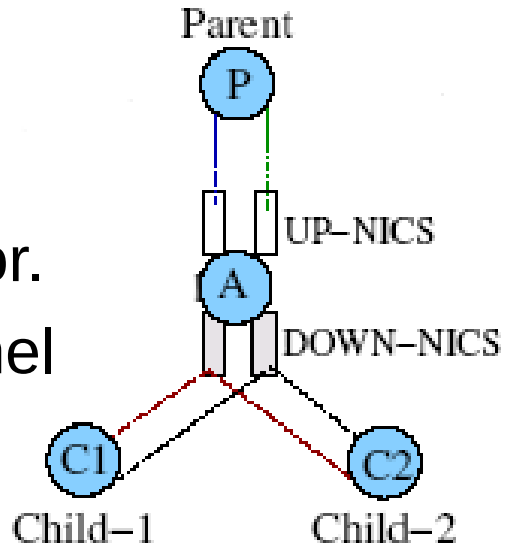
- Interfaces can frequently switch from one channel to another.
- When nodes want to communicate, they need to coordinate on a unified channel.
- Utilize many channels in a few interfaces system.
- Switching delay & need coordination mechanism (e.g., rendezvous).

Distributed CA for Hyacinth Architecture (D-HYA) [3, 4]

- Based on Hyacinth network arch.
- React to traffic load changing.
- Build on a spanning tree network topology (Gateways are the roots).
- No dependency among neighbors (no ripple effect).
- No coordination mechanism is needed.
- Tree topology restriction (multi-path).

D-HYA

1. **Neighbor to interface binding**:



- which interface to use with which neighbor.
- A node can change its DOWN-NIC channel only, this will eliminate the ripple effect problem.
- Gateway nodes only have DOWN-NICs.
- CA start with Gateways (highest priority).
- The priority of a node based on the number of hops separate it from the Gateway.

D-HYA

2. Interface to channel binding:

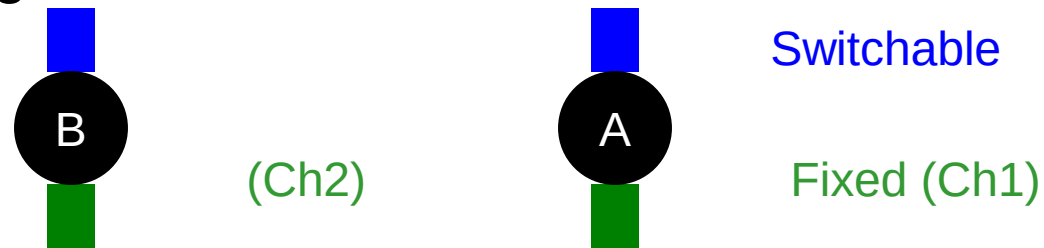
- which channel assigned to which interface.
- Each node sum its interference neighbor's load to calculate the least used channel and assign it to its link.
- Nodes exchange the channel usability status to dynamically reassign channels (every Tc time unit) that are used on lightly loaded links.

Hybrid CA

- Fixed CA at some interfaces.
- Others are switchable interfaces.
- Use fixed CA to coordinate between nodes.
- Flexible by utilizing channels through switchable interfaces.
- Switching delay.

Link Layer Protocol (LLP) [5]

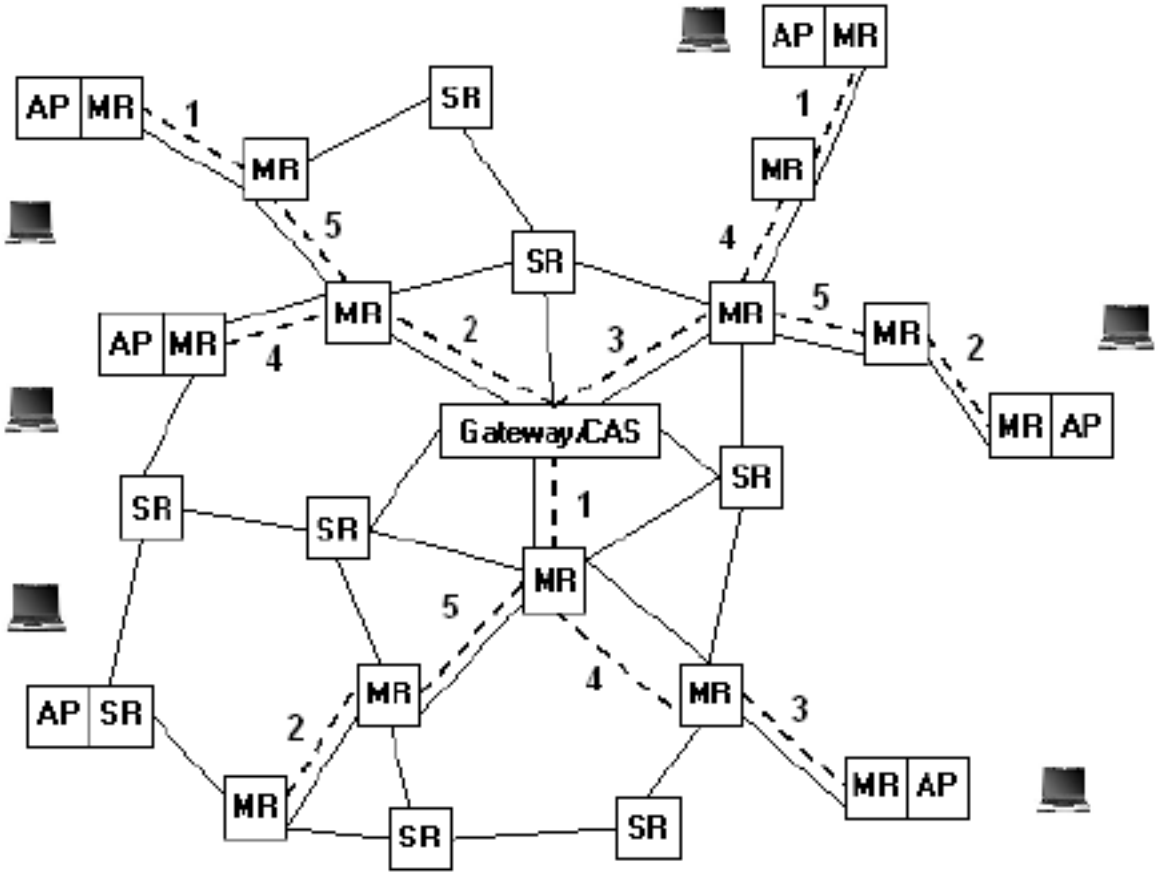
- Is also known as receiver fixed.
- Each node has a fixed interface assign a unique channel.
- Other interfaces on a node are switchable.
- Based on Traffic, switch the switchable interface to the channel of the fixed node to which need to communicate.
- Coordination protocol is needed to know the fixed channel of each neighboring node.



Interference-Aware CA (IACA) [6]

- Using the fixed conflict graph.
- Using Multi-radio Conflict Graph (MCG).
- Each node has a default interface tuned on the default common channel (*ensure connectivity*).
- Traffic is redirected over the default channel.
- Interference and BW estimation based on number of interfering radios.
- Channels with high rank (high interference, high load) is assigned higher cost.

IACA



Comparison

Property	Fixed CA				Hybrid CA		Dynamic CA
	CCA	C-HYA	CLICA	MesTiC	LLP	IACA	D-HYA
Switching time	No switching required	No switching required	No switching required	No switching required	Switching over-head involved	Infrequent switching	Infrequent switching
Connectivity	Ensured by the CA scheme	Ensured by the CA scheme	Ensured by the CA scheme	Ensured by default radio	Ensured by channel switching	Ensured by default radio	Ensured by the CA scheme
Ripple effect	No	Yes	No	No	No	No	No
Interference model	N/A	Protocol model	Protocol model	Protocol model	Protocol model	Trace driven	Trace driven
Traffic pattern	Not considered	Considered	Not considered	Considered	Not considered	Considered from external radios	Considered
Topology control	Fixed	Fixed	CA scheme defines the topology	Fixed	Dynamically chaging	Fixed	No, topology is defined by the routing tree
Control philosophy	N/A	Centralized	Centralized	Centralized	Distributed	Centralized	Distributed

Open Research Issues

- Multi-rate capability.
- Channel switching delay.
- Quality of service.
- Directional antennas.

Conclusion

- The use of multiple channel can improve the performance of WMN.
- Key: how efficiently utilize the available channels.
- CA and topology planning are related in WMN.

References

[1] A. Raniwala, K. Gopalan, and T. Chiueh, “Centralized Channel Assignment and Routing Algorithms for Multichannel Wireless Mesh Networks,” *ACM Mobile Comp. and Commun. Rev.*, Apr. 2004, pp. 50–65.

[2] M. Marina and S. R. Das, “A Topology Control Approach for Utilizing Multiple Channels in Multi-Radio Wireless Mesh Networks,” *Proc. Broadnets*, Oct 2005, pp. 381–90.

[3] A. Raniwala and T. Chiueh, “Evaluation of a Wireless Enterprise Backbone Network Architecture,” *Proc. 12th Hot-Interconnects*, 2004.

[4] A. Raniwala, and T. Chiueh, “Architecture and Algorithms for an IEEE 802.11-Based Multi-Channel Wireless Mesh Network,” *Proc. IEEE INFOCOM*, Mar 2005, pp. 2223–34.

[5] P. Kyasanur and N. Vaidya, “Routing and Interface Assignment in Multi-Channel Multi-Interface Wireless Networks,” *Proc. IEEE Conf. Wireless Commun. And Net. Conf.*, 2005, pp. 2051–56.

[6] K. Ramachandran *et al.*, “Interference Aware Channel Assignment in Multi-Radio Wireless Mesh Networks,” *Proc. IEEE INFOCOM*, Apr. 2006.

Q & A

Thank you.

Channel Assignment

- Static vs. Dynamic CA

- CA's consideration:
  - Interference-aware
  - Traffic-aware
  - Location-aware
    + optimize channel reusability location.

WFCA-MR

- Weighted Fixed CA for Multiple Radios.
- Objective: maximize the number of simultaneous transmissions in the network.
- Subject to: Interference constraints and connectivity restrictions.