Network Laboratory – Wireless research Group

Interference-Aware Routing by modeling link capacity in Multi-hop 802.11-based WMN.

"Problem Formulation & Background"

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Background

- Routing in Wireless Mesh Network (WMN) is not yet optimal.
- Cross-layer solution is required for an acceptable modeling and design.
- Selecting a good route is based on selecting high capacity links along the route.
- In WMN, link capacity is influenced by the interference that is caused by the surrounding co-channel links.

Background

- In 802.11 protocol, based on CSMA/CA, the interference can be partially avoided using one of the two carrier sensing techniques:

  1- Physical Carrier Sensing (PCS) using Clear Channel Assessment (CCA) threshold, or

  2- Virtual Carrier Sensing (VCS) using RTS/CTS handshake.

Background

- Using RTS/CTS in 802.11 can avoid interference (collisions caused by Hidden nodes) in the single-hop WMN.

- This is not true when we have multi-hop WMN ➔ Extended Hidden node problem.

- Therefore, 802.11 alone can't handle the multi-hop WMN.

- Hence, while using 802.11, an intelligent techniques in routing, channel assignments, etc, need to be implemented.

Background

- Hidden nodes:

  - Two transmitters not within hearing range, but one of them (or both) are within the interference range of the receivers.

- Exposed nodes:

  - Two transmitter within same hearing range, but non of them within the interference range of the receivers

- In 802.11, both hidden and exposed node problems cause throughput degradation.

Related Work

- Modeling link capacity in 802.11 passed through different stages of development in the literature:

1- Simi Wired-base model (no interference).

2- Consider interference:

→ Single interferer only (not realistic),

→ Allow no interfering link to be active,

→ Consider one interference domain e.g. Sensing range (ignore hidden node problem),

→ Consider one collision domain e.g. Interference range, or

→ Consider two ranges (sensing/interference) based on physical details.

Modeling Approach

- PCS will be used instead of RTS/CTS because, in addition to, RTS/CTS can't avoid the multi-hop hidden nodes problem, it adds more overhead traffic.
- Capture the different effects from carrier sensing range and interference range.
- Using only high level parameters (Location/Distance) to model the interference-aware link capacity.
- This high level parameters are link-aware which satisfy the cross-layer condition.
- Multi-path routing.

Analytical Model

- Input: Network topology, channel assignment, and load (traffic) matrix.
- Output: Set of optimal routes that maximizes network throughput.

Notations

Input

$\aleph$	set of all nodes in the network.
N	total number of nodes in the network ($N = \|\aleph\|$).
A_i	node n_i's adjacent set of nodes.
C_{ij}^{max}	is the maximum link capacity of link L_{ij}.
CS_{ij} ★	set of links $\in R_{cs}^{ij}$ of L_{ij} and assigned to the same channel of L_{ij}.
I_{ij} ★	set of links $\in R_{I}^{ij}$ of L_{ij} and assigned to the same channel of L_{ij}.
Dcs_{ij}^{xy} ★	$= 1$ when L_{xy} is within R_{cs}^{ij}.
DI_{ij}^{xy} ★	$= 1$ when L_{xy} is within R_{I}^{ij} and outside R_{cs}^{ij}.
d_{ij}	distance between node n_i and node n_j.
d_{ij}^{xy}	distance between L_{ij} and L_{xy}.
d_{ij}^{max}	maximum distance at which other co-channel links can not interfere with L_{ij} ($= R_{I}^{ij}$).
T^{sd}	traffic from source node n_s to destination node n_d.

Variables

C_{ij}	link capacity of L_{ij}.
$\alpha_{ij}^{sd,t}$	$= 1$ when $L_{ij} \in path(p_{sd})$ and the t^{th} unit of T^{sd} is carried from n_s to n_d by L_{ij}.
β_{xy} ★	$= 1$ when L_{xy} carries traffic.
S^{sd} ★	succeeded transmitted flow from node n_s to node n_d.

Analytical Model

<u>Objective Function:</u>

Maximize Throughput $\{\text{Maximize } (\sum_{\forall(s,d)} S^{sd}).\}$

<u>Traffic Constraint:</u>

$$\beta_{xy} = \max_{\forall(s,d)} \alpha_{xy}^{sd,t}.$$

$$S^{sd} \leq T^{sd}, \forall(s,d)$$

Analytical Model

Routing Constraints:

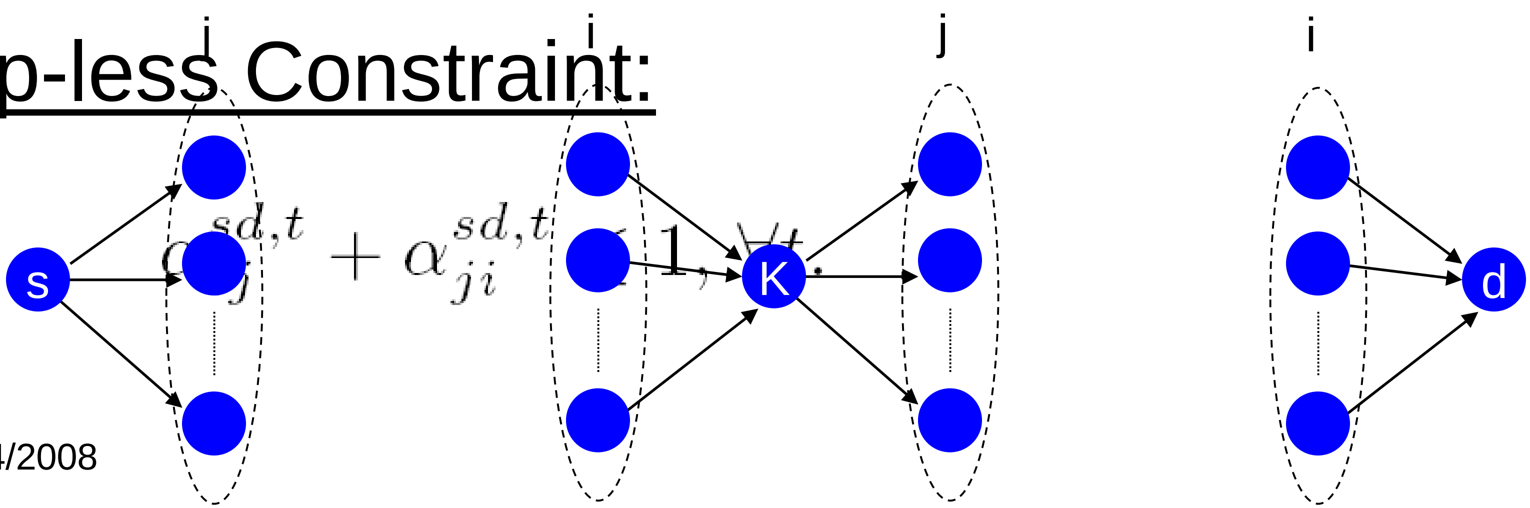
$$S^{sd} = \sum_{\forall j \in A_s} \left(\sum_{\forall t} \alpha_{sj}^{sd,t}\right), \forall (s,d).$$

$$\sum_{\forall i \in A_k} \left(\sum_{\forall t} \alpha_{ik}^{sd,t}\right) = \sum_{\forall j \in A_k} \left(\sum_{\forall t} \alpha_{kj}^{sd,t}\right), \forall k \in \aleph, \forall (s,d).$$

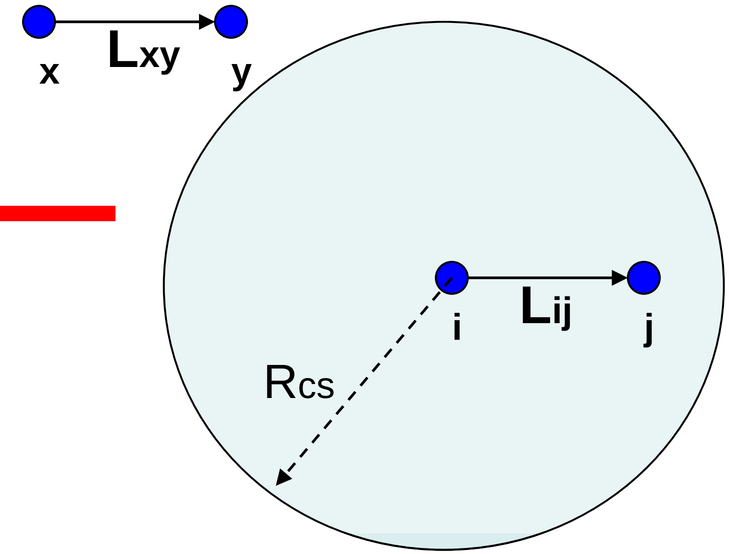
$$S^{sd} = \sum_{\forall i \in A_d} \left(\sum_{\forall t} \alpha_{id}^{sd,t}\right), \forall (s,d).$$

Loop-less Constraint:

$$\alpha_{ij}^{sd,t} + \alpha_{ji}^{sd,t} \le 1, \forall t.$$



Analytical Model



Capacity Constraints:

$$\sum_{\forall(s,d)} \sum_{\forall t} \alpha_{ij}^{sd,t} \leq C_{ij}, \forall L_{ij}.$$

→ Special case (at most single interferer exist):

$C_{ij}^{xy} =$

- Lij has no traffic
- Lij 's interferer is located in the hearing range
- Lij 's interferer is located in the interference range
- Lij 's has no interferers

1.

$$C_{ij}^{xy} = \{(\frac{1}{2} * Dcs_{ij}^{xy} + \frac{d_{ij}^{xy}}{d_{ij}^{max}} * DI_{ij}^{xy}) * \beta_{xy} + (1 - \beta_{xy})\} * \beta_{ij} * C_{ij}^{max}.$$

Analytical Model

Capacity Constraints:

→ General case (Multiple interferers exist):

$$C_{ij} = \begin{cases} 0 & \beta_{ij} = 0, \\ \frac{1}{1+\sum_{\forall L_{xy} \in CS_{ij}} \beta_{xy}} * C_{ij}^{max}, & Dcs_{ij}^{xy} = 1, \beta_{ij} = 1, \\ \frac{\sum_{\forall L_{xy} \in I_{ij}} [\frac{d_{ij}^{xy}}{d_{ij}^{max}} * (\beta_{xy} + (1-\beta_{xy}) * \frac{d_{ij}^{max}}{d_{ij}^{xy}})]}{\sum_{\forall L_{xy} \in I_{ij}} (\beta_{xy} + (1-\beta_{xy}))} * C_{ij}^{max}, & only if I_{ij} \neq \phi, DI_{ij}^{xy} = 1, \beta_{ij} = 1, \forall d_{ij}^{xy} < d_{ij}^{max} \\ C_{ij}^{max}, & Dcs_{ij}^{xy} = DI_{ij}^{xy} = 0, \beta_{xy} = 0, \beta_{ij} = 1 (\forall L_{xy}). \end{cases}$$

$$C_{ij} = \left\{ \frac{1}{1 + \sum_{\forall L_{xy} \in CS_{ij}} \beta_{xy}} \right\} * \left\{ \frac{\sum_{\forall L_{xy} \in I_{ij}} [\frac{d_{ij}^{xy}}{d_{ij}^{max}} * (\beta_{xy} + (1-\beta_{xy}) * \frac{d_{ij}^{max}}{d_{ij}^{xy}})]}{\sum_{\forall L_{xy} \in I_{ij}} (\beta_{xy} + (1-\beta_{xy}))} \right\} * \beta_{ij} * C_{ij}^{max}$$

Challenges

- Solve a non-linear programming.
- Avoid unrealistic approximations and assumptions.

Acknowledgment

- Thanks to:
  - Marwan,
  - Vishwanath,
  - Wei Wang.

Q & A

Thank you.