Some Thoughts on Wireless Network Modelling

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INDIN 2007
5th IEEE International Conference on Industrial Informatics

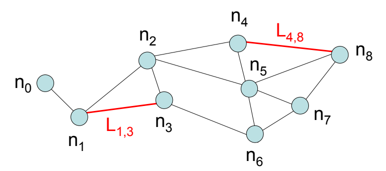
Overview

- We consider **wireless multi-hop networks with omni-antennas** (eg. ad-hoc or wireless mesh networks) using **CSMA/CA.**
- Traditional wireless routing algorithms as shown eg. in [1, 2] model wireless networks with a reachability graph:
  - Edges signify links between nodes and
  - are considered independent of each other ("tunnels" between nodes).

This does not reflect reality very well:

- Links in a wireless network are not well defined [3].
- Radio propagation does not behave like a "tunnel" [4].
- "Unicasts" are like broadcasts which are ignored by non-intended receivers.
- Carrier sensing (CCA) is not covered by "traditional" links because the carrier sensing range is larger than the transmission range (=link).

Figure 1. Traditional Reachability Graph.



vs.

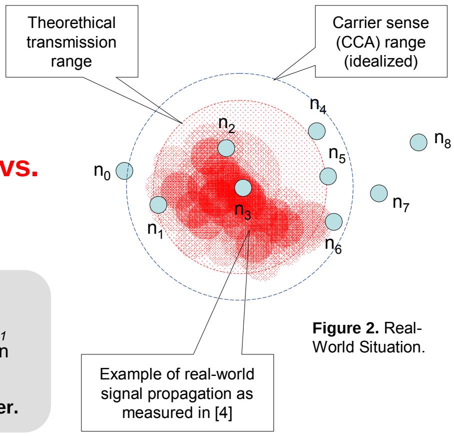


Figure 2. Real-World Situation.

Reachability graph *G*:

- Link defined as in [3]: $\exists L_{1,3}$ in *G* iff n_1->n_3 and n_3->n_1 have a packet loss rate below a certain threshold (an ETX rate ≤ 3); ETX…expected transmissions [6].
- Links **$L_{1,3}$ and $L_{4,8}$ seem independent of each other.**

When n_3 transmits to n_1 using $L_{1,3}$:

- Other nodes in the transmission range $\{n_2, n_6\}$ receive the transmission and must refrain from sending (**exposed node problem**).
- Transmissions to them from other nodes (eg. n_7->n_6) are interfered with on layer 1 (**hidden node problem**).
- Nodes in the carrier sense range $\{n_0, n_4, n_5\}$ also detect the channel as busy and refrain from sending (ditto **exposed node problem**).
- => $L_{4,8}$ can not be used!
- We know from literature that carrier sensing seems to be a major cause of layer 2 interference between two or more links [3, 5].
- The reachability graph **does not** reflect these problems!

Situation over time:

- Transmitting a data packet from n_1->n_3 disables set of nodes $N_S = \{n_0, n_2\}$ => disables links $L_S = \{L_{0,1}, L_{1,2}, L_{2,3}, L_{2,4}, L_{2,5}\}$
- Transmitting ACK from n_3 -> n_1 influences set of nodes $N_D = \{n_0, n_2, n_4, n_5, n_6\}$ => degrades links $L_D = \{L_{0,1}, L_{1,2}, L_{2,3}, L_{2,4}, L_{2,5}, L_{3,6}, L_{4,5}, L_{4,8}, L_{5,6}, L_{5,7}, L_{5,8}, L_{6,7}\}$
- Since ACKs are short and less frequent than data packets their influence is smaller.

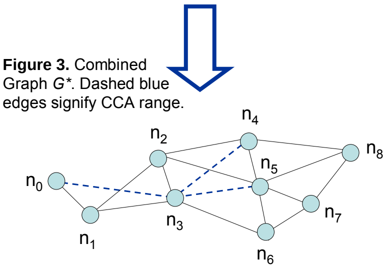


Figure 3. Combined Graph *G**. Dashed blue edges signify CCA range.

Suggestions how to use combined graph *G**:

a. **New routing protocols** can take CCA-edges directly into account.

b. **Recalculate link weights** to account for influence of sending on a link

$w'=f(w_{orig}, (\alpha_1*|N_S|), (\alpha_2*|L_S|). (\beta_1*|N_D|), (\beta_2*|L_D|))$

then use legacy routing protocols as usual.

c. **Use new time-variant graph aware protocols** on time-variant graph *G*(t)* (impractical).

Construction of graph:

- All nodes take turns sending hello messages at defined intervals (similar to ETX measurements in [5]) but using defined time slots.
- Listening nodes can determine whether a link or a CCA-edge exists.

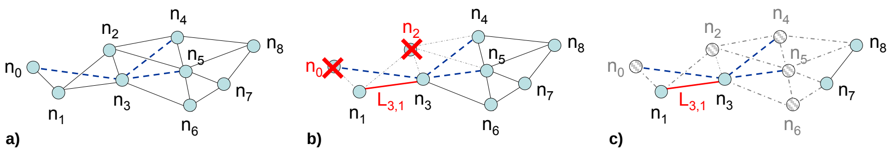


Figure 4. Time-variant graph *G*(t)* when sending from n_1 to n_3.
a) Before and after transmission. **b)** During data packet transmission n_1->n_3. **c)** During transmission of ACK n_3->n_1.

Conclusion and Future Work

- Literature shows the importance of taking the carrier sensing range into account [3, 5] to determine layer 2 interference between links.
- Therefore, **the reachability graph should be expanded to include edges modeling the CCA-range.**
- New routing protocols taking advantage of *G** need to be developed.
- Alternatively, a weight recalculating function *f* and its respective parameters α_1, α_2, β_1, and β_2 need to be derived.

References

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Acknowldegements

This Research has been funded by the Austrian Federal Ministry for Education, Science, and Culture, and the European Social Fund (ESF) under grant 31.963/46-VII/9/2002.

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