Minimal-Overlap Centrality-Driven Gateway Designation for Real-Time TSCH Networks

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Introduction: Real-time TSCH networks

Objective: To judiciously designate the gateway or sink to improve network *schedulability* by design.

Real-time applications

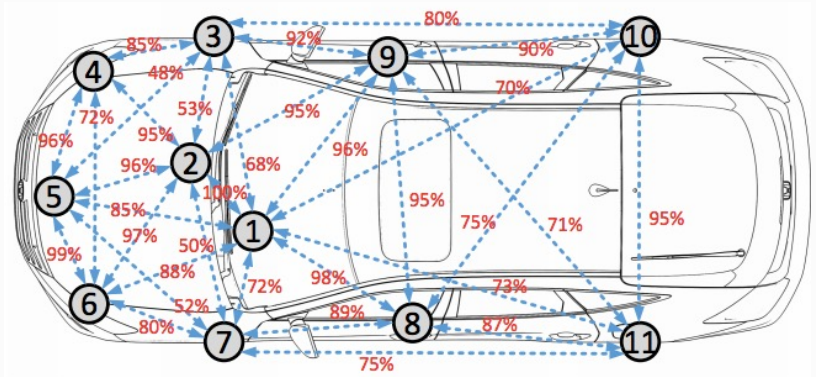
- Monitoring & process-control
- Safety-related audio announcements

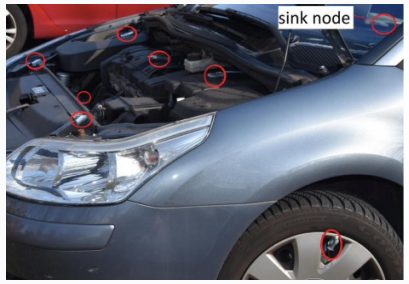
Time-Synchronized Channel-Hopping (TSCH)

- IEEE 802.15.4e
- ISA100.11a
- WirelessHART
- 6TiSCH

Network features

- Multi-channel TDMA MAC
- Per-slot/hop/channel transmissions
- Centralized network management





source: 10.1109/TII.2018.2853986

Automotive

source: https://www.emerson.com/

Oil & Gas

Preliminaries: System model

Network model

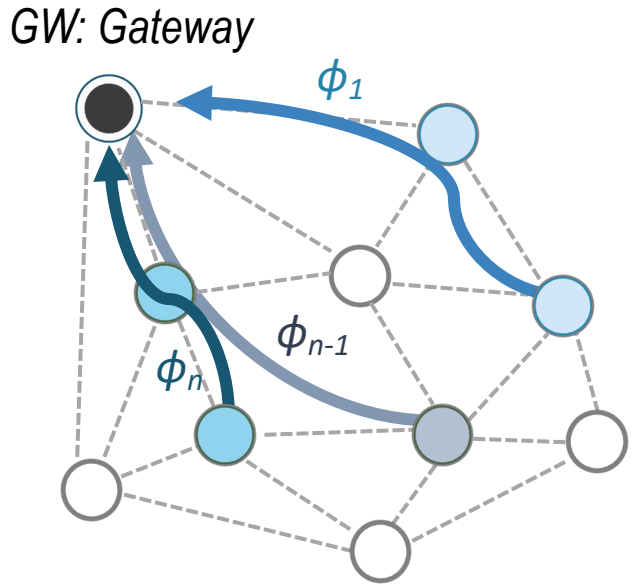
- Undirected graph G=(V,E)
- |V| vertices or nodes
- |E| edges or links

Flow model

- Time-sensitive
- Constrained deadlines
- **EDF scheduling**

Network centrality metrics

Metric	Definition
Eigenvector	$EC(v_q) = \frac{1}{\lambda_{max}(A)} \cdot \sum_{j=1}^{N} a_{j,q} \cdot x_j$
Closeness	$CC(v_q) = \frac{1}{\sum_{p \neq q} distance(v_p, v_q)}$
Betweenness	$BC(v_q) = \sum_{q \neq r} \frac{sp_{r,s}(v_q)}{sp_{r,s}}$
Degree	$DC(v_q) = \frac{degree(v_q)}{N-1}$



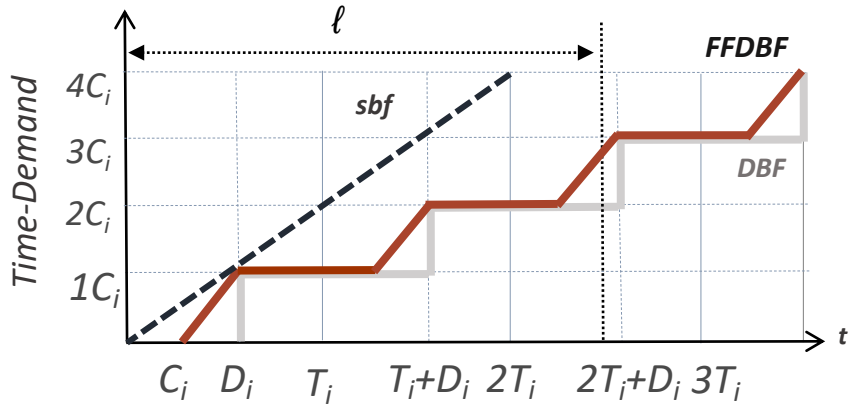
$$F_i = \langle C_i, D_i, T_i, \Phi_i \rangle \qquad D_i \leq T_i$$

C_i: (# of hops)*ts	D_i: deadline
T_i: period	Φ_i: route path

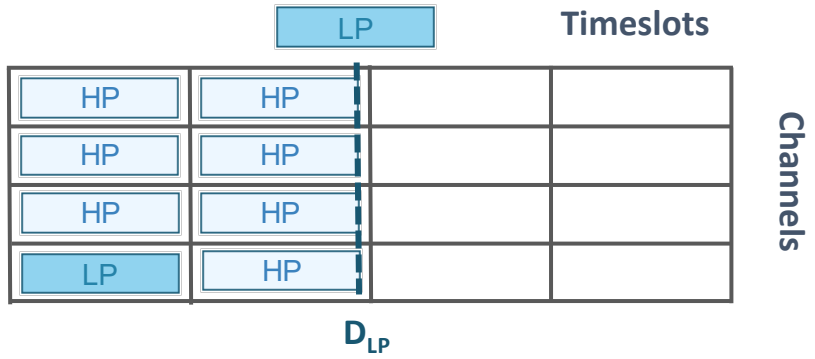
Preliminaries: Performance model

FFDBF-WIN schedulability test for wireless industrial networks

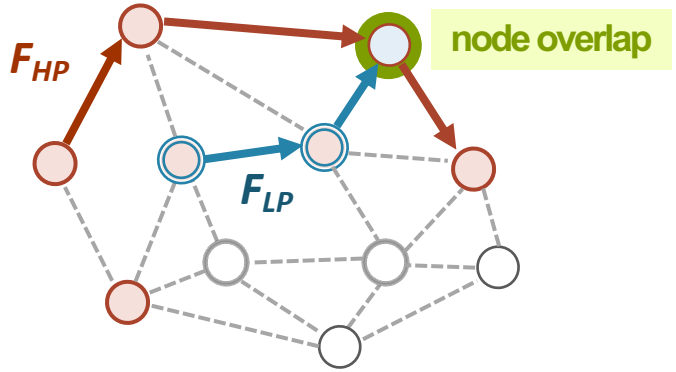
- **Supply:** minimal transmission capacity offered by **"*m*"** channels
- **Demand:** upper bound on the maximum demand for $F=\{F_1, F_2, \ldots\}$



① **Channel contention**

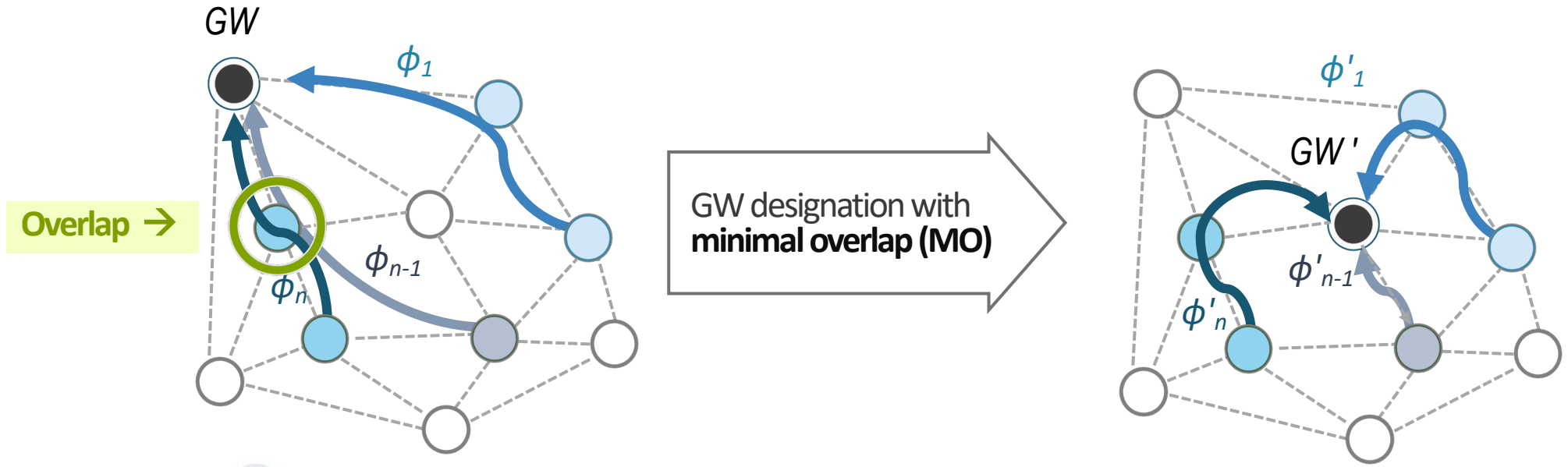


② **Transmission conflicts**



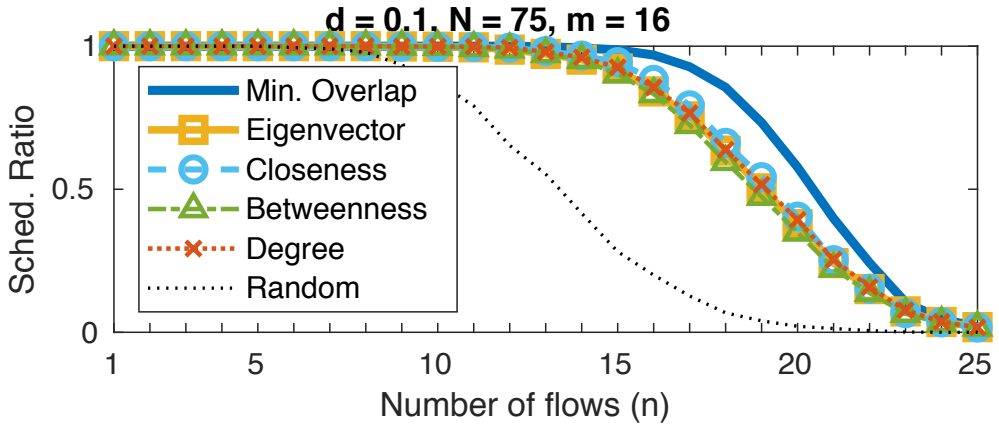
Contribution: Minimal-overlap centrality-driven GW designation

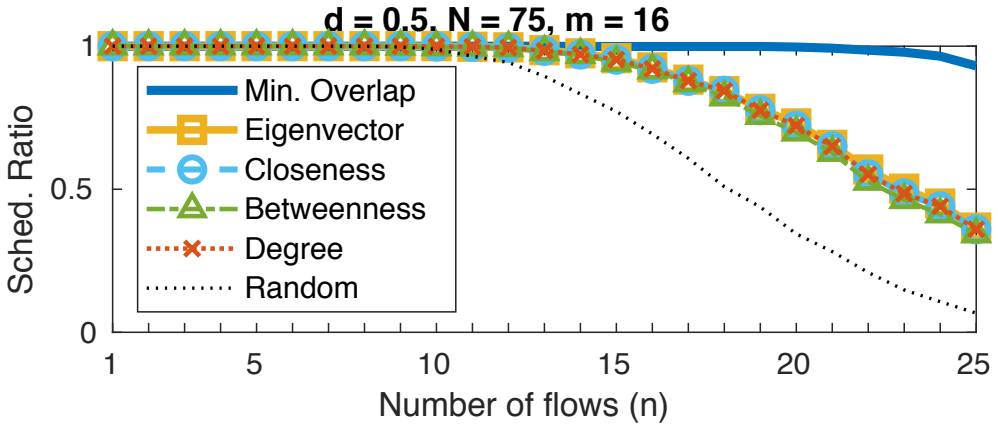
We propose a new ***network centrality*** metric termed minimal-overlap (MO) centrality. The goal is to enhance WSN traffic schedulability by design, particularly, by exploiting the relationship between ***path node-overlaps*** and **gateway designation**.

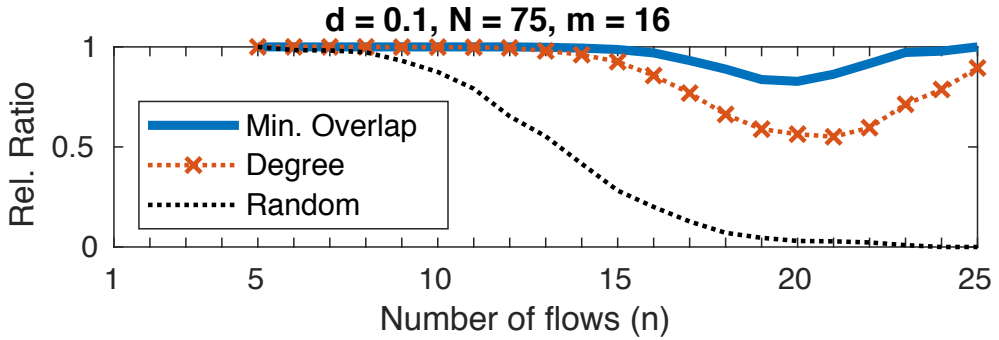


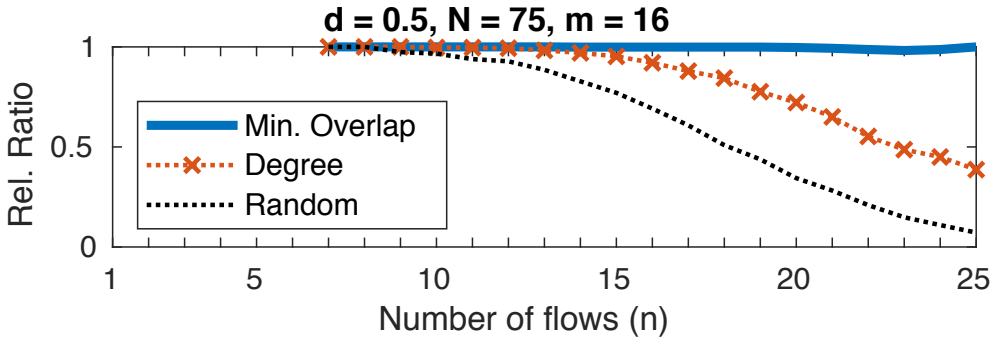
The method uses a pre-defined routing scheme

Performance evaluation: Schedulability ratio



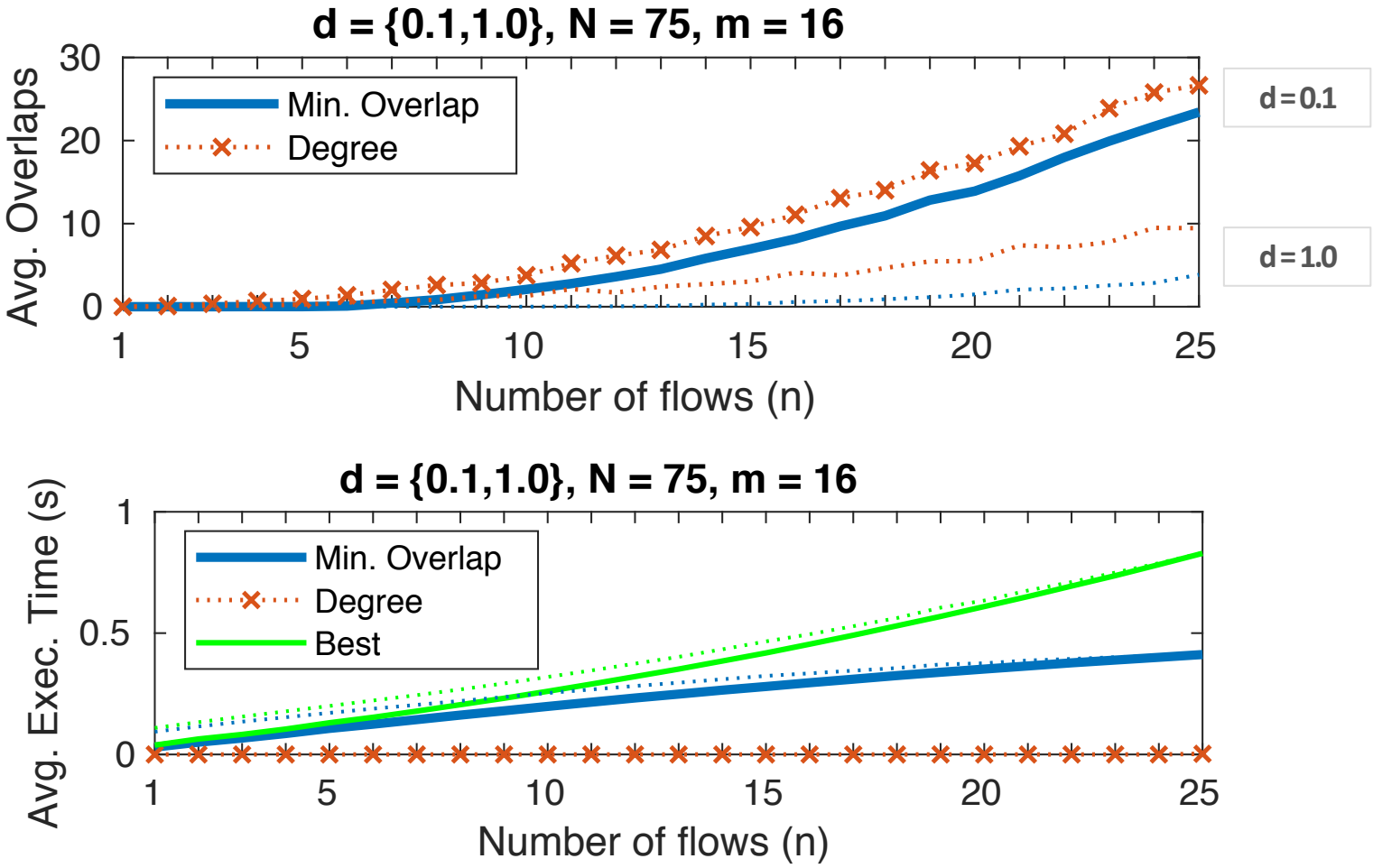






Simulation setup uses shortest path routing

Performance evaluation: # of overlaps and execution time



Summary

- This work proposed the **minimal-overlap centrality** (MOC) metric for **gateway designation** in real-time TSCH networks.
- MOC is built upon the computation of the ***overall minimal path overlapping*** resulting from the superposition of all (shortest-path) flow routes in the network.
- We demonstrated by **simulations** that **MOC** is **dominant** over classical network centrality metrics from social network analysis, achieving *nearly optimal performance* while showing lower execution times than the optimal case.
- In **future work**, we aim at to extend the idea to **multiple gateways**, as well as to evaluate its applicability in the context of wireless edge-node placement.