Integrated Access and Backhaul (IAB) Topology Formation for 5G Networks

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Motivation

Integrated Access and Backhaul (IAB) topology formation for fifth generation (5G) networks will be considered in release 17 of third generation partnership project (3GPP). IAB networks are setup to improve capacity, coverage and latency while limiting the cost of backhaul links (relay link between base station and IAB nodes). This is especially true for scenarios where IAB networks are used to provide additional capacity at events e.g., at sporting events and concerts, or are used to reduce latency for remote surgery, or cloud gaming. In this scenarios IAB nodes can be activated and deactivated or new users can join the network. In general, the integration of IAB nodes and users into the network can result in different topologies, that is, graphs, depending on the approach selected. The resulting topology will have a significant impact on the performance of latency and capacity. For example, sub-optimal topologies may result in slow connection or out of coverage. To avoid (minimize) this unwanted situation, an optimal topology formation is needed and it will have impact on society by enabling low latency and high throughput applications.

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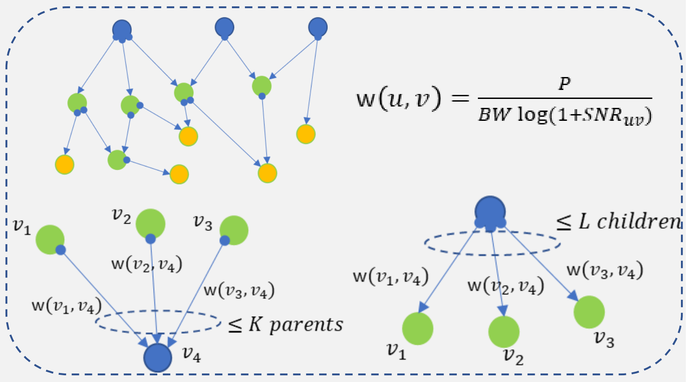
PROBLEM DEFINITION

Problem:

- Connecting user devices to internet backbone using multiple infrastructure base stations trough millimeter wave beamformed channels.
- Minimizing network latency while connecting all users to the network.

Formulation:

- Consider graph: $G = (V, E)$
- V is set of nodes, E is set of edges
- $V = \{$●,●,●$\} = \{\text{Source, basestation, user}\}$



Goal:

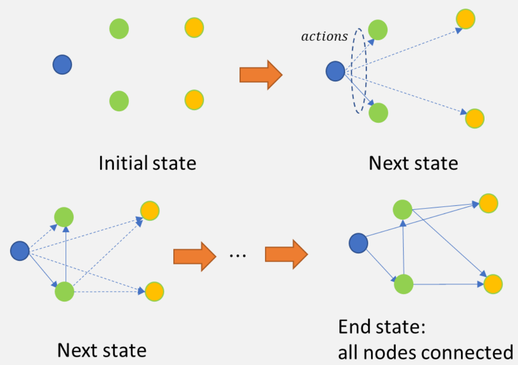
- Find edges such that latency over the nodes are minimized for a given graph G

$$\mathrm{f(G)} = \min\left(\sum_{k=1}^{|V|-1}\sum_{j=1}^{|V|}\left[\ln\left(\left(e^{\mathrm{A}\odot\mathrm{W}}\right)^{k}\right)\right]_{0,j}\right)$$

METHOD

Challenges:

- Consider search algorithm for centralized topology formation
- Optimal topology formation problem is NP hard.



Solution approach: Dynamic programming

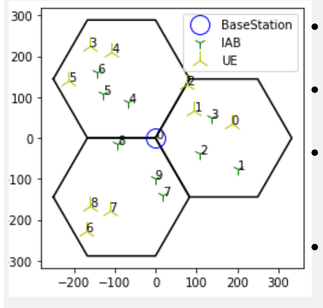
- Define sub-connected graph as a state.
- Initial state is unconnected graph
- Consider edge addition to sub-graph as a action
- Each edge addition modifies nodes scores (latency)
- The cost is added latency due to new edge (or node)
- The end state is such that all nodes are connected

States:

T_v = (# of potential parent; # of potential child; node latency; connection status)

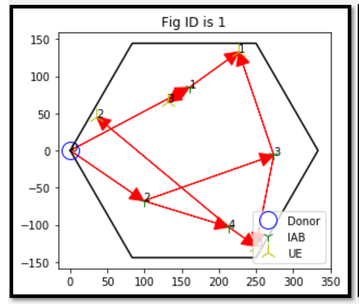
$$s = [T_{v_1}, T_{v_2}, \dots, T_{v_{|V|}}]$$

IMPLEMENTATION

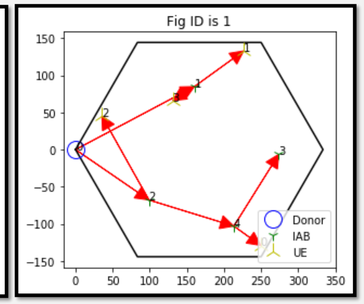


- IAB and users are deployed according to 3GPP standard
- Each user and IAB reports their link quality RSRP measurements
- Channel is line-of-sight mmWave channel which is generated according to location of nodes
- Arbitrary number of user and IAB can be added to network.

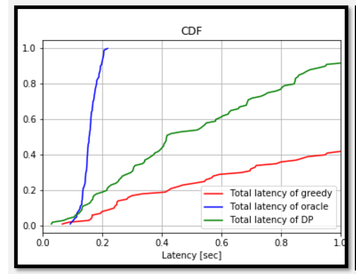
RESULTS & ANAYSIS

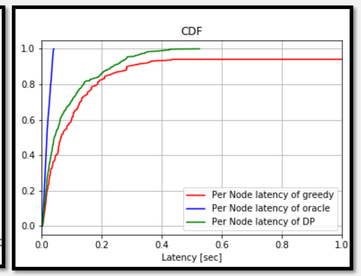


Greedy topology



DP topology





- Total network latency improved by 50% on average over heuristic greedy topology
- Results show that each user benefits from lower latency

CONCLUSION & FUTURE WORK

- Dynamic programming gives us the optimal solution in reasonable complexity
- Greedy approaches have significantly higher latency
- In practice, dynamic programming can be still complex for larger scenarios, and it requires centralized solution
- GCN and RL will be considered as future work

REFERENCES

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[2] H. Dai, et., al., "Learning Combinatorial Optimization Algorithms over Graphs," 31st Conference on Neural Information Processing Systems (NIPS 2017), Long Beach, CA, USA
[3] 5G; Study on channel model for frequencies from 0.5 to 100 GHz, https://www.etsi.org/