Joint Optimization of Routing and Radio Configuration in Fixed Wireless Networks

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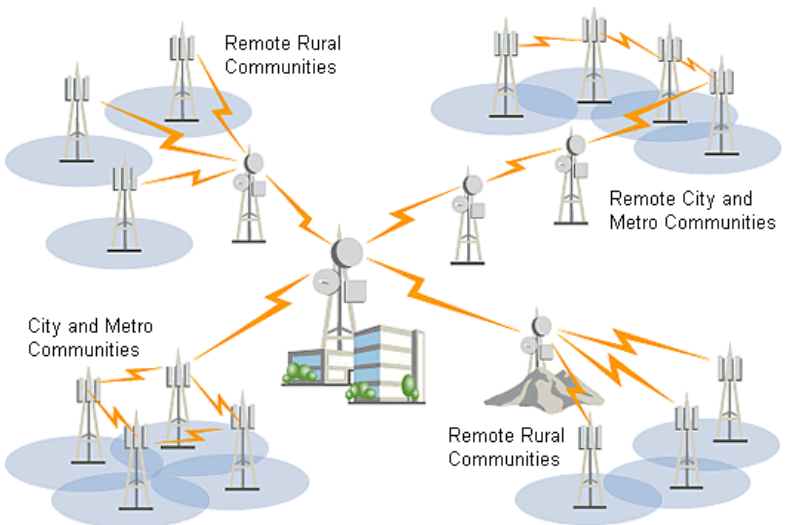
Context

Microwave radio links have become a common preference over leased lines to build broadband communication networks.

- Economical equipment cost
- Easy installation
- Disaster resiliency

- High-bandwidth applications
- Very bursty traffic behaviors
- Tremendous rise of energy



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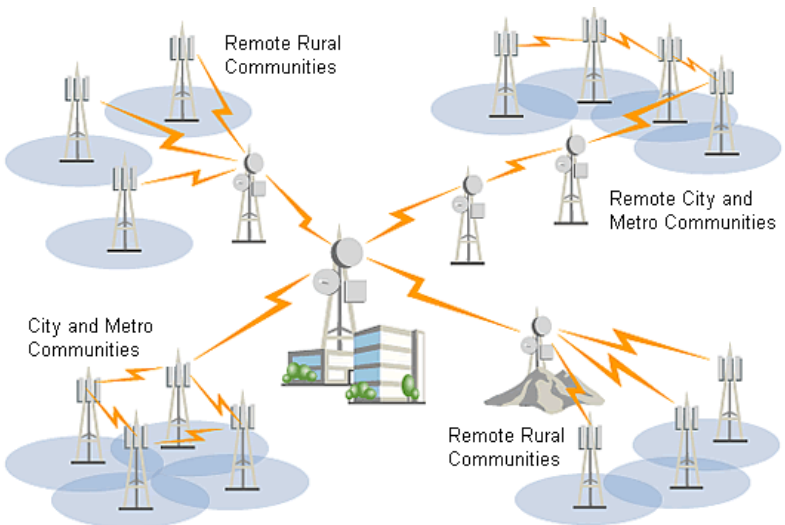


How to reduce operating costs ?

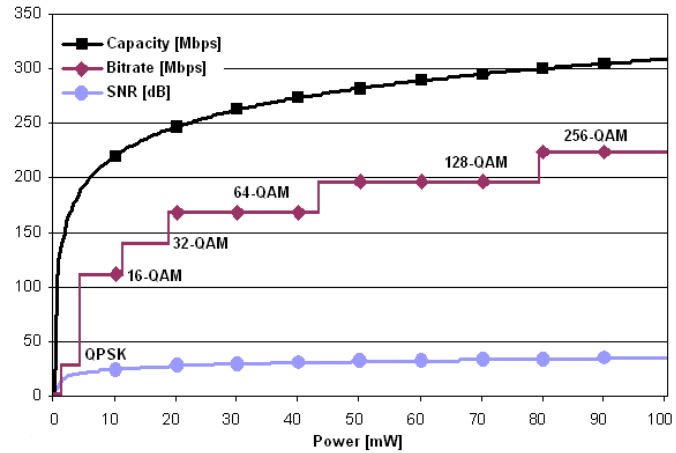
Capacity & energy cost

Theoretical capacity:

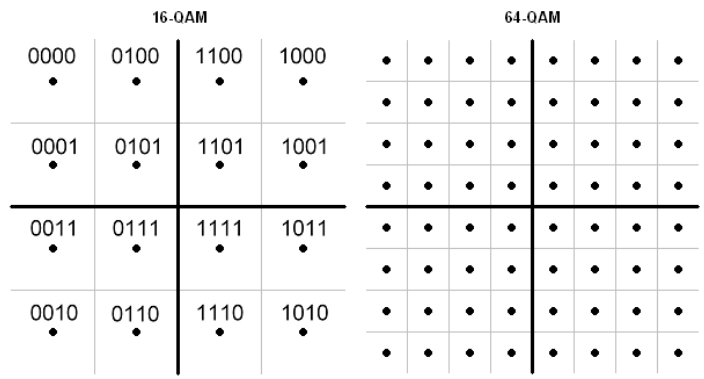
$$C[bits/s] = B[Hz] * log_2(1 + \frac{S[W]}{N[W]})$$

Pratical bitrate:

$$C[bits/s] = B[Hz] * log_2(m), m = 2^n$$



In practice, as the modulation scheme changes to accommodate higher data rates, the SNR requirement increases to preserve the BER performance !



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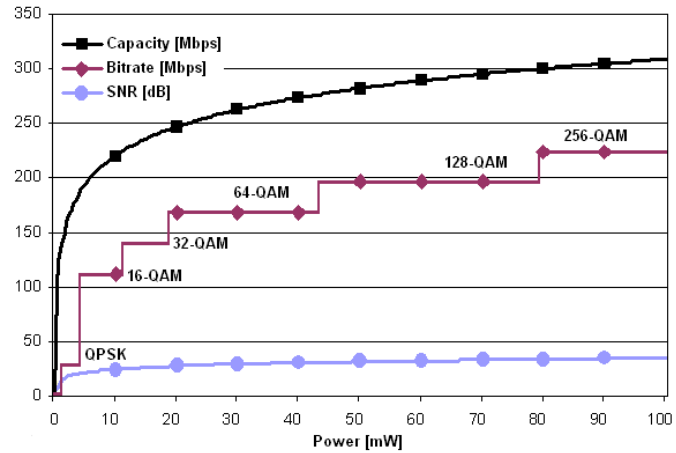

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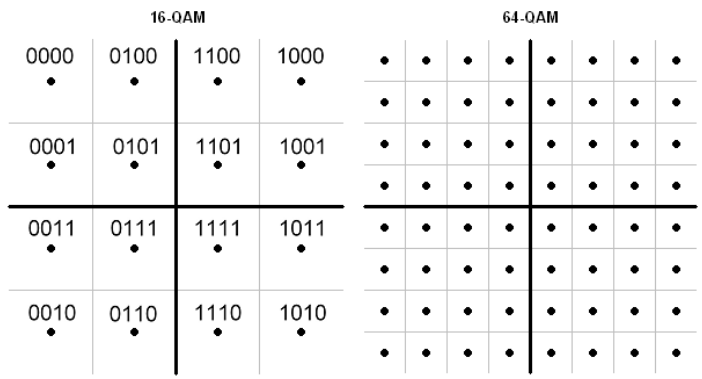

Power-efficient configuration

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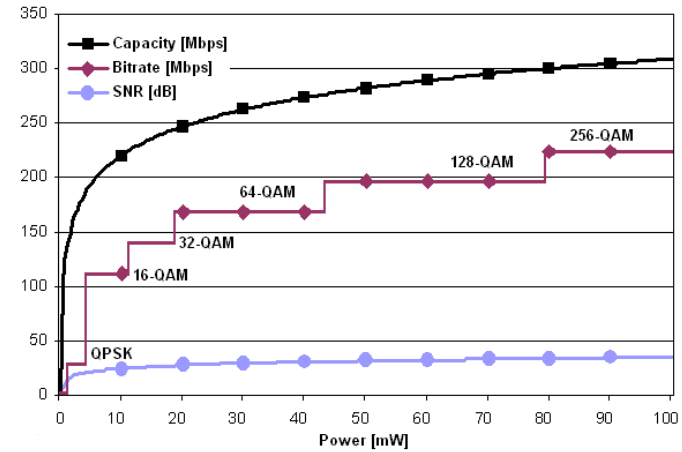
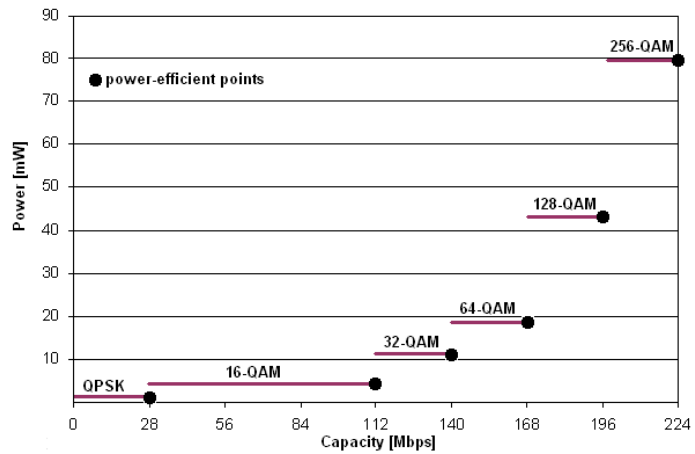
- Modulation scheme
- Transmission power level

Energy cost

- Step increasing energy cost functions on the links

For each modulation scheme, only the most right point of the curve represents a power-efficient configuration !





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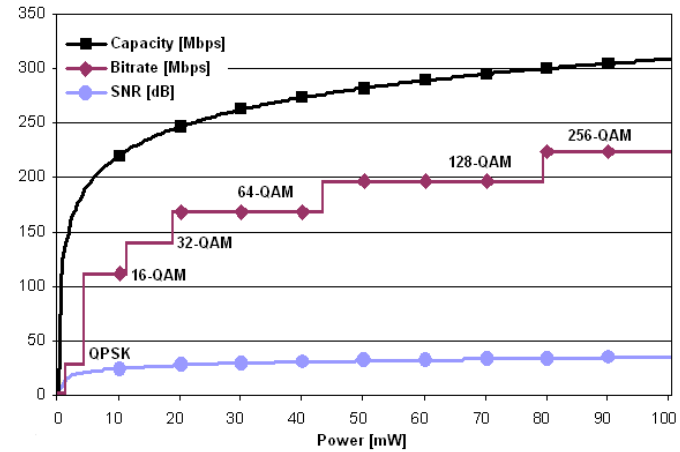
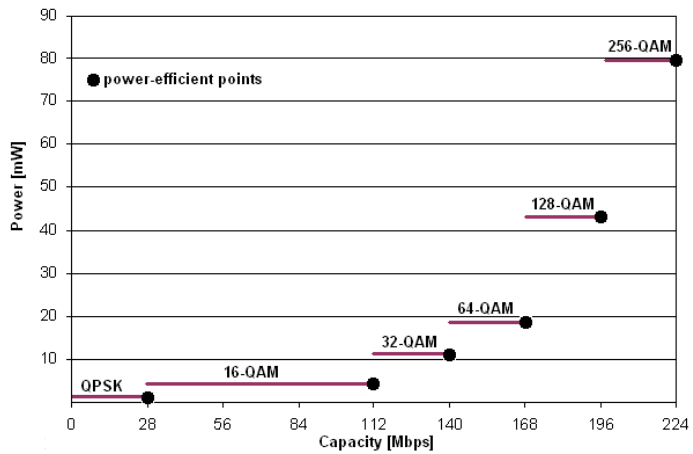




Problem description

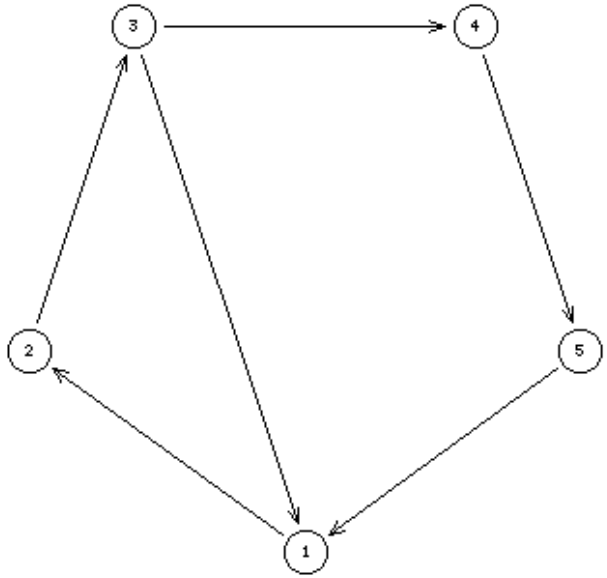
Network's topology

- Nodes: radio base stations
- Arcs: radio links

Power-efficient configurations

- Link's capacity
- Link's energy cost

Traffic requirements



The network's configuration and flows that minimize the total energy expenditure, while handling all the traffic requirements.

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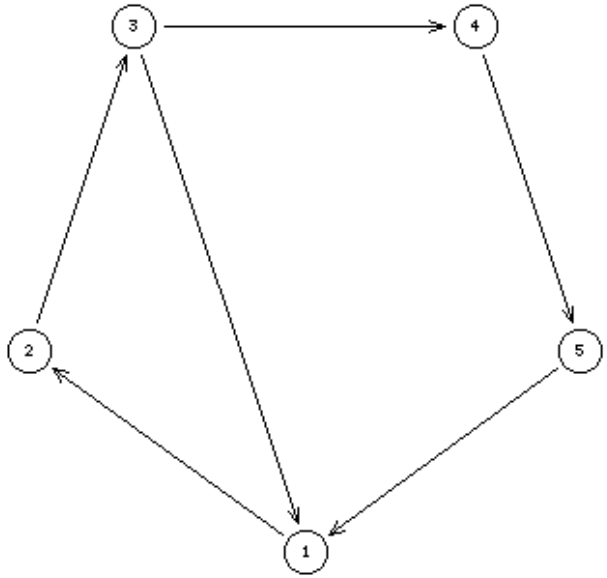

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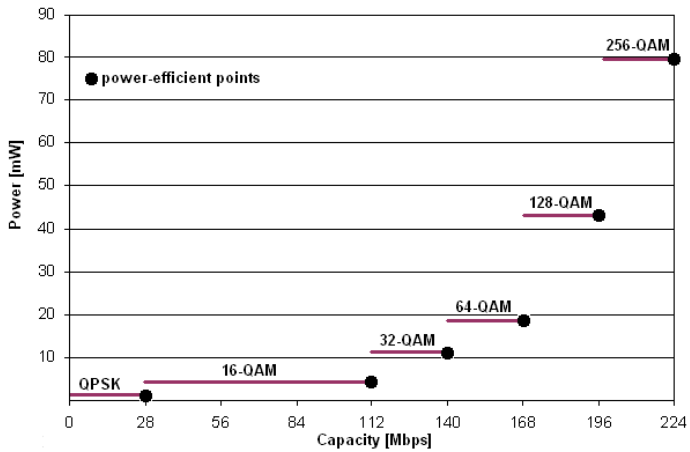
Mathematical Models

Exact formulation

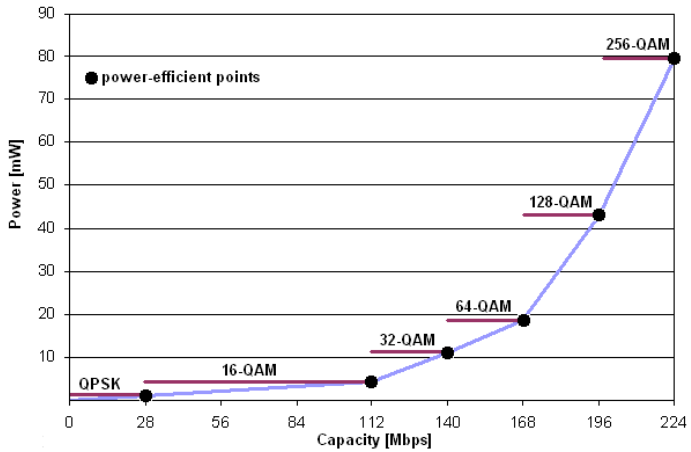
- MCMCF with step increasing cost functions
- Large scale integer linear programs
- Very hard to solve in practice
- Optimal feasible solutions



Mathematical Models

Model relaxation

- MCMCF with piecewise linear convex cost functions
- Large scale continuous linear programs
- Lower bounds on the energy consumption
- Feasible solutions based on the fractional optimum



Heuristic that assigns the lowest-level power-efficient configuration capable of routing the network's flows.

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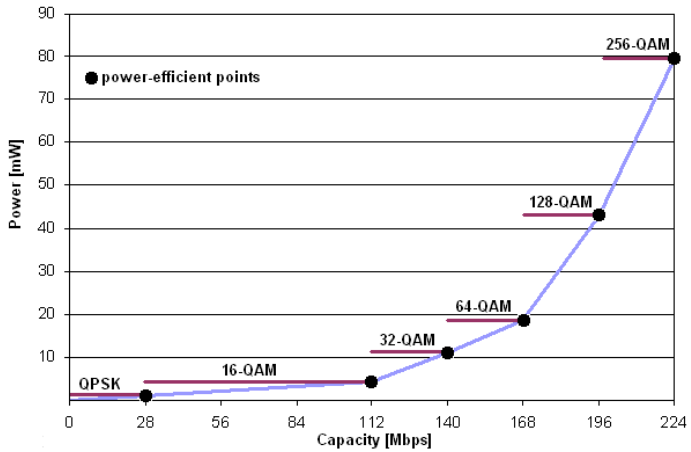

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Simulation parameters

- Channel Bandwidth: 28 MHz
- Operated Frequency: 13 GHz
- Antenna Gain: 30 dBi
- Receiver Sensitivity: -90 dBm
- Distance: 1000 m

Modulation	Power	Capacity	Marginal Cost	SNR
QPSK	0.88 mW	28 Mbps	0.031 mW	14.21 dB
16-QAM	4.20 mW	112 Mbps	0.040 mW	21.02 dB
32-QAM	11.10 mW	140 Mbps	0.247 mW	25.24 dB
64-QAM	18.47 mW	168 Mbps	0.263 mW	27.45 dB
128-QAM	42.81 mW	196 Mbps	0.869 mW	31.10 dB
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Computational results

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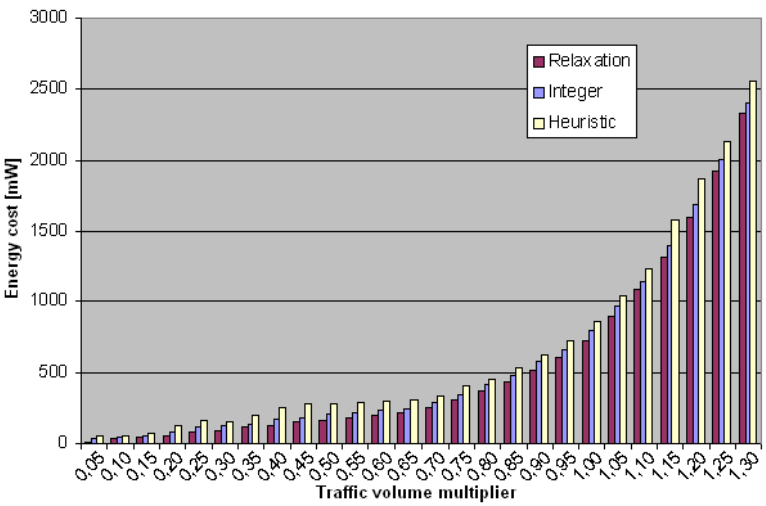

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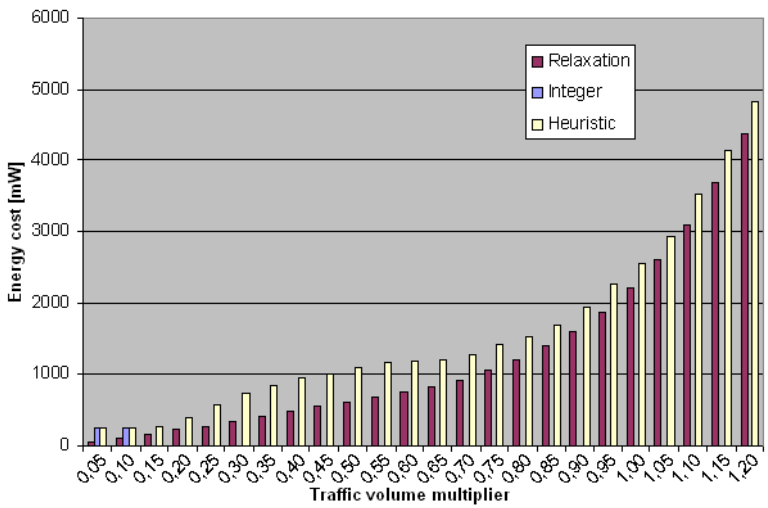

Heuristic performs well and allows solving instances that are not reachable with the exact model.

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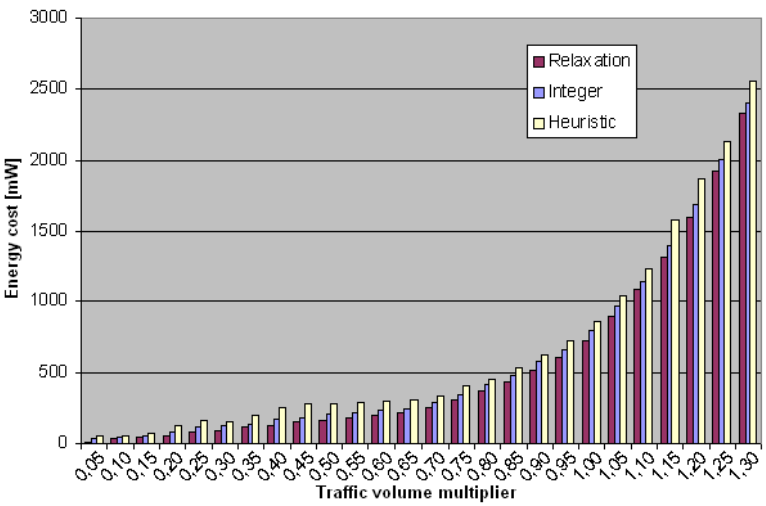

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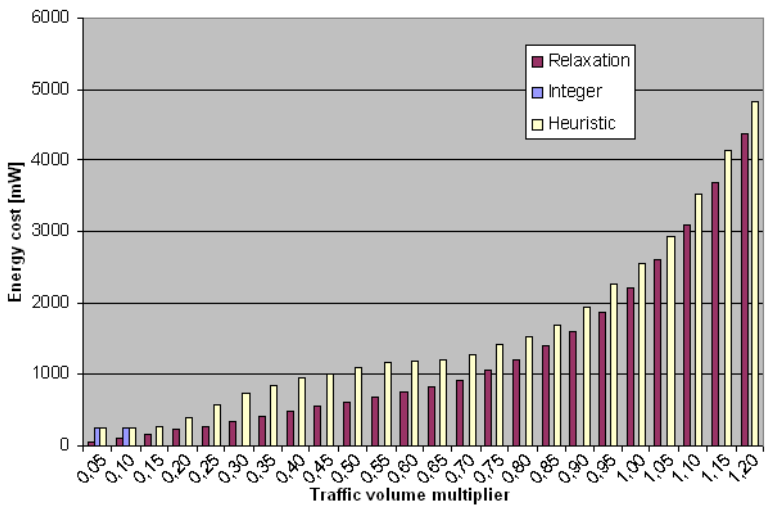

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Conclusion & future work

Joint optimization of data routing and radio configuration

- An exact mathematical formulation
- A model relaxation
  - Lower bounds on the energy consumption
  - Heuristic feasible solutions

Future work

- More realistic scenarios
- Alternative relaxations and heuristics
- Decrease the gap to the exact solution

Merci !

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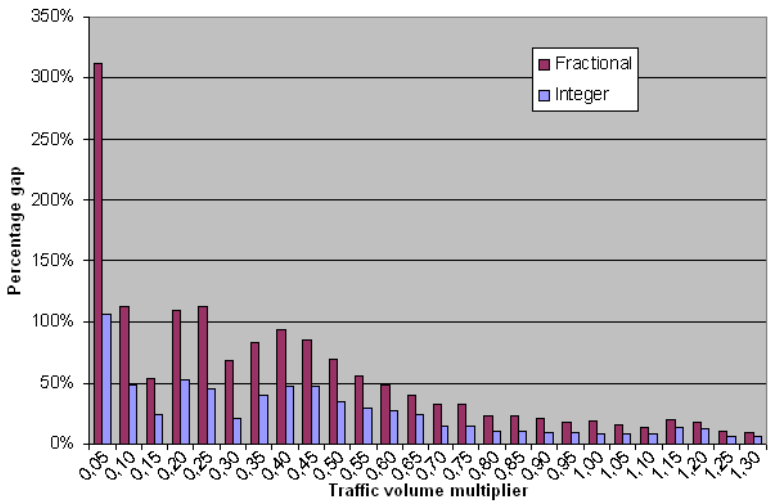

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