Minimizing power consumption in virtualized cellular networks

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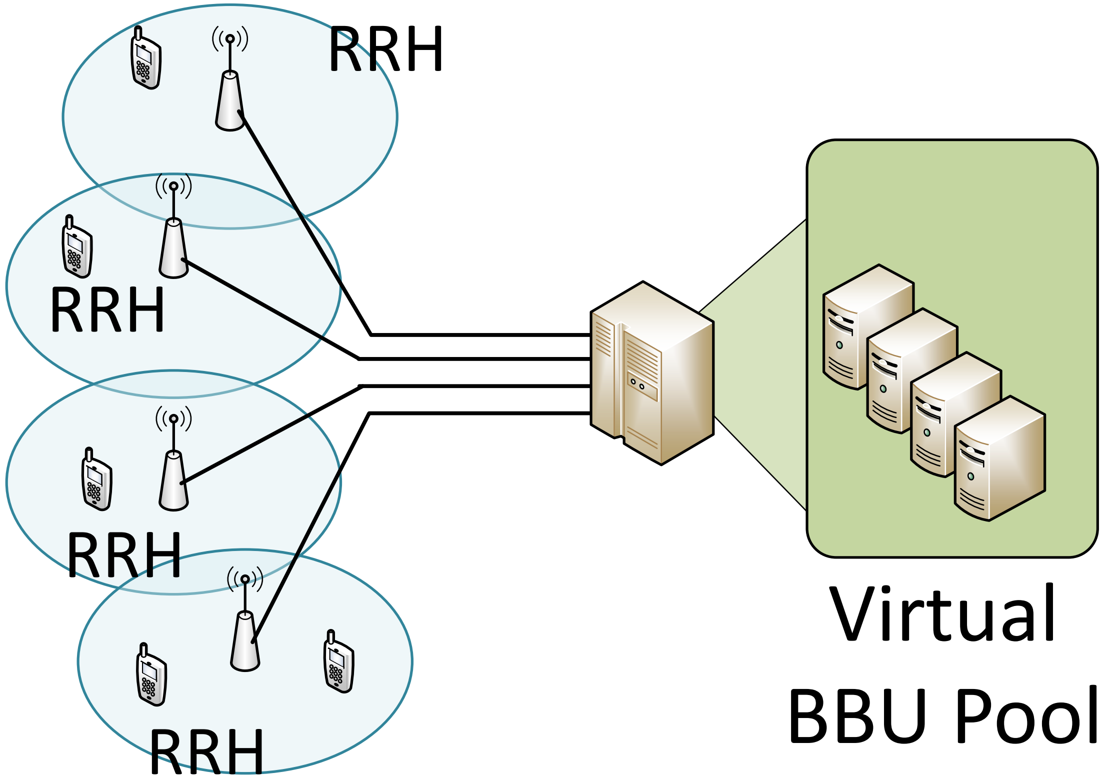
Towards 5G: The C-RAN

Split → Centralize → Virtualize

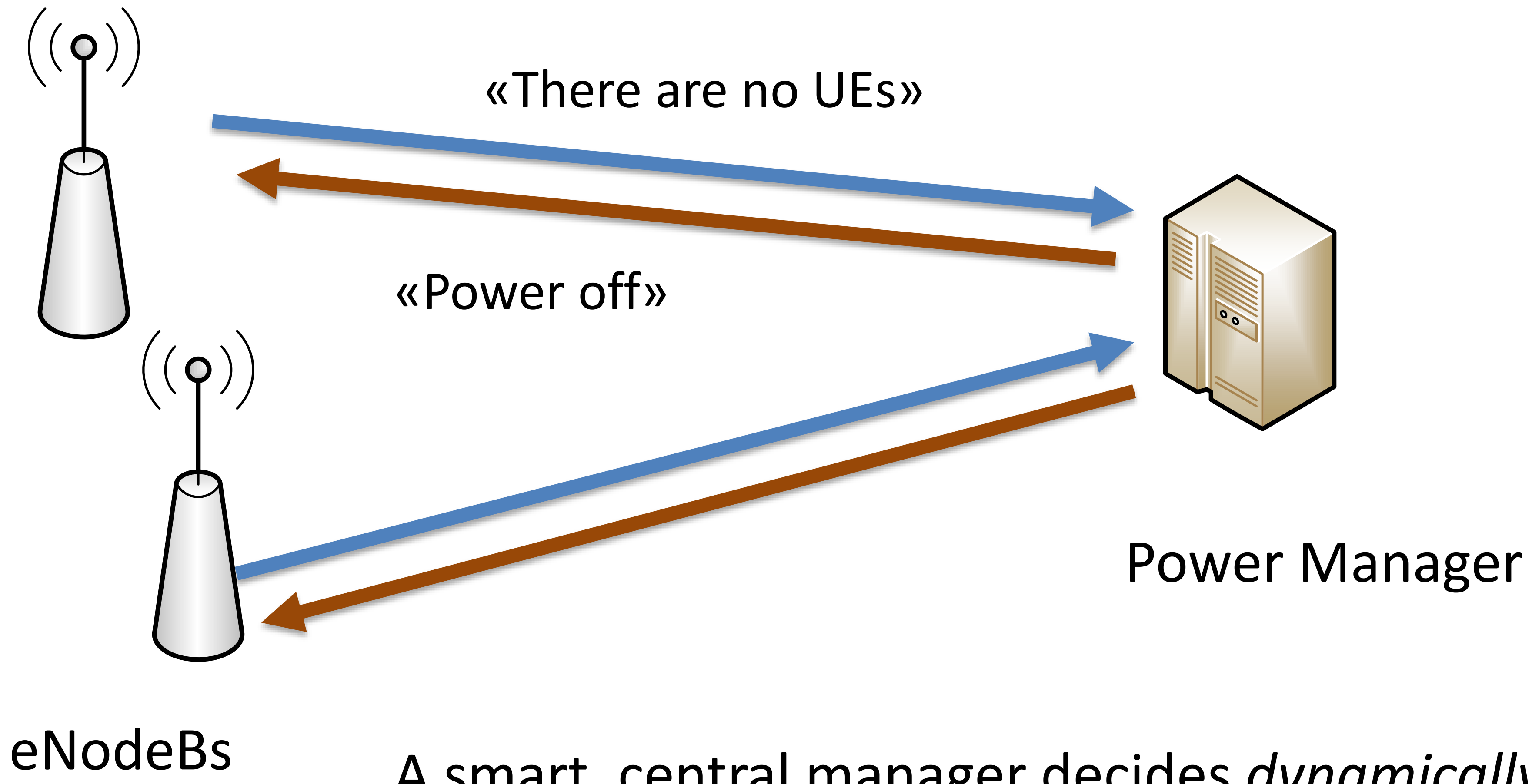


✓Greener

✓Cheaper

✓*Smarter*

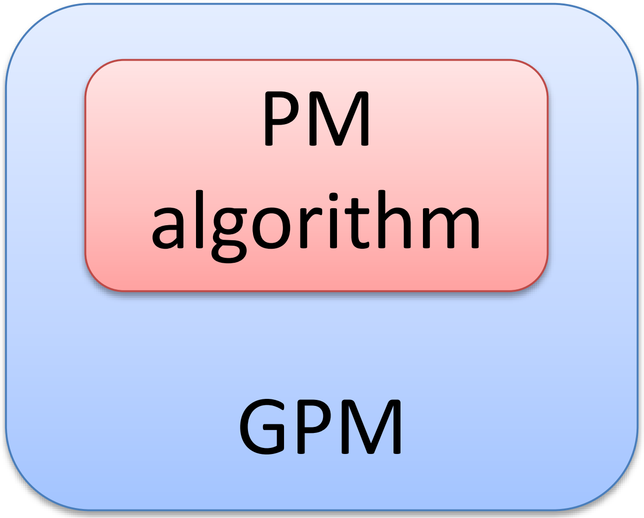
Power Management



A smart, central manager decides *dynamically* to switch on/off eNBs

Our contribution

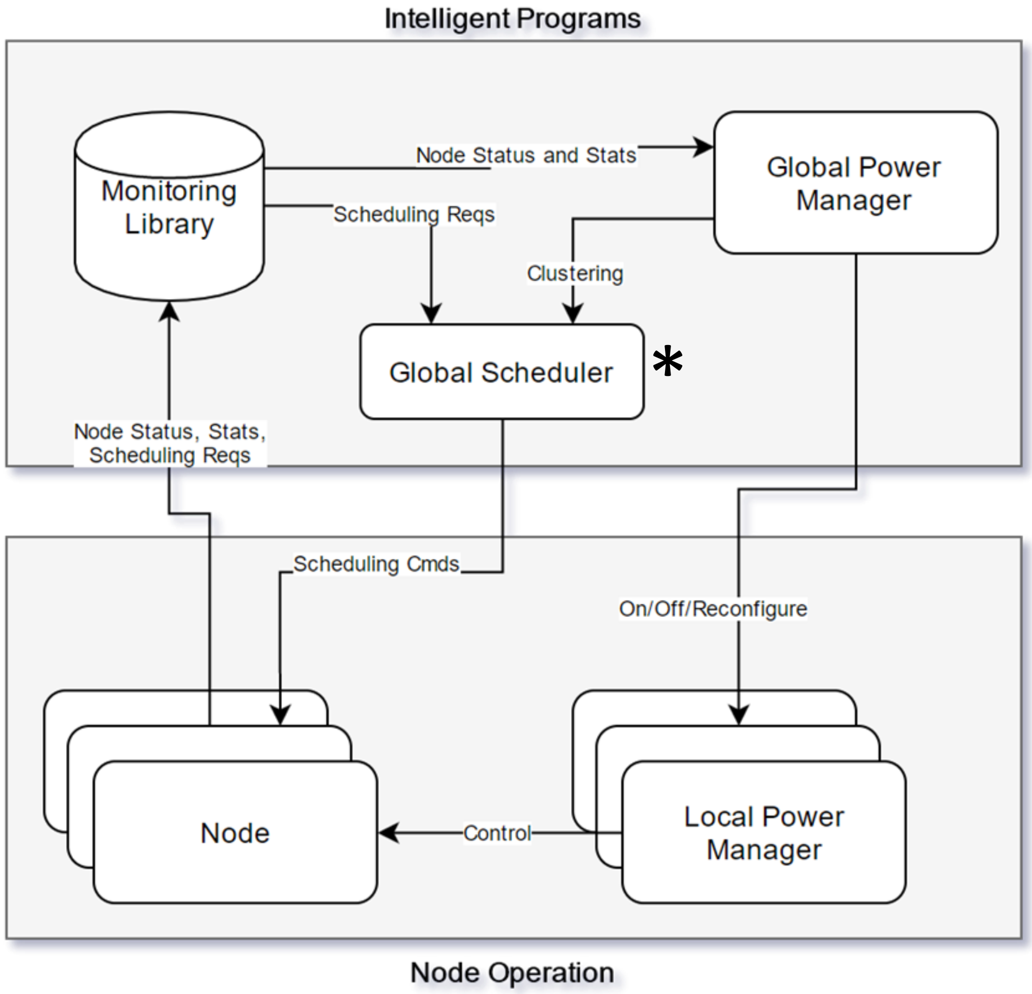
- Dynamic power management algorithm
- A Global Power Manager that runs the algorithm*



*The GPM is part of the framework described in:

- N. Iardella, et al., "A testbed for flexible and energy-efficient resource management with virtualized LTE-A nodes", CLEEN 2017, Turin, Italy, 21-22 June 2017

Software Framework

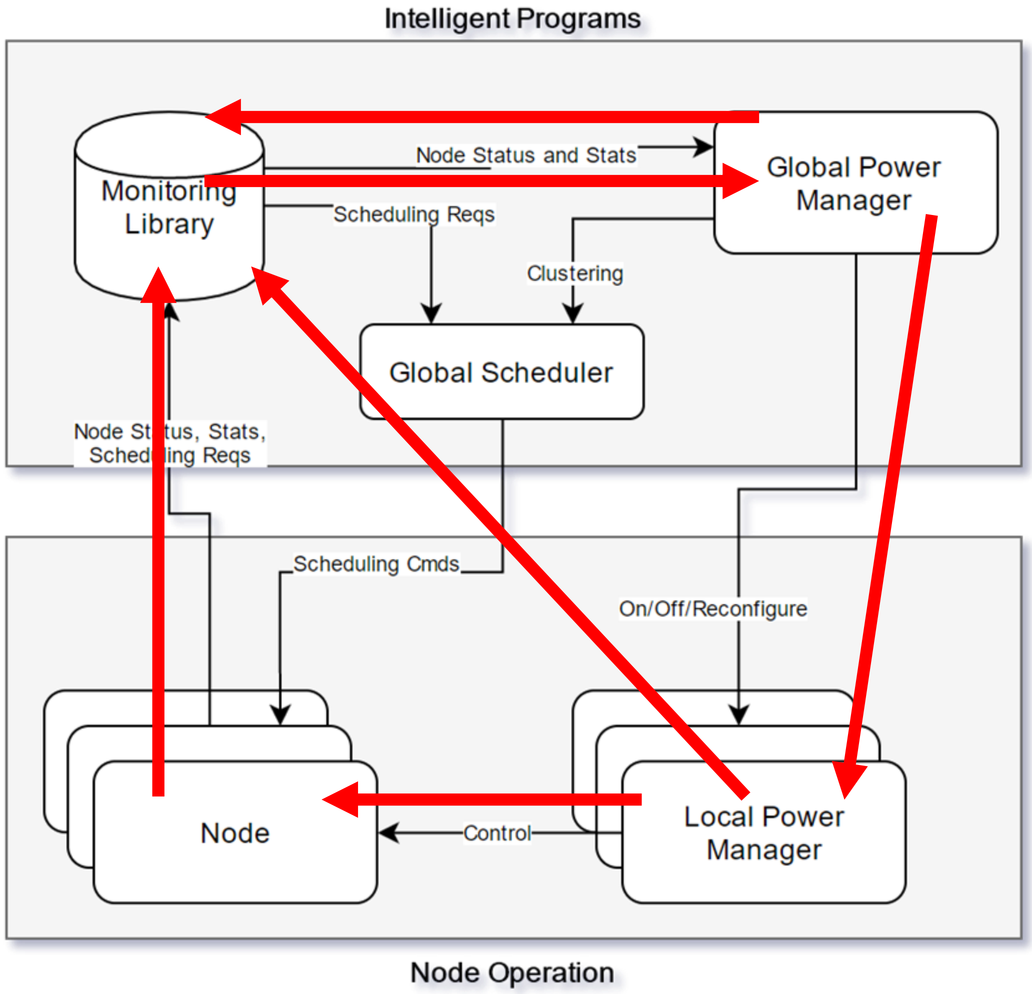


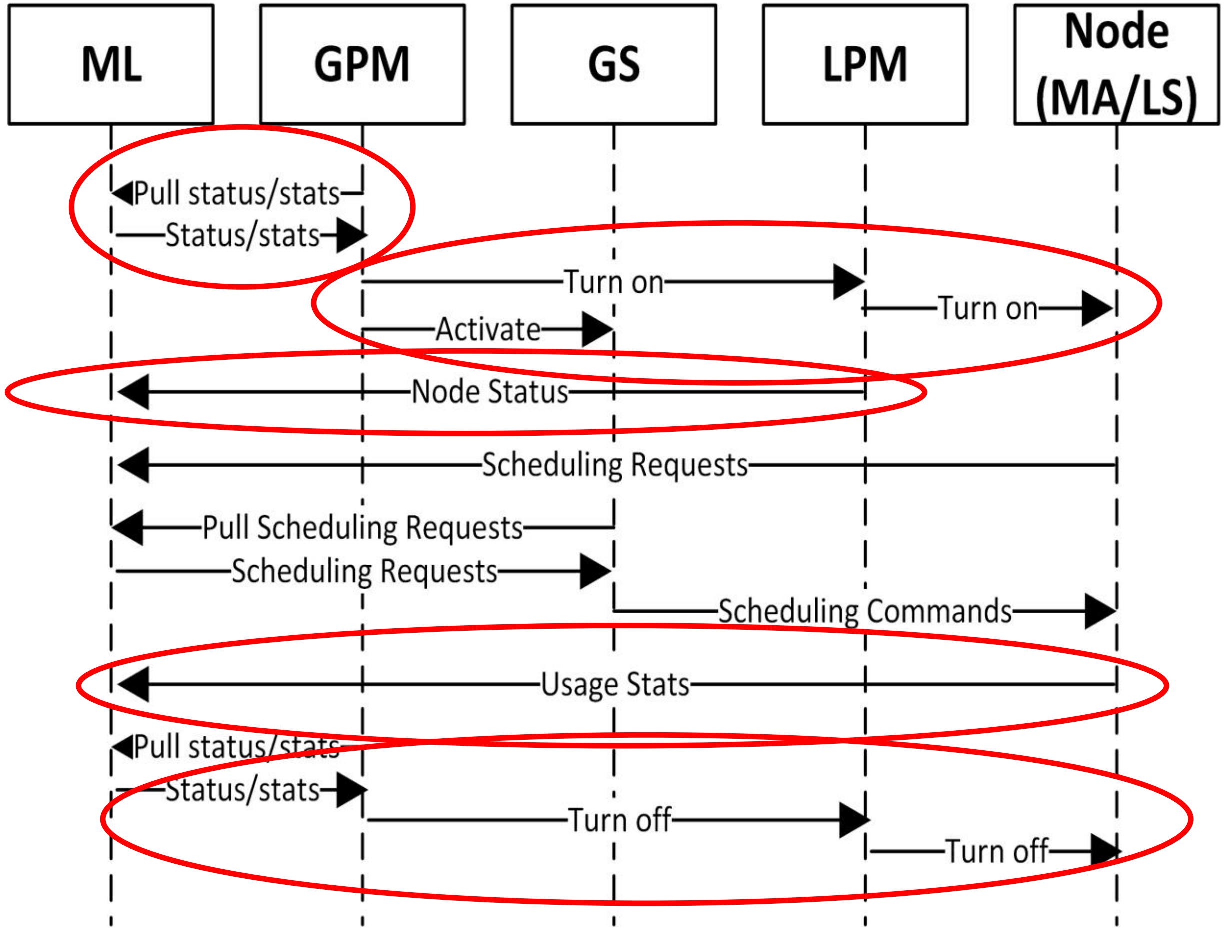
- Monitoring Library contains network status and information;
- Global Power Manager reconfigures and manages all the Nodes;
- A Local Power Manager controls (e.g. a single Node);
- A Node serves a cell and allocates resource to its Users.

* The Global Scheduler operation is described in:

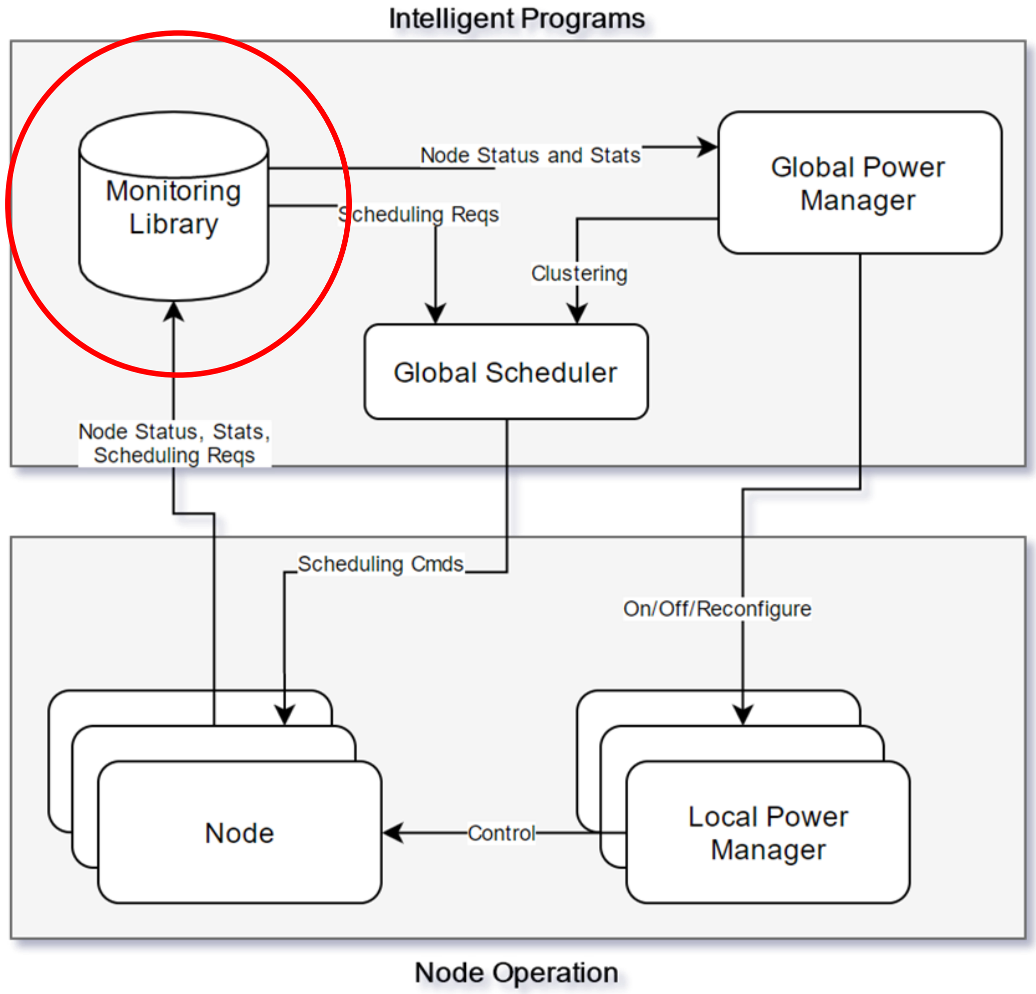
- G. Nardini, et al., "Scalability and energy efficiency of Coordinated Scheduling in cellular networks towards 5G", CLEEN 2017, Turin, Italy, 21-22 June 2017

Software Framework





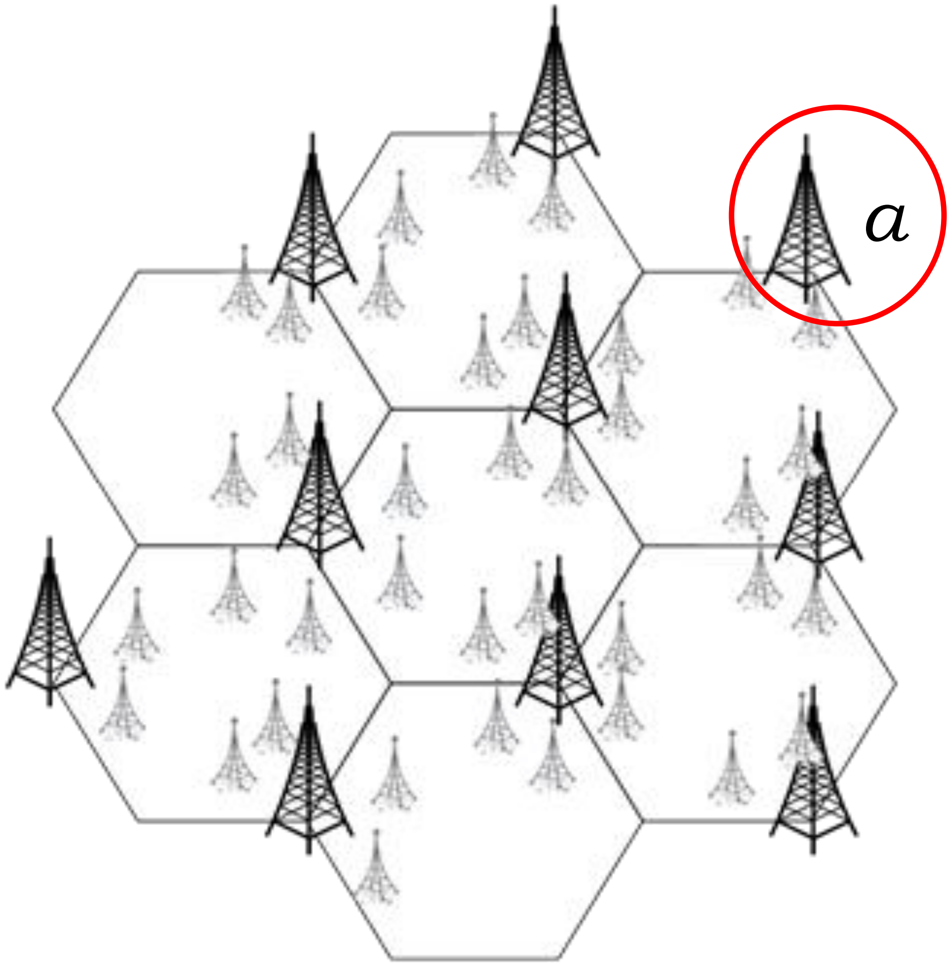
Software Framework



Monitoring Library contains network status and information:

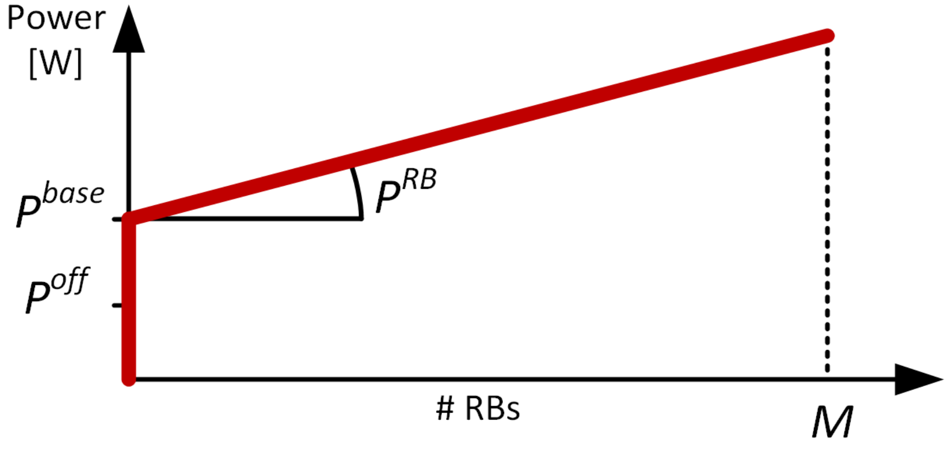
- *Node status* (e.g. on/off)
- *Usage stats* (i.e. requested data rate)
- *Expected traffic profiles*
  - Historical records
  - Context information (e.g. upcoming events)

GPM algorithm



Power consumed by node a:

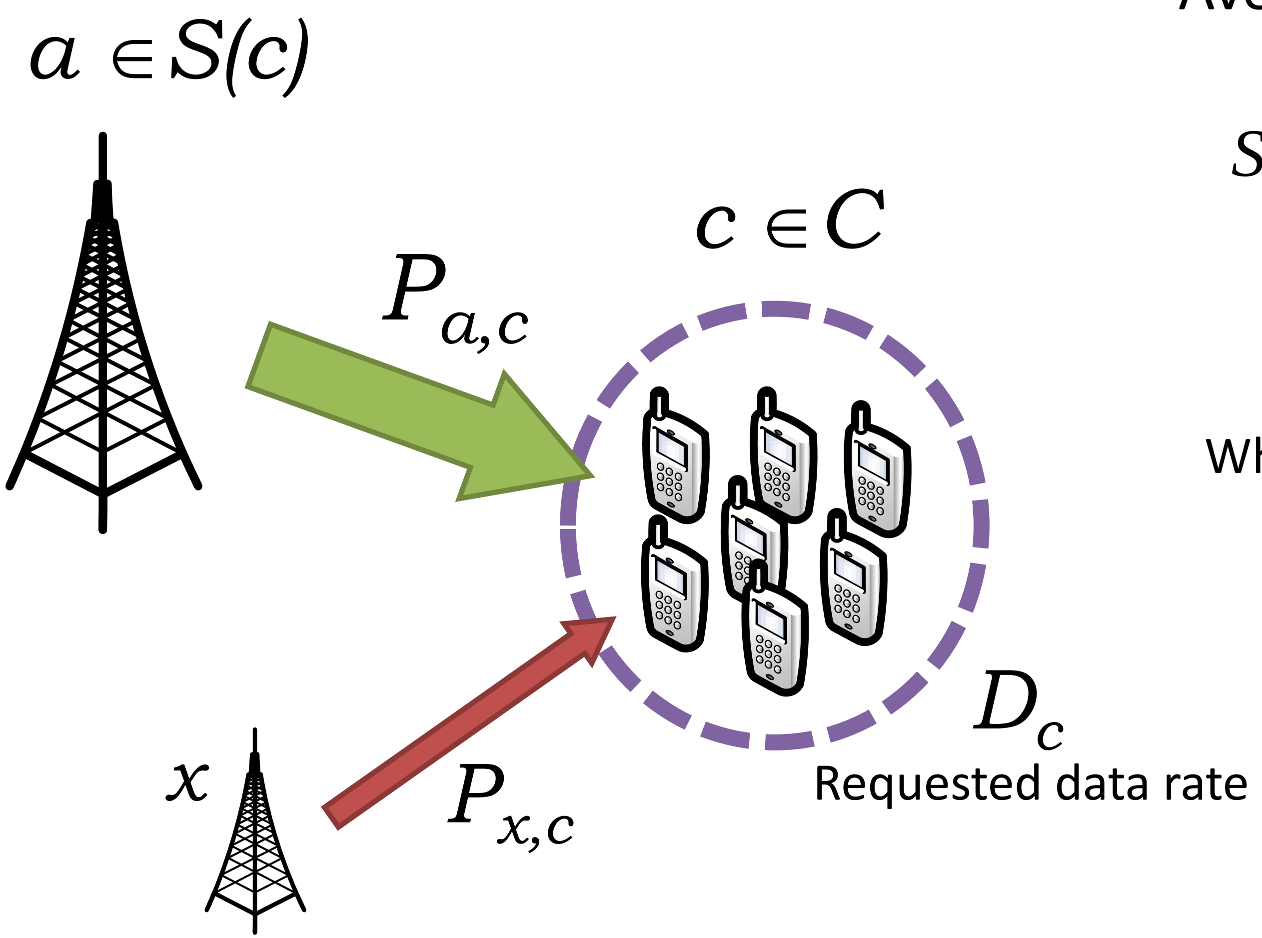
$$p_a = P_a^{base} + P_a^{RB} \cdot n_a$$



Where n_a is the number of allocated RBs

$$n_a \leq M$$

GPM algorithm



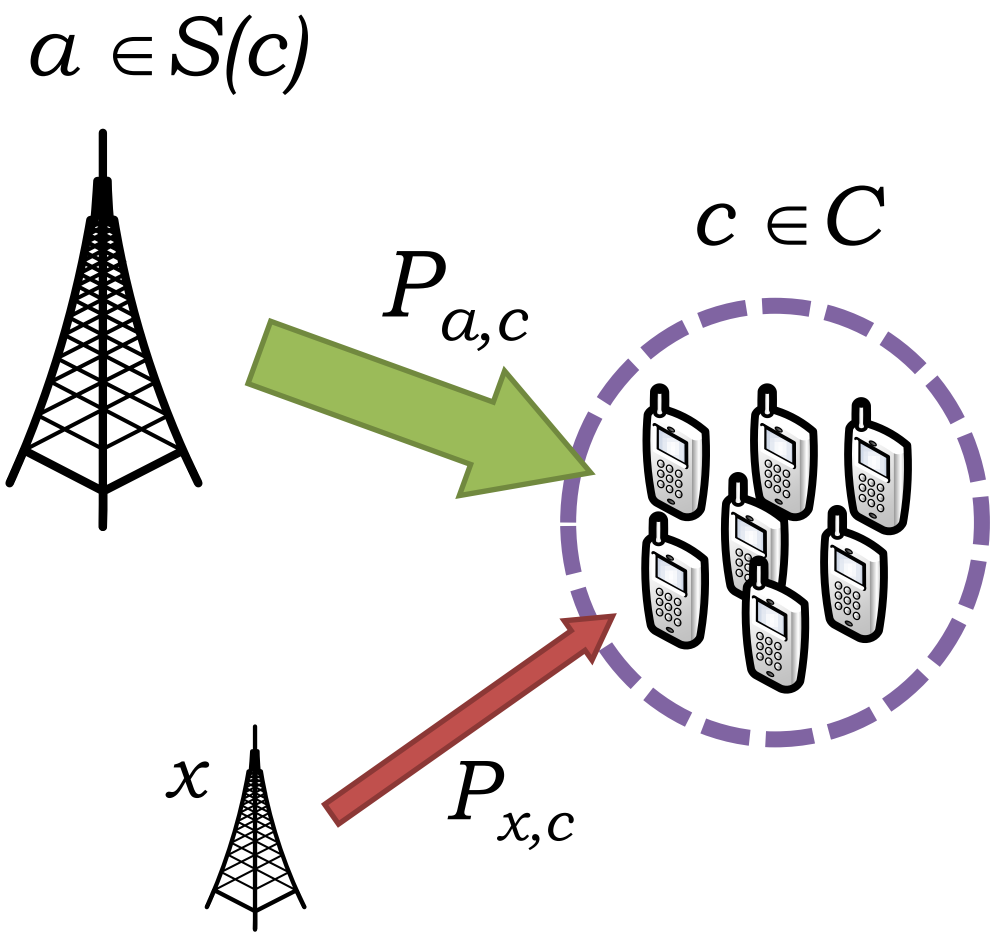
Average SINR perceived by c, from node a:

$$SINR(n)_c^a = \frac{P_{a,c}}{N_G + \sum_{x \neq a} P_{x,c} \Delta_{a,x} / n_a}$$

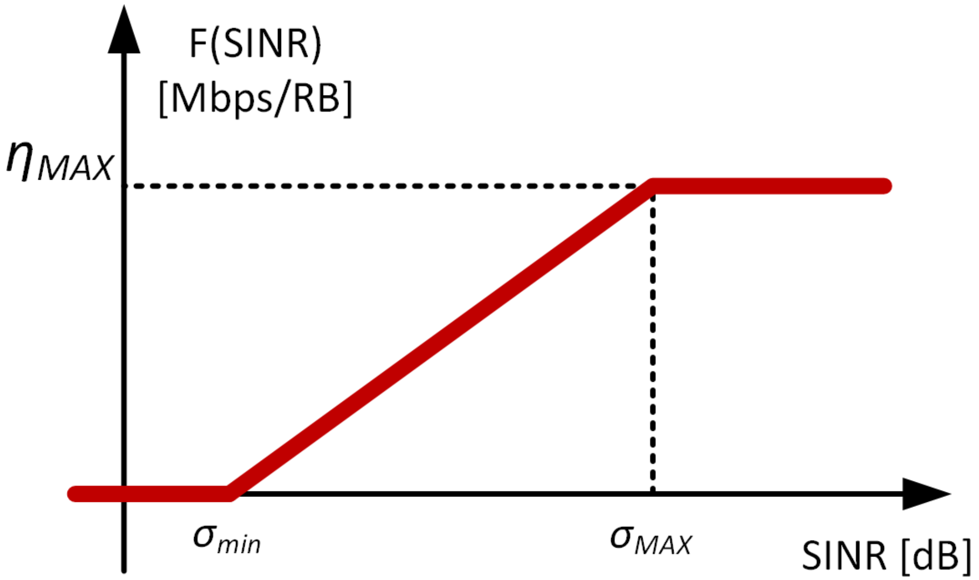
Where the average number of overlapping RBs is:

$$\Delta_{a,x} = (n_a n_x)/M$$

GPM algorithm



We obtain the data rate from the SINR through link-level measurements:



GPM algorithm

- Optimization problem:

$$\min \sum_a P_a^{base} x_a + P_a^{RB} n_a$$

$$\sum_a F\left(SINR(n)_c^a\right) m_c^a \geq D_c \qquad \forall c \in C \qquad (i)$$

$$\sum_c m_c^a \leq n_a \qquad \forall a \qquad (ii)$$

$$0 \leq m_c^a \leq M \qquad \forall (a,c) \in Q \qquad (iii)$$

$$0 \leq n_a \leq M x_a \qquad \forall a \qquad (iv)$$

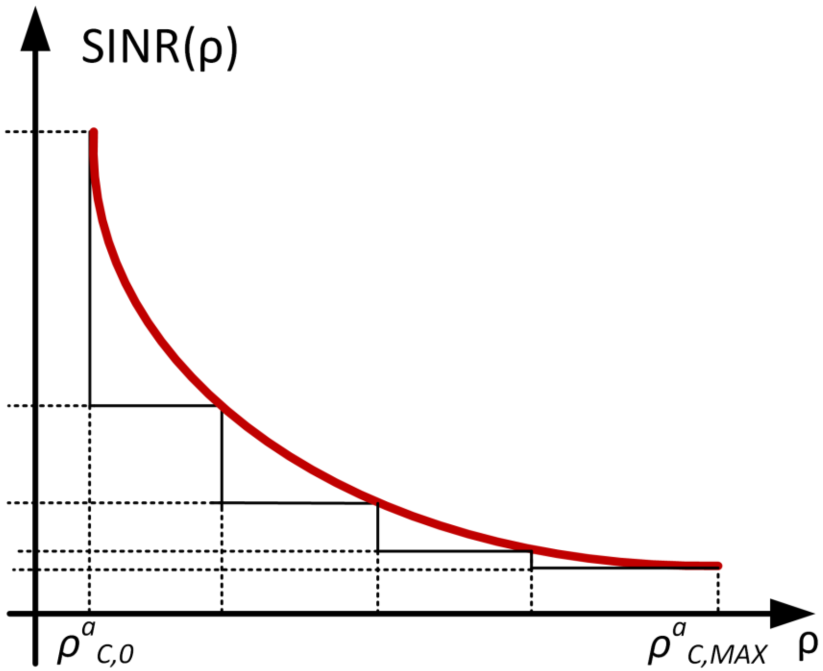
$$x_a \in \{0,1\} \qquad \forall a \qquad (v)$$

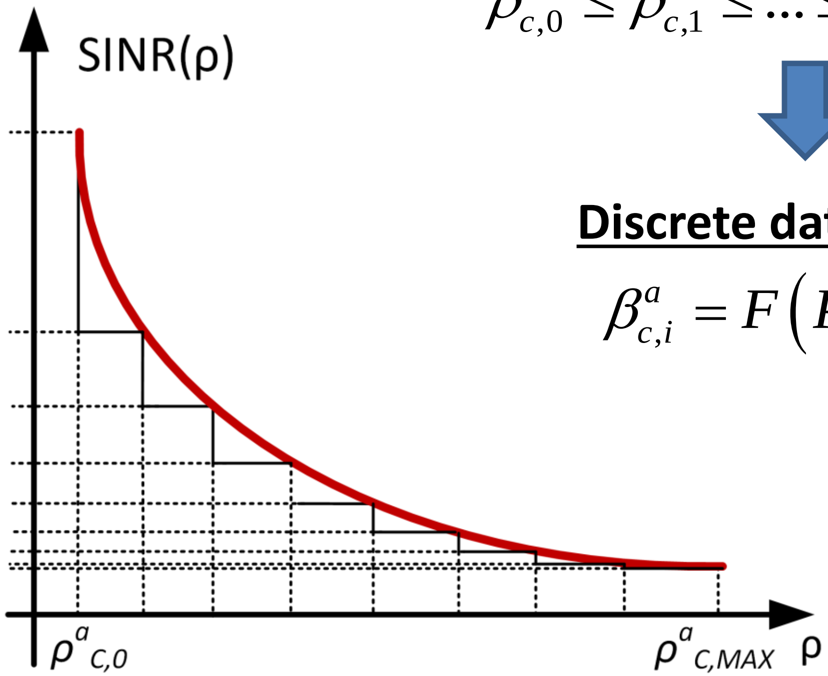
GPM algorithm

- Problem is non-linear and non-convex
- We discretize the interval of possible interference values into K portions

$$SINR(n)_c^a = \frac{P_{a,c}}{N_G + \sum_{x \neq a} P_{x,c} \Delta_{a,x} / n_a}$$

$$\rho_{c,0}^a \le \rho_{c,1}^a \le \ldots \le \rho_{c,k-1}^a \le \rho_{c,\max}^a$$

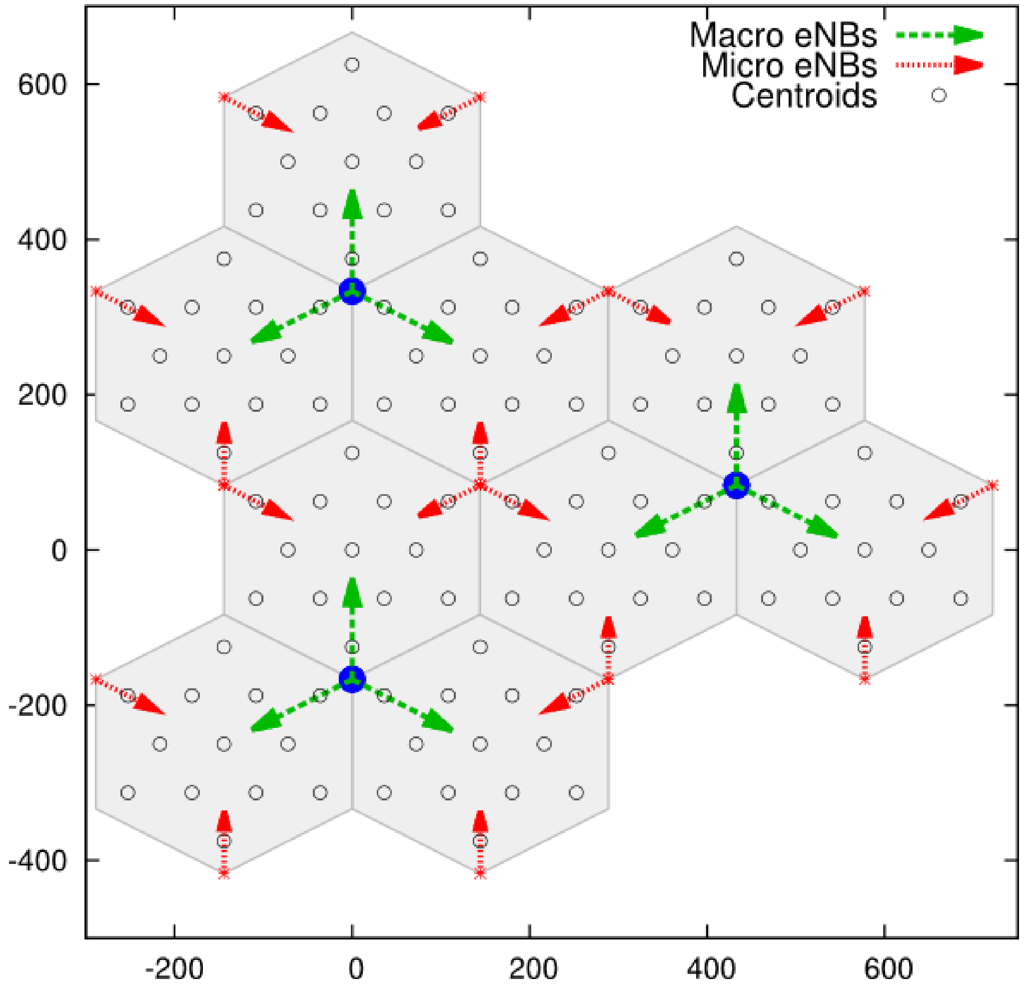




Discrete data rate values

$$\beta_{c,i}^a = F\left(P_a^c / \rho_{c,i}^a\right)$$

Simulation scenario

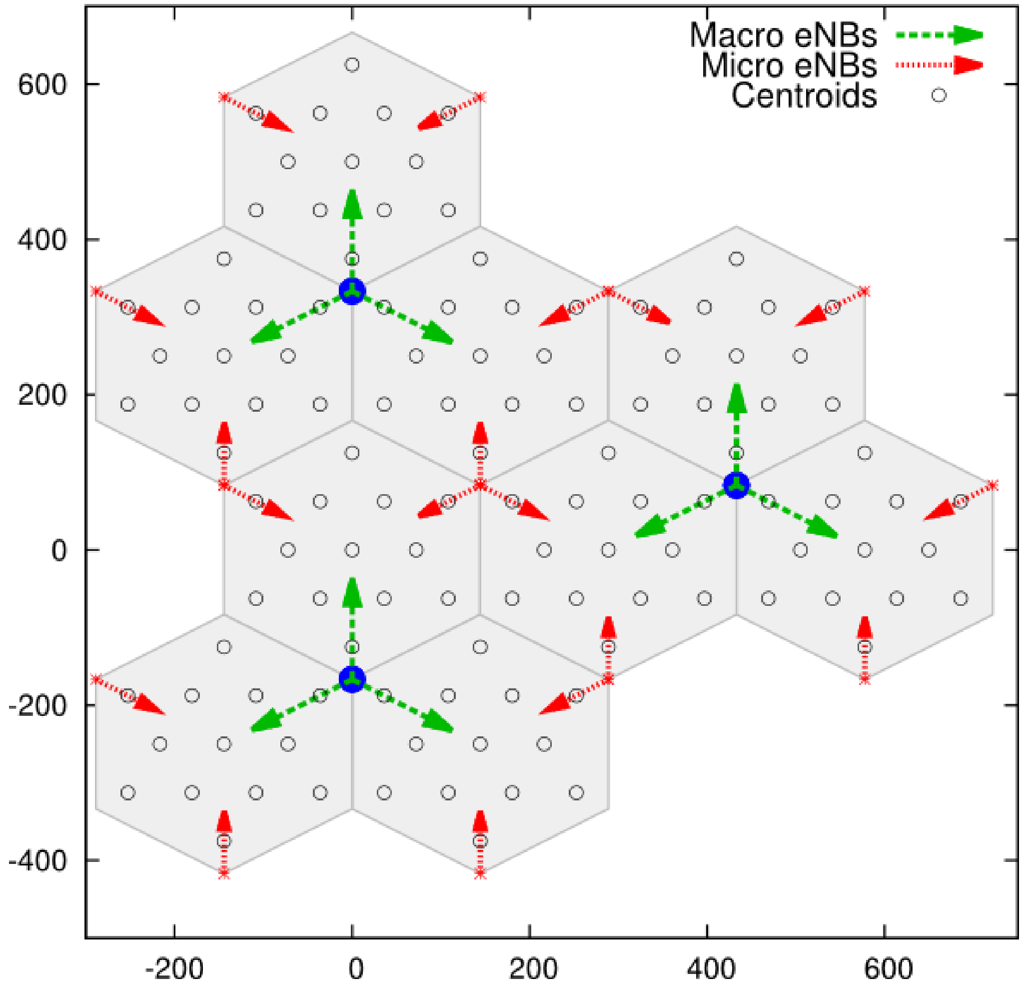


- Each cell hosts 1 macro and 2 micro eNBs
- 50 MHz bandwidth (250 RBs)

Table 1 - Power model parameters

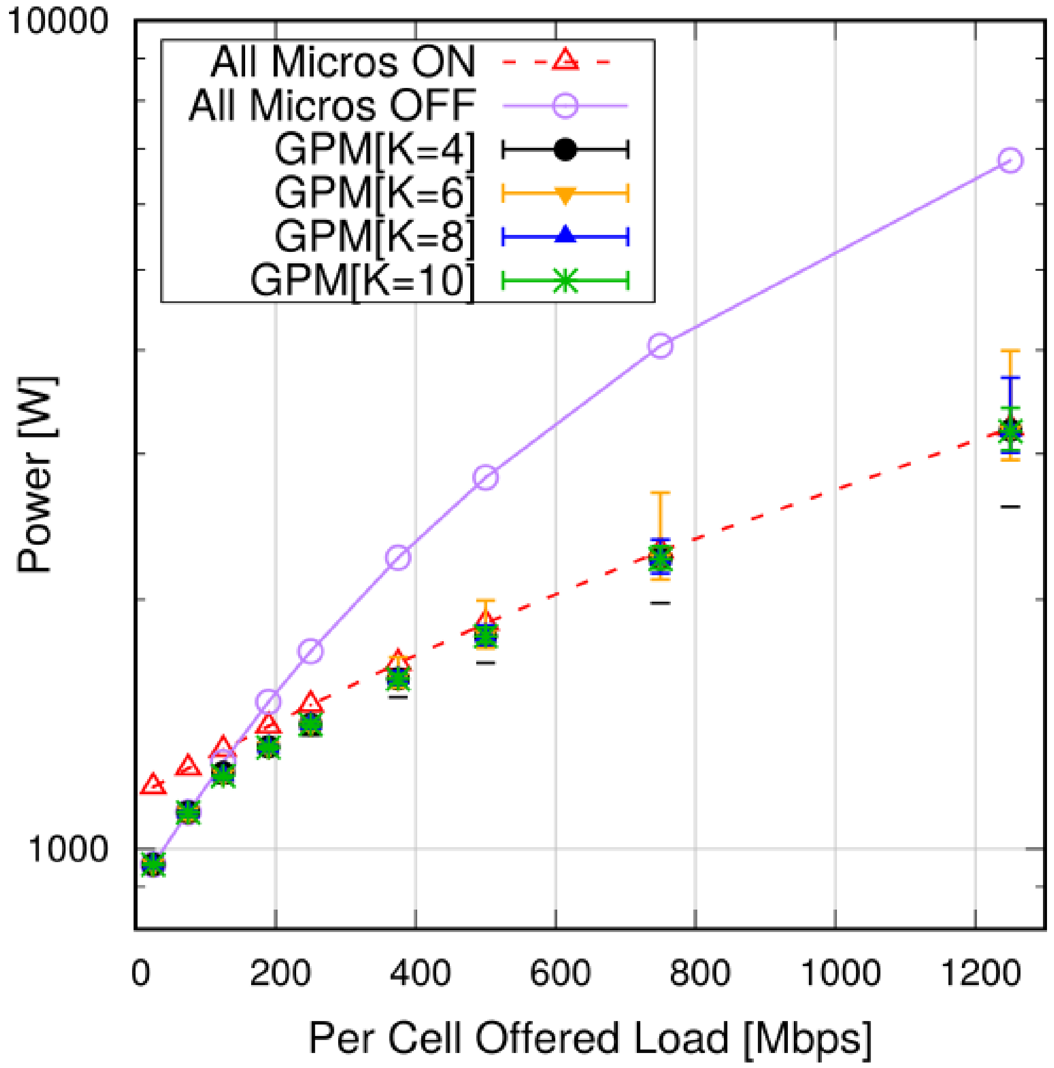
	Macro eNB	*Micro eNB*
Tx Power	46 dBm	38 dBm
Antenna gain	18 dBm	11 dBm
P^{off}	101 W	33.88 W
P^{base}	200 W	48.65 W
P^{RB}	3.332 W/RB	0.384

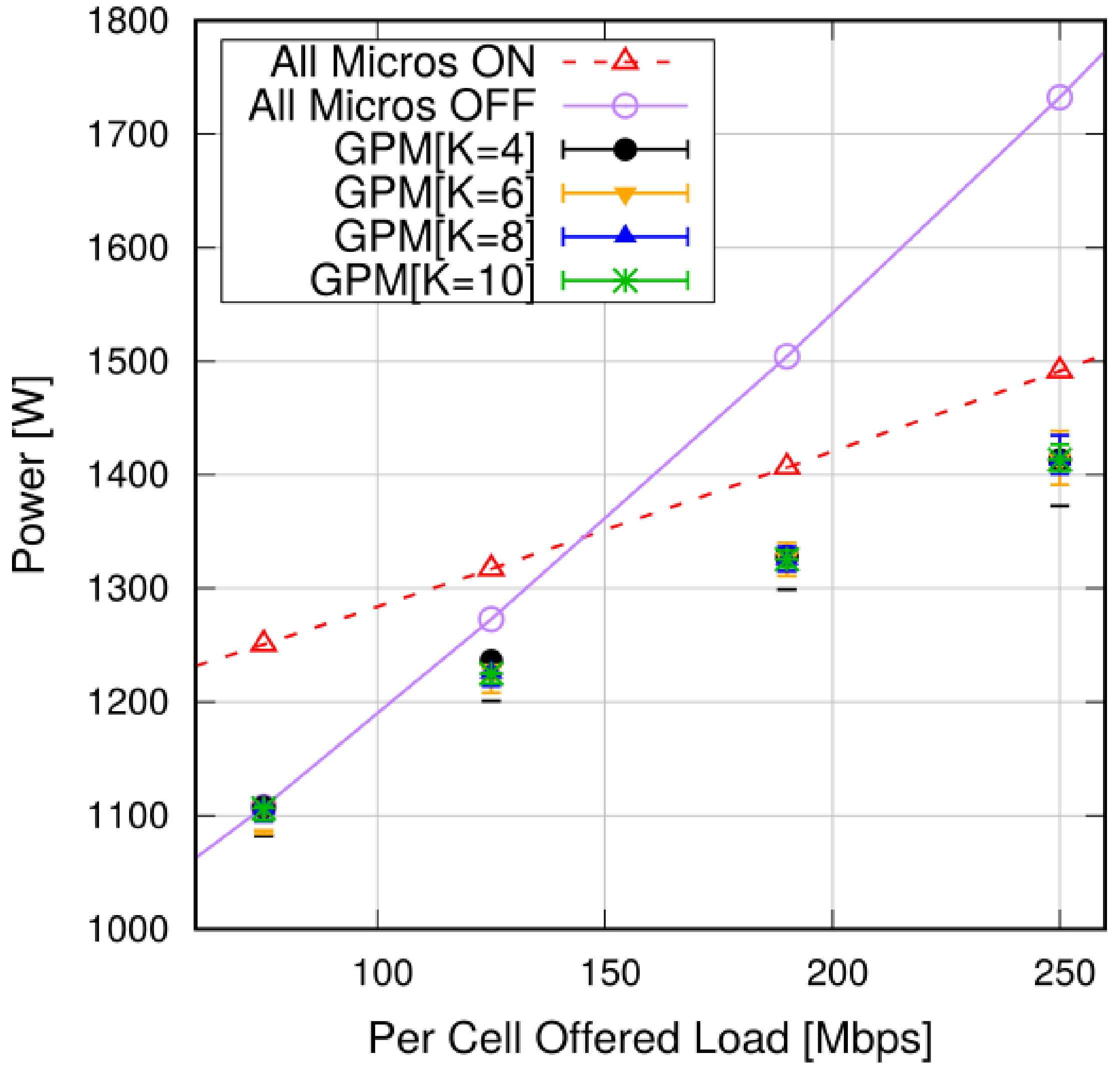
Simulation scenario



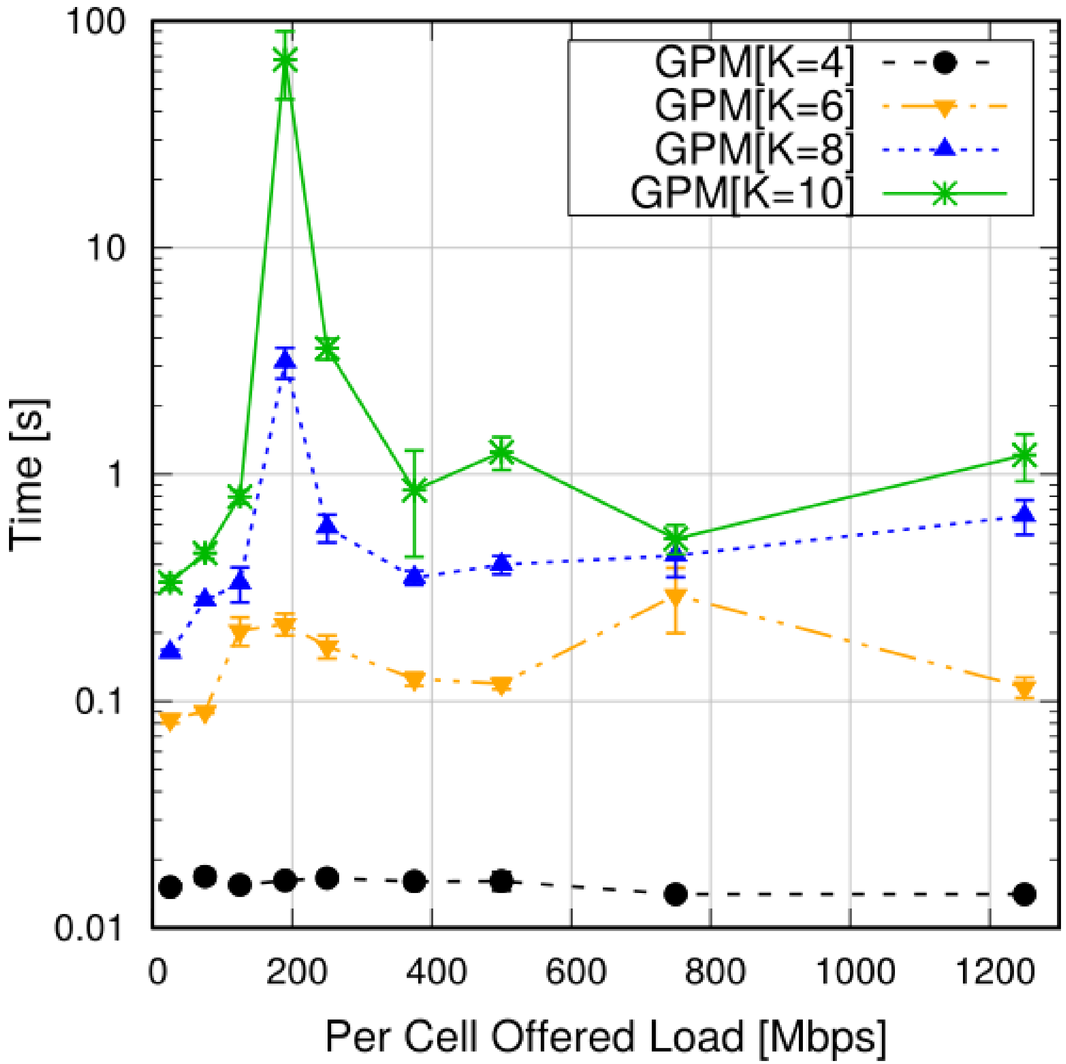
- 2 baselines: micros always on/always off
- Three configurations:
  1. Macros always on and centroids always prefer macros;
  2. Macros always on, centroids can use micros even if macro's signal is better (hence privileging power saving);
  3. Macros can be turned off.
- K=4, 6, 8, 10

Results: power consumption (conf. 1)



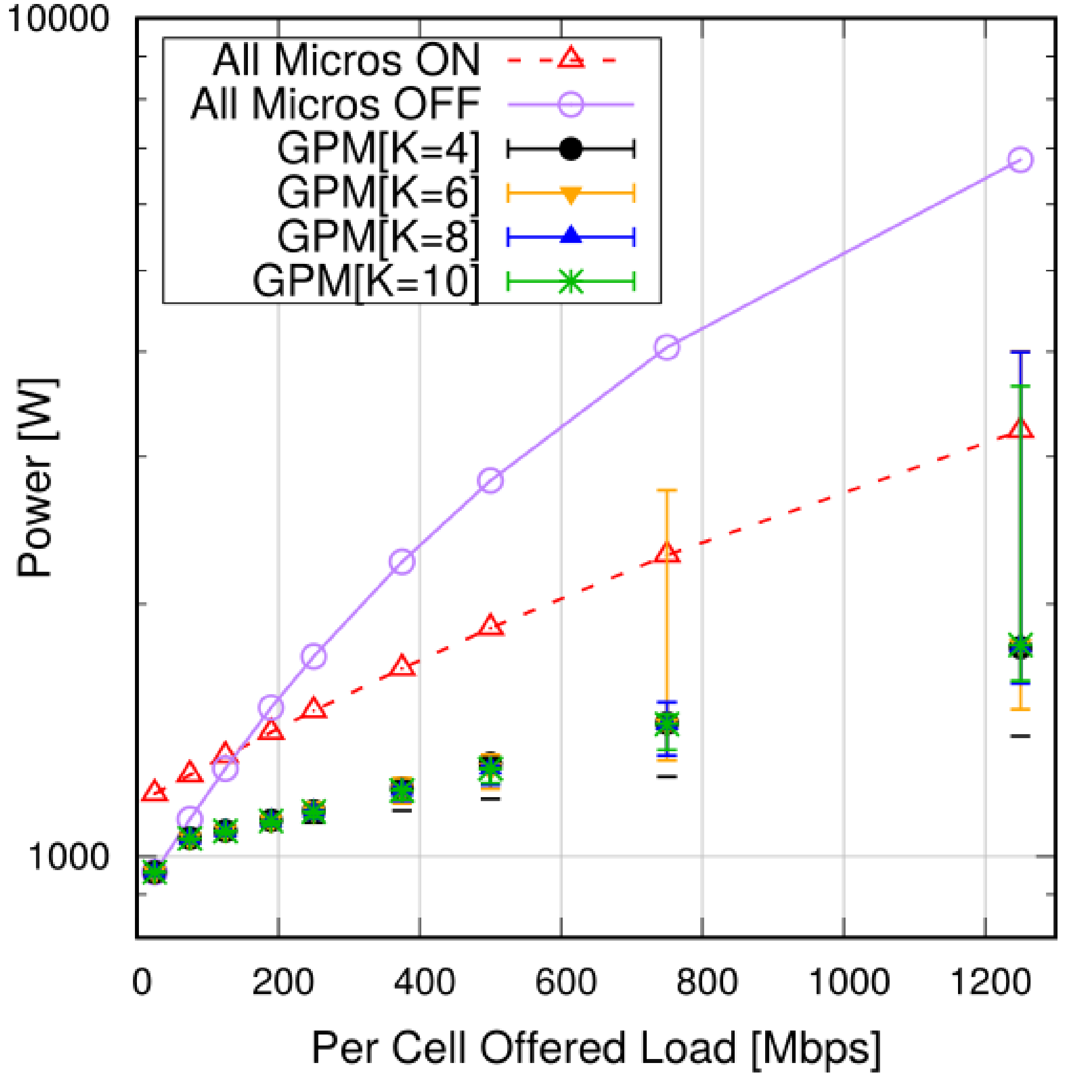


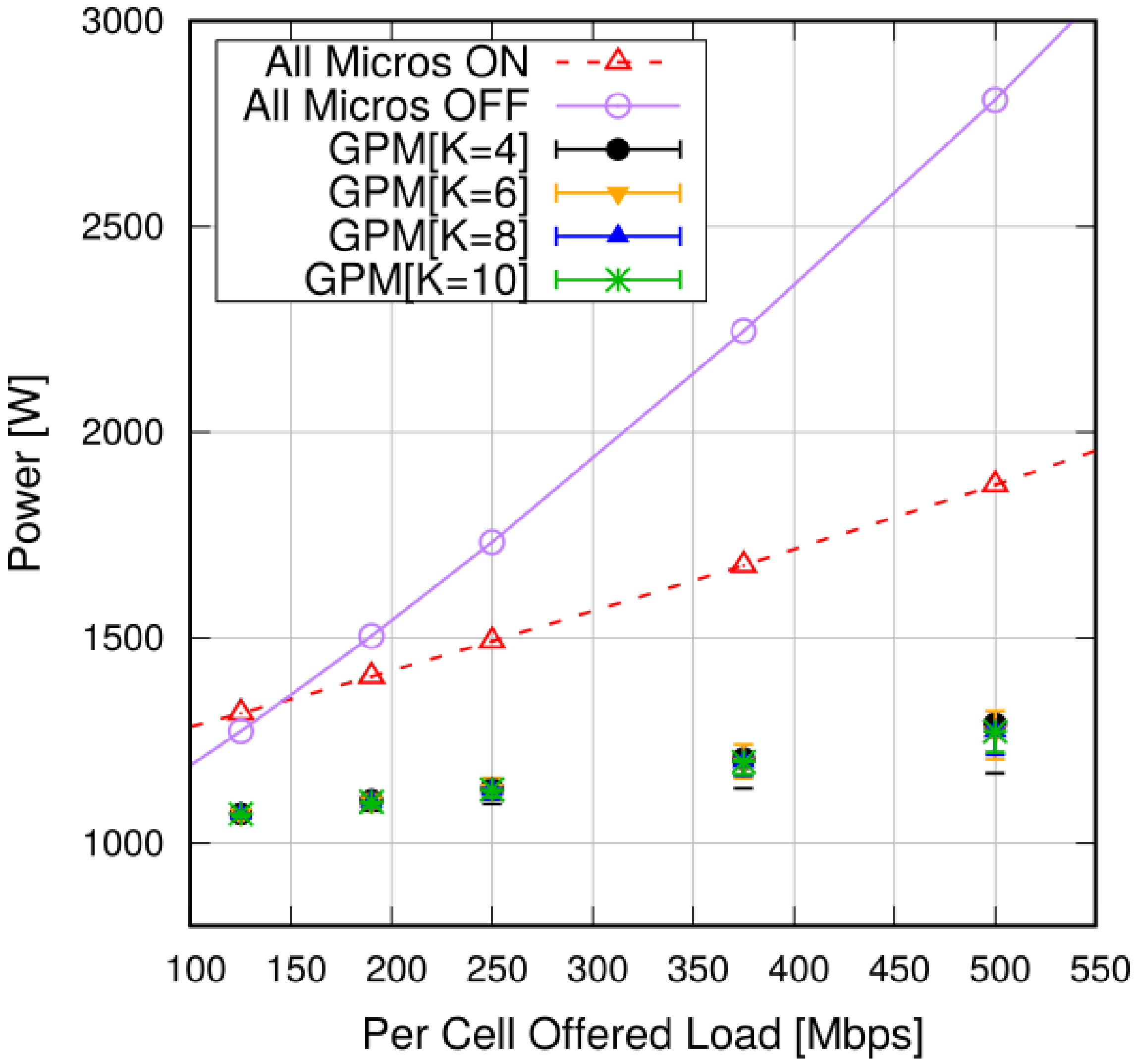
Solving time



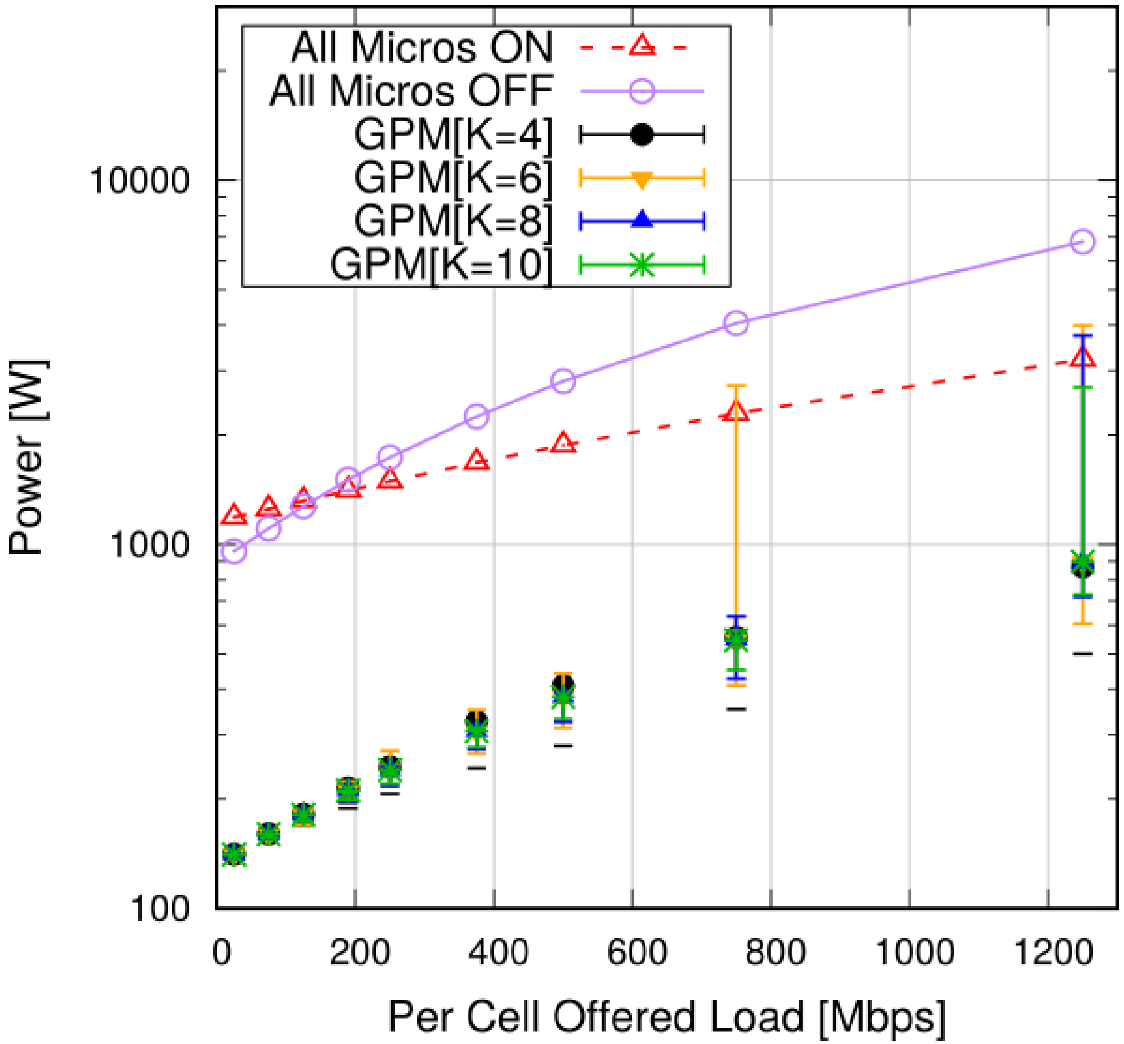
- Average solving time stays below 100 s
- The problem is solvable at the timescales the GPM is meant to run

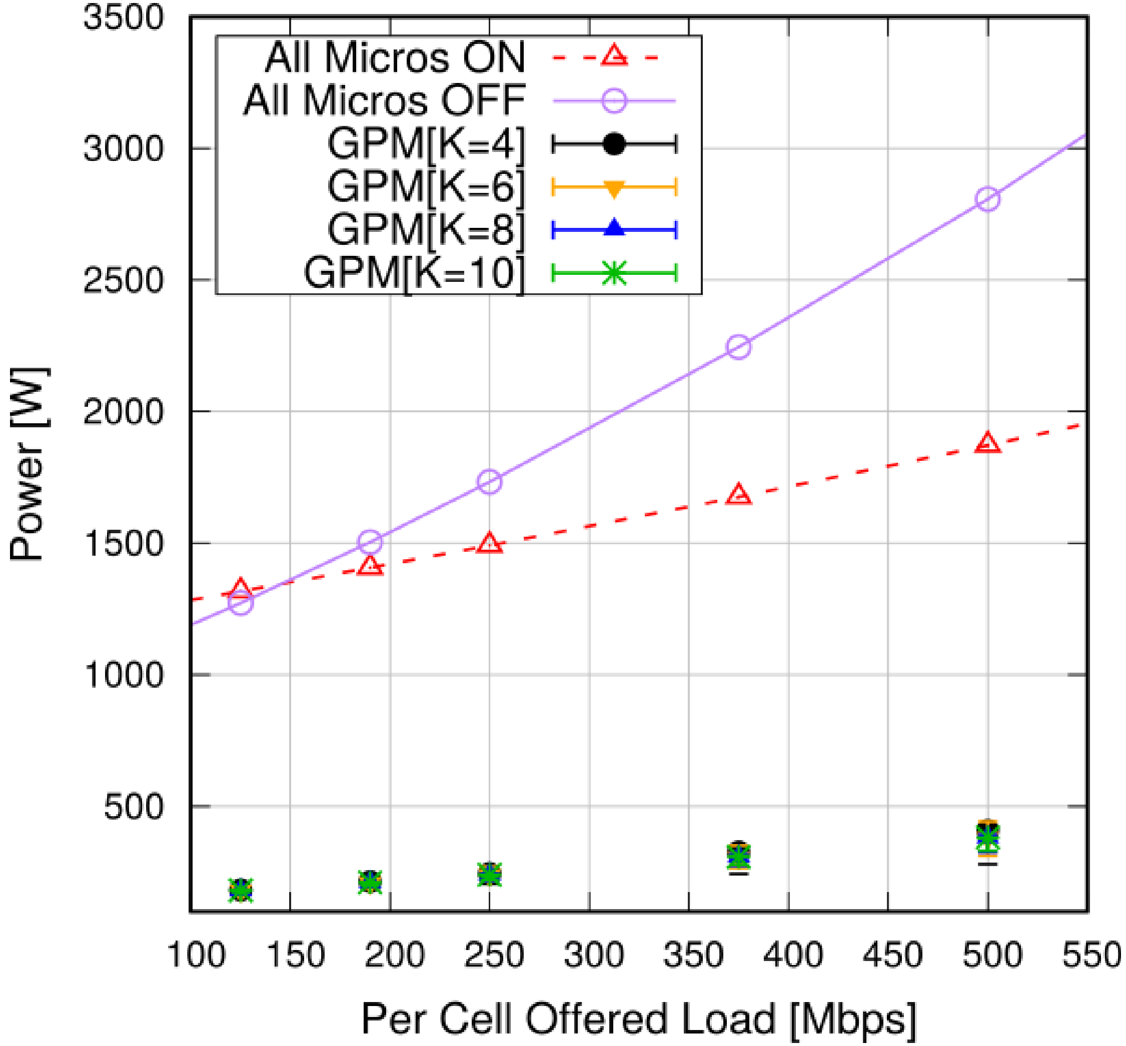
Results: power consumption (conf. 2)



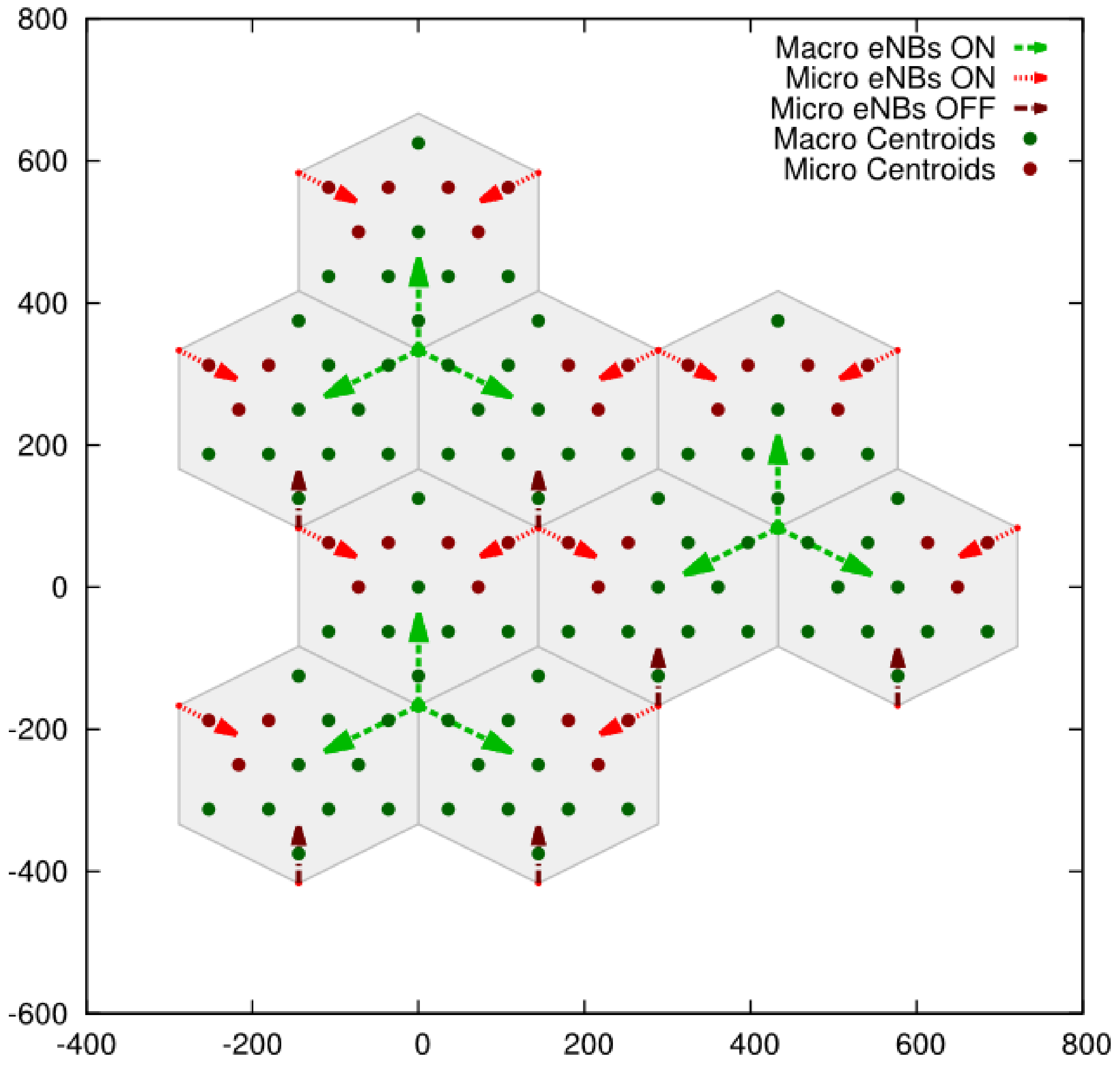


Results: power consumption (conf. 3)



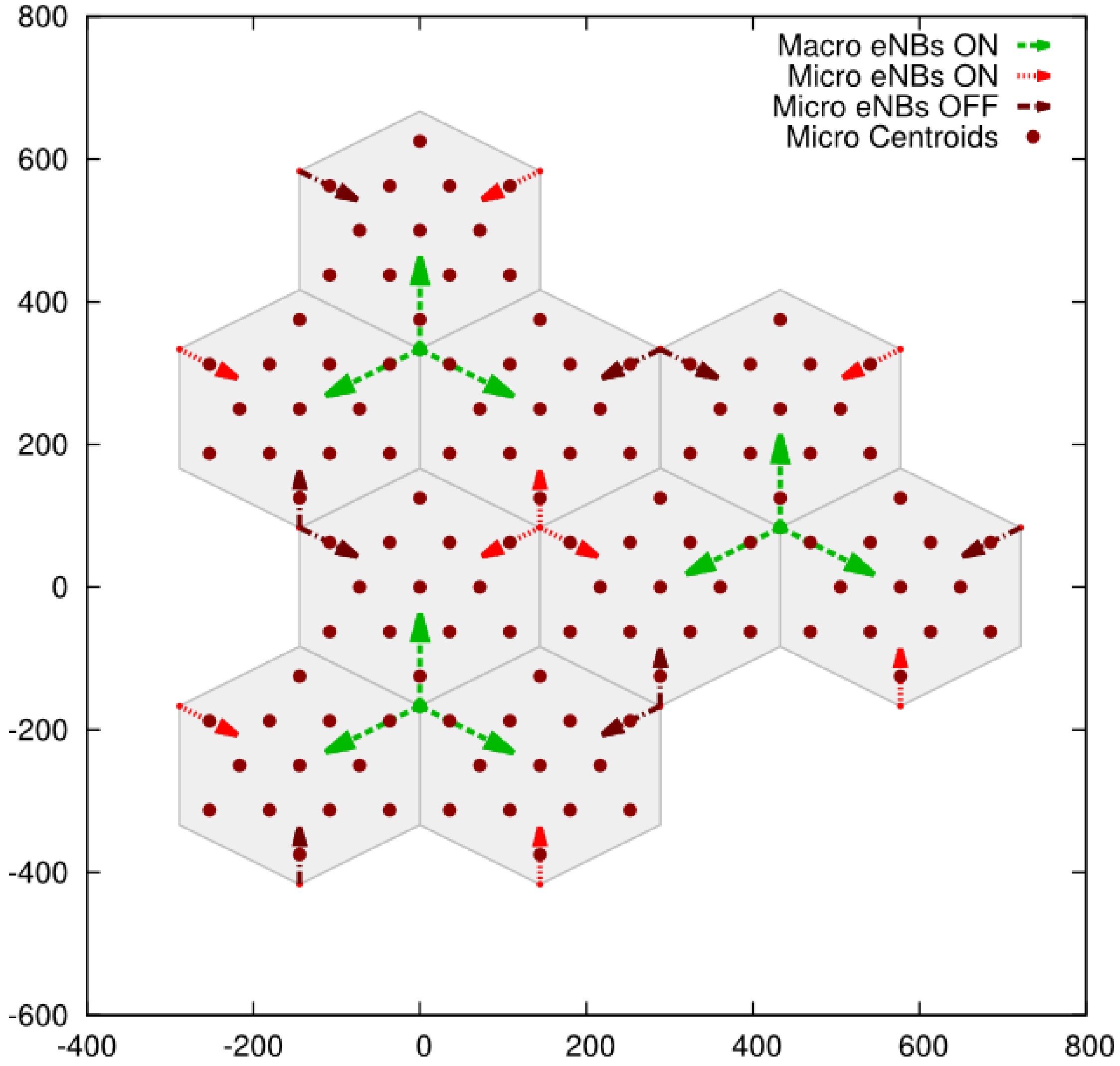


Activation patterns



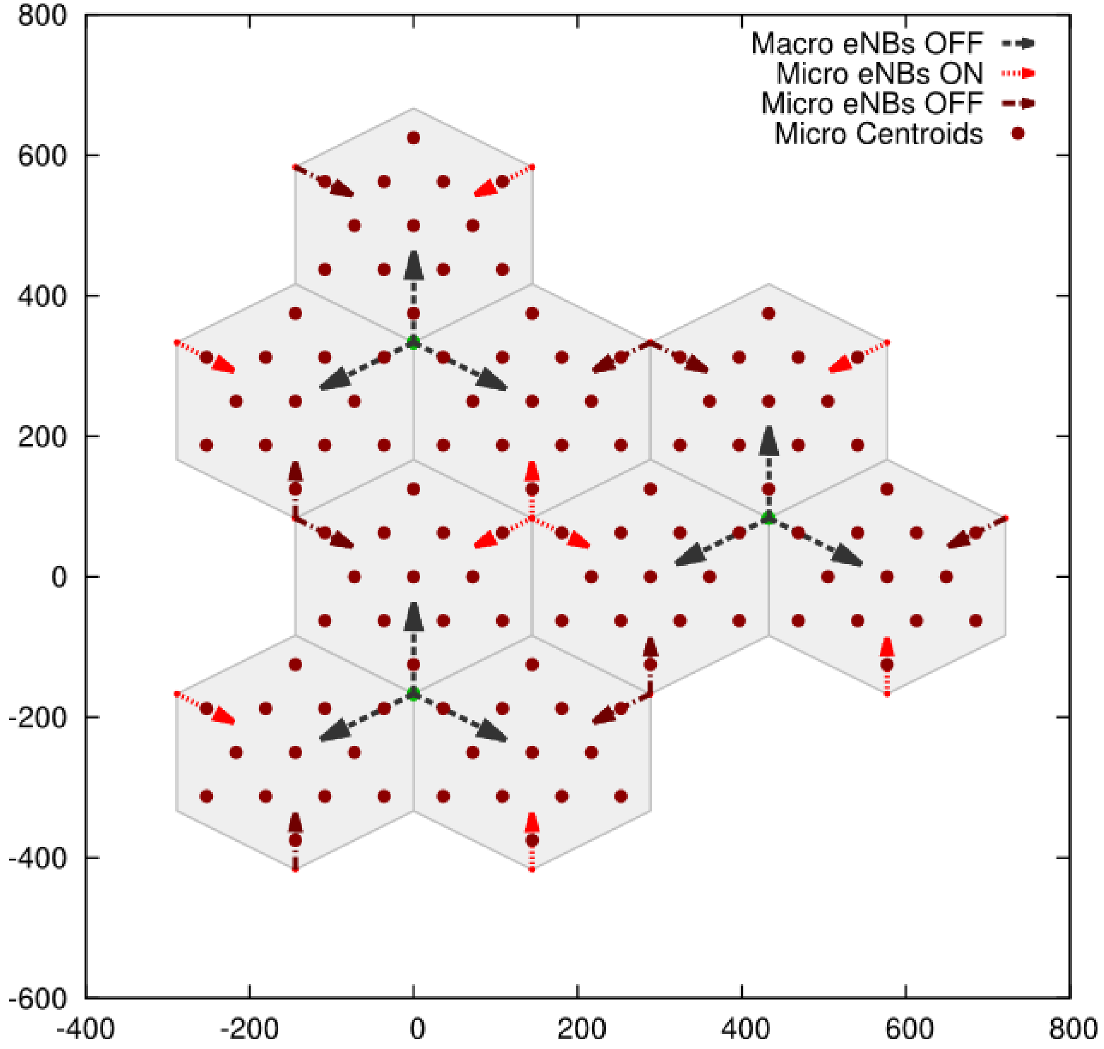
- Config 1
  - All macros on
  - Some micros on
  - Centroids prefer macros
  - Centroids use micros only when close

Activation patterns



- Config 2
  - All macros on
  - Some micros on
  - Centroids prefer micros
  - All centroids use micros

Activation patterns



- Config 3
  - Macros can be turned off
  - Centroids prefer macros
  - All macros are off

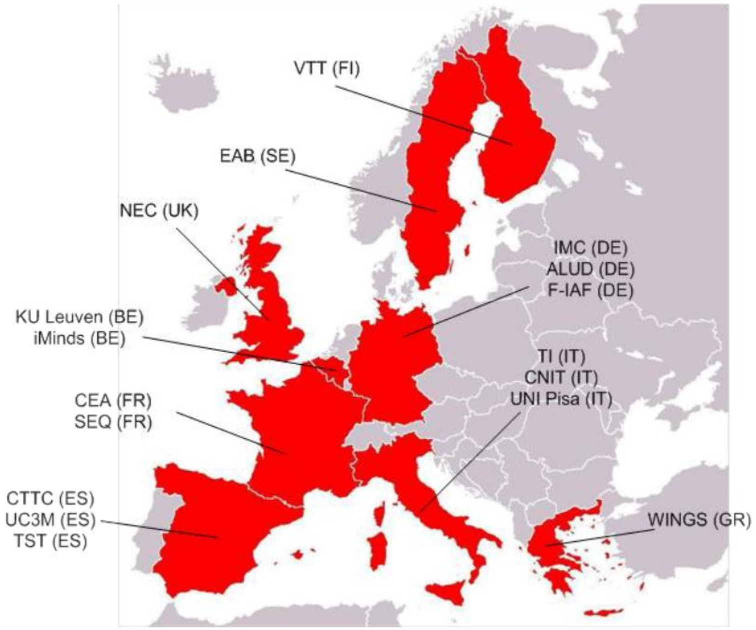
Conclusions

- We presented a framework for power optimization of virtualized cellular networks
- We presented an algorithm based on an optimization model
- Our results show that:
  - The solution time for the optimization model is affordable
  - The framework discovers and applies the min-power configuration at various loads in hetnet deployments
  - Power saving depends on configuration, and is major if macros can be turned off when load is low

Flex5Gware https://www.flex5gware.eu

«Flexible and efficient hardware/software platforms for 5G network elements and devices»

- Project number: 671563
- Project Coordinator: Intel
- Technical Management: CTTC
- Call / topic: H2020-ICT-2014-2 /ICT-14-2014Objective 1.1
- Duration: 24 months
- Start: 01 July 2015



- Industry partners
  - Intel Mobile Comm. (DE)
  - Alcatel Lucent (DE)
  - Ericsson (SE)
  - NEC (UK)
  - Telecom Italia (IT)
- Research institutes
  - CEA (FR)
  - CNIT (IT)
  - CTTC (ES)
  - Fraunhofer Institut (DE)
  - iMinds (BE)
  - VTT (FI)
- SMEs
  - Sequans (FR)
  - TST Sistemas (ES)
  - WINGS (GR)
- Universities
  - KU Leuven (BE)
  - Univ. Carlos III de Madrid (ES)
  - University of Pisa (IT)

HORIZON 2020

Thanks for your attention!

Università di Pisa

Questions?

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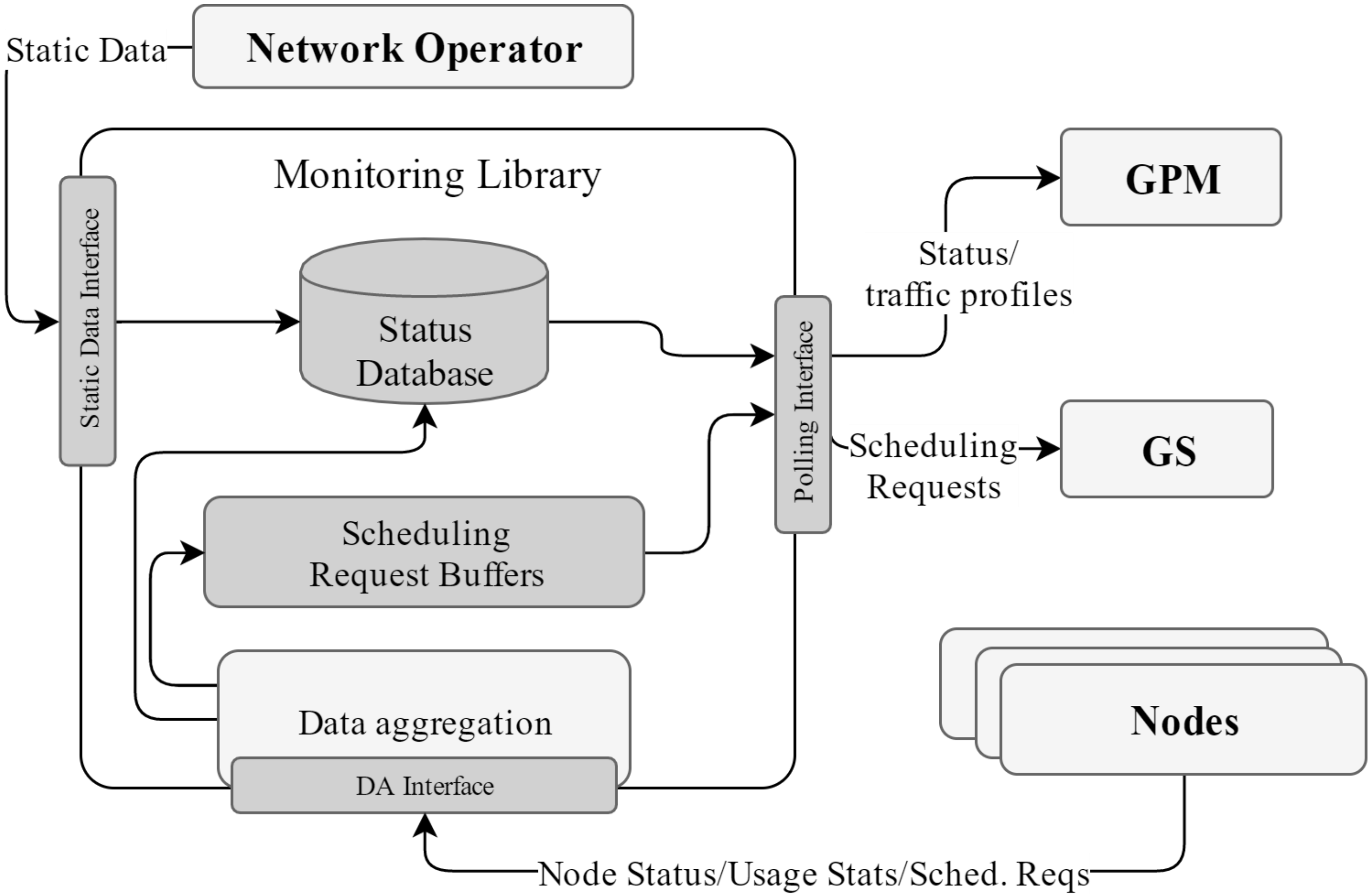
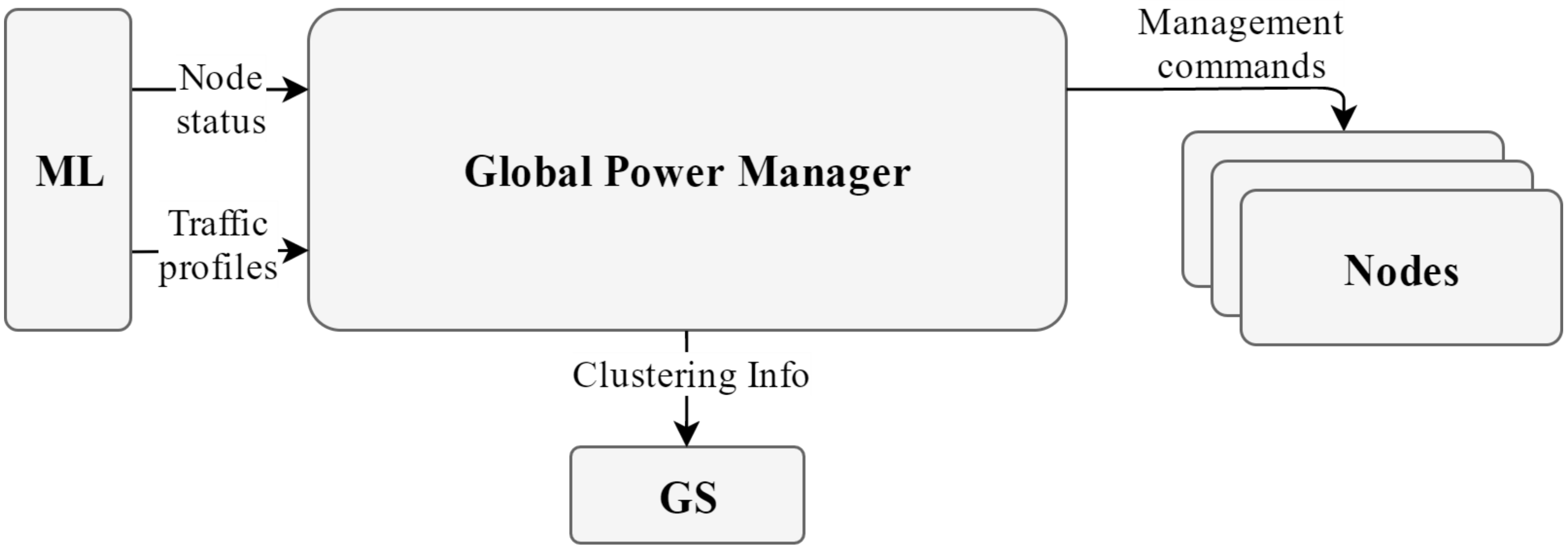
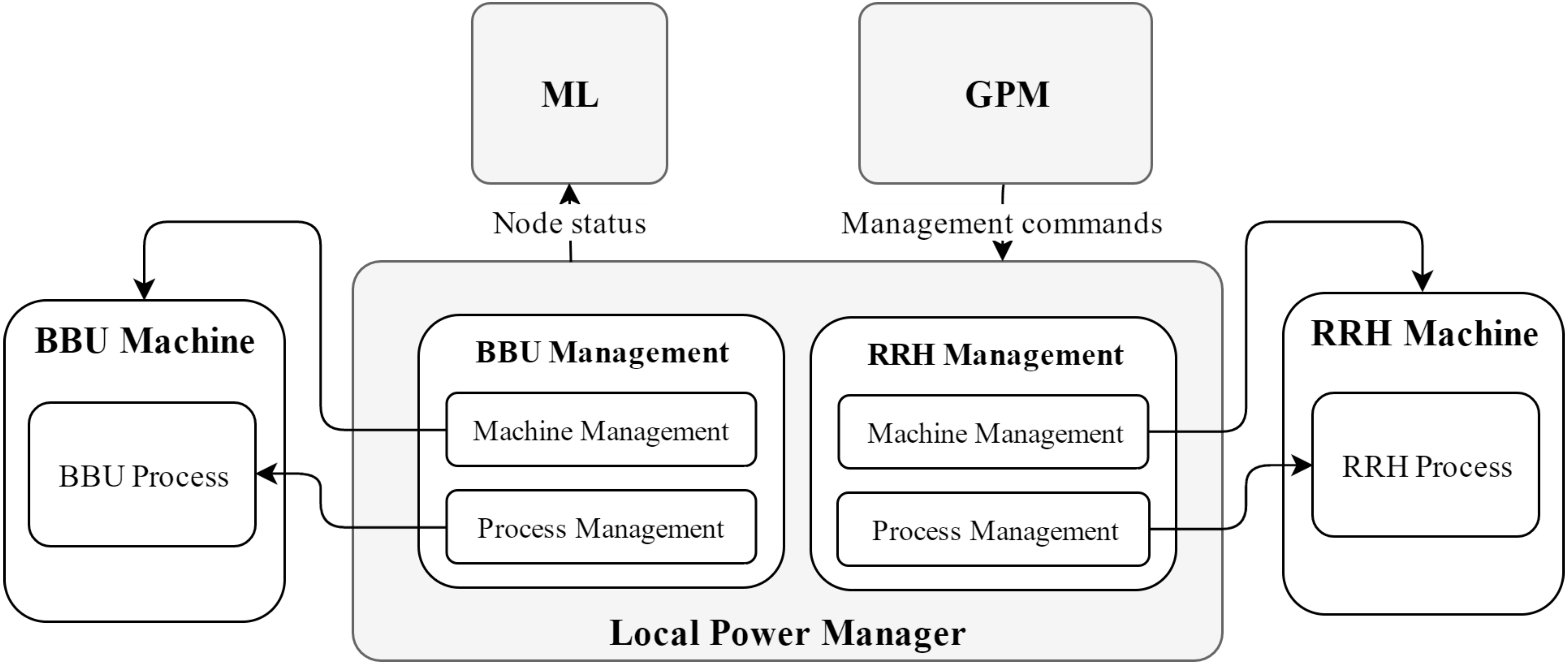
Monitoring Library



Global Power Manager



Local Power Manager



Local Power Manager