A Mixed Criticality Approach for Industrial Smart Energy Management and Demand Response

Laurent George

Laurent.George@esiee.fr

RTSOPS'2017 - Dubrovnik

UNIVERSITÉ PARIS-EST

Gaspard - Monge Laboratoire d'informatique

ESIEE PARIS

Energy efficiency in factories

- At European level: H2020 Call on Factory of the Futur (FoF)
- In Germany: Industry 4.0
- In France: Industry of the futur, Alliance: Fives, Schneider Electric, Dassault Systèmes, EADS, Astrium
- In US:
  - Industrial Internet Consortium (General Electric, IBM and Intel)
  - 20 top US industries have at least 12GW of load flexibility [2]
- 4th industrial revolution (Forum on sustainable economy at Davos, 20 - 23 Jan. 2016)
  - Energy transition : change centralized energy production models to a distributed sustainable energy model

Applications of Energy Efficiency

Building Automation

Smart City

Smart Lighting

Smart Grids

Micro smart Grid

Factory of the future

Distributed Energy sources ?

Many existing solutions:

- Solar
- Wind
- Co-generation
- Energy Harvesting (Vibration, piezo, thermic, RF, …)
- Battery

Problem with distributed energy sources:

- Fluctuation of power supply
- Need for efficient power forecasts

A new Energy Paradigm based on Demand Response

Legacy energy providers use demand response to shape energy pics at country level to reduce energy costs

How ?

- Ask their clients (factories in our case) to reduce their power consumption for a given time, clients are paid for reducing their power consumption
- Use Demand Response to ask their clients if they can reduce their power consumption
- Clients can use their local sustainable energy (wind, solar, battery,…) during demand response to maintain their activity

A new Energy Paradigm based on Demand Response

Problems to be solved:

- How to decide on-line if a power reduction in my factory is possible and for how long ? DR deadline in the order of 10 min to 1 hour
- How to adapt current production to satisfy the new power constraint ?
- Determine which scheduling decisions should be taken in the factory to satisfy the level of power requested by legacy energy provider upon demand response

If local distributed energy is available (out of the scope of this presentation):

- Characterize power demand curves of production lines (based on IoT)
- Characterize power Supply functions of sustainable energy sources

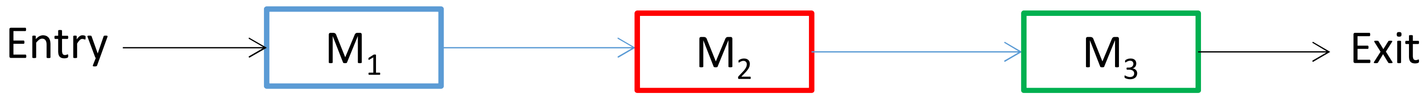
A new Energy Paradigm based on Demand Response

Is Automatic Demand Response possible ?

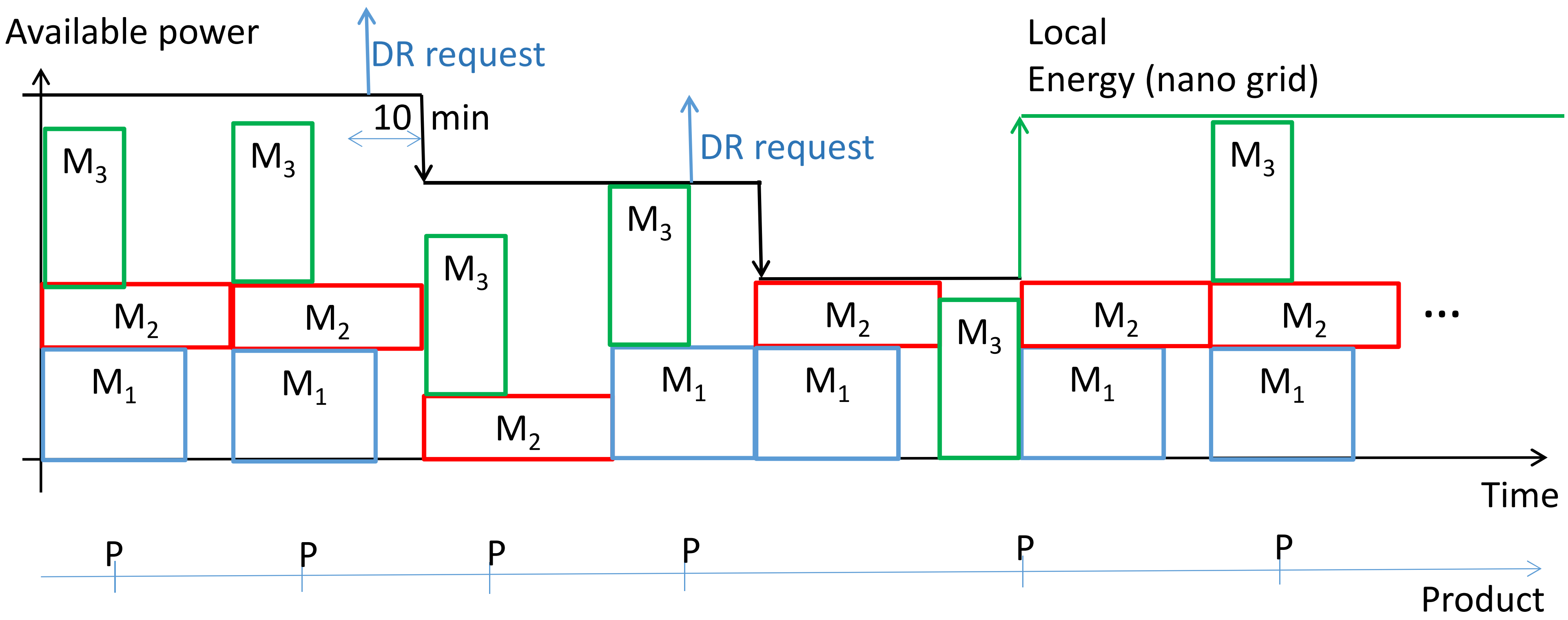
- New protocol: OpenADR (Open Automatic Demand Response)
- Social network approach for energy negotiation in a factory (an equipment can twit to negotiate with others)

Energy efficiency scheduling problem

A simple example of a production line (tasks of same criticality):

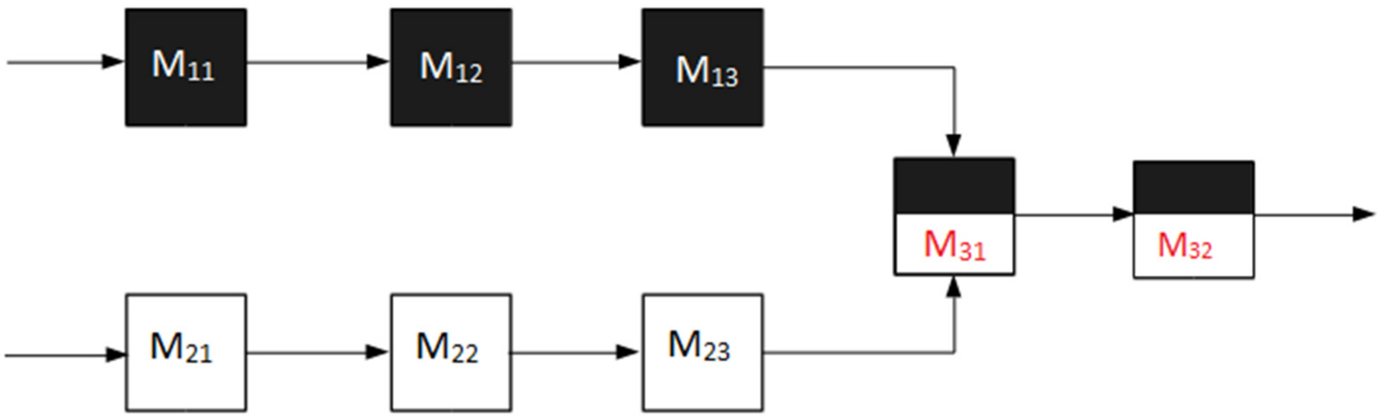


Energy consumption problem: maximize production rate under power constraints



Energy efficiency scheduling problem

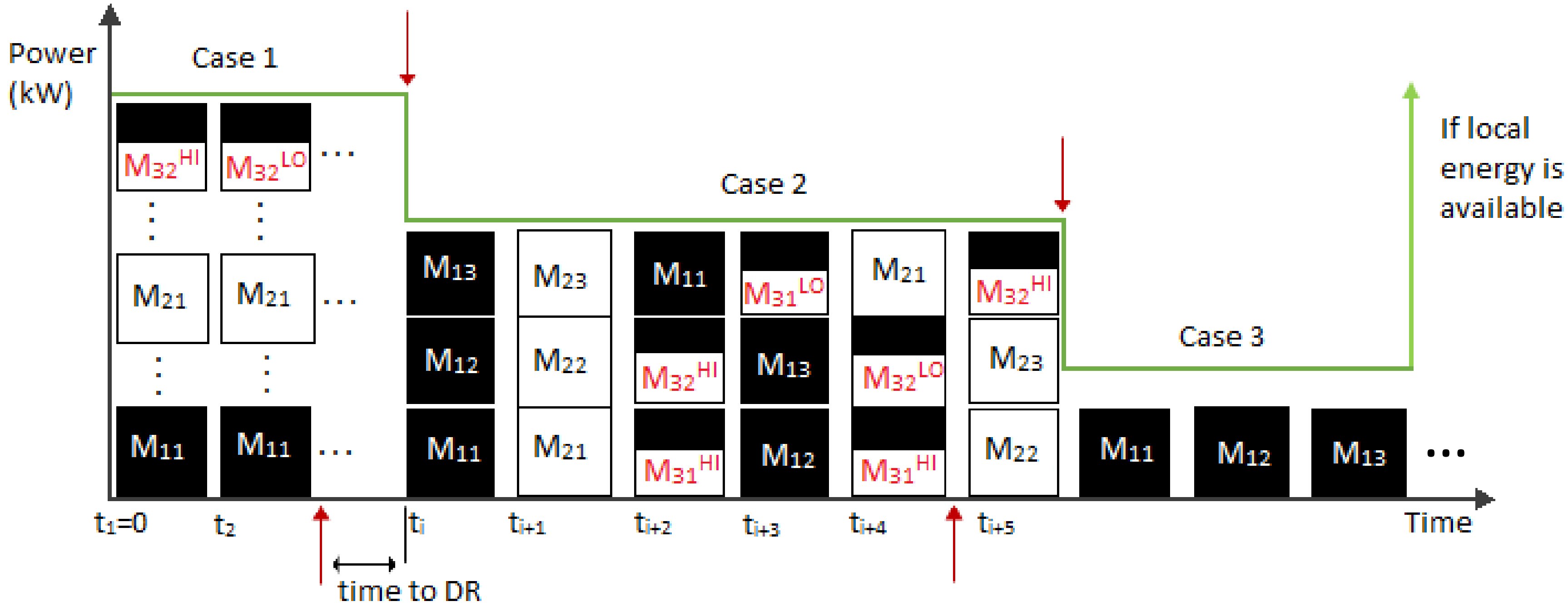
A multi-criticality production line:



- Machine M_{11}, M_{12}, M_{13} produce HI-Crit product
- Machine M_{21}, M_{22}, M_{22} produce LO-Crit product
- Machine M_{31}, M_{32} can produce HI-Crit or LO-Crit products

Energy efficiency scheduling problem

Adaptation of the production line to DR:



- Case 1, Case 2 and Case 3 are possible steady states
- Problem to be solved:
  - How to find the steady state maximizing HI-Crit production for a given power constraint ?
  - How to Adapt on-line the production line to go from one steady state to another so as to maximize HI-Crit production and satisfy DR Deadline?

Energy efficiency scheduling problem

One solution for steady states: scheduling tables

	Time	M_{11}	M_{12}	M_{13}	M_{21}	M_{22}	M_{23}	M_{31}^{HI}	M_{31}^{LO}	M_{32}^{HI}	M_{32}^{LO}
Case 1	t_1	1	1	1	1	1	1	1	0	1	0
	t_2	1	1	1	1	1	1	0	1	0	1
	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
Case 2	t_i	1	1	1	0	0	0	0	0	0	0
	t_{i+1}	0	0	0	1	1	1	0	0	0	0
	t_{i+2}	1	0	0	0	0	0	1	0	1	0
	t_{i+3}	0	1	1	0	0	0	0	1	0	0
	t_{i+4}	0	0	0	1	0	0	1	0	0	1
	t_{i+5}	0	0	0	0	1	1	0	0	1	0

Problem: How to find a consistent path from one scheduling table to another ?

Energy efficiency scheduling problem

Conclusion

- DR is a new approach to reduce power consumption at country level
- Requires to rescheduling the activity in a factory
- DR has a deadline ranging from 10 min to 1 hour
- Steady states for given power consumption can be defined
- Open problem: how to move on-line from one steady state to another in a time less or equal to the DR deadline