10th International Conference on Mobile and Ubiquitous Systems: Computing, Networking and Services, 02 December, 2013, Tokyo, Japan

Modelling Energy-Aware Task Allocation in Mobile Workflows

Bo Gao and Ligang He

Department of Computer Science, University of Warwick, UK

THE UNIVERSITY OF WARWICK

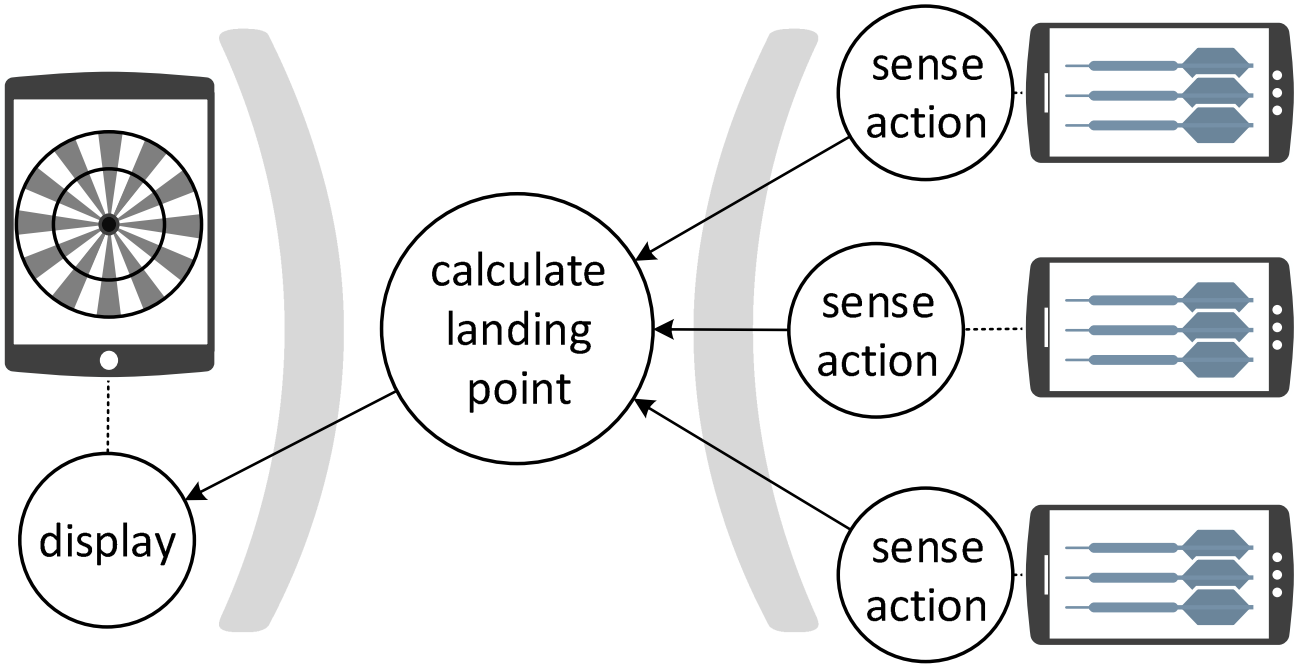
Rise of the Smart-Devices (Battery Limited)

2001	• Nokia 8310,		830mAh
	• Ericsson T68,		650mAh
2003	• Sony Ericsson P900:	156MHz	1000mAh
2005	• Nokia N91,	220 MHz	900mAh
2007	• Blackberry 8800:	312MHz,	1400mAh
	• iPhone 1:	412MHz,	1400mAh
2009	• HTC Hero:	528MHz,	1350mAh
	• Palm Pre:	600MHz,	1150mAh
2013	• Sony Z1:	Quad-Core 2.2GHz,	3000mAh
	• iPhone 5S:	Dual-Core 1.3GhZ,	1560mAh
		(iPad Air	8820mAh)

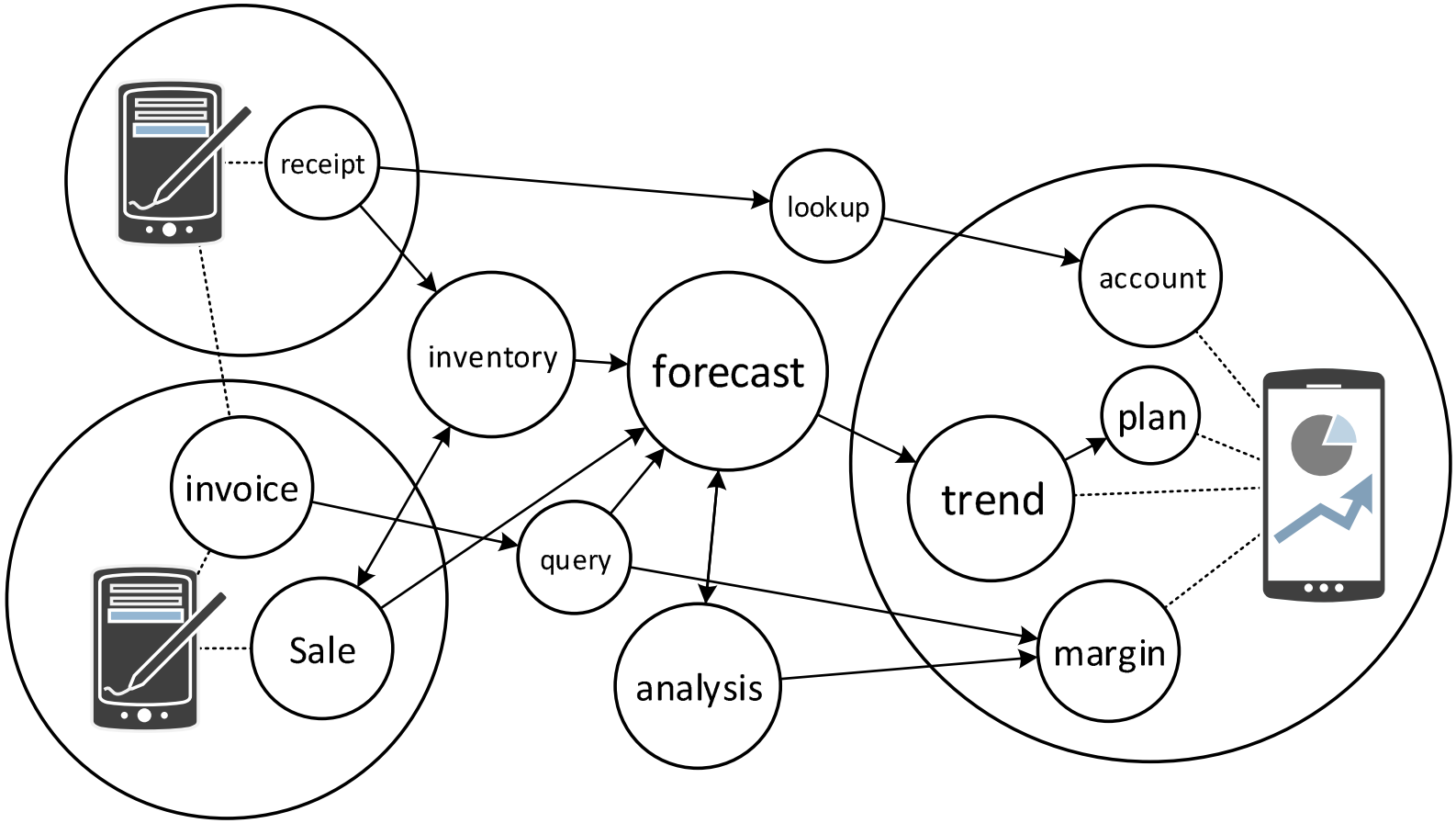
Battery Management Tools

- Hardware
  - Fast Charging
  - Energy-Efficient Processors, Displays
  - New Chemical Compound?
- Software
  - Energy Profiling
    - PowerTop, Trepn Profiler, PowerTutor, AppScope, etc.
  - Workload Offload
    - Cuckoo, CloneCloud, MAUI, etc.

Mobile Workflow Example 1



Mobile Workflow Example 2



Energy Model

Given an allocation scheme $\psi : T \rightarrow M$, we first derive the energy cost of computing $t_a, a \in \{1, \ldots n\}$ to be

$$\mathcal{E}^{cmp}_{a\psi(a)} = e^{cmp}_{\psi(a)} \times \frac{c_a}{s_{\psi(a)}} \tag{1}$$

where $\psi(a)$ is the device to which t_a is assigned. Secondly, we have the energy cost of transferring d_{ab}, $(t_a, t_b) \in R$ as

$$\mathcal{E}^{tran}_{ab\psi(a)\psi(b)} = \underbrace{e^{snd}_{\psi(a)} \times \frac{d_{ab}}{b_{\psi(a)\psi(b)}}}_{\text{sender's cost}} + \underbrace{e^{rcv}_{\psi(b)} \times \frac{d_{ab}}{b_{\psi(a)\psi(b)}}}_{\text{receiver's cost}} \tag{2}$$

Formulation

To represent an allocation scheme ψ, we first construct an $n \times m$ binary matrix $X = (x_{ai})$, such that

$$x_{ai} = \begin{cases} 1 & \text{if } \psi(a) = i, \\ 0 & \text{otherwise.} \end{cases} \tag{3}$$

We call matrix X an **assignment matrix** and a **valid** assignment must satisfy the following constraints

$$\sum_{i=1}^{m} x_{ai} = 1, \quad a = 1, 2, \ldots, n, \tag{4}$$

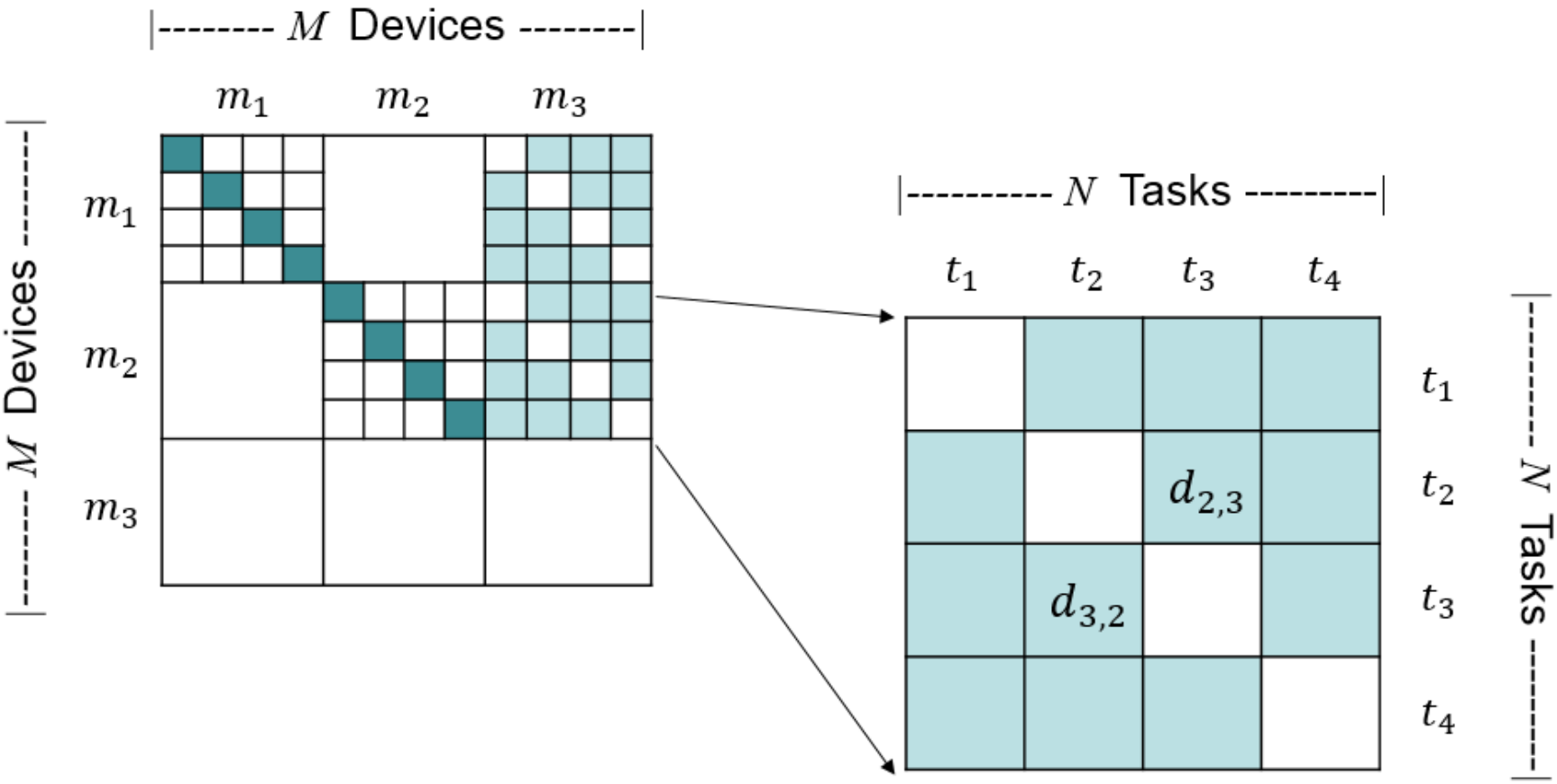
$$x_{ai} \in \{0, 1\}, \quad a = 1, 2, \ldots, n, \quad i = 1, 2, \ldots, m. \tag{5}$$

Formulation (cont.)

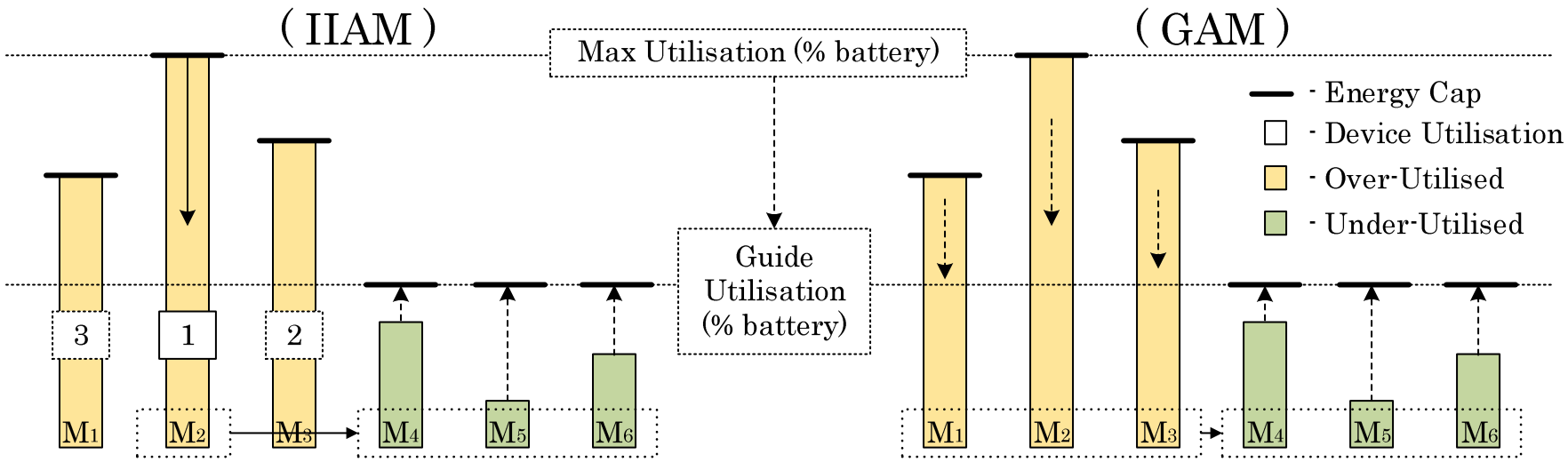
Let coefficients q_{aibj} *be the entries of an* $mn \times mn$ *matrix* Q*, such that* q_{aibj} *is on row* $(i-1)\,n + a$ *and column* $(j-1)\,n + b$*, and* $x = vec(X) = (x_{11}, x_{12}, \ldots, x_{1n}, x_{21}, \ldots, x_{mn})^T$ *be the vector formed from the columns of* X*. Equivalent formulations for the minimum workflow energy cost problem's objective function are given by* (8) *and*

$$vec\,(X)^T\, Q\, vec\,(X) \tag{9}$$

Coefficient Matrix Q



Adjustment Algorithms

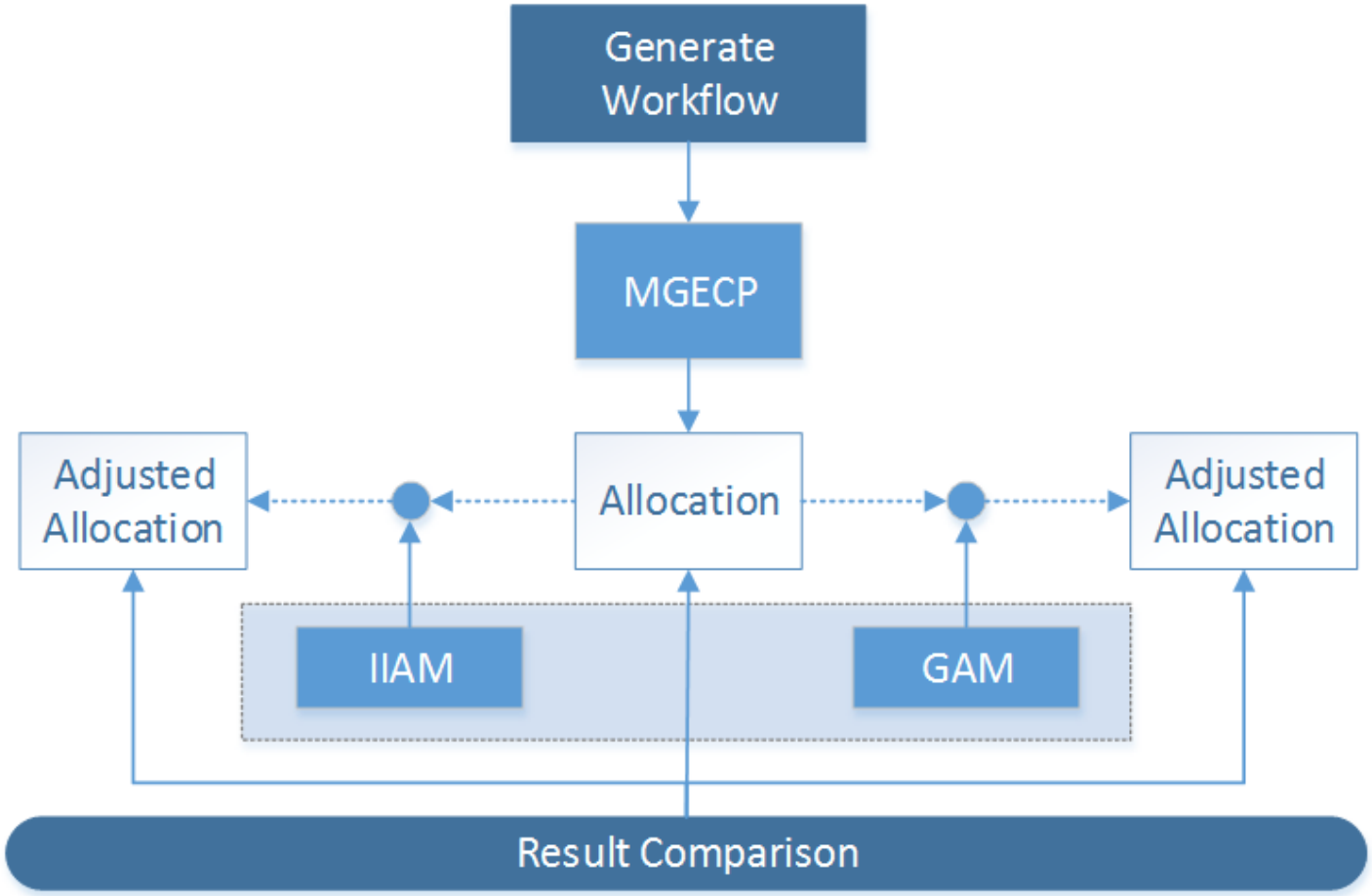


Simulation Definition

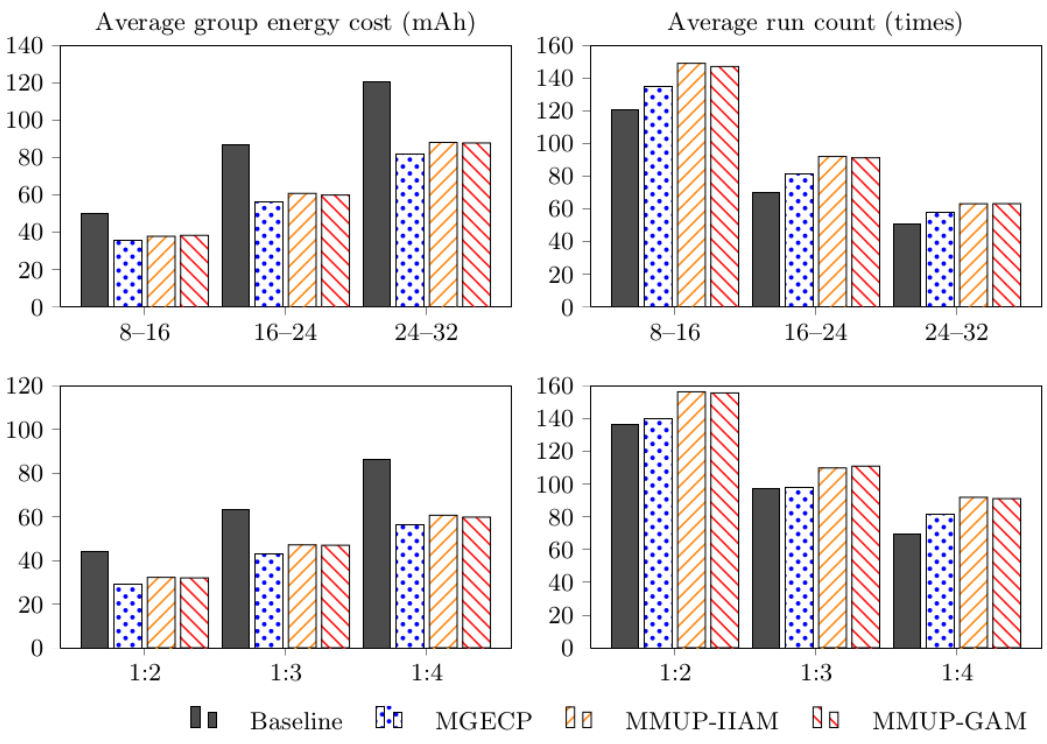
Definition 3.
A **typical mobile device** has a battery capacity of 2000mAh, draws a current of 250-400mA during data transmission and 100-200mA when executing local computation tasks.

Definition 4.
A task has a **unit workload** if its execution takes 1 second to complete on a typical device.

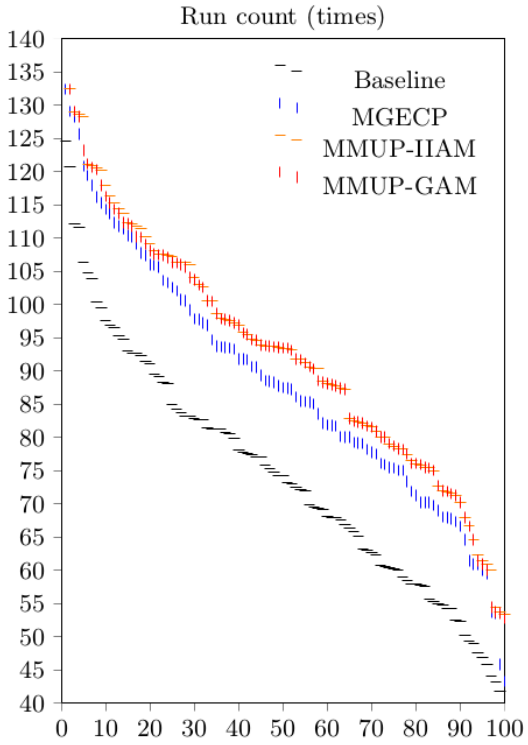
Simulation Definition (cont.)



Simulation Results



(a) Lower group energy cost and higher run count.



(b) Sorted run counts

Fig. 3: Reduction in group energy cost and increase in workflow run count

Simulation Results

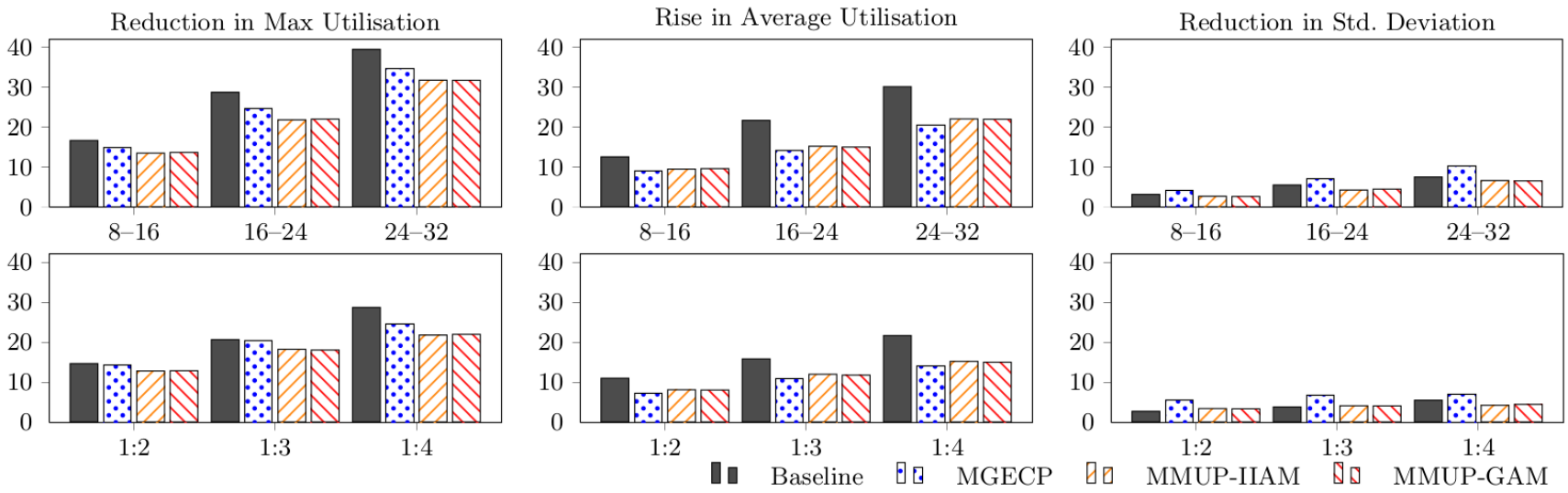


Fig. 4: Effect of adjustments within the MP.

Summary

- Energy Cost Model
- Formulate Optimisation Problems
- Adjustment Algorithm
- Verified by Simulation

Thank you ありがとう

Bo Gao
Department of Computer Science, University of Warwick, UK.
bogao@dcs.warwick.ac.uk