WESTERN SYDNEY UNIVERSITY

Resource Allocation in Mobile Edge Cloud Computing for Data-Intensive Applications

A/Prof. Bahman Javadi

School of Computer, Data and Mathematical Sciences
Western Sydney University, Australia

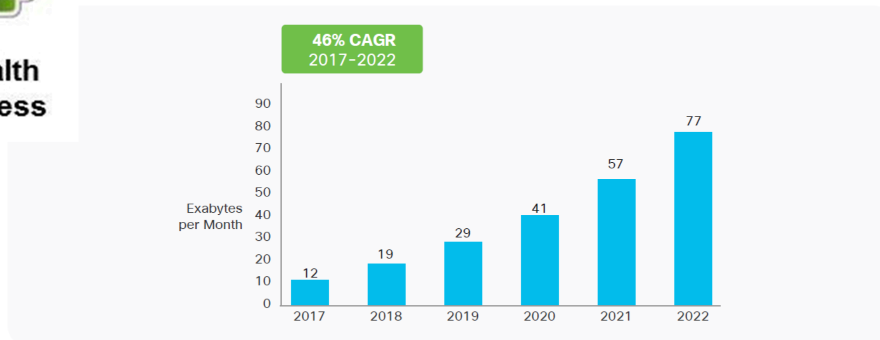
2nd International Conference on Advanced Computing and Applications (ICACA 2021)
March 2021

Acknowledgment: Dr. Mohammad ALKHALAILEH

WESTERN SYDNEY UNIVERSITY

Data-Intensive Applications

Smart Grid | Safety Security | Connected Home | Building Automation | Lighting Control | Smart Devices | Health Fitness

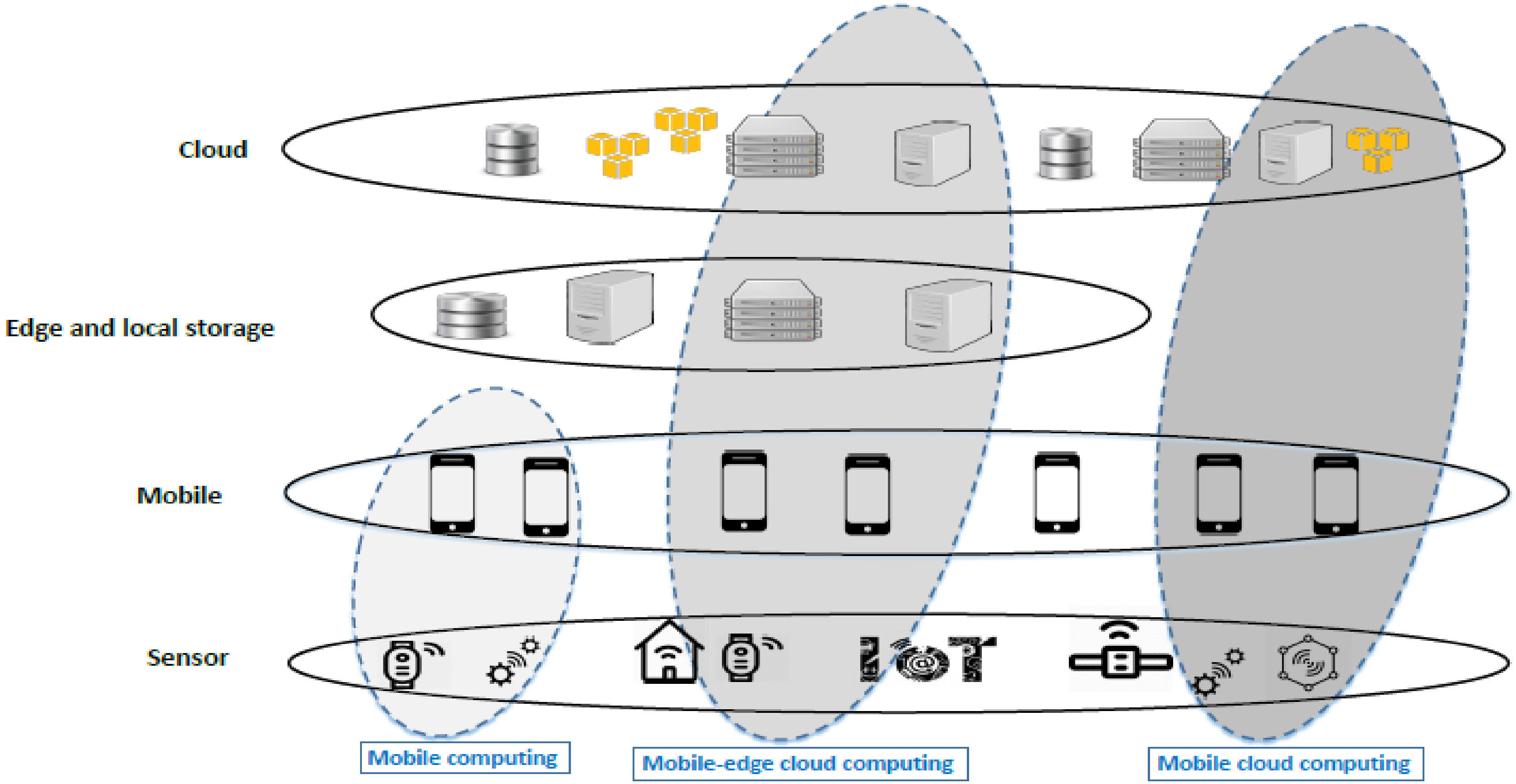


Source: Cisco VNI Mobile, 2019

Cisco Forecasts 30.6 Exabyte per Month of Mobile Data Traffic by 2022

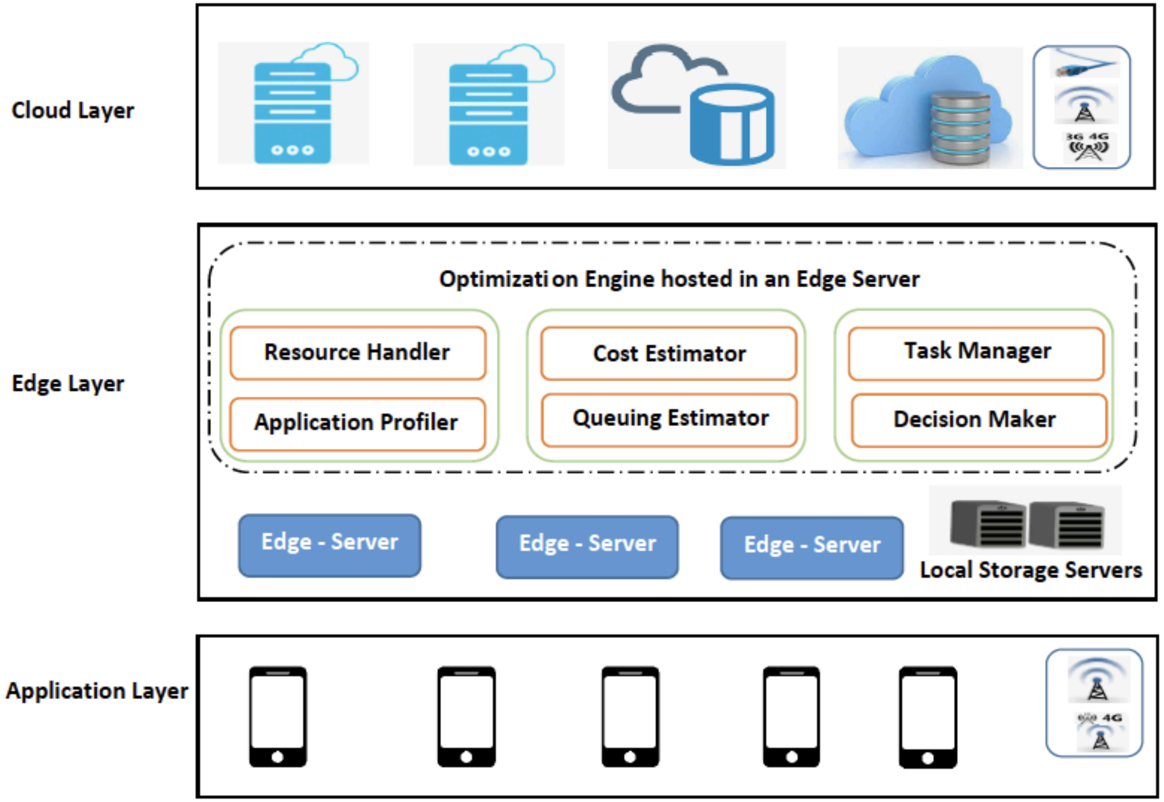
System Architecture

WESTERN SYDNEY UNIVERSITY



Mobile-edge cloud computing architecture

High Level System Architecture



Mobile-edge cloud computing (MECC) framework

System Modelling

- Task Modelling
  - Set of independent tasks.
    - Deadline
    - Data size and location
- Resource Modelling
  - Mobile, Edge , public Cloud
- Application Execution Models
  - Task Execution Time Model (T)
    - Processing time, data communication time, waiting time for remote execution.
  - Mobile Device Energy Model (E)
    - Processing energy, data transfer energy, waiting energy.
  - Monetary Cost Model (C)
    - Data communication cost, resources computation cost.

$$D_i = D_i^P + D_i^C + D_i^W$$

$$D_i^P = \frac{I_i}{w_{target}} + (s_i.\omega_i)$$

$$D_i^C = \frac{s_i}{\beta} + l$$

System Modelling

- **Problem Formulation:**
  - find the best mobile application offloading plan
    - C : monetary cost
    - E : mobile energy consumption

$$P_0 : min(E * C)$$

Subject to R_0

$$D_{t_i} < \partial_i, \forall t_i \in A$$

$$E < e$$

Proposed Offloading Technique

- Basic offloading using particle swarm optimization (PSO)
- Adopted Mixed Integer Liner Programming (MILP)
- find the best offloading plan based on optimization objective
- Example:

t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9	t_{10}
M	ED	ED	C	C	C	M	C	M	ED

Task to Resource Mapping

t_1	t_7	t_9
M	M	M

Mobile Resource

t_4	t_5	t_6	t_8
C	C	C	C

Cloud Resource

t_2	t_3	t_{10}
ED	ED	ED

Edge Resource

Proposed Offloading Algorithm

Algorithm 1 Find optimal application tasks schedule

Inputs:
Application tasks $A = \{t_i, ..., t_n\}$
Computation resources $R = \{r^l, (r_1^f, ..., r_m^f),\ r_1^c\}$
Output:
initial subproblem P_0
Initialise:
$optVal = \infty$
$bestSol = \{\}$
$subP = \{P_0\}$
while $Len(subP > 0)$ **do**
  $toChecksol = subP[0]$
  $solObjValue = callSolObjectiveValue(A, R, toChecksol)$
  if $solObjValue > optVal$ **then**
    $subP.removeAt(0)$
  else
    if $solObjValue < optVal$ **then**
      $bestSol = toChecksol$
      $optVal = solObjValue$
    else
      $toAddSubProblems = Branch(subP[0])$
      for $i = 1$ to $Len(toAddSubProblems)$ **do**
        if $checkIntegerConstraints(toAddSubProblems[i]) == True$ **then**
          $subP.insertAt(0, toAddSubProblems[i])$
        end if
      end for
    end if
  end if
end while
RETURN $s, optVal$

Experimental Setup

- Computation Resources Configuration

Resource Type	No. Cores	Memory (GB)
EC2 Linux t2.2xlarge Intel Xeon	8	32
Cloudlet Intel Xeon	4	8
LG Nexus 5 Qualcomm	2	2

- Mobile network bandwidth: 3G, 4G, Wi-Fi

Network Type	Bandwidth (MB/s) [Min, Max]	Cost ($/GB)
3G	[2,5]	1.0
4G	[8,12]	1.0
WiFi	[25,30]	0.05
Latency	**Min. Latency (s)**	**Max. Latency (s)**
	0.85	6.5

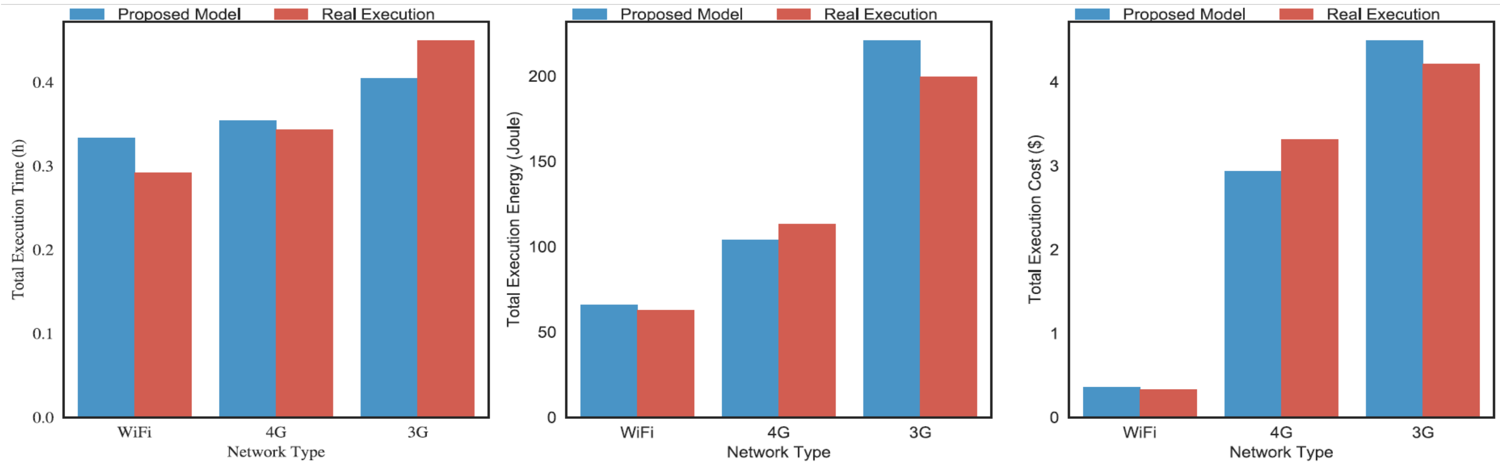
- Application tasks structure
  - Computation requirement (task workload)
  - The task data in random locations
  - Task data size (s) model: small, medium, large.

Data Distribution	Min. Size (MB)	Max. Size (MB)
Small	20	200
Medium	200	500
Large	500	2000
X-Large	2000	4000

Model Validation

WESTERN SYDNEY UNIVERSITY

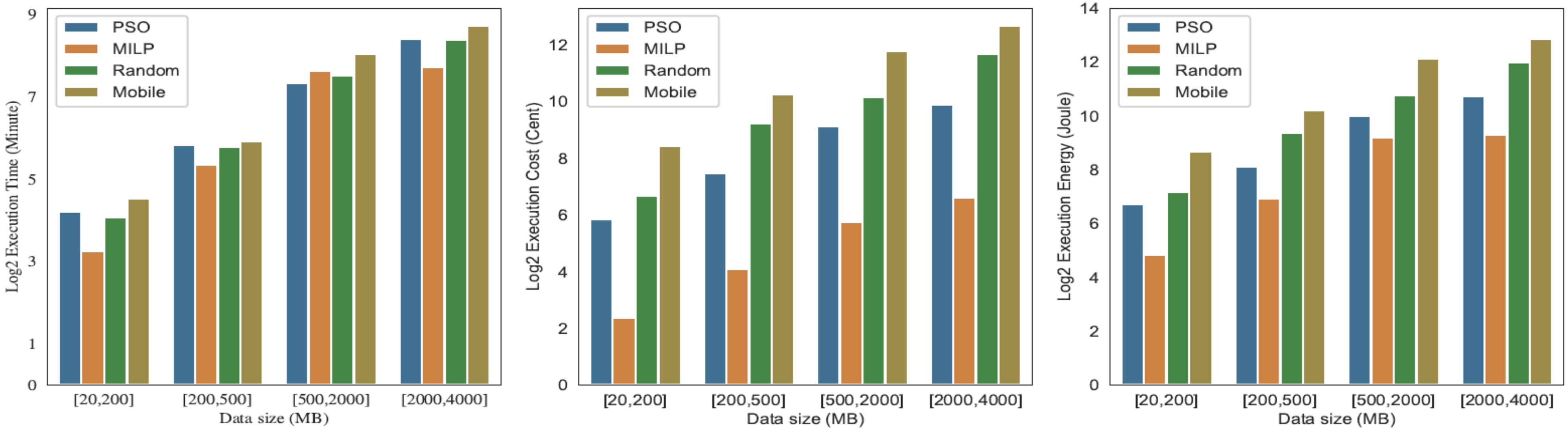
- Real-time execution
- Application with 30-task of small data model
- The average errors are
  - 8% for execution time.
  - 11% for energy consumption.
  - 15% for the monetary cost.



System Evaluation (4G Network)

WESTERN SYDNEY UNIVERSITY

- Reduced the execution cost for data-intensive applications by an average of 46% and 76%, in comparison to PSO and full execution on a mobile device, respectively.
- In addition, provides energy reductions of 35% and 84%, respectively.

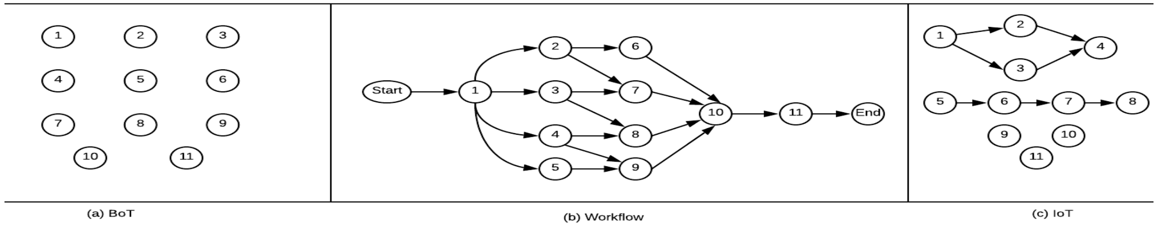


(a) Execution time (b) Monetary cost (c) Mobile energy

Performance Analysis of Mobile, Edge, and Cloud Computing Platforms for Distributed Applications

Application Model:

- BoT
- Workflow
- IoT



System Model:

- Mobile Computing (MC)
- Mobile Cloud Computing (MCC)
- Mobile Edge Cloud Computing (MECC)

Experimental Setup

- Computation Resources Configuration

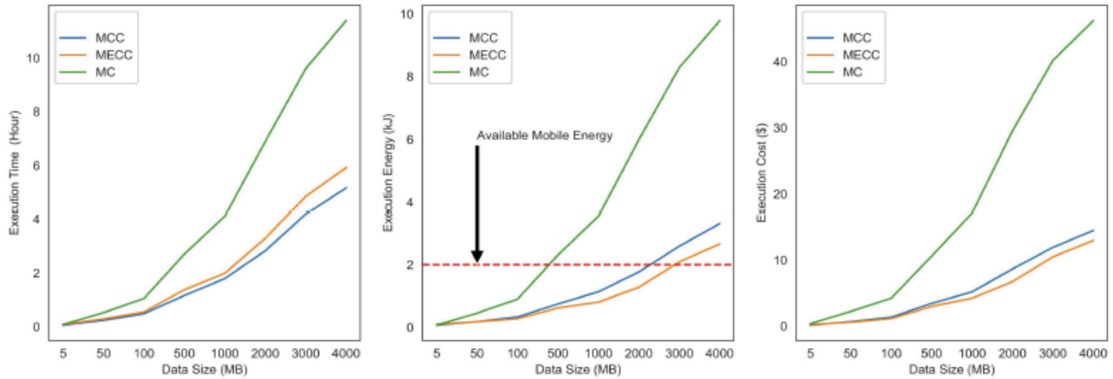
Resource Name	#Cores	Computation Cost ($/Hour)
Mobile Device	4	0.001
Edge Node	16	0.0742
Cloud Server	32	0.3712

- mobile network bandwidth: 3G, 4G, Wi-Fi
- application tasks structure
  - Computation requirement (task workload)
  - The task data locations
  - Task data size (s) model: small, medium, large.

Number of Images [min, max]	Data Size [min, max] (MB)
[1, 10]	[5,50]
[10, 20]	[50,100]
[20, 100]	[100,500]
[100, 200]	[500,100]
[200, 400]	[1000,2000]
[400, 600]	[2000, 3000]
[600, 800]	[3000, 4000]
Image Size Distribution	[3.9, 5.2]

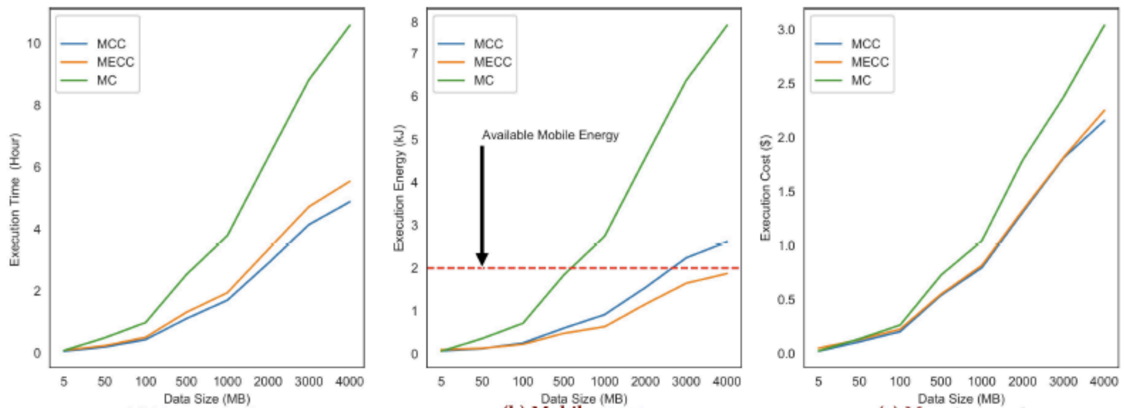
Results

WESTERN SYDNEY UNIVERSITY



(a) Execution time (b) Mobile energy (c) Monetary cost

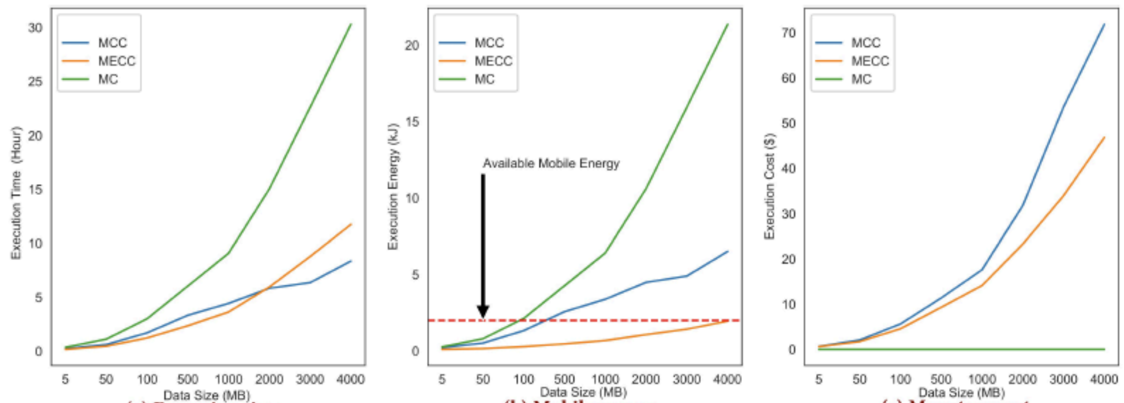
Fig. 5. BoT application model: 4G network



(a) Execution time (b) Mobile energy (c) Monetary cost

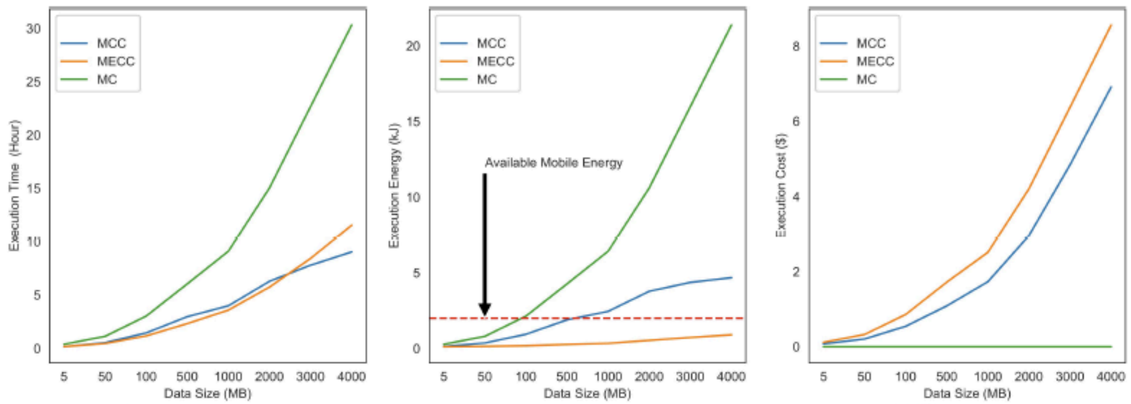
Fig. 6. BoT application model: WiFi network

Results



(a) Execution time (b) Mobile energy (c) Monetary cost

Fig. 7. Workflow application model: 4G network



(a) Execution time (b) Mobile energy (c) Monetary cost

Fig. 8. Workflow application model: WiFi network

Results

WESTERN SYDNEY UNIVERSITY

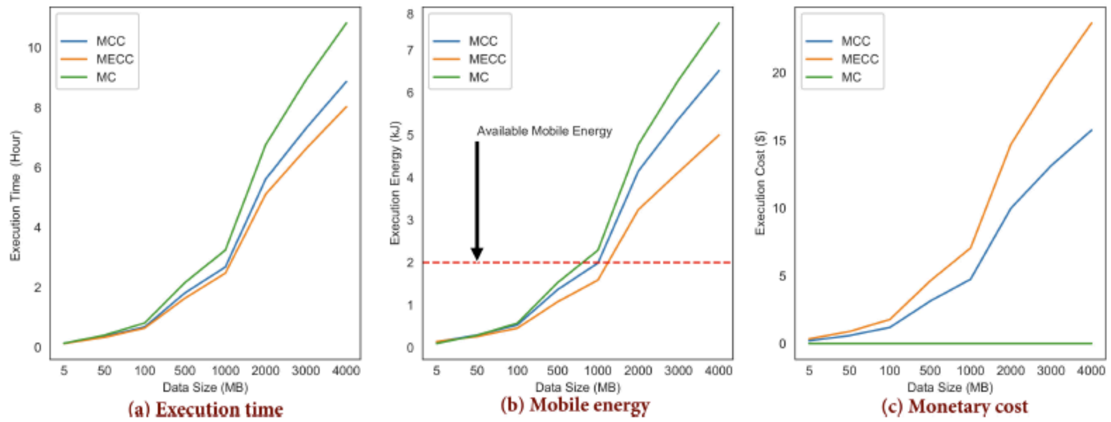


Fig. 10. IoT application with mobile data collection : 4G network

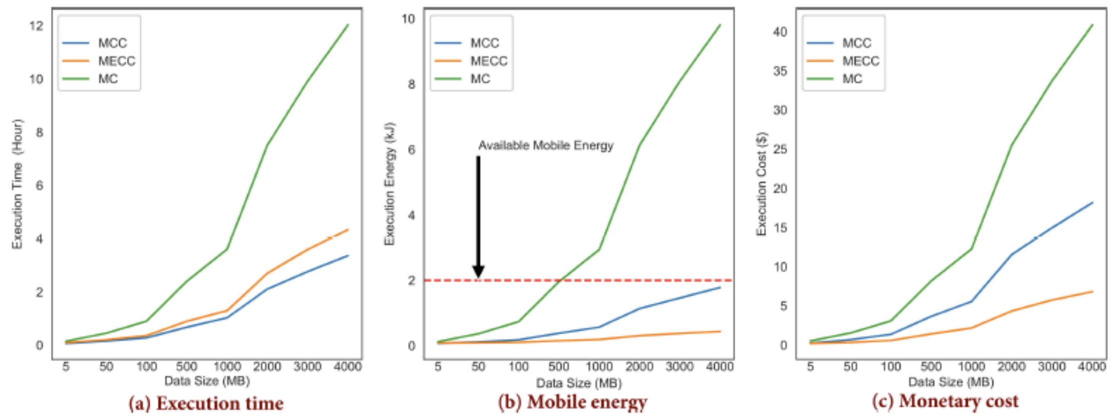


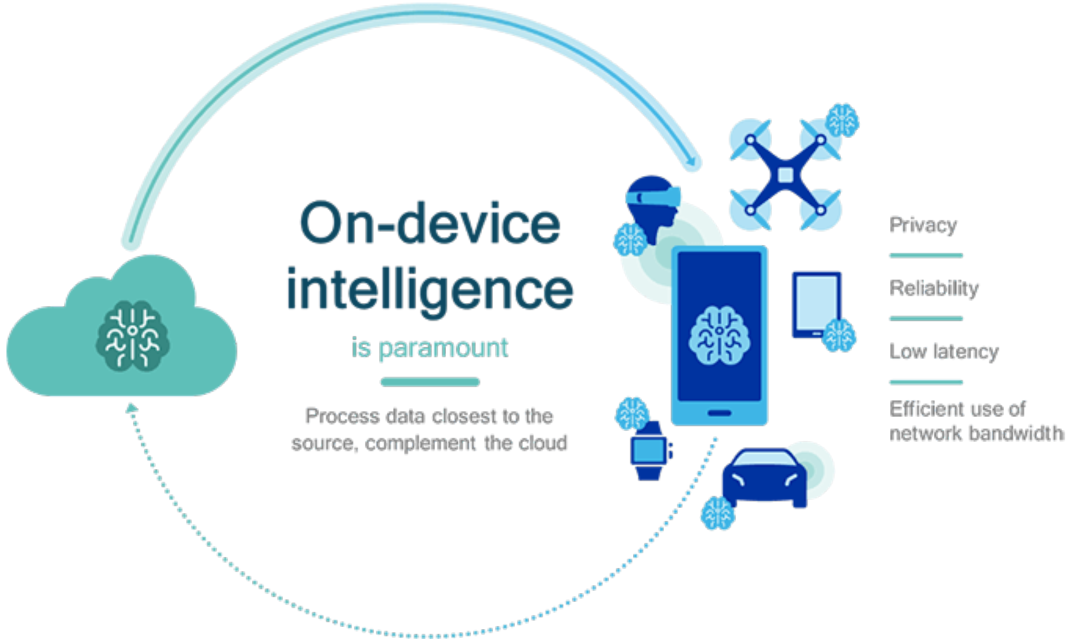
Fig. 13. IoT application with edge data collection : 4G network

WESTERN SYDNEY UNIVERSITY

Conclusions

- Proposed algorithms and techniques for optimising the execution of data-intensive applications through adopting data-oriented application modelling.
- Selection of a computing environment to reduce consumed energy and monetary cost is highly dependent on the size of data to be transferred over the communication network.
- There is promising potential for use of edge resources with on-edge data collection (for example for IoT applications).
- The data dependency between application tasks plays a significant role in resources allocation planning (for example for workflow applications)

Open Challenges and Future Work



- Privacy-aware offloading
- Reliable computation offloading
- Offloading for streaming applications

References

WESTERN SYDNEY UNIVERSITY

- Alkhalaileh, Mohammad, Rodrigo N. Calheiros, Quang Vinh Nguyen, and Bahman Javadi.
“Dynamic resource allocation in hybrid mobile cloud computing for data-intensive applications."
In International Conference on Green, Pervasive, and Cloud Computing, pp. 176-191. Springer, Cham, 2019.

- Alkhalaileh, Mohammad, Rodrigo N. Calheiros, Quang Vinh Nguyen, and Bahman Javadi.
“Data-intensive application scheduling on Mobile Edge Cloud Computing.”
Journal of Network and Computer Applications (2020): 102735.

- Alkhalaileh, Mohammad, Rodrigo N. Calheiros, Quang Vinh Nguyen, and Bahman Javadi.
“Performance Analysis of Mobile, Edge, and Cloud Computing Platforms for Distributed Applications”.
In MEC2020, Mobile Edge Computing (“in press, 2020.")

Thank You

Email: b.javadi@westernsydney.edu.au
Twitter: @bjavadi
https://www.linkedin.com/in/bahmanjavadi/