CLOUD COMPUTING ASSIGNMENT REPORT

An Energy and Delay-Efficient Partial Offloading Technique for Fog Computing architectures

Team members:

Bharath R - 191CS112
Chethan Hebbar - 191CS114
Shyamsundar N R -191CS157
Karthik Chandra -191CS222

Submitted to:

Dr. Sourav K. Addya
Asst Professor
CSE Department
NITK Surathkal

INTRODUCTION

The paper “**An Energy and Delay-Efficient Partial Offloading Technique for Fog Computing Architectures”** talks on the infrastructure of the fog computing systems where in architecture composed of two layers, one including Fog Nodes (FNs) and another the Fog Access Points (F-APs). While FNs are usually battery operated, the F-APs are instead connected to the electrical networks having unlimited energy.

Among different applications that can be envisaged in a fog computing infrastructure, we focus here on computation offloading characterized by the possibility of offloading some tasks to be computed by the nearby devices. However, due to the limited FNs capabilities, sometimes they could not suffice in an efficient implementation of the fog infrastructure. To this aim a joint exploitation of both FN and F-AP is here considered. In particular we will focus here on a partial offloading approach enabling FNs to distribute high computational tasks among several FNs or F-APs , by optimizing the partial offloading sharing among the devices, we aim at minimizing the FN energy consumption and the task processing delay while increasing the network lifetime.

It has been proved that offloading might not always be the best solution for reducing the energy consumption when intensive communication is required in the offloading process. The task offloading problem has been formulated as a joint radio and computational resources optimization. Energy consumption and latency have also been targeted for an offloading approach.

We have considered FN energy consumption for selecting the FNs able to perform the computation. Moreover, we introduce a new paradigm working on both FN and F-AP layers considering the node energy consumption and the task processing delay for a suboptimal solution to the partial offloading problem.

FNs are considered to be fixed devices with the possibility of offloading their tasks to the neighboring FNs or to the upper layer F-APs for computation. The focus in our scenario is on increasing the interaction among nodes at the edge of the network, with the objective of minimizing the task processing delay and the FNs energy consumption.

Each FN can be in one of four possible states $\mathscr{S} = \{tx, rx, com, id\}$, transmitting, receiving, computing or idle. While the first two states are referred to the interaction with other FNs or F-APs, the computing state refers to the computation performed in the FN itself (either for a local task or for an offloaded task), while the idle state refers to the idling occurring otherwise. To this aim, the overall energy consumed by the ith FN can be defined as,

$$E^i_{FN} = E^i_{tx} + E^i_{rx} + E^i_{com} + E^i_{id}$$

We aim to minimize the energy transmitted by the ith FN.This leads to a formulation of the partial offloading problem as an Integer Linear Programing (ILP), with the help of constraints.

AlGORITHM IMPLEMENTATION

This paper gives us an algorithm about implementing the algorithm with the help of 4 parameters which are FN classification, LPFN selection, Local computation parameter , Partial offloading parameter.
At first, all FNs are classified into two groups, High Power FNs (HPFN) and Low Power FNs (LPFN), using a quantile function that considers the distribution of the energy of all the FNs in the network. It is worth to be noticed that the FNs classification is performed at run time each time a new task should be executed; this ensures that the HPFN are always those FNs having the highest amount of energy.

LPFN are classified into two based on the the way they are assigned .According to the algorithm if they are assigned to FN they are classified as **‘a’** type fog node or if they are assigned to fog nodes or fog access points then they are classified as type **‘b’** nodes.

Then we compute with the help of local computation parameter and partial offloading parameter and with the help of the energy offloaded equations we compute the total energy offloaded which is written in the case of algorithm two.

Algorithm 1 LPFN assignment

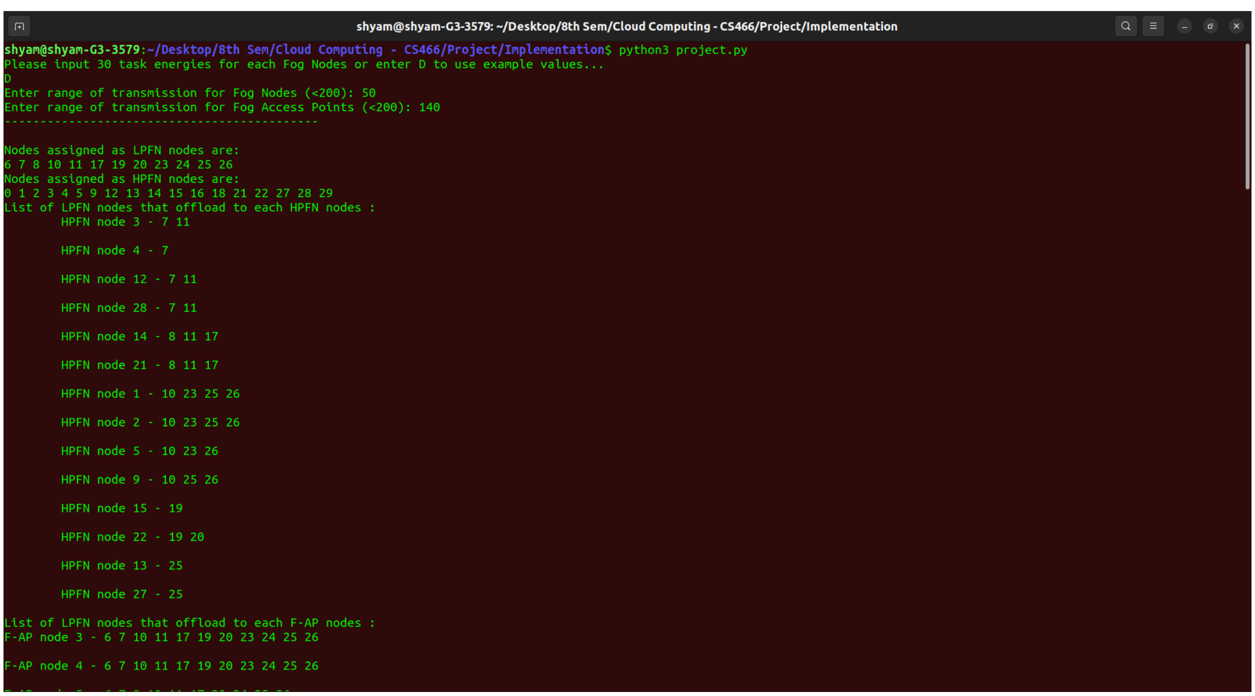
Input: $\mathcal{U}$
Output: HPFN and F-AP list
Quantile ($\mathcal{U}$) **which gives** I
for each $u_i \in \mathcal{U}$ **do**
  if $u_i \geq I$ **then**
    $HPFN \leftarrow u_i$
  else
    $LPFN \leftarrow u_i$
  end if
end for
if LPFN selection=a **then**
  for each LPFN$\in\mathcal{U}$ **do**
    for each $HPFN$ **do**
      if d($HPFN_j$,$LPFN_k$) $\leq R$ **then**
        $HPFN_j list \leftarrow LPFN_k$
      end if
    end for
    $LocalCom \leftarrow$ rest of the $LPFNs$
  end for
else if LPFN selection=b **then**
  for each LPFN$\in\mathcal{U}$ **do**
    for each $HPFN_j$ **do**
      if $d(HPFN_j, LPFN_k) \leq R$ **then**
        $HPFN_j list \leftarrow LPFN_k$
      end if
    end for
    for each $F - AP_M$ **do**
      if $d(F - AP_M, LPFN_k) \leq F$ **then**
        $F - AP_M list \leftarrow LPFN_k$
      end if
    end for
  end for
end if

Algorithm 2 α_{loc}^{l} and β_i

Input: HPFN and F-AP list
Output: α_{loc}^{l}, β_k
for each LPFN$\in\mathcal{U}$ **do**
    if Local computation Parameter=Energy **then**
        α_{loc}^{l} calculation using (24)
    else
        α_{loc}^{l} calculation using (31)
    end if
    β_k calculation using (33)
end for

Results:

Inputting Task Energies and calculating LPFN and HPFN nodes



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shyam@shyam-G3-3579: ~/Desktop/8th Sem/Cloud Computing - CS466/Project/Implementation
shyam@shyam-G3-3579:~/Desktop/8th Sem/Cloud Computing - CS466/Project/Implementation$ python3 project.py
Please input 30 task energies for each Fog Nodes or enter D to use example values...
D
Enter range of transmission for Fog Nodes (<200): 50
Enter range of transmission for Fog Access Points (<200): 140
--------------------------------------------

Nodes assigned as LPFN nodes are:
6 7 8 10 11 17 19 20 23 24 25 26
Nodes assigned as HPFN nodes are:
0 1 2 3 4 5 9 12 13 14 15 16 18 21 22 27 28 29
List of LPFN nodes that offload to each HPFN nodes :
        HPFN node 3 - 7 11

        HPFN node 4 - 7

        HPFN node 12 - 7 11

        HPFN node 28 - 7 11

        HPFN node 14 - 8 11 17

        HPFN node 21 - 8 11 17

        HPFN node 1 - 10 23 25 26

        HPFN node 2 - 10 23 25 26

        HPFN node 5 - 10 23 26

        HPFN node 9 - 10 25 26

        HPFN node 15 - 19

        HPFN node 22 - 19 20

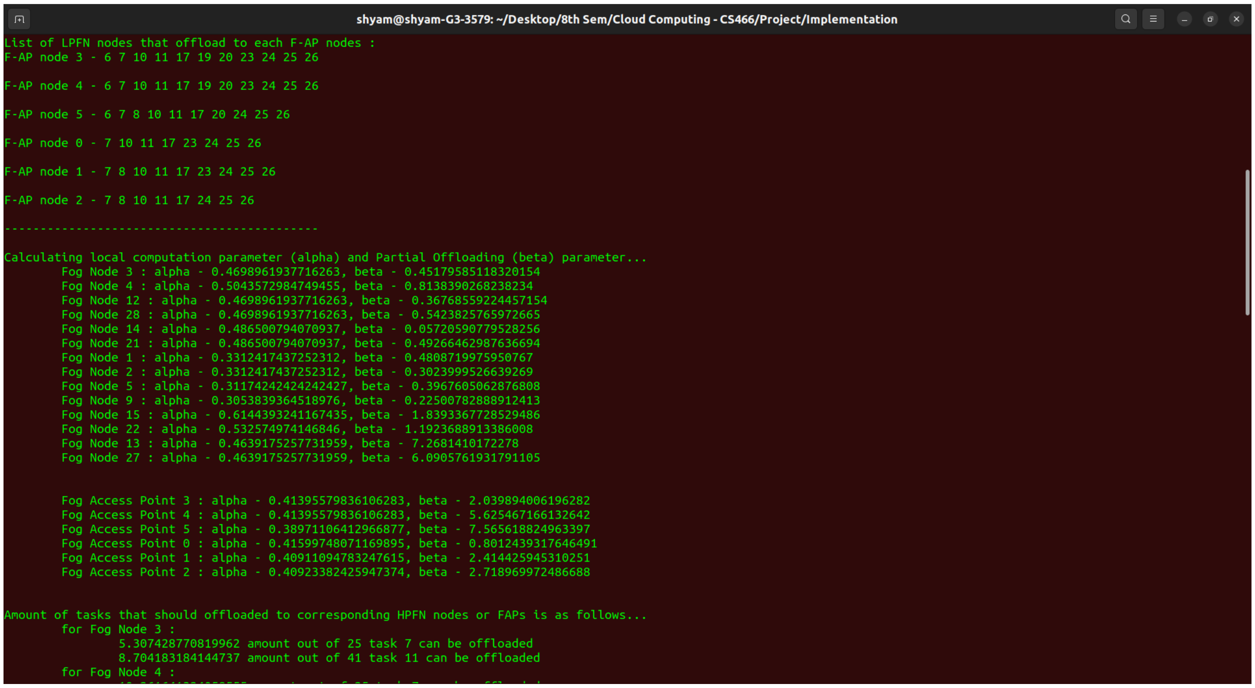
        HPFN node 13 - 25

        HPFN node 27 - 25

List of LPFN nodes that offload to each F-AP nodes :
F-AP node 3 - 6 7 10 11 17 19 20 23 24 25 26

F-AP node 4 - 6 7 10 11 17 19 20 23 24 25 26
```

Calculating list of LPFN nodes that offload to each Fog Access Point



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List of LPFN nodes that offload to each F-AP nodes :
F-AP node 3 - 6 7 10 11 17 19 20 23 24 25 26

F-AP node 4 - 6 7 10 11 17 19 20 23 24 25 26

F-AP node 5 - 6 7 8 10 11 17 20 24 25 26

F-AP node 0 - 7 10 11 17 23 24 25 26

F-AP node 1 - 7 8 10 11 17 23 24 25 26

F-AP node 2 - 7 8 10 11 17 24 25 26

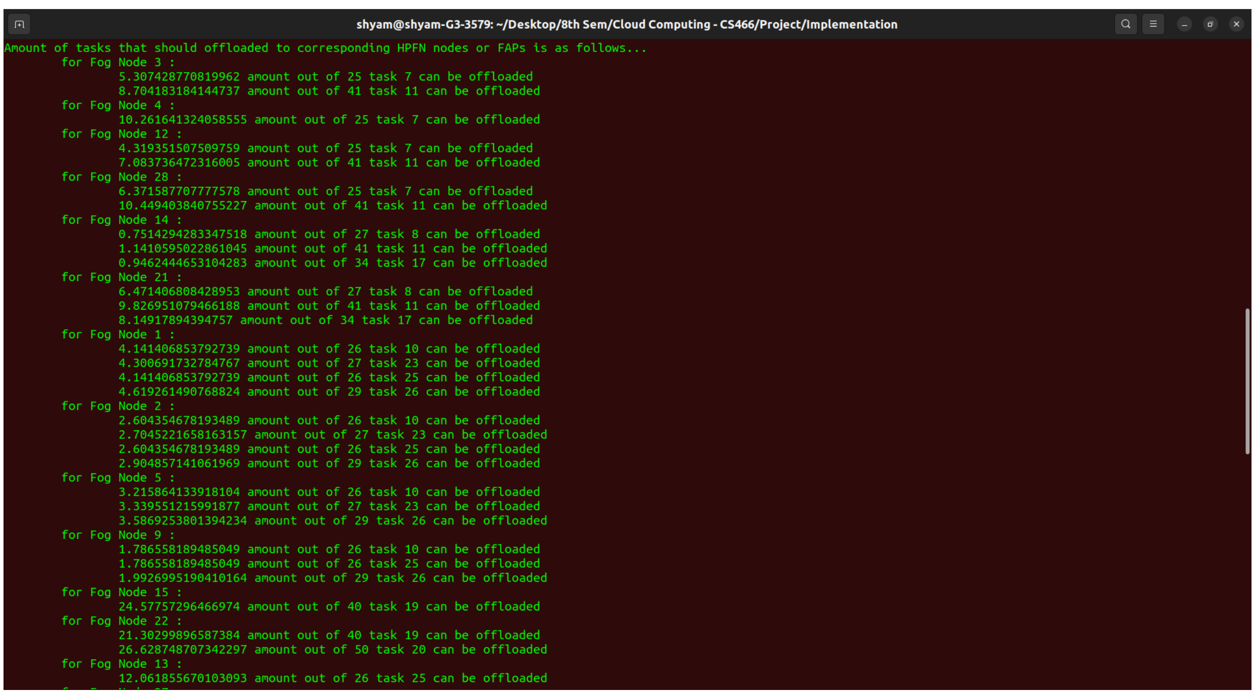
--------------------------------------------

Calculating local computation parameter (alpha) and Partial Offloading (beta) parameter...
        Fog Node 3 : alpha - 0.4698961937716263, beta - 0.45179585118320154
        Fog Node 4 : alpha - 0.5043572984749455, beta - 0.8138390268238234
        Fog Node 12 : alpha - 0.4698961937716263, beta - 0.36768559224457154
        Fog Node 28 : alpha - 0.4698961937716263, beta - 0.5423825765972665
        Fog Node 14 : alpha - 0.486500794070937, beta - 0.05720590779528256
        Fog Node 21 : alpha - 0.486500794070937, beta - 0.49266462987636694
        Fog Node 1 : alpha - 0.3312417437252312, beta - 0.4808719975950767
        Fog Node 2 : alpha - 0.3312417437252312, beta - 0.3023999526639269
        Fog Node 5 : alpha - 0.31174242424242427, beta - 0.3967605062876808
        Fog Node 9 : alpha - 0.3053839364518976, beta - 0.22500782888912413
        Fog Node 15 : alpha - 0.6144393241167435, beta - 1.8393367728529486
        Fog Node 22 : alpha - 0.532574974146846, beta - 1.1923688913386008
        Fog Node 13 : alpha - 0.4639175257731959, beta - 7.2681410172278
        Fog Node 27 : alpha - 0.4639175257731959, beta - 6.0905761931791105


        Fog Access Point 3 : alpha - 0.41395579836106283, beta - 2.039894006196282
        Fog Access Point 4 : alpha - 0.41395579836106283, beta - 5.625467166132642
        Fog Access Point 5 : alpha - 0.38971106412966877, beta - 7.565618824963397
        Fog Access Point 0 : alpha - 0.41599748071169895, beta - 0.8012439317646491
        Fog Access Point 1 : alpha - 0.40911094783247615, beta - 2.414425945310251
        Fog Access Point 2 : alpha - 0.40923382425947374, beta - 2.718969972486688


Amount of tasks that should offloaded to corresponding HPFN nodes or FAPs is as follows...
        for Fog Node 3 :
                5.307428770819962 amount out of 25 task 7 can be offloaded
                8.704183184144737 amount out of 41 task 11 can be offloaded
        for Fog Node 4 :
```

Calculating the amount of task that needs to be offloaded to each HPFN or F-AP



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Amount of tasks that should offloaded to corresponding HPFN nodes or FAPs is as follows...
        for Fog Node 3 :
                5.307428770819962 amount out of 25 task 7 can be offloaded
                8.704183184144737 amount out of 41 task 11 can be offloaded
        for Fog Node 4 :
                10.261641324058555 amount out of 25 task 7 can be offloaded
        for Fog Node 12 :
                4.319351507509759 amount out of 25 task 7 can be offloaded
                7.083736472316005 amount out of 41 task 11 can be offloaded
        for Fog Node 28 :
                6.371587707777578 amount out of 25 task 7 can be offloaded
                10.449403840755227 amount out of 41 task 11 can be offloaded
        for Fog Node 14 :
                0.7514294283347518 amount out of 27 task 8 can be offloaded
                1.1410595022861045 amount out of 41 task 11 can be offloaded
                0.9462444653104283 amount out of 34 task 17 can be offloaded
        for Fog Node 21 :
                6.471406808428953 amount out of 27 task 8 can be offloaded
                9.826951079466188 amount out of 41 task 11 can be offloaded
                8.14917894394757 amount out of 34 task 17 can be offloaded
        for Fog Node 1 :
                4.141406853792739 amount out of 26 task 10 can be offloaded
                4.300691732784767 amount out of 27 task 23 can be offloaded
                4.141406853792739 amount out of 26 task 25 can be offloaded
                4.619261490768824 amount out of 29 task 26 can be offloaded
        for Fog Node 2 :
                2.604354678193489 amount out of 26 task 10 can be offloaded
                2.7045221658163157 amount out of 27 task 23 can be offloaded
                2.604354678193489 amount out of 26 task 25 can be offloaded
                2.904857141061969 amount out of 29 task 26 can be offloaded
        for Fog Node 5 :
                3.215864133918104 amount out of 26 task 10 can be offloaded
                3.339551215991877 amount out of 27 task 23 can be offloaded
                3.5869253801394234 amount out of 29 task 26 can be offloaded
        for Fog Node 9 :
                1.786558189485049 amount out of 26 task 10 can be offloaded
                1.786558189485049 amount out of 26 task 25 can be offloaded
                1.9926995190410164 amount out of 29 task 26 can be offloaded
        for Fog Node 15 :
                24.57757296466974 amount out of 40 task 19 can be offloaded
        for Fog Node 22 :
                21.30299896587384 amount out of 40 task 19 can be offloaded
                26.628748707342297 amount out of 50 task 20 can be offloaded
        for Fog Node 13 :
                12.061855670103093 amount out of 26 task 25 can be offloaded
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        for Fog Node 27 :
                12.061855670103093 amount out of 26 task 25 can be offloaded


        for Fog Access Point 3 :
                10.762850757387634 amount out of 26 task 6 can be offloaded
                10.348894959026572 amount out of 25 task 7 can be offloaded
                10.762850757387634 amount out of 26 task 10 can be offloaded
                16.972187732803576 amount out of 41 task 11 can be offloaded
                14.074497144276137 amount out of 34 task 17 can be offloaded
                16.558231934442514 amount out of 40 task 19 can be offloaded
                20.697789918053143 amount out of 50 task 20 can be offloaded
                11.176806555748696 amount out of 27 task 23 can be offloaded
                14.488452942637199 amount out of 35 task 24 can be offloaded
                10.762850757387634 amount out of 26 task 25 can be offloaded
                12.004718152470822 amount out of 29 task 26 can be offloaded
        for Fog Access Point 4 :
                10.762850757387634 amount out of 26 task 6 can be offloaded
                10.348894959026572 amount out of 25 task 7 can be offloaded
                10.762850757387634 amount out of 26 task 10 can be offloaded
                16.972187732803576 amount out of 41 task 11 can be offloaded
                14.074497144276137 amount out of 34 task 17 can be offloaded
                16.558231934442514 amount out of 40 task 19 can be offloaded
                20.697789918053143 amount out of 50 task 20 can be offloaded
                11.176806555748696 amount out of 27 task 23 can be offloaded
                14.488452942637199 amount out of 35 task 24 can be offloaded
                10.762850757387634 amount out of 26 task 25 can be offloaded
                12.004718152470822 amount out of 29 task 26 can be offloaded
        for Fog Access Point 5 :
                10.132487667371388 amount out of 26 task 6 can be offloaded
                9.742776603241719 amount out of 25 task 7 can be offloaded
                10.522198731501057 amount out of 27 task 8 can be offloaded
                10.132487667371388 amount out of 26 task 10 can be offloaded
                15.97815362931642 amount out of 41 task 11 can be offloaded
                13.250176180408738 amount out of 34 task 17 can be offloaded
                19.485553206483438 amount out of 50 task 20 can be offloaded
                13.639887244538407 amount out of 35 task 24 can be offloaded
                10.132487667371388 amount out of 26 task 25 can be offloaded
                11.301620859760394 amount out of 29 task 26 can be offloaded
        for Fog Access Point 0 :
                8.332886426240762 amount out of 25 task 7 can be offloaded
                8.666201883290391 amount out of 26 task 10 can be offloaded
                13.665933739034848 amount out of 41 task 11 can be offloaded
                11.332725539687436 amount out of 34 task 17 can be offloaded
                8.999517340340022 amount out of 27 task 23 can be offloaded
```

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                14.488452942637199 amount out of 35 task 24 can be offloaded
                10.762850757387634 amount out of 26 task 25 can be offloaded
                12.004718152470822 amount out of 29 task 26 can be offloaded
        for Fog Access Point 5 :
                10.132487667371388 amount out of 26 task 6 can be offloaded
                9.742776603241719 amount out of 25 task 7 can be offloaded
                10.522198731501057 amount out of 27 task 8 can be offloaded
                10.132487667371388 amount out of 26 task 10 can be offloaded
                15.97815362931642 amount out of 41 task 11 can be offloaded
                13.250176180408738 amount out of 34 task 17 can be offloaded
                19.485553206483438 amount out of 50 task 20 can be offloaded
                13.639887244538407 amount out of 35 task 24 can be offloaded
                10.132487667371388 amount out of 26 task 25 can be offloaded
                11.301620859760394 amount out of 29 task 26 can be offloaded
        for Fog Access Point 0 :
                8.332886426240762 amount out of 25 task 7 can be offloaded
                8.666201883290391 amount out of 26 task 10 can be offloaded
                13.665933739034848 amount out of 41 task 11 can be offloaded
                11.332725539687436 amount out of 34 task 17 can be offloaded
                8.999517340340022 amount out of 27 task 23 can be offloaded
                11.666040996737065 amount out of 35 task 24 can be offloaded
                8.666201883290391 amount out of 26 task 25 can be offloaded
                9.666148254439284 amount out of 29 task 26 can be offloaded
        for Fog Access Point 1 :
                10.227773695811903 amount out of 25 task 7 can be offloaded
                11.045995591476856 amount out of 27 task 8 can be offloaded
                10.636884643644379 amount out of 26 task 10 can be offloaded
                16.773548861131523 amount out of 41 task 11 can be offloaded
                13.909772226304188 amount out of 34 task 17 can be offloaded
                11.045995591476856 amount out of 27 task 23 can be offloaded
                14.318883174136666 amount out of 35 task 24 can be offloaded
                10.636884643644379 amount out of 26 task 25 can be offloaded
                11.864217487141808 amount out of 29 task 26 can be offloaded
        for Fog Access Point 2 :
                10.230845606486843 amount out of 25 task 7 can be offloaded
                11.04931325500579 amount out of 27 task 8 can be offloaded
                10.640079430746317 amount out of 26 task 10 can be offloaded
                16.778586794638425 amount out of 41 task 11 can be offloaded
                13.913950024822107 amount out of 34 task 17 can be offloaded
                14.32318384908158 amount out of 35 task 24 can be offloaded
                10.640079430746317 amount out of 26 task 25 can be offloaded
                11.86778090352474 amount out of 29 task 26 can be offloaded
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CONCLUSION

In this paper, a partial offloading approach for fog computing is introduced. We have defined various policies considering energy consumption and task processing delay for deciding the amount of tasks to be offloaded. By considering also the F-AP for offloading it is possible to increase the network lifetime, especially in high demand scenarios that consume much more the network resources.The two algorithms can be selected which help us in calculating the energy offloaded. Hence in real life scenarios based on the classification of FN and LPFN the minimum energy transmitted is calculated which help in reducing the task processing delay and increasing the network lifetime.