Outline

1. State of the art
    1. MADM
    2. Learning
    3. Fuzzy Logic
    4. Utility Function
    5. Game Theory
    6. Matching Theory
    7. Discussion

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MADM

Related work

$$
Qn,m = \begin{array}{c} \\ Configuration_1 \\ Configuration_2 \\ \vdots \\ Configuration_n \end{array} \begin{array}{c} \begin{array}{cccc} Metric_1 & Metric_2 & \ldots & Metric_m \end{array} \\ \begin{pmatrix} q_{11} & q_{12} & \cdots & q_{1m} \\ q_{21} & q_{22} & \cdots & q_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ q_{n1} & q_{n2} & \cdots & q_{nm} \end{pmatrix} \end{array}
$$

$$
ETC_{ij} = \begin{array}{c} \\ Metric_1 \\ Metric_2 \\ \vdots \\ Metric_n \end{array} \begin{array}{c} \begin{array}{cccc} Metric_1 & Metric_2 & \cdots & Metric_m \end{array} \\ \left\{ \begin{array}{cccc} ETC_{11} & ETC_{12} & \cdots & ETC_{1m} \\ ETC_{21} & ETC_{22} & \cdots & ETC_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ ETC_{n1} & ETC_{n2} & \cdots & ETC_{nm} \end{array} \right. \end{array}
$$

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1. Bandit Algorithm
2. Genetic Algorithm
3. Q-Learning
4. Marcov Chain

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Multi-Armed-Bandit Algorithm

Related work

- **Arms: K = 1, ... , K**
- **Decision: T = 1, ... , T**
- **Reward:** X_t^k **with** μ_t^k **= E** $[X_t^k]$
  - **Best reward:** X_t^* **with** μ_t^* **= max** μ_t^k**, k**$\in$**K**

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Genetic Algorithm

Related work **alkhawlani_access_2008a**

- **N** transceiver configurations: $(x_1, ..., x_n)$
- **I** QoS metrics $(m_1, ..., m_i)$. ex: the operators, the applications, and the network conditions.
- **I** weights $(w_1, ..., w_i)$ are sent to the MCDM in the second component.
- GA component assigns a suitable weight (w 1 ,w 2 ,...,w i)

Genetic Algorithm

Related work

Evaluation function

Define the number of parameters	{SF, Tx, CR, BW}
Define the target QoS	{RSSI, SNR, delay, PDR, RTD}
Define evaluation function	Score(SF, Tx, CR, BW) -> {RSSI, SNR, delay, PDR, RTD}

Parameters

Define a population of individuals (solutions)	6720
Define probabilities of crossing and mutating	0.5, 0.2
Define the number of generations	60

Generations

Select individuals randomly	$\{SF_i, Tx_i, CR_i, BW_i\}^{random}$
Clone, crossover and mutate this individuals	$\{SF_{i+1}, Tx_{i+1}, CR_{i+1}, BW_{i+1}\}^{random}$
Evaluate the offspring with an invalid Fitness	Score$(SF_{i+1}, Tx_{i+1}, CR_{i+1}, BW_{i+1})$

(Crossover, Mutation)

Remove some bad solutions
Duplicate some good solutions
Make small changes to some of them

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Q Learning

Related work

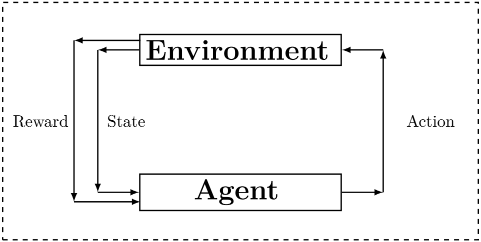

Figure 1. qlearning.

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Marcov chain

Related work

$$V(s,\pi) = \mathbb{E}_s^{\pi}\left(\sum_{k=0}^{\inf} \gamma^k \cdot r(s_k, a_k)\right), s \in \mathbb{S} \tag{1}$$

$$r(s_k, a_k) = G_k \cdot PRR(a_k) \tag{2}$$

$$\pi^* = \arg\max_{\pi} V(s,\pi) \tag{3}$$

$$PRR = (1 - BER)^L \tag{4}$$

$$BER = 10^{\alpha e^{\beta SNR}} \tag{5}$$

Learning iterative steps:

- **Choose** action $a_k(t) \sim \pi_k(t)$
- **Observe** game outcome
  - $a\_k(t)$
  - $u_k(a_k(t), a\_k(t))$
- **Improve** $\pi_k(t+1)$

Thus, we can expect that ∀k ∈K

$$\pi_{k(t)} \xrightarrow{t \longrightarrow \infty} \pi_k^* \quad (6)$$

$$u_k(\pi_k(t), \pi\_k(t)) \xrightarrow{t \longrightarrow \infty} u_k(\pi_k^*, \pi^*\_k) \quad (7)$$

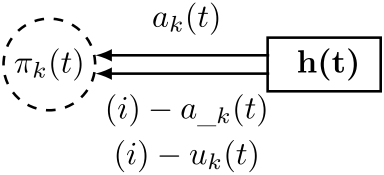

Figure 2. .

Where:

- $\pi^* = (\pi_1^*, ..., \pi_k^*)$ is the NE strategy profile

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Fuzzy Logic

Related work

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Notations

Related work

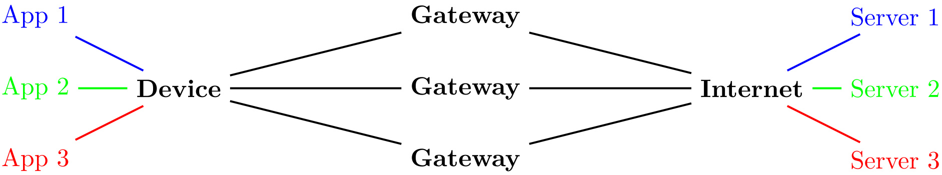

Figure 3. Network selection problem.

Notations
Related work

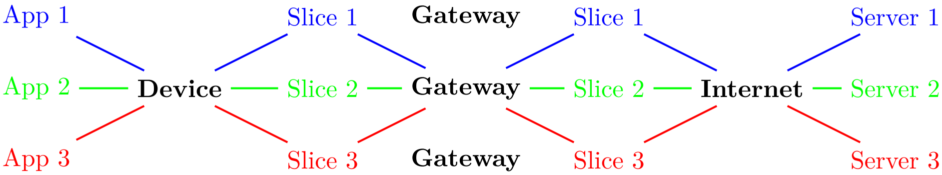

Figure 4. Slice orchestration problem.

Set of devices, slices, gateways and flows

G	set of LoRa Gateways
S	set of Slices
D_s	cluster of devices associated to slice s
Parameters	
F_c	packets with SF = c
$BW_{s,g}$	bandwidth assigned for slice s over GW g
P_g^{Tx}	transmission power of GW g
Constants	
$i_{d,s}$	association index of device d to slice s
$i_{d,g}$	association index of device d to GW g
w_d	urgency factor for device d
w_s	priority of slice s
w_r	weight of reliability
w_{ld}	weight of load
Metrics	
$DR_{d,s,g}$	data rate achieved by a device d
$SINR_{i,j}$	SINR with SF=i and SF=j
$G_{d,g}^{tx}$	power gain between a GW g and a device d
$S_{d,s,g}^{rx}$	Receiver sensitivity
RTD_d	instant packet delay for device d
PLR_d	packet loss rate of device d
$U_{d,s,g}$	utility for device d in slice s on GW g

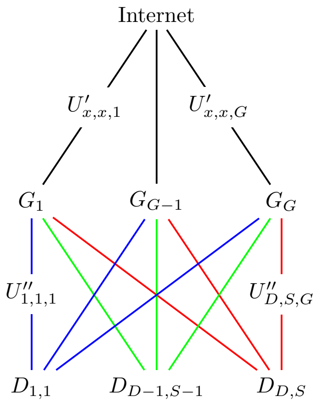

Figure 5. Slicing.

Utility function

Related work

- **G = {1, ... , G}:** Set of gateways
- **S = {1, ... , S}:** Set of slices
- **D = {1, ... , D}:** Set of devices
- $\mathbf{D_s} = \{\mathbf{1}, ..., \mathbf{D_s}\} \in \mathbf{D}$: Cluster of devices in slice s
- $\mathbf{F_{d,s,g}} = \{\mathbf{1}, ..., \mathbf{D_s}\}$: Virtual flow for device d in slice s through GW g

- $\mathbf{i_{d,s}} \in \{0,1\}$ Association index of device d to slice s
- $\mathbf{i_{d,g}} \in \{0,1\}$ Association index of device d to GW g

- $\mathbf{w_d} \in [0,1]$ Urgency factor for device d
- $\mathbf{w_s} \in [0,1]$ Priority of slice s
- **wr** $\in [0,1]$ Weight of the impact of reliability (SINR)
- **wld** $\in [0,1]$ Weight of the impact of load (congestion)

Utility Function

Related work

$$\sigma_r = SINR_{d,s,g} / SINR_{max}$$

$$U_{HCC} = \delta_r (\sigma_r w_r + \sigma_{ld} w_{ld}) \quad with \quad \delta_r \in \{0, 1\}$$

$$U_{MCC} = \sigma_r w_r + \sigma_{ld} w_{ld} \tag{8}$$

$$U_{LCC} = \sigma_{ld} w_{ld}$$

$$U_{d,s,g} = U'_{d,s,g} + U''_{d,s,g}$$

$$E_{d,s,g} = \frac{p_i^{tx} + p_i^{rx}}{V + epa} \cdot d_{tx/rx}$$

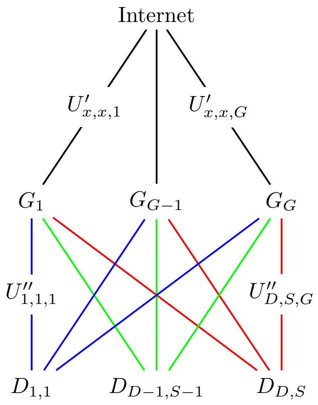

Figure 6. Slicing.

BIRCH: Clustering

balanced iterative reducing and clustering using hierarchies

T: max number of device per cluster,
B: maw number of childes per cluster.

t_0 : number of clusters = number of devices;
t_i : get D2 the set of closest devices to cluster D1

- if D1+D2 < T -> merge
- eif D2< B -> create sub-cluster D2 of D1

$$CF : (D_s, LS, SS) = \left(D_s, \sum_{d=1}^{D_s} w_d, \sum_{d=1}^{D_s} w_d^2 \right) \tag{9}$$

Constraints/Hypothesis

Related work

$$\max \sum_{d \in D} \sum_{s \in S} i_{d,s} \cdot U_{d,g,s} \qquad , g \in G \tag{10}$$

$$\begin{aligned}
C1 &: \textstyle\sum_{s \in S} i_{d,s} && = 1, \forall d \in D \\
C2 &: \textstyle\sum_{d \in D} i_{d,g} \cdot P^{tx}_{d,s,g} && \leqslant P^{tx\ max}_{g}, \forall g \in G, \forall s \in S \\
C3 &: \textstyle\sum_{d=1}^{N} i_{d,s} \cdot i_{d,g} \cdot DR_{d,s,g} \cdot && \leq BW_{s,g}, \forall s \in S, \forall g \in G
\end{aligned} \tag{11}$$

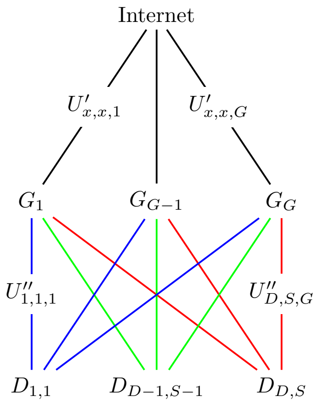

Figure 7. Slicing.

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Game theory

Related work

- **Players:** $K = \{1, ..., K\}$
- **Strategies:** $S = S_1 \times \ldots \times S_K$
  - S_k **is the strategy set of the** k^{th} **player.**
- **Rewards:** $u_k : S \longrightarrow R_+$ **and is denoted by** $r_k(s_k, s_{-k})$
  - $s_{-k} = (s_1, \ldots, s_{k-1}, s_{k+1}, \ldots, s_K) \in S_1 \times \ldots \times S_{k-1} \times S_{k+1} \times \ldots \times S_K$

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Game theory

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Discussion

- a
- b

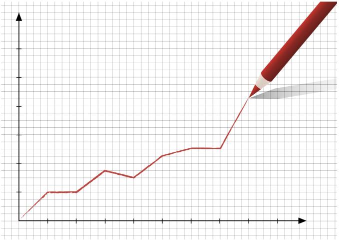

Figure 8. .

References