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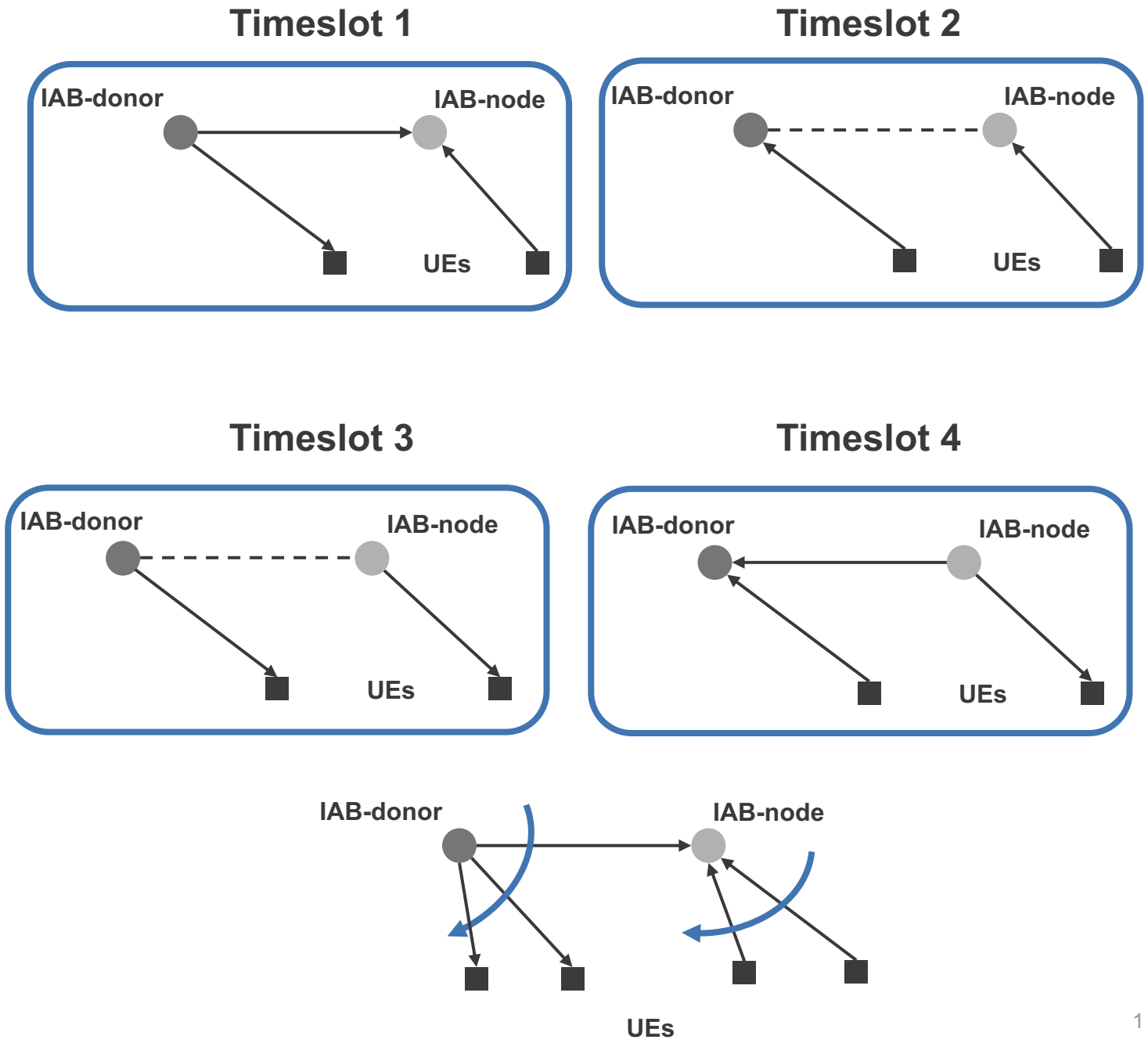
Optimization problem

We formulated the optimization problem as linear programming (LP) problem

Considered scenario:

- Single-hop, single-connectivity network
- Both access and backhaul are mmWave
- In-band operation mode
- Time division multiplexing (TDM)
- **Single beam at the IAB-donor**: backhaul time-frequency resources are shared between UEs connected to IAB-donor and IAB-nodes
- IAB-nodes have separate radios for backhaul and access (both are single-beam)
- IAB-nodes are capable of storing the incoming data to further transmit it at the following timeslot

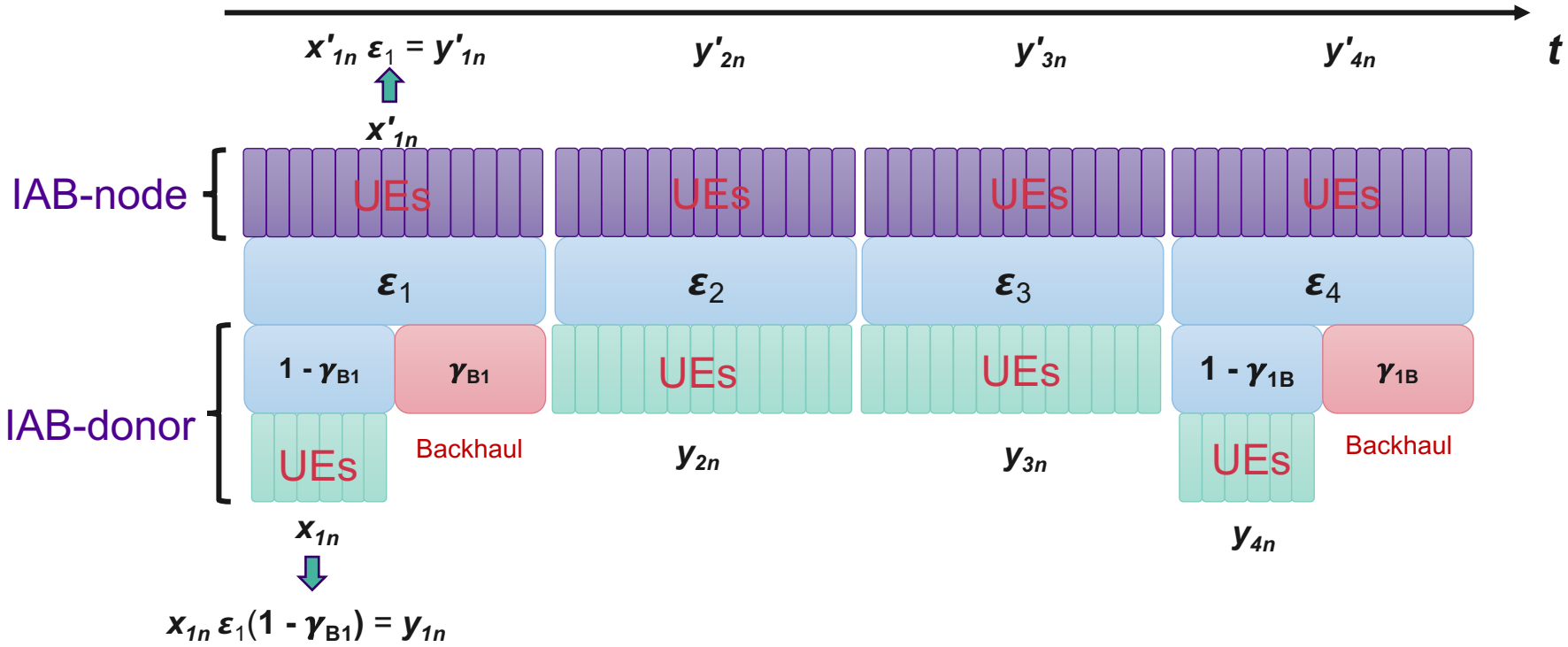


Optimization problem

The problem can be presented as a linear programming (LP) problem **(linear optimization):**

$$x_{1n}\epsilon_1(1-\gamma_{B1}) \rightarrow y_{1n}, n = 1...N_1$$
$$x_{2n}\epsilon_2 \rightarrow y_{2n}, n = 1...N_1$$
$$x_{3n}\epsilon_3 \rightarrow y_{3n}, n = 1...N_1$$
$$x_{4n}\epsilon_4(1-\gamma_{1B}) \rightarrow y_{4n}, n = 1...N_1$$
$$\gamma_{B1}\epsilon_1 \rightarrow y_{B1}$$
$$\gamma_{1B}\epsilon_4 \rightarrow y_{1B}$$

$$x'_{1n}\epsilon_1 \rightarrow y'_{1n}, n = 1...N_2$$
$$x'_{2n}\epsilon_2 \rightarrow y'_{2n}, n = 1...N_2$$
$$x'_{3n}\epsilon_3 \rightarrow y'_{3n}, n = 1...N_2$$
$$x'_{4n}\epsilon_4 \rightarrow y'_{4n}, n = 1...N_2$$



Optimization problem

Maximize:

$$\min(h_n^{DL}, h_n^{UL}, h_n^{'DL}, h_n^{'UL})$$

Subject to:

1. Downlink:

$$h_n^{DL} = B\Delta s_{0n}(y_{1n} + y_{3n}), n = 1...N_1$$
$$h_n^{'DL} = B\Delta s_{1n}(y'_{3n} + y'_{4n}), n = 1...N_2$$

2. Uplink:

$$h_n^{UL} = B\Delta s_{n0}(y_{2n} + y_{4n}), n = 1...N_1$$
$$h_n^{'UL} = B\Delta s_{n1}(y'_{1n} + y'_{2n}), n = 1...N_2$$

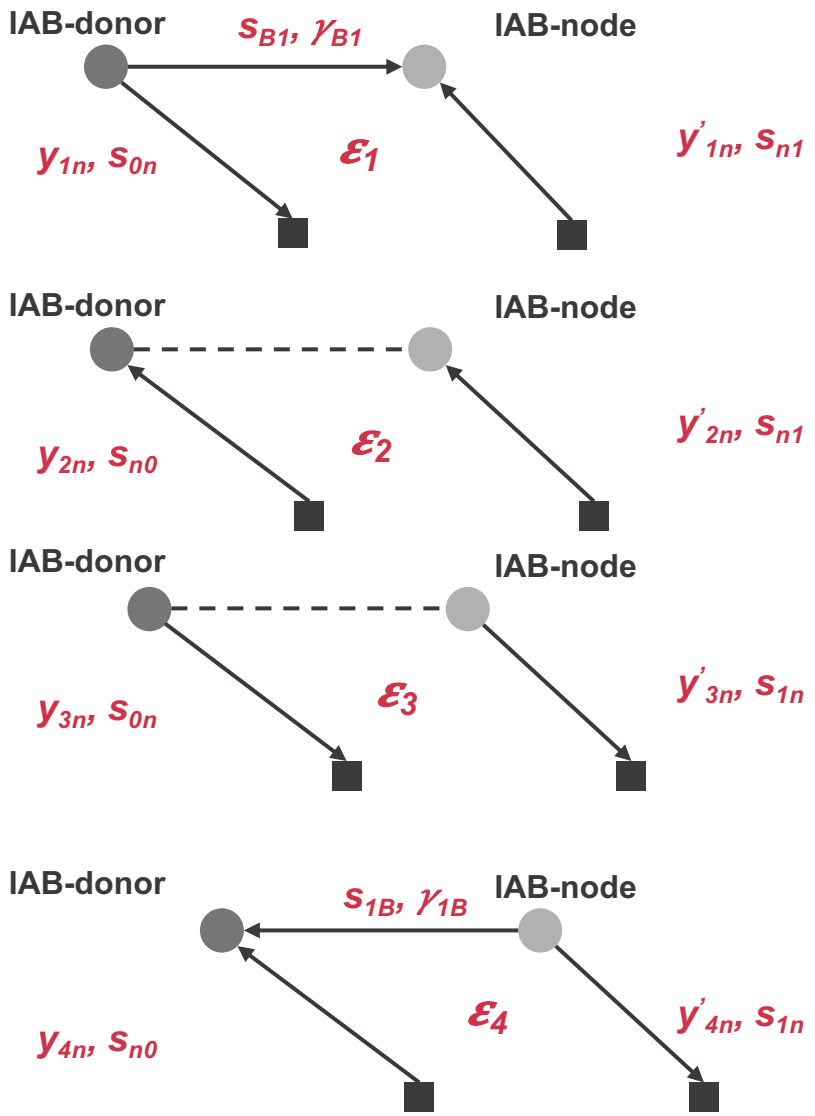
3. Backhaul constraints:

$$B\Delta(\sum_{n=1}^{N_2} s_{1n}y'_{3n} + \sum_{n=1}^{N_2} s_{1n}y'_{4n}) \leq B\Delta s_{B1}y_{B1}$$
$$B\Delta(\sum_{n=1}^{N_2} s_{n1}y'_{1n} + \sum_{n=1}^{N_2} s_{n1}y'_{2n}) \leq B\Delta s_{1B}y_{1B}$$

4. Timeslots constraints:

$$\epsilon_1 + \epsilon_2 + \epsilon_3 + \epsilon_4 = 1$$
$$\sum_{n=1}^{N_1} y_{1n} + y_{B1} \leq \epsilon_1, \sum_{n=1}^{N_2} y'_{1n} \leq \epsilon_1$$
$$\sum_{n=1}^{N_1} y_{2n} \leq \epsilon_2, \sum_{n=1}^{N_2} y'_{2n} \leq \epsilon_2$$
$$\sum_{n=1}^{N_1} y_{3n} \leq \epsilon_3, \sum_{n=1}^{N_2} y'_{3n} \leq \epsilon_3$$
$$\sum_{n=1}^{N_1} y_{3n} + y_{1B} \leq \epsilon_4, \sum_{n=1}^{N_2} y'_{3n} \leq \epsilon_4$$

- h_n *[bits]* is the amount of data for a particular UE
- B *[Hz]* is the total available bandwidth
- Δ *[s]* is the frame duration
- y *[0 ≤ x ≤1]* is UE time allocation
- y_{Bi} *[0 ≤ x ≤1]* is the fraction of the time allocated for communication with the IAB-node ***i***
- s_{ij} *[(bit/s)/Hz]* is spectral efficiency of the link between the **transmitting** node ***i*** and the **receiving** node ***j***
- ε_i *[0 ≤ ε_i ≤1]* is a fraction of time allocated for timeslot ***i***



System model

Input:

- System parameters
- Positions of IAB-donor, IAB-nodes, and UEs

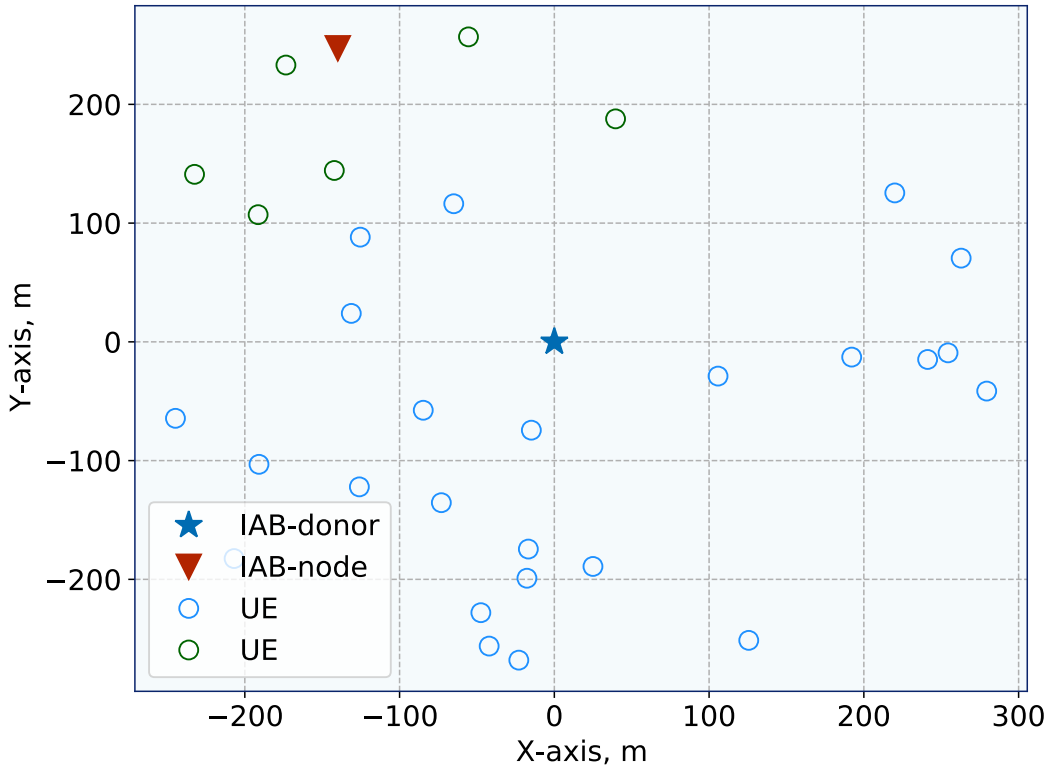
Variables:

$y_{1n}, y_{2n}, y_{3n}, y_{4n}, y'_{1n}, y'_{2n}, y'_{3n}, y'_{4n}, y_{B1}, y_{1B}, \varepsilon_1, \varepsilon_2, \varepsilon_3, \varepsilon_4, z$

Optimization tool:

GEKKO https://machinelearning.byu.edu/

Parameter	Value
Number of UEs	**30**
Backhaul bandwidth, B	400 MHz
Access bandwidth	400 MHz
Carrier frequency, f_c	FR2: 30 GHz
IAB-donor height	25 m
IAB-node height	15 m
UE height	1.5 m
IAB-donor Tx power	40 dBm
IAB-node Tx power	33 dBm
Interference margin	3 dB



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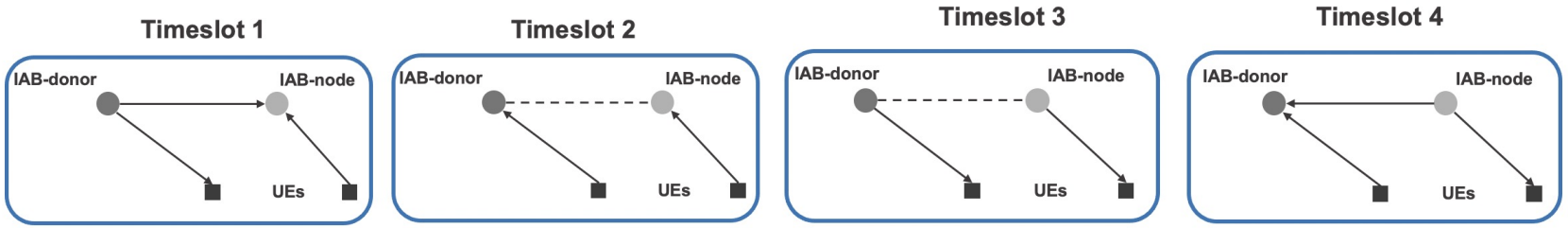
Results



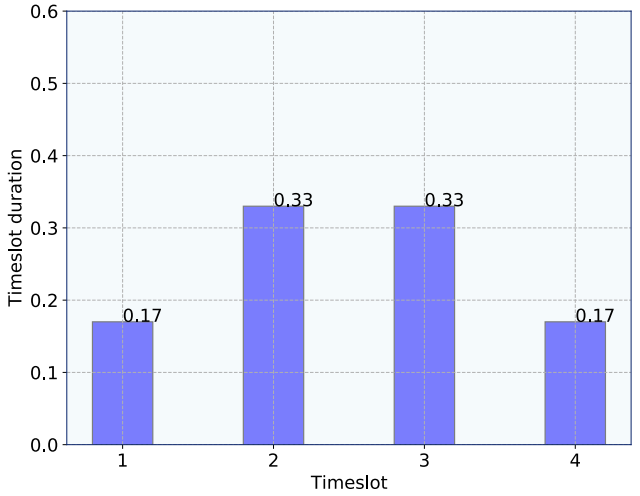
Output:

- UE data rates
- Timeslots duration ($\varepsilon_1, \varepsilon_2, \varepsilon_3, \varepsilon_4$)
- Optimized timeslots at the IAB-donor ($y_{1n}, y_{2n}, y_{3n}, y_{4n,}$)
- Optimized timeslots at the IAB-node ($y'_{1n}, y'_{2n}, y'_{3n}, y'_{4n}$)

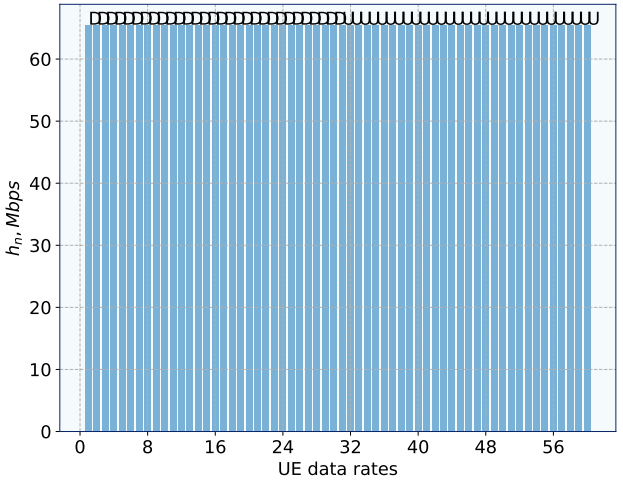
- Optimization objective: Max-min fairness
- **Downlink and uplink for each UE are optimized separately:**

$$\textbf{Maximize:}$$
$$\min(h_n^{DL}, h_n^{UL}, h_n^{'DL}, h_n^{'UL})$$

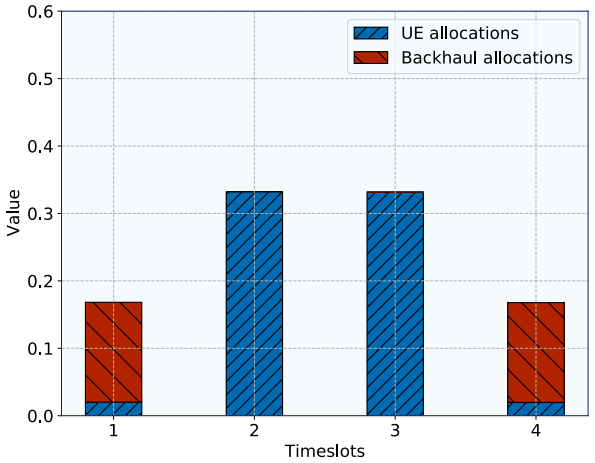
- Fairness criterion affects the UE data rates distribution and, therefore, timeslots durations
- Not used timeslots are flexible and not allocated meaning that they are idle during this timeslots



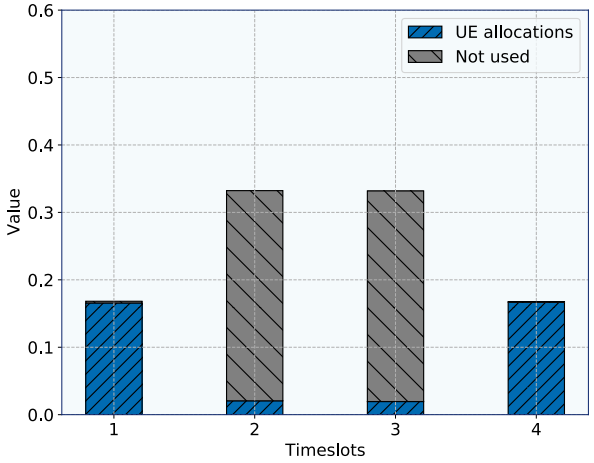
(1) Timeslots duration



(2) UE data rates



(3) Optimized timeslots (IAB-donor)



(4) Optimized timeslots (IAB-node)