Apps tandem for scalable optimization of network energy efficiency

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All things wireless

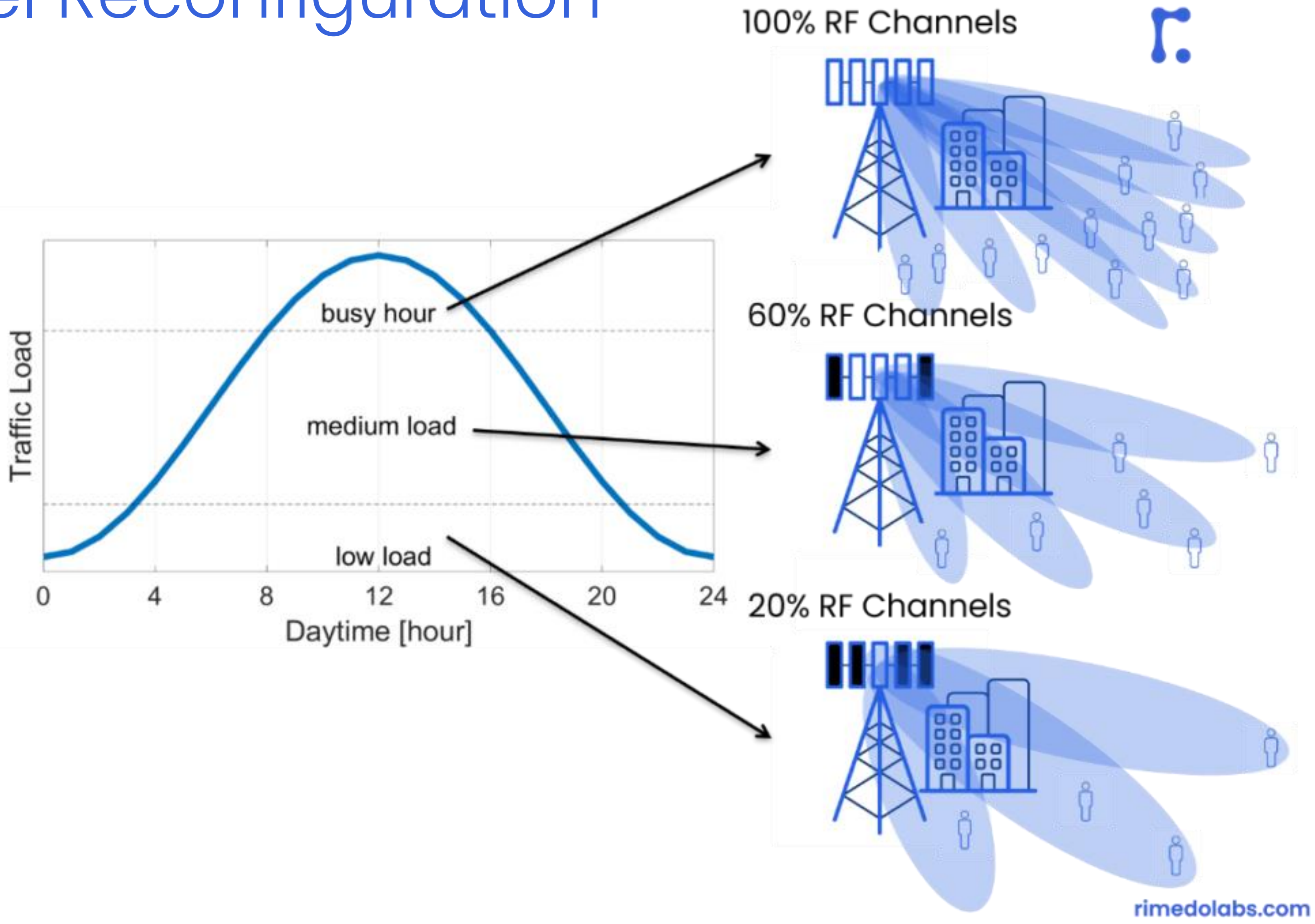
Agenda

- Energy efficiency topic within Open RAN
- Limitations of existing Cells ON/OFF Switching algorithms
- Apps tandem as a scalable solution for COOS
- Apps tandem vs current O-RAN standard

Energy efficiency within Open RAN

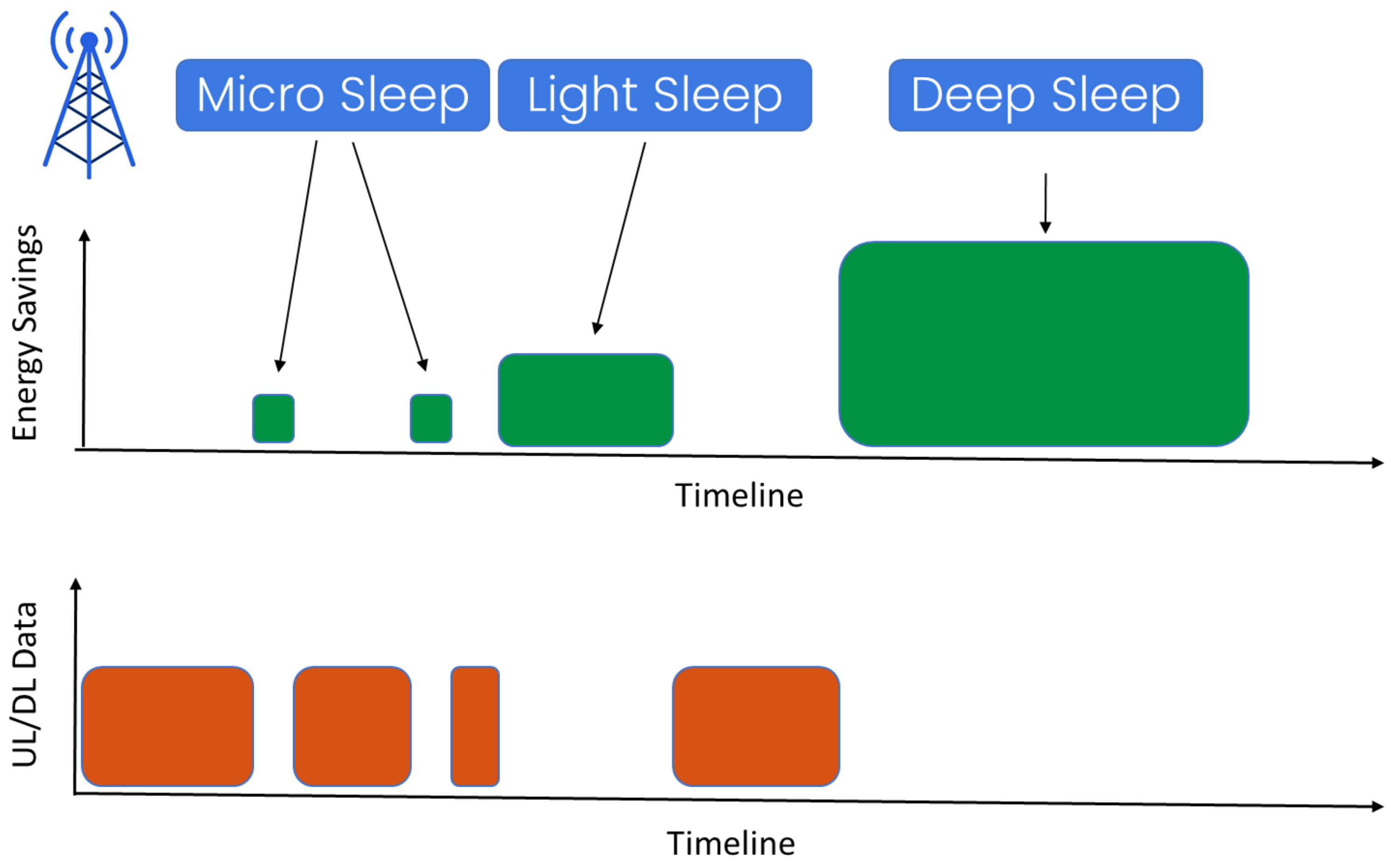
Option 1: RF Channel Reconfiguration

- For M-MIMO
- Possible either in Non-RT RIC or Near-RT RIC
- Before June 2024: Standard not specific for Near-RT RIC yet.
- Not every hardware ready



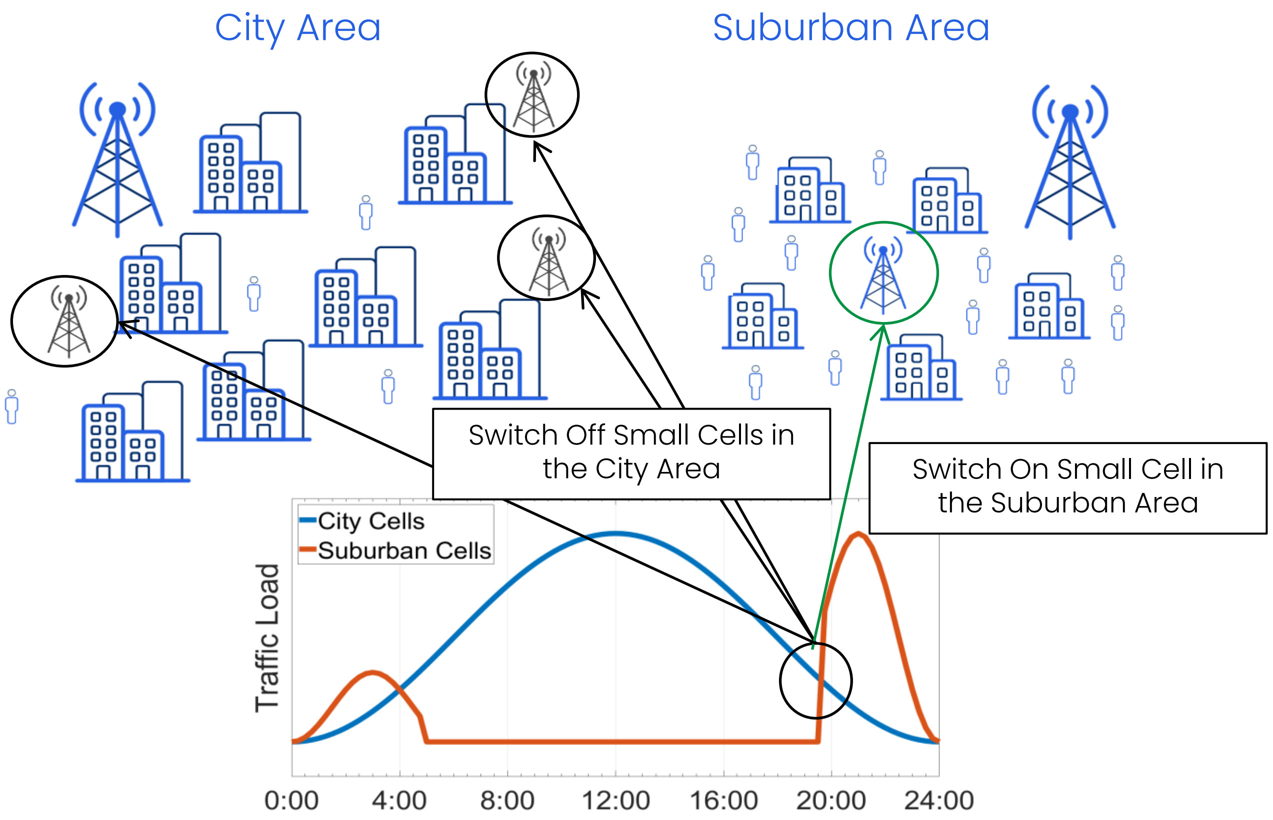
Option 2: Advanced Sleep Mode

- turn OFF for O-RU over an OFDM symbol (ASM1), slot (ASM2) or frame (ASM3)
- for Near-RT RIC, under development in the standard
- too complex for standard implementations (hardware)
- recall this decision influences the scheduler- maybe some coordination is needed. Cannot collide with periodic control signals



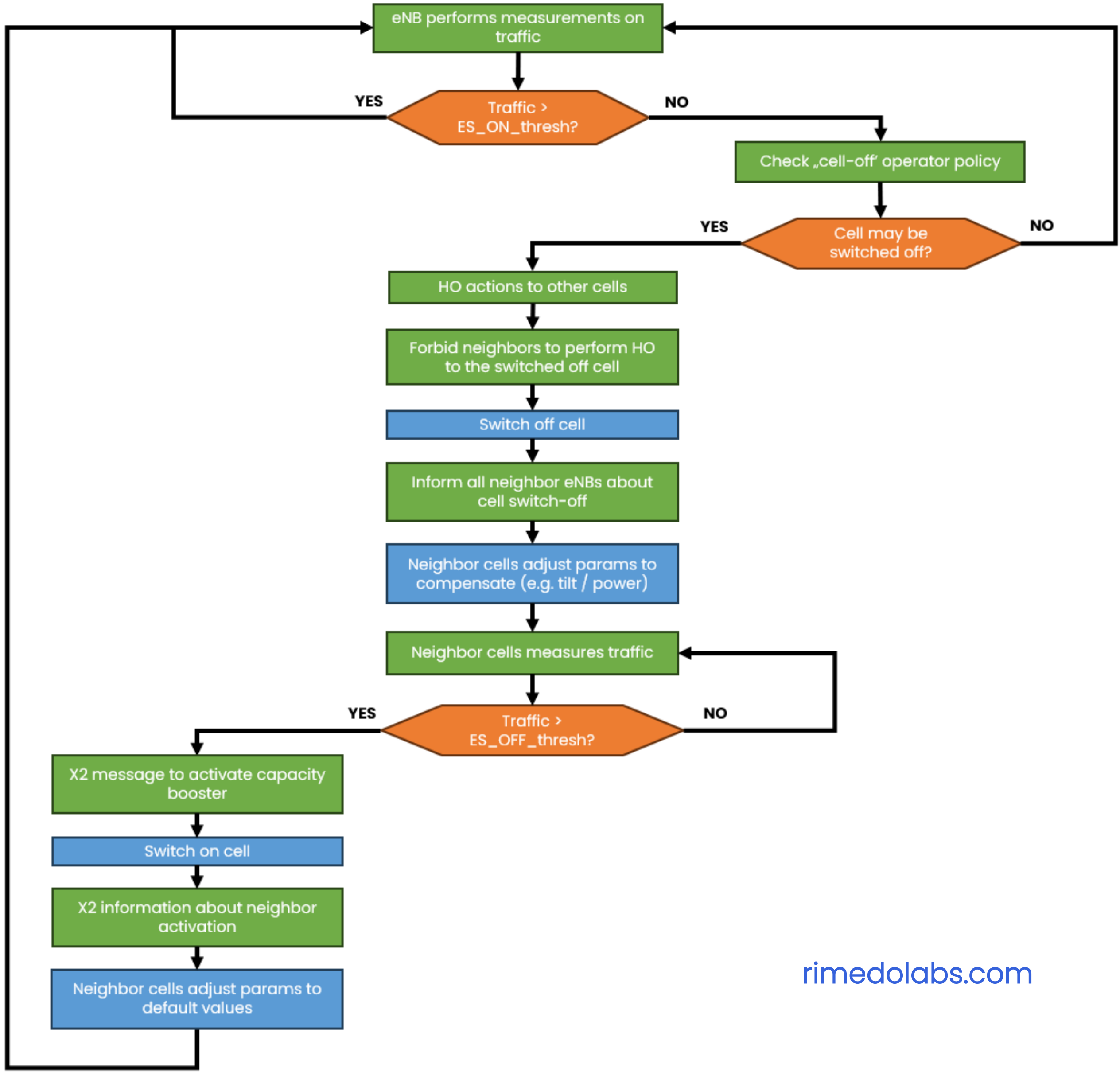
Option 3: Cell ON/OFF Switching

- Turns off a single cell/carrier
- Mostly standardized and available in RIC/RAN emulator platforms
- Less flexible than other Energy Serving methods
- Simple radio hardware possible (even legacy, non-O-RAN)
- Multiple algorithms for this purpose:
  - Survey from 2015: around 160 cited papers
  - Self Organizing Networks: reference design [simpler but closer to real implementation]

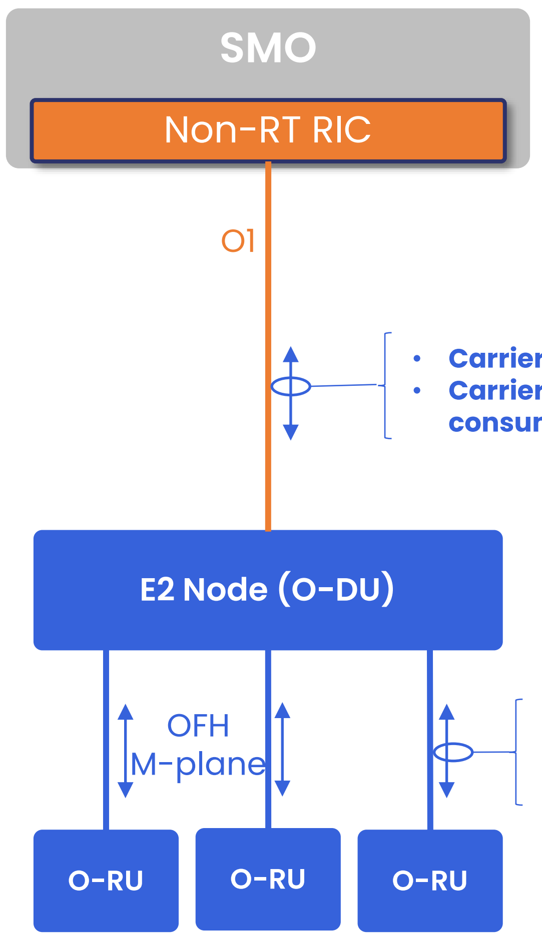


COOS in Self Organizing Network

- Called therein:
  Energy Saving Management
- Thresholds based
- SON: Not general but per use case
- Fallback procedure



Architecture: COOS in O-RAN Alliance spec.



- **Collect configurations, KPIs and measurement reports** – (e.g. cell load related and traffic info, EE meas. Reports, geolocation info) from SMO, E2 nodes and O-RU to make decisions using ML training and inference
- **Analyze received data** from SMO, E2 and O-RU to determine EE/ES optimization (e.g. if carriers or cells are recommended to be switched Off/On)
- **Signal updated config for EE/ES optimization** to E2 Nodes via R1/O1

- **Carrier/cell ON/OFF recomendation (down)**
- **Carrier/cell characteristic, EE/EC meas. Reports, load stats per cell/carrier, UE mob info, Energy consumption (up)**

- **Report cell config/KPI and meas reports (e.g. cell locad, traffic info)** to SMO via O1
- **Perform actions for EE/ES optimization** e.g. check ongoing emergency calls/warning messages, perform preparation for Off switching (e.g. modify/disable CA or DC, trigger HO traffic and UEs to other cells, etc), for On switching (e.g. cell probing, neighbor info update) and make a final decision on switch off/on and notify SMO via O1 about actions

- **Cell on/off commands (down)**
- **Power consumption metrics (up)**

- **Report** EC and EE-related info via Open FH M-plane to O-DU or directly to SMO with required granularity to SMO over O1
- **Support actions** required to perform EE/ES optimization (updated carrier config, activation/deactivation/sleep)

Based on: O-RAN.WG1.NESUC-R003-v01.00

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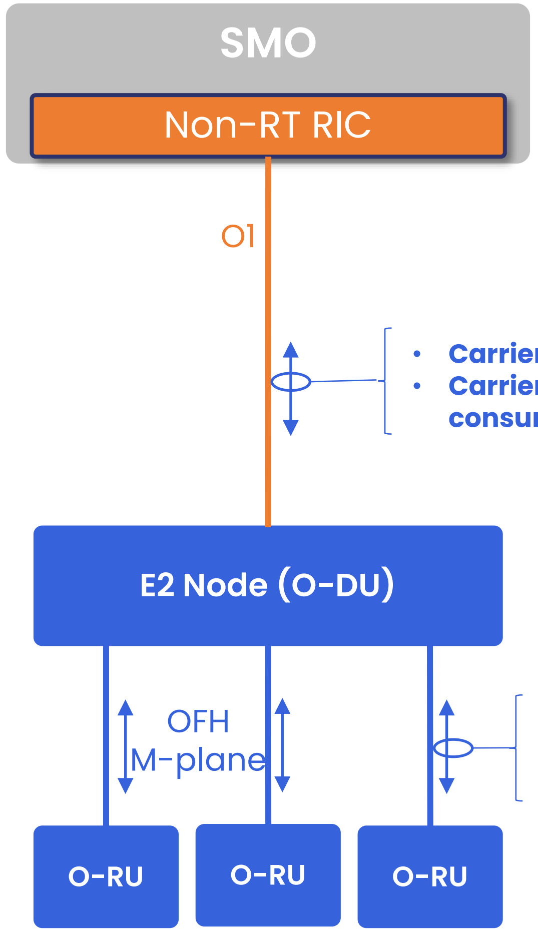

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Disadvantages:

- Possible substantial delay on O1 interface
- Centralized approach (bad scalability).

- **Carrier/cell ON**
- **Carrier/cell ch**
consumption

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Based on: O-RAN.WG1.NESUC-R003-v01.00

Limitations in existing COOS algorithms

Limited scalability

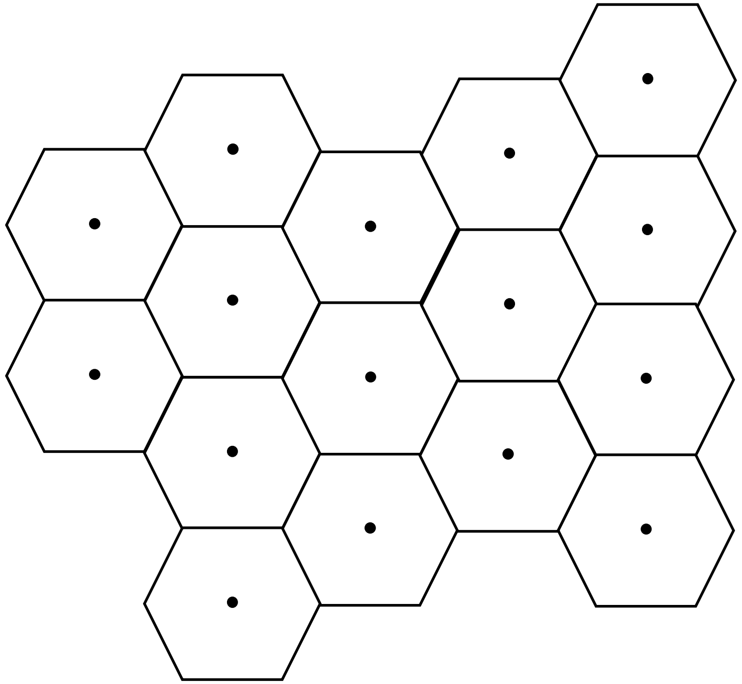
- Spatial (small network, heterogenous including multifrequency), temporal ("per snapshot" decision)
- Computational complexity, control information (volume, delay) issue vs optimality

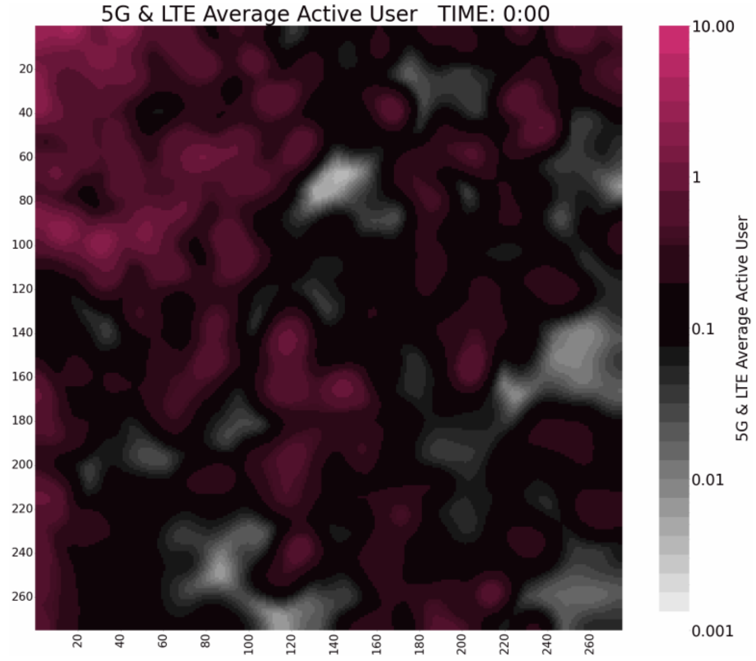
Exhaustive search vs real network

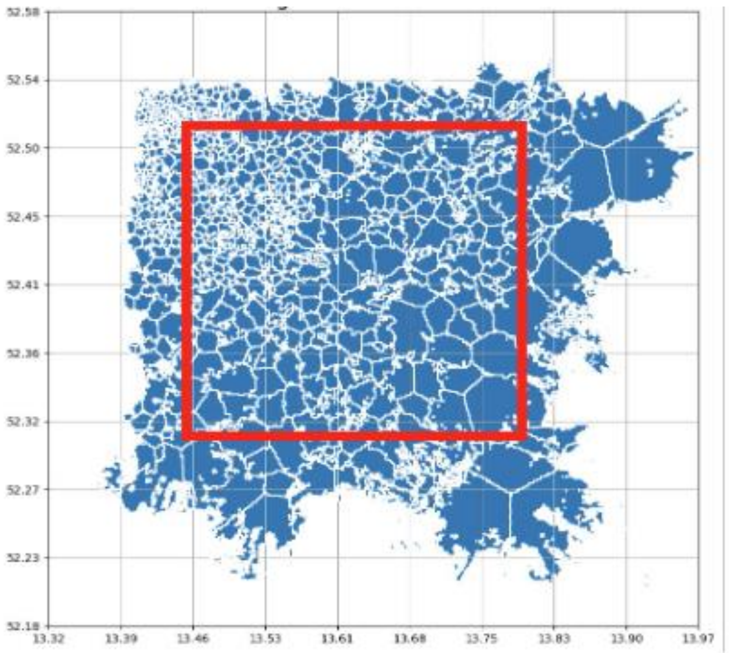
- Some cells cannot be turned OFF
- Limit on the number of tested COOS patterns (caused by: continuous network QoS, hardware failure probability increase): problem for many (especially Machine Learning) algorithms

“Typical network” vs realistic network

- Both traffic and sites deployment







COOS algorithm: Requirements

Large & heterogeneous network:

- Parallel (“soft borders”) COOS in different cells but not adjacent (prevent ping-pong):
  - Turning OFF cells=increased load in adjacent cells
- “Parallel” but as continuous time optimization adjacent cells can block each other. Important order of checking cells for turn ON/OFF (not cell ID number)
- Works with various frequency and power (size) cells

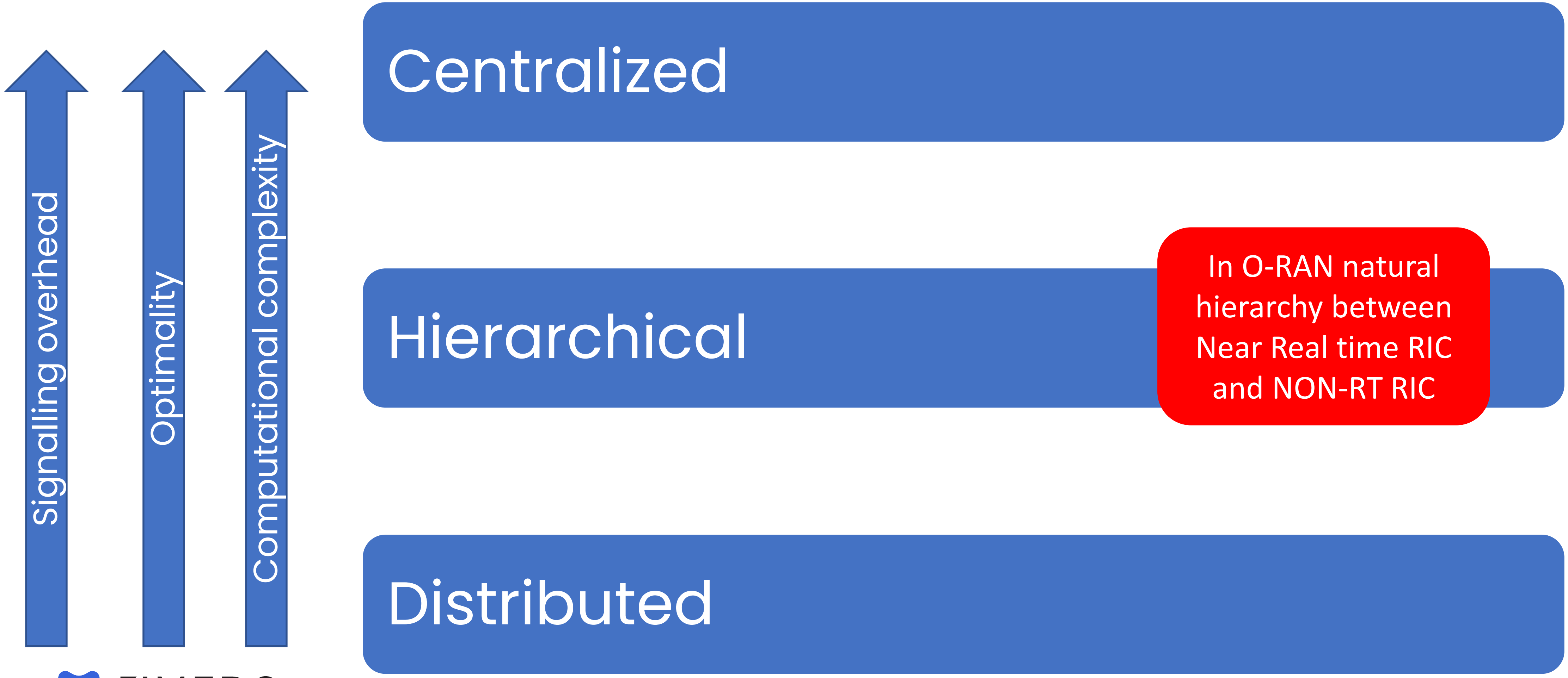
Timescale:

- Operate “with memory” (no snapshot-like)
- Reactive to medium-term variations (e.g. react to instantaneous increased traffic in one network area) vs. long-term predictive (UEs demand changes depending on the hour of a day)

Load balancing – strong dependence:

- In time (COOS waits for TS result)
- COOS uses load (result of TS) as decision metric e.g.,
  perfect Load balancing keeps equal load among cells vs keeping busy coverage cells

Algorithm topology



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COOS algorithm tandem

Global entity (all cells coordination):
- coordinate local optimization
- block cells (e.g. coverage layer)
- modify parameters (e.g. thresholds) of local entity to obtain given goal e.g., Energy Efficiency maximization
- Goal function with "soft borders" (not per cell- optimum to turn off cell)

Local entity (per cell operation):
- turn on/off single cell based on load metric (own for turn OFF, adjacent for turn ON)
- Each state change blocks this and adjacent cells for some time (reduces ping-pong)
- most of the computations and short-term control messages

Non-RT RIC

Near-RT RIC

E2 Nodes/Network

Summary: xApps turns ON/OFF cells, rApp provides constraints and learned parameters. (hierarchy, non overlapping in functions – to prevent ping-pong effect). xApp can operate on its own with limited performance

Apps tandem in O-RAN- limitations

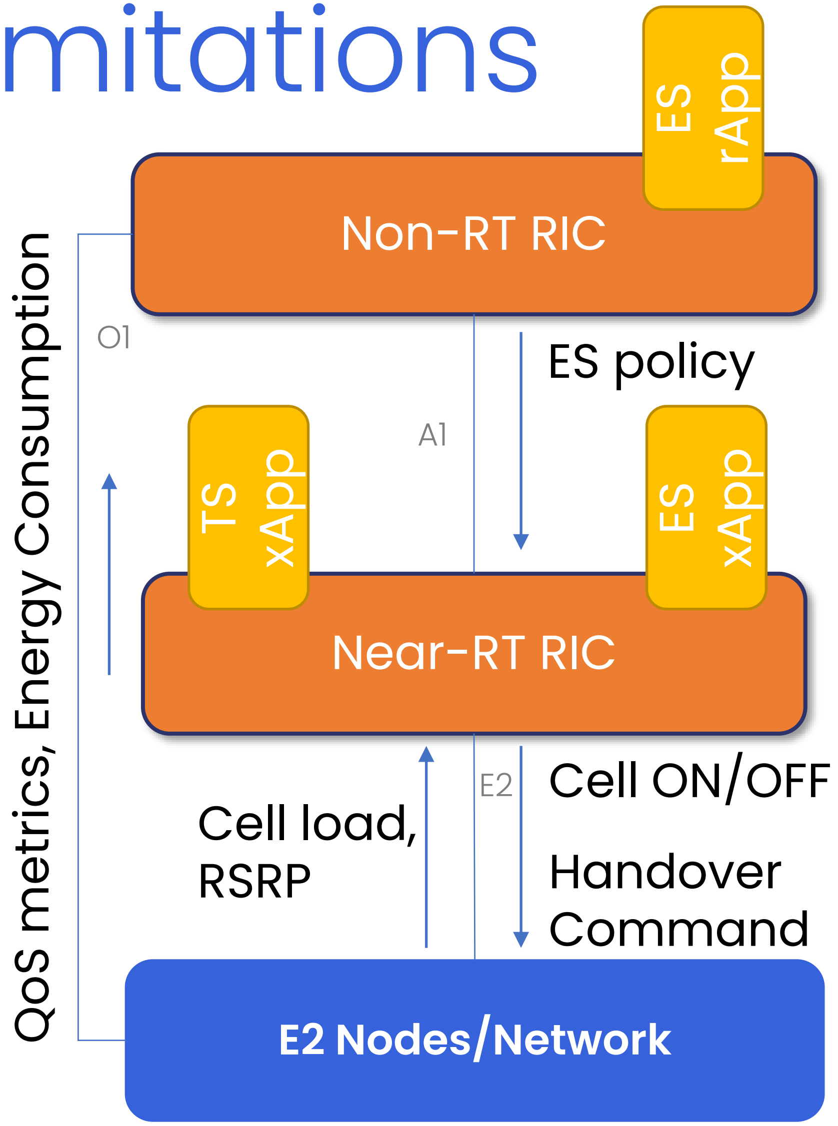
•Main problem: ES rApp-> ES xApp interface. On A1 only "ES policy exchanged", i.e., ES goal. One-way communications

•Can ES rApp and ES xApp come from different vendors? YES

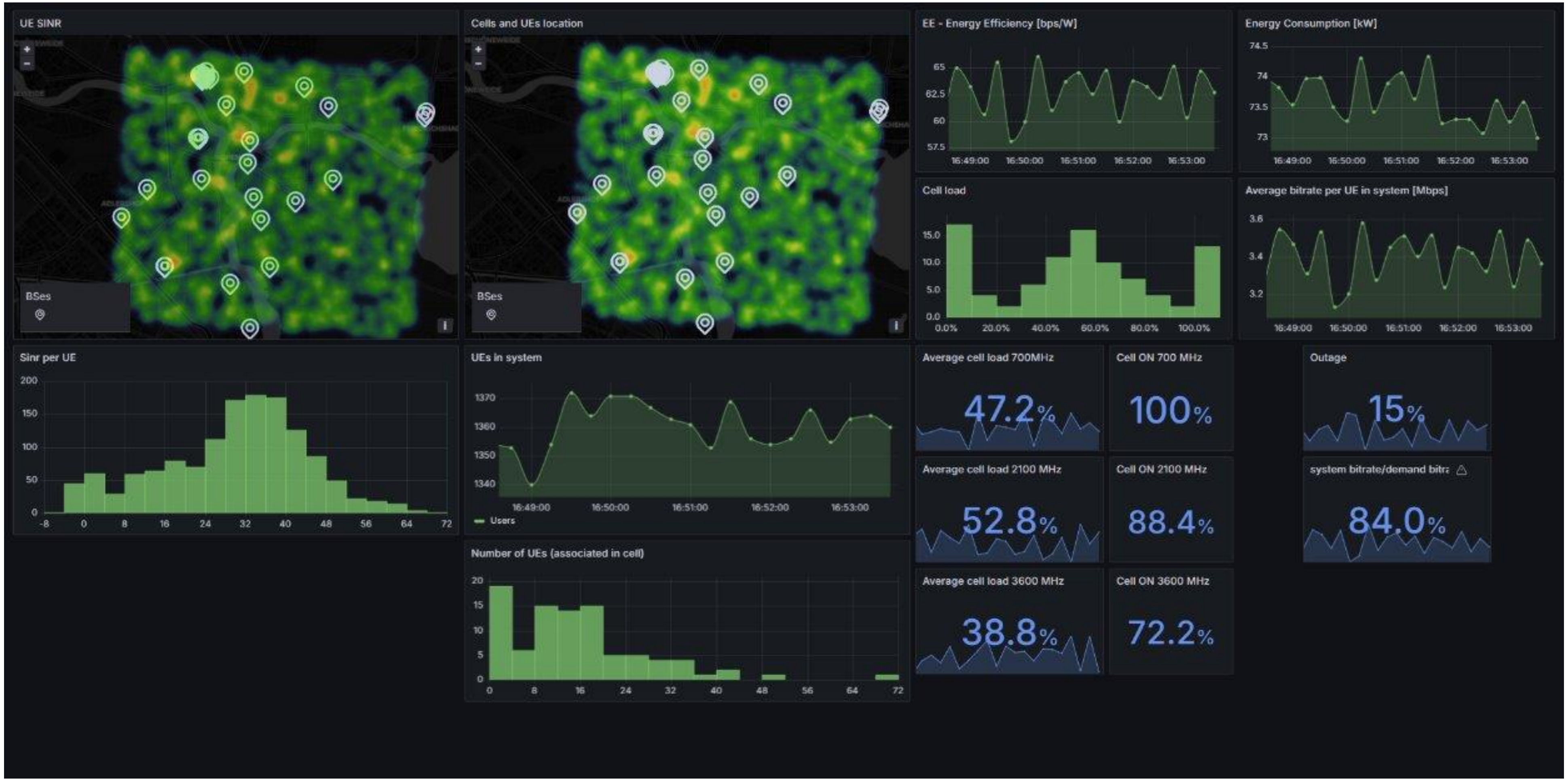
•Advantage of rApp and xApp coming from the same vendor? YES (knowledge of internal behavior, goal function, etc.):
OUR UNDERSTANDING OF TANDEM APPS

•There is no way in the standard for the App to learn about other apps deployed (especially inter-RIC), only subscribe to specific messages e.g. revealing TS App is operating: maybe some "manifesto" should be exchanged?

•The coordination by a Non-RT RIC is important as a standard does not allow an interface between Near RT RICs.



Demo/video


UE SINR
BSes
Cells and UEs location
BSes
EE - Energy Efficiency [bps/W]
Energy Consumption [kW]
Cell load
Average bitrate per UE in system [Mbps]
Sinr per UE
UEs in system
Users
Average cell load 700MHz
47.2%
Cell ON 700 MHz
100%
Outage
15%
Average cell load 2100 MHz
52.8%
Cell ON 2100 MHz
88.4%
system bitrate/demand bitr
84.0%
Average cell load 3600 MHz
38.8%
Cell ON 3600 MHz
72.2%
Number of UEs (associated in cell)

Summary

Summary

- Energy efficiency is one of the two most crucial topics for further O-RAN development
- Cell ON/OFF switching one of the most mature in standard, algorithms, and real hardware (legacy)
- Big, heterogenous networks, with realistic traffic can profit from Apps tandem deployment
- The O-RAN standard limits information exchange between tandem Apps

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Let’s keep in touch!

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