Building Flexible, Low-Cost Wireless Access Networks With Magma

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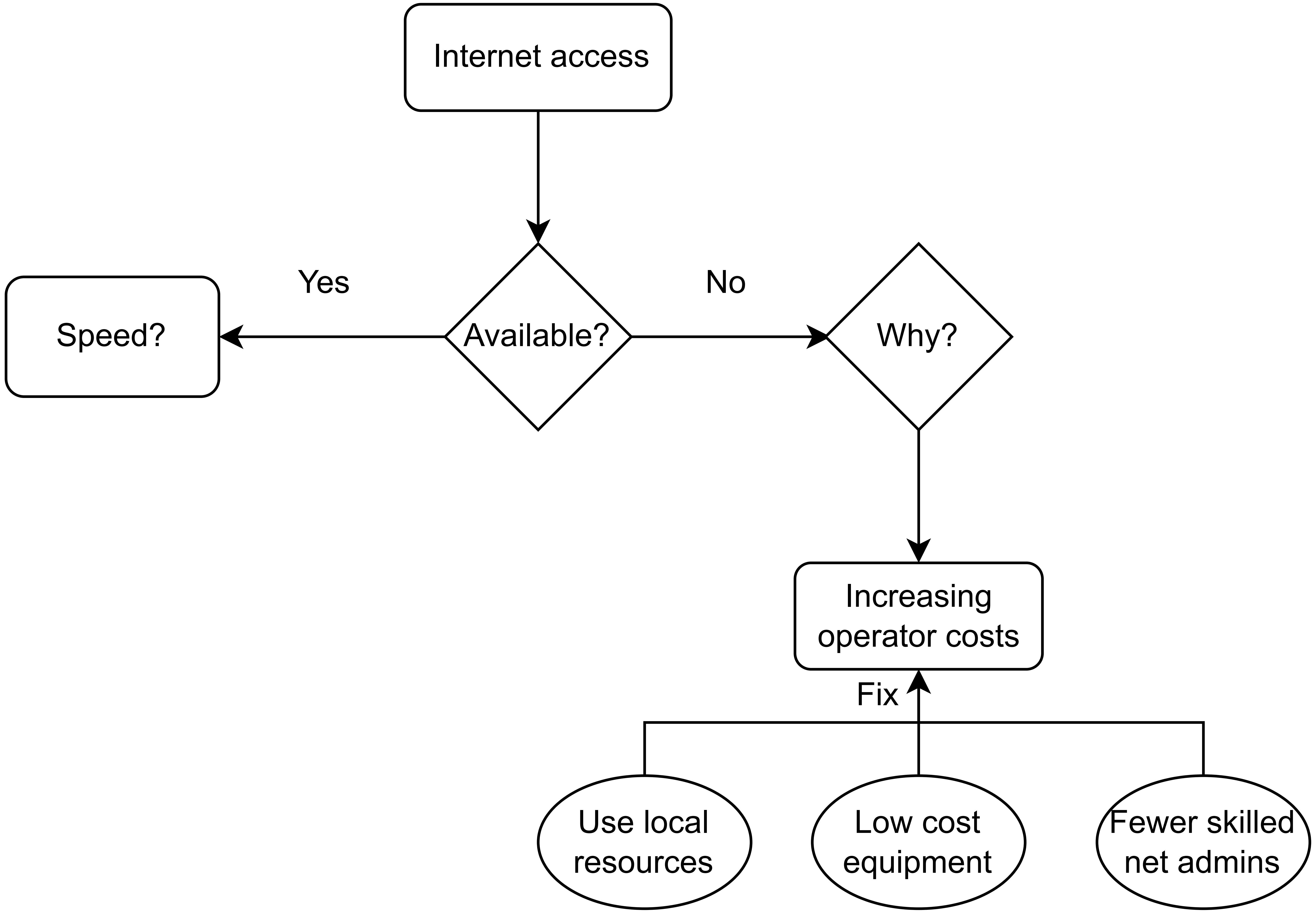
Summary slides by Milind Kumar V

Overview

- The problem of internet access
- Magma as a solution
    - For scaling, up and down
    - For deployment simplification
    - Architectural decisions for reliability
- Does Magma fulfill its promise?
    - Measuring throughput performance
    - Control and user plane load handling
- Magma deployments
- Future directions

Internet access is not ubiquitous



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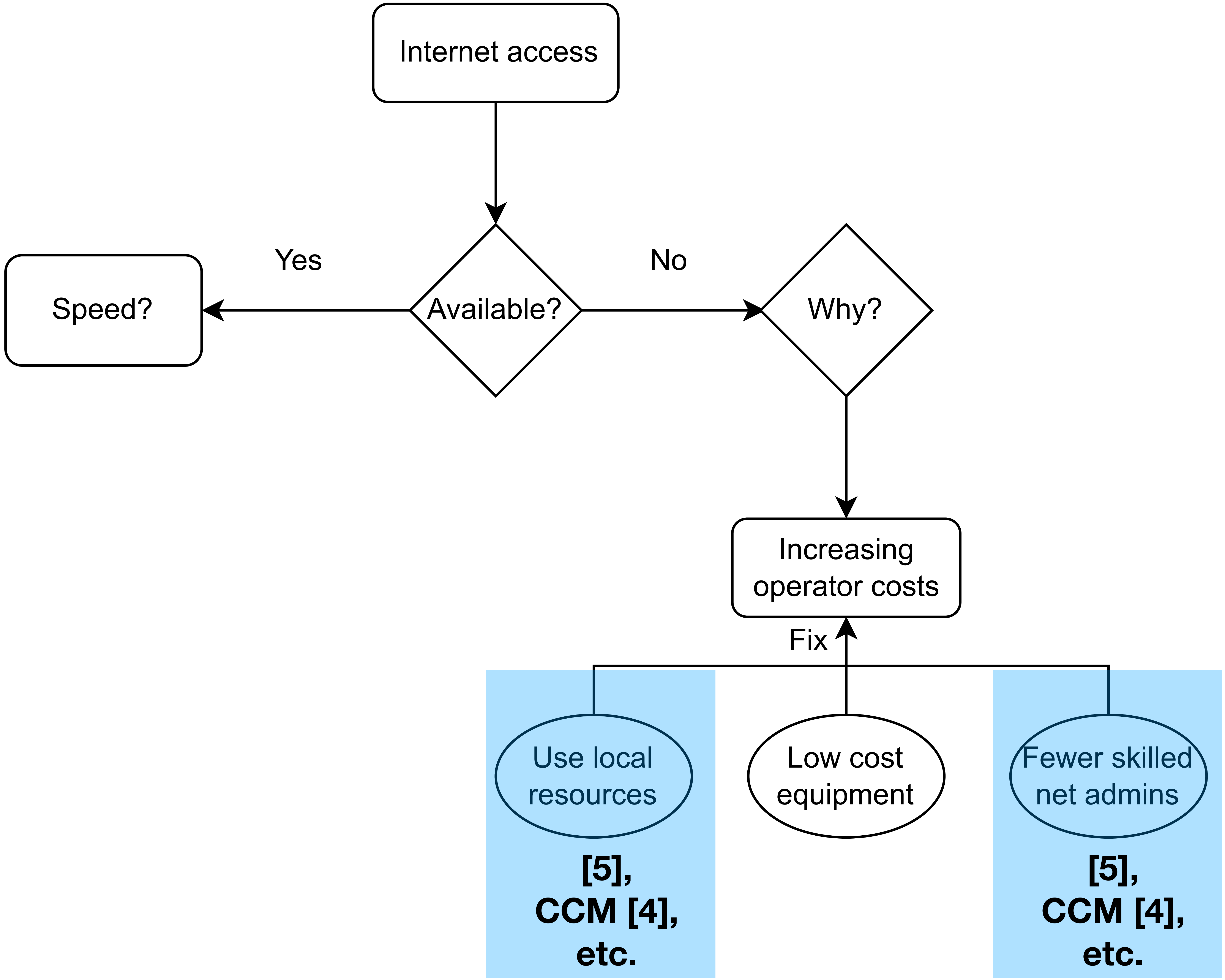

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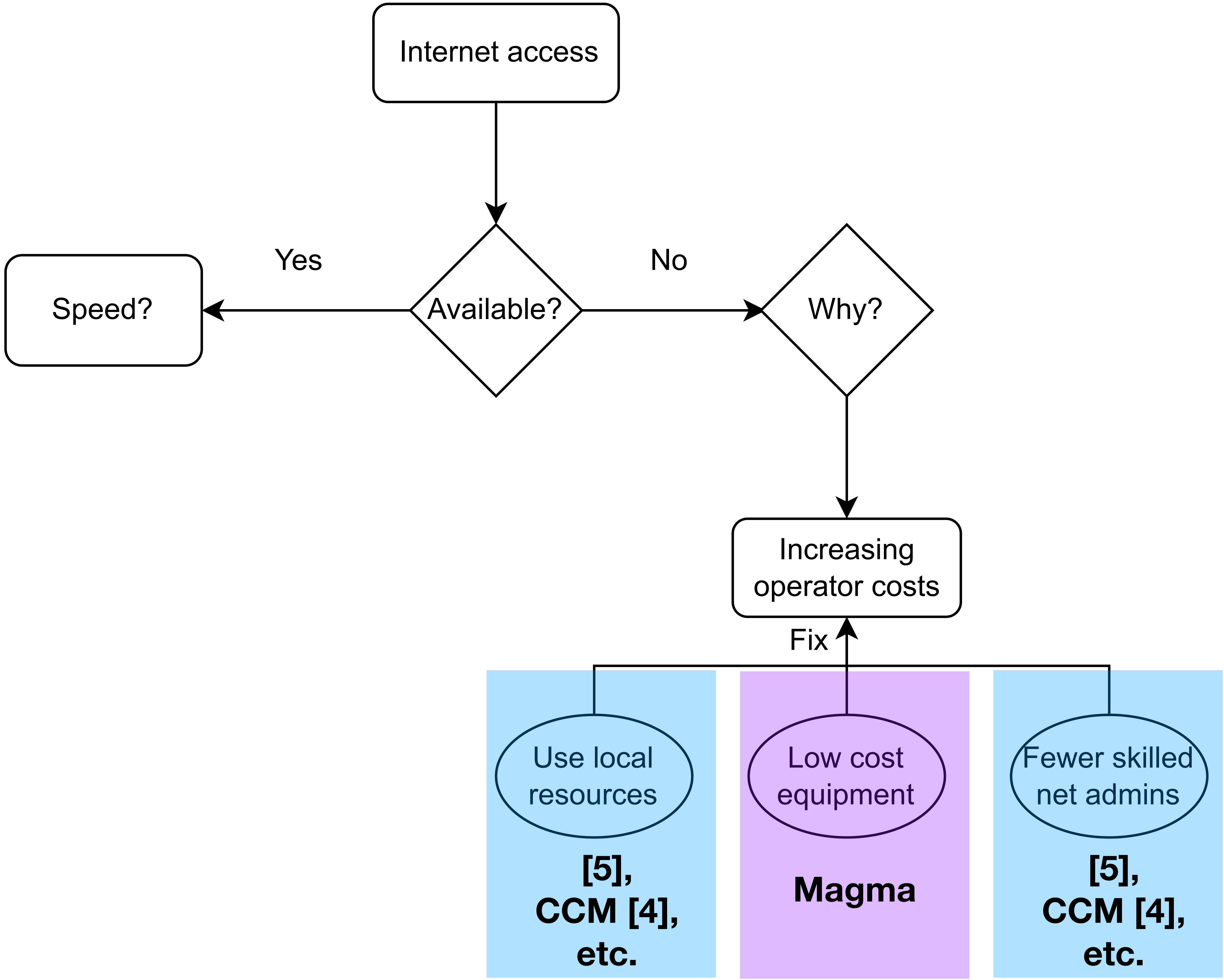
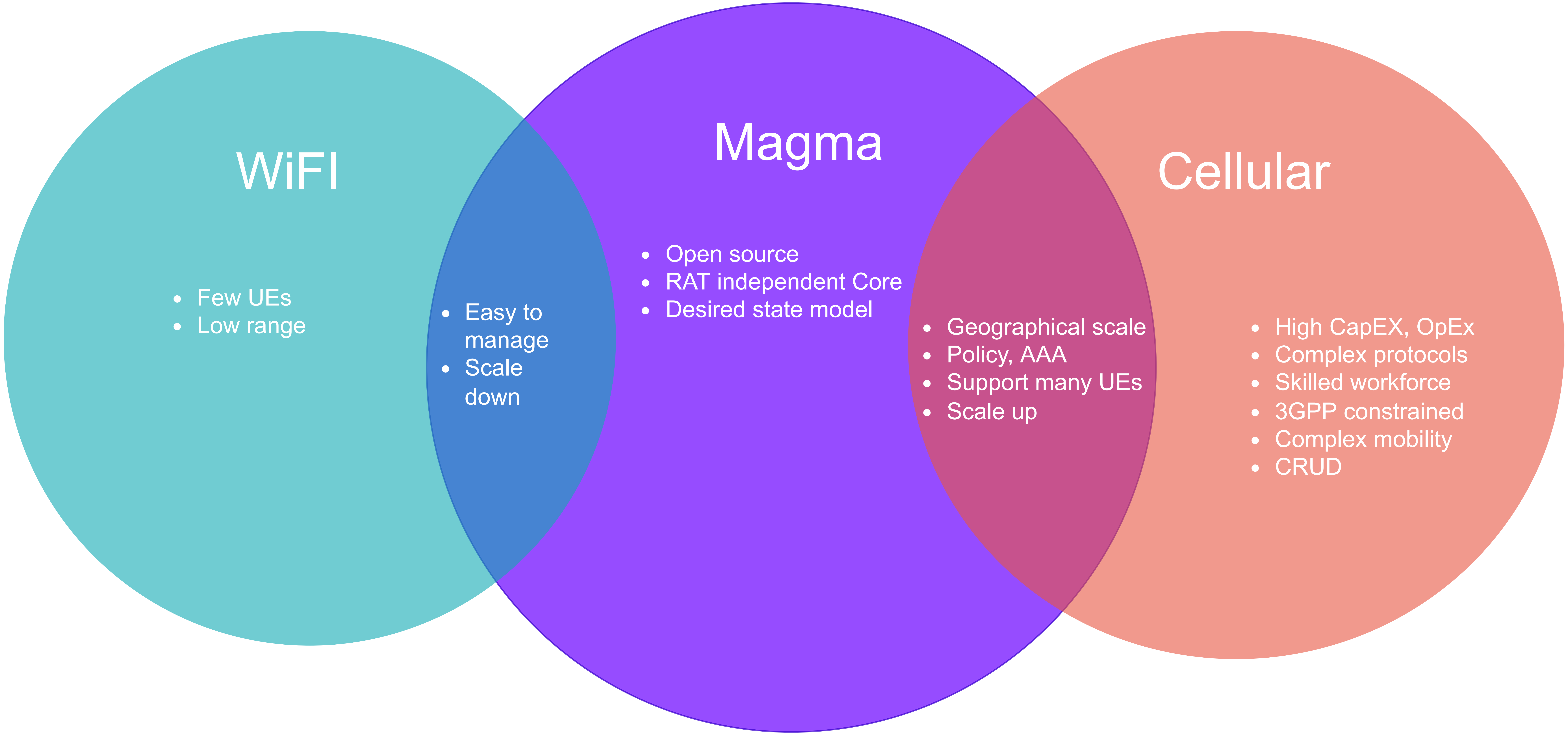
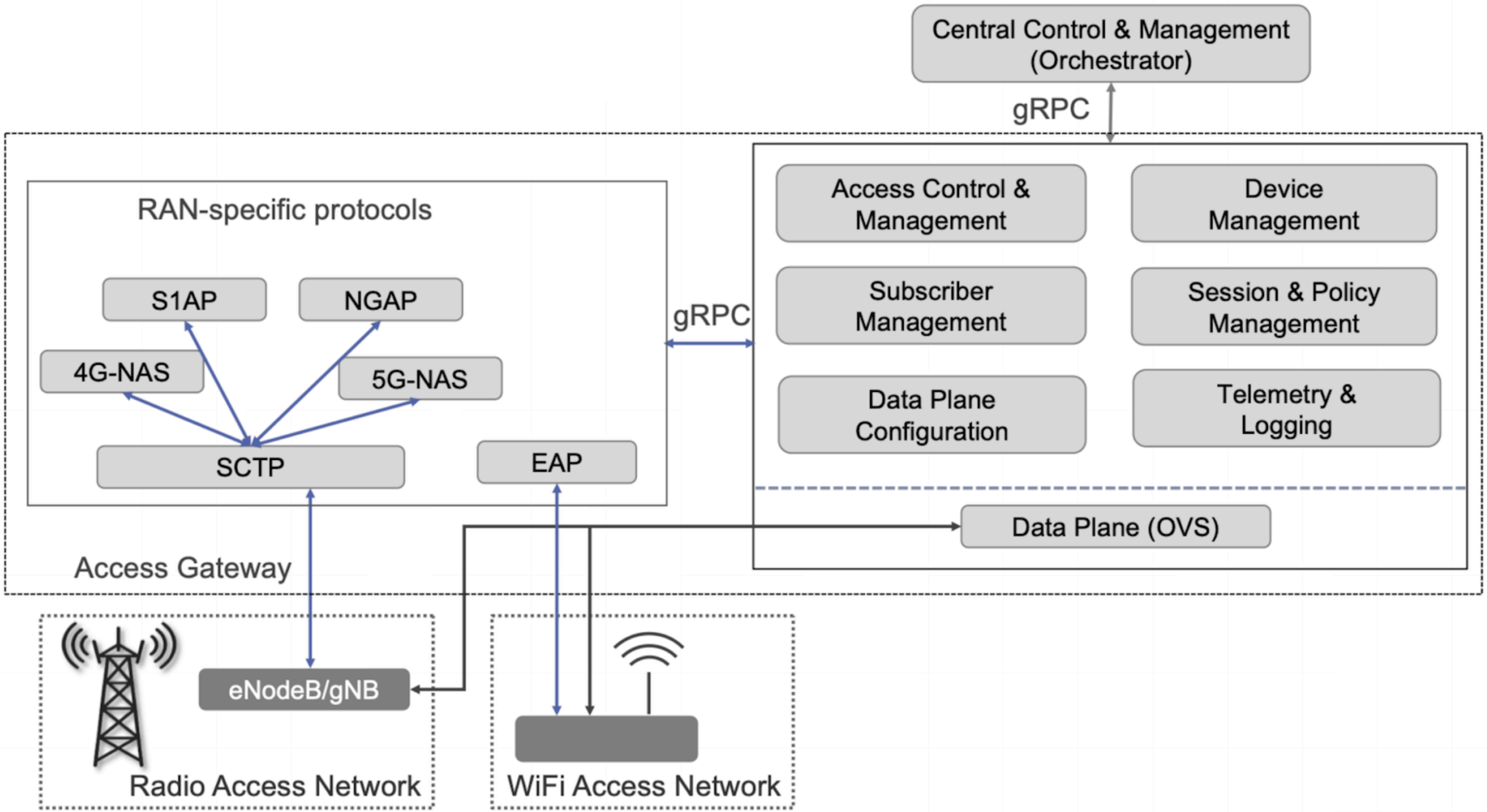


Magma: scale of WiFi and power of cellular



Up or down, how does Magma scale?

RAT core separation in Magma



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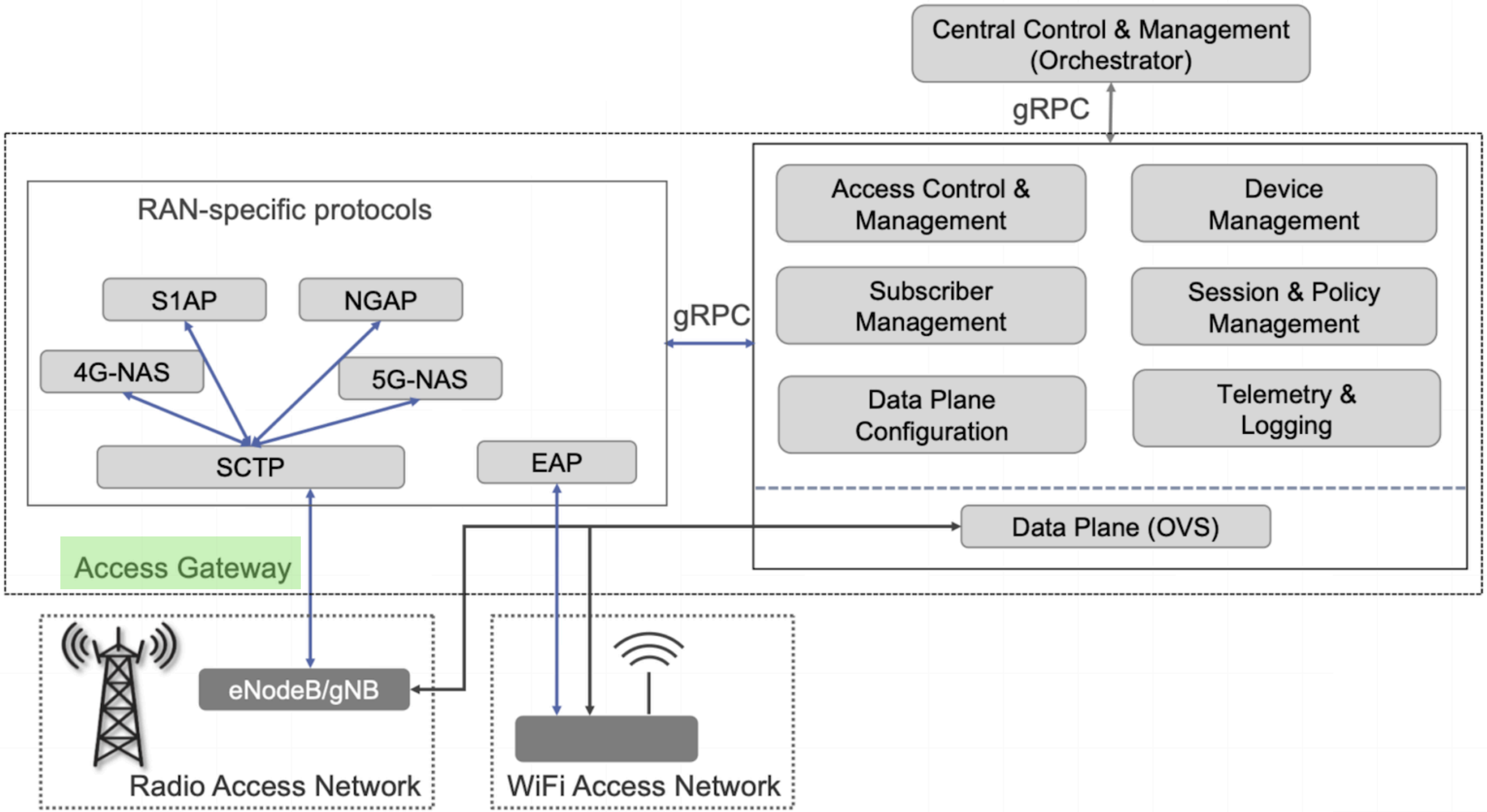

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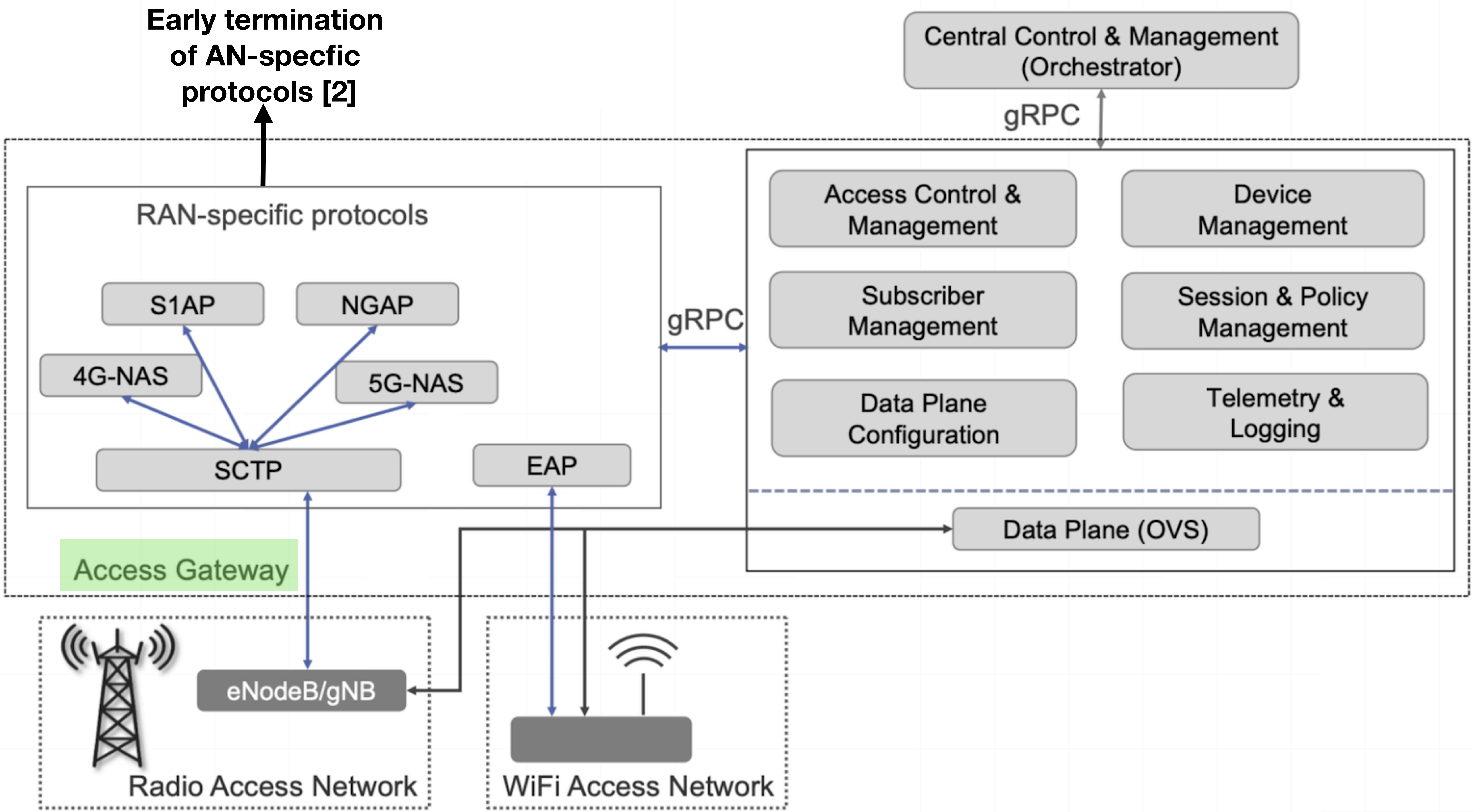

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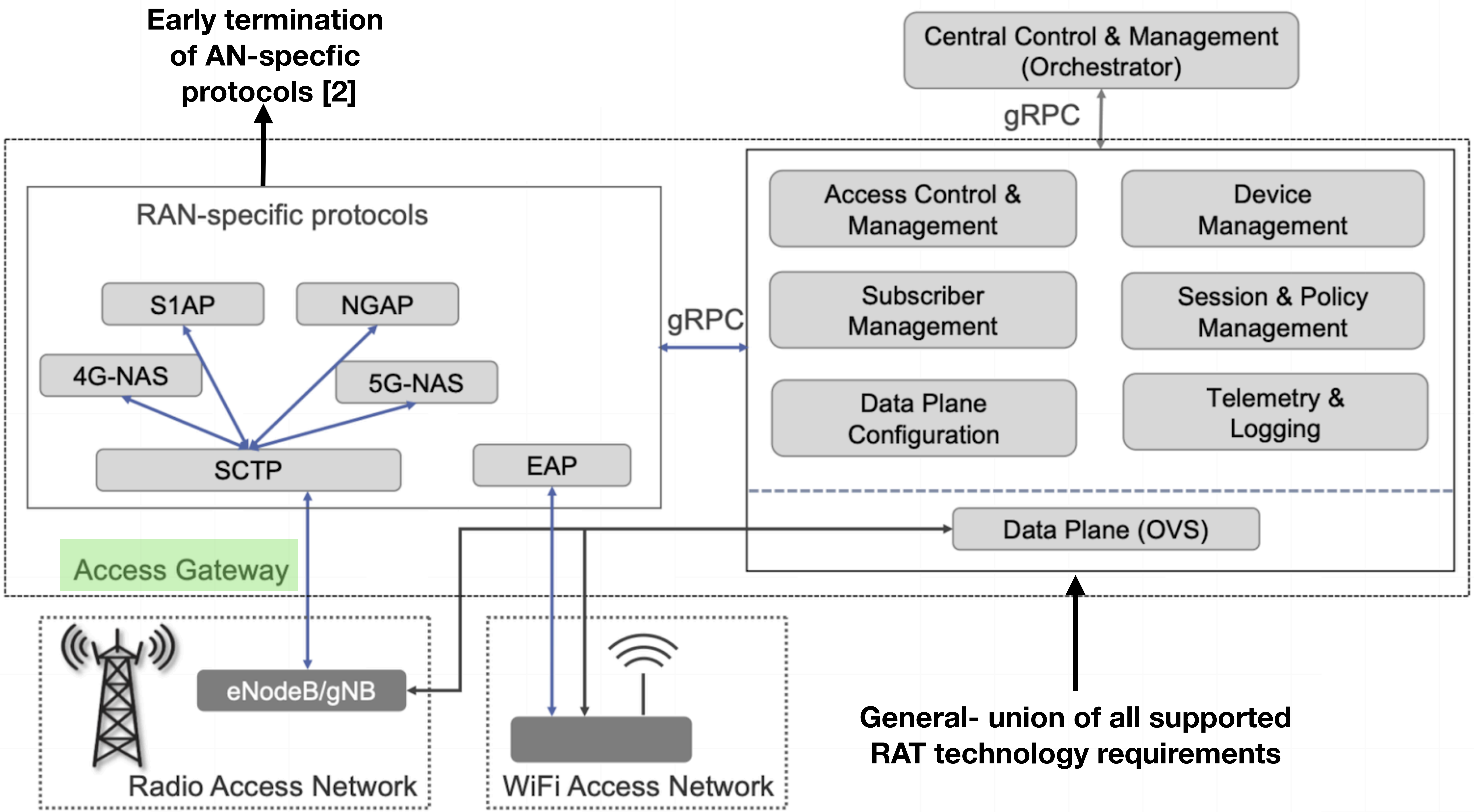

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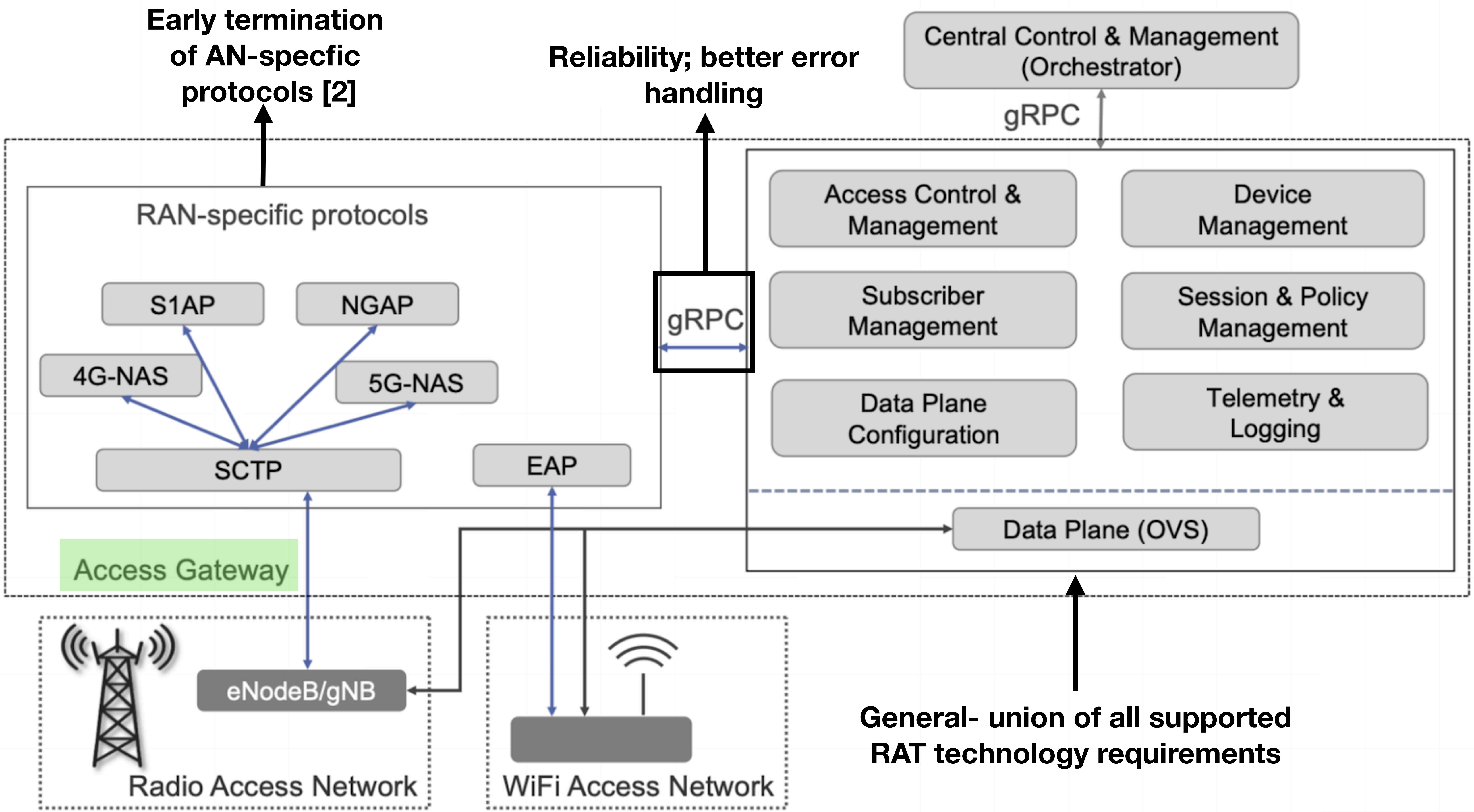
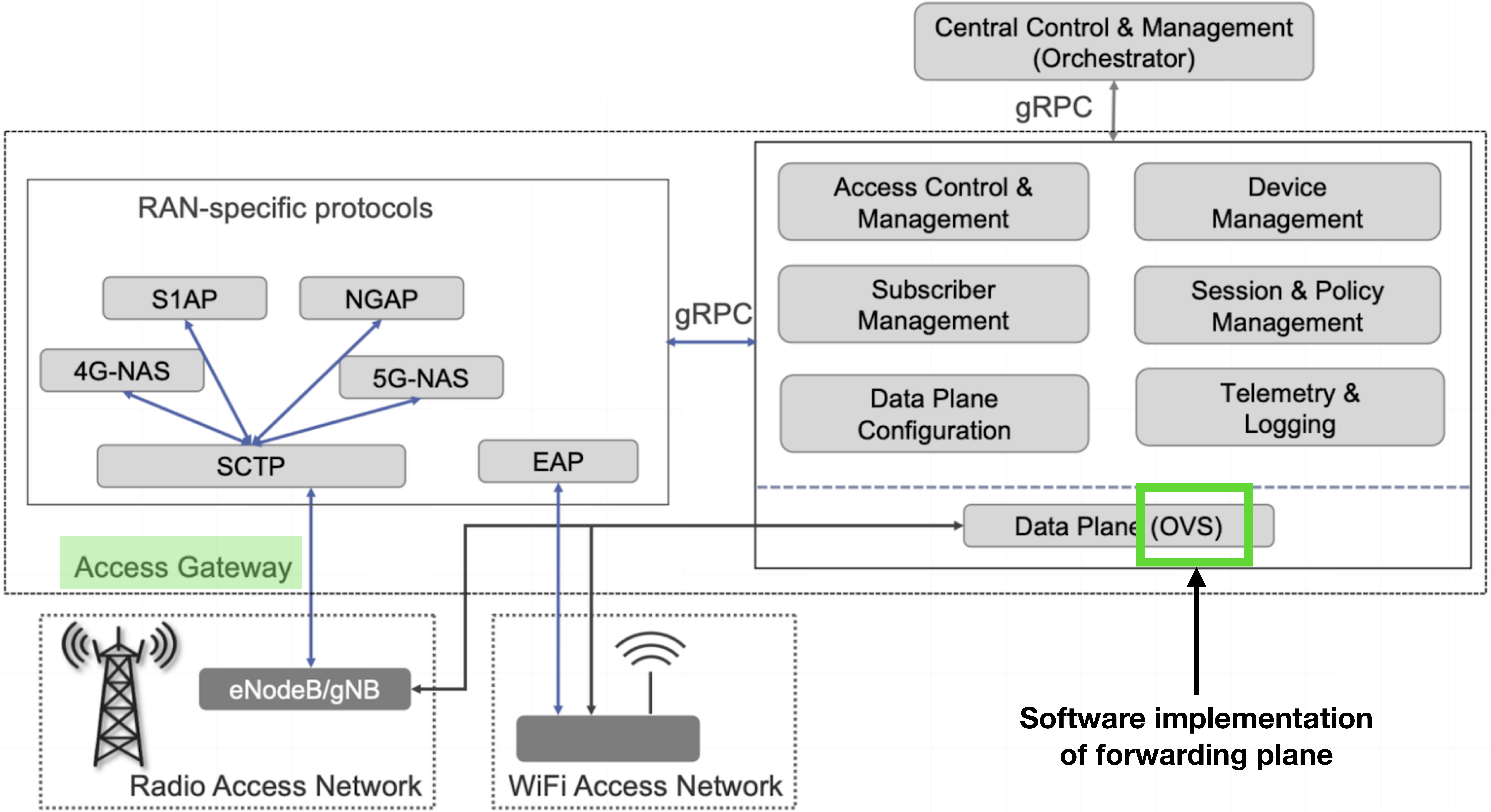


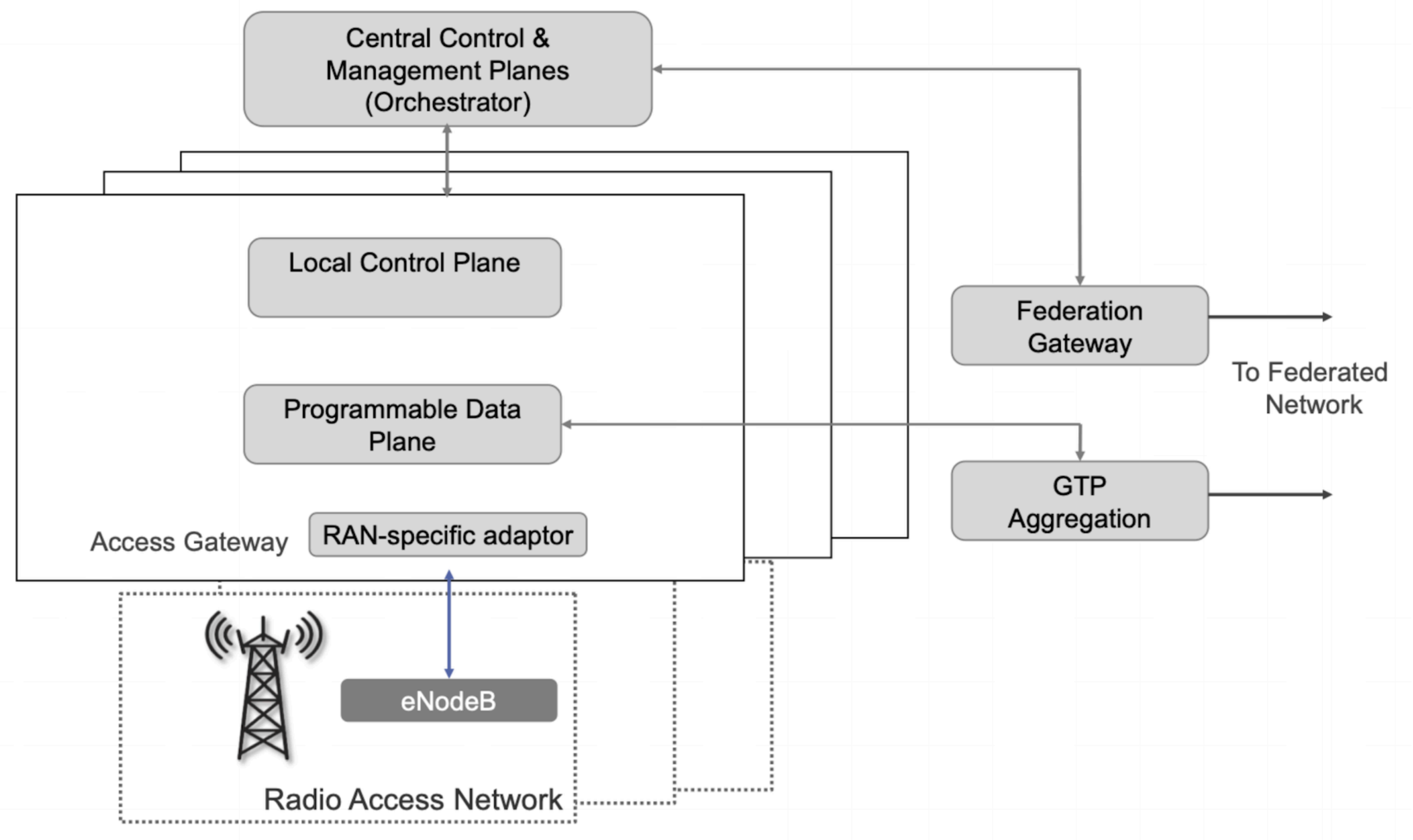
Magma capitalizes on CUPS to decrease operational complexity and commoditize hardware!

Magma uses OVS in the data plane



Software implementation of forwarding plane

Magma reduces operational complexity with a hierarchical SDN Control Plane



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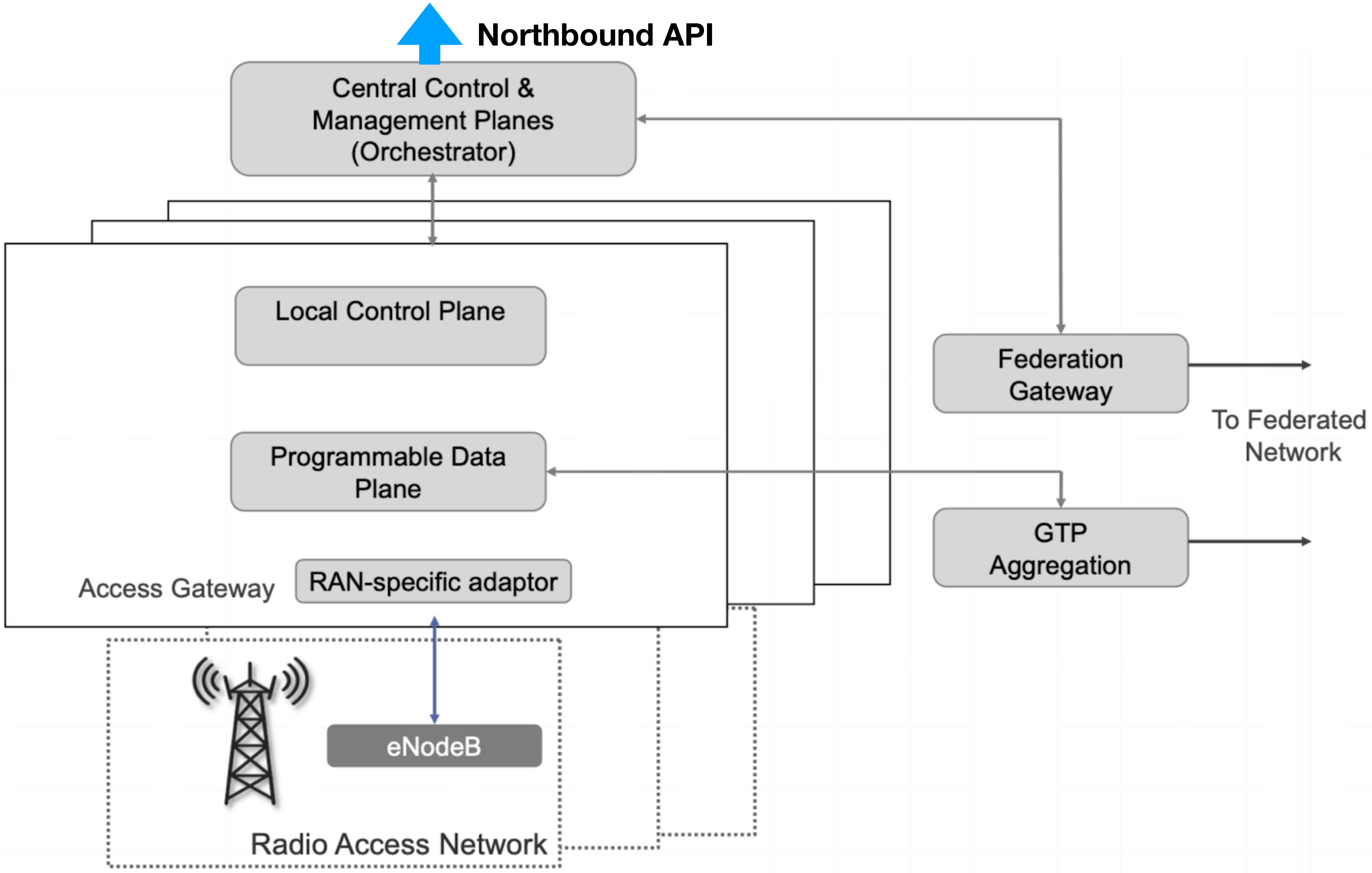

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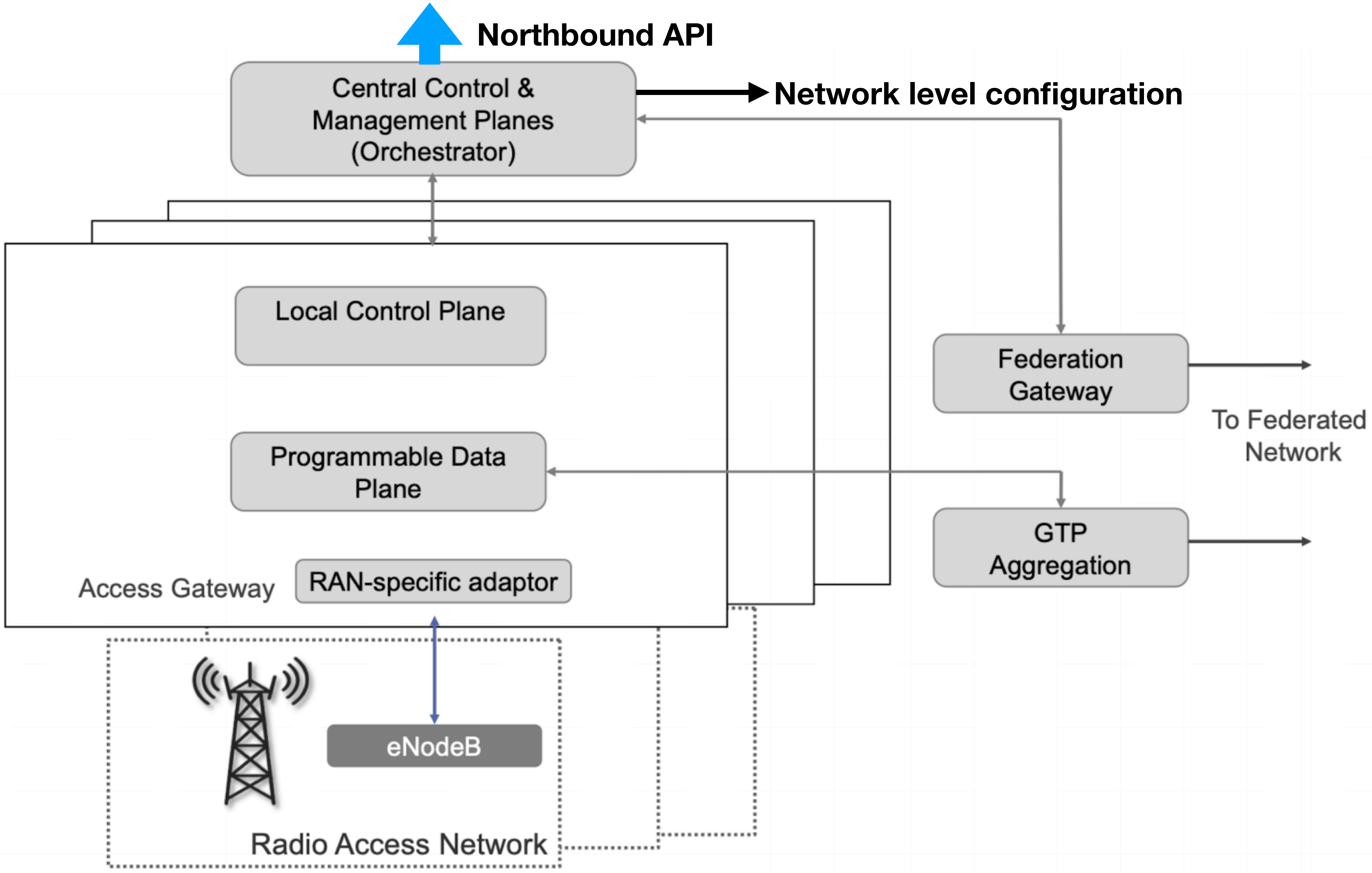
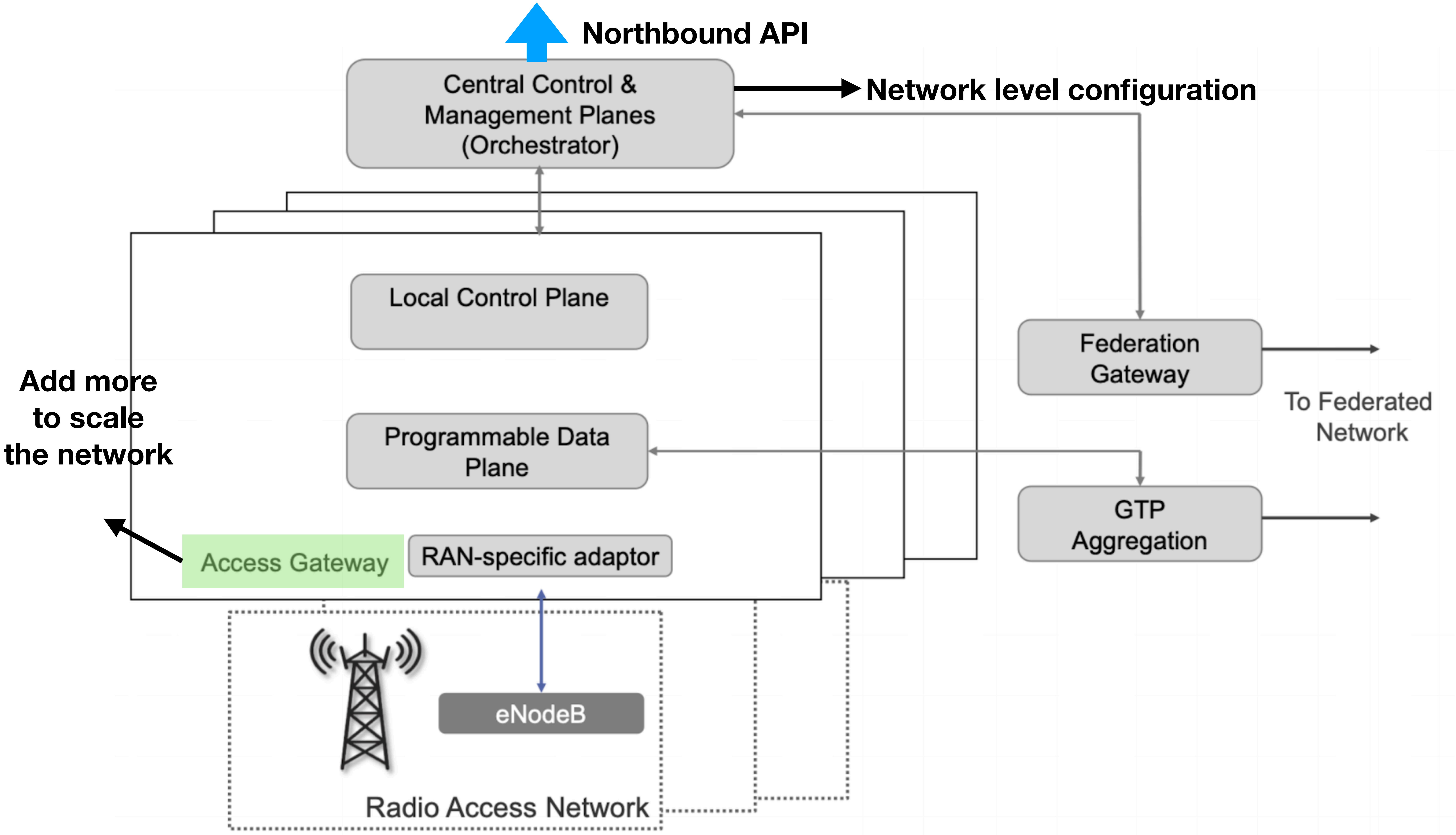
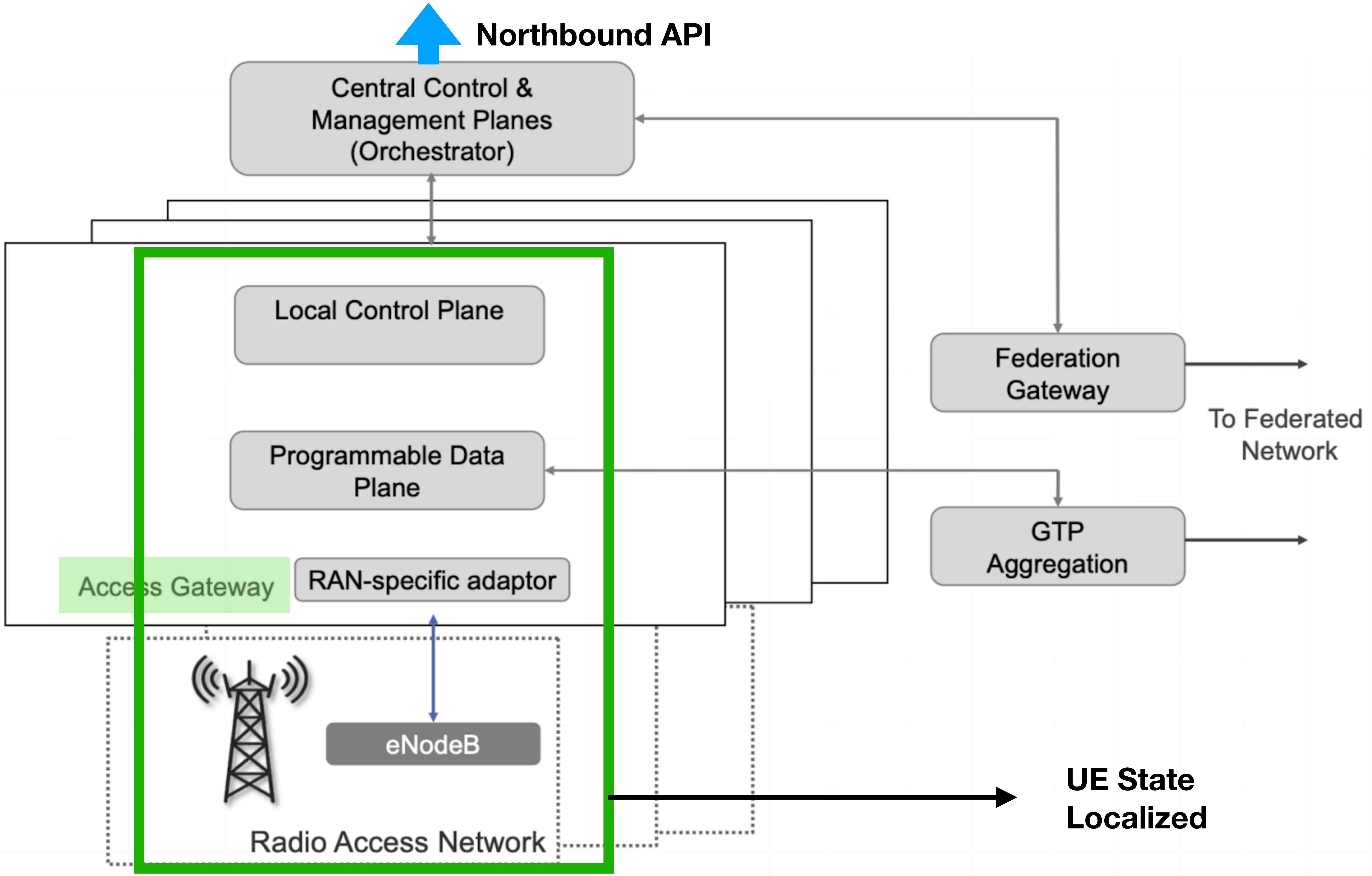


Magma serves more UEs by adding more AGWs



Does Magma’s SDN architecture sacrifice reliability for commoditization?

An AGW is a small fault domain



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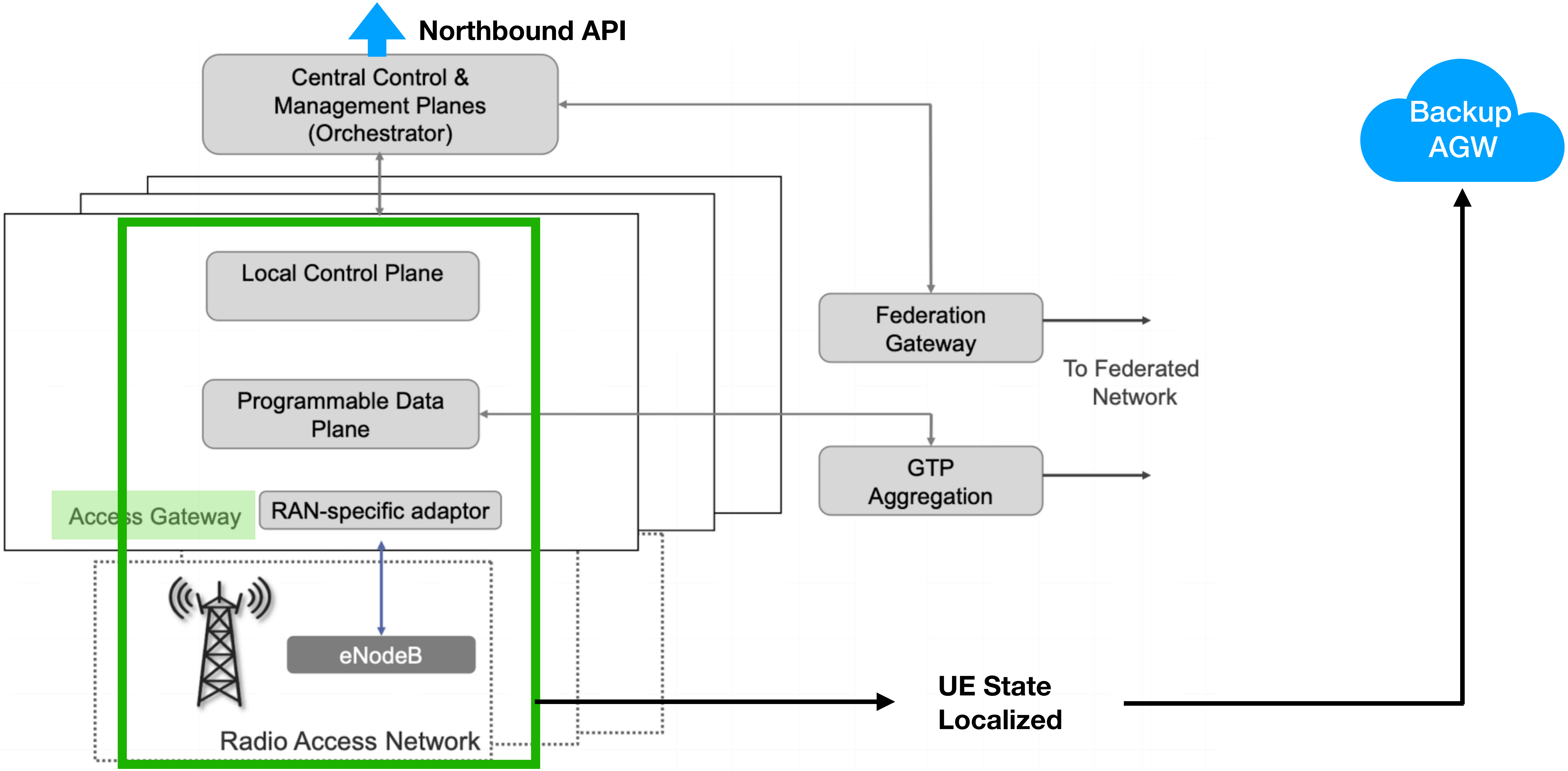
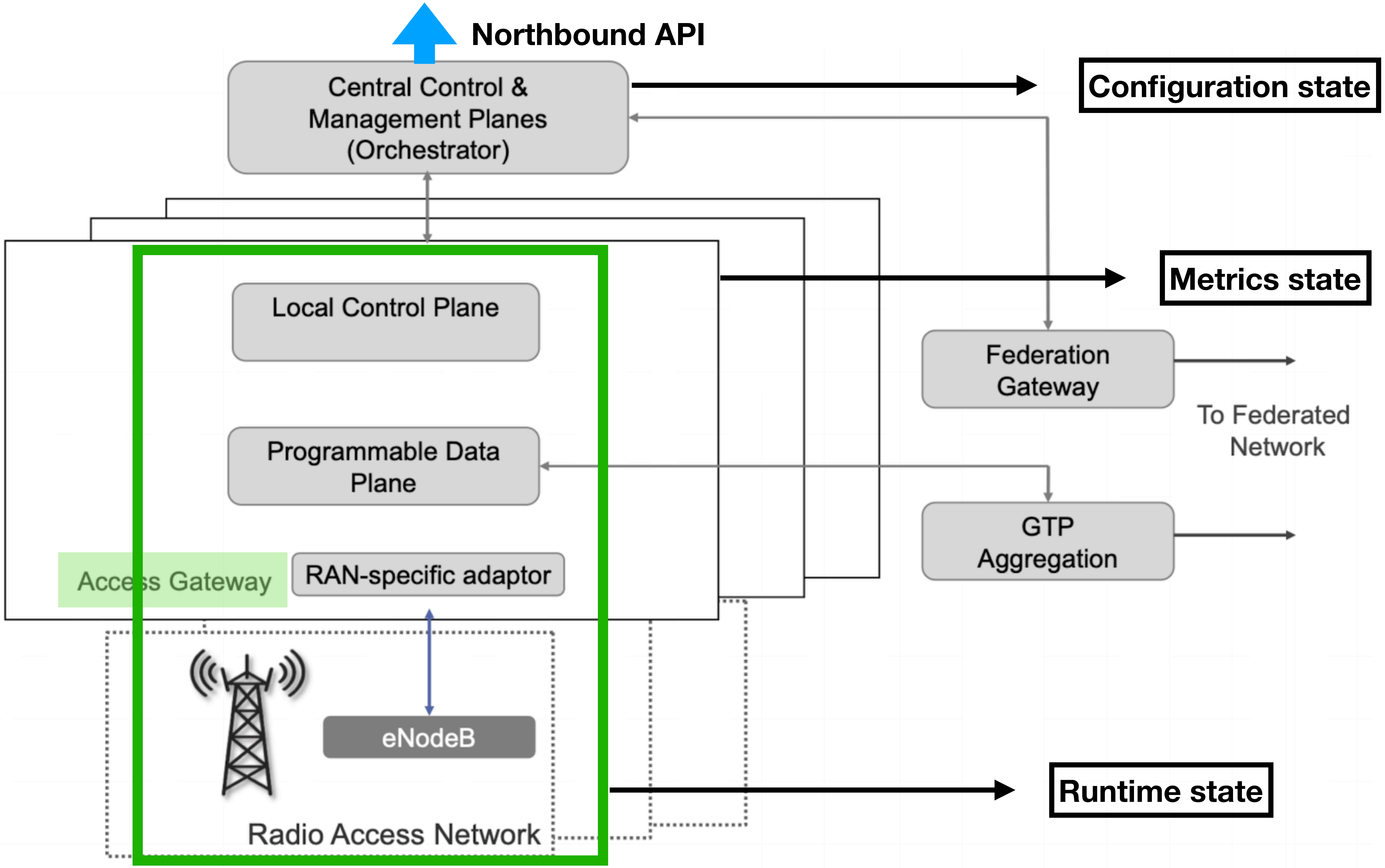


Magma has three kinds of state



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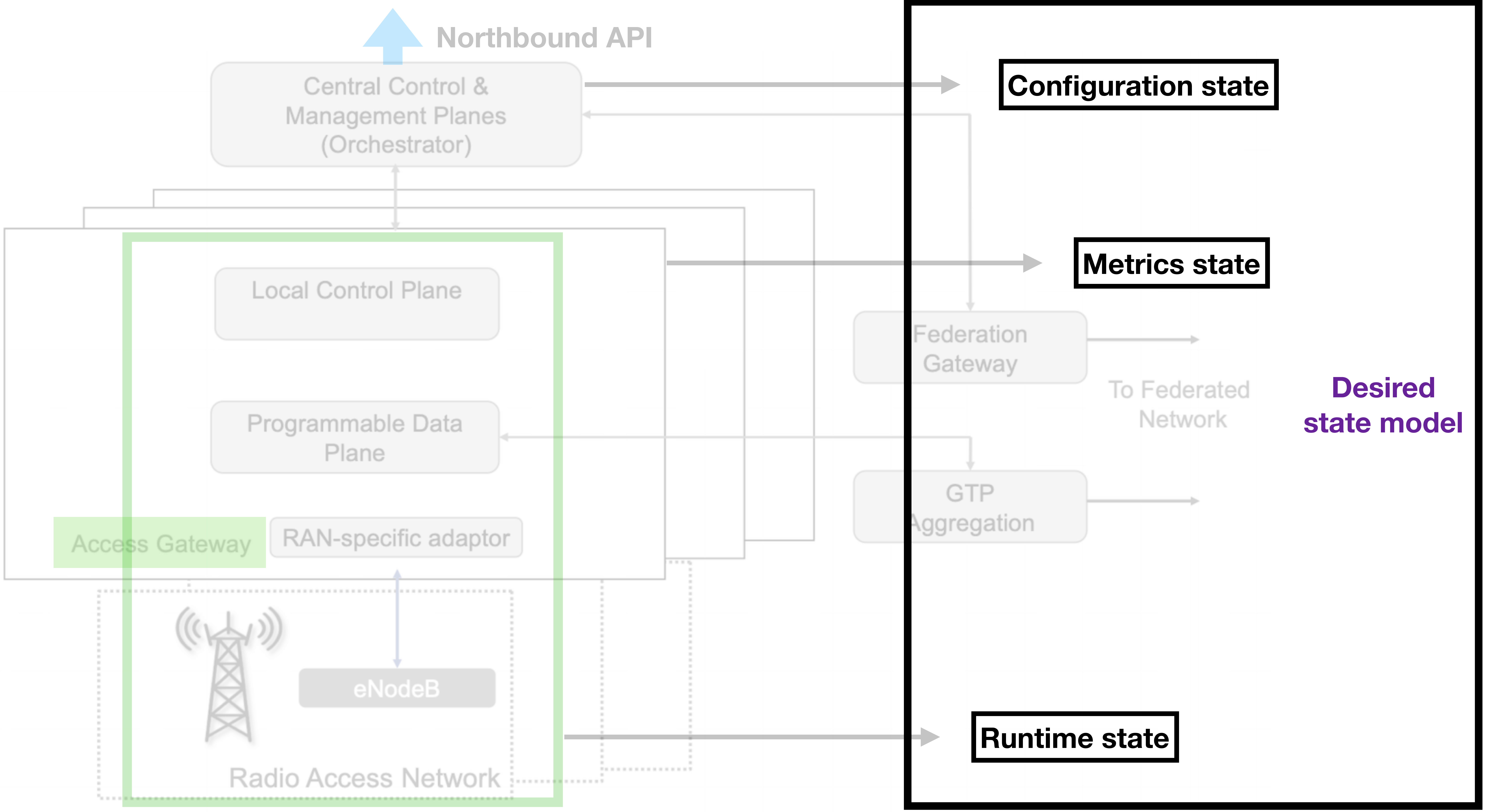
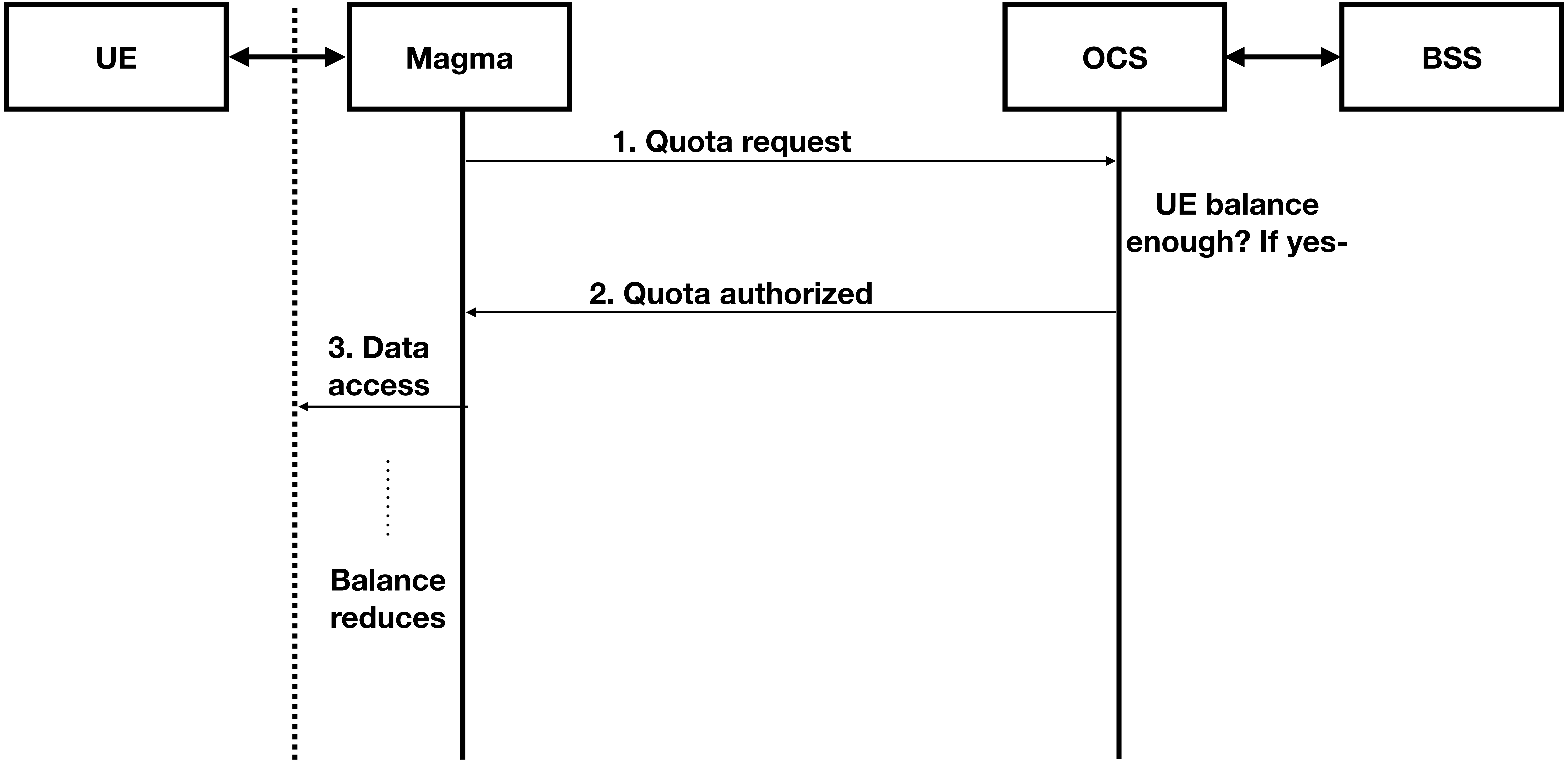


Magma uses OCS integration for billing



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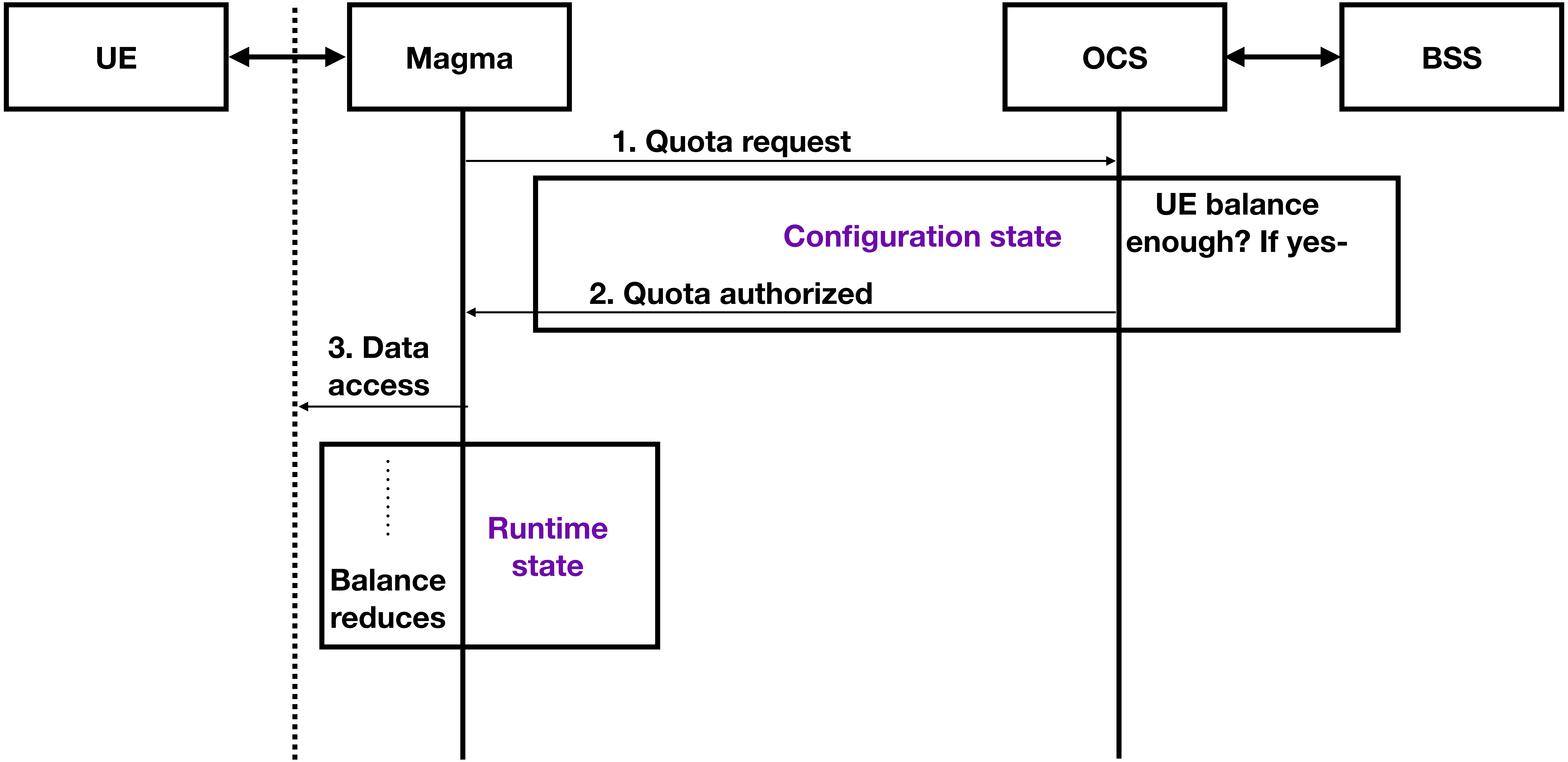
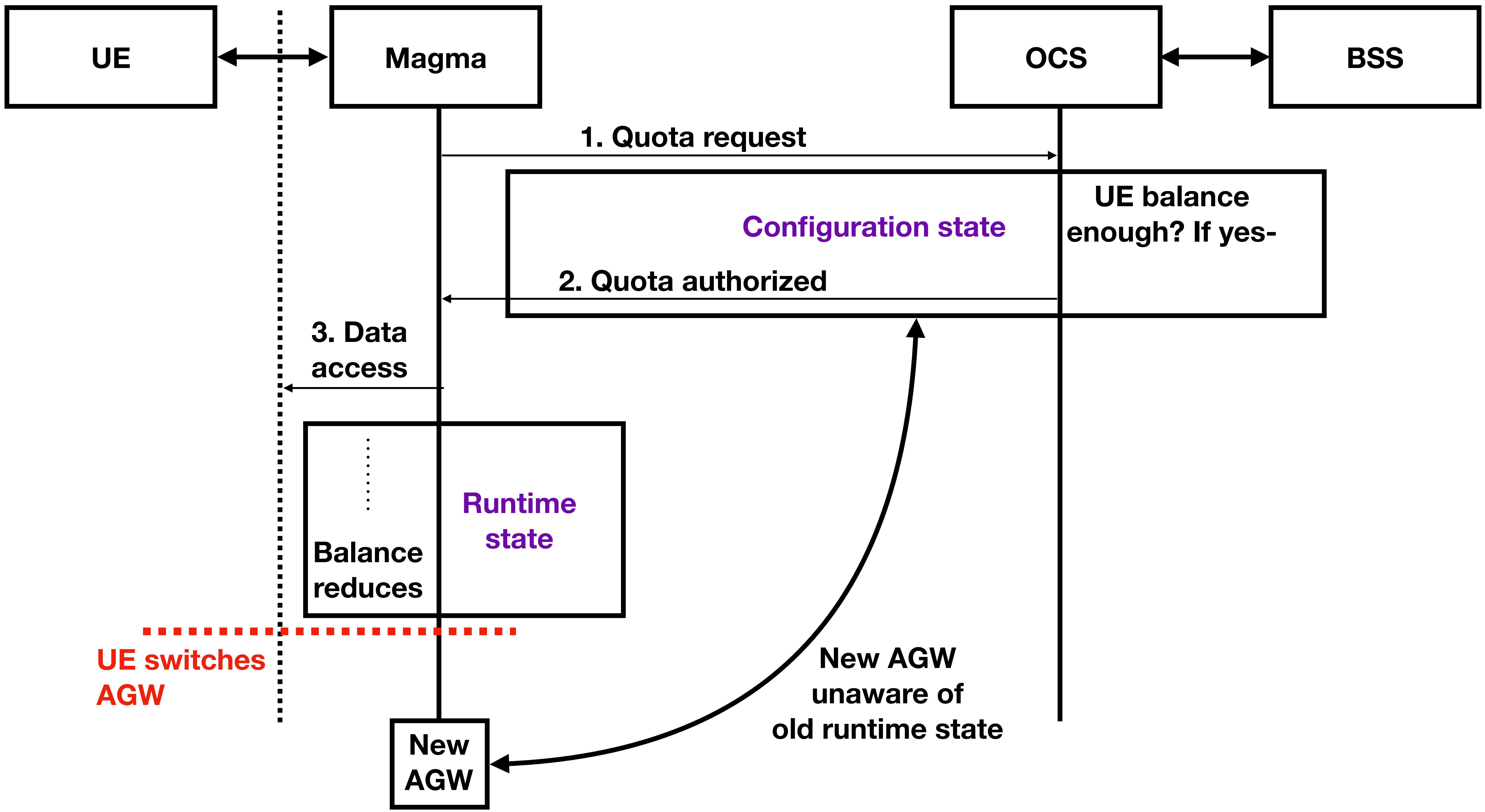
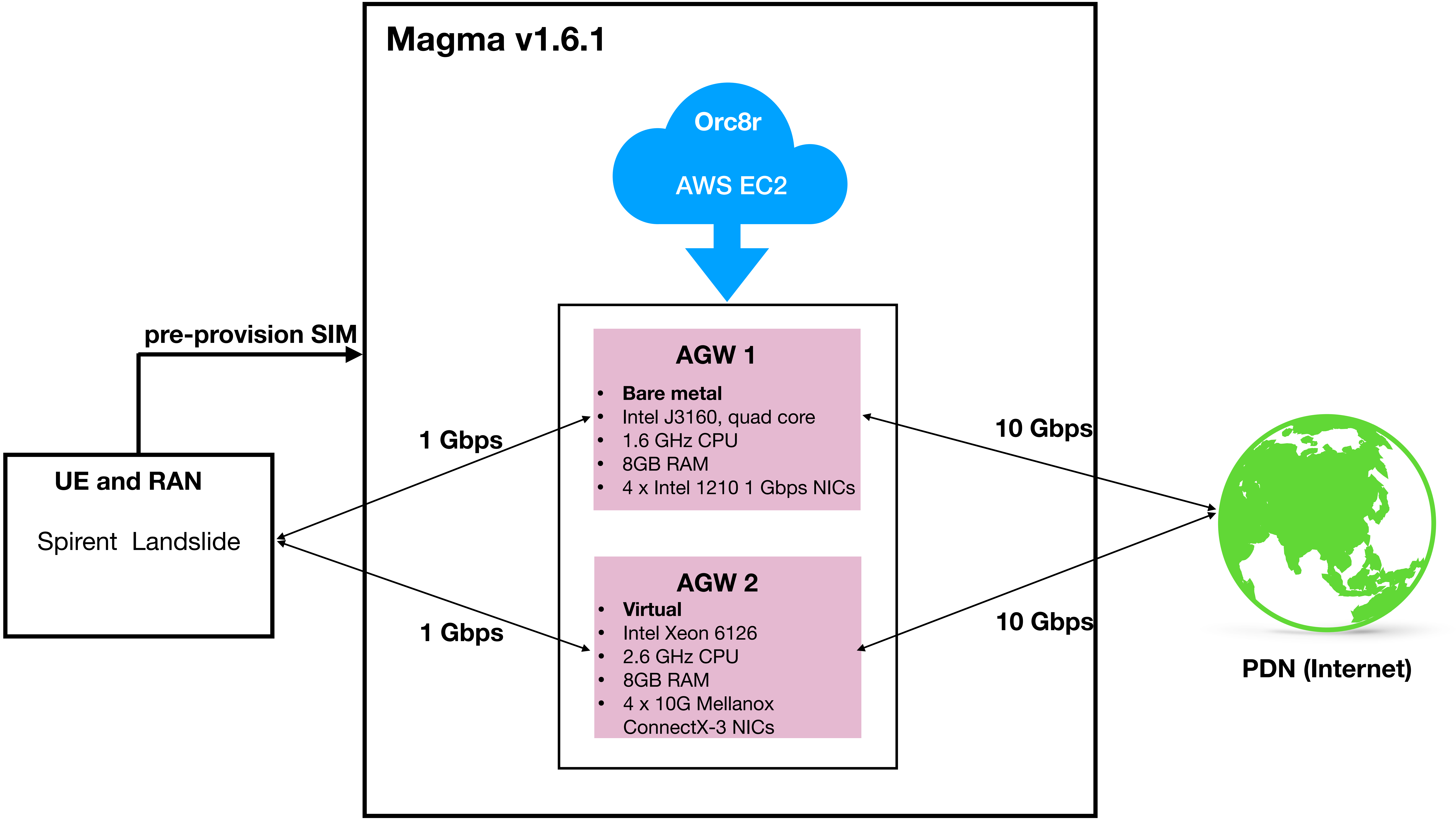


Attack: UE consumes more than allocated quota



Can Magma meet usage requirements and handle typical loads?

Emulation setup


Magma v1.6.1
Orc8r
AWS EC2
pre-provision SIM
AGW 1
Bare metal
Intel J3160, quad core
1.6 GHz CPU
8GB RAM
4 x Intel 1210 1 Gbps NICs
AGW 2
Virtual
Intel Xeon 6126
2.6 GHz CPU
8GB RAM
4 x 10G Mellanox ConnectX-3 NICs
1 Gbps
1 Gbps
10 Gbps
10 Gbps
UE and RAN
Spirent Landslide
PDN (Internet)

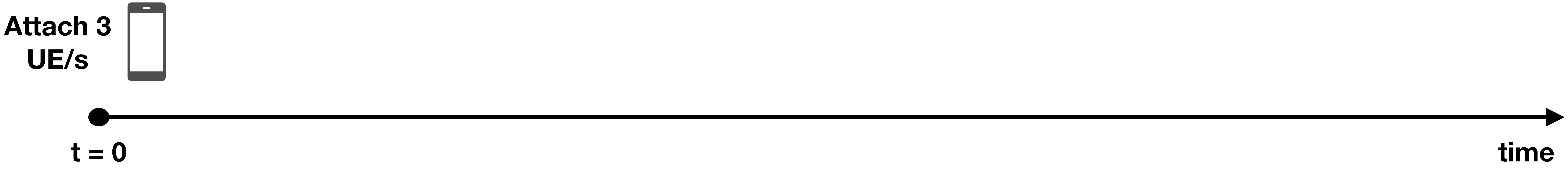
Bottleneck for throughput:
RAN vs AGW

Can the AGW support typical configurations?

- 1 Cell site: 1-3 eNB
- 1 eNB: 96 users
- 20 MHz channel
- Aggregate throughput per eNB: 126 Mbps

Can the AGW handle this?

Measuring if AGW bottlenecks throughput



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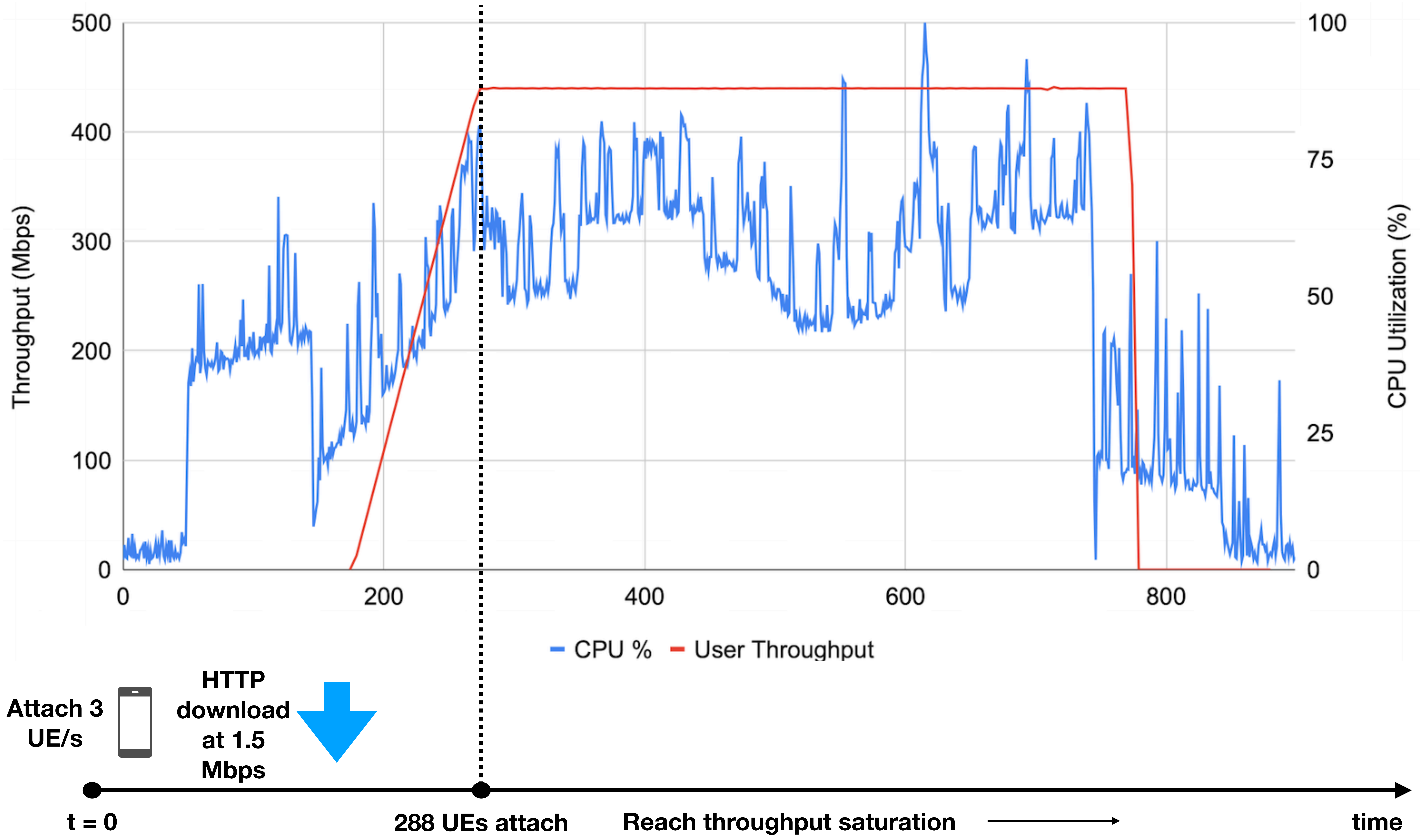
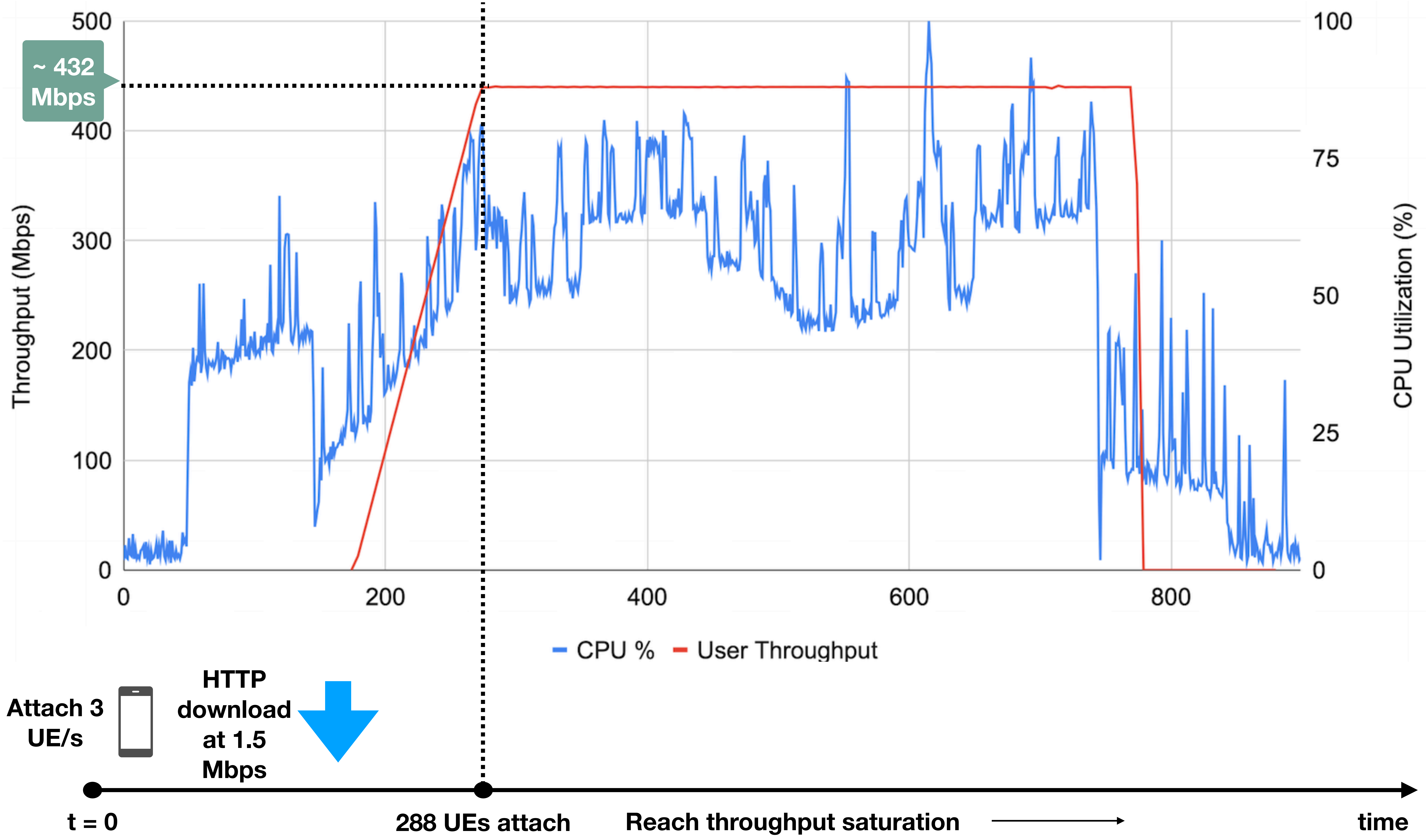


500
400
300
200
100
0
Throughput (Mbps)
100
75
50
25
0
CPU Utilization (%)
0
200
400
600
800
CPU %
User Throughput
Attach 3 UE/s
HTTP download at 1.5 Mbps
t = 0
288 UEs attach
Reach throughput saturation
time


~ 432 Mbps
Throughput (Mbps)
CPU Utilization (%)
500
400
300
200
100
0
100
75
50
25
0
0
200
400
600
800
CPU %
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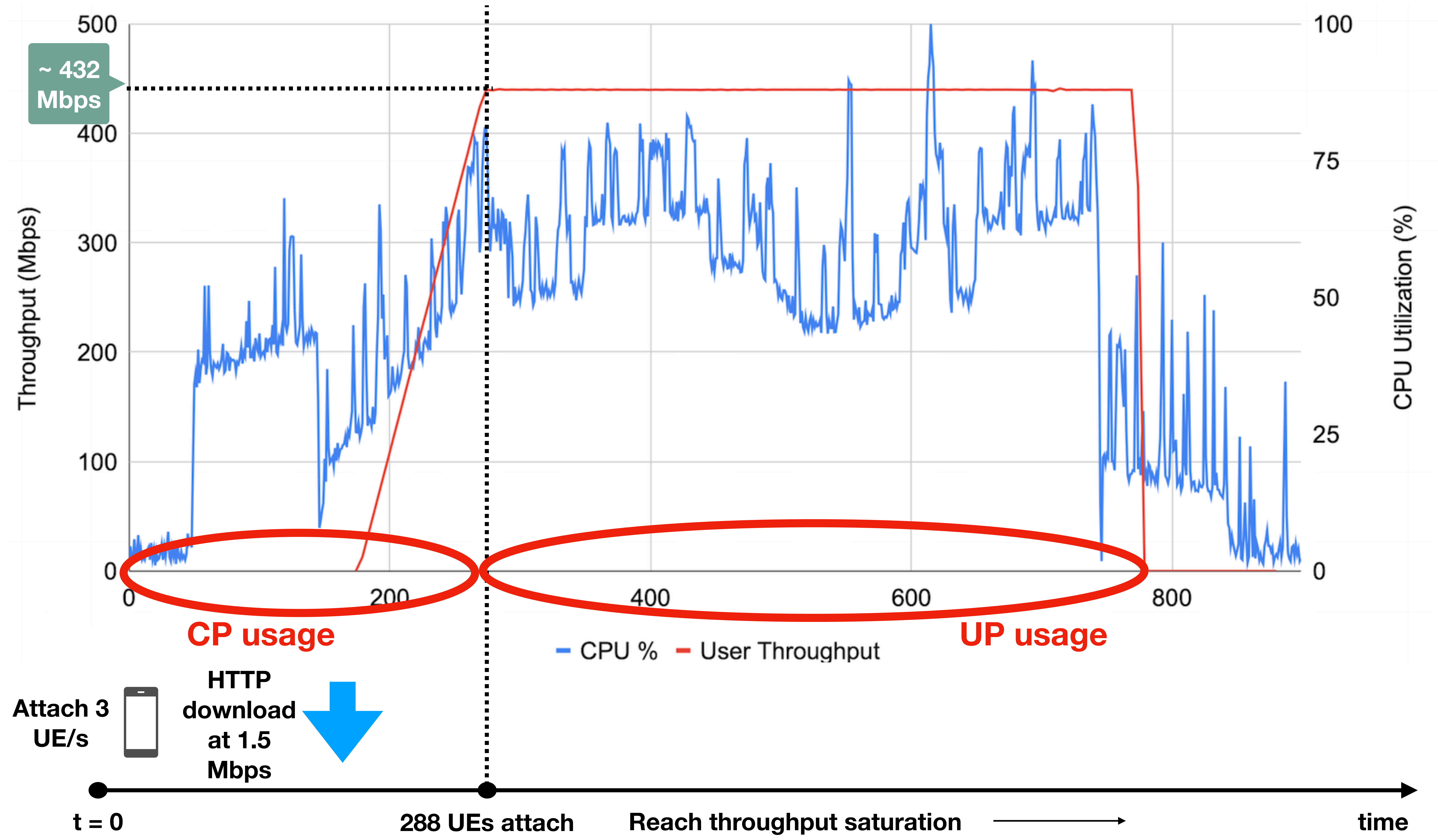


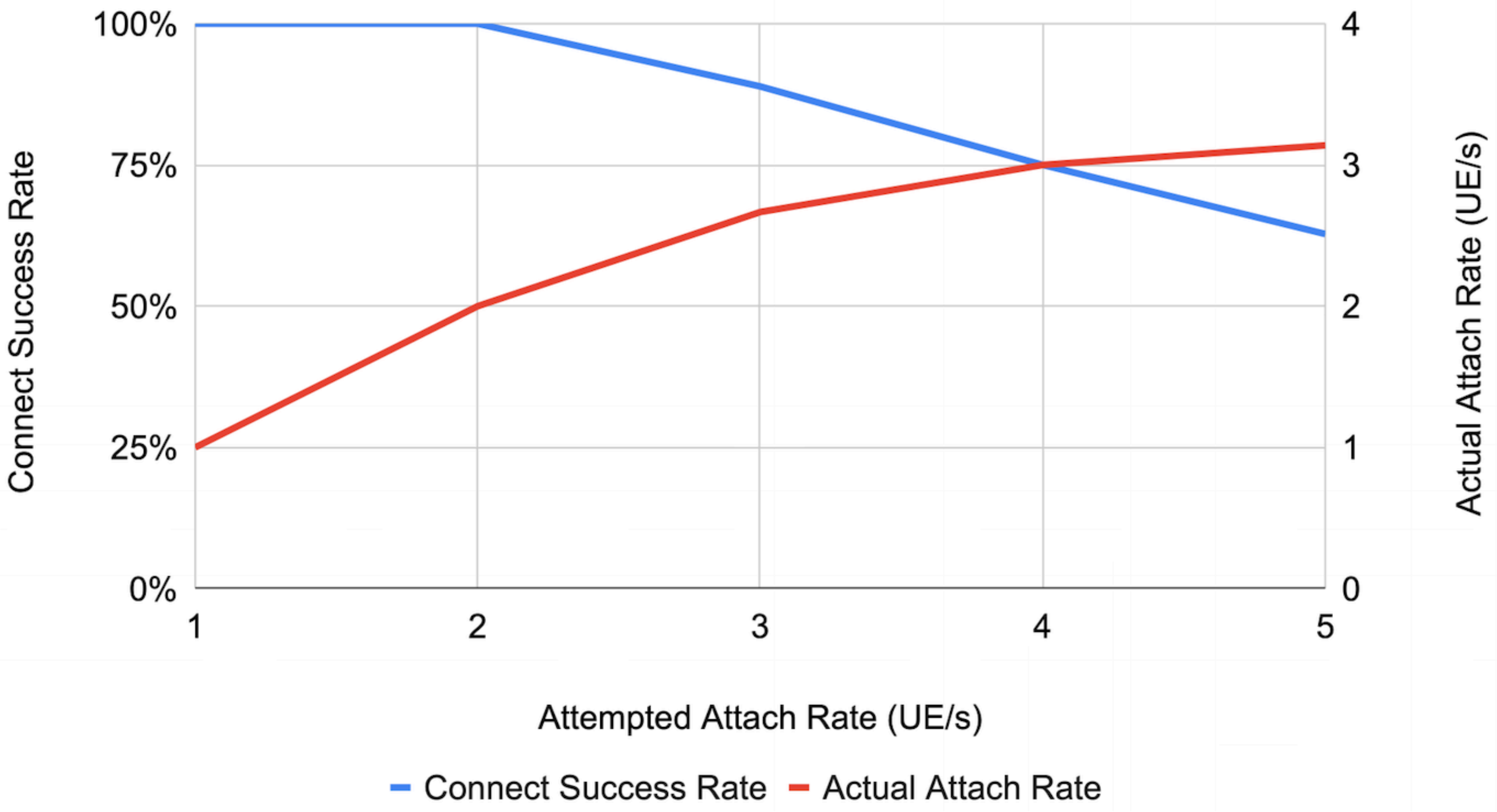
~ 432 Mbps
500
400
300
200
100
0
Throughput (Mbps)
100
75
50
25
0
CPU Utilization (%)
0
200
400
600
800
CP usage
UP usage
CPU %
User Throughput
Attach 3 UE/s
HTTP download at 1.5 Mbps
t = 0
288 UEs attach
Reach throughput saturation
time

CUPS in Magma: effect of resource allocation

CP performance: a surge of new UEs

- Bare metal AGW
- $\text{CSR} = \dfrac{\text{\# successful connections}}{\text{\# total connection attempts}}$ in 5s bin (averaged in plot?)

CP performance: a surge of new UEs



Throughput performance: limit UP cores in VM AGW

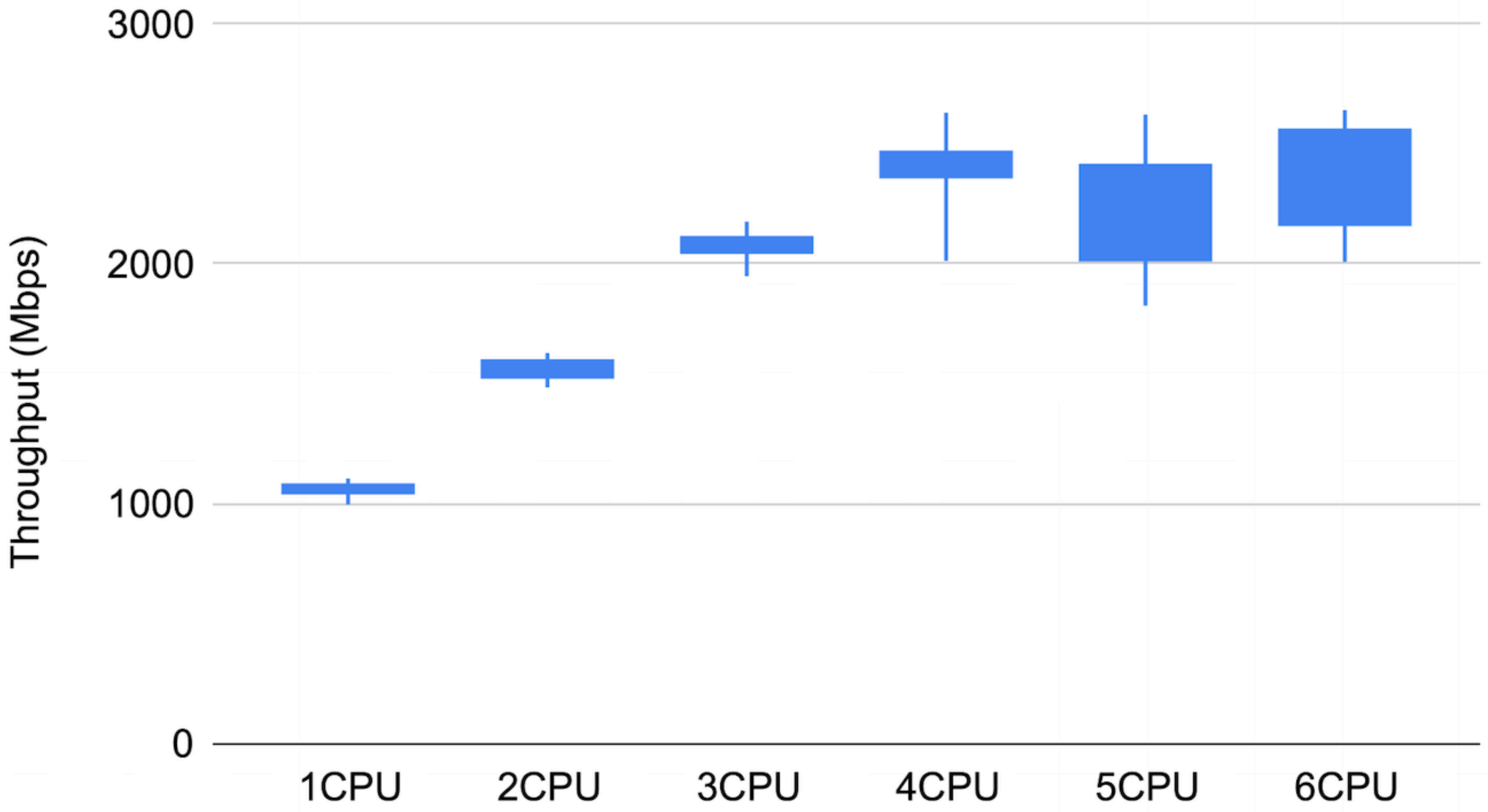
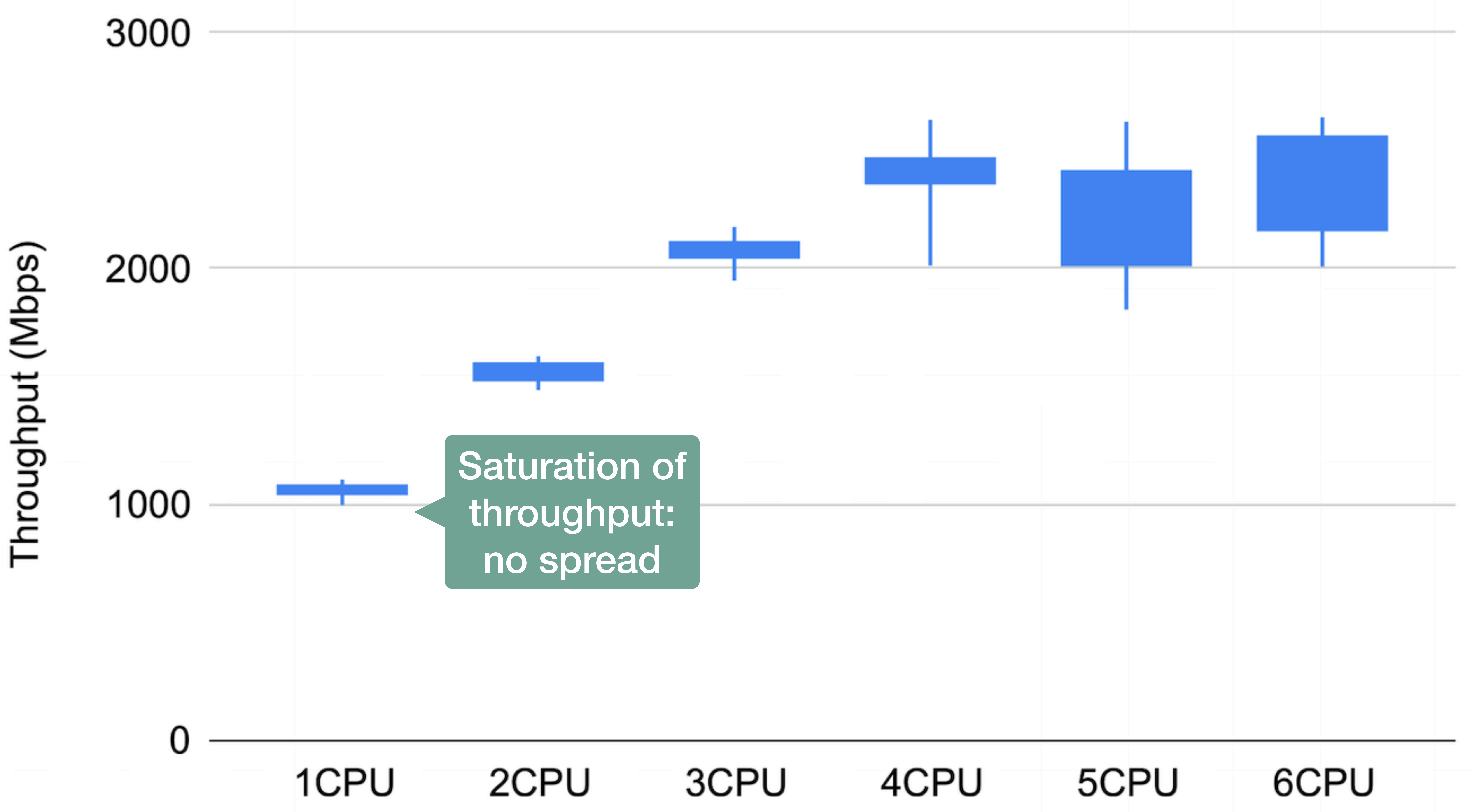


Figure 7: Steady state throughput vs. CPUs allocated to user plane. Note our traffic generator was unable to saturate the virtual AGW's user plane in the 5CPU case and above.

Support higher throughput with more cores

Throughput performance: limit UP cores in VM AGW



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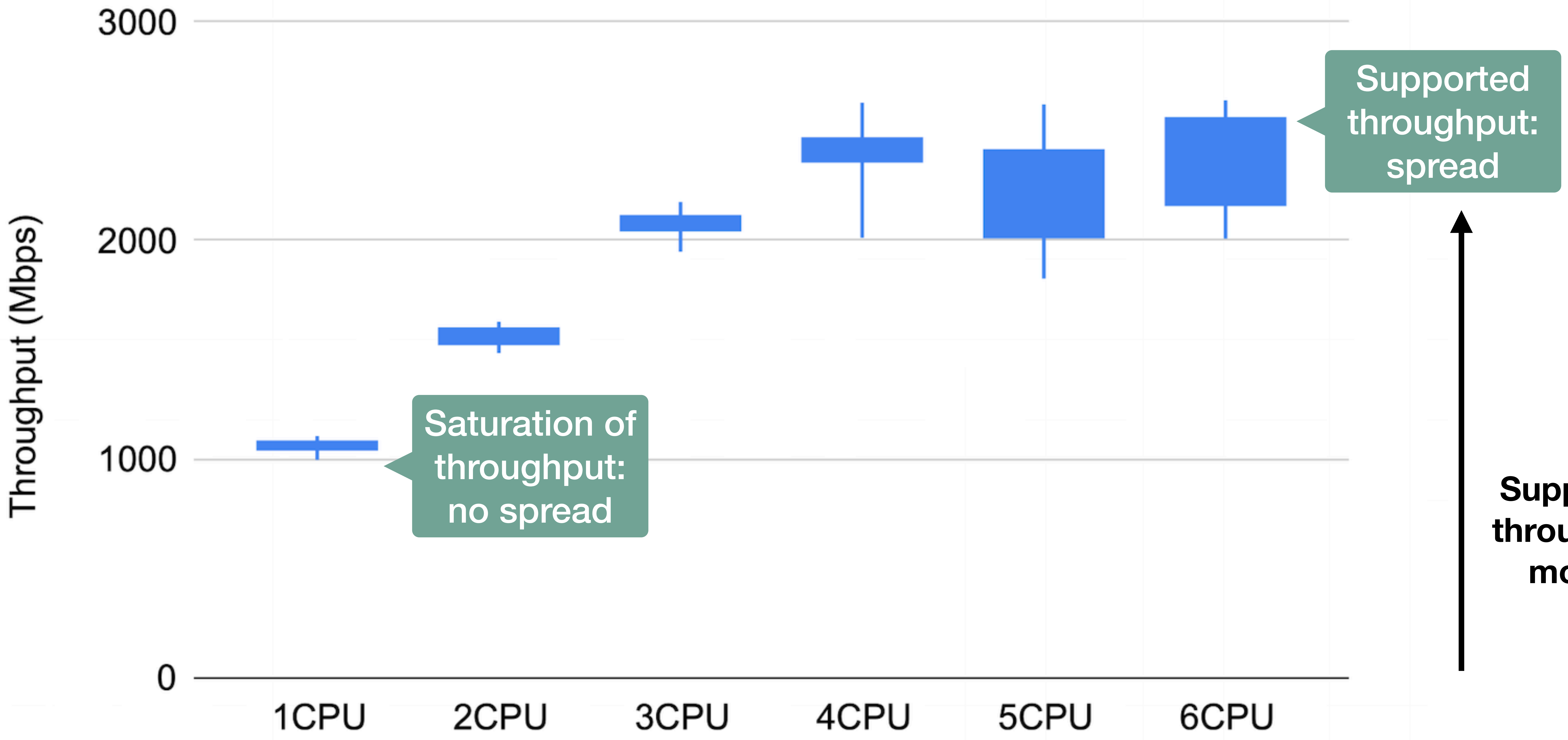

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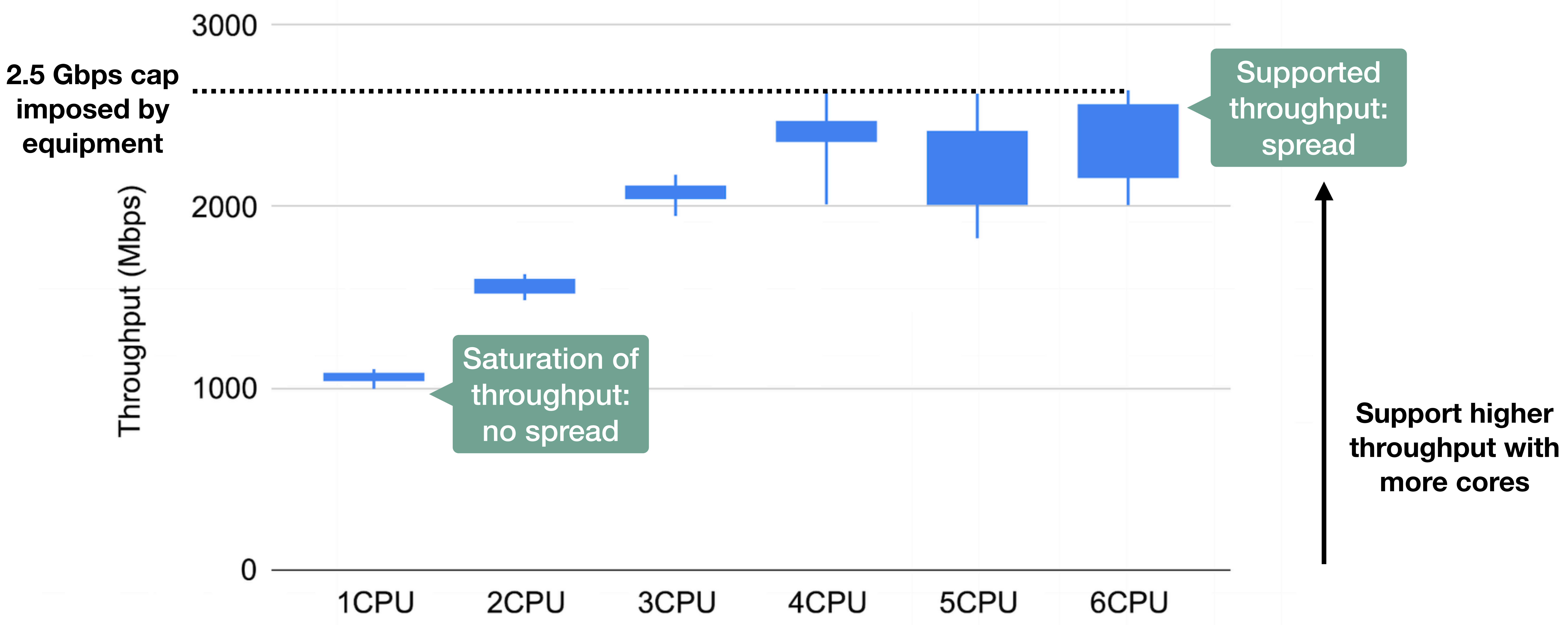

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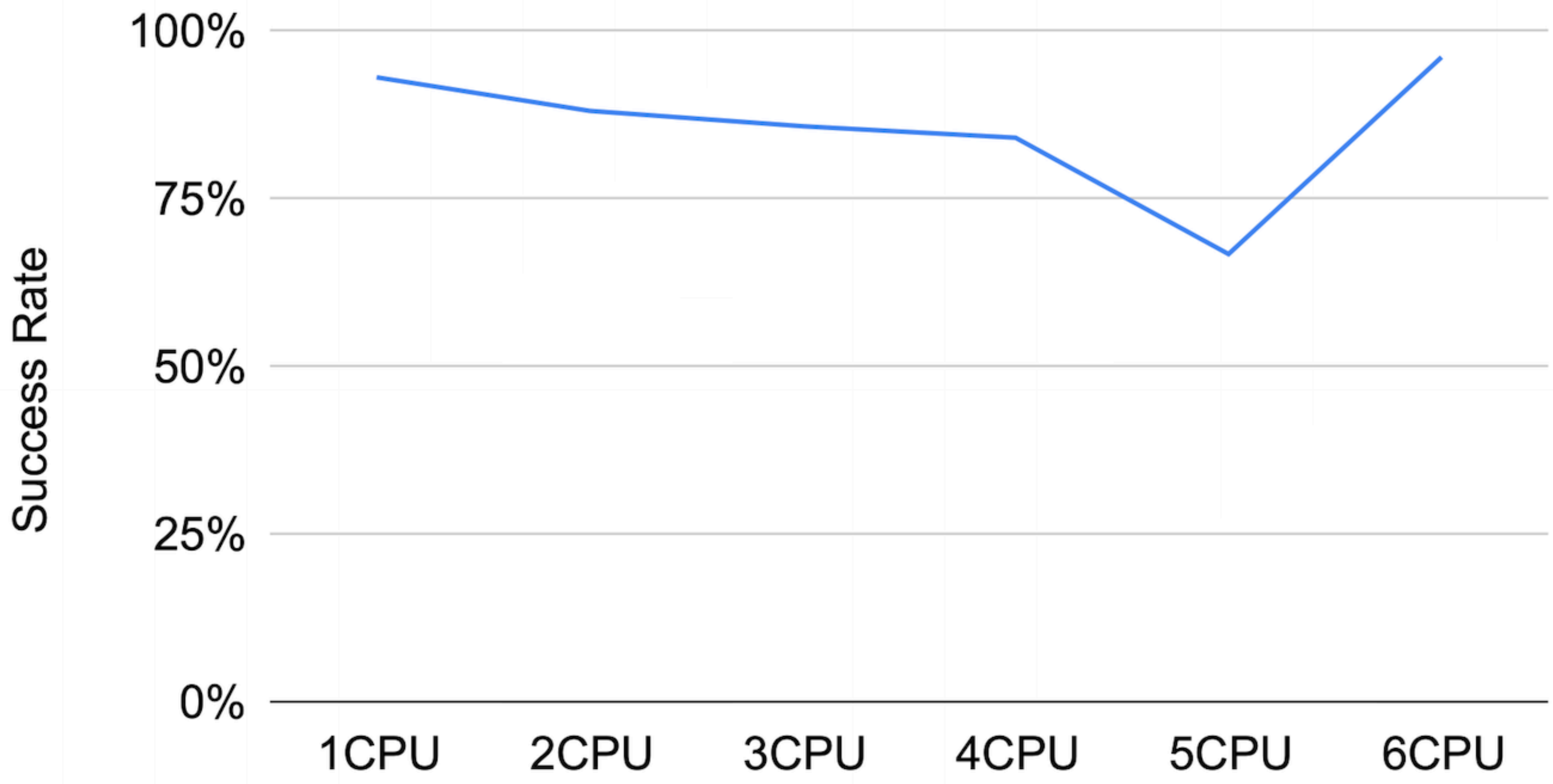


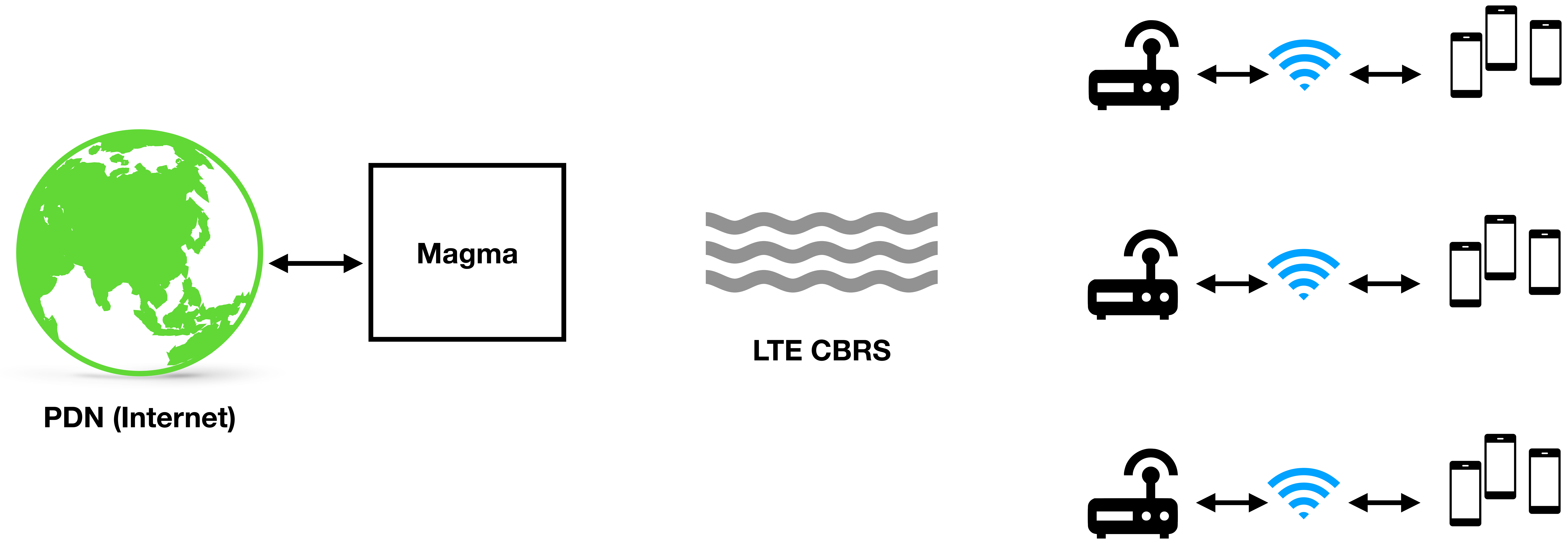
Figure 8: Median connection success rate vs CPUs allocated to user plane.

Magma can handle the desired workload

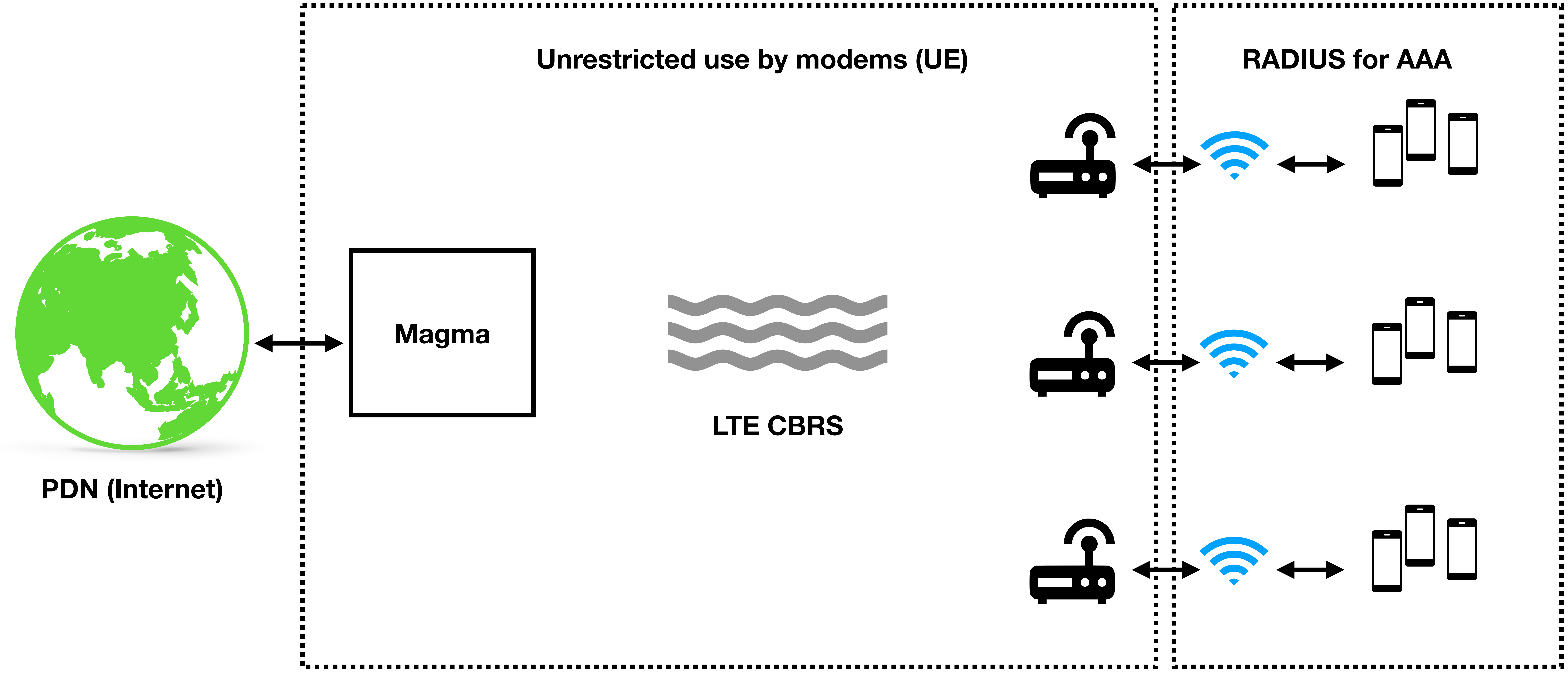
- Scale CP/UP with hardware
- Network capacity = linear in number of AGWs

Commercial deployments

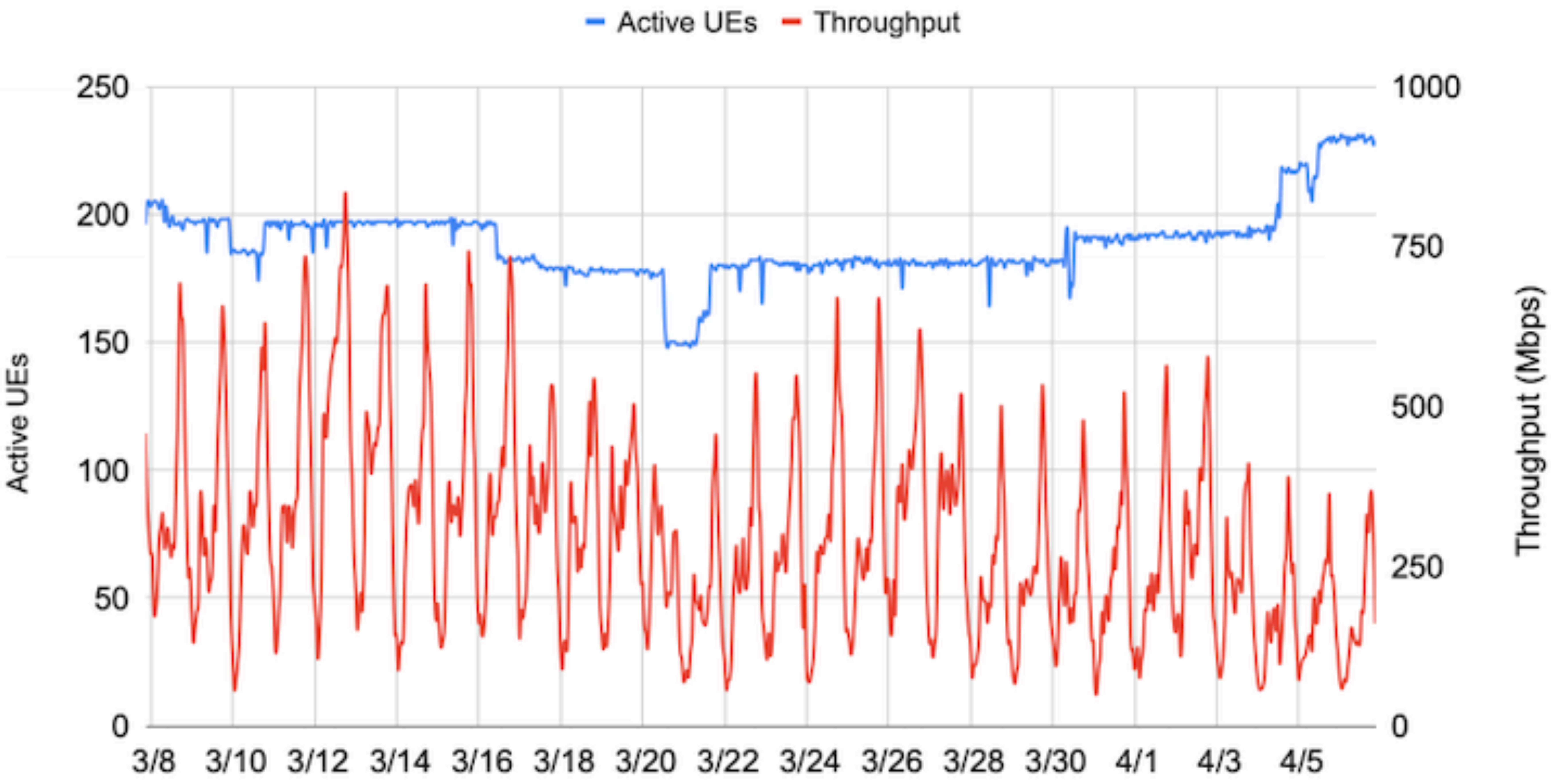
AccessParks [3]



AccessParks [3]



AccessParks: adoption



Franchised MNO

- Neutral host network by FreedomFi
- CBRS

Well, what next?

Exciting recent developments and future directions

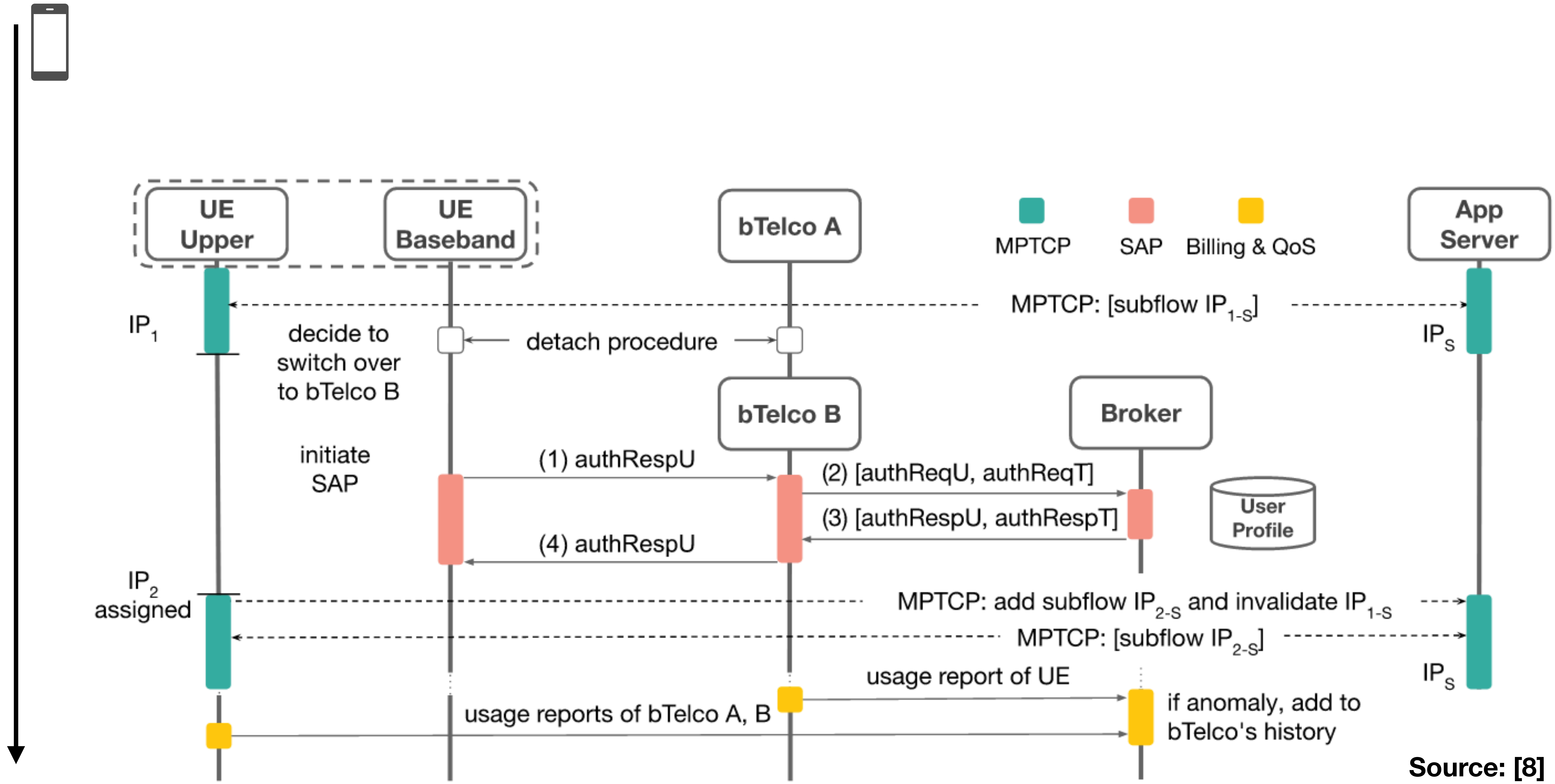
Supporting 5G

- 5G NSA Fixed Wireless Access [6,7] (Newberry and Mayon)
- 5G SA Fixed Wireless Access [7]

Mobility with Magma

- An AGW supports a cell site
  - 1-3 eNBs
  - Mobility within them supported
  - Mobility between AGWs?

Magma, mobility and decentralization : CellBricks [8]



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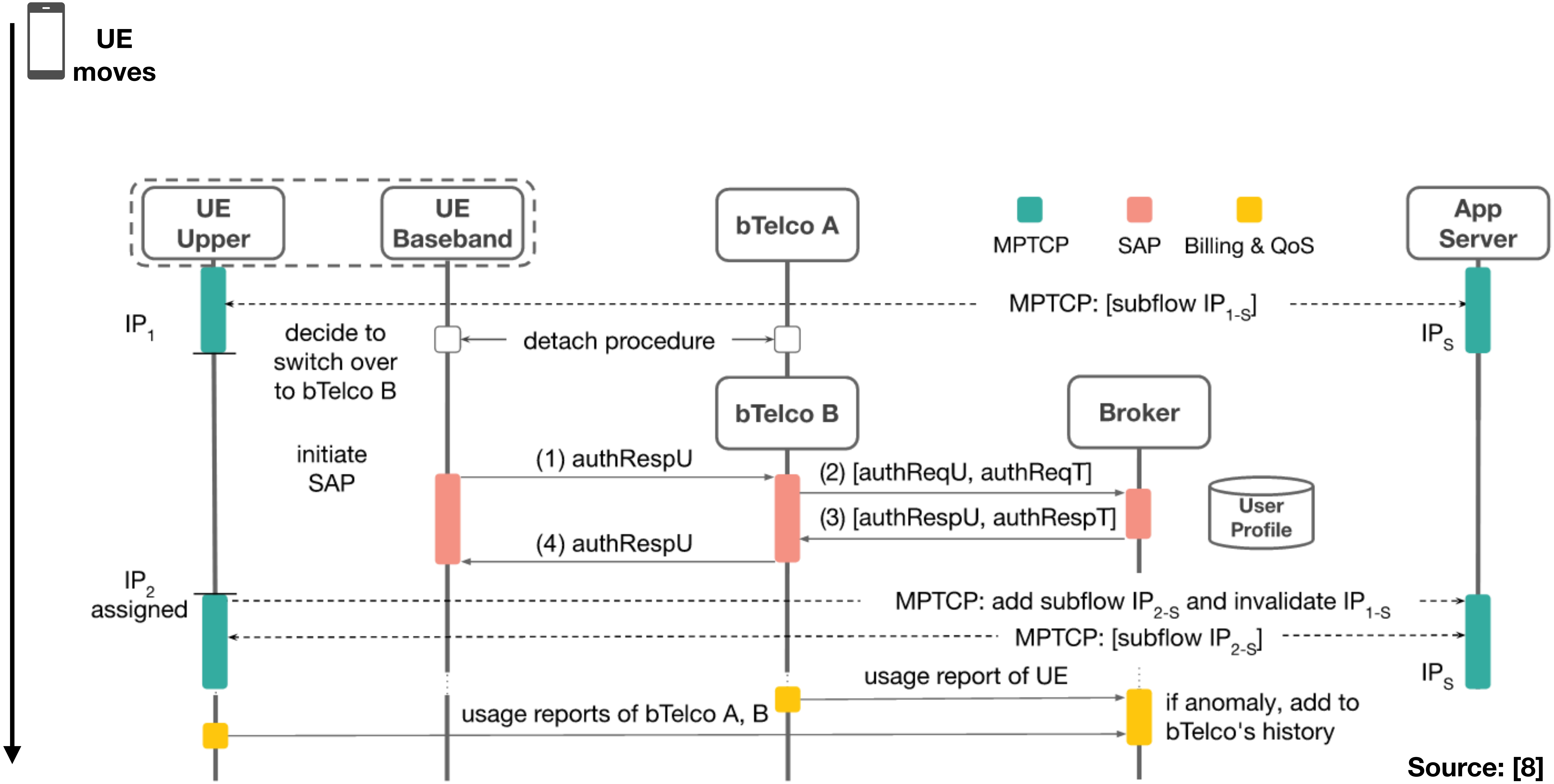

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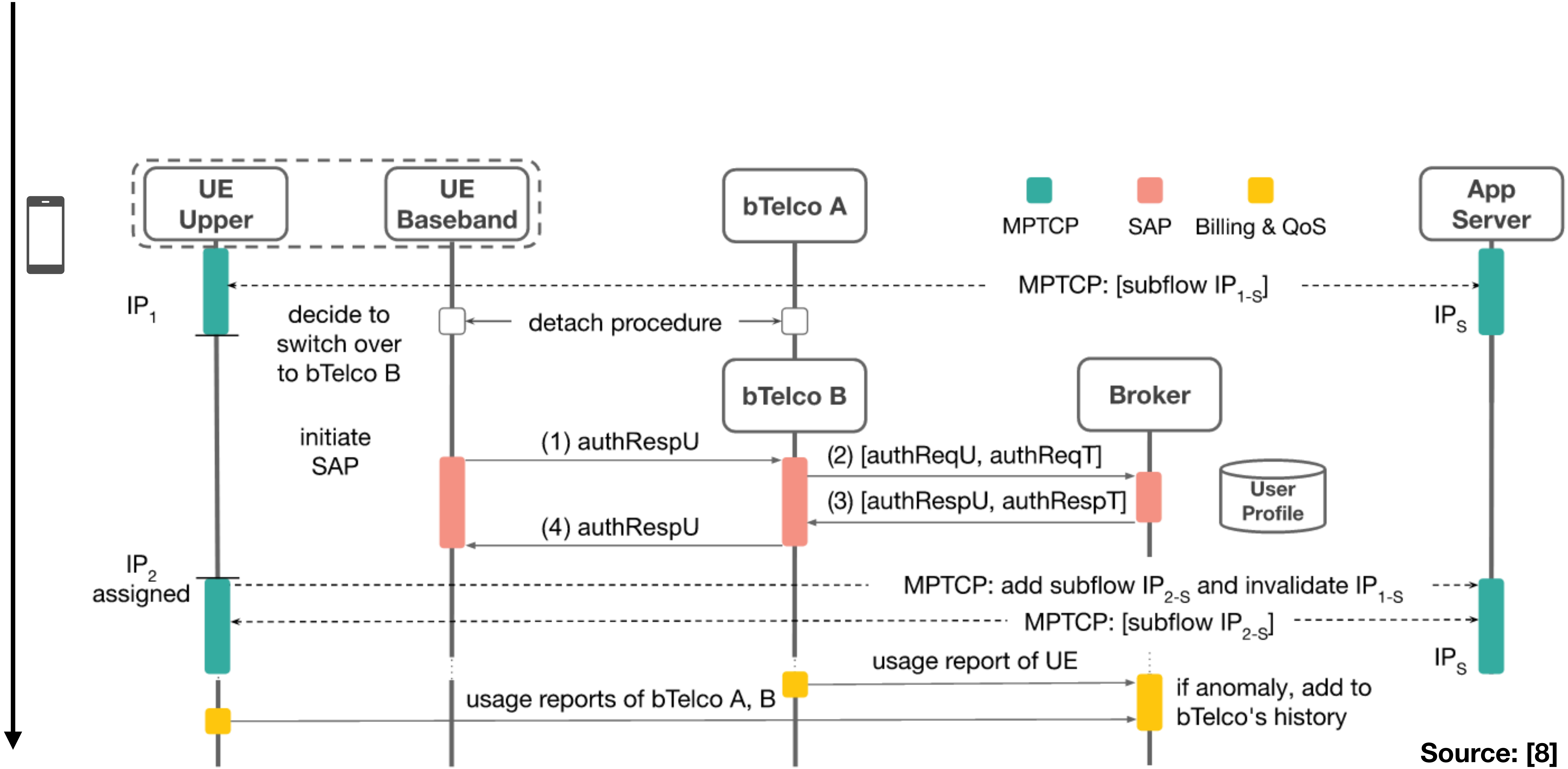

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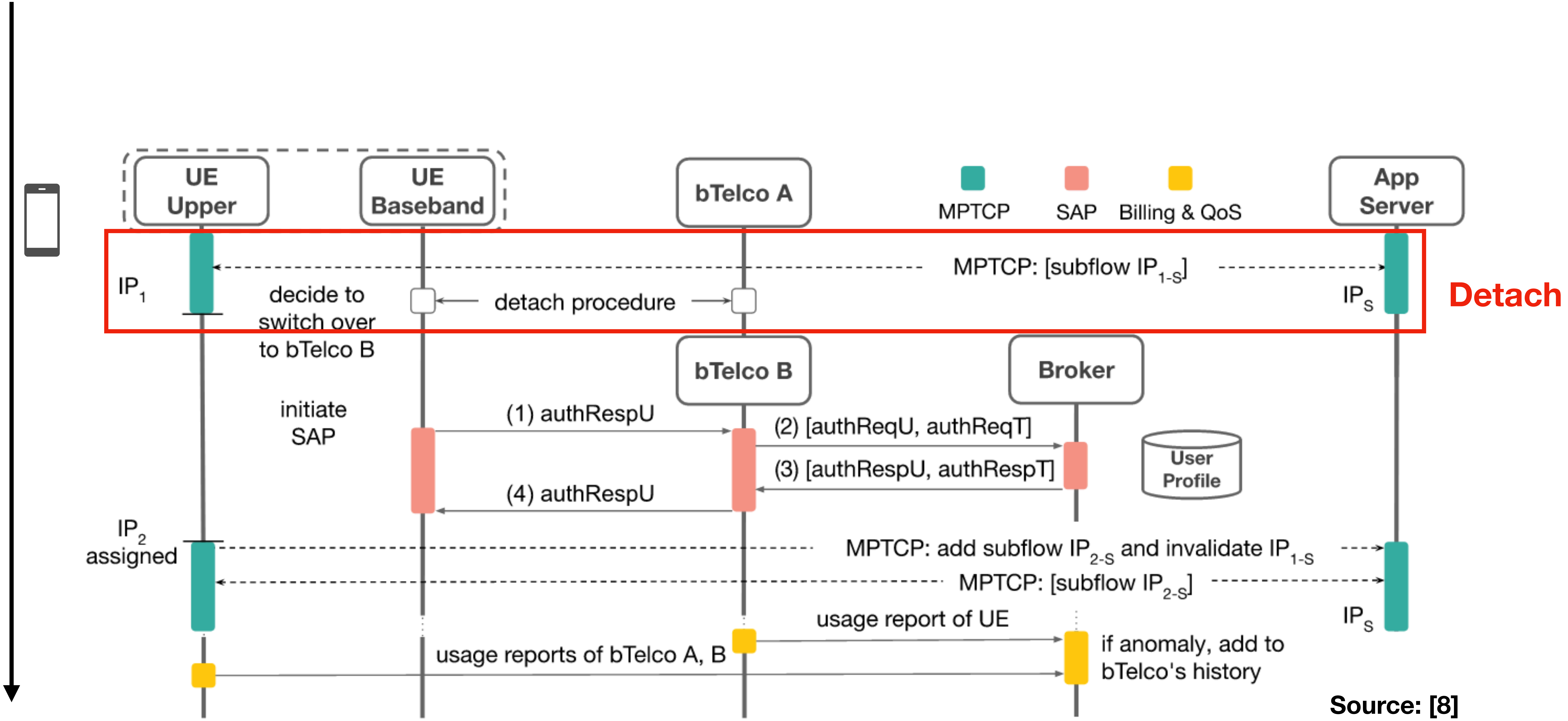

Source: [8]

Magma, mobility and decentralization : CellBricks [8]

Source: [8]

Containerization

- Containerizing AGW
- Extending AGW to Arm [6]

Billing and OCS in a decentralized setting with Magma: Witness Chain [9]

- Neutral host solution: application layer on Magma

- Two sided measurements [10]

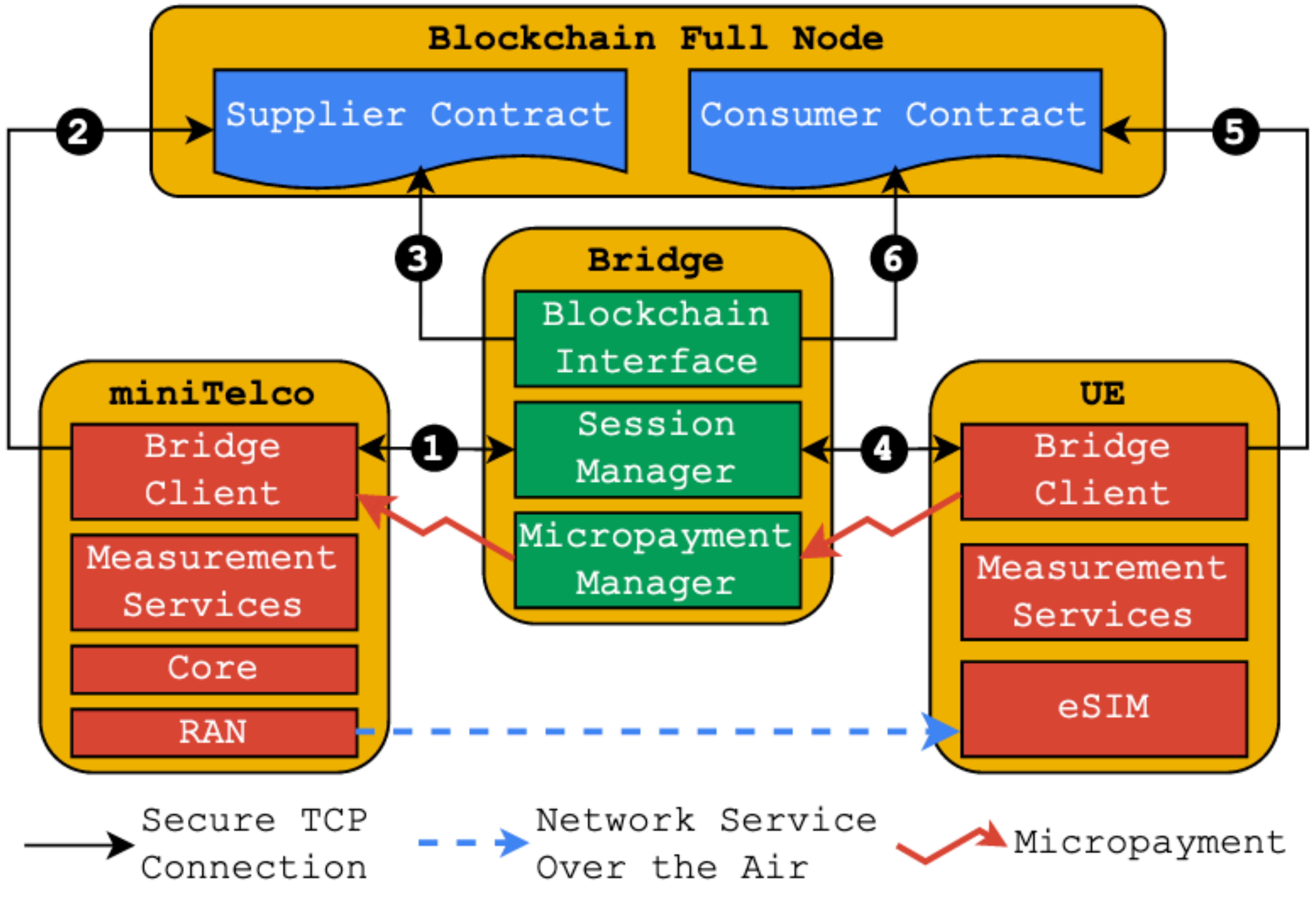

Figure 1: Decentralized cellular networks. Each orange block can be owned by a different entity without trust in others.

Source: [10]

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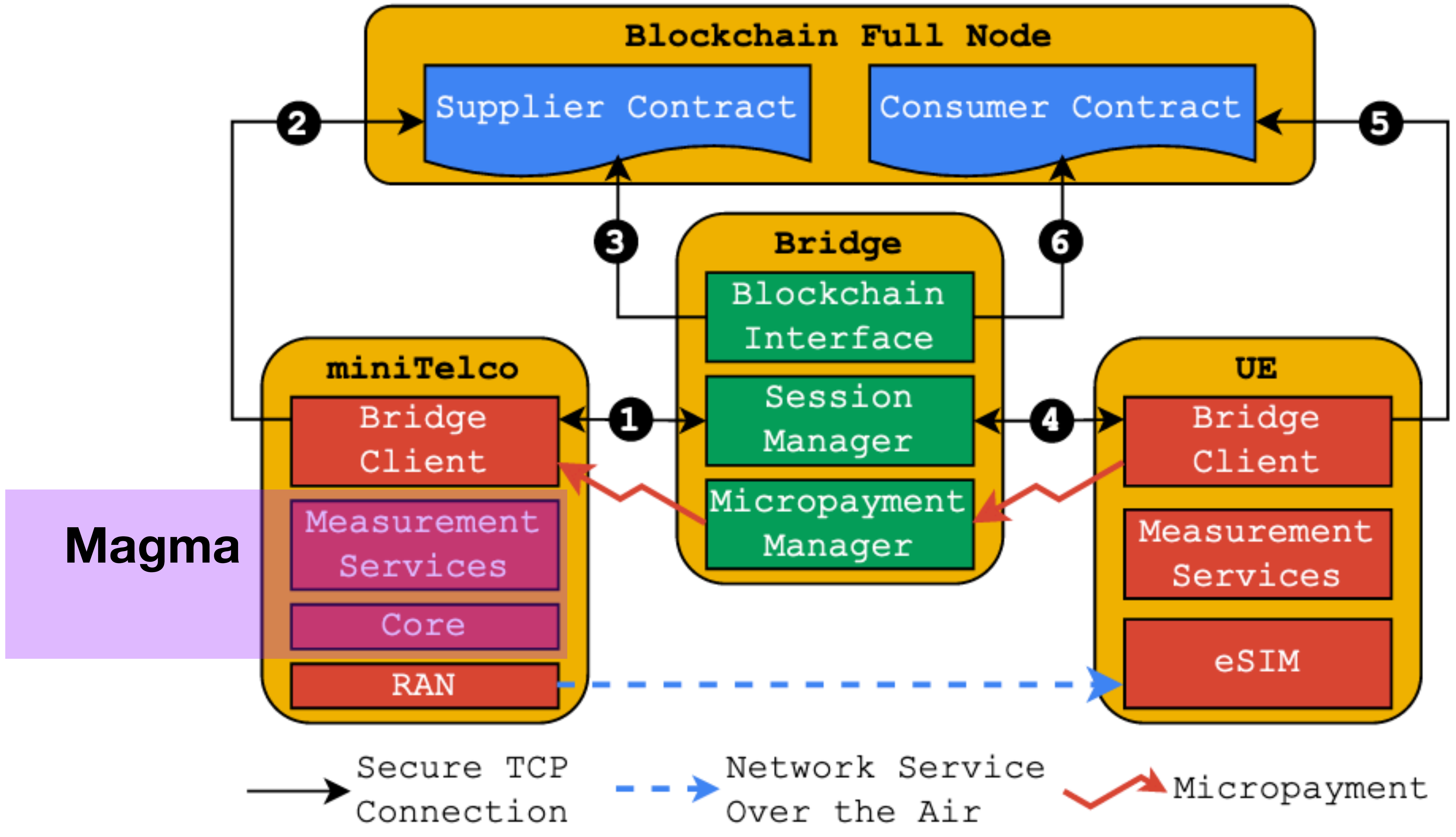

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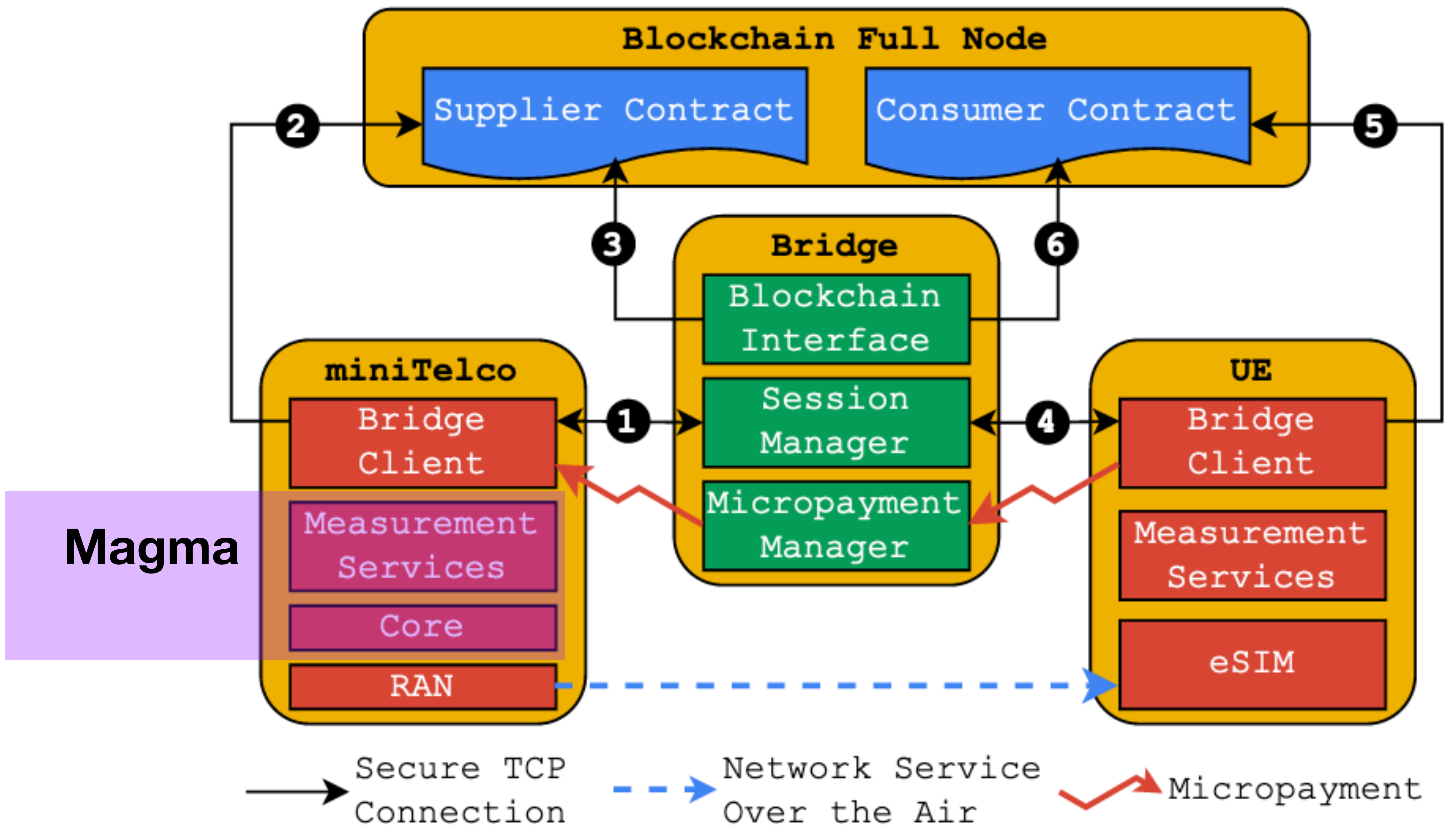
Billing and OCS in a decentralized setting with Magma: Witness Chain [9]

- Neutral host solution: application layer on Magma
- Two sided measurements [10]
- No trust between UE (consumer) and carrier (supplier/miniTelco)



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Source: Trust-free Service Measurement and Payments for Decentralized Cellular Networks [10]

References

1. S. Hasan *κ.ά.*, ‘Building Flexible, Low-Cost Wireless Access Networks With Magma’, *arXiv preprint arXiv:2209. 10001*, 2022

2. Implications of the Magma Architecture: Interoperability, Scale and Resilience, Bruce Davie, 9 August 2022

3. AccessParks

4. S. Hasan, M. C. Barela, M. Johnson, E. Brewer, and K. Heimerl, ‘Scaling Community Cellular Networks with CommunityCellularManager’, *16th USENIX Symposium on Networked Systems Design and Implementation (NSDI 19)*, 2019, σσ. 735–750.

5. M. W. Johnson, E. H. B. Jang, F. O’Rourke, R. Ye, και K. Heimerl, ‘Network Capacity as Common Pool Resource: Community-Based Congestion Management in a Community Network’, *Proceedings of the ACM on Human-Computer Interaction*, τ. 5, τχ. CSCW1, σσ. 1–25, 2021.

References

6. Magma v1.8.0 (Newberry)

7. Magma v1.7.0 (Mayon)

8. Z. Luo, S. Fu, M. Theis, S. Hasan, S. Ratnasamy, και S. Shenker, ‘Democratizing cellular access with CellBricks’, στο *Proceedings of the 2021 ACM SIGCOMM 2021 Conference*, 2021, σσ. 626–640.

9. https://witnesschain.com/

10. S. V. R. Anand *κ.ά.*, ‘Trust-free Service Measurement and Payments for Decentralized Cellular Networks’, 2022.

Appendix

The open source network ecosystem

Project	Features
free5GC	5G Core implementation
OAI	5GCN and gNB software stack implementations
Open5GS	C implementation of 5GC and EPC
srsRAN	4/5G UE, eNB, gNB and EPC impelementations

Internet access to underserved populations

Paper	Summary
El Paquete Semanal: The Week's Internet in Havana	Cuban offline internet
Kiosknet/Daknet	Mechanical backhaul
CommCongestion [5]	Game theory approach to congestion control
CCM [4]	Leveraging MNO-community interactions to extend access to rural areas

Alternate core structures

Paper	Summary
PEPC	Distributed state management requires repeated synchronization. Improves scaling by refactoring core based on how state is managed. Puts state in one place.
ECHO	Reduce dependence on vendor specific hardware setups. Switch to unreliable public cloud. EPC is UE state machine. Do SMR to increase availability.
SCALE (2015)	MME will be overloaded with increasing IoT. How to provision VMs on cloud to scale operations efficiently (CP traffic provides no profit to operator).
KLEIN	Resource management for NFV.