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Network Energy Savings Beyond 5G: 3GPP RAN Perspective

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Fraunhofer Institut für Integrierte Schaltungen IIS

Standardization, Partnerships and Associations of Fraunhofer Society

Contributions since 2015:
***Network Energy Savings (NES)**, NTN, V2X,*
MIMO, XR, Positioning, RedCap, AI/ML…

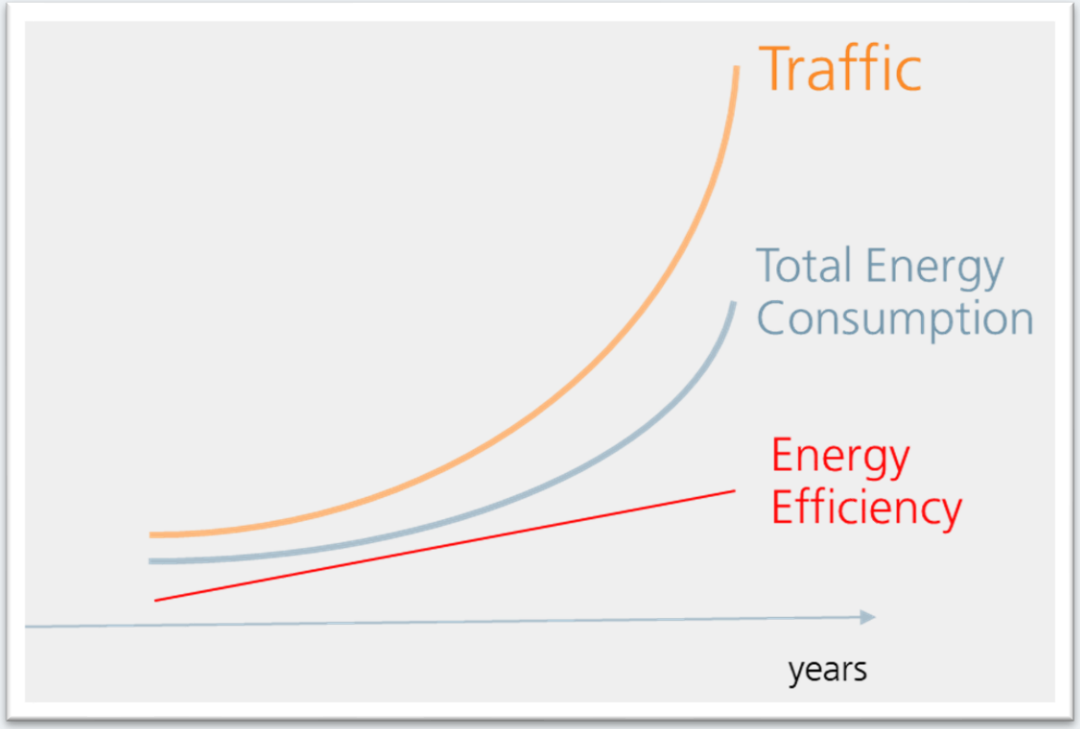
Member since 06/24

Non-profit organization, founded 1985, >1100 employees, annual budget approx. 168 Mio €
16 locations in 12 cities: **Erlangen**, Nuremberg, Fuerth, Ilmenau, Dresden, …

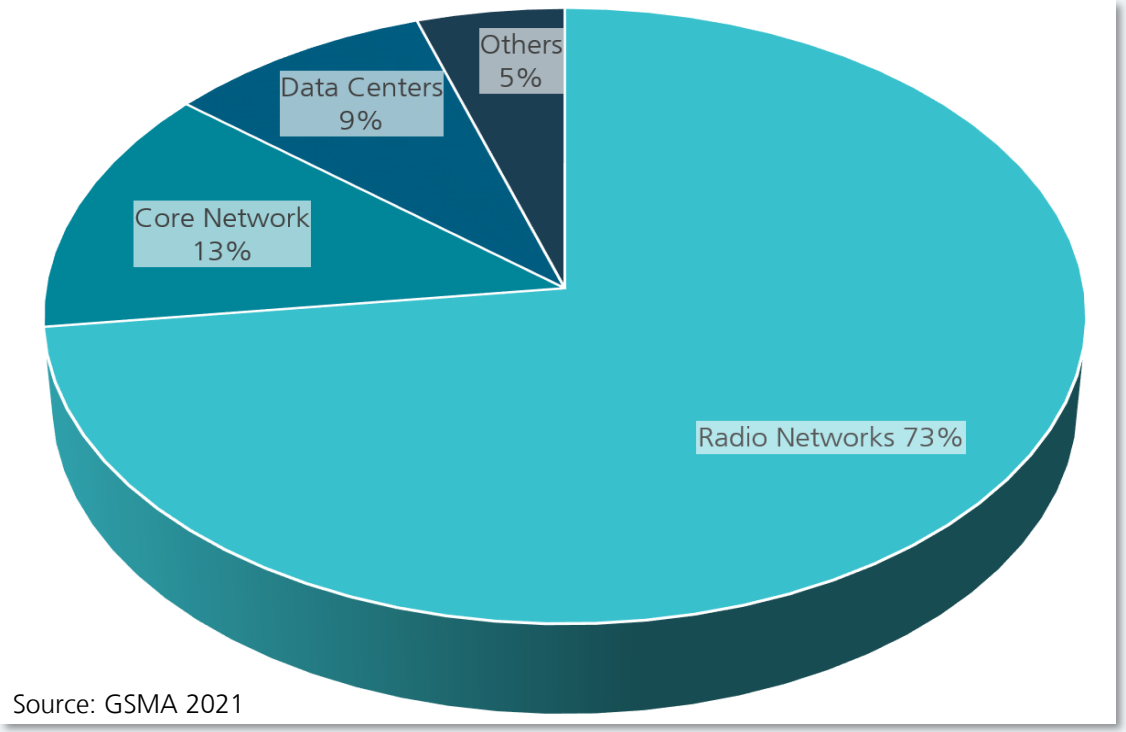
Energy Consumption in Cellular Networks

5G is more energy efficient than 4G but consumes much more energy

Increasing Network Energy Consumption



Network Energy Consumption Breakdown

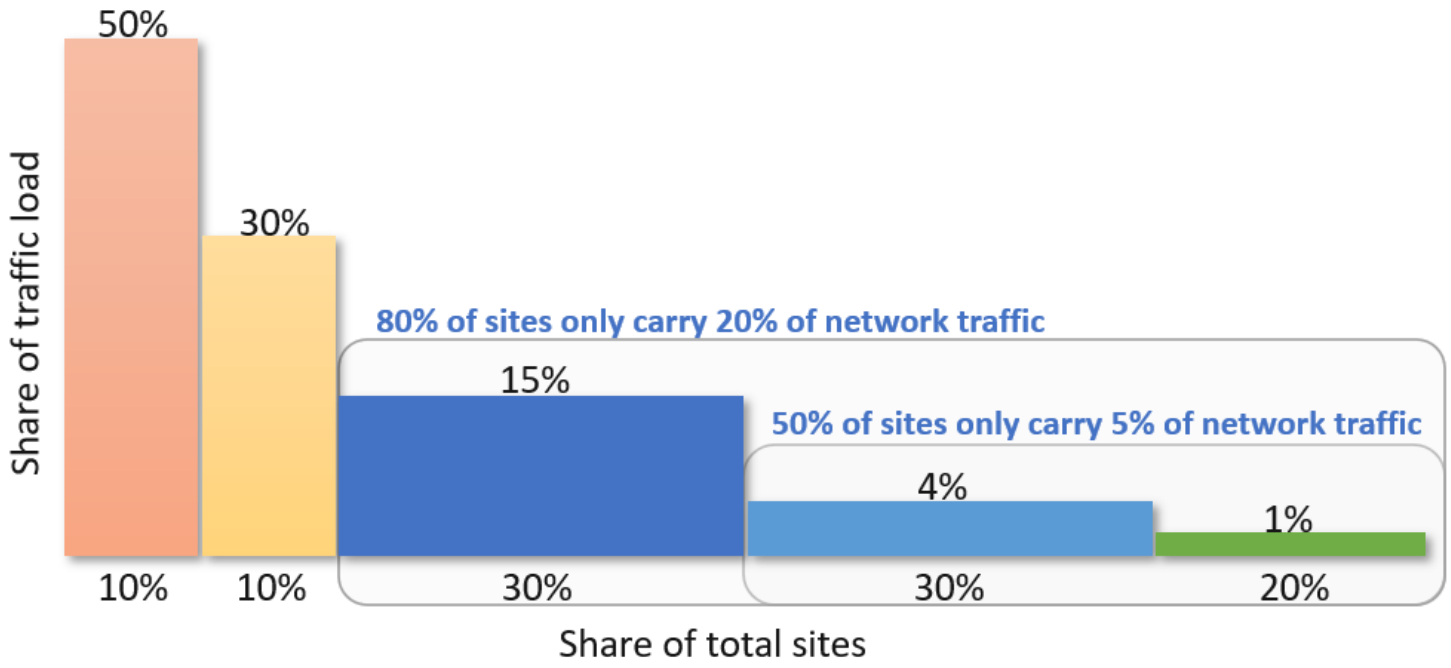


Source: GSMA 2021

→ Energy savings needed for meeting sustainability goals and reducing operational expenditures

Distribution of Network Data Traffic Load

Large share of energy inefficient lightly-loaded cells

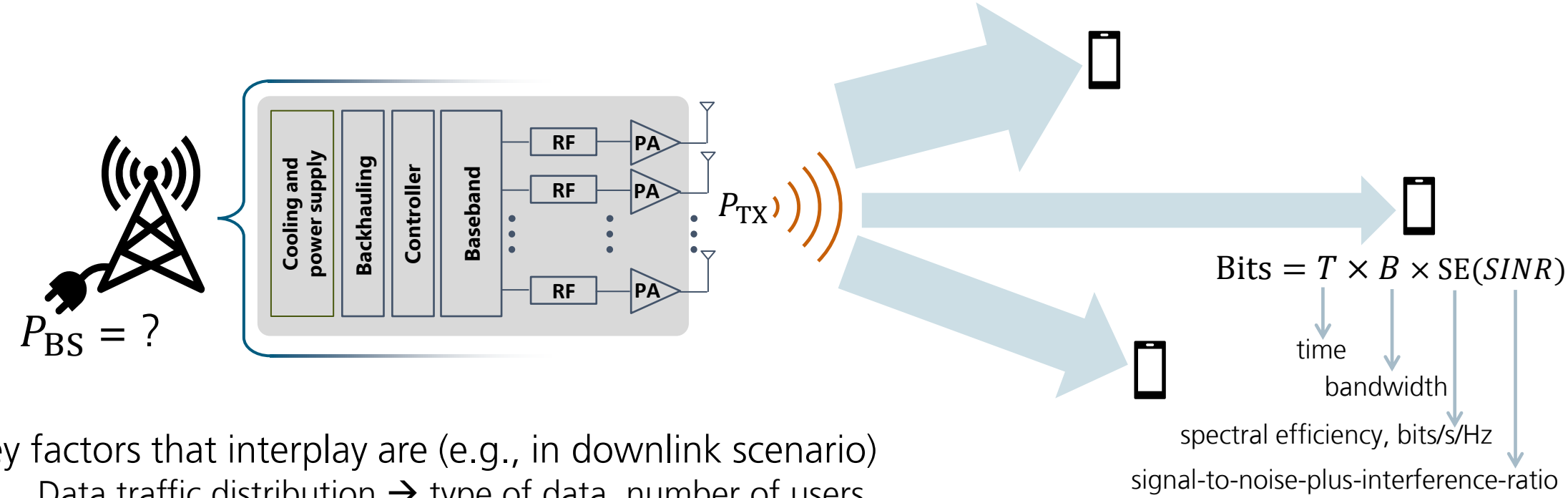


Source: Mavenir Intel Whitepaper, "A Holistic Study of Power Consumption and Energy Savings Strategies for Open vRAN Systems", Feb 2023

- Always-ON common signals are transmitted from all sites irrespective of traffic load
  - ➢ gNB sites consume significant energy even with no traffic load

Energy Savings and Network Performance

How is base station energy consumption related to performance metrics?



- Key factors that interplay are (e.g., in downlink scenario)
  - Data traffic distribution → type of data, number of users
  - Transmission rates to each user → resource (time/spatial/frequency/TX-power domains) occupancy, channel quality, UE reception quality* (noise figure, demodulation, detection)
  - Base station power consumption P_{BS} in **active transmission** and in **non-active (sleep) states**
- Several research problems to be explored in modeling and analysis

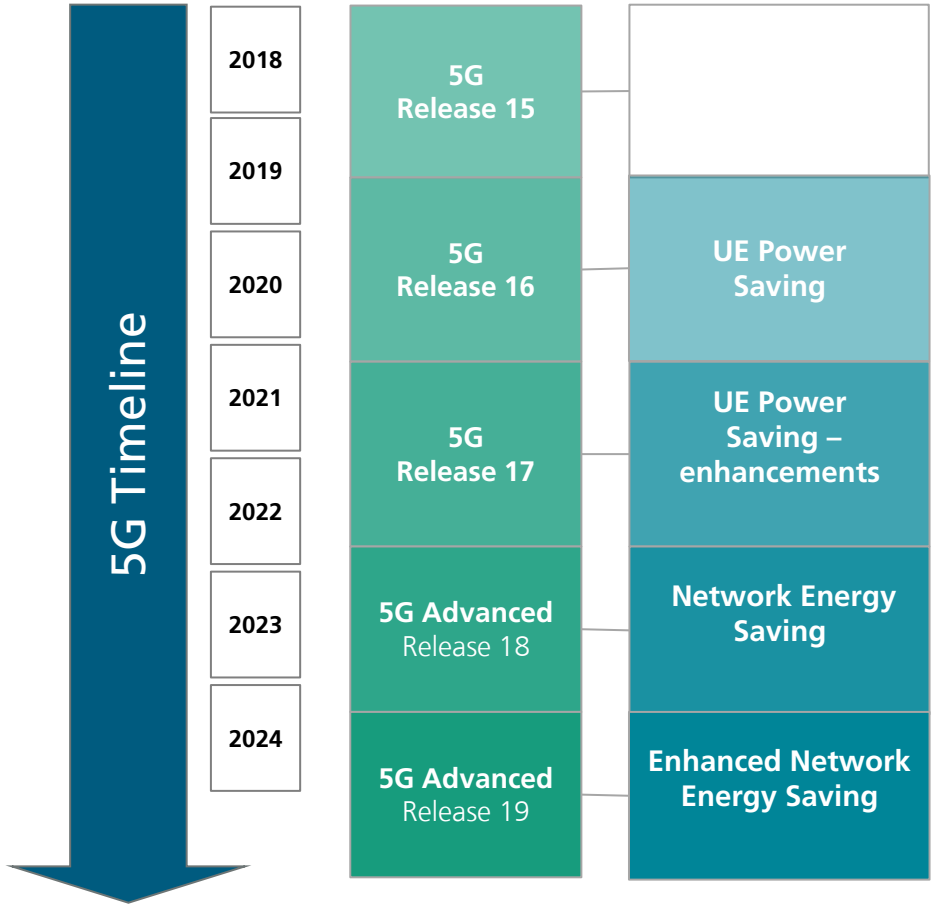
**NGMN Alliance Whitepaper, "Green Future Networks, Network Energy Efficiency V1.1" July 2021.*

Energy Savings in 3GPP 5G NR

3GPP Timeline

Network Energy Savings (NES) in RAN

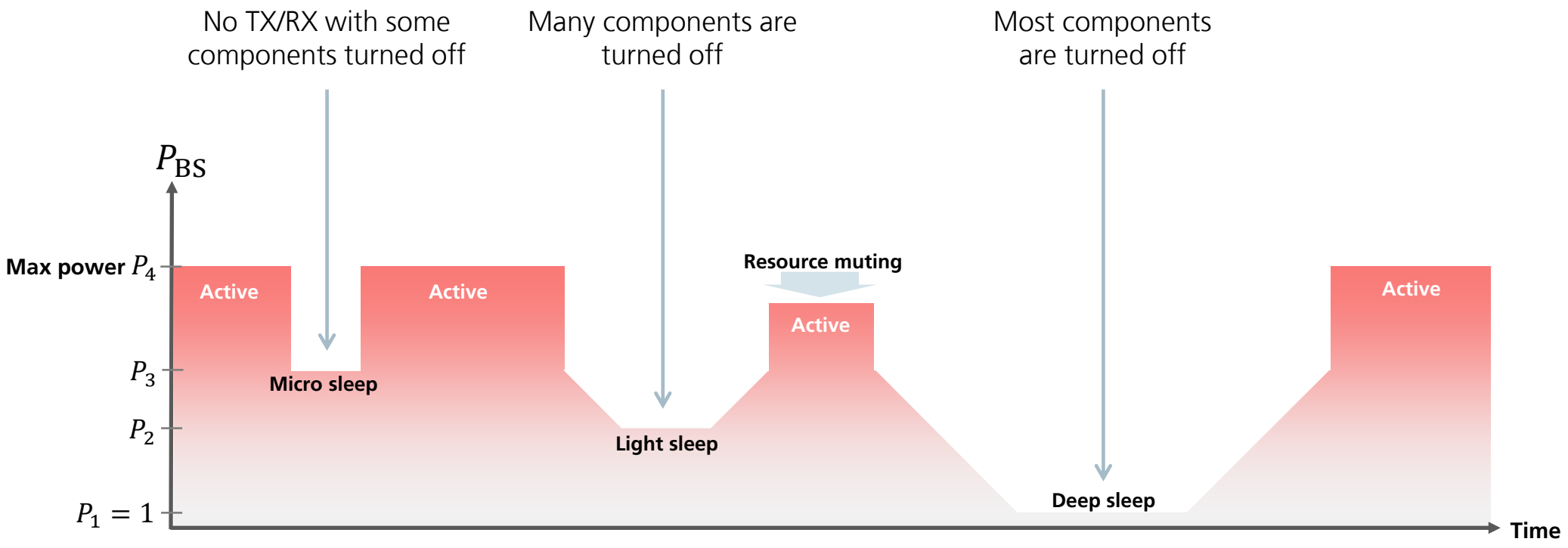
- Release 18
  - Study Item on NES (finalized by Q4 2022)
  - Work Item on NES (Q1 to Q4 2023)
- Release 19
  - Work Item on further enhancements on NES (ongoing, started in Q1 2024)



NES in 3GPP: Release 18 Study Item

BS power consumption modeling [TR 38.864]: sleep states and active downlink/uplink

- Different sleep states: relative power levels with increasing transition times to deeper states
- Active DL/UL: power consumption scaled with antenna/bandwidth/TX-power resources



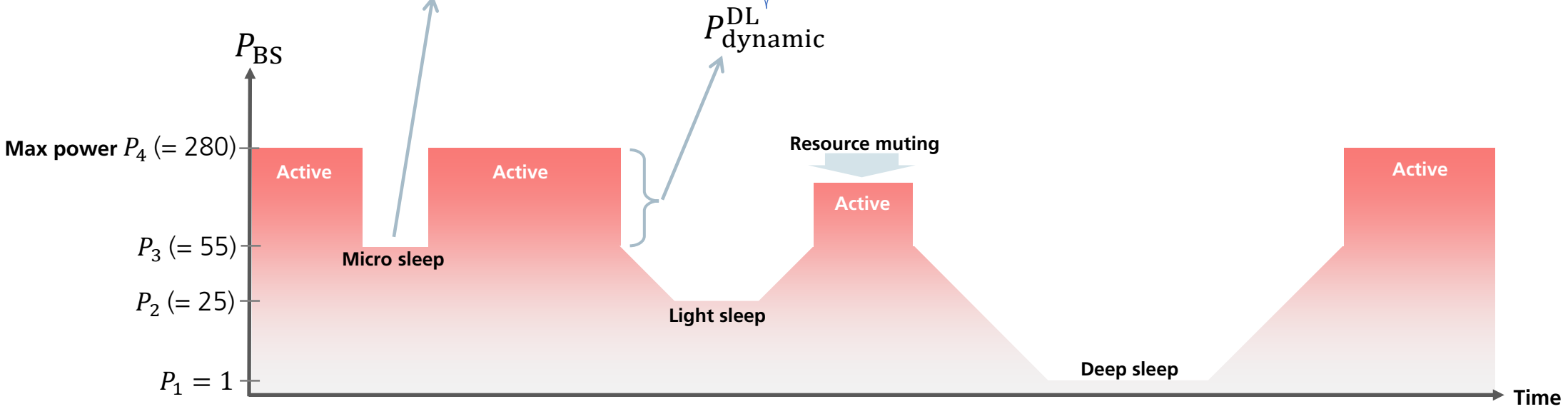
NES in 3GPP: Release 18 Study Item

BS power consumption modeling [TR 38.864]: downlink example

Consider DL power consumption (with example relative power levels):

Share of antenna (s_a), bandwidth (s_f), TX-power (s_p) resources and PA efficiency (η)

$$P_{BS} = P^{DL}_{static} + \underbrace{s_a\, P_{dyn,ante} + s_a\, s_f\, s_p\, P_{dyn,joint}/\eta}_{P^{DL}_{dynamic}}$$

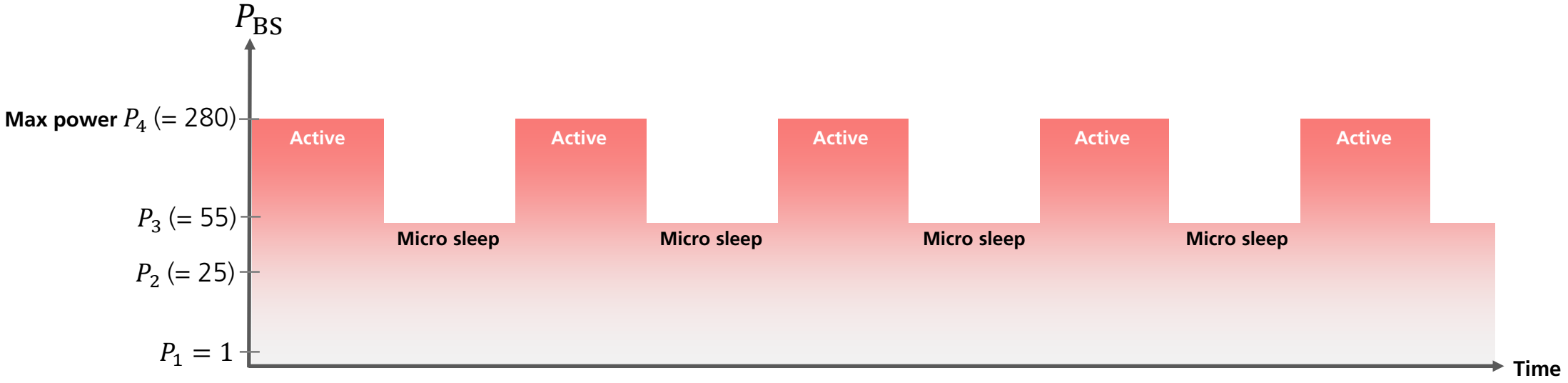


NES in 3GPP: Release 18 Study Item

BS power consumption modeling [TR 38.864]: downlink example

Consider DL power consumption (with example relative power levels):

- Simply micro-sleeping 50% of the time gives 40% NES
  - ➢ Time domain techniques to enter sleep states are very beneficial for NES in sparse traffic
- Disabling 50% antennas gives 40% NES
  - ➢ Adaptation of spatial elements can provide significant NES gains
- Scaling bandwidth or TX-power down by 50% gives 24% NES
  - ➢ TX-power adaptation has less performance impact compared to bandwidth adaptation



NES in 3GPP: Release 18 Study Item

BS power consumption modeling [TR 38.864]: downlink example

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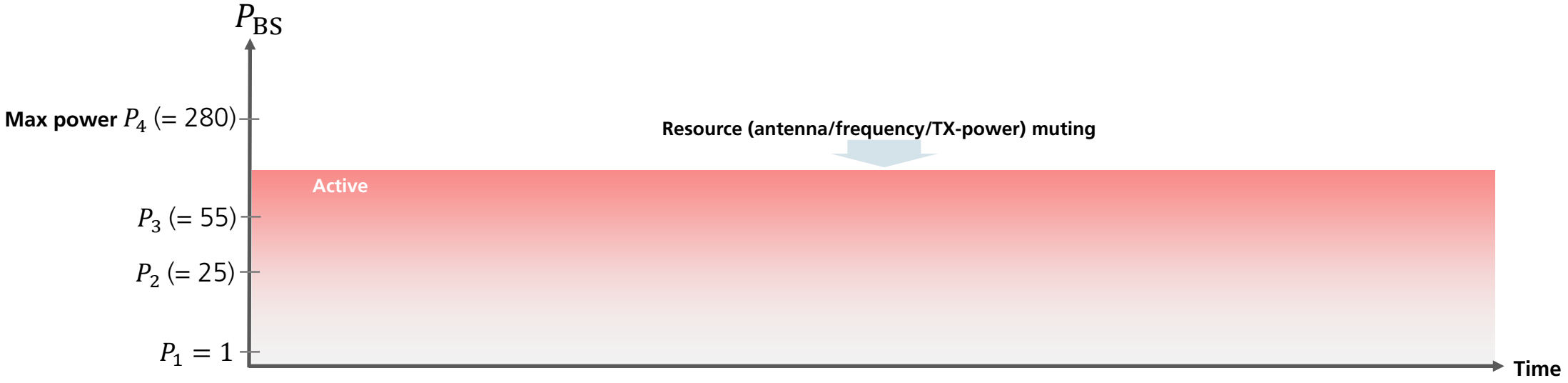


NES in 3GPP

Categorization of NES techniques

Time domain: increase inactive periods to enter sleep modes

Frequency/Time domain: increase inactive periods in a subset of carriers in carrier aggregated systems

Spatial domain: use only a subset of antenna elements and/or TRPs (TX/RX points) in multi-TRP operation

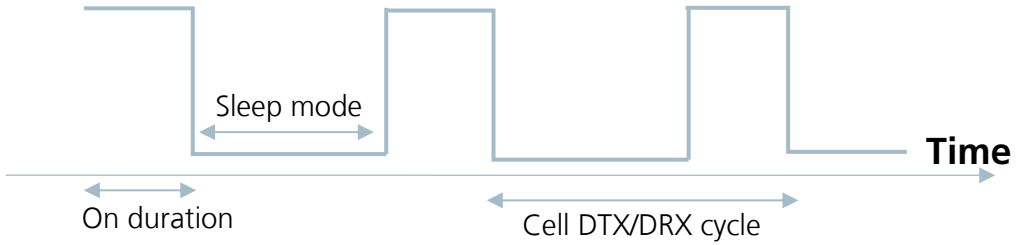
Power domain: TX power adaptation, energy efficient TX

Along with NES benefits, impact on performance (coverage, throughput, delay, UE power consumption, UE complexity etc.) and specification effort play key roles in reaching standardization agreements

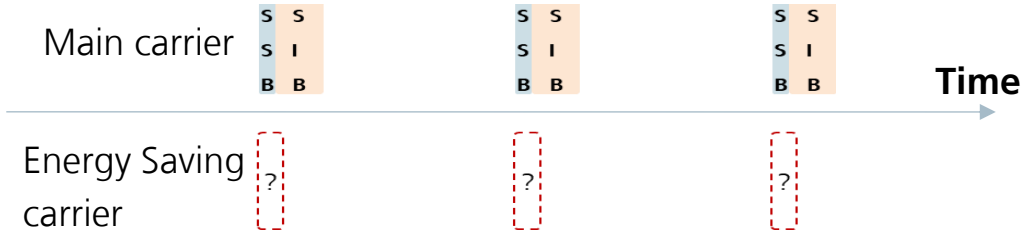
NES in 3GPP: Release 18 Work Item

No impact on IDLE/INACTIVE UEs, no adaptation of common signals (Q1 to Q4 2023)

Time domain: Cell DTX/DRX (discontinuous transmission/reception) mechanism

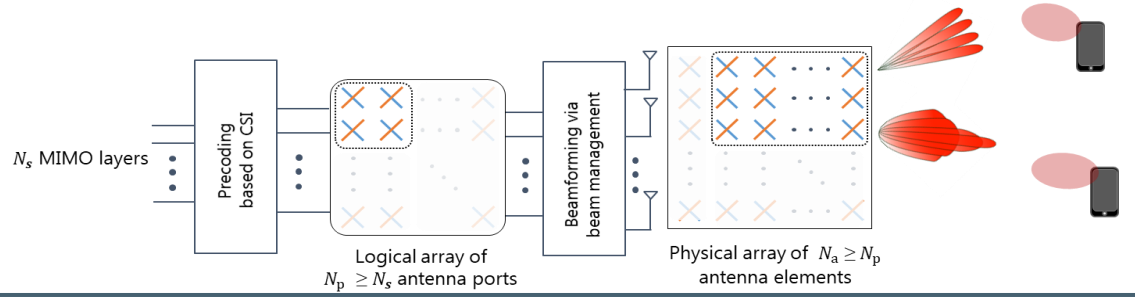


Frequency domain: In carrier aggregated systems, secondary carriers to transmit without synchronization signals (SSB)



Spatial domain: Dynamic adaptation of spatial (antenna) elements, necessary enhancements to CSI (channel state information)

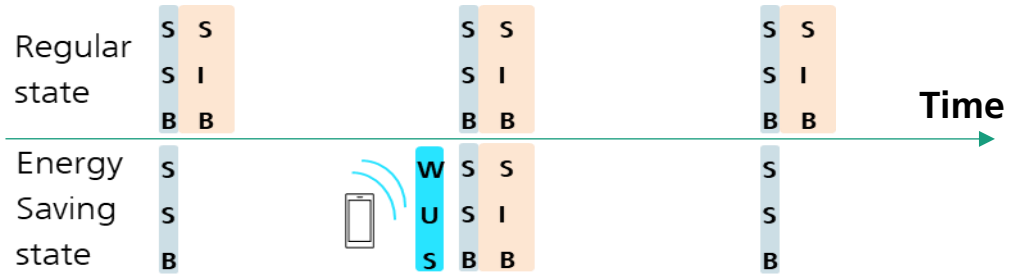
Power domain: Dynamic adaptation of DL data transmission power, necessary enhancements to CSI



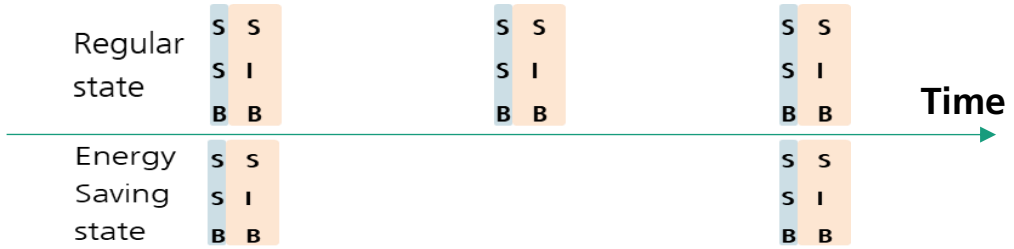
NES in 3GPP: Release 19 Work Item

Common signal adaptation is being considered (ongoing, started in Q1 2024)

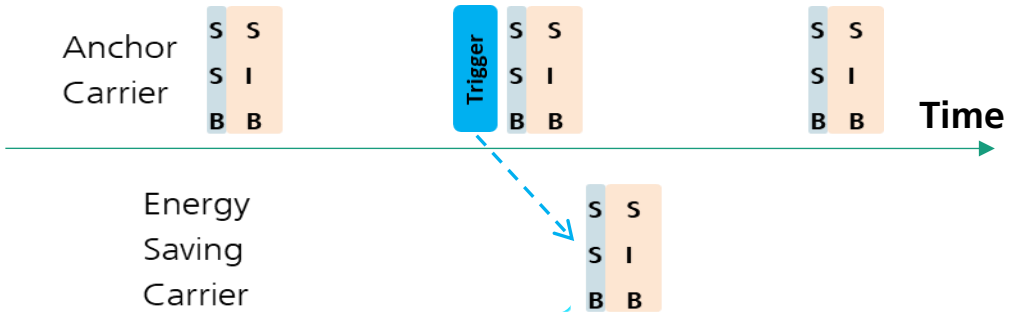
Time domain: On-demand transmission of system information block (SIB1) signals



Time domain: Adaptation of common signals and channels, such as synchronization signal blocks (SSB)



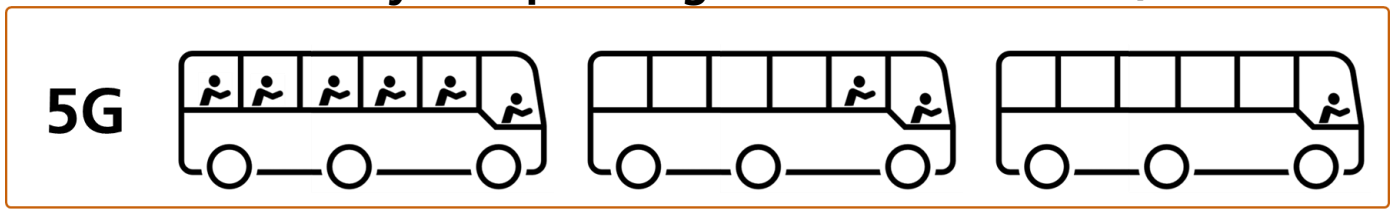
Frequency/Time domain: On-demand transmission of synchronization (SSB) signals on secondary carriers in carrier aggregated systems



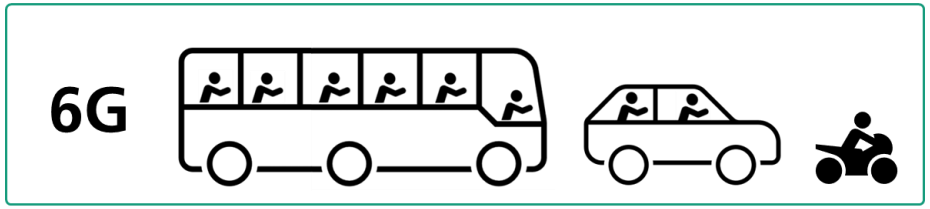
Desired Power vs Load Profile

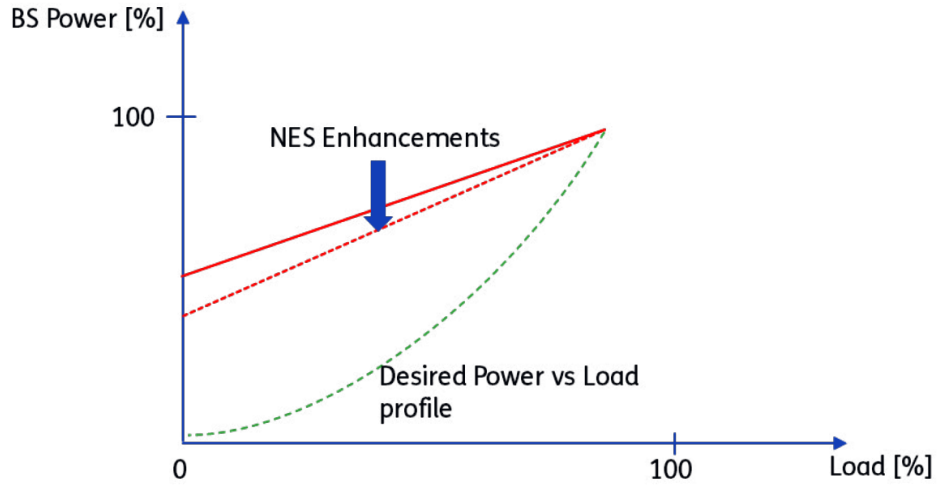
Need for network design with focus on low energy consumption

"We designed a "bus"! Very efficient! But what if there is only one passenger?" – Cicek Cavdar, KTH



What should 6G be?





Source: NGMN Alliance, "Green Future Networks: A Roadmap to Energy Efficient Mobile Network", July 2024.

- Ideal BS power profile: power consumption close to zero Watt for zero carrier load
  - ➢ Would require hardware optimizations together with NES enhancements in standardization

6G Vision for Enhanced Network Energy Savings

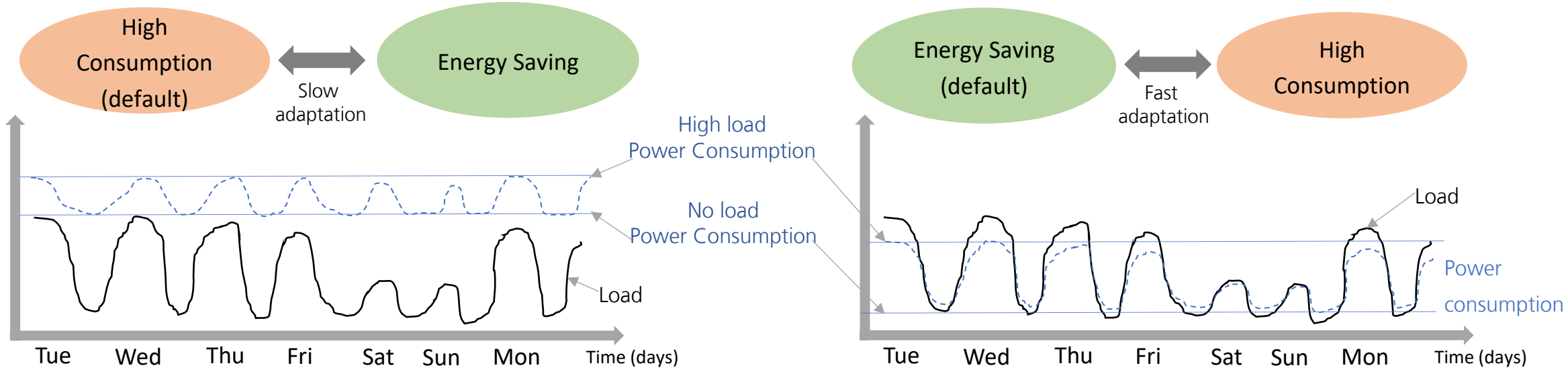
Network design with focus on low energy consumption

Today

- Network designed for high capacity
  - Implies high energy consumption by default
  - Energy consumption is inelastic to load
- Basic NES techniques to opportunistically reduce energy consumption

Future

- Network design for low energy consumption
  - Adaptively ramp up consumption as per load
  - Longer periods in energy saving states
- NES techniques with more specification efforts: redesign of waveform, initial access …



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Thank you

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