Energy Efficiency and Cloud Radio Network

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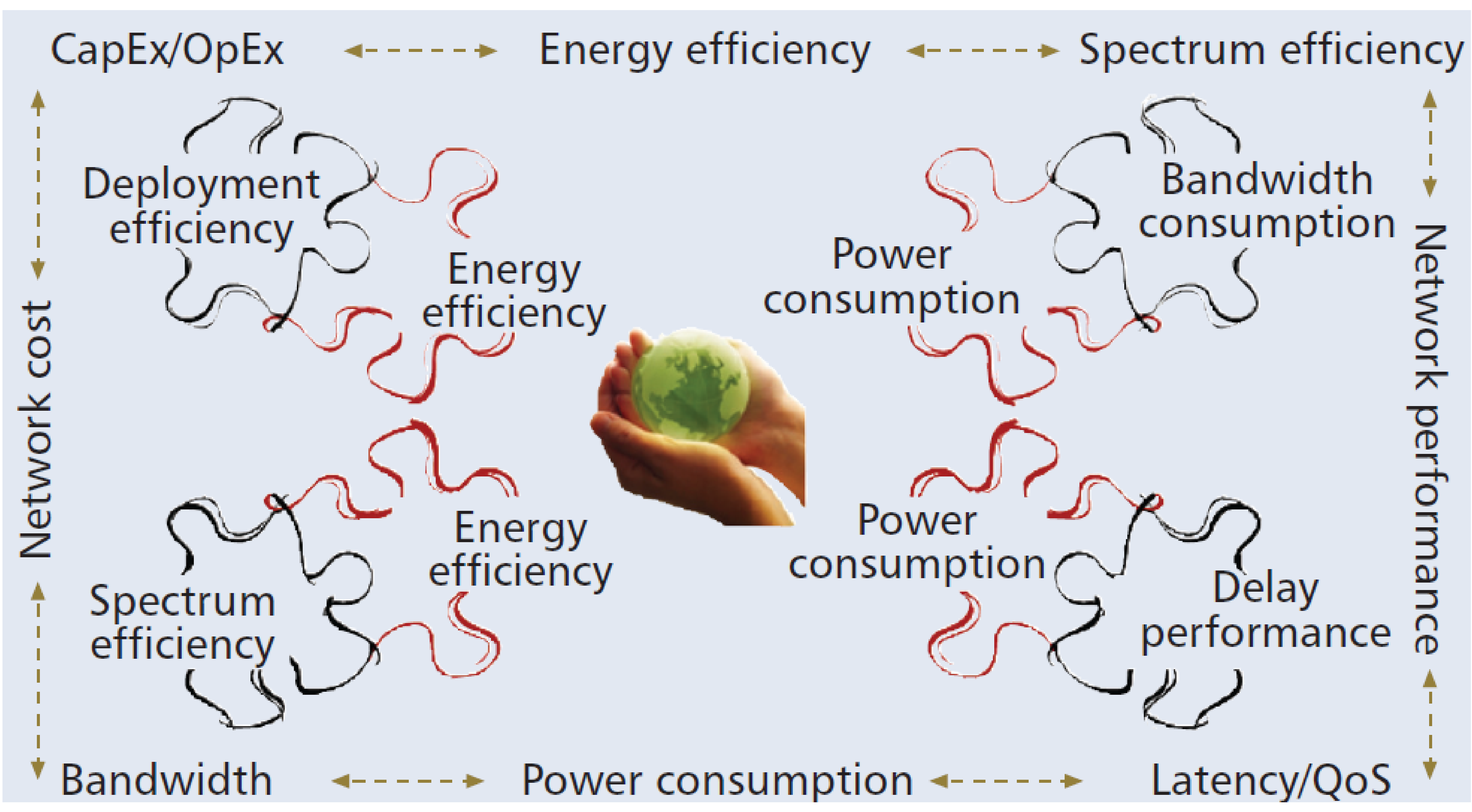
I. Context and Motivations

- **Exponential growth of mobile Internet traffic volume**
  - Emergence of 4G/5G coupled with Internet-capable mobile devices
  - New applications and services : M2M, online gaming, interactive mobile video and mobile TV, context-aware and 3D applications
- **But, the revenues are not increasing with the traffic volume**
  - Per-bit energy consumption cannot follow traffic growth
  - Overall operating BS cell power cannot follow BS growth
- **Operators are seeking more cost-effective solutions to**
  - Introduce new applications and services, and enhance user QoE
  - Increase system capacity, 1000 times of today's throughput
  - Cope with the network traffic workload demand and supply due to sptio-temporal traffic fluctuations
  - Reduce the total energy budget, and EMF emission
- **Green radio key enablers**
  - Small cell, HetNet, Relaying, Massive MIMO, and **Cloud –RAN**
  - Traffic management, offloading, content-optimized network
  - Virtualization, cloud computing, Software-defined network (SDN)
  - Network-wide coordination and orchestration

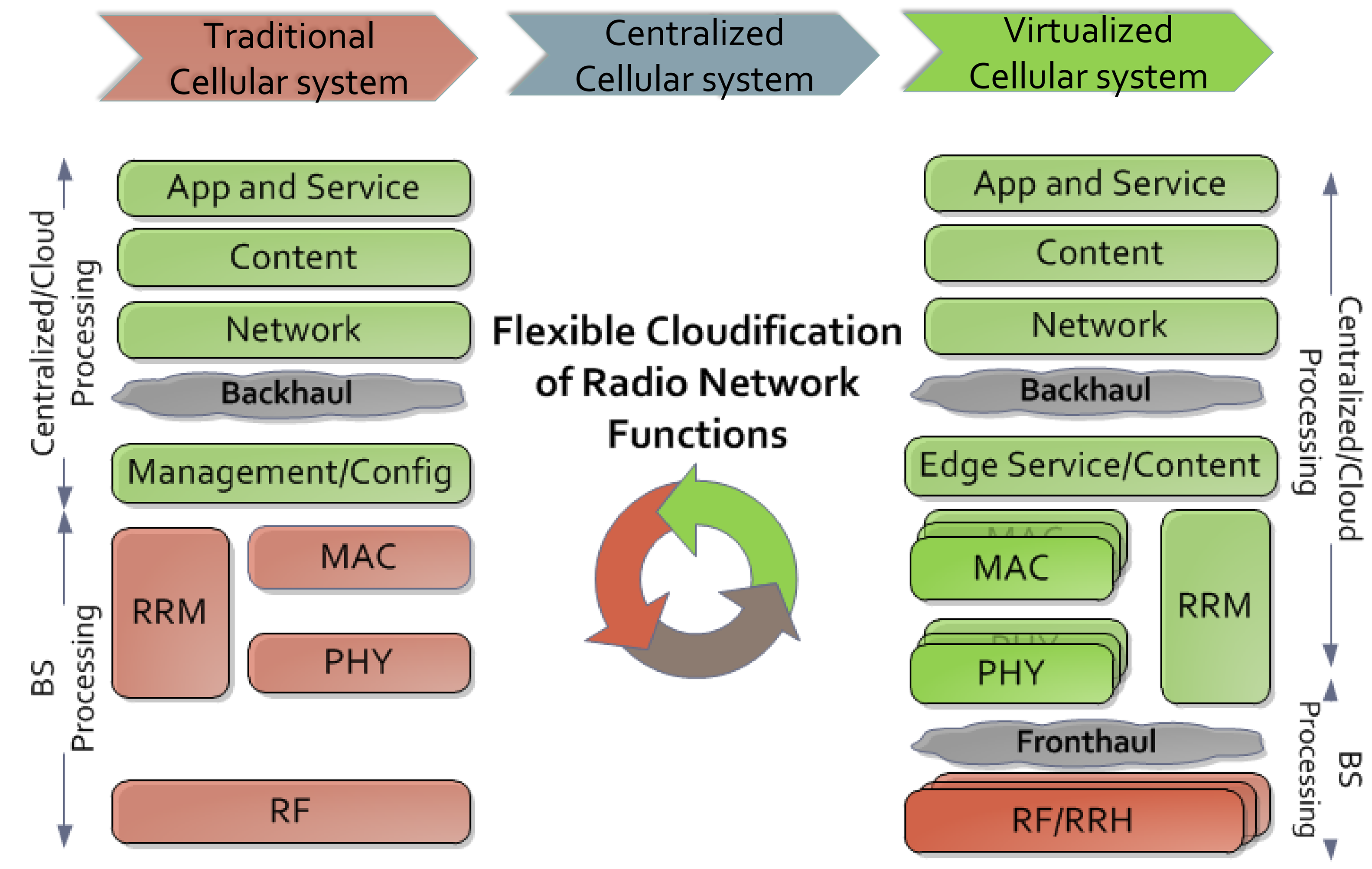
II. Fundamental Trade-offs on Green Radio



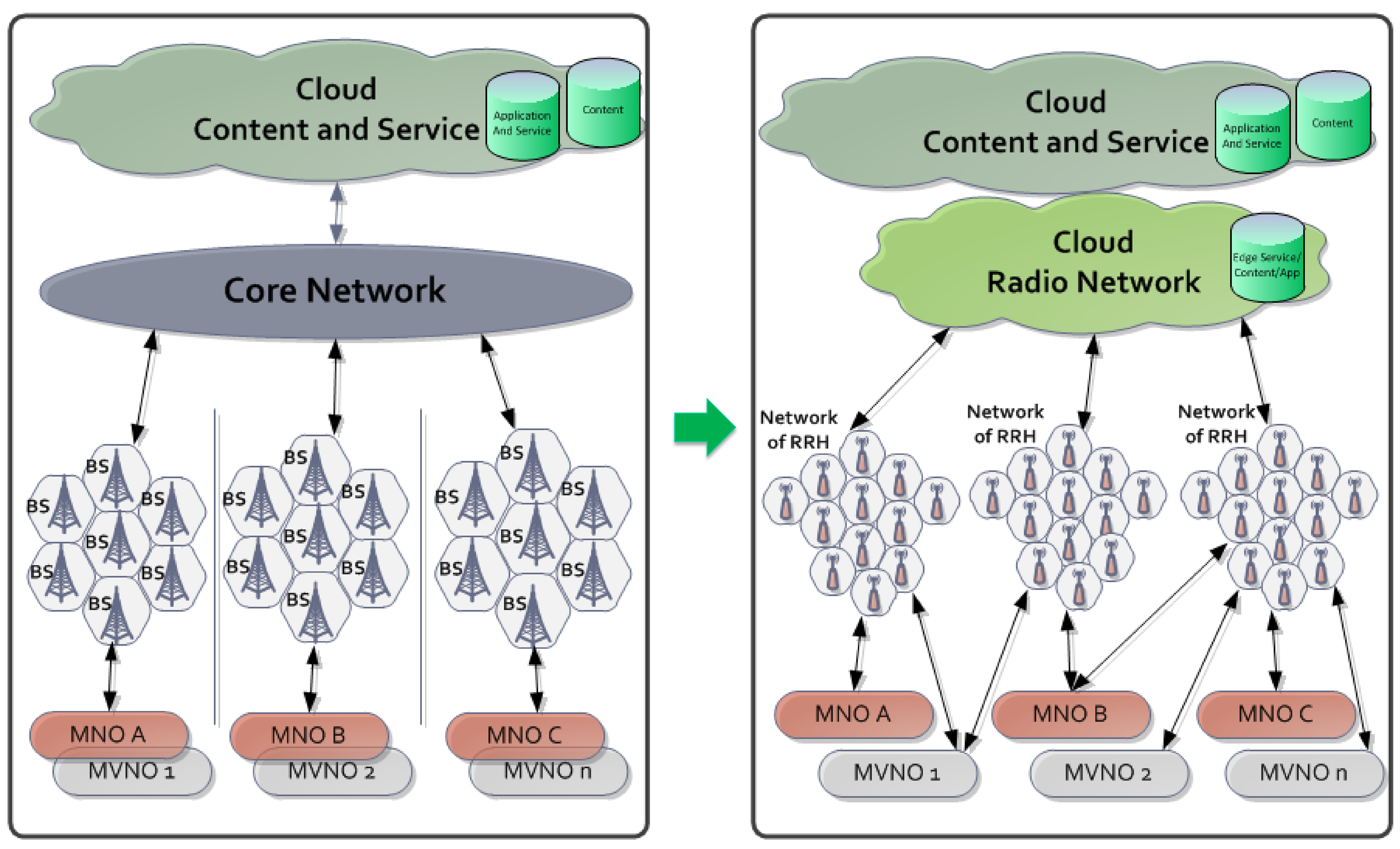
Source: Fundamental Trade-offs on Green Wireless Networks, IEEE Communication Magazine

- **Interplay between cost, latency, bandwidth, rate, and energy**
- **Trading for power**
  - Expanding the **bandwidth** for a given rate requirement ?
  - Reducing the **transmission rate** for a given bandwidth ?
  - **Delaying the service time** without deviating a given QoS ?
- **BS cell size and energy efficiency**
  - Reducing the cell size shorten distances between network and terminals →Lower the TX power up to 10dB and same SINR
- **Latency and energy efficiency**
  - Minimizing protocol latency minimizes energy consumption in DSP, embedded system, and processor on both network and terminal
- **BS availability and energy efficiency** (Traffic Migration)
  - Only 20% of BS sites carry 80% of traffic
  - Turn BS on and off for dynamic load balancing and traffic flow offloading → adjust the network workload demand and supply
- **Content availability and energy efficiency**
  - The majority of mobile data is content-based services (video, web)
  - Place and store popular content at the network edge (prefetching/caching) → reduce the E2E latency/energy
- **Novel Radio transmission technologies and architectures**
  - Radio network cloudification and delivery as a service

III. Cloudification of Radio Network



- **Centralized/virtualized base station pool**
  - Migration from expensive specific hardware to GP platforms → **lower the cost of equipment**
  - Load balancing and traffic offloading to meet traffic fluctuation → **energy saving by dynamically turning on and off the RAN**
  - Rapid provisioning and new service adoption → **meet new traffic demands**
  - Efficient coordination and interference management across cells → **increase the overall system capacity and radio collaboration**
- **Scenarios**
  - **MVNOaaS:** value-added content and service bundle
  - **PMRaaS:** dedicated and reliable content and service bundle

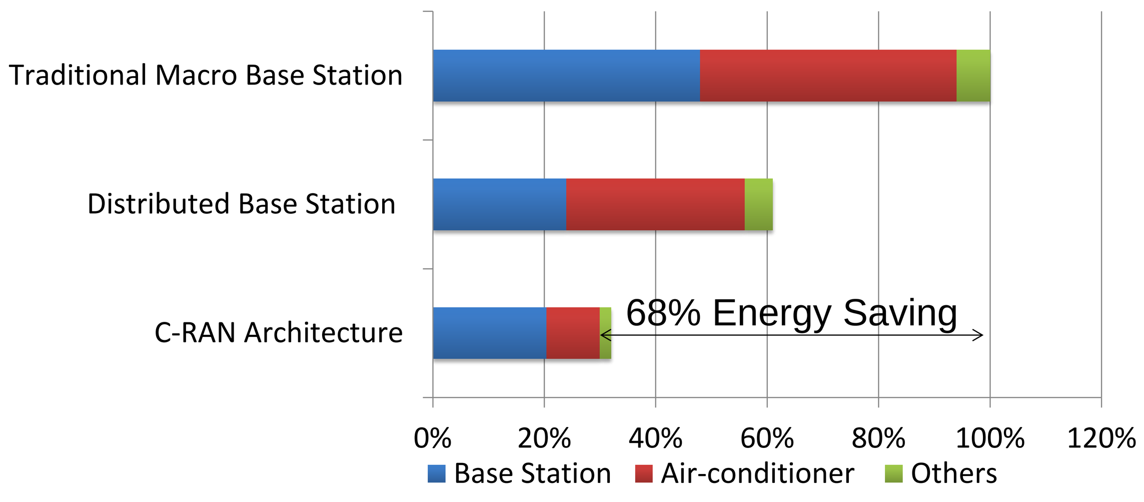


IV. Cloud-RAN Reduces 68% Power Consumption*

- **Majority of power consumption is from BS**
  - 50% by RAN
  - 50% by Air conditioning and other facility equipment

Scenario : China Mobile typical site model, total power consumption of traditional macro BS is 100%

RAN Energy Budget	Base Station	Air Conditioning	Other Major equipment	Total	Energy saving (%)
Traditional Macro Base Station	48%	46%	6%	100%	NA
Distributed Base Station	24%	32%	5%	61%	39%
C-RAN Architecture	20.4%	9.6%	2%	32%	68%



*Source: China Mobile and ZTE

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