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Evolution of Mobile Communication

Matthias Lott DOCOMO Euro-Labs, Germany

19. VDE/ITG Workshop on „Mobile Communication“, May 21.-22., 2014

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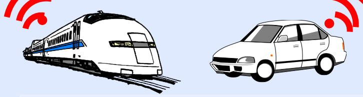
Everything Connected by Wireless

Monitor/collect information & control devices

Multiple personal devices

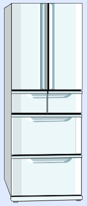
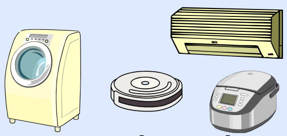
Interaction across multiple devices

Transportation (Car/Bus/Train)



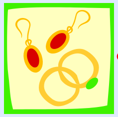
Entertainment, Navigation
Traffic information

Consumer electronics

Remote operation using personal terminal

Watch/jewelry/cloth

Human interface and healthcare sensors

House

Remote control of facilities
House security

Sensors

Smart power grid
Agriculture and farming
Factory automation
Weather/Environment

Cloud computing

All kinds of services supported by the mobile personal cloud

Extension/enrichment of wireless services

Deliver rich contents in real-time & ensure safety

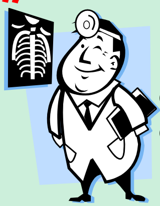
Video streaming

4K/8K video resolutions
Video on newspapers
Background video

New types of terminal/HI

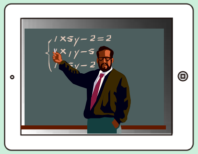
Glasses/Touch internet

Healthcare



Remote health check & counseling

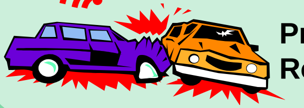
Education



Distance (remote) learning
Any lesson anywhere/anytime

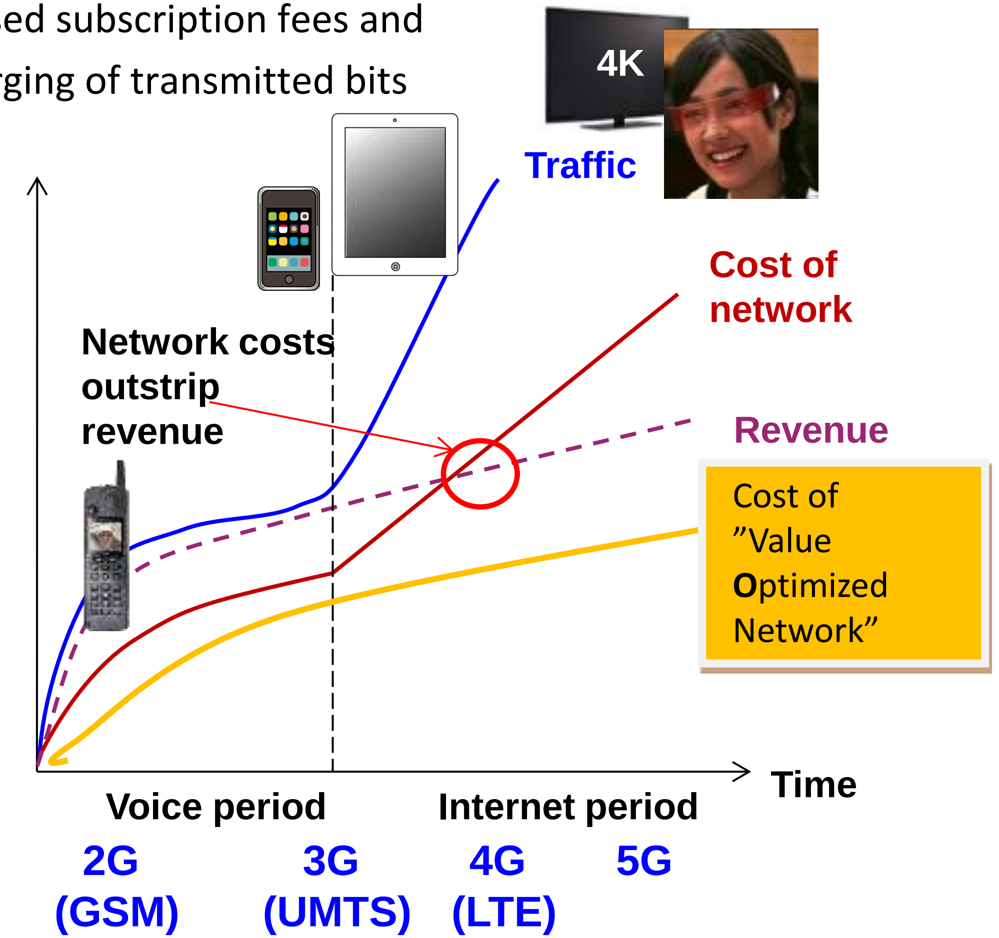
Safety and lifeline system





Prevention of accidents
Robustness to disasters

- Mobile business will not be sustainable if mobile operators rely on traditional model of
  - volume based subscription fees and
  - simple charging of transmitted bits



→ Value of individual consumer experience should be linked to provided service and quality

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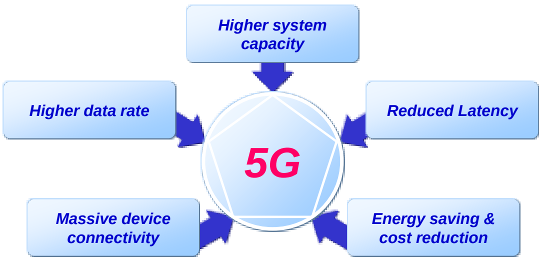
5G

- to meet future requirements
- **"5G = E2E"**
  - will be an end-to-end (e2e) topic
  - changes in RAN & core network



New Business

- New revenues streams become important for mobile operators
- MTC / M2M has big potentials
- Collaborations with OTT is another example
- …

System

Focus of this talk

Operations

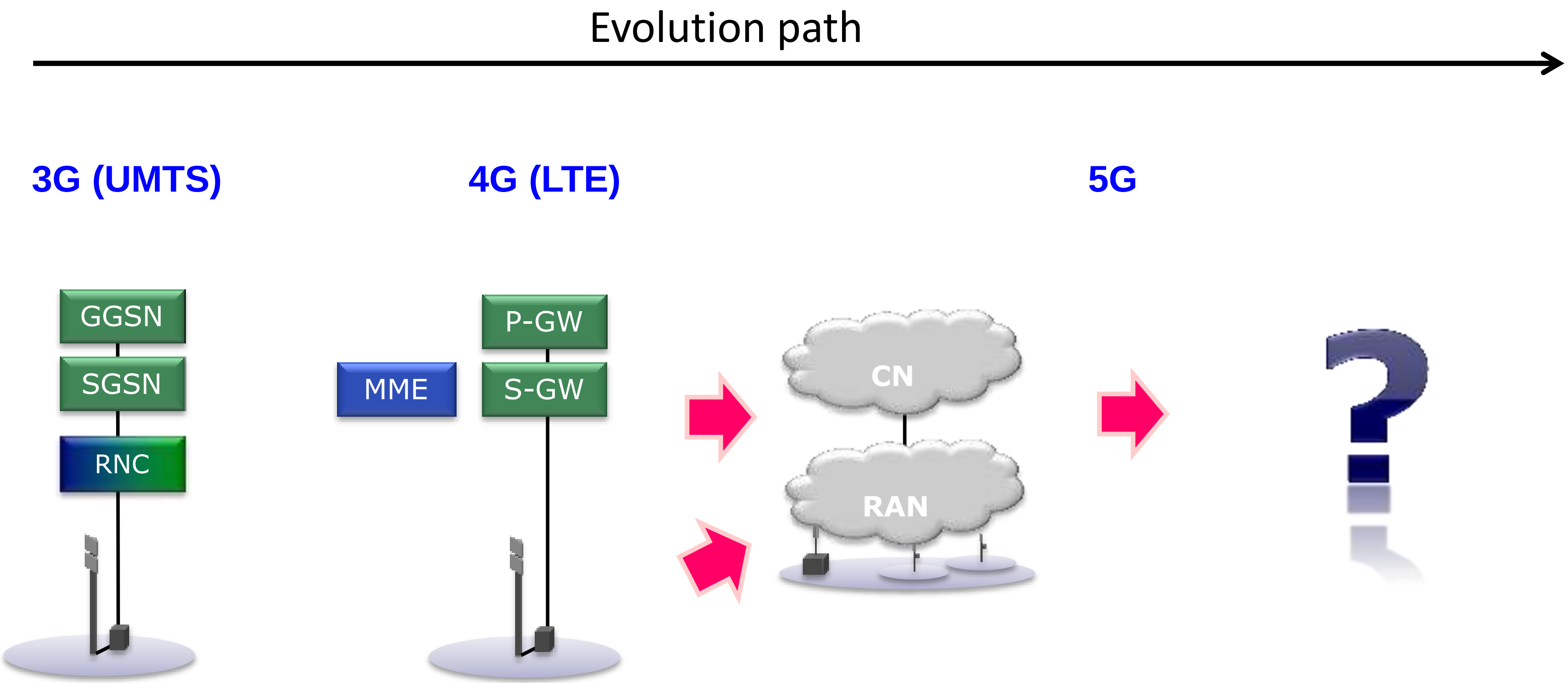
Business

Dynamic & Reliable Operations

- Application-aware traffic control
- Efficient support for variety of traffic types
- Support of different types of devices
- Fast deployment of new services
- High-availability
- Resiliency / fault-tolerance

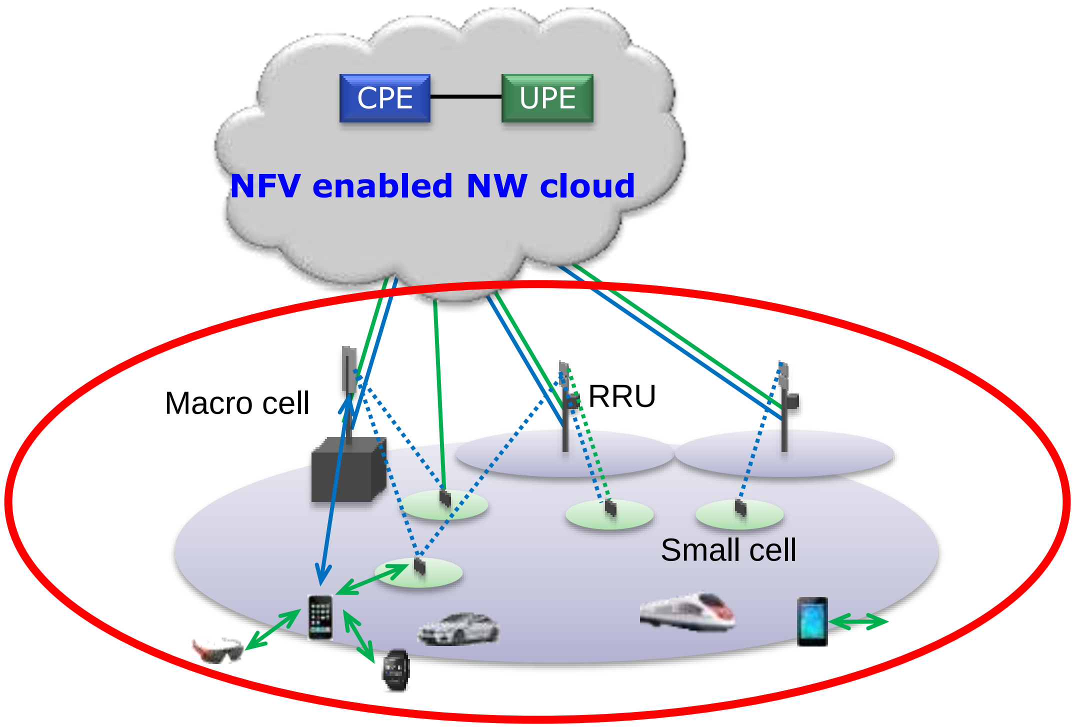
Virtualization as Enabling Technology

- Cost reduction (CAPEX, OPEX)
- New business
- Flexible & intelligent service offerings



GGSN	GW GPRS Support Node	P-GW	Packet Data Network - GW	CN	Core Network
SGSN	Serving GPRS Support Node	S-GW	Serving - GW	RAN	Radio Access Network
RNC	Radio Network Controller	MME	Mobility Management Entity		

Future Radio Access (FRA)

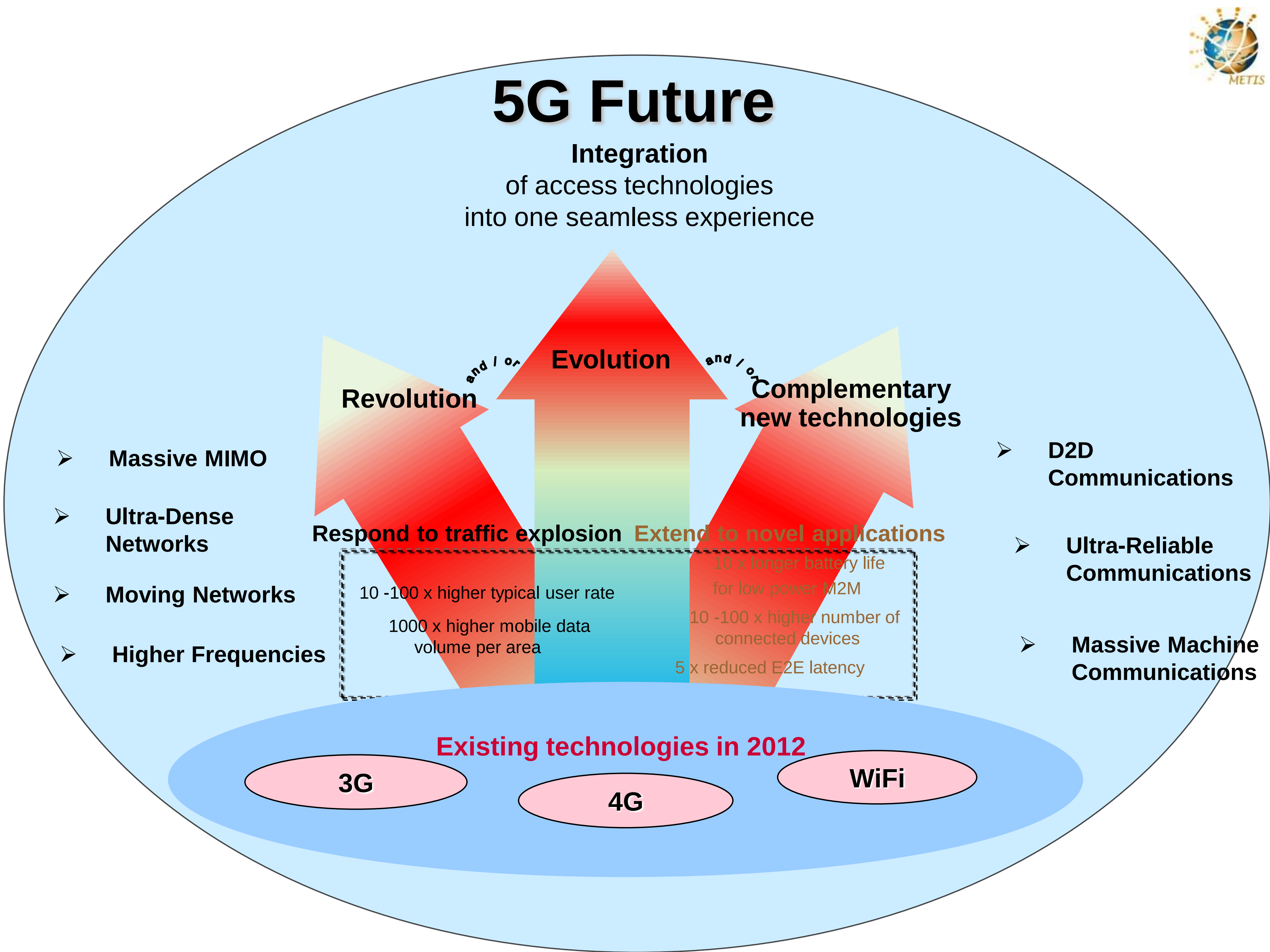


METIS

Fact Sheet

METIS **M**obile and wireless communications **E**nablers for **t**he 2020 **I**nformation **S**ociety

- An Integrated Project under EU Framework Programme 7 Call 8
- Budget: 27 M€
- Project Length: 30 months (from 2012-11-01 to 2015-04-30)
- Resource: ~ 80 persons working full time
- Contact & Information:
  www.metis2020.com
  facebook.com/metis2020
  twitter.com/metis2020


5G Future
Integration
of access technologies
into one seamless experience
Revolution
and / or
Evolution
and / or
Complementary new technologies
Massive MIMO
Ultra-Dense Networks
Moving Networks
Higher Frequencies
D2D Communications
Ultra-Reliable Communications
Massive Machine Communications
Respond to traffic explosion
Extend to novel applications
10 -100 x higher typical user rate
1000 x higher mobile data volume per area
10 x longer battery life for low power M2M
10 -100 x higher number of connected devices
5 x reduced E2E latency
Existing technologies in 2012
3G
4G
WiFi
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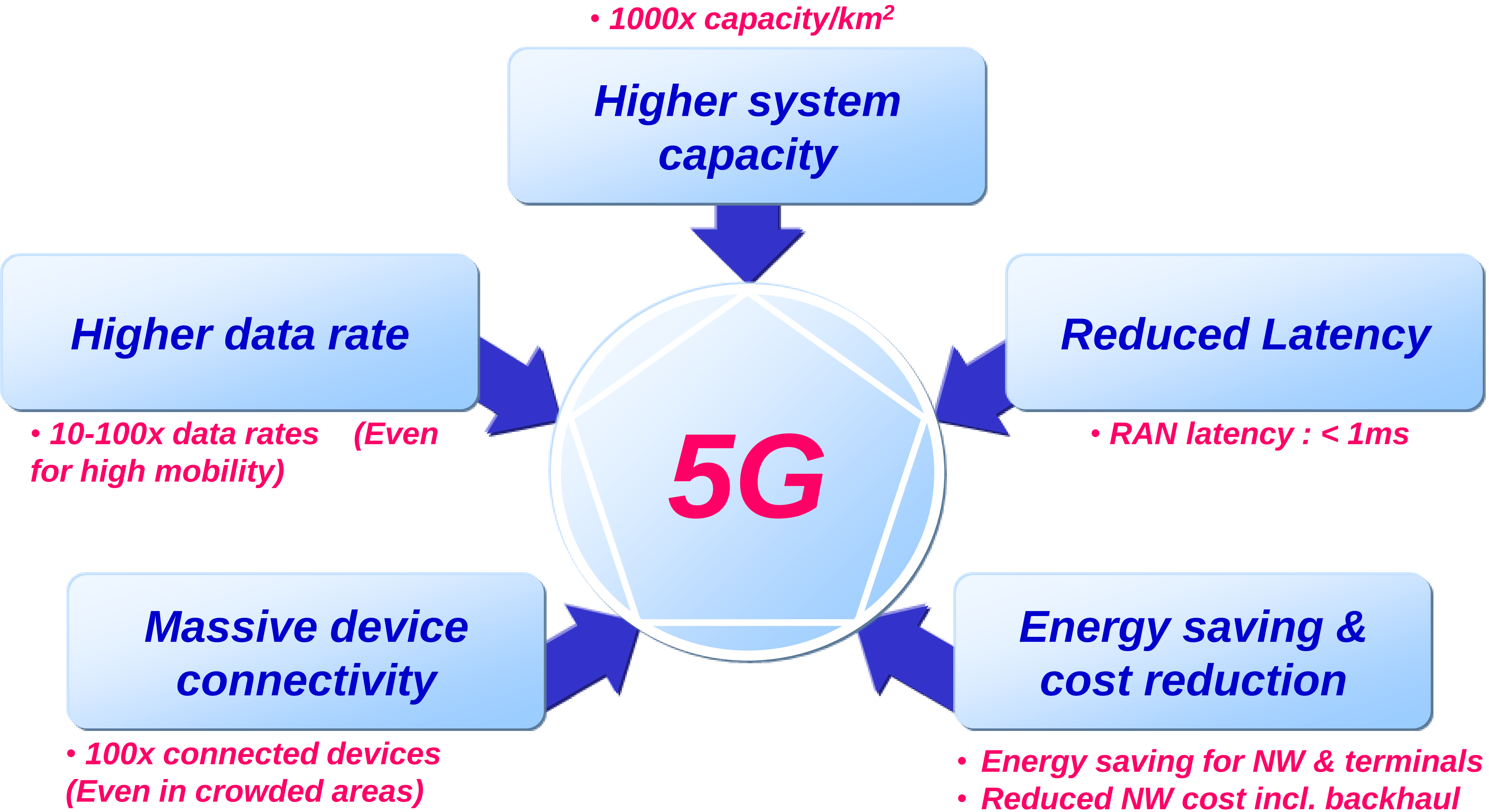
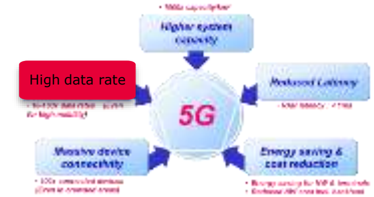
5G to provide a total solution to satisfy the wider range of requirements of the 5G era (2020s)

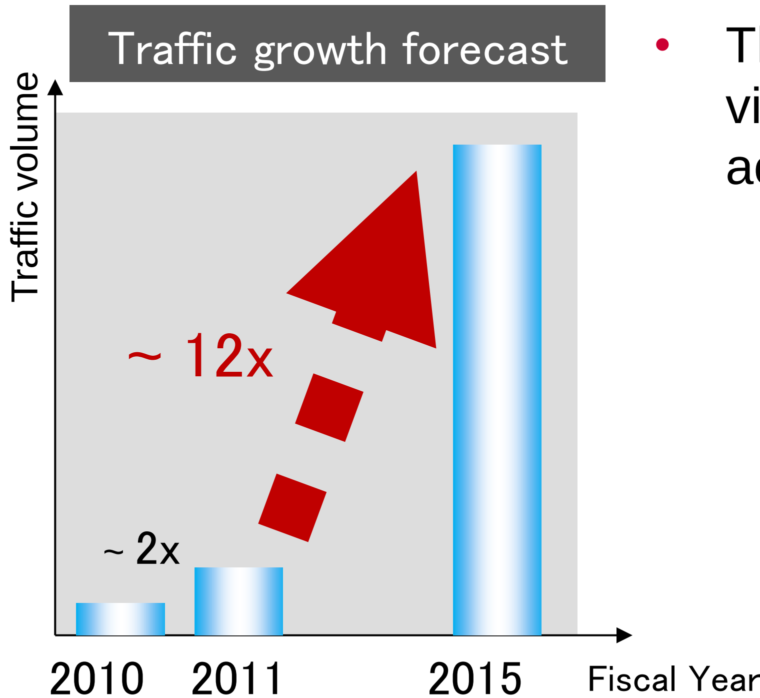


Support for Traffic Explosion



- **Higher system capacity:**
  - Report ITU-R M.2243 (IMT.UPDATE):

    15～30 times traffic growth is envisioned between 2010 and 2015
  - Mobile data traffic is continuously growing over DOCOMO network
    - Approx. 1.6 times per year (2004 – 2009)
    - **Approx. 2 times per year (2010 – 2011)**
    - **Approx. 12 times traffic growth is envisioned between 2011 and 2015**



- The main drivers are smartphones, video services and high-speed data access

Mobile data traffic is expected to grow beyond 1000x in 10 years (2010 – 2020)

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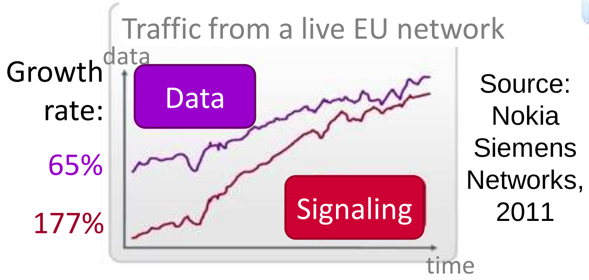
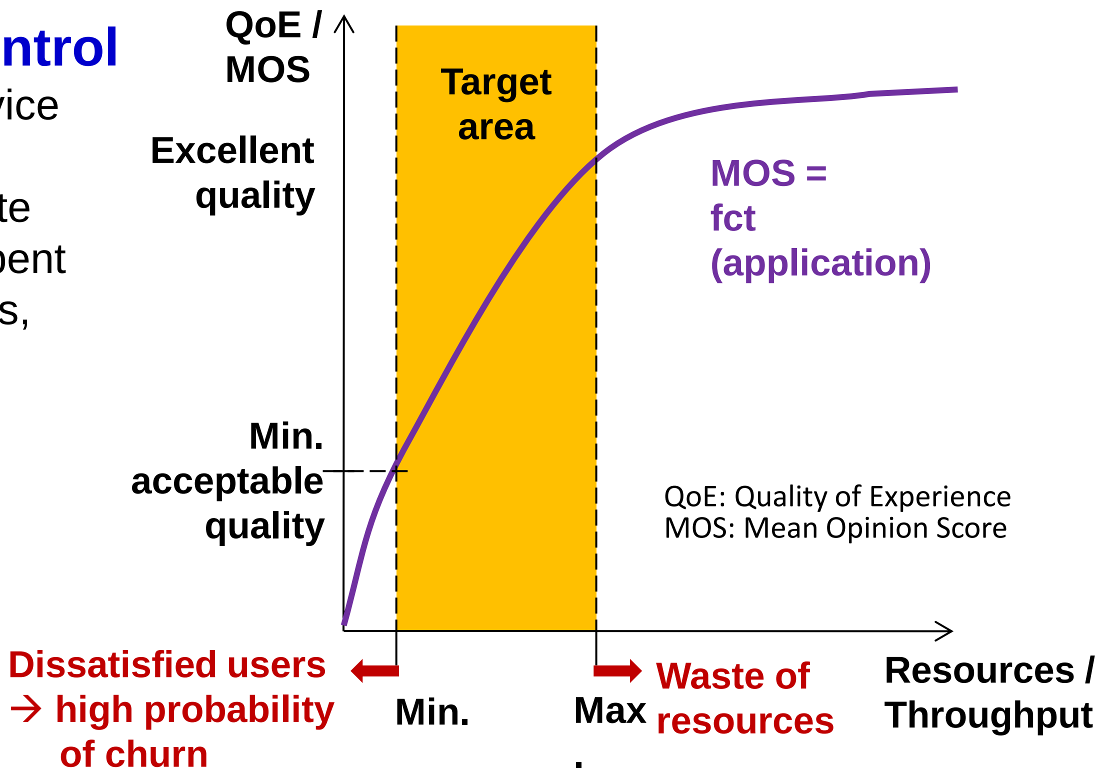
- **Efficient support for variety of traffic types**
  - Signaling traffic from smartphones
  - Low latency traffic for cloud applications
  - Large number of small data packets for M2M
  - etc.

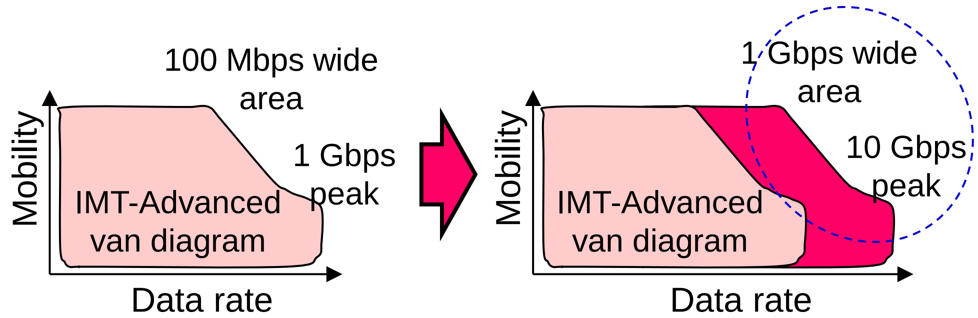


- **Application-aware traffic control**
  - Willingness to pay for better service quality (QoE) does not linearly increase with the offered data rate
  - optimize the balance between spent resources and charging and, thus, revenues



- **Higher data rate and user-experienced throughput**
  - Gbps-order experienced throughput
  - Low latency for improving user experience

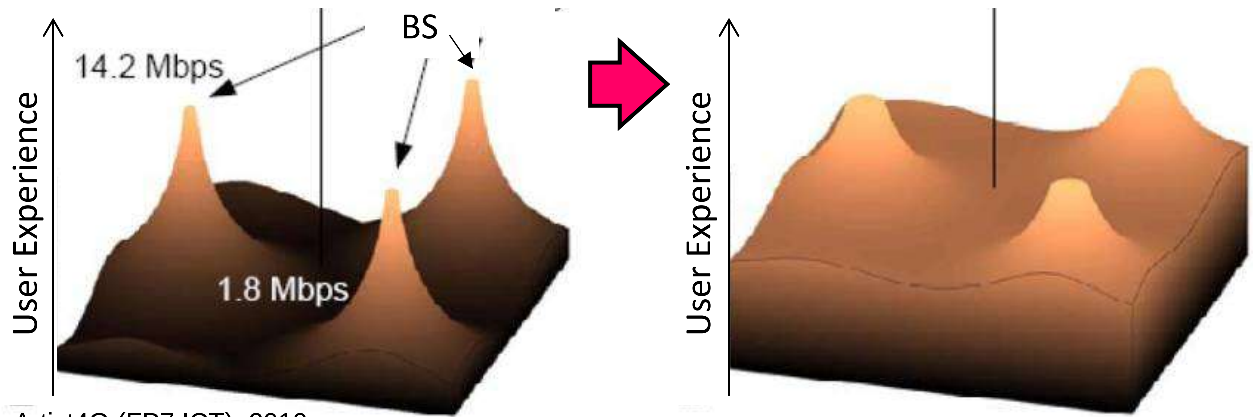
10x improvement in the next decade



- **Fairness of user throughput**
  - Improve cell-edge throughput
  - Lower system impact from few heavy users

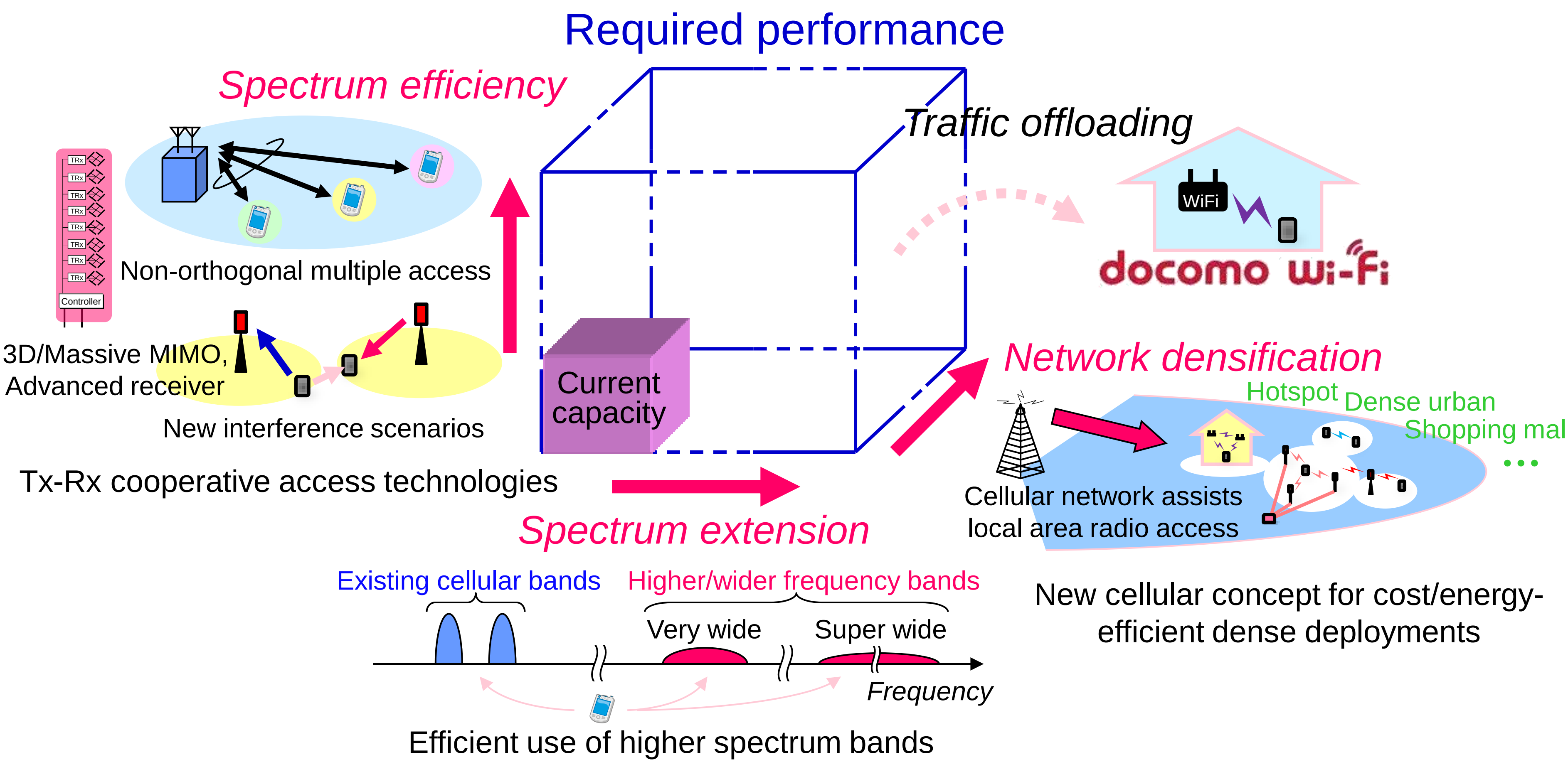
Cell edge users obtain only fraction of average throughput

Cell edge user experience strongly improved



Source: Artist4G (FP7 ICT), 2010

A set of radio access technologies is required to satisfy future requirements



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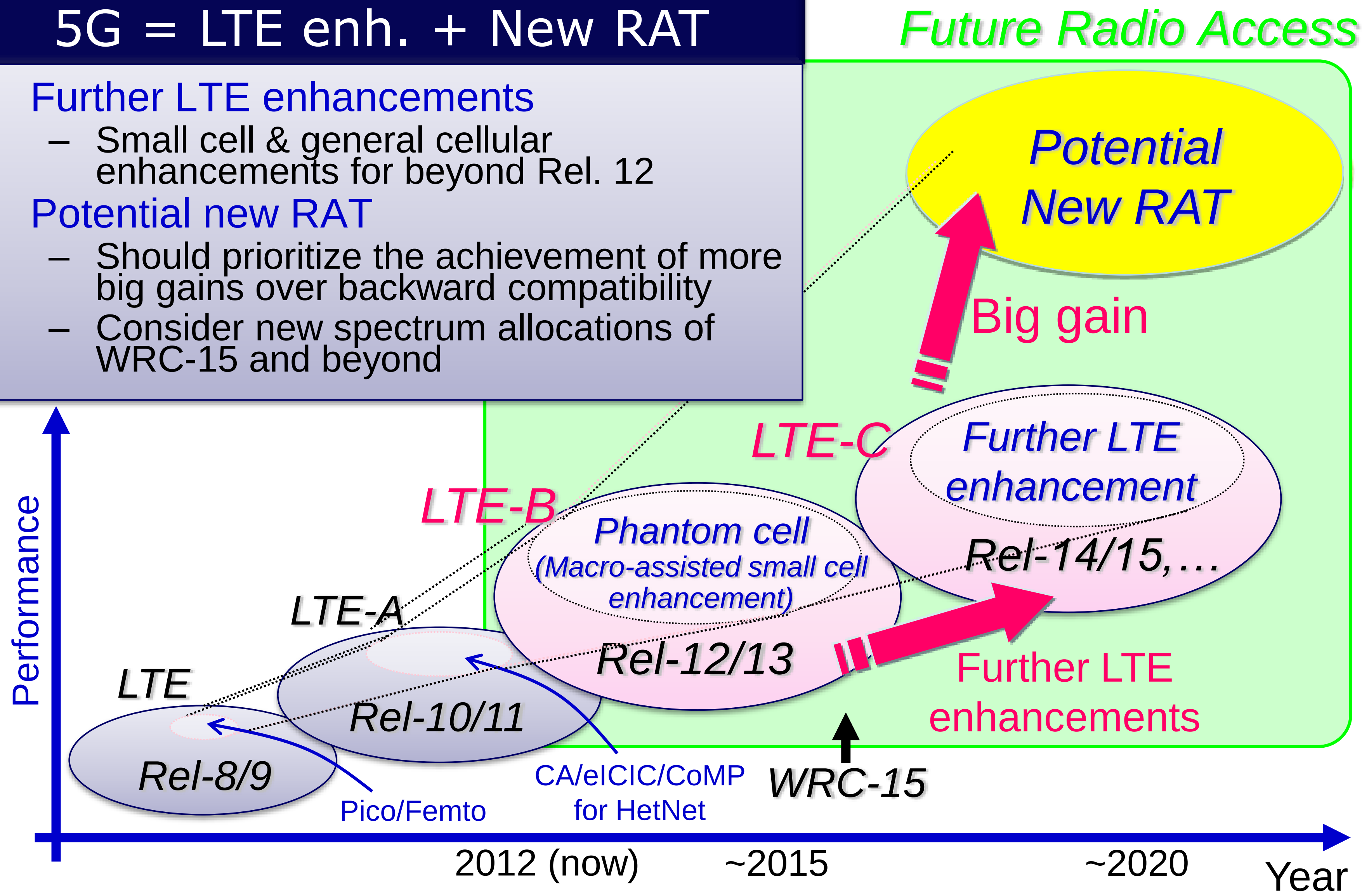
5G = LTE enh. + New RAT

- Further LTE enhancements
  - Small cell & general cellular enhancements for beyond Rel. 12
- Potential new RAT
  - Should prioritize the achievement of more big gains over backward compatibility
  - Consider new spectrum allocations of WRC-15 and beyond



Potential New RAT

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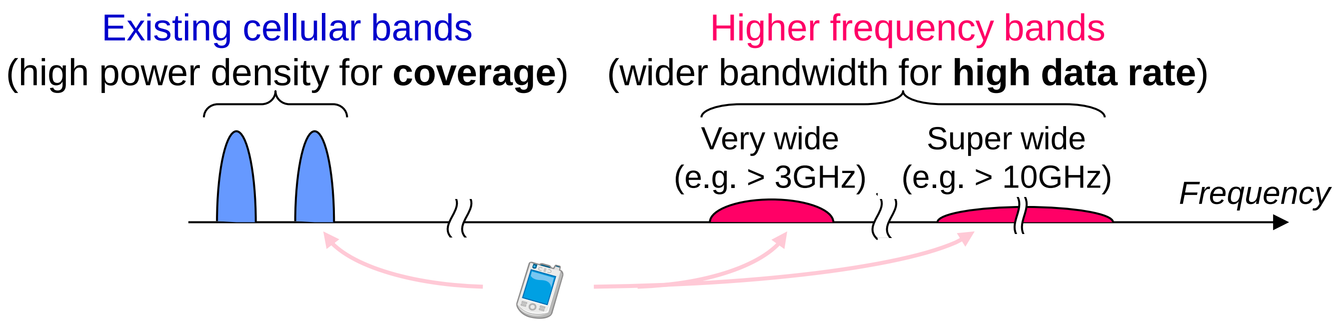
Video streaming

New types of terminal/HI

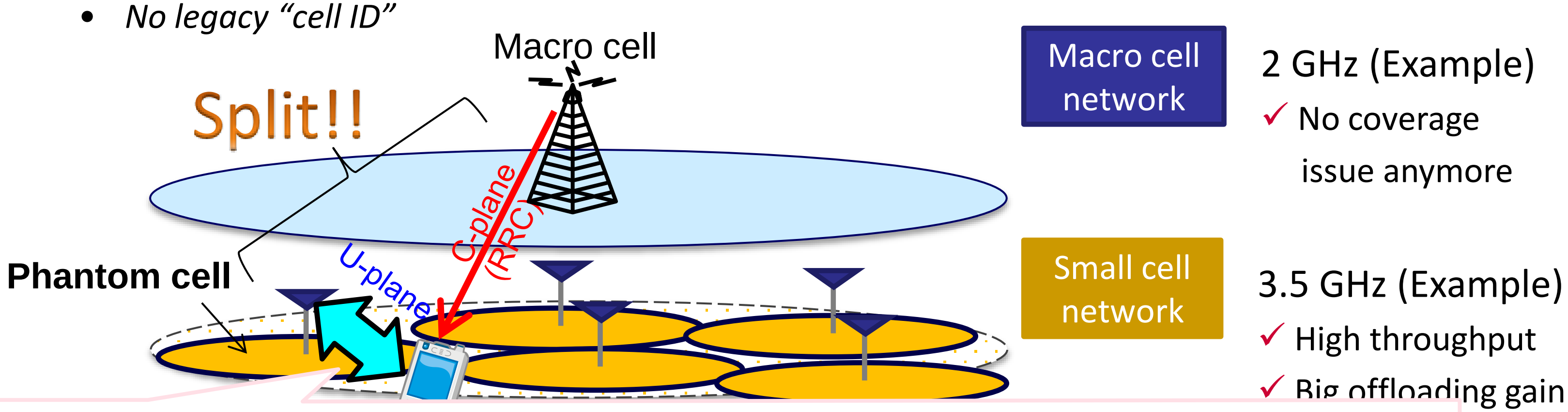
- Significant gains to justify the "5G"
  - Higher data rate (> 10Gbps) → Bandwidth ↗ (Nx100MHz ~ GHz)
  - Very low latency → Shorter TTI (~ 0.1ms order)
- Adaptation to higher frequency bands
  - Consider scalability of LTE numerology
    - Low complexity implementation for dual-mode terminals
    - Easy support of carrier aggregation between LTE and new RAT
  - Robustness against phase noise → e.g. wider subcarrier spacing
- Signal waveform candidates:
  - Multi-carrier (OFDM as baseline - high affinity with MIMO, or FBMC)
  - Single carrier (e.g. DFT-Spread OFDM – for coverage & high frequencies)

  → Waveform & bandwidth may depend on applied frequency bands
- Flexibility to support variable scenarios (D2D, wireless backhaul, multi-hop, etc.) → RAT design considering DL/UL symmetry
- Flexible Duplex (FleD) – Associated with carrier aggregation / dual connectivity functionality
  - Joint operation of FDD & TDD (or one-way link, i.e., DL/UL only)
  - Opportunistic carrier selection including unlicensed bands

- Proposed macro-assisted small cell – *"Phantom cell"*
  - Split of C-plane and U-plane between macro & small cells in different bands
    → Hybrid usage of lower & higher frequency bands (e.g. 2 GHz & 3.5 GHz)



  - Small cell with new carrier type (NCT) becomes *"Phantom cell"*
    - *No legacy "cell ID"*



New RAT will be required to exploit higher frequency bands for 5G (e.g. > 10GHz)

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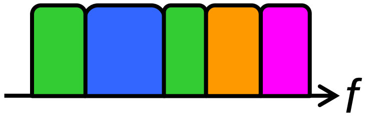
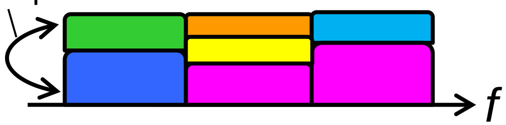
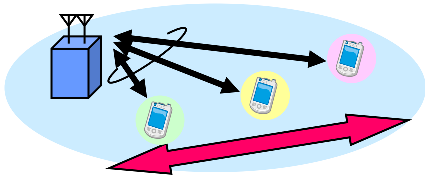
- More efficient multiple access scheme
  - **Non-Orthogonal Multiple Access (NOMA)**

	W-CDMA	LTE	FRA
Radio resource allocation	Non-orthogonal (CDMA)	Orthogonal (OFDMA)	Orthogonal (OFDMA) + Superposition/Cancellation (NOMA)
Link adaptation	Fast TPC (TPC: Transmission Power Control)	AMC (AMC: Adaptive Modulation & Coding)	MUPA/AMC (MUPA: Multi-User Power Allocation)
Multiple access image	Non-orthogonal assisted by power control 	Orthogonal between users 	Superposition & interference cancellation 

- **Why NOMA?** – Multiple access using interference cancellation itself is very old technology (for uplink in particular)
  - **Evolution of device processing capabilities for interference cancellation**
    - Moore's law: 100x processing power after 10 years
    - In OFDMA, frequency-domain signal processing becomes possible
  - **Exploitation of path loss difference among users**
    - Multi-path fading is exploited by OFDMA, but path loss still needs to be further exploited



NOMA utilizes path loss difference for efficient user multiplexing

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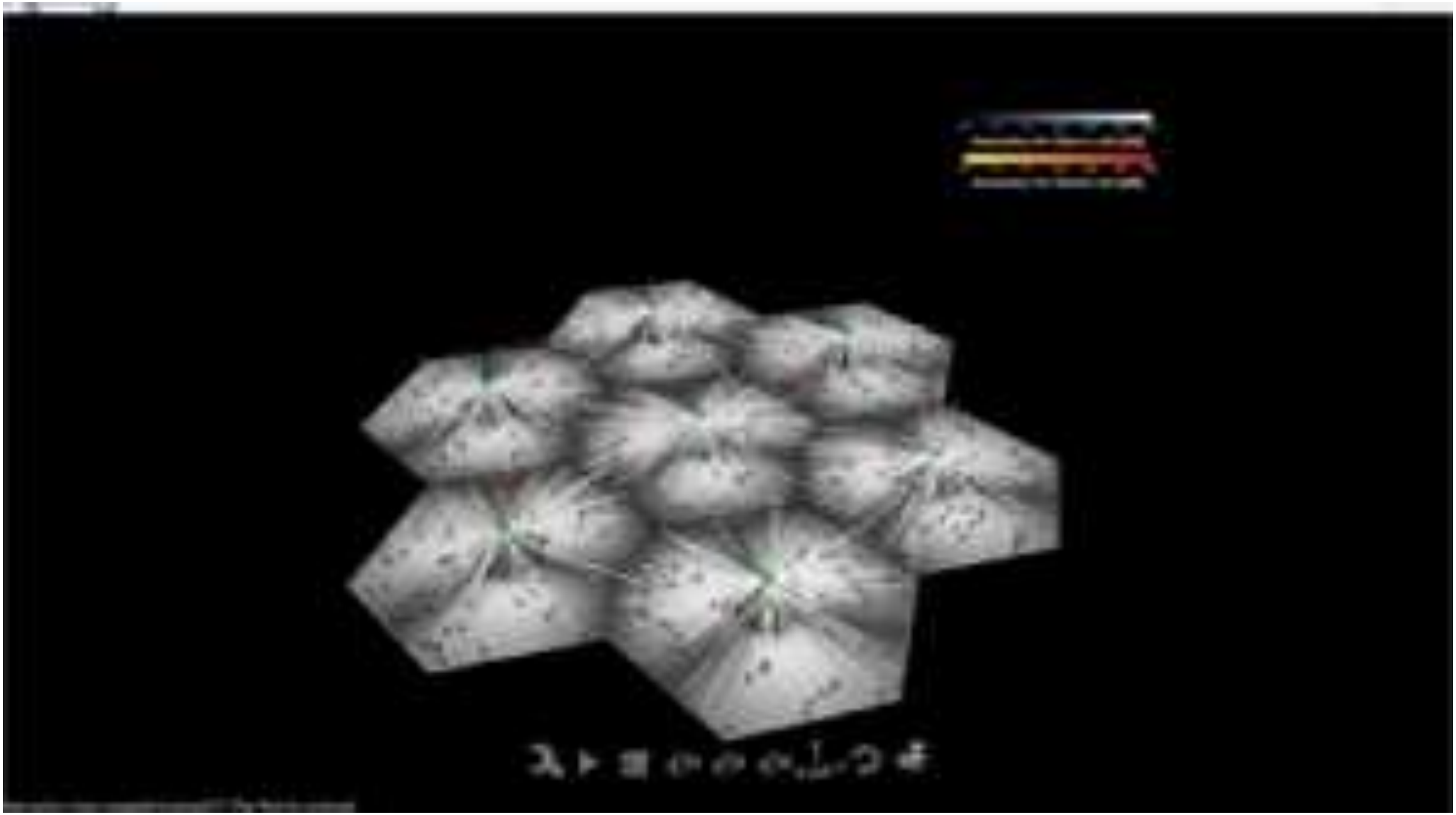
Future Radio Access (FRA)
Real-Time Simulator

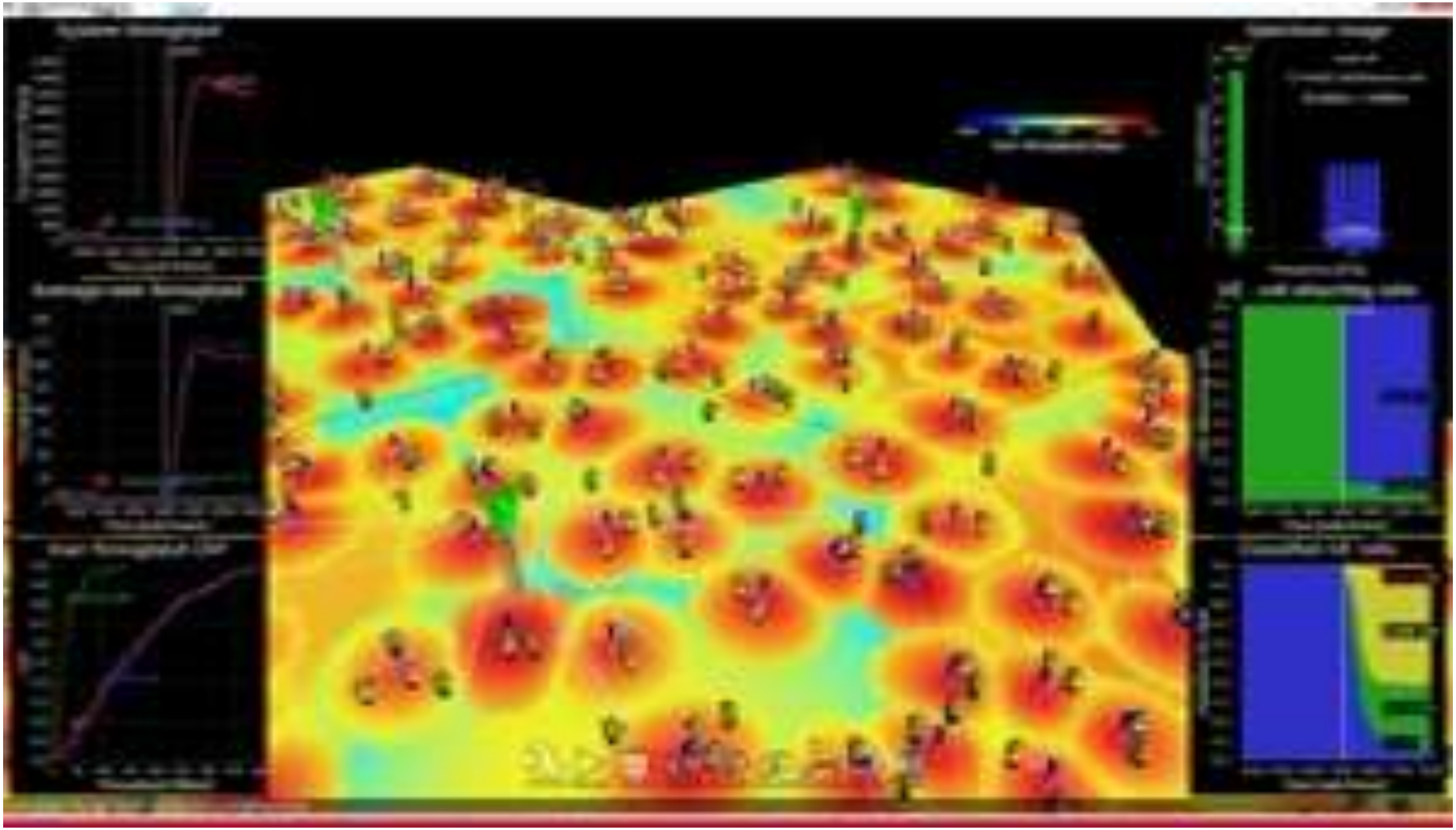
Configuration of Real-Time Simulator (Details)

	Macro cell	Small cell
Carrier frequency (System bandwidth)	**2GHz (20MHz)**	**f=3.5GHz (100MHz), 5GHz (200MHz), 10GHz (400MHz), 20GHz (600MHz)**
Cellular layout	**7 cell sites, 3 cells per site**	**12 small cells per cell**
Distance-dependent path loss	**$128.1 + 37.6\log_{10}(R)$ dB** ***R* in km**	**$36.7\log_{10}(d) + 22.7 + 26\log_{10}(f)$** **[UMi] (ITU-R M. 2135, p.31)** ***d* in m, f in GHz (e.g., f = 3.5)**
Shadowing standard deviation	**8 dB**	**10 dB**
Shadowing correlation	**0.5 (between cell sites), 1 (between cells)**	**0.5**
Correlation distance of Shadowing	**50 m**	
Penetration loss	**20 dB**	
Moving speed	**3 km/h**	
Antenna pattern	**See Table 2.1.1-2 [TR 36.814]**	**$A(\theta)$ = 0 dB (horizontal)**
Total BS TX power (Ptotal)	**46 dBm**	**30 dBm (constant)**
Antenna configuration	**2 x 4 MIMO**	**4 x 4 MIMO**
Antenna gain	**14 dBi**	**5 dBi**
Receiver type	**MMSE**	
Traffic model	**Full buffer**	**Bursty traffic**
Scheduling algorithm	**Proportional fairness**	
HARQ	**Chase combining**	

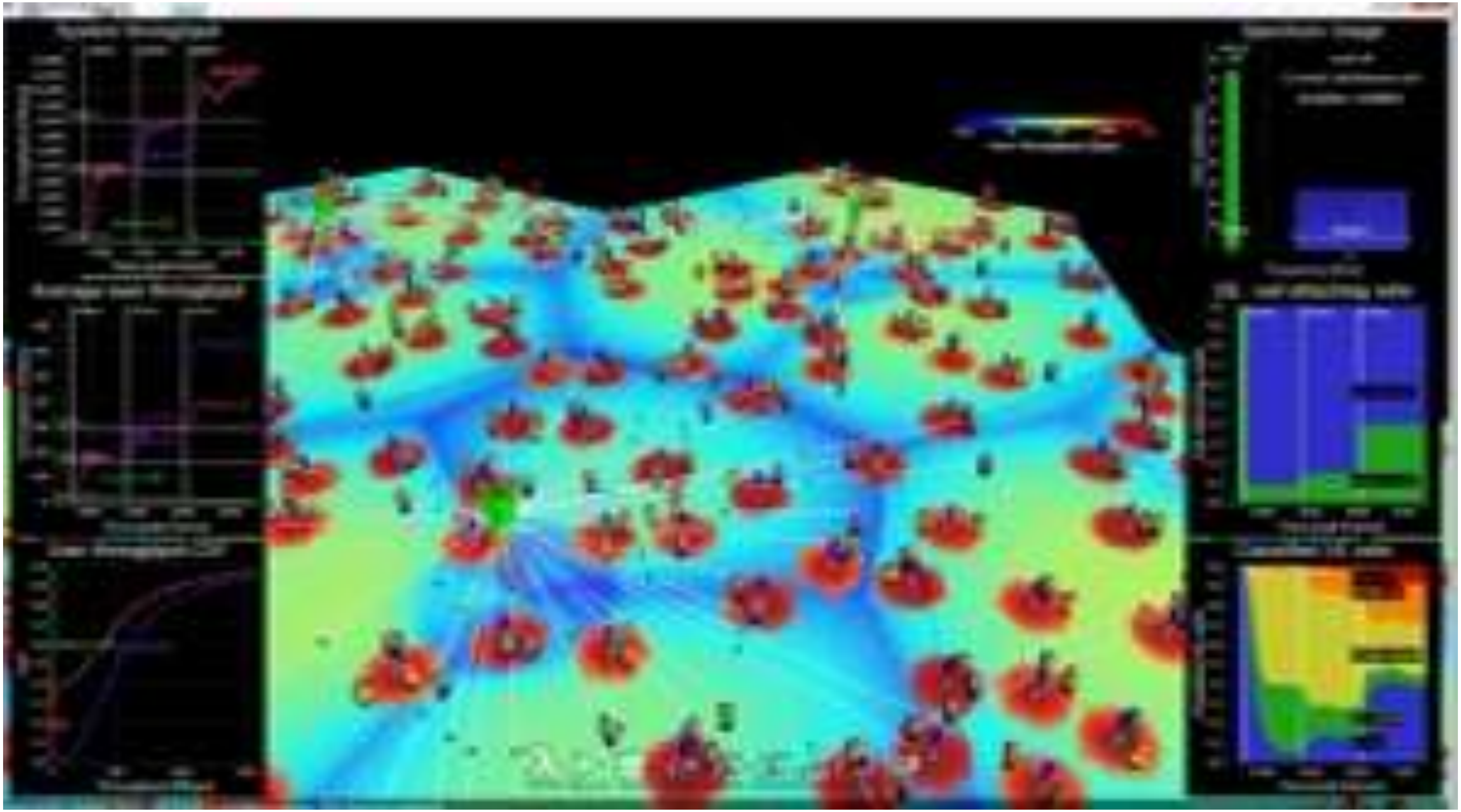
Macro Cell Only → Macro + 12 small Cells, 100 MHz BW@3.5 GHz



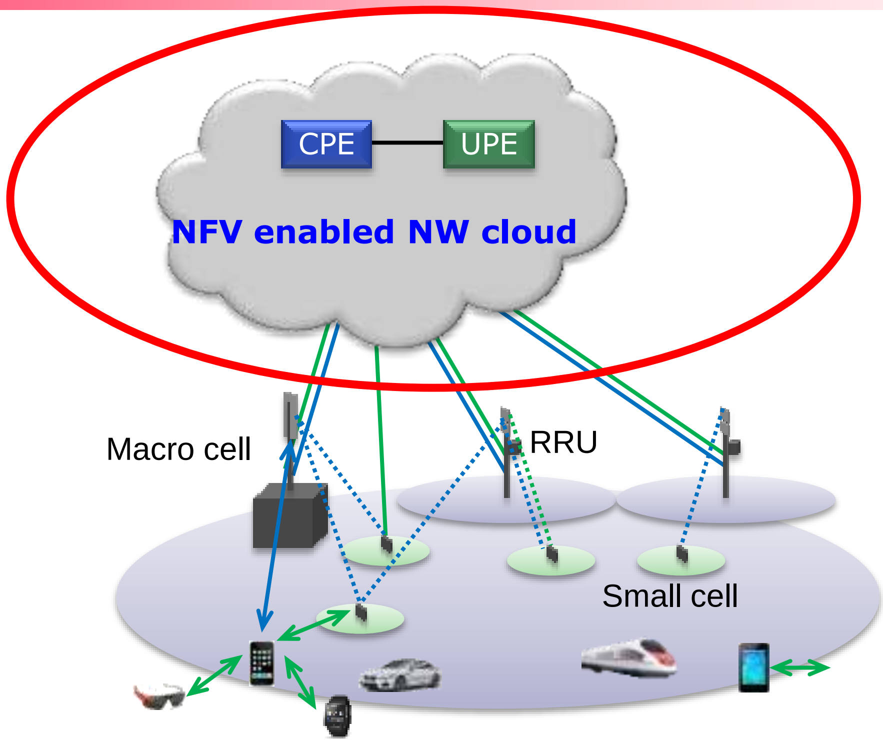
100 MHz BW@3.5 GHz → 200 MHz BW@5GHz → 400 MHz BW@10 GHz



400 MHz BW@10 GHz → 600 MHz BW@20 GHz → With Massive MIMO

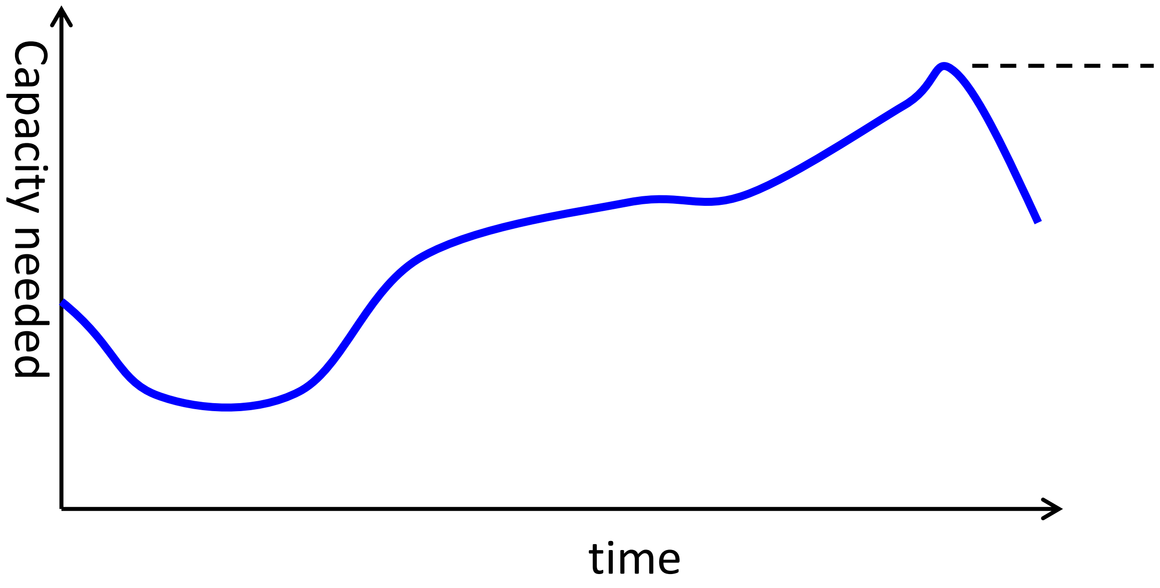


Core Network Evolution



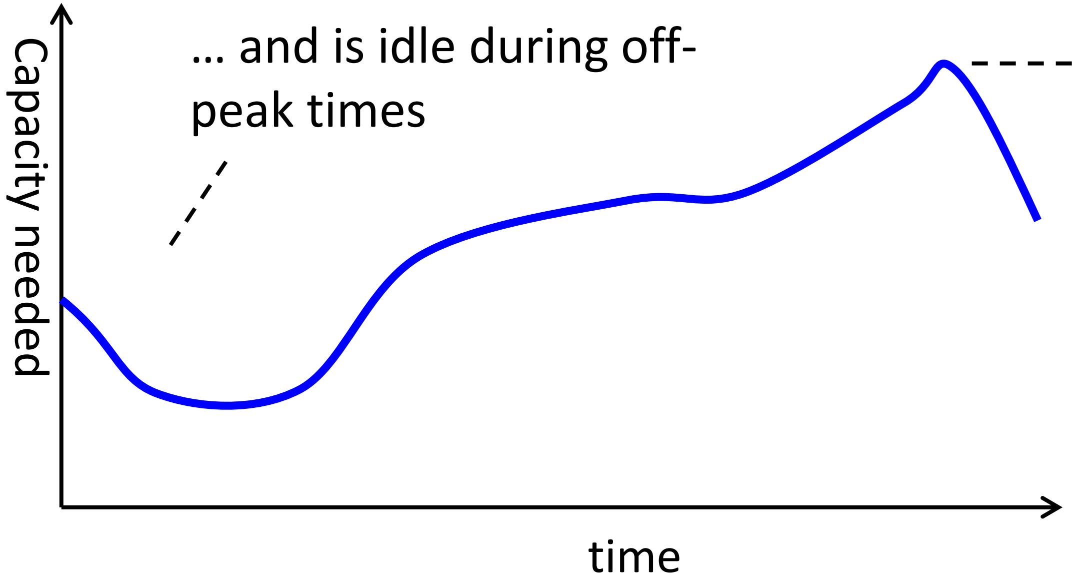
Technical realization of core network today:

- Hard- and software combined in a device
- Many different **physical devices**



The core network must support the peak load …

Capacity not needed in off-peak times



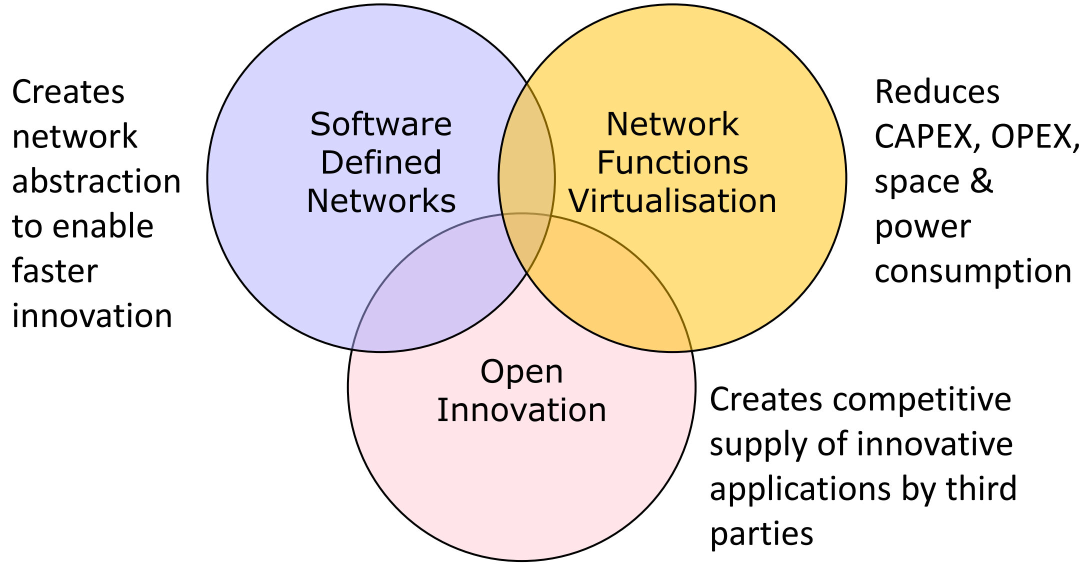
... and is idle during off-peak times

The core network must support the peak load ...

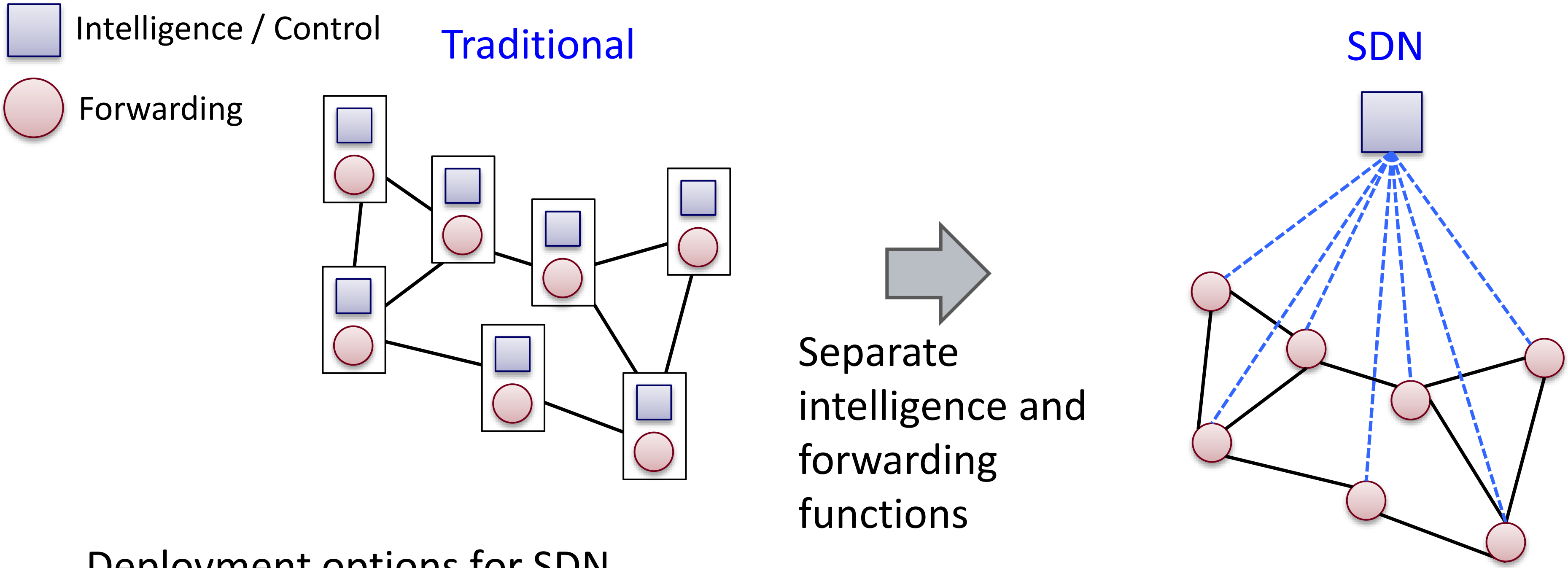
SDN & NFV as enablers for a flexible and cost efficient 5G architecture

- Network Function Virtualization (NFV) is complementary to Software Defined Networking (SDN)
- SDN: Abstraction and programmability of virtualized transport
- NFV: Realization of network functions on commodity IT servers by means of virtualization and cloud technologies

- What can SDN and NFV provide to fulfill future requirements of a 5G architecture?
  - Open interfaces → To help integrate different components holistically
  - HW independency →Possible due to decoupling of SW and HW
- Pre-standardization by ETSI NFV



NFV relationship with SDN [ETSI NFV White Paper]



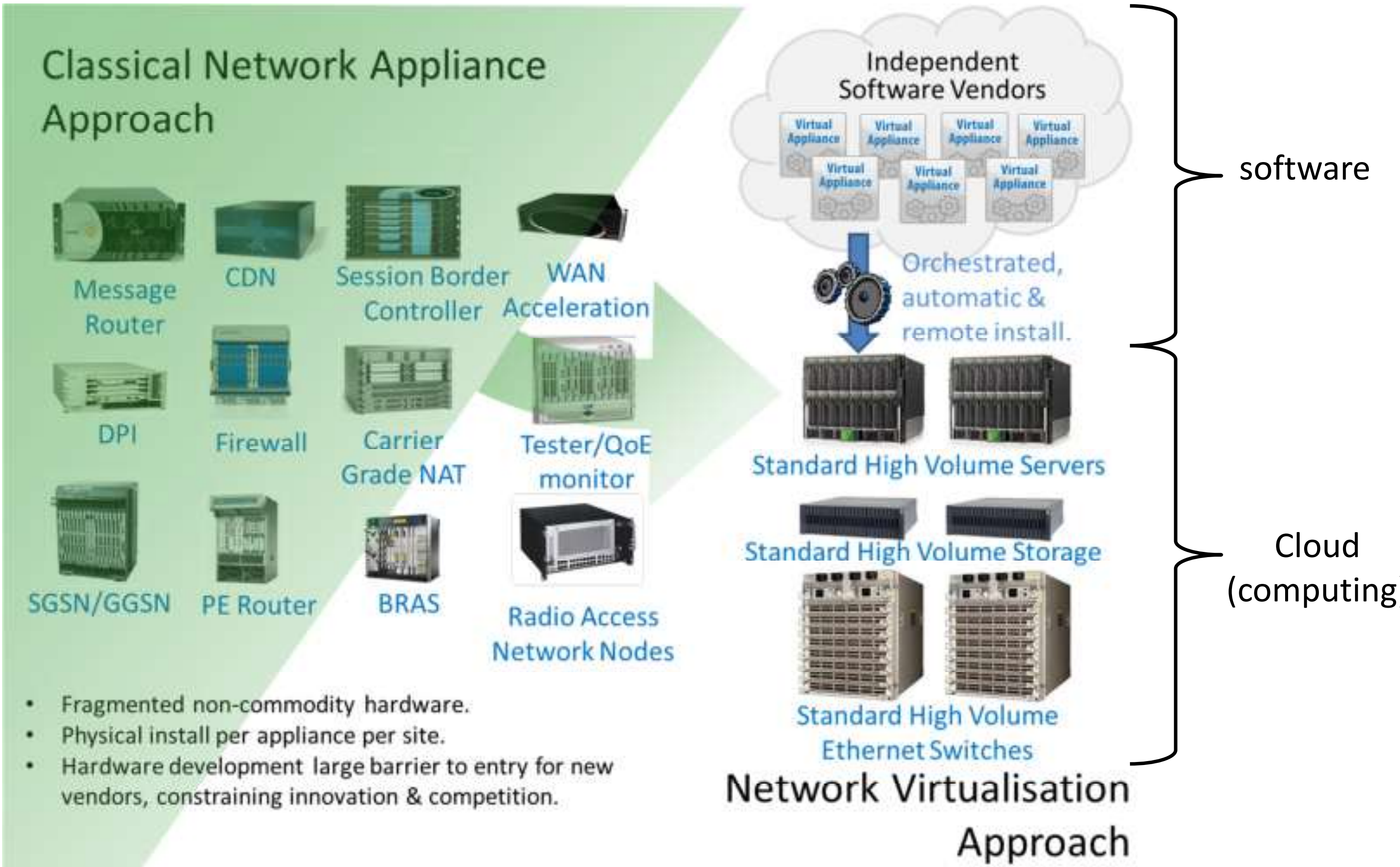
Deployment options for SDN

1. For intra- and inter-datacenter communication[1]
2. To implement mobile network gateways themselves[2]

[1] S. Jain et. al, "Experience with a globally-deployed software defined WAN", SIGCOMM 2013;

[2] G. Hampel et. Al, "Applying Software-Defined Networking to the Telecom Domain", IEEE Global Internet Symposium 2013

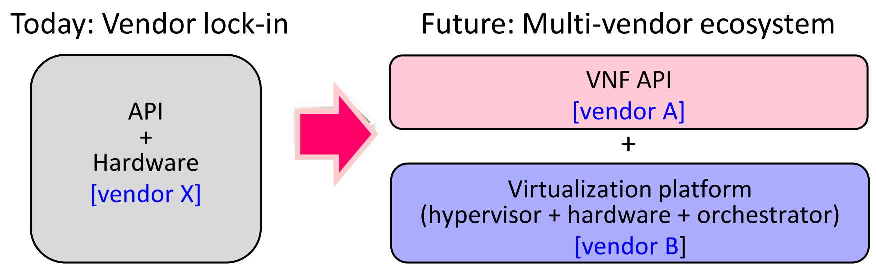
Network Function Virtualization (NFV) – Idea



(from white paper "Network Functions Virtualisation An Introduction, Benefits, Enablers, Challenges & Call for Action")

Benefits

- **CAPEX reduction**
  - Use of high volume industry standard hardware (e.g. x86-based servers)
  - Open interface for holistic integration of components & applications
  - Multi-vendor ecosystem for HW, platform and telco applications (avoiding vendor lock-in)



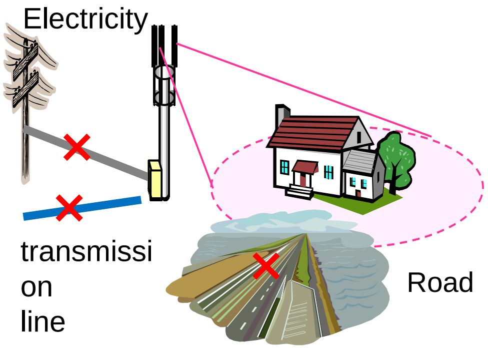
  - Multiplexing gain: Optimization of resource sharing between different services
- **OPEX reduction**
  - Quick & easy deployment of new services
  - Dynamic and flexible resource allocation (scale-in / scale-out)
  - Energy efficient operation (shut-down of unused resources)
- **Resiliency**
  - Fault tolerance - resource usage by different geographical areas
  - Auto-healing

A large disaster like the Great East Japan Earthquake damages mobile networks in a variety of ways.

Damage on Facilities

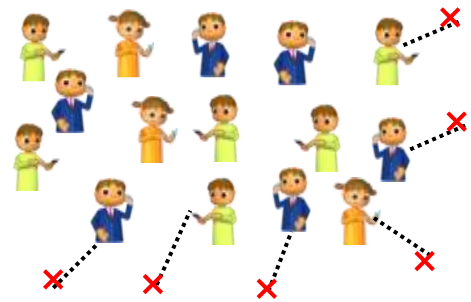
Physical damage on facilities disrupt services.
Facilities include:
- Mobile base stations
- Equipment
  (e.g. P-/S-GW)
- Building Structure

Infrastructure Outages



Mobile networks depend on social infrastructure such as
- Electricity
- Transmission lines
- Transport (Road, Bridges etc.)

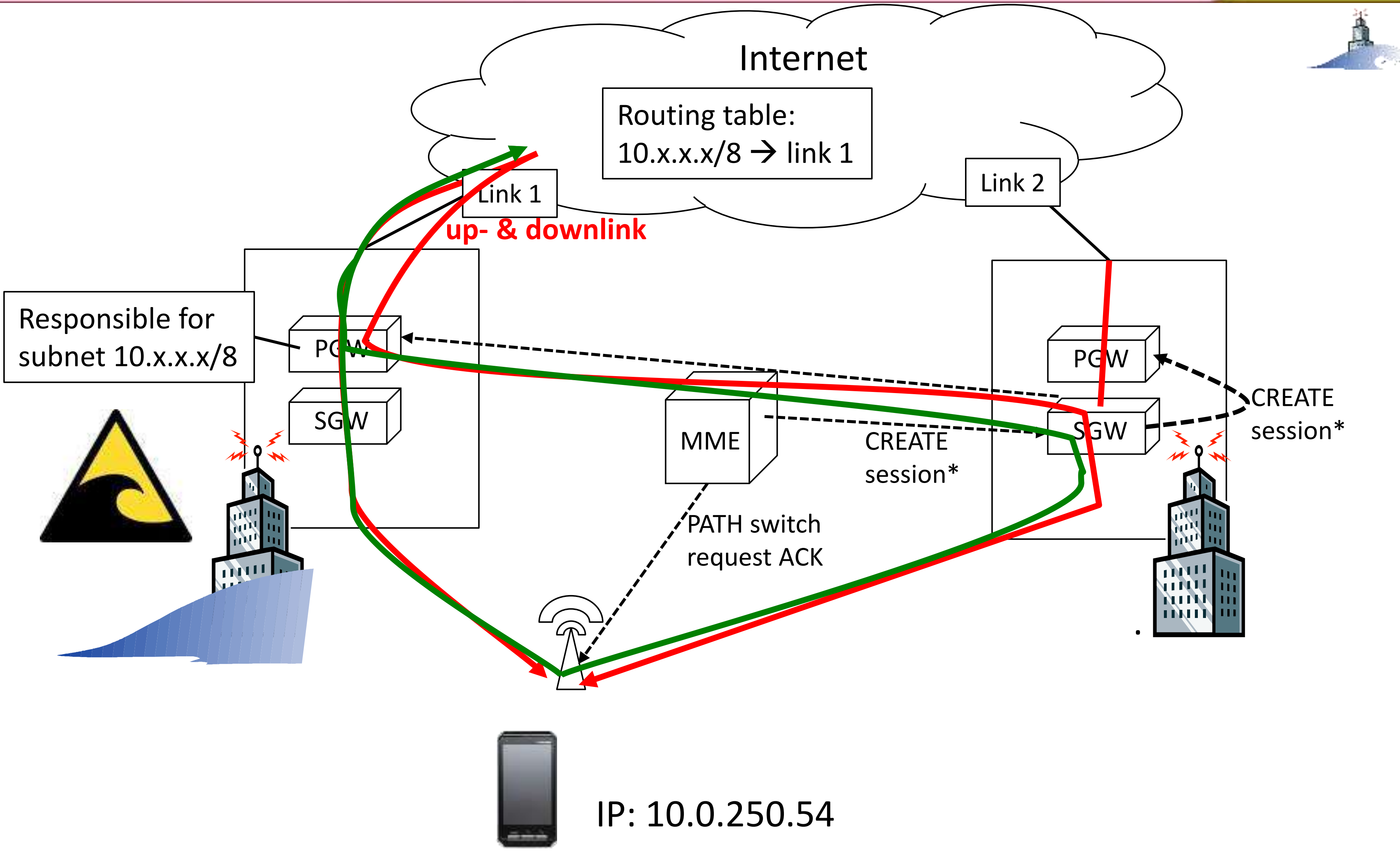
Massive Congestion



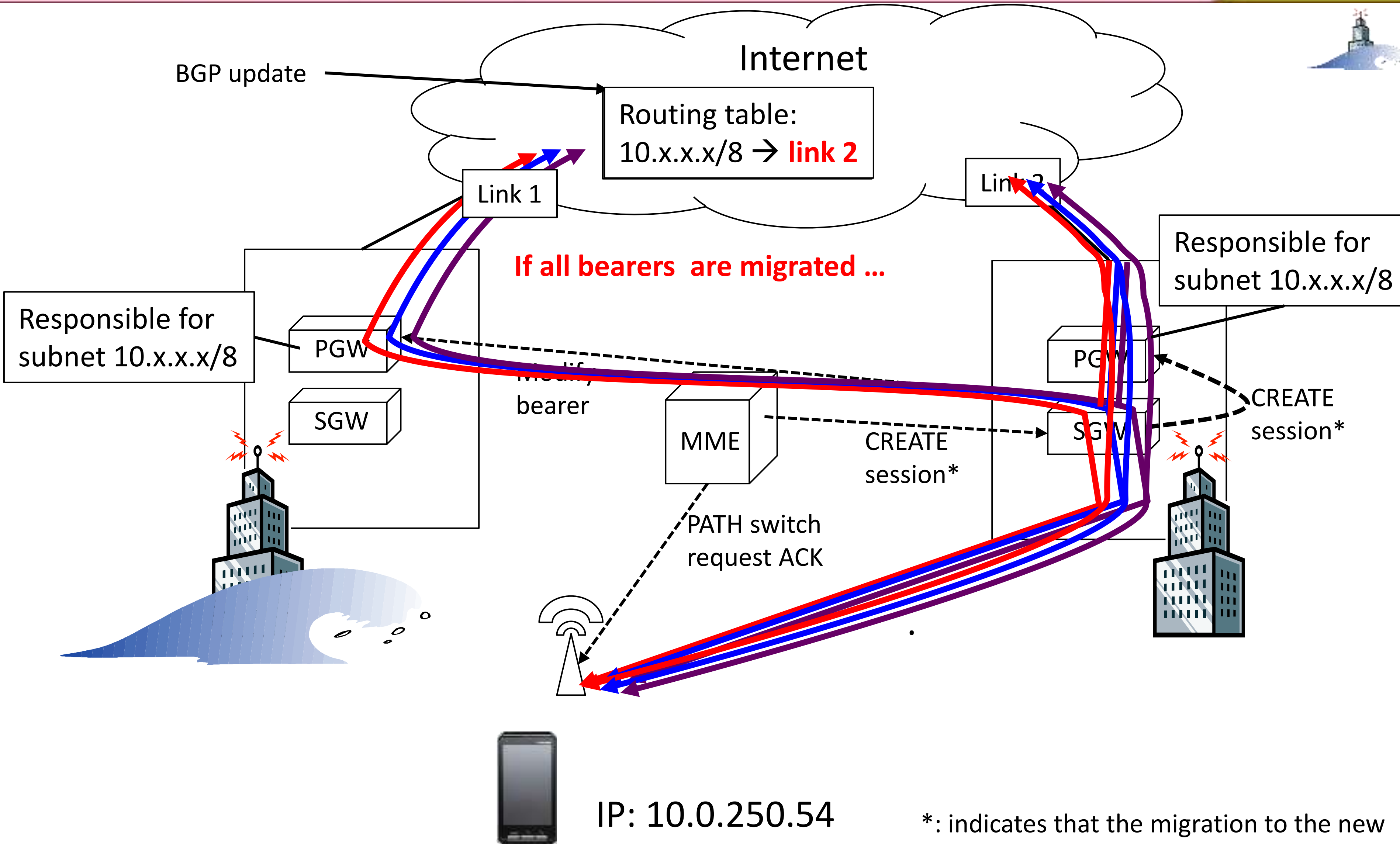
Massive number of call attempts to confirm safety of relatives and friends.

The wider the affected area is, the severer the congestion becomes

NFV case study – Recover from damage on facilities (1/2)



NFV case study – Recover from damage on facilities (2/2)



*: indicates that the migration to the new PGW should be prepared

NFV case study – Congestion caused by call attempts

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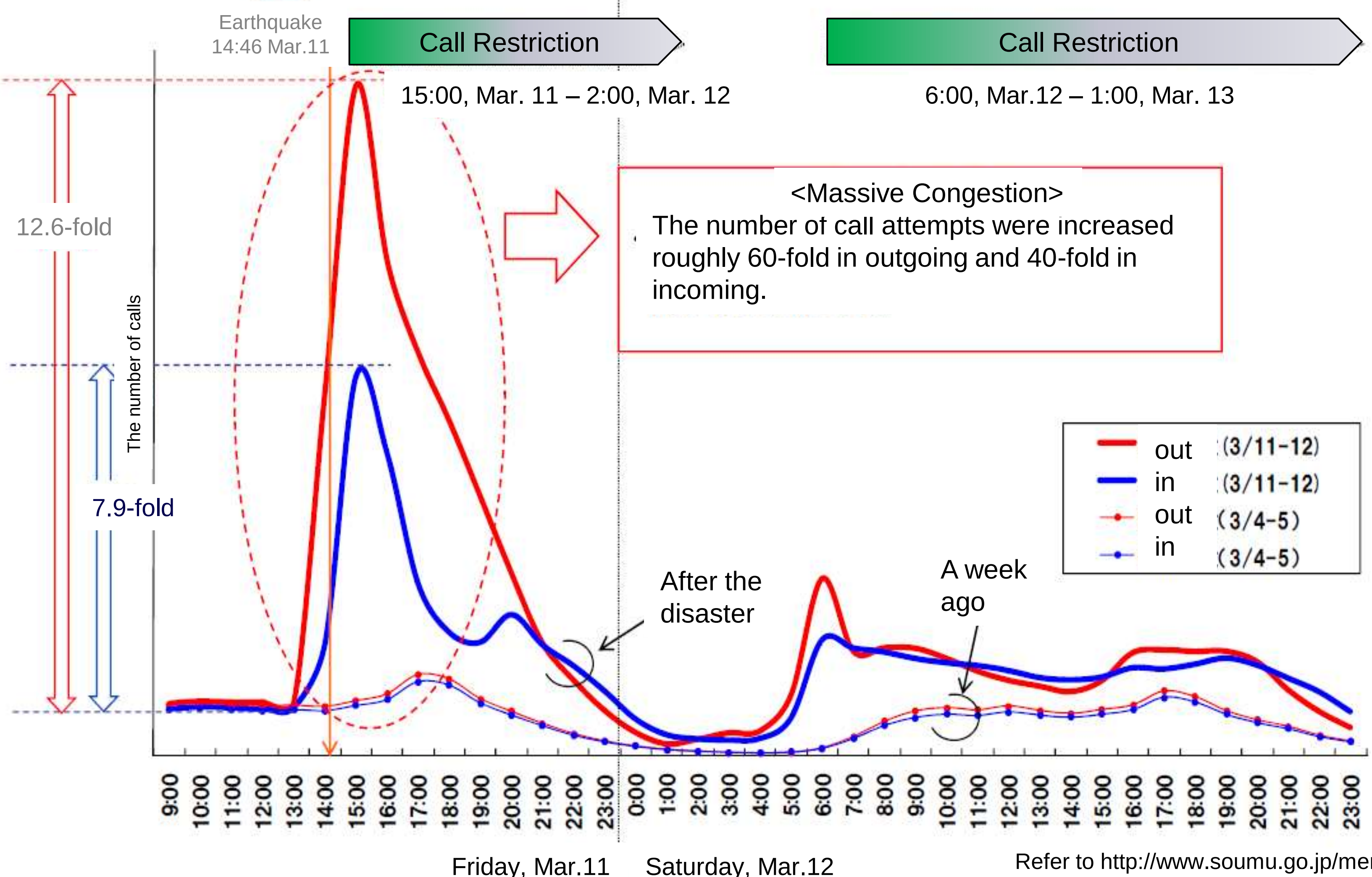
Massive number of call attempts (**roughly 60-fold increase**) were made.
Call restriction control were in place.



Refer to http://www.soumu.go.jp/menu_news/s-news/01kiban02_02000043.html

NFV case study – Approach to Flexible Mobile Networks

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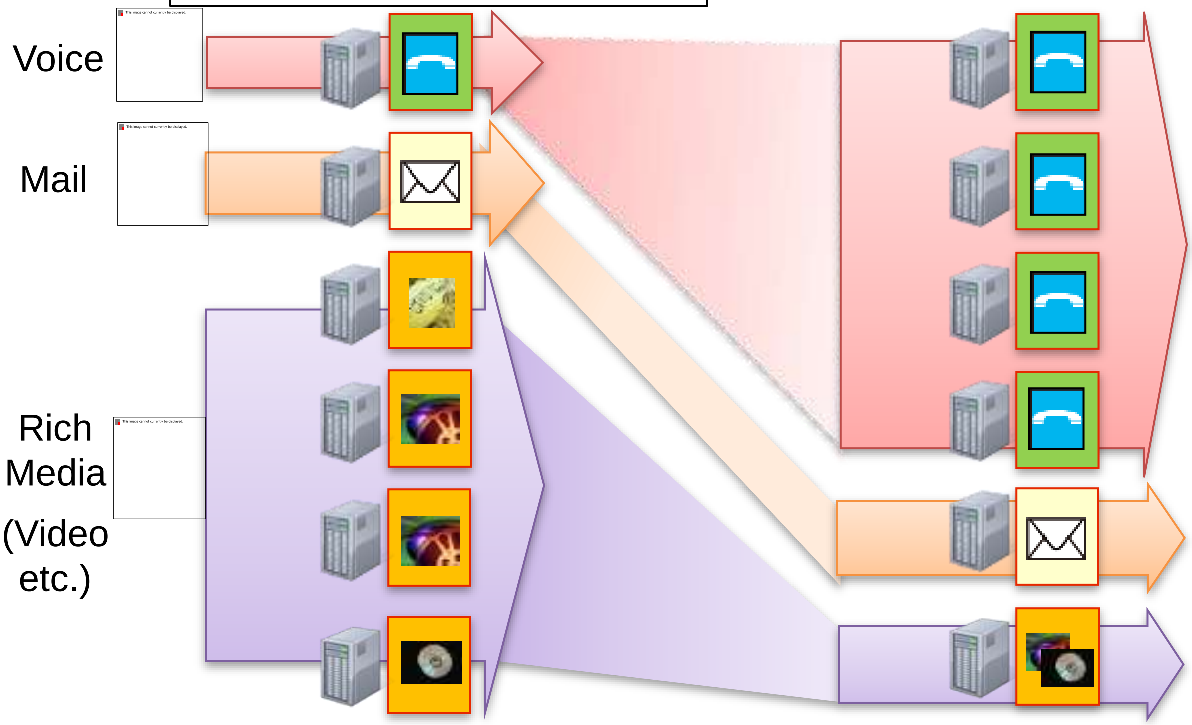
Normal	At disaster
More Internet access (Rich media Contents) than voice calls	More voice calls etc. to confirm safety of relatives and friends



How to develop flexible call/service control systems?

System for voice
I M S (IP Multimedia Systems)

System for Rich media
E P C (Evolved Packet Core)

QoE - Provide high quality service at reasonable price

Prepare to support all the necessary communications

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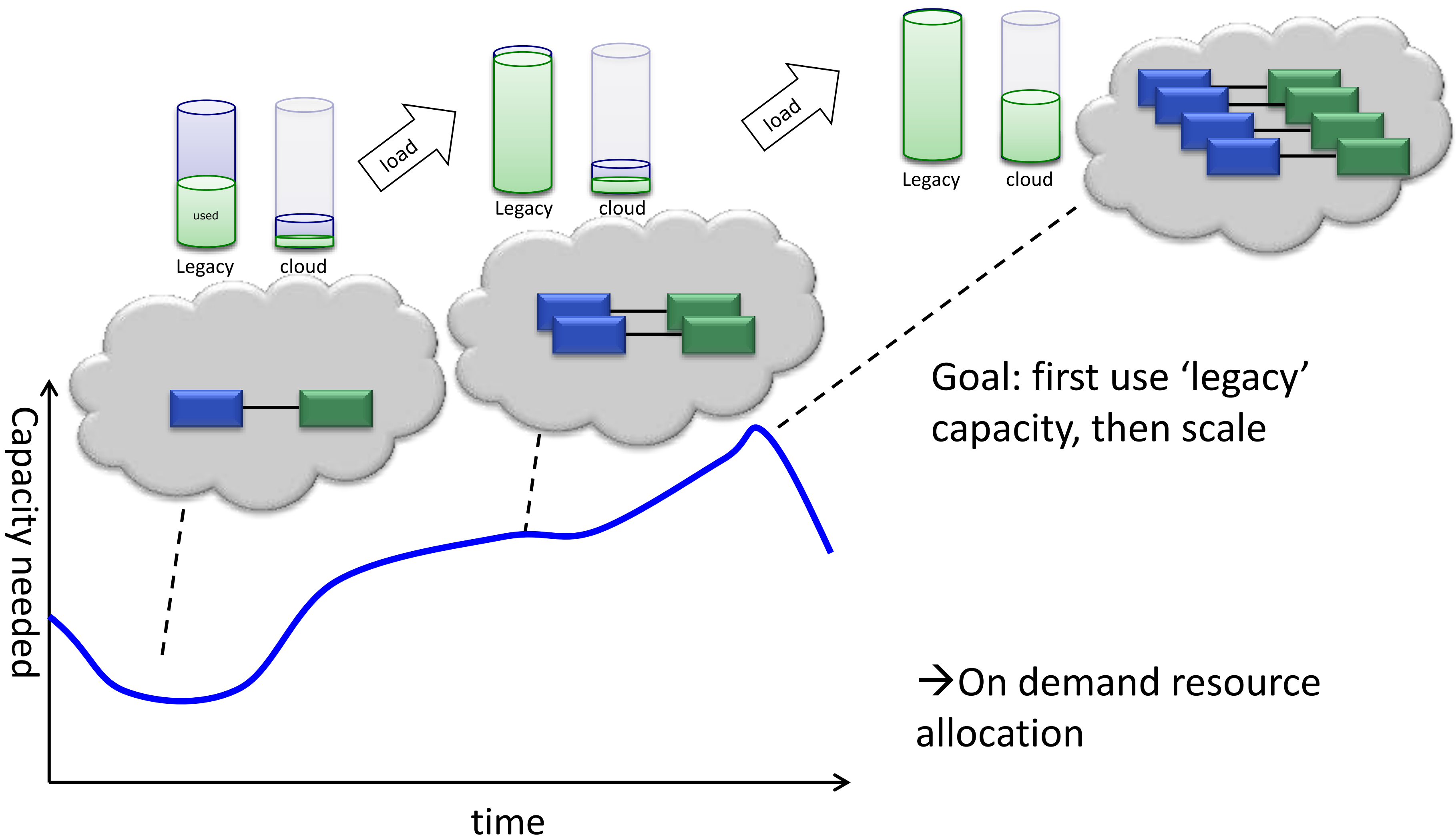
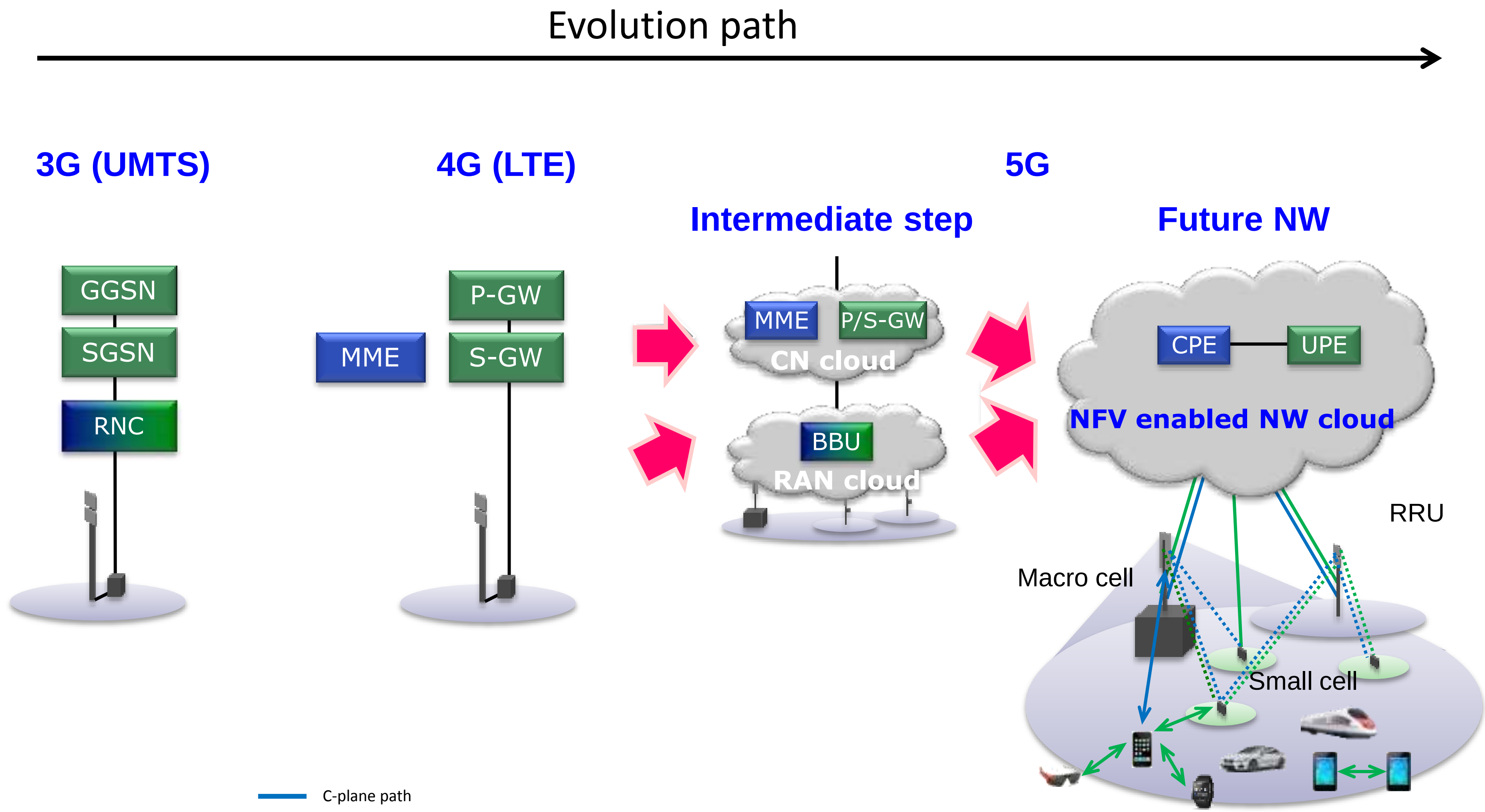


Goal: first use 'legacy' capacity, then scale

→On demand resource allocation

Mobile network architecture: evolution path



CPE	C-plane entity
UPE	U-plane entity

- C-plane path
- U-plane path
- Radio access link
- Backhaul (fiber, copper, cable)
- Wireless backhaul

BBU	Baseband unit
CN	Core network
OTT	Over-the-top player
RAN	Radio access network
RRU	Remote radio unit

Ultimate goal: all mobile network functions as software in the cloud