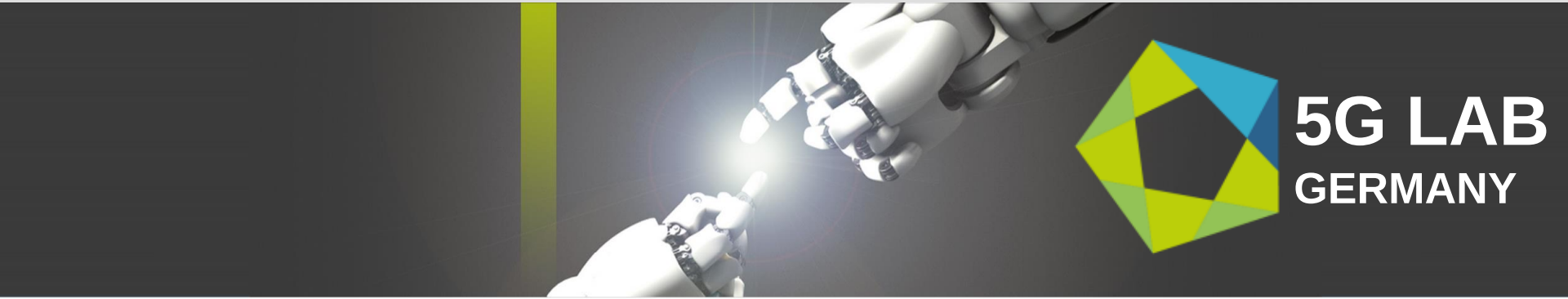


5G Tactile Internet: Application, Challenges and First Solutions

Prof. Dr.-Ing. Dr. h.c. Gerhard Fettweis
Prof. Dr.-Ing. Dr. h.c. Frank H.P. Fitzek

vodafone
ROHDE&SCHWARZ
CLAAS
NATIONAL INSTRUMENTS
NOKIA
NEC
LIEBHERR
ERICSSON
Hewlett Packard Enterprise
BOSCH
IDT
Telemotive AG
a company of Magna
BMW
GLOBALFOUNDRIES
VOLKSWAGEN
AKTIENGESELLSCHAFT
Racyics
accenture
High performance. Delivered.


Holistic
IEEE 5G Summit Dresden


Holistic View on 5G
IEEE 5G Summit Dresden

5G Lab Germany Members

5G LAB GERMANY

SILICON SYSTEMS & WIRELESS


Frank Ellinger


Gerhard Fettweis


Karlheinz Bock


Dirk Plettemeier


Christian Mayr


Michael Schröter


Kambiz Jamshidi

NETWORK & CLOUD


Frank Fitzek


Diana Göringer


Wolfgang Nagel


Hermann Härtig


Thorsten Strufe


Christel Baier


Christof Fetzer


Eduard Jorswieck

TACTILE INTERNET APPLICATIONS


Uwe Aßmann


Ercan Altinsoy


Thomas Herlitzius


Jens Krzywinski


Klaus Janschek


Leon Urbas

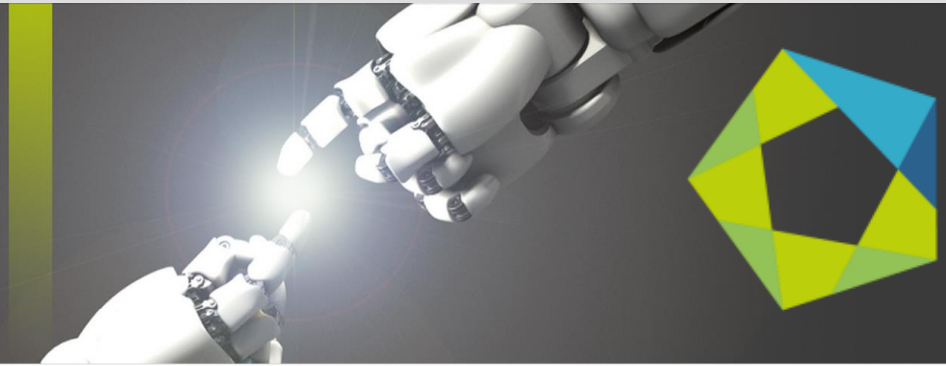

Jürgen Weber


Peter Birkholz

[Team of 600+ Researchers]

TECHNISCHE UNIVERSITÄT DRESDEN

Holistic 5G



5G LAB GERMANY

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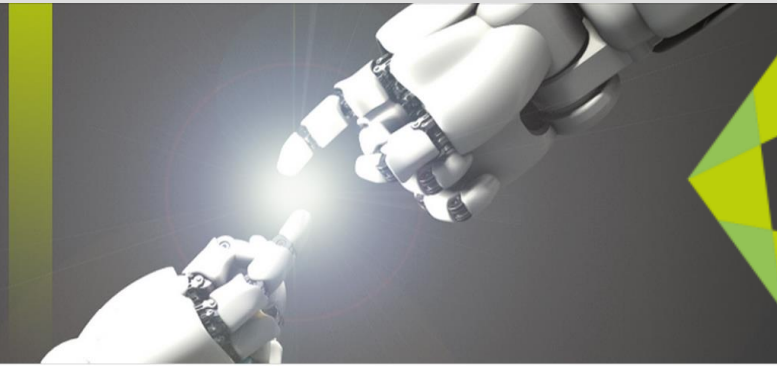
Holistic 5G



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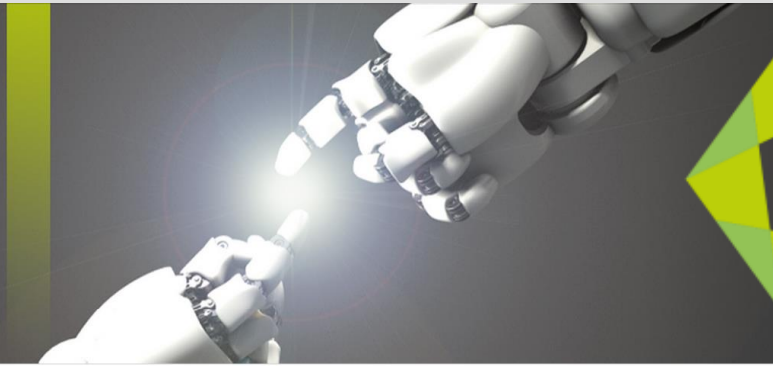
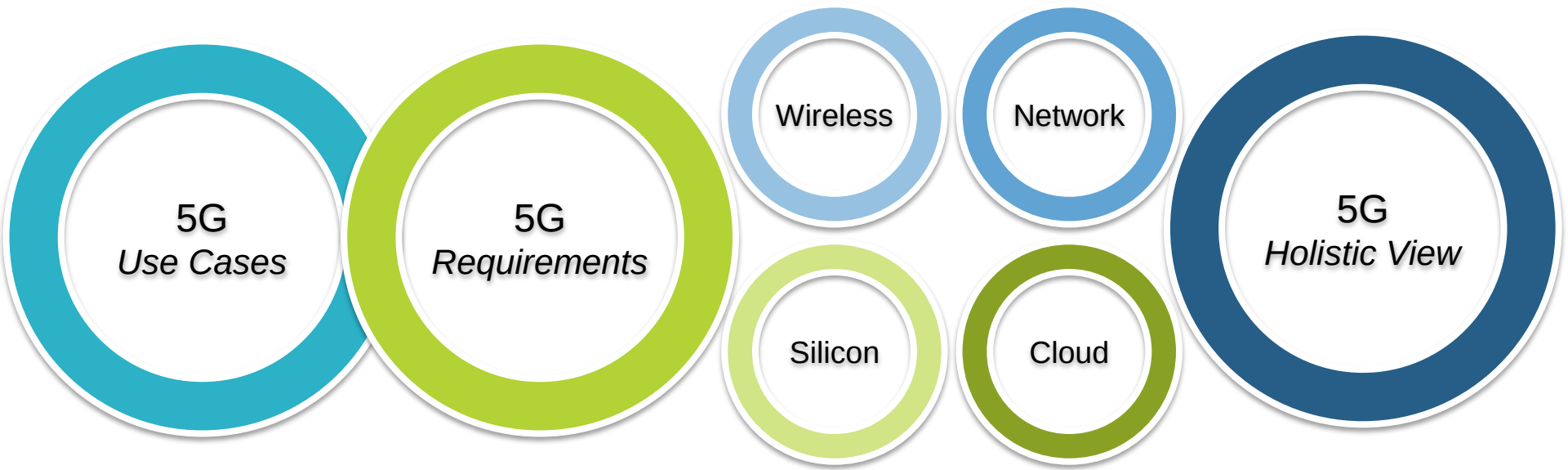
Holistic 5G



5G LAB GERMANY



5G LAB
GERMANY

THE WAY TOWARDS 5G

Quelle: japantimes.co.jp/news/2014/09/30/asia-pacific/hong-kong-democracy-protesters-set-deadline-for-demands/

Quelle: japantimes.co.jp/news/2014/09/30/asia-pacific/hong-kong-democracy-protesters-set-deadline-for-demands/

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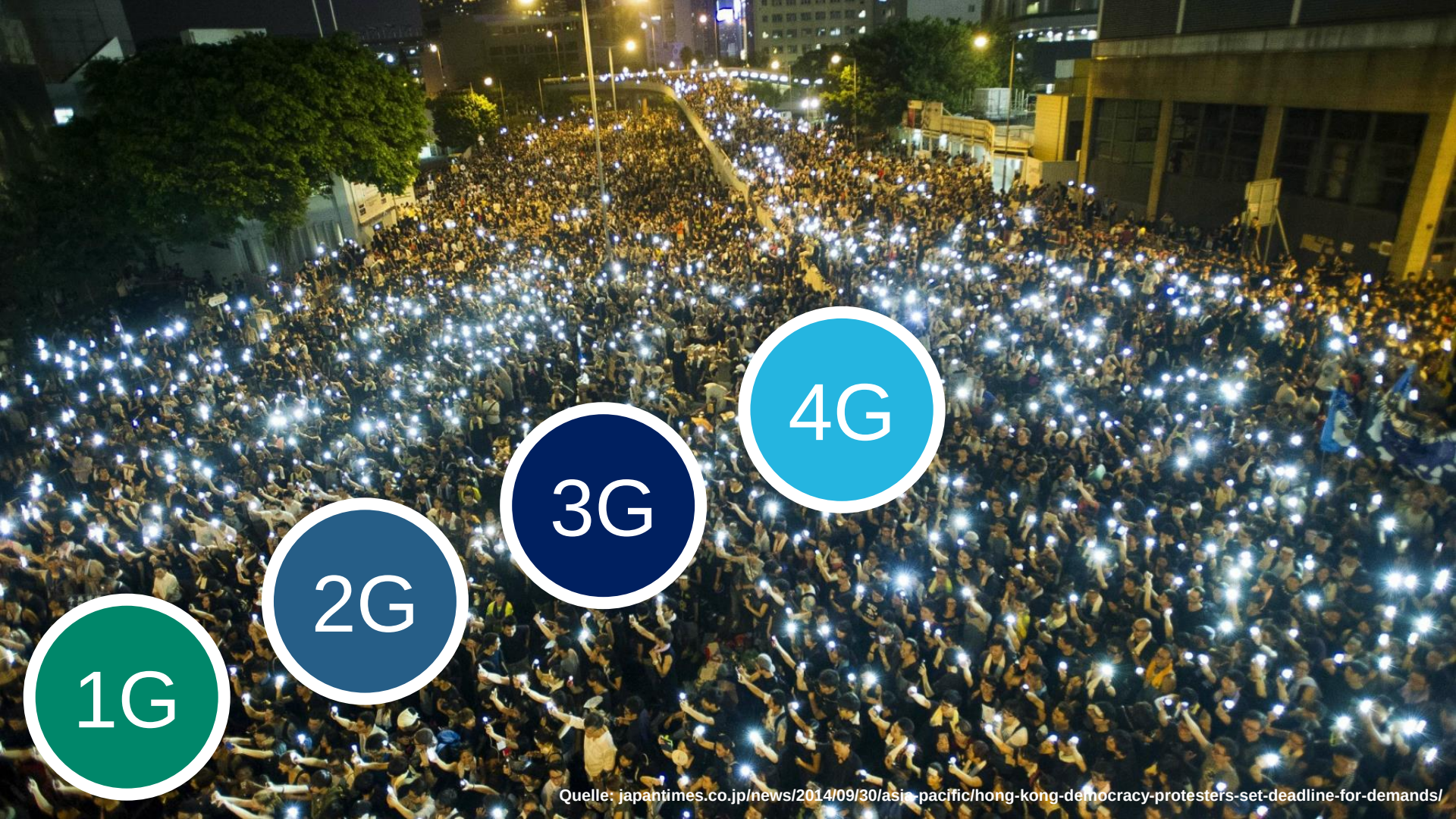
Quelle: japantimes.co.jp/news/2014/09/30/asia-pacific/hong-kong-democracy-protesters-set-deadline-for-demands/


You don't know where you're going until you know where you've been.
1G
2G
3G
4G
5G



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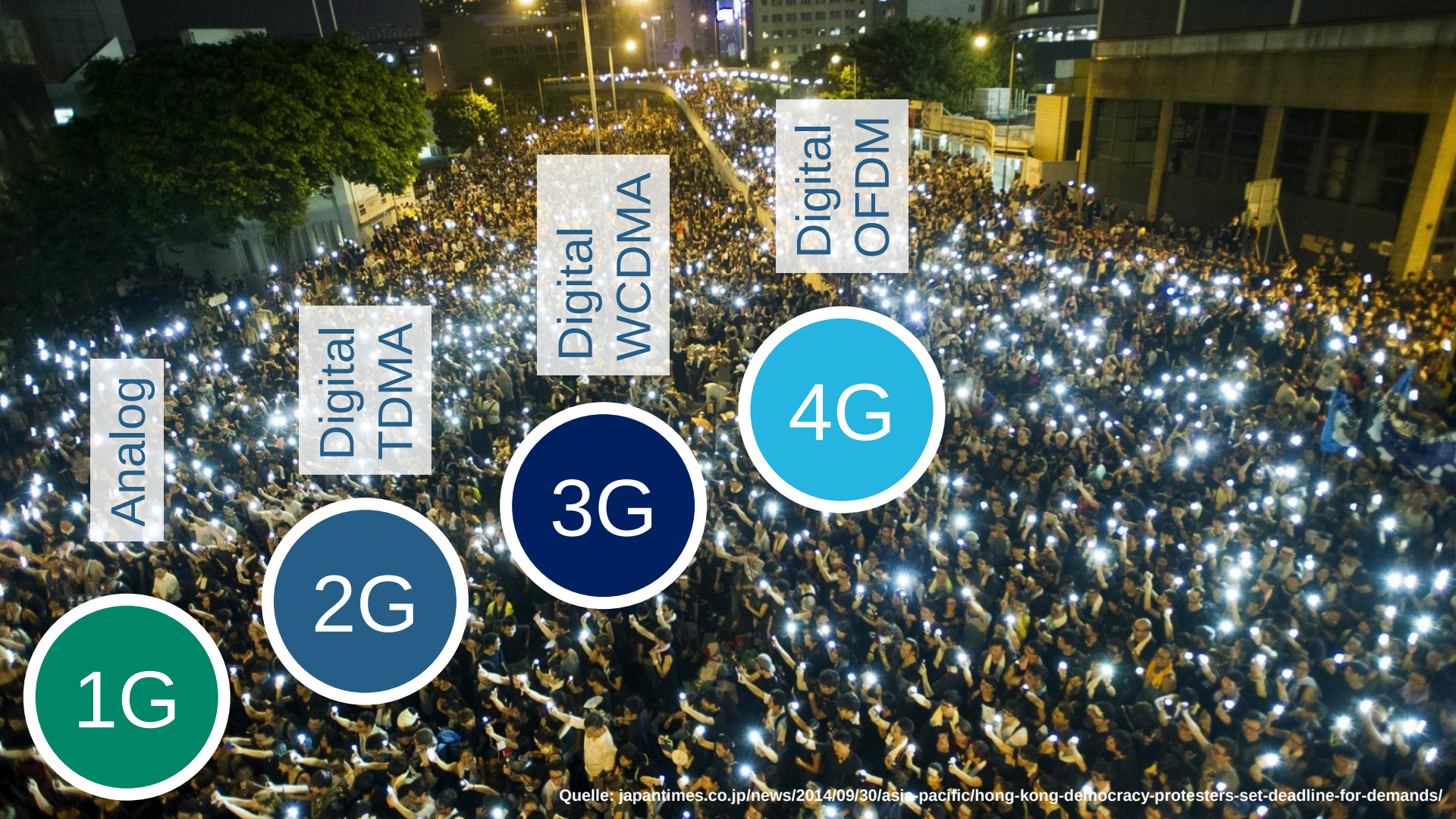
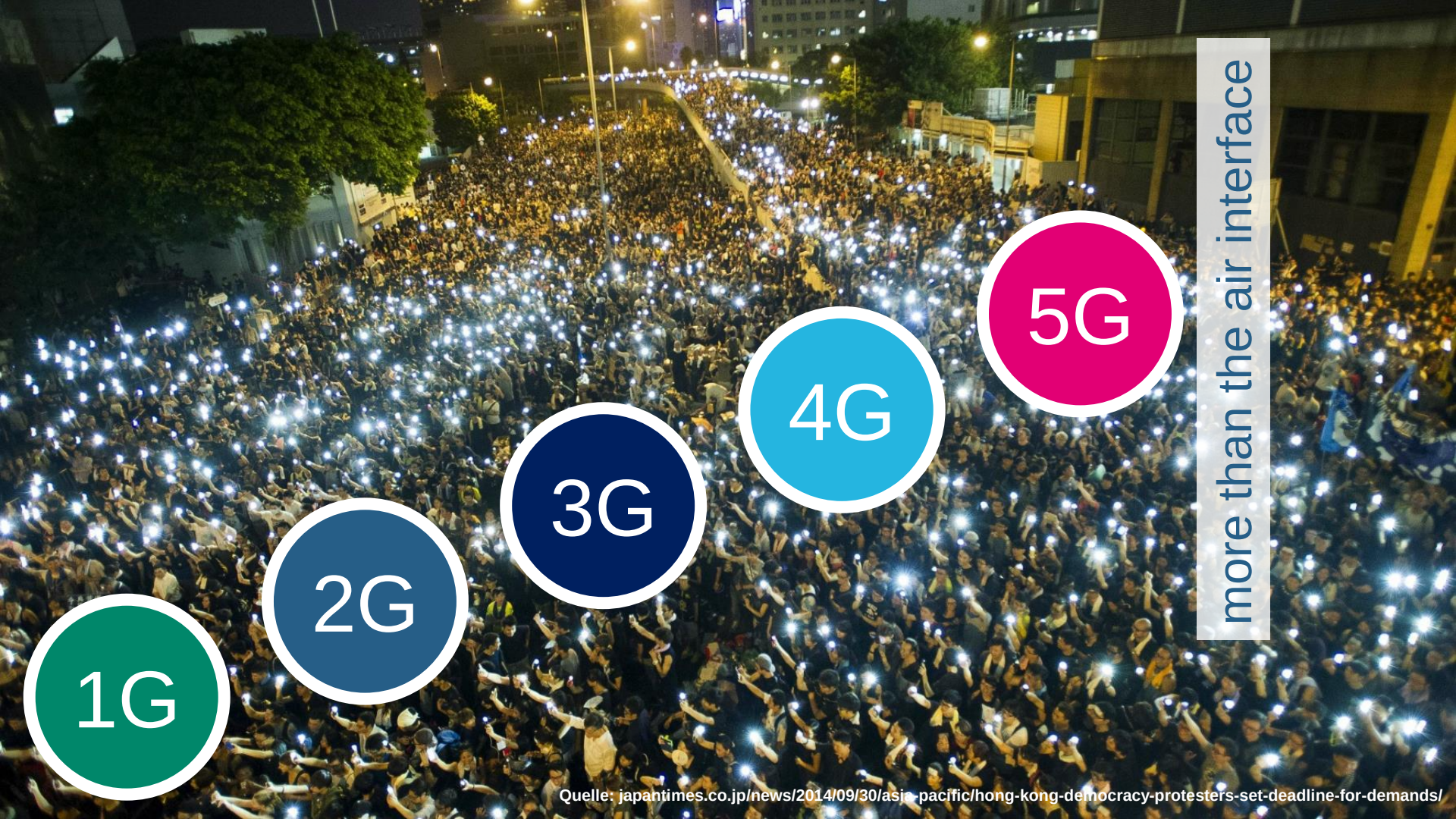
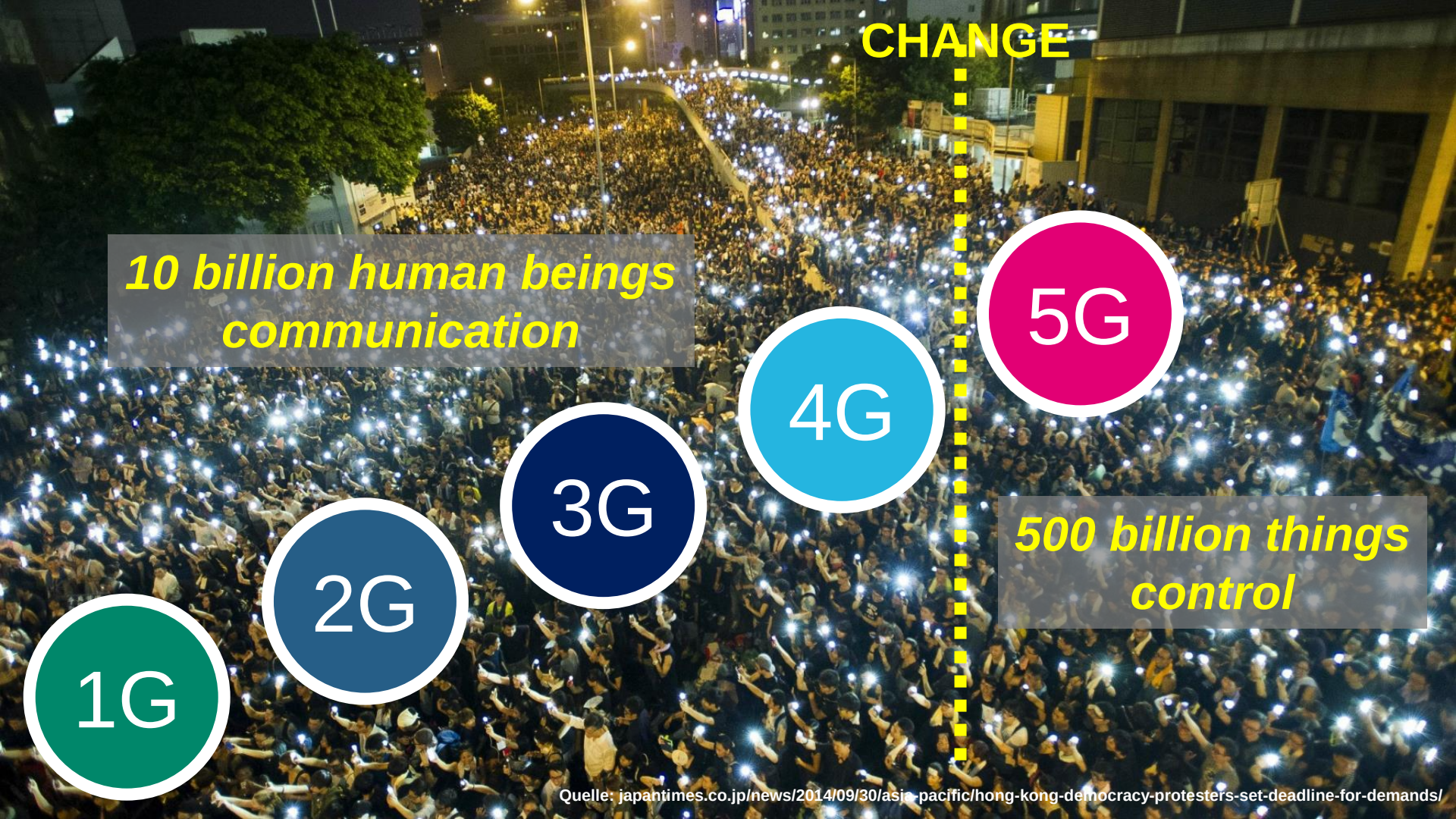


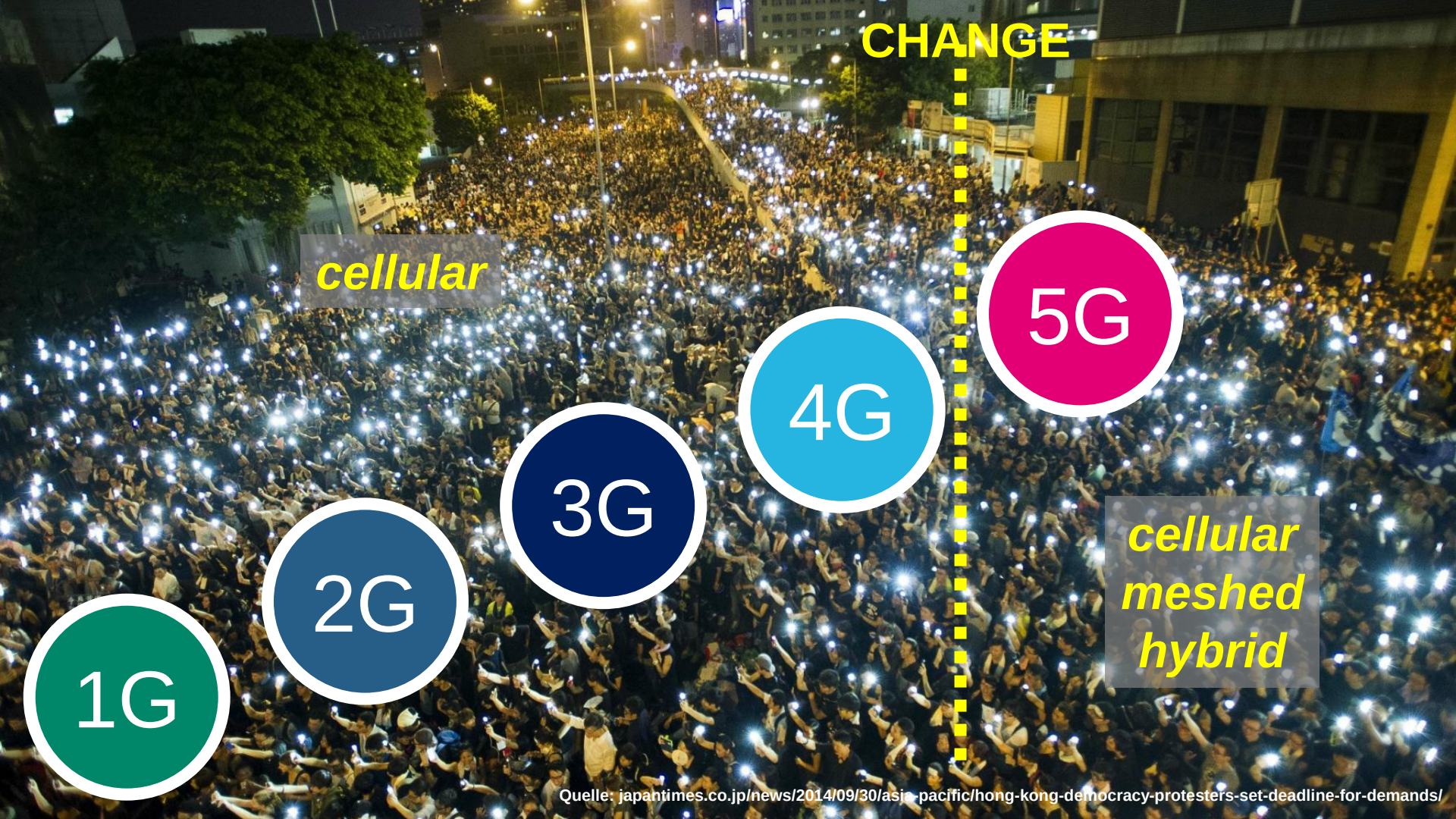
Quelle: japantimes.co.jp/news/2014/09/30/asia-pacific/hong-kong-democracy-protesters-set-deadline-for-demands/



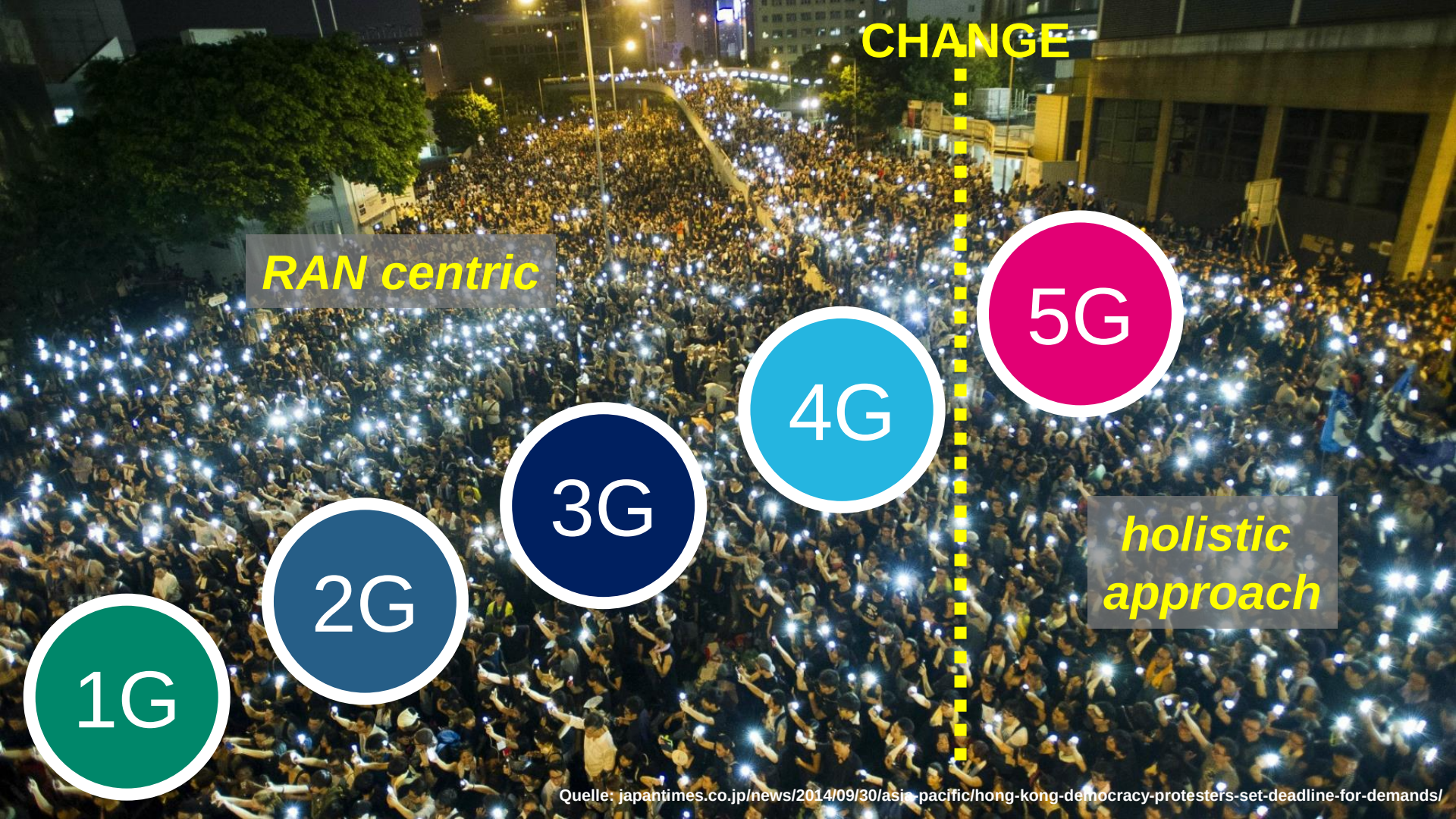
Quelle: japantimes.co.jp/news/2014/09/30/asia-pacific/hong-kong-democracy-protesters-set-deadline-for-demands/



Quelle: japantimes.co.jp/news/2014/09/30/asia-pacific/hong-kong-democracy-protesters-set-deadline-for-demands/

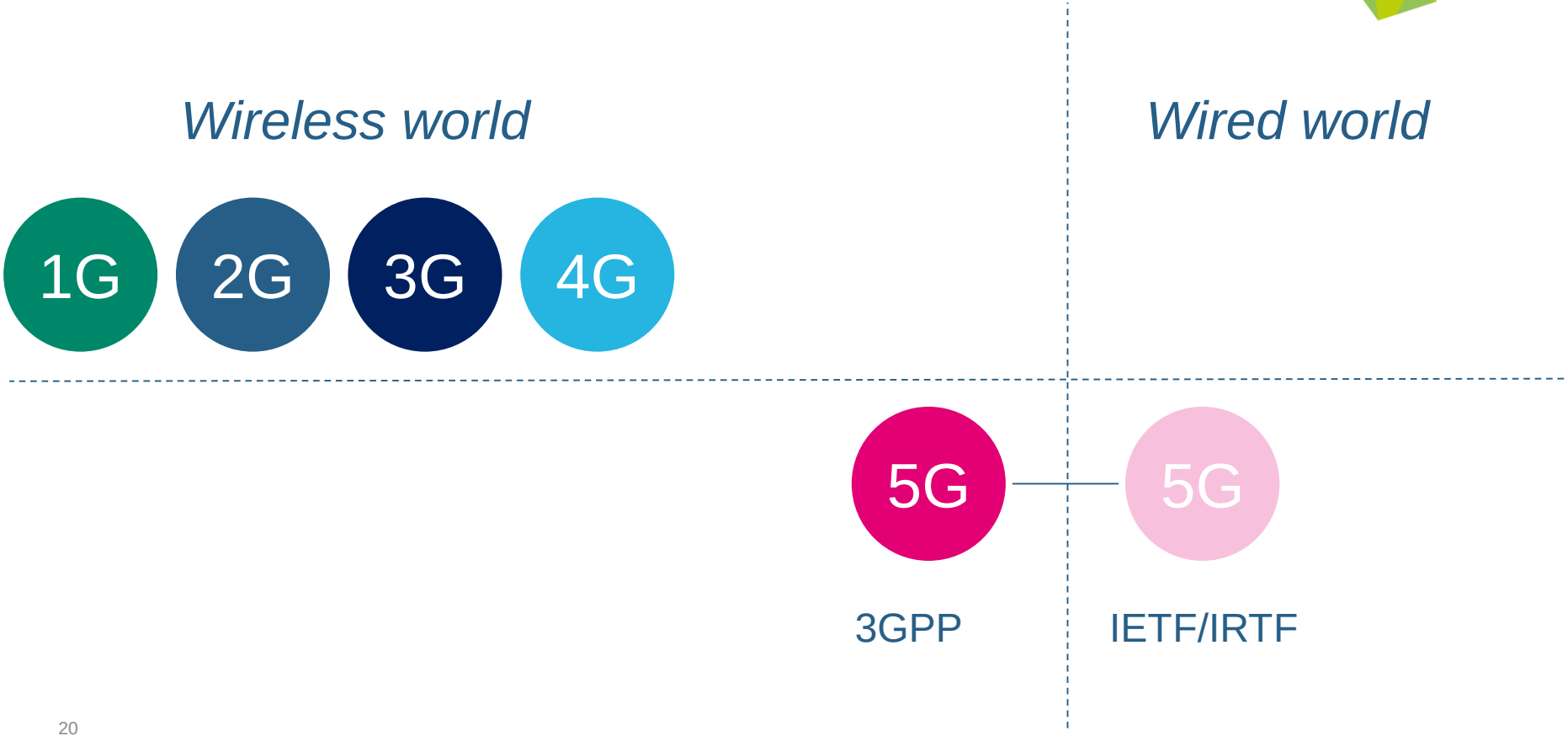


Quelle: japantimes.co.jp/news/2014/09/30/asia-pacific/hong-kong-democracy-protesters-set-deadline-for-demands/

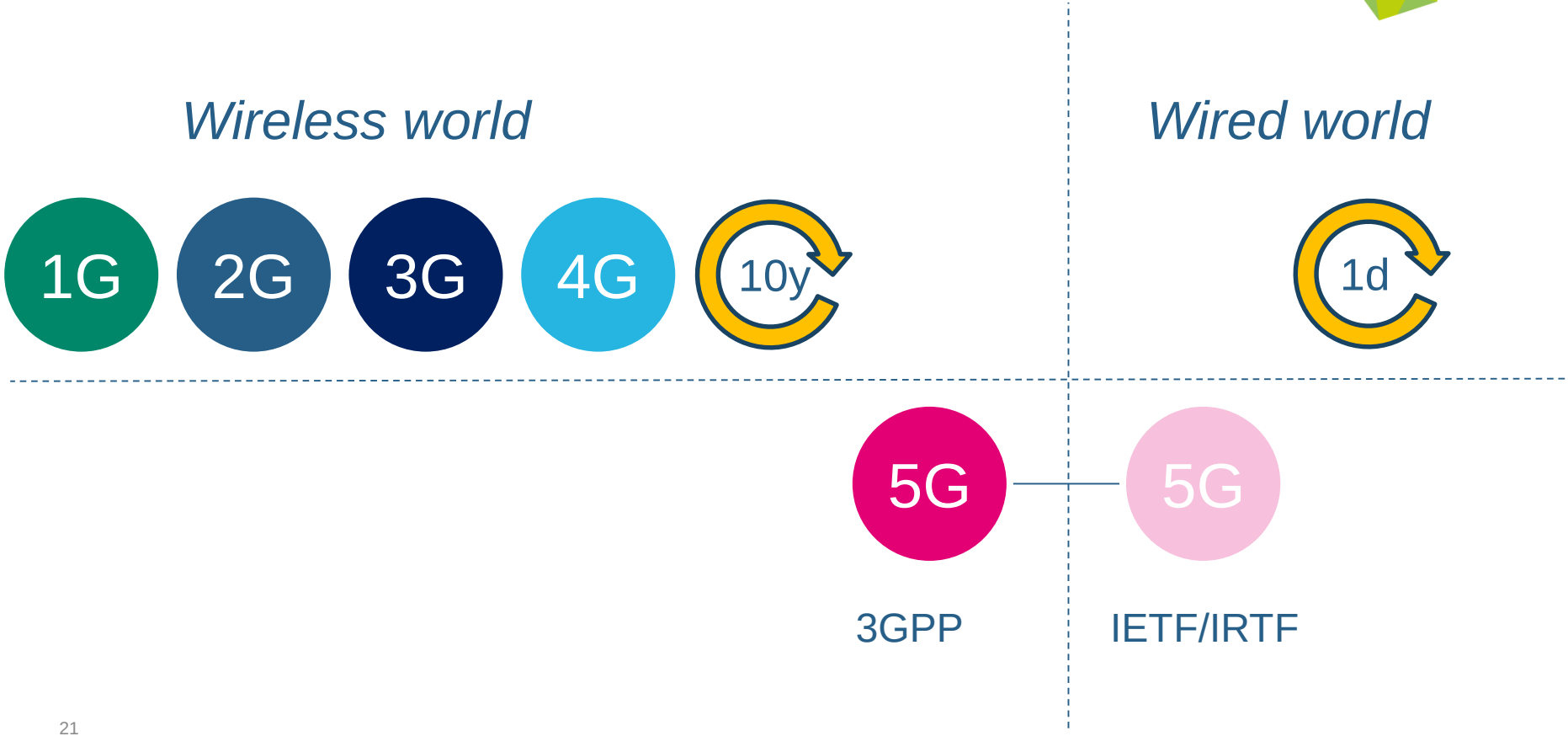


Quelle: japantimes.co.jp/news/2014/09/30/asia-pacific/hong-kong-democracy-protesters-set-deadline-for-demands/

General 5G Definition



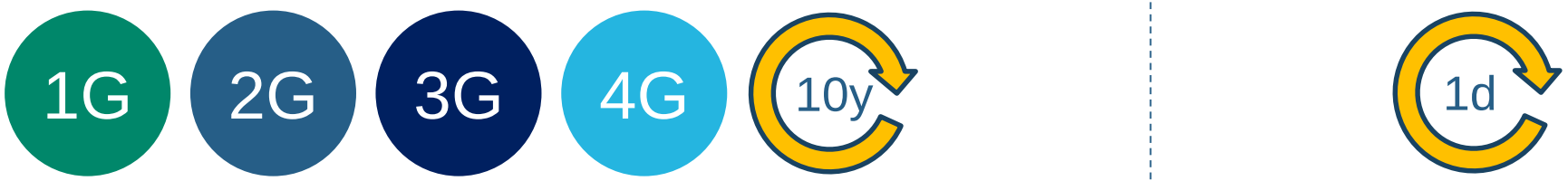
General 5G Definition



General 5G Definition

Wireless world

Wired world



5G — 5G

3GPP

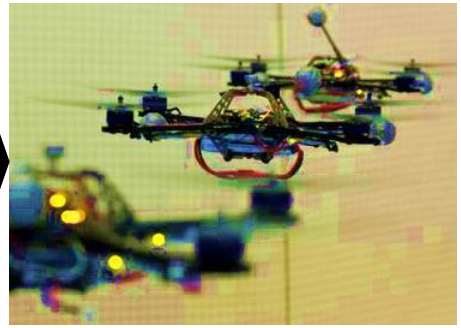
HARDWARE

IETF/IRTF

SOFTWARE

So is 6G next?

Revolution Ahead



5G:

Ubiquitous

Steering & Control Communications

≤ 4G:

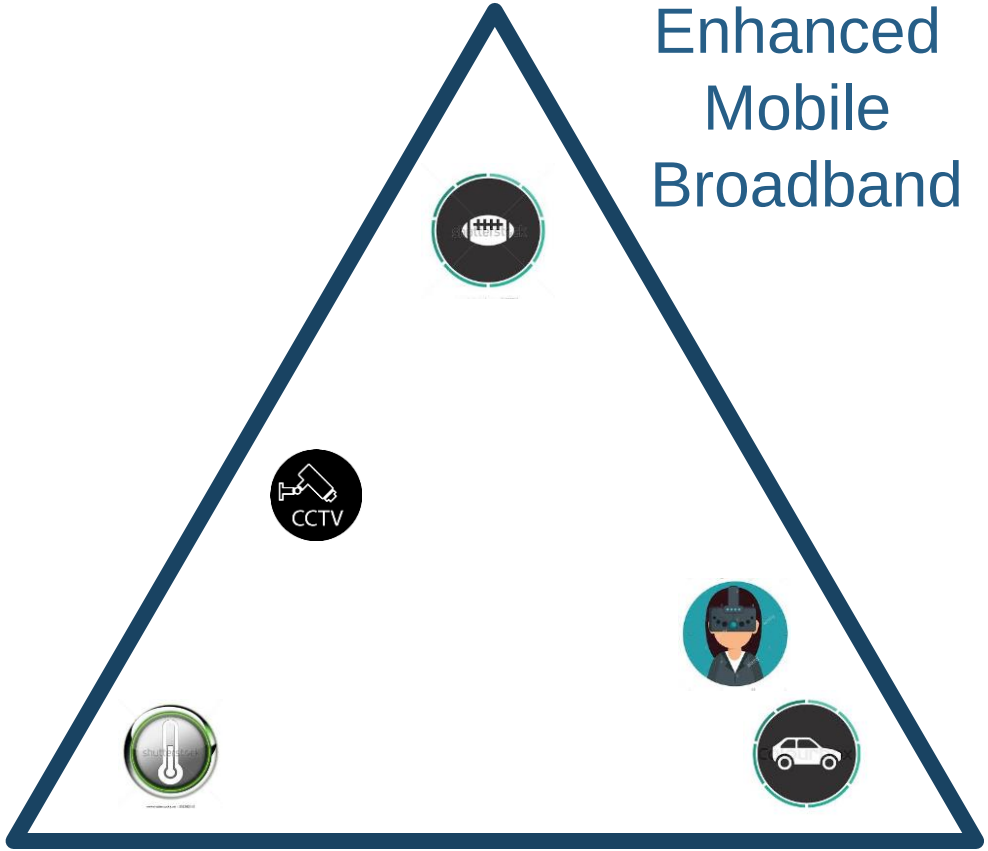
Ubiquitous

Content Communications

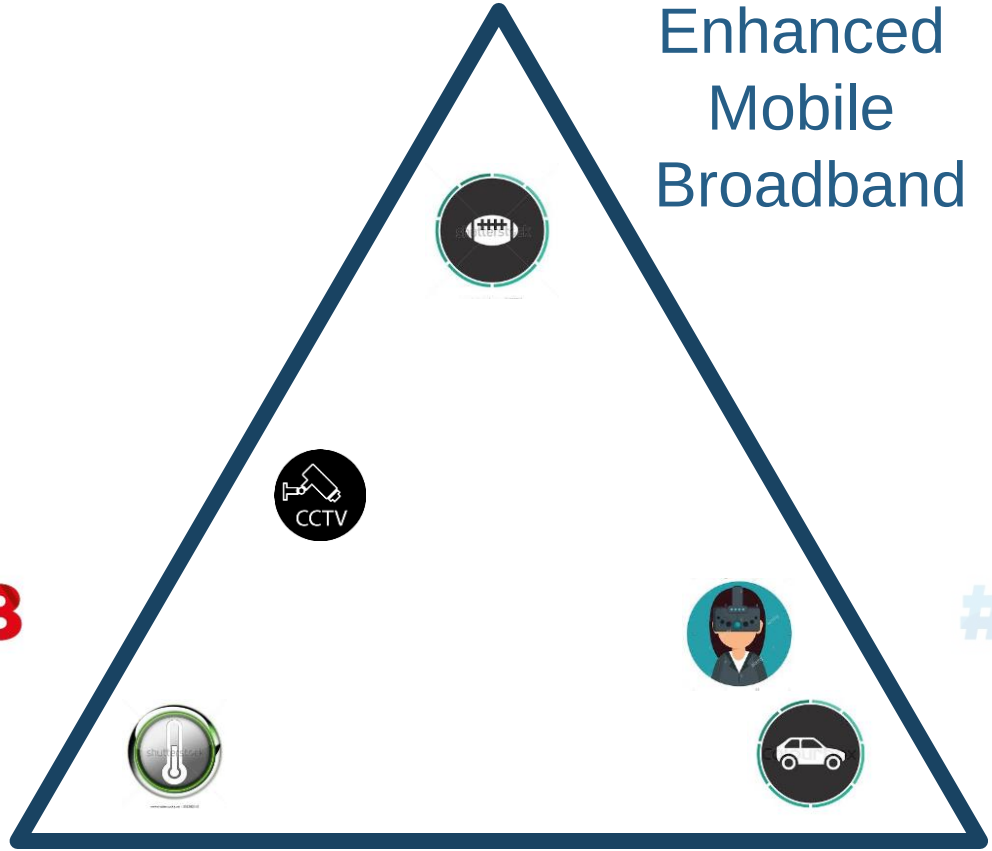
5G LAB
GERMANY

5G DEFINITION

General 5G Definition



General 5G Definition



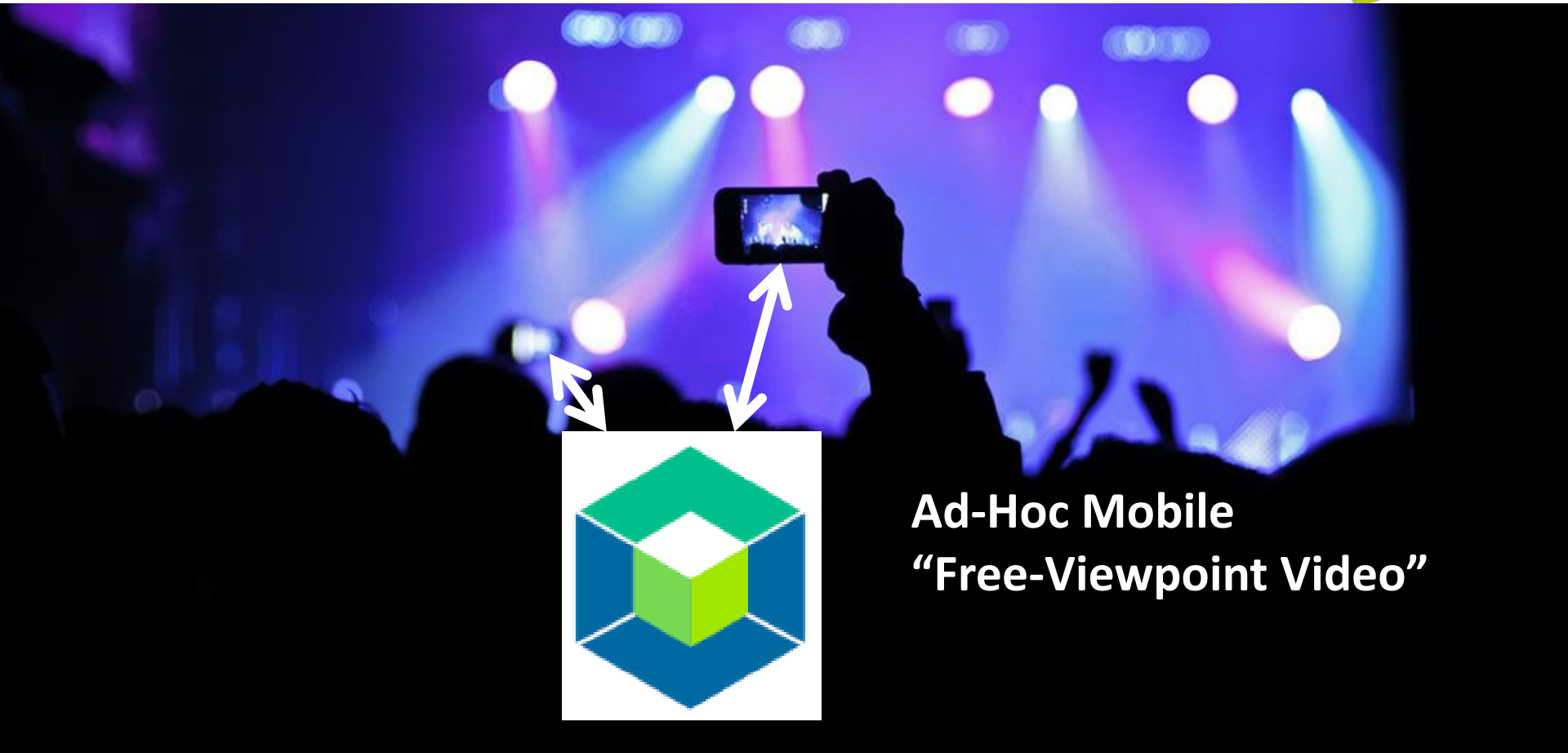
Enhanced Mobile Broadband

Massive IoT

Low Latency

#MWC18

Free-Viewpoint Video



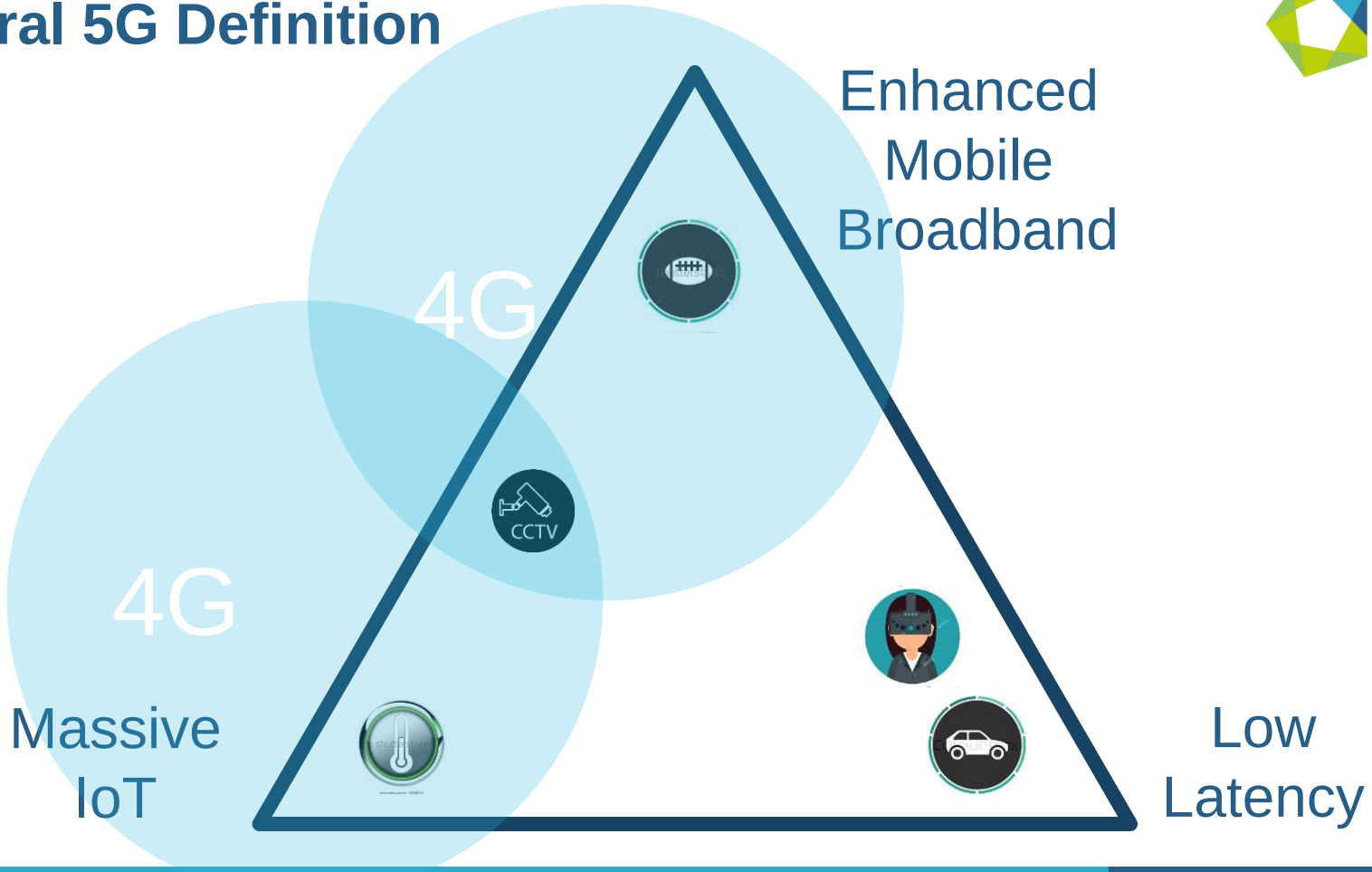
Ad-Hoc Mobile
“Free-Viewpoint Video”

Tactile Internet Killer App: Free Viewpoint Video

Tactile Internet Killer App: Free Viewpoint Video


Reliable and
Synchronous
Multicast

General 5G Definition



The 5G Atom

The 5G Atom

5G LAB
GERMANY

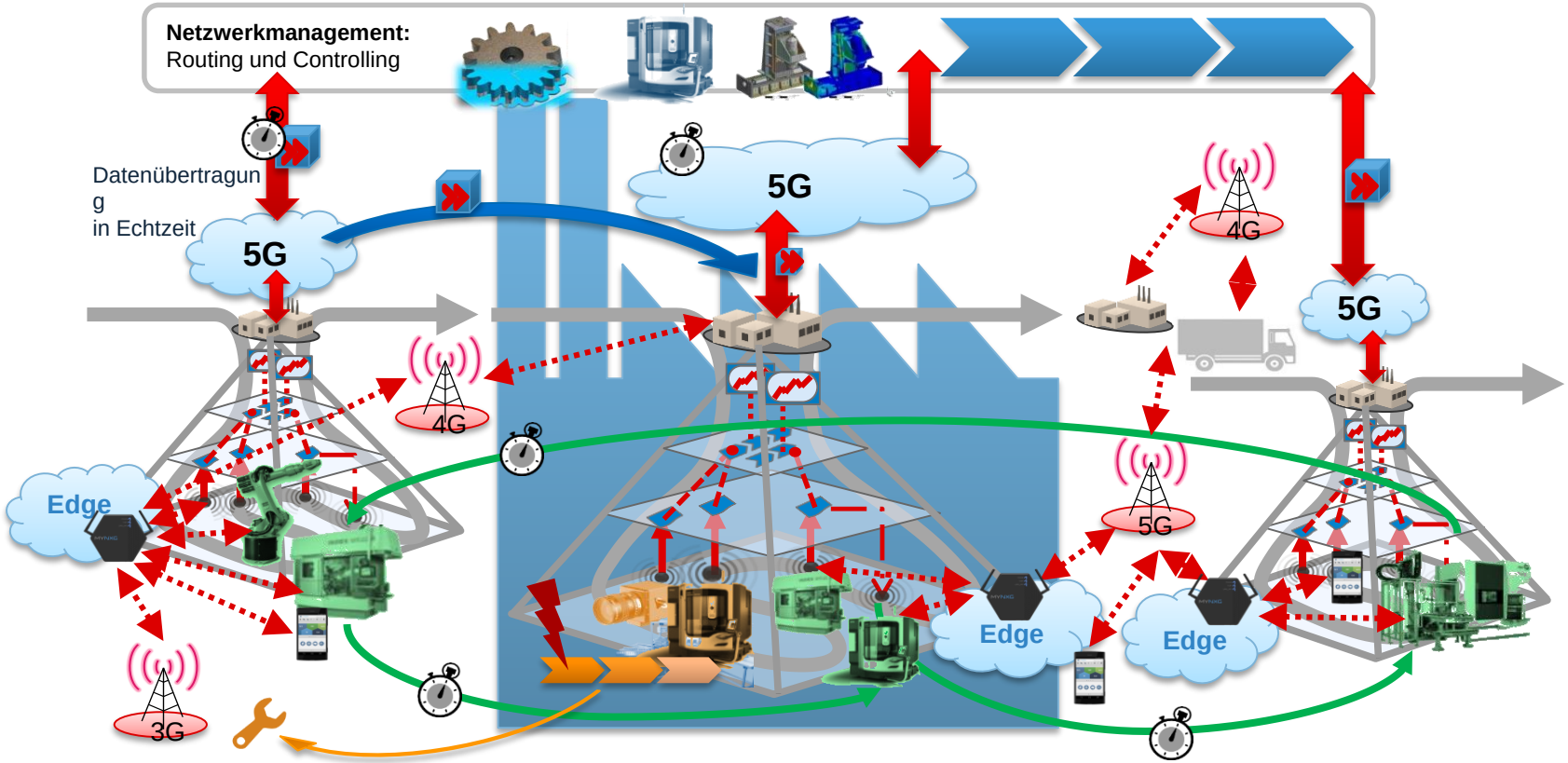
5G USE CASES

Industry 4.0

http://jerryrushing.net/wp-content/uploads/2012/04/robotic_assembly_line1.jpg

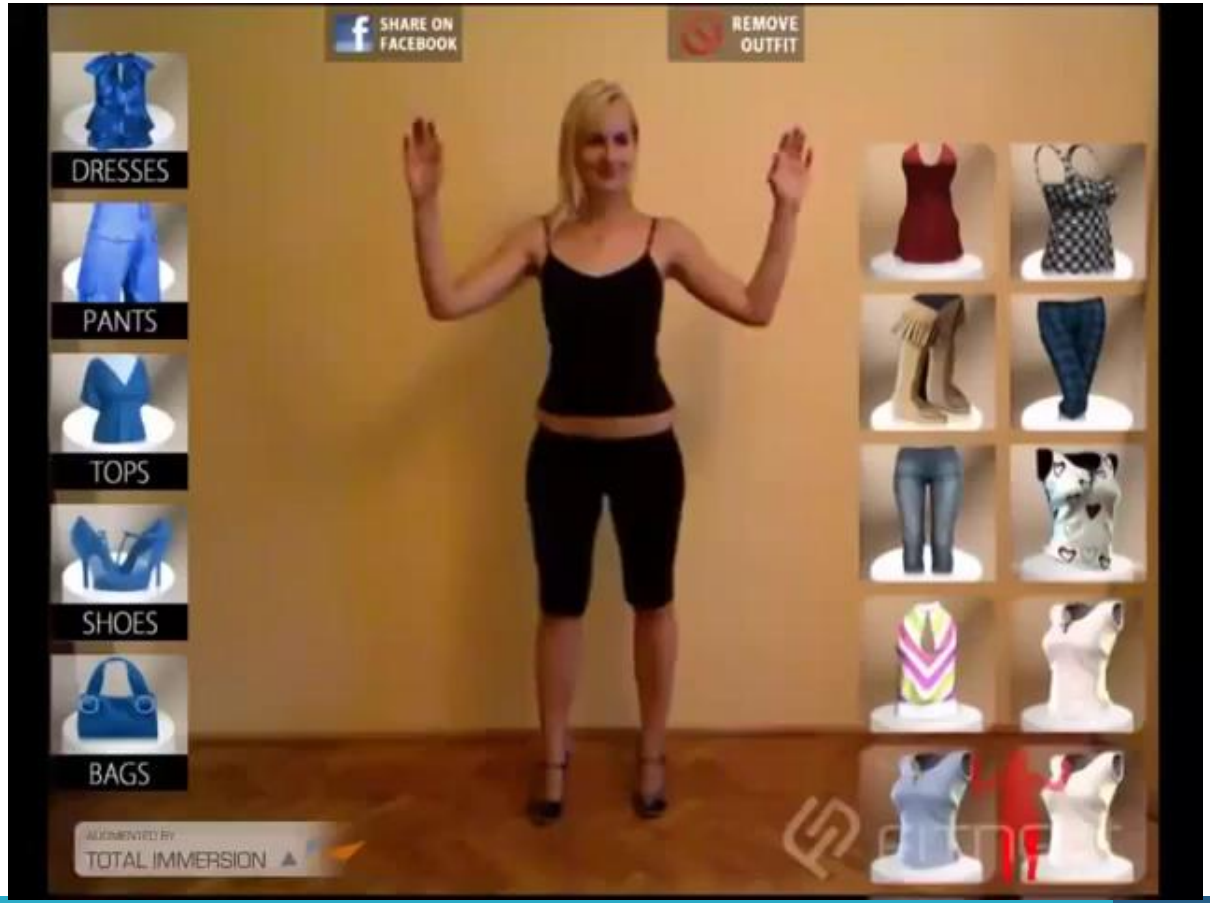
http://www.witchdoctor.co.nz/wp-content/uploads/2013/01/robot-fabrication-station.jpg

BMBF 5Gang


Netzwerkmanagement:
Routing und Controlling
Datenübertragung
in Echtzeit
5G
5G
4G
4G
5G
5G
Edge
Edge
Edge
3G

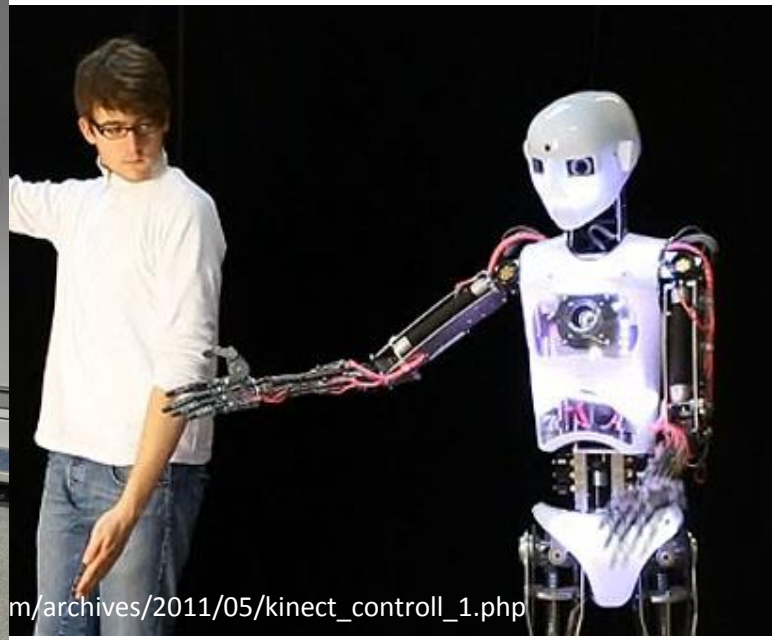
Design Service: A Job Machine

Tactile Internet Needed!



The Tactile Internet: Remote Controlled Humanoid Robots

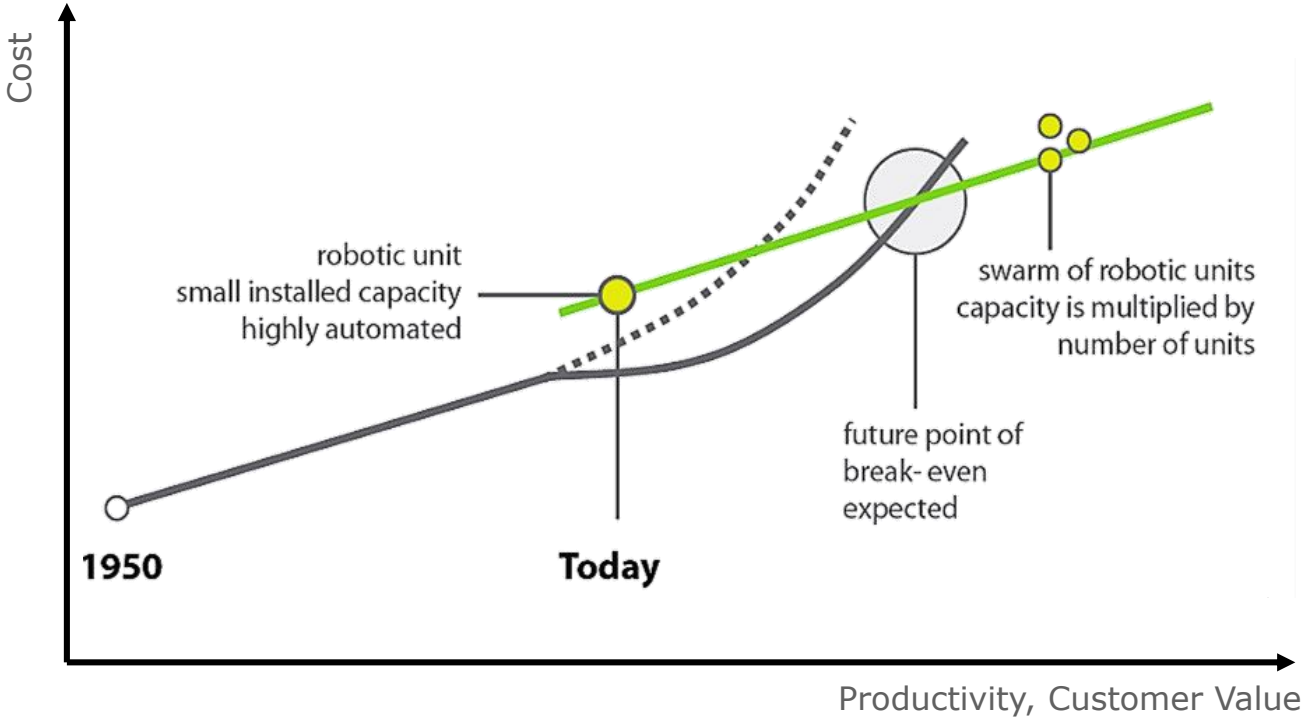
The Tactile Internet: Remote Controlled Humanoid Robots

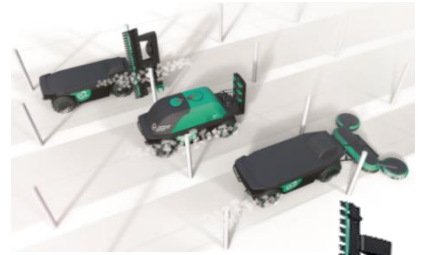


Agriculture

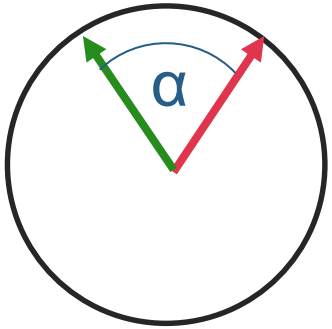
Precision Farming

Future of Farming





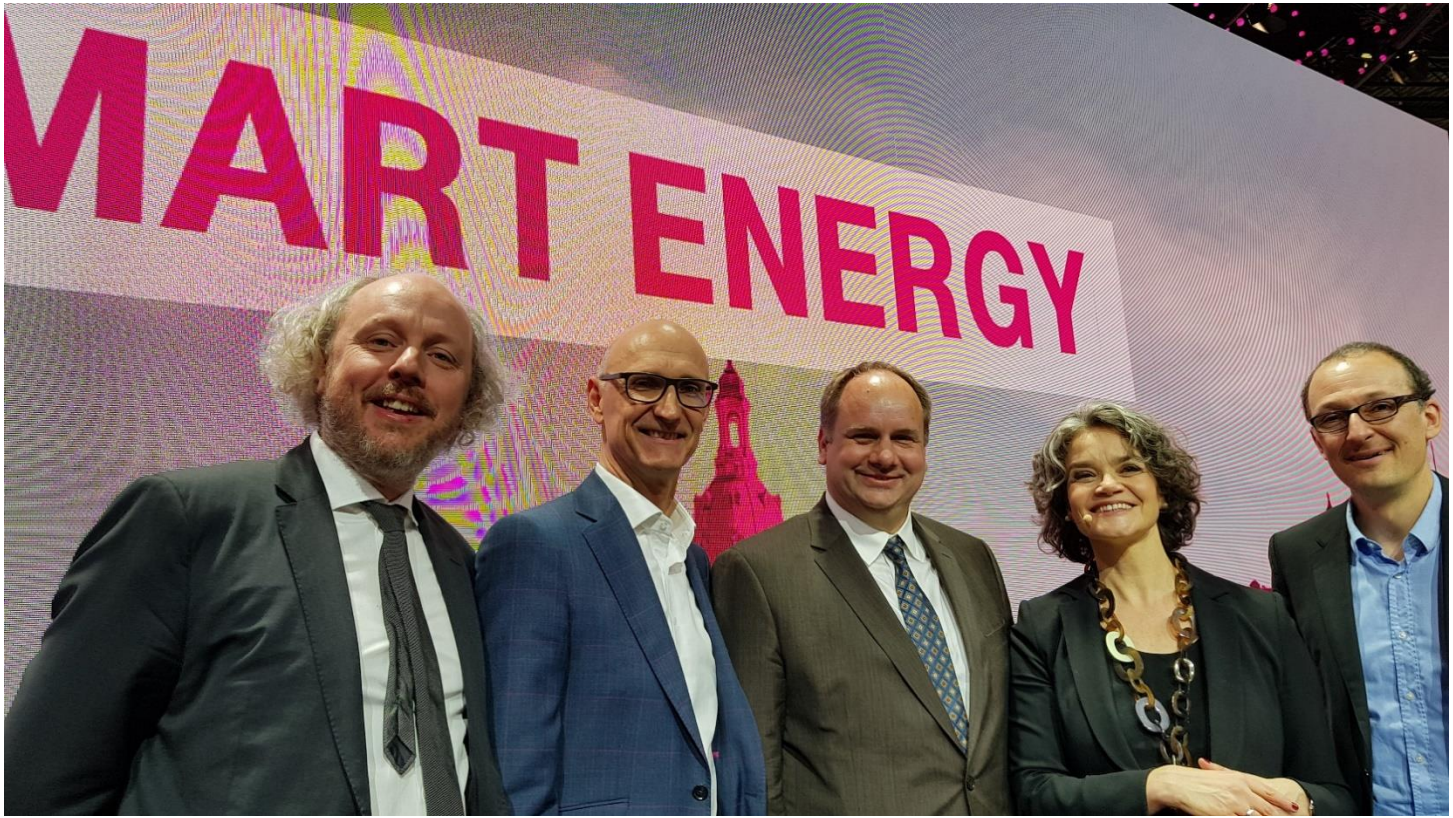
Smart Grids / Micro Grids

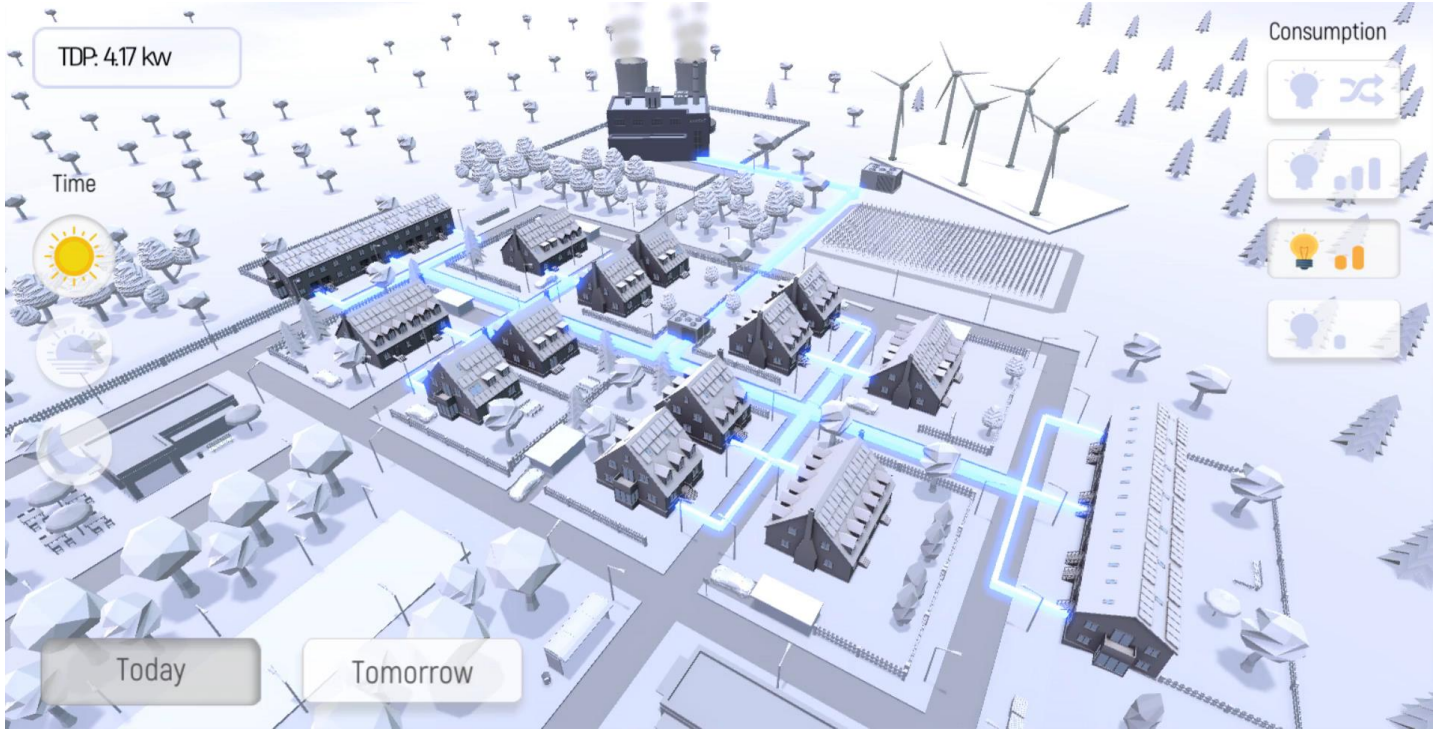


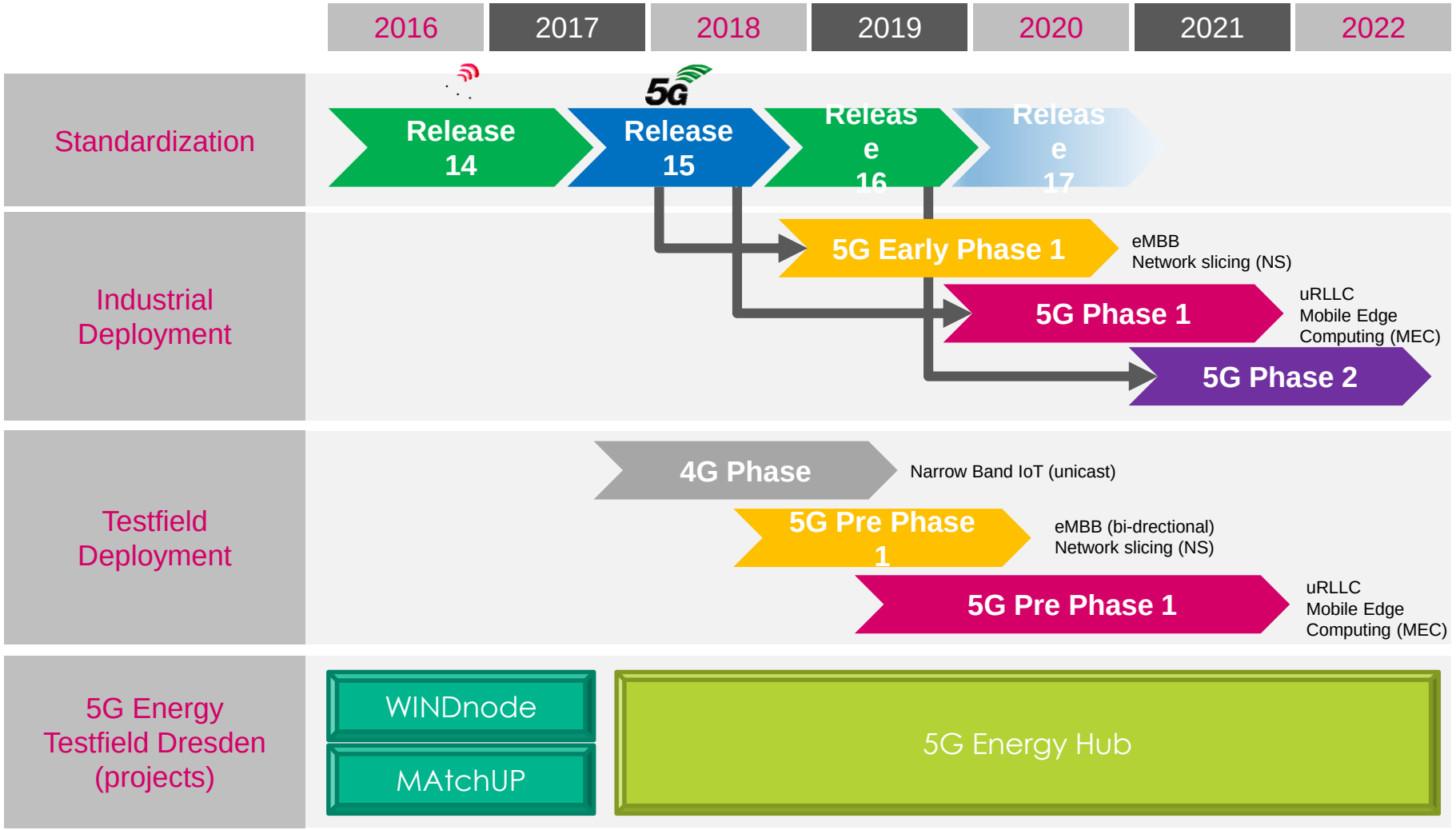
1ms

18°

5G Energy Hub




TDP: 4.17 kw
Time
Consumption
Today
Tomorrow


2016
2017
2018
2019
2020
2021
2022
Standardization
Release 14
Release 15
Releas e 16
Releas e 17
Industrial Deployment
5G Early Phase 1
eMBB
Network slicing (NS)
5G Phase 1
uRLLC
Mobile Edge Computing (MEC)
5G Phase 2
Testfield Deployment
4G Phase
Narrow Band IoT (unicast)
5G Pre Phase 1
eMBB (bi-drectional)
Network slicing (NS)
5G Pre Phase 1
uRLLC
Mobile Edge Computing (MEC)
5G Energy Testfield Dresden (projects)
WINDnode
MAtchUP
5G Energy Hub

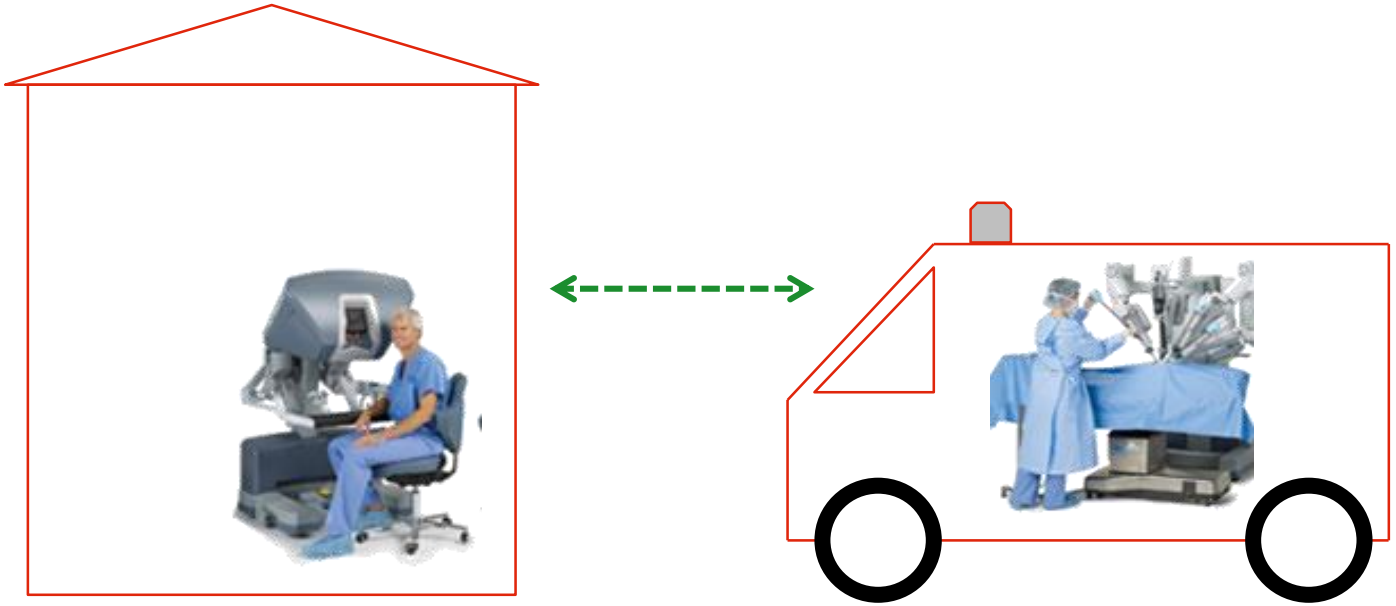
Reinventing “Latin Classes”

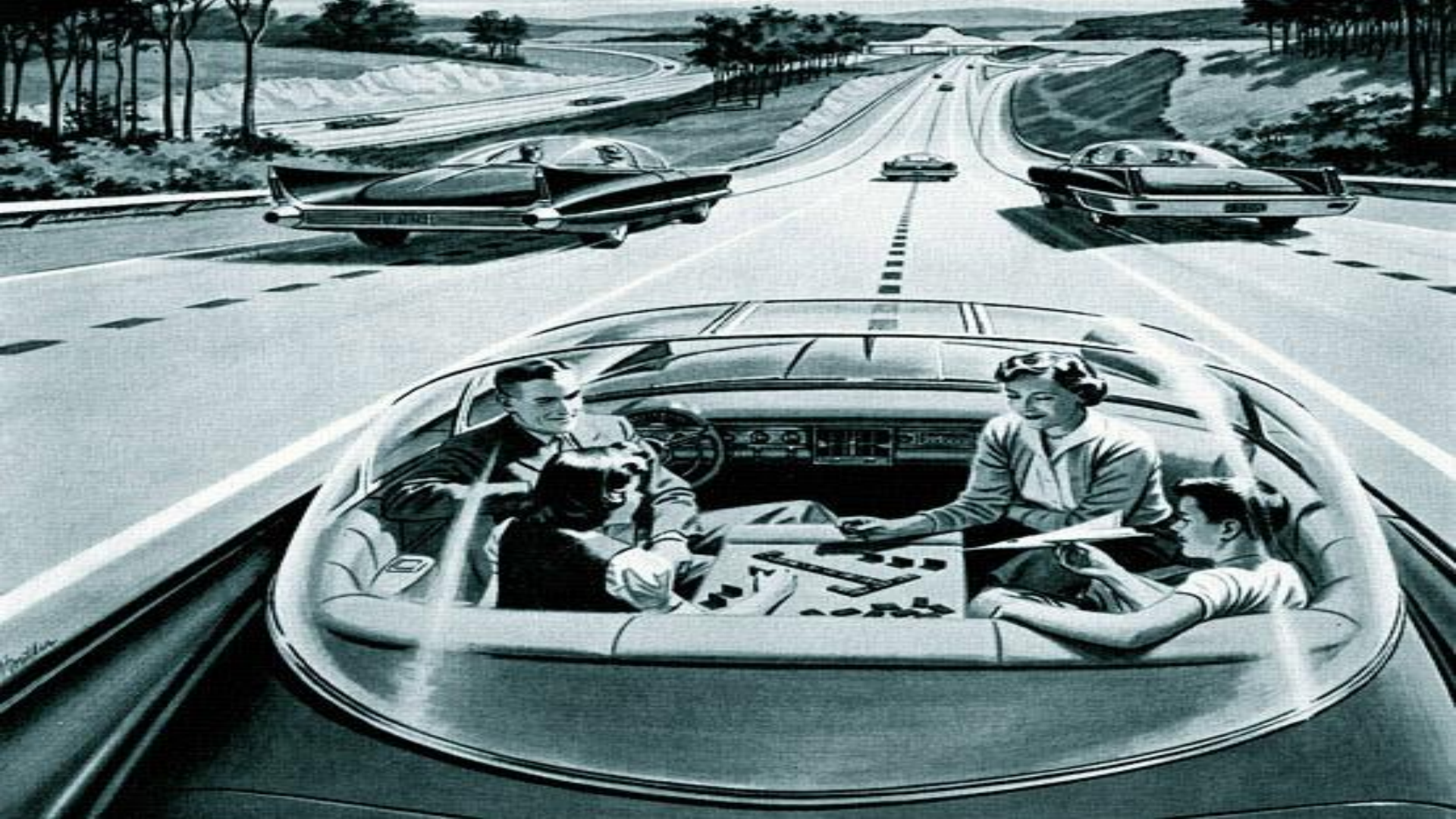
Human Touch

Robotic Assisted Surgery Today

Remote Medical Provisioning

Enabled by Tactile 1ms Realtime Wireless

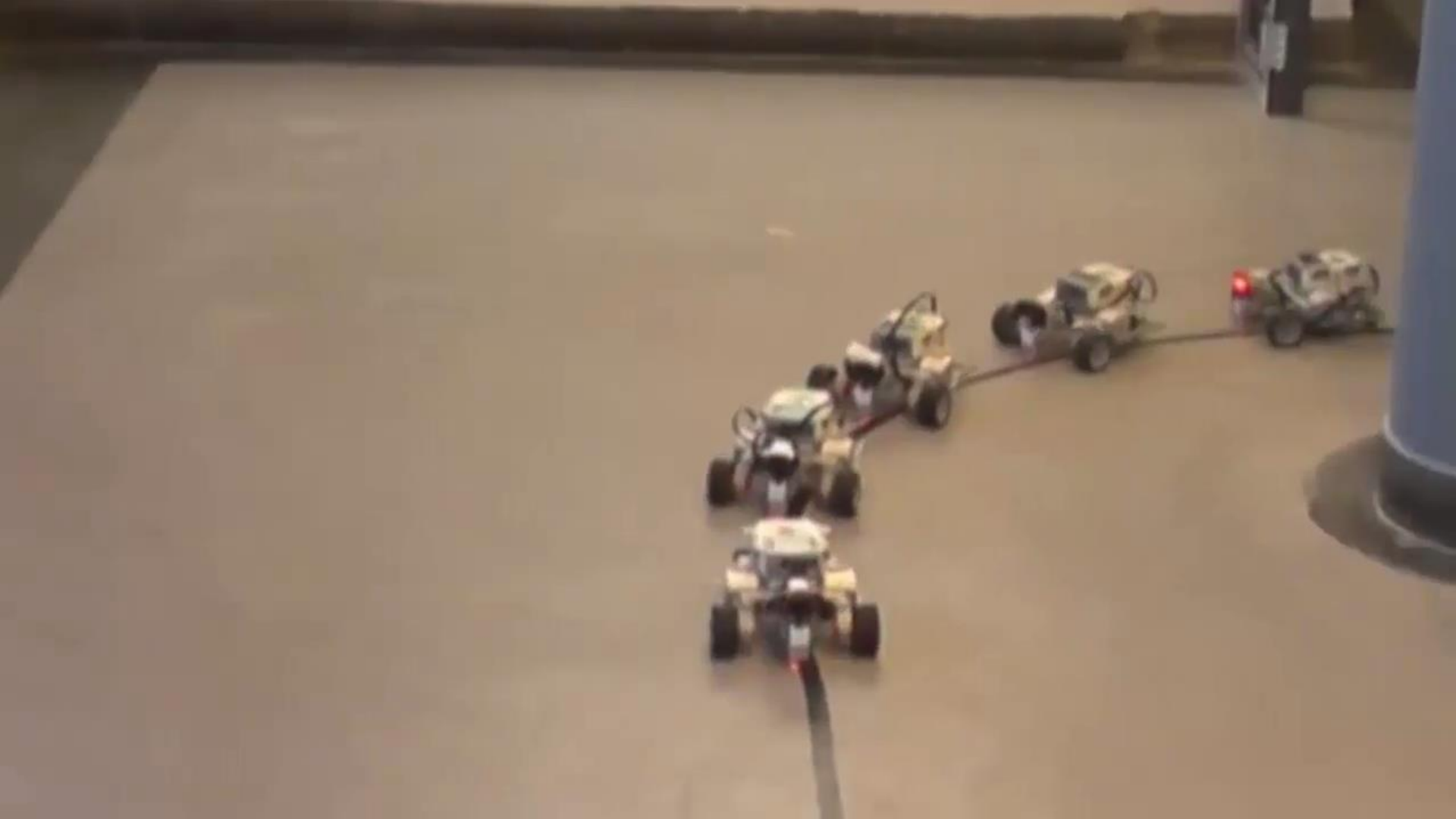




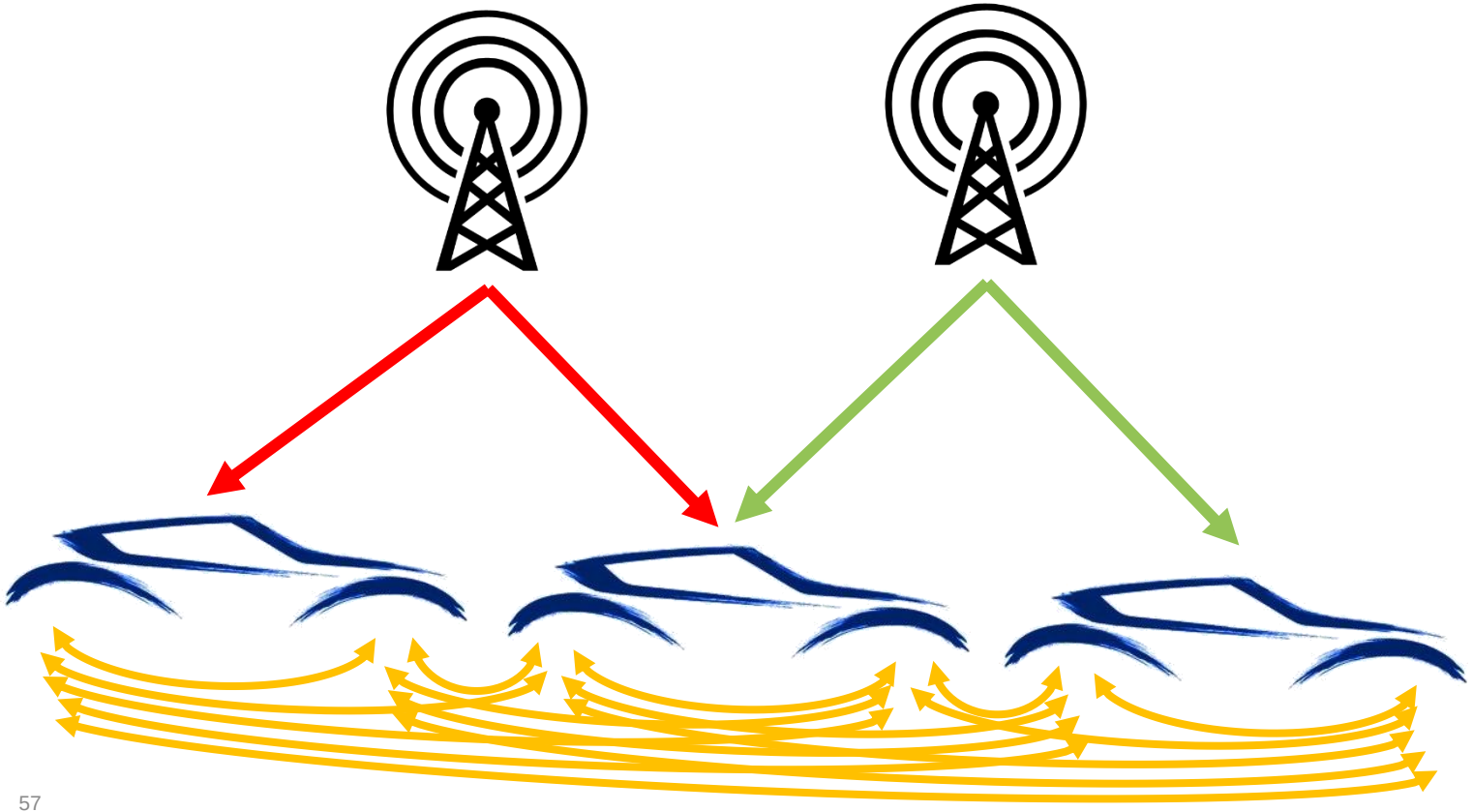
Platooning

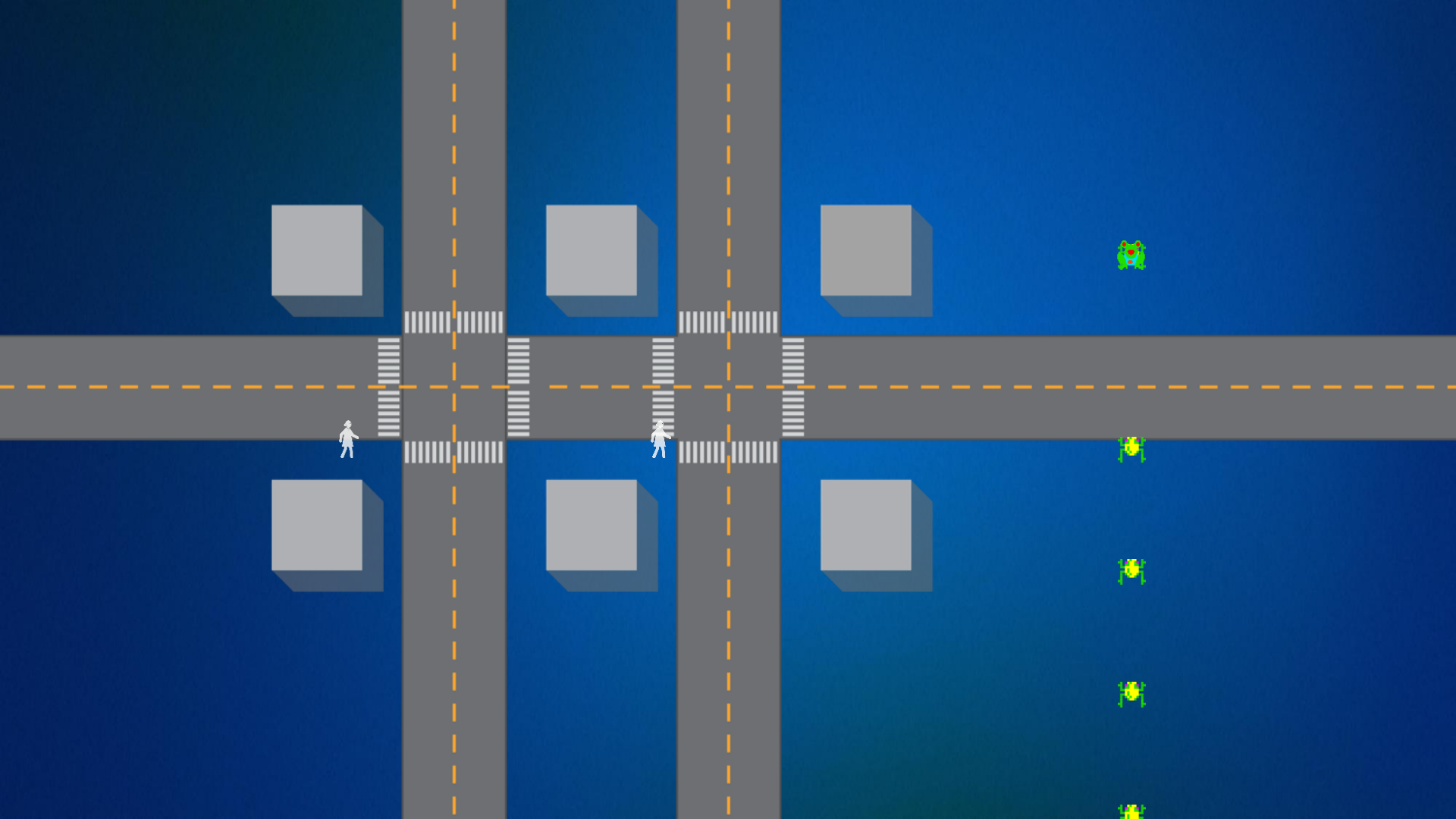
1-2 ms: ESC, ABS

Bald platooned ESC & ABS



Car Communication Networks





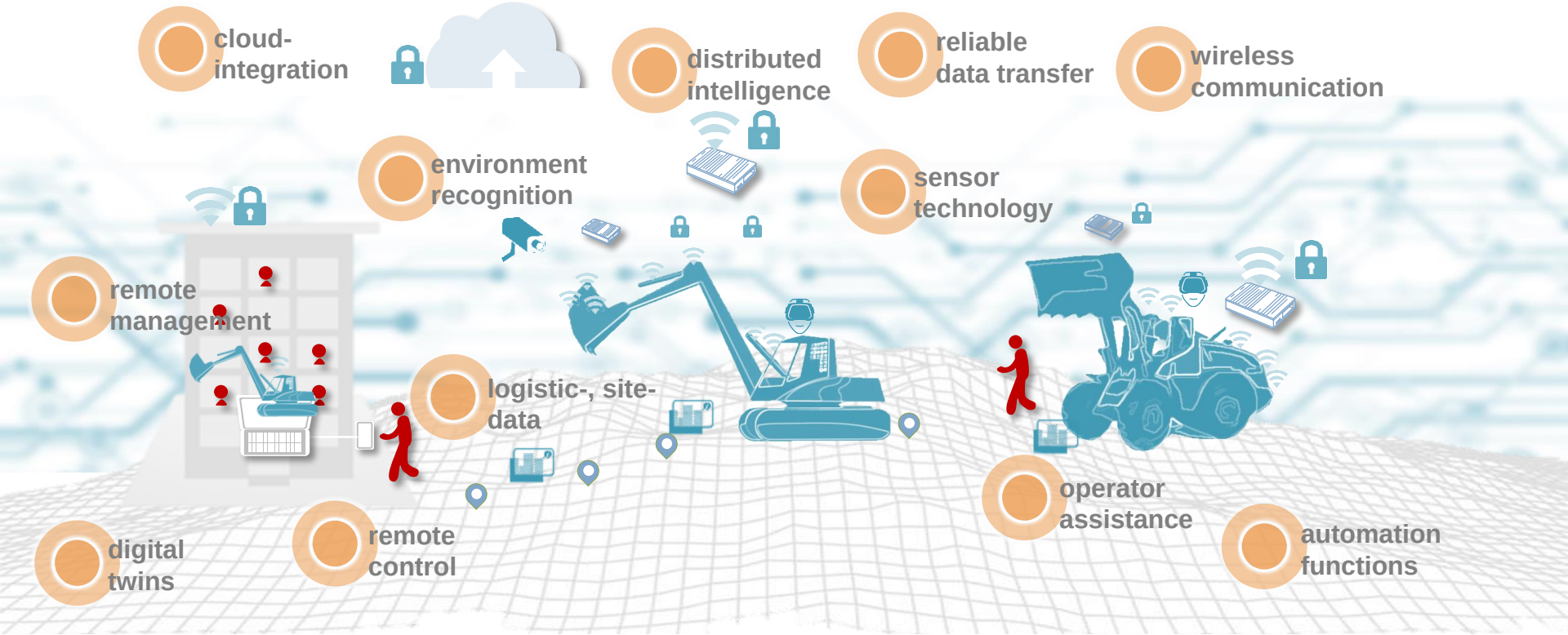

GSMA
MOBILE
WORLD CONGRESS
BARCELONA 22-25 FEB 2016

5G NETMOBIL AT A GLANCE

5G NETMOBIL – 5G SOLUTIONS FOR FUTURE CONNECTED MOBILITY

SPONSOR	Federal Ministry of Education and Research
CALL	5G Tactile Internet within the german research program „IKT 2020 – Research for Innovation“
PARTNERS	Bosch (Coordinator), Technische Universität Dresden (Co-Coordinator), Acticom, BMW AG, CLAAS, Deutsche Telekom, dresden elektronik, Ericsson, Fraunhofer Heinrich-Hertz-Institut, Heusch Boesefeldt, Hochschule für Technik und Wirtschaft des Saarlandes, Logic Way, Nokia, Technische Universität Kaiserslautern, Vodafone, Volkswagen AG
BUDGET	14.9 Mio. € (8,5 Mio. € Funding)
DURATION	01.03.2017 – 29.02.2020

Vision - digital construction site



Partners

5G LAB GERMANY

Consortium

- 18 Industry partners
- 4 University partners
- Associations (VDMA, VDBUM, VDI, ZDB)
- Research cluster (5G Lab)

TECHNISCHE UNIVERSITÄT DRESDEN

5G Lab GERMANY

tum fml

DIE DEUTSCHE BAUINDUSTRIE BAUEN UND SERVICES

VDMA

ZENTRALVERBAND DEUTSCHES BAUGEWERBE ZDB

Project duration

- 36 month starting 2019

STRABAG

LEONHARD WEISS BAUUNTERNEHMUNG

PUSCH

Danfoss Power Solutions

VEMCON

O&O Software

dresden elektronik

TOPCON

RIB

acticom

LIEBHERR

PAUS ...the people who care

HYDRIVE ENGINEERING

WACKER NEUSON

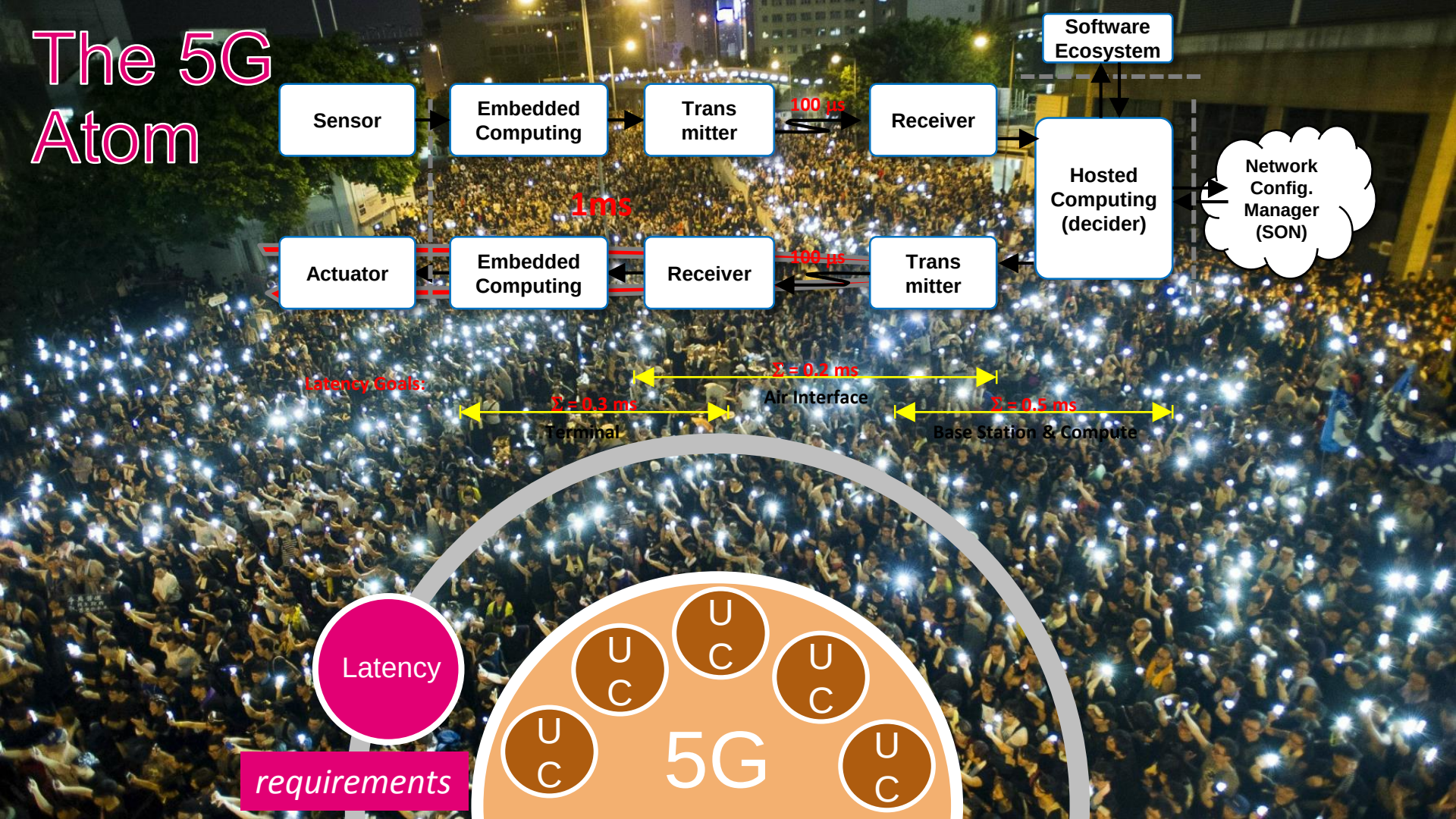
Rexroth Bosch Group

HYDAC INTERNATIONAL

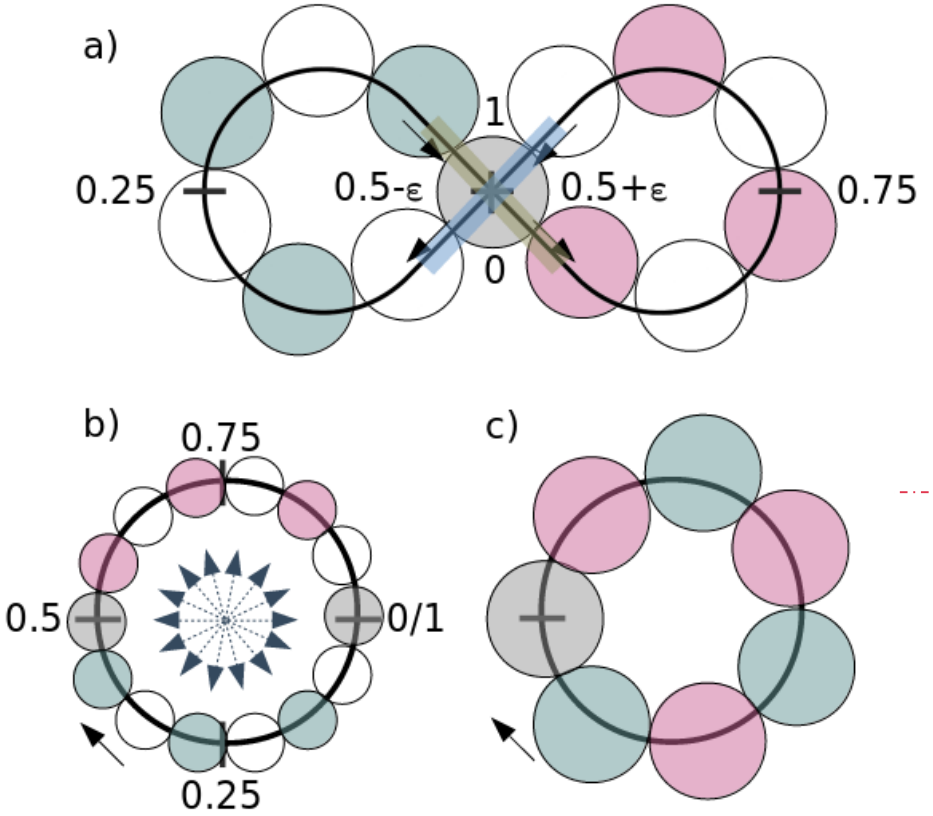
BAUER

The 5G Atom

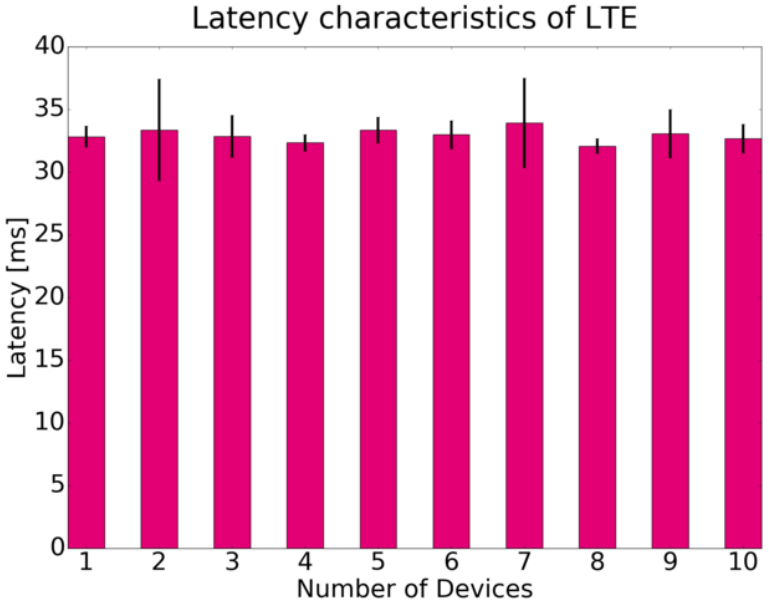

Through-put
Massive
Resilience
Security
Energy
Latency
Hetero-geneity
UC
UC
UC
UC
UC
5G
requirements

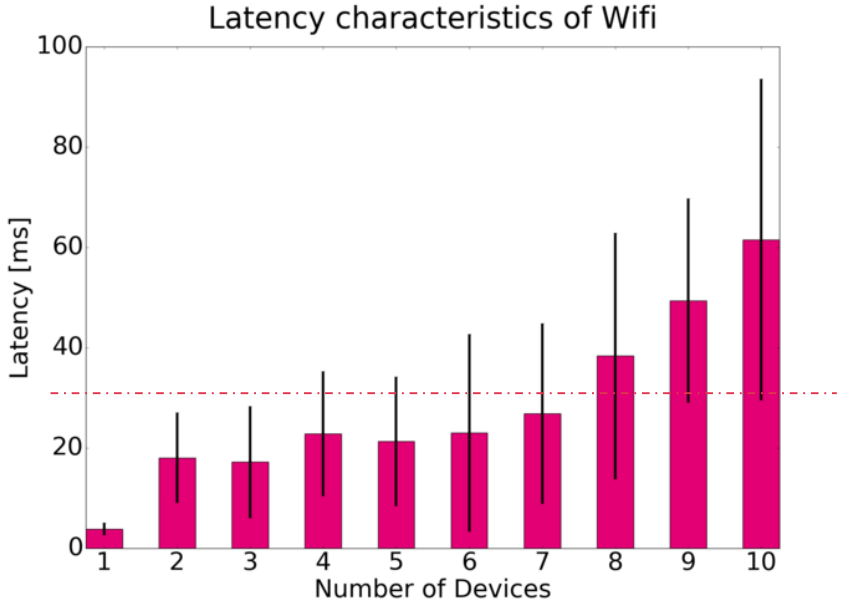

The 5G Atom
Sensor
Embedded Computing
Trans mitter
100 µs
Receiver
Software Ecosystem
Hosted Computing (decider)
Network Config. Manager (SON)
1ms
Actuator
Embedded Computing
Receiver
100 µs
Trans mitter
Latency Goals:
Σ = 0.2 ms
Air Interface
Σ = 0.3 ms
Terminal
Σ = 0.5 ms
Base Station & Compute
Latency
requirements
UC
UC
UC
UC
UC
5G

Impact of Latency on Efficiency



SoA Latency Values





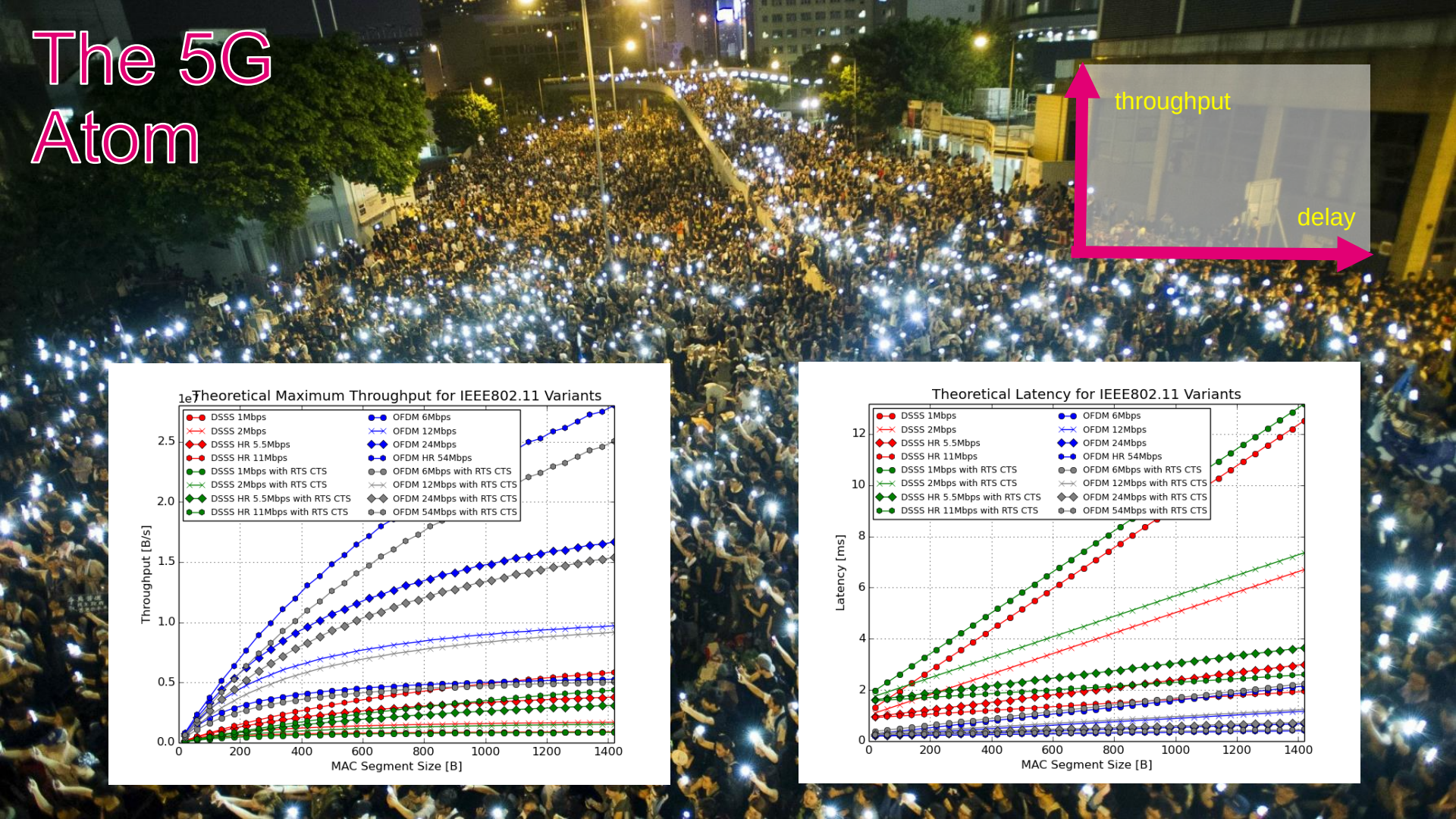
The gamers were the first ….

5G LAB GERMANY

The 5G Atom


throughput
delay
Through-put
Latency
requirements
UC
UC
UC
UC
UC
5G

The 5G Atom


throughput
delay

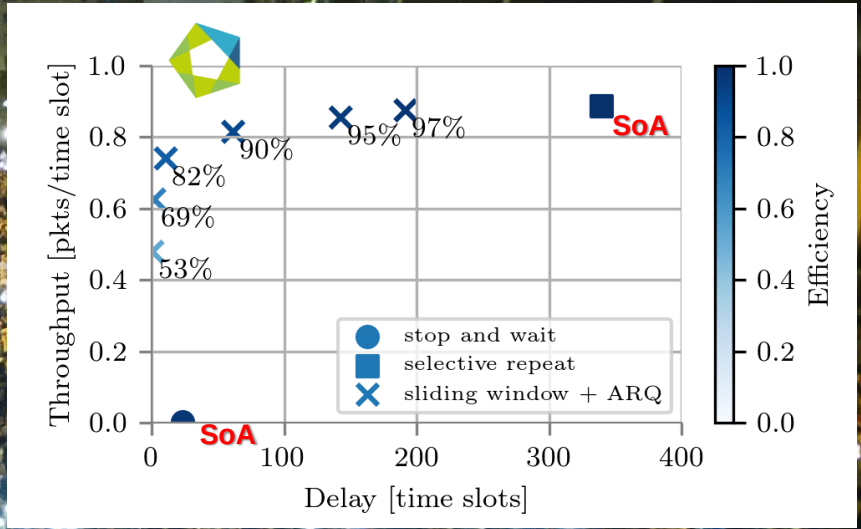
Theoretical Maximum Throughput for IEEE802.11 Variants
1e7
Throughput [B/s]
MAC Segment Size [B]
DSSS 1Mbps
DSSS 2Mbps
DSSS HR 5.5Mbps
DSSS HR 11Mbps
DSSS 1Mbps with RTS CTS
DSSS 2Mbps with RTS CTS
DSSS HR 5.5Mbps with RTS CTS
DSSS HR 11Mbps with RTS CTS
OFDM 6Mbps
OFDM 12Mbps
OFDM 24Mbps
OFDM HR 54Mbps
OFDM 6Mbps with RTS CTS
OFDM 12Mbps with RTS CTS
OFDM 24Mbps with RTS CTS
OFDM 54Mbps with RTS CTS

Theoretical Latency for IEEE802.11 Variants
Latency [ms]
MAC Segment Size [B]
DSSS 1Mbps
DSSS 2Mbps
DSSS HR 5.5Mbps
DSSS HR 11Mbps
DSSS 1Mbps with RTS CTS
DSSS 2Mbps with RTS CTS
DSSS HR 5.5Mbps with RTS CTS
DSSS HR 11Mbps with RTS CTS
OFDM 6Mbps
OFDM 12Mbps
OFDM 24Mbps
OFDM HR 54Mbps
OFDM 6Mbps with RTS CTS
OFDM 12Mbps with RTS CTS
OFDM 24Mbps with RTS CTS
OFDM 54Mbps with RTS CTS

The 5G Atom


throughput
delay
resilience
Through-put
Resilience
Latency
requirements
UC
UC
UC
UC
UC
5G

The 5G Atom



Through-put

Resilience

Latency

UC UC UC UC UC

5G

requirements

The 5G Atom


Content Delivery Networks
Network Slicing
Multi-Path
Mobile Edge Cloud
Through-put
Massive
Mesh
Resilience
Hetero-geneity
Security
Air Interface
Latency
Energy
concepts
requirements
UC
UC
UC
UC
UC
5G

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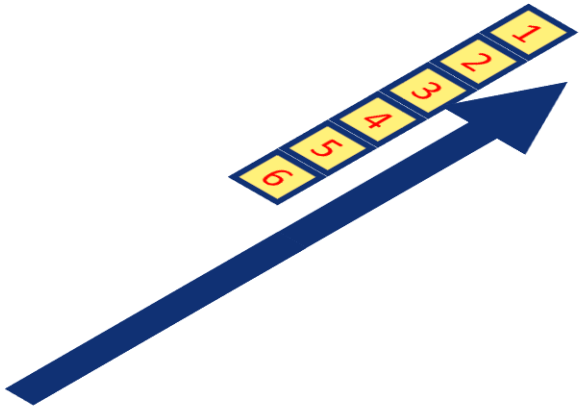
MULTI-PATH

Multi-Path Explanation



Single Path

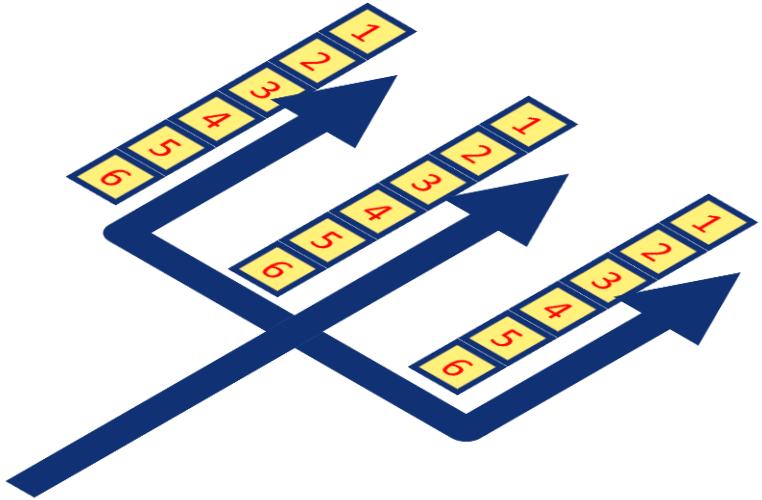
Throughput

Resilience

Security

Latency

Multi-Path Explanation



Multi-Path

Replication

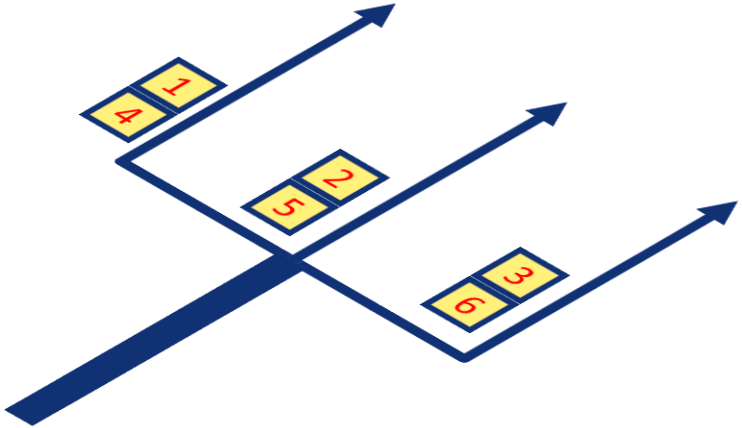
Throughput

Resilience

Security

Latency

Multi-Path Explanation



Multi-Path

Splitting

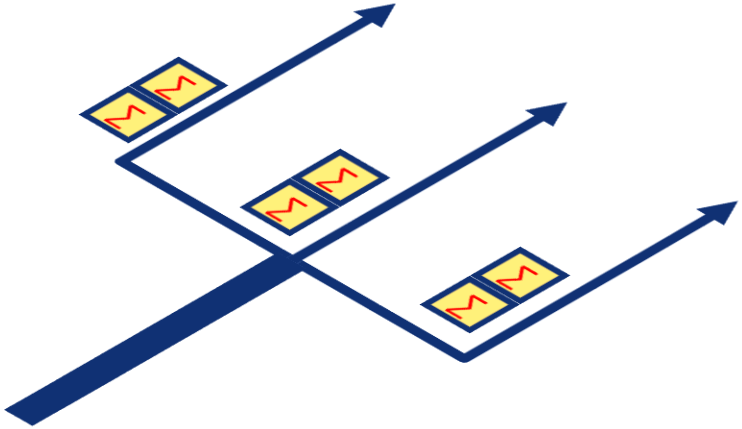
Throughput

Resilience

Security

Latency

Multi-Path Explanation



Multi-Path

Coding

Throughput

[redacted]

Resilience

[redacted]

Security

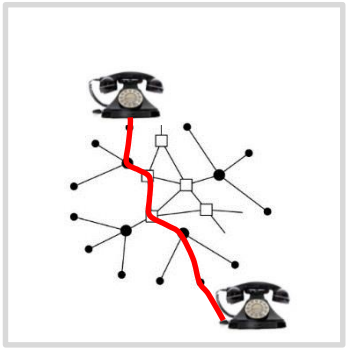
[redacted]

Latency

[redacted]

Communication Networks

Circuit Switched Networks

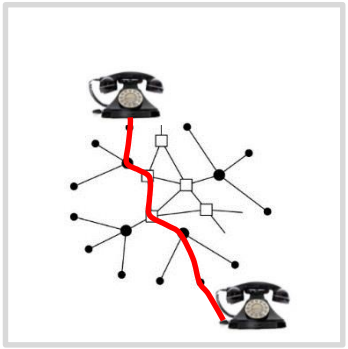


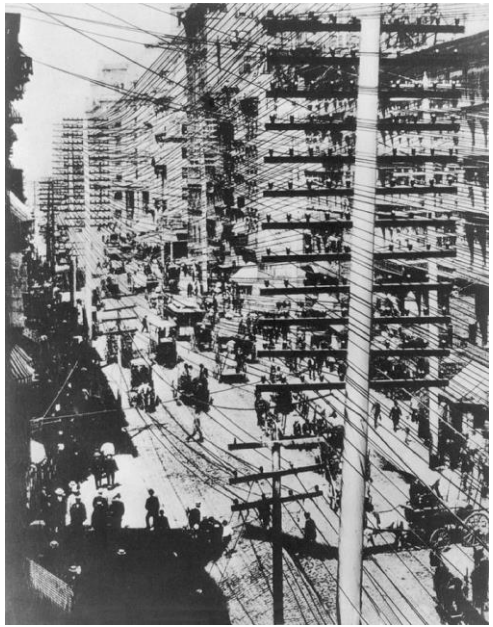
Voice

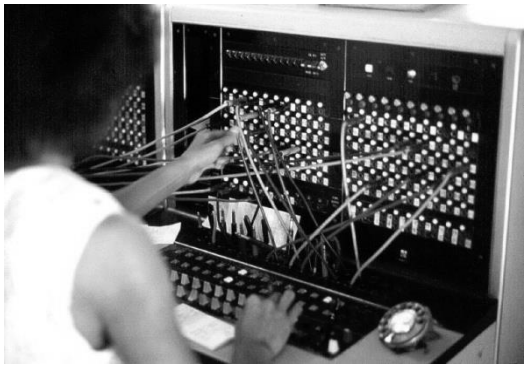
Places

Communication Networks

***Circuit* Switched Networks**



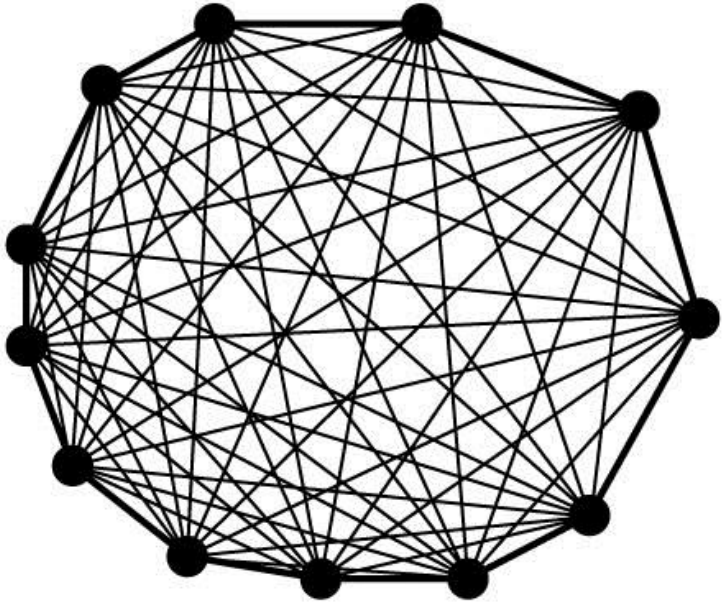


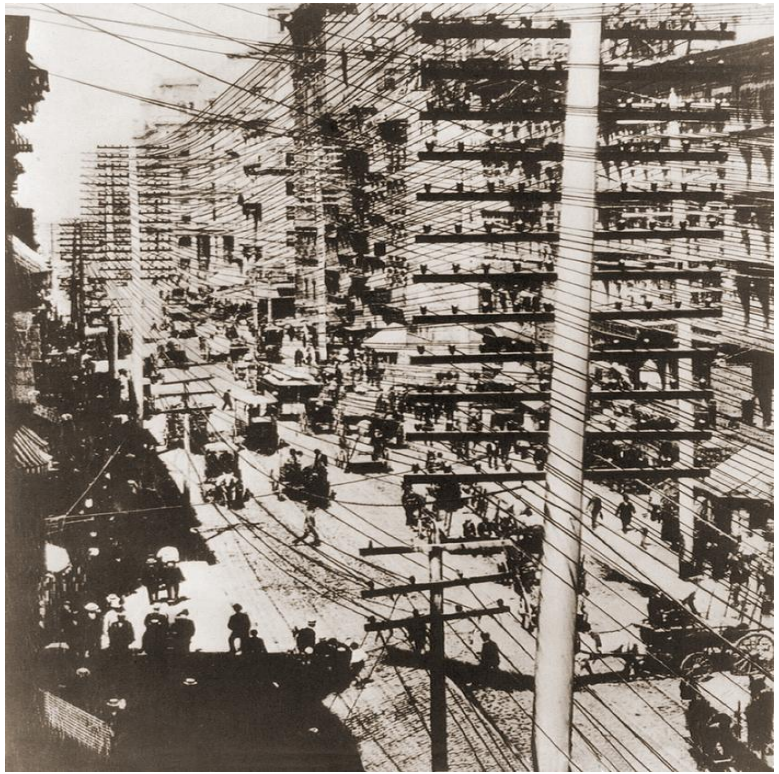


Voice

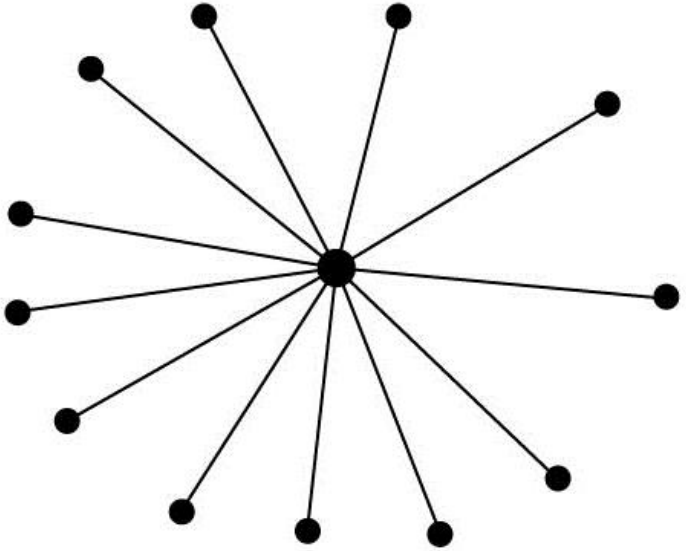
Places

The Telephone System

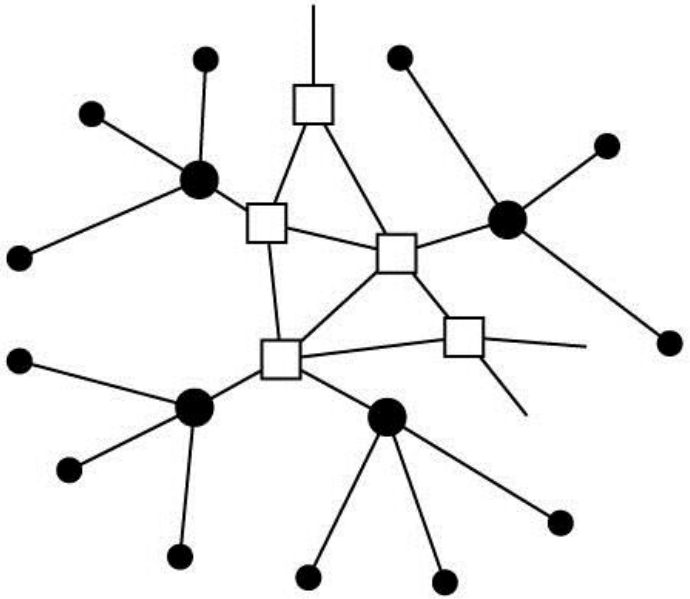


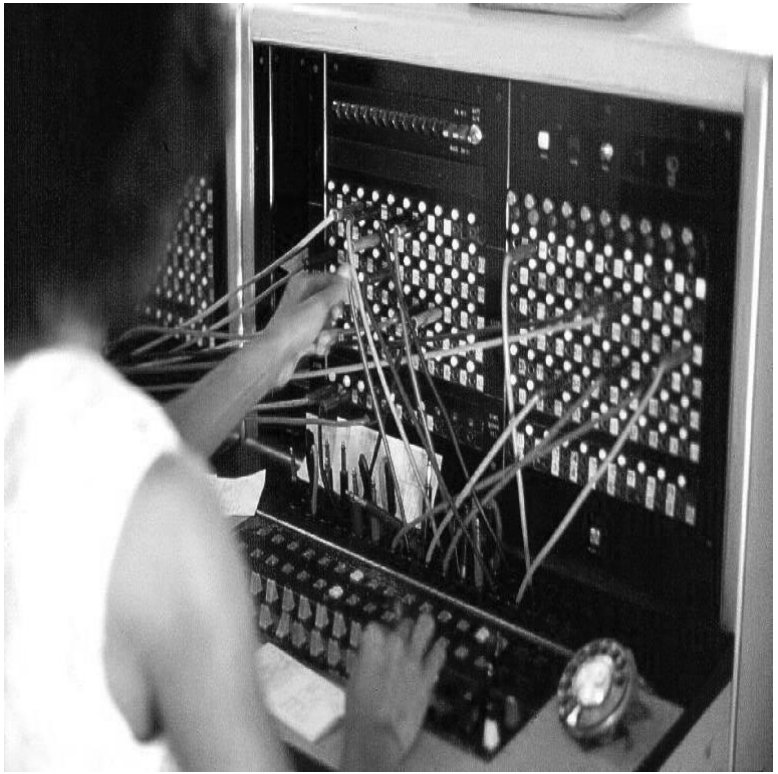


The Telephone System



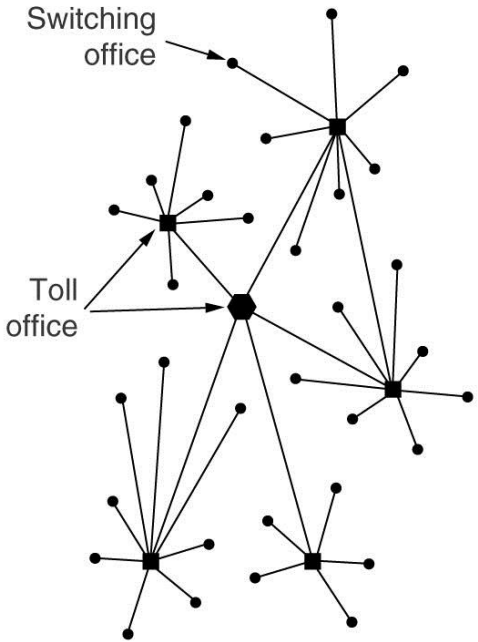
The Telephone System



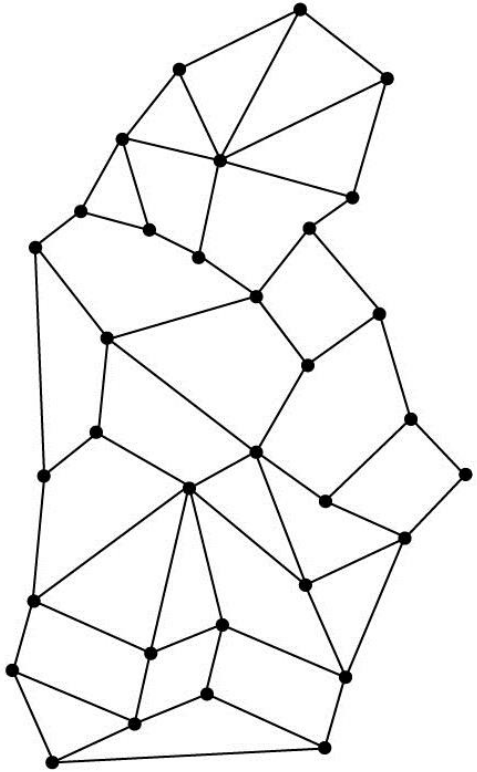


The Internet

Paul Baran 1969

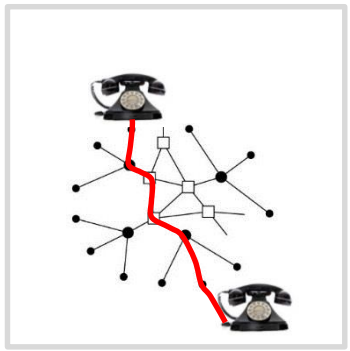


Circuit switched to packet switched



Communication Networks

***Circuit* Switched Networks**



Voice

Places

Revolution

***Packet* Switched Networks**

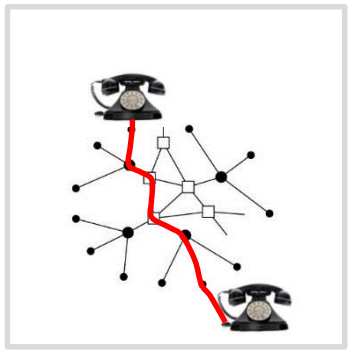
Data

Voice

People

Communication Networks

***Circuit* Switched Networks**



Revolution

***Packet* Switched Networks**

Voice

Places

Data

Voice

People

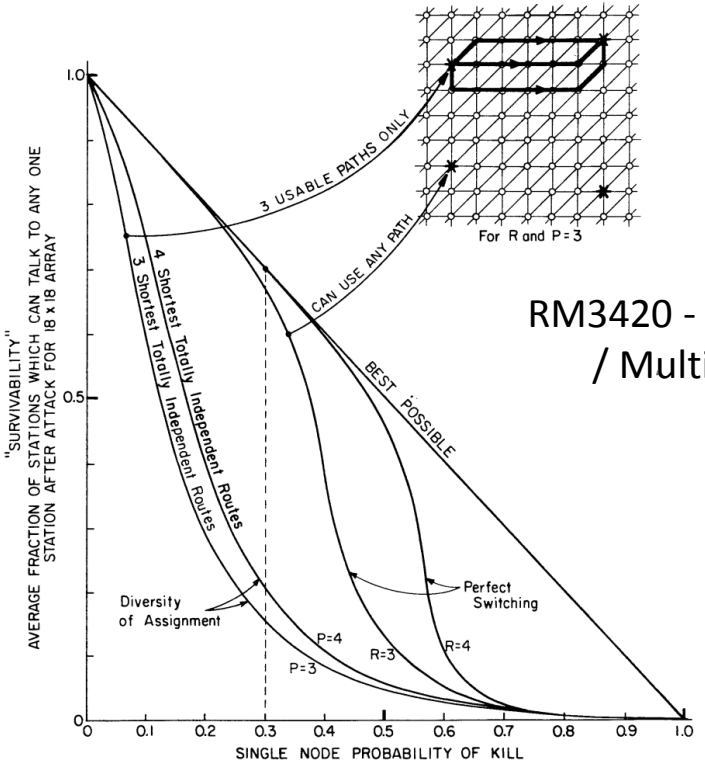
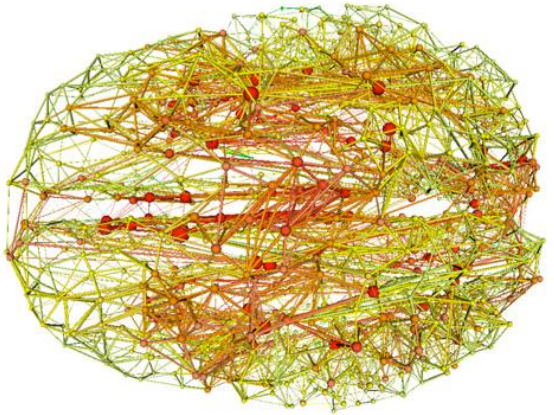


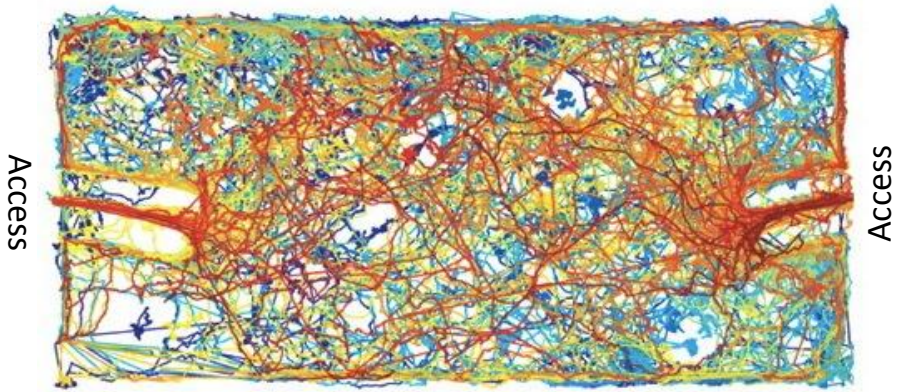
FIG. 8 — Diversity of Assignment vs. Perfect Switching in a Distributed Network.

RM3420 - Diversity / Multipath

Single Path vs. Multi Path

- Comparison with the **brain**
- Our brain uses multiple paths
- Reliability (Pain)





- Comparison with **ants**
- Food retrieval strategies

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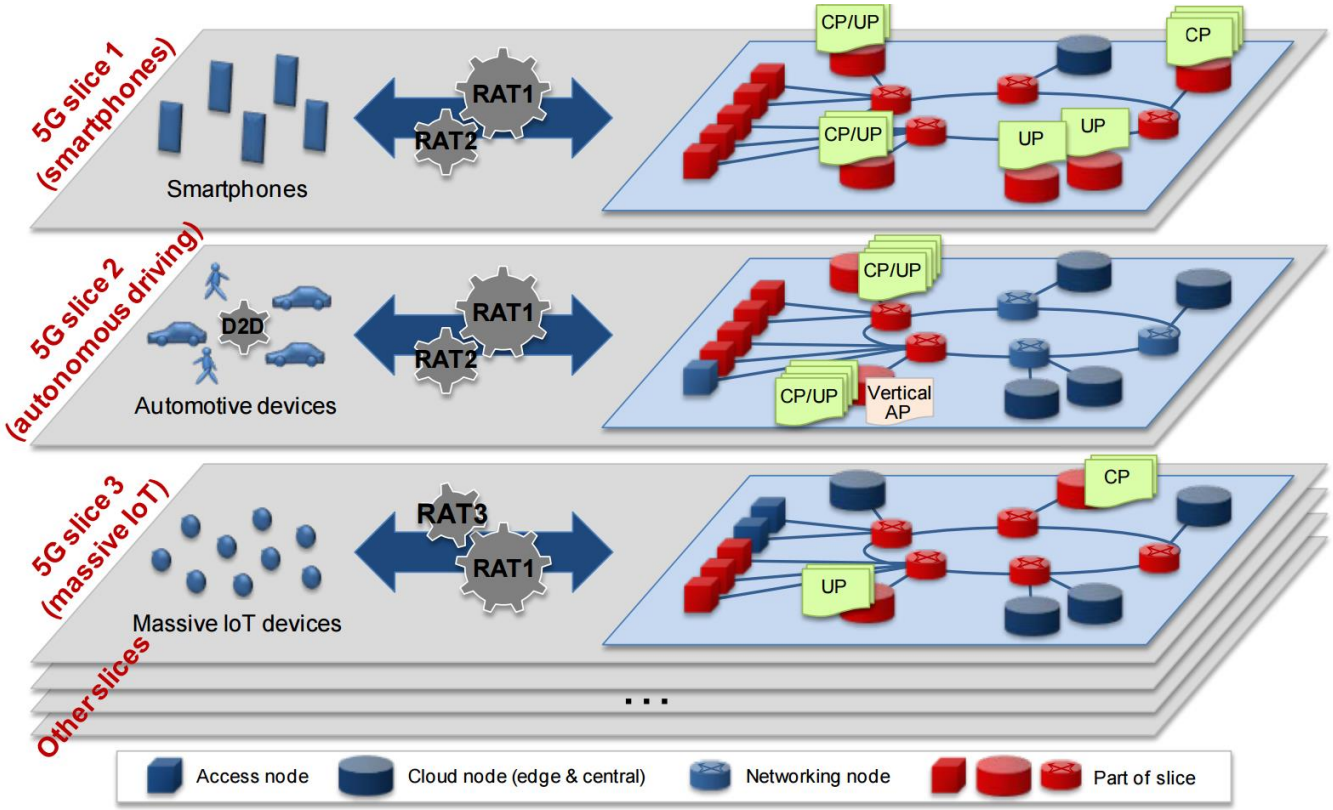
NETWORK SLICING

Network Slicing



NGMN Alliance, “5G White Paper”, White Paper, Feb. 2015.

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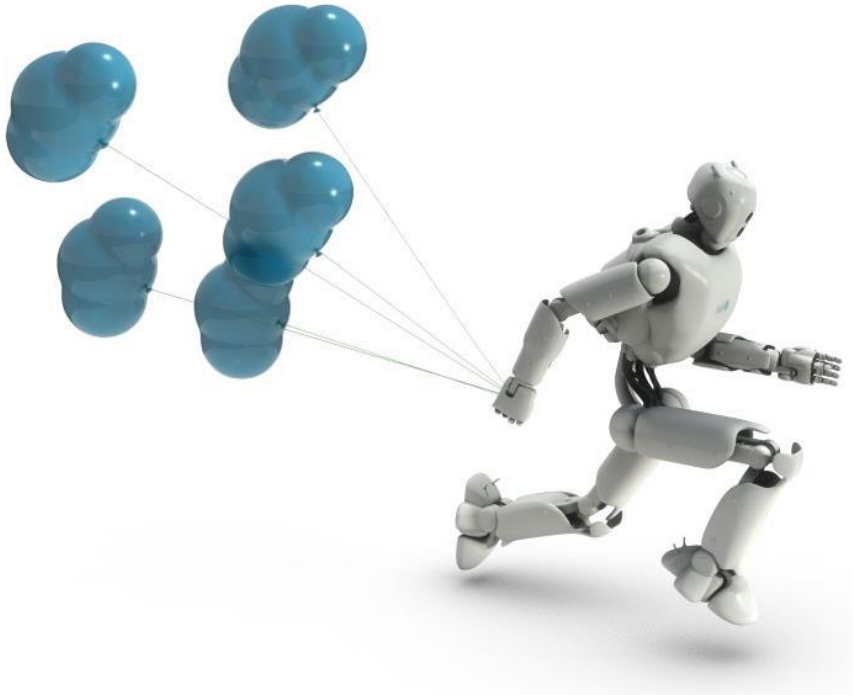
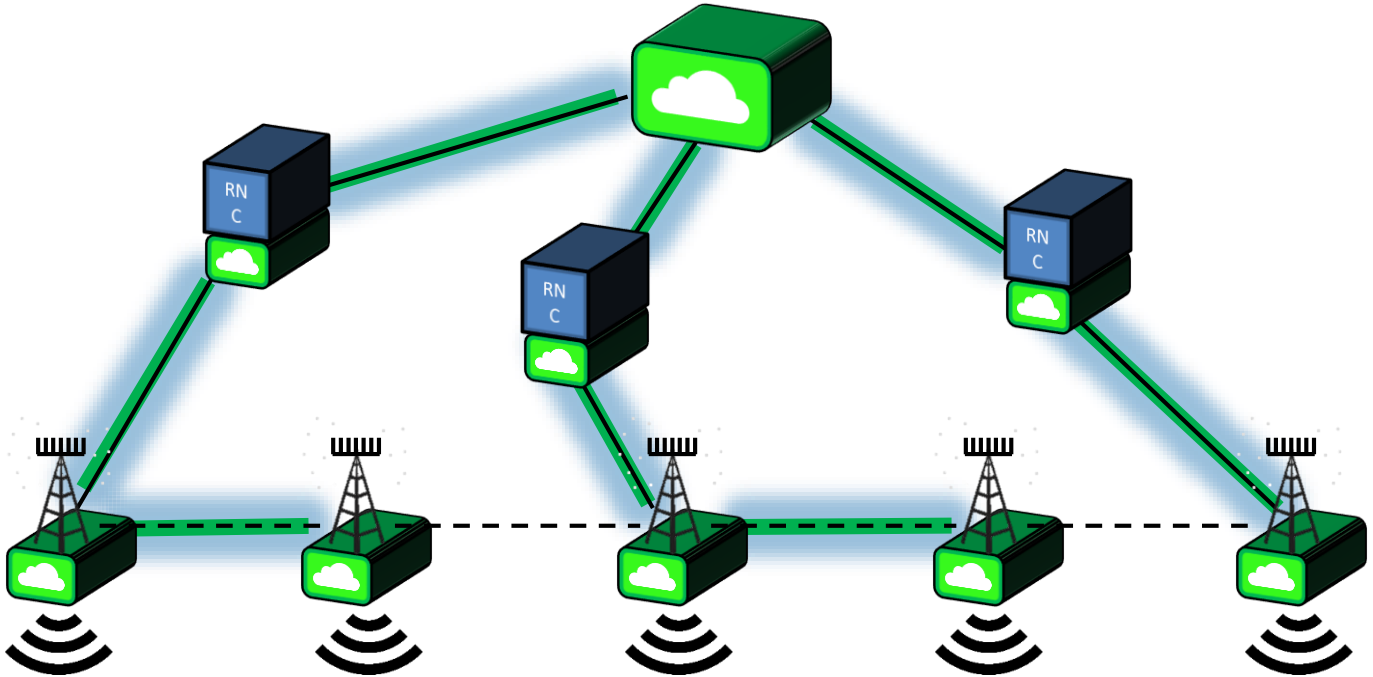
5G MOBILE EDGE CLOUD COMPUTING

Agile Distributed Mobile Edge Cloud

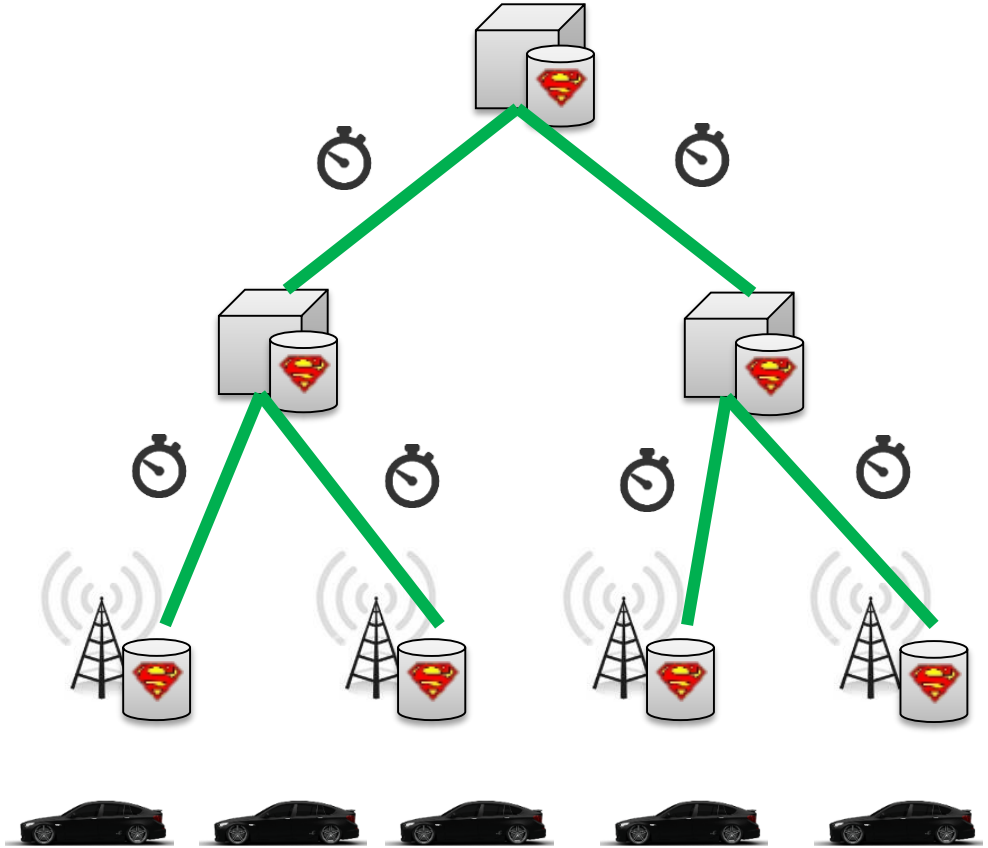
X



Mobile Edge Cloud / Micro Cloud / Cloud



Mobile Edge Cloud / Micro Cloud / Cloud



Communication and Control Units

openstack™

compute

storage

networking

Actuators and Sensors

Implementation Mobile Edge Cloud

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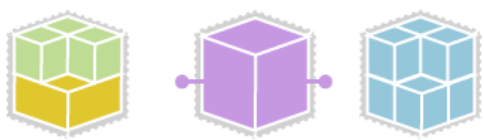
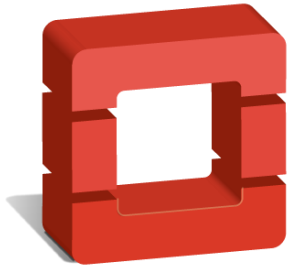
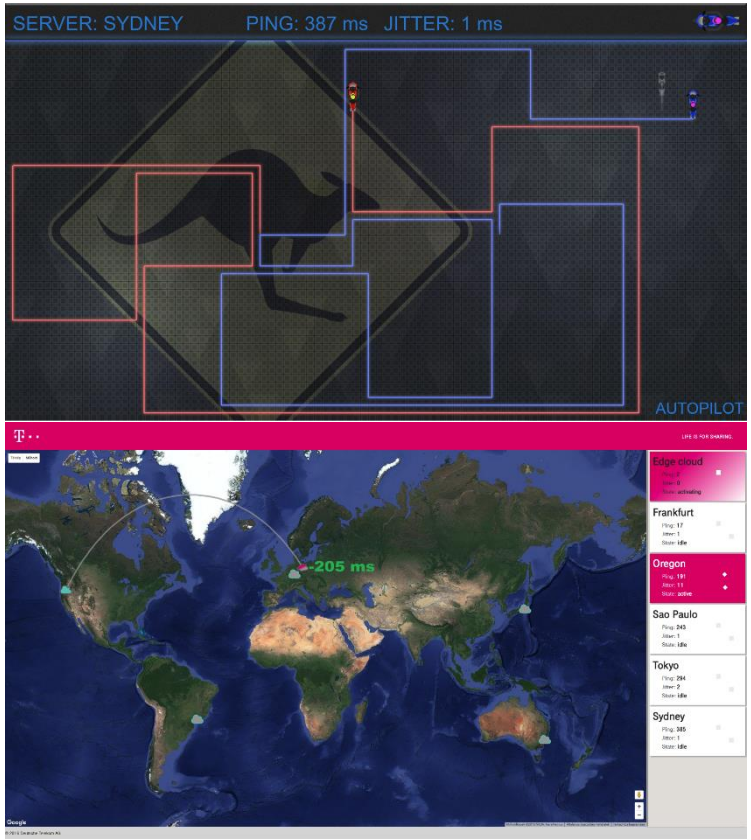
4 elements with 16 odroids each equals 512 cores controlled by openstack





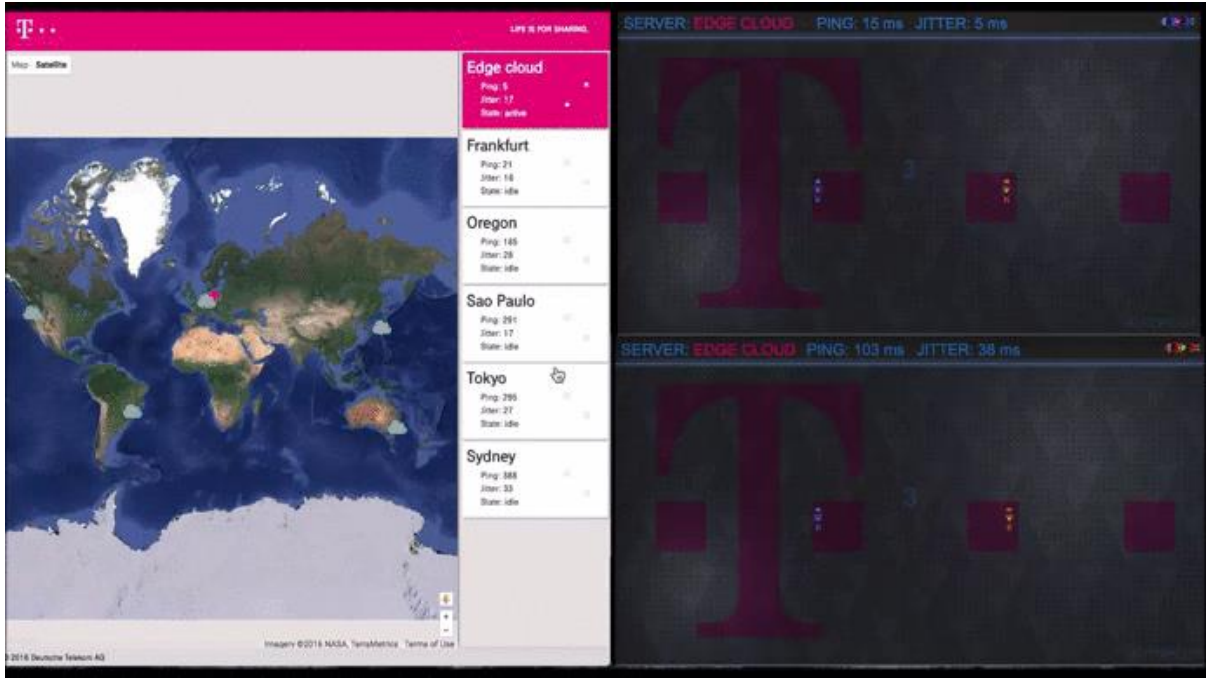
Mobile Edge Cloud Demo

- Browser based multiplayer game
- Game servers:
  - Run in the cloud, as a service
  - Latency to the cloud affects the game play (classic gamer's ping problem)
- Game can be migrated **LIVE** between the different cloud servers.
- Thus game always can run on the closest edge cloud server.



Mobile Edge Cloud Demo

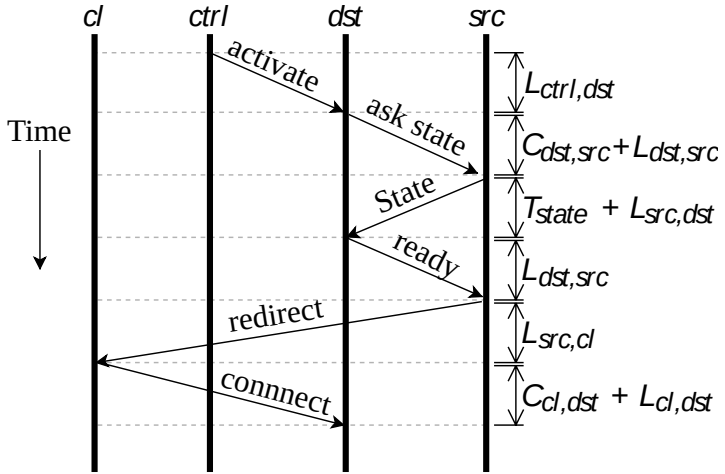
- Five cloud servers: Oregon (US), Frankfurt, Sao Paulo, Tokyo, Sydney
- One edge cloud
- Soft handover – Zero downtime.
- ‘Ghost’ bots to show latency effect
- Display latency, Jitter to each server.

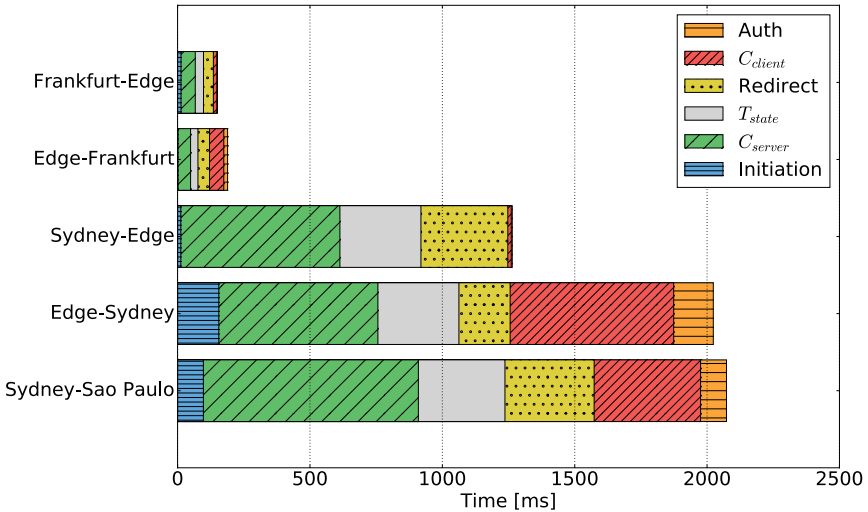



JITTER: 3.11 MS
LATENCY: 82 MS

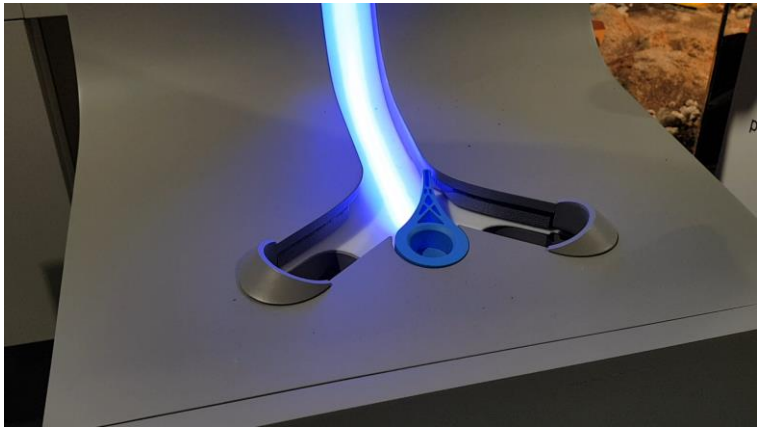
Mobile Edge Cloud Demo - Measurement

- Use of Agile Cloud Migration (ACM) protocol, designed at TUD.
- Handover time (not downtime) – Function of inter-server latency





Mobile Edge Demos



Mobile Edge Demos


The 5G Atom
SDR
NFV
SDN
ICN
Content Delivery Networks
Network Slicing
Multi-Path
Mobile Edge Cloud
Through-put
Massive
Resilience
Mesh
Hetero-geneity
Security
Air Interface
Latency
Energy
UC
UC
UC
UC
UC
5G
technologies
concepts
requirements

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5G SDR SDN NFV

Software Defined Radio

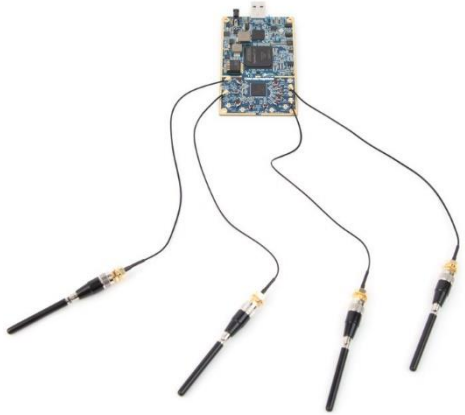
GNUradio

New kid on the block LimeSDR

Current activites at the chair

Interesting

- Low latency
- Network coding at the edge
- Analog network coding
- Multi connectivity



PreSDN - Active Networking

Active networking is a concept for communication networks that allows packets flowing through a telecommunications network to dynamically modify the operation of the network by means of protocols.

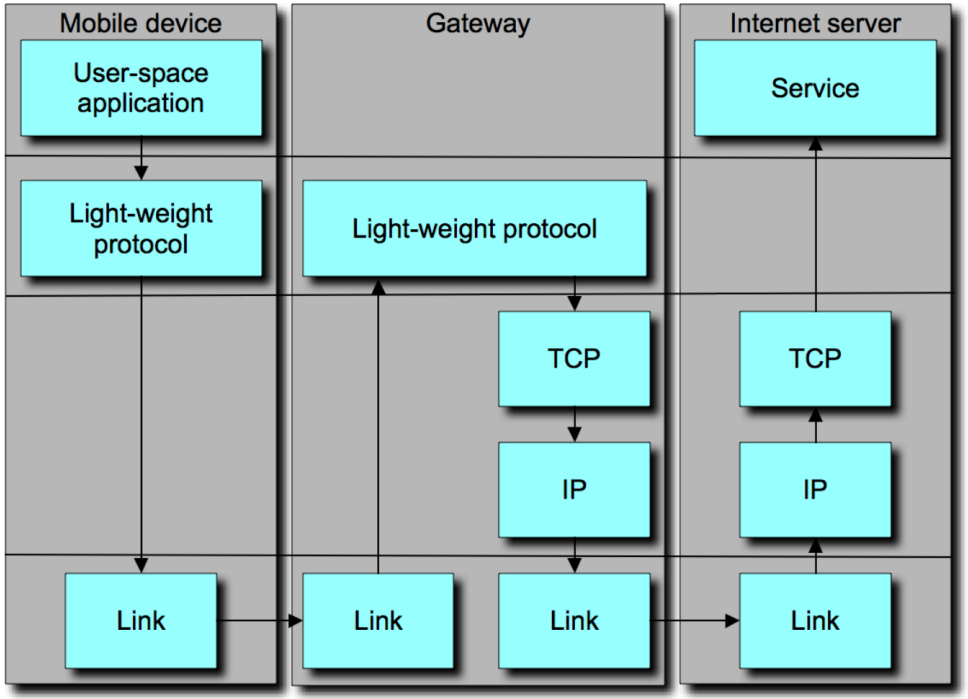
Changing protocols on the fly.

Change protocols on the need based on:

- Security protocols
- Complexity

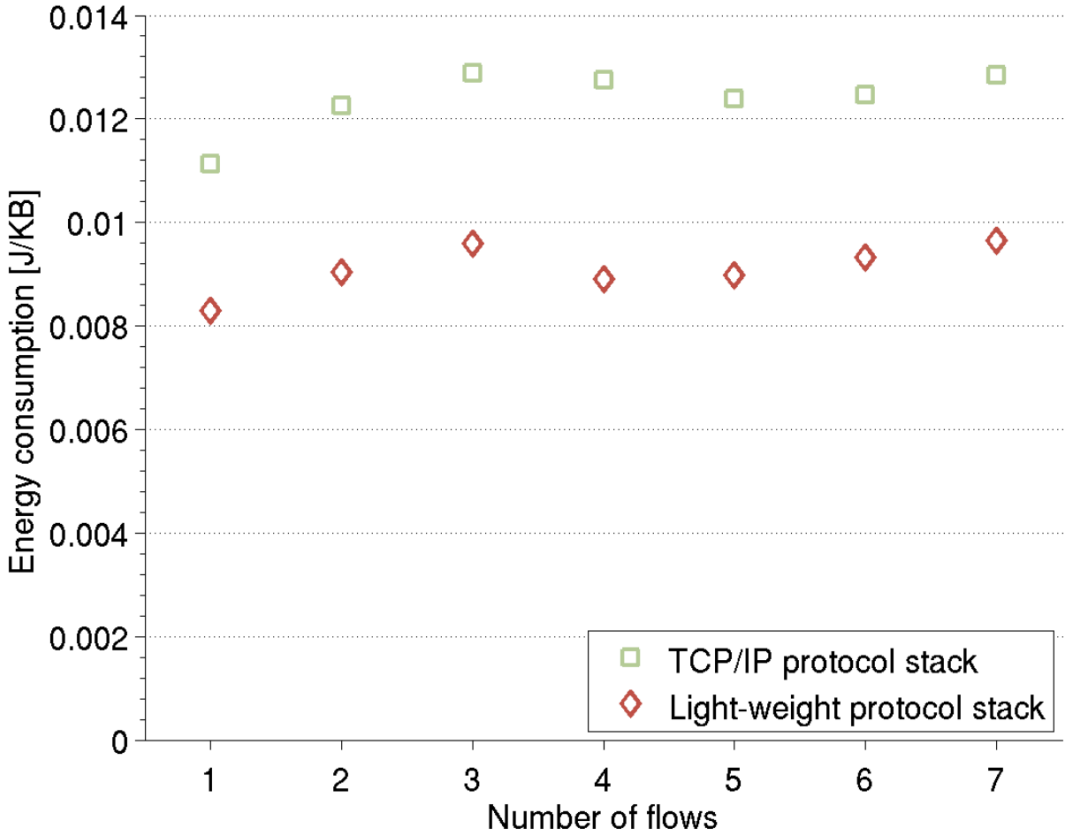
K. Revsbech, J. Heide, K. Hojgaard-Hansen, G.P. Perrucci, and F.H.P.Fitzek, “Energy saving potential using active networking on linux mobile phones,” in European Wireless 2009, Aalborg, Denmark, may 2009.

Active Networking Example



K. Revsbech, J. Heide, K. Hojgaard-Hansen, G.P. Perrucci, and F.H.P.Fitzek, “Energy saving potential using active networking on linux mobile phones,” in European Wireless 2009, Aalborg, Denmark, may 2009.

Active Networking



SDN & NFV

Software Defined Networks

SDN advocates to replace distributed static network protocols with centralized flexible software applications.

- Enables fast experiments with new ideas
- Fast deployment of software compared to long lasting standardization processes
- Optimization due to centralized control as a function of time
- New functionality can be deployed in nearly no time relocated, and upgradet depending on the needs.

Network Function Virtualisation (NFV)

NFV advocates to use generic hardware running software solution compared specialized hardware.

- Hardware becomes cheaper (COTS)
- Relocation of functionality to optimize network performance such as latency, capacity, etc.
- New functionality can be deployed in nearly no time relocated, and upgradet depending on the needs.

Motivation for SDN and NFV

SDN was motivated by the relation of ***computation*** and ***communication***, which led to new principles for ***software*** and ***networking***.

NFV was motivated by the flexibility, timely deployment and financial gains of ***cloud and OTT providers***, which was not available to ***network operators.***

SDN and NFV are often intertwined

Motivation for SDN and NFV

SDN was motivated by the relation of ***computation*** and ***communication***, which led to new principles for ***software*** and ***networking***.

communication

computation

computation and ***communication***

Benefits & Promises of NFV

- Reduced equipment costs (CAPEX), through consolidating equipment and economies of scale of IT industry.
- Increased speed of time to market, by minimising the typical network operator cycle of innovation.
- Availability of network appliance multi-version and multi-tenancy, allows a single platform for different applications, users and tenants.
- Enables a variety of eco-systems and encourages openness.
- Encouraging innovation to bring new services and generate new revenue streams.

Benefits & Promises of NFV

- Flexibility to easily, rapidly, dynamically provision and instantiate new services in various locations
- Improved operational efficiency by taking advantage of the higher uniformity of the physical network platform and its homogeneity to other support platforms.
- Software-oriented innovation to rapidly prototype and test new services and generate new revenue streams
- More service differentiation & customization with reduced (OPEX) operational costs: reduced power, reduced space, improved network monitoring
- IT-oriented skillset and talent

SDN/NFV Demo


The 5G Atom
novelty
Machine learning
SDR
NFV
Network Coding
Block Chaining
Content Delivery Networks
Network Slicing
SDN
Com-pressed Sensing
Multi-Path
Through-put
Massive
Mobile Edge Cloud
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Hetero-geneity
Resilience
technologies
Security
concepts
Air Interface
Latency
UC
UC
UC
UC
UC
5G
Energy
requirements

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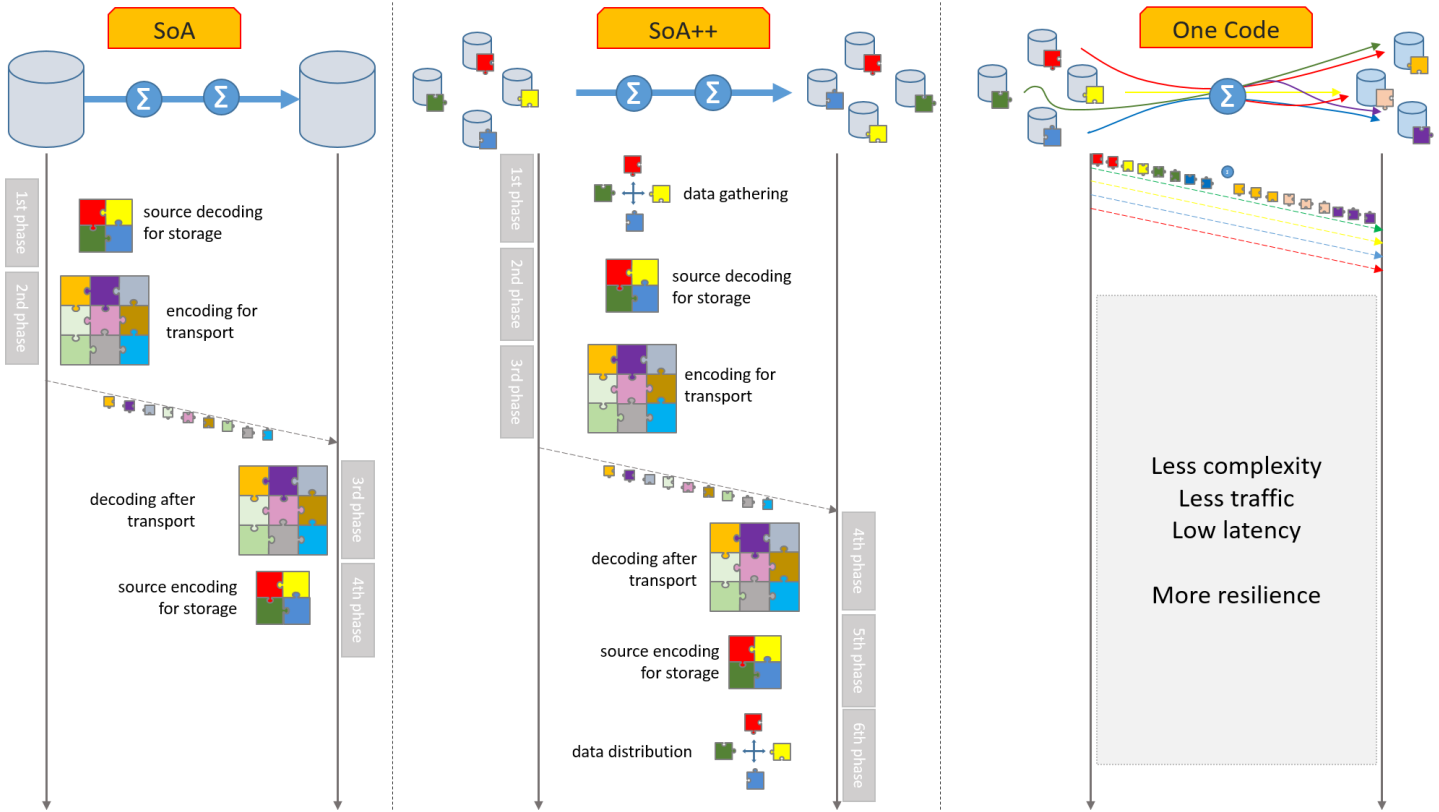
GERMANY

5G COMPRESSED SENSING

Advantage of NC over SoA Codecs




ONE CODE
TO RULE THEM ALL!

Compressed Sensing and Network Coding Characteristics

Compressed Sensing

- Linear superposition
- Random (sampling)
- Source aware
- Sparsity
- Under-determined
- Optimisation problem

$$y^{m\times 1} = A^{m\times n} x^{n\times 1}, m \ll n$$

Network Coding

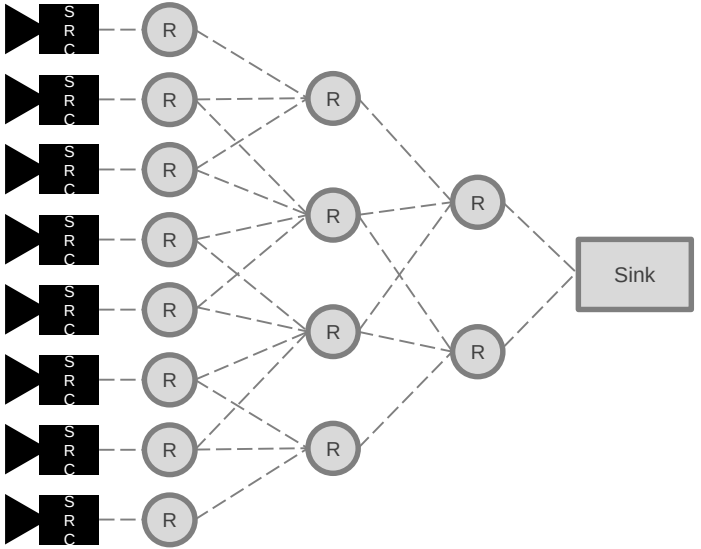
- Linear superposition
- Random (coefficients)
- Source agnostic

- Over-determined (full rank)
- Linear system of equations

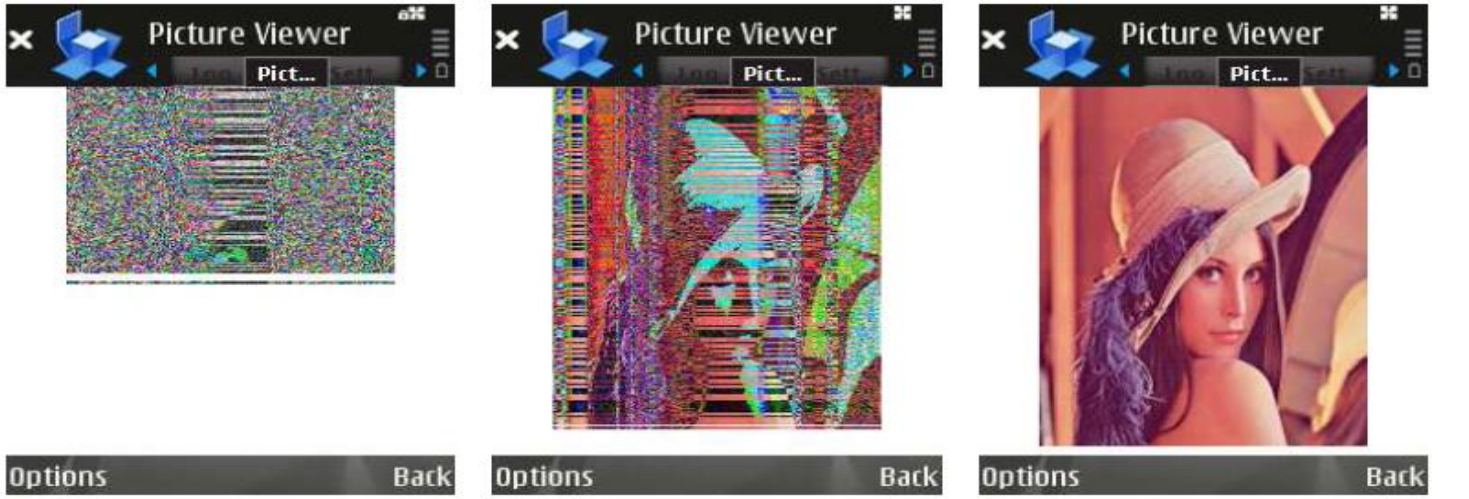
$$y^{(n+r)\times 1} = A^{(n+r)\times n} x^{n\times 1}, r \geqslant 0$$

Combine NC and CS

- Objective: Combine CS and NC (analog and digital) in theory and implementation to improve delay ↓, resilience ↑ and complexity ↓.
- Agnostic combination CS/NC: Only individual gain per camera (spatial correlation not exploited), reconstruction/decoding at the sink resulting in high complexity
- Proposed joint CS/NC design (analog and digital): Holistic in-network processing based on compressed compute and forward (CCF) with distributed partial decoding and clever protocol design (active sensing).



Motivation – Pure Network Coding in GF2 (2009)

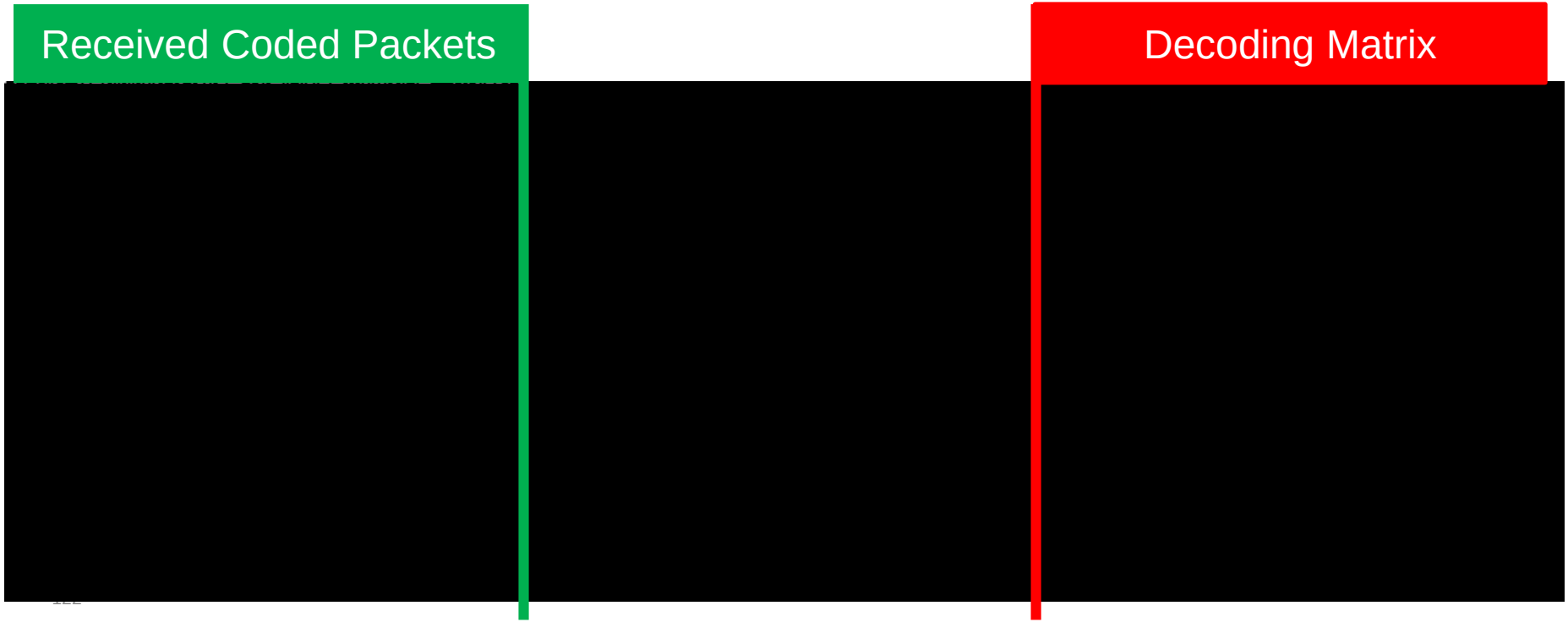


$$\begin{pmatrix} \alpha_{1,1} & \alpha_{1,2} & \alpha_{1,3} & \alpha_{1,4} \\ \alpha_{2,1} & \alpha_{2,2} & \alpha_{2,3} & \alpha_{2,4} \end{pmatrix} \begin{pmatrix} \alpha_{1,1} & \alpha_{1,2} & \alpha_{1,3} & \alpha_{1,4} \\ \alpha_{2,1} & \alpha_{2,2} & \alpha_{2,3} & \alpha_{2,4} \\ \alpha_{3,1} & \alpha_{3,2} & \alpha_{3,3} & \alpha_{3,4} \end{pmatrix} \begin{pmatrix} \alpha_{1,1} & \alpha_{1,2} & \alpha_{1,3} & \alpha_{1,4} \\ \alpha_{2,1} & \alpha_{2,2} & \alpha_{2,3} & \alpha_{2,4} \\ \alpha_{3,1} & \alpha_{3,2} & \alpha_{3,3} & \alpha_{3,4} \\ \alpha_{4,1} & \alpha_{4,2} & \alpha_{4,3} & \alpha_{4,4} \end{pmatrix}$$

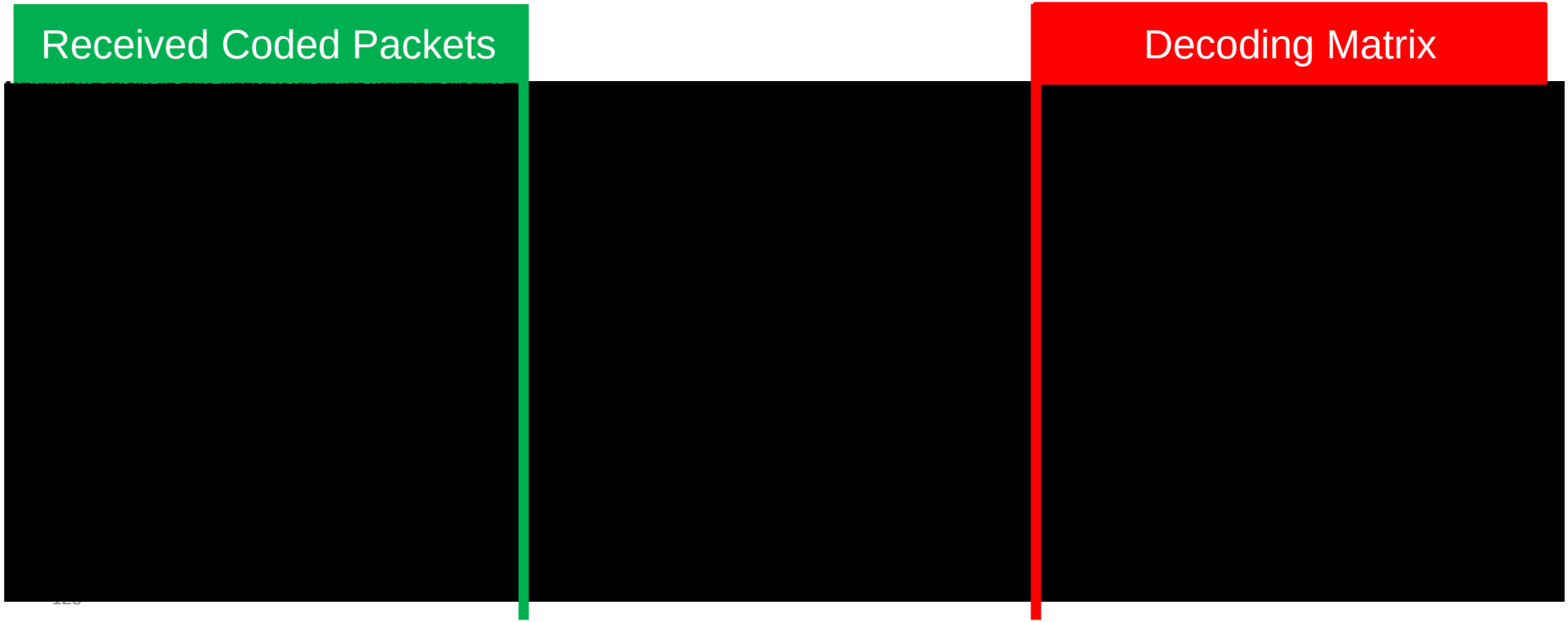
Sparsity in the field size!

MV Pedersen, J Heide, FHP Fitzek, T Larsen; PictureViewer-a mobile application using network coding; European Wireless Conference, 2009; EW 2009; pages 151-156.

Motivation – Pure Network Coding in GF2

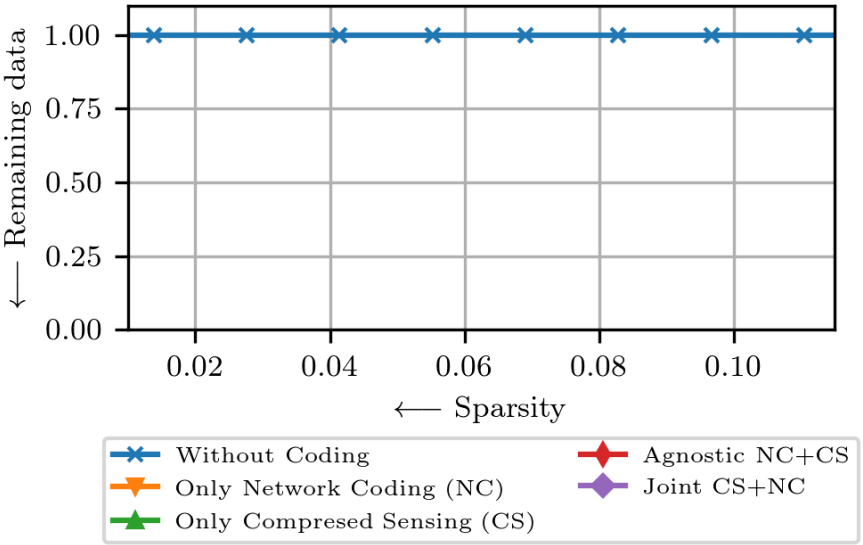


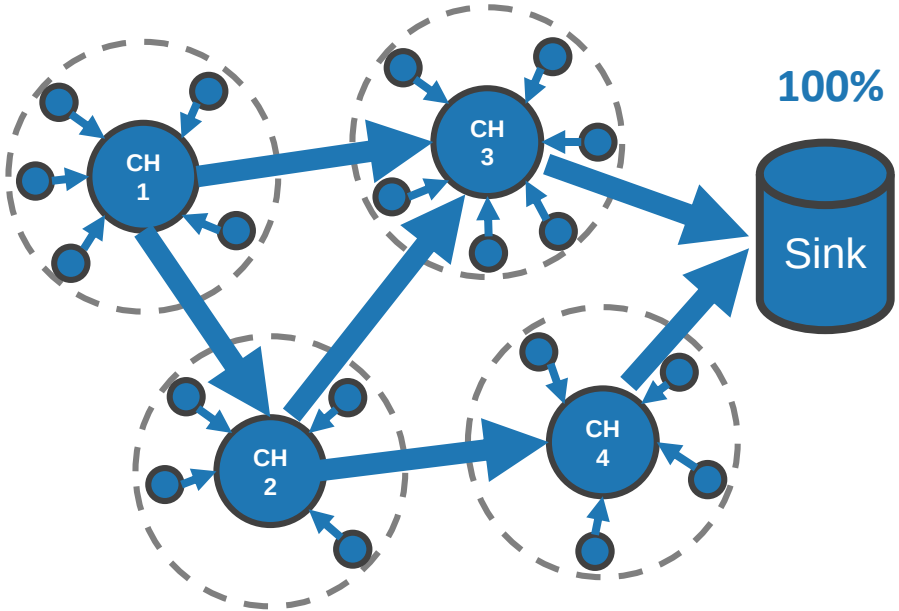
Motivation – Network Coding in GF2 with Sorting



Results – Phase I

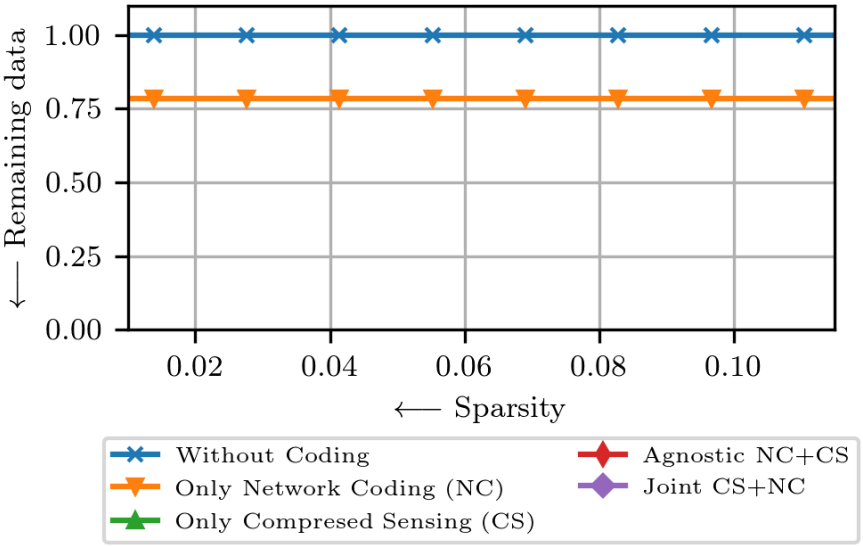
Performance Evaluation

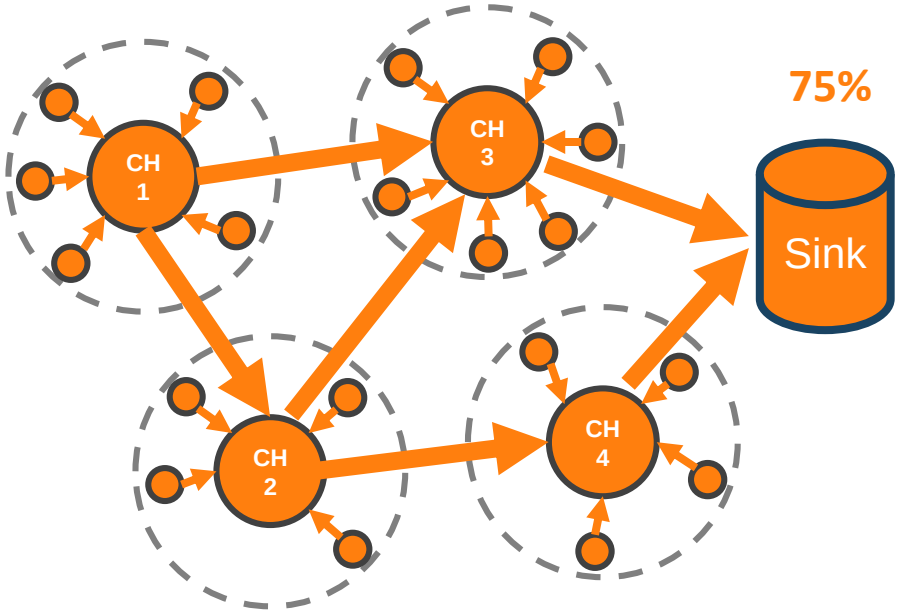




Results – Phase I

Performance Evaluation





Results – Phase I

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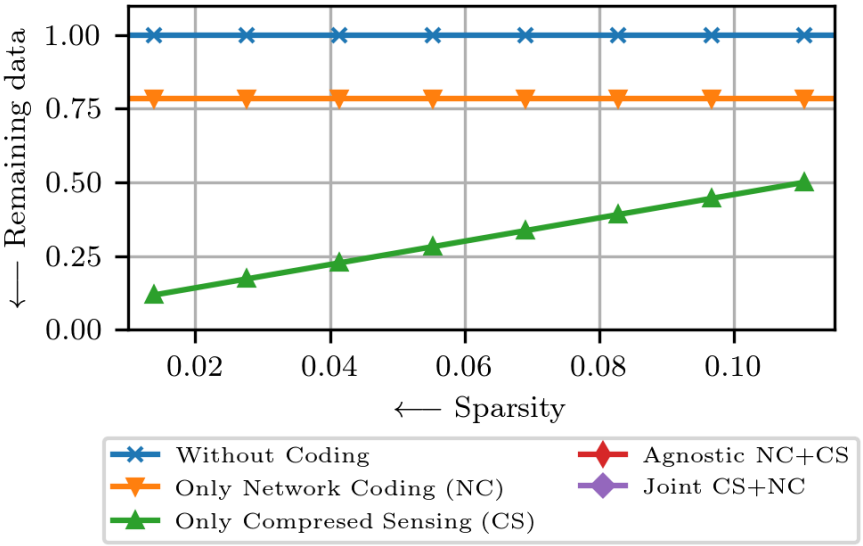

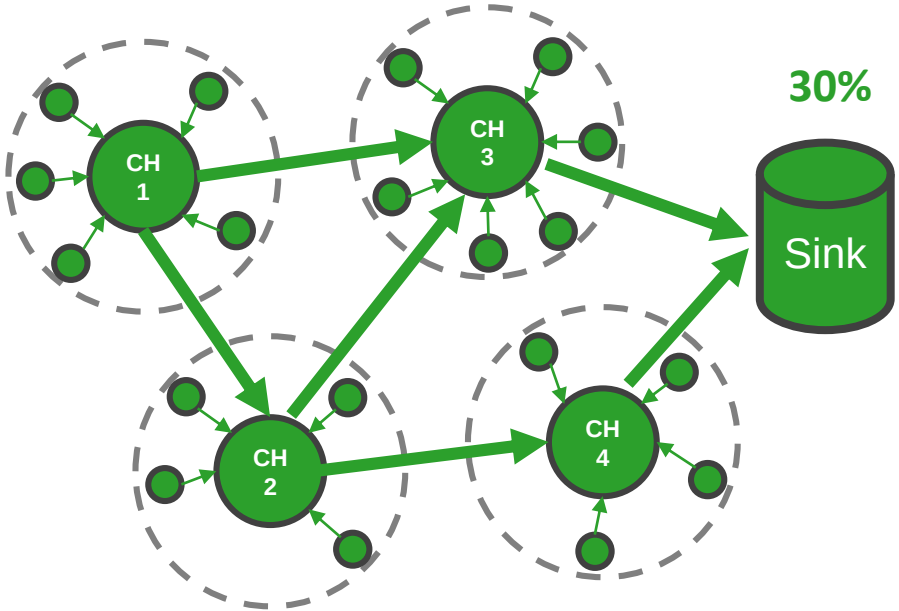

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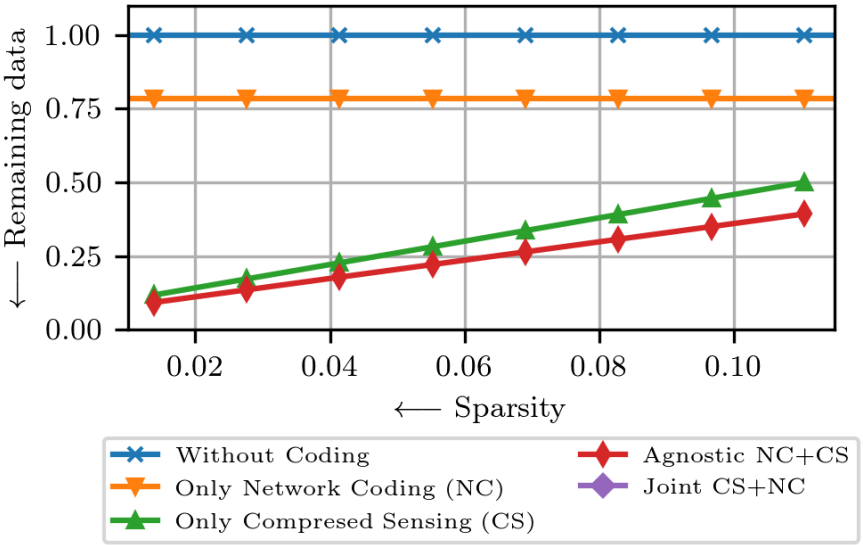

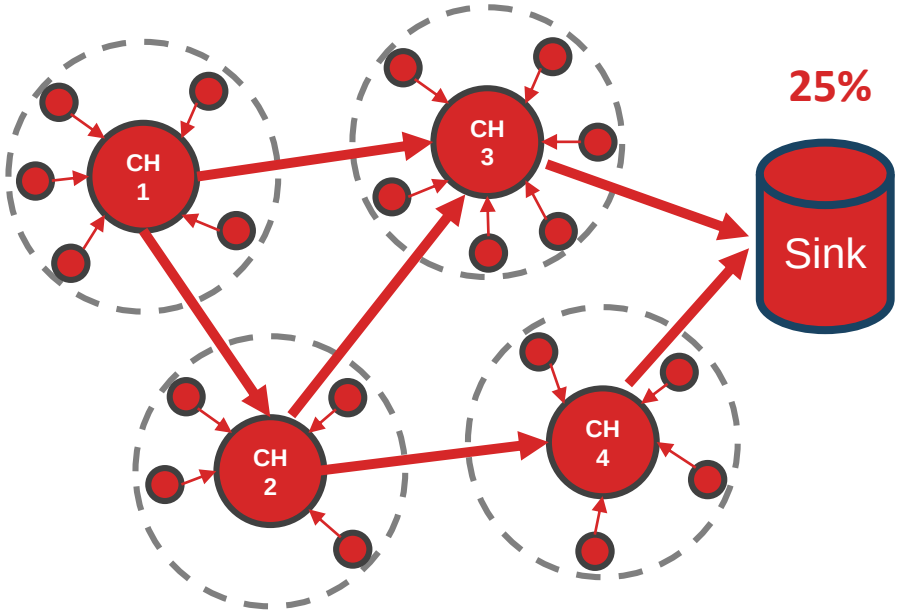

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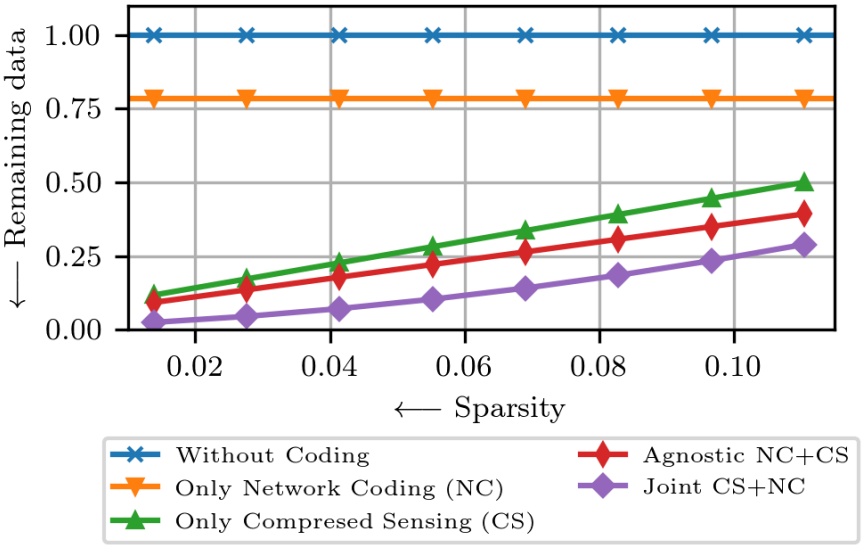

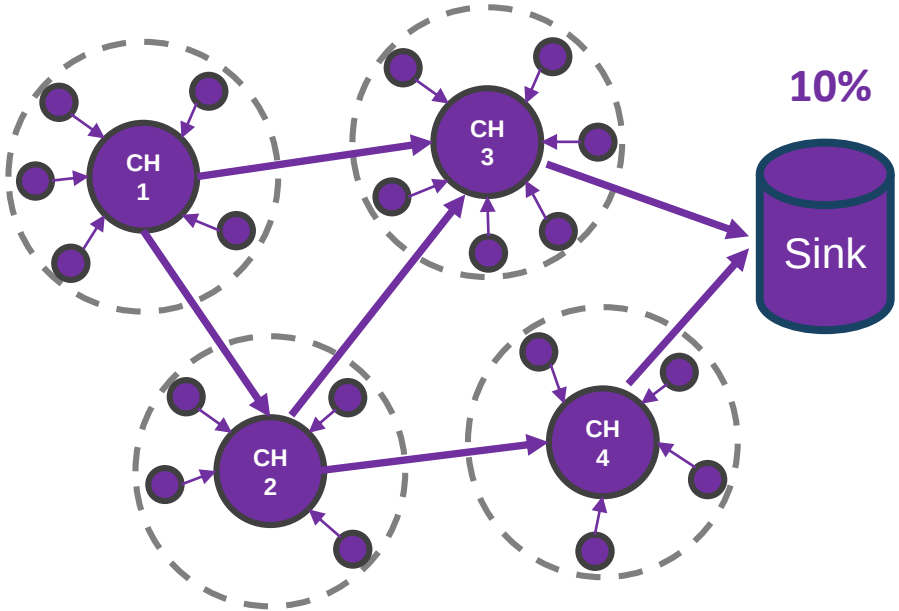

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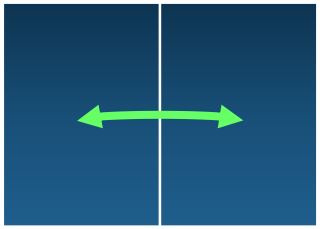
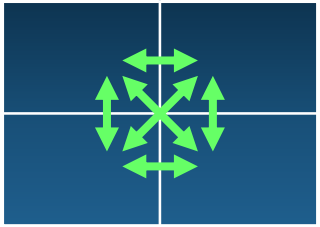
5G SILICON

Communication Bottleneck of Parallel Computing



Parallelism = 2
Comm. Links = 1

P = 16
C = 120



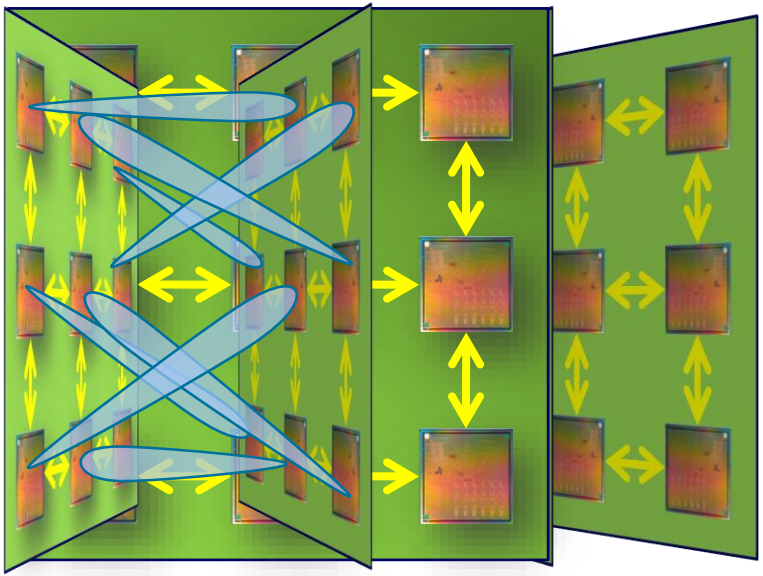
P = 4
C = 6

P = 32
C = 496

P = 8
C = 28

P = 64
C = 2016

Highly Adaptive Energy-Efficient Computing
High-Rate Inter-Chip Communications



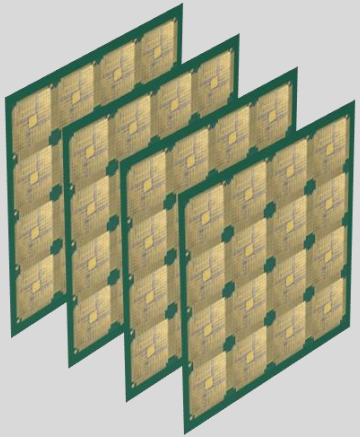
Optical Interconnect
- adaptive analog/digital circuits for e/o transceiver
- embedded polymer waveguide
- packaging technologies (e.g. 3D stacking of Si/III-V hybrids)
- 90° coupling of laser

Radio Interconnect
- Top-of-3D-stack antenna arrays
- analog/digital beam steering and interference minimization
- 100Gb/s – 1Tb/s
- 25 GHz channel @ 200GHz carrier
- 3D routing & flow management

The Outlook: The HAEC Box in 2030+

Assume 64K processors per chip

160x chips stacked in 3D



4x4 chip-stacks, double-sided board

4x boards in a box

HAECBox

10m² Si

in 10x10x10 cm³ (1 liter) ➔ **10^8 processors!**

1.6K processor + 16K memory chips ➔ **10^4x performance of today!**

HAEC Playground

- Compute-cluster: Multiple compute units
  - Compute node: quad-core Odroid (bigLITTLE)
  - 4 modules x 4 boards x 4 Odroids (~ 1000 cores in total)
- Controller: Manages compute units
  - Inter-connected per-layer controllers
  - Controls network configuration and processes
- Network: Realizes flexible topology
  - Single switch per layer (managed & stackable)
  - Flexible reconfiguration according to chosen scenarios
- Gateway: Connects to external network
  - Single gateway per cluster
  - Separation of internal from external network

- API for HAEC Hardware: USB 3.0, SPI & I2C, GPIO
- API for HAEC Software:
  - Virtualization over all cores and storage places
  - Using OpenStack as cloud operating system

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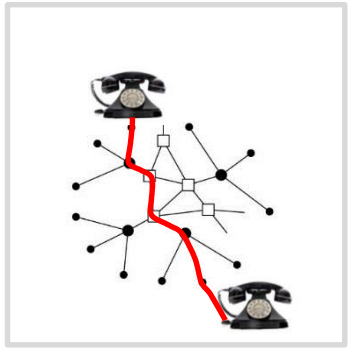
COMMUNICATION NETWORKS

Communication Networks

***Circuit* Switched Networks**



Voice

Places

Revolution

***Packet* Switched Networks**

Data

Voice

People

Technical Challenges

Massive throughput

Massive reduction in delay

Massive resilience

Massive safety & security

Massive heterogeneity

Massive sensing

Massive energy saving

Use Cases

Internet of Things (IoT)

Smart Grids

Remote Cars

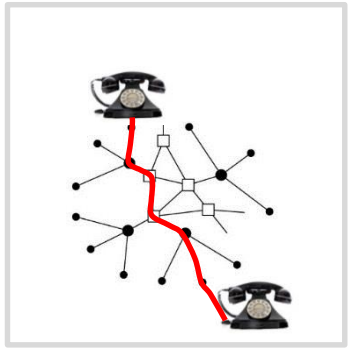
eHealth

Flying Internet

Robotics

Communication Networks

***Circuit* Switched Networks**



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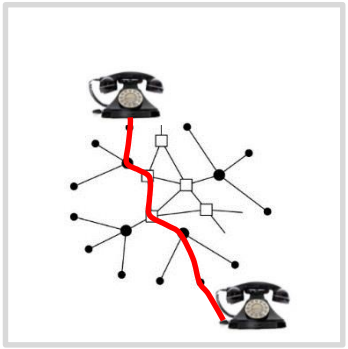

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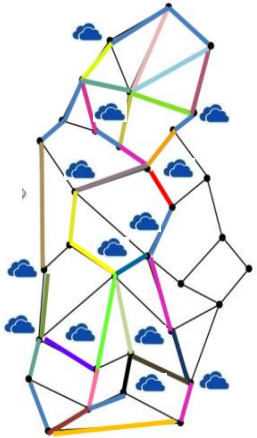
***Code* Centric Networks**



Control

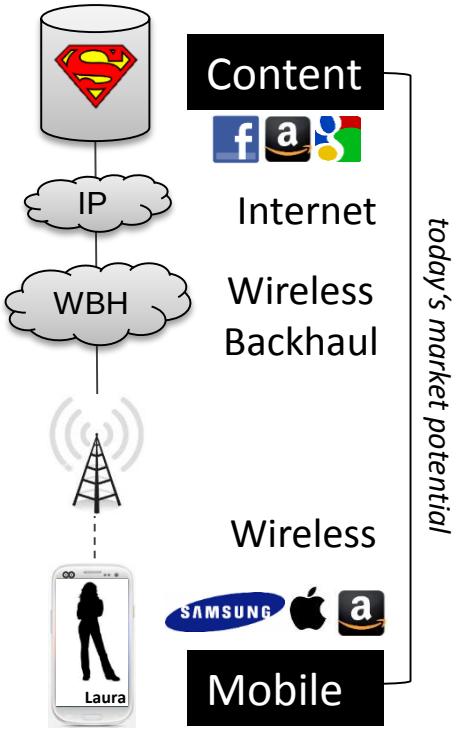
Data

Voice

Things

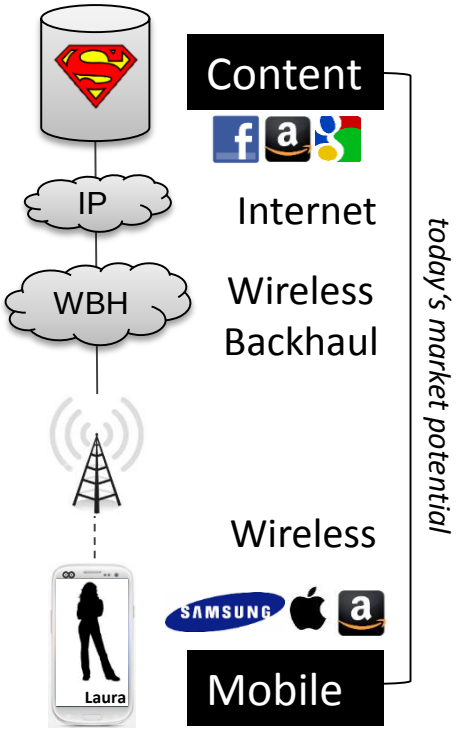
5G the game changer

4G and before



5G the game changer

4G and before



5G the game changer

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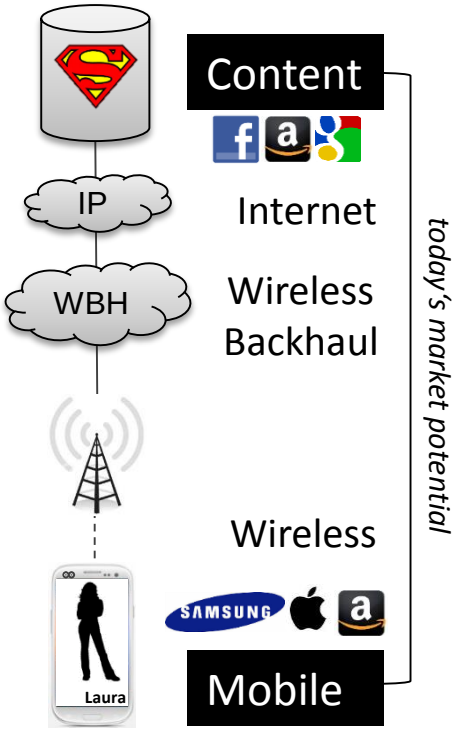


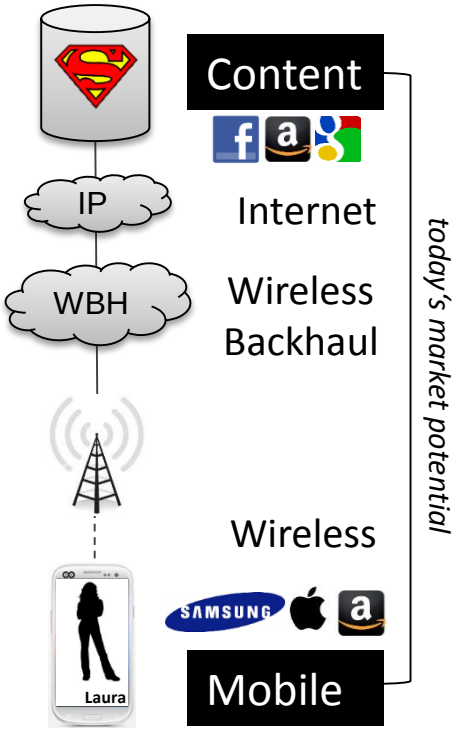
API available

No API available

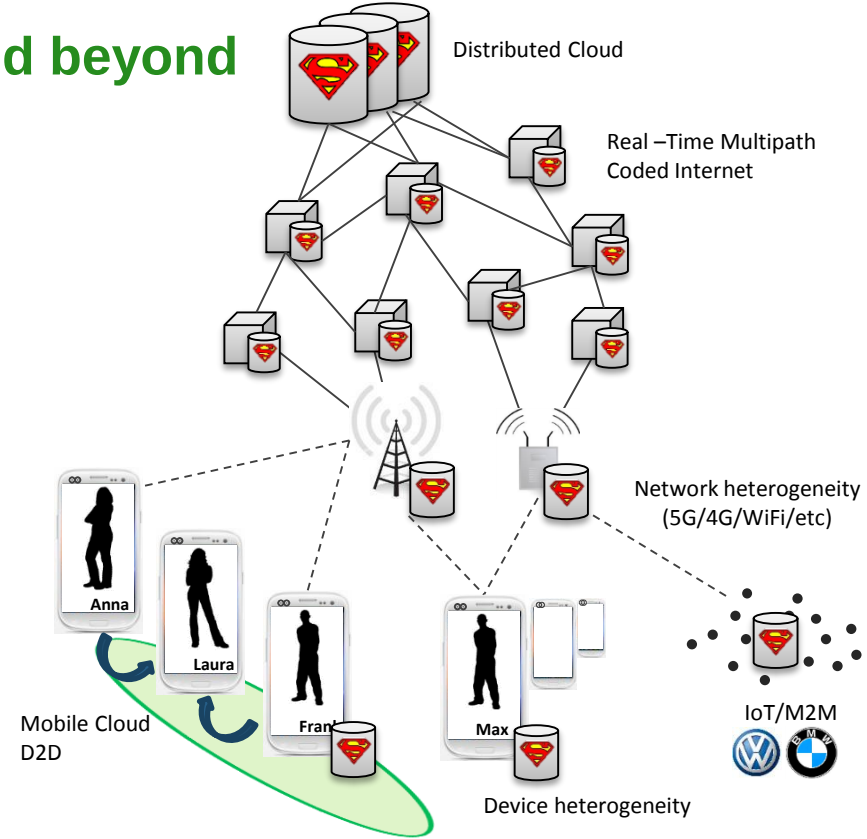
API available

5G the game changer

4G and before

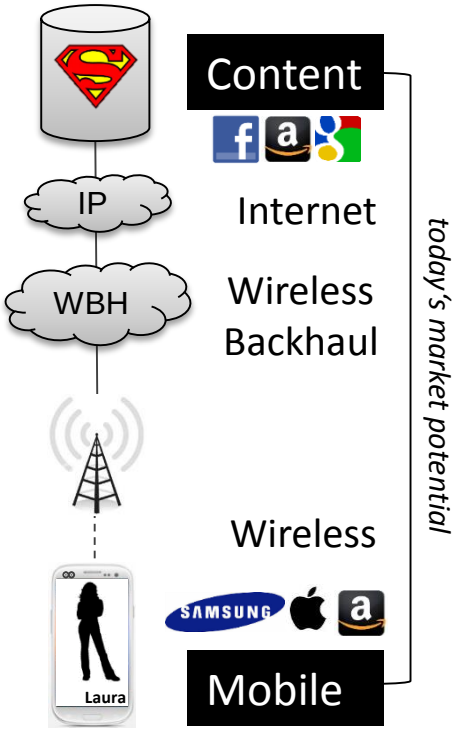


5G and beyond

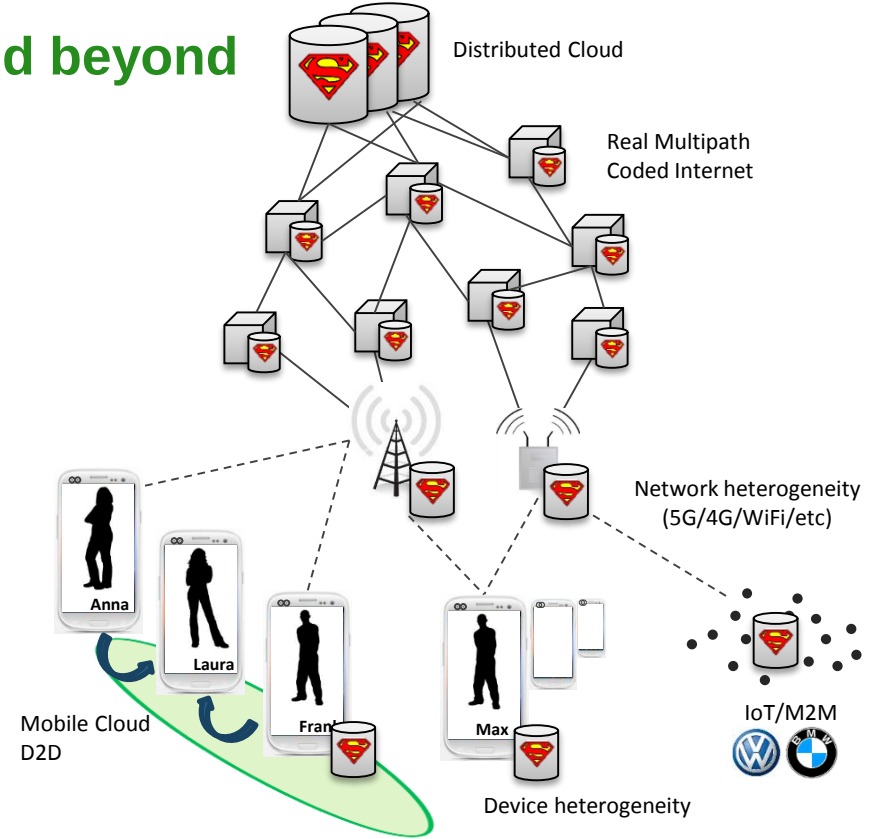


5G the game changer

4G and before

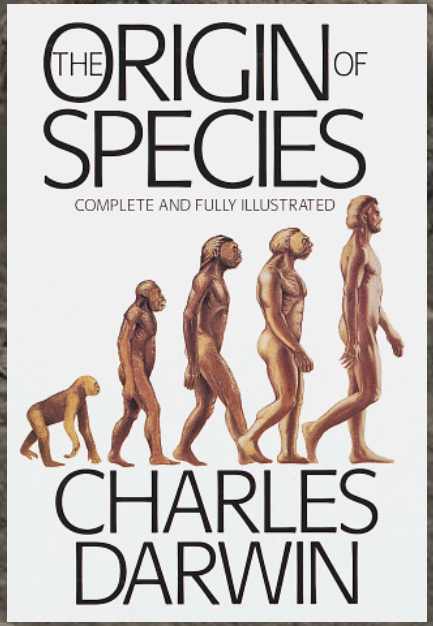


5G and beyond

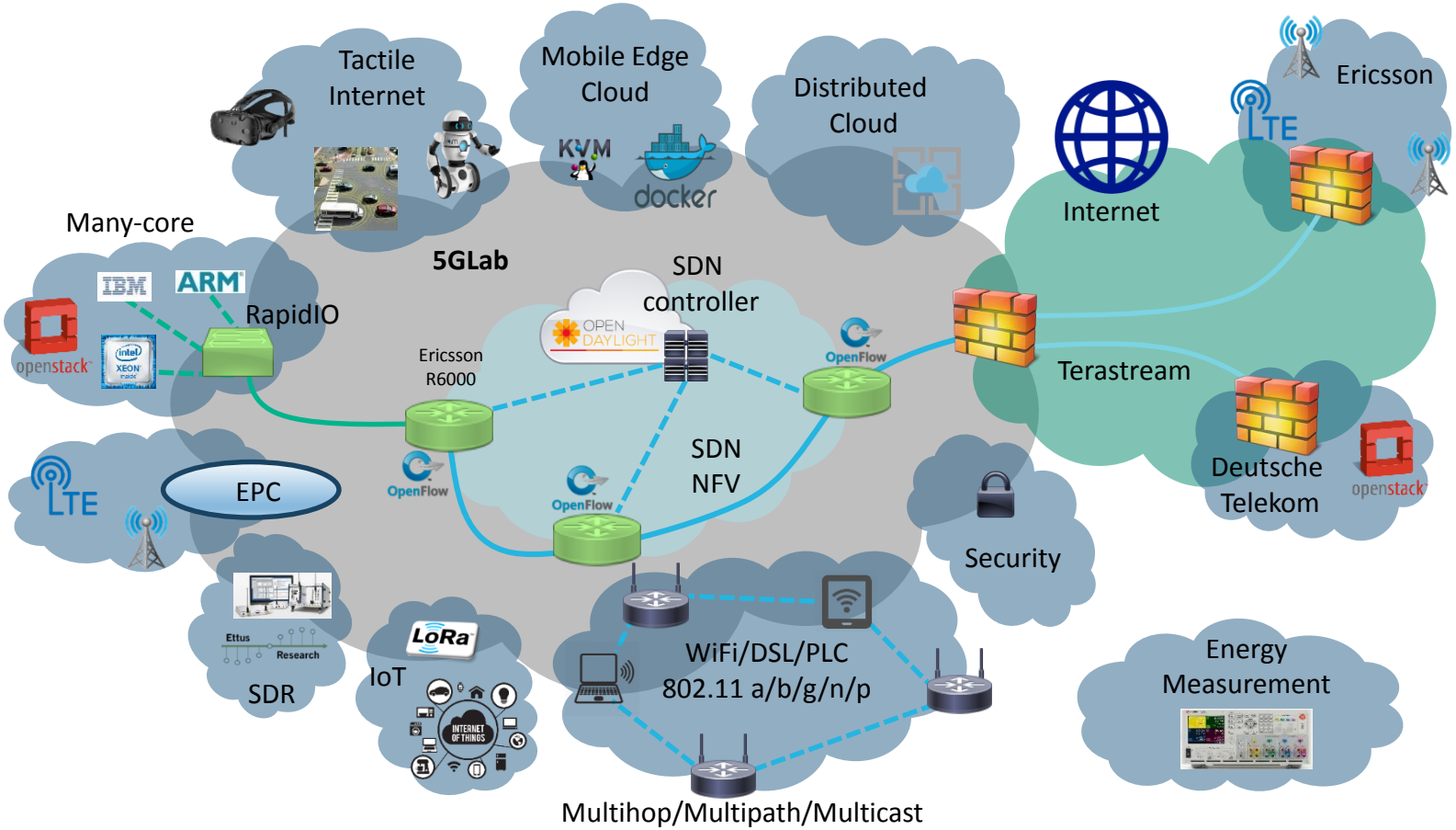


„It is not the strongest or the most intelligent who will survive, but those who can best manage change."

Charles Darwin



ComNets Testbed



5G makes everybody happy!

Tactile Internet

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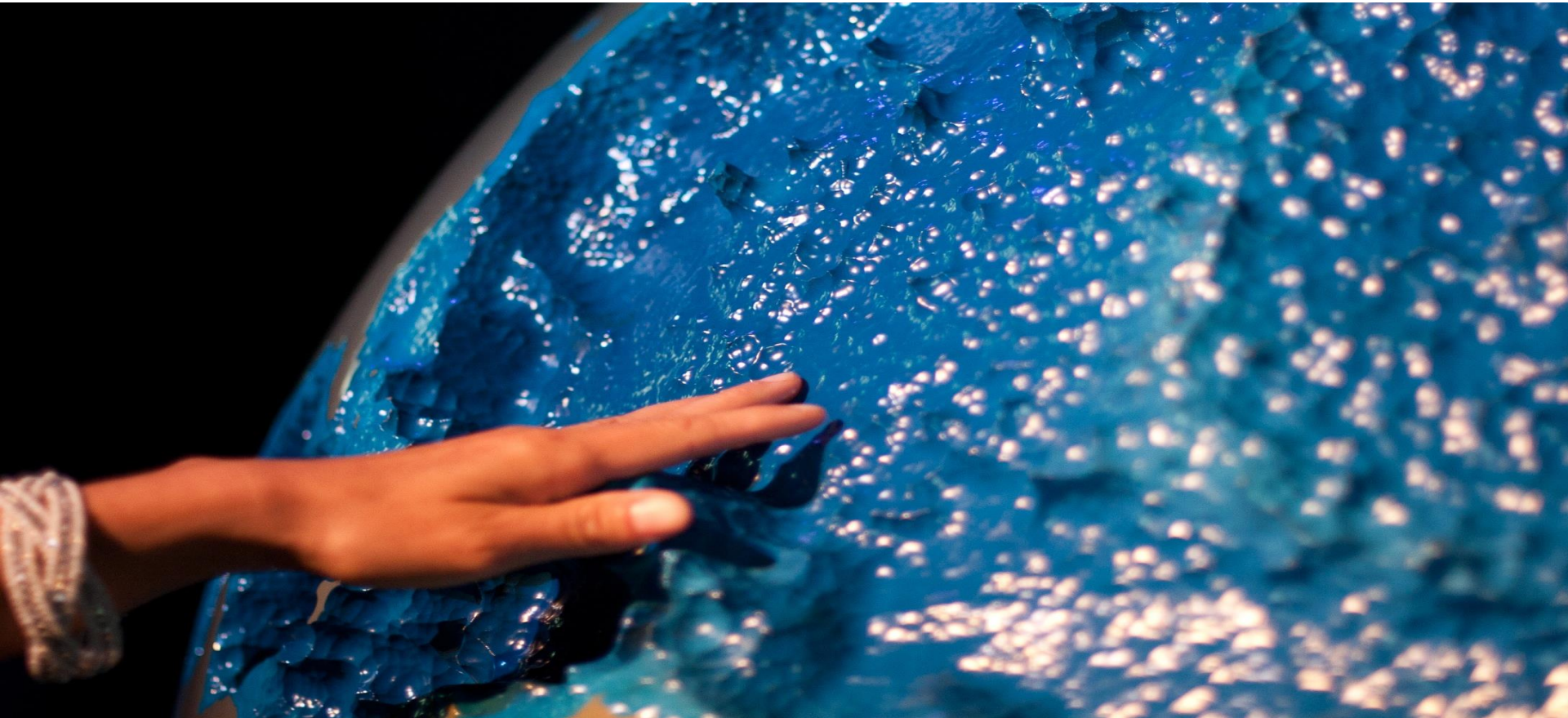
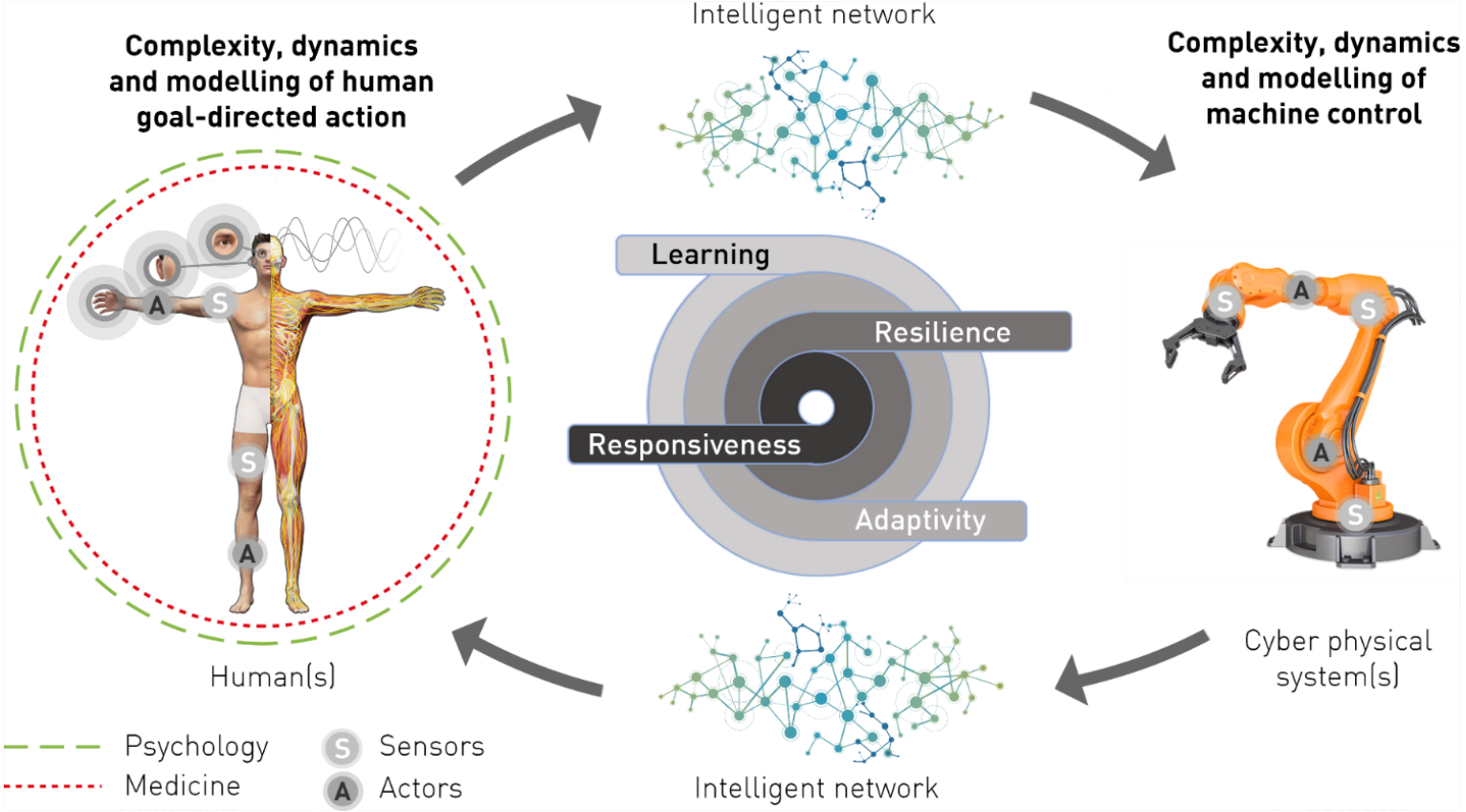


Definition

Recently, the Tactile Internet has been defined by the IEEE P1918.1 Tactile Internet ad-hoc definition group as

"*A network or network of networks for remotely accessing, perceiving, manipulating or controlling real or virtual objects or processes in perceived real time by humans or machines*."

Motivation - What are we doing it?

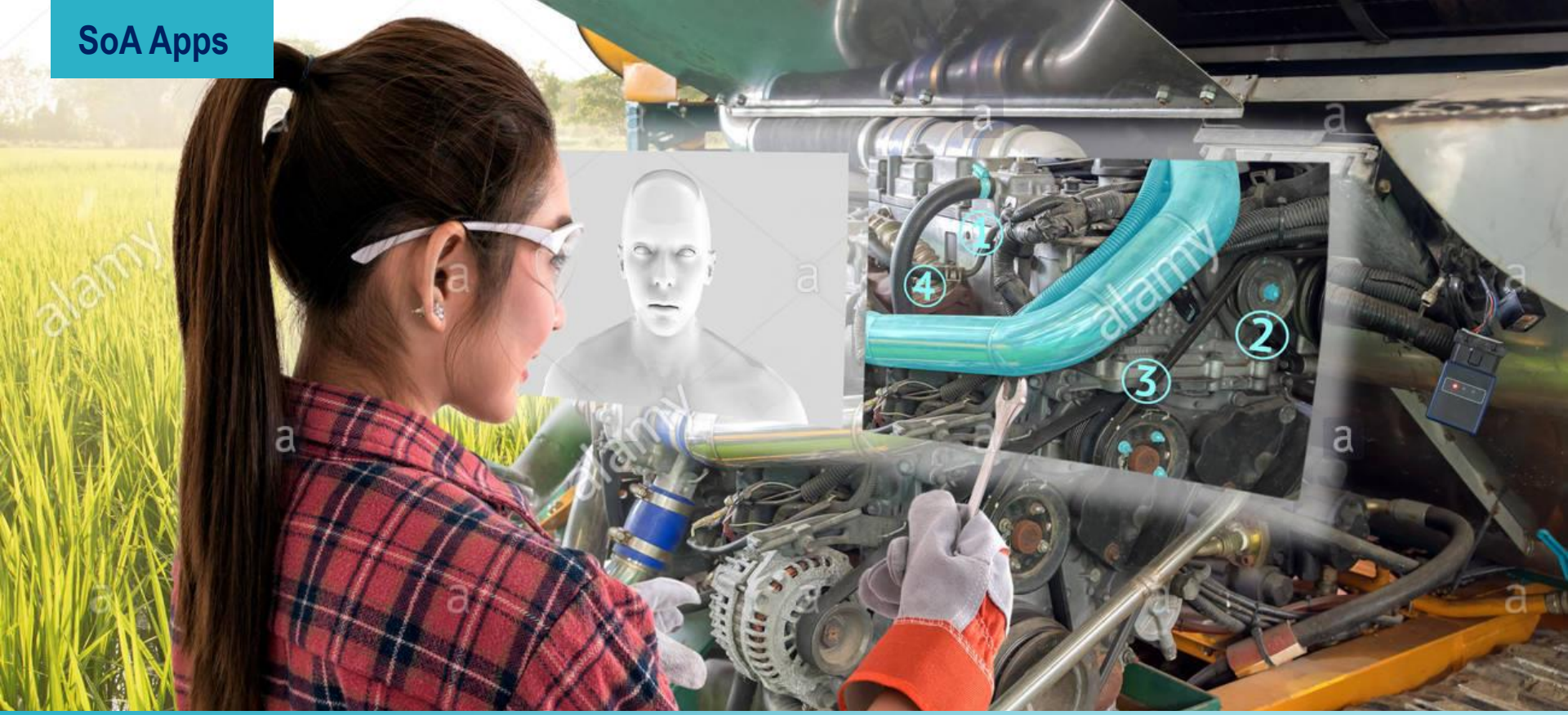


Telemedicine

Internet of Skills

Co-Habitation

SoA Apps



Current VR/AR solution have onboard computing to support …

SoA Apps

Current VR/AR solution have onboard computing to support standalone apps to show static behavior or to show video (unicast).

PROBLEM Content

In-flight entertainment disturbs other passengers while not providing any privacy for the individual, furthermore restricted physical space for screens depending on eco, business or first class

SOLUTION Content

„Glasses for the Masses“, our innovative concept, creates a new flying experience

Enjoying in-flight entertainment through glasses: Private, nondisturbing, light-weight and virtually unlimted

SOLUTION Content

Not only entertainment – airlines can show in-flight safety videos to every passenger while they still are able to interact with the environment → MULTICAST

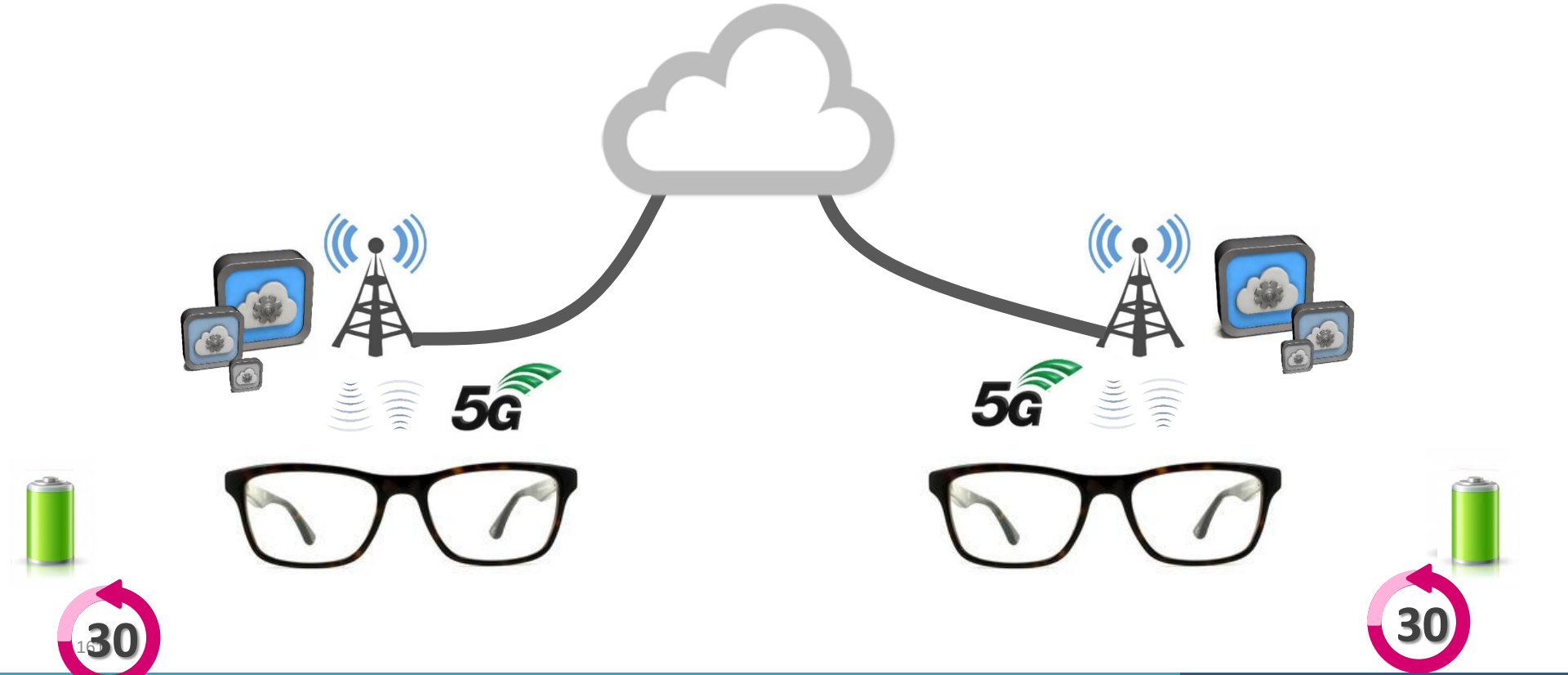
Implementation of multicast into glasses with network coding.

Tactile Internet – Stand Alone App

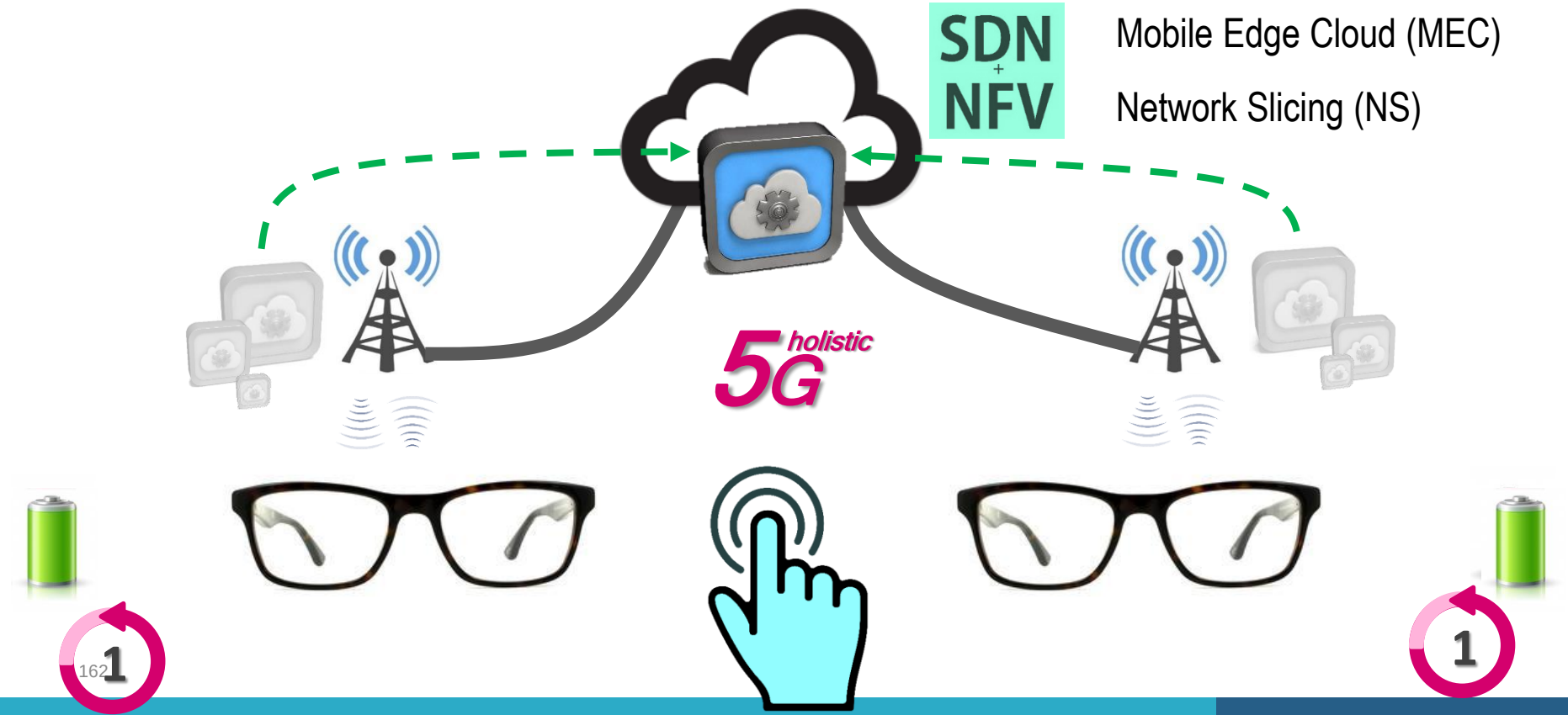
Tactile Internet – Outsource Complexity

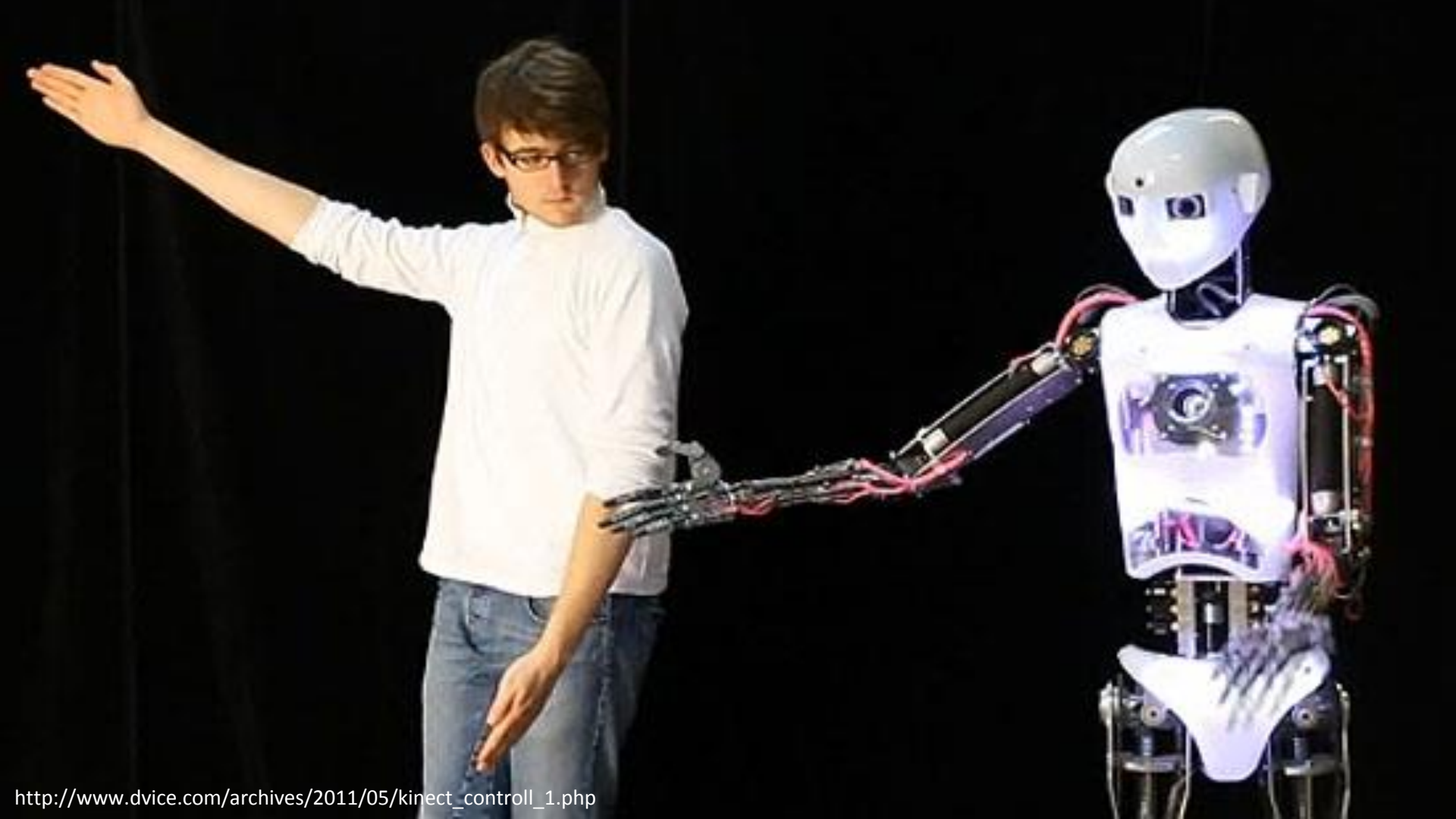
Tactile Internet – Outsource Complexity

Tactile Internet – Outsource Complexity

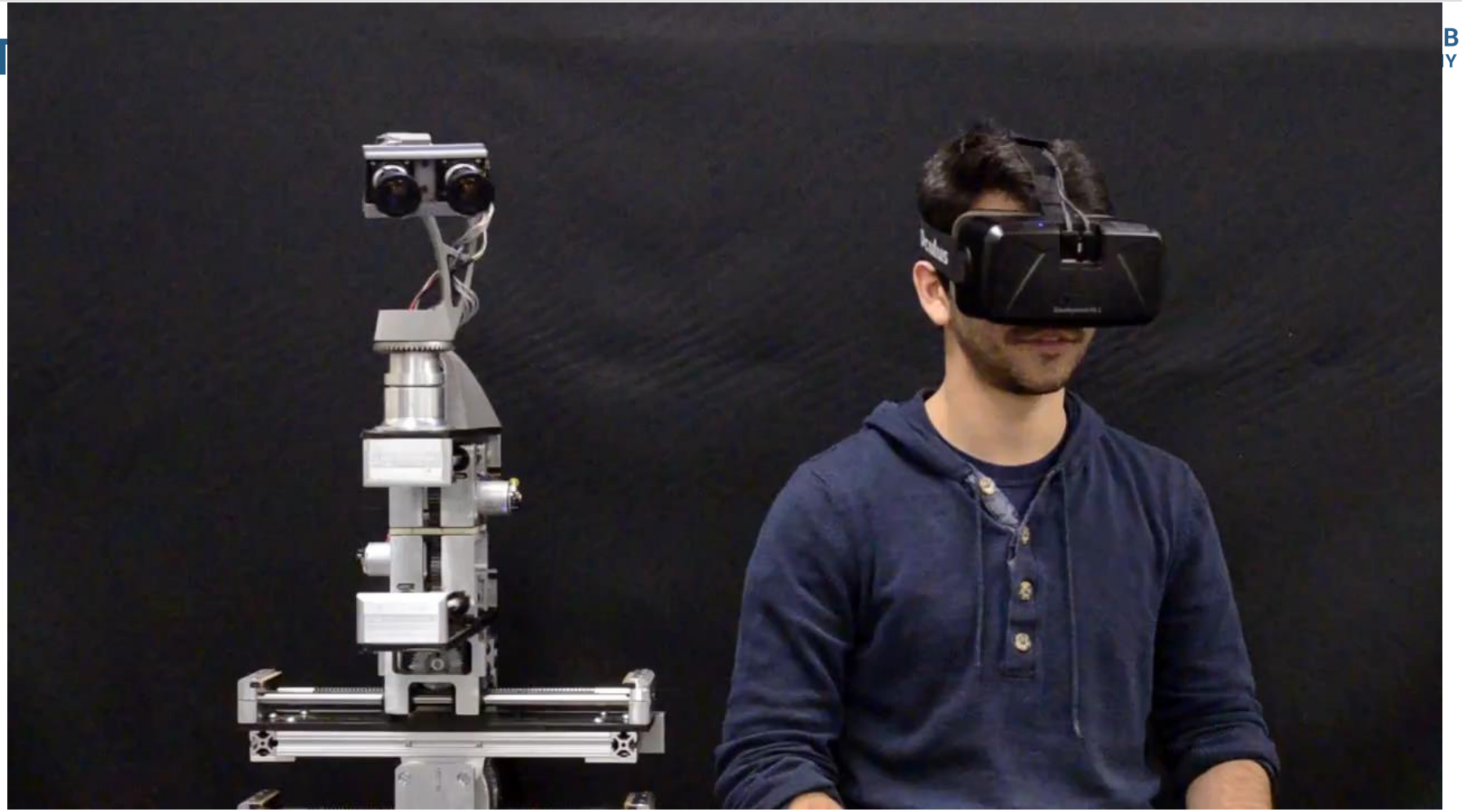


Tactile Internet – Interactive Apps





http://www.dvice.com/archives/2011/05/kinect_controll_1.php

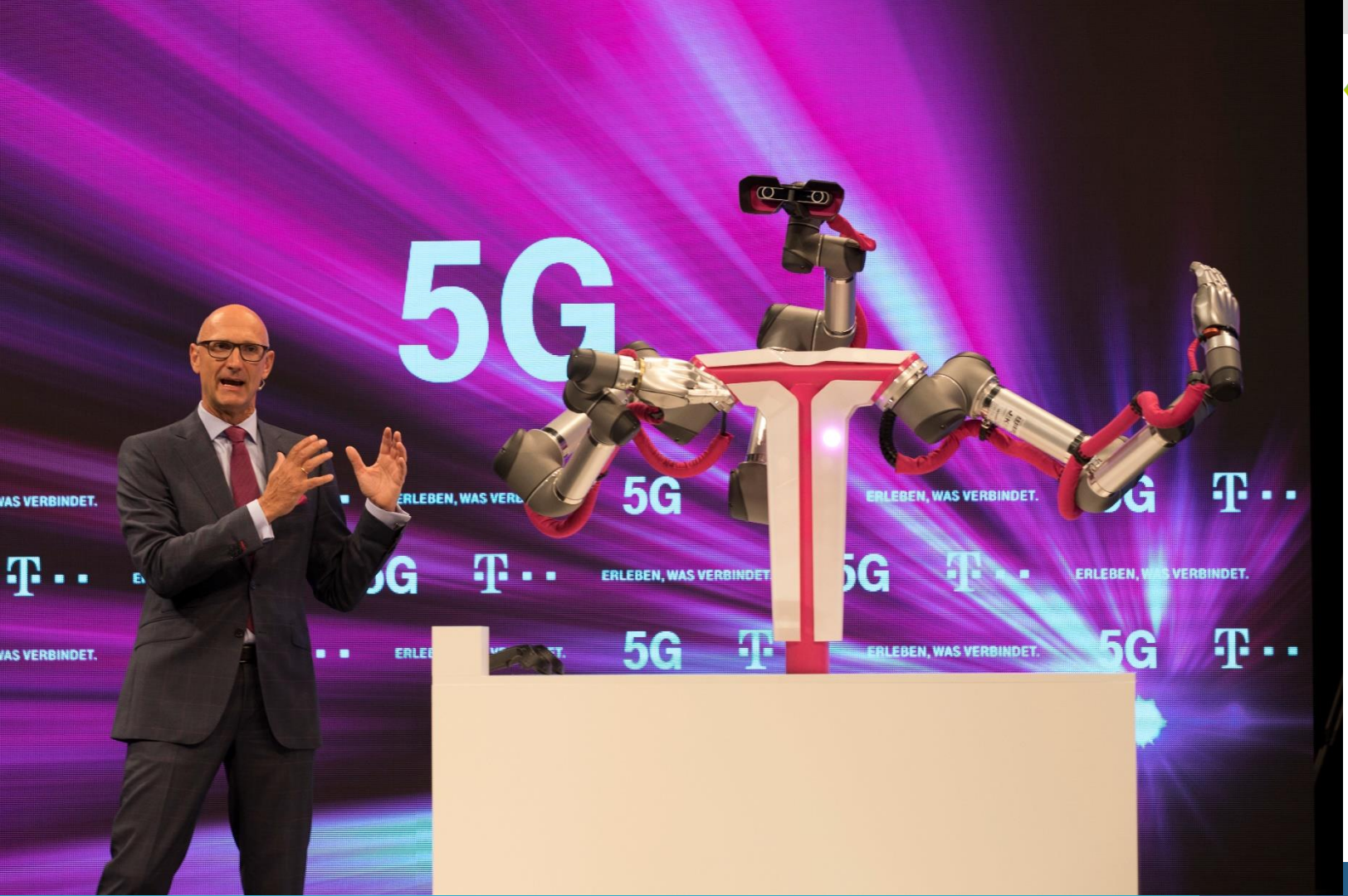


One Example

GSMA MOBILE™ WORLD CONGRESS

BARCELONA 27 FEB - 2 MAR 2017


Orchestrating a brighter world
Prepare for billions
Hewlett Packard Enterprise
Transport SDN
10:35
GSMA
MOBILE
WORLD CONGRESS
BARCELONA 27 FEB - 2 MAR 2017



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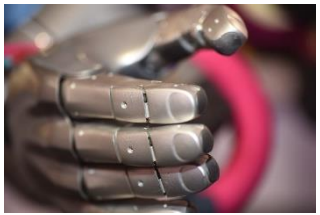
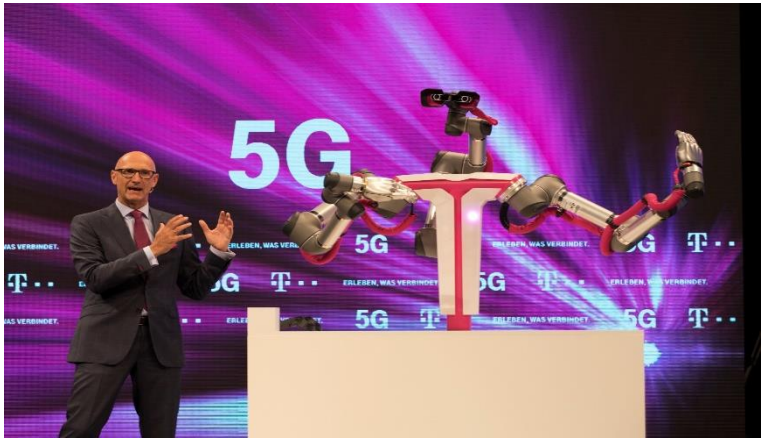
Microsoft
Progress through IoT – Telekom as your enabler




5G
5G
5G
5G

Current challenges

- Sensor and Actuators
- Communication Networks
- Human modelling and understanding

wandelbots


TCL
KUKA
MIDEA


KUKA


wandelbots