Bahagia dan Sukses Studi S2 dan S3: Dari Pola Studi Sampai Teknologi

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IEEE Indonesia Section, 2020, 2021
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Presented at Penyambutan Mahasiswa Baru Pascasarjana Telkom University 2021/2022

Bandung, 12 February 2022

Following Sinusoidal Wave

1

2

3

1996–2000	: B. Eng., Institut Teknologi Bandung (ITB)
2000–2002	: PT. Astragraphia Information Technology, Jakarta
2002–2003	: Tokyo Institute of Technology
2003–2005	: M. Eng, Nara Inst. of Science and Tech. (NAIST)
2005–2008	: Dr. Eng., Nara Inst. of Science and Tech. (NAIST)
2008–2016	: Asst. Prof., Japan Adv. Inst. of Sci. and Tech. (JAIST)
2016–Present	: Asct. Prof., School of Electrical Eng., Telkom University

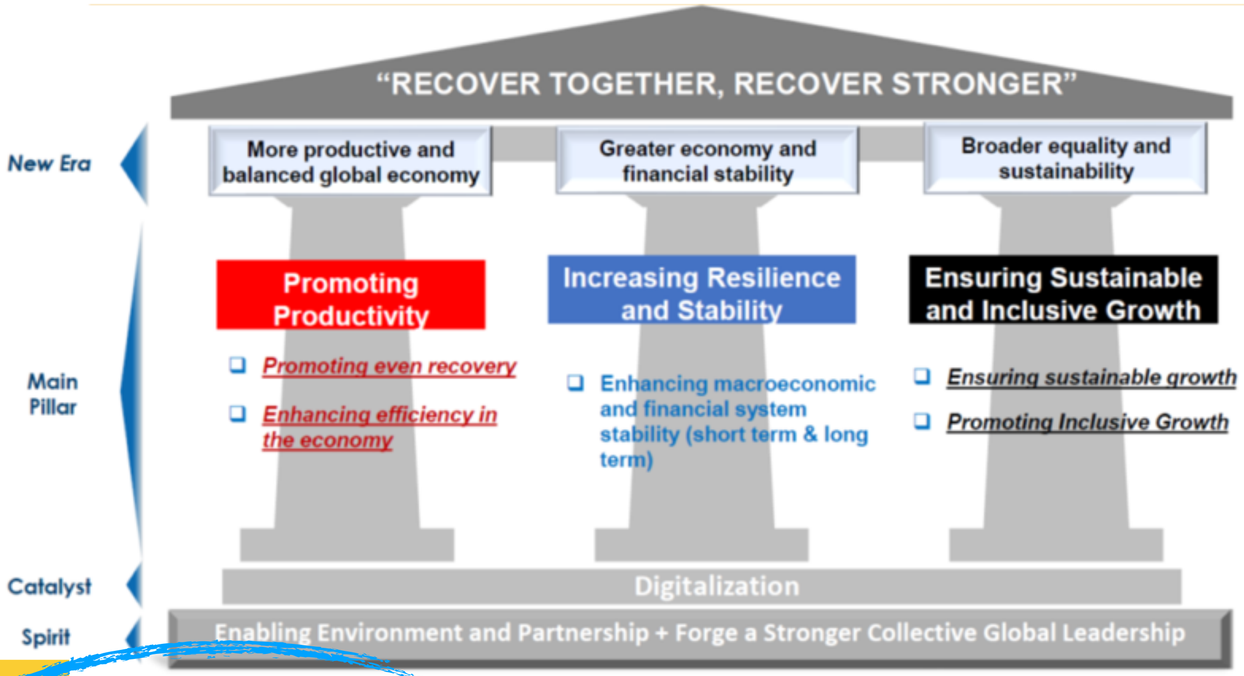
[1] Best Student Paper Award, IEEE RWS'06, California, USA, Jan 2006.

[2] Master and PhD Thesis are adopted by ITU-R Standard for Satellite Communication in the world, 2011.

[3] Achmad Bakrie Award 2014.

T20 for G20 2022

G20 Indonesia Pillars



TF1	Open trade and sustainable investment	**TF2**	Digital connectivity, cyber security and inclusivity	**TF3**	Governing climate target, energy transition and environmental protection
TF4	Food security and sustainable agriculture	**TF5**	Demographic transitions and well-being: inequality, human capital and social cohesion	**TF6**	Global health security and COVID-19
TF7	International finance and economic recovery	**TF8**	Resilient infrastructure and financing	**TF9**	Global cooperation for SDGs financing

PUI-PT AICOMS Transformation Since 2016

TELECOM INFRA PROJECT

TELECOM INFRA PROJECT

Telkom University

PUSAT UNGGULAN IPTEKS PERGURUAN TINGGI

PUSAT UNGGULAN IPTEKS PERGURUAN TINGGI

2016

AdWITech center for Telkom University

Established

2017

AdWITech center for Telkom University

Starting to Learn

Proect of UK
Internal
Ristekdikti
(700 Juta)

2018

AdWITech center for Telkom University

Achievement 1

LPDP
Insinas
Ristekdikti
(2.5 M)

2019

AdWITech center for Telkom University

Achievement 3

LPDP
Insinas
Ristekdikti
(2.5 M)

2020

AICOMS The University Center of Excellence for Advanced Intelligent Communications - Telkom University

Achievement 4: Transforming

LPDP, ASEAN IVO
Ristekdikti, PUI-PT
Dikbud
(4 M)

2021

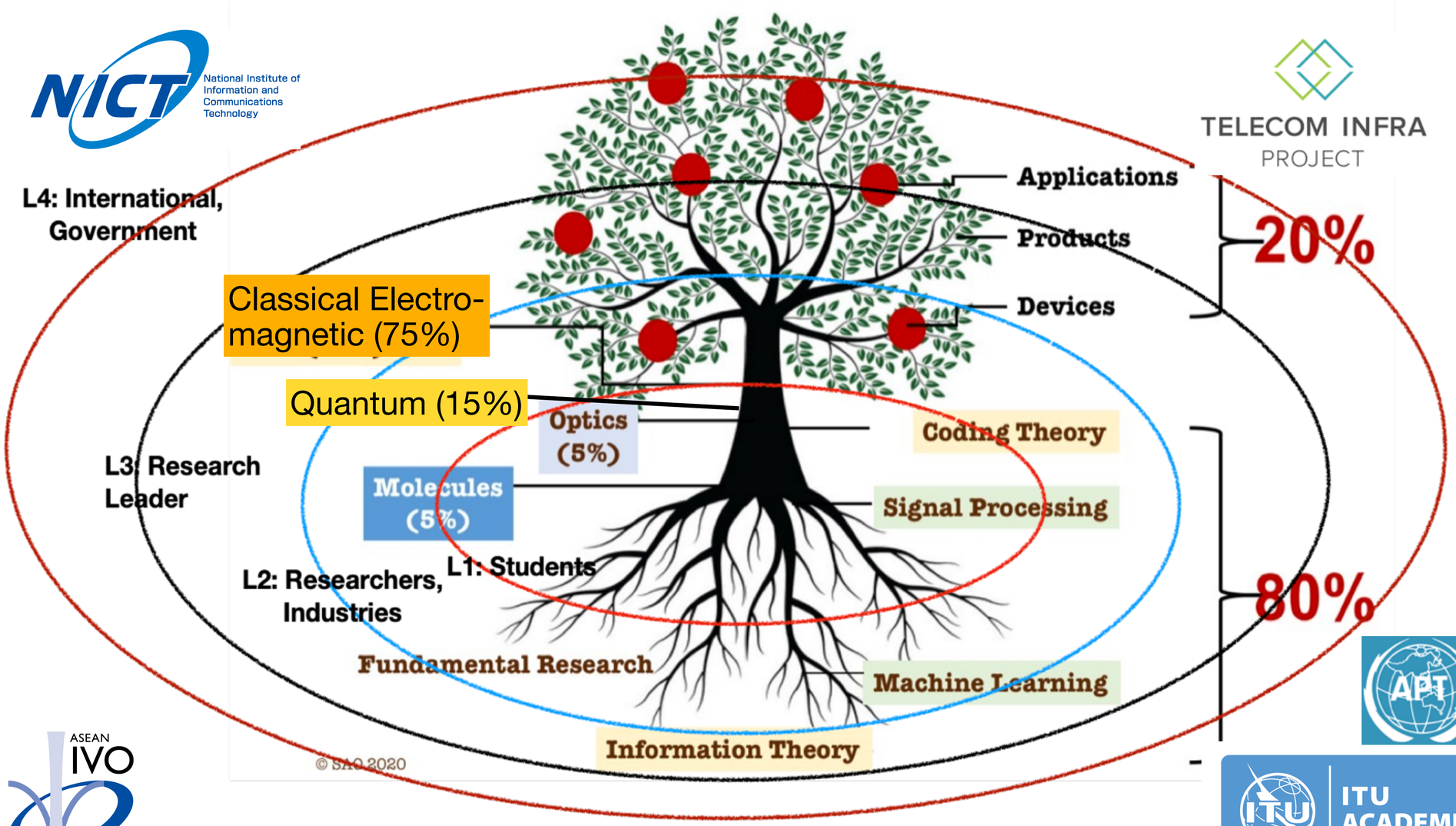
AICOMS The University Center of Excellence for Advanced Intelligent Communications - Telkom University

Achievement 5: National & Bigger

LPDP, ASEAN IVO
Dikbud, Ristekdikti
TIP Lab
Industry, PUI-PT
(4M)

Vision and Mision: 4 Levels of Influences

- Becoming one of the **world-class leading research center** in the field of Advanced Intelligent Communications



1. Developing model for ideal collaborative research.
2. Enhancing research quality towards world-class recognition.
3. Enhancing research collaboration with other universities, industry, start-up company, and goverment to build world-class leading research center in the field of Advanced Intelligent Communications.

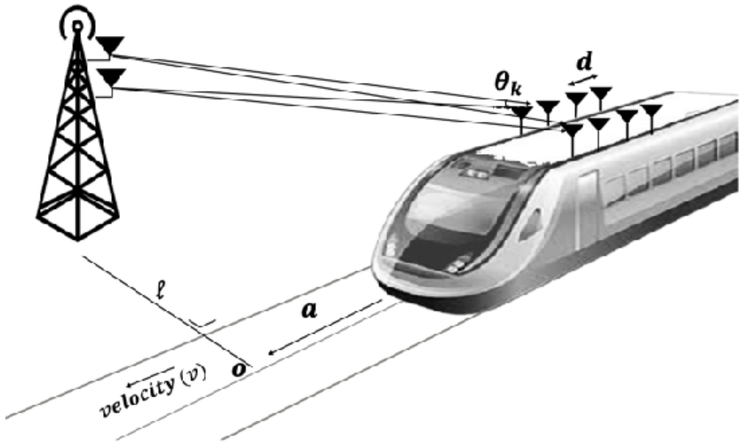
AICOMS Current 5 Top Products/Projects

(1) MCRBS
& 5G-MERDEKA

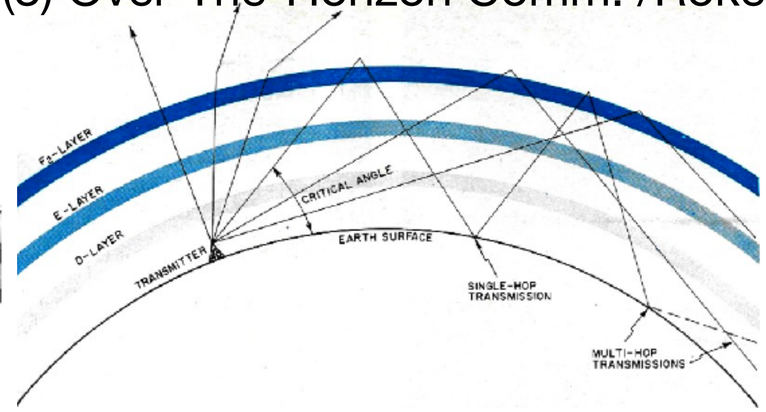
Mobile Cognitive
Radio Base Station

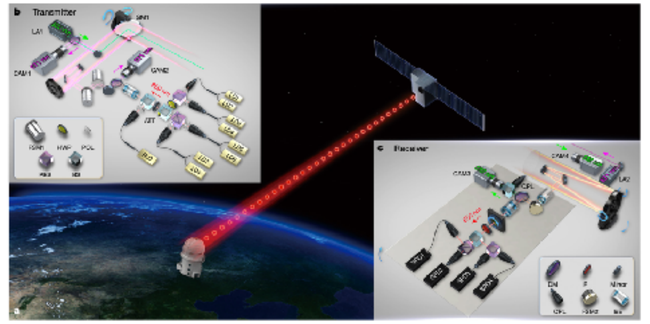
image: © K. Anwar, Telkom University, 2020.

(2) Kereta Cepat
(5G-FRMCS)



(3) Over-The-Horizon Comm. /Roket.





(4) Next Generation IoT

Contention-based Access	IoT Technologies	Throughput
Pure ALOHA	SigFox, LoRa	0.18 pck/slot
Slotted ALOHA	RFID, RACH of LTE, NB-IoT (CIoT), Weightless	0.37 pck/slot
Non-slotted CSMA/CA	Zigbee, WiFi	0.5–0.8 pck/slot
Slotted CSMA/CA	Zigbee	0.8 pck/slot
Coded Random Access	AICOMS, Telkom Univ.	0.9-3.7 pck/slot

(5) Quantum Coding and Security

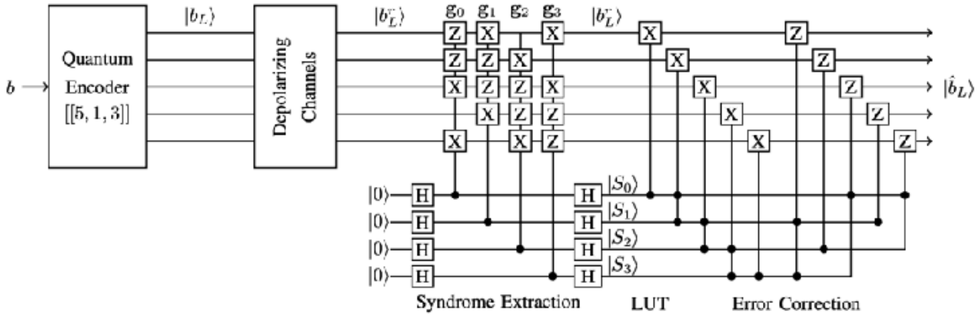


Fig. 3. The quantum circuit of the proposed perfect $[[5, 1, 3]]$ quantum accumulate codes.

image: © K. Anwar, IEEE APCC2021.

Executive Summary

- Understanding Ikigai is important for happiness and success.
- **Happy**: feeling pleasure, convenience
- **Success**: he accomplishment of an aim or purpose
- Having best plan for Master and PhD from start by joining lab.
- Pain is temporary, pride is forever.
- Understanding trend of technology is later.
- 5G-Advanced (approved in Q4-2021) is the prologue to 6G
- RAN-MERDEKA is a promising method for massive deployment of 5G and 6G in Indonesia with affordable price in the near future.

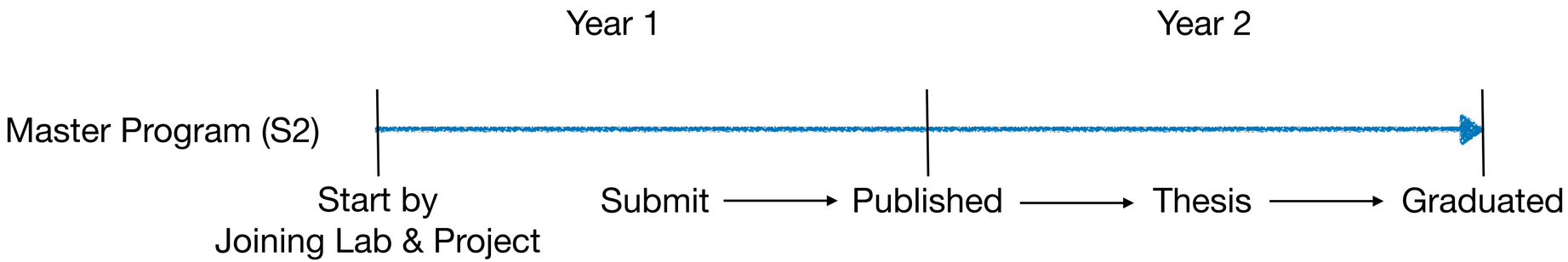
Defining Happiness and Success

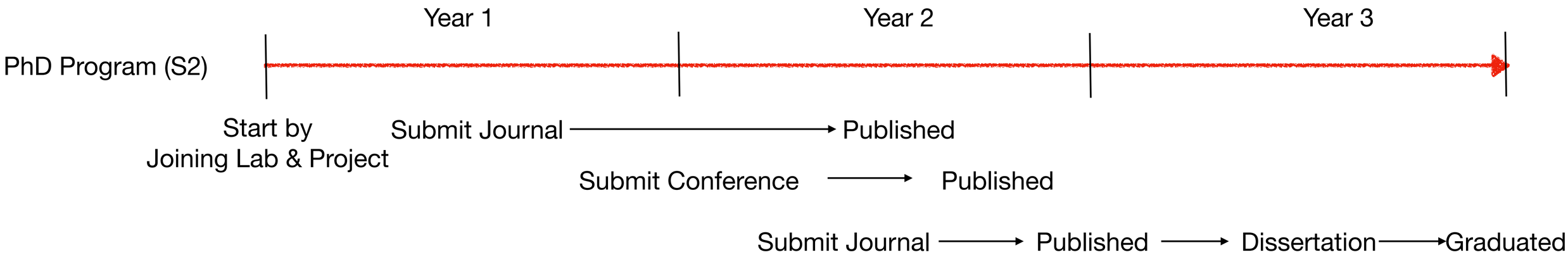
- **Happy**: feeling pleasure, convenience
- Based on Cabinet Office, 2011: Factor of Happiness
  - The first is **socioeconomic condition**: wealth, income, work, housing, education, security, and safety.
  - The second is **health:** physical and mental health.
  - The third is **relatedness:** bonds with family, bonds with community, and lifestyle.
- **Success**: he accomplishment of an aim or purpose
  - Graduated from Master or PhD Program only?
  - Or More?

Image: tienwong

Cabinet Office (Council for Science, Technology and Innovation) (2017) Comprehensive strategy on science, technology and innovation (STI) for 2017 (released on June 2, 2017), p 2

Best Time Schedule for Master and PhD





Understanding Ikigai (生き甲斐)

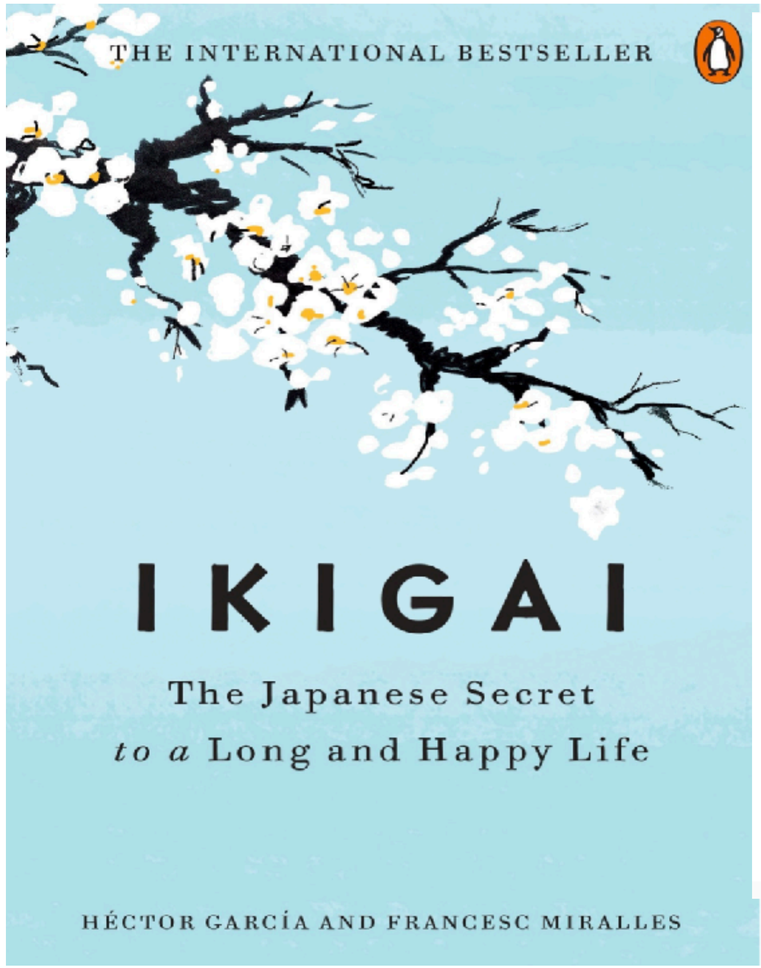
- 生き：生きる：Ikiru

  (hidup, menjalani hidup) JLPT N4

- 甲斐: Kai (bermakna)

  - 甲: Kou (kelas satu, Nilai A) JLPT N1
  - 斐: i, hi (cantik, elegant, keren) JLPT N1

- 言い甲斐：iigai (perkataan bermakna, bernilai)



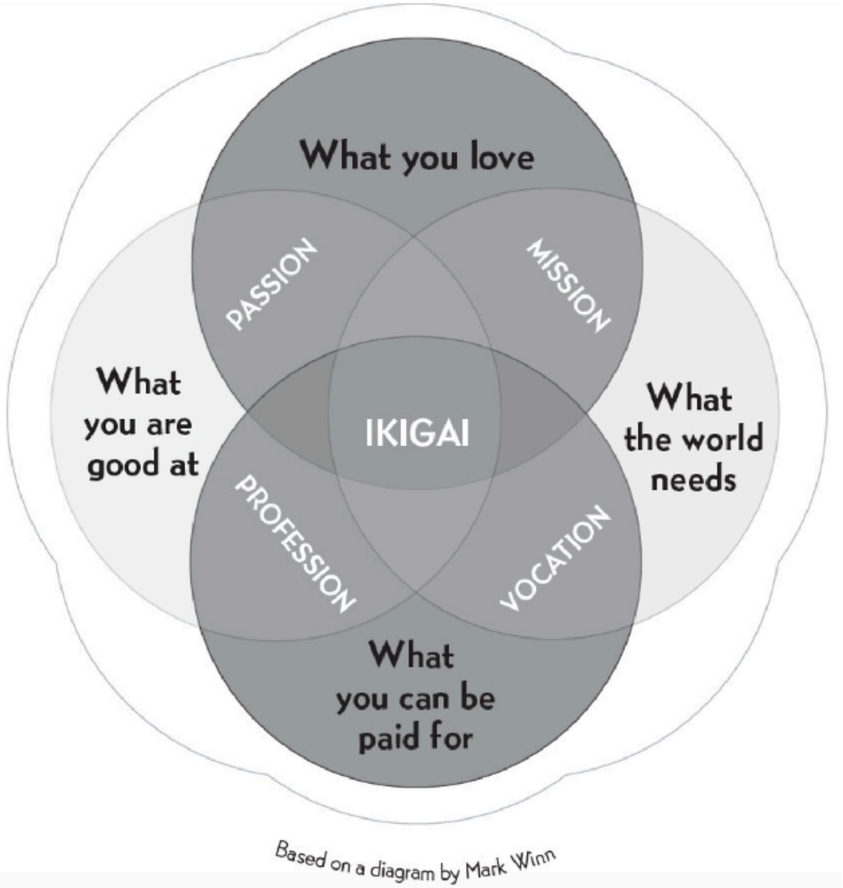
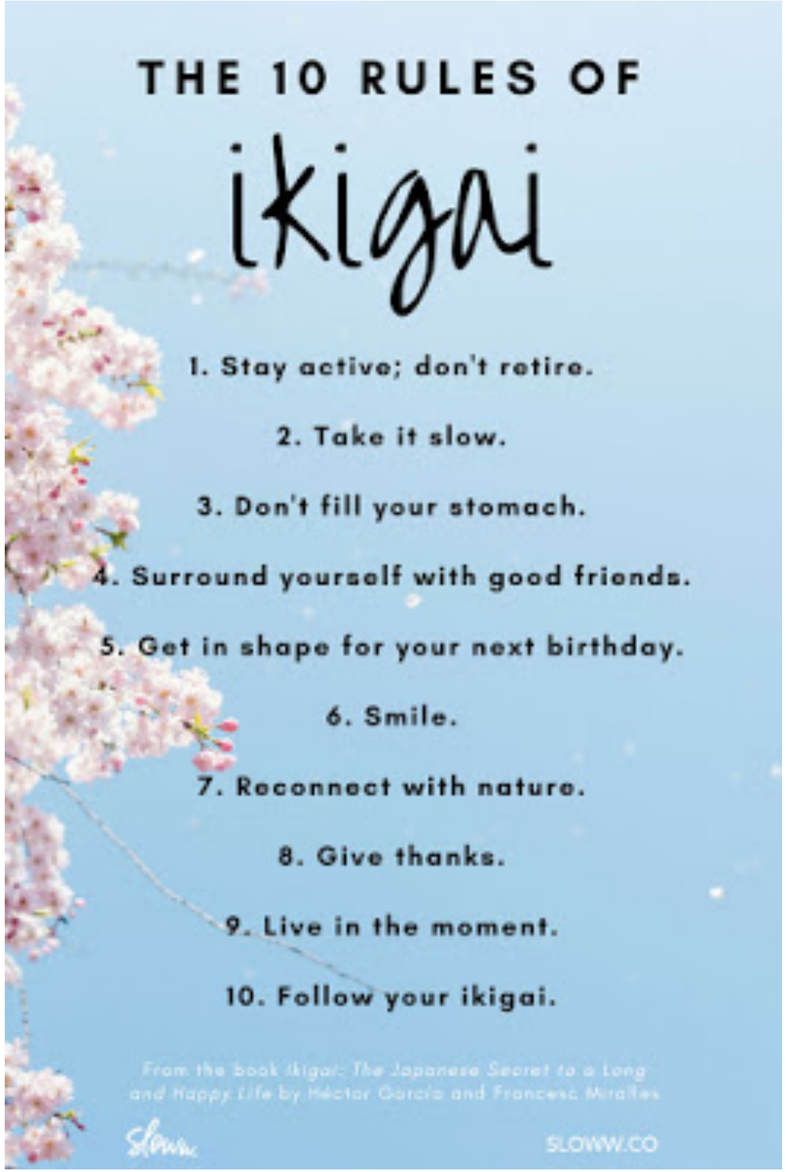


Image: Hector

Ikigai: The Art of Living (1+6/10)

- 幸せはいつも自分の心が決める

- Stay active, do not retire.
- Surround yourself with good friends.
- Smile.
- Give thanks (to your ancestors, to nature).
- Live in the moments.
- Follow your ikigai. (There is a passion inside you, a unique talent that gives meaning to your days)



Hayao Miyazaki (Ghibli) and Ikigai

Miyazaki 2012

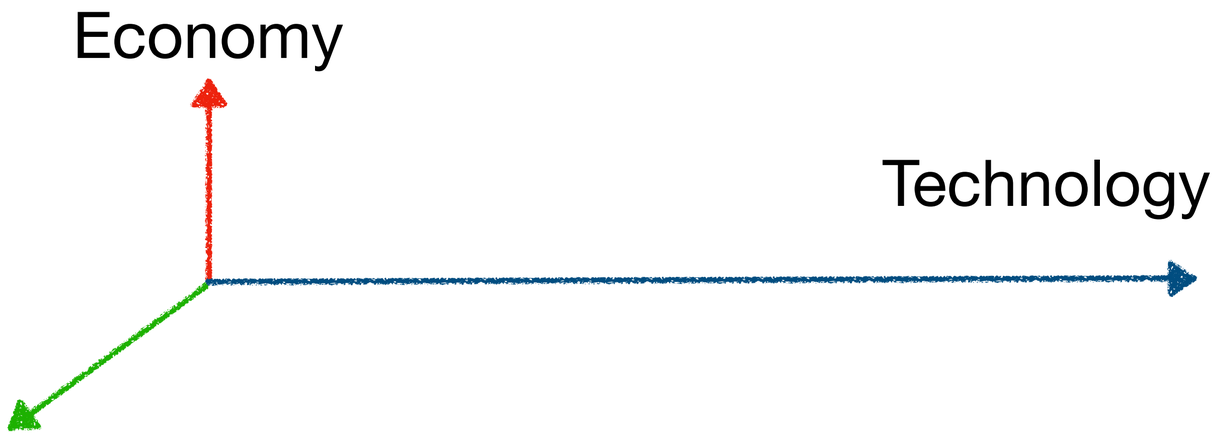
Sen to Chihiro no Kamikakushi

Tonari no Totoro

Image: wikipedia

Ikigai: Industrial Revolution 4.0 vs Society 5.0

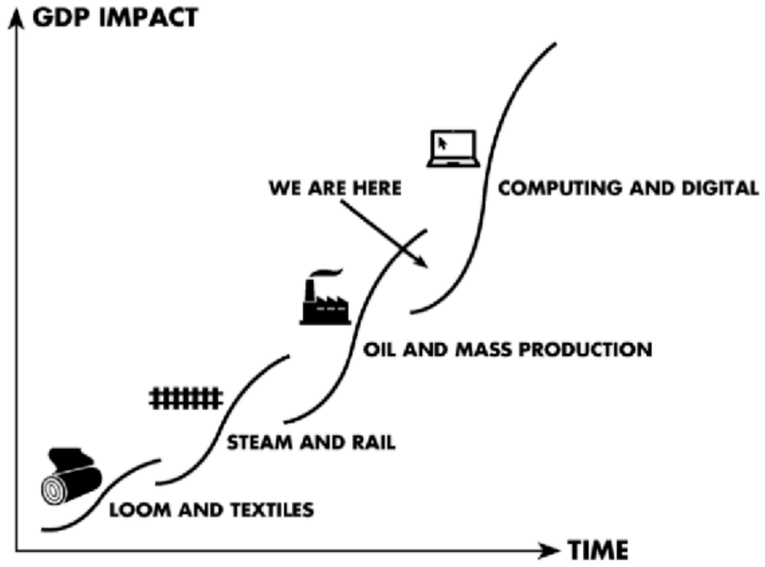
image: K. Anwar, Tarbawi, 2010.

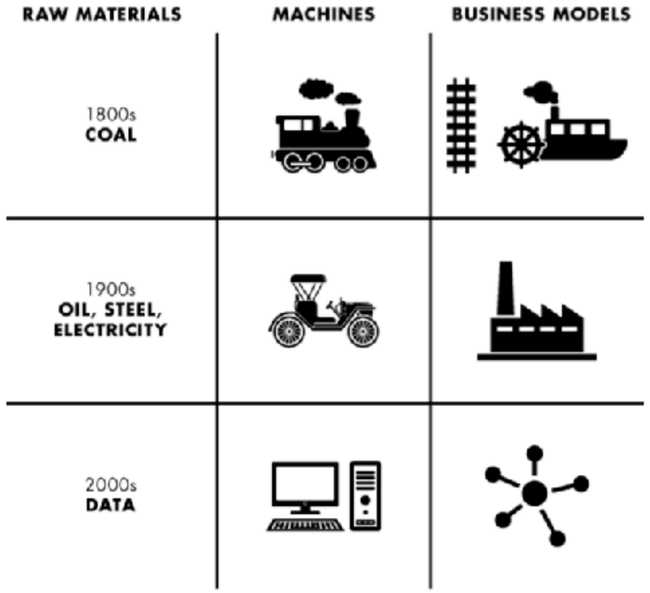


- We knew this long time ago, but no formalization.
- Japan has achieved the high quality of development of technology realizes the aging society.
- For Japanese, the next is human.

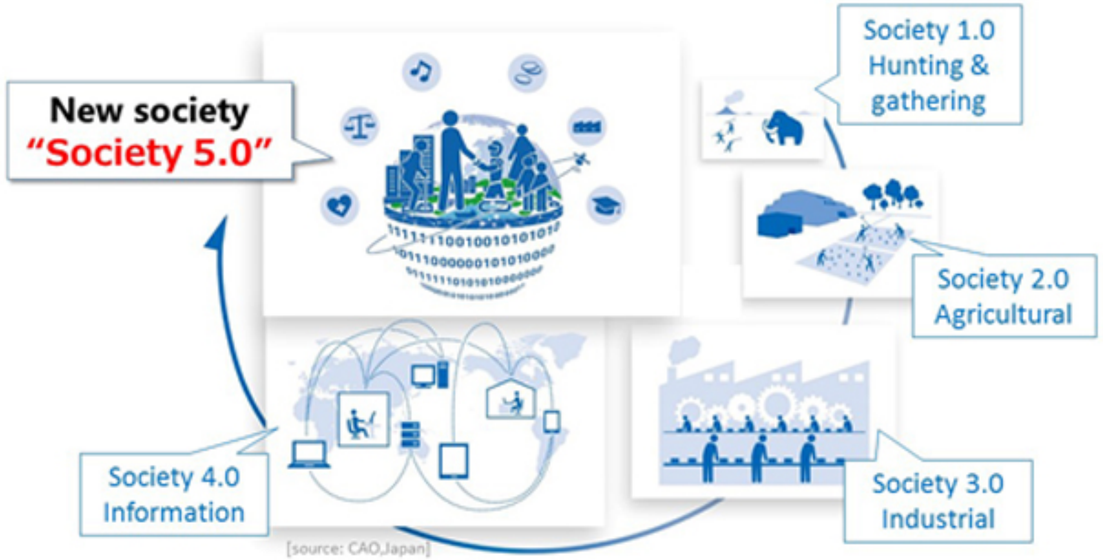
image: www8.cao.go.jp

Industrial Revolution 4.0 vs Society 5.0





- IR 4.0 focuses on the development of technology for economy (GDP)
- Society 5.0 focuses on technology for human happines or comfort lives.
- IR has 3M keywords: Materials, Machines, Business Model.
- Society 5.0 has 3 keywords: Comfort, Vitality, Life Quality.



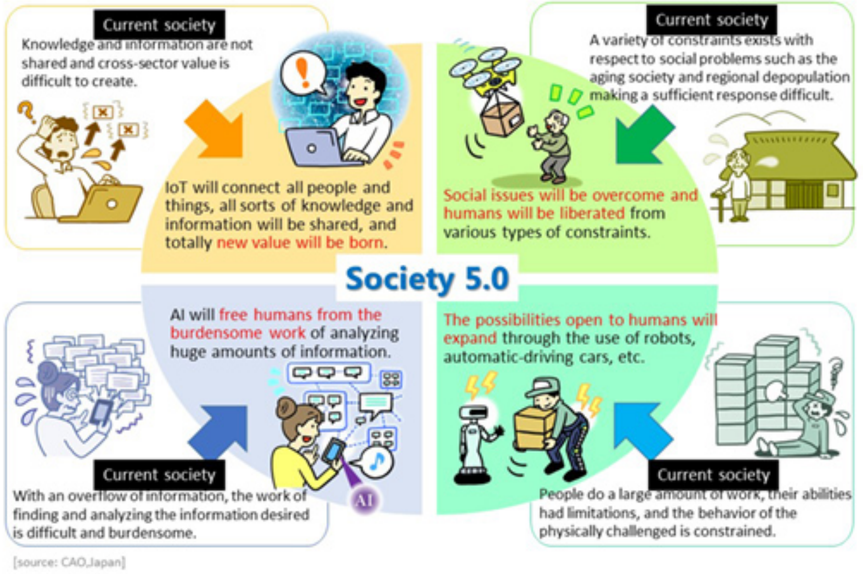
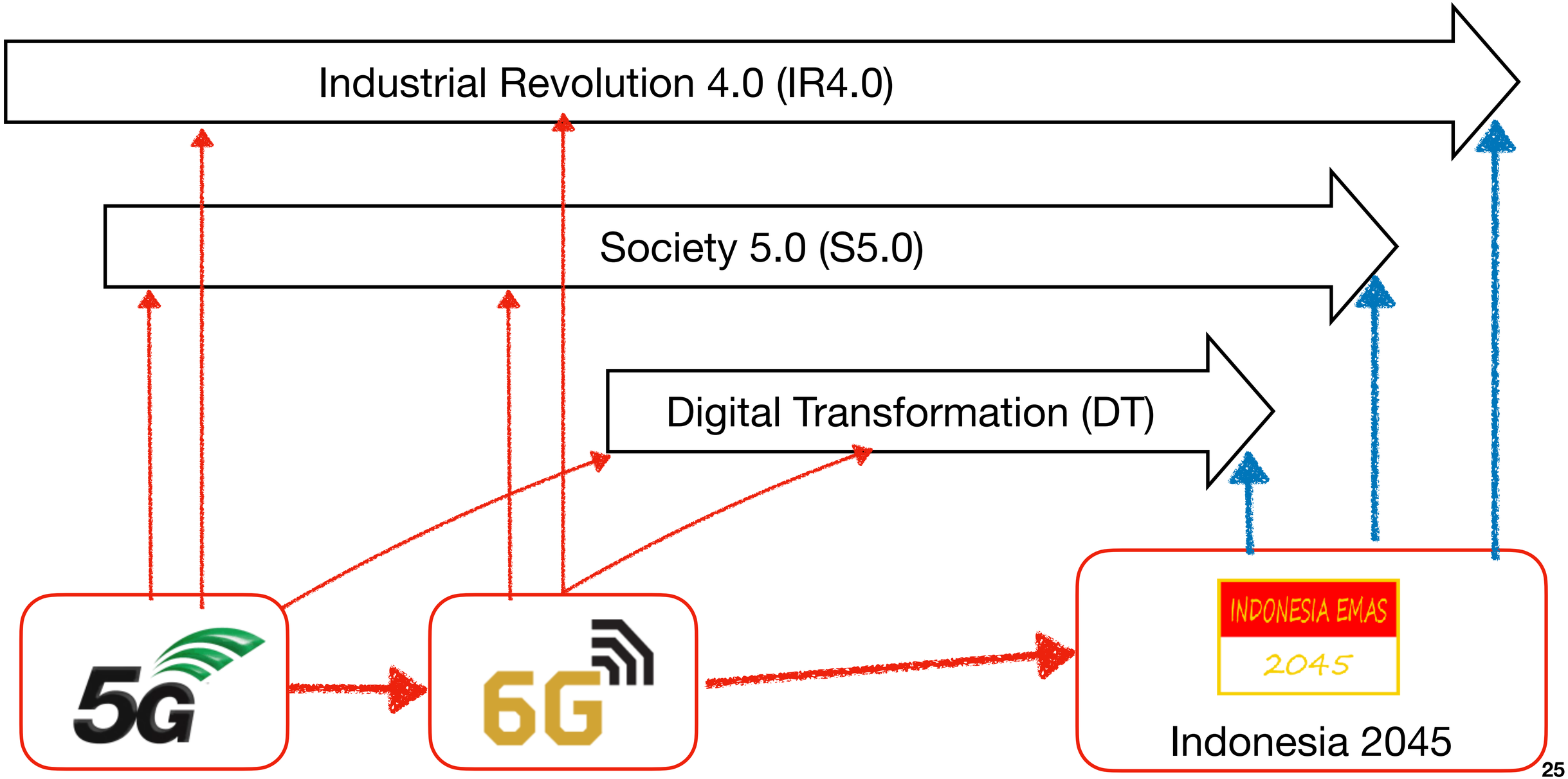


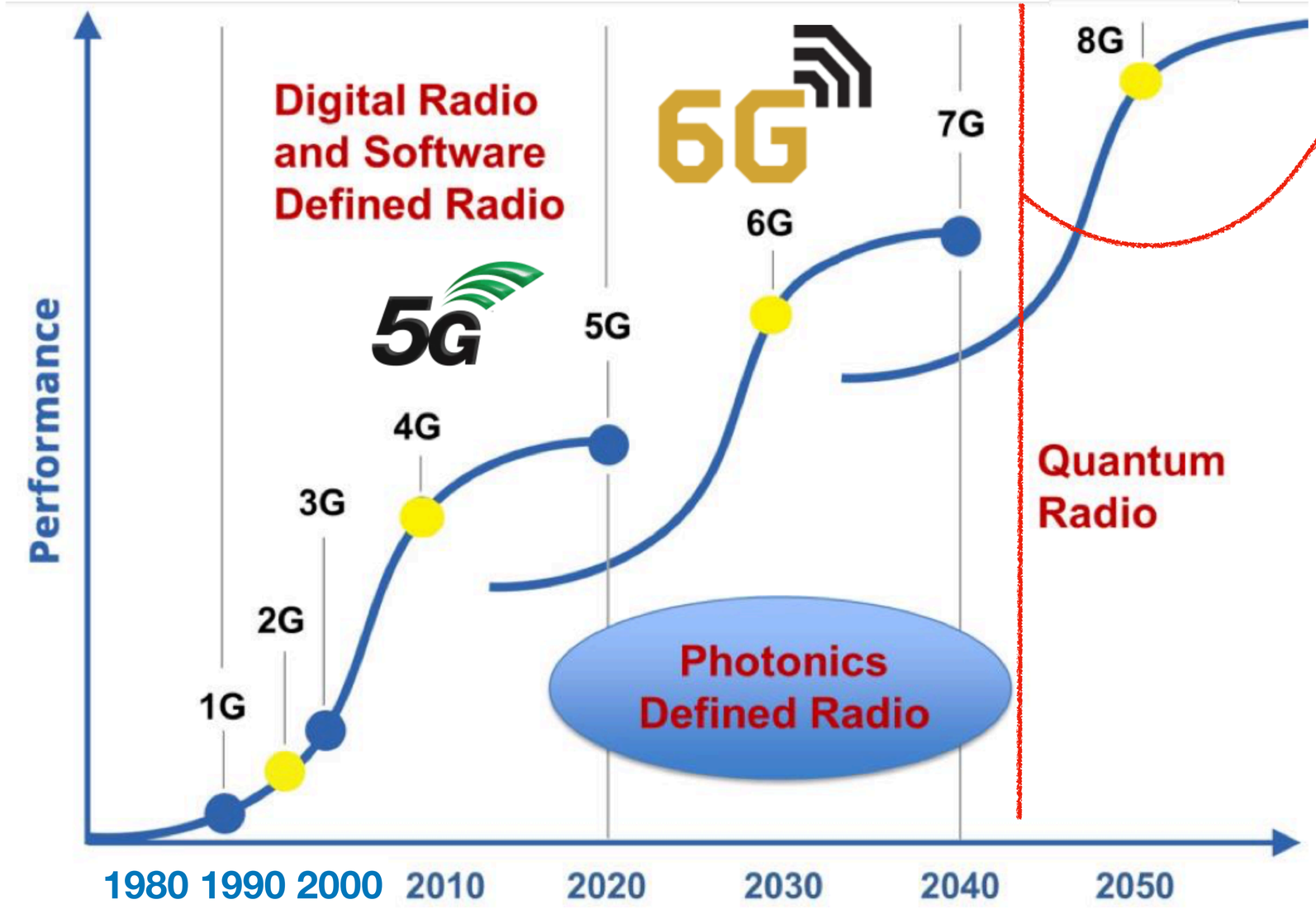
image: M. Frank, P. Roehrig, and B. Pring, "What to do when machines do eveything", Wiley, 2017.

image: www8.cao.go.jp

Motivation 1: For Industries, 6G, and Indonesia 2045



Motivation 2: Telecommunications Trend at Every 10 Years



- Certain problems are hard for Turing machine, but easy for Quantum machine
- Google claimed in 2019 that Quantum machine Sycamore did the task in 200 seconds which would have taken 10,000 years for a supercomputer to perform.

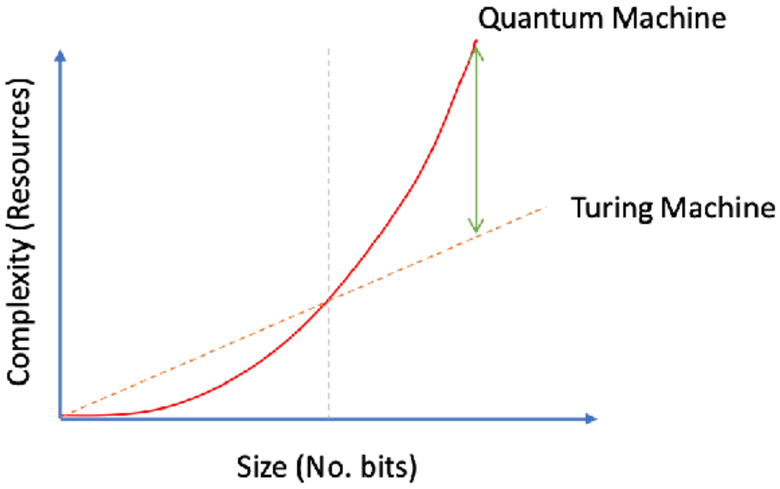


image: 6G Summit, Finland, 2019

5G vs 6G: Technology Key Enabler

		4G	5G	6G
KPI	Peak Data Rate	100 Mb/s	20 Gb/s	≥1 Tb/s
	Experienced Data Rate	10 Mb/s	0.1 Gb/s	1 Gb/s
	Spectrum Efficiency	1×	3× that of 4G	5–10× that of 5G
	Network Energy Efficiency	1×	10–100× that of 4G	10–100× that of 5G
	Area Traffic Capacity	0.1 Mb/s/m^2	10 Mb/s/m^2	1 Gb/s/m^2
	Connectivity Density	10^5 Devices/km^2	10^6 Devices/km^2	10^7 Devices/km^2
	Latency	10 ms	1 ms	10–100 μs
	Mobility	350 km/h	500 km/h	≥1,000 km/h
Technologies		• OFDM • MIMO • Turbo Code • Carrier Aggregation • Hetnet • ICIC • D2D Communications • Unlicensed Spectrum	• mm-wave Communications • Massive MIMO • LDPC and Polar Codes • Flexible Frame Structure • Ultradense Networks • NOMA • Cloud/Fog/Edge Computing • SDN/NFV/Network Slicing	• [illegible] Communications • SM-MIMO • LIS and HBF • OAM Multiplexing • Laser and VLC • Blockchain-Based Spectrum Sharing • Quantum Communications and Computing • AI/Machine Learning

Image: Zhang et. al, “6G WIRELESS NETWORKS Vision, Requirements, Architecture, and KeyTechnologies”, IEEE VT Magazine, July 2019.

Maximizing 5G to Prepare 6G

REVIEW

Machine Type Communications: Key Drivers and Enablers Towards the 6G Era

Nurul Huda Mahmood[1*], Stefan Böcker[2], Ingrid Moerman[3], Onel A. López[1], Andrea Munari[4], Konstantin Mikhaylov[1], Federico Clazzer[4], Hannes Bartz[4], Ok-Sun Park[5], Eric Mercier[6], Selma Saidi[2], Diana Moya Osorio[1], Riku Jäntti[7], Ravikumar Pragada[8], Elina Annanperä[1], Yihua Ma[9,10], Christian Mietfeld[2], Martin Andraud[7], Gianluigi Liva[4], Yan Chen[11], Eduardo Garro[12], Frank Burkhardt[13], Chen-Feng Liu[1], Hirley Alves[1], Yalcin Sadi[14], Markus Kelanti[1], Jean-Baptiste Doré[6], Eunah Kim[5], JaeSheung Shin[5], Gi-Yoon Park[5], Seok-Ki Kim[5], Chanho Yoon[5], Khoirul Anwar[15] and Pertti Seppänen

Radiocommunication Study Groups

Received: 31 May 2021

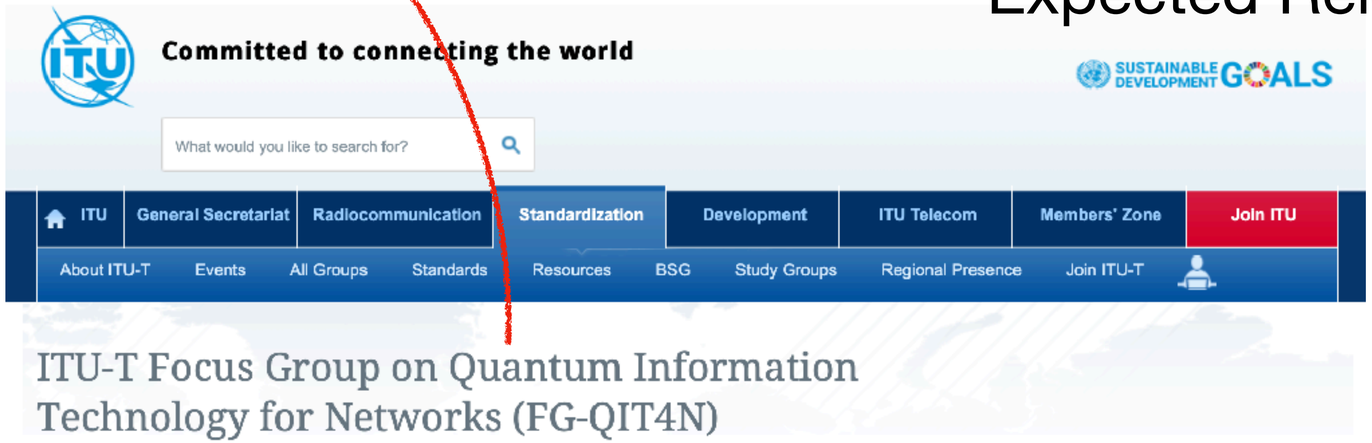
Subject:

Document 5D/-E
31 May 2021
Original: English
TECHNOLOGY ASPECTS

Finland

UPDATE PROPOSAL TO WORKING DOCUMENT TOWARDS PRELIMINARY DRAFT NEW REPORT ITU-R M.[IMT.FUTURE TECHNOLOGY TRENDS TOWARDS 2030 AND BEYOND]

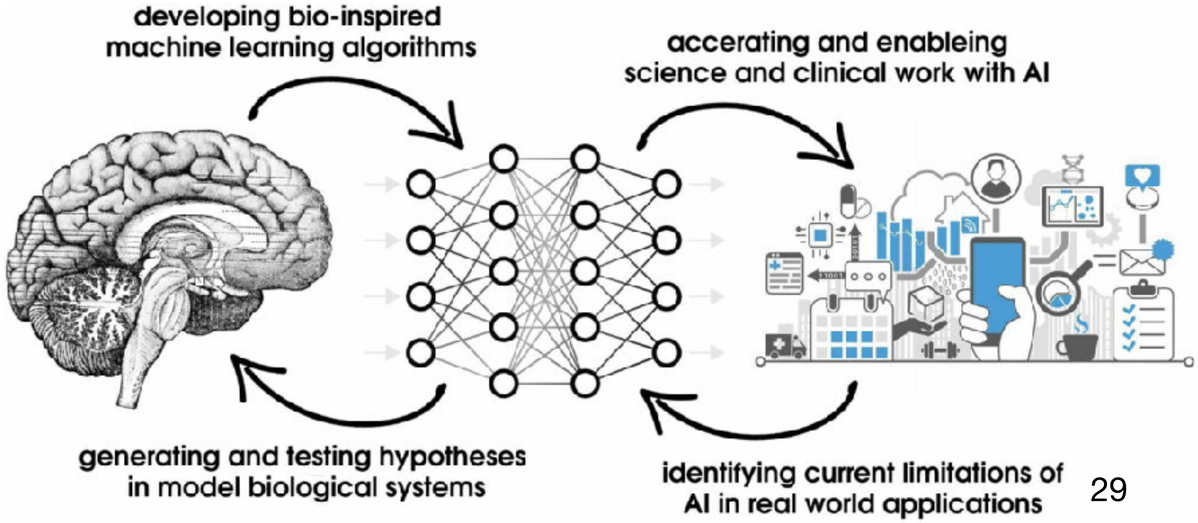
2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030



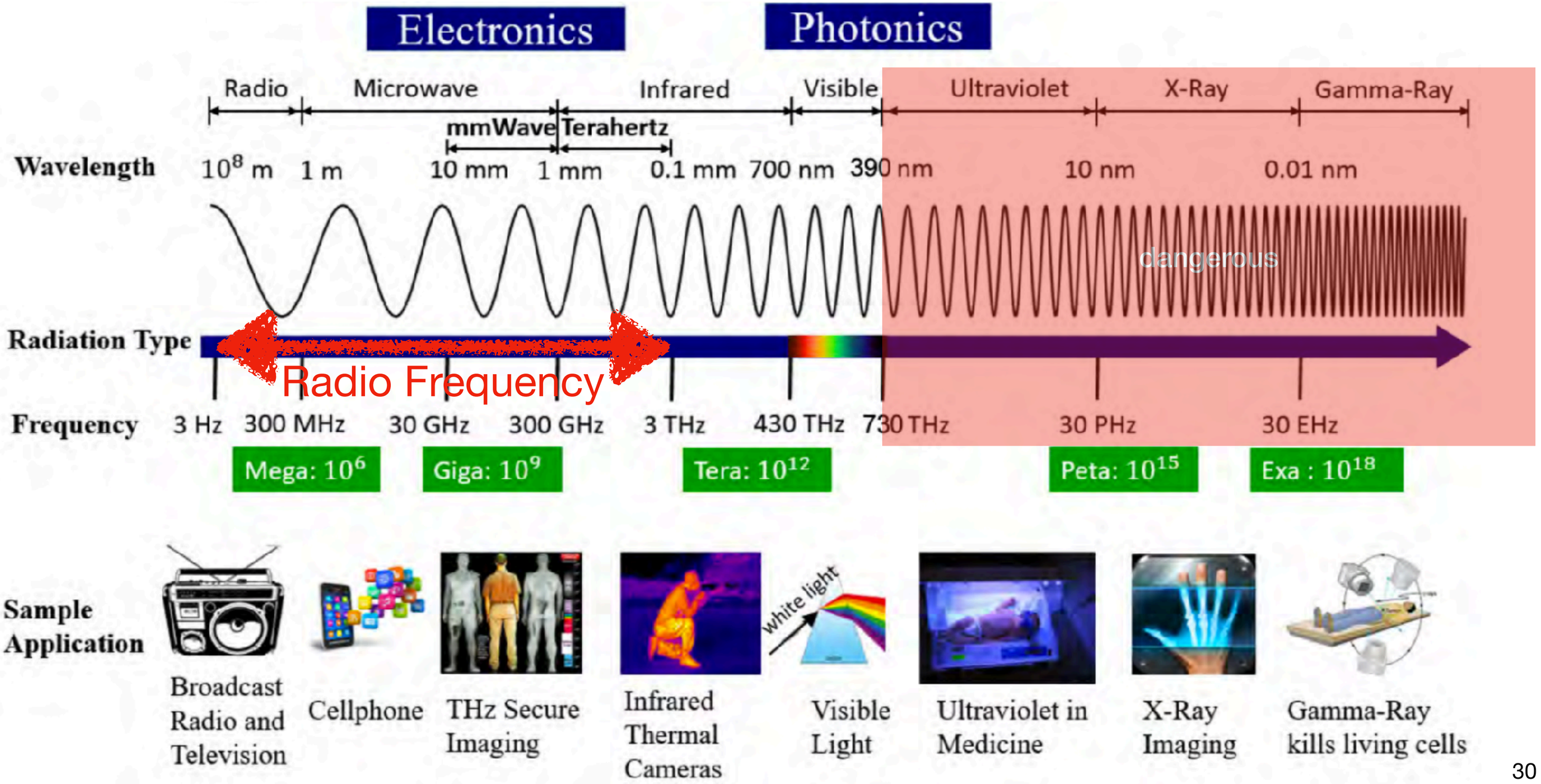
Expected Released 6G Standard

Motivation 7: Speed of 6G vs Human Brain

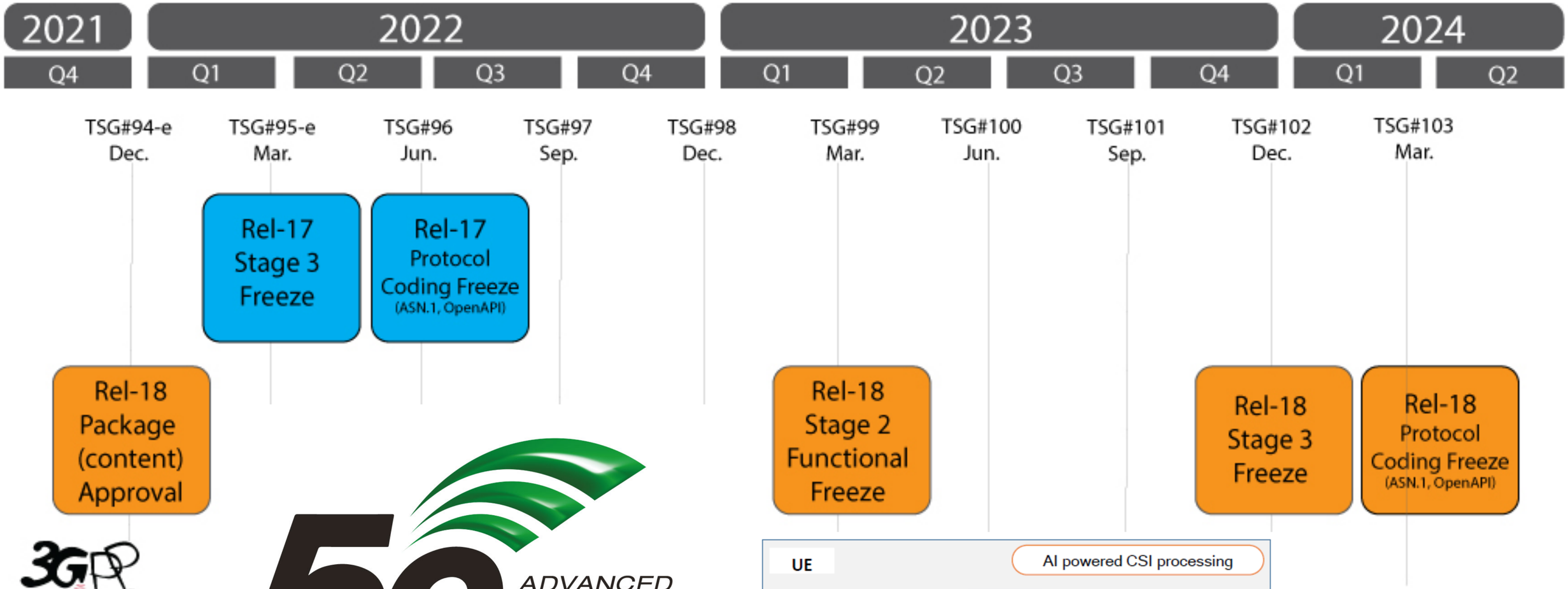
- There are about 100 billion (10^{11}) neurons in the human brain
- Every neuron can fire 200 times per second (5 ms update rate),
- Each neuron is connected to about 1000 others,
- Resulting in a computation speed of 20×10^{15} floating-point operations per second (flops)
- If each operation is assumed to be binary, we require a data rate of 20,000 Tbps as
- $H_B = 10^{11}$ neurons $\times$ 200 flop/sec $\times 10^3$/neuron
- $= 20 \times 10^{15}$ flop/sec
- $= 20$ petaflops/sec $\times 1$ bit/flop
- $= 20{,}000$ Tbps .
- 6G has speed > 1 Tbps

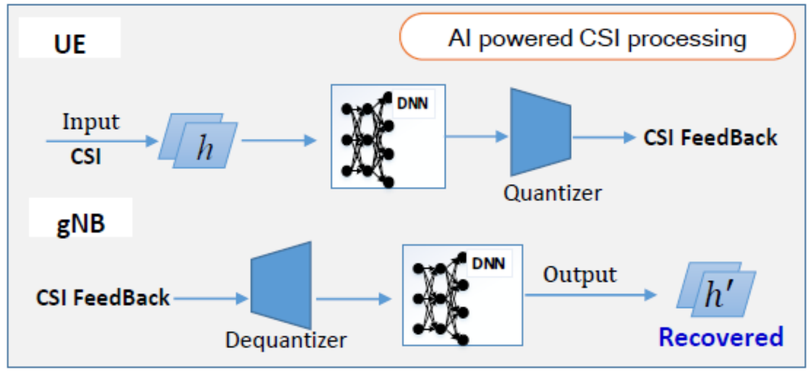


Motivation 3: Possible Band for Future Telecommunications



Motivation 4: The 5G-Advanced: Starting form Rel-18 (Prologue to 6G)





Source: 3GPP Summit, CEATEC2021, Japan, Oct. 2021.

Motivation 5: Why Security

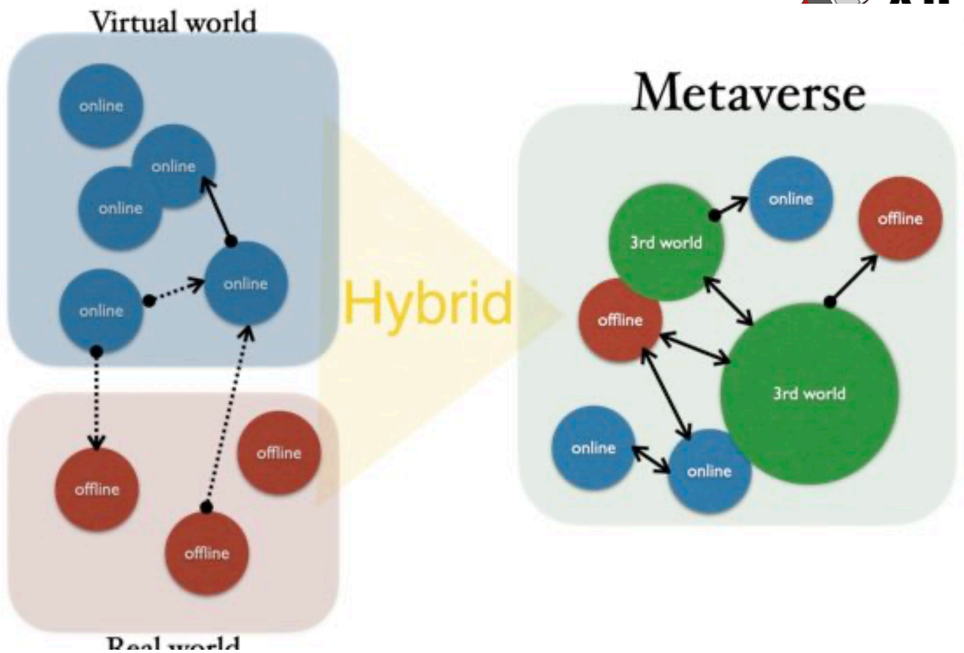
- Contracts and transactions are at the heart of our modern society.
- Their paper-based and digital records define the most important structures of our administrative economic, legal, political, and social systems by setting associated regulatory boundaries.
- They govern interactions among nations, public and private organizations, communities, and individuals worldwide.
- This is why they are frequently subject to **digital abuse and fraud**, which is why **cybersecurity is more important than ever in the digital age**.

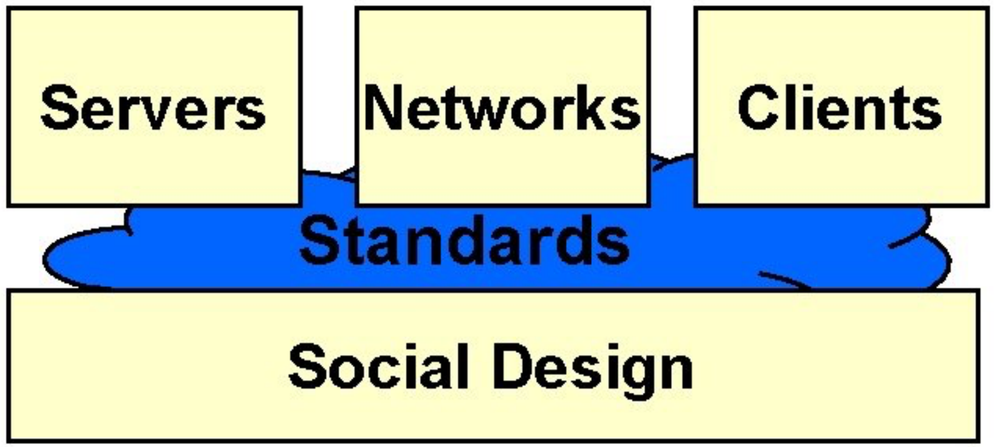
Type	Appearance	Advantages (+) and Disadvantages (–)
Primitive money	Pre-Christian	+ Itself immediately usable – Difficult to ascertain the value, not very handy, partly perishable
Noble metals	Bronze Age	+ Nonperishable, can be casted into basic tools, stable value due to rarity – Difficult to form and cast, not very handy
Coin money	8th century	+ Very handy, nonperishable, stable value due to rarity of raw material – Bulky in large volumes, subject to robbery
Paper money	11th century	+ Very handy, easily scalable by printing – No intrinsic value, subject to inflation, subject to robbery and fraud
Book money	14th century	+ Very handy, easy and safe storage, simple monetary transactions – Only virtually existent, no intrinsic value, not backed by commodity, subject to fraud
Fiat money	20th century	+ Simple monetary transactions, safe transaction due to cryptography, monetary policy being defined by the central bank and its "official legal currency" – Only virtually existent, no intrinsic value, and not backed by commodity
Cryptocurrencies	21st century	+ Very simple monetary transactions, very safe transaction due to cryptography, cost efficiency facilitating micropayments, self-regulated policy by open network, transfer without intermediary – No control of inflation due to absence of regulating authority, only virtually existent, no intrinsic value, not backed by commodity

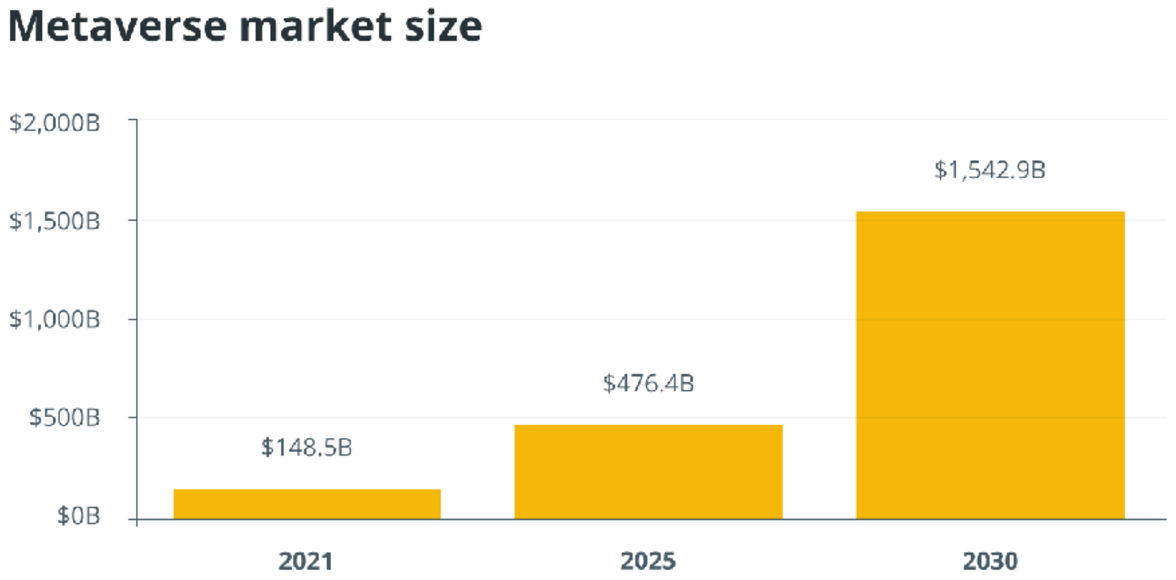
Understanding Metaverse

- A virtual-reality space in which users can interact with a computer-generated environment and other users.

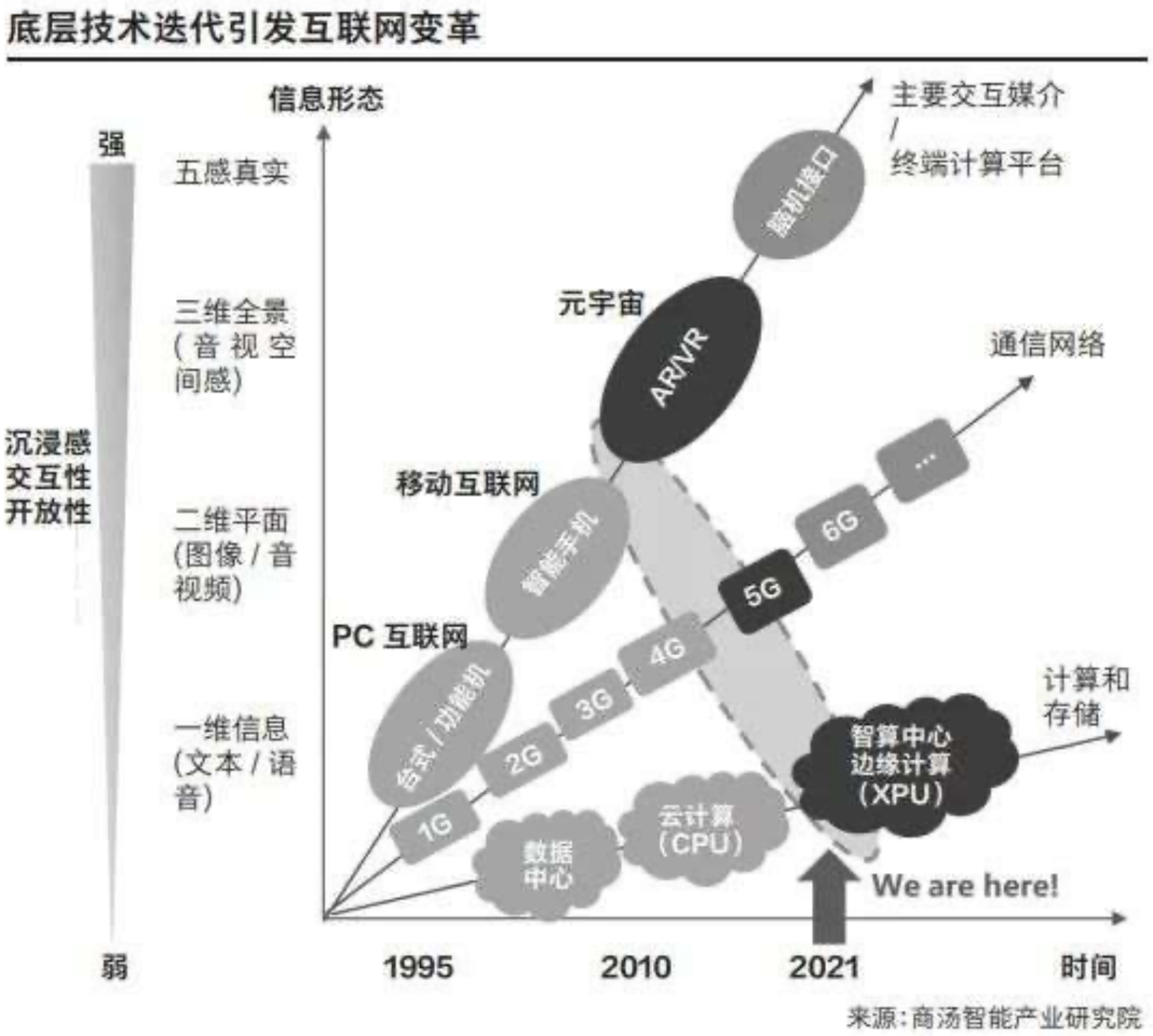
- Metaverse is coined by Neal Stephenson's fiction novel "Snow Crash" (1992).







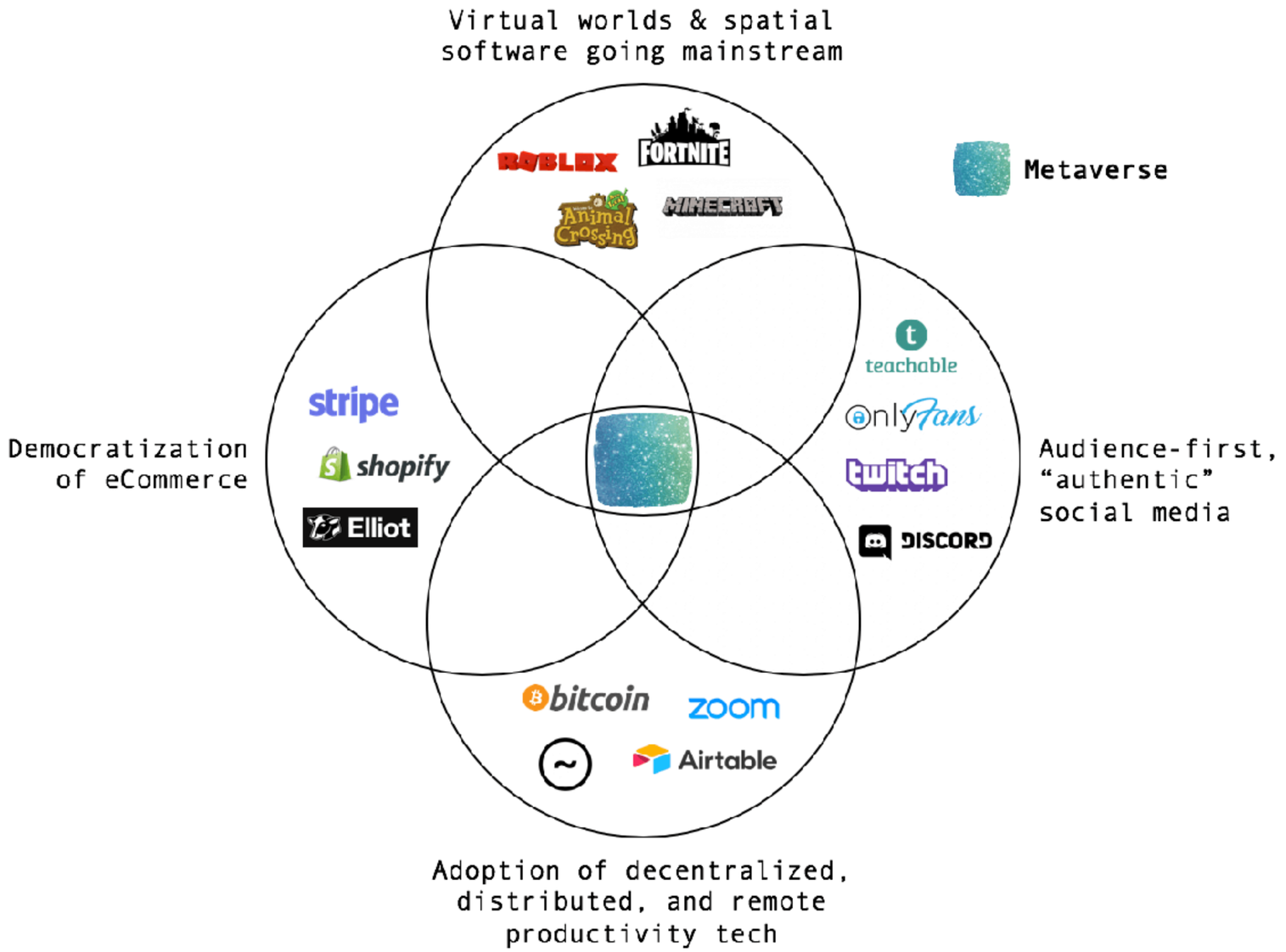
Five Trend in Metaverse



- 1. Creation Upgrade: AI digital content
- 2. Computing Upgrade: Huge demand for computing resource
- 3. Experience Upgrade: AR/VR
- 4. Decision Making Upgrade: Volume and Dimension of data
- 5. Commercial Upgrade: Metaverse is still internet, but the content is closer to reality.
- According to Bloomberg Information analysis, by 2024, the market size of Meta Universe will reach 800 billion U.S. dollars. PricewaterhouseCoopers predicts that the market size of Meta Universe will reach US$1.5 trillion by 2030.

Source: coinyuppie, 15 Nov 2021

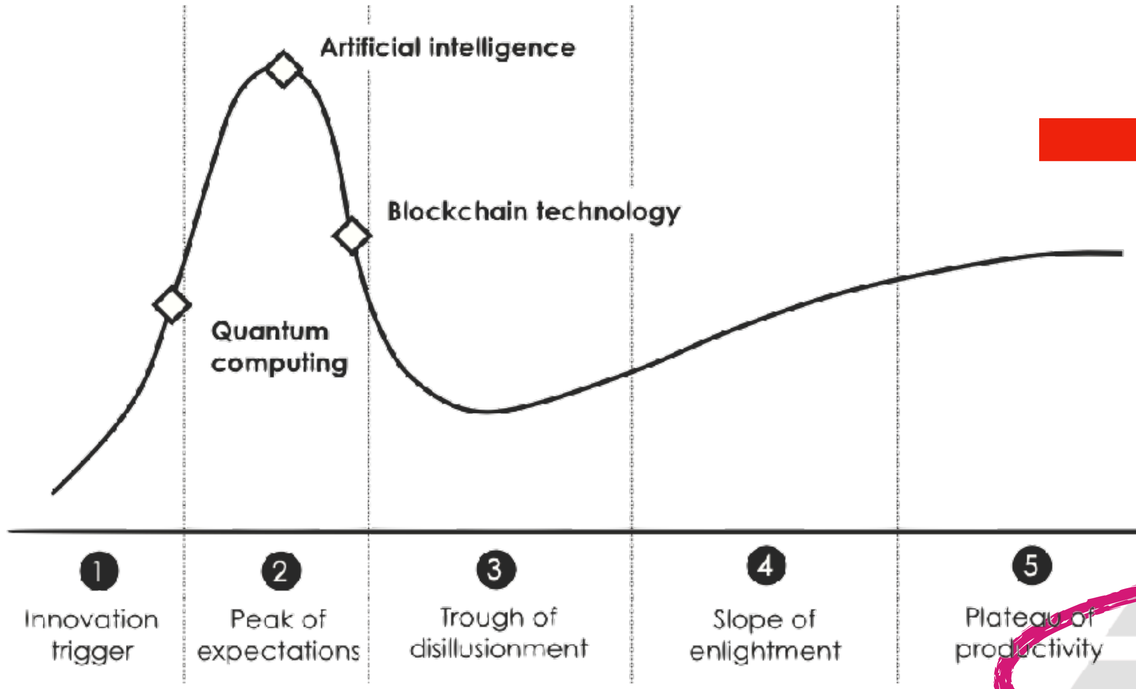
A Sketch of Tech and Trends Shaping Metaverse



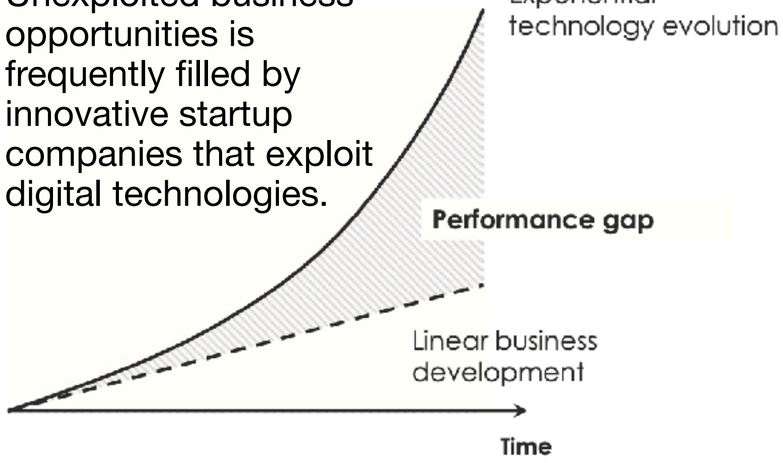
- Two months into the new normal, we're starting to pick up strong signals about how entertainment, work, school, and common modes of social interaction will change. What can we expect in the near future?
  - Video game will guide the way
  - Spatial software is coming
- Spatial software is characterized by the ability to move bodies and objects freely, in a parallel to the real world. This is opposed to traditional software, which uses some other logic to organize its interface.

source: Pulsarplatform, 2021

Motivation 8: Succesful Digital Transformations



Unexploited business opportunities is frequently filled by innovative startup companies that exploit digital technologies.



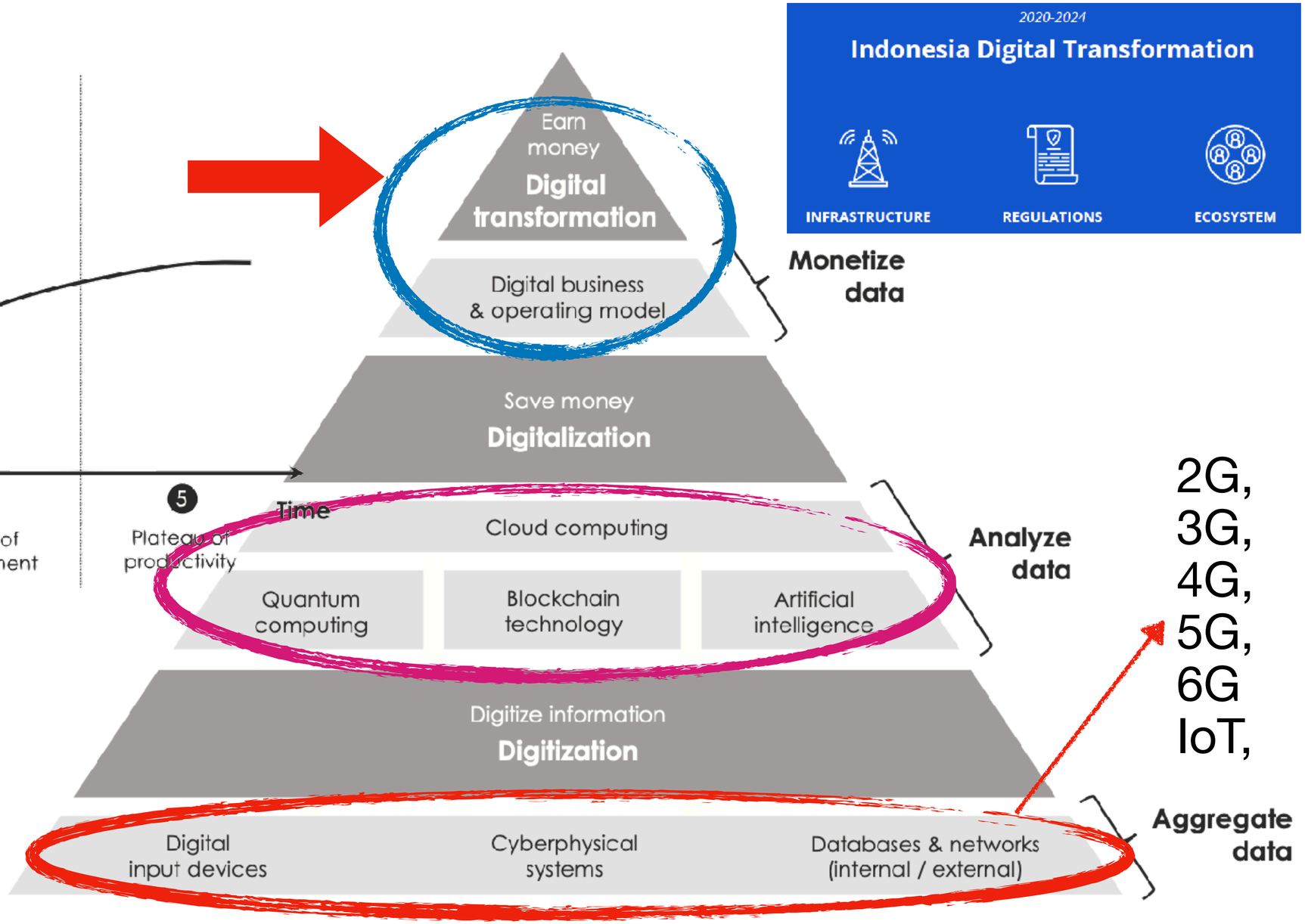


image: Volker Lang, Digital Fluency, Apress, 2021

Quantum Mechanic and Quantum Information

W. K. Heisenberg

Matrix mechanics (1925) and Indetermination principle (1927).

P. A. M. Dirac, P. Jordan


Theory of transformations.

H. Weil

Group theory.

J. von Neumann

Quantum measurement.

R. Feynman

A. Holevo

Quantum information theory (1970s).

Google AI

…

1900

2000

Time

M. Planck

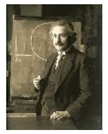
Black-body radiation and discrete nature of atomic and sub-atomic physics.

E. Fermi

L. De Broglie, E. Schrödinger


Wave mechanics (1924-1926).

A. Einstein, B. Podolski, N. Rosen

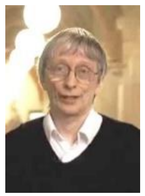


EPR Paradox (1935).

J. S. Bell

Bell's Theorem (1965)

D. Deutsch

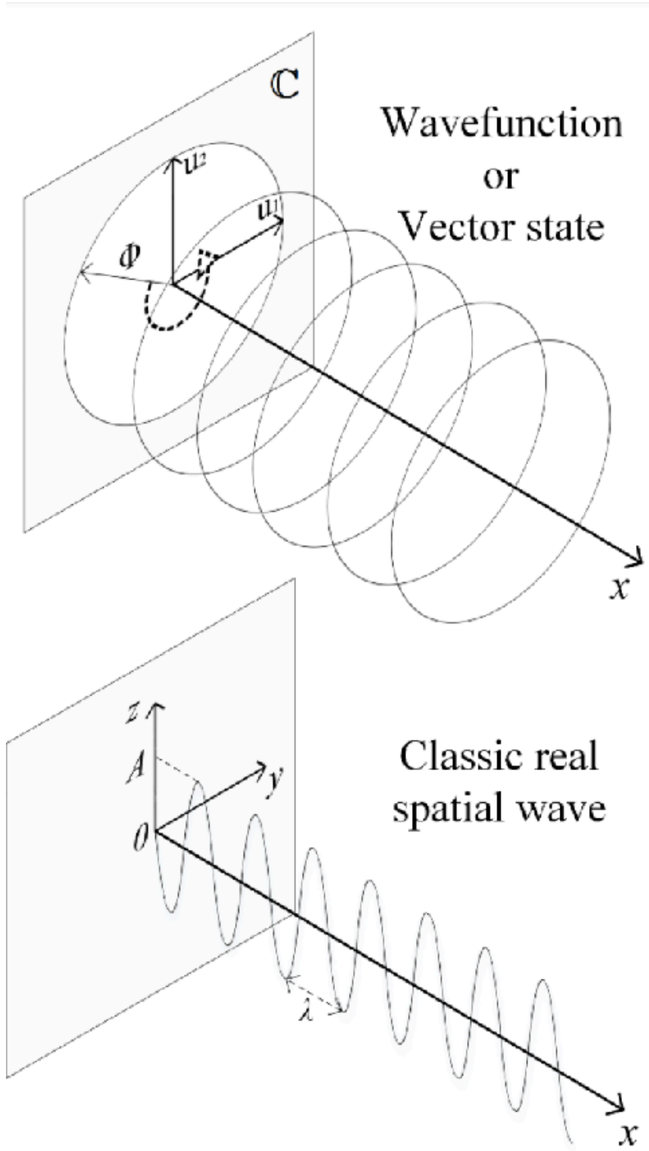


Preliminary formulation of quantum computation (1985)

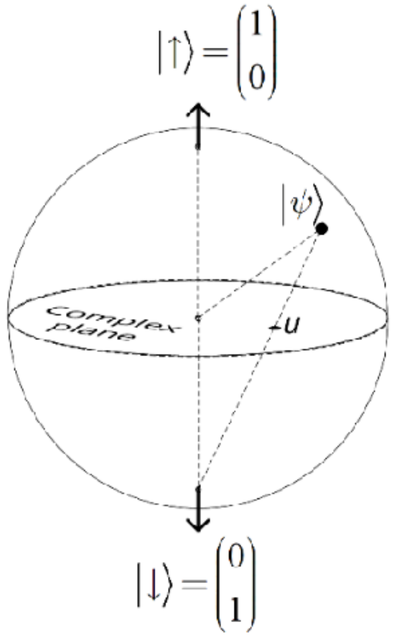
IBM Q

image: Bassoli, "Entanglement-assisted (Quantum) Communication Networks", IEEE International Conference on Communications 2021 (ICC21), 14-23 June 2021

Wave and Bit: Classical and Quantum



$$|\psi\rangle = c_1 |\uparrow\rangle + c_2 |\downarrow\rangle$$



XOR (sum) (= b)

AND (product) (= b)

Classical bit
$b \in \mathbb{F}_2$

- Classical: the bit represents the fundamental element, which only gets two values {0,1}.
- Quantum: quantum bit (qubit) is the wavefunction of a two-state quantum system, which can get infinite values in from superposition of values 0 and 1.

image: Bassoli, “Entanglement-assisted (Quantum) Communication Networks”, IEEE International Conference on Communications 2021 (ICC21), 14-23 June 2021

What is Special from Quantum Information (1/2)

Classic:

0 or 1

Quantum:

$|0\rangle$ and $|1\rangle$

Sequence of 11 bits:

11111100101

stores only **one number**: 2021

Sequence of 11 quantum bits:

$$(\alpha_1|0\rangle+\beta_1|1\rangle)(\alpha_2|0\rangle+\beta_2|1\rangle)(\alpha_3|0\rangle+\beta_3|1\rangle)(\alpha_4|0\rangle+\beta_4|1\rangle)$$
$$(\alpha_5|0\rangle+\beta_5|1\rangle)(\alpha_6|0\rangle+\beta_6|1\rangle)(\alpha_7|0\rangle+\beta_7|1\rangle)(\alpha_8|0\rangle+\beta_8|1\rangle)$$
$$(\alpha_9|0\rangle+\beta_9|1\rangle)(\alpha_{10}|0\rangle+\beta_{10}|1\rangle)(\alpha_{11}|0\rangle+\beta_{11}|1\rangle)$$

stores **all numbers** from 0 to 2047

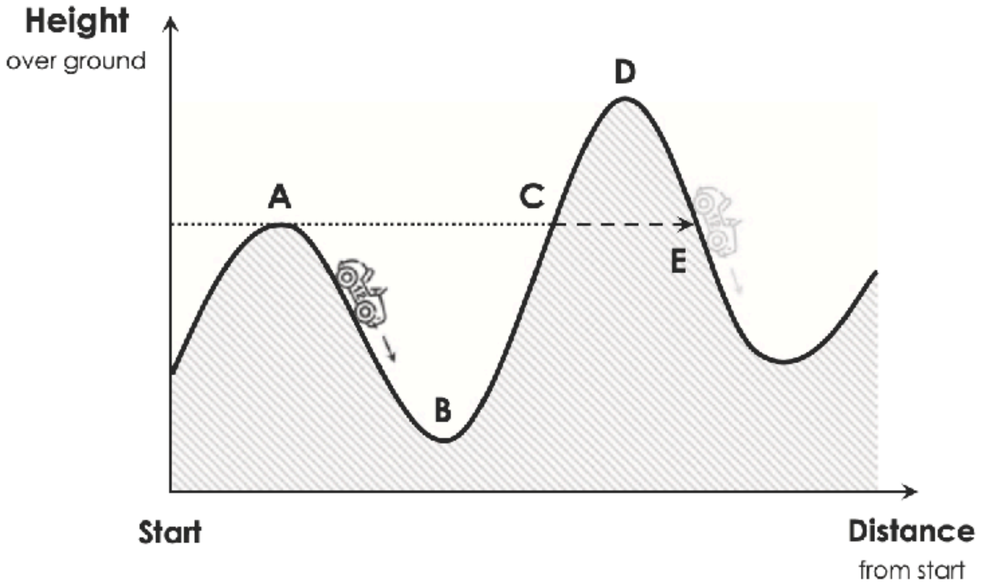
Step 1: 00+01=01 (or 0+1=1 in decimal numbers)

Step 2: 01+01=10 (or 1+1=2 in decimal numbers)

$$|01\rangle\oplus(\alpha\cdot|00\rangle+\beta\cdot|01\rangle)=\alpha\cdot|01+00\rangle+\beta\cdot|01+01\rangle$$
$$=\underbrace{\alpha\cdot|01\rangle}_{\text{Result of step 1}}+\underbrace{\beta\cdot|10\rangle}_{\text{Result of step 2}}$$

faster and efficient

What is Special from Quantum Information (2/2)



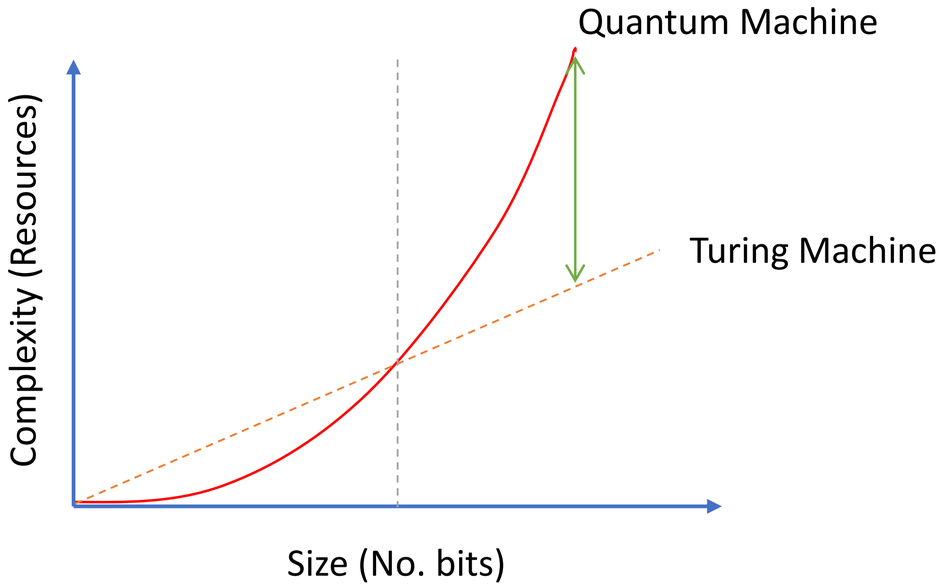
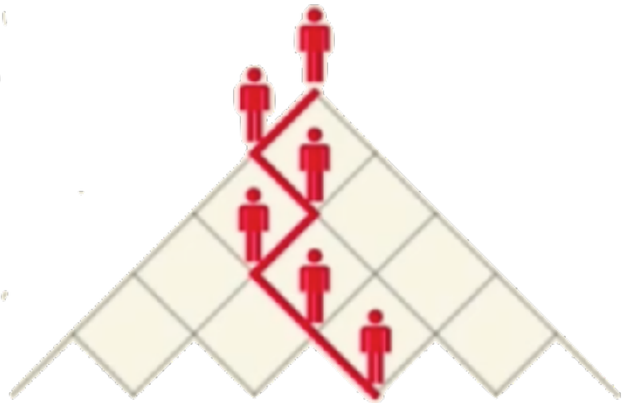
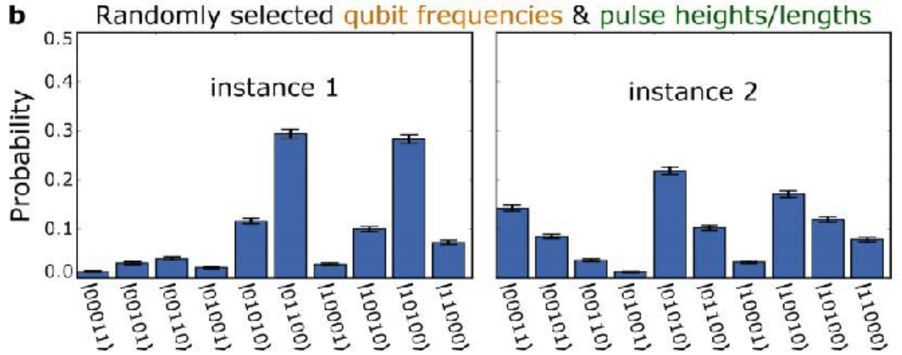


image: Walmsley, IC London

Classic



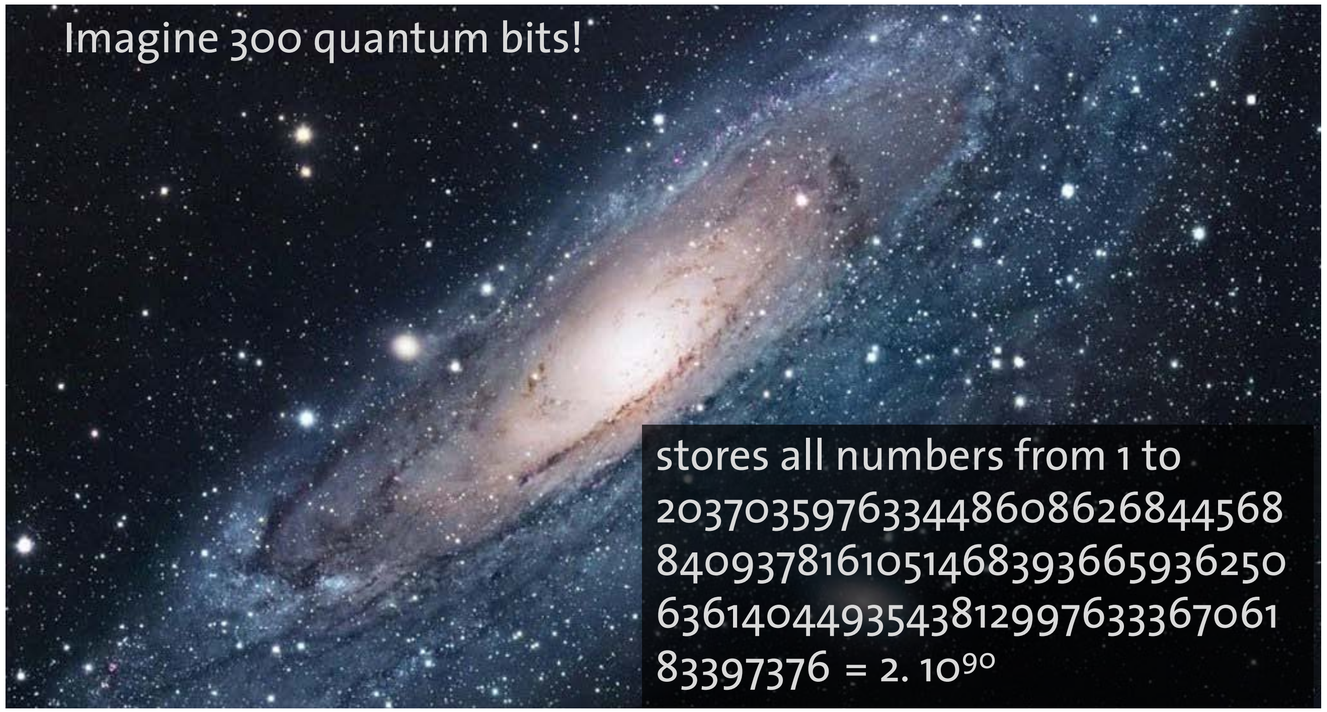
Quantum



- Classical approch move through the search space one solution at a time.
- Quantum approach operates in all states in parallel because superposition of states is possible.
- Quantum selects the best answer depending on the highest probability.

A Vast Amount of Quantum Information

A number larger than number atoms in the universe.



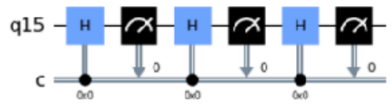

```
In [3]: # import all necessary objects and methods for quantum circuits
        from qiskit import QuantumRegister, ClassicalRegister, QuantumC

        # define a quantum register with a single qubit
        q = QuantumRegister(1)
        # define a classical register with a single bit
        c = ClassicalRegister(1,"c")
        # define a quantum circuit
        qc = QuantumCircuit(q,c)

        for i in range(3):
            qc.h(q[0]).c_if(c,0)
            qc.measure(q,c)

        # draw the circuit
        qc.draw(output="mpl")
```

Out[3]:



Current Quantum Computer by August 2020

Company	Name	Type	No. of Qubits
D-Wave Systems	5000Q	Annealer [a]	5,000
D-Wave Systems	2000Q	Annealer [a]	2,000
NIST	n.n.	Simulator [b]	300
IonQ	n.n.	Computer [c]	79
Google	Bristlecone	Computer [a]	72
IBM	Hummingbird	Computer [a]	65
Google	Sycamore	Computer [a]	54
IBM	Q53	Computer [a]	53
Intel	Tangle Lake	Computer [a]	49
IBM	Qiskit	Simulator [b]	30
IBM	Raleigh	Computer [a]	28
Rigetti Computing	19Q Acorn	Computer [a]	19
Alibaba	Aliyun	Computer [a]	11
Honeywell	Model H1	Computer [c]	10
Honeywell	Model H0	Computer [c]	6

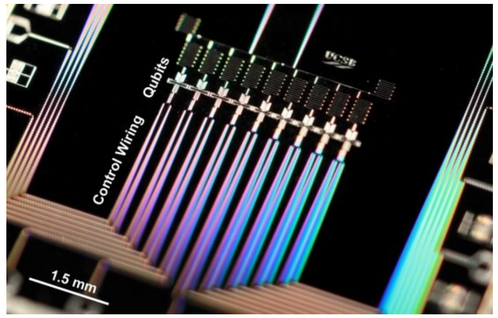
[a] *Superconducting circuit*

[b] *Classical computing hardware*

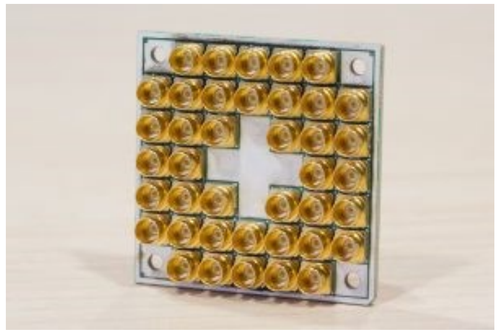
[c] *Linear ion trap microchip*

image: Volker Lang, Digital Fluency, Apress, 2021

“Q-Day”



Google: 9 qubit trapped ion device, 2016



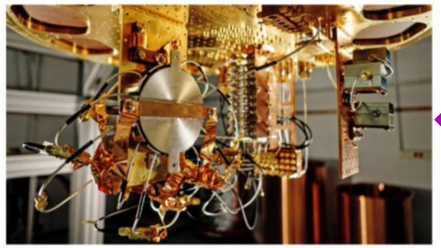
Intel: 17 superconducting qubit chip, 2017

IBM:
50 qubit trapped ion machine, 2017

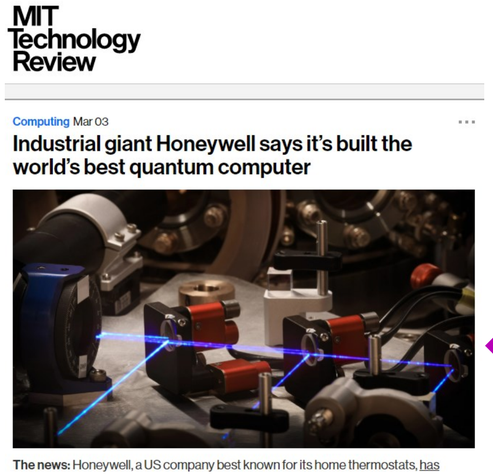
Google:
72 qubit ‘Bristlecone’, 2018

China: $11bn quantum computing investment

?



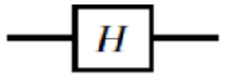
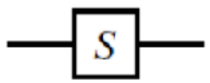
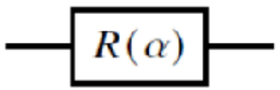
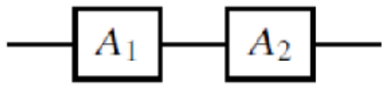
Sep 21st 2019

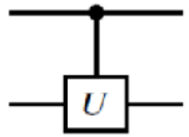
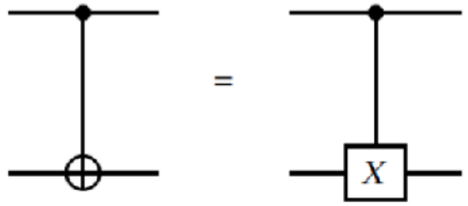
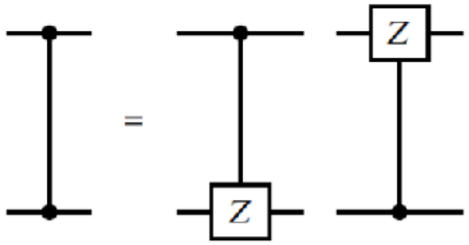


March-June 2020

image: British Telecom

Quantum Gates: Do not Exist in Classical

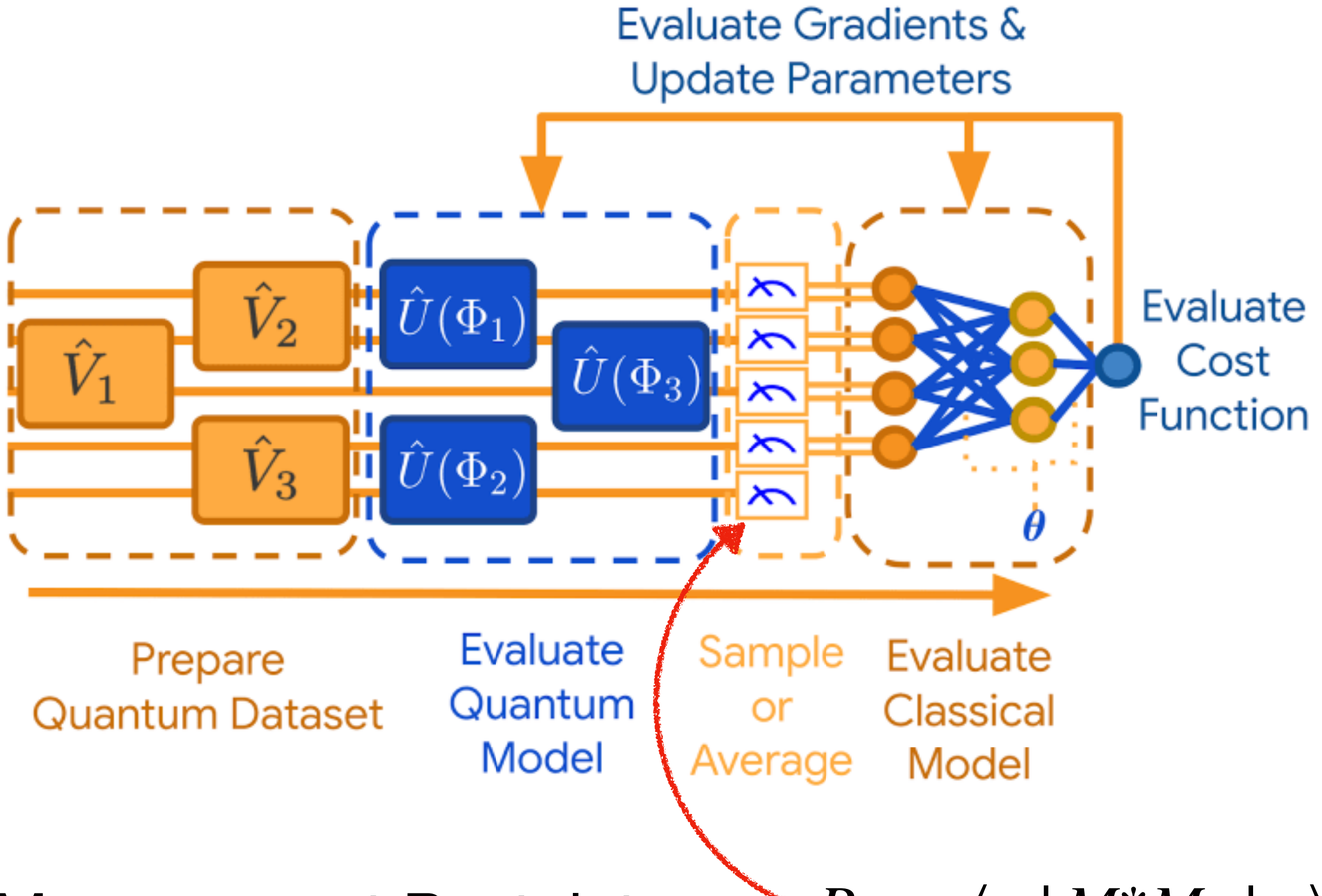
Qubit Gate	Circuit	Matrix
Hadamard		$H = \frac{1}{\sqrt{2}}\begin{bmatrix}1 & 1\\ 1 & -1\end{bmatrix}$ $\lvert a\rangle \rightarrow \frac{1}{\sqrt{2}}(\lvert 0\rangle + (-1)^a \lvert 1\rangle)$
Pauli X (Bit flip, NOT)		$X = \begin{bmatrix}0 & 1\\ 1 & 0\end{bmatrix}$ $\lvert a\rangle \rightarrow \lvert a \oplus 1\rangle$
Pauli Y (Bit&Phase flip)		$Y = \begin{bmatrix}0 & -i\\ i & 0\end{bmatrix}$ $\lvert a\rangle \rightarrow i(-1)^a \lvert a \oplus 1\rangle$
Pauli Z (Phase flip)		$Z = \begin{bmatrix}1 & 0\\ 0 & -1\end{bmatrix}$ $\lvert a\rangle \rightarrow (-1)^a \lvert a\rangle$
Phase gate (S or P gate)		$S = \begin{bmatrix}1 & 0\\ 0 & i\end{bmatrix}$ $\lvert a\rangle \rightarrow (-1)^a \lvert a\rangle$
Phase shift/rotation		$R(\alpha) = \begin{bmatrix}1 & 0\\ 0 & e^{i\alpha}\end{bmatrix}$ $\lvert a\rangle \rightarrow e^{ia\alpha} \lvert a\rangle$
Z Measurement		not a matrix $C \otimes \lvert a\rangle \rightarrow CC^\dagger \otimes \lvert a\rangle\langle a\rvert$
Serial gates		$A_2 A_1$

Multiqubit Gate	Circuit	Matrix
CU (Controlled U)		$\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & 1 & 0 & 0\\ 0 & 0 & U & \\ 0 & 0 & & \end{bmatrix}$ $\lvert a, b\rangle \rightarrow \lvert a\rangle \otimes U^a \lvert b\rangle$
CNOT (Controlled X)		$\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & 1 & 0 & 0\\ 0 & 0 & 0 & 1\\ 0 & 0 & 1 & 0\end{bmatrix}$ $\lvert a, b\rangle \rightarrow \lvert a, a \oplus b\rangle$
CZ (Controlled Z)		$\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & 1 & 0 & 0\\ 0 & 0 & 1 & 0\\ 0 & 0 & 0 & -1\end{bmatrix}$ $\lvert a, b\rangle \rightarrow (-1)^{a \cdot b} \lvert a, b\rangle$

- Gates for multiple qubits may not be constructed from the single qubit.
- Measurement is a must in quantum.

image: Bassoli, “Entanglement-assisted (Quantum) Communication Networks”, IEEE International Conference on Communications 2021 (ICC21), 14-23 June 2021

Motivation 11: When Quantum Meet AI



Drug discovery

Data encryption

Logistics

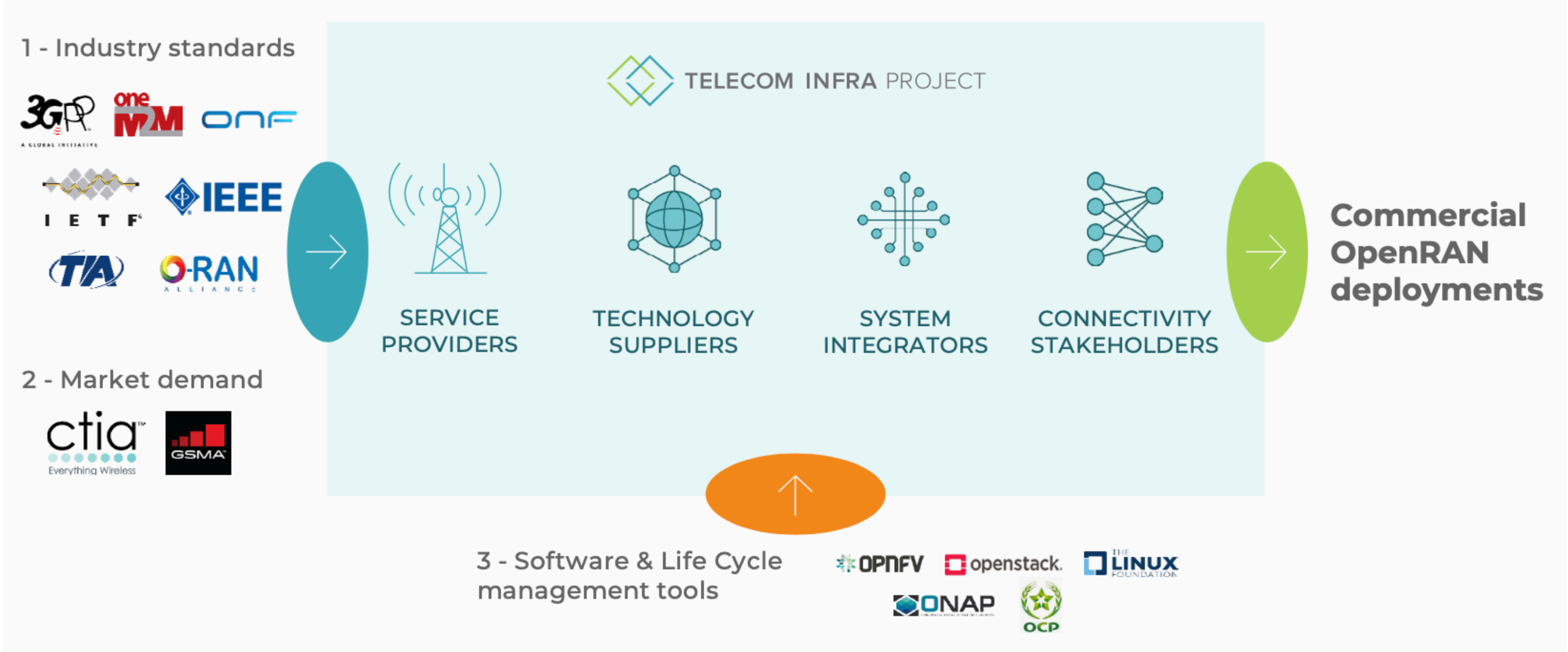
Big Data

Measurement Postulate: $P_m = \langle \psi | M_m^* M_m | \psi \rangle$

Post Measurement State: $|\psi'\rangle = \frac{M_m |\psi\rangle}{\sqrt{P_m}}$

image: Walmsley, IC London

Opportunity 2: Cellular Infrastructure, from Design to Commercialization



- The new supply chain is rapidly expanding, aiming to provide much more vendor choice to mobile operators globally.

image: TIP, 2021

Opportunity 4: Unique Modular Concrete Poles that are Simple and Cost Effective

Cost Effective

40%

40% less cost compared to building top macro

Concrete Pole

Ease of Installation

Deploy maximum no. of poles nationwide

Complete Control

Ease of Access

To site maintenance

Modular

5G Ready

Minimum required space

image: Rakuten