

Softwarization of the Internet

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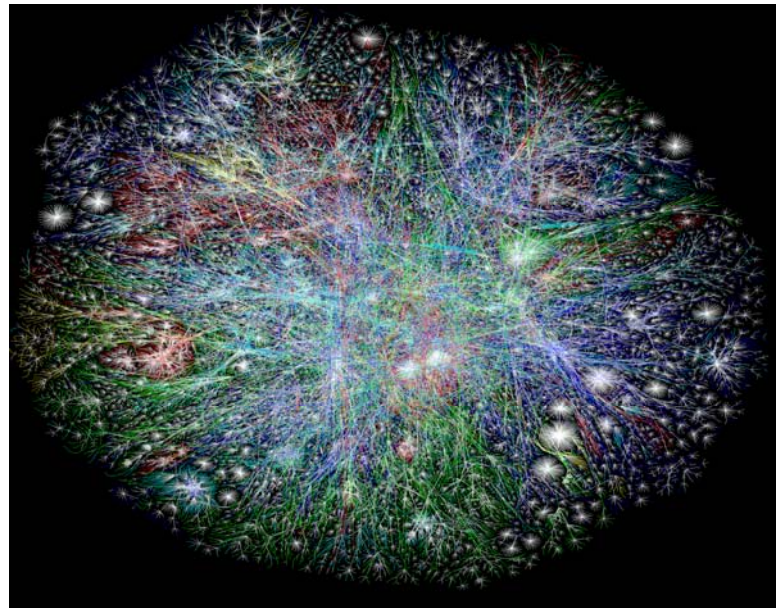
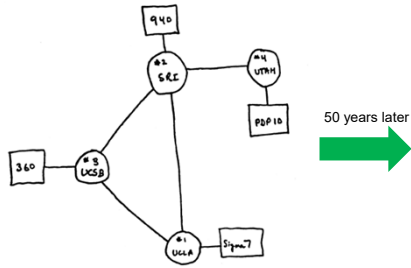
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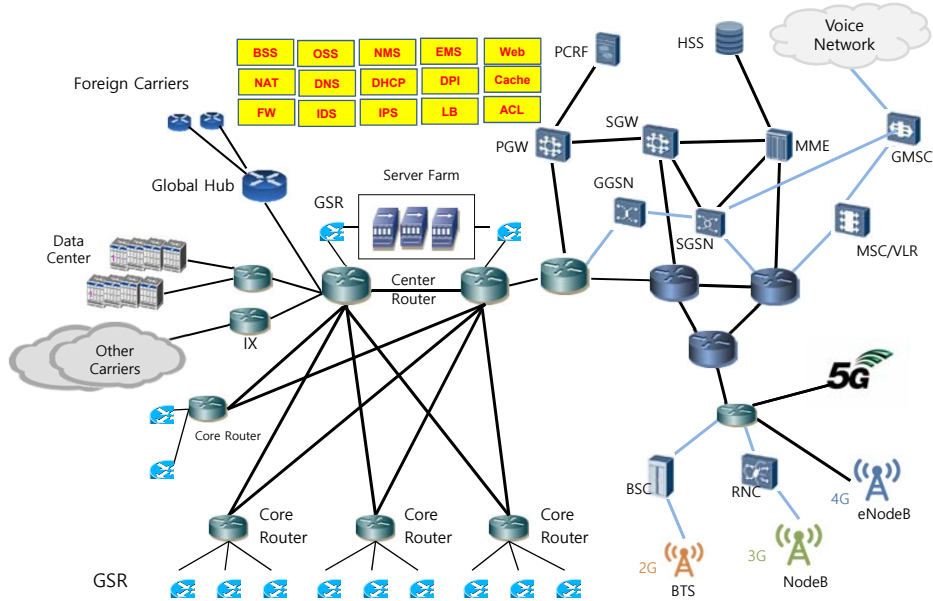
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Internet History

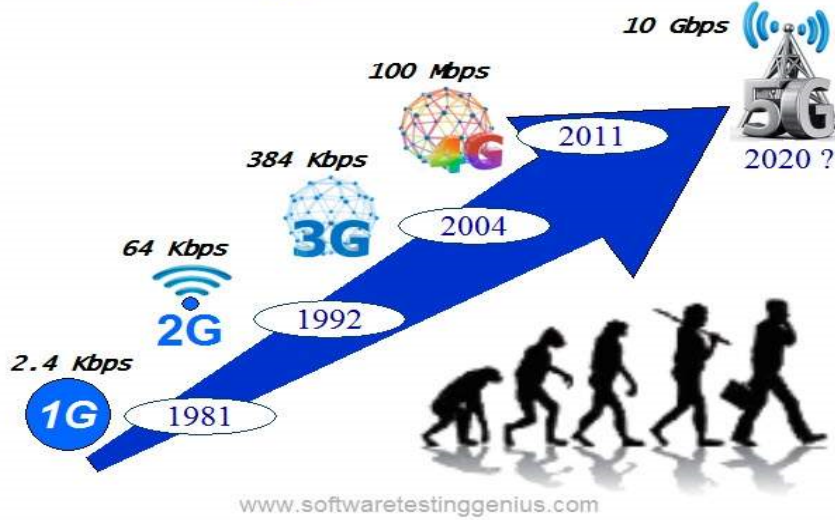


Evolution of Telco Networks



Evolution of Mobile Networks

'G'-Technology - A Race to Innovation




Evolution of Mobile Communications

Mobile communications: from 1G to 5G

Generation	Device	Specifications
1G		<p>1G</p> <p>Year: 1981-85</p> <p>Standards: AMPS, TACS</p> <p>Technology: Analog</p> <p>Bandwidth: Analog</p> <p>Data rates: ...</p>
2G		<p>2G</p> <p>Year: 1991</p> <p>Standards: GSM, GPRS, EDGE</p> <p>Technology: Digital</p> <p>Bandwidth: Narrow Band</p> <p>Data rates: ...</p>
3G		<p>3G</p> <p>Year: 2001</p> <p>Standards: UMTS, HSPA</p> <p>Technology: Digital</p> <p>Bandwidth: Broad Band</p> <p>Data rates: ...</p>
4G		<p>4G</p> <p>Year: 2010</p> <p>Standards: LTE, LTE-Advanced</p> <p>Technology: Digital</p> <p>Bandwidth: Broad Band</p> <p>Data rates: ...</p>




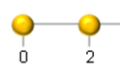
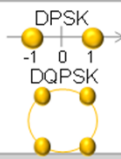
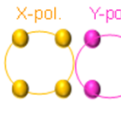
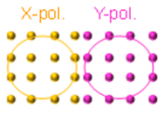
Evolution of Wireless Networks (WiFi)



IEEE Standard	Year Adopted	Frequency	Max. Data Rate	Max. Range
802.11a	1999	5 GHz	54 Mbps	400 ft.
802.11b	1999	2.4 GHz	11 Mbps	450 ft.
802.11g	2003	2.4 GHz	54 Mbps	450 ft.
802.11n	2009	2.4/5 GHz	600 Mbps	825 ft.
802.11ac	2014	5 GHz	1 Gbps	1,000 ft.
802.11ac Wave 2	2015	5 GHz	3.47 Gbps	10 m.
802.11ad	2016	60 GHz	7 Gbps	30 ft.
802.11af	2014	2.4/5 GHz	26.7 Mbps – 568.9 Mbps (depending on channel)	1,000 m.
802.11ah	2016	2.4/5 GHz	347 Mbps	1,000 m.
802.11ax	2019 (expected)	2.4/5 GHz	10 Gbps	1,000 ft.
802.11ay	late 2019 (expected)	60 GHz	100 Gbps	300-500 m.
802.11az	2021 (expected)	60 GHz	Device tracking refresh rate 0.1-0.5 Hz	Accuracy <1m to <0.1m

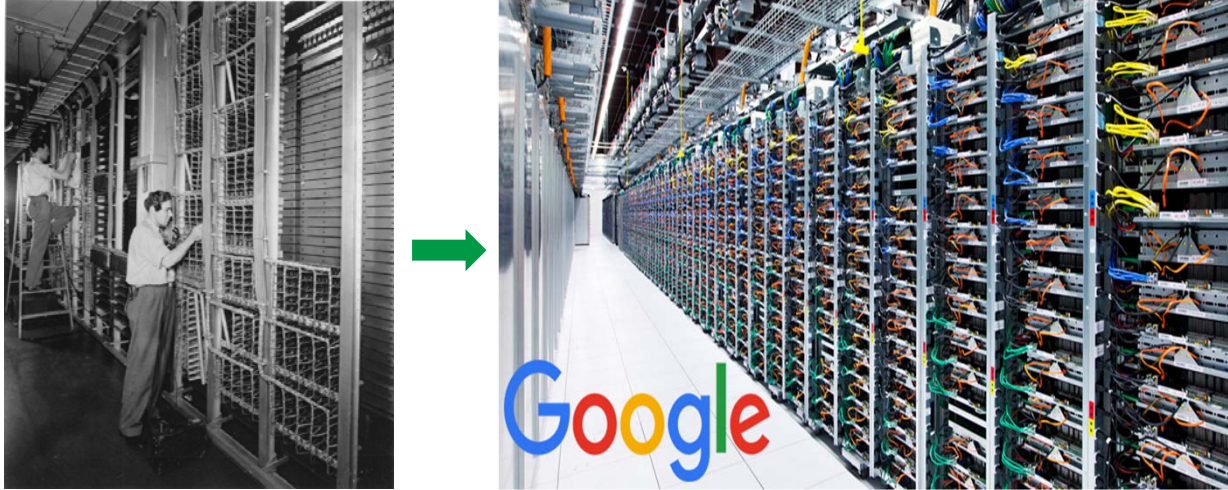
Source: L-com

Evolution of Optical Networks

Year:	1980	1990	2000	2010	2020
Data rate per channel	2.5 Gb/s	10 Gb/s	40 Gb/s	100 Gb/s	200G/400G/1T and beyond
Modulation format (typical)	OOK (NRZ) 	OOK (RZ) 	DPSK, DQPSK 	PDM-QPSK 	PDM-16QAM 
System features (newly added)	Single-span, Single-channel	Multi-span with EDFAs, WDM	DWDM, Raman amplification, and ROADMs	1:N WSS, CDC-ROADMs	Flexible-grid WDM, M:N WSS
System capacity (typical)	2.5 Gb/s (single channel)	400 Gb/s (40 WDM channels)	1.6 Tb/s (40 WDM channels)	8 Tb/s (80 DWDM channels)	20 Tb/s (50 flexible-grid WDM channels)
System reach (typical)	100 km (single span)	1000 km	1000 km @40G 3000 km @10G	2000 km @100G	4000/2500 km @100(200)G
Enabling technologies	Optical modulation and detection	High-speed modulation, HD-FEC	Differential phase-shift-keying	Coherent detection with ODSP	SD-FEC, PDM-QAM, FTN, Superchannel

Source: Huawei

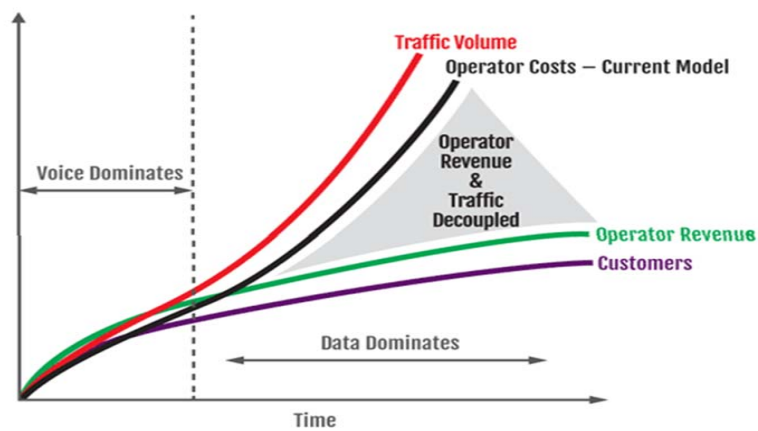
Evolution of Data Centers



Source: Huawei

Challenges of Telcos (1/2)

- ❖ These advances in communications/networking technologies along with innovations on smart phones & apps resulted in **explosive traffic growth on the Internet**



Source: Accenture Analysis

Challenges of Telcos (2/2)

❖ Reasons for Data Explosion

- Smart Phones & Devices
- Increase of Multimedia Contents
 - Photos, YouTube, Sports, K-Pop Music Videos, K-Dramas...
- Super Highways
 - 3G → 4G (LTE, LTE-A) → 5G

❖ Increased CAPEX/OPEX for Telcos

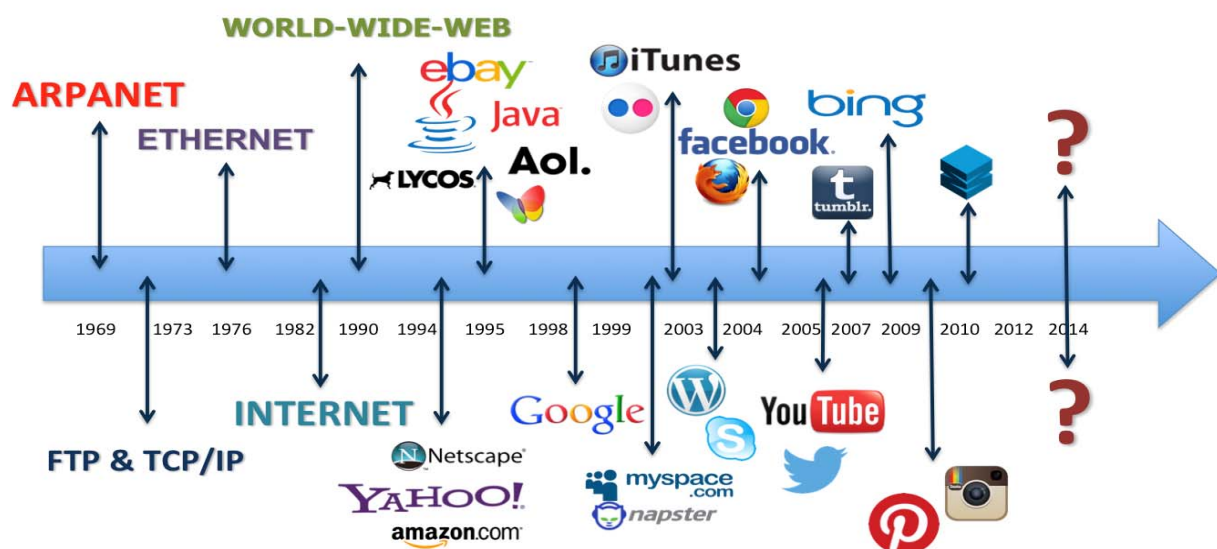
- Incredibly high cost in buying spectrums
- Very expensive black boxes (routers/switches/middleboxes)

❖ What about Revenues & Profits?

- the revenues have not kept up and profits decreased

Source: Accenture Analysis

Internet Applications (1992~2010)



Internet Applications (2010~present)



Mobile Instant Messaging Apps

WhatsApp (USA)



- Started: Nov. 2009
- Active Users: 1.5 Billion
- Dominant: USA, Europe, Brazil, Mexico, India
- Acquired by Facebook (Feb. 2014) for \$19B

KakaoTalk (Korea)



- Started: March 2010
- Active Users: 49.8 Million
- Dominant: Korea (90% of Koreans use)
- Revenue from gaming, emoticon, finance
- 90% drop in Telco SMS Usage for last 6 years in Korea

WeChat (China)



- Started: Jan. 2011
- Active Users: 1 Billion
- Dominant: China but growing in USA, Europe & Africa
- Revenue from gaming, shopping, banking

Line (Japan/Taiwan)



- Started: June 2011
- Active Users: 217 Million
- Dominant: Japan, Taiwan, Southeast Asia and South America
- Revenue from gaming, stickers, ads

Source: techcrunch.com, Statista (www.statista.com)

MOOC-based Education for Industry by POSTECH

The screenshot shows the homepage of www.postechx.kr with four featured MOOC programs:

- AI · 블록체인 NanoMaster**: POSTECH 정보통신대학원 AI · 블록체인 정규 석사과정 강좌입니다. (AI · Blockchain NanoMaster: Regular graduate course in AI · Blockchain at POSTECH Graduate School of Information and Communications.)
- 『미래 사업을 선도하는 인재 양성 교육』**: 미래 신기술 학습을 희망하는 KT임직원 누구나 참여 가능합니다. (『Education for nurturing talents leading future businesses』: Anyone who wishes to learn new technologies for the future can participate.)
- AI · 빅데이터 · IoT 인재양성 온라인 기초과정 (MOOC)**: 취업 준비생 누구나 포항공대와 포스코가 제공하는 무료 온라인 교육 과정에 참여할 수 있습니다. (AI · Big Data · IoT Talent Training Online Basic Course (MOOC): Anyone preparing for a job can participate in the free online education program provided by Pohang University of Science and Technology and POSCO.)
- 정보통신대학원 MOOC 프로그램**: 전공자 및 실무자 대상의 빅데이터 · IoT · 네트워크 · 소프트웨어 관련 심화과정입니다. (Information and Communications Graduate School MOOC Program: Advanced courses related to Big Data · IoT · Network · Software for majors and practitioners.)

<http://www.postechx.kr>

Internet Applications (Present to Future)?



2019 IEEE Int. Conference on Blockchain & Cryptocurrency (May 14-17, Seoul, Korea)



IEEE International Conference on Blockchain and Cryptocurrency
14-17 May 2019 // Seoul, South Korea



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2019 IEEE International Conference on Blockchain and Cryptocurrency (ICBC 2019)



2019 IEEE International Conference on Blockchain and Cryptocurrency (ICBC 2019) will be held in beautiful and vibrant Seoul, Korea during May 14-17, 2019. ICBC 2019 will be the first premier technical conference on Blockchain and Cryptocurrency that will be sponsored by IEEE Communications Society (ComSoc). ICBC 2019 will

IMPORTANT DATES

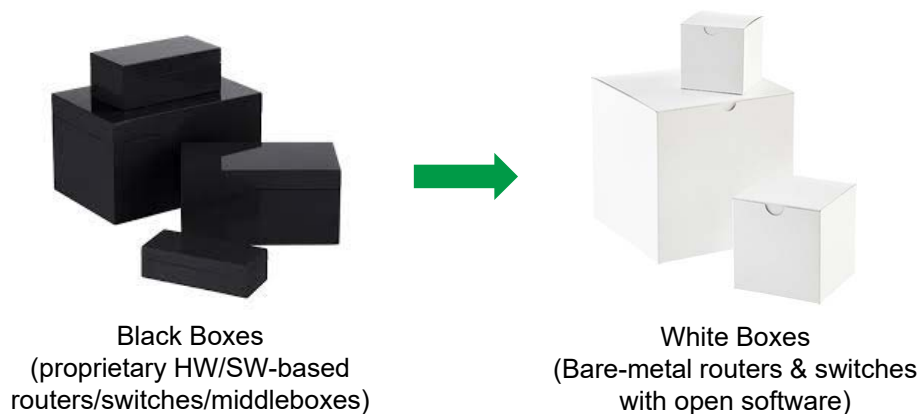
Paper Submission Deadline:
21 Dec 2018 (Extended)

Tutorial Proposal Submission Deadline:
31 Jan 2019

Acceptance Notification:

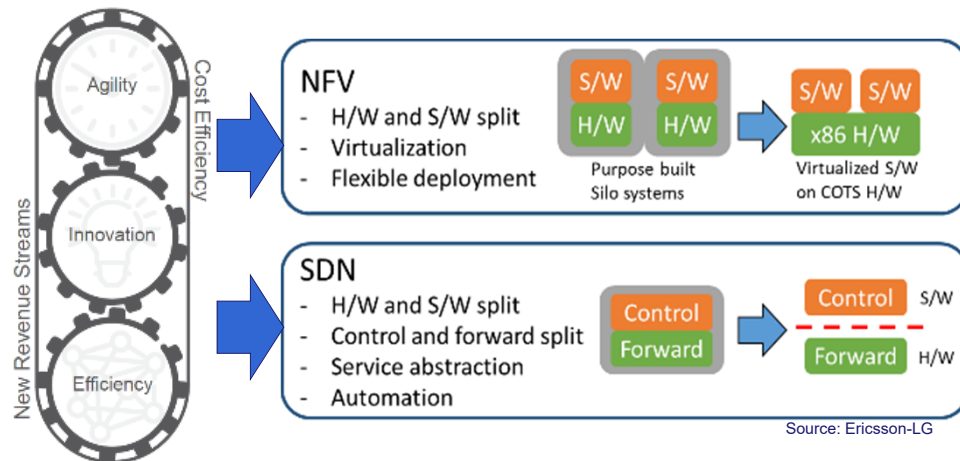
<http://icbc2019.ieee-icbc.org/>

What does Network Softwarization mean?



Softwarization - SDN/NFV

❖ SDN/NFV – Key to network softwarization



Softwarization – Open Source Projects

❖ Work with open projects, organizations and solution providers

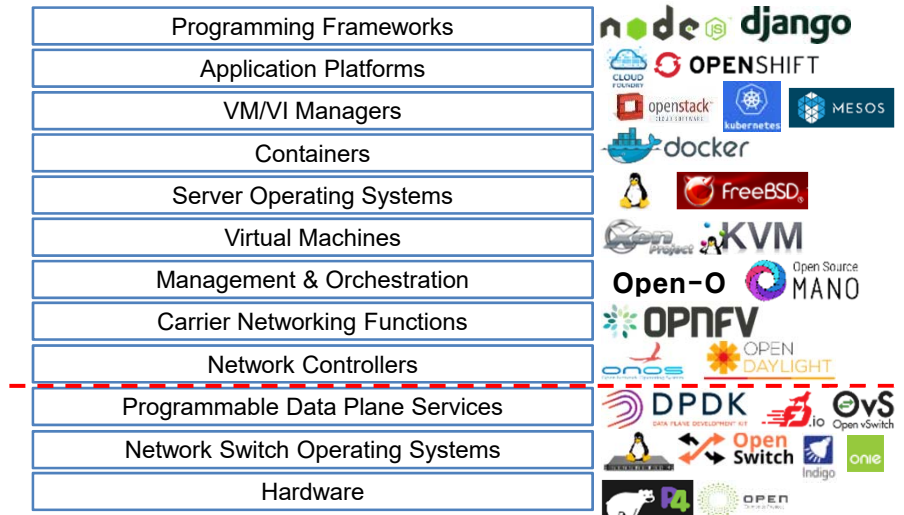
- ONF (Open Networking Forum)
- Open Compute Project (OCP)
- ONAP, OPNFV, OpenStack, OSM, P4
- **SDN/NFV Forum (<http://sdnfv.org>)**
- IETF, ETSI, Linux Foundation
- Barefoot Networks, Edgecore Networks,

❖ Hire more software/innovative people!

❖ Re-educate people

Softwarization - Open Networking Ecosystem

❖ Open Networking Reference Model



Source: Huawei

Softwarization Status

Network or Data Center	Softwarization Status
Enterprise networks	Very slowly
Research networks	Slowly
Telco networks	Very slowly
5G core networks	Yes!
Public networks	Very slowly
Data centers of cloud service providers (e.g., Google, Amazon, Microsoft)	Yes!
Data centers of enterprises (companies, universities, government organizations)	Very slowly
Data centers of telcos	Very slowly

Concluding Remarks

- ❖ The Internet has been growing continuously over the past 50 years and has become an essential infrastructure in what we do
- ❖ It will continue to grow and support more applications including blockchain applications and services
- ❖ The Internet infrastructure needs to be
 - **softwarized** → more affordable, flexible and agile
 - **smarter** → automated, intelligent and self-driving using AI technology
- ❖ More R&D is needed to achieve these
- ❖ People need to be **softwarized** as well!!!

