Softwarization of the Internet

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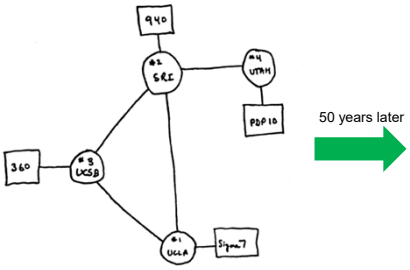
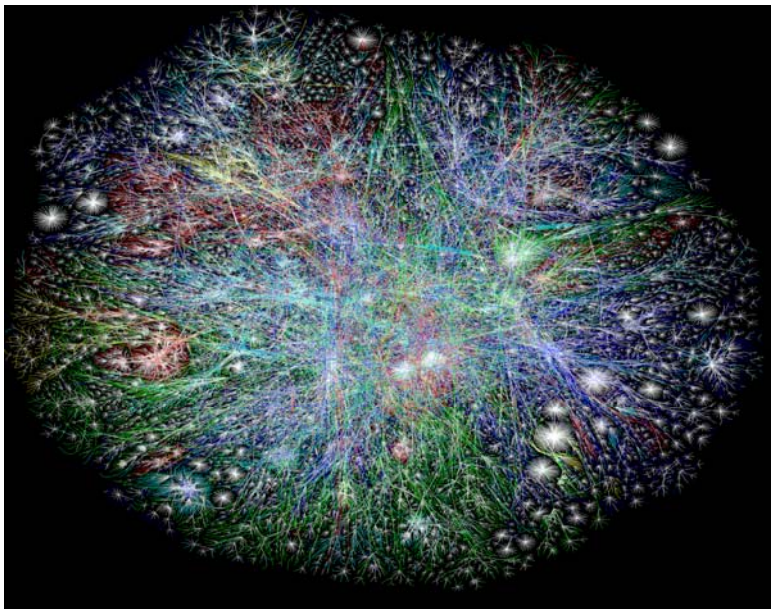
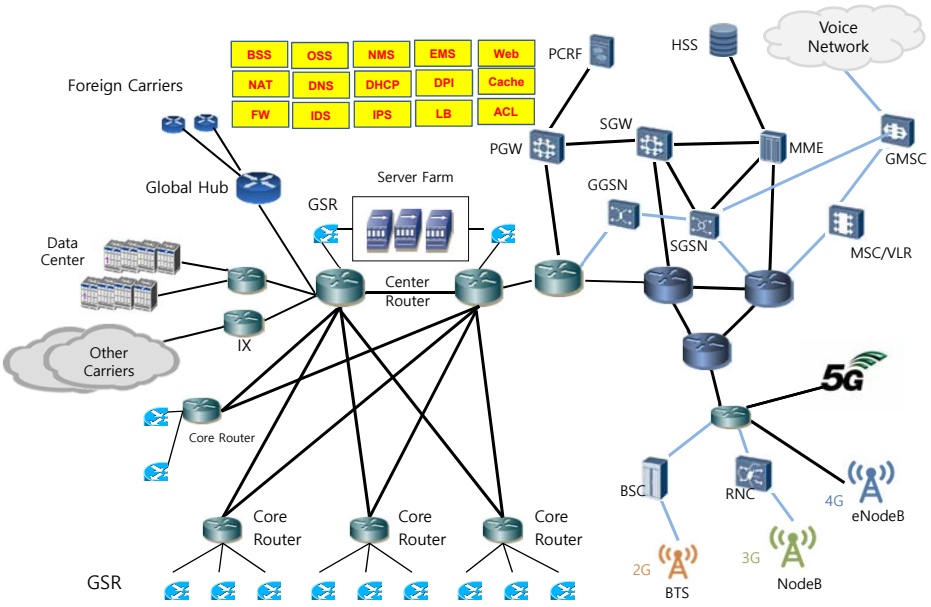
Internet History

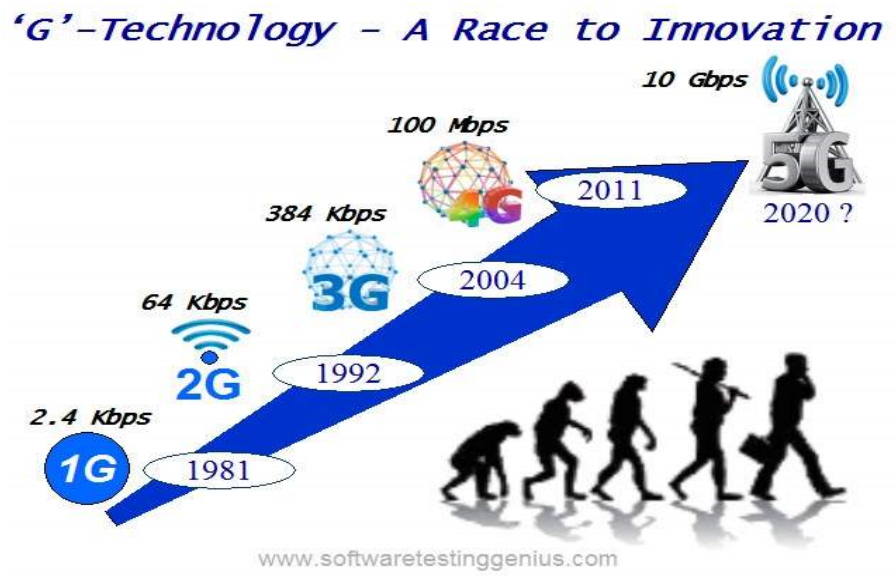




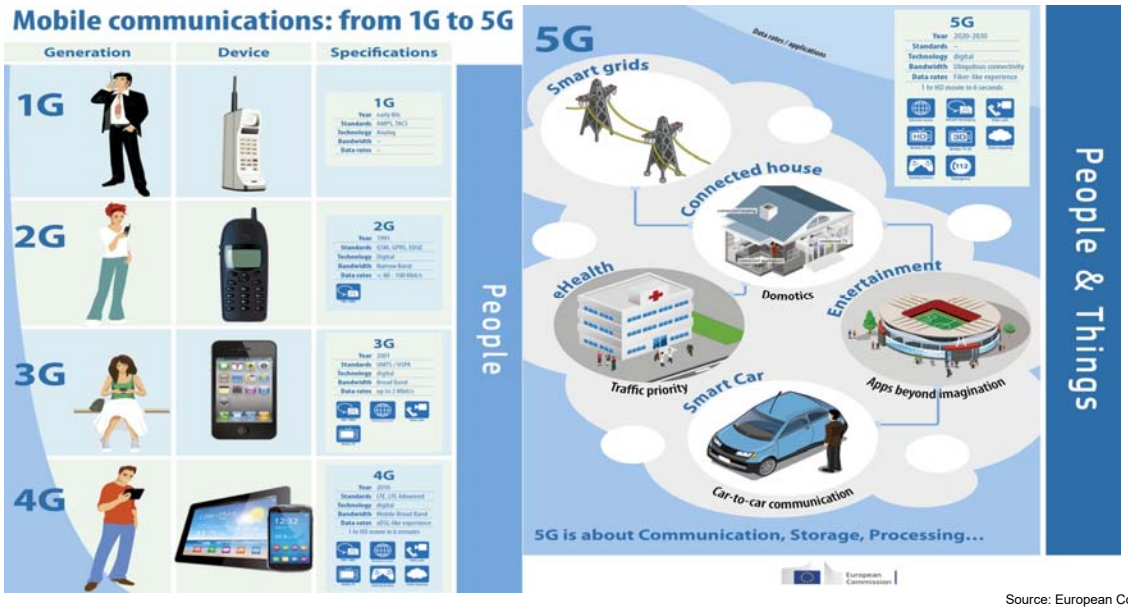
Evolution of Telco Networks



Evolution of Mobile Networks



Evolution of Mobile Communications



Source: European Commission

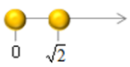
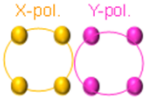
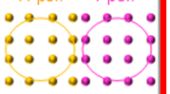
Evolution of Wireless Networks (WiFi)

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

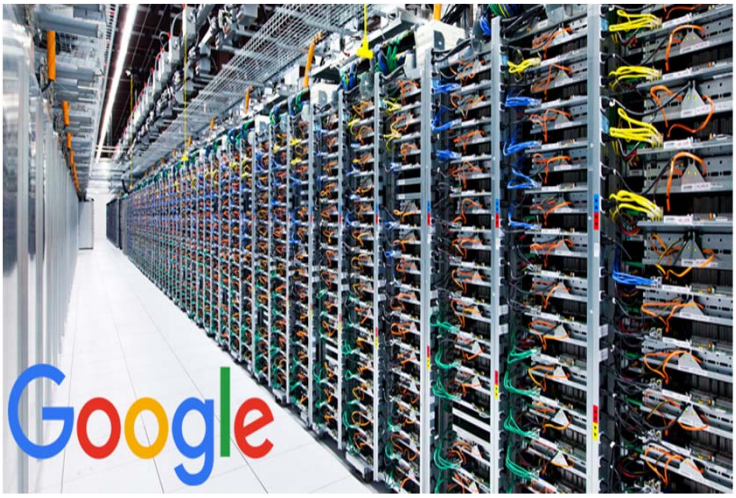
Evolution of Optical Networks

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

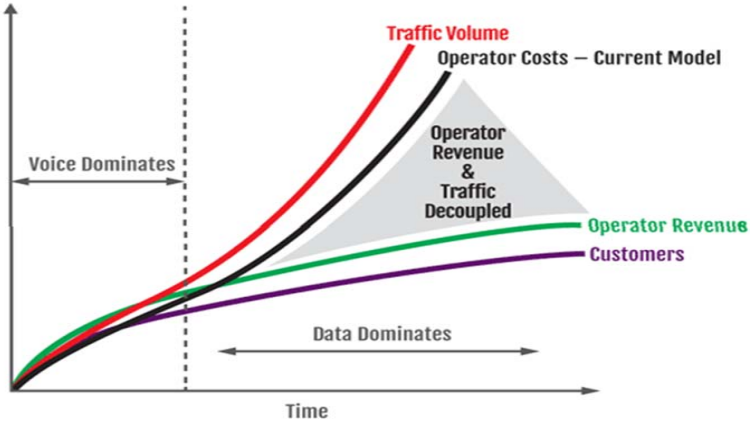
Evolution of Data Centers



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



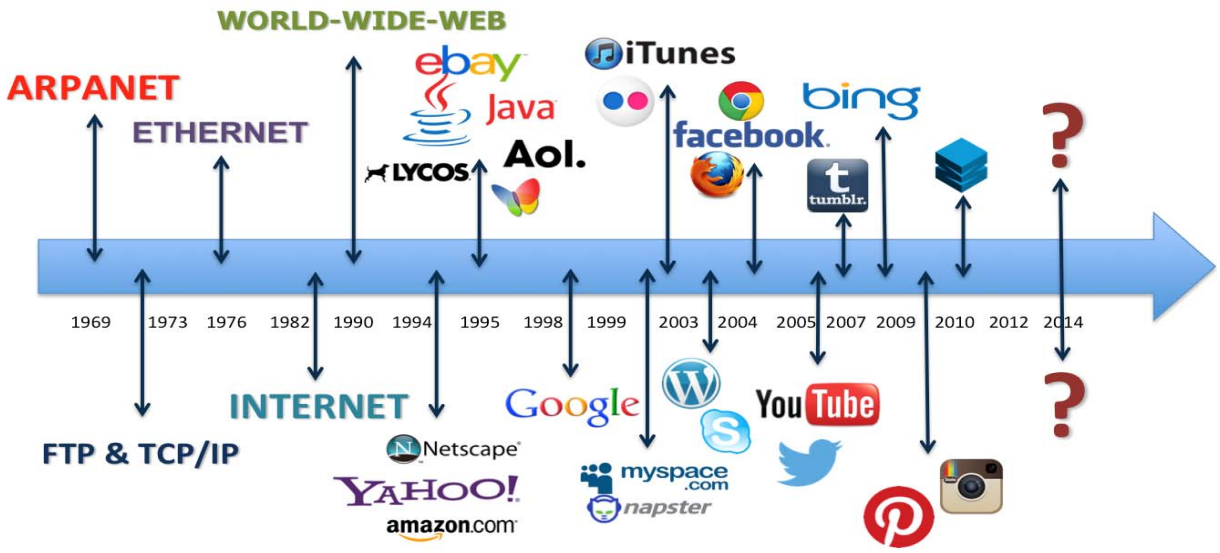
Source: Accenture Analysis

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)

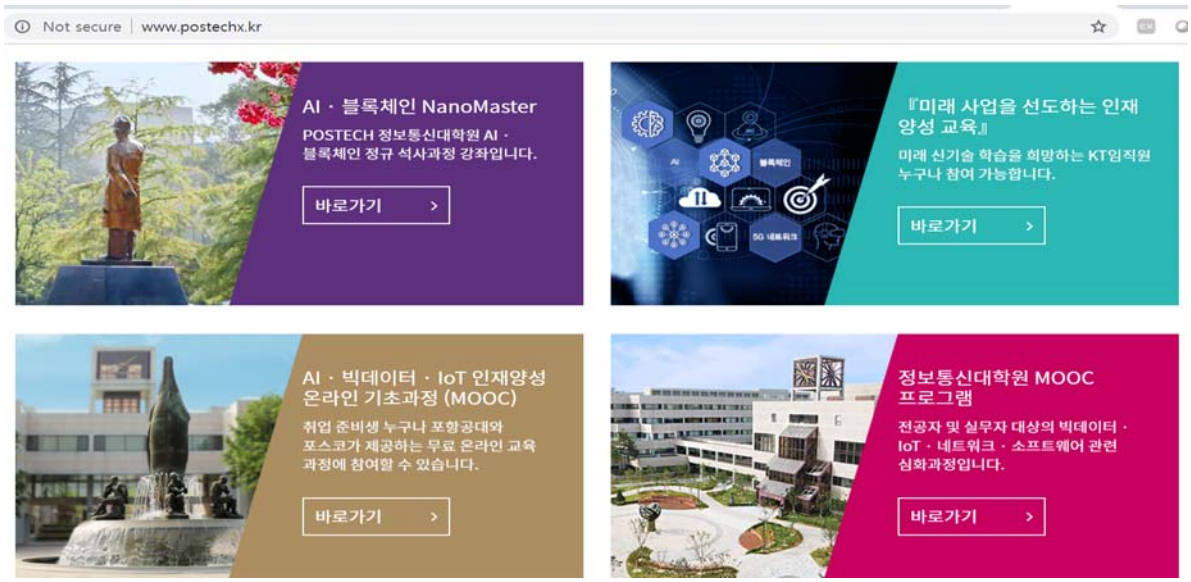
- Started: Jan. 2011
- Active Users: 1 Billion
- Dominant: China but growing in USA, Europe & Africa
- Revenue from gaming, shopping, banking

Line (Japan/Taiwan)

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

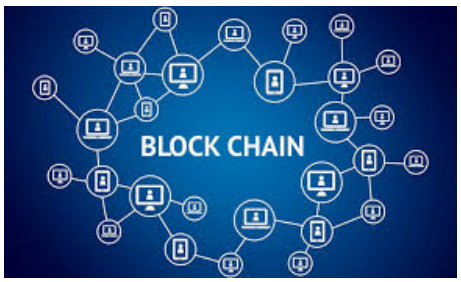
Source: techcrunch.com, Statista (www.statista.com)

MOOC-based Education for Industry by POSTECH



http://www.postechx.kr

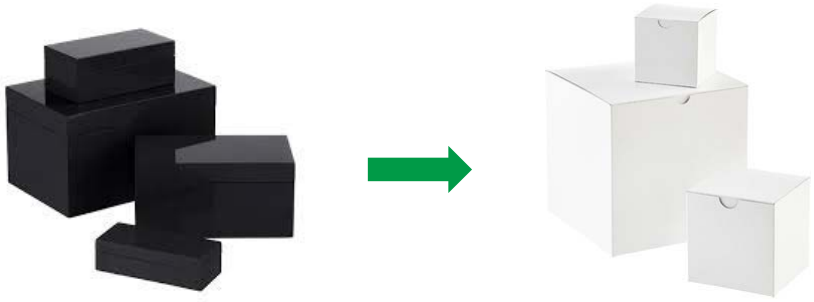
Internet Applications (Present to Future)?



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

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

What does Network Softwarization mean?

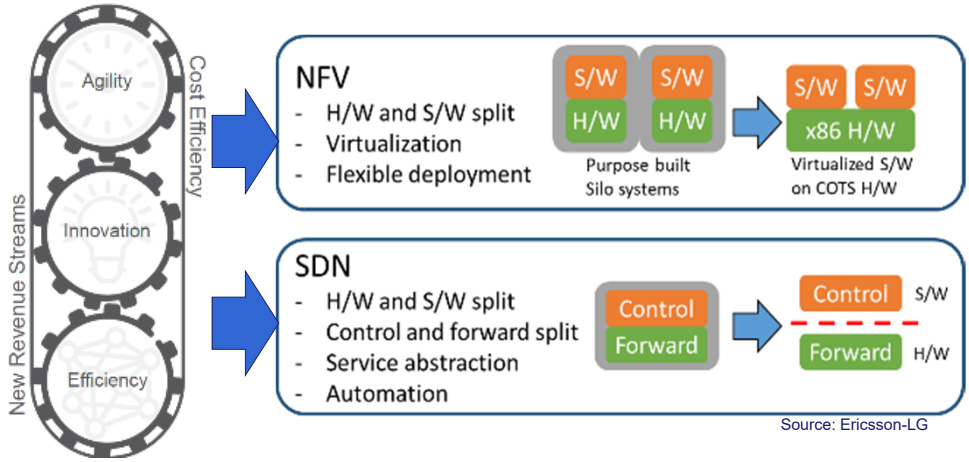


Black Boxes
(proprietary HW/SW-based routers/switches/middleboxes)

White Boxes
(Bare-metal routers & switches with open software)

Softwarization - SDN/NFV

❖ **SDN/NFV – Key to network softwarization**



Source: Ericsson-LG

Softwarization – Open Source Projects

❖ **Work with open projects, organizations and solution providers**

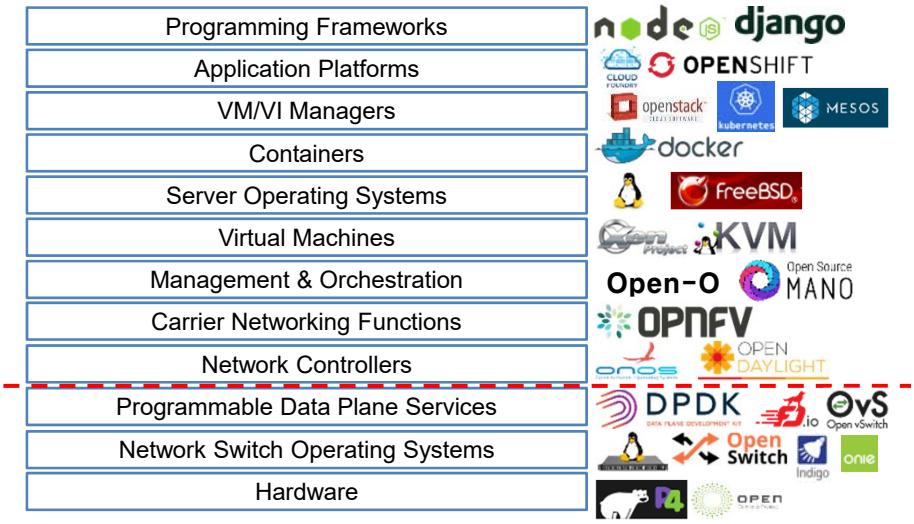
- ONF (Open Networking Forum)
- Open Compute Project (OCP)
- ONAP, OPNFV, OpenStack, OSM, P4
- **SDN/NFV Forum (http://sdnnfv.org)**
- IETF, ETSI, Linux Foundation
- Barefoot Networks, Edgecore Networks,

❖ **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!!!