



# 5G & Net Neutrality

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# How to be Non- Net Neutral

## APPLICATION

Deep packet inspection  
Block Skype  
User tracking

## TRANSPORT

Block transport protocol  
Block ports  
Insert RST

## NETWORK

Block IP address  
QoS discrimination  
Zero-rating

*Source: H. Schultsrinne, 2018*

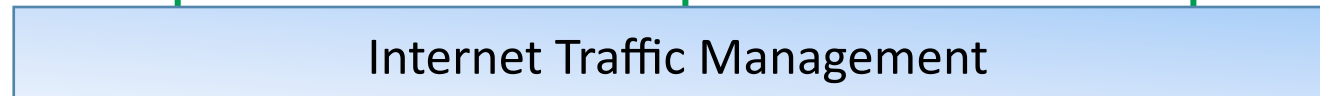


# Internet Traffic Management

Traffic management only  
applied during periods  
of high congestion

Blocking illegal content:  
e.g., spam, hacking,  
illegal contents, etc.

Offering services with  
different priority/quality  
at different price:  
managed services



Best efforts  
- no priority  
- no traffic  
management

Offering for free  
priority to most  
vulnerable  
services, e.g.,  
voice,  
videogames,  
vidostreaming,  
etc..

Throttling/  
Degrading of  
some type of  
traffic, e.g., P2P

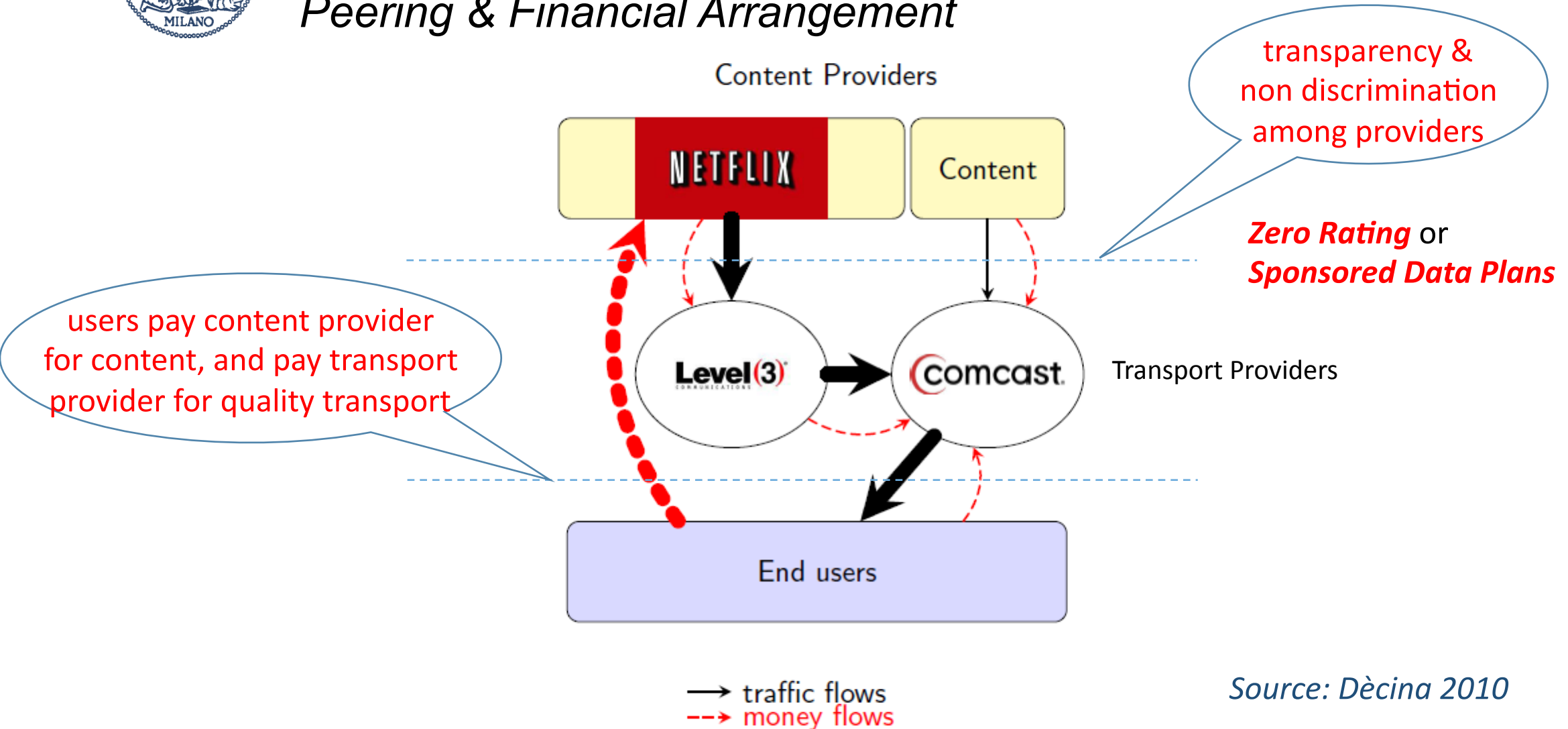
Blocking legal  
contents and  
applications, e.g.,  
VoIP, rival IPTV  
service

*Source: OFCOM, 2011*



# Netflix, Level 3 & Comcast

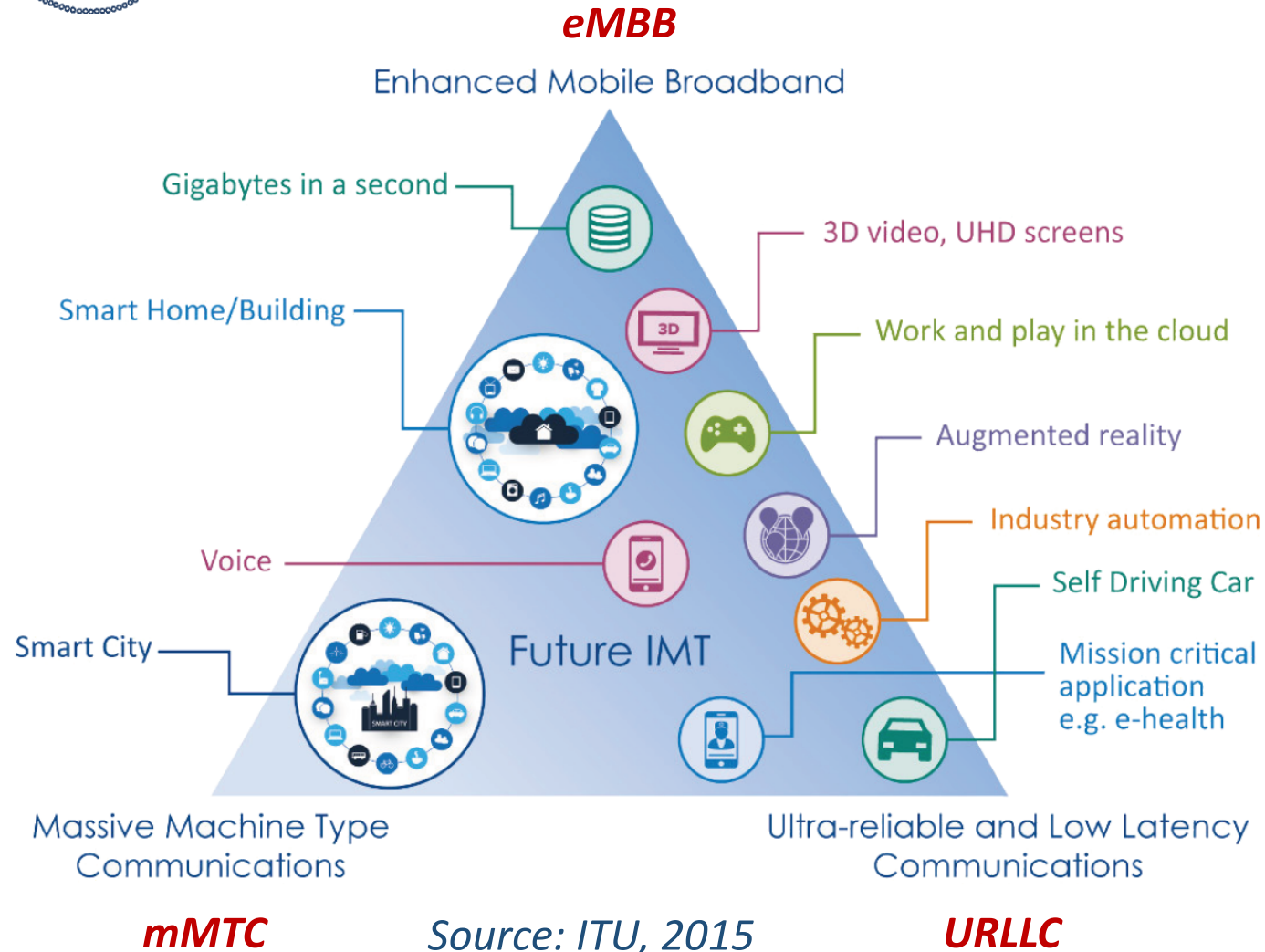
## Peering & Financial Arrangement



Source: Dècina 2010



# 5G Application Clusters

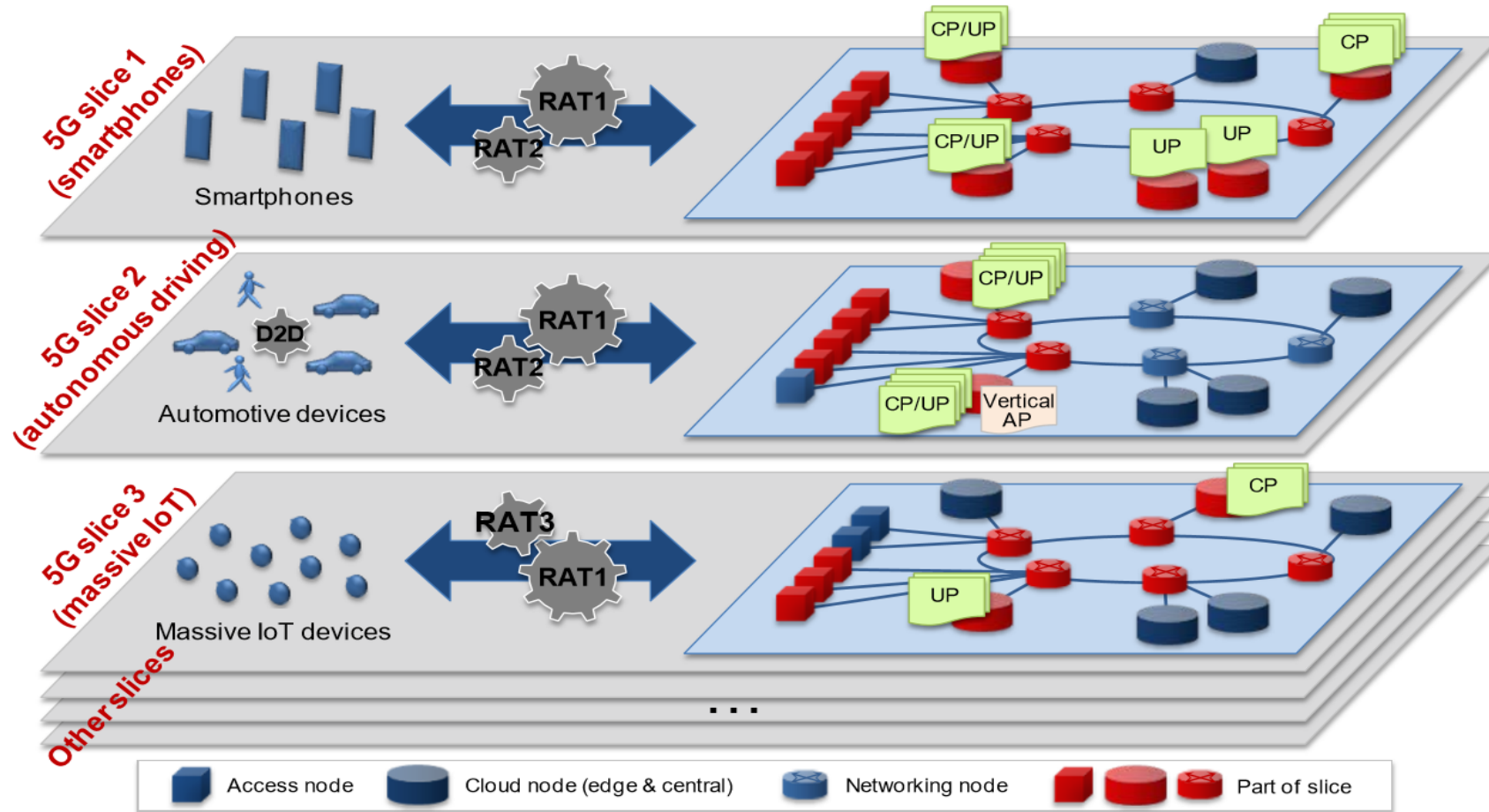


## 5G ARCHITECTURE KEY FEATURES

- Control & User Plane Separation
- Multi-access Edge Computing
- Massive MIMO
- Evolved vRAN (Protocol Separation)
- Full Virtualization (SDN/NFV)
- Service Based Architecture (Network Slicing)
- New Radio Spectrum (mmWave)



# 5G Network Slicing



Source: NGMN, 2015



# NFV and SDN to kill Net Neutrality?

## *Routing in Virtual Networks*

- Much greater and finer control on overall network resources allow sophisticated routing schemes executable by each application and each session/transaction
- **Personalized path selection and routing on the basis of each single subscriber satisfaction targets on a set of resources**, e.g., desired targets of price, QoS, strategic value of session/transaction, security & privacy policies, etc.
- *PCE Path Computation Element*: to set up «**application aware**» Label Switching Paths using Generalized Multi Protocol Label Switching (GMPLS)
- *ALTO Application Layer Traffic Optimization* by IETF, attempts to standardize an inter-organizations (e.g., Akamai to Verizon) common framework for PCE-like policies from one administrative boundary to another

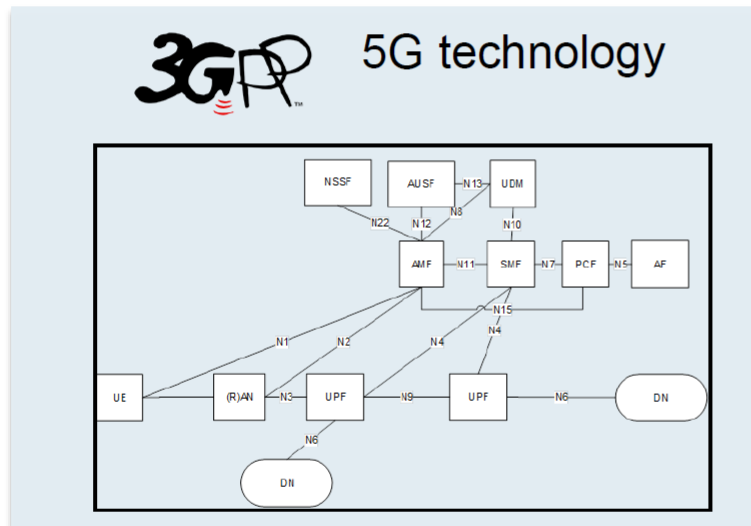
*Source: M. Dècina, 2014*



# TNO Study on 5G & Net Neutrality

**TNO** innovation for life

## TNO HAS INITIATED A STUDY ON 5G AND NET NEUTRALITY TO FEED THE POLICY DISCUSSION



Regulation and Guidelines

This section displays regulatory and guideline documents. On the left is the flag of the European Union. On the right is the logo for BEREC (Body of European Regulators for Electronic Communications). Below these are two document covers: one titled 'REGULATIONS' and another titled 'BEREC Guidelines on the Implementation by National Regulators of European Net Neutrality Rules'.



April 2018





# Rules for Internet Access Service (IAS)

## Traffic management

1. “providers of internet access services ... **shall treat all traffic equally** ... irrespective of ...the content accessed or distributed, the applications or services used or provided”
2. “The first subparagraph shall not prevent providers of internet access services from implementing **reasonable traffic management measures.**”  
... such measures shall be **transparent, non-discriminatory and proportionate**... not be based on commercial considerations but on **objectively different technical quality of service requirements of specific categories of traffic.** ...
3. (additional stipulations related to *exceptional or temporary network congestion*)

## Sub-internet Services and limited number of reachable end points

“internet access service’ means a publicly available electronic communications service that provides access to the internet, and thereby **connectivity to virtually all end points of the internet,** irrespective of the network technology and terminal equipment used.”

Source: BEREC, 2016



# Rules for Specialised Services (SpS)

## Specialised Services only if optimisation is necessary for specific quality

*“Providers ... shall be free to offer **services other than internet access services** which are **optimised for specific content, applications or services**, or a combination thereof, where the **optimisation is necessary in order to meet requirements of the content, applications or services for a specific level of quality.**”*

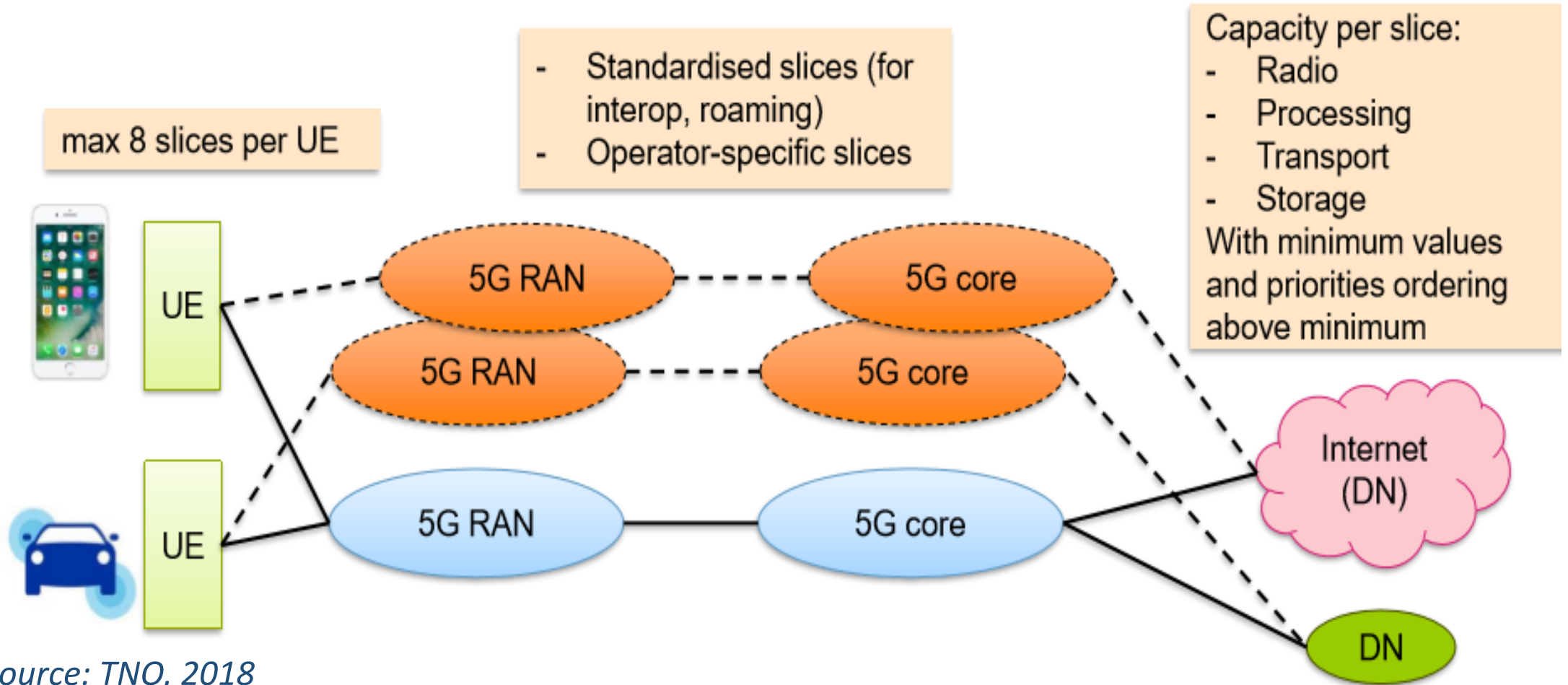
## and only if they do not replace IAS or degrade the quality of IAS

*Providers ... may offer or facilitate such services only if the **network capacity is sufficient** to provide them in addition to any internet access services provided. Such services shall **not be usable or offered as a replacement for internet access services**, and shall **not be to the detriment of the availability or general quality of internet access services** for end-users*

*Source: BEREC, 2016*



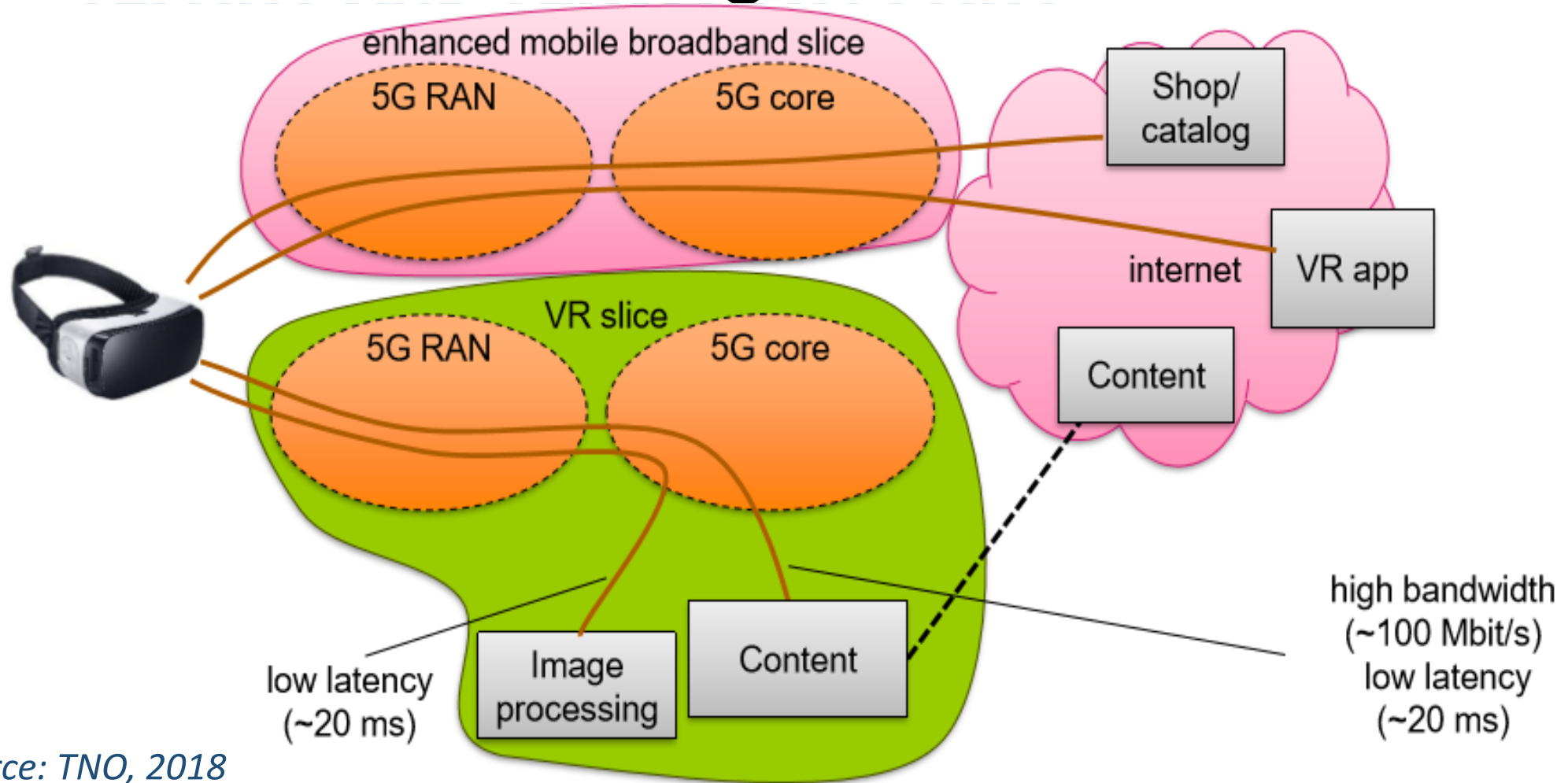
# Network Slicing



Source: TNO, 2018



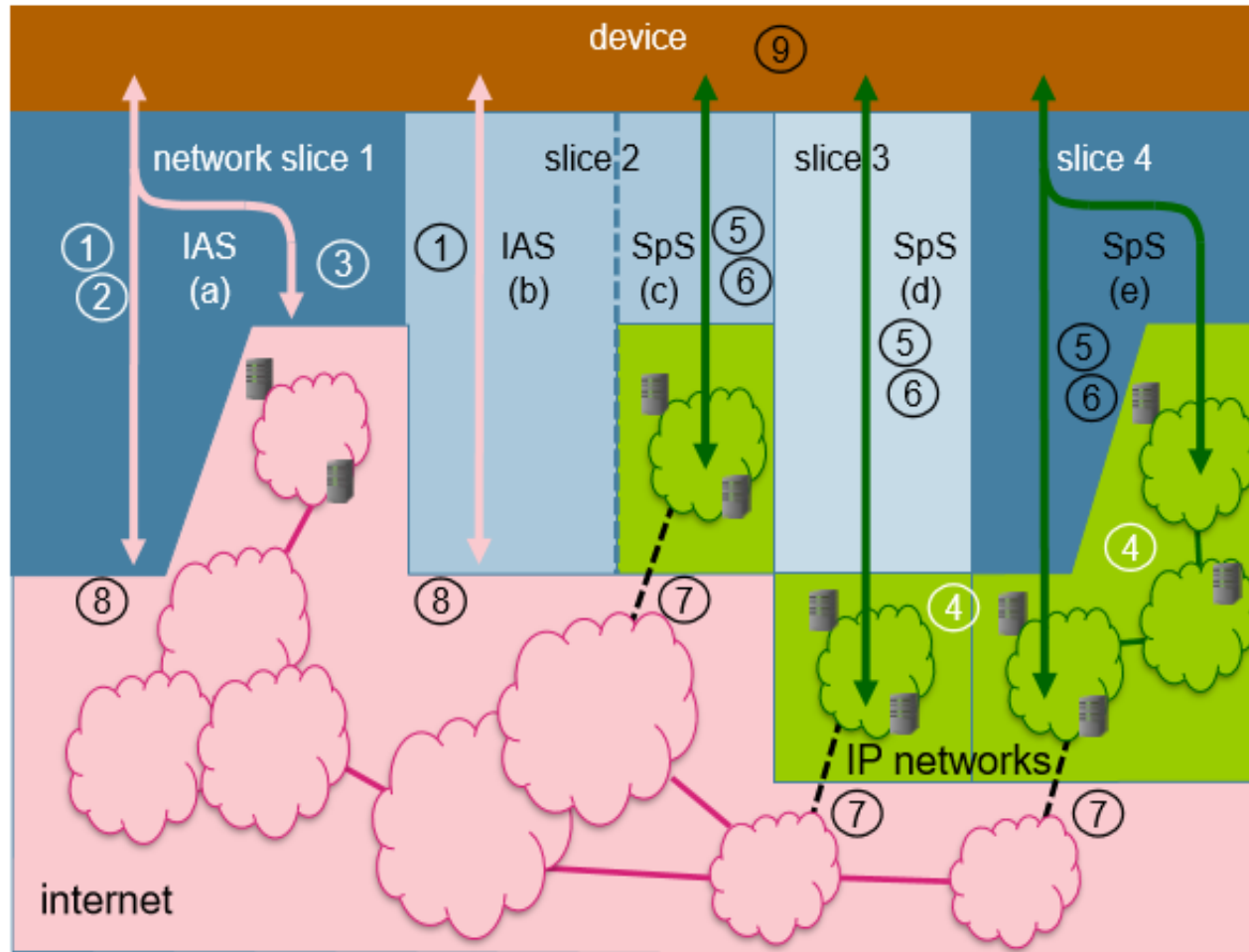
# Use Case: Virtual Reality, Slicing & Service Hosting



Source: TNO, 2018



# TNO Study Items on 5G & NN



1. Multiple IASs with different traffic management settings in one network
2. QoS differentiation within IAS
3. Local access to the internet
4. Public and private services and associated networks
5. Objective need for optimisation in SpS
6. Impact of SpS on IASs
7. SpS and connections to the internet
8. Connectivity to limited number of internet end points
9. Access control

Source: TNO, 2018



# Regulatory Complexity of 5G&NN Topics

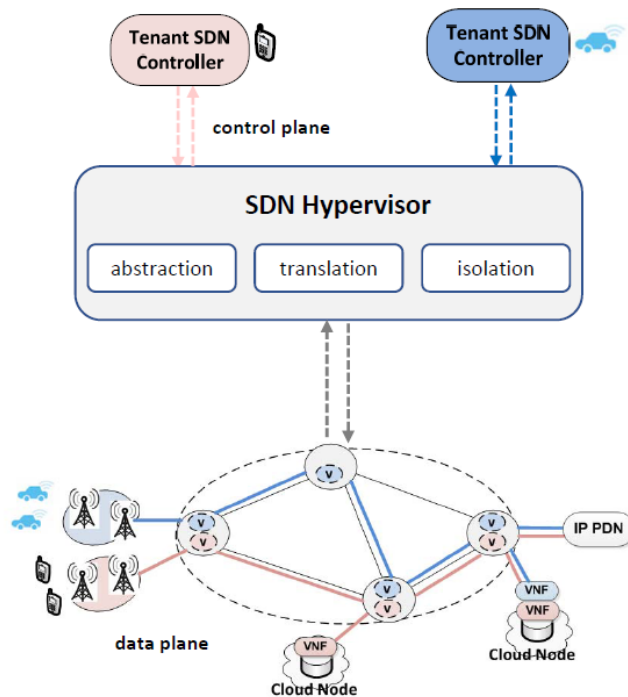
Topic	Key points identified in analysis	Relative regulatory complexity	
Multiple IASs with different traffic management settings	<ul style="list-style-type: none"> <li>Interpretation of <i>sender and receiver</i> in Art 3.3 of the Regulation</li> <li>Note: assumption needed in remainder of analysis - it is allowed to have multiple IASs with different traffic management settings for a given end user</li> </ul>	low	
QoS differentiation within IAS	<ul style="list-style-type: none"> <li>Applications with multiple different traffic flows</li> <li>Transparency through 5QI values or other methods</li> <li>Dependency of ISP on other entities for assignment of traffic flows to traffic categories</li> <li>Duration of QoS differentiation</li> </ul>	medium	to high
Local access to the internet	<ul style="list-style-type: none"> <li>(potentially:) IP interconnection of local networks</li> </ul>	low	
Public and private services and associated networks	<ul style="list-style-type: none"> <li>Size and scope of predetermined group of end users in private service</li> </ul>	low to	medium
Objective need for optimisation in SpS	<ul style="list-style-type: none"> <li>Determination of IAS for benchmark in case of multiple IAS offers</li> <li>Variation of IAS performance between geographical regions and operators</li> <li>Services comprising multiple traffic flows</li> </ul>	high, except if SpS requirements are clearly much stricter than achievable over IAS.	
Impact of SpS on IASs	<ul style="list-style-type: none"> <li>Multiple IASs affected by one SpS, within and outside the slice used for the SpS.</li> <li>Isolation of the effect of the SpS on IAS from other effects occurring in mobile network at the same time</li> <li>Complexity of network and capacity management in mobile network with many services and applications in general</li> </ul>	high	
SpS and connections to the internet	<ul style="list-style-type: none"> <li>Connectivity to internet from SpS through separate IAS</li> <li>Connectivity between different legs between end user device and internet</li> </ul>	low	
Connectivity to limited number of internet end points	<ul style="list-style-type: none"> <li>Evaluation whether sub-internet service is acceptable for providing connectivity in specific situations</li> </ul>	medium	



# Network Slicing Resource Allocation

## HyperFLEX

bring your own SDN controller



- **HyperFLEX**: SDN virtualization layer for flexible, reliable and dynamic SDN slicing and interconnecting Virtual Network Functions

- **On-demand** virtual network resources to the service providers, i.e. tenants
- **Dynamic changes** during the **run-time** – coping with VNF migrations

- **Isolation** and **performance guarantees** for the tenant

- **Multiple tenants** or service providers coexist on the same network without performance degradation

- **Admission Control**

- Automated request of Slices
- Guarantees for mapping of request to HV resources
- Run time update to slice

[3] A. Blenk, A. Basta, W. Kellerer. **HyperFlex: An SDN virtualization architecture with flexible hypervisor function allocation.** Integrated Network Management (IM), 2015 IFIP/IEEE International Symposium on. IEEE, 2015.



TANDON SCHOOL OF ENGINEERING

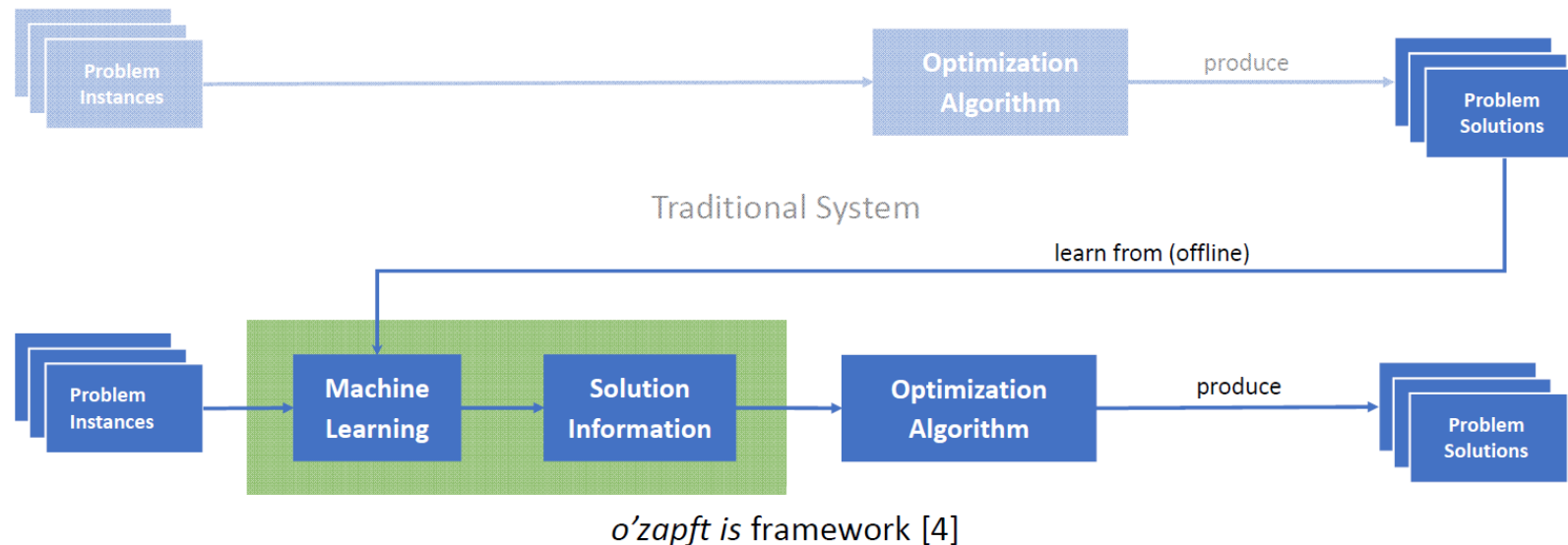


Source: W. Kellerer, TU Munich, 2018



# Resource Allocation Optimization Algorithms

How can we boost the solving of the related optimization problems?



- **State-of-the-art:** Neglects produced data!
- **Idea:** Use problem/solution data generated by algorithms regularly solving problems

*O'zapft is!*  
Si stappi!  
*Octoberfest*

[4] A. Blenk, P. Kalmbach, S. Schmid, W. Kellerer: *o'zapft is: Tap Your Network Algorithm's Big Data!* ACM SIGCOMM 2017 Wrksp. on Big Data Analytics and Machine Learning for Data Communication Networks (Big-DAMA), 2017.

**Data Available:** P. Kalmbach, J. Zerwas, M. Manhart, A. Blenk, S. Schmid, W. Kellerer. Data on "o'zapft is Tap Your Network Algorithm's Big Data!"; 2017 <https://doi.org/10.14459/2017md136158>;

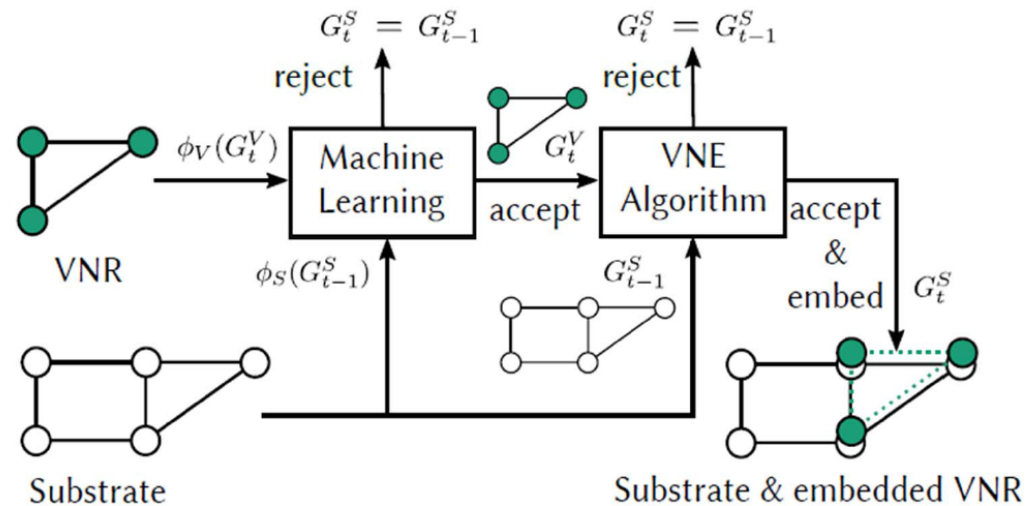
*Source: W. Kelleler, TU Munich, 2018*





# Machine Learning for Virtual Network Reconfiguration

## Case Study: Predicting Acceptance Probabilities of VNE Requests



VNE- Virtual Network Embedding  
VNR – Virtual Network Reconfiguration

- Supervised learning: use data with accepted and rejected requests! Offline training!
- Recurrent neural network (RNN) for classification
- Filter infeasible and requests with unacceptable algorithm runtime (“no solution“)



Source: W. Kelleler, TU Munich, 2018



# 5G & Net Neutrality: Key Takeaways

- Network Neutrality standing Issue: **IAS and SpS coexistence** in the Big Internet is alike coexistence in a single slice; managing multiple slices per user device strongly increases complexity of the Issue
- **Network Slicing traffic management rules and algorithms** should be developed to guarantee performance of IAS and SpS: e.g. by using *optimization tools for the dynamic allocation of resources into slices*, via programming/greedy algorithms
- **Machine Learning & Artificial Intelligence algorithms** should be used to manage predictive behaviour of IAS and SpS traffic, and implement suitable Network Slicing management rules (*planning, scheduling and optimization*)
- When approaching significant interference conditions to IAS, **Admission Control Rules** could be applied to throttle or block access of SpS services



# Neutralità Generalizzata

- I costruttori impediscono l'installazione di programmi non coerenti con la loro strategia commerciale: a lungo Apple ha osteggiato l'uso di Flash di Adobe sui propri terminali; a luglio Apple ha bloccato Google Voice. Il "Jailbreaking" per superare le limitazioni imposte dal "walled garden" di Apple: nell'underground si sviluppano strumenti per violare le limitazioni e nascono AppStore per applicazioni non autorizzate da Apple (Cydia)
- Apple ha intimato ad una serie di editori di giornali europei di non rendere accessibili contenuti via iPad ai propri abbonati alle pubblicazioni tradizionali, senza passare attraverso iTunes (e quindi senza riconoscere royalty a Apple)
- Annunci di grande portata: Embedded SIM, Embedded Secure Element sia hardware che software (es. Intel Insider, Android), iPhone 5 NFC

- Gli Application Store si propongono come le nuove dogane di accesso ad Internet e i loro gestori hanno un potere di discriminazione sull'ammissione delle applicazioni che possono essere ospitate: tale discrezionalità rappresenta una possibile via per fenomeni di concorrenza sleale (praticabile con l'esclusione dei concorrenti o l'introduzione di compensi economici penalizzanti): i clienti di Biblet di Telecom Italia (libreria digitale con 4mila bestseller fruibili da tablet) dovrebbero iscriversi a iTunes (revenue sharing 30-70 con Apple)
- Jimmy Wales, fondatore di Wikipedia, addita gli AppStore come fenomeni più dannosi della "Net Freedom" rispetto alla Net Neutrality

- Skype impedisce ai suoi utenti l'interconnessione con Fring (applicazione gratuita per chiamate VoIP, video-chiamate e chat per terminali mobili), dichiarando un uso improprio della API (violazione dei "Terms of Use"), impedendo l'interconnessione con un'applicazione concorrente
- Google Chrome non supporta video codificati con H.264, sostenendo che supporterà solo codec aperti (per ora il suo WebM e Theora)

- I motori di ricerca mediano l'accesso alle informazioni, contenuti e servizi di Internet attraverso i loro algoritmi di ranking e le loro tecniche di remunerazione per una maggiore visibilità. Il potere di discriminazione dei motori di ricerca nell'accesso ai contenuti è abbastanza evidente ed è legato agli algoritmi di ranking, volutamente non completamente trasparenti: player dominanti, come Google, iniziano ad essere sotto osservazione



## Neutralità dei terminali



## Neutralità degli Application Store



BLOCKS



## Neutralità delle applicazioni e dei servizi



## Neutralità dei motori di ricerca

Source: M. Dècina, 2011