

Networking Education During and After the Pandemic

Luciano Paschoal Gaspar - UFRGS, Brazil

<http://www.inf.ufrgs.br/~paschoal>

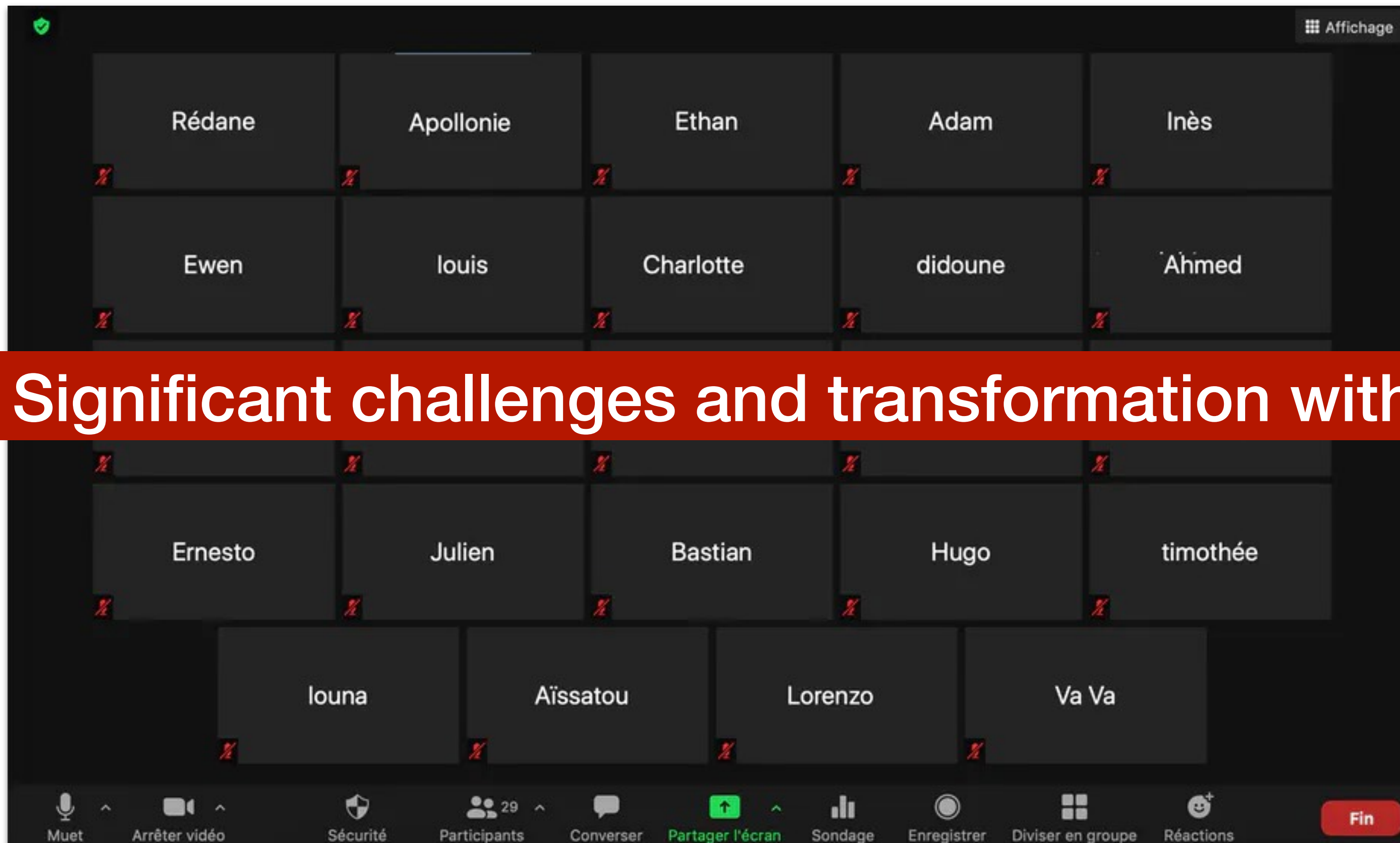
paschoal@inf.ufrgs.br

Panel Discussion - theNetworkingChannel - 13 October 2021

The pandemic required us to change the way we learn and teach

Lots of asynchronous messages
through forums, WhatsApp, ...

Teaching, in general, without seeing and listening to students



:wait a second
:ok, i will keep searching
:"The Fragmentable Part of the original packet is divided into fragments, each, except possibly the last ("rightmost") one, being an integer multiple of 8 octets long. " is it?
:uhmm, not should be 224?
:The Fragmentable Part of the original packet is divided into fragments. The lengths of the fragments must be chosen such that the resulting fragment packets fit within the MTU of the path to the packet's destination(s). Each complete fragment, except possibly the last ("rightmost") one,

Significant challenges and transformation within a very short time frame

Hours and hours of video content preparation



Source: <https://theconversation.com/five-tips-on-how-to-reinvent-remote-teaching-155389>

Source: <https://www.epiphany.com/blog/lecture-recording-studio/>

Status quo change

For both students and teachers

- Nearly **anytime, anywhere** education
- Regardless of education method, be it synchronous or asynchronous
- Several potential advantages:
 - Time savings (e.g., mobility to Campus)
 - Flexibility to varying learning paces
 - More opportunities to multi-tasking (e.g., study+work, travel)

We all became used to this new reality



Source: <https://www.forbes.com/sites/forbesbusinesscouncil/2020/11/18/evaluating-time-management-for-the-automotive-industry/>



Source: <https://www.inc.com/business-insider/study-reveals-commute-time-impacts-job-satisfaction.html>

How can the lessons we learned help improving or even transform networking education after the pandemic?

Pre-recorded videos

Blessing or curse?

- My experience with inverted classroom, *i.e.*, pre-recorded videos + live Q&A sessions
 - Students less motivated to content exploration
 - Low attendance in Q&A classes, mainly because did not watch videos previously
 - Wrong assumption that it suffices to watch the videos (*i.e.*, resistance to reading the textbook)
- Complex contents are hard to explain/learn without eye content, live annotations, heated Q&A, ...

Live annotations on slides to explain a mechanism

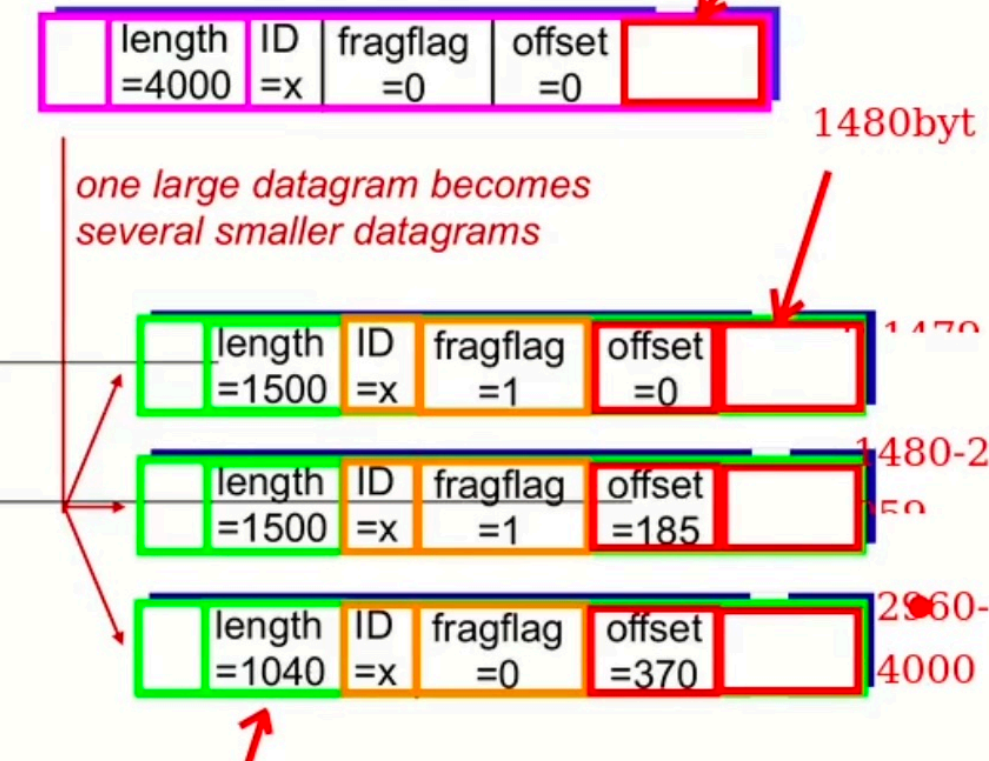
IP fragmentation, reassembly

example:

- ❖ 4000 byte datagram
- ❖ MTU = 1500 bytes

1480 bytes in data field

offset = 1480/8

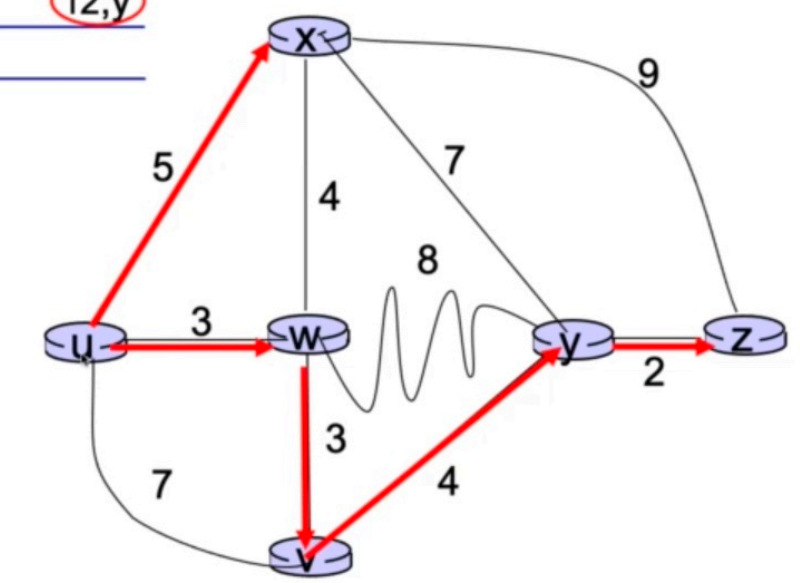


Dijkstra's algorithm: example

Step	N'	D(v) p(v)	D(w) p(w)	D(x) p(x)	D(y) p(y)	D(z) p(z)
0	u	7,u	3,u	5,u	∞	∞
1	uw	6,w	5,u	11,w	∞	∞
2	uwv	6,w		11,w	14,x	
3	uwvx			10,v	14,x	
4	uwvxy				12,y	
5	uwvxyz					

notes:

- ❖ construct shortest path tree by tracing predecessor nodes
- ❖ ties can exist (can be broken arbitrarily)



Network Layer: Control Plane 5-15

Source: Slides from Kurose and Ross' networking book

Royal Portuguese Reading Cabinet in Rio de Janeiro



Source: <https://viajantecurioso.com.br/rio-de-janeiro/biblioteca-rio-de-janeiro/>

**The challenge
of meeting
excellency in
networking
education after
the pandemic**

**+ increasing
number of topics
+ new teaching
methods**

Digital meets traditional

Best of the two worlds

- Face-to-face classes for **fundamental & complex topics**, student engagement and exams
- + Topics that typically spark student curiosity
- Videos + Q&A online classes for easy-to-understand topics

Syllabus of the Computer Networks course I teach to CS/CE undergrad.
based on Computer Networking: A Top-Down Approach - Kurose and Ross

Internet + The Network Edge and Core

Delay, Loss, and Throughput in Packet-Switched Networks

Protocol Layers and Their Service Models

Principles of Network Applications

HTTP

SMTP, POP, IMAP

DNS

Socket Programming

Introduction and Transport-Layer Services

Multiplexing and Demultiplexing

UDP

Principles of Reliable Data Transfer

TCP

Principles of Congestion Control

Introduction + Virtual Circuit and Datagram Networks

What's Inside a Router?

IP

Routing Algorithms

Routing in the Internet (focus on OSPF and BGP)

Introduction to the Link Layer + Error-Detection and Correction

Multiple Access Links and Protocols

Switched Local Area Networks: ARP, Ethernet, VLANs

MPLS

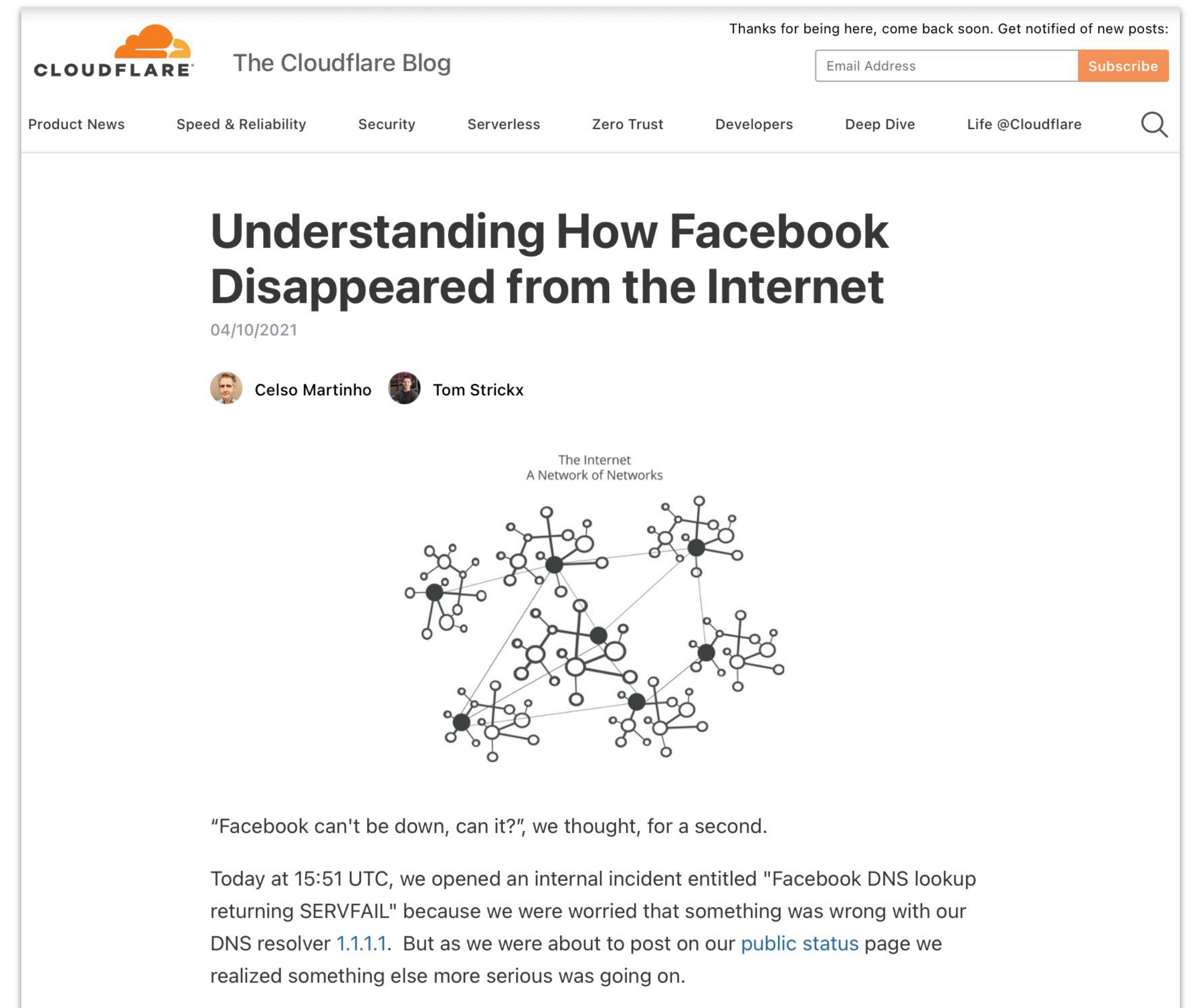
Principles of Wireless and Mobile Networks

My personal feeling of complex topics marked in red above

Digital meets traditional

Best of the two worlds

- Face-to-face classes for **fundamental & complex topics**, student engagement and exams
- + Topics that typically that spark student curiosity
- Videos + Q&A online classes for easy-to-understand topics



Source: <https://blog.cloudflare.com/october-2021-facebook-outage/>

Project-based learning

A truly engaging experience

- Work on **projects** based on **OpenFlow** and **P4** to solve different networking problems
- Traffic load balancing, green networking-oriented routing, QoE-oriented routing, network telemetry, ...
- Deliverables: working prototype, technical report/paper and presentation → opportunity to develop "soft" skills

INT-oriented flow monitoring with P4

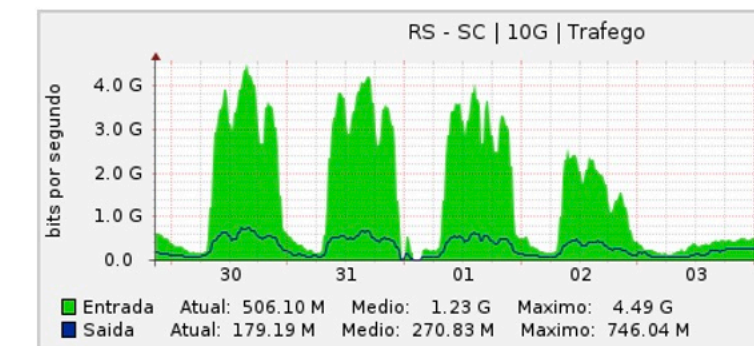
UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL - UFRGS
INSTITUTO DE INFORMÁTICA - INF
PROGRAMA DE PÓS-GRADUAÇÃO EM COMPUTAÇÃO - PPGC

DISCIPLINA: CMP182 – Redes de Computadores I
PROFESSOR: Luciano Paschoal Gasparly

TRABALHO EXTRA-CLASSE – EXPLORANDO OPENFLOW RUMO A SOFTWARE-DEFINED NETWORKS

Desenvolva um controlador OpenFlow que operacionalize a “aplicação” abaixo.

Redes Elásticas: (Re)Dimensionando Periodicamente Infraestruturas de Rede visando à Economia de Energia. Esta aplicação consiste em, tirando proveito do OpenFlow, criar políticas dinâmicas de fluxo para apoiar o redimensionamento periódico de infraestruturas de rede empregadas no âmbito de ISPs. O objetivo é – a cada janela de tempo – avaliar a demanda de tráfego na rede e redimensioná-la de acordo, apagando dispositivos (roteadores) ociosos (ou com pouca demanda) e desativando *links*. No caso do aumento da demanda, o contrário deve ser feito. Nesse processo, é fundamental que as otimizações realizadas **não** impeçam o escoamento de nenhum fluxo. A título de ilustração da pertinência desse redimensionamento periódico proposto, considere a ilustração abaixo. Ela apresenta o semana no *link* da RNP que liga o RS a SC (um dos caminhos na rede acadêmica para esse link). Como resultado final, espera-se poder observar as políticas de fluxos sendo executadas eficientemente de tráfego em uma infraestrutura de rede de tamanho sempre compatível com



OBSERVAÇÕES IMPORTANTES

- O trabalho é **individual**.
- Deverá ser entregue:
 - o código fonte do controlador, fartamente documentado;
 - artigo científico resumindo o trabalho conduzido e os resultados obtidos.
- A nota do trabalho está condicionada à apresentação do mesmo, em data a ser definida.
- Data de entrega do trabalho: 21/06

Green networking-oriented routing with OpenFlow

UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL - UFRGS
INSTITUTO DE INFORMÁTICA - INF
PROGRAMA DE PÓS-GRADUAÇÃO EM COMPUTAÇÃO - PPGC

DISCIPLINA: CMP182 – Computer Networks
PROFESSOR: Luciano Paschoal Gasparly

TRABALHO EXTRA-CLASSE – EXPLORANDO P4 PARA DEPURAÇÃO DE PROBLEMAS DE DESEMPENHO EM APLICAÇÕES

Do ponto de vista de redes de telecomunicações 4G/LTE, o *backhaul* é tipicamente composto de níveis hierárquicos de agregação, tal como ilustrado na Figura 1 abaixo (extraída de R. da Costa Filho *et al.* [1]). **RAN/Edge** é o ponto de agregação mais próximo dos dispositivos finais, implantado na casa dos milhares em uma rede de escala nacional, juntando muitas (ordem de 10) estações rádio-base (RTT \approx 4-6 ms). **Aggregation** consiste em ponto intermediário de agregação, implantado na casa de muitas centenas ou alguns poucos milhares (RTT \approx 5-12 ms). **Core** é o ponto de agregação mais próximo do núcleo da rede, implantado na casa de poucas centenas (RTT \approx 7-20 ms). Outro aspecto importante dessas infraestruturas é a presença de pontos destinados ao armazenamento temporário de conteúdos, dos quais usuários finais podem recuperá-los mais eficientemente (*e.g.*, com menores atrasos fim-a-fim).

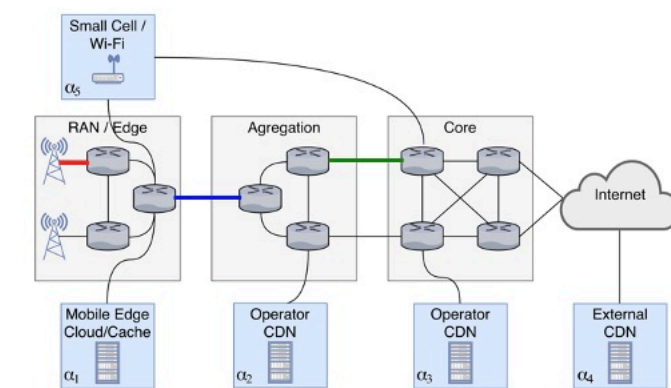


Figura 1: Redes de telecomunicações 4G/LTE, sua estrutura hierárquica e oportunidades de offloading de conteúdos
Fonte: R. da Costa Filho *et al.* [1]

Apresentadas as informações contextuais acima, e assumindo uma rede totalmente programável via SDN/P4, projete e desenvolva um mecanismo que permita – via *In-Band Network Telemetry* [2,3] – depurar precisamente problemas de desempenho em uma aplicação (*i.e.*, conjunto de fluxos) de interesse. A ideia básica é que cada pacote desse(s) fluxo(s), ao ingressar na rede, tenha um cabeçalho de telemetria adicionado. A cada salto, incluindo o primeiro e o último, devem ser coletadas e armazenadas “condições” de rede (*e.g.*, *timestamp*, *delay* do salto, tamanho da fila e fluxos competidores) observadas pelo pacote. No último salto, o cabeçalho de telemetria deve ser removido do pacote e enviado a uma aplicação de monitoração executando em um controlador externo. Essa aplicação de monitoração deve, em tempo real, apresentar o desempenho da aplicação escolhida e, em caso de degradação (*e.g.*, *delay* acumulado acima de um limiar), informar a(s) potencial(is) razão(ões).

REFERÊNCIAS

- [1] R. da Costa Filho, W. Lautenschläger, N. Kagami, M. Luizelli, V. Roesler, L. Gasparly. **Scalable QoE-aware Path Selection in SDN-based Mobile Networks**. In Proceedings of the IEEE INFOCOM 2018 - IEEE Conference on Computer Communications, 2018.
- [2] **In-band Network Telemetry (INT)**, Working Draft. <https://github.com/p4lang/p4-applications/blob/master/docs/INT.pdf>. August 2018.
- [3] **Telemetry Report Format**, Working Draft. https://github.com/p4lang/p4-applications/blob/master/docs/telemetry_report.pdf. April 2018.

OBSERVAÇÕES IMPORTANTES

Project-based learning

A truly engaging experience

- Lots of online materials available (tutorials, virtual machines, examples, *etc.*) and an active community
- Mechanisms can be designed and tested using a single machine
- Assignment preparation and development can be very time-consuming
- Possibility to correlate concepts from CS, CE, and other areas

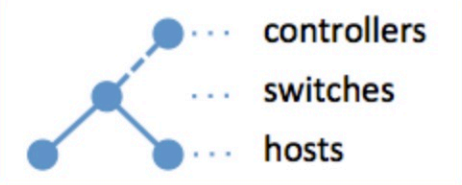
Mininet

An Instant Virtual Network on your Laptop (or other PC)

Mininet creates a **realistic virtual network**, running **real kernel, switch and application code**, on a single machine (VM, cloud or native), in seconds, with a single command:

> sudo mn

→



... controllers
... switches
... hosts

Because you can easily [interact with](#) your network using the Mininet [CLI](#) (and [API](#)), [customize](#) it, [share](#) it with others, or [deploy](#) it on real hardware, Mininet is useful for [development](#), [teaching](#), and [research](#).

[Mininet](#)
[Get Started](#)
[Sample Workflow](#)
[Walkthrough](#)
[Overview](#)


[Download](#)
[Documentation](#)
[Papers](#)
[Videos](#)
[Wiki](#)

Emulating Software Defined Wireless Networks (2015 –)



Mininet-WiFi


Emulator for Software-Defined Wireless Networks



Ecosystem Specifications Learn Blog Events Community ▾

P4 Open Source Programming Language

Programming Protocol-independent Packet Processors (P4) is a domain-specific language for network devices, specifying how data



```
table routing {  
  key = { ipv4.dstAddr : lpm; }  
  actions = { drop, router; }
```

Networking Education During and After the Pandemic

Luciano Paschoal Gaspar - UFRGS, Brazil

<http://www.inf.ufrgs.br/~paschoal>

paschoal@inf.ufrgs.br

Panel Discussion - theNetworkingChannel - 13 October 2021