BEIJING

SIGCOMM 2019

2nd NEAT Workshop

Panel

Enabling holographic media for future applications: Missing pieces and limitations in networks

Networks for Future Applications?

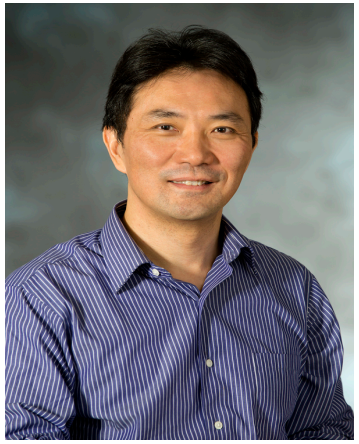
- For the last several decades: Applications have taken advantage of evolving networking technology and protocols
  - “Convergence” – achieved
  - Applications and society adapted to a best-effort Internet
- Dependence on communications has grown - challenges have grown
  - Avoid impairments for future applications – more stringent needs
- Application providers evolving: bypass Internet with dedicated infrastructure for application delivery
  - Google, Facebook, Microsoft backbones; Even Akamai has own backbone
- Wither Internet and IP Protocol Stack for emerging applications?

Panelists

Start Clayman
Principle Research Fellow,
University College of London

Dr. Richard Li
Chairman, FG 2030,
ITU SG 13

Dr. Chongfeng Xie
China Telecom



Prof. Zhi-Li Zhang
McKnight Distinguished University Professor
University of Minnesota

Prof. **Mohamed Faten Zhani**
Associate Prof.
l'École de Technologie Supérieure (ÉTS Montreal) in Canada

Brief Intro’ of Panelists

- Dr.Chongfeng Xie: Chief Technology Director, New Information Technology Institute, China Telecom.
  - Ph.D. (Electronic Engg.),Tsinghua University, China.
  - Research: network architecture & protocols,IPv6,SDN,NFV,etc.
  - As chief scientist of IPv6 project, actively pushed forward transition of China Telecom's network to IPv6.
- Dr. Richard Li: Chief Scientist & Vice President of Network Technologies, Futurewei Technologies Inc., USA.
  - Chairman of the ITU-T FG Network 2030; Vice Chairman of the European ETSI ISG NGP (Next-Generation Protocols)
- Dr. Start Clayman: Ph.D., UCL, 1993, Principle Research Fellow, University College of London
  - Extensive experience in architecture & development for software engineering, distributed systems and networking systems
- Prof. Zhi-Li Zhang (Univ. of Minnesota) and Prof. Mohamed Faten Zhani (ETS, Montreal)

Some initial questions posed to the panel

- The future of holographic media: reality vs myth.
  - What in your mind is most appealing application using holographic media?
  - Are we too early in predicting that the year 2030 will be a holographic society?
- How do we deal with the high bandwidth and low latency that these future media demand.
- Readiness and role of networks:
  - What are the challenges and gaps in current network architectures and protocols?
  - Is TCP/IP the right protocol suite for holographic media.
- Is there a need for more network-aware media formats?
- Who are the key stake holders?
  - Is there a need for standardization and collaboration for holographic media?
  - Role of service providers, content providers and vendors.

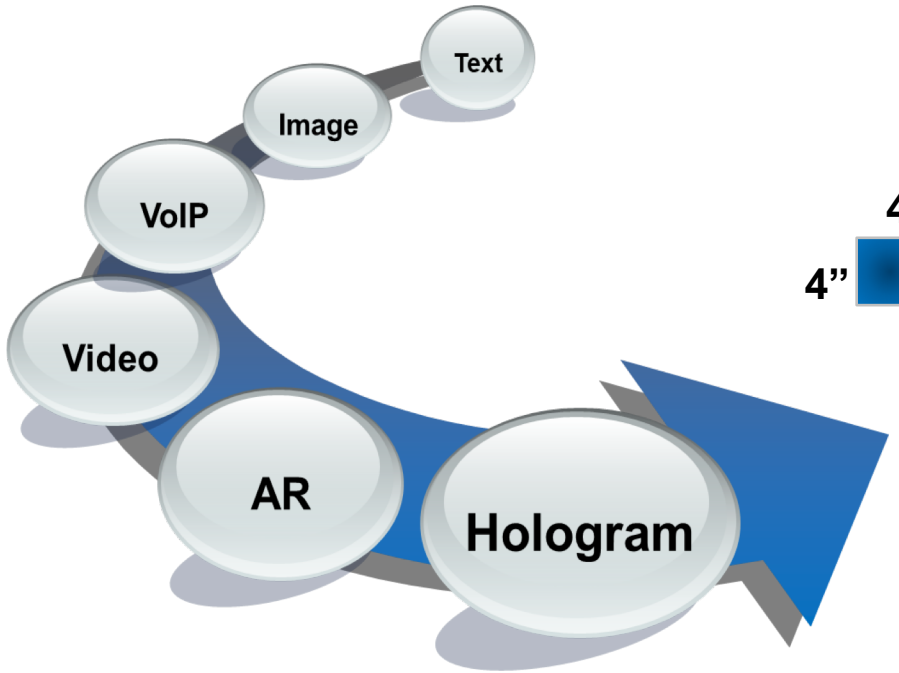
NEAT 2019 – Panel

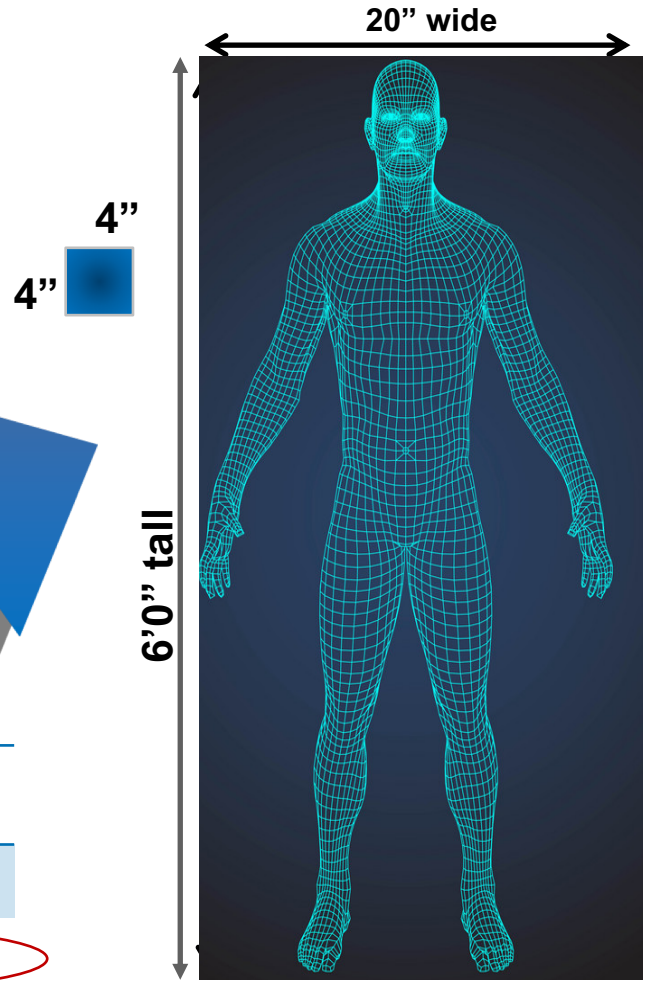
Enabling Holographic media for Future Applications: Identifying the missing pieces and limitations in Networks

Richard Li, Ph.D.

Futurewei Technologies, Inc.
USA

Holograms and Holographic Type Communications





	Dimensions	Bandwidth
Tile	4 x 4 inches	30 Gbps
Human	72 x 20 inch	4.32 Tbps

- Raw data; no optimization or compression.
- color, FP (full parallax), 30 fps

(reference: 3D Holographic Display and Its Data Transmission Requirement, 10.1109/IPOC.2011.6122872), derived from for ‘Holographic three-dimensional telepresence’; N. Peyghambarian, University of Arizona)

Throughput goes up higher and higher

4K/8K HD		VR/AR		Hologram
35Mbps~140Mbps	band width	25Mbps~5Gbps	band width	4 Tbps~10 Tbps

Latency falls down lower and lower

4K/8K HD		VR/AR		Hologram
15 ms~35 ms	delay	5 ms~7 ms	delay	Sub ms~7ms

Synchronization of parallel streams

4K/8K HD		VR/AR		Hologram
Audio/Video(2)	streams	Multiple tiles (12)	streams	~thousands (view-angles)

Holographic-Type Communications as Societal Transit Infrastructure

Animal-Aided 20 km/hour	Labor-Mechanic 20 km/hour	Electric Powered 60 km/hour	Electric Powered 1000 km/hour	Optical Transmitted 200 km/ms
				
Horse	Bikes	Trains	Airplane	Holographic Teleport

- Make shorter physical distances between people
- Make it faster to travel between places
- Make it easier for people to co-work

Applications

- Holographic Concert
- Holographic Soccer Broadcasting
- Holographic Games (Badminton, for example)
- Holographic Education, Healthcare, etc

Challenges

- ❑ Volumetric Data
- ❑ Coordination
- ❑ Retransmission
- ❑ Blended with Five-Senses

Cerf-Kahn-Mathis Equation:

$$T \leq \min(BW, \frac{WindowSize}{RTT}, \frac{MSS}{RTT} \times \frac{C}{\sqrt{\rho}})$$

It specifies the maximum throughput at which data can be transported over a path of a specified bandwidth in the presence of round-trip time, packet loss, and flow control window size.

Example (source: Richard Li, Keynote Speech at IEEE NetSoft 2018, Montreal, Canada, 2018) :

Given: Packet loss: 1 packet every 10,000 packets; Throughput: 12Gbps

Then, the delay will be 114 micro-seconds, nearly impossible in the reality.

Conclusion: Applications in the range of 10 Gbps can't run on the Internet. We are reaching the Internet limit.

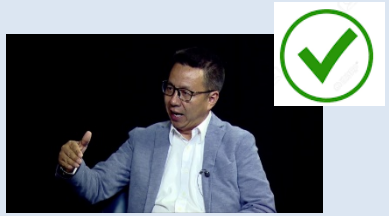
Going beyond the Cerf limit: Qualitative Communications

Current: Quantitative Communications

Sender Receiver

What is sent = What is received

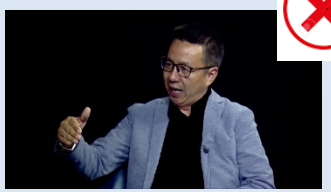
Packet



Packet

If they are not the same, the sender retransmits it until the receiver gets exactly the same copy

Packet



Corrupted Packet

New: Qualitative Communications

- What is received is not required to be exactly the same as what is sent, accepting partial or degraded, yet useful, delivery of a packet
- What is received may be repaired and recovered before being rendered
- Intermediate routers may drop less significant chunks to avoid being discarded when congested

Qualitative Packet

Noisy link

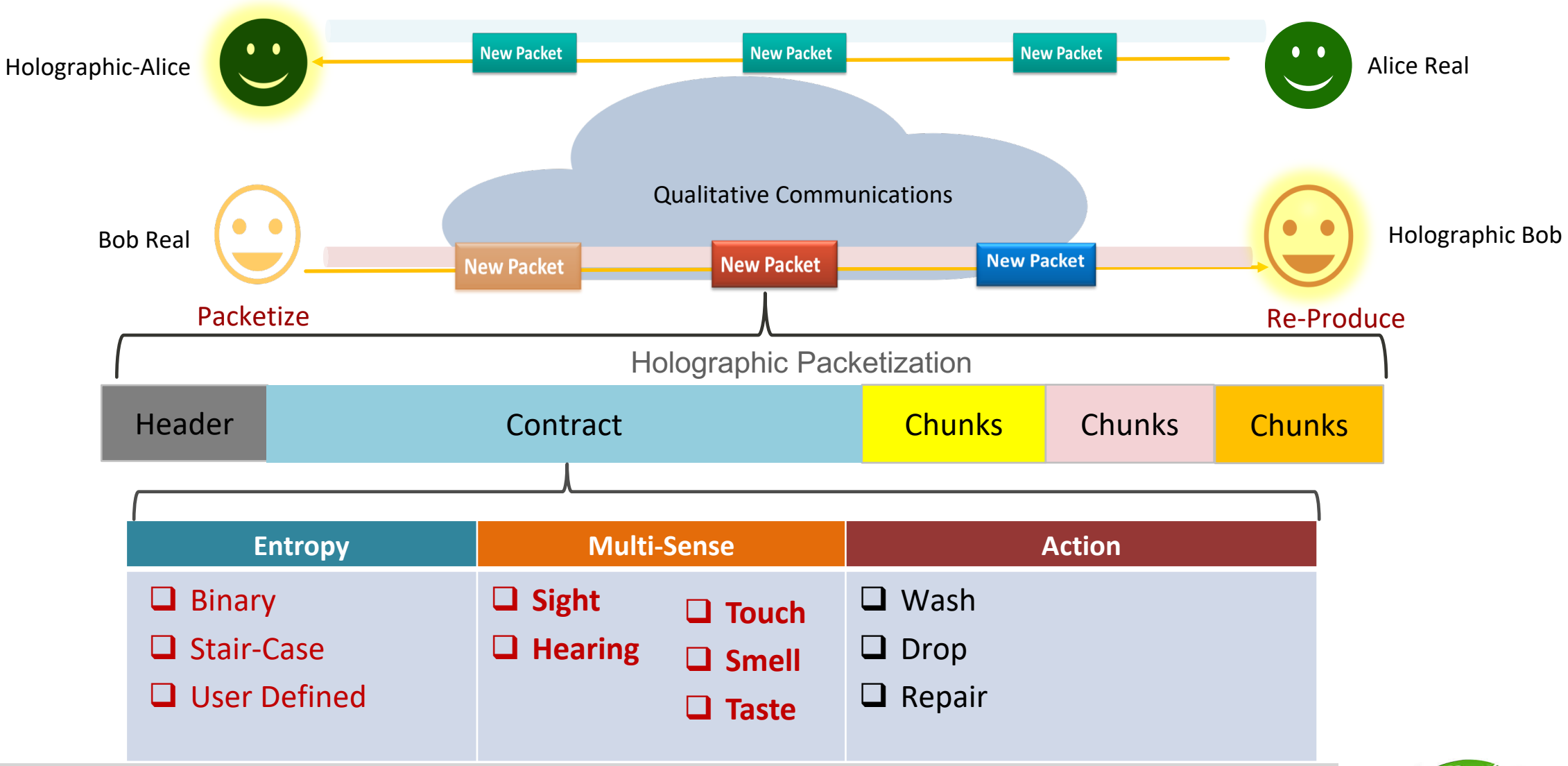
Congested Node

Congested Node

Congested Node

Bits and bytes are not equally significant

Non-Linear Packetization and New Services: Holographic Type Communications



Holographic-Media and Future Networks

Chongfeng Xie@China Telecom

Aug. 19, 2019

Visions of the future networks

Bandwidth

- Super high-bitrate: Tbps
- VR/AR, holographic videos

Connections

- Massive connections:~ 100 billions
- Resource manageable

Detnet

- Low latency, loss, and jitter
- High reliability

Secure

- Built-in security
- Trustworthy, Source Address Validation and Anti-spoofing

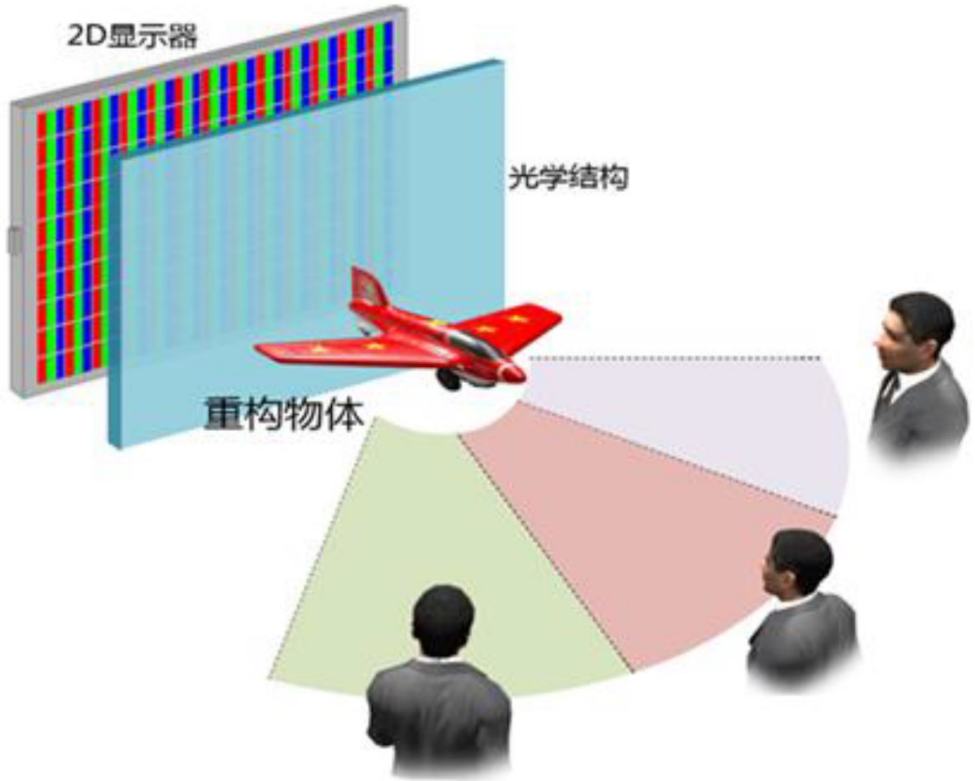
Management

- SDN/NFV, AI
- Self-management
- Self-organizing

Possible applications of Holographic-media

A hologram is an image that appears to be three dimensional and which can be seen with the naked eye. Typically, a hologram is a photographic recording of a light field, rather than an image formed by a lens.

- **Education and training**
- **Tourism and entertainment**
- **Medical treatment**
- **Collaborative design**
- **Online-gaming**
- **…**



Holographic services mean ultra-high bitrate

参数	Phone (5.9 inchs)	HD TV(70 inchs)	Hologram(5.9 inchs)	Hologram(70 inchs)
分辨率	1920*1080 (1080p)	7680*4320 (8K)	124,800*70,200	1,536,000*864,000
点距 Dot Pitch	65um【典型值】	200um【典型值】	1um【波长大小】	1um【波长大小】
显示大小	12.48cm*7.02cm	153.6cm*86.4cm	12.48cm*7.02cm	153.6cm*86.4cm
Bits per Pixel	24bits/pixel	24bits/pixel	24bits/pixel	24bits/pixel
静态压缩率	20:1	20:1	40:1	40:1
动态压缩率	200:1	200:1	1000:1	1000:1
静态图储存量	2.49Mbits	39.8Mbits	5.25Gbits	796Gbits
动态图传输数据率(60FPS)	14.93Mbps	238.89Mbps	12.6Gbps	1.9Tbps

Possible changes to the networks in 2030

- New network architecture and protocols
- New transmission techniques
- New business models

中国电信
CHINA TELECOM

5G hello

Thank you!

ACM SIGCOMM 2019 Workshop on Networking for Emerging Applications and Technologies (NEAT 2019)

Panel: Enabling Holographic media for Future Applications: Identifying the missing pieces and limitations in Networks

Slides by Mohamed Faten Zhani

École de technologie supérieure (ÉTS Montreal)

University of Quebec

Canada

Beijing, China, 19 August 2019

Holographic media Requirements & Characteristics

- Holoportation: a technology that allows Holograms to be captured, compressed, transmitted and reconstructed anywhere in the world in real-time
- Requirements:
  - High processing power: real-time processing
  - High bandwidth (e.g., 30Gbps to 4.62 Tbps)
  - Latency: Ultra-low (1ms to 20ms)
    - Multi-flow synchronization
  - High availability
- Characteristics
  - Octopus-like applications: huge number of flows, multiple destinations
  - Requirements can change over time

ÉTS
Le génie pour l'industrie

Questions

1. The Future of holographic media: reality vs myth
   - What in your mind is most appealing application using holographic media?
   - Are we too early in predicting that the year 2030 will be a holographic society?
2. Readiness and role of networks:
   - What are the challenges and gaps in current network architectures and protocols?
   - Is TCP/IP the right protocol suite for holographic media.
3. Who are the key stakeholders?
   - Is there a need for standardization and collaboration for holographic media?
   - Role of service providers, content providers and vendors.
4. Is there a need for more network-aware media formats?
5. How do we deal with the high bandwidth and low latency that these future media demand?

Suggested Answers

FlexNGIA Architecture

Computing resources	Business model	Cross-layer Design (Transport+Network)	Application-Aware Network Management	Flexible headers
- In-Network Computing: any function anywhere	- Multiple source destination Service Function Chains - Stringent performance requirements	- Breaking the end-to-end paradigm - In-network advanced transport functions - Better congestion control - Stringent performance and reliability guarantees	- Advanced functions tailored to applications - App-aware traffic engineering	- Tailored to the application

Le génie pour l'industrie

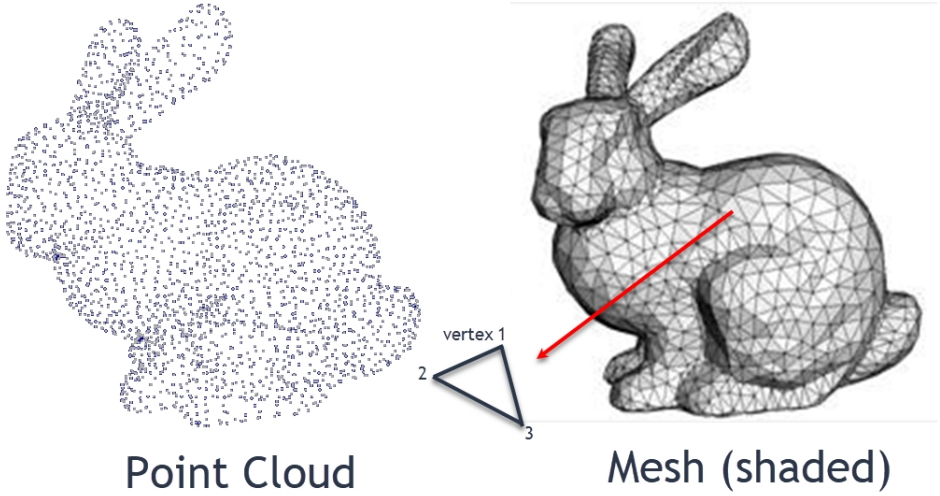
Thank You

Questions

Slides courtesy of Feng Qian

Volumetric Videos (Holographic Media?)

- 3D animated point cloud or mesh

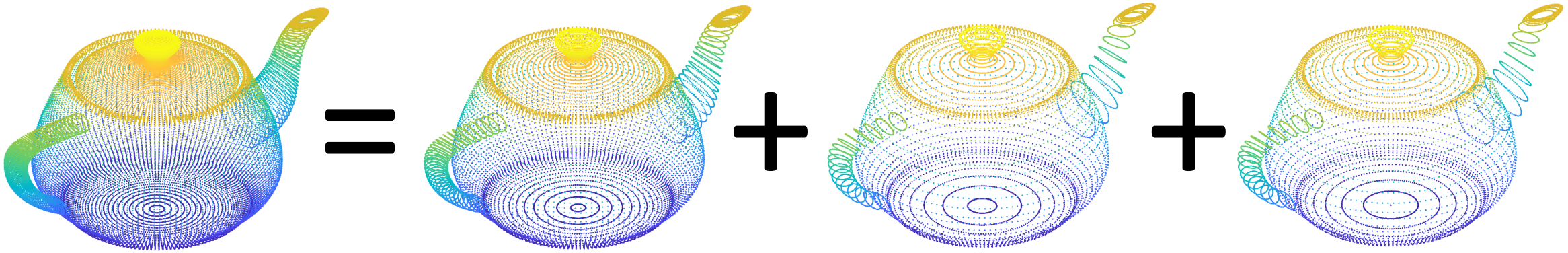


- 6-DoF
- Captured by RGB-**D** cameras with **D**epth sensors
- Immersive telepresence experience
- Many applications: gaming, entertainment, medical, education, …

Image source: “Learn ARCore - Fundamentals of Google ARCore by Micheal Lanham”

Layered Content Organization

- Geometry-based volumetric content can be easily “split and merged”



The entire scene
100% of points

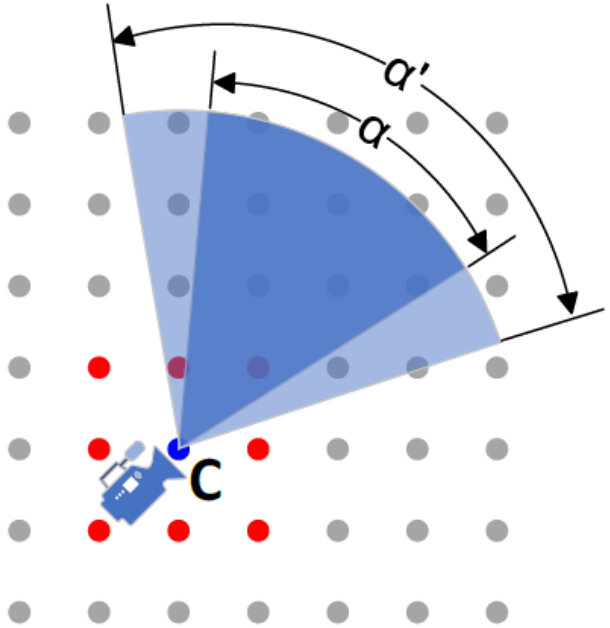
Layer 0 (base layer)
50% of points

Layer 1
25% of points

Layer 2
25% of points

- Layered representation (similar to SVC, Scalable Video Coding):
  Quality n = Layer 0 (base layer) + Layer 1 + … + Layer n-1
- Allows video quality to be incrementally upgraded
  - Flexible, adaptive to the network dynamics

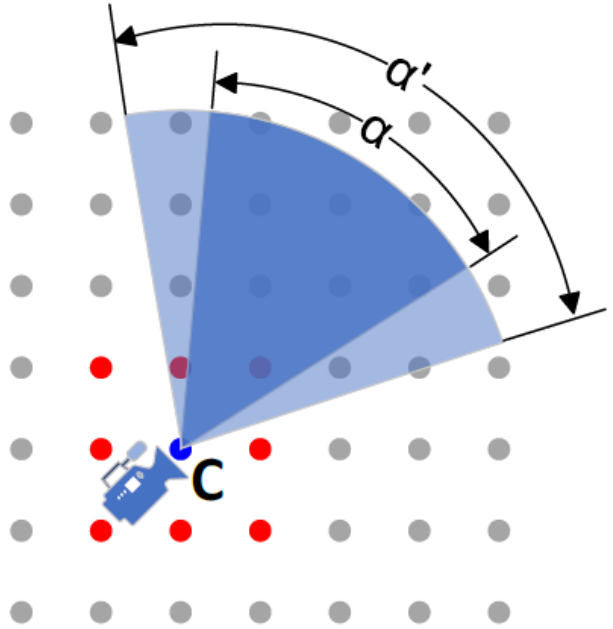
Edge Assistance



- Client sends 6-DoF viewport movement to edge
- Edge …
  - performs (short-term) 6-DoF viewport prediction
  - transcodes volumetric content into regular (2D) video
  - sends transcoded 2D video to smartphones
- Challenge
  - How to predict 6-DoF viewport movement? User study, machine learning…
  - How to tolerate inaccurate prediction? Multiview encoding (next slide)
  - System-level optimization: pipelining, accelerating point cloud decoding using GPU…

Multiview Encoding

- Render and encode multiple views with a larger FoV (field-of-view) to tolerate inaccurate viewport prediction



Enabling Holographic media for Future Applications: Identifying the missing pieces and limitations in Networks

Panel

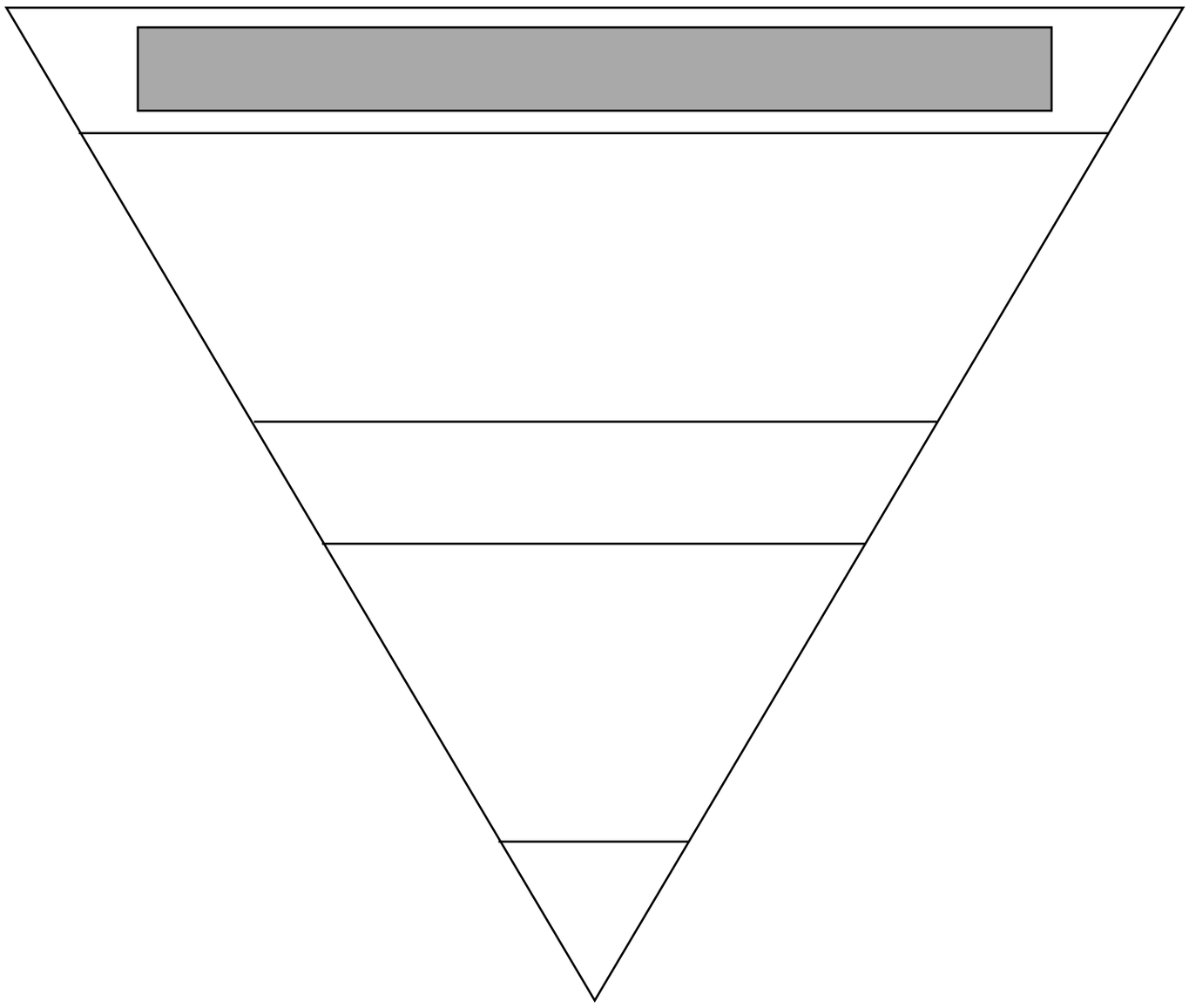
Stuart Clayman
University College London

NEAT 2019 - Beijing

Issues

- Consider some fundamental aspects and issues that won't go away easily.
- Tension between apps and the network
- Misunderstanding what IP is and what TCP provides
- Lack of Socket options
- Lack of new protocols being deployed
- Middle-boxes undermine the end-points

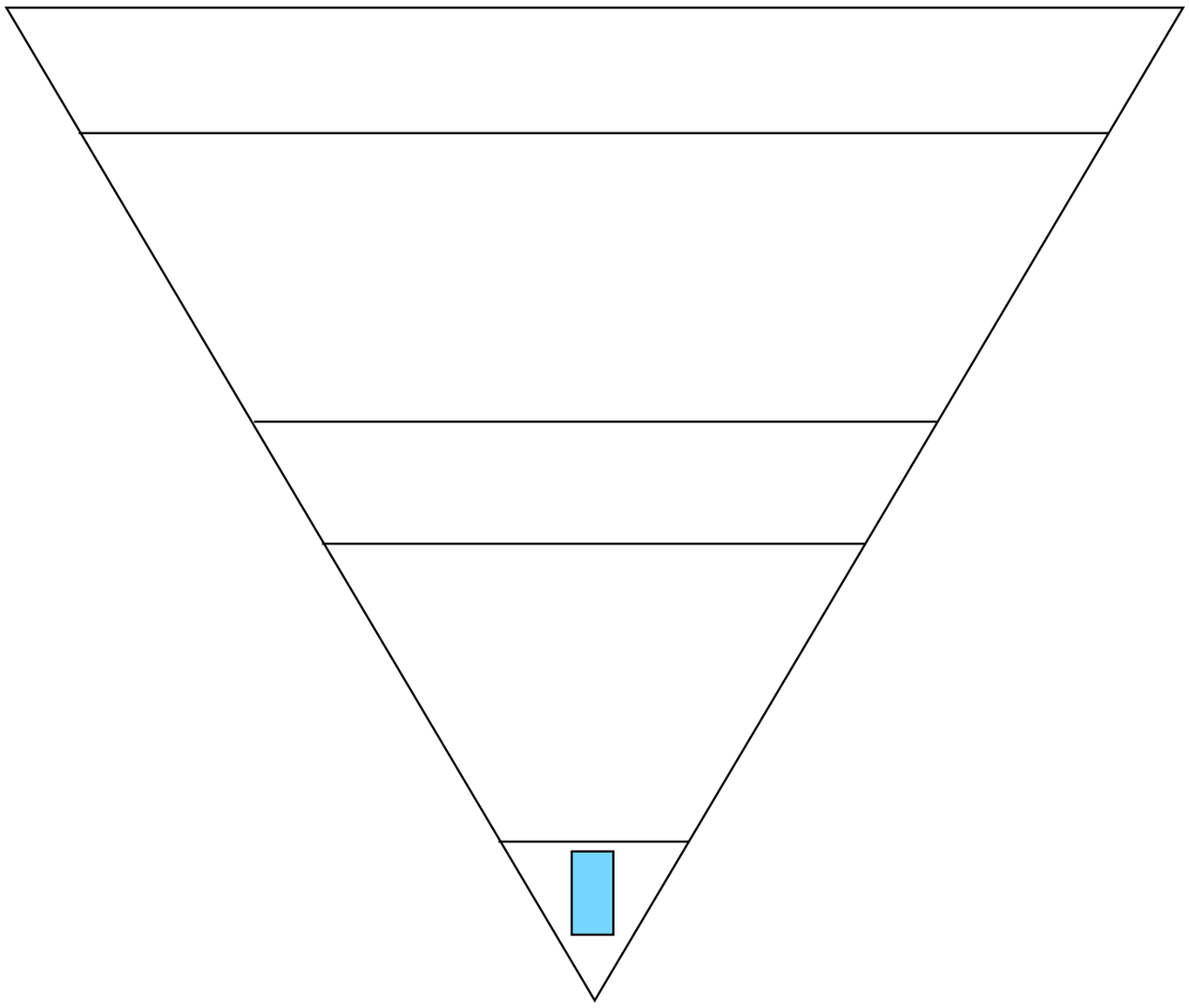
Tension



The application wants to send large amounts of data.

For holographic apps, data could be in chunks 100s Kb or Mb, to get transmission rates of Tbps.

Tension



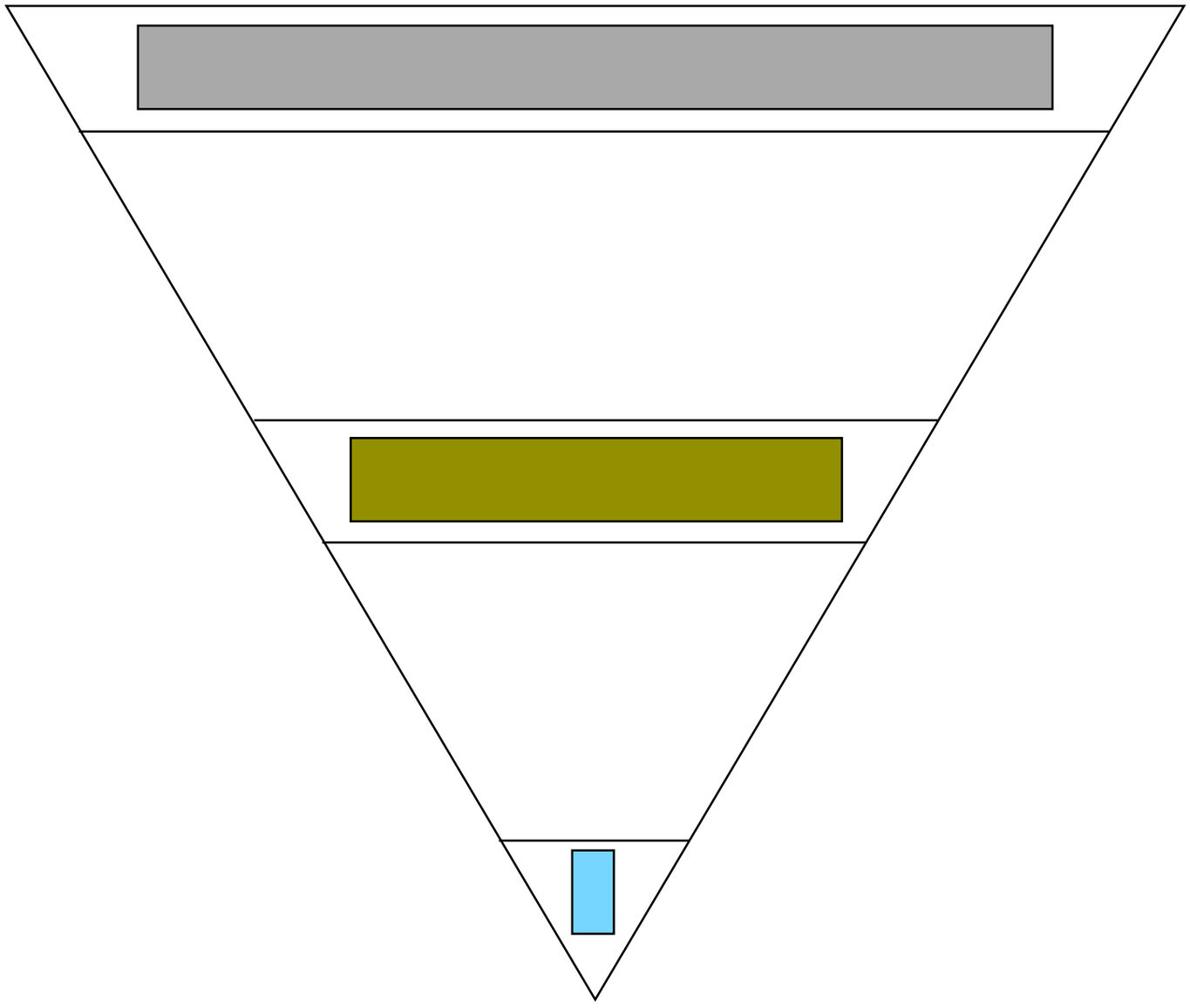
application

network

But the network wants to switch on very small frames, so transfer is very quick.

The faster the clock in the switch, the smaller it wants frames.

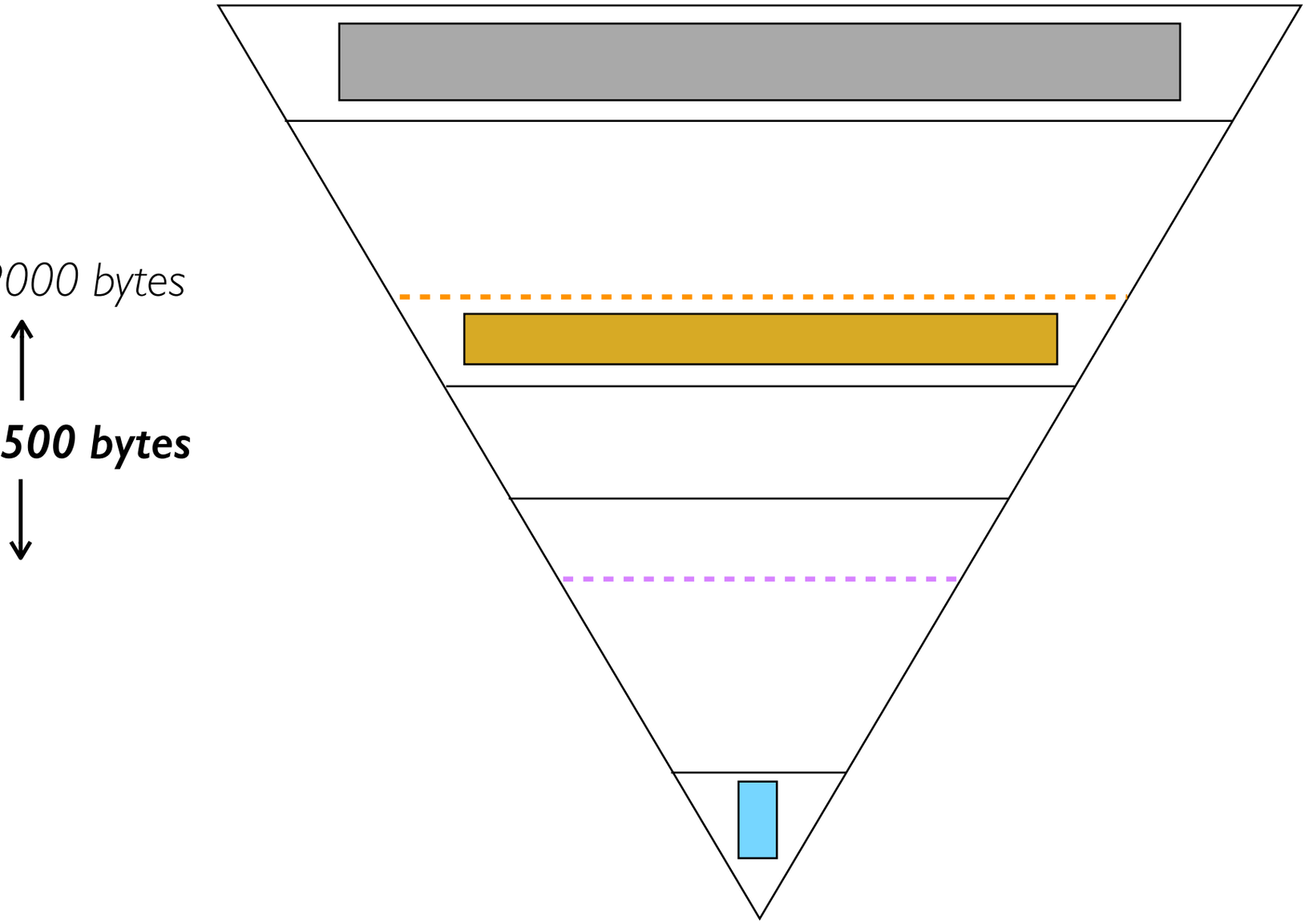
Tension



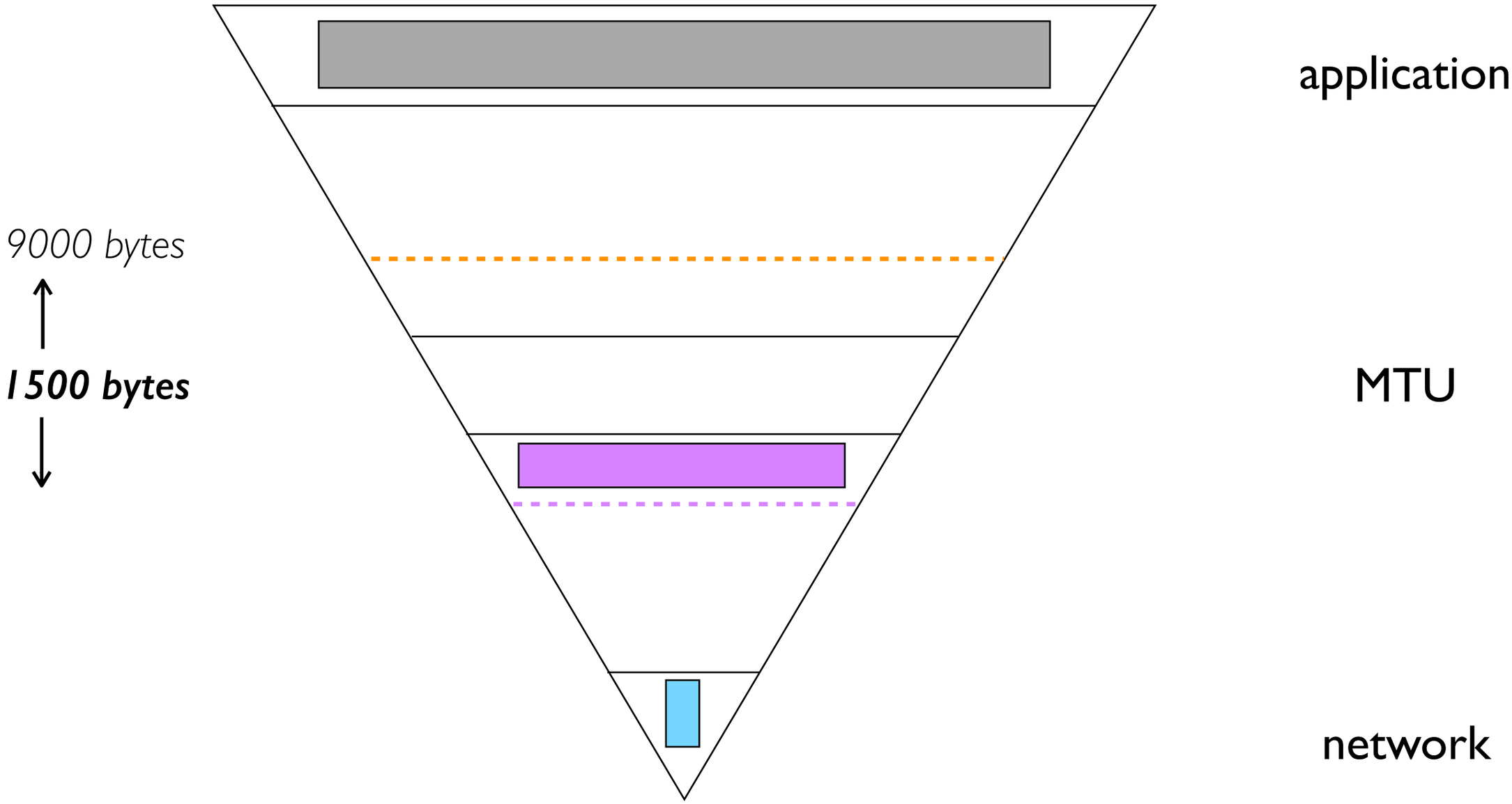
So there is a pull in different directions, and therefore a tension.

The current MTU is usually 1500 bytes (because it is a good middle value). What does the future hold ??

Tension

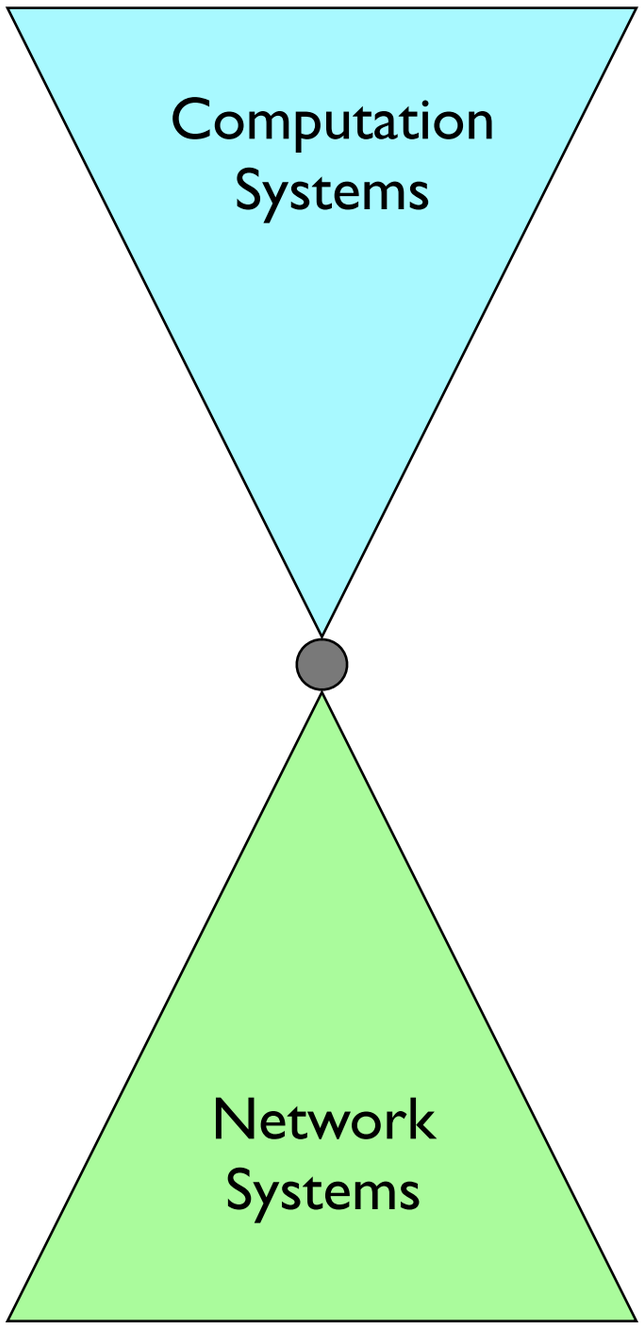


We can try to push the MTU to a bigger value.
9000 bytes is a good start, as it is the size of a jumbo frame,
and it is directly supported by current ethernet hardware.
This means we can test against real hardware if needed.



We can also try to shrink the MTU to a smaller value. Suggest trying 512 next, then 256, 128, 64, as this gets closer to the size of a switchable 'slot'.

IP Networking

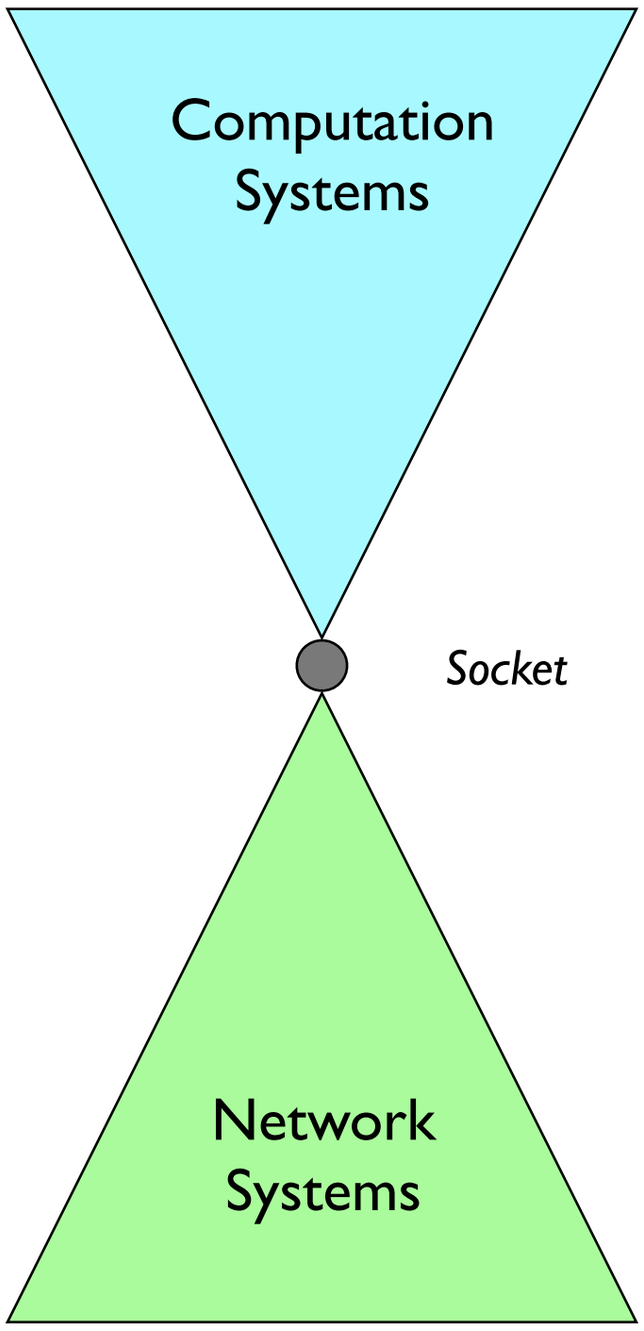


The Internet is made up of two great infrastructures:

- the computational systems
- the networked systems

They are intrinsically linked, however there is a another tension regarding the exposed set of functions.

IP Networking

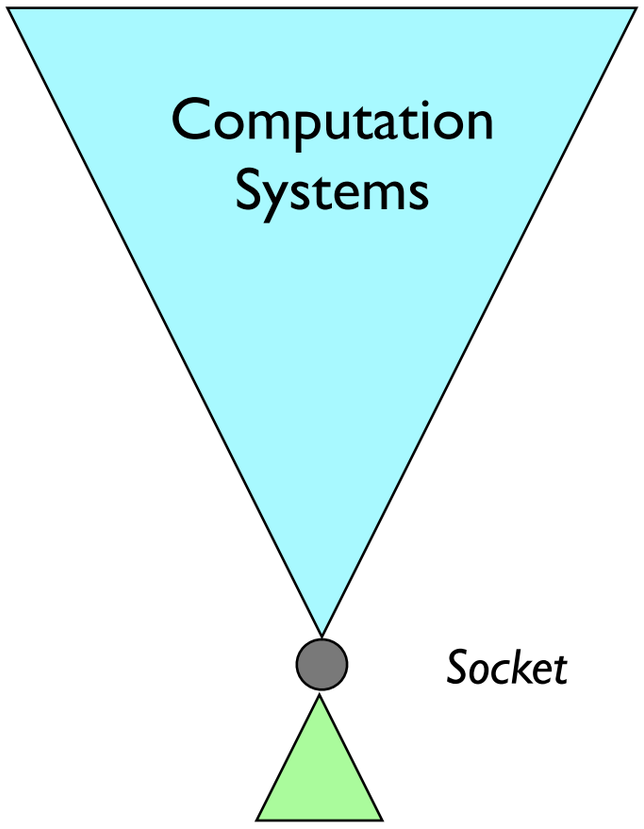


Both systems are joined using the Socket.

The Socket is an abstraction that allows data to travel from one point to another.

All applications use Sockets to communicate.

IP Networking



As far as the computation systems are concerned, the network could be simplistic and not very featureful.

The network is abstracted away as a delivery mechanism. Also the network operators hide the network features and attributes. So programmers and users cannot always get the benefit of both systems.

IP Networking

- The underlying networking hardware on many machines supports link layer transmission mechanisms, and can operate using very different schemes, including: ethernet, optical, wireless, WiFi, bluetooth, and so on.
- The networking layer of most current operating systems is presented using TCP/IP. In essence, this gives the user / programmer two kinds of network interaction:
  - UDP – an unreliable datagram delivery mechanism, and
  - TCP – a reliable stream delivery mechanism
- A Socket is a uniform abstraction as a network access point, that supports operations for sending and receiving data. Both UDP and TCP are accessed via a Socket API.

IP Networking

- The use of the Socket abstraction and TCP/IP hides all of these different networking interfaces, and they can all co-exist in the same machine.
- One might consider that TCP itself is another layer of abstraction over the network transport. To the user it presents a reliable stream, and to the network it sends packets. Each piece of data presented by the user to a TCP socket stream will become many packets at the network level, all of which are intrinsically managed.
- This differs from UDP, whereby each piece of data presented to a UDP socket will become one network packet.

IP Networking

- TCP actually has 3 abstraction mechanisms:

  (i) two byte streams – an input stream and an output stream which can be accessed from either end of the TCP connection, and is used by applications and programmers.

  (ii) a reliable transport mechanism – such that any data loss between the end-points is overcome through re-sending lost data packets

  (iii) a congestion control mechanism – such that TCP can adapt its sending rate, both up and down, depending on how it perceives any congestion in the network.

Socket options are lacking

- The use of this simple Socket abstraction hides all of the complexities of the network.
- Remember, all applications use Sockets. There is nothing else !! So all the clever network features you hear about are inaccessible to application programmers.
- Unfortunately, there are very few options on a Socket. Mostly they are end system related, such as buffer size.
- There is no way for a Socket to tell the network anything useful, such as: latency, throughput, jitter, reliability, timeliness, etc. etc.
- The network is required to do delivery of packets in a best-effort manner.

No new protocols

- We observe that, in the range of protocols, UDP is at one end (simple packets and lossy), and TCP at the other (stream based and reliable).
- There have been many protocols suggested and defined which are between these 2 ends, but they do not get deployed into the end-systems that need to use them.
- For example, SCTP is available in Linux and BSD. It is not available in iOS, Android, MacOS, or Windows.
- So no one can write phone apps that use SCTP.
- The trouble is, that if useful and well defined protocols never make it to the end systems, how do we make progress ?

Middleboxes

- IP networking has a foundation of end-points interacting with each other.
- However, many network operators and ISPs have been persuaded by manufacturers to buy middle boxes.
- These boxes try to do clever things with the packets by inspecting the headers and content, and then doing various manipulations, such as splitting into smaller packets, or patching up bits in the header.
- This destroys the end-to-end interactions.
- So any tweaks to the protocols in the end systems for performance improvements, or the introduction of new protocols is undermined by these boxes.

Summary

- Overcoming the tension between apps and the network is hard, as it is a systemic issue. As everything is connected, as you optimise one part, you lose elsewhere.
- Create a lot more Socket options so that the apps can interact with the network
- Try to understand what TCP provides, and if it's not needed provide new kinds of protocol.
- Need to put pressure on phone / device manufacturers to support new protocols being deployed
- Have less middle-boxes undermine the end-points

Rate Adaptation & Network Awareness?

- Rate adaptation: selects video quality level based on network capacity

- Proxy – Client
  - Regular video
  - Leverage existing rate adaptation algorithms
  - Consider multiview encoding

- Server – Proxy: an uncharted territory, need to…
  - identify the QoE metrics
  - adaptively perform incremental quality upgrade for layered representation
  - develop an efficient online algorithm

KolmoLD?