ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

IKEK
Departement Informationstechnologie und Elektrotechnik

Communication Systems Group (CSG)

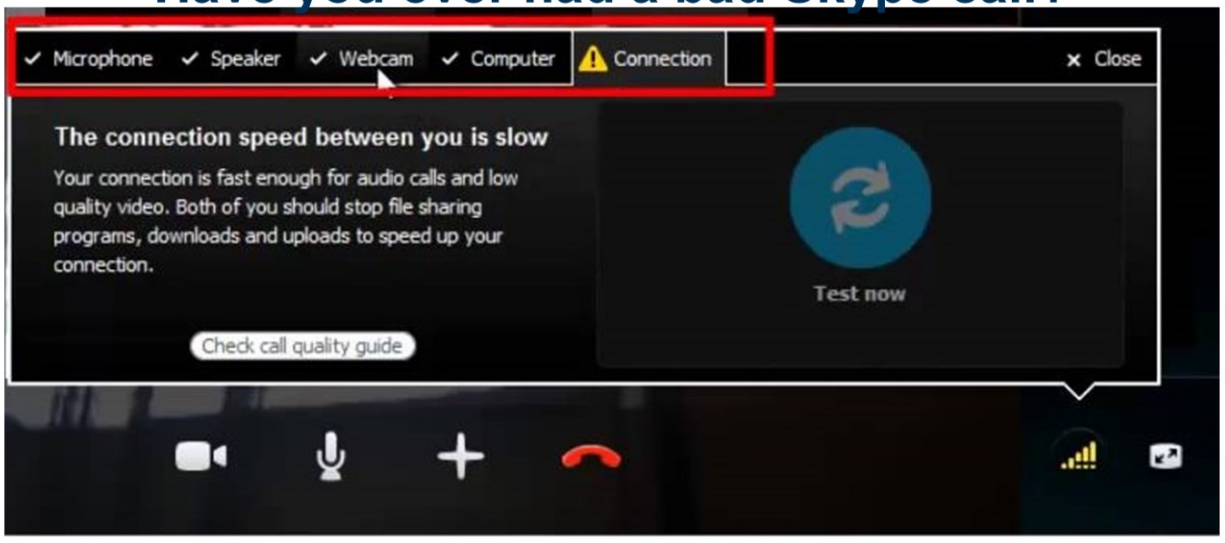
Control Exchange Points: Providing QoS-enabled End-to-End Services via SDN-based Inter-domain Routing Orchestration

Vasileios Kotronis[1], Xenofontas Dimitropoulos[1,2], **Rowan Klöti**[1], Bernhard Ager[1]
Panagiotis Georgopoulos[1], Stefan Schmid[3]

[1]ETH Zurich, Switzerland, [2]Foundation of Research and Technology Hellas (FORTH), [3]T-Labs & TU Berlin, Germany

- This paper was a joint work with Vasileios**,** Xenofontas, Bernhard, Panagiotis and Stefan

Have you ever had a bad Skype call?



- Have you ever had a Skype call drop?
- Have you ever had poor quality video and lag?

Would you perform a duet over the Internet?

http://www.internetsociety.org/sites/default/files/pdf/accepted/32_LOLA.pdf

- What do you think about playing a piano duet with someone – over the Internet?
- Careful coordination is required, so latency must be very low.
- This has been implemented – the implementation requires that uncompressed video be sent!

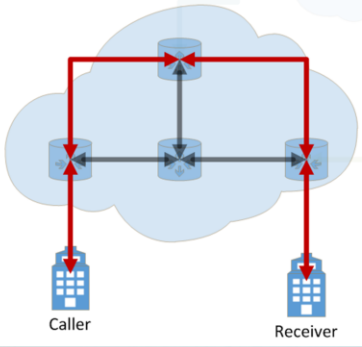
What about having telesurgery?

http://news.bbc.co.uk/2/hi/science/nature/1552211.stm

- What about having an operation performed from another continent?
- Not only do we require uncompressed video, but also high resolution.
- Not to mention high availability!

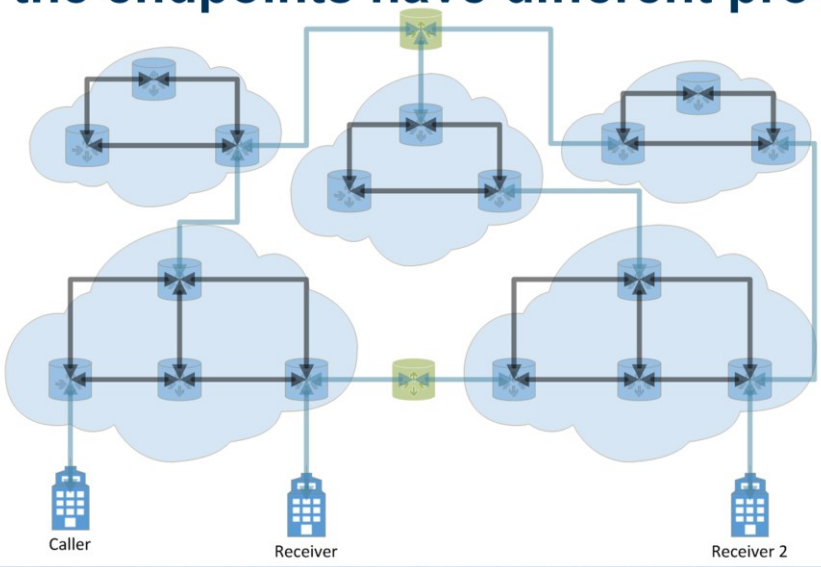
Possible for a single provider

- An ISP can allocate resources within their domain
  - ISP has full overview of link utilization
  - ISP controls the embedding of its traffic matrix



- QoS guarantees are possible if a caller and a receiver have the same provider.
- The provider has the overview of its link utilisations and solutions exist to allow it to embed its traffic matrix to meet guarantees.

What if the endpoints have different providers?



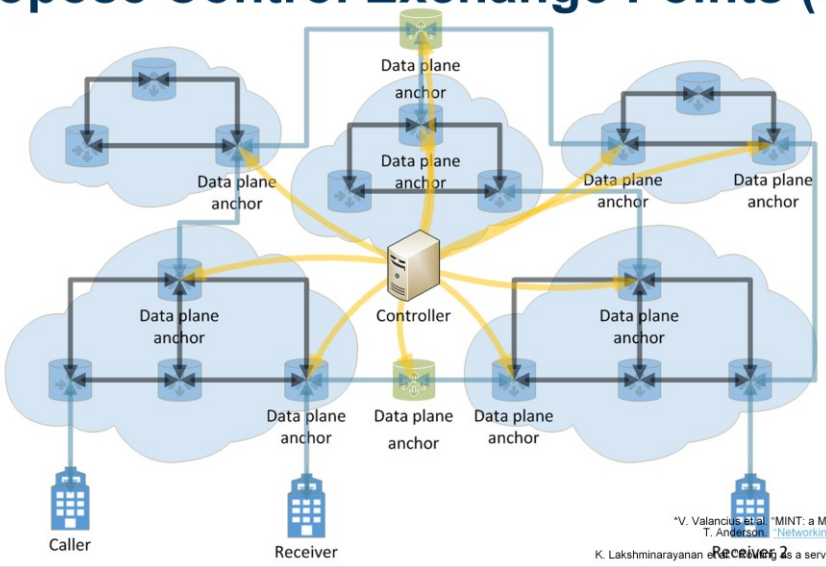
- If a caller and receiver have difference providers, then QoS is very difficult with the current Internet.

Inter-domain routing limits us

- No end-to-end guarantees for:
  - Availability
  - Latency
  - Bandwidth
  - ...
- Current inter-domain routing (BGP) does not allow this
  - BGP focuses on *reachability*, not *Quality of Service*
  - We can't replace BGP (easily)

- Between domains, there are no guarantees of bandwidth or latency, or even end-to-end connectivity.
- The current inter-domain routing protocol BGP focuses on reachability rather than QoS.
- Replacing BGP is far from straightforward.

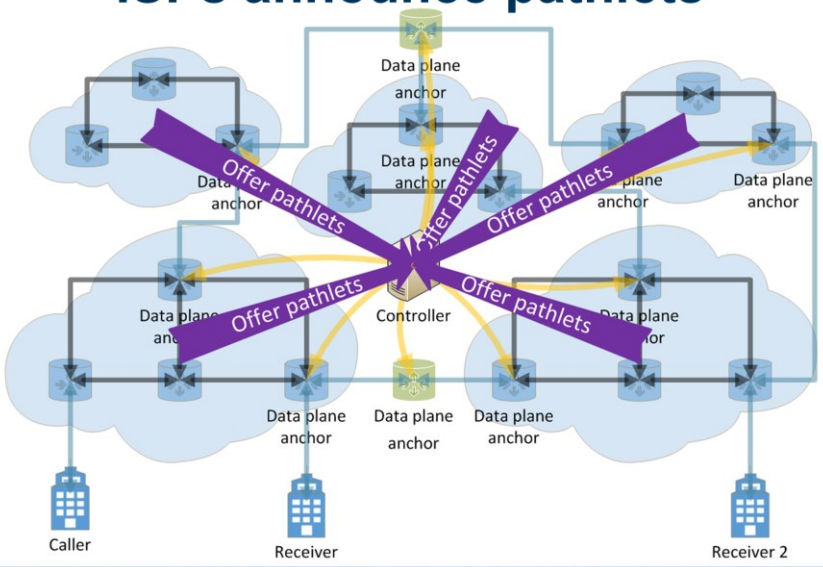
We propose Control Exchange Points (CXPs)



"V. Valancius et al. "MINT: a Market for INternet Transit", In *CoNEXT '08*
T. Anderson. "Networking as a Service", *HOTI-21 keynote. (2013)*
K. Lakshminarayanan et al. "Routing as a service". Tech. Rep. UCB-CS-04-1327 (2004)

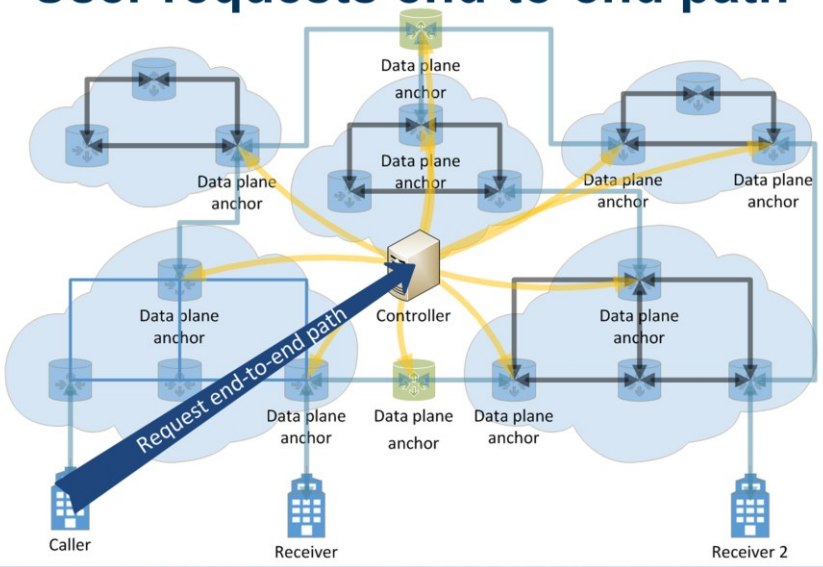
- We propose Control Exchange Points
- Control Exchange Points provide application-specific SDN-based peering.
- Each Control Exchange Point consists one logically centralised controller and many data plane anchors which are operated by the controller
- Data plane anchors are situated on the edge of ISP networks.
- The solution allows for multiple competing CXPs as well as the coexistence with existing inter-domain routing.
- Some of the concepts of this paper have been discussed in prior work.

ISPs announce pathlets



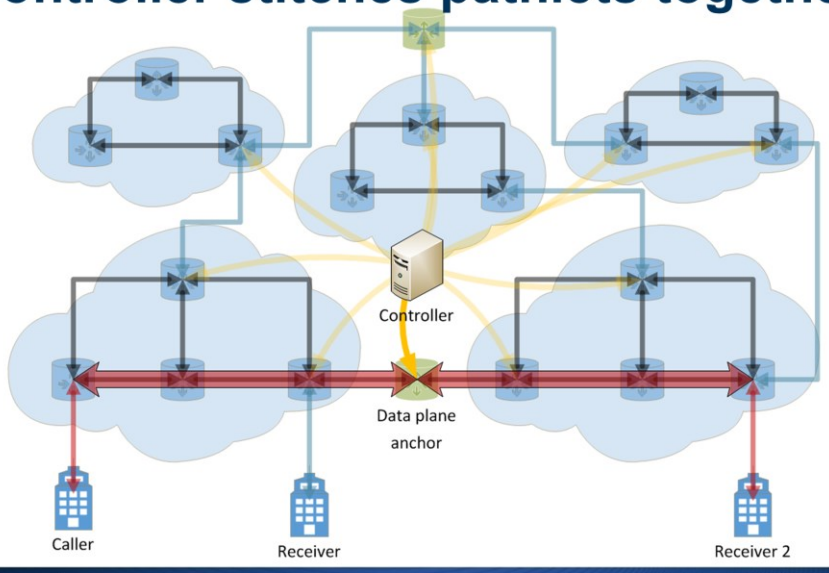
- ISP participating in the scheme announce pathlets to the controller.
- The pathlets connect between data plane anchors and are annotated with performance guarantees.
- The ISPs are paid for the use of the pathlets.

User requests end-to-end path



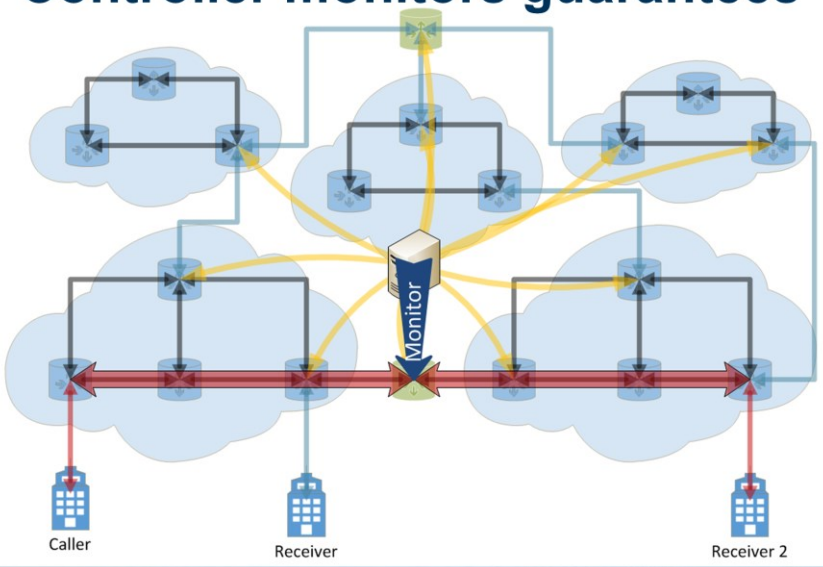
- A user who wants an end-to-end path with QoS guarantees sends a request with the endpoints and the required guarantees to the controller.

Controller stitches pathlets together



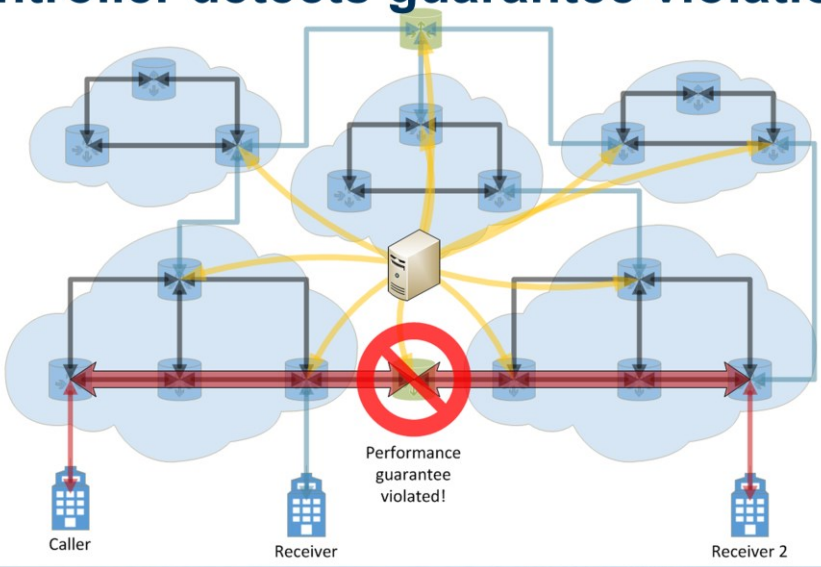
- The controller computes several valid paths using the offered pathlets and selects one.
- The remaining paths may be kept as a backup.

Controller monitors guarantees



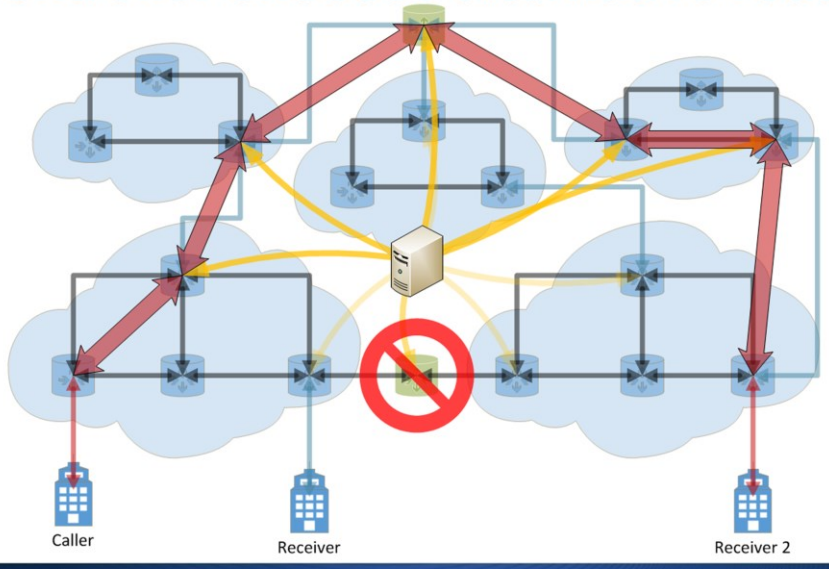
- After establishing the path, the controller continues to monitor the performance of the path via instrumentation at the data plane anchor and possibly at the endpoints.

Controller detects guarantee violations



- The controller can detect violations of QoS guarantees, or even a completely failed link.

Controller chooses alternative route



- When QoS guarantees are violated, the controller performs a dynamic rerouting using an alternative path.
- The caller and receiver need not notice the change of route.

Best location for CXP data plane anchors?

- Good path diversity
- Maximal coverage of potential users
- Well-connected deployments
- High bandwidth and availability
- Provider neutrality

- The question remains: where to deploy these data plane anchors?
- We need a central location with good path diversity and high bandwidth and availability, but without depending on a single provider.

IXPs have the desired properties!

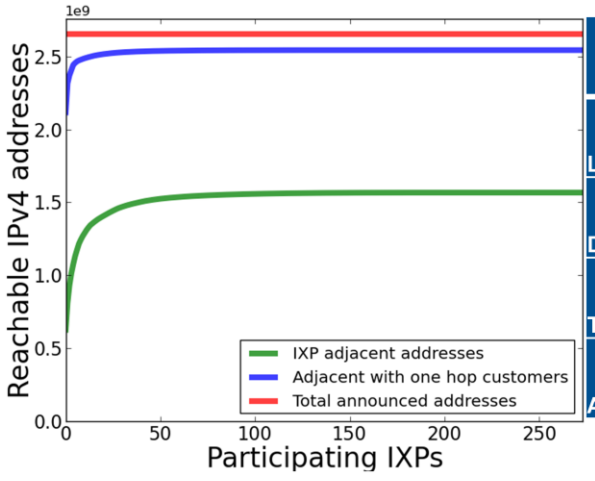
- Internet Exchange Points are public peering points
- They can have hundreds of providers participating
- They exchange up to Tbps of traffic
- They are independent of individual members

- But what about path diversity?
  - Coverage?

- We propose to use Internet Exchange Points for data plane anchors.
- They have hundreds of participants (DE-CIX has over 600).
- They exchange terabits of traffic every second but yet are not controlled by individual ISPs.

- But what about path diversity and coverage?

Path diversity and coverage



	LINX	DE-CIX Frankfurt	Terremark	AMS-IX
LINX	512	209	51	241
DE-CIX Frankfurt	-	516	47	275
Terremark	-	-	151	48
AMS-IX	-	-	-	629

Euro-IX: https://www.euro-ix.net/
CAIDA: http://www.caida.org/data/overview/

- We investigated path diversity and coverage.

- The plot on the left shows how many IP addresses we can service from a given number of IXPs.
- The green curve is for providers attached directly to IXPs.
- The blue curve is for providers attached to IXPs and their customers over one hop.
- The red line is total number of announced IPv4 addresses.
- We can service a large portion of the Internet address space from just a modest number of IXPs and, if we allow for a single customer-provider hop, virtually the entire Internet.

- On the right you can see a table showing just how many members the largest IXPs have in common.
- With dozens and even hundreds of members connecting between the IXP pairs, the path diversity available is large.

Current and future work

- Simulation
  - Refinement of path embedding algorithm
  - Sensitivity analysis
- Investigate CXP deployment strategy
- Emulation of system
  - SDN northbound APIs between ISPs-IXPs and CXPs
  - SDX* concept suitable for deploying CXP anchors

*N. Feamster et al. "SDX: A Software Defined Internet Exchange". In *ONS, (2013).*

- We are currently working on the simulation of path embedding, in order to refine the algorithm and perform sensitivity analysis.
- We are investigating deployment scenarios.
- We will be developing an emulation of the working system, in order to test APIs, as well as considering the Software Defined Exchange concept introduced by Nick Feamster et al.

Conclusions

- Interdomain Quality of Service
- Control Exchange Points
  - Data plane anchors deployed in IXPs or other peering points
  - ISPs offer pathlets between data plane anchors
  - Controller stitches these to obtain end-to-end tunnels
  - Controller monitors and reroutes
- Questions?

- In this talk we have proposed a solution for interdomain QoS.
- We presented the concept of Control Exchange Points, which employ SDN to offer dynamically routed end-to-end paths with performance and connectivity guarantees.