

What if we'd designed measurement as a first-order service?

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measurement and architecture for a middleboxed internet

measurement

architecture

experimentation



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Overview



- Network measurement is hard.
 - Which tool? What to measure? How often?
- Getting it right is even harder.
 - „*Wer misst, misst Mist*“ *
misst=measure & Mist=bullshit
- Why is it so hard?
 - “Big five” metrics (loss, latency, jitter, rate, reordering)
- How hard can it be?
 - Path layer providing explicit in-band measurement!



Example: latency/RTT

- Ping?
 - ICMP often blocked
 - Differential Treatment possible
- TCP TSOPT timestamps for latency/jitter
 - Only works with TCP, enabled on about 30% of hosts
 - No application hooks for *explicit* enablement
 - Need heuristics to estimate sender clock rate



Example: Loss/reordering

- TCP throughput testing... is hard to get right [1]
 - High network load and unwanted interference
- Ping Mesh?
 - Overhead is not applicable for Internet measurement
 - Do we really measure what we want to measure?
- TCP seq/ack number analysis for loss/reorder?
 - Always exposed, and roundly abused in the Internet
 - Only works with TCP



Everything after ping is a hack

- And even ping doesn't work that well:
 - ICMP blocked, different codepaths, ECMP routing.
- Traceroute: overload ICMP Time Exceeded messages to infer Layer 3 topology
 - Same problems as ping, but ECMP is worse.
- Passive measurement, e.g. Netflow/IPFIX:
 - Passive RTT measurement [2] broken by ACK optimizations [3], etc.
 - Inflexible, low-rate sampling, even though we know better [4].



What do we really need?

- “Big five” metrics: loss, latency, jitter, rate, reordering
 - as socket properties, with API for access
 - exposed to the network, explicitly for measurability
- Transport-independent header fields explicitly defined for measurability
 - Constant-rate timestamps for latency/jitter
 - Exposure of loss/reordering
 - Detection of header manipulation (required for dynamic transport selection)
- Explicit endpoint control over measurement exposure
- Exposure in header allows passive as well as endpoint measurement



Sounds great. Let's do it!

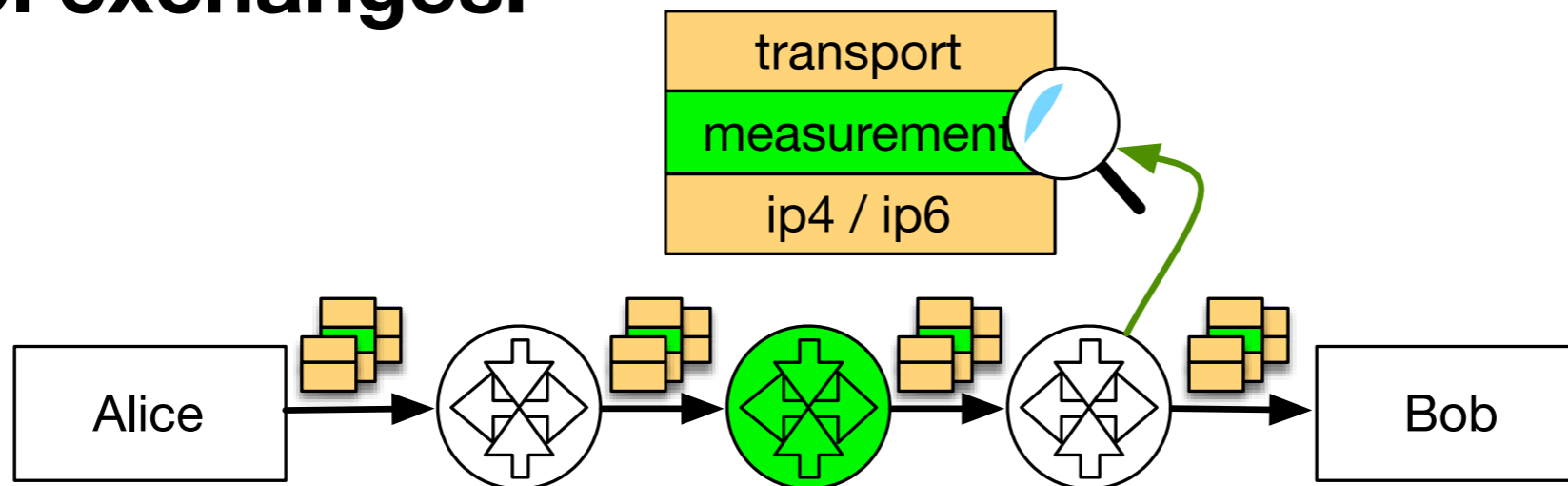
Now we just have to find the bits...

- IPv6 Destination Options [5]?
 - not very deployable, may be nearing deprecation, v6 only.
- IPv4 options?
 - even less deployable, v4 only.
- in the TCP header?
 - TCP only; options hard to deploy
 - HICCUPS [6] reclaimed a few bits from the header itself



A Measurement Layer

... for explicit exposure of information as part of **normal protocol exchanges!**



- ➔ You don't have to instrument every packet, every endpoint, or every router to get *much* better information than we have today.



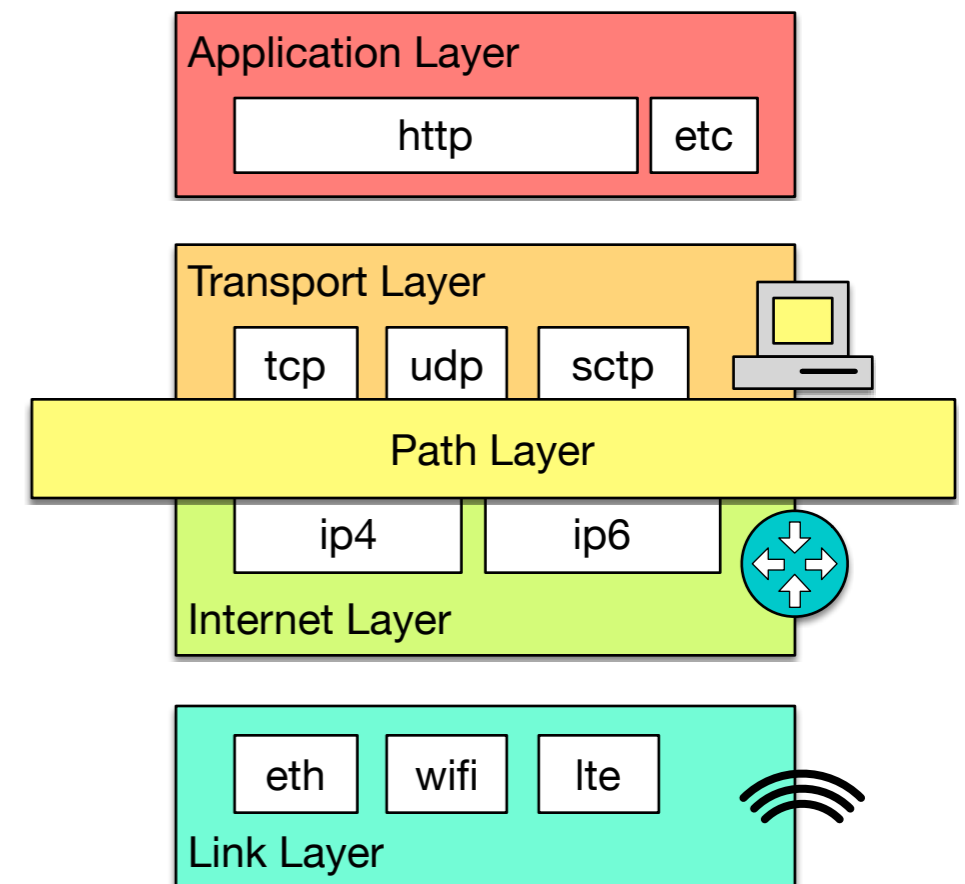
Adding new layers to the stack for fun and profit

Our “measurement layer” is a special case of a more general problem [7]:

- Where do all of the complex, stateful, not necessarily end-to-end functions we’ve built go?

Solution: “**Path layer**”

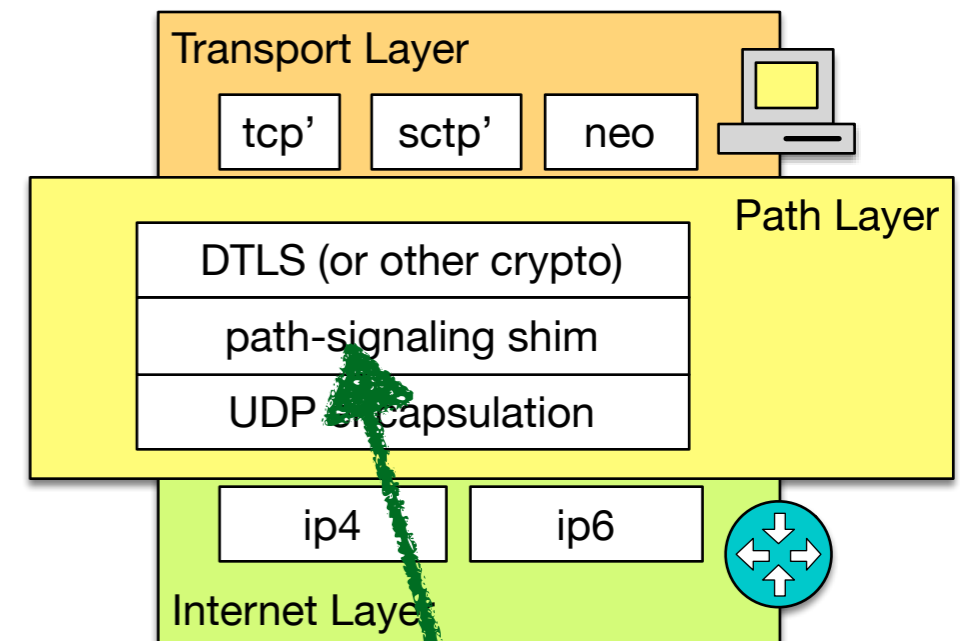
- Encryption of transport layer and above to enforce end-to-end-ness
- Explicit exposure from endpoints to the path of appropriate information





Path layer requirements

- Packets grouping for property binding, on-path state management
- Efficient per-packet signaling
- Integrity protection for exposed headers, allowing modification with endpoint permission
- Protection against trivial abuse of UDP
- Work in progress:
draft-trammell-spud-req [8],
spud@ietf.org



measurement
goes here



Will it deploy?

- You can't add a new layer that today's routers won't route.
 - NAT: hard* to deploy protocols other than TCP or UDP

Conclusion: “path layer” headers as shim over UDP

- Initial findings: 3-6% of Internet hosts may have broken or no UDP connectivity, so we'll need a backup.
- See presentation by Brian Trammell in MAT WG

Conculsion



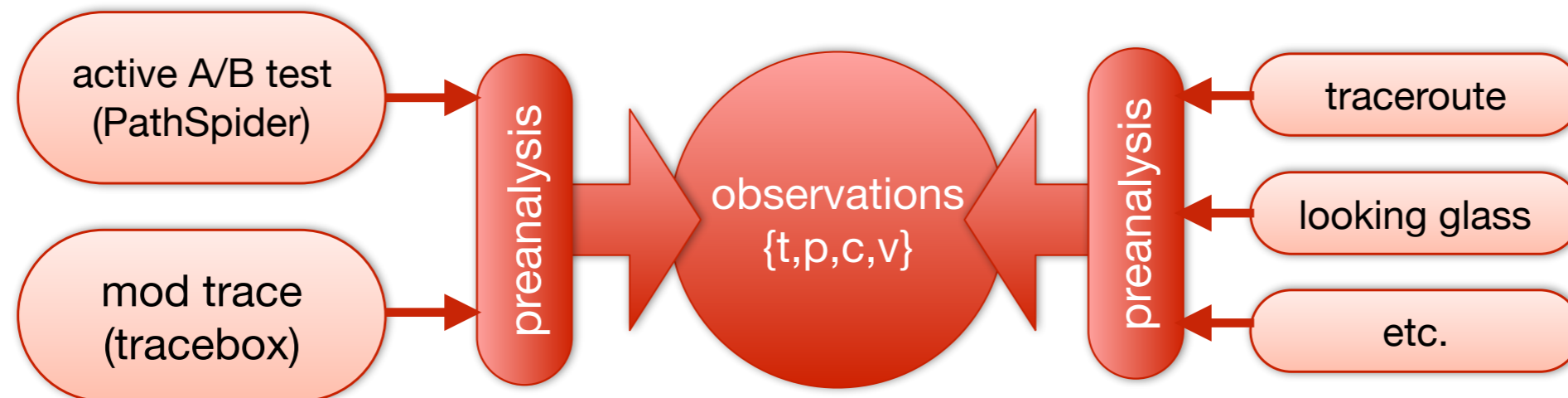
- Yes, measurement is hard.
- Let's make it better!

Missing:
Path layer for explicit exposure
of traffic and measurement information



Path Transparency Observatory

- Observatory (public release end 2016) to derive common **observations** about **conditions** on a given **path** at a given **time**
 - Active measurements, made by the project
 - External measurements (e.g. traceroutes, BGP, traces)
- Combining disparate measurements leads to better insight
 - How likely is it that a certain path impairment impacts my traffic?



Follow <http://mami-project.eu> for updates on data model & availability!

References



- [1] draft-ietf-ippm-model-based-metrics (IETF IPPM WG Internet-Draft)
- [2] Trammell et al “On Inline Data Integrity Signals for Passive Measurement”, TMA 2014
- [3] Ding et al “TCP Stretch Acknowledgements and Timestamps: Findings and Implications for Passive RTT Measurement”, Comput. Commun. Rev. 45(3), Jul. 2015.
- [4] Estan et al “Building a better NetFlow”, SIGCOMM 2004.
- [5] draft-ietf-ippm-6man-pdm (IETF IPPM WG Internet-Draft)
- [6] Craven et al “A middlebox-cooperative TCP for a non end-to-end Internet”, SIGCOMM 2014.
- [7] draft-kuehlewind-spud-use-cases (IETF individual Internet-draft)
- [8] draft-trammell-spud-req (IETF individual Internet-draft)

Backup



measurement and architecture for a middleboxed internet

measurement

architecture

experimentation

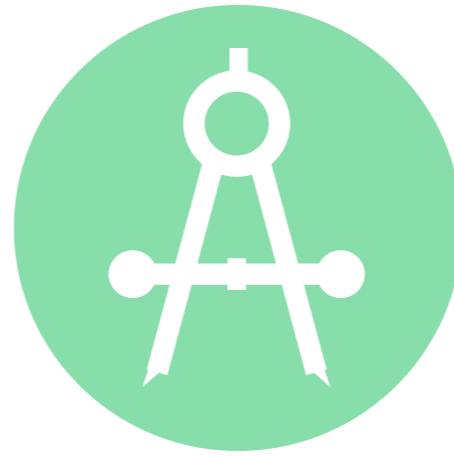
The MAMI Project

Measurement and Architecture for a Middleboxed Internet



measurement

of deployed middleboxes



architecture

for middlebox cooperation



experimentation

of use case applicability
and deployability

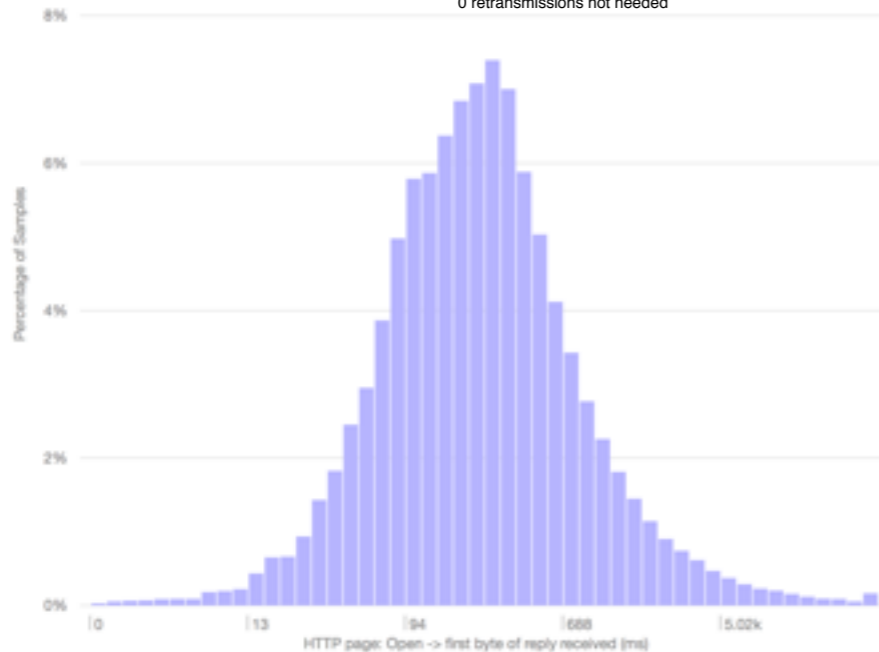
- Strong interaction with relevant standards organizations for impact on deployment
- FIRE testbed (MONROE) support for measurement as well as experimentation, especially on mobile broadband access networks
- Learn more at <http://mami-project.eu/>



How close are we to the goal?

```
% netstat -s -p tcp
tcp:
136072 packets sent
36226 data packets (12605543 bytes)
52 data packets (19892 bytes) retransmitted
1 resend initiated by MTU discovery
86569 ack-only packets (49 delayed)
0 URG only packets
0 window probe packets
7894 window update packets
5277 control packets
0 data packets sent after flow control
6 checksummed in software
  6 segments (339 bytes) over IPv4
  0 segments (0 bytes) over IPv6
164742 packets received
34764 acks (for 12593499 bytes)
1246 duplicate acks
0 acks for unsent data
143462 packets (152392523 bytes) received in-sequence
62 completely duplicate packets (49185 bytes)
0 old duplicate packets
0 received packets dropped due to low memory
0 packets with some dup. data (0 bytes duped)
434 out-of-order packets (532085 bytes)
0 packets (0 bytes) of data after window
0 window probes
19 window update packets
286 packets received after close
0 bad resets
0 discarded for bad checksums
6 checksummed in software
  6 segments (496 bytes) over IPv4
  0 segments (0 bytes) over IPv6
0 discarded for bad header offset fields
0 discarded because packet too short
2736 connection requests
9 connection accepts
0 bad connection attempts
0 listen queue overflows
2611 connections established (including accepts)

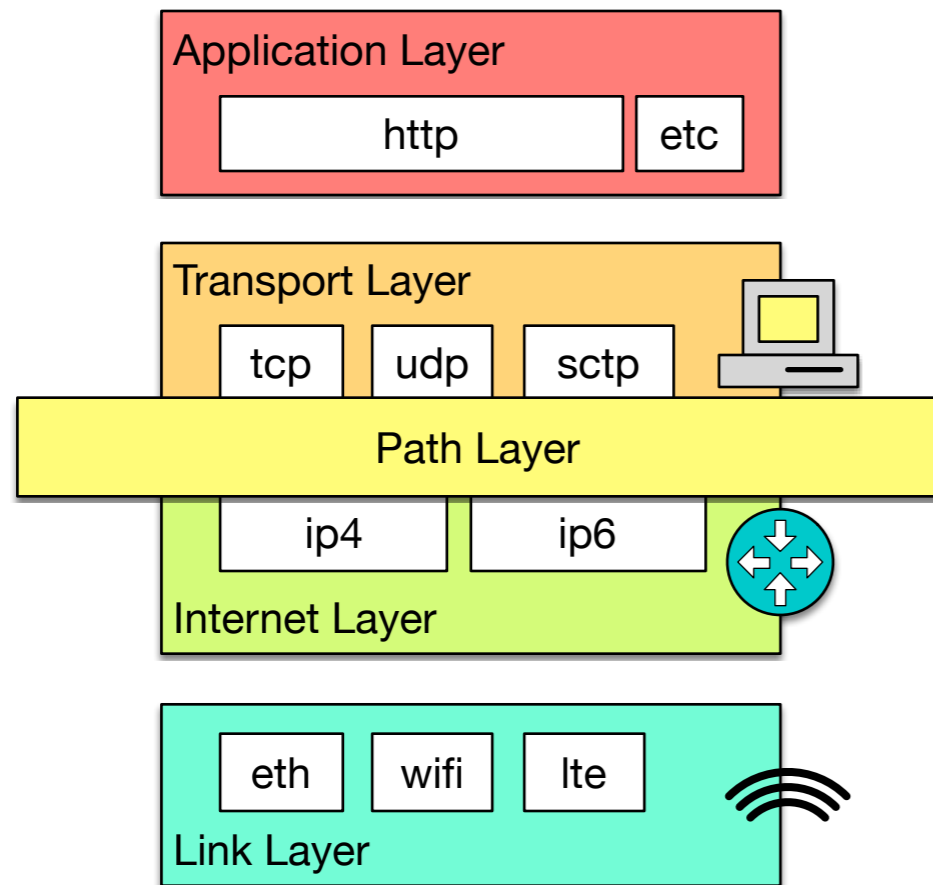
2823 connections closed (including 50 drops)
  96 connections updated cached RTT on close
  96 connections updated cached RTT variance on close
  5 connections updated cached ssthresh on close
0 embryonic connections dropped
70310 segments updated rtt (of 31390 attempts)
83 retransmit timeouts
  0 connections dropped by rexmit timeout
  0 connections dropped after retransmitting FIN
0 persist timeouts
  0 connections dropped by persist timeout
40 keepalive timeouts
  40 keepalive probes sent
  0 connections dropped by keepalive
78 correct ACK header predictions
126450 correct data packet header predictions
28 SACK recovery episodes
2 segment rexmits in SACK recovery episodes
1454 byte rexmits in SACK recovery episodes
69 SACK options (SACK blocks) received
303 SACK options (SACK blocks) sent
0 SACK scoreboard overflow
0 LRO coalesced packets
  0 times LRO flow table was full
  0 collisions in LRO flow table
  0 times LRO coalesced 2 packets
  0 times LRO coalesced 3 or 4 packets
  0 times LRO coalesced 5 or more packets
0 limited transmits done
28 early retransmits done
1 time cumulative ack advanced along with SACK
0 probe timeouts
  0 times retransmit timeout triggered after probe
  0 times fast recovery after tail loss
  0 times recovered last packet
1606 connections negotiated ECN
  0 times congestion notification was sent using ECE
  21 times CWR was sent in response to ECE
0 times packet reordering was detected on a connection
0 times transmitted packets were reordered
0 times fast recovery was delayed to handle reordering
0 times retransmission was avoided by delaying recovery
0 retransmissions not needed
```



- Modern networking stacks are heavily instrumented
- `netstat -s -p tcp` on OSX yields 82 event counters.
- Application instrumentation also includes collection
- e.g. telemetry.mozilla.org
- Phase 1: generalizing and standardizing access to data we already have.
- e.g. mPlane [4]



Why a new shim layer?



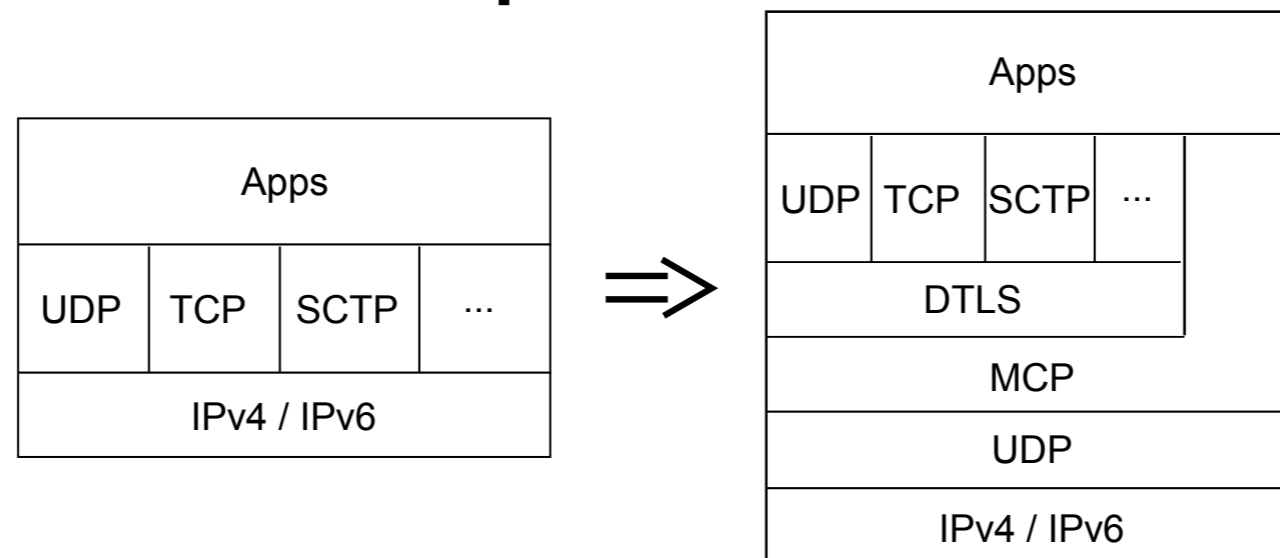
- Transport layer: end-to-end sockets
- flow information
- stateful and stateless processing at the edge
- **Missing: Per-flow information for stateful in-network functions**
- stateful information processing
- stateless and simple processing in the middle

➔ **Path layer** for explicit cooperation with middleboxes instead of implicit assumptions



Implementing an Explicit Path Interface

- Application can directly indicate requirements to path layer
 - Transport can use the path layer to expose parts of its functionality/intentions to the network
 - *Middlebox Cooperation protocol* (MCP) signals these information appropriately to on-path middleboxes
- ➔ **Minimize the information exposed!**





How to implement a new path layer?

- Transport-layer **encapsulation over UDP**
 - Need ports for NAT
 - Impossible to deploy with new protocol number across the Internet
 - Userspace (and kernelspace) implementation possible
- **Magic number** for easy recognition, protection against reflection
- **Flags** for “SYN/ACK” condition for state decision delegation to endpoint
 - All traffic bidirectional
 - Data in first packet possible
- Signals fit in a single packet (**no segmentation or reliability**)
- **Checksum** for error detection, cryptographic integrity checks available



Why should I trust what you say about your flows?

- **Default:** *trust but verify*
 - declarative signaling: **no** negotiation, **no** guarantees
 - the best way to prevent cheating is to make it useless to do so
 - minimize the information exposed!
- Leverage existing trust relationships for higher-assurance declarations
 - e.g. your enterprise firewall, access network middleboxes, etc.



A Measurement Layer

- Insight: shifting the burden to analysis-time **reduces the runtime burden.**
- Cumulative nonce ($n_{tx}, \sum n_{rx}$) added to each / sample of packets [8] allows loss rate estimation.
- Timestamp echo ($t_{tx}, t_{rx}, t_{\Delta rx}$) with constant-rate clock [7] and remote delta allows latency and jitter estimation.
- Protected header hash echo (h_{tx}, h_{rx}) allows detection of header manipulation [6].
 - Shared-secret protected hashes allow secure detection by endpoints
 - Unprotected hashes detect only accidents
- Insight: Each of these can work at **low sampling rates for large flows.**
 - How much smarter can we be for less than one bit per packet?