Minion: An All-Terrain Packet Packhorse to Jump-Start Stalled Internet Transports

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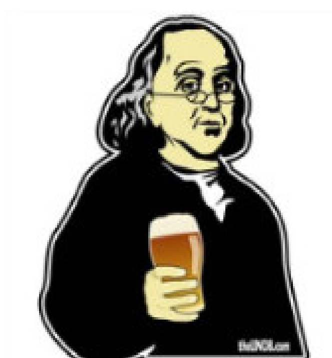

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Transports come and transports go ...

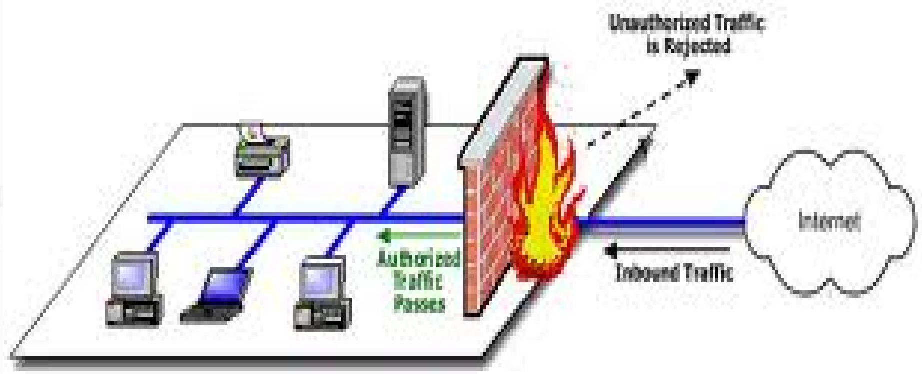
- SCTP
  - multistreaming, message boundaries, multihoming, partial reliability, unordered delivery
  - RFCs 4960, 3257, 3309, 3436, 3554, 3758, 3883 …
  - NAT behavior: draft-stewart-behave-sctpnat
- DCCP
  - Unreliable, congestion-controlled, datagram service
  - RFCs 4336, 4340, 4341, 4342, 5238, 5634, …
  - NAT behavior: RFC 5597

… but the Internet remains loyal!

- TCP and/or UDP get through all middleboxes
  - UDP does not get through all middleboxes, but TCP does
  - (see paper for more on why UDP is insufficient)

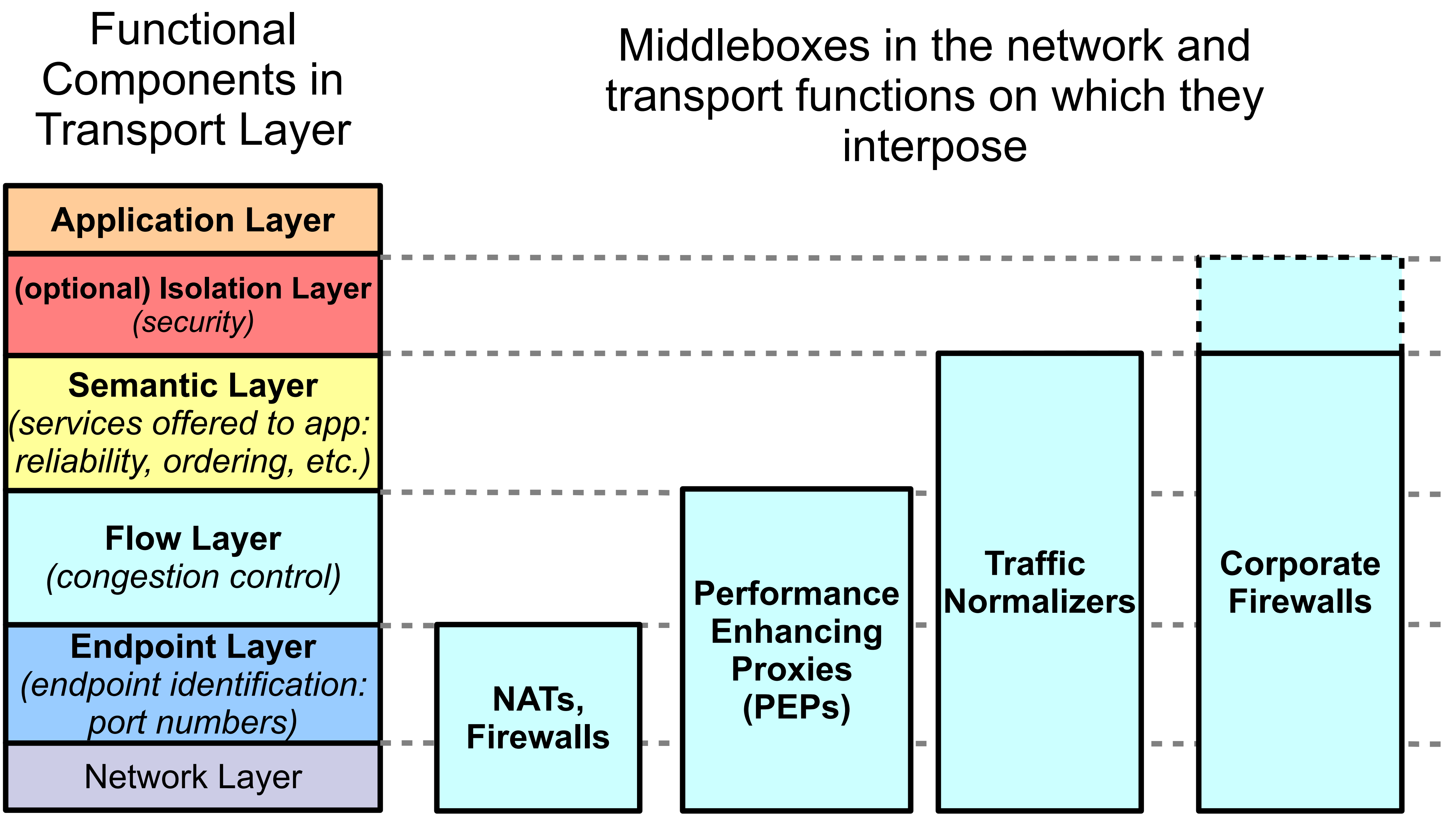
- Other transports do not get through
  - SCTP and DCCP not supported by middleboxes
  - Practically impossible to get support for any new transport

How deep does this loyalty run?

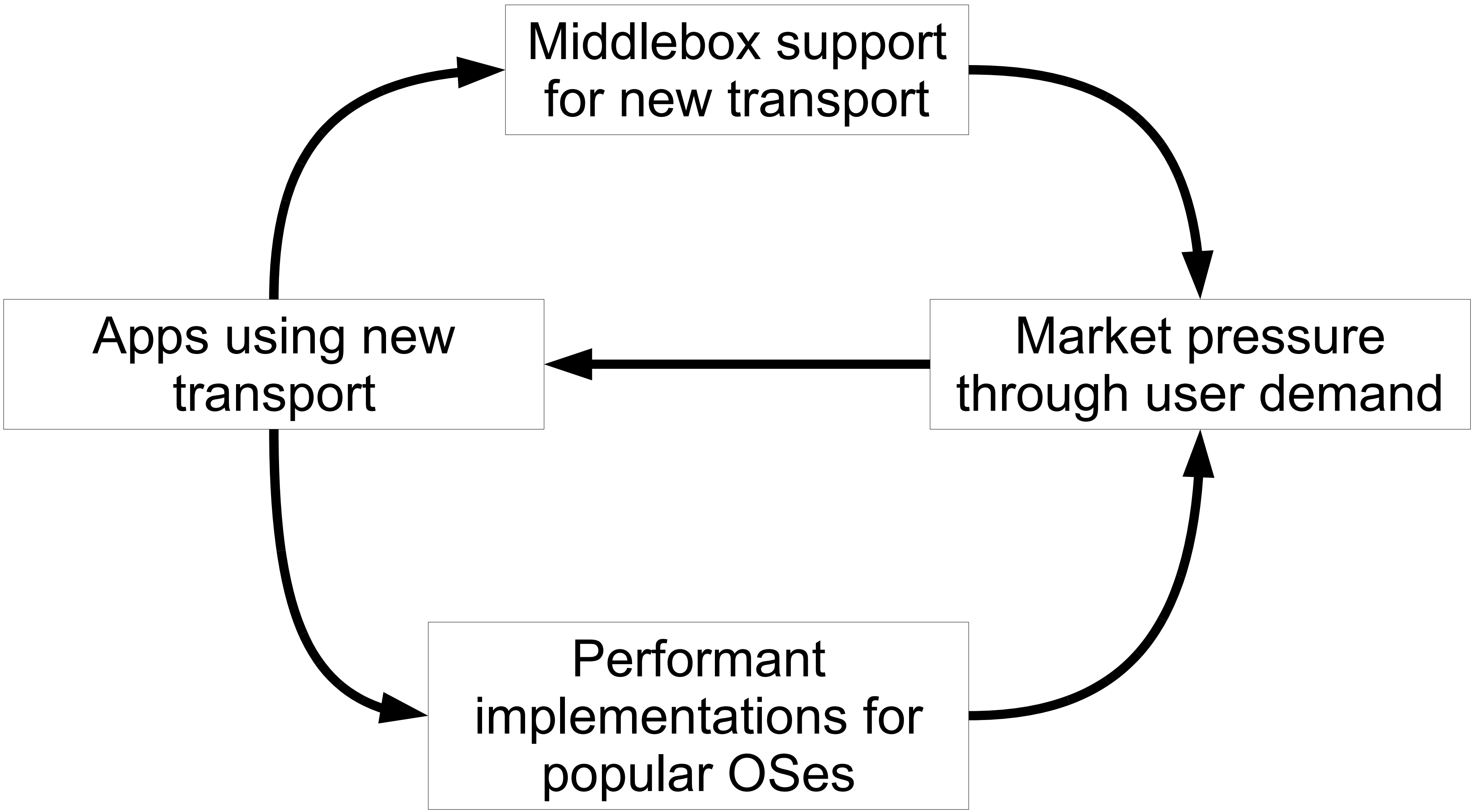


- Network Address Translators (NATs)
  - Cheap and ubiquitous, entrenched in the network
- Firewalls
  - Rules based on TCP/UDP port numbers; possibly DPI
- Performance Enhancing Proxies (PEPs)
  - Transparently used for improving TCP performance

A taxonomy of transport functions



Deployment Impossibility-Cycles



What have we done so far?

- “NATs are evil. We won't care about them.”
- “It will all change with IPv6.” ← **Denial**
- “Don't design around middleboxes, that will only encourage them!” ← **Anger**
- “Alright, we'll specify how middleboxes *ought* to behave with different protocols. But they still have to behave.” ← **Bargaining**
- “Why build a new transport?? It won't get deployed anyways.” ← **Depression***

**Kübler-Ross model: Five stages of grief*

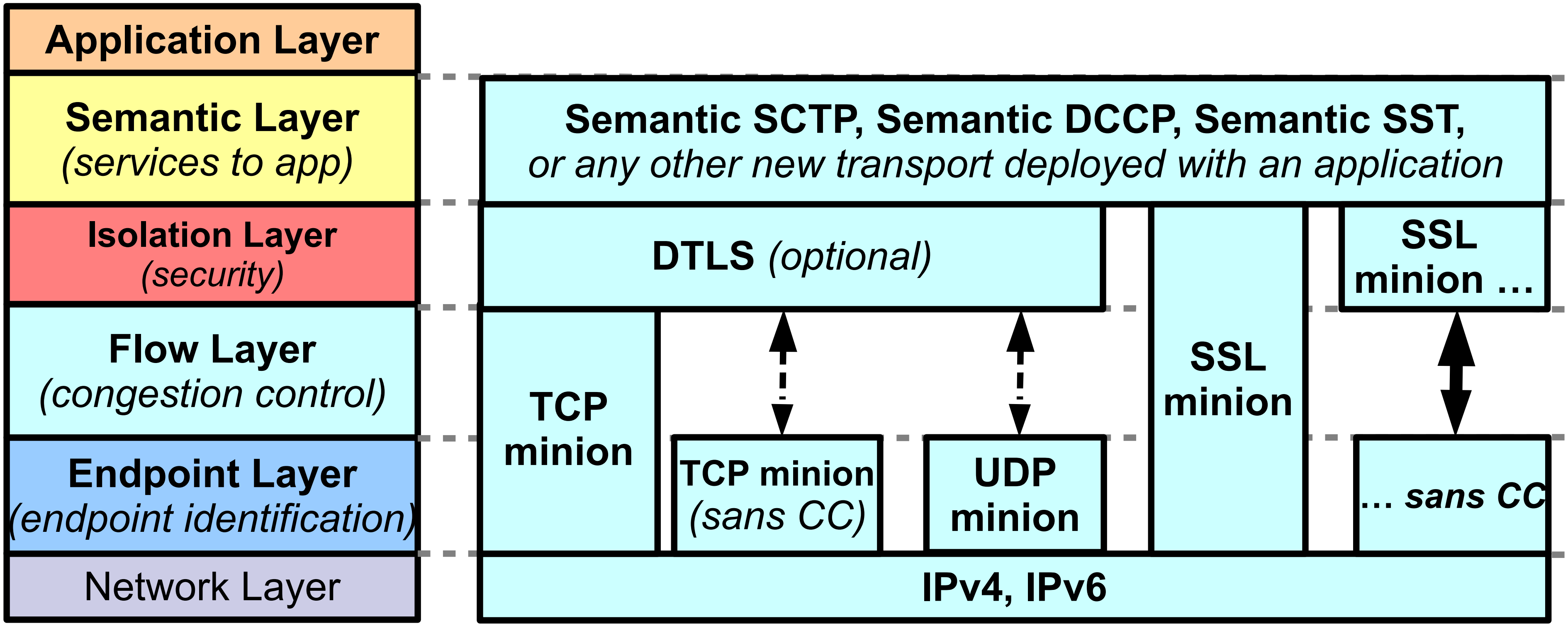
The final stage: Acceptance

- Design assumptions for new transport services:
  - New transport services should *require* modifications to *only* endhosts
  - Middleboxes are here to stay
- Consequences:
  - New end-to-end services *should not require* changes to middleboxes.
  - New end-to-end services must use protocols that appear as legacy protocols on the wire.
- Eg: MPTCP

The Minion Suite

- ***Uses legacy protocols …***
  - TCP, UDP, SSL
- ***… as a substrate …***
  - turn legacy protocols into *minions* that offer an unordered datagram service
- ***… for building new services that apps want***
  - multistreaming, message boundaries, unordered delivery, optional congestion control
  - *(working on: stream-level receiver-side flow control, multihoming and multipath, partial reliability)*

What's in the Minion Suite?



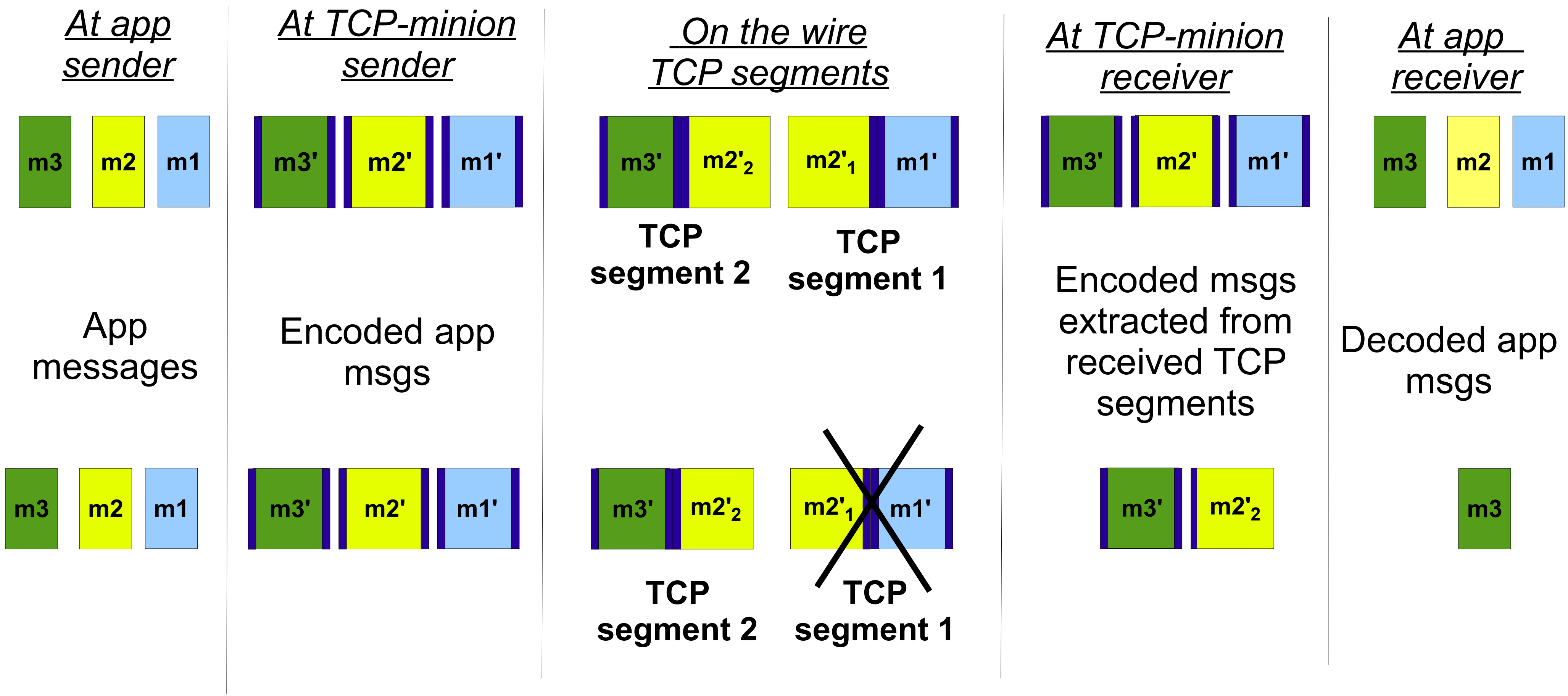
- Reduce legacy protocols to *endpoint-* and *flow-layer* minions on which middleboxes can interpose
- Build more sophisticated services on top of minions

TCP Minion

- Retain TCP protocol semantics on the wire
  - Connection-oriented → setup/teardown preserved
  - Fully reliable → retransmissions
  - Byte-stream → re-segmentation in network tolerated

- Provide datagram service to app/semantic layer
  - embed upper layer messages in byte-stream
  - extract and deliver messages at receiver from byte-stream without regard to order *(COBS encoding)*
  - (cannot forgo TCP retransmissions → reliable datagram service)

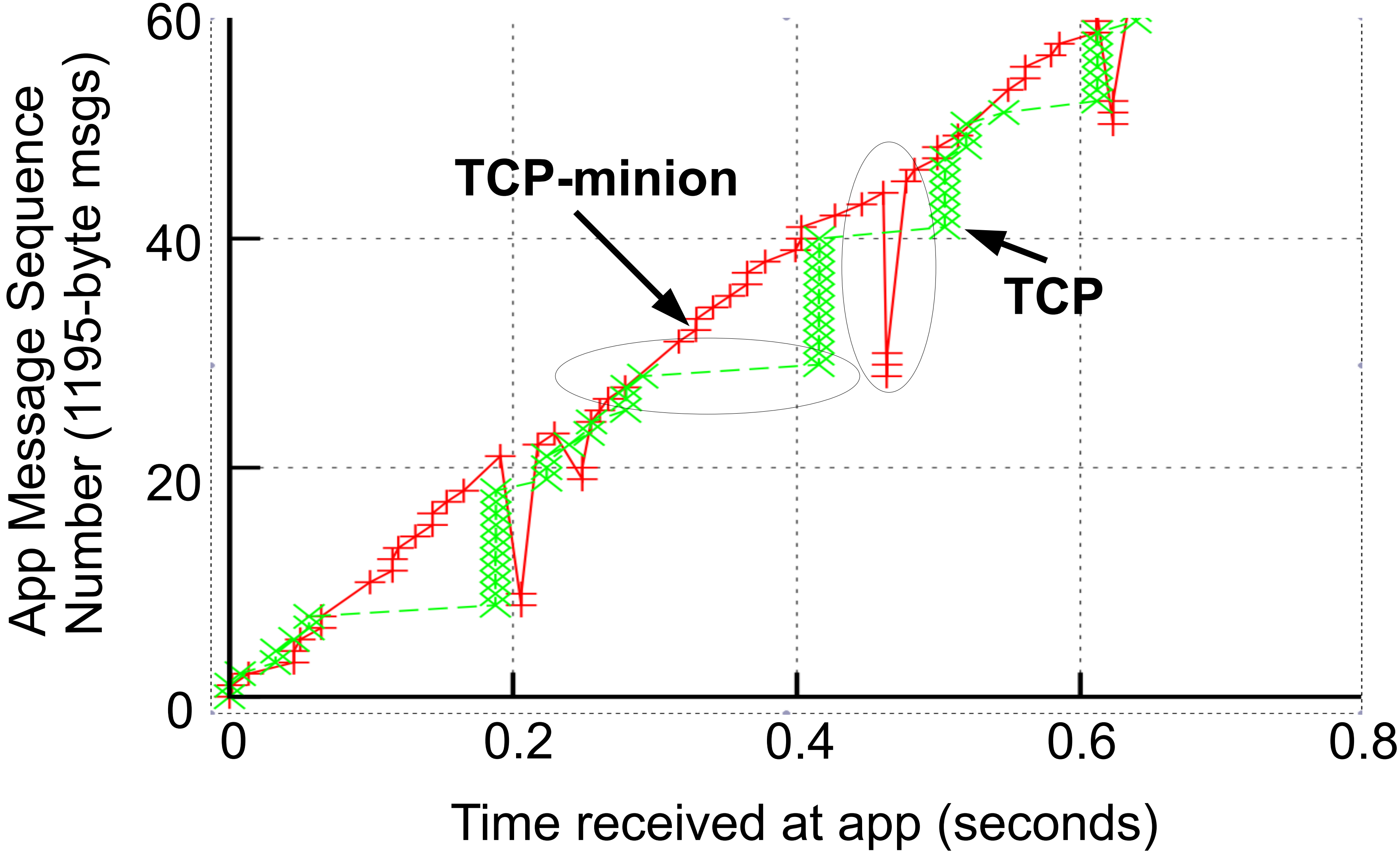
TCP minion in operation



COBS encoding

- Size-preserving encoding that eliminates all occurrences of delimiter byte
  - Max overhead of 0.4% (5 bytes for 1250-byte msg)
  - Delimiter byte then inserted between messages
  - Receiver extracts messages, decodes, delivers up
- We make one modification
  - We insert delimiter byte both before *and* after msg
    - Increases max overhead to 0.8%
  - To deal with common cases for apps
    - App sends only one message (eg: HTTP GET req)
    - Each app msg gets encap'd in its own TCP segment

App messages with TCP (TLV encoding) vs. TCP-minion



Stacking new services

- Semantic SCTP:
  - message boundaries, multistreaming, unordered delivery, multihoming, multipath, (partial reliability)
- Semantic DCCP:
  - TCP-minion service is exactly the same as DCCP with TCP-like congestion control (CCID-2)
  - negotiate CC on top of TCP-minion, and change CC algo used in kernel during runtime
- Semantic SST:
  - receiver-side per-stream flow control
  - stream prioritization

SSL Minion

- SSL-minion protects end-to-end signaling and data,
  - appears as SSL on the wire, and
  - provides a reliable datagram service
- App messages are broken into SSL records at sender, and authentication code (MAC) is appended
- Receiver uses SSL's basic record header as a "weak" recognizer of a record delimiter
  - record authentication successful $\rightarrow$ record delimiter accurate!

UDP Minion

- Provides UDP encap of new transport
  - Similar to “GUT” proposal
  - Importantly, contains accurate app endpoint information: UDP source/dest port numbers are the ports that apps are bound to.

Our implementation of the minions

- Some inside Linux kernel, the rest in userspace libraries
- Added SO_UNORDERED sockopt to SOCK_STREAM
  - subsequent read()s results in a *contiguous byteblock* being returned, without regard to order
  - TCP sequence number returned with byteblock
  - This minor change is the only one required in-kernel
- Userspace library for rest of TCP- and SSL-minion
  - reassembles byteblocks, extracts message, decodes, and delivers up
  - can ship as part of apps

In Conclusion

- **TCP, SSL, UDP work on the Internet**
  - mature, performant implementations
  - *workhorses* of the Internet

- **We can implement new services by modifying ends and retaining on-the-wire protocols**
  - Most mods deployable with apps
  - Turn workhorses into *packhorses*!