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

The current Internet protocol stack has very limited build-in facilities for network measurement and diagnostics. The only explicit measurement feature in the stack is ICMP Echo ("ping"). In the meantime, the Internet measurement community has defined many inference- and assumption-based approaches for getting better information out of the network: traceroute and BGP looking glasses for topology information, TCP sequence number and TCP timestamp based approaches for latency and loss estimation, and so on. Each of these uses values placed on the wire for the internal use of the protocol, not for measurement purposes, and do not necessarily apply to the deployment of new protocols or changes to the use of those values by protocol implementations. Approaches involving the encryption of transport protocol and application headers will break most of these, as well.

Replacing the information used for measurement with values defined explicitly to be used for measurement in a transport protocol independent way allows explicit endpoint control of measurability and measurement overhead. Therefore, we proposed to use a new Substrate Protocol for User Datagrams (SPUD) as a transport independent shim layer (encapsulated in UDP) to allow explicit cooperation with middlebox and thereby provides the needed information for in-band measurement. We note that current work in IPPM working group in the IETF proposes a roughly equivalent, IPv6-only, kernel-implementation-only facility.

Based on this approach, the next question is what does such a transport independent protocol need to provide? For most basic measurements (in this layer) we only need the "big five" metrics -- latency, loss, jitter, data rate / goodput, and reordering. These metrics can be measured using a relatively simple set of primitives. Packet receipt acknowledgment using a cumulative nonce echo allows both endpoint and on-path measurement of loss and reordering as well as goodput (when combined with layer 3 packet length headers). A timestamp echo facility, analogous to TCP's timestamp option but using an explicitly defined, constant-rate clock and exposure of local delta (time between receipt and subsequent transmission). This enables measurement of end-to-end latency as well as jitter.

The information exposed is roughly equivalent than that currently exposed by TCP as a side effect of its operation, but defined such that they are explicitly useful for measurement, useful regardless of transport protocol, and such that information exposure is in the explicit control of the endpoint (even when the transport protocol's headers are encrypted).